Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study

Stages 1 to 3 –
Review and Flood Warning System Options

Report MHL2969

October 2023.

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Foreword

NSW government’s professional specialist advisor, Manly Hydraulics Laboratory (MHL) were commissioned by Shoalhaven City Council (Council) to undertake the Shoalhaven Intermittently Closed and Open Lake and Lagoon (ICOLL) Catchments Flash Flood Warning System Scoping Study. The scoping study covers the ICOLL catchment areas of Lake Conjola, Burrill Lake and Tabourie Lake. The project includes two main reporting deliverables:

- Stages 1 to 3 – Review and Flood Warning System Options (***this report***)
- Stages 4 to 8 – Detailed Development of Preferred Flood Warning System Option

This report provides outcomes from Stages 1 to 3 of the Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study. It includes a review of available flood warning information, previous studies, multi-criteria analysis of flood warning system design components, and development of preliminary flood warning system options.

The report was prepared by Matthew Phillips and Bronson McPherson.

This report is classified as public. The current version (Draft Final) of this document is draft and is subject to future revision following exhibition and consideration of further feedback.

Executive Summary

Lake Conjola is situated in the traditional boundaries of the Jerrinja people. Burrill Lake and Tabourie Lake are situated in the traditional boundaries of the Murramarang people. For thousands of years, these coastal lakes have provided a long and rich heritage of life, community, culture, and spiritual connection for Aboriginal people.

This report forms the initial stages of the Shoalhaven Intermittently Closed and Open Lake and Lagoon (ICOLL) Catchments Flash Flood Warning System Scoping Study. The overall project aims to scope the requirements and determine feasible options for the implementation of a fit-for-purpose and location-based Total Flood Warning System (TFWS) for the three catchments of Lake Conjola, Burrill Lake and Tabourie Lake to improve the flood warning and evacuation capabilities within the townships in these areas.

This report summarises outcomes of Stages 1 to 3 of the project, namely, a review of background information, initial community/stakeholder questionnaire findings, and development of fit-for-purpose Total Flood Warning System preliminary options.

The review of previous flood studies outlines the present and future flood risk of low-lying settlements in the Lake Conjola, Burrill Lake and Tabourie Lake catchment areas. Key flood information has been summarised from the study areas to help inform development of trigger levels for warnings and flood levels for key assets. This information for each catchment shall be reviewed in subsequent project stages during the detailing of a preferred flood warning system.

In all floodplain risk management studies, the fundamental importance of successful implementation of a Total Flood Warning System is noted and is a priority action to reduce risk to life during flood events. These previous studies have been undertaken with extensive community consultation. Existing flood warning arrangements are noted to provide insufficient warning time to the NSW State Emergency Service (SES), Shoalhaven City Council (Council) and the community during flood events.

Preliminary fit-for-purpose flood warning system options have been developed based on multi-criteria analysis of a range of component design options considering all aspects of flood warning including monitoring, prediction, interpretation, message construction, communication, protective behaviour and review. Three preliminary flood warning system options were developed for each catchment and include:

1. Predictive flood warning and decision support (utilising present gauge network)
2. Predictive flood warning and decision support with priority 1 gauge installation works
3. Predictive flood warning and decision support with priority 2 gauge installation works

It is recommended that a predictive flood warning and decision support with priority 1 gauge installation works (Option 2) be considered for the initial development of TFWS design. Components included in this option are outlined in Table E.1 for the Lake Conjola, Burrill Lake and Lake Tabourie catchment areas. Under this approach, predictive flood warning and decision support (Option 1) is to provide the minimal basis for flood warning in each catchment and additional priority gauging is undertaken as required to support more robust flood warning operation.

A preferred flood warning system option for each catchment is to be selected in consultation with Council, the NSW State Emergency Service, the Bureau of Meteorology (the Bureau), Department of Planning and Environment, Environment and Heritage Group (DPE EHG), and the community. Detailed development of a preferred flood warning system option for each catchment is to be undertaken in subsequent stages.

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for these catchments.

Although not noted in previous floodplain risk management studies, development of a flood warning system and improved lake level intelligence in each of these catchments may also have potential benefits to help inform pre-flood entrance management procedures which is outside the scope of the present study.

