Floodplain Risk Management Study

Bega & Brogo Rivers FRMSP

59916044

Prepared for
Bega Valley Shire Council

26 March 2018

Adopted by Bega Valley Shire Council
11 April 2018

Cardno
Shaping the Future

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Executive Summary

Cardno were commissioned by Bega Valley Shire Council to undertake the Floodplain Risk Management Study and Plan for the Bega and Brogo Rivers region.

Flooding in the study area can pose a hazard to some residents and properties near creeks and overland flow paths. The purpose of this study is to identify and examine options for the management of flooding within the study area.

The study area is located in the Bega Valley Shire LGA on the South Coast of NSW, approximately 80 km from the Victorian border. The total catchment area of the two river systems is 1,810 km^2 at the confluence at Bega, of which the Bega River contributes 1,030 km^2, and the Brogo River 780 km^2.

In the upper catchment is the township of Candelo. Candelo Creek runs through the middle of the Candelo Township, with a single crossing in the middle of town. While access over this bridge is lost in flood events above the 5% AEP, both sides of the community have flood free evacuation roads out of Candelo.

The township of Bega is the largest settlement within the catchment area. The township is primarily residential, with a central commercial district. Small areas at the edge of the town are light industrial. Outside the township is open pasture for cattle grazing. Due to historical flooding experiences, much of the developed areas of Bega are outside of the mainstream 1% AEP flood extent, although some low-lying regions at the edges of the township are inundated by this event. The lower areas of the town are typically used for open space and recreational purposes.

Flooding of the Bega Township is largely driven by overbank flows from the Bega River. Flooding from the Bega River is compounded by flows from the Brogo River, as the systems are adjacent to each other and of a similar size, so peak flows arrive at Bega at similar times.

Downstream of Bega, approximately half way to the river's outfall into the Tasman Sea, are two inter-related geographic features, Bottleneck Reach and Jellat Jellat.

Bottleneck Reach runs for approximately 7 km and fully contains all events up to and including the PMF. Bottleneck Reach also results in backwater effects extending upstream towards Bega. In the PMF event, this backwater effect extends as far as the Princes Highway.

Because of this constriction a large storage area forms upstream of Bottleneck Reach. This region, Jellat Jellat, is a permanent water body. In flood events, the restriction at Bottleneck Reach causes the area to operate as a significant flood storage area. In the 1% AEP, the region stores approximately 9.7 million cubic metres of water. In the PMF, this storage volume increases to approximately 21.9 million cubic metres. In comparison to the total flow volumes, this represents storage of 2% of the total flood volume in the 1% AEP and 1% in the PMF.

The outlet of the Bega River is located at Mogareeka. 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.

An assessment was undertaken to identify the number of properties affected by different frequency storm events, as well as an estimate of the appropriate economic damages for that event. The table over page summarises these results.

Options to reduce or manage the impact of flooding in the catchment were investigated, and a mix of strategies to manage the risks of flooding were developed.

Under the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and stakeholders, a number of potential options for the management of flooding and/or the associated risks to life and property were identified.

Table i Flood affected properties and damages under existing conditions

Flood Event	Properties with Over-floor flooding	Properties with Over-ground flooding	Flood Damage
10% AEP	13	24	$1,435,177
5% AEP	40	59	$6,333,165
2% AEP	66	98	$10,764,761
1% AEP	96	137	$16,419,641
0.5% AEP	112	145	$18,261,042
0.2% AEP	116	148	$19,231,182
PMF	351	284	$55,349,244
Average Annual Damage			**$875,879**

These options included:

> Flood modification measures;

> Property modification measures; and

> Emergency response measures.

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

Of the 24 options that proceeded to assessment in the multi-criteria matrix, the top three were:

> P 2 Building and development controls

> EM 2 Flood Warning System

> EM 3 Public Awareness and Education.

Of the structural options assessed, excluding the road raising options for emergency access only, the top three options identified by the multi-criteria analysis were:

> L.2.3: 1% AEP Levee – Auckland Street

> L.1.3: 1% AEP Levee – Bega and Auckland Streets

> L.4.3: 1% AEP Levee – Bega Street.

Given these levee options are mutually exclusive, the other levee options for Auckland Street (L.2.1 and L.2.2), Bega and Auckland Streets (L.1.1 and L.1.2), and Bega Street (L.4.1 and L.4.2) would not be adopted in the FRMP.

It is recommended that the top 12 highest-ranking options, representing those options that provide the greatest benefit to the community on a value for money basis, be adopted as actions in the FRMP. The ranking of the options is proposed to be used as the basis for prioritising the components of the FRMP.

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** Figures are attached as A3 plots at conclusion of report.*

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 each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
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.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g., some roads may be designed to be overtopped in the 1 in 1 year or 100% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
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.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain that causes it.
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 super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land that is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures that might be feasible for the management of a particular area.

Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High flood island	The flood island includes enough land higher than the limit of flooding (i.e. above the PMF) to cope with the number of people in the area. During a flood event the area is surrounded by floodwater and property may be inundated. However, there is an opportunity for people to retreat to higher ground above the PMF within the island and therefore the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
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.

Low flood island	The flood island is lower than the limit of flooding (i.e. below the PMF) or does not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwater and property will be inundated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded on the island may drown and property will be inundated.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures that are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Net Present Worth (NPW)	The value in the present of a sum of money, in contrast to some future value it will have when it has been invested at compound interest.
Overland flow	The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation, see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
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.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.

Topography	A surface that defines the ground level of a chosen area.

* Terminology in this Glossary have been derived or adapted from the NSW Government Floodplain Development Manual (2005) where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
AHIMS	Aboriginal Heritage Information Management System
ARI	Average Recurrence Intervals
ASS	Acid Sulfate Soils
BC Act	NSW *Biodiversity Conservation Act 2016*
BoM	Bureau of Meteorology
DCP	Development Control Plan
EECs	Endangered Ecological Communities
EMP	Estuary Management Plan
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FPA	Flood Planning Area
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
ha	Hectare
HHWSS	High High Water Solstice Springs
IFD	Intensity Frequency Duration
IPCC	Intergovernmental Panel on Climate Change
km	Kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detecting and Ranging
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
MCA	Multi-criteria Assessment
ML	Mega Litres
mm	Millimetre
m/s	Metres per second
NPV	Net Present Value
NP&W Act	NSW *National Parks and Wildlife Act 1974*
NPW	Net Present Worth
NSW	New South Wales

OEH	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
POEO Act	NSW *Protection of the Environment Operations Act 1997*
RCP	Representative Concentration Pathway
SEPP	State Environmental Planning Policy
SES	State Emergency Service

1 Introduction

This report details the work undertake as part of Stage 2 of the Floodplain Risk Management Study (FRMS).

1.1 Report Context

The NSW Floodplain Risk Management Process progresses through the following six stages (also shown diagrammatically in **Figure 1-1**):

1. Formation of a Floodplain Management Committee.
2. Data Collection.
3. Flood Study.
4. **Floodplain Risk Management Study.**
5. **Floodplain Risk Management Plan.**
6. Implementation of the Floodplain Risk Management Plan.

This report is the Flood Risk Management Study (FRMS) prepared in accordance with Step 4. Its companion document is the Floodplain Risk Management Plan (FRMP), prepared in fulfilment of Step 5 of the process.

Figure 1-1 Floodplain Risk Management Process

1.2 Report Objectives

The objective of this report is to provide details of the following:

> Determination of flood damages;

> Classification of flood hazard and hydraulic categories; and

> Development and assessment of flood mitigation options.

2 Catchment Description

The study area is located within the Bega Valley Shire local government area (LGA) on the South Coast of NSW, approximately 80 km from the Victorian border. The total catchment area of the two river systems is 1,810 km^2 at the confluence at Bega (refer **Figure 2-1**), of which the Bega River contributes 1,030 km^2, and the Brogo River 780 km^2.

The two rivers meet at the Bega Township and eventually discharge into the Tasman Sea at Mogareeka, 24 km downstream from Bega. The region between the Bega Township and Mogareeka contributes another 125 km^2 of catchment area. The total catchment area for the Bega River at its outlet is approximately 1,935 km^2.

The upper catchment is significantly higher than the lower catchment, with elevations of up to 1,320 mAHD, compared with 15 mAHD at Bega. The terrain falls sharply from these heights to a large central plain that includes the townships of Bemboka, Kameruka, Candelo, Brogo and Bega.

Water supply dams are located in the upper catchment 15 km upstream of Brogo and 16 km upstream of Bemboka. The dam upstream of Bemboka, Cochrane Dam, also operates as a hydroelectric scheme for power generation.

The upper regions of the catchment remain forested, while the central valley and downstream regions have been cleared for agriculture. This central valley has historically been known for dairy produce.

In the upper catchment is the township of Candelo, which is located on Candelo Creek, an indirect tributary of the Bega River. Candelo Creek flows into Tantawangalo Creek approximately 5 km downstream of Candelo. Tantawangalo Creek flows into the Bega River approximately 7 km downstream of the confluence with Candelo Creek.

Candelo Creek runs through the middle of the Candelo Township, with a single crossing in the middle of town. While access over this bridge is lost due to overtopping in flood events above the 5% Annual Exceedance Probability (AEP) event, both sides of the community have flood free evacuation roads out of Candelo.

The township of Bega is the largest settlement in the catchment. The Bega Township is bordered by the Bega River on its western, northern and eastern sides. The confluence with the Brogo River is immediately north of the township.

The township is primarily residential, with a central commercial district. Small areas at the edge of the town are light industrial. Outside the township is open pasture for cattle grazing.

Due to historical flooding, much of the developed areas of Bega areas outside the mainstream 1% AEP flood extent, although some low-lying areas at the edges of the township are affected by this event. The lower lying areas of the town are typically utilised for open space and recreational purposes.

Flooding of the Bega Township is largely driven by overbank flows from the Bega River. Flooding from the Bega River is compounded by flows from the Brogo River, as the systems are adjacent to each other and of a similar size, so peak flows arrive at Bega at similar times.

In addition to riverine flooding, the Bega Township is also affected by local catchment flooding and overland flow, which can result in local flooding issues and loss of access, independent of flooding in the Bega River. Investigations into selected local sub-catchments has been undertaken as part of this study, namely:

> Ravenswood Street – Charlotte St Bega Tributary, southwest of central Bega;

> Rawlinson St – East St Bega Tributary, south of central Bega; and,

> Boundary Road – Kerrisons Lane, southeast of central Bega.

Downstream of Bega, approximately half way to the river's outfall into the Tasman Sea, are two inter-related geographic features, Bottleneck Reach and Jellat Jellat.

Bottleneck Reach is a significant constriction, throttles the flow from over 1,000 m wide upstream in the 1% AEP and Probable Maximum Flood (PMF) events down to 300m through the constriction. In the 1% AEP flood, flows reduce to 3,900 m^3/s through Bottleneck Reach, down from 10,400 m^3/s in the Bega River upstream of this feature; a reduction of over 60%.

Bottleneck Reach runs for approximately 7 km and fully contains all events up to and including the PMF. Bottleneck Reach also results in backwater effects extending upstream towards Bega. In the PMF event, this backwater effect extends as far as the Princes Highway.

Because of this constriction, a large storage area forms upstream of Bottleneck Reach. This region, Jellat Jellat, is a permanent water body bounded to the north by the Bega River, and large ranges on the east and west and a smaller range to the south. In flood events, the restriction at Bottleneck Reach causes the area to operate as a significant flood storage area. In the 1% AEP, the region stores approximately 9.7 million cubic metres of water. In the PMF, this storage volume increases to approximately 21.9 million cubic metres. In comparison to the total flow volumes, this represents storage of 2% of the total flood volume in the 1% AEP and 1% in the PMF.

As noted above, the terrain to the south also rises, but not as sharply as the ranges to the east and west. As a result, in the PMF event, this southern terrain overtops and floodwaters flow from Jellat Jellat into Wallagoot Lake.

The outlet of the Bega River is located at Mogareeka. The tidal influences extend upstream approximately 15 km to Jellat Jellat, although in large flood events the influence of ocean levels extends as far upstream as Bega.

The study areas are shown in **Figure 2-2**.

3 Review of Available Data

3.1 Previous Reports and Studies

The Bega and Brogo Rivers Flood Study at Bega (SMEC, 2014) included a substantial data review, which was used to inform the hydraulic and hydrologic modelling undertaken for this FRMS. It is Cardno's opinion that many of the documents and data reviewed as a part of the Flood Study are equally applicable for use within the context of this Flood Risk Management Study and Plan. As a result, the following data review lists the data previously reviewed in the Flood Study (**Table 3-1**), before providing a more detailed review of the Flood Study itself, as well as any additional data sets that have been made available since the Flood Study was developed.

Table 3-1 Summary of Previously Reviewed Studies and Reports (after: SMEC, 2014)

Study / Report	Year	Author
Floods of February 1971 on the South Coast	1976	Water Resources Commission
Flood Inundation Map - Bega and Brogo Rivers at Bega	1979	Water Resources Commission
Draft Bega River Estuary Sediment Study	1999	Coastal and Marine Geosciences (in association with Environmental Sciences & Engineering)
Bega Street Development Flood Study	2005	Environmental Resources Management Australia
Bega Valley Floodplain Management Appraisal Volume 1 Report	1987	Willing and Partners
Tathra Erosion Study	1980	NSW Public Works

Documents that were not previously reviewed as a part of the Flood Study (2014) are outlined in **Table 3-2**.

Table 3-2 Summary of Additional Studies and Reports

Document	Description
Bega and Brogo Rivers Flood Study at Bega – SMEC 2014	This flood study describes the process undertaken to determine a range of design flood events for the Bega and Brogo River Catchments. The study area included two primary catchments: ▪ Bega River Catchment - 5 km upstream of Bega - 1,030 km^2 ▪ Brogo River Catchment - 8.5 km upstream of the Bega-Brogo Rivers junction along the Brogo River - 780 km^2. The model extended to the outlet to the sea at Mogareeka. Candelo Creek at Candelo was modelled in 1D in addition to the Bega and Brogo River models. Hydraulic and hydrological models were developed during the study to assess mainstream flooding, providing information on flood depths, extents, water levels, flows and velocities for design flood events including 10%, 5%, 2%, 1%, 0.2% AEP and PMF. The study identifies hydraulic and preliminary hazard categorization for these design events, as well as providing preliminary Flood Planning Levels (FPLs) for the catchment, with consideration of catchment and ocean flooding. Estimated joint probability of occurrence of the peak flows from the Bega River and water level conditions from the ocean were adopted to establish downstream conditions. The adopted Catchment and Ocean Flooding Combinations are shown in Table 15.5 of the Flood Study report. An XP-RAFTS hydrological model was set up to generate inflows for a XP-SWMM2D hydraulic model. Percentage imperviousness values were specified according to the land use zoning. Losses and roughness values were altered to calibrate the model to four historical events. Spatially variable rainfall maps were developed through daily rainfall gauges, these isohyetal maps were used to prescribe varying amounts of rainfall to each sub-catchment for a particular event. Pluviograph data was used to inform the temporal

Document	Description
	distribution of rainfall events. The events adopted for calibration and validation were February 1971, March 2011, March 1983 and February 2010. The hydrological models were calibrated with Streamflow Gauging Stations and Water Level Recording Stations at various locations in the catchment. The adopted initial and continuing losses were 10 mm and 2.5 mm/hr, respectively. The hydraulic model adopted a 25 m grid and 1-second time-step. The model included rivers and obstructions as 1D elements, informed by riverbed cross-sections from either the ground/bathymetric survey, DTM or interpolations. The February 1971 and March 2011 events were used to calibrate the hydraulic model by means of flood marks throughout the catchment (23 and 46 respectively). Overall, the hydraulic and hydrologic models showed a reasonable representation of these historical events. A detailed review of the Flood Study modelling approach is provided in **Section 3.4**.
Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways – NSW OEH 2015	The guide recommends approaches to derive ocean boundary conditions and design flood levels for the investigation of flooding scenarios in coastal waterways. This guideline facilitate a defensible approach to modelling both catchment flooding and oceanic inundation in the context of a FRMS&P. The Flood Study (SMEC, 20143) included several recommended combinations of catchment flooding and oceanic inundation scenarios (specifically the 1% AEP Envelope Levels). Table 8.1 of the guidelines suggest several combinations that have not been previously modelled, including the 1% AEP Envelope velocity scenario. However, the Flood Study sensitivity analysis identified that the flood levels within the developed portions of the floodplain are not particularly influences by the downstream conditions.
Bega Valley Local Environment Plan (LEP) – Bega valley Shire Council 2013	Bega Valley Local Environment Plan (LEP 2013) has been updated since the Flood Study. Changes include land rezoning and the establishment of new permitted and prohibited use of land zones. This document will be used to inform both the review of flood planning considerations and options assessment in the FRMS&P.
Bega Valley Development Control Plan (DCP) – Bega Valley Shire Council 2013	The Development Control Plan (DCP 2013) supplements the LEP by providing greater detail to guide development in the Bega Valley. This document was used to inform both the review of flood planning considerations and the options assessment of the present study, ensuring they are in line with objectives and controls outlined in the DCP 2013.
South Coast Regional Sea-level Rise Planning and Policy Response Framework - Whitehead & Associates in consultation with Coastal Environment 2014	This Regional Sea Level Rise Planning and Policy Response Framework (2014) was developed for Eurobodalla Shire Council and Shoalhaven City Council to inform coastal planning. The report: ▪ Highlights the fact that in order for councils to take advantage of the s733 exemption of the *Local Government Act 1993* which aims to provide local councils with exemption from liability relating to coastal planning, future sea level rise cannot be ignored ▪ The framework draws from IPCC AR5 report, which is considered 'widely accepted by competent scientific opinion' as per Coastal Zone Management Plan requirements (OEH, 2013) ▪ Advocates the adoption of IPCC's Representative Concentration Pathway (RCP) 8.5 sea level rise projection. This is the highest of the four RCPs in the IPCC AR5 report; therefore, it represents a conservative approach, albeit a not unreasonable one. ▪ Highlights that in many locations detailed studies will be required to translate offshore water levels into shoreline or estuarine hazards. ▪ Discusses the importance of effective communication in acknowledging the uncertainty associated with the timing of sea-level rise projections at 2100 and into the future. ▪ Recommends the adoption of the following Coastal Hazard Planning Areas: - Current Hazard – areas that are presently, or will become imminently threatened by the 'design' hazards (including flooding) over the next 15 years - Medium Term Projected Hazard – Areas that are projected to be impacted within the next 15 to 35 years - Strategic Projected Hazard Planning – Areas containing development that are projected to be impacted within the next 35 to 100 years. - Possible Maximum Strategic Hazard – Areas of existing or proposed critical infrastructure that are projected to be impacted over the next 100 years if a very high sea-level rise scenario (greater than RCP8.5) occurs.

Document	Description
	▪ Other recommendations Include: - Existing development should be allowed to remain as long as it is feasible from both practical and safety perspectives, without adversely impacting on neighbours or the broader community. - Proposed development should be adaptable and subject to controls that ensure the development is safe for the course of its expected life and can be decommissioned or suitably adapted with relative ease. This document was considered in the context of managing the impacts of flooding for climate change scenarios for future projections.
Bega River Estuary Management Plan: Estuary Processes – WBM Oceanics 2006	The Bega River Estuary Management Plan (EMP; WBM Oceanics, 2006) covers the following topics: ▪ Tides, floods and the entrance; ▪ Water quality; ▪ Sediments; ▪ Bank erosion; ▪ Ecology; ▪ Waterway usage; ▪ Human impacts on the estuary; and ▪ Climate change. This document is useful to gain an understanding of the estuary and the influence of water levels to flooding events both downstream and upstream. Any flood management options developed as part of the FRMS were considered in the context of the environmental conditions outlined in the EMP and take into account the estuary management options recommended in the EMP.
Bega Valley Shire Urban Stormwater Management Plan 2002	Bega Valley Shire developed a stormwater management plan in response to NSW EPA's requirements. The document includes information about water quality and rainfall and runoff. The Stormwater Management Plan (SMP, 2002) may be a useful reference when considering on-site detention and other flood management options as a part of the FRMS&P. The document highlights water quality issues to be considered during the preparation of flood management options. Where dual benefits for water quality and flood management can be achieved, this was considered in the scoring and ranking of flood management options.
Community Strategic Plan: Bega Valley 2030 2011	The Community Strategic Plan (2011) sets the direction for the Bega Valley Shire towards 2030. The report was useful to gain insight into Council's medium term plans for the area and to ensure flood mitigation strategies align with these objectives.
State of the Environment Report 2011/2012 – Bega Valley Shire Council	The State of the Environment (2011) report outlines the current natural and built environment and identifies key issues and trends for Bega Valley Shire. The report also provides indication of council's progress towards achieving environmental objectives prescribed in the Community Strategic Plan (2011). The SoE report was used to ensure proposed flood mitigation works align with Council's environmental strategies and community concerns.
Bega Valley Shire Flood Risk Assessment - URS 2006	The Flood Risk Assessment (2006) reviews the policies and procedures behind Flood Management for the LGA, providing recommendations on how to address flooding issues effectively (such as formation of a Floodplain Risk Management Committee). Among other things, the report promotes development of FRMS&Ps, highlights potential causes for concern such as flood awareness and climate changes, and suggests consideration of extreme events in the development proposal process.
Bega Valley Shire Coastal Processes and Hazards Definition Study – BMT WBM 2015	The report examines a range of coastal processes and hazards that impact the coastal zones within the LGA. With regard to processes, the report examined: ▪ Regional geomorphology and coastlines processes; ▪ Waves and storms; ▪ Elevated water levels; ▪ Longshore and cross-shore sediment transport; ▪ Coastal entrance dynamics; and ▪ Projected sea level rise and climate change impacts.

Document	Description
	The report found that the regional wave climate, governed by east coast lows and mid-latitude cyclones, were the dominant process in the region. A number of coastal hazards were identified in the report: ▪ Beach erosion; ▪ Shoreline variability to variations in wave climates; ▪ Long term recession; ▪ Coastal inundation; ▪ Coastal entrance instability; and ▪ Sand drift. With regard to the study area, Tathra beach was identified as being at risk of significant shoreline recession as a result or rising sea levels

3.2 Survey Information

Council has supplied structure survey and design information for the following during the Flood Study:

> Bega Bypass plans – NSW Roads and Maritime Services (RMS);
> Bridge over Bega River (Tarraganda Bridge) at Tarraganda – DMR;
> Bridge over Bega River Anabranch at Bega – DMR;
> Bridge over Candelo Creek at Candelo – DMR;
> Bega River Anabranch River Clearing and Stop Bank – Bega Valley Shire Council;
> Reconstruction of Handcock Bridge, Tathra - Mumbulla Shire Council;
> 'School Bridge' over Tantawangalo Creek - Mumbulla Shire Council;
> Proposed Double Creek Bridge Replacement, Upper Cobargo Road – Andrew Marshman & Associates;
> Proposed McCarthys Creek Bridge Replacement, Upper Cobargo Road – Andrew Marshman & Associates;
> RTA (now RMS) bypass plans issued for construction and dated 21/10/2011; and
> CivilCAD survey data in a local datum for three locations, namely Jauncey Bridge, Sandy Creek, and Slaters Bridge.

3.2.1 Additional Survey

Additional ground and bathymetric survey was obtained to inform the Flood Study (SMEC, 2014). The survey included:

> Princes Highway bridge;
> Both the river and anabranch bridges at Tarraganda Lane;
> Tathra-Bermagui Road bridge; and
> Candelo town bridge.

The survey was undertaken to supplement existing bridge design drawings. The following details for each bridge were provided to Cardno:

> Top of the deck or road level above the structure (whichever was higher). For the bridge decks that were not horizontal, levels at both ends and at the high point were surveyed;
> Deck soffit level;
> Height of railing/safety barriers; and
> Cross-section at the bridge.

In addition, the survey included detail of Jellat Jellat weir (also known as Russells Creek Weir) and topographic survey of Candelo Creek (beyond council's LiDAR survey).

Floor level and ground level survey data was collected for around 400 properties within the PMF extent in October to December of 2016.

3.2.2 Community Survey

The community consultation undertaken during the Flood Study was useful to inform the FRMS&P. The consultation results indicated areas most affected by flooding, as well as community concerns and suggestions for improvement of flood response.

During the public exhibition of the Flood Study, comments were received on Emergency Response Planning. This shows there is an existing community concern around flood related emergencies and illustrates the importance of further community consultation during the FRMS&P.

3.2.3 Dam Information

The Flood Study gathered detail for Brogo Dam and Cochrane Dam to inform the hydrological modelling. The information gathered for this study is summarised in **Table 3-3**. This information was used in the FRMS&P to inform mitigation options such as dam modifications (as required).

