Preferred Mitigation Options Final Report

Bega and Brogo Rivers Flood Warning Scoping and Feasibility Study

NW30062

Prepared for

Bega Valley Shire Council

12 December 2022

Cardno

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Stantec

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1 Introduction

1.1 Project Overview and Objectives

The Bureau of Meteorology and NSW State Emergency Service (NSW SES) provide flood warning services for the Bega River at Bega (Gauge No. 219900). However, the 2018 Bega and Brogo Rivers Floodplain Risk Management Study & Plan (BBR FRMS&P) identified that improving on the current flood warning system would assist in reducing flood impacts & the risk to life in the other parts of that study area.

Cardno now Stantec were engaged to review the existing flood warning system and recommend options to improve its functionality and effectiveness. To this end Cardno now Stantec worked in collaboration with the Bega Technical Working Group, which includes representatives from Bega Valley Shire Council, NSW State Emergency Service (SES), Bureau of Meteorology (BOM) and the NSW Department of Planning and Environment (DPE). Additionally, a focus group including Councillors and community representatives were consulted during the project. This focus group has now been superseded with the governance arrangements for the Coast and Flood Management Committee changed with a technical sub-committee now established. It is understood this technical sub-committee may be responsible for overseeing implementation of the key recommendations within this report.

The objectives of the project are set out in the Brief, and include:

1. Scope the requirements and determine feasible options for the implementation of a fit for purpose location-based warning system for the settlements of Bemboka, Wolumla, Candelo, Bega, Kalaru, Tathra and Mogareeka (and potentially the Bournda Parkway area) which will satisfy the objectives of the associated recommendations outlined within the BBR FRMS&P. This should include an audit of the existing flood warning infrastructure to assess its fitness for purpose for the current and potential enhanced flood warning system.
2. Provide advice on the system design based on the optimal Total Flood Warning System (TFWS) based on the scoping work which includes operational protocols and preliminary costing for both the capital and ongoing maintenance costs of the system/s for consideration by council.
3. Develop documentation for a draft flood warning system owner's manual (consistent with the current guidance available from DPE) based on the recommended system design.
4. Provide recommended wording for amendments or inclusions of the key system functionality within the relevant local flood plan.
5. Develop a draft communication, consultation and education plan on the recommended system to inform the community of the intent of the system, the delivery of warnings and the limitations of the system.
6. The proposed system, communication plan and associated documentation will be developed and project delivered in consultation with a technical working group (TWG) made up of Council staff, DPE and NSW SES with input from the Bureau of Meteorology, key stakeholders and the community.
7. Development of a draft scope of work which can be considered by Council in developing a technical brief to invite relevant specialists to deliver the agreed TFWS for Council.
8. Investigate the opportunities, practicalities and cost/benefit of incorporating IoT (Internet-of-things) technologies into the TFWS within the constraints of the Bureau of Meteorology Flood Warning Infrastructure Standard (FWIS).
9. Evaluate the suitability and any opportunities for enhancement of available flood warning infrastructure to provide an adequate level of flood warning for both riverine and flash flooding scenarios at the key population centres throughout the catchment.

This report does not cover flood risks associated with Wolumla and Kalaru significantly. This is based on the following:

- **Limited knowledge:** there is limited flood knowledge regarding the communities of Wolumla – to address the knowledge gaps for Wolumla a flood study is being undertaken as part of the 2022-2023 Floodplain Management Program; and
- **Themes, options and recommendations emerging during consultation:** options and recommendations associated with the townships of Wolumla and Kalaru were considered but did not emerge during the study, the consultation with the community or the technical working group.

The detailed Wolumla Flood Study will help inform an increased understanding of flood risks and potential flood mitigation options. Furthermore, actions to manage the rural inundation, infrastructure disruptions and isolation are appropriate for the community of Kalaru.

1.2 Project Approach & Staging

The Bega and Brogo Rivers Flood Warning System Scoping and Feasibility Study is being undertaken in stages. These are set out in **Table 1-1**.

Table 1-1 Project Staging and Deliverables

Stage	Key Deliverables	Status
1	▪ Data Collection and Review	Completed - October, 2020
	▪ Fit for Purpose Total Flood Warning System Options ▪ Community Consultation	Completed – February 2021
2	▪ Detailed Preferred Options Report ▪ Community Consultation, Public exhibition of the draft report and presentation	Completed – September 2021
	▪ Cost benefit analysis of the preferred optimised system ▪ Final Flood warnings options report	Completed - March 2022
3	▪ Draft Flood Warning System Owners' Manual	Final Report for endorsement – December 2022
4	▪ Outline key inclusions for the NSW SES Local Flood Plan	
5	▪ Draft education and awareness program for the system	
6	▪ Draft scope of work for system implementation	
7	▪ Handover of materials and project closeout	June 2023

1.3 The Total Flood Warning System Framework

The approach to community consultation and option identification has been guided by the Total Flood Warning System components (Australian Emergency Manual Series, Manual 21, Flood Warning, Australian Government 2009), shown on **Figure 1-1**, which includes:

- **Monitoring and Prediction:** detecting environmental conditions that lead to flooding, and predicting river levels during the flood
- **Interpretation**: identifying in advance the impacts of the predicted flood levels on communities at risk;
- **Message Construction:** devising the content of the message which will warn people of impending flooding;
- **Communication:** disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood;
- **Protective Behaviour:** generating appropriate and timely actions and behaviours from the agencies involved and from the threatened community; and
- **Review:** examining the various aspects of the system with a view to improving its performance.

A successful flood warning system must be effective in each of these components.

This framework is used throughout consultation to identify strengths and opportunities for improvement and shapes the way that these gaps are addressed in the option identification stage.

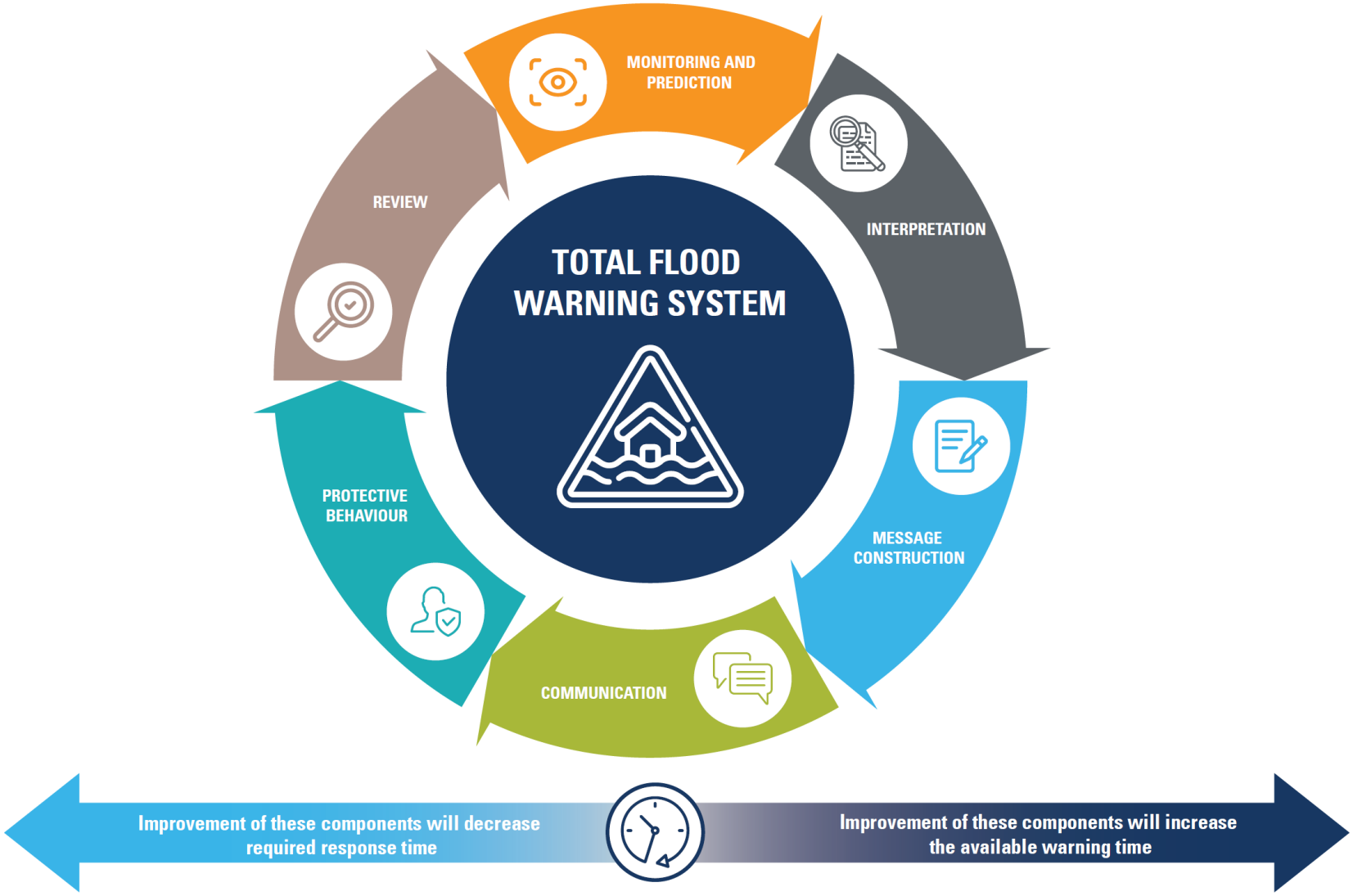


Figure 1-1 The components of the Total Flood Warning System (Australian Emergency Manual Series, Manual 21, Flood Warning, Australian Government 2009)

1.4 Flood history

The Bega and Brogo River catchments have a history of flooding. Smith, E (1978) provides an insight into flood events in Bega from the period 1851 – 1978 including details of when the large floods have occurred, the rainfall received that resulted in the floods and the consequences associated with the flood events with reference to fatalities, property damage and road closures.

The *Bega and Brogo Rivers Floodplain Risk Management Study and Plan* (Cardno, 2018) provide further insights into flood events that occurred prior to 2014 and 2018 respectively.

From the community consultation undertaken and documented by SMEC (2014), the following flood events were remembered by residents:

- February 1971;
- March 1983;
- February 2010;
- February 2011;
- March 2011; and
- March 2014.