Table E.1 Recommended flood warning system preliminary options

Catchment	Recommended TFWS option for initial development	Monitoring	Prediction	Interpretation	Message construction	Communication	Protective behaviour
Lake Conjola	**Option 2** - Predictive flood warning and decision support with priority 1 gauge installation works	Maintain operation of existing rain and water level gauge network with the following: • M.1 Additional automatic water level station upstream at Conjola Creek Princes Hwy • M.3 Integrate entrance channel data from latest Council surveys and Lake Conjola M2 tidal analysis; • M.5 Integrate ocean wave and tide data.	Realtime flood level predictions using: • P.2 Realtime; hydrology modelling • P.4 Realtime simplified lake hydraulic modelling; • P.5 Bureau rainfall forecast services (Rainfields and Meteye); • P.6 Entrance channel predictions; • P.7 Ocean water level predictions. • P.1 Rate-of-rise and trigger level based predictions (as backup prediction mechanism)	• I.1 Trigger levels for known flood impacts; • I.2 Detailed flood evacuation plan; • I.3 Web based system to provide tailored decision support.	*To be determined during next phase of detailed flood warning system design*	• C.1 Integrated alerting system based on gauge trigger levels to Council & SES; • C.2 Integrated alerting system based on predictive flood modelling to Council & SES; • C.3 Tie automated alerting into procedures for warning messaging for SES to disseminate to community; • C.5 Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	*Emergency Management Flood Response Arrangements to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS.*
Burrill Lake	**Option 2** - Predictive flood warning and decision support with priority 1 gauge installation works	Maintain operation of existing rain and water level gauge network with the following: • M.1 Additional automatic water level station upstream at Stony Creek Woodstock R; • M.2 Additional automatic rainfall station upstream at Stony Creek Woodstock Rd; • M.4 Integrate entrance channel data from latest Council surveys; • M.6 Integrate ocean wave and tide data.					
Tabourie Lake	**Option 2** - Predictive flood warning and decision support with priority 1 gauge installation works	Maintain operation of existing rain and water level gauge network with the following: • M.2 Additional automatic rainfall station upstream at Brandaree Creek (TBC); • M.3 Integrate entrance channel data from latest Council surveys; • M.5 Integrate ocean wave and tide data.					

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1 Introduction

1.1 Background

Under the NSW Government's Flood Prone Land Policy (2023), primary responsibility for floodplain risk management rests with local government. Shoalhaven City Council (termed Council) is responsible for local planning and land management throughout the Local Government Area (LGA) including the management of flood prone land.

As part of the Flood Risk Management process, it is important for Council to have a clear understanding of the potential for flooding within the LGA with sufficient lead time for emergency services to alert and evacuate residents and visitors. This requires both pre-knowledge of the catchment flood behaviour as determined through Council flood studies as well as the implementation effective Total Flood Warning System (TFWS) infrastructure developed in accordance with following key guideline documents:

- Australian Emergency Manual series - Manual 21 – Flood Warning, Australian Institute for Disaster Resilience (2009);
- National Arrangements for Flood Forecasting and Warning, Bureau of Meteorology (2013);
- Intergovernmental Agreement on the Provision of Bureau of Meteorology Hazard Services to the States and Territories, Bureau of Meteorology (2018);
- Provision and Requirements for Flood Warning in New South Wales, NSW State Emergency Services (2019);
- Australian Warning System, Australian Institute for Disaster Resilience (2021); and
- NSW Flood Prone Land Policy and Flood Risk Management Manual (2023).

Shoalhaven City Council have received grant funding from the Australian Government through the National Recovery and Resilience Agency's *Preparing Australian Communities Program – Local Stream* to undertake a scoping study for the implementation of a TFWS covering three catchments within the Shoalhaven LGA: Lake Conjola, Burrill Lake and Tabourie Lake.

These coastal catchments are classified as Intermittently Closed and Open Lakes and Lagoons (ICOLLs), with low-lying infrastructure and townships susceptible to flooding and downstream oceanic conditions. None of these catchments are currently included in the Bureau of Meteorology's (the Bureau) Flood Warning Service[1], such that implementation of a TFWS is warranted in each of these catchments to provide timely warning informing proactive emergency and community response.

Measures to improve flood warning and response through the implementation of a TFWS were identified and adopted for implementation in the Lake Conjola Floodplain Risk Management Study & Plan (FRMS&P) (BMT WBM, 2013b), the Burrill Lake Floodplain Risk Management Study & Plan (FRMS&P) (BMT WBM, 2013a) and Tabourie Lake Floodplain

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[1] Limited to riverine flooding when rain-to-flood delay time is typically more than six hours.

Risk Management Study & Plan (FRMS&P) (Cardno, 2016). It was recommended as a suitable measure to reduce flood impacts and the risk to life within the catchments.

While this project is funded by a federal grant, and not by financial support from the NSW Floodplain Management Program, it has been undertaken in accordance with the NSW Flood Prone Land Policy, the NSW Flood Risk Management Manual and in close collaboration with the NSW State Emergency Services (SES), the NSW Department of Planning and Environment (DPE), the Bureau of Meteorology (the Bureau) and other agencies and stakeholders as required.

1.2 Study area

1.2.1 Lake Conjola catchment

Lake Conjola is situated in the traditional boundaries of the Jerrinja people, approximately 10 km north of the township of Ulladulla on the south coast of NSW (Figure 1.1). The Lake Conjola catchment covers approximately 145 km^2 and includes the tributaries of Luncheon Creek, Conjola Creek, Gooloo Creek and Bunnair Creek. The main lake waterbody has a surface area of approximately of 4.3 km^2 and is connected to the ocean by a 3.5 km shoaled tidal entrance channel. Water level records at Lake Conjola (station 216420 and 216420D, MHL) indicate an average lake level of approx. 0.38 m AHD over the last approximately 31 years of monitoring (Sep 1992 to May 2023). During this monitoring period Lake Conjola has recorded eight events with peak flood levels exceeding 1.2 m AHD with the largest recorded events during this period listed below:

- February 2020: 2.04 m AHD (entrance closed prior to event);
- August 2015: 1.94 m AHD (entrance closed prior to event);
- March 2022: 1.57 m AHD (entrance open prior to event); and
- June 2016: 1.51 m AHD (entrance closed prior to event).