Table 3-3 Summary of Dam Information

	Brogo Dam	Cochrane Dam
Full Supply Level	102.60 m AHD	910.13 m RL
Spillway Level	102.60 m AHD	910.13 m RL
Storage Capacity	8980 ML	385 ML
Dam Crest Level	118.1 m AHD	915.1 m RL
Stage Discharge Relationship	Available	Available
Storage Discharge Relationship	Available	Available
Historic event flow releases including any environmental flows or low flows	Available	Environmental or low flows during flood events assumed to be negligible

3.3 Topographic, GIS and Other Relevant Data

3.3.1 Topographic and GIS Data

The topographic and GIS data that was adopted for the Flood Study (SMEC, 2014) was relevant to the FRMS&P. The FRMS&P was also informed by any updated data such as the 2014 aerial photographs supplied by council and the GIS layers resulting from the Flood Study. Available GIS data to inform the FRMS&P includes:

> Mogareeka Inlet historical aerial photographs (March 1944 – May 2011);
> Flood extents, water levels, velocities, provisional hazard categories and hydraulic categories;
> Sub-catchment boundaries;
> State Forest;
> Flood marks and locations;
> Roughness zones;
> Land use zones (from the LEP 2013);
> Flora and fauna mapping;
> Soil mapping;
> Acid sulphate soil mapping;
> Geological mapping;
> Waterways mapping (and any additional attribute data, e.g. riparian conditions, stream order etc.);
> Land use mapping (if different from LEP zones); and
> Heritage items (European and Aboriginal).

3.3.2 Physical Process Data

Physical process data gathered during the Flood Study includes rainfall (both daily and pluviograph), streamflow and water level data from several gauges located in the catchment.

3.3.3 Flood Marks and Photographs

The historical flood levels gathered during the community consultation phase of the Flood Study were surveyed to provide accurate levels, dates, locations, descriptions and confidence ratings before being added to Council's existing dataset. This dataset is available to Cardno to inform the modelling and illustrate areas of concern.

3.3.4 Historical Data

In addition to providing the rainfall and flow data, WRC (1976) provides information about the scale and damage caused by the February 1971 flood. The report notes that the flood levels recorded during this event were the highest level in more than 100 years of records.

The report also listed the following damages:

> Two lives lost during the event;
> Over 50 bridges destroyed;
> Damages of over $7 million (presumably 1971 dollars);
> Electricity and phone lines out of service; and
> Towns to the South of Bega were out of water supply due to destruction of the mains.

3.4 Flood Study Model Review

A review was undertaken of the hydrological and hydraulic models developed for the Flood Study to determine if they are appropriate for use in the FRMS.

The key findings of the review were:

> The Candelo model is 1D, due a lack of LiDAR data in the region.
> A grid cell size of 25 m was used for the 2D model. This resolution may restrict the assessment of local mitigation options such as levees or small detention basins. Furthermore, the resolution may result in unusual mapping at some locations that could cause issues concerning community interpretation and acceptance of the results.
> The calibration events adopted a fixed entrance, while the design events have adopted a dynamic entrance. This was done because photographs of the entrance were available for the calibration events. However, it does mean that the dynamic scouring of the entrance during a storm event has not been calibrated. In order to calibrate the entrance opening, it would have been more appropriate to adopt a dynamic entrance for the calibration to ensure that he entrance opened in the model in line with the historic photographs.
> Hydrology assumed both dams in the catchment were full at start of event. This is a reasonable assumption, and will result in a conservative flow estimate.
> Design models assume that Council opens the entrance at the trigger level, as per the adopted entrance opening policies. However, opening is not always safe, and is unlikely to be possible during a large flood event. For a conservative assessment of flooding, it would be more appropriate to assume that Council are not able to open the entrance during a storm event.

The review found that the models are generally suitable for use in the FRMS. However, the review noted three points that may affect the suitability of the model for the current study:

> The 25 m grid cell size;
> A lack of calibration of the entrance failure; and
> An assumption that Council would open the entrance in design events.

As a result, for this FRMS, a nested grid was adopted for the township of Bega in order to allow a more detailed assessment of this region. For other areas of the study area, most developed regions are outside the 1% AEP extent. Those areas that are affected are all ponding or backwater storage areas, with consistent flood levels across the region, so a 25 m grid was considered suitable for these locations.

The PMF affects a larger area, but similar to the above, this inundation is largely ponding or backwater, so the 25 m grid was considered suitable for use. There is some flooding in the north of Tathra, but given these lots are only affected in the PMF, and are unlikely to warrant structural options, the 25 m grid remains reasonable for this region.

With regard to the entrance condition, sensitivity assessments undertaken in the Flood Study showed that entrance condition adopted has a minimal impact on flood levels that impact developed areas. A sensitivity assessment was undertaken using the updated entrance survey provided by the Office of Environment and Heritage (OEH) that showed negligible changes (less than 0.01 m) in flood levels. Furthermore, a sensitivity assessment was undertaken assuming that Council did not open the entrance, which found that resulting changes in upstream levels were less than 0.05 m. Another assessment was undertaken to consider the sensitivity of flooding to the height of the berm height. The assessment found that increasing the height of the entrance berm by a full metre only resulted a flood impact of <0.1 m across areas with development or infrastructure, which would be the regions we are looking at with regard to mitigation options and risks assessments. Consequently, it was concluded that the current entrance setup is appropriate for assessment of mitigation options and emergency response as part of the FRMS.

4 Community Consultation

Community consultation was undertaken in three key phases over the course of the project:

> Community Information Brochure and Questionnaire;
> Community Drop-In Sessions; and
> Public Exhibition of Draft FRMS&P.

4.1 Community Information Brochure and Questionnaire

4.1.1 Purpose and Scope

The community information brochure and questionnaire informed the community that the FRMS was being undertaken, as well as the context and the purpose of the FRMS. It provided an opportunity to understand the community impacted by the study, their experiences with flooding, their key concerns relating to flooding of the local area and any suggestions for ways to manage flood risk that could be investigated further as part of the FRMS.

An information brochure and questionnaire (refer **Appendix A**) were distributed to the owners of property within the study area in April 2016. The survey was also available on Council's website. A separate mail out and assessment was undertaken for the Bournda Parkway dam. The results of this survey and the associated dam break assessment are provided in **Appendix B**. Council are not the owners of Bournda Dam. The Bournda Dam survey was undertaken by Council for the sole purpose of gathering community opinion on the dam's future, and not through any legislative or ownership responsibility on behalf of Council.

The brochure and questionnaire were delivered to approximately 1,568 property owners in the catchment. The FRMS was also advertised in the local newspaper, informing residents of the study and advising that the survey was being undertaken. A total of 94 responses were received representing a return of approximately 5% of direct distribution. Of these, the vast majority were from Bega and surrounding suburbs, with only one respondent from Candelo.

The survey was conducted outside of peak holiday times, and was mailed to property owners, so the survey does not take into account the flooding knowledge and experiences of the visitors and tourists that visit the region during holiday periods.

4.1.2 Summary of Findings

Questions 1 to 3 of the questionnaire were aimed at gathering contact details. The responses to remaining questions are provided in the following section.

4.1.2.1 Flood Risk

Questions 4 and 5 related to understanding the respondents concerns about flood risk. Respondents could nominate more than one answer in these questions.

Risk to property was of highest concern, followed by inconvenience and risk to life. Some additional risks were identified, such as pollution of waterways and the potential impacts of sea level rise on flooding.

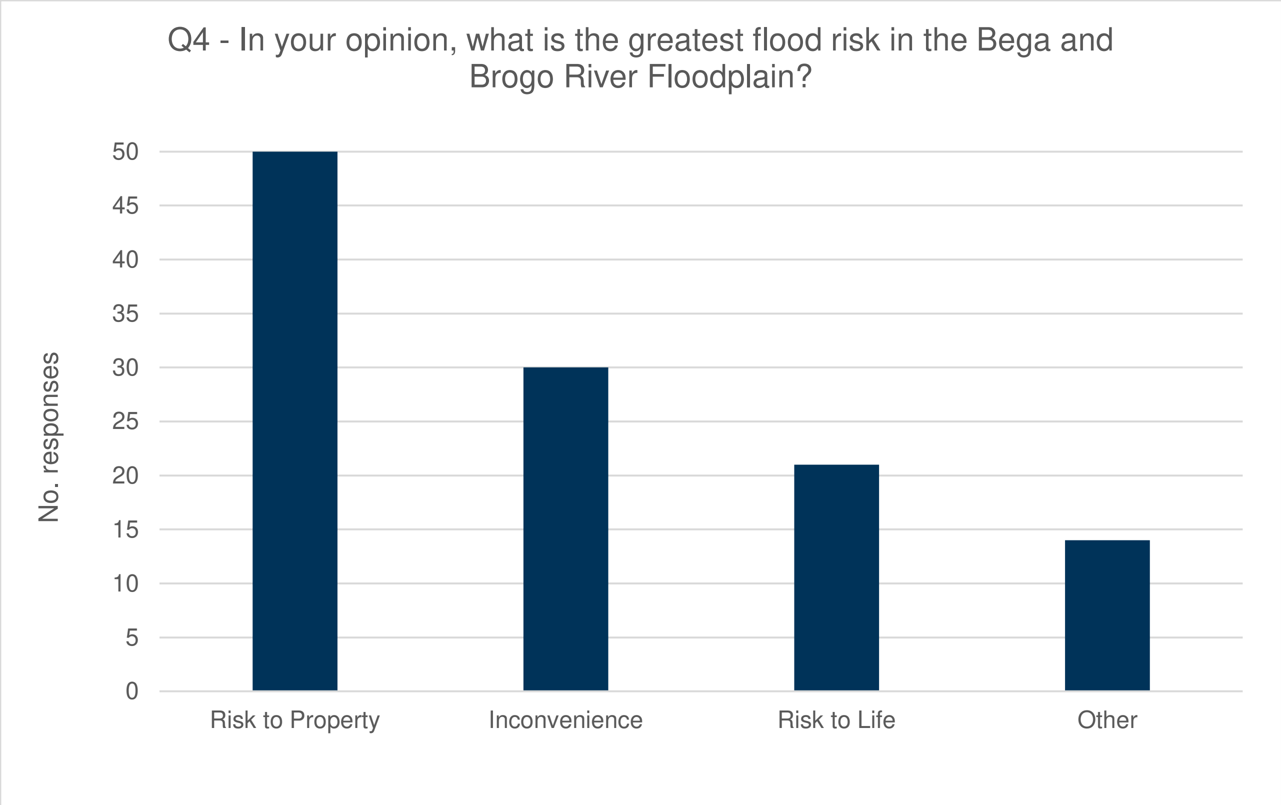
Specific areas identified as being subject to flood risk included roads, respondents own property, public areas and other areas.

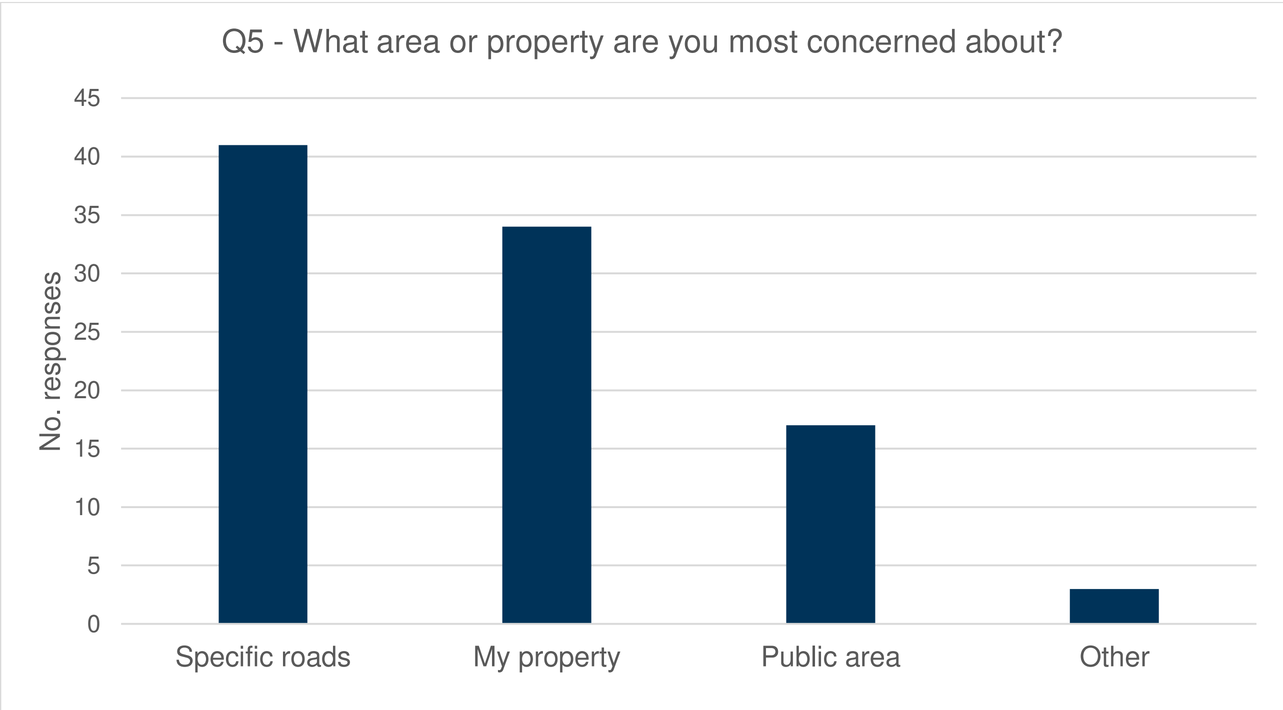
Roads frequently identified by respondents as being flood affected included:

> Tathra Road;
> Tarraganda Lane;
> Reedy Swamp Road; and
> Old Wallagoot Road.

Public areas identified as being flood affected included:

> Kisses Lagoon;
> Sports fields; and
> Shopping areas and town centres.





4.1.2.2 Flood Planning and Mitigation

The purpose of Questions 6 and 7 was to understand how respondents felt about flood related development controls and how they felt controls should be applied. Question 8 aimed to determine residents' preferred flood mitigation options.

The following questions were asked about Flood Planning Levels (FPLs):

> Q6a - Have you heard of Flood Planning Levels before?

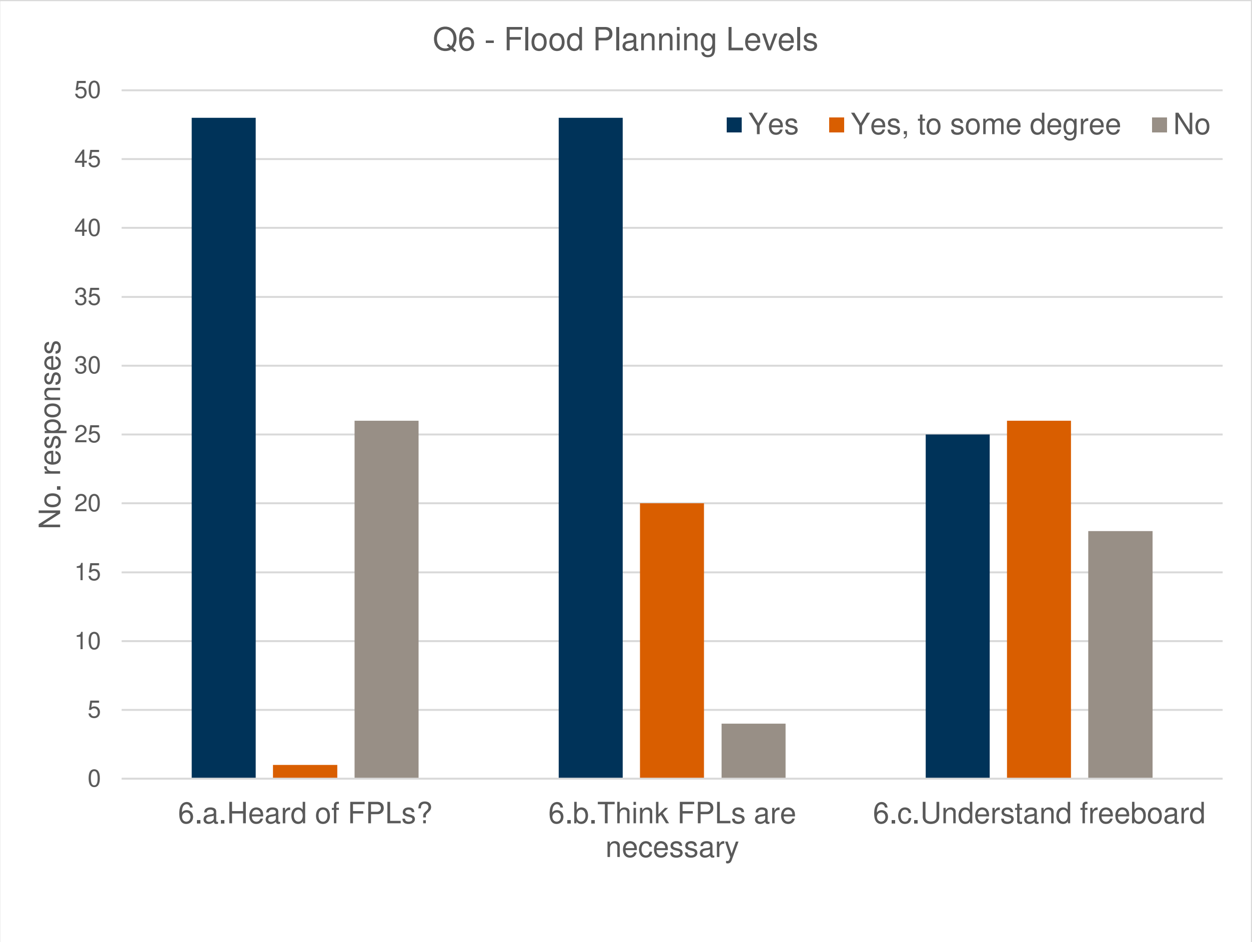
> Q6b - Do you feel that Flood Planning Levels are necessary for the protection of property and life?

> Q6c - Do you understand what a freeboard is and why it is included in the Flood Planning Levels?

Many residents responded that they have heard of FPLs and thought they were necessary; however, responses were mixed when residents were asked whether they understood what a freeboard was and why it is included in the FPLs.

Concerning controls placed on new developments, respondents nominated the placement of restrictions on flood-prone land as the most favoured option to minimise flood risk. No responses indicated that there should not be any controls on development in flood-affected areas.

Table 4-1 highlights the preferred flood mitigation options based on the community questionnaire. Each option had its total score calculated based on the responses received and were ranked from the most preferred to the least preferred option.



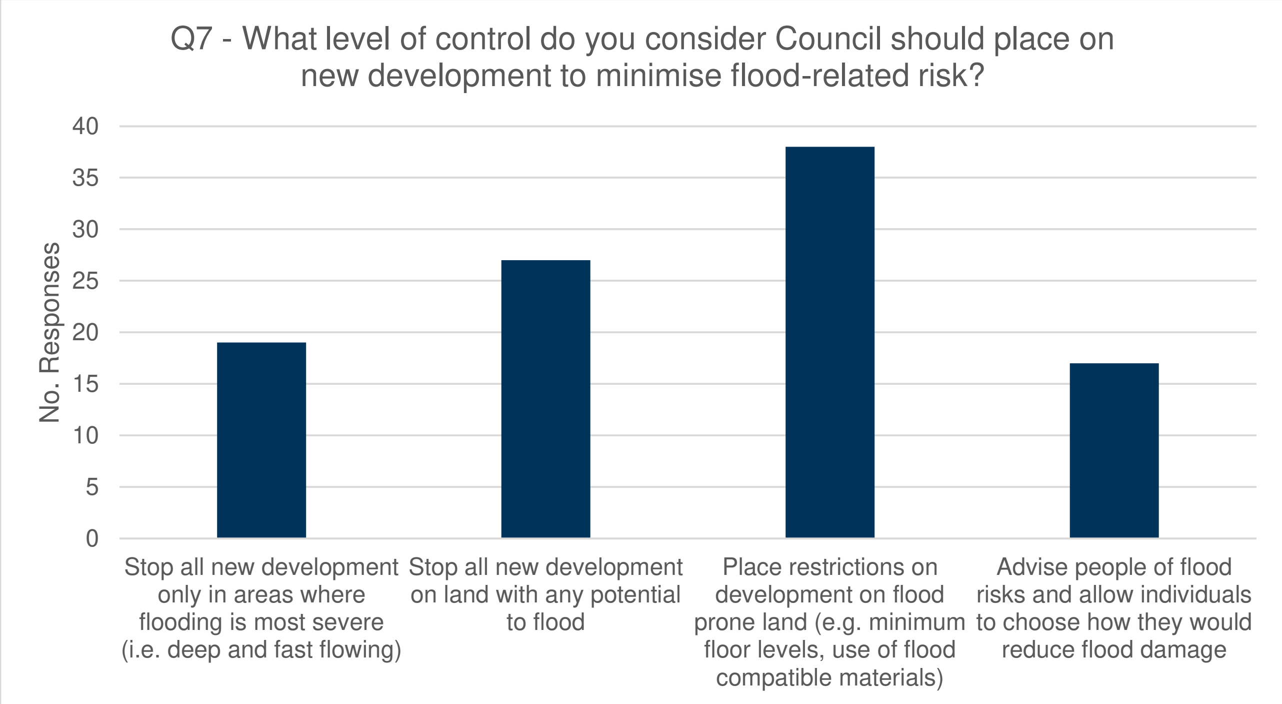


Table 4-1 Question 8 -Preferred Flood Mitigation Options

Floodplain Management Option	Rank
Planning and flood related development controls to ensure future development does not add to the existing flood risk	1
Environmental channel improvements, including removal of weeds and/or bank stabilisation	2
Flood forecasting, flood warning, evacuation planning and emergency response such as early warning systems, improved local SES capabilities/resources or improved radio and phone communication	3
Improved flood flow paths through drain reshaping	4
Raising of bridges, enlarging pipes under road crossings	5
Education of community, providing greater awareness of potential hazards and ways to maximise your own personal safety	6
Retarding or detention basins; these temporarily hold water and may reduce flooding	7
Levee banks	8
Voluntary purchase of highly affected properties by Council and demolition of any buildings on the property	9

4.1.3 Outcomes of Community Questionnaire

Based on the feedback provided in the returned questionnaires, the following key outcomes have been derived:

> A significant number of respondents (65%) were concerned with risk to property due to flooding, 39% were concerned with inconvenience related to flooding, and 27% were concerned with risk to life due to flooding;

> More than half (55%) of respondents were concerned with floods affecting specific roads in the area, 45% of respondents were concerned with flooding at their property, and 23% were concerned with flooding in public areas;

> Many respondents (60%) had heard of FPLs and felt that they were necessary for the protection of property and life, while only some (31%) of respondents understood what a freeboard is and why it is included in the FPLs;

> The most popular option chosen by respondents to minimise flood-related risk was the placing of restrictions on development on flood-prone land with 50% of respondents choosing this option. A total of 35% of respondents considered stopping all new developments on land with any potential to flood as needed to minimise flood-related risk;

> The implementation of planning and flood-related development controls was the most popular management option chosen by residents for the Bega River and Brogo River area with 51% of respondents choosing this option as most preferred. On the other hand, the voluntary purchase of highly affected properties by Council was the least popular management option with only 12% of respondents choosing it as their most-preferred option.

These outcomes were taken into account during the formulation and assessment of potential flood mitigation options in later stages of this project. It is noted that as the returned responses represent a small percentage of the overall population, they cannot be considered "community views". These comments will be revisited after the public workshops, once the community has had the opportunity to review the quantified hazards and risks, and the community are able to provide opinions that are more informed.

4.2 Community Workshops

As part of the FRMS&P, two community workshops were held to present the status of the study and any associated findings to residents, and to provide an opportunity for the community to offer their comments and feedback on the findings and any other concerns or issues relating to flooding and the study.

4.2.1 Workshop 1 – Formulate Management Options

The first workshop was held at Bega Valley Shire Council Chambers building in Bega on Wednesday 6 April 2016. Two sessions were held, one during the day, and one in the evening, in order to cater to the needs of the community. The workshop was undertaken to introduce the study to the community, and to hold a preliminary discussion on potential mitigation strategies.

Key comments and feedback that was provided by the community during the workshop included:

> There was generally a good understanding of flood risk from the Bega and Brogo Rivers. Residents and business owners seemed well prepared for these events and therefore the impacts of the flooding were often mitigated to some effect.

> The impacts of overland flows from rainfall within the local catchments were less well understood, and hence residents were less prepared for the impacts.

> There are isolation issues in several locations, in particular the area downstream of Bega which can have roads cut by floodwaters for over three days.

> The Bega and Brogo Rivers, as well as local creeks and streams, are overgrown with willows and other invasive species, which increases flooding problems.

> There was a high level of interest in flood warning systems.

> Bridges and culverts are often blocked by debris during flood events.

4.2.2 Workshop 2 – Feedback on Proposed Management Options

The second series of workshops was held following the development of the potential flood risk management options, during the public exhibition period.

4.3 Public Exhibition

The Draft Bega and Brogo Rivers Flood Risk Management Study and Plan was placed on public exhibition from 11 October 2017 to 5 November 2017. A variety of methods were employed to inform the community of the exhibition process and to invite them to view the plan and indicate the extent of their support for the plan.

These methods included:

- Notification placed on Council's website;
- Media release issued in local paper;

- Attendance by Council at a radio spot on local ABC radio;
- A series of community workshops; and,
- A formal submission portal on Council's website.

4.3.1 Workshops

The community workshops were run as drop in sessions where interested community member could discuss the project and its recommendations with Council, Cardno and OEH staff. Throughout the public exhibition period four (4) workshops were held: 3 in Bega and 1 in Candelo.