During the course of this study in November 2021, the *Bega Valley Shire Local Flood Emergency Sub Plan Vol. 2* was updated and provided to Cardno now Stantec. A comprehensive flood history is detailed within this plan including more recent flood events than 2014. This includes reference to flood events in January 2016 and June 2016. The Sub Plan provides the estimated peak levels at the Bega North Gauge (219900) for all known historic events dating back as early as 1851. From the earliest historic flood recorded on the list provided from 1851, there are ten (10) floods that have exceeded the Major Flood Level of 8m, ten (10) flood events that have reached or exceeded the Moderate Flood Level of 7m and eight (8) floods listed that have exceeded the Minor Flood Level of 4.6m. It should be noted that for one (1) flood event that is listed the level or flood classification is not listed and it is not intended to be a list that captures all flood events that have occurred.

The highest recorded flood event reached 9.78m on 6 February 1971, *Bega Valley Shire Local Flood Emergency Sub Plan,* Vol 2 (November 2021). WRC (1975) report documented the impacts of the 1971 flood event which included the loss of two lives in the South Coast region, over 50 bridges being destroyed and loss of critical infrastructure including water supply, electricity and communications services. Flood Warning can play a role to reduce the exposure to damages from floods and minimise the risks to life. A series of images from the 1971 floods are provided below.

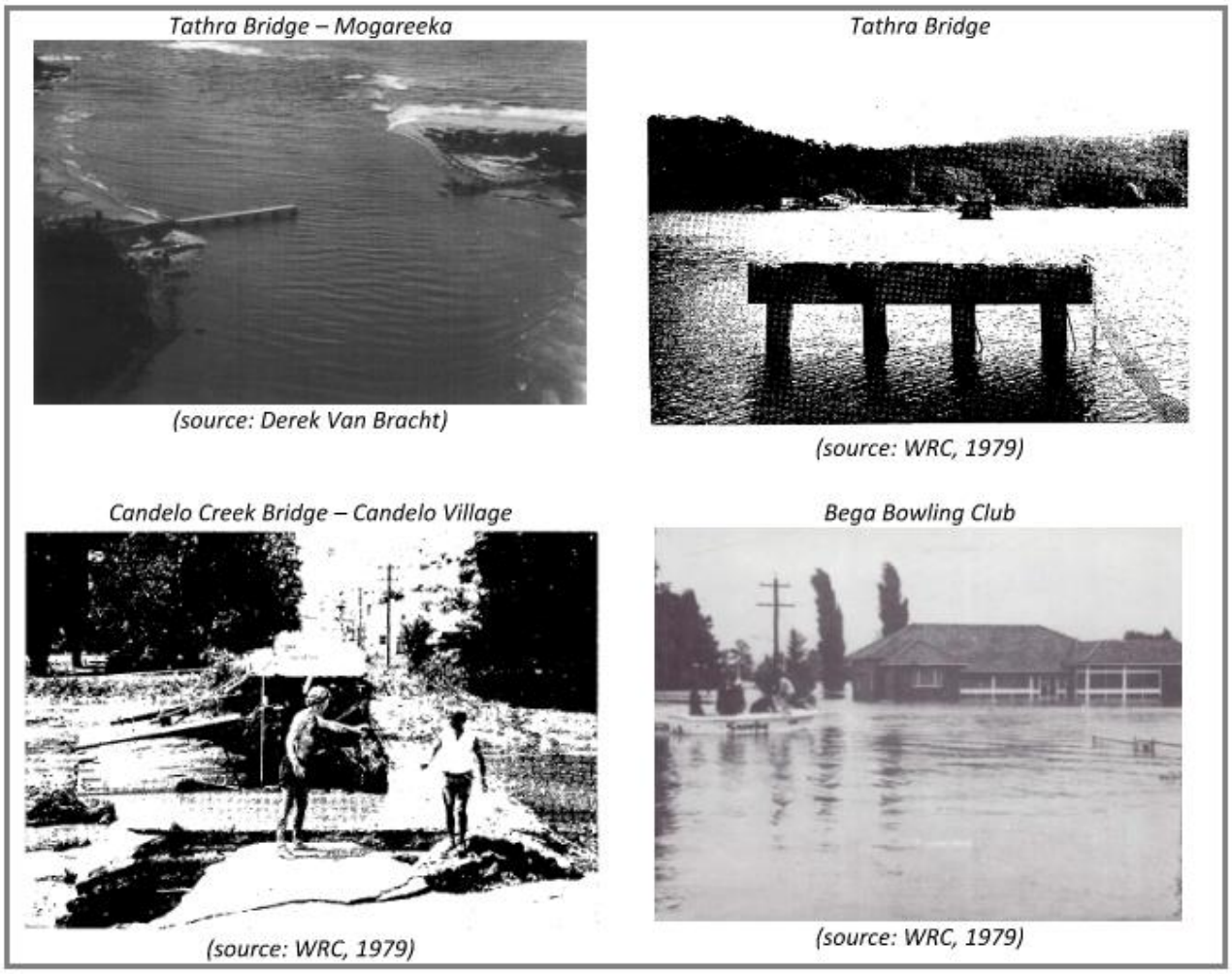


Figure 1-2 Historic flood photos – February 1971 flood event

1.5 Analysis of recent flooding

In addition to the above, the Bega and Brogo River catchments have experienced the cumulative impact of a series of recent flood events during 2020, 2021 and 2022 which has been the cause of significant damage to key infrastructure. More information regarding the recovery efforts from one of these recent events during 2021 is highlighted on Council's website.[1]

The March 2021 flood event occurred during the course of undertaking the study and as such was assessed by the project team undertaking the study. Data was accessed from BoM's website from the period of 20th March 2021 to 25th March 2021 to assess the rate of rise and fall for some of the key gauges of interest over the course of the flood event. The gauges analysed and the key high level findings are detailed below:

- **Bemboka R at Morans Crossing:** start of rise occurred around 1200hrs on the 23rd March, 2021 and peaked approximately 6 hours later at around 1800hrs on 23rd March, 2021. Refer to Figure 1-3 for details.

[1] Bega Valley Shire Council, *Flood recovery works across the shire,* https://begavalley.nsw.gov.au/council/flood-recovery-works-across-the-shire accessed 9th March 2022.

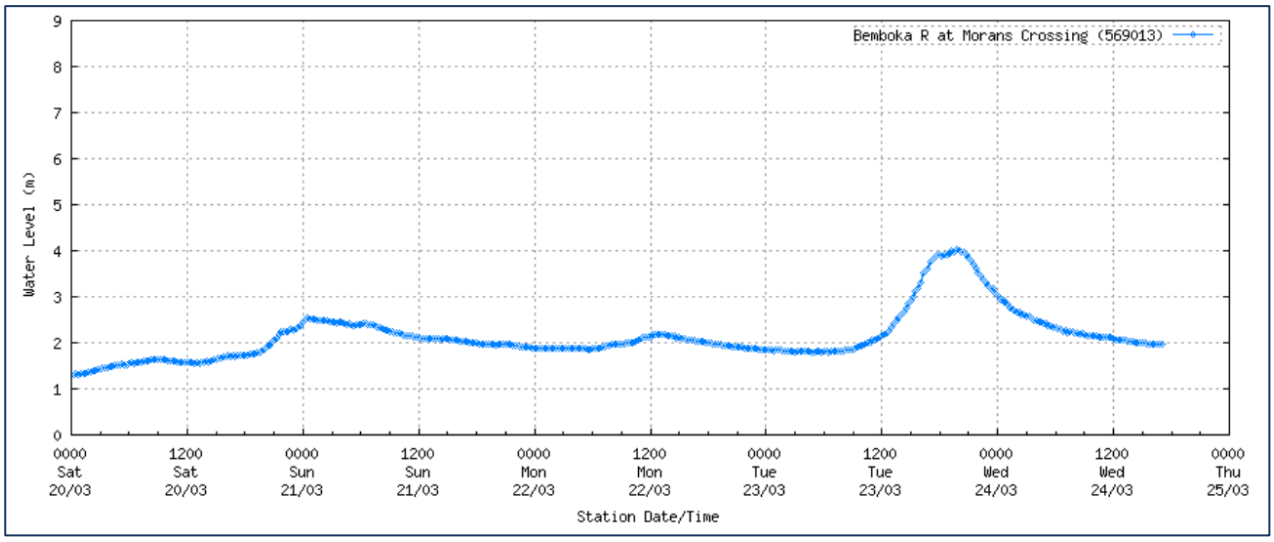


Figure 1-3 Bemoka River at Morans Crossing (Source: Bureau of Meteorology)

> **Bega River at Kanoona:** start of rise occurred around 3:00PM on 23rd March, 2021 and peaked approximately 6 hours later at around 9:00PM on 23rd March, 2021. Refer to Figure 1-4 for details.

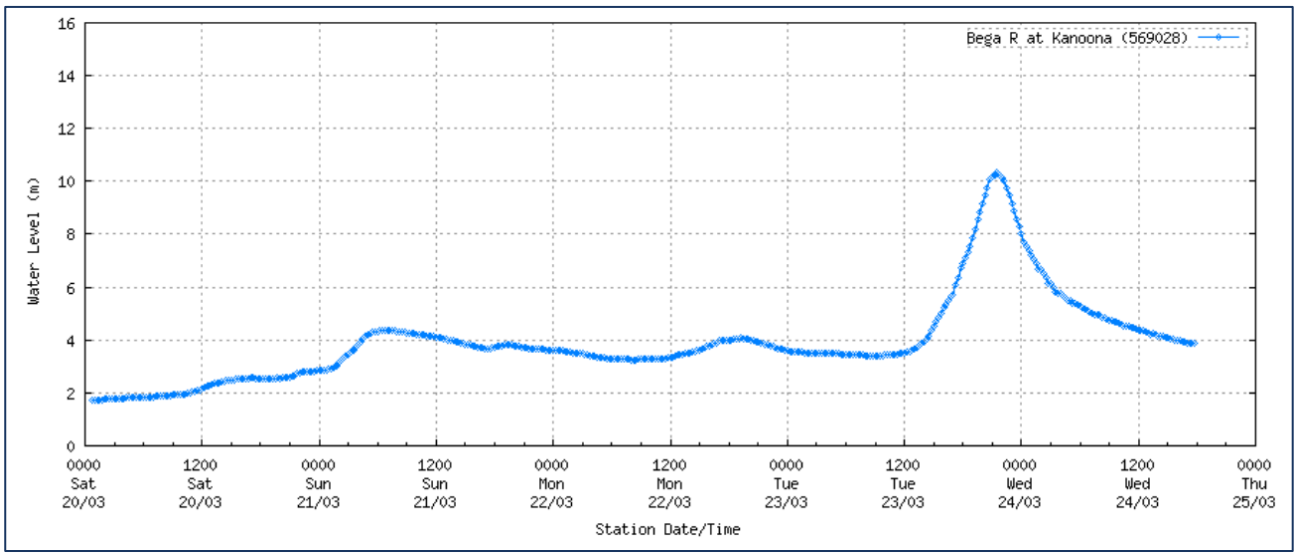


Figure 1-4 Bega River at Kanoona (Source: Bureau of Meteorology)

> **Bega River Entrance:** start of rise occurred around 11:00PM on 23rd March, 2021 and peaked approximately 9 hours later at around 8:00AM on 24th March, 2021. Refer to Figure 1-5 for details.