Historical flood marks indicate more significant flooding in earlier decades, reaching more than 2.5 m AHD (e.g., February 1971) (BMT WBM, 2007b).

Primary land use in the catchment is predominantly forest within Conjola and Morton National Parks (85%) with smaller urban and rural residential areas (around 10%) (DPE, 2022b). Residential areas within the catchment include Lake Conjola Village, Killarney, Conjola Park, Conjola West, Fisherman's Paradise and Berringer. Combined, these areas have a total population of approx. 1,650 people (2021 Census, Australian Bureau of Statistics). Areas susceptible to flooding include low-lying regions in Lake Conjola Village. Lake Conjola Village has a total population of 687 with 520 private dwellings, where people aged 65 years and over make up 38.5% of the population. Lake Conjola is also a popular regional tourist destination with a high visitor population during holiday periods.

1.2.2 Burrill Lake catchment

Burrill Lake is situated in the traditional boundaries of the Murramarang people, approximately 5 km south-south-west of the township of Ulladulla on the south coast of NSW (Figure 1.1). The Burrill Lake catchment covers approximately 78 km^2 and includes the tributaries of Stony Creek, Woodstock Creek, Leaneys Creek and Pettys Creek. The main lake water body has a surface area of approximately of 4 km^2. Water level records at Burrill Lake Bridge (station 216435, MHL) indicate an average lake level 0.35 m AHD over the last approximately 32 years of monitoring (Nov 1991 to May 2023). During this monitoring period Burrill Lake has recorded nine events with peak flood levels exceeding 1.2 m AHD with the largest recorded events during this period listed below:

- June 2016: 1.57 m AHD (entrance open prior to event);
- August 2015: 1.44 m AHD (entrance open prior to event);
- July 2020: 1.40 m AHD (entrance open prior to event); and