- Workshop 1, Friday 20 October, Bega
- Workshop 2, Wednesday 1 November, Bega
- Workshop 3, Thursday 2 November, Bega
- Workshop 4, Thursday 2 November, Candelo

In total, twenty one (21) residents attended the community workshops during the public exhibition. Discussion at all the workshops centred around four key themes:

- The effect of the updated flood extents on insurance premiums. Many residents were concerned that these results may cause an increase in their premiums;
- How the 1% AEP and PMF event will restrict development opportunity on flood affected land;
- For the Bega workshops, discussion was around the difference between mainstream flooding (as shown on the maps) and overland flood arising from local rainfall; and
- How the 1% AEP flood extent compared against the 1971 event. There was a common community perception that the 1971 event was the largest flood that could be experienced, and that if land wasn't flooded in 1971, then it was in fact flood free. This was discussed at each workshop and the community were informed that larger flood events are certainly possible.

Throughout the exhibition period, Council received phones calls and office visits with regards to the study. A small number of one-on-one meetings were also held with interested individuals onsite to discuss the project.

4.3.2 Submissions

In all ten (10) formal submissions were made by residents throughout the exhibition period. Overall, the public exhibition garnered a good community response, with a number of highly informed submission made regarding the study. A summary of submissions received and responses to those submissions are provided in **Appendix F**.

In response to the community feedback received throughout the public exhibition, a number of updates and additions to the draft Study and Plan were undertaken. These changes include:

- The aerial imagery for the Bega maps were updated to show a more recent image, which includes the hospital and by-pass;
- An option to assess the impact of vegetation management was undertaken and additional discussion was provided in the report with regard to vegetation management; and
- An option to install flap gates on Sharpe St culverts in Candelo was included to prevent floodwaters from backing up into properties.

5 Catchment Flood Behaviour

5.1 Existing Behaviour

The primary study area is subject to mainstream river flooding, local catchment flooding and tidal influences. The following sections discuss the flood behaviour at key locations throughout the river reach.

5.1.1 Riverine Model Results

A flood extent map comparing the extents of the 10% AEP, 1% AEP and PMF events is shown in **Figure 5-1**. This provides an overview of the areas impacted by flooding and what additional land is impacted as the severity of the flood increases.

Flood depths for the 10% AEP, 5% AEP and 1% AEP events and the PMF are shown in **Figure 5-2** to **Figure 5-5** respectively.

A peak flood profile along the Bega River is shown below in **Figure 5-6**.

A summary of the behaviour along the Bega and Brogo rivers is provided below.

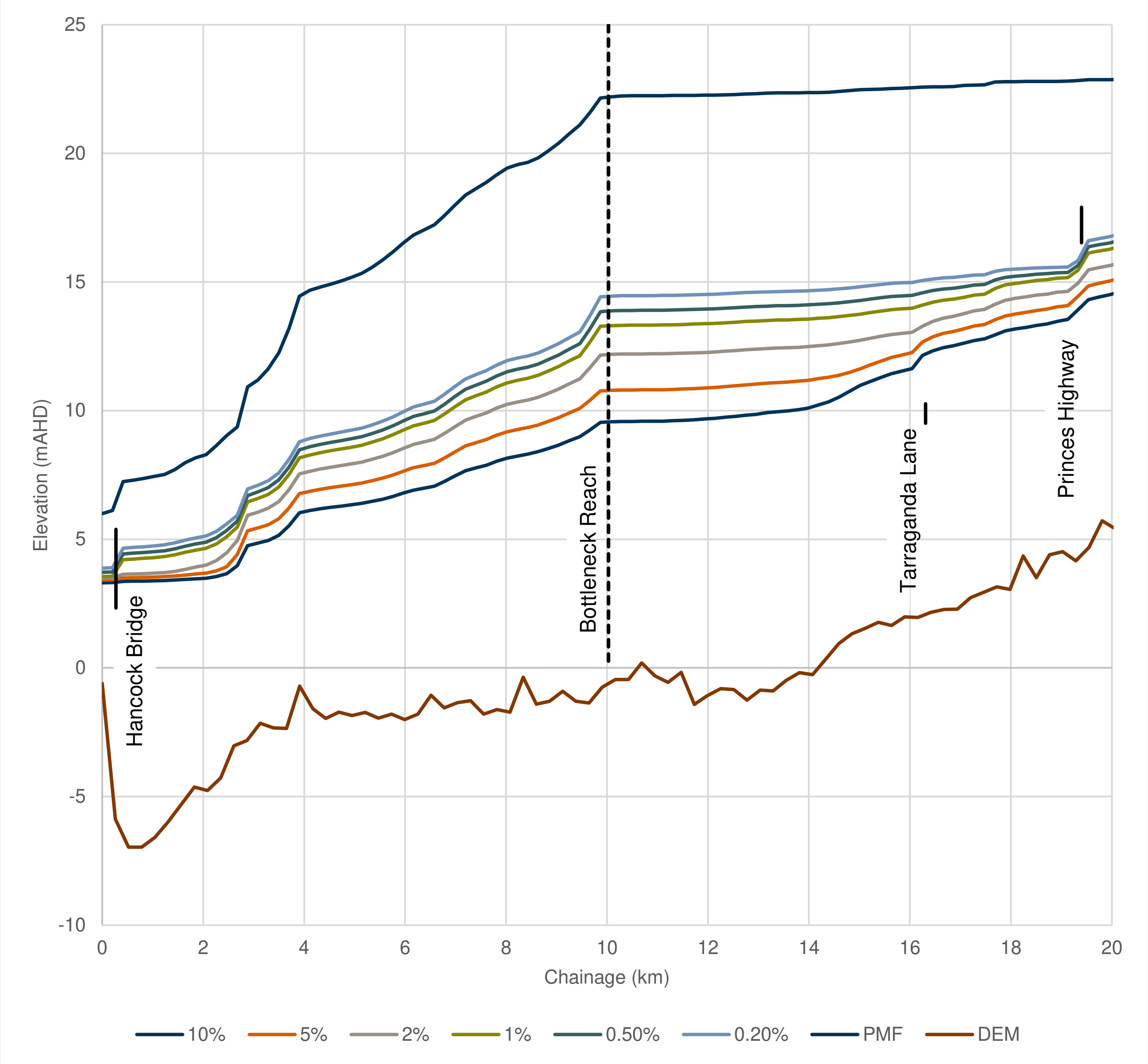


Figure 5-6 **Bega River Long-section**

5.1.1.1 Candelo Creek

The township of Candelo lies on Candelo Creek, a tributary of the Bega River with its confluence approximately 15 km upstream of the Bega Township. Flooding of Candelo Creek is typically well contained in events up to the 10% AEP event, with some road affectation in reaches with low banks. Dwelling affectation commences in the 10% AEP for properties located adjacent to the creek. Although property affectation increases with larger events, the terrain general contains flooding in larger events to the area immediately adjacent to the creek.

5.1.1.2 Bega River Upstream of Bega

Flooding in the Bega River Upstream (upstream of the Princes Highway Bridge) is largely contained within agricultural land. The terrain is generally steep as the river flows through the valley, resulting in high flood depths in the mainstream (in excess of 10 m in some locations for the 1% AEP event).

Properties at the western end of High Street are likely to be impacted by flooding in the 1% AEP, although flooding is expected to be confined to the rear of the properties. The flow velocity is largely greater than 1.5 m/s across the floodplain, and as high as 4 m/s in some locations.

A large length of Buckajo Road (from Spring Creek downstream to the Princes Highway Bridge) will be inundated by high hazard flooding in events greater than and including the 10% AEP, with flood depths greater than 1 m likely to occur across the length of the Road. This will affect the ability of some residents to access the Bega Township during and following a flood event.

5.1.1.3 Brogo River

The Brogo River discharges to the Bega River north of the Bega Township.

Upstream of the confluence, flow is contained within a valley, resulting in flood depths of up to 10 m in the 1% AEP event (high hazard)

Flooding of the Brogo River impacts Angledale Road, although the community does have access to the Princes Highway and can reach the Bega Township if required.

Development is generally confined to areas that are more elevated. Low-lying areas impacted by flooding are generally used for agricultural purposes.

5.1.1.4 Bega Environs

The Bega River (downstream of the Princes Highway Bridge) flows adjacent to the Bega Township then through agricultural land for which development is largely contained outside of the 1% AEP flood extent. The key flood mechanism is overbank flooding from the Bega River. Flooding can extend some 500 m across both the right and left sides of the floodplain.

The Princes Highway Bridge remains flood free in the 1% AEP event, allowing traffic movement to and from the Bega Township to the north. It is noted that the study area does not extend further north, and hence there would be a reliance on adjacent studies to understand impact on traffic movements to the north.

Some properties on the northern and eastern outskirts of the Township are impacted by the 1% AEP flood, with a small proportion of properties also impacted by the 10% AEP. Most properties are constructed on elevated land around the floodplain.

The Bega Township is also subject to flooding from local catchment flows. An assessment of three local sub-catchments has been undertaken, and is discussed in **Section 5.1.2**.

5.1.1.5 Bega River Downstream

Tarraganda Lane will be inundated in the 10% AEP event, with flood depths greater than 2 m on the road likely. This will impact the ability for the community to travel between the left bank of the Bega River (Bega Country Club) to the Bega Township.

East Street and Tathra Road are also impacted in both the 10 and 1% AEPs, with some adjacent properties situated in low-lying areas. Alternate routes are available to access essential services.

Aerial imagery suggests parking or camping is permitted at the corner of Park Lane and East Street. This site is likely to flood in the 10% AEP event.

A sewage treatment plant is situated on the edge of the floodplain at the end of Taronga Crescent. Parts of the facility are likely to be impacted in the 1% AEP and flooded roads could impact access to the facility.

5.1.1.6 Jellat Jellat

Upstream flows from both the Bega and Brogo Rivers are generally constrained by their respective valleys. As the flow continues further downstream, the floodplain expands providing more flood storage. Flow is then constrained downstream of the confluence of Jellat Jellat Creek by Bottleneck Reach.

Because of the Bottleneck Reach constriction, overbank flooding at this location is directed to Benooka Lake and then Horse Shoe Lagoon, Penuca Swamp and Betunga Swamp. The surrounding floodplain, the lake and lagoon provide significant flood storage. In the 1% AEP, the region stores approximately 9.7 million cubic metres of water. In the PMF, this increases to approximately 21.9 million cubic metres. This represents storage of 2% of the total flood volume in the 1% AEP and 1% of the PMF.

A velocity plot for the region for the 1% AEP is shown in **Figure 5-7**. Arrows for velocities less than 0.5 m/s have been filtered out of the plot. The figure shows that overbank flows from the Bega River shed into the region relatively uniformly along the interface between Jellat Jellat and the River corridor. The velocity arrows show some flow re-entering the Bega River at the start of Bottleneck Reach, but this flow is isolated and appears to be overbank flows re-entering the channel, as opposed to water exiting the storage area.

There are elevated flow velocities between the separate lake bodies, while velocities within the lakes are generally small and moving southeast as the lakes fill with floodwaters. The velocity in the Bega River drops sharply from 3 m/s in the upstream reach to 0.7m/s immediately upstream of Bottleneck Reach.

This flood behaviour results in Tathra Road becoming inundated. Peak flood depths of approximately 4 m and 8 m for the 10% and 1% AEP respectively are likely. This would prevent access along Tathra Road between Bega and Tathra.

To the north of the Bega River, flooding extends as far as Reedy Swamp Road. Blocking access in multiple locations. A number of dwellings located on Emma Road would be somewhat isolated in flood events as small as the 10% AEP.

The inundation of these roads, along with Tarraganda Lane further upstream, means access between Bega and smaller towns such as Kalaru and Tathra would be difficult during flood events. Access would likely be restricted for as long as three days.

The sparse development is concentrated on elevated ridges outside the floodplain. In some instances, parts of properties could be impacted in the 1% AEP event, although flooding will not likely impact buildings.

5.1.1.7 Bottleneck Reach

Bottleneck Reach is a significant constriction that lies immediately downstream of Jellat Jellat. The Reach throttles the flow from over 1,000 m wide upstream in the 1% AEP and PMF events, down to 300 m through the constriction. In the 1% AEP, flow reduces from 10,400 m^3/s in the Bega River upstream down to 3,900 m^3/s through Bottleneck Reach; a reduction of over 60%.

Velocities through the Reach are elevated, rising from 0.7 m/s upstream of the reach to 7 m/s through the reach itself.

Bottleneck Reach runs for approximately 7 km and fully contains all events up to and including the PMF. Bottleneck Reach also results in backwater effects extending upstream towards Bega. In the PMF event, this backwater effect extends as far as the Princes Highway. This effect can be seen on the flood profile (refer **Figure 5-6**), which shows flatter water levels upstream of Bottleneck Reach as a result of the flow throttling arising from the Reach.

5.1.1.8 Tidal Regions

Flow between Jellat Jellat Flats and the outlet to the Tasman Sea in constrained in a well-confined valley known as Bottleneck Reach. Depths of approximately 9 m and velocities in excess of 4 m/s for the 1% AEP event result in very hazardous flood conditions through this region.

Forest and vegetation is present on the steep banks, with minimal development present. Access roads (likely private roads) can access high-risk flood area.

Further downstream, Tathra-Bermagui Road is likely to become inundated in the 10% AEP event. This will restrict access along the road.

In addition to mainstream flooding and ocean surges, the tidal region is affected by low level flooding in High High Water Solstice Spring (HHWSS) tides that have the potential to impact low-lying areas, in particular at the ocean entrance.

In order to assess the tidal inundation of low-lying areas, the TUFLOW model was run with a time varying downstream boundary representative of the HHWSS tide. The tidal inundation model did not include wave processes or catchment rainfall. The model was run for current conditions, a 2050 scenario incorporating projected sea level rise of 0.4 m and a 2100 scenario incorporating seal level rise of 0.9 m.

Tidal extents for the existing, 2050 and 2100 scenarios are shown in **Figure 5-8**.

In general, the results show a noticeable change in tidal extents between the existing and 2050 scenarios. The change between the 2050 and 2100 scenarios was not as marked.

In both the existing and 2050 scenarios, the tidal extent is limited to waterways and adjacent swampy or vegetated areas, such as the region behind the sewage treatment plant. The existing and 2050 tidal extents do not affect developed areas or access through the region.

Although the 2100 extent does not significantly change from 2050, in 2100 the increase in water levels results in overtopping of Tathra-Bermagui Road, south of the Bega River Bridge. Immediately south of the bridge, tidal depths are 0.15 m, which is still trafficable. However, 250 m south of the bridge, the tidal levels reach 0.45 m, cutting access along the road. Access is lost for three hours, until the outgoing tide causes the water levels to drop.

No developed properties are affected by tidal inundation in the 2100 scenario.

5.1.1.9 Wallagoot Lake

Wallagoot Lake is located immediately south of Tathra and adjacent to Jellat Jellat Flats. While notionally in a separate catchment area, the Flood Study results demonstrated that in the PMF event, levels in the Bega catchment were sufficiently high to overtop the ridge separating the Bega catchment from Wallagoot Lake, resulting in overtopping flows from Jellat Jellat Flats discharging into Wallagoot Lake.

This breakout only occurred in the PMF event, and only in the short duration scenario; the long duration PMF event did not show this overtopping.

In translating the Flood Study model into TUFLOW, some peak level differences occurred between the two models. One of these was a slight reduction in the peak flood levels at the extent of Jellat Jellat Flats, which resulted in this flow path no longer activing in the PMF event.

However, as the Flood Study demonstrates, activation of this flow path is possible and will become increasingly likely as flood levels increase due to climate change. It should be noted, however, that the activation of this flow path would always be a rare event, even under climate change conditions.

The peak overtopping depth observed in the Flood Study was 0.28 m, with a flow width of approximately 50 m. The flow path was active for approximately eight hours. The peak flow rates 49 m^3/s, with a total discharge of 637,000 m^3 over the eight hours.

A review of available aerial photography suggests that Wallagoot Lake is often closed to the ocean. Taking this condition as a worst-case scenario, whereby floodwaters would be fully contained within the lake, the discharge would result in lake levels increasing by approximately 0.9 m.

Infrastructure around the lake edge is generally 0.4 – 0.6 m above this lake level. As such, this increase is not expected to adversely affect any of the existing development around the lakeshore.

It should be noted that this assessment is based on a flood in the Bega River, and no flooding in the Wallagoot Lake catchment. In a PMF event however, it would reasonable to expect that the Wallagoot Lake catchment would be experiencing substantial rainfall, as well as elevated ocean levels. The 0.9 m increase from Bega River flooding would then be in addition to elevated lake water levels due to local catchment and ocean flooding. The modelling of this coincident flooding is beyond the scope of this study. However, assuming that ocean levels in the PMF are similar to those occurring at Tathra, this would result in an increase of lake levels of 1.5 m due to ocean conditions alone. As such, the flood increase arising from Bega River overtopping flows are not considered the primary driver of flooding in the region, and are likely to be significantly overshadowed by local ocean and catchment flooding in a PMF event.

5.1.2 Local Sub-catchment Model Results

As previously noted, Bega is subject to flooding from both overbank riverine flows from the Bega River as well as flooding from local catchment flows. To further investigate the impact of local catchment flooding, three sub-catchments were identified for assessing local catchment flood behaviour:

> Downstream of the Bega Bypass and Finucane Lane in the Ravenswood Street / Charlotte Street area;

> Between Boundary Road and Kerrisons Lane; and

> Between Rawlinson Street and Applegum Close.

These regions are adjacent to one another. As such, a single local model was prepared to assess the overland flow behaviour of these regions. The local model adopted the same terrain data and model parameters as the larger model, with the exception of rainfall, which was applied directly to the 2D grid to assess overland flow behaviour.

The model boundary and sub-catchment areas are shown in **Figure 5-9**.

Peak flood depths for the 1% AEP event are shown in:

> **Figure 5-10** for the Ravenswood Street/Charlotte Street area;

> **Figure 5-11** for the Rawlinson Street and East Street; and,

> **Figure 5-12** for the Boundary Road and Kerrisons Lane.

Provisional hazard mapping (refer **Section 5.1.4** for further details) for the 1% AEP is shown in:

> **Figure 5-13** for the Ravenswood Street/Charlotte Street area;

> **Figure 5-14** for the Rawlinson Street and Applegum Close; and,

> **Figure 5-15** for the Boundary Road and Kerrisons Lane.

Ravenswood Street / Charlotte Street

In the Ravenswood Street / Charlotte Street sub-catchment, the corner of Ravenswood Street and Charlotte Street is overtopped in the 10% AEP event by 0.2 m. In the 1% AEP, these depths increase to 0.3 m.

The flows result in loss of access to the residential properties at the corner of Charlotte Street and Ravenswood Street. The property is outside the 10% AEP local flood extent, but experiences lot flooding in the 1% AEP. The house floor levels are above the local catchment 1% AEP levels.

In the 1% AEP, the provisional hazard of all local flooding was found to be low, because of both shallow depths and low velocities.

Rawlinson Street / East Street

The corner of Rawlinson Street and East Street is overtopped in the 10% AEP event, by 0.05 m. In the 1% AEP, these depths increase to 0.1 m.

In the 10% AEP event, some light industrial areas on Rawlinson Street experience flooding by depths of up to 0.15 m. In larger events, residential properties in the blocks north and south of Rawlinson Street experience flooding; however, the depths are minor with peak depths in the order of 0.05 m.

In the 1% AEP, the provisional hazard of all local flooding was found to be low, because of both shallow depths and low velocities.

Boundary Road / Kerrisons Lane

In the Boundary Road sub-catchment, Tathra Road is overtopped by flows in the 10% AEP event over a length of approximately 500 m. In the 1% AEP, the extent of inundation increases to 1,500 m. However, in both scenarios, the peak depth is less than 0.05 m.

In the 5% AEP, flooding proceeds up Glen Mia Drive, but does not affect property lots until the 1% AEP.

The bulk of the flooding in events up to the 1% AEP is restricted to open space and does not affect developed areas, with the exception of the previously mentioned flooding on Glen Mia Drive.

The local catchment flooding is generally low hazard. There are some high hazard regions because of flood depth in local water bodies, and in some ponding behind Tathra Road. These high hazard regions do not affect developed areas.

5.1.3 Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the FRMP. The Floodplain Development Manual (NSW Government, 2005) defines flood prone land into three hydraulic categories:

> 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 storage area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked, would cause peak flood levels to increase by 0.1 m and/or would cause the peak discharge to increase by more than 10%.

> Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas were defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Floodways were determined for the 1% AEP event by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below (based on Howells et al., 2003).

As a minimum, the floodway was assumed to follow the creekline from bank to bank.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%.

All flood areas that were not categorised as Floodway or Flood Storage are represented as Flood Fringe.

A provisional categorisation was completed based on a function of flood depth and velocity. This was then manually adjusted based on the nature of the flood behaviour.

Hydraulic category mapping was undertaken as for the 10% AEP, 5% AEP, 1% AEP and the PMF (refer **Figure 5-16** to **Figure 5-19** respectively).

5.1.4 Flood Hazard

5.1.4.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters (**Figure 5-20**; NSW Government, 2005) as follows:

> High hazard – possible danger to personal safety, evacuation by trucks difficult, able-bodied adults would have difficulty in wading to safety, potential for significant structural damage to buildings; and

> Low hazard – should it be necessary, a truck could be used to evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.

Provisional flood hazard mapping was used as the basis for developing the True Flood Hazard categories.

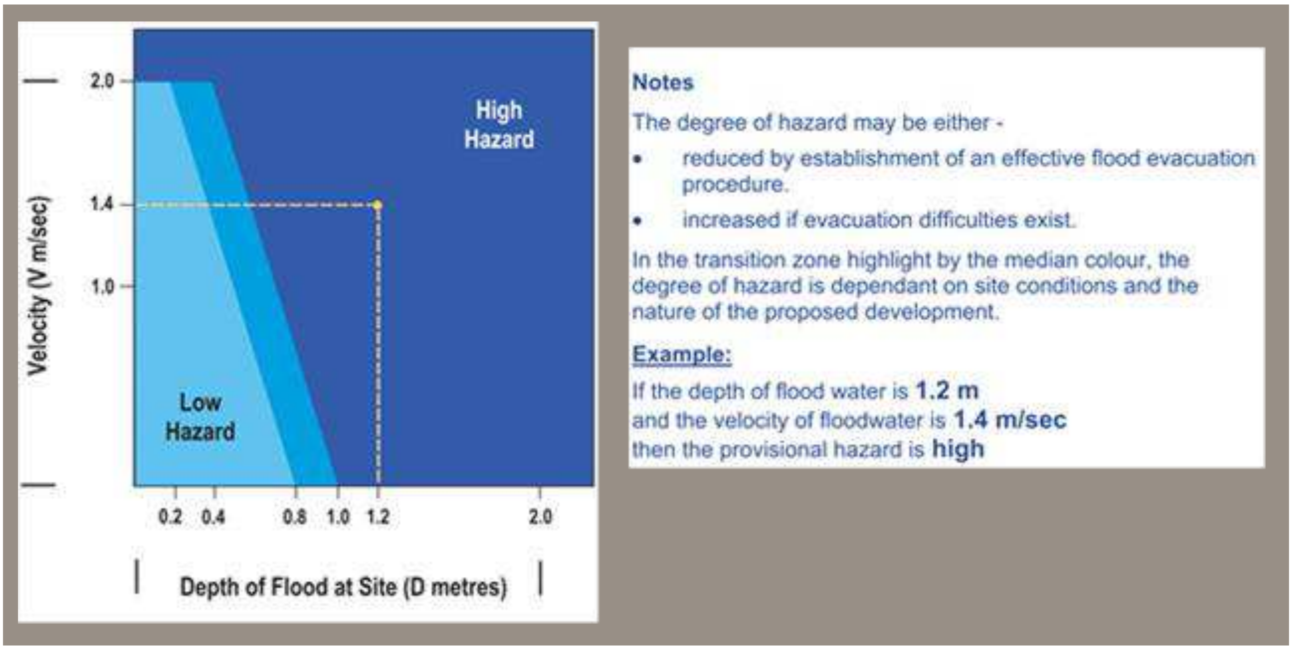


Figure 5-20 Provisional Hazard Categories (Source: Appendix L of the Floodplain Development Manual)

5.1.4.2 True Flood Hazard

Provisional flood hazard categorisation based on hydraulic parameters does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include the:

> Size of the flood;
> Effective warning time;
> Flood readiness;
> Rate of rise of floodwaters;
> Duration of flooding;
> Ease of evacuation; and,
> Effective flood access.

In the Bega and Brogo River catchments, many of the above factors are not applicable for hazard identification or do not affect the hazard mapping. However, consideration of these factors is an important process to identify the particular issues that may result in hazardous conditions for specific locations or the entire study area.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this study, provisional flood hazard has been assessed for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP events and the PMF.

Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate mitigation actions (such as lift or transport belongings and/or evacuation). The effective warning time is always less than the total warning time available to emergency service agencies. This is due to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures.

The time at which flood liable land becomes impacted following the onset of flooding is approximately six hours for the 1% AEP event, at which point roads and private properties begin to be inundated. It is noted the flood peak does not arrive for some 15 hours from the onset of flooding, and flood levels are likely to remain elevated for multiple days.