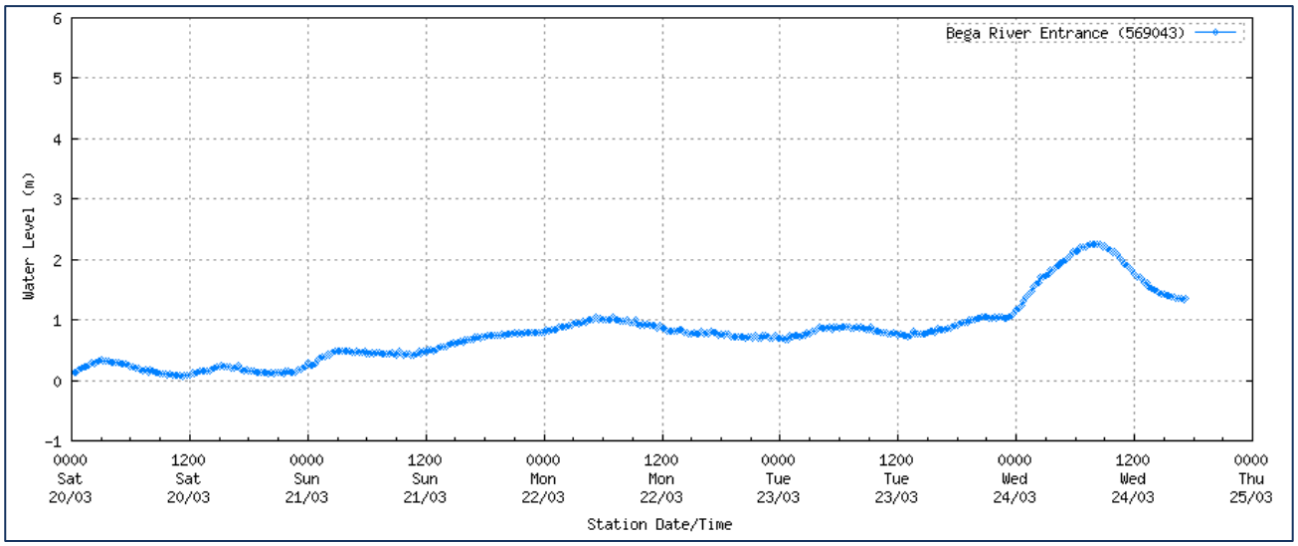


Figure 1-5 Bega River Entrance (Source: Bureau of Meteorology)

> **Brogo Dam:** start of rise occurred around 12:00PM on 23rd March, 2021 and peaked approximately 9 hours later at around 9:00PM on 23rd March, 2021. Refer to Figure 1-6 for details.

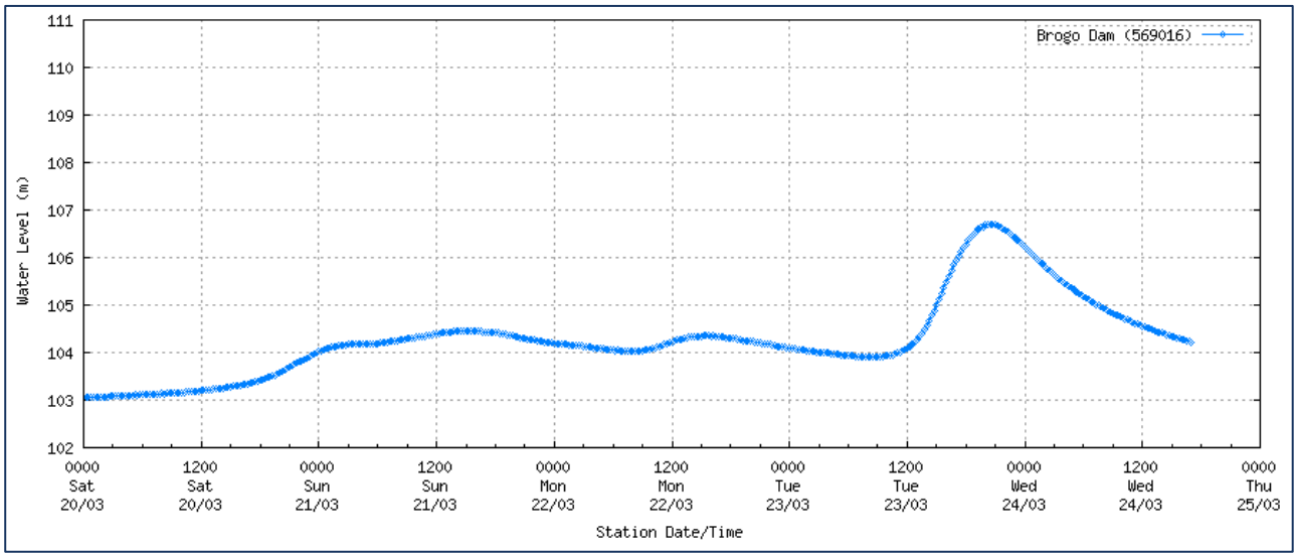


Figure 1-6 Brogo Dam (Source: Bureau of Meteorology)

> **Brogo R at North Brogo:** start of rise occurred around 12:00PM on 23rd March, 2021 and peaked approximately 8 hours later at around 8:00PM on 23rd March, 2021. Refer to Figure 1-7 for details.

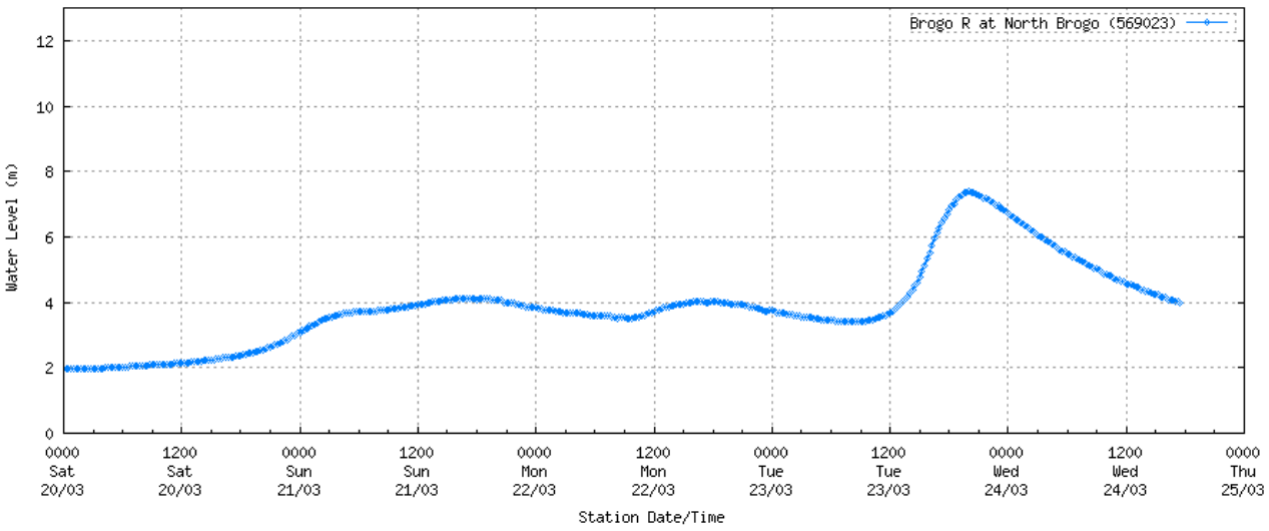


Figure 1-7 Brogo River at North Brogo (Source: Bureau of Meteorology)

> **Brogo R at Angledale:** start of rise occurred around 1:00PM on 23rd March, 2021 and peaked approximately 9 hours later at around 10:00PM on 23rd March, 2021. Refer to Figure 1-8 for details.

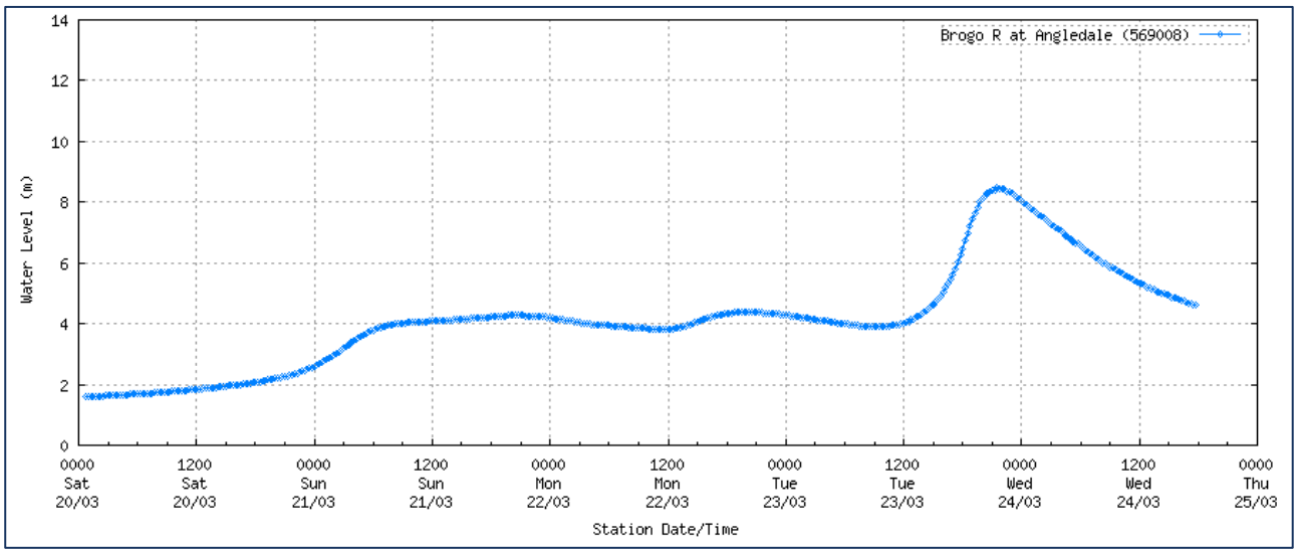


Figure 1-8 Brogo River at Angledale (Source: Bureau of Meteorology)

> **Tantawangalo Creek at Candelo Damsite:** start of rise occurred around 10:00AM on 23rd March, 2021 and peaked approximately 10 hours later at around 9:00PM on 23rd March, 2021.