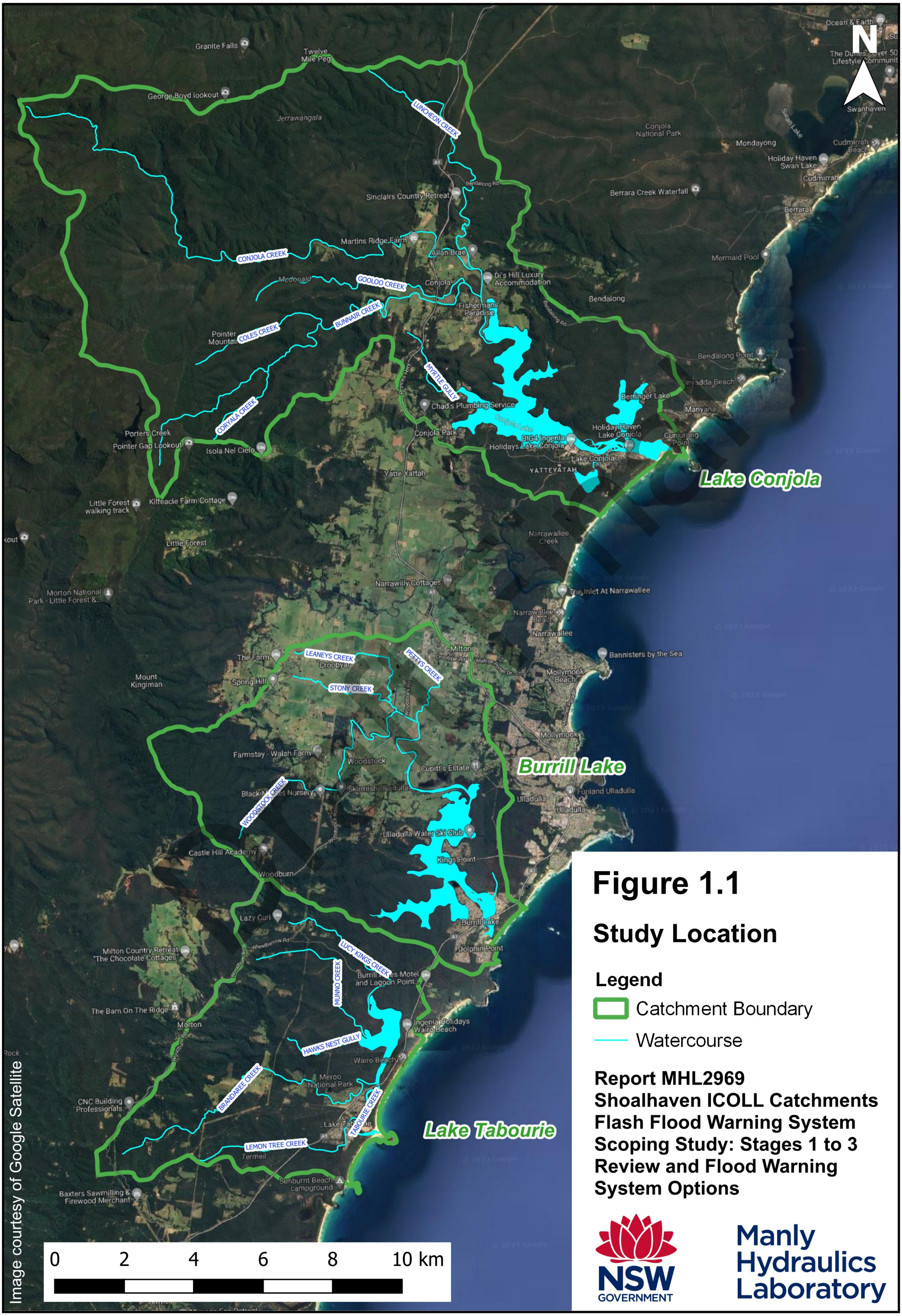

Image courtesy of Google Satellite

Figure 1.1

Study Location

Legend

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- April 2013: 1.35 m AHD (entrance open prior to event).

More significant flooding is reported to have occurred in earlier decades and include major events in 1971, 1991 and 1992 (Cardno, 2007).

Primary land use in the catchment is predominantly rural residential and agricultural grazing (nearly 50%), forest within Meroo National Park and Morton National Park (40%) and smaller urban residential areas surrounding lake foreshores (less than 10%) (DPE, 2022b). Residential areas within the catchment include Dolphin Point, Burrill Lake Village, Bungalow Park and Kings Point. Combined, these areas have a total population of approx. 2,750 people (2021 Census, Australian Bureau of Statistics). Areas susceptible to flooding include low-lying regions of Burrill Lake Village, Dolphin Point and Kings Point. Burrill Lake Village has a population of 1,782 with 980 private dwellings, where people aged oved 65 make up 28.2% of the population. Kings Point has a population of 609 with 301 private dwellings, where people aged oved 65 make up 22.8% of the population. Dolphin Point has a population of 354 with 197 private dwellings, where people aged oved 65 make up 24.8% of the population. The Burrill Lake area is also a popular regional tourist destination with a high visitor population during holiday periods.

1.2.3 Tabourie Lake catchment

Tabourie Lake is situated in the traditional boundaries of the Murramarang people, approximately 10 km south-south-west of the township of Ulladulla on the south coast of NSW (Figure 1.1). The Tabourie Lake catchment covers approximately 51 km^2 and includes tributaries of Brandaree Creek, Hawks Nest Gully, Munno Creek and Lucy Kings Creek. The main lake water body has a surface area of approximately of 1.5 km^2.

Water level records at Lake Tabourie (station 216440, MHL) indicate an average lake level 0.53 m AHD over the last approximately 31 years of monitoring (Sep 1992 to May 2023), with the highest recorded peak flood levels during this period listed below:

- June 2016: 1.77 m AHD (entrance closed prior to event);
- June 2013: 1.55 m AHD (entrance closed prior to event);
- September 1996: 1.53 m AHD (entrance closed prior to event); and
- November 2021: 1.36 m AHD (entrance closed prior to event).

More significant flooding is reported to have occurred in earlier decades including major events in 1971, 1975, 1988 and 1991 (BMT WBM 2010).

Land use in the Tabourie Lake catchment is over 80% forest within Meroo National Park, 15% grazing and a small urban residential area of Lake Tabourie adjacent to the foreshore near the entrance (DPE, 2022b). Lake Tabourie has a total population of approx. 689 people with 442 private dwellings, of which people aged over 65 years make up 28.4% of the population (2021 Census, Australian Bureau of Statistics). Lake Tabourie is also a popular regional tourist destination with a visitor population of approximately 3,000 during holiday periods (Cardno, 2016).

1.2.4 Ocean and catchment interface

All three catchments are connected to the ocean through a naturally dynamic entrance region characterised by varying ocean wave and tidal conditions, catchment rainfall-runoff flows, dynamic entrance channel morphology and a range of ecological habitats. All three entrance channels are subject to natural processes that result in changing entrance conditions and depending on prevailing conditions may lead to periodic closure of the entrance channel to the ocean (termed Intermittently Closed and Open Lakes and Lagoons or ICOLLs).

The frequency and duration of entrance closure differs between each of the locations and is related to a number of factors that drive rates of sediment infill and scour of the entrance channel. These include tidal prism characteristics (i.e., the volume of water leaving an estuary during an outgoing tide), catchment rainfall, coastal processes including local wave and ocean conditions, as well as site-specific entrance factors. The degree of tidal penetration into the estuary and inundation due to elevated ocean water levels with large coastal events (e.g., during king tides and large swell events such as May 1974) is dependent on the state of the entrance. When large coastal events coincide with heavy catchment rainfall, flooding can be exacerbated. Flooding of low-lying areas in the respective catchments is expected to worsen with sea level rise.