However, as there is no warning system in place at present, the long durations associated with Bega and Brogo River events do not necessarily translate to long warning times for residents. For many residents the first warning they may have of a flood occurring is inundation of their property or loss of access along roadways.

Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond efficiently to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The most recent flood event occurred in January 2016, during which a number of roads closed and as a result, a large proportion of the community was impacted.

Historical flooding has somewhat defined the location of development within the Bega Township and surrounding communities, with most of the development contained to elevated areas. Therefore, it is likely that the community is relatively prepared for flooding.

Results from the resident survey indicate that the community are aware of flooding and no particular part of the community is more aware than any other.

Depth and Velocity of Flood Waters

Depth and velocity are used to determine the provisional flood hazard using purely hydraulic considerations, as discussed above) In addition to low and high hazard categories defined by the Floodplain Development Manual (NSW Government, 2005), there is also a ‘Transitional Hazard’ categorisation (refer **Figure 5-20**), which is conservatively assumed to be high hazard. The provisional hazard mapping was undertaken in line with the methodology set out in the Floodplain Development Manual (NSW Government, 2005), and has been used as the base to determine true flood hazard.

The provisional hazard mapping shows the majority of the study area mapped as high hazard.

The Bega and Brogo rivers are contained within confined valleys. As such, flows cannot disperse and are constrained, resulting in deep, fast moving floodwater. Peak flood depths for some locations can be as great as 10 m.

An example cross-section of the Bega River is presented in **Figure 5-19**. This shows the terrain and the 1% AEP flood level. The majority of the cross section is subject to deep floodwater (greater than 5 m) which would result in high hazard. At the intersection between the flood surface and the terrain, the terrain is steep. This means the transition from deep water to shallow water occurs over a short distance, resulting in a rapid change from high hazard to low hazard.

Rate of Rise of Flood Waters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr or more has been adopted as indicative of hazardous conditions. There are no conclusive guidelines on this parameter. As such, this value has been selected arbitrarily to provide an indication of locations where waters can reach hazardous depths in a relatively short period.

It is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 0.2 m, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in identifying hazardous areas.

A flood depth of 0.5 m was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 0.5 m flood depth is well within the range of available information as to when vehicles become unstable, even with no flow velocity (NSW Government, 2005).

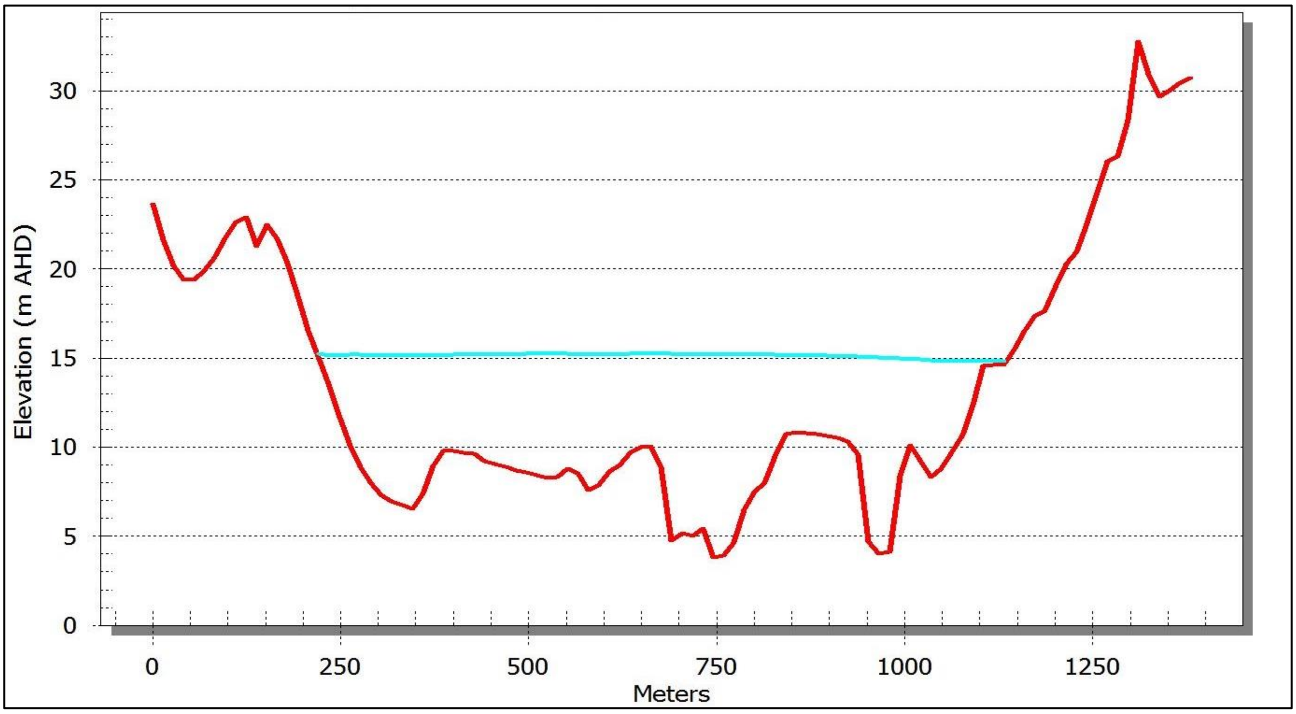


Figure 5-21 Example River Cross-Section (1% AEP Flood)

There are no properties in the study area with flow behaviour within these constraints that are not already captured by the provisional high hazard criteria. The rate of rise mapping does identify additional land subjected to high true hazard, particularly for rare events, although the mapped areas do not increase such that additional hazard is identified.

Duration of Flooding

The duration of flooding, or length of time a community, town or single dwelling is cut off by floodwaters, can have a significant impact on the costs and disruption associated with flooding. Flood durations are generally in the order of multiple days for the Bega and Brogo Rivers. A number of key access roads will be flooded for an extended period and will cause inconvenience, although alternate routes are available for some parts of the community.

Ease of Evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult because of a number of factors, including:

> The number of people requiring assistance;

> Mobility of people;

> Time of day; and

> Lack of suitable evacuation equipment.

A flood event in the catchment is likely to be a influenced by rising river levels in the Bega and Brogo Rivers, with overbank flooding impacting surrounding areas. The time difference of around six hours between rainfall predictions that trigger a 'Flood Watch' and the time for flows to reach the Bega Township and communities downstream allows time to prepare for and manage an evacuation or shelter in place, if required.

Effective Flood Access

The availability of effective access routes to or from flood-affected areas can directly influence personal safety and damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

Access issues vary across the floodplain. For the purposes of this assessment, properties were identified as being in one of these flood access categories:

> Site is flooded and evacuation required through a high hazard flooded roadway;

> Site is flooded and evacuation is required through a flooded roadway; or

> Site is flood free, however all road access is impeded by floodwaters.

To consolidate these categories and determine the implication of flood access issues on hazard mapping, criteria were set to establish effective flood access. It was determined that effective access is a road that is flooded by less than 0.3 m of water. For the purposes of this assessment 0.3 m is the threshold depth at which vehicles become unstable, even at very low flow velocities.

The assessment is based on vehicles able to access either the Bega Township or the Princes Highway as these remain flood free up to the PMF and are likely to provide the essential services that the community may require.

Properties located east of the Bega River and south of the Brogo River (Tarraganda Lane and Corridgeree Lane) will have all major access roads cut during a flood. The only access is through State Forest, which is unlikely to suitable as an effective access route.

Residual Flood Risk

The flood results show that there is a significant increase in the PMF event over the other AEP events assessed. This is largely due to the downstream constriction and the basin-like landform of the study area, which results in the greater volume of floodwater in the PMF held in the floodplain around the Township.

This results in PMF flood levels being, on average, 2.7 m deeper across properties when compared to the 1% AEP (3.9 m compared to 1.2 m). For the most severely affected properties, the PMF depth is 7.9 m higher that the 1% AEP (11.7 m compared to 3.8 m).

5.1.4.3 Outcomes of Hazard Assessment

The provisional hazard mapping was reviewed against the factors for true hazard. Several key issues were identified relating to flood hazard and risk because of this review.

In most cases, the provisional hazard mapping already identified items discussed in the true hazard assessment. Areas that are not directly impacted by floodwaters, but access to and from a property has been restricted are included in the true hazard mapping.

True hazard mapping has been undertaken for the 10%, 5%, 1% AEP events and the PMF (refer **Figure 5-22** to **Figure 5-25** respectively).

5.1.5 Flood Emergency Response Planning Classification of Communities

Flood emergency response classifications provide an indication of the relative vulnerability of the community and provides the State Emergency Service (SES) with valuable information for managing emergency responses to flood events.

The classifications are shown in **Figure 5-26**, and include:

> Low Flood Island – region is first surrounded, and then impacted by flooding in the PMF;

> High Flood Island – region is not inundated by the PMF but access may be restricted;

> Overland Escape Route – region and access impacted by PMF. People can escape rising flood waters by moving overland to higher ground;

> Rising Road Access – regions where access roads rise steadily to flood free ground and allow egress as flood waters rise; and

> Indirectly Affected Areas – regions that are outside the flood limit that retain access.

These classifications have been undertaken in accordance with the floodplain risk management guideline Flood Emergency Response Planning Classification of Communities (DECC, 2007).

Local evacuation or vertical refugia should be considered for properties in areas identified as low flood islands. This is discussed further in **Section 10**.

5.2 Predicted Future Flood Behaviour due to Climate Change Impacts

Climate change has the potential to impact flood behaviour in the study area due to both increases in sea levels and increases in rainfall intensity.

5.2.1 Sea Level Rise

Sea levels are projected to increase by 0.4 m in 2050 and 0.9 m in 2100. In addition, Council has undertaken additional assessments on a 0.98 m rise by 2100.

For the 1% AEP event, impacts on flood behaviour from sea level rise are focused on coastal areas. In the 2050 scenario, peak flood levels increase by 0.33 m at the Tathra-Bermagui Road Bridge at Mogareeka. Increases in river levels are observed 4.1 km upstream from Mogareeka, to just inside the downstream extent of Bottleneck Reach.

In the 2100 scenario, peak levels increase by 0.67 m at the Tathra-Bermagui Road Bridge at Mogareeka. Upstream impacts extended for a significantly greater distance, up to 21 km upstream from Mogareeka, beyond the Bega River and Brogo River junction. While the extent was significant, the increase was generally minor, with increases of 0.01 m at Bega, and 0.07 m at the upstream end of Bottleneck Reach.

The alternative 2100 assessment with sea level increase of 0.98 m did not significantly alter flood behaviour compared to the 0.9 m 2100 scenario. The extent of the increases was similar, as were the impacts at Bega and Jellat Jellat Flats. The 0.98 m sea level rise resulted in slightly higher levels compared with the 0.9 m scenario immediately downstream of Bottleneck Reach of 0.02 m, and at the Tathra-Bermagui Road Bridge at Mogareeka of 0.04 m.

Based on these results, sea level rise is not expected to have a large impact on development upstream of Bottleneck Reach.

Downstream of Bottleneck Reach, and in particular at the townships of Mogareeka and Tathra, sea level rise has the potential to exacerbate existing flooding conditions.

These results support Council's current development controls that require a 0.4 m sea level rise to be considered as part of coastal and estuary developments. Council should consider replacing this requirement with one that uses the 0.9 m sea level rise projection new development as time passes, or where the design life of the proposed development merits this approach.

5.2.2 Rainfall Intensity Increase

Unlike sea level rise projections, the nature of changing rainfall intensities are not as well understood. Based on current guidance (OEH, 2011), rainfall increases of 10% and 30% were assessed for the study area in the Flood Study.

It was found that the catchment is highly sensitive to a 30% increase in rainfall intensity in the 1% AEP.

A 30% increase in rainfall intensity resulted in a flow increase of 37% at the Bega River / Brogo River confluence. This increase in flow translated to an increase in flood levels throughout the model area of around 0.9 m to 2.5 m.

Bottleneck Reach remains a key hydraulic control, with levels upstream of the reach through Jellat Jellat Flats increasing by 2.5 m, while levels downstream at the Tathra-Bermagui Road Bridge increased by 0.9 m. In and around Bega, levels increased at the Princes Highway by 1.2 m, at the Brogo River confluence by 1.7 m, and at Tarraganda Lane by 1.6 m.

Flood level increases were observed across the full model area, with increases in peak levels of 1.4 m observed 5 km upstream of the Princes Highway Bridge at the model boundary.

It is noted that these increases are all above the 0.5 m freeboard that would be provided for any structural levees constructed within the Bega region (refer **Section 11**). Based on current rainfall increase projections, the service level of the levees would be substantially reduced by a 30% increase in rainfall intensity. It is noted that the levees, if constructed, would likely be flood walls due to the height requirements. It would be worth considering the possibility of future-proofing the construction by ensuring the design would allow for additional height to be added at a later stage, in response to increased rainfall intensity (if realised).

AR&R (2016) has identified that smaller magnitude increases in rainfall intensity are more likely. The Flood Study did consider a 10% increase in rainfall intensity and assessed changes in flow magnitude in the hydrology model; however, it was not modelled in the hydraulic model (XPSWMM-2D).

The Flood Study found that a 10% increase in rainfall intensity under climate change conditions was analogous to the 0.2% AEP event based on peak flows at the confluence of the Bega and Brogo Rivers. The XP-RAFTS model outputs for the 1% AEP peak flowrate were as follows:

- 6,893 m^3/s in the Bega River upstream of the confluence, a 12% increase over existing;
- 3,568 m^3/s in the Brogo River upstream of the confluence, a 13% increase over existing; and
- 10,379 m^3/s at the confluence of the Bega and Brogo Rivers, a 12% increase over existing.

The Flood Study concluded that a 10% increase in rainfall intensity would be likely to have an impact on potential flood levels and a minor impact on flow velocities. Given the hydraulic model (XPSWMM-2D) was not run for this scenario, the predicted magnitude of change in flood levels, extents and velocities is not known; however, it is reasonable to assume it would be lower than that predicted for a 30% increase in rainfall intensity and (given the hydrological model results) similar to the 0.2% AEP results.

At this time, the uncertainty around expected changes to rainfall intensity make it difficult for Council to incorporate it into future planning. However, the significant changes to flood levels because of increased rainfall intensity demonstrate that it is an area that warrants monitoring. It is recommended that Council continue to monitor projected and actual changes in rainfall intensities, and as these begin to become more certain, to consider the resultant changes in flood behaviour and incorporation of appropriate revised FPLs in their planning controls, similar to their approach to managing sea level rise.

6 Current Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are categorised as tangible and intangible; these are summarised in **Table 6-1**.

Table 6-1 Types of Flood Damages

Type		Description
Tangible	Direct	Building contents (internal) Structural damage (building repair) External items (vehicles, contents of sheds, etc.)
	Indirect	Clean-up (immediate, removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public service)
Intangible		Social (increased levels of insecurity, depression, stress) Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress, which are difficult to quantify in economic terms. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spreadsheets. For the purposes of this project, a custom tool developed by Cardno was used based on a combination of OEH residential damage curves and FLDamage.

6.2 Damage Analysis

The flood damages assessment for existing catchment conditions completed as part of this study are based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and as such, damage curves from other catchments and available research in the area are used as a substitute.

OEH has conducted research and prepared a draft methodology to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

Commercial damage curves were adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties, namely, low value commercial, medium value commercial and high value commercial.

The damage methodology is provided in **Appendix C**.

6.3 Results

The results from the damage analysis are expressed in terms of total damages and average annual damages (refer **Table 6-3**). The total damages are the economic value of the tangible damages likely to result from a specific design flood event. The average annual damage (AAD) takes into the account the expected damage from each design event and the likelihood of that event occurring in any given year, and provides an average cost to the community per year because of flooding over the long term.

The average annual damages for the Bega and Brogo Rivers floodplain under existing conditions is estimated to be $875,879. This includes damages from the Candelo Township.

The assessment found that the total damage amount was highly sensitive to assumptions relating to below floor damage. The damage curves commence at -1.5 m with respect to floor level in order to capture damages that arise to footings and foundations as floodwaters rise. In order to ensure that these are accurately represented, the surveyed ground level was used to check if below floor flooding was expected. Due to the grid resolution, it is possible that while the grid cell is shown as flooded, the actual property may be located on a local rise that is below the grid resolution. If a property has flooding shown, but the surveyed ground level was above the recorded flood level, no below floor damages were adopted. If however, the surveyed ground level was below the recorded flood level, damages were calculated for the depth relative to the floor level.

The results show that overfloor flooding occurs in the 10% AEP event. Although the number of properties affected is relatively small (13 in total, including six residential) the extent of overfloor flooding is significant with a peak overfloor flooding depth of 1.17 m occurring at the residential properties, and 1.45 m for commercial buildings.

As the severity of flooding increases, the number of properties with over floor and overground flooding consistently increases.

Damages increase consistently as the severity of the flood event increases. This is attributed to the flood depth within properties increasing consistently.

The PMF results in substantially higher damages than the 1% AEP because of the peak flood level being 7.5 m higher in the PMF compared to the 1% AEP event.

It is noted that the majority of flood affected residential properties in large events are single storey. Occupants of single storey buildings are at greater risk during flood events, as they do not have a vertical evacuation option of last resort (noting that this comes with its own risks of isolation and the possible creation of low flood islands).

The number of flood affected properties is highlighted in **Table 6-2**. The economic damages to residential properties affected are presented in **Table 6-3,** including both single and multi-storey buildings.

Table 6-2 Properties with Over floor Flooding

Event	Single Storey Residential	Multi-Storey Residential	Total Residential
10% AEP	3	3	6
5% AEP	12	10	22
2% AEP	24	14	38
1% AEP	34	21	55
0.5% AEP	43	23	66
0.2% AEP	46	24	70
PMF	186	26	212

Table 6-3 Bega & Brogo Rivers Existing Damage Analysis Results

	Over floor flooding	Maximum Over floor Depth (m)	Over ground flooding	Total Damages ($Dec 2016)
PMF				
Residential	212	10.79	212	$ 32,706,217
Commercial	71	7.48	71	$ 22,528,752
Industrial	68	10.54	1	$ 114,275
Total	**351**		**284**	**$ 55,349,244**
0.2% AEP				
Residential	70	4.18	95	$ 7,898,960
Commercial	45	4.44	52	$ 11,219,371
Industrial	1	0.27	1	$ 112,851
Total	**116**		**148**	**$ 19,231,182**
0.5% AEP				
Residential	66	4.05	93	$ 7,426,756
Commercial	45	4.29	51	$ 10,762,252
Industrial	1	0.14	1	$ 72,035
Total	**112**		**145**	**$ 18,261,042**
1% AEP				
Residential	55	3.81	86	$ 6,480,135
Commercial	41	4.08	50	$ 9,904,483
Industrial	0	0.04	1	$ 35,023
Total	**96**		**137**	**$ 16,419,641**
2% AEP				
Residential	38	3.19	59	$ 4,145,498
Commercial	28	3.48	39	$ 6,619,263
Industrial	0	0.00	0	$ -
Total	**66**		**98**	**$ 10,764,761**
5% AEP				
Residential	22	2.53	39	$ 2,426,445
Commercial	18	2.81	20	$ 3,906,720
Industrial	0	-	0	$ -
Total	**40**		**59**	**$ 6,333,165**
10% AEP				
Residential	6	1.17	15	$ 617,225
Commercial	7	1.45	9	$ 817,952
Industrial	0	-	0	$ -
Total	**13**		**24**	**$ 1,435,177**

7 Environmental & Social Characteristics

Social and environmental characteristics of the study area may influence the type and extent of flood management options that may be considered.

Social characteristics such as housing and demographics may impact the community's response to flooding and therefore affect the type of flood management options proposed.

Environmental characteristics, such as ecologically sensitive habitats, threatened species, topography and geology are constraints of structural flood modification options.

The following social and environmental characteristics were considered in the assessment:

> Demographic characteristics;

> Geology and soils;

> Flora and fauna; and

> Aboriginal and non-Aboriginal cultural heritage.

7.1 Demographic Characteristics

A knowledge of demographic character of residents of the floodplain assists in the preparation and evaluation of flood management options to ensure they are appropriate for the local community. For example, the data is relevant in the consideration of emergency response or evacuation procedures, such as where information may need to be presented in a range of languages, or special arrangements may need to be made for less mobile members of the community.

The demographic characteristics of the Bega and Brogo River catchments was sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census and aggregated to produce an overall synopsis for the catchment / region. The demographic data presented include the part or all of following settlements: Angledale, Bega, Bemboka, Bournda, Brogo, Buckajo, Candelo, Coopers Gully, Jellat Jellat, Kalaru, Mogareeka, Nelson, Reedy Swamp, Stoney Creek, Tarraganda, Tathra and Wallagoot.

These suburbs are shown in **Figure 7-1**.

A summary of the demographic data is (ABS, 2011):

> The median age of people living within the Bega and Brogo River catchments was between 45-49 years. Sixty seven per cent (67%) of the population were aged below 55 years. This indicates a community that is likely to be able-bodied and able to evacuate effectively and/or assist with evacuation procedures.

> In the Bega and Brogo River catchments, 92% of people were born in Australia. The most common countries of birth outside of Australia were England and New Zealand.

> English was the only language spoken in approximately 97% of homes in the Bega and Brogo River catchments. The most common languages spoken at home other than English were German, Dutch, Italian, and French. This indicates that there may not be a requirement for flooding information to be prepared in languages other than English.

> The average median weekly income for individuals in the region was $477, compared to the NSW average of $561. This trend of below average income for the region compared to the NSW average was also evident for family ($1,091 compared to $1,477 for NSW) and household incomes ($908 compared to $1,237 for NSW). This may have implications for the economic damages incurred on property contents during a flood event, and the ability of residents to recover after a flood event.

> In the catchment, the average median house price is $394,750, and the unit price is $290,000 (realestate.com.au, 2016). In NSW, the median house price is $566,000 and unit price is $585,000 (Australian Property Monitors, 2015). This information has implications for the economic damages incurred during a flood event.

7.2 Geology and Soils

7.2.1 Geology

When developing floodplain management options it is important to understand the geology of the catchment to ensure appropriate locations for management options are selected and to assist with the planning of suitable foundations and other constructions to cope with the geology.

The Bega and Brogo River catchments are situated on a number of geologic groups including Adaminaby Group, Bemboka Suite, Merrimbula Group, Boyd Volcanic Complex, Brogo Suite, Candelo Suite, Mumbulla Suite and Kameruka Suite.

Adaminaby Group is a sedimentary rock laid down in the Ordovician period between 485 and 443 million years ago. This geologic group consists of interbedded sandstone, mudstone, shale, carbonaceous shale and greywacke.

Merrimbula Group is a sedimentary rock formed in the Devonian period between 419 and 358 million years ago. This geologic group consists of Interbedded red shale, coarse quartzofeldspathic sandstone, and rare pebble sandstone.

Boyd Volcanic Complex is an igneous felsic volcanic group formed of acid volcanics, basalts, quartz porphyries and minor sediments.

The Bemboka, Brogo, Mumbulla, Candelo and Kameruka Suites are igneous felsic intrusive formations. The Bemboka, Brogo and Mumbulla Suites are granite formations, the Candelo Suite is formed of tonalite, and the Kameruka Suite is a biotite granodiorite.

The geological constraints on floodplain management depend on the management options selected. However, no significant geological constraints have been identified which would impact the assessment of options for this FRMS.

7.2.2 Soils

According to the Soil Landscapes of the Eden-Green Cape 1:100,000 Sheets, the Bega and Brogo River catchments are situated on 65 different soil landscape groups. These landscape groups are presented in **Table 7-1**.

Many soils may have a high soil erosion hazard, which can exacerbate flooding. Any flood modification works should consider the impacts on the numerous soil landscapes.

7.2.3 Acid Sulfate Soils

Acid Sulfate Soils (ASS) occur when soils containing iron sulfides are exposed to air and the sulfides oxidise producing sulphuric acid (DECC, 2008). This usually occurs when soils are disturbed through excavation. The production of sulfuric acid results in numerous environmental problems. It is therefore important to be aware of the distribution of ASS within the catchment, so that potential management options are developed and assessed in a manner that is sensitive to the problems of ASS (both potential and actual ASS).

The majority of the Bega and Brogo River catchments has a low probability of ASS. Some Class 1 and 2 ASS are present near the entrance to the Bega River. There are threats to the surrounding environment (e.g. the release of acid and/or the mobilisation of heavy metals) if high risk materials are disturbed. Soil investigations would be necessary to assess these areas for acid sulfate potential should any flood management works be proposed in these locations.