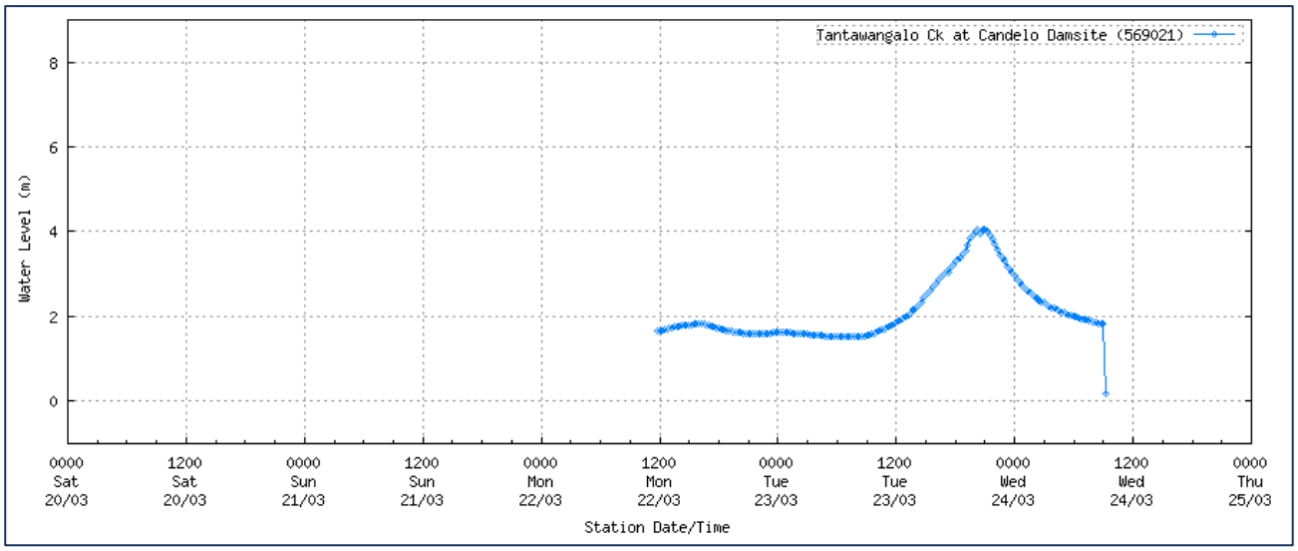


Figure 1-9 Tantawangalo Ck at Candelo Damsite (Source: Bureau of Meteorology)

In summary the analysis of a select set of stream gauges within the Bega and Brogo River catchments demonstrated that the time varied between 6-10 hours from the start of stream rises to peak levels being reached.

As shown in the above figures, the hydrographs generally present as peaky with most having high rates of rise for the gauges analysed. This included an approximate rate of rise of 0.31m/hr for the Bemboka R at Morans Crossing gauge, 0.66m/hr for the Bega River at Kanoona gauge, 0.13m/hr for the Bega River Entrance gauge, 0.47m/hr for the Brogo Dam gauge, 0.43m/hr for the Brogo R at North Brogo gauge, 0.45m/hr for the Brogo R at Angledale gauge and 0.22m/hr for the Tantawangalo Creek at Candelo Damsite gauge.

2 Review of Current Flood Warning System

The review of the current flood warning system has been undertaken, and has involved:

- Desktop data collection and review (presented in Appendix B)
- Site Visits (described in Appendix B)
- Meetings with key stakeholders, the Technical Working Group (Council officers, NSW SES, Bureau of Meteorology, NSW DPE and MHL) and the Focus Group including Councillors and and community; and
- Community Consultation (presented in Appendix C and D).

2.1 The Flood Warning System features for the Bega and Brogo River catchment

Key features of the Flood Warning System including existing warning services and emergency plans for the Bega and Brogo River catchments are summarised below. Further details are documented within Appendix E within the '*Draft Flood Warning System Manual.'*

Table 2-1 Key features of the TFWS – Warnings and Emergency Plans

Key features	Comments
Severe Weather Warning: The BoM may issue a **Severe Weather Warning** for the *South Coast* region as defined by the BoM (www.bom.gov.au).[2] Sever weather warnings are issued for potentially hazardous or dangerous weather that may include severe thunderstorms.	Severe weather warnings issued for the *South Coast* region may provide a 'heads up' for Council, emergency management personnel and the community for a severe weather event.
Flood Watch: The BoM may issue a **Flood Watch** for the *Bega River* catchment as defined by the BoM (www.bom.gov.au).[3] The flood watch areas defined by the BoM are defined by the BoM (www.bom.gov.au).[4] A Flood Watch is issued to provide early advice of a developing situation that may lead to flooding. It may provide guidance of forecast rainfall totals, identify catchments at risk of flooding and indicate possible severity. A Flood Watch may identify local flooding or tidal impacts and is generally issued up to four (4) days in advance of the expected onset of flooding.	A Flood Watch for the *Bega River* catchment may provide a 'heads up' for Council, emergency management personnel and the community for an impending flood event. In additional to the potential for riverine flooding, within the Bega and/or Brogo River catchment, the BoM may provide advice regarding the potential for flash flooding within a Flood Watch. This is noted as local flooding.
Minor, Moderate and Major Flood Warnings: The BoM provides a **flood warning service** for the township of Bega with reference to water level gauge, Bega North (219900) which includes the	Flood warnings are issued for the township of Bega. Reference to other locations may be provided within flood warnings issued by the BoM. Further details of the quantitative flood warning service provided by the BOM is specified in the

[2] Bureau of Meteorology, *New South Wales Forecast Area Map,* http://www.bom.gov.au/nsw/forecasts/map.shtml accessed 9th March 2022.
[3] Bureau of Meteorology, *Flood Warning Services*, http://www.bom.gov.au/water/floods/floodWarningServices.shtml accessed 9th March 2022.
[4] Bureau of Meteorology, *Flood Watch Areas, New South Wales,* http://www.bom.gov.au/water/floods/image/BOM_Flood_Watch_Areas_map_NewSouthWales_2017.pdf?=v3 accessed 9th March 2022.

Key features	Comments
issuing of Minor, Moderate and Major Flood Warnings. The BoM provides a target warning lead time of 3 hours with the trigger height set at 4.6m, the Minor Flood Class Level.	*Service Level Specifications for Flood Forecasting and Warning Services for New South Wales and the Australian Capital Territory,* version 3.13. This is available from the BoM's website.
NWS SES Flood Bulletins: Flood Bulletins for the NSW SES South Eastern Zone are issued to various media outlets and organisations. NSW SES are typically closely guided by the BoM regarding the information presented within its Flood Bulletins and the timing of their release. Flood Bulletins may contain information relating to a Flood Watch, Minor, Moderate and Major Flood Warnings, road closure information, evacuation warnings and orders, isolation and resupply matters, emergency relief centres, critical infrastructure impacts and other information about risks to life, damage to property and infrastructure. The intent of NSW SES Flood Bulletins is that in addition to bringing attention to warnings issued by the BoM, that they contain information on likely flood consequences in the local area and what protective actions are required or advised. NSW SES Flood Bulletins are available on the NSW SES website.[5]	NSW SES Flood Bulletins available from the NSW SES website include: > options for the reader to access information from an interactive map; > links to more detailed information about the Flood Bulletin; and > links to further information from social media.
NSW SES Livestock and Equipment Warnings: Livestock and Equipment Warnings can be issued where there is a known risk to landowners and farmers from flooding. Livestock and Equipment Warnings can assist landowners and farmers to take early and necessary action to relocate or move farm machinery, pumps or livestock to higher ground and when access may become restricted.	Across the Bega and Brogo River catchment there are a number of locations where landowners and farmers are exposed to flood risks. This includes areas along the Brogo River including downstream of the Brogo Dam and areas along Candelo Creek in the upstream catchment. It is understood from Livestock and Equipment Warnings have not been a feature of previous flood events within the Bega and Brogo River catchments.
Bega Valley Shire Flood Emergency Sub-Plan, 2021 The Bega Valley Shire Flood Emergency Sub-Plan (the Flood Plan, Vol. 2) was recently updated in November 2021 and covers the preparation for, response to and recovery from flooding emergencies for the LGA.	Given the recency of the last update being to the Flood Emergency Sub-Plan (November 2021), it is considered an opportune time to test and exercise the Sub-Plan with key organisations.

[5] NSW SES, *Current NSW SES community advice,* https://www.ses.nsw.gov.au/ accessed 9th March 2022.

Key features	Comments
The SES Flood Plan Vol. 1 and 2 focus on flooding emergencies, and more explicitly defines the roles and responsibilities of parties in a flood event. It also makes note of flood prone locations, gauge triggers, identifies flood impacts and consequences including which key roads can be flood affected and details evacuation arrangements.	
Flood Intelligence materials There are a range of Flood Intelligence materials and sources including but not limited to: > NSW Flood Data Portal – provides information about the Bega and Brogo River catchment's flood risk[6] > The Bega Valley Shire Local Flood Emergency Sub Plan Vol. 2 contains a range of flood intelligence and flood mapping including gauge triggers, flood consequence information, flood travel times and a range of other information. > BoM Flood Scenarios Outlook products – a tailored product for emergency managers, issued for riverine catchments specified in an issued Flood Watch. It details possible flood response for different rainfall scenarios.	Specialised staff from Council and emergency services organisation have access to a range of flood intelligence materials that are critical to helping deliver a targeted and tailor TFWS. This includes helping to inform flood preparedness, required local flood responses and the provision of content within flood warnings that is relevant to local communities at risk of flooding.

2.2 Description of component options

As illustrated in Figure 1-1 all elements within the Total Flood Warning System (TFWS) are interdependent of one another. In practical terms, this emphasises the importance of investing in all components of the TFWS. For example, it is important that if Council is going to be making investments in enhancing the 'Monitoring and Prediction' element, for the value of the investment to be realised there is a need to invest also in how the enhanced 'Monitoring and Predictive' services will be interpreted by forecasters and emergency service organisations and what the enhancements will mean for how flood information and warnings are communicated.

The following sections details the TFWS design options alongside industry case studies which aim to assist in conceiving what options are on the table, what has been undertaken in other contexts and what is feasible and/or achievable for investments in flood warning improvements.

2.2.1 Monitoring and Prediction overview

As detailed in the *Service Level Specification for Flood Forecasting and Warning Services for New South Wales and the Australian Capital Territory,* version 3.13 there is one (1) water level gauge within the study area that is identified as a forecast location. The BoM used data from this gauge, rainfall gauges in the catchment and other information to help inform its prediction and warning services for the Bega and Brogo River catchments. The current target warning lead time is 3 hours for this gauge based on the *Service Level Specification for Flood Forecasting and Warning Services for New South Wales and the Australian Capital Territory,* version 3.13.