According to entrance status records from 1916 to 2019, Lake Conjola entrance was open for approximately 89% of the time and closed for the remaining 11% of the time (provided by Council courtesy of Isabelle Ghetti Spreadsheets from Ken Dodimead).

Tabourie Lake is more prone to entrance closure that Lake Conjola. Analysis of lake water level data extending from 1992 to 2017 was undertaken by Cardno (2019) and showed that the lake was open approximately 32% of the time during that period and closed for the remaining 68% of the time.

Burrill lake on the other hand typically maintains an open entrance for the majority of the time, however can close on the odd occasion for extended periods (Peter Spurway & Associates Pty Ltd, 2008). Haines (2006) estimated that Burrill Lake entrance is open to the ocean approximately 98% of the time and closed the remaining 2% of the time.

Example images of the entrances in open and closed states are shown in Figure 1.2. It should be noted that flooding can occur both with and without open entrance conditions as has been observed historically and investigated in previous flood studies.

Lake Conjola

Open entrance (2 Sep 2021) Closed entrance (2 Feb 2020)

Burrill Lake

Open entrance (27 Nov 2019) Heavily constricted entrance (17 Sep 2009)

Tabourie Lake

Open entrance (31 May 2022) Closed entrance (2 Feb 2020)

Images courtesy of Shoalhaven City Council and Google Satellite

Figure 1.2: Example images of open and closed entrance conditions.

1.3 Study aims and scope

The primary aims of Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study are to:

- Scope the requirements and determine feasible options for the implementation of a fit for purpose location-based Total Flood Warning System (TFWS) for the three catchments of Lake Conjola. Burrill Lake and Tabourie Lake to improve the flood warning and evacuation capabilities within the townships in these areas.
- Provide advice on the system design for an 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 systems for consideration by Council.

The study consists of the following components:

1. Review of background information **(this report)**
2. Community and stakeholder engagement **(initial consultation in this report)**
3. Determine fit-for-purpose TFWS options **(this report)**
4. Detail preferred TFWS option
5. Develop a draft Flood Warning System Owner's Manual
6. Outline key inclusions for the NSW SES Local Flood Plan
7. Potentially develop a draft education and awareness program for the TFWS in consultation with the NSW SES (to be confirmed)
8. Develop a draft scope of works for implementation of the TFWS

This report summarises outcomes of Stages 1 to 3 of the Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study including:

- Stage 1 Review of background information (Section 2) including overview of flood risk and flood warning from literature:
  - Lake Conjola - Section 2.1.1
  - Burrill Lake – Section 2.1.2
  - Tabourie Lake – Section 2.1.3
- Stage 2 Initial community/stakeholder questionnaire (Section 2.2 and 2.3)
- Stage 3 Determine fit-for-purpose TFWS options (Section 3) including multi-criteria assessment and component options:
  - Lake Conjola TFWS Options - Section 3.3
  - Burrill Lake TFWS Options – Section 3.4
  - Tabourie Lake TFWS Options – Section 3.5
- Conclusions and recommendations (Section 4)

2 Review of available information

2.1 Overview of flood risk and flood warning from literature

2.1.1 Lake Conjola

2.1.1.1 Flood risk

Flooding in Lake Conjola predominantly occurs due to three main mechanisms (including combinations of) (BMT WBM, 2013b):

- Catchment flooding occurs as a result of intense rainfall of a few hundred of millimetres over periods of typically 1-2 days (typically in excess of 150 mm/day). The catchment has a critical design storm duration of 36 hours. The lake storage itself provides for some flood attenuation. The progression of floodwaters from the onset of heavy rainfall to rising levels in the lower lake system can occur over a matter of several hours with little warning time (e.g., overnight as in February 2020). Rate of rise of lake level during a flood depends on the temporal distribution of rainfall over the catchment and is in the order of 0.1 to 0.3 m/hour. Shorter duration rainfall events can cause localised flash flooding, however due to the storage of the lakes system, this typically does not result in major lake flooding.
- Oceanic inundation occurs with open entrance conditions during coastal events with high ocean tides, storm surge, tidal anomalies and large swell at the entrance (e.g., king tides and the 1974 event). When coinciding with catchment flooding, these events can result in worsened flooding to low-lying areas e.g., increase in peak flood level for a 1% Annual Exceedance Probability (AEP) event by 0.5 m.
- Low-level persistent flooding, occurring through a gradual and prolonged increase in lake levels during periods of entrance closure when the trigger levels for entrance opening have not yet been reached. Low-level persistent flooding predominantly impacts public foreshore areas including boat ramps and jetties, situated at elevations of less than 1.2 m AHD. An Interim Entrance Management Policy (GHD, 2013) was developed to help alleviate low-lying flooding by opening the entrance when the water level reaches the trigger levels of:
    - 1.0 m AHD for planned openings with forecast moderate or heavy rainfall;
    - 1.2 m AHD for emergency opening when flooding is imminent.