Table 7-1 Soil Landscapes in the Bega and Brogo River Catchments

Soil Landscape Group	Process	Soil Landscape Group	Process
Anembo	Residual	Mount Darragh variant a	Residual
Bald Hills	Transferral	Mumbulla Mountain	Colluvial
Bega River	Alluvial	Mumbulla Mountain variant a	Colluvial
Bega River variant a	Estuarine	Mumbulla Mountain variant b	Colluvial

Soil Landscape Group	Process	Soil Landscape Group	Process
Bega River Variant b	Estuarine	Murrah	Erosional
Bemboka	Transferral	Murrah variant a	Erosional
Biamanga	Erosional	Numbugga-Buckajo Swamps	Alluvial
Biamanga variant a	Erosional	Nunnock Swamp	Swamp
Big Badja	Erosional	Pambula	Residual
Black Ada Swamp	Swamp	Pambula variant b	Residual
Bournda	Erosional	Penooka Swamp	Swamp
Bournda variant a	Erosional	Penooka Swamp variant a	Swamp
Brogo Pass	Colluvial	Penooka Swamp variant b	Swamp
Brogo Pass variant a	Colluvial	Penooka Swamp variant c	Swamp
Brogo Pass variant b	Colluvial	Pigeon Box Mountain	Colluvial
Celeys Creek	Erosional	Pigeon Box Mountain variant a	Colluvial
Disturbed Terrain	Disturbed Terrain	Pigeon Box Mountain variant b	Colluvial
Duck Hole Creek	Residual	Tanja	Transferral
Glenbog-Coolangubra	Erosional	Tantawangalo Escarpment	Colluvial
Glenbog-Coolangubra variant a	Erosional	Tantawangalo Escarpment variant a	Colluvial
Goalen Head	Transferral	Tathra	Aeolian
Jellat Flat	Alluvial	Tathra variant c	Aeolian
Kalaru	Residual	Towamba River	Alluvial
Kangarutha Point	Colluvial	Towamba River variant b	Estuarine
Kydra Peaks	Vestigial	Upper Tuross	Erosional
Lower Brogo	Transferral	Wadbilliga	Colluvial
Lower Brogo variant a	Transferral	Wapengo Lake	Estuarine
Meringola Peak	Erosional	Water	Water
Meringola Peak variant a	Erosional	Wolumla Creek	Alluvial
Milligandi	Residual	Yellow Pinch	Erosional
Milligandi variant a	Residual	Yellow Pinch variant a	Erosional
Milligandi variant b	Residual	Yellow Pinch variant d	Erosional
Mount Darragh	Residual		

7.2.4 Contaminated Land and Licensed Discharges

Contaminated land is any land that contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the *Contaminated Land Management Act 1997*. The OEH is authorised to regulate contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination.

A search of the OEH Contaminated Land Record on 5 January 2016 identified no premises within Bega Valley Shire Council contaminated sites. It should be noted that contamination may be present on a site even if it is not listed on the record. Site history should be considered when undertaking flood modification works. Flood modification works within the catchment should consider the impacts that may be caused due to potential contamination on a site.

A search of the public register under *section 308 of the Protection of the Environment Operations Act 1997* (the POEO Act) on 5 January 2016 three premises within the catchment licenced by the EPA. These sites are detailed in **Table 7-2**. Flood modification works within the catchment should consider the impacts that may be caused due to these licensed premises.

Table 7-2 POEO Act Premises Licenced by the EPA

Location Name	Address	Licensed Activity
Bega Cheese Limited	Lagoon Street, Ridge Street, Buckajo Road and Angledale Road, Bega	Dairy processing
Bega Sewage Treatment Plant & Associated Sewerage Network	Lot No. 8 Taronga Crescent, Bega	Sewage treatment by small plants
Bega Valley Shire Council Central Waste Facility	Wanatta Lane, Frogs Hollow	Waste disposal by application to land

7.1 Flora and Fauna

A search of the NSW Bionet Wildlife Atlas (OEH, 2014a) on 23 July 2015 for threatened flora species recorded since 1980 showed 29 known threatened flora species within a 55 km by 70 km area including the catchment, and 65 known threatened fauna species. These species are listed under the *Biodiversity Conservation Act 2016* (BC Act).

A search was also undertaken using the *Environment Protection and Biodiversity Act 1999* (EPBC Act) Protected Matters Search Tool with a 55 km by 70 km search area around the catchment, which identified the following:

> Four Threatened Ecological Communities:
  - Littoral Rainforest and Coastal Vine Thickets of Eastern Australia;
  - Lowland Grassy Woodland in the South East Corner Bioregion;
  - Natural Temperate Grassland of the Southern Tablelands of NSW;
  - Subtropical and Temperate Coastal Saltmarsh;
> 80 threatened species; and
> 51 migratory species.

Several threatened bat species have been recorded within the catchment area:

> Grey-headed Flying-fox (*Pteropus poliocephalus*);
> Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*);
> Eastern Freetail-bat (*Mormopterus norfolkensis*);
> Eastern False Pipistrelle (*Falsistrellus tasmaniensis*);
> Golden-tipped Bat (*Kerivoula papuensis*);
> Little Bentwing-bat (*Miniopterus australis*);
> Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis*);
> Southern Myotis (*Myotis macropus*); and
> Greater Broad-nosed Bat (*Scoteanax rueppellii*).

Threatened bat species may utilise culverts or bridges as roosting habitat. Any proposed flood modification measures or flood protection works should consider the potential impacts on roosting bat species, or any other of the identified threatened species could be affected.

7.1.1 Native Vegetation

Based on the Endangered ecological communities (EECs) of the Shoalhaven, Eurobodalla and Bega Valley local government areas (VIS ID 3901) (OEH, 2013), 13 endangered or threatened ecological communities as listed under the NSW BC Act and four communities listed under the EPBC Act are present within the study area, as shown in **Table 7-3**.

Table 7-3 Threatened Ecological Communities of the Bega and Brogo River catchments

Listed under TSC Act	Corresponding community listed under EPBC Act
Bangalay Sand Forest in the Sydney Basin and South East Corner Bioregions	
Brogo Wet Vine Forest in the South East Corner Bioregion	
Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Subtropical and Temperate Coastal Saltmarsh
Dry Rainforest of the South East Forests in the South East Corner Bioregion	
Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	
Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Littoral Rainforest and Coastal Vine Thickets of Eastern Australia
Lowland Grassy Woodland in the South East Corner Bioregion	Lowland Grassy Woodland in the South East Corner Bioregion
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps	
Natural Temperate Grassland of the Southern Tablelands (NSW and ACT)	Natural Temperate Grassland of the Southern Tablelands of NSW and the ACT
River-flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions	
Swamp oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner bioregions	
Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	
Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions	

7.2 Aboriginal and Non-Aboriginal Cultural Heritage

7.2.1 Aboriginal Cultural Heritage

A preliminary investigation of indigenous heritage was undertaken by searching the Aboriginal Heritage Information Management System (AHIMS) (OEH, 2015) in January 2016 for known or potential indigenous archaeological or cultural heritage sites within or surrounding the Bega and Brogo River catchments. Over 400 sites were identified within the catchments and one Aboriginal Place, Biamanga, was identified. Biamanga is located predominantly within Biamanga National Park. Biamanga is a sacred ceremonial site.

The locations of the Aboriginal sites are not provided herein, however, the large number of sites identified indicates that Aboriginal heritage should be considered for all works proposed, particularly for works adjacent to waterways. A more detailed heritage assessment should be undertaken prior to implementation of any management actions to ensure that any proposed flood modification works will in the first instance seek to avoid impact upon these sites.

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act). Known Aboriginal sites should be left undisturbed if possible, however if a management measure requires their destruction, an

Aboriginal Heritage Impact Permit must be sought from OEH. Under the NPW Act it is a requirement that any developments show "due diligence" with regard to Aboriginal heritage in the area.

7.2.2 Non-Aboriginal Heritage

There are three different types of statutory heritage listings of non-Aboriginal significance; local, state or national heritage items. The category of an item depends on whether it is considered to be significant to the nation, state or a local area. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Aboriginal heritage was undertaken for the catchment. Databases searched include:

> Australian Heritage Database (incorporates World Heritage List; Register of the National Estate, Commonwealth Heritage List);

> NSW Heritage Office – State Heritage Register;

> Bega Valley LEP 2013.

No items were listed on the National Heritage List. Over 30 items were listed in the Register of the National Estate (Non-Statutory Archive).

The State Heritage Register returned the following items listed under the NSW Heritage Act: CBC Bank (former), 21 Auckland Street, Bega.

Over 200 heritage items of local significance were found within the catchments which are listed under Schedule 5 of the both the LEP 2013.

Part 5, Clause 5.10 of the LEP 2013 provides an outline of the provisions that must be followed in relation to heritage items. It is recommended that a heritage assessment is undertaken prior to the implementation of any management options, as there are development restrictions and procedures that may need to be followed.

7.3 Summary of Environmental and Social Issues

Environmental and social issues to be considered in the development of floodplain management strategies for the catchment include:

> The catchments have a low probability of ASS except for the area around the mouth of Bega River. There is the potential for severe environmental risk if ASS materials are disturbed by activities such as shallow drainage, excavation or clearing;

> English was the only language spoken in most homes (approximately 97% of homes) in the catchment areas. The most common languages spoken at home other than English were German, Dutch, Italian and French.

> A number of threatened and endangered species have been identified in the catchment, including the threatened microbat species;

> Over 400 Aboriginal heritage items and one Aboriginal Place were identified within the catchments; and

> Four items listed on the State Heritage Register are located within the catchments. More than 30 items are listed on the Register of the National Estate (Non-Statutory Archive) and more than 200 items are listed by Bega Valley Shire Council as having local heritage significance.

8 Policies & Planning

The study area is located within the Bega Valley Shire LGA where development is primarily controlled by the Bega Valley LEP and the DCP. The LEP is a planning instrument that designates land use and development that is exempt, permissible or permissible with consent. The DCP regulates development with specific guidelines and controls. It is noted that, while the LEP has statutory force, the DCP does not.

8.1 Local Environment Plan

The Bega Valley LEP 2013 was gazetted on 2 August 2013.

The LEP 2013 incorporates a section on flood affected land. The objectives stated in Clause 6.3: Flood Planning are:

a) "*To minimise the flood risk to life and property associated with the use of land,*

b) *To allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,*

c) *To avoid significant adverse impacts on flood behaviour and the environment."*

The land to which this clause applies is that "*at or below the flood planning level*", which is defined under sub-clause (5) as the 1% AEP flood extent plus a 0.5 m freeboard.

The relevant climate change impacts with respect to flooding are not articulated.

8.2 Development Control Plan

A DCP is prepared by Council and gives effect to the requirements of the LEP by specifying detailed development guidelines and controls.

The *Environmental Planning and Assessment Amendment Act 2017* recently passed, requiring development of standard instrument DCPs by local Councils. These standard instrument DCPs will contain a set of model provisions for application by local Councils across NSW. In developing a new DCP, Bega Valley Shire Council will also be required to review the LEP for consistency.

It is anticipated that there will be a period prior to the issue of the standard instrument DCP, and hence this review focusses on the existing DCP. Bega Valley Shire Council's existing DCP 2013, came into effect on 11 September 2013.

The following sections of the existing DCP have relevance to floodplain management.

Section 5.8.1 Flood Planning

Section 5.8 Planning for Hazards deals with respond to a variety of hazards including, flood, coastal hazards, contaminated land and bushfire. The objectives are to:

> "*Minimise the impacts of flooding on development within flood prone land or potentially flood prone land.*

> *Ensure that development on flood prone land is consistent with the objectives of the NSW Flood Prone Land Policy 1984 and the NSW Floodplain Development Manual 2005.*

> *Ensure the impact of climate change is considered when assessing development on flood prone land*".

Due to the large number of systems within the Bega Valley LGA that do not have catchment specific flood studies, Section 5.8.1 applies to land that:

> Is flood prone (below the FPL, based on results from a Flood Study);

> Is within 40 m of a creek;

> Is within 10 m of a major drainage system, local overland flow path or drainage easement;

> Has a history of flooding; or,

> Is considered flood prone by Council's Development Engineer.

Section 5.8.1 requires that:

> In estuarine areas, new residential building applications must include the impact of 0.4 m sea level rise in the determination of the flood planning level.

> All new subdivision or major development applications must include the impact of 0.9 m sea level rise.

> For development below the FPL:

  - Buildings and structures will be designed and constructed with appropriate water resistant materials.
  - Any fill or excavation must be minimised and must not adversely affect neighbouring properties or the overall flood behaviour and flood storage volume.
  - Development in areas designated as flood storage is not permitted unless it can be demonstrated that there will be no decrease in net flood storage available on the site.
  - All development applications must demonstrate that the proposed structure can withstand the force of floodwater, debris and buoyancy through a report prepared by a suitably qualified and experienced engineer.
  - All habitable rooms within residential development must be at or above the flood planning level.
  - Flood free access is required for all dwellings, caravan parks, schools, hospitals and other public building.
  - No excavated underground car parking in commercial and industrial development is permitted on land at or below the flood planning level. Ground floor parking is however appropriate.
  - All development applications for industrial and commercial development must be supported by a flood emergency response plan. Appropriate warning and advisory signage must be prominently visible at entry/exit points.

The Section also notes that the NSW Government has adopted sea level rise benchmarks of 0.4 m by 2050 and 0.9 m by 2100 (compared to 1990 levels), but does not explicitly state that these are applicable to development within Bega Valley LGA.

Section 5.8.5 Climate Change

Section 5.8.5 notes that climate change will affect flooding and sea levels within the Bega Valley LGA, with the stated objective to: "*Provide information on the impact of climate change related to housing design*".

It does not prescribe any requirements for development. Rather, the section advises that developers and purchases be aware of climate change risks and to exercise caution on commissioning or purchasing homes that may be impacted.

The DCP also notes that as information improves, Council may require mandatory controls be applied in future.

Section 6.1 Roads & Easements

This section contains requirements for the creation and construction or roads and easements. With respect to flooding, Section 6.1.2.5 Caravan Parks contains the requirement that: "*Access to accommodation facilities is to be flood free, and suitable for its intended use to accommodate a two-wheel drive vehicle in all weather conditions*."

Section 6.3 Soil & Stormwater Management

Section 6.3 sets out the requirements of stormwater management by subdivisions. Under Section 6.3, subdivision are required to:

> Safely convey the 1% AEP and greater without damage to property and infrastructure; and

> Residential flows above the 20% AEP and commercial and industrial flows above the 10% AEP are not required to be piped, so long as a designated overland flow path is provided.

8.3 Recommendations for Planning Controls for Development on Flood Prone Land

The key planning requirement for the FRMP is to undertake a review of the flood planning requirements of the LEP and DCP, and ensure the development controls related to flood planning are consistent with those in the LEP. The review should also ensure that the key controls in the DCP are given statutory effect in the LEP.

To facilitate the review, some suggested amendments to the LEP and DCP are provided in **Table 8-1**. These recommendations are proposed with a view to increasing the effectiveness of the planning controls for the Bega and Brogo Rivers study area taking into account the level of flood risk in the catchments. These recommendations will also generally benefit management of flood risk across the LGA.

Table 8-1 Review of Bega Valley Shire Council Planning Controls

Item No.	Existing Control	Recommendation
1	**LEP Section 6.3 - Flood planning** *(1) The objectives of this clause are as follows:* *…..* *(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change.* *….*	At present, the LEP does not specify the relevant parameters when considering flood hazard under climate change conditions. It is recommended that a new clause be inserted to Section 6.3 of the LEP to demonstrate compliance with sub-clauses (1) and (3). The new clause should require consideration of the potential impacts of climate change on the FPL, taking into account the relevant projections for sea level rise and changes in rainfall intensity that are likely to occur over the design life of the development. This new clause is intended to give statutory effect to the requirements in the DCP around climate change considerations. The benefit of this proposed clause is that, in moving the sea level rise requirement under Section 6.3, it would also reduce reliance on Section 6.4 – Coastal Hazards where coastal processes impact on flood behaviour.
2	**LEP Section 6.3 – Flood planning** *(2) This clause applies to land at or below the flood planning level.*	It is recommended that consideration be given to amending this sub-clause to apply to all flood prone land (i.e. all land at or below the PMF) and land mapped in this FRMS as being high flood island in **Figure 5.26**, rather than just land at or below the flood planning level. The FPL is set based on current climate conditions, and does not currently take into account the projected impacts of climate change on flood behaviour detailed in the Flood Study and summarised in **Section 5.2**. The current FPL applies to land located at or below the 100 year ARI flood level plus 0.5m freeboard. Properties located above this FPL may: ▪ Fall within the PMF extent; ▪ Be located on land prone to flooding in future due to climate change; and/or ▪ Be isolated during a flood. In order to give effect to the proposed changes described in recommendations no. 1 and 3 of this table, it is recommended that this sub-clause be amended to apply to all flood prone land (i.e. all land at or below the PMF) and land mapped in this FRMS as being high flood island in **Figure 5.26**. This will ensure that Clause 6.3 is triggered for all flood prone land, including land that is not currently at or below the FPL. This may require special approval under PS 07-003

<table>
<tr><th>Item No.</th><th>Existing Control</th><th>Recommendation</th></tr>
<tr><td>3</td><td>LEP Section 6.3 – Flood planning
(5) In this case, the FPL means the level of a 1:100 year ARI flood event plus a 0.5 m freeboard.</td><td>The current FPL does not take into account the following:
The higher flood risk to vulnerable developments or critical infrastructure; or
The significant increase in risk in the PMF, when compared to the 1% AEP, for the Bega and Brogo Rivers catchments.
It is recommended that a risk-based approach be adopted for FPLs for development in the study area, as follows:
For re-development of existing residential properties, FPLs should be set at the 1% AEP plus freeboard of 0.5 m;
For major re-developments of existing residential properties and new residential developments, FPLs should be set at the 1% AEP plus a freeboard of 0.5 m, taking into account climate change, as per recommendation no. 1 (see above);
FPLs for re-development of existing, or new, critical infrastructure be set at the PMF;
For new vulnerable developments where the proponent can demonstrate evacuation via rising road egress route is possible within the effective warning time, the FPL could be set at the 0.2% AEP plus a freeboard of 0.5 m. If rising road egress is not available, the FPL should be set at the PMF.
Definitions of “critical infrastructure” and “vulnerable development” will need to be provided to support these proposed FPLs. The intent is that “critical infrastructure” include hospitals and utilities that provide essential services (in particular to vulnerable developments), such as key power sub-stations, key sewage treatment plants, key potable water treatment/supply facilities, key telecommunications stations and evacuation centres. “Vulnerable developments” may include schools, other medical facilities, childcare and aged care facilities that are difficult to evacuate in a flood.
The above FPL definitions, critical infrastructure and vulnerable development definitions will either need to be defined in the LEP, or the definition of FPL removed such that the FPL can be defined in a matrix based on flood risk precincts and development type.</td></tr>
<tr><td>4</td><td>DCP Section 5.8.1 - Objectives
Minimise the impacts of flooding on development within flood prone land or potentially flood prone land;
Ensure that development on flood prone land is consistent with the objectives of the NSW Flood Prone Land Policy 1984 and the NSW Floodplain Development Manual 2005;
Ensure the impact of climate change is considered when assessing development on flood prone land.</td><td>The objectives do not currently address properties that may be isolated during a flood event, but are not located on flood prone land and otherwise unaffected by flooding. This is a significant issue in the catchment and a number of areas would fall under this category. At present, such developments are not required to address the risk arising from isolation by floodwaters, which may be significant for some types of development due to the long period of inundation.
It is recommended that Council consider the need to add another bullet point. The additional objective could cover the appropriate management of risk to the broader community arising from flooding, such as where access is lost during a flood or where development becomes isolated by floodwaters.</td></tr>
</table>

Item No.	Existing Control	Recommendation
5	**DCP Section 5.8.1 - Application** *This Section applies to development on flood prone land within the Bega Valley Shire as well as land that is not classified as flood prone but meets one of the following criteria:* ▪ *Is within 40 m of a creek;* ▪ *Is within 10 m of a major drainage system, local overland flood path or drainage easement;* ▪ *Has a history of flooding; orIs considered to be flood prone by Council's Development Engineer.*	Similar to the point raised in recommendation no. 4 above, it is noted that the current clause does not address properties that may become isolated during a flood event, but are not located on flood prone land and otherwise unaffected by flooding. It Is recommended that the following be included at the end of this section: "*This Section also applies to development on land that becomes isolated by flooding in any event up to and including the 1% AEP event, irrespective of whether the land is flood prone or meets any of the abovementioned criteria.*"
6	**DCP Section 5.8.1** *A number of catchments within the Shire have not been the subject of a flood study and will not be studied in the near future. Development applications proposing works within such areas may require a Flood Assessment Report be provided by a suitably qualified Hydraulic Engineer.*	It is recommended that a Flood Assessment Report be prepared for all developments below the FPL, regardless of whether a Flood Study has been undertaken or not. The report should demonstrate that the development does not result in adverse impacts off-site, result in high hazard conditions within the site, and that the requirements of the LEP and DCP have been met.
7	**DCP Section 5.8.1** *Climate change is expected to have impacts on sea levels and rainfall intensities, both of which may influence flood behaviour at specific locations. The NSW Government has adopted sea level rise planning benchmarks of 0.4 m by 2050 and 0.9 m by 2100 (as measured by an increase above 1990 mean sea levels). To date no relevant planning benchmarks have been adopted by Government related to intensity changes.*	The sea level rise projections referred to in the DCP are no longer endorsed by the NSW Government, and have not been replaced. Updated policy or advice may become available following the conclusion of the NSW Coastal Reforms, which is likely to occur in 2018. Further, it is noted that new climate change projections regularly become available. Until updated Government advice is provided, it is recommended that the sea level rise planning benchmarks be retained. A 5% increase in rainfall intensity per °C increase in local warming should be adopted, consistent with AR&R 2016. Further, it is recommended that Council consider the need to amend this text to explicitly require adoption of the projections for the climate change scenario of relevance to the design life of the development (consistent with recommendation no. 1 above).
8	**DCP Section 5.8.1.1** *For areas where Council has not adopted a Floodplain Risk Management Plan these general requirements apply.* *Where a site is classified as partially flood affected, it is strongly recommended to consider development only on the flood free portion of the allotment.* ▪ *Applicants must have regard to the provisions of Clause 6.1 of the LEP.* ▪ *In estuarine areas new residential building applications must include the impact of 0.4m sea level rise in the determination of the flood planning level.* ▪ *All new subdivision or major development applications must include the impact of 0.9m sea level rise.*	It is stated that the conditions following are applicable to regions for which a Flood Study has not been undertaken. No information is provided as to what requirements are applicable to regions for which a study has been completed. It is recommended that the test be changed to "*These general requirements apply to all flood prone land as per 5.8.1.*" The requirement to include the impact of a 0.4 m sea level rise is restricted to estuarine areas, while the requirement to include a 0.9 m sea level rise applies to all subdivision and major developments. As impacts from a sea level rise may extend beyond the "estuarine area", it is recommended that this requirement be revised to cover all new developments, consistent with recommendations no. 1 and 7. It is assumed that the first bullet point in Section 5.8.1.1 is meant to refer to Clause 6.3 of the LEP, and should be updated accordingly.

Item No.	Existing Control	Recommendation
9	**DCP Section 5.8.1.2** ▪ *Development in areas designated as flood storage is not permitted unless it can be demonstrated that there will be no decrease in net flood storage available on the site.*	No explicit restrictions based on hazard or floodways. A requirement to maintain existing flood conveyance should be incorporated. Review clause 5.8.1.2 to incorporate consideration of flood storage, floodways, hazard categories and maintenance of flood conveyance as key considerations for development below the flood planning level. However, it is noted that Section 5.8.1 – Objectives does broadly cover these items through reference to *development on flood prone land is consistent with the objectives of the NSW Flood Prone Land Policy 1984 and the NSW Floodplain Development Manual 2005.*
10	**DCP Section 5.8.1.2** ▪ *Flood free access is required for all dwellings, caravan parks, schools, hospitals and other public building.*	This requirement may be difficult to implement for areas that have significant PMF flooding. It may also result in neighbouring properties having very different access requirements if one is just above the FPL, and the other just below. It is recommended that Council amend this point to require continually rising road egress routes for all critical infrastructure and vulnerable developments, as defined in recommendation no. 3. For all other development at or below the 1% AEP, or that becomes isolated during the 1% AEP, Council may wish to include a requirement to have continually rising egress routes, and that the proponent demonstrate there is sufficient effective warning time to enable evacuation via the nominated egress route. Where this cannot be achieved, the development should be required to demonstrate that it provides for vertical evacuation sufficient to accommodate the residents / occupants of the development during the 1% AEP (as a minimum).
11	**DCP Section 5.8.3 Additional requirements for Specific Areas**	It is recommended that properties that are above the PMF, but that become isolated during a flood (for any event up to and including the PMF), are required to prepare a Flood Emergency Response Plan that demonstrates their preparedness to evacuate and/or shelter in place in the event egress is not available.
12	**DCP Section 6.3.1** *Subdivisions will be designed so that stormwater flows for rainfall events of a 100 year average recurrence interval (ARI) and greater can pass without causing damage to property and infrastructure. Stormwater flows for events larger than the 5 year ARI for residential development and 10 years for commercial and industrial development are not required to be contained within piped drainage systems however the overflow path must be planned, clearly evident on the site and contained within suitable easements, public reserves and road reserves.*	There is some ambiguity in the phrase "*rainfall events of a 100 year average recurrence interval (ARI) and greater.*" In order to improve clarity, it is recommended that this be revised to "*rainfall events up to and including the PMP (Probable Maximum Precipitation) event.*"
13	**DCP Section 5.8.1** General comment.	Throughout the document, floods are referred to in terms of ARI. It is recommended that the nomenclature be revised to use % AEP terminology. This will be consistent with the recommendations to change terminology for FPLs in the LEP to % AEP (refer recommendation no. 3).