It is well documented that there is often a level of hesitancy and a lag time associated with people commencing and undertaking flood response actions upon receipt of a flood warning message. As documented in the NSW SES Evacuation Timeline diagram (NSW SES, 2013) there is a lag associated with flood warnings that seek

[6] NSW SES, NSW Flood Data Portal, https://flooddata.ses.nsw.gov.au/ accessed 9th March 2022.

a community to act, in this case to evacuate. Refer to Figure 2-1 for the components of a conceptual '*Emergency Evacuation Timeline.'* (NSW SES, 2013).

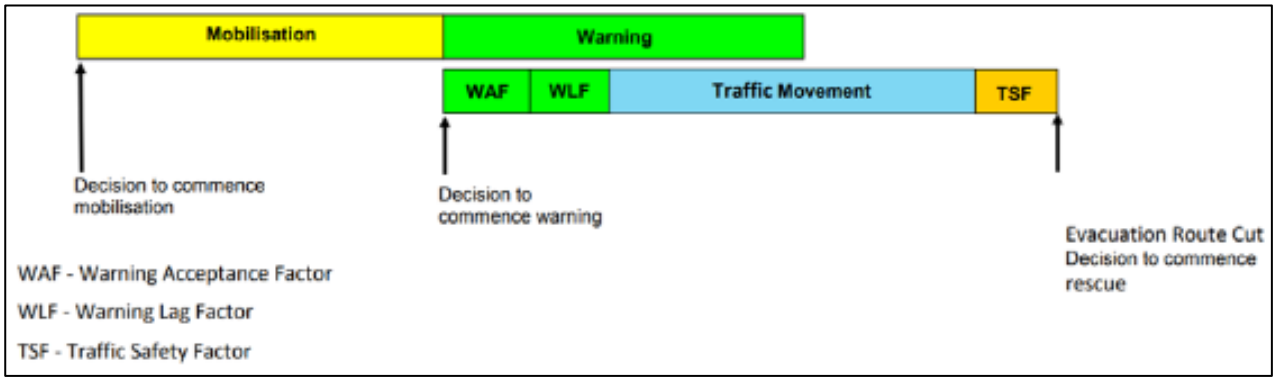


Figure 2-1 Conceptual Emergency Evacuation Timeline (NSW SES, 2013)

2.2.2 Interpretation overview

NSW SES have recently updated the *Bega Valley Shire Local Flood Emergency Sub Plan, Vol. 2* with the latest draft version being finalised in November 2021.

The *Interpretation* element of the TFWS requires identifying in advance the impacts of predicted flood levels on communities at risk. Whilst it needs to be said that '*no two floods are the same*' the knowledge from historic floods enables emergency services agencies including the NSW SES to collate a record of impacts and consequences from historic flood events help to build a knowledge base to enable NSW SES and Council to establish an enhanced understanding of how flood consequences relate to predictions and warnings provided by the BoM.

Additionally, given the nature of the flood risk where not all flood risk is associated with riverine flooding and as such not all locations in the Bega and Brogo River catchment can rely on receiving a flood warning from the BoM, there are other initiatives that are required for an effective flood response. This includes:

- Monitoring regional weather forecasts and flood watches;
- Monitoring stream and rainfall gauges in the upstream catchment; and
- Referencing historic flood events, flood intelligence, flood mapping and enacting flood plans.

2.2.3 Message Construction & Communication

Pre-defined flood warning information or messages can be devised to be tailored for those at risk of flooding. The intended recipients, the mediums by which warnings are being communicated and the systems of technology being utilised all have an influence on the content that is developed for the messaging. Given the highly variable nature of flooding and the notion that '*no two floods are the same'* those responsible for constructing and communicating flood information and warnings during flood responses need to adapt to the circumstances facing them with the particular behaviour and characteristics of the flood event. For flood risk locations in upstream locations such as Candelo there is limited lead time to provide advanced notice ahead of a flood event. Technology that enables automated alerts and/or predictive messages can be utilised as a means of alerting selected users such as key operational staff and/or a defined community at risk of flooding.

2.2.4 Protective Behaviour

Protective behaviour includes enabling appropriate and timely actions and behaviours of the flood threatened community. This includes enabling communities to take actions to minimise risks to life and contribute to the overall safety of those faced with the impending or actual flood event. It may include community members relocating to a safer place and implementing evacuation plans.

3 Total Flood Warning System Case Studies

Several industry case studies were considered across all elements of the TFWS. The case studies summarised below are presented for the purpose of taking a wide view of other initiatives that have been undertaken to improve gaps and deficiencies in the TFWS in other locations.

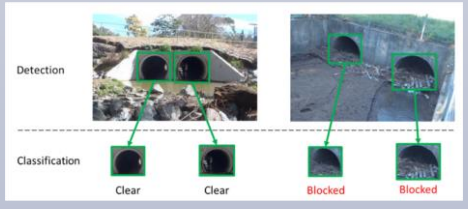
3.1 Monitoring and Prediction Case Study – Use of Technology to enhance flood monitoring and prediction: Illawarra Shoalhaven Smart Water Management Project

Case Study – Use of Technology to enhance flood monitoring and prediction: Illawarra Shoalhaven Smart Water Management Project

Over a 50 year period the Illawarra-Shoalhaven area experienced 33 floods classified as serious to extreme. This project was a collaboration between Wollongong City Council, Shellharbour City Council, Kiama Municipal Council, Shoalhaven City Council, Lendlease Calderwood Valley Communities and the Smart Infrastructure Facility, University of Wollongong and involved the use of environmental sensors using cameras, LiDAR and ultrasonic waves and data analytics to detect culvert blockages, manage estuaries and stormwater assets with the intent of achieving greater flood risk protection by improving the accuracy and timeliness for flood warnings and provide information about the region's waterways.

Some of the Smart Waterways services developed include:

- **Flood Aware Flash Flood Warning System:** utilises an GIS Agent-based Modelling Architecture to translate rainfall to flood flows through the catchment and provides this information to the *Wollongong Dashboard;*
- **Go Flow Smart intermittently closed lakes lagoons (ICOLLS) Management:** provides active monitoring of lagoon entrances with the monitoring stations consisting of static LiDAR, (Ception P60), an inertial measurement unit (IMU) and an edge-computing device (NVIDIA Jetson Nano) to acquire and process data and provide this information to the *Wollongong Dashboard* and *Shoalhaven Dashboard;*
- **Stop Block – Stormwater Culvert Blockage Management**
  - provides monitoring of culvert blockages utilising Artificial Intelligence (AI) technology via CCTV camera with information provided to Council's operations teams via purpose built password protected dashboards referred to as the *Wollongong Dashboard* and *Kiama Municipal Council Dashboard;*
  - monitoring occurs via detection of the culvert opening using YOLO v4 and a ResNet-50 device which classifies the blockage status as either clear of blocked; and
  - the system is powered via solar power and battery with a demand of 9.1W on average.
  - Refer https://visionillawarra.org.au/smart-waterways/stop-block/ for information on 'stop block'



- **Smart Schools:** as part of the project the project engaged with schools across each of the four (4) councils; and

Extension of the LoRaWAN (Long Range Wide Area Network) with 4 additional Gateways: the project used the *Things Network* to deploy its regional IoT network and liaised with other stakeholders to install additional gateways.

*Refer to *https://www.infrastructure.gov.au/territories-regions-cities/cities/smart-cities/collaboration-platform/Smart-Water-Management-Project-Illawarra-Shoalhaven* and https://visionillawarra.org.au/smart-waterways/ for further information about this case study.

3.2 Interpretation Case Study – Flood Gauge Mapping System: Bundaberg Regional Council

Case Study - Flood Gauge Mapping System: Bundaberg Regional Council

Bundaberg Regional Council have established a 'Flood Gauge Mapping System.' The Flood Education tool allows communities to better understand how different gauge levels may affect their community or individual property. The Flood Gauge Mapping System provides reference to levels recorded for historic floods, provides gauged matched flood maps, details the relationship of Paradise Dam and Walla Gauge flood levels to Bundaberg Gauge and provides an 'estimated flood travel time map (relative to Paradise Dam).

Further information on the 'Flood Gauge Mapping System' can be found on Council's website (https://www.bundaberg.qld.gov.au/flood-gauge-mapping-system).

3.3 Message Construction & Communication Case Study – Grantham Siren

Case Study – Grantham Siren

In January 2011 the Grantham community suffered significant loss of life and devastation from a flood of significant magnitude. Since the floods in 2011 there have been a number of changes that have occurred including the relocation of large part of the town to higher ground via a land swap negotiated between the Lockyer Council and some of the residents within Grantham. Another change to occur since these floods has been the installation of a purpose built flood emergency siren to alert residents of a flood emergency.

The siren is one of many tools used to provide warning for flood emergencies and is activated by authorised officers from emergency services and government agencies with the siren providing an alert tone which is then followed by a verbal message of:

"Attention! Attention! This is a flood warning announcement. Go to higher ground now. Avoid low lying areas. I repeat this is a flood warning. Go to higher ground now."

Further information is available on the *Grantham Siren* can be found on Council's website (https://www.lockyervalley.qld.gov.au/our-services/disaster-management/grantham-siren).

3.4 Message Construction & Communications Case Study - WaterNSW Insights Portal

Case Study – WaterNSW Insights Portal

In July 2020, WaterNSW launched the Water Insights portal providing information on river flows, dam storages, water availability and weather outlook information.

Further information can be found on WaterNSW's website (https://realtimedata.waternsw.com.au/).