  The trigger levels in the Interim Entrance Management Policy (GHD, 2013) have been superseded by the latest Review of Environmental Factors and Crown Land Licence to undertake mechanical opening of the Lake Conjola Entrance. This licence outlines the following intervention trigger levels:

    - 0.8 m AHD for planned opening when water level has reached or exceeded and maintained for more than three consecutive months;
    - 1.0 m AHD for emergency opening when flooding is imminent.

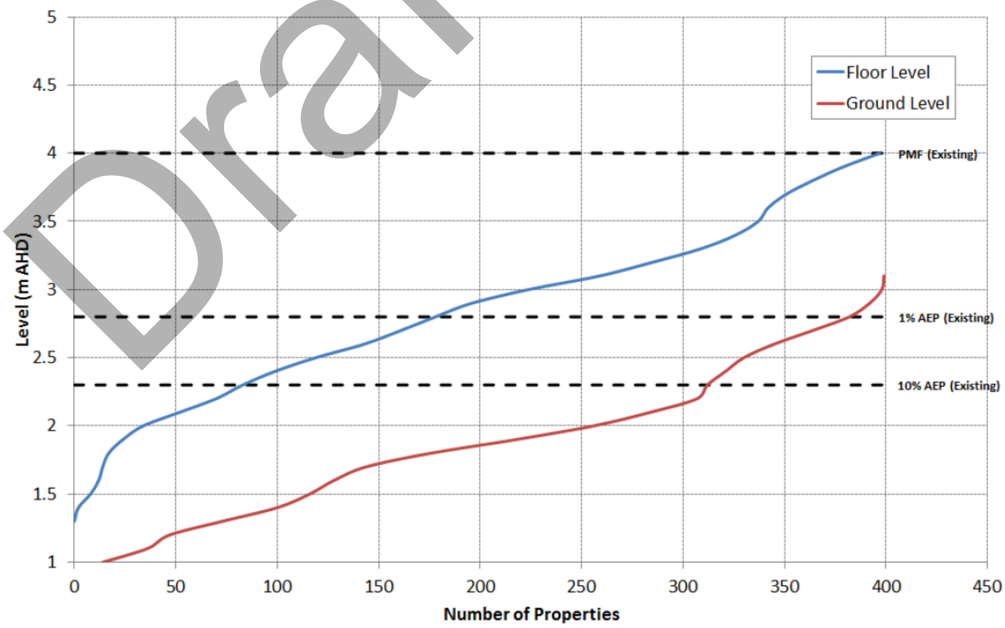
Flooding of building floor levels and property ground levels are shown in Figure 2.1 (BMT WBM, 2013b). Low-lying areas typically begin flooding at water levels of 1.0 to 1.5 m AHD. Some low-lying areas of Deepwater Resort commence flooding at lake levels of 1.0 m AHD. At lake levels of 1.2 m AHD, flooded regions include public foreshore spaces (boat ramps, jetties and other public recreational infrastructure) as well as areas of Deepwater Resort, Holiday Haven Lake Conjola Tourist Park and Big4 Ingenia Holiday Park. Low-lying properties typically have floor levels of the order of 1.4 to 1.5 m AHD. At 1.5 m AHD, flooded regions include substantial areas of Holiday Haven Lake Conjola Tourist Park, properties at Garrad Way and Edwin Avenue (BMT WBM, 2013b).

BMT WBM (2013b) found the number of properties impacted by flooding above habitable floor levels (i.e., excluding non-habitable buildings) for existing conditions at the time of the study to be the following:

- 70 for a 10% AEP flood event (approx. 2.3 m AHD);
- 183 for a 1% AEP flood event (approx. 2.8 m AHD); and
- 335 for a Probable Maximum Flood (PMF) event (approx. 4 m AHD).

It is noted that the number of properties at risk of overfloor flooding may have increased due to new development in the area since the BMT WBM (2013b) study was undertaken.

Properties at most risk of being affected by overfloor flooding and/or isolation due to floodwaters are predominantly located in Milham St, Edwin Ave, Garrad Way, Spinks Avenue, Carroll Ave, Conley Avenue, Aney Street, Marshal Avenue, Craig Street, Thorne Street and Lake Conjola Entrance Road (SES, 2021).



From BMT WBM (2013b)

Figure 2.1: Lake Conjola building and property inundation at nominal water levels.

A supplementary report to the Lake Conjola FRMS&P (BMT WBM, 2013c) was undertaken to assess the sensitivity of modelled flood levels to entrance channel conditions. A summary of peak flood levels for open and closed entrance conditions represented by a berm level of 1.0 m AHD is shown in Table 2.1. Differences of up to 0.16 m were noted for more frequent flood events (20% and 10% AEP) with minor differences for more extreme events. However further sensitivity testing of the 1% AEP event with berm levels at 2.0 m AHD indicate differences in peak flood levels of 0.2-0.3m at the Holiday Haven Caravan Park. The findings suggest that differences in peak flood levels in the order 0.1-0.3 m can arise as a result of natural changes in entrance channel conditions, and may vary in reality depending on coinciding ocean conditions.