8.4 Section 149 Certificates

Under Section 149 of the *Local Government Act 1993*, Council provides information on hazards affecting individual lots to property owners (or purchasers) via what is known as an "s149 Certificate". Where the subject land is notified as being subject to a hazard (such as flooding) under Section 149(2), there are development controls that apply to the land. Where the subject land is notified as being subject to hazard under Section 149(5) of the Act, there are no specific development controls governing the use of the land.

The application of clauses relating to hazard from mainstream and coastal flooding are discussed below.

8.4.1 Mainstream Flooding

A clause is added to the s149(2) certificate if the part of the property falls within the flood planning area. The current clause states:

"Yes, development of the land is subject to flood related development controls. See Clause 6.3 of the Bega Valley Local Environmental Plan 2013. (However, it is strongly recommended that the purchaser make their own enquiries in regard to flooding)."

It is suggested that the existing clause be expanded slightly to provide more upfront information on why the land is subject to controls and where additional flood information can be collected:

"Yes, development of the land is subject to flood related development controls as the land lies within the Flood Planning Area. See Clause 6.3 of the Bega Valley Local Environmental Plan 2013. Further information on the flooding that occurs on the site may be provide by Council through the request of a s149(5) certificate. (However, it is strongly recommended that the purchaser make their own enquiries in regard to flooding)."

8.4.2 Coastal Inundation

If the property falls within the 3 m contour or is at or below the 100 year ARI coastal inundation or erosion event, a clause is added to the *s149(5)* certificate for coastal inundation. The clause states:

"This land has been identified in Clause 6.4 of the Bega Valley Local Environmental Plan 2013 as having an exposure to coastal hazards. The land is identified Clause 6.4 of the Bega Valley Local Environmental Plan 2013 because it is located or partially located within the coastal zone below the 3 metre AHD contour and reflects information available at this time. At this time, Council is not in a position to clearly identify whether the coastal hazard is a current or future hazard. Contact Council on 6499 2222 for more information."

However, the land that is the subject of this clause does not encompass all land subject to flooding in future as a result of sea level rise. The inundation mapping prepared for the Flood Study (refer to the 1% AEP flood extents under sea level rise conditions in Appendix H) shows that sea level rise increases the 1% AEP flood extents beyond the land that would be subject to coastal hazards as defined in Clause 6.4. Hence, it is suggested that a new clause be provided, as follows:

"Future flood hazard from sea level rise

This land has been identified in Clause 6.3 of the Bega Valley Local Environmental Plan 2013 as having an exposure to flood hazard under sea level rise conditions.

The Bega and Brogo Rivers Flood Study at Bega (2013) (the "Flood Study") and the Bega and Brogo Rivers Floodplain Risk Management Study and Plan (2018) (the "FRMS&P) were adopted by Council on [insert date] and [insert date] (respectively) and relate to this land.

The FRMS&P does not contain any development controls, but may form the basis of flood related development controls in future.

The Flood Study and FRMS&P Reports can be inspected at Council."

9 Flood Planning Level Review

9.1 Background

The FPL for the majority of areas across NSW has traditionally been based on the 1% AEP flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 – 0.5 m for residential properties, and can vary for industrial, commercial and other types of properties.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain. Consequently, different types of land use need to be accounted for in the setting of an FPL.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues for consideration:

> Risk to life;
> Land availability and needs;
> Existing and potential land use;
> Current flood level used for planning purposes;
> FPL for flood modification measures (levee banks etc.);
> Changes in potential flood damages caused by selecting a particular flood planning level;
> Consequences of floods larger than the flood planning level;
> Flood warning, emergency response and evacuation issues;
> Flood readiness of the community (both present and future);
> Land values and social equity; and
> Duty of care.

These issues are dealt with collectively in the following sections.

9.2 Planning Circular PS 07-003

The Planning Circular was released by the NSW Department of Planning in January 2007, and provides advice on a number of changes concerning flood-related development controls on residential lots. The package included:

> An amendment to the *Environmental Planning and Assessment Regulation 2000* in relation to the questions about flooding to be answered in s149 planning certificates;
> A revised ministerial direction regarding flood prone land (issued under section 117 of the *Environmental Planning and Assessment Act 1979*); and
> A new Guideline concerning flood-related development controls in low flood risk areas.

The Guideline states that, unless there are exceptional circumstances, councils should adopt the 1% AEP +0.5 m as the FPL for residential development. The need for an alternative FPL to be adopted would be based on an assessment local flood behaviour, flood history, associated flood hazards or a particular historic flood, which would have to demonstrate that exceptional circumstances exist within the study area to warrant a different FPL.

The Circular establishes the 1% AEP +0.5 m as the default FPL. The following sections assess the conditions in the study area against a range of criteria to determine if the 1% AEP +0.5 m is a suitable FPL.

9.3 Likelihood of Flooding

Table 9-1 was reproduced from the NSW Floodplain Development Manual (2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

The data presented in **Table 9-1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70-year period. Given this potential, it is reasonable from a risk management perspective to consider the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the intangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there remains a 30% chance of exposure to at least one flood of a 0.5% AEP magnitude over a 70-year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the FPL for some types of development.

Table 9-1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs; after: NSW Government, 2005)

Likelihood of Occurrence in any year (AEP)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10%	99.9	99.3
5%	97	86
2%	75	41
1%	50	16
0.5%	30	5

9.4 Risk to Life

Flooding poses a significant risk to life for the community in the study area. Large flood events result in the creation of low flood islands, which can rapidly be inundated with little to no warning.

Access roads within the study area are cut in events as frequent as the 10% AEP, which results in the region becoming fragmented. Access roads outside of the catchment are also likely to be cut during flood events, which will restrict the ability of emergency personnel to service the community.

These risks increase with flood severity. Unless the PMF is adopted as the FPL, there will be a residual flood risk within the community, even if all development is built at the FPL. This residual risk for Bega is significant.

The community should be assisted in understanding that adhering to flood development controls does not mean that they are free of flood risk.

9.5 Existing and Potential Land Use

The hydrological regime of the catchment can change because of changes to the land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can increase.

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. The DCP 2013 restricts building within the floodway, and recommends against filling in flood storage areas. In general, the DCP 2013 limits development in flood prone land.

Given this and other controls (refer **Section 8**), this is not considered to be a significant issue within the catchment.

9.6 Land Availability and Needs

Issues of land availability are not of particular concern in the study area due to a modest rate of population growth in the Bega Valley Shire, and an availability of vacant residential lots for development that are in flood free areas, such as the recent development off Tathra Road opposite the hospital. Consequently, land availability is not considered an issue in setting the FPL.

9.7 Changes in Potential Flood Damages Caused by Selecting a Particular Flood Planning Level

Based on typical overfloor flood damages for a property of approximately $50,000, the incremental difference in AAD was calculated for different design flood events. **Table 9-2** shows the AAD of a given property that experiences overfloor flooding in each design event, and the net present value (NPV) of those damages over 50 years, adopting a discount rate of 7%.

Table 9-2 indicates that the largest incremental difference between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 50% and 20% AEP events. The differences between the 5% and 1% AEP event, and the 1% AEP event and the PMF are relatively small, suggesting that increasing the FPL beyond the 5% AEP level does not significantly alter the savings achieved from a reduction in damages.

Table 9-2 Differential Damage Costs between AEP Events

Event (AEP)	AAD	Change in AAD	NPV of AAD	Change in NPV
50%	$25,000	-	$345,000	-
20%	$10,000	$15,000	$138,000	$207,000
10%	$5,000	$5,000	$69,000	$69,000
5%	$2,500	$2,500	$34,500	$34,500
1%	$1,000	$1,500	$13,800	$20,700
PMF	$500	$500	$6,900	$6,900

9.8 Incremental Height Differences Between Events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the average incremental height difference between events for residential properties is shown for selected events in **Table 9-3**. These are based on the flood levels at each of the properties within the catchment and were calculated as part of the flood damages analysis. Note that differences are only calculated where flood levels are reported in the 5% AEP event.

Table 9-3 Average Differences Between Design Flood Levels For Flood Affected Properties

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)	Difference to 2% AEP (m)
1%	4.55	-	-
2%	4.64	0.07	-
5%	4.71	0.16	0.1

Table 9-3 indicates a significantly larger difference in flood level of the PMF event compared to other events. The change between the 2% and 1% AEP events is relatively small (0.07 m), suggesting that the adoption of the 1% AEP event would provide an increased level of risk reduction over the 2% AEP event without a significant effect on FPLs.

The adoption of the PMF event as the FPL would result in more significant increases in levels over the 1% AEP event (in the order of 4.55 m) and would therefore present an issue for the setting of FPLs in the catchment.

9.9 Consequences of Floods Larger than the Flood Planning Level

As shown above, there is a significant height difference between the 1% AEP and the PMF. While the average difference across flood-affected properties is 4.55 m, the maximum difference, which occurs along East Street, is 6.98 m. This means that for properties built at an FPL of the 1% AEP +0.5 m, the PMF would result in overfloor flooding depths in excess of 6 m at some properties. Even if these properties are double storey (and as shown in **Section 6.3** most are single storey), floodwaters would still inundate second storey floor levels, and as such no on-site refuge would be available.

Coupled with limited, or no warning, and an under appreciation of flood risks by the community, the PMF flood depths result in a significant residual risk for flood affected properties adjacent to the Bega River.

9.10 Flood Warning and Emergency Response

A discussion on flood warning and emergency response issues relating to the study area is provided in **Section 10**. The assessment found that:

> Warning times will be limited, and potentially non-existent. The first indication that many residents will have that a flood is occurring will be inundation of their dwelling.

> The ability of emergency services to respond to flooding in the study area will be limited by the flooding of roads both to and within the region.

> For the township of Candelo, flooding occurs over the course of several hours. This also inhibits the ability of emergency services to provide assistance, as by the time they are able to access the region, the flood waters are likely to have receded.

> The community will need to be flood resilient, and will need to largely self-manage flood concerns.

9.11 Social Issues

The FPL can result in housing being constructed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. A requirement for higher floor levels (or higher road levels) also imposes additional construction costs on new developments. The cost of constructing a building with habitable floor levels set at the PMF would be significantly higher than for the 1% AEP due to the large increase in flood levels in the PMF.

9.12 Freeboard Selection

The freeboard may account for factors such as:

> Changes in the catchment;

> Changes in the creek/channel vegetation; and

> Accuracy of model inputs (e.g. of ground survey, design rainfall inputs for the area, etc.).

Model sensitivity:

> Local flood behaviour (e.g. due to local obstructions etc.);

> Wave action (e.g. such wind-induced waves or wash from vehicles or boats); and

> Culvert blockage.

The impact of typical elements factored into a freeboard can be summarised as follows:

> Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1 m) (Gillespie, 2005);

> Local wave action (allowances of ~0.1 m are typical) (truck wash etc.);

> Accuracy of ground / aerial survey ~ +/-0.15 m; and

> Sensitivity of the model ~ +/-0.15 m (based on a 10% change in model parameters).

Based on this analysis, the total sum of the likely variations is in the order of up to 0.5 m.

A review of the potential impacts of sea level rise and increased rainfall intensity was investigated in the Flood Study, as summarised in **Section 5.2**. The increase in 1% AEP flood levels arising from sea level rise were generally fairly low and within the freeboard amount. In the upper catchment, the increase in flood levels was typically less than 5 cm.

The impact of increases in rainfall intensity was more significant, noting that the only results available are for a 30% increase in rainfall intensity for the 1% AEP. As discussed in **Section 5.2**, there is a high level of uncertainty around the magnitude and likelihood of changes in rainfall, and at present, it is thought that a smaller increase in intensity of around 5% per °C regional warming is more likely. This would translate to around 10% increase based on current projections.

Given the assessment of model sensitivity, and the uncertainty around climate change projections for changes in rainfall, it is considered that a freeboard of 0.5 m is suitable for the Bega and Brogo Rivers catchment for the time being. It is recommended that Council monitor changes in rainfall and assess new projections as they become available, with a view to reviewing the freeboard if required.

9.13 Flood Planning Level Recommendations

The FPL investigation largely supports Council's current FPLs, with some modifications proposed to address the increase in risk under the PMF (refer **Table8-1**):

> For re-development of existing residential properties, FPLs should be set at the 1% AEP plus freeboard of 0.5 m;

> For major re-developments of existing residential properties and new residential developments, FPLs should be set at the 1% AEP plus a freeboard of 0.5 m, taking into account climate change as appropriate to the design life of the development;

> FPLs for development of new critical infrastructure, or re-development of existing critical infrastructure be set at the PMF; and

> FPLs for new vulnerable developments be set at the PMF, unless the proponent can demonstrate evacuation via rising road egress route is possible within the effective warning time, in which case the FPL can be set at the 0.2% AEP plus a freeboard of 0.5 m.

Commercial and/or industrial properties have adopted higher frequency flood events such as the 5% AEP planning level based on the perception of risk. These occupants can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots don't generally provide an income to offset losses. Additionally, inventory, machinery and other assets can be stored above flood levels to lessen economic loss during a flood event.

However, as there are a relatively low number of commercial and industrial sites in the study area that are affected by floods, the adoption of the 1% AEP +0.5 m as the FPL for commercial and industrial properties is appropriate for the study area.

It should be noted that an FPL set at the 1% AEP + 0.5m level will still result in significant over floor flooding in the PMF event of up to 6.98 m. These depths are such that even properties with second floors would not be suitable for shelter in the building during a flood event. It is therefore important that other strategies be put in place, such as education and community awareness measures and the provision of flood refuges, to address this risk to life.

The flood planning area (FPA) arising from this FPL is shown in **Figure 9-1**.

9.14 Duty of Care

As noted above the adoption of the 1% AEP +0.5 m level as the FPL, while suitable, results in a residual flood risk for properties affected by the PMF. It is important that these properties be made aware of this residual risk, and that they are assisted in developing appropriate strategies to manage their safety during large flood events.

Further information on the options available to manage this residual risk are provided in **Section 10**.

10 Emergency Response Arrangements

Flood emergency measures are an effective means of reducing the risks of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for managing flooding in the Bega Valley Shire LGA are discussed in this section.

10.1 Emergency Response Documentation

10.1.1 DISPLAN

Flood emergency management for the Bega Valley Shire LGA is organised under the Bega Valley Local Disaster Plan (DISPLAN) (2003), which has effect under the authority of the *State Emergency and Rescue Management Act 1989* (as amended).

The DISPLAN details emergency preparedness, response and recovery arrangement for the region to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies.

The plan is consistent with similar plans prepared for areas across NSW and covers roles and responsibilities in emergencies, preparedness measures, response operations and co-ordination of immediate recovery measures.

The DISPLAN outlines the key responsibilities of the different organisations involved in emergency management. It is generally the responsibility of the SES, as the “combat” agency, to respond to and coordinate the flood emergency response. It is the responsibility of Council and OEH to manage flood prevention / mitigation through development controls, the floodplain management process and mitigation schemes.

The Bega DISPLAN identifies flood hazard to be a high probability with high consequences. It should be noted that this categorisation is a general one for the whole LGA.

The current DISPLAN was issued in 2003. It is recommended that the DISPLAN be reviewed and updated to ensure that the information contained is still accurate, and incorporates any new data collected since 2003. In particular, Annex A which details supporting plans and sub plans should be reviewed and updated to ensure that the latest plans are referenced.

10.1.2 Bega Valley Shire Flood Emergency Sub-Plan

The SES, in conjunction with Council, has prepared a sub-plan to the local DISPLAN. The Bega Valley Shire Flood Emergency Sub-Plan (the Flood Plan) was prepared in 2017, and covers the preparation for, response to and recovery from flooding emergencies for the LGA.

The Flood Plan focuses exclusively on flooding emergencies, and more explicitly defines the roles and responsibilities of parties in a flood event. It also makes note of which key roads can be flood affected.

The Flood Plan notes that Bega, Candelo and Tathra are all flood prone regions of the catchment. The Flood Plan also notes that a number of roads are cut in flood events, resulting in the disruption of movement throughout the catchment. The Flood Plan lists affected roads and their usual point of closure.

A key outcome of this study is the transfer of flood information to the SES. It is recommended that the Flood Plan be updated in consultation with the SES to incorporate the additional flooding information available following the completion of the both the Flood Study and this FRMS.

The key sections of the Plan to be revised are:

- Annex B: Effects of Flooding on the Community (including access road overtopping); and
- The attached maps showing the flood extents across flood affected areas.

10.2 Emergency Service Operators

The Bega and Brogo Rivers floodplain lies within the Illawarra / South Coast region of the SES. The Illawarra / South Coast region office is located at 6-8 Regent St, Wollongong.

The SES is listed as the "Combat Agency" for flooding and storm damage control in the DISPLAN, as well as the primary coordinator for evacuation and the initial welfare of affected communities.

The SES is primarily a volunteer organisation. In times of emergency, the SES operates a paging service for on-call volunteers. However, more experienced crew know when to mobilise based on their understanding of the local area.

The role of the SES in flash flood areas such as local creeks is generally at the clean-up stage. For longer duration flooding, the SES can assist in evacuation and protection of properties.

Table 10-1 Emergency Service Provider Locations

Emergency Service	Location
SES, Local Unit Headquarters	247 Newtown Road, Bega
Southeast Regional Hospital	4 Virginia Drive, Bega
Bega Valley Private Hospital	31 Parker Street, Bega
Bega Police Station	167 Auckland Street, Bega
Bega Fire Station	Gipps Street, Bega
Ambulance Service of NSW	3/1 Canning Street, Bega

10.3 Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation of residents from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

10.3.1 Access Road Flooding

Summarised in **Table 10-2** below are the key access routes out of, and through, the study area. The locations at which flood depths have been extracted are shown in **Figure 10-1**.

The table shows that while some access routes are flood free in the 10% AEP event, most are impacted by flood waters even in the 10% AEP event. The majority of the roads are inundated by 2% AEP event and all are inundated by flood waters in the PMF event.

Book 6, Chapter 7, of AR&R (2016) examined the stability of pedestrians and vehicles during flood events. The assessment found that:

> The maximum depth stability limit was 0.5 m for children and 1.2 m for adults. However this reduces to 0.15 m and 0.2 m if velocities exceeded 3 m/s;

> Small cars became unstable at 0.3 m of still water, or at 0.1 m if velocities exceeded 3 m/s.

Based on these findings, the majority of crossings are unsuitable for cars and children in events larger than the 10% AEP. All crossings were found to be unsuitable for adults in the PMF.

It is noted that roads outside of the study may also be flood affected during storm events, so that even if roads within the study area are flood free, access may still be lost between adjacent townships (and emergency response units).

Table 10-2 Flooding Depth and Duration of Inundation of Key Access Roads

Location	10% AEP Depth (m)	5% AEP Depth (m)	2% AEP Depth (m)	1% AEP Depth (m)	0.2% AEP Depth (m)	PMF Depth (m)
Tarraganda Lane	0.82	2.24	2.90	3.54	4.45	10.97
Princes Highway	3.63	4.95	5.63	6.21	6.61	12.72
Bega St	2.35	3.75	4.42	5.05	5.36	11.85
Auckland St	-	-	0.28	0.87	1.23	7.51
Lagoon St	-	0.46	1.21	1.78	2.1	8.74
East St	1.50	2.92	3.58	4.22	5.2	11.68
Park St	-	-	-	-	-	1.43
Carp St	-	-	-	-	0.06	5.83
Gipps St	-	-	-	-	-	1.15
Nelson St	2.87	4.24	4.90	5.51	5.89	11.59
Tathra Road 1	-	-	0.11	0.72	2.15	8.17
Ravenswood St	0.73	2.09	2.72	3.29	3.89	8.05
Tathra-Bermagui Road	1.67	1.97	2.61	3.04	3.07	5.66
Tathra Road 2	-	-	1.77	2.79	5.57	11.02
Sapphire Coast Drive	-	-	-	0.17	1.71	8.15
Wallagoot Ln	-	2.42	3.69	4.71	6.62	12.94
Tathra Road 3	1.39	3.73	5.00	6.01	8.04	14.24
Rawlinson St	-	-	-	0.38	2.18	7.83
High St	-	0.48	1.13	1.73	2.11	7.86
Reedy Swamp Rd	2.81	5.15	6.41	7.43	9.62	15.67
Henry Taylor Rd	0.48	2.65	3.92	4.94	6.84	13.18

10.3.2 Driving Condition Analysis

Movement during a storm event is likely to be by car, or similar vehicle. The safety of operating such a vehicle needs to be determined if movement options are to be recommended.

During an extreme rainfall event, the intensity of rainfall as well as other factors (such as wind and debris), would make driving either difficult or potentially more dangerous than sheltering in place. These factors would not be unique to a floodplain, and would be equally as dangerous if an extreme event were to occur in any location. It would be expected that the risk to life of driving in these conditions would increase with lower frequency rainfall events.

A review was therefore undertaken on driver safety related to rainfall events. This assessment has been based on the rainfall intensity and does not account for risks associated with flood depths and velocities (refer **Section 9.3.1**)

A study of single-vehicle crash severities based on an analysis of crash and traffic data for the Wisconsin area in the USA for the period 2004 - 2006 found that rainfall events with a mean rainfall intensity of 3.16 mm/hr resulted in an increased likelihood of crashes ranging in severity from fatal to possible injury (Jung, Qin, & Noyce, 2009). An analysis of data for the cities of Calgary and Edmonton, Canada, during 1979 - 1983 concluded that the overall accident risk during rainfall conditions was 70% higher than normal (Andrey, 1993).

Andreescu and Frost (1998) in an analysis of data for Montreal, Canada, 1990 - 1992, found that a best fit line of data found a linear increase in number of accidents in relation to increased daily rainfall intensity (mm/day; reproduced in **Figure 9-2**). It is noted that there is significant scatter in the source data and that the correlation is relatively low. However, the data does demonstrate a link between daily rainfall and accidents.

The RMS's *Road User's Handbook* (RTA, 2010) states that "*Driving during extreme weather events or conditions should be undertaken with care and caution. Driving should be avoided in extreme conditions*."

The rainfall intensity temporal distribution for the 1% AEP 36 hours event is shown in **Figure 9-3**. These are exclusive of climate change impacts on rainfall intensities. The figure shows that rainfall intensities are generally greater than 10 mm/hr, with peaks of 93.5 mm/hr, 66 mm/hr and 49 mm/hr at 18 hours, 20 hours, and 22 hours into the storm respectively.

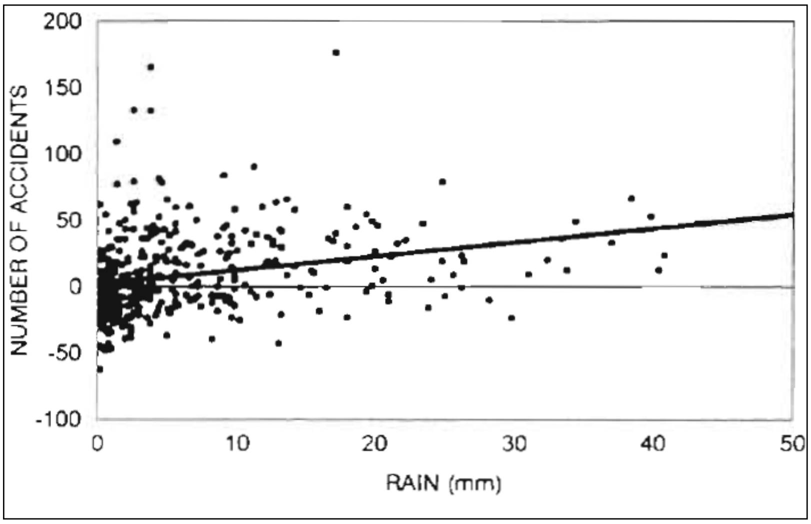


Figure 10-2 Accidents per day vs daily rainfall (Andreescu & Frost, 1998)

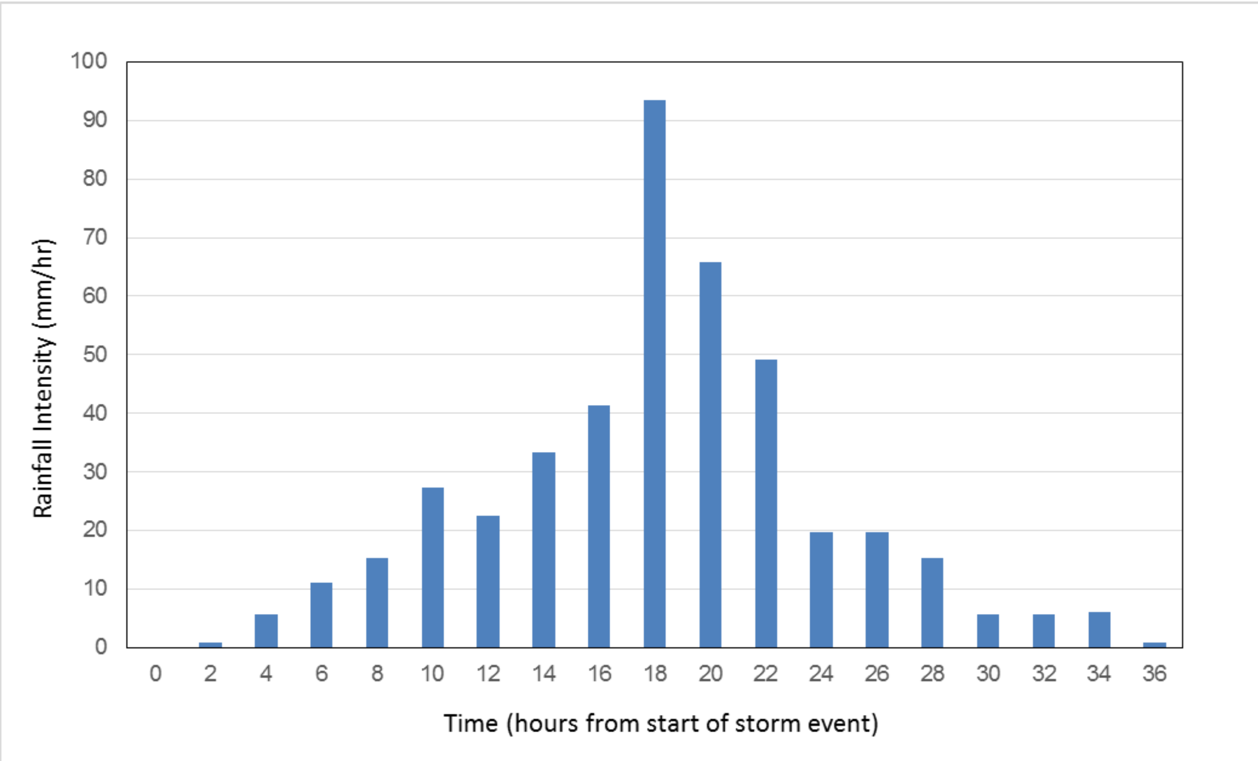


Figure 10-3 Bega 1% AEP 36hr Temporal Rainfall Distribution

The literature evaluated does not give a definitive threshold of rainfall intensity for which unsafe driving can be expected, with the exception of Jung (2009) which has a very low intensity of only 3 mm/hr, which can be expected in relatively frequent events.