3.5 Message Construction & Communications Case Study – Tweed Shire Council Emergency Dashboard

Case Study – Tweed Shire Council Emergency Dashboard

Resilience NSW as part of the Regional Disaster Preparedness Program piloted the use of Disaster Dashboards to 27 NSW Council during the 2020/2021 summer. The Disaster Dashboards were set up to provide communities with real-time information about local emergencies and to help communities to prepare and survive natural disasters.[1]

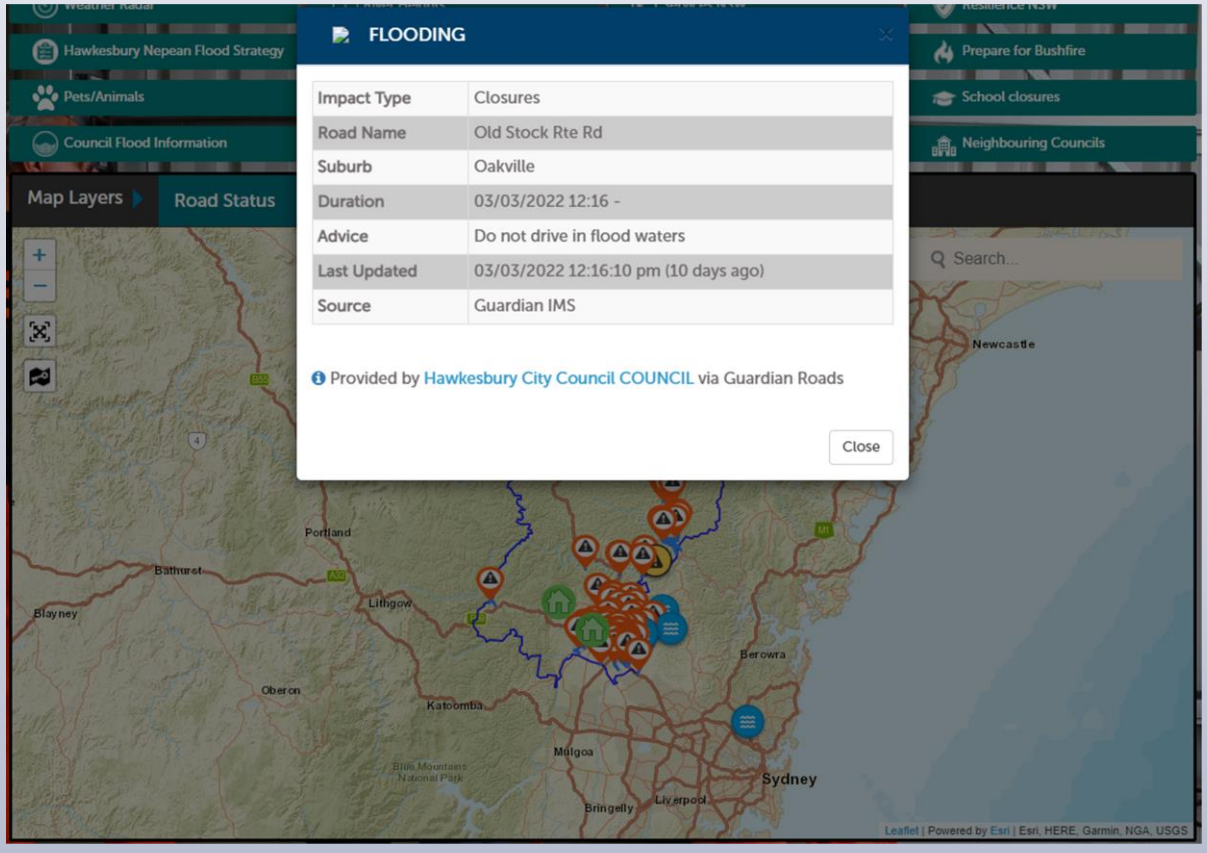
The Tweed Shire Council's Emergency Dashboard is one example of a Disaster Dashboard in NSW. The dashboard contains links to key information including but not limited to: key agency and emergency contact details, links to warnings, river heights, rainfall and river conditions, road hazards and closures, power outages, water and sewer service interruptions, links to further information including social media and news articles.

Further information can be found on Council's website (https://emergency.tweed.nsw.gov.au/home).

3.6 Message Construction & Communications Case Study – Real-time information on road closures: Hawkesbury City Council Disaster and Emergency Dashboard

Case Study – Real-time information on road closures: Hawkesbury City Council Disaster and Emergency Dashboard

Council's in NSW are increasingly relying on their Disaster and Emergency Dashboards to communicate real-time road closure information to communities which includes the Hawkesbury City Council. During the March 2022 flood event the Council relied on this tool to provide a 'source of truth' for the community which included the communication of road closure information. A screenshot of the information published on this site is provided below.



Hawkesbury City Council Disaster and Emergency Dashboard – (Screenshot taken 13th March 2022 at 4:15PM)

3.7 Protective Behaviour Case Study - Flood Ready Dairying project: North Coast Region, NSW

Case Study – Flood Ready Dairying project: North Coast Region, NSW

The Flood Ready Dairying Strategic Plan for the North Coast Region of NSW sets out a framework to increase the capacity and capability of the dairy industry to better prepare, respond and recover from the risk and impact of floods.

The program includes a range of tools and resources tailored for dairy farmers including a self-assessment tool, emergency preparedness checklist, information tailored for use during response and a range of tools and checklist tailored to support dairy farmers during the recovery phase.

The project commenced in 2013, was funded by the joint Federal and State Natural Disaster Program. Further information can be found on the Department of Primary Industries website (https://www.dpi.nsw.gov.au/emergencies/emergency/community/before-an-emergency/flood-ready-dairying-on-the-north-coast-of-nsw).

4 Key findings, learnings and potential opportunities

Based on the investigations undertaken as part of this study there were a number of learnings, findings and potential opportunities identified. These have been presented below and are linked to each component of the Total Flood Warning System framework.

In addition to the key findings, key learnings and potential opportunities detailed below, some key limitations and constraints are summarised as follows:

- **Reliance on the Bega North gauge (219900)**: confidence in the accuracy of flood warnings for the Bega township is considered high given the location of the gauge. However, it does mean that warning lead times are low as compared to being able to rely on a river gauge in an upstream location which does constrain the ability of emergency service organisations to execute an effective evacuation;
- **Bega and Brogo Rivers only:** given that the smaller local tributaries in the Bega and Brogo River catchments experience short duration flooding, it was assessed that providing an effective and reliable flood warning system was not able to be achieved for any river systems outside of the Bega River and Brogo River systems.
- **Funding options for implementation:** There is a need for ongoing and follow up work to implement the key recommendations set out in this study including obtaining funding to deliver some of the recommendations from this study and the need to fund operational costs associated with the options being delivered.

4.1 Monitoring and Prediction – Key findings, learnings and potential opportunities

Key findings, learning and potential opportunities were identified against each element of the TFWS during the study and are captured below with different colours aligned to the capture of findings, learnings and opportunities. More detail of findings, learnings and opportunities can be found in Appendix B, C and D.

Monitoring and Prediction

Key finding:

The existing IoT SCADA network was identified as not being suitable to be utilised for flood warning purposes due in part to how it is currently being used by Council, network and cyber security issues and the large area associated with the Bega and Brogo River catchment giving rise to the lack of opportunity presented by the existing SCADA network to be used for flood warning purposes

Key learning:

It was generally perceived that there are sufficient rain gauges throughout the catchment

Key learning:

The significance of the Bega North Gauge 219900 failure during the 2011 event was confirmed with warnings not able to be issued during this event as a result

Key learning:

Survey respondents, Council staff and participants at drop-in sessions identified a range of locations where it may be useful to provide an alerting function to existing gauges. These are listed and mapped in **Appendix D** with the highest priority locations being Tarraganda Bridge and other priority locations being Buckajo Road, Double Creek Bridge, Bemboka River Crossing, Jauncey's Bridge, Angledale Road with other broad locations identified being Mogareeka, Candelo, Bemboka and Brogo River Dam.

Key learning:

Many participants noted the value in providing warnings at Tarraganda Bridge to both provide information on the Brogo River, which joins the Bega River downstream of the Bega North Gauge, and to inform residents of potential closure of the bridge causing isolation of some residents

Potential Opportunity:

Opportunity to improve communication of recorded rainfall was suggested

Potential Opportunity:

Opportunity to leverage and enhance the current service being provided by the MHL FIT operational tool

4.3 Interpretation – Key findings, learnings and potential opportunities

Interpretation

Key learning:

Multi-generation farming families with experience of previous floods tend to be well aware of their flood risk, confident in interpreting forecasts and rainfall data and familiar with protective actions required such as moving stock and/or removing river pumps

Potential Opportunity:

Improved availability of information and education for hobby farmers and residents that are 'newer' to the valley and may not have lived experience of flooding

Potential Opportunity:

Identifying gauges at key locations for communities with specific gauge height and messaging/actions

Potential Opportunity:

Expansion of the Brogo River Early Warning Network (which provides SMS alerts to those registered) to other rivers

Potential Opportunity:

A warning or alert system was identified by a participant at Candelo given the nature of the flooding for Tantawangalo Creek rising and falling very quickly. This was echoed by members of the farming community

4.4 Message Construction – Key findings, learnings and potential opportunities

Message Construction

Key finding:

Clear messaging in warnings about required actions and timeframes were considered particularly important for newer residents

Potential Opportunity:

Targeted early warnings for graziers and water licence holders to provide time to remove pumps from the river and prepare properties for flooding

Potential Opportunity:

Targeted and tailored flood warning services for residents outside of Bega itself, including further upstream and downstream

Potential Opportunity:

Tailored information for residents on the northern side of Brogo River (e.g. Tarraganda) regarding preparation for potential isolation and notification when safe access across Tarraganda Bridge is available following a flood

Potential Opportunity:

Tailored information for residents of Candelo, particularly regarding road closures and when safe access becomes available again

4.5 Communication – Key findings, learnings and potential opportunities

Communication

Key learning:

In the past, the 'bush telegraph' has been an effective means of information sharing ahead of a flood event, however as the area continues to grow, there may be less connectivity between neighbours

Key finding:

Community look to and rely on Council to provide flood information and warnings

Key finding:

Strong preference for the use of multi-faceted/ multipronged communication methods – particularly Council website, text messaging, social media, local networks, all radio stations to reach as many people as possible, and to ensure some redundancy in case of network outages

Key finding:

Text messages/ alerts preferred by respondents from the farming community/ water licence holders and residents alike

Key finding:

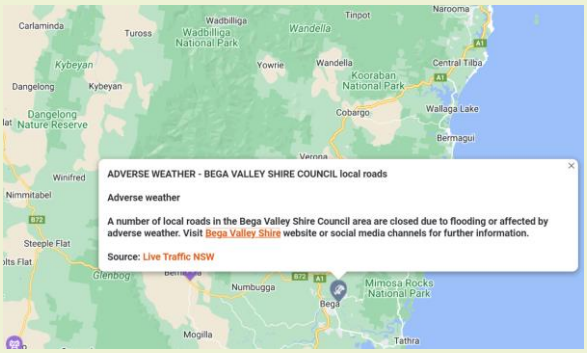
There was no direct correlation with where people had received warnings in past flood events and how they would like to receive them in the future, which may indicate a need to re-direct effort to ensure warnings more strongly correlate to community preferences

Potential Opportunity:

There was strong community support for an "Emergency Dashboard" on Council's website before and during flood events as a central source of information

Potential Opportunity:

Improved communication of road closures including continued use of OneRoads platform with direct fee to TfNSW Live Traffic. This follows a suggestion during the project for a live GIS map interface using 'MyRoadInfo' (https://myroadinfo.com.au/landing.asp) (refer screenshot below) and/or Council's website (Council's intended migration to ESRI GIS platform is noted)



Potential Opportunity:

"Weatherproof Communication" with redundancy in case of power outage or storm damage

4.6 Protective behaviour - Key findings, learnings and potential opportunities

Protective Behaviour

Key learning:

Water licence holders (irrigators) need to disconnect power and remove pumps from the river, which is estimated to take at least 30 minutes which highlights the importance of early warnings

Key learning:

It was confirmed that residents of Tarraganda in attendance were well aware of their isolation and resupply risks when bridges are overtopped and the subsequent isolation of the town for 3-4 days (or longer) and it was confirmed that SES cannot access Tarraganda to respond to the flood event

Key finding:

The most popular protective behaviours noted in the questionnaire were to move equipment, stock or machinery to higher ground, and to take alternate routes to avoid road closures

Potential Opportunity:

Community perception that only a few properties are at risk of inundation. This presents an opportunity to educate the broader community about the potential risk in rarer events.