Flood damages from the Lake Conjola FRMS&P (BMT WBM, 2013b) are also shown in Table 2.1. Annual average damages due to flood impacts in Lake Conjola are estimated to be $1.8M and are expected to increase with sea level rise to $2.1M by 2050 and $4.1M by 2100 (BMT WBM, 2013). It is noted that flood damages may have increased due to new development in the area since the BMT WBM (2013b) study was undertaken.

Table 2.1: Lake Conjola modelled peak flood levels for open and closed entrance.
From BMT WBM (2013c)

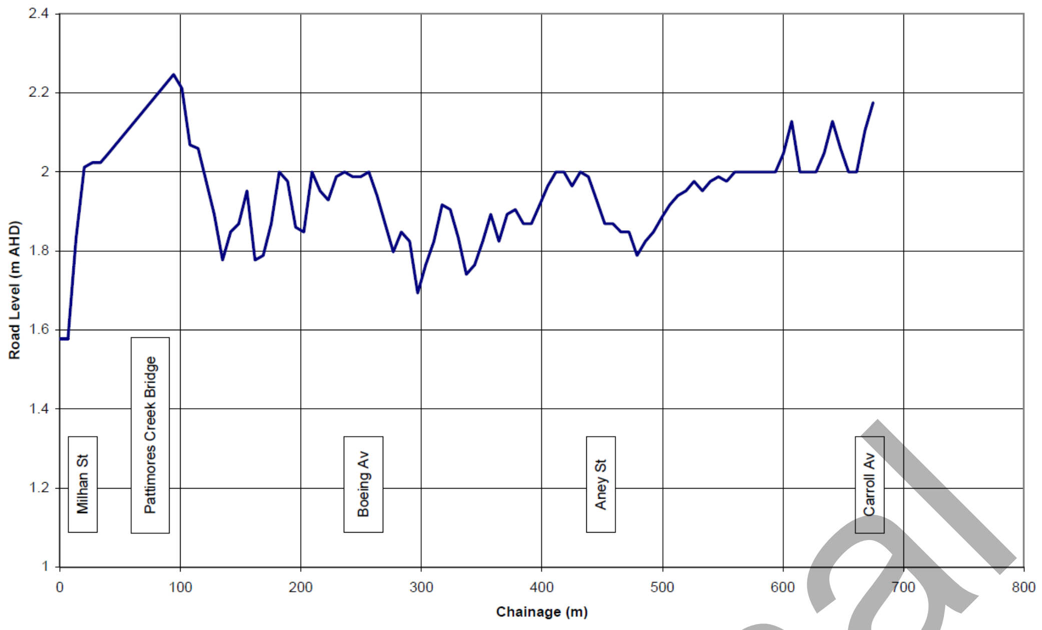
Flood event	**Peak flood levels (m AHD)**				**Flood Damages from FRMS&P ($M)#**
	Entrance Channel gauge		**Lake (“The Steps”)**		
	Open entrance	**Closed entrance***	**Open entrance**	**Closed entrance***	
20% AEP	1.81	1.93	2.25	2.41	$3.1
10% AEP	1.94	2.03	2.47	2.59	$4.7
5% AEP	2.09	2.14	2.74	2.83	$7.7
2% AEP	2.21	2.24	2.98	3.04	$10.4
1% AEP	2.33	2.35	3.23	3.25	$13.7
PMF	3.28	3.30	4.54	4.54	$34.0
				Annual Average Damages	***$1.8***

** Closed entrance conditions represented by a berm level of 1.0m AHD and 250m wide.*

 # Annual Average Damages (BMT WBM, 2013b) is based on an envelope of the highest modelled water level between two design flood scenarios, considering a “the most restricted entrance” scenario and “the least restricted entrance” scenario as outlined in the Lake Conjola Flood Study (BMT WBM, 2007b)

2.1.1.2 Evacuation access

A large proportion of Lake Conjola Village, including three caravan parks, require evacuation in a major flood event. Low-lying land below 1.5 m AHD and would be subject to inundation relatively quickly. The main evacuation route is the Lake Conjola Entrance Road, with elevations shown in Figure 2.2.



From BMT WBM (2007b)

Figure 2.2: Lake Conjola Entrance Road Longitudinal Profile.

Toward its eastern end, Lake Conjola Entrance Road has low points around 1.6 and 1.7 m AHD, with the remainder of roads typically around 1.8 to 2.2 m AHD. This road and some adjacent local streets would be subject to inundation even for relatively small flood events. For major events such as the 1% AEP event, depths of inundation at the peak of the flood can be in excess of 1 m (BMT WBM, 2007b). For such events, parts of these roads may become impassable well before the flood peak and thereby limiting flood access and potentially isolating a significant number of residents.

Evacuations during major flood events are likely to be necessary in Milham Street, Edwin Avenue, Garrad Way, Carrol Avenue, Chinamans Island and Lake Conjola Entrance Road. Evacuations of Eastern Lake Conjola to an official evacuation centre should be completed before road access along Lake Conjola Entrance Road is cut off by floodwaters (SES, 2014).