Average rainfall intensities for the 1% AEP 36 hour event are well in excess of the values identified in the literature as beginning to have an effect on driving risk.

Consequently, it is not recommended that people attempt to drive during a significant rain event. As the most intense rainfall will be associated with short duration storms, the safer option is to wait for the rain to abate before attempting to drive. During longer duration events, where flood warning may be possible, the rainfall intensity will be reduced, and may allow evacuation whilst the rain is falling. However, in general, it is recommended that driving not be undertaken during intense rainfall periods unless there is a risk to life at the property resulting from rising flood waters.

10.4 Flood Emergency Response

10.4.1 Flood Response Time

Flood response time is a key factor in determining appropriate flood emergency response. Flood response time is the time required determine a flood event is taking place, alert those at risk, and to begin responding to the risks posed by flood event. This time is influenced by the flood warning available, the ease of communication with the population at risk, the population's appreciation of the risk, and the population's knowledge of appropriate emergency responses.

Flash flooding results in limited flood response times. The Australasian Fire and Emergency Service Authorities Council (AFAC) define flash flooding as:

> *"Flash flooding may be defined as flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity."*

For the critical duration event, peak flood levels occur in Bega 24 hours after the onset of rainfall, and in Jellat Jellat Flats 30 hours after the onset of rainfall. This would allow for an evacuation warning to be issued, and for residents to safely evacuate their properties in advance of floodwaters.

However, this evacuation is dependent on suitable warning being provided. At present, there is no formal flood warning available. Due to the size of the catchment, it is possible that heavy rainfall could generate flooding in Bega, with no, or minimal, rainfall actually occurring over the township. The first indication that residents would then have of flooding would be observing the river breaking its banks. If the flood occurs at night, residents would not even have this; the first knowledge would be flooding in their property at which time access from their property would already be, if not lost, heavily restricted. Hence, there would be benefit in establishing a flood warning system.

Furthermore, the flood response, when it begins, is relatively rapid. Once river levels begin rising, they do so at a rate of 0.5 m an hour at Bega, and 1.2 m an hour at Jellat Jellat Flats, upstream of Bottleneck Reach.

10.4.2 Flood Warning

The Bureau of Meteorology (BoM) provides a flood warning service for the township of Bega, utilising information collected from the river gauge at Bega (gauge number 219900 at Princes Highway). Based on data from this gauge, coupled with data from rainfall gauges in the catchment, the BoM aims to provide three hours advance warning of major flood events.

Further warnings are provided as:

> BoM Flood Watches: SES Flood Bulletins are issued by the Illawarra South Coast SES Region Headquarters to various media outlets and agencies each time the BoM issues a Flood Watch. However, as this catchment is subject to flash flooding, the BoM will not issue a warning for this catchment in particular. Only a generic warning across the whole region would be available.

> BoM Severe Weather Warnings: For the management of coastal erosion and inundation, BoM will issue Sever Weather Warnings to the SES, radio stations and other organisations prior to and during potential and actual coastal erosion events.

> SES Livestock and Equipment Warnings: following heavy rain, or when there are indications of significant creek or river rises, the SES Local Operations Controllers will advise SES Region Headquarters, which will issue SES Livestock and Equipment Warnings.

> Evacuation Warnings by radio, door-knocks and telephone.

The catchment size and response time are suitable for the installation of a comprehensive flood warning system for the full study area. There are existing gauges in the catchment area that could be utilised for flood warning systems. These existing gauges would be made more useful by the installation of additional gauges at key locations.

Generally speaking, gauges higher in the catchment offer more warning time, but reduced accuracy, while gauges located nearer to townships have shorter warning times, but more accurate predictions. For the Bega region, it would be recommended to utilise both upstream and downstream gauges for flood warning. The layout of a possible warning system is shown in **Figure 10-4**. The system utilises existing upstream gauges, as well as the installation of new gauges in the Bega and Jellat Jellat Flats regions.

Gauges higher in the catchment tied to either rainfall or flow would be used to issue initial warnings to Council, SES and residents. These warnings would inform of a likely flood event, and allow time for spreading of the warning, and of initial preparations within flood-affected areas. Depending on the intensity of the rainfall / flow observed, evacuation of high-risk locations (childcare centres for example) may be commended at this time. The gauges indicated would provide a warning time in the order of 12 hours depending on the trigger levels adopted. Given that flooding of properties occurs in relatively small events, a “be aware” warning could be issued when rainfall or flows exceed the 20% AEP design event, with “evacuate” warnings provided to key locations when rainfall or flows exceed the 10% AEP design event. This warning could also be issued to farmers with cattle to allow them time to move the cattle to a safe location.

The upstream gauge on the Bega River could also be utilised to provide imminent flood warnings to the Candelo township.

Once the community has been primed to act, those gauges closer to the townships would be used to trigger the evacuation of the bulk of residents. Warnings from these gauges could be sent directly to affected residents to ensure they have as much time as possible for evacuation. If warnings were issued just prior to the Bega River breaking its banks at the Brogo confluence, this would provide a warning time of 2-3 hours for Bega and Jellat Jellat Flats.

Council and the SES have access to BoM's Enviromon software, which provides live water level and rain gauge readings. Automated emails can be sent from this program to Council for set trigger levels at the gauges. These alerts could then be forwarded to the SES and residents.

The trigger level adopted should be determined in consultation with the community. Lower trigger levels will provide more warning time, but will result in the alarm being triggered more frequently. Given the relatively short evacuation distances required (as all evacuation will be local, within the township), significant warning times are not required.

10.4.3 Community Response to Flooding

To minimise the flood risk to residents, it is important that properties have provisions to facilitate flood emergency response. There are two main forms of flood emergency response that may be adopted by people within the floodplain:

> Shelter-in-place: The movement of residents to a building that provides vertical refuge on the site or near the site before their property becomes flood affected; and

> Evacuation: The movement of residents out of the floodplain before their property becomes flooded.

Each of these options have particular requirements given the nature of flooding within the study area, and associated advantages and disadvantages. Each option is discussed below.

10.4.3.1 Shelter in Place

The use of shelter in place requires a place within the building to be above the PMF level. The primary advantage of shelter in place is that it does not require any special understanding of flood response on behalf of the residents. People would naturally move higher in the property as flood levels raise. Shelter in place does, however, result in people becoming isolated during flood events, which creates risk around reaching people in case of medical emergencies during flood events.

Controls to achieve shelter in place for new developments would require Council to be able to enforce flood related development controls outside of the flood planning area, which would require special approval under PS 07-003.

Given the significant difference between the PMF and the other design events, a key concern with the use of shelter in place within the Bega region is that it would require buildings to be constructed with three storeys in order to ensure that the top floor is above the PMF. The top flood may be a loft or attic space rather than a complete floor. Such a space would have to accessible during a flood event, which would necessitate safe, flood proof internal access. Apart from imposing additional construction costs on builders, the height requirement may conflict with other planning controls in relation to building height, shading and privacy (views into adjacent yards).

Buildings would also need to be constructed to be able to safely withstand flooding in events up to the PMF. Notwithstanding risks to the building itself, there is also a risk that supporting services for the building (water, power, sewer, etc.) would be disrupted during a major flood event.

Furthermore, shelter in place would largely only be suitable for new buildings as existing buildings are unlikely to have been constructed with a view to withstanding PMF flooding.

Given these issues, shelter in place is only of limited suitability in the study area.

10.4.3.2 Evacuation

The two key requirements for an evacuation strategy are appropriate prior warning to allow evacuation, and a safe refuge to evacuate to.

Unlike shelter in place, which would require significant re-development to existing properties in order to be effective, evacuation could be facilitated for existing properties by ramps or regraded front yards to provide rising egress from flood affected properties.

At present, the community does not have sufficient warning time to allow evacuation. The first knowledge many will have of flooding will be inundation of their property, by which time either access from their property, or access to the refuge, may be lost. However, sufficient effective warning time could be provided if a flood warning system is implemented.

As evacuation will be undertaken on a local scale, significant warning time would not be required, as residents will be able to evacuate relatively rapidly. A warning time of 60 to 90 minutes would give residents sufficient time to relocate some household objects, pack some belongings, and walk to the refuge centre. A warning linked to a water level gauge on the Bega River could provide this warning.

In order for an evacuation strategy to be effective, a second flood refuge may need to be constructed somewhere in the township that is above the PMF level, and of a suitable size to shelter those residents whose properties are flood affected in the PMF event.

The currently identified evacuation centre for Bega is the Bega Showground, located on Tathra Road, between Upper Street and Park Lane. While the show ground field is flood affected in the PMF, the Showground buildings remain flood free. Access during the peak of the flood event is maintained via Newtown road, which allows emergency access to the Showgrounds from the hospital.

The location is a suitable flood refuge for the Bega Township.

It is noted that the wider region will not be able to access this refuge during a major flood. This is of less concern for Candelo, where flood responses are quick, and overland escape routes are short. However, some consideration should be given to providing a formal refuge location of Tathra and Mogareeka. Under current flooding conditions, it is suggested that the Tathra Bowling Club would be a suitable, flood free location. However, as flood impacts increase in the future due to climate change, and the number of affected residents increase, a large site may be required to effectively shelter all affected residents.

10.4.4 High Flood Risk Locations

10.4.4.1 Childcare Centres

There are a couple of childcare centres in Bega. The locations at which flood depths have been extracted are shown in **Figure 10-4.**

The table shows that while none of the childcare centres is affected in the 10% AEP event, one is affected in the 5% AEP, and all are impacted by flood waters in the PMF event.

Table 10-3 Childcare Centres affected by flood

Name	10% AEP Depth (m)	5% AEP Depth (m)	2% AEP Depth (m)	1% AEP Depth (m)	0.2% AEP Depth (m)	PMF Depth (m)
Sunshine and Puddles Family Day Care	-	-	-	-	-	2.6
Bega Valley Family Day Care	-	0.1	0.8	1.4	1.7	7.8
Mackillop Family Services	-	-	0.4	1.0	1.4	7.6
Mission Australia	-	-	-	-	-	4.9

10.4.4.2 Caravan Parks

The Tathra Beachside accommodation park is located between Andy Poole Drive and the ocean beach. Regions of the park are located on low-lying land adjacent to the ocean and are affected by flooding from both catchment rainfall and ocean inundation.

The caravan park is of particular concern during flood events due to:

> Access being lost before the site experiences flooding;
> The possibility of a number of people being concentrated at the property during a flood event;
> The likelihood that patrons will be from outside the catchment, and may not appreciate the flood risks during a storm event; and
> A lack of vertical evacuation and shelter in place options.

A Flood Emergency Response Plan is required for caravan sites as part of the Bega Valley Shire Flood Emergency Sub-Plan.

10.5 Recovery

In a major flood event, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery operation. The Department of Community Services is responsible for the long-term welfare of the affected community. However, the immediate action is likely to be undertaken by the SES Local Controller.

11 Potential Floodplain Risk Management Options

Flood risk can be categorised as existing, future or residual risk:

> **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding.

> **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built.

> **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it will be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 11-1**.

Table 11-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding because of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

> **Flood modification measures** – Flood modification measures are structural options aimed at preventing / avoiding or reducing the likelihood of flood risks through modifying the flood behaviour.

> **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks.

> **Response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks through modifying the way the community and emergency services respond during a flood event.

The objective of the FRMS is to consider a range of potential floodplain risk management measures and subject these to a preliminary cost-benefit assessment to:

> Identify which of the options considered should be adopted in the FMRP for implementation by Council: and

> Of those options recommended for adoption, to rank (or prioritise) them based on how effectively they reduce flood risk on a value for money basis.

These measures will likely require further detailed assessment and detailed investigation prior to implementation.

The options assessment methodology and outcomes are reported in **Sections 12** and **13**.

11.1 Flood Modification Measures

Based on the flood model results, historical information, community feedback and engineering judgement, possible flood modification options (i.e. structural options) for the study area were identified. These options are outlined in **Table 11-2** and shown in **Figure 9-1** for the Bega study area options and **Figure 9-2** for the

Candelo study area options. From these options, a selection were assessed in the hydraulic model, based on their feasibility and expected flood benefits. These options are summarised in **Table 11-3**.

It is noted that the suitability of structural options was limited by the significant flood depths that occur in even relatively small events. As such, property and emergency response measures are likely to be more applicable to the study area.

Table 11-2 **Bega and Brogo Flood Modification Options**

Option ID	Details	Expected Benefit	Constraints	Assess in Hydraulic Model?
Levees These options are focused on the potential construction of levee banks or flood walls to create barriers to flood waters				
L.1	Construction of levee behind properties on Bega and Auckland Streets, Bega (4.2m for 10% AEP, 4.8m for 5% AEP, 5.9m for 1% AEP).	Protection of properties from Bega River flooding. The numbers quoted are the peak flood heights in those events. The levees constructed would also include a 0.5m freeboard. All levees modelled have 0.5m added to the heights listed.	All the options have a significant constraint with regard to the flood levels and the amount of road raising required to achieve the flood protection required. Even protecting to the 10% AEP requires levee heights of up to 5.5m. This poses construction constraints, pedestrian access constraints, has negative visual impacts, and would require upgrades to all associated property accesses. As heights increase, the footprint of the levee also increases. For higher levees, a floodwall may be more appropriate. For costing purposes, it was assumed that a flood wall would be required once heights exceed 3m. This means that the greatest footprint for a levee would be 13m wide, based on a levee of 3m height with 1:4 sides and a 1m crest. For completeness, and discussion with the community, all levees have been assessed for all three crest levels, to provide protection in the 10% AEP, 5% AEP and 1% AEP events.	Yes (1% and 10% AEP events)
L.2	Construction of levee behind properties on Auckland Street, Bega (2.75m for 10% AEP, 3.3m for 5% AEP, 4.5m for 1% AEP).			
L.3	Construct levee behind properties on Millowine Avenue, Bega (2.5m for 10% AEP, 3m for 5% AEP, 4.3m for 1%AEP).			
L.4	Construction of a flood wall or levee a block north of Bega Street (5.5m for 10% AEP, 6m for 5% AEP, 7.2m for 1% AEP).			
Road Raising These options propose improved access during flood events by raising road levels and, where possible, create detention basins (using the raised road as a levee) upstream of flooding issues				
R.1	Raising of Carp Street, Bega, to improve level of protection (5m for 10% AEP, 5.6m for 5% AEP, 7m for 1% AEP).	All road raisings design to improve access and egress during flood events. Potentially, raised roads can also double as levees to protect upstream properties.	As with the levee options, a significant number of these options require substantial road raisings to achieve flood free status in even small events, and significant raises for 1% AEP protection (up to 10m in some locations). Large road raises in developed areas are not feasible due to maintaining connections with properties (as discussed above). Within developed areas of Bega, three locations would be feasible if raising was limited to 1.0m. However, this raising would only serve to provide flood free access. No benefits to property flooding would be realised, as the properties behind the raised road are not flood affected in the 10% AEP event. In Candelo, road raising to the 1% AEP level would also protect properties behind the raised roadway. For regional roads where there no existing development constraints, raising to the 1% AEP to improve regional access has been assessed.	No
R.2	Raising of East Street, Bega (0.8 m for 10% AEP, 1.3m for 5% AEP, 2.6m for 1% AEP).			Yes (10% AEP)
R.3	Raising of Tathra Road, Bega, location A (6m for 10% AEP, 7.4m for 5% AEP, and 8.4m for 1% AEP).			No
R.4	Raising of Tathra Road, Jellat Jellat, location C (6m for 10% AEP, 7.5m for % AEP, 9.7m for 1% AEP).			Yes (1% AEP)
R.5	Raising of Ravenswood Street, Bega, to improve flood access for currently isolated property. Would also serve as a levee to protect properties from inundation from the Bega River (3m for 10% AEP, 3.5m for 5% AEP, 4.7m for 1% AEP).			Yes (5% AEP)
R.6	Raising of Tathra-Bermagui Road, Tathra (2m for 10% AEP, 2.2m for 5% AEP, 2.9m for 1% AEP)			Yes (1% AEP)
R.7	Raising of Tathra Road, Jellat Jellat, location D (1.9m for 10% AEP, 3.1m for 5% AEP, 5.1m for 1% AEP).			Yes (1% AEP)
R.8	Raising of Tathra Road, Jellat Jellat, location E (1m for 10% AEP, 2.4m for 5% AEP, 4.5m for 1% AEP).			Yes (1% AEP)
R.9	Raising of Tathra Road, near Bega, location B (3.5m for 5% AEP, 6m for 1% AEP).			Yes (1% AEP)
R.10	Raising of Bega Road, Bega, to improve level of protection and to prevent flooding impacting properties on the southern side of the road (2.7m for 10% AEP, 3.3m for 5% AEP, 4.4m for 1% AEP).			No
R.11	Raising of Kirkland Road, Bega, to improve flood access for properties currently on a flood island (0.75m for 10% AEP, 1.25m for 5% AEP, 2.5m for 1% AEP).			Yes (10% AEP)
R.12	Raising of Power Street, Sharper Street and William Street in Candelo.			Yes (1% AEP)

Option ID	Details	Expected Benefit	Constraints	Assess in Hydraulic Model?
Vegetation Management These options primarily focus on increasing capacity and efficiency of creeks through the removal of debris and invasive species				
V.1	Vegetation management along the Bega River adjacent to the township. Option would see overgrown vegetation removed, and old, unused bridge structures removed.	Option aims to improve flow conveyance and reduce breakouts from River in large events. May also reduce peak levels along the river.	Community suggested option. May impact downstream locations. Given volume of flow in river, benefits may be minor. However, the works would have environmental and geomorphic benefits.	Yes
Road Upgrades These options look to improve existing access routes to ensure they are safe for a high level of traffic in a flood event				
U.1	Upgrade of Boundary Road, near Bega, to provide access to hospital in PMF event. Road is not currently flooded, so already provides some alternative access. Option would see current dirt road upgraded to a sealed road, which would be safer in a large rainfall event.	Flood safe alternative access to hospital.	No major constraints	No (but included as emergency response option)
U.2	Installation of flood flaps on culverts under Sharpe Street, Candelo.	Prevention of backwater flows from Candelo Creek into properties on Sharpe Street.	No major constraints	No (but included as option)

Table 11-3 Preliminary Options for Assessment

ID	Option Details	Changes to Hydraulic Model
L.1-L.4	Option to assess the potential levees, with crest levels equivalent to the 10% and 1% flood levels (refer **Table 11-2**).	Breaklines were added to the hydraulic model to represent the levees.
R.1-R.12	Option to assess the potential road raisings with crest levels equivalent to the 10% and 1% flood levels (except for Candelo Road; refer **Table 11-2**).	Breaklines were added to the hydraulic model to represent the raised road levels.
V.1	Vegetation management option (refer **Table 11-2**).	Roughness values were reduced to 0.035 along the Bega River around the township to reflect the clearing and revegetation works.

11.1.2 Preliminary Options Assessment

To test the feasibility of each of the hydraulically assessed structural options, they were first run for the 10% AEP and 1% AEP events to ensure they worked as expected and did not result in adverse flooding behaviour. The results of this analysis are summarised below in **Table 11-4**. The table summarises the outcome of the 10% and 1% AEP runs, and whether the option should be considered for further analysis.

Table 11-4 Preliminary Options Assessment Outcome

ID	Assessment Outcome	Suitable for further assessment?
L.1-L.4	The levees were found to protect the properties behind them in events up to the 1% AEP. In events larger than the 1% AEP, the levees overtopped and the flooding across properties behind the levee were largely the same as in the existing case. In the 1% AEP, there was some water level increases (<0.1 m) immediately upstream of the levee, but this increase remained within the river corridor and did not affect adjacent properties.	Yes. All three crest levels for each of the four options was subject to assessment as requested by OEH.
R.1-R.12	For the Bega options, results from the road raising options demonstrated that the raising did not result in any adverse impacts to adjacent properties, and that the raising provides flood free access along the road lengths in events up to the 10% AEP. This is particularly important for Kirkland Avenue (R.11), where properties are located on a low flood island, as road access is lost in advance of lot flooding and there is no easy overland escape option available. As noted above, these options were assessed in the hydraulic model only to determine impacts; they do not directly reduce flood damages for any properties. For the Candelo road raising (R.12), the higher road levels resulted in minor, localised increases in both river levels and velocity. All increases were restricted to the river channel and did not impact adjacent development. Levels increased by 0.03 m and 0.07 m in the 10% and 1% AEP events respectively. In both cases, velocities in the river increased by less than 0.2 m/s.	Yes – Candelo (R.12), Ravenswood Road (R.5), and Kirkland Avenue (R.11) options only.
V.1	Vegetation management along the reach of the Bega River adjacent to the township was found to have no impact on peak flood levels in either the 10% AEP or 1% AEP. This is likely because the changes made as a result of the option were relatively minor in comparison to both the width across the floodplain and the volume of water in the Bega River during flood events. Furthermore, the influence of Bottleneck Reach in restricting downstream conveyance will reduce the effectiveness of any upstream channel works, particularly around Tarraganda Lane, to where the backwater effect of Bottleneck Reach extend in events below the PMF.	No

11.1.3 Environmental Considerations

According to *State Environmental Planning Policy (SEPP) (Infrastructure) 2007*, flood mitigation works "*may be carried out by or on behalf of a public authority without consent on any land*". These works include construction, routine maintenance and environmental management works which applies to most of the flood mitigation options in **Table 11-4**. Although consent is not required, most flood mitigation works will require further environmental assessment.

The determining authority, in this case Council, is required to "*examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity*" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors.

When carrying out flood mitigation works, Council will be required to take out further permits, licenses and approvals such as:

> Flood mitigation works which involve activities listed under Schedule 1 of the POEO Act (e.g. release of water into a water body) will need an Environment Protection Licence;

> Activities involving the removal of vegetation or woody debris in a water body, harm the habitat of threatened species, or to (fully or partially) obstruct fish passage may need a permit under the *Fisheries Management Act 1994*; and

> Impacts to threatened species or communities listed under the BC Act or the EPBC Act may trigger an additional approval.

11.2 Property Modification Options

A number of property modification options were identified for consideration for implementation in the study area. These options fall into two categories; those for which OEH support is available, and those that would be required to be implemented fully by Council.

Options for which funding may be available from OEH are:

> House raising; and

> Voluntary purchase .

Details of the OEH grants available may be found at
www.environment.nsw.gov.au/coasts/Floodgrants.htm

Additional property modification options that may be pursued by Council are:

> Building and development controls;

> House re-building;

> Land swap;

> Council re-development;

> Flood proofing.

Of these options, those that were found to be suitable for the study area were:

> Voluntary purchase;

> Building and development controls; and

> Flood proofing.

11.2.1 PM 1 – Voluntary Purchase

Voluntary purchase is a scheme where by the affected property is purchased by Council. Council would then demolish the building and re-zone the land to a more flood appropriate zone. It is an option of last resort, and would be undertaken to remove residents and properties from high risk locations for which other structural and property modification options are not feasible.

OEH has prepared the Guidelines for voluntary purchase schemes (OEH, 2013) to assist in determining when and where voluntary purchase schemes may be suitable. The guideline recommends that voluntary purchase be considered where:

> There are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;

> A property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function; and/or

> Purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.

The first scenario of highly hazardous conditions make voluntary purchase a suitable option for those properties affected by significant flood depths in the 5% AEP event. Of the 22 residential properties affected by overfloor flooding in the Bega and Candelo model areas, in the 5% AEP event, nine properties have overfloor depths of greater than 1m, and five of these have depths greater than 1.5 m. In the 1% AEP, these properties experience overfloor depths of over 2.3 m, with four experiencing overfloor depths of greater than 3 m.