Potential Opportunity:

Opportunity to enhance community understanding of evacuation planning arrangements in the event of a flood

4.7 Review - Key findings, learnings and potential opportunities

Review

Key learning:

Some concern was raised over asset ownership, coordination and roles and responsibilities

Key learning:

There was a perception that gauges were not well maintained or protected from debris and failure risk with the failure of the Bega North gauge in 2011 cited

Key learning:

There was support for the development of a Flood Warning System Owner's Manual being included within the scope of this study

Key learning:

Given the existing warning system in place there were questions raised regarding the efficacy and value of further investments in the Flood Warning System

Key learning:

Concerns were expressed about the cumulative impact of vegetation densification, sand deposition and debris in rivers on flood behaviour

Potential Opportunity:

Communications with residents on the costs and benefits for investing in flood warning system improvement initiatives

5 Preliminary Option Identification

A list of potential options to improve and enhance the existing flood warning system in Bega is presented in **Table 5-1** overleaf. This list of options has been developed based on the data review process, site visit and community consultation.

Table 5-1 also presents a comparative assessment, indicating the relative levels of costs, technical feasibility and potential benefits for each option. The following methodology has been used in defining these aspects of the options:

- **Expected Cost ($, $$, $$$):** is based on capital and operational costs of new hardware. For example, if a new rain or stream level gauge is required, it is expected to be relatively high cost ($$$) compared to other options. An option that can be implemented readily (e.g. by Council in-house), or would incur a one-off capital expense, are designated a lower relative cost ($).
- **Technical Feasibility (Easy, Average, Difficult)** is mostly linked to constructability, ease of access (e.g. to new gauge locations), land ownership, and the degree of coordination between agencies required. Projects that have a greater degree of difficulty will likely require additional investigations, whereas options that have a higher technical feasibility may be more readily implemented.
- **Community Benefit (Good, moderate, limited)** considers both the breadth of benefit (e.g. greatest number of residents benefited) and degree of benefit (e.g. greatest improvement in flood warning time).

A ‘first pass’ recommendation referred to as the ‘Preliminary Recommendation’ in Table 5-1 was communicated to the community as part of the Public Exhibition undertaken. The comparative assessment undertaken informed the basis of the ‘Preliminary Recommendation.’

Following the Public Exhibition undertaken a ‘Final Recommendation’ was made and agreed to by the Technical Working Group. This is detailed further below in section 6 of this report.

Table 5-1 Flood Warning System: Preliminary Option Identification

ID	TFWS Component	Option Name	Description	Source of Identified Option	Option Requirements	Expected Cost ($, $$, $$$)	Technical Feasibility (Easy, Average, Difficult)	Community Benefit (Good, Moderate, Limited)	Preliminary Recommendation
1	Monitoring & Prediction	Install Stream Gauge and provide a level of service (i.e. information, alert, warning) at Tarraganda Bridge	Installation of gauge at Tarraganda Bridge and dissemination of information, alerts and/or warnings related to this location, based on levels in the Brogo River	Community consultation, Council	> Consequences to community at different levels (modelling may be required); > Understanding of travel time and rate of rise and fall; > Message construction and education; > Coordination of BOM, WaterNSW and Council.	$$$	Average	Good	Option recommended for implementation. Recommended for further investigation
2	Monitoring & Prediction	Install additional BoM rain gauges in upper catchment areas	Provides additional rainfall data in upper catchment areas, may improve lead time for some catchments.	Council, Cardno now Stantec	> Assess which locations meet BOM criteria (accessibility, power, land tenure); > Investigate cost and hardware options; > Confirm coordination and ownership requirements with BOM; > Option to include SMS alert functionality;	$$	Average	Limited	Not recommended to be pursued at this stage
3	Monitoring & Prediction	Install additional stream level gauges in upper catchment areas	Provide stream gauges in upper catchment areas for Candelo township (Candelo Creek)	Council, Cardno now Stantec	> Trigger levels, rate of rise and consequences may be obtained from FRMSP if modelling available; > Possible limitation: does the river rise and fall faster than a message can be disseminated; > Shortlist of preferred locations, balancing lead time (higher in the catchment) and accuracy (lower in the catchment); > Confirm most appropriate location on Candelo Creek.	$$	Average	Limited	Value to Council & Community to be confirmed
4	Monitoring & Prediction	Install level sensors at key roads	Install level sensors with alert functionality to notify Council when a specified threshold is reached, indicating need for road closure.	Council, Cardno now Stantec	> Hardware and messaging platform options, including capital and ongoing costs; > Identify and shortlist preferred location(s) in consultation with Council; > Response required; > Option to add flashing lights/ signage for motorist safety.	$$	Average	Medium	Value to Council to be confirmed

ID	TFWS Component	Option Name	Description	Source of Identified Option	Option Requirements	Expected Cost ($, $$, $$$)	Technical Feasibility (Easy, Average, Difficult)	Community Benefit (Good, Moderate, Limited)	Preliminary Recommendation
5	Monitoring & Prediction	Realtime hydrologic modelling	Develop and run hydrologic model with observed and forecast rainfall inputs to give peak flow predictions. Relate flow to levels based on Flood Study/ rating curves. Highly sophisticated computing system required (likely to be external to Council). Ongoing maintenance and support required.	Council, Cardno now Stantec	> Investigate capital and ongoing costs; > Supplier and external modelling computer environment options; > Capacity of Council to incorporate into emergency management arrangements.	$$$	Difficult	Medium	Not recommended to be pursued at this stage
6	Interpretation	Static inundation maps linked to trigger levels	Develop stage - inundation relationships from flood study at intervals at a gauge location (e.g. Bega North) Maps could be for internal use or publicly available to improve community flood awareness and education. Provides clarification to "minor, moderate, major"	Cardno now Stantec	> Preferred gauge location and trigger levels/ interval to include; > Consultant required to extract result grid at each stage; > Preferred method of providing information to Council (e.g. online GIS portal); > Community information and education required, including messaging that every flood is different; > Ensure flood modelling includes current catchment conditions. Additional bathymetric information may be required following deposition of silt following 2020 bushfires.	$	Easy	Good	Recommended for further investigation
7	Message Construction/ Communication	Add alerting capability to selected rain gauges and stream level gauges	Add additional infrastructure to specific rainfall gauges and stream level gauges to enable automatic SMS/email alerts to be sent to selected users. No interpretation of consequences provided (not suitable for public)	Community consultation, Council	> Which gauges would this information be of most value – potential to consult further with key community stakeholders (i.e. farmers); > Develop list of selected users to receive alerts; > Investigate infrastructure/hardware options; > Accompanying education/interpretation.	$$	Average	Good	Recommended for further investigation

ID	TFWS Component	Option Name	Description	Source of Identified Option	Option Requirements	Expected Cost ($, $$, $$$)	Technical Feasibility (Easy, Average, Difficult)	Community Benefit (Good, Moderate, Limited)	Preliminary Recommendation
8	Communication	Council Website Emergency Dashboard	Front page of Council website utilised during a flood event to provide a central source of information. May include consolidation of information from BOM, NSW SES, WaterNSW, live road closures (as interactive map) and links to further information.	Community consultation	> Ability to reproduce information from other agencies without 're-interpreting' core messages; > Will Council's existing website support this functionality? > Does Council have the ability to set up and maintain this website in-house, or is external support required; > Consistency across all of Council's communication platforms.	$$	Average	Good	Recommended for further investigation
9	Communication	Early warning alert or messaging service for irrigators and directly affected residents	Develop database of selected users to receive BOM Flood Watch alerts or Brogo Dam Releases, (WaterNSW), Cochrane Dam (privately owned)	Community consultation	> Third party required (e.g. Council, local SES) or alternatively utilise existing technology (e.g. BoM app notifications); > Accompanying education/information for users to assist interpretation; > Confirm locations/systems where early warning is of most value.	$	Average	Good	Recommended for further investigation
10	Communication	Live Road Closure Updates provided as map on Council's website	Provide mapped information of road closures (particularly smaller, local roads) to provide context to residents.	Cardno, Community Consultation	> Preferred Council GIS environment; > Accompanying promotion and education/information for users to assist interpretation; > Explore avenues for integration with Live Traffic (NSW Govt App) or Google Maps to provide way-finding functionality for detours.	$$	Easy	Medium	Value to Council & Community to be confirmed

6 Conclusions and final recommendations

6.1 Overview of final Technical Working Group considerations and recommendations

Following completion of the 'Public Exhibition' period, the Technical Working Group were presented with the detailed findings of the feedback received. The options and preliminary recommendations presented to the community within the 'Public Exhibition' period were discussed in detail which culminated in a final Working Group recommendation for each of the ten (10) options.

The final recommendations confirm the following:

- six (6) of the ten (10) options are supported and endorsed for implementation;
- three (3) of the ten (10) options are not supported for implementation; and
- one (1) of the ten (10) options is not being pursued at this time and has potential to be part of a future initiative.

The final Technical Working Group recommendations are summarised below:

Recommended for Further Investigation & Implementation:

- Option 1: Install Stream Gauge and provide a level of service (i.e. information, alert, warning) at Tarraganda Bridge;
- Option 6: Static inundation maps linked to trigger levels;
- Option 7: Add alerting capability to selected rain gauges and stream level gauges;
- Option 8: Council Website Emergency Dashboard;
- Option 9: Early warning alert or messaging service for irrigators and directly affected residents

Not being pursued at this time:

- Option 3: Install additional stream level gauges in upper catchment areas;
- Option 4: Install level sensors at key roads;
- Option 10: Live Road Closure Updates provided as map on Council's website;

Not Recommended for Further Investigation

- Option 2: Install additional BoM rain gauges in upper catchment areas;
- Option 5: Realtime hydrologic modelling.

6.2 Prioritisation and indicative delivery timeframe for the recommended options

Of the five (5) options recommended for further investigation and implementation the following table ranks each option based on the outcome of the consultation process undertaken after completion of the multi-criteria assessment. The initial priority ranking was based on the preliminary multi-criteria assessment undertaken with the final priority ranking based on the outcome of the extensive community and stakeholder consultation undertaken.

A staged delivery approach is advised to progressively implement the recommended options to account for resource and funding limitations and with the intent of delivering continuous and steady improvement over time to the TFWS for the Bega and Brogo River systems.

Table 6-1 Option ranking and indicative delivery timeframe

Option ID	Description	Initial Priority Ranking*	Final Priority Ranking**	Indicative Delivery Timeframe***
Option 1	Install Stream Gauge and provide a level of service (i.e. information, alert, warning) at Tarraganda Bridge	5	1	Year 1 & 2: 2022/23 FY and 2023/24 FY (subject to securing funding)
Option 7	Add alerting capability to selected rain gauges and stream level gauges	3	2	Year 2 & 3: 2023/24 FY and 2024/25 FY (subject to securing funding)****
Option 8	Council Website Emergency Dashboard (as the Emergency Dashboard is already established this option would be more focussed on how Council uses this based on system interoperability)	2	3	Year 2 & 3: 2023/24 FY and 2024/25 FY (subject to resourcing & capacity)
Option 6	Static inundation maps linked to trigger levels	1	4	Year 4 & 5: 2025/26 FY and 2026/27 FY (subject to securing funding)
Option 9	Early warning alert or messaging service for irrigators and directly affected residents	3	5	Year 4: 2025/26 FY (subject to resourcing & capacity)

*Initial priority ranking was based on the preliminary multi-criteria assessment undertaken.

**The final priority ranking is made with consideration of the findings from the consultation undertaken with the community and input from the Technical Working Group following completion of the second round of consultation.

***The indicative delivery timeframe assumes that delivery of the outcomes of this study will be delivered over a 10 year delivery program with the first five (5) years targeted at delivering the key recommendations of this study with the remaining five (5) years being focussed on revisiting the three (3) options that were determined not to be pursued at this time and focussed on embedding and/or enhancing the preferred options implemented over the course of the first five (5) years of the ten (10) year delivery program.

****This option would require an ongoing investment by Bega Valley Shire Council and its partners over the life of the 10-year delivery program however the indicative delivery timeframe is more representative of the capital investment, testing and implementation phase.

6.3 Funding options for the recommended options

There are a range of funding options available to the Bega Valley Shire Council and its partner stakeholders to implement the recommended options.

The NSW Government provides financial support to local government via the Floodplain Management Program (*the program*) to manage flood risk. *The program* is administered by the Department of Planning and Environment (DPE).

DPE provide guidance to Council's within the *Guidelines for Applicants 2022-23, Floodplain Management Program* (2022). The Guidelines set out the eligibility requirements for *the program* including which local government bodies are eligible and details what can be funded.

Refer to Table 6-2 below for a preliminary assessment whether funding from the program may be obtainable based on an assessment against the current eligibility criteria detailed within the Guidelines (2022). This preliminary assessment should be validated with a representative from DPE who assists in administering *the program.*

6.4 Options, opportunities and final recommendations overview

Details of the ten (10) options and the final recommendations are provided below in Table 6-2. Additionally preliminary advice on the eligibility for the option to be funded by the DPE Floodplain Management Program is provided below.

Further details of the options and recommendations are provided in Appendix C.

Table 6-2 Options, opportunities and final recommendations overview

TFWS Element	Option	Recommendation
Monitoring and Prediction 	**Option 1:** **New water level gauge and level of service (LoS) (i.e. information, alert, warning) at Tarraganda Bridge** > This option involves the installation of a water level gauge at Tarraganda Bridge to allow for the provision of a level of service for the flood affected communities of Tarraganda and Tanja. > The level of service will aim to provide information, alerts and/or warnings during a flood event. > Implementation of this option would help to improve the knowledge base, flood preparedness levels and contribute to enabling more targeted flood alerts and/or warnings based on levels in the Brogo River and address an identified gap in the *Monitoring and Prediction* element of the TFWS in the Bega and Brogo River catchment.	**This option is recommended for implementation** Refer to Appendix C for further details of option 1. Refer to Appendix F for a '*Draft Scope of Work of System Implementation*.' √ Potential to be funded by the DPE Floodplain Management Program
	Option 2: **Install additional BoM rain gauges in upper catchment areas** > This option involves the installation of rain gauges within the upper portion of the catchment areas. > Implementation of this option would lead to an improvement to the monitoring network, improve the knowledge base and lead to increased lead times for flood warnings.	**Not recommended to be pursued at this time** The outcome from this study was that this option would not be pursued at this time due to the expected limited benefit to the TFWS. Refer to Appendix C for further details of option 2. √ Potential to be funded by the DPE Floodplain Management Program.
	Option 3: **Install additional stream level gauges in upper catchment areas** > This option involves the installation of additional stream level gauges in the headwaters of the catchment contributing to flooding in the Candelo Township.	**Not recommended to be pursued at this time** The outcome of this study was that after a process of investigating the value of this option with Council and the community, this option would not be pursued at this time.

TFWS Element	Option	Recommendation
	> Implementation of this option would likely result in additional lead time and alerts to the community.	Refer to Appendix C for further details of option 3. √ Potential to be funded by the DPE Floodplain Management Program
	Option 4: **Install level sensors at key roads** > This option involves the installation of water level sensors with alert functionality to notify Council when a specified threshold is reached, indicating need for road closure. > Implementation of this option would have the potential to improve road safety and contribute to enhancing real time capability to facilitate a proactive response to road closures during flooding.	**Not recommended to be pursued at this time** The outcome of this study was that after a process of investigating the value of this option with Council and the community, this option would not be pursued at this time however given the nature of the flood risk and community interest in this option, that this option would form part of a medium to long term strategy to implement this option over time as part of 10 year delivery timeframe. Refer to Appendix C for further details of option 5. √ Potential to be funded by the DPE Floodplain Management Program
	Option 5: **Realtime hydrologic modelling** > This option involves running hydrologic models for catchments using observed and forecast rainfall inputs to provide peak flow predictions and relate flow to levels based on rating curves. > Implementation of this option would lead to increasing the accuracy and confidence levels of flood predictions.	**Not recommended to be pursued at this time** The outcome of this study was that this option would not be pursued at this time. This was largely based on the significant costs associated with this option, the technical constraints to effectively implement this option and the limited benefits of this option in the context of being able to enhance and be a fit-for-purpose option for the TFWS for the Bega and Brogo River catchments. Refer to Appendix C for further details of option 5. √ Potential to be funded by the DPE Floodplain Management Program
Interpretation 	**Option 6:** **Static inundation maps linked to trigger levels** > This option involves the development of flood maps that illustrate the extent of flood	**This option is recommended for implementation** The outcome of this study was to recommend this option for implementation. Refer to Appendix C for further details of option 6.

TFWS Element	Option	Recommendation
	inundation at various river heights at gauges throughout the catchment. > Implementation of this options would provide an integral link between key flood trigger heights and flood consequences through flood extent mapping and lead to enhancing the capacity to implement flood education and increase understanding of flood risks within communities.	√ Potential to be funded by the DPE Floodplain Management Program
Message Construction & Communication  	**Option 7:** **Add alerting capability to selected rain gauges and stream level gauges** > This option involves improving the functionality of existing rainfall and stream gauges to enable automatic SMS/email alerts to be sent to selected users. The alerting capability would be established for Council use and or a selected user group who can interpret the information. > Implementation of this option would have the potential to improve flood response times and enable Council to initiate actions earlier including having the potential to contribute to facilitating protective actions to be undertaken in a timely manner.	**This option is recommended for implementation** This option is recommended. Following further conversations with Council's operational teams, the potential to integrate into existing tools, systems and capability within Council was explored in detail. This option has been explored in further detail and discussion within Appendix F which provides a '*Draft Scope of Work of System Implementation*.' Refer to Appendix C for further details of option 7 . √ Potential to be funded by the DPE Floodplain Management Program
	Option 8: **Council Website Emergency Dashboard** > This option involves the development and maintenance of a Council website used specifically during a flood event to act as a central and consolidated source of information. > The option has already been implemented and has the potential to contribute to the facilitation of a source of truth and a consolidated point of information to be accessed during a flood event and potentially during recovery and planning phases also. The dashboard also has the potential to promote consistency of messaging.	**This option is recommended for implementation** This option is recommended. The outcome of this study was to recommend this option for further investigation and implementation noting that an Emergency Dashboard is now in place after it was established for Council with the support of Resilience NSW. A review of the existing Emergency Dashboard in its current form and its fit for purpose should form part of this option. Refer to Appendix C for further details of option 8. X Its assumed that if funding is required it would be sourced internally.

TFWS Element	Option	Recommendation
	Option 9: **Early warning alert or messaging service for irrigators and directly affected residents** > This option involves the development of a database of selected users to receive BoM Flood Watch alerts or Brogo Dam releases (WaterNSW), Cochrane Dam (privately owned). > Implementation of this option would lead to increasing personal flood resilience and empowering communities with information to assist them in being informed during flood events.	**This option is recommended for implementation** The outcome of this study is that the option is recommended for further investigation and implementation. Further work to establish arrangements for the services would be necessary given the personalised service offerings proposed and the varied ways in which the service would be provided. For example, the WaterNSW Insights portal allows open access to information relating to releases from its dams, which would assist with information relating to the Brogo Dam releases however Cochrane Dam is privately owned and separate arrangements would be necessary. Refer to Appendix C for further details of Option 9. √ Potential to be funded by the DPE Floodplain Management Program
	Option 10: **Live Road Closure Updates provided as a map on Council's website** > This option would involve the provision of mapped information of road closures particularly smaller local roads where this information may not be available from other sources. > Implementation of this option would assist with enhancing Council and NSW SES flood intelligence and may help inform evacuation planning arrangements. > Via the adoption of OneRoads platform which is a backend data tool for updates to feed directly to the TfNSW Live Traffic app this option may be at least partially implemented however its considered that a review of its functionality as it relates to incorporating flood data should be undertaken.	**This option is recommended for implementation** The outcome of this study is that after a process of investigating the value of this option with Council and the community the option is supported. X Its assumed that if funding is required it would be sourced internally.
General comments	**Communications with key customers of flood warning services**	**N/A**

TFWS Element	Option	Recommendation
	> Leveraging existing organisations and contacts, such as the water licence holder database and members of the Livestock Marketing Centre could have benefits to achieving an enhanced TFWS	
	Collaborating with key stakeholders > Collaboration across the key organisations who have a role in the TFWS is critical. The initiatives and activities as part of the project had a role in facilitating this collaborative process between the key stakeholders.	**N/A**

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