While some of these properties benefited from the structural options identified (refer to **Section 9.2**), none of the structural options investigated were able to substantially reduce the flood hazard of this area in events above the 10% AEP, with the result that these properties remain as significant risk during large floods even if structural works are implemented.

However, there are a range of activities that need to be undertaken to enable the voluntary purchase of any individual property. The implementation of this option would involve the development of a Voluntary Purchase policy that outlines the circumstances under which Council would potentially acquire significantly flood affected properties. The Council would then prepare a voluntary purchase scheme which details:

> The properties that are the subject of the scheme;

> Their relative priorities for acquisition;

> The cost of the proposed acquisitions; and

> The anticipated schedule.

It is an OEH requirement that a Voluntary Purchase Scheme be prepared, and only after a Scheme is in place may a local Council apply for the necessary funding to undertake the acquisition(s). The Scheme is considered valid for a period of three years, after which is expires and must be updated and approved by OEH for eligibility for a subsequent three year term. Further, it is noted that there is no guarantee of funding to any specific scheme during the three year term, as OEH allocates funding to similar schemes across the State.

Participation of residents in such a scheme is entirely voluntary. It is not expected that residents would be amenable to such a scheme at this time. However, support may change in the future following a large flood event that highlights to the community the flood risks of this region. If such a scheme gains future support, it is recommended that initial priority be given to those properties with the most significant overfloor flooding depths.

11.2.2 PM2 – Building and Development Controls

The key documents for flood related controls in the Bega Valley Shire are the LEP 2013 and the DCP 2013.

This option provides for a review of the LEP 2013 and DCP 2013 by Council, taking into account the advice and recommendations made in **Section 8.2**. Any changes to the DCP should be consistent with the relevant Clause(s) in the LEP.

Following review, should amendments to the LEP and/or DCP be required, these would be achieved via a Planning Proposal prepared under s3.33 of the *Environmental Planning and Assessment Act 1979*, in accordance with A Guide to Preparing Planning Proposals (DP&E, 2016). The planning proposal is required to explain the intended effect of a proposed amendment to the LEP and set out the justification for the proposed change(s). The Secretary (or their delegate) can then issue a Gateway determination that specifies if the proposal can proceed, and under what circumstances. For example, it may specify additional studies or consultation required, and a schedule for implementation.

11.2.3 PM3 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures in order to reduce the damage caused to the property by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding.

These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating, to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of proofing measures include:

> All structural elements below the flood planning level shall be constructed from flood compatible materials; and

> All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed and protected if installed below the FPL.

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties. It is noted that there are three commercial / industrial properties that experience flooding in the 5% AEP event or greater.

These measures should be carried out according to a pre-arranged plan. These measures may include:

> Raising belongings by stacking them on shelves or taking them to a second storey of the building;

> Secure objects that are likely to float and cause damage;

> Re-locate waste containers, chemical and poisons well above floor level;

> Install any available flood proofing devices, such as temporary levees and emergency water sealing of openings.

The NSW SES business Flash Flood Tool Kit Invalid source specified. provides businesses with a template to create a flood-safe plan and to be prepared to implement flood-proofing measures. It is recommended that this tool kit be distributed to the flood affected businesses within the floodplain.

11.3 Emergency Response Modification Options

A number of emergency response modification options are suitable for consideration within the Bega and Brogo Rivers floodplain. These are:

> Information transfer to the NSW SES EM1

> Flood warning system EM 2

> Upgrade of Boundary Road U.1

> Flood flaps on Sharpe Street culverts U.2

> Raising of Ravenswood Street R.5

> Raising of Tathra Road and Kirkland Avenue R.11

> Candelo road raising option R.12

> Public awareness and education EM 3.

These options are discussed in detail below.

11.3.1 EM 1 – Information transfer to NSW SES

The findings of the Flood Study and the FRMS&P provide an extremely useful data source for the SES. Transfer of the flood intelligence from this study, such as road overtopping depths and timings, the locations of flood-affected properties, and the flood behaviour of high-risk regions, would be communicated to the NSW SES to assist in their flood response strategies.

11.3.2 EM 2 – Flood Warning System

Existing water level and flow gauges are installed throughout the Bega and Brogo Rivers catchment area. There are two water level gauges within the study area; the first at the Princes Highway Bridge adjacent to the township and the second at the ocean outlet in Tathra. There are also flow gauging stations on both the Bega River and Brogo River, each approximately 10 km upstream of the Bega Township.

As discussed in **Section 10.4.2**, a flood warning system would utilise these gauges, as well as installing new gauges adjacent to Bega and Mogareeka.

Warnings issued from the upstream flow gauges would provide a warning time of approximately 12 hours depending on the trigger levels adopted. Warnings issued from the water level in the township would be a better indicator of risk, but warning times would be reduced to 2 to 3 hours.

Given that local evacuation is possible within these timeframes, and that no regions are required to travel large distances to escape from floodwaters, the warning from nearby gauges would be suitable to allow the safe evacuation of residents to flood free areas, particularly if residents had been primed by an earlier warning from the upstream gauges. The warning may be issued by automated SMS, phone calls or a siren, triggered when either overfloor flooding of properties or loss of access to properties was imminent. Such a warning would only allow the immediate evacuation of residents to local flood refuges. It would not provide sufficient time to move or evacuate belongings.

Should a system be implemented, it will be important for the community to understand the operation of the system and its limitations. A key point to inform the community of will the likely frequency of warnings issued from the gauge. In order for the warning to be effective, it will need to be issued before property flooding commences. The community will need to understand that there will be false positives reported from the system, and that for the system to be effective, they will need to continue to respond to the evacuation warning, even after a number of issued warnings that were not followed by subsequent flooding.

It should also be noted that the warnings would only be applicable to flooding occurring from the Bega and Brogo Rivers. The smaller, local tributaries experience shorter duration flooding are not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

In summary, a flood warning system would allow effective and safe evacuation of flood affected areas, and this option provides for the necessary investigations to be undertaken to establish a flood warning system.

11.3.3 U.1 – Upgrade of Boundary Road

Upgrade of Boundary Rd to provide access to hospital in PMF event. The road is not currently flooded, so already provides some alternative access. However, the road is currently unpaved, and may prove unsafe to use in heavy rain. The option would see current dirt road upgraded to a sealed road that would be safer in a large rainfall event.

11.3.4 U.2 – Flood Flaps on Sharpe Street Culverts

The flood flaps would prevent backwater flows from Candelo Creek inundating properties on Sharpe Street, and would provide egress during a flood event.

11.3.5 R.5 – Road Raising of Ravenswood Road

Raising of Ravenswood Street to improve flood access for currently isolated property in the 10% AEP (refer **Figure 11-1**). The significant flooding depths that occur in larger events prohibits providing any further flood immunity to these roads.

11.3.6 R.11 – Road Raising of Tathra Road and Kirkland Avenue

Raising sections of Tathra Road and Kirkland Avenue (refer **Figure 11-1**) to provide flood free access in the 10% AEP. The significant flooding depths that occur in larger events prohibits providing any further flood immunity to these roads.

11.3.7 R.12 – Road Raising in Candelo

This option involves raising of Power Street, Sharpe Street and William Street in Candelo (refer **Figure 11-2**). In Candelo, road raising to the 1% AEP level would enable residents from properties to the west of the river that would become isolated during a flood to travel to the east of the township. This option would also protect properties behind the raised roadway.

11.3.8 EM 3 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

11.4 Data Collection Strategies

This would involve the preparation of a flood data collection form and the use of this form following a flood event. This would allow for more information to be gathered concerning the nature of flooding within the catchment, building on the knowledge from the Flood Study.

12 Economic Assessment of Potential Options

It is possible to quantitatively assess the economic benefits of some of the options, namely those that were hydraulically modelled, and those with known benefits. For those options, a benefit-cost ratio can be calculated. This calculation is described below. For other options, it may not be possible to specifically calculate benefits. In this case, those options have only been assessed using a multi criteria matrix approach.

12.1 Preliminary Costing of Options

12.1.1 Flood Modification Options

Cost estimates were prepared for those options that allow for an economic assessment. A summary of these estimated capital costs are provided in **Table 10-1**. Details of these costings are provided in **Appendix D**.

Prior to an option proceeding, it is recommended that in addition to detailed analysis and design of the option, the costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

Table 12-1 Cost Estimates for Flood Modification Options

Option ID	Option	Capital Cost (Ex GST)	Ongoing Cost (per year)
LEVEES			
10% AEP			
L.1.1	Bega and Auckland Streets levee	$4,423,500	$20,000
L.2.1	Auckland Street levee	$1,207,300	$10,000
L.3.1	Millowine Ave Levee	$599,000	$5,000
L.4.1	Bega Street levee	$5,470,100	$30,000
5% AEP			
L.1.2	Bega and Auckland Streets levee	$4,178,300	$30,000
L.2.2	Auckland Street levee	$2,780,300	$15,000
L.3.2	Millowine Ave Levee	$1,407,000	$10,000
L.4.2	Bega Street levee	$6,094,400	$40,000
1% AEP			
L.1.3	Bega and Auckland Streets levee	$4,246,700	$40,000
L.2.3	Auckland Street levee	$3,791,200	$25,000
L.3.3	Millowine Ave Levee	$2,344,900	$15,000
L.4.3	Bega Street levee	$7,313,300	$50,000
ROAD RAISING			
R.11	Candelo Road Raising	$2,325,000	$25,000

12.2 Annual Average Damages Assessment

The total damage costs were evaluated for each of the options assessed by hydraulic modelling (quantitative assessment). The reduction in AAD for each of the options is shown comparatively against the existing case in **Table 10-2**.

Levee L2 resulted in a reduction of flood levels across four properties protected by the levee. Levee L3 did not result in any reduction in property flooding; the reduction reported arose from savings in garden damages.

Whilst the options are successful in reducing flood levels, these reductions do not result in significant numbers of properties moving from having over-floor flooding, to no over-floor flooding. Whilst the AAD is reduced to various degrees for different options, this reduction needs to be offset against the capital and recurrent costs of the option. This is investigated below.

Table 12-2 Reduction in Damages Associated with Flood Modification Options

Option ID	Option	AAD ($)	Reduction in AAD ($)
Existing	Existing scenario	$875,879	-
LEVEES			
10% AEP			
L.1.1	Bega and Auckland Streets levee	$848,499	$27,380
L.2.1	Auckland Street levee	$840,124	$35,755
L.3.1	Millowine Ave Levee	$874,926	$953
L.4.1	Bega Street levee	$846,238	$29,641
5% AEP			
L.1.2	Bega and Auckland Streets levee	$771,939	$103,940
L.2.2	Auckland Street levee	$779,667	$96,212
L.3.2	Millowine Ave Levee	$874,952	$927
L.4.2	Bega Street levee	$769,678	$106,201
1% AEP			
L.1.3	Bega and Auckland Streets levee	$670,016	$205,863
L.2.3	Auckland Street levee	$699,826	$176,053
L.3.3	Millowine Ave Levee	$873,617	$2,262
L.4.3	Bega Street levee	$667,243	$208,636
ROAD RAISING			
R12	Candelo Road Raising	$847,105	$28,774

12.3 Benefit to Cost Ratio of Options

The economic evaluation of each modelled option was performed by considering the reduction in the amount of flood damages incurred for the design flood events and then comparing this value with the cost of implementing the option.

The existing flood damages assessment was used as the base case to compare the performance of modelled options. Inputs for the assessment include those data derived from the floor levels and property survey, along with damage curves for other similar areas. The preliminary costs of each measure were used to undertake a benefit-cost analysis on a purely economic basis.

Table 10-3 summarises the results of the economic assessment of each of the flood management options. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C), which is a function of the net present worth (NPW) of the benefits (reduction in AAD) and the costs (of implementation), adopting a 7% discount rate and an implementation period of 50 years.

The B/C ratio provides an insight into how the damage savings from a measure relate to its cost of construction and maintenance:

> Where the B/C ratio is greater than one the economic benefits are greater than the cost of implementing the measure;

> Where the B/C ratio is less than one but greater than zero there is still an economic benefit from implementing the measure, but the cost of implementing the measure is greater than the economic benefit;

> Where the B/C ratio is equal to zero, there is no economic benefit from implementing the measure;

> Where the B/C ratio is less than zero, there is a negative economic impact of implementing the measure.

The results indicate that, overall, the structural options have low B/C ratios, with the implementation costs exceeding the benefits delivered. This is a result of the significant flood depths and extents in floods in the study area, which restricts the deployment of structural measures to control flood flows.

Generally, the higher the levee, and subsequent level of protection, the higher the B/C ratio. This is due to levees becoming more effective and benefiting greater numbers of properties as their height is increased.

The best performing option was the Auckland Street levee. This option delivered a B/C ratio of 0.4 for a 10% AEP levee, increasing to 0.6 for a levee for the 1% AEP. The Bega and Auckland Street levee option also scored a B/C ratio of 0.6 for the 1% AEP event.

No other option delivered a B/C ratio of better than 0.6 for any of the levees and protection alternatives identified.

Table 12-3 Economic Benefit / Cost Assessment of Flood Modification Options

Option ID	NPW of Yearly Reduction in AAD	NPW of Cost of Implementation	B/C Ratio	Economic Ranking
LEVEES				
10% AEP				
L.1.1	$377,864	$4,669,515	0.1	10
L.2.1	$493,446	$1,345,307	0.4	3
L.3.1	$13,152	$668,004	0.0	13
L.4.1	$409,068	$5,884,122	0.1	9
5% AEP				
L.1.2	$1,434,450	$4,592,322	0.3	6
L.2.2	$1,327,797	$2,987,311	0.4	5
L.3.2	$12,793	$1,545,007	0.0	12
L.4.2	$1,465,653	$6,646,430	0.2	7
1% AEP				
L.1.3	$2,841,063	$4,798,635	0.6	2
L.2.3	$2,429,663	$4,136,219	0.6	1
L.3.3	$31,217	$2,551,911	0.0	11
L.4.3	$2,879,333	$8,003,337	0.4	4
ROAD RAISING				
R.12	$397,103	$2,670,019	0.1	8

13 Multi-Criteria Assessment of Potential Options

To assist Council in identifying the flood management options that provide the most benefits for the community, all options need to be compared against each other based on factors including but not limited to the reduction in flood risk and economic flood damages.

Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Impacts associated with flooding include risk to assets, and risk to life. Regional areas impacted by flooding are valued in a number of ways by communities, organisations and individuals. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of the MCA is to attempt to directly incorporate multiple values held by community and stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In doing so, one can consider different floodplain management options in the context of economic criteria as well as other criteria such as social, regulatory or environmental aspects. Community and stakeholders can also identify their preferences and priorities. Therefore, MCA provides opportunities for the direct participation of community and stakeholders in the analysis.

A MCA approach was used for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach uses a subjective scoring system to assess the merits of each option. The principal value of such a system is that it allows comparisons to be made between alternatives using a common index. In addition, the MCA makes the assessment of alternatives “transparent” (i.e. all important factors are included in the analysis).

However, this approach does not provide an absolute “right” answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which Council, community and stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring system simple a framework has been developed for each criterion.

13.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion.

Each of the criteria has been given a weighting to reflect its importance concerning floodplain management. This weighting was developed in discussion with Council and reviewed with regards to submissions received from the public during the public exhibition period.

The criteria used are:

Economic	Benefit cost ratio
	Capital and operating costs
	Reduction in risk to property (economic damages)
Social	Reduction in risk to life in 1% AEP
	Reduction in social disruption
	Community support
	Compatibility with legislation, policies and plans
Environmental	Fauna / flora and heritage constraints
	Impact on surface and groundwater
	Impact on/of soils

The score for each category (i.e. economic, environment and social) is determined by the score for each criteria, factored by a weighting as shown in **Table 13-1**.

The overall MCA score for the option is then calculated by the weights for each of the categories as follows:

> Category Weighted Score = Category Weighting X Criteria Weighting X Criteria Score; and

> MCA Score = Category Factor X Category Weighted Score.

Table 13-1 Details of Adopted Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Score				
				-2	-1	0	1	2
Economic	2	Benefit Cost Ratio (function of cost of implementation / reduction in AAD)	1	0 to 0.2	0.2 to 1	1	1 to 1.5	>1.5
		Reduction in Risk to Property [1]	0.5	Major increase in AAD (>$20,000)	Slight increase in AAD (<$20,000)	No Improvement	Slight decrease in AAD (<$20,000)	Major decrease in AAD ($>20,000)
Social	1	Reduction in Risk to Life	1	Widespread or significant increase in risk to life	Localise or slight increase in risk to life	No change in risk to life	Localised or slight reduction of risk to life	Widespread or significant reduction of risk to life
		Reduction in Social Disruption	1	Major increase in social disruption (road overtopping increased by >0.2m)	Slight increase in social disruption (road overtopping increased by <0.2m)	No change to social disruption	Slight reduction of social disruption (road overtopping reduced by <0.2m)	Major reduction of social disruption (road overtopping reduced by >0.2m)
		Council Support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Community Support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans [2]	1	Completely incompatible	Slightly incompatible	Compatible	NA	NA
Environment	1	Surface Water Quality	1	Likely impacts to quality of catchment inflows or reduction in water exchange with ocean and freshwater inputs	Possible impacts to quality of catchment inflows or reduction in water exchange with ocean and freshwater inputs	No impacts on catchment inflows or water exchange with ocean and freshwater inputs	Possible improvements to quality of catchment inflows or increase in water exchange with ocean and freshwater inputs	Likely improvements to quality of catchment inflows or increase in water exchange with ocean and freshwater inputs
		Groundwater	1	Likely interception of groundwater flow contamination of groundwater quality during construction or after implementation	Possible interception of groundwater flow contamination of groundwater quality during construction or after implementation	No impact on groundwater flow or quality	Possible improvements to groundwater flow or quality	Likely improvements to groundwater flow or quality
		Fauna/Flora Impact[3]	1	Likely to impact on EECs, wetlands, seagrasses or large areas of vegetation. Restricts connectivity between areas of habitat and waterways	Possible impacts on EECs, wetlands, seagrasses or removal of isolated trees / vegetation. Restricts connectivity between degraded habitat and waterways	No impact	Restoration of small areas of habitat	Restoration of large areas of habitat
		Acid Sulfate Soils	1	Any work within Class 1 ASS area. Any excavation work within Class 2 ASS area. Excavation >1m within Class 3 ASS area. Excavation >2m within Class 4 ASS area.	Surface works within Class 2 ASS area. Excavation <1m or surface works within Class 3 ASS area. Excavation <2m or surface works within Class 4 ASS area.	Works not within areas identified as PASS	N/A	N/A
		Heritage [4]	1	Works within 10m of known heritage item(s)	Works within 30m of known heritage item(s)	No likely impact	N/A	N/A

[1] Values of likely AAD reduction assumed where actual assessment not undertaken

[2] The options have been assessed for the compatibility with Council policies and plans:

[3] Location of Endangered Ecological Communities (EECs) derived from AHA Ecological vegetation mapping (2008). Location of seagrasses derived from SCC (2012).

[4] Indigenous heritage items identified through AHIMS search.

13.2 Options Assessment Outcomes

A total of 24 potential flood management options were subject to a multi-criteria matrix assessment. Each of the options was then ranked against each other based on the total scores, allowing identification of the preferred options, namely those that provide the greatest benefit to the community.

The options scoring for each criterion is shown in its entirety in **Appendix E**.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the option on flooding as well as its affordability. Options that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are also shown in **Appendix E**. It must be emphasised that the scoring shown in **Appendix E** is not "absolute" and the proposed scoring and weighting should be reviewed at regular intervals to ensure they are still representative.

The options assessment outcomes are summarised in **Table 13-1**.

Table 13-2 Options Rankings

ID	Description	Rank
PM2	Building and development controls	1
EM2	Flood warning system	2
EM3	Public awareness and education	3
EM1	Information transfer to the SES	4
PM3	Flood proofing guidelines	5
DC1	Data collection following a flood event	6
PM1	Voluntary purchase	7
U.2	Flood flaps on Sharpe Street culverts	8
U.1	Upgrade of Boundary Road	9
L.2.3	1% AEP Levee - Auckland Street	10
L.1.3	1% AEP Levee - Bega and Auckland Streets	11
L.4.3	1% AEP Levee - Bega Street	12
R.11	Raising of Tathra Road and Kirkland Avenue	17
R.12	Candelo Road Raising	19
R.5	Raising of Ravenswood Road	20
L.3.3	1% AEP Levee – Millowine Avenue	21

Of the structural options assessed, excluding the road raising options for emergency access only (options U.1 and U.2), the top three options identified by the multi-criteria analysis were:

> L.2.3: 1% AEP Levee – Auckland Street

> L.1.3: 1% AEP Levee – Bega and Auckland Streets

> L.4.3: 1% AEP Levee – Bega Street.

Given these levee options are mutually exclusive, the other levee options for Auckland Street (L.2.1 and L.2.2), Bega and Auckland Streets (L.1.1 and L.1.2), and Bega Street (L.4.1 and L.4.2) would not be adopted in the FRMP.

The rankings are proposed as the basis for selecting management options for inclusion in the FRMP, and for prioritising their implementation.

It is recommended that the top 12 highest-ranking options, representing those options that provide the greatest benefit to the community on a value for money basis, be adopted as actions in the FRMP. The ranking of the options is proposed to be used as the basis for prioritising the components of the FRMP. The options selected for inclusion should be based on both their likely benefits and the likely funding available from Council and the State Government.

14 Conclusions and Recommendations

Flooding in the Bega and Brogo Rivers catchments can pose a hazard to some residents and properties near creeks and overland flowpaths. The purpose of this study is to identify and examine options for the management of flooding within the study area.

This report presents the findings of the Floodplain Risk Management Study stage of the Flood Risk Management Process for the Bega and Brogo Rivers catchment, in accordance with the Floodplain Development Manual (NSW Government, 2005). The investigations undertaken as part of this process identified a number of issues within the floodplain. Based on these issues, a series of floodplain management options were developed and recommended.

An extensive list of potential options was assessed against a range of criteria (technical, economic, environmental and social; refer **Section 13**). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure (refer **Section 12**).

The outcomes of the MCA provide a sound basis upon which Council can make decisions about undertaking works, making planning decisions and developing response arrangements to reduce the impact of flooding on property and life.

The options identified as having significant flood reductions that also do not have adverse social or environmental impacts will be incorporated into the Bega and Brogo Rivers FRMP as the proposed management actions. This document will recommend a cost-effective plan to manage flood risk and will outline the process of implementation for recommended management actions within the floodplain.

The shortlist of 12 floodplain management measures recommended for inclusion in the FRMP are generally based on opportunities for short to medium term work and comprise levees, road raising, and flood warning systems. The majority of the measures are independent and therefore can be undertaken as isolated projects. These measures will likely require further detailed assessment and detailed investigation prior to any implementation.

The implementation strategy may not necessarily approach the options from “highest ranking to lowest ranking” but will also need to incorporate various other considerations such as existing works programs, availability of funding and other opportunities to combine floodplain works with other activities.

While the rankings of the shortlisted options are useful, it should be recognised that the FRMP needs to retain sufficient flexibility such that Council (or other responsible agencies) may implement any of the measures at any time, regardless of their ranking. Such an instance may arise, for example, where funding becomes available through a specific grant or funding program, which would allow for the implementation of a lower ranked option before a higher ranked option. Alternatively, opportunities to implement specific options ancillary to another project may arise from time to time, such as when a road is proposed for upgrade the road raising may be undertaken concurrently.

For less expensive measures, Council may be able to source funding readily and these measures can progress through implementation relatively quickly. For more expensive measures, Council will need to submit an application for funding assistance to OEH and other agencies as appropriate. Some measures can be implemented by Council fairly readily, such as those related to planning or development controls. In contrast, a flood modification option will need to progress to a detailed design stage before it can be built.

Additional investigations and design development are required for flood modification or property modification options to further assess feasibility, develop a more detailed cost estimate, and to develop the level of detail necessary for construction, taking due consideration of all physical, environmental and social constraints.

The recommended flood modification options as described in this FRMS may be modified marginally or significantly because of this process, and the detailed design will need to be (re-)modelled to demonstrate the mitigation benefits of the final design are appropriate and meet the flood mitigation objectives. The final step in progressing a flood modification option to implementation is to conduct an environmental impact assessment in accordance with the requirements of the EP&A Act (refer **Section 7.3**). Other approvals, permits or licences may be required prior to implementation. This process may also be applicable to other types of management options, such as the design, development and implementation of flood warning systems.

For property modification measures, such as P1, which recommends voluntary property acquisitions, the development of a policy and accompanying scheme for must be undertaken to allow Council to apply for the necessary funding and to enable them to discuss the proposed acquisitions strategy with the community. These activities must take place before any acquisitions, if approved by Council and the relevant landowner could occur.

Hence, it is recommended that the Plan be regarded as a “living document” requiring review and modification over time. The catalysts for change may include new flood events and experiences, legislative change, changes in the availability of funding, reviews of Council’s strategic plans prepared under the Integrated Planning and Reporting System, or amendments to their planning policies.

15 Qualifications

This report has been prepared by Cardno for Bega Valley Shire Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence, there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe date provided.

Study results should not be used for purposes other than those for which they were prepared.

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