2.1.1.3 Emergency response

Evacuation procedures for Lake Conjola rely upon realtime water level monitoring at the Lake Conjola Entrance gauge and Severe Thunderstorm Warnings or Severe Weather Warnings that may lead to flooding issued by the Bureau (See Section 2.1.1.6). Evacuation of residents and caravan parks in the low-lying areas subject to inundation is considered in conjunction with: local knowledge of the flood behaviour; if floodwaters are expected to reach 1.3 m AHD at the Lake Conjola Entrance Park; additional rainfall is expected; and lake rises or tidal changes are also expected (BMT WBM, 2013b).

The Lake Conjola FRMS&P also notes a number of existing limitations for SES emergency response deployment at Lake Conjola during the rapid onset of flooding (BMT WBM, 2013b):

- The SES is principally a volunteer organisation and the time required to mobilise personnel could exceed the warning time available;

- A major flood event in Lake Conjola is likely to coincide to major flooding in other catchments within the Shoalhaven Local Government Area further stretching already limited emergency response resources;
    - Many of the principal roads within the Local Government Area are cut early in major floods making access difficult for mobilising or responding; and
    - There is generally insufficient time and resources to undertake tasks such as sandbagging or evacuation to reduce impacts on property or people.

Noting these limitations, the Lake Conjola FRMS&P recommended a “Community Flood Emergency Response Plan” to equip local residents and the community to take appropriate actions to protect themselves and property during flood events with information regarding evacuation routes, refuge areas, what to do/not to do during a flood event etc. Successful implementation of such a plan on a community level was noted to have the potential to help strengthen self-sufficiency in terms of flood response and maximise potential for effective emergency response and a non-reliance on formal emergency services (BMT WBM, 2013b).

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for the catchment.

2.1.1.4 Flood awareness

The Lake Conjola FRMS&P (BMT WBM, 2013b) undertook community engagement to better understand the level of flood awareness in the community. The findings include:

- Lack of lived experience through major flood events in the community over recent decades and resulting potential unawareness of flood risk;
- A significant proportion of the community were unaware if their property was at risk flooding at all, unaware of any flood warning procedures or available flood information, and generally indicated a low-level of flood preparedness in terms of personal flood emergency response; and
- High tourist population during holiday periods with lower level of flood risk awareness and preparedness than that of the resident community.

The FRMS&P recommended ongoing community engagement initiatives to improve flood awareness such as an ongoing flood awareness program, media releases, SES community education training, additional brochures targeting sectors of the community, flood risk workshops with community groups, tourist park owners, and businesses.

It is noted that since the FRMS&P was completed, the Lake Conjola community have experienced a number of moderate floods (e.g., February 2020) and ongoing engagement which may have changed perceptions of flood risk in the community.

2.1.1.5 Warning time

Flood warning time categories for Lake Conjola were documented in FRMS&P (BMT WBM, 2013b) and are presented in Table 2.2. Short warning time can mean that SES on-ground assistance can be limited due to rapid flooding onset. However, agencies do have an important role to play in helping to inform community decisions during floods, provision of flood warning infrastructure to support community led emergency response, development of flood emergency planning provisions, and flood preparedness programs in the community before the event. Adequate warning time is important to allow residents to safely move valuable goods and evacuate to higher ground.

In the case of widespread regional flooding (including regional lakes and rivers), adequate warning time for emergency response will varying depending on the availability of competing emergency resources that may be spread across the broader Ulladulla SES unit area of responsibility.

Table 2.2: Lake Conjola flood warning time categories.
From BMT WBM (2013b)

Category	Warning time	Description
No effective warning	<1 hr	No time for pro-active and systematic organisation of flood mitigation, evacuation, emergency response etc. Individuals would be self-directed in regards to emergency response.
Minimal warning	1-6 hrs	Limited assistance and direction likely from emergency services. Measures requiring minimal time for implementation may be appropriate for flood management.
Moderate warning	6-12 hrs	Potential assistance and direction from emergency services, depending on time of day. Measures requiring moderate time, or less, for implementation may be appropriate for flood management.
Good warning	12+ hrs	Significant assistance and direction from emergency services may be available, including assistance with evacuation. Most measures requiring some form of on-demand implementation would be appropriate for flood management.

2.1.1.6 Existing flood warning arrangements

There is no site-specific flood warning system for Lake Conjola. Council and SES emergency response to flood events currently rely upon on the following information sources:

- Bureau of Meteorology Warning Services:
    - Severe Thunderstorm Warnings - typically provide 0.5 to 2 hours' notice. These short-range forecasts are based upon radar, data from field stations, reports from storm spotters as well as synoptic forecasts; and
    - Severe Weather Warnings - for synoptic scale events that cause a range of hazards, including flooding. Examples of synoptic scale events are the deep low-pressure systems off the NSW coast.
- Realtime rainfall and water level information is provided by Manly Hydraulics Laboratory (MHL) and Council at the Lake Conjola Entrance as listed in Table 3.2. MHL also provide realtime tidal harmonic analysis on the Lake Conjola Entrance gauge to provide indication of entrance constriction and openness. The Council gauge is currently operated with automatic alert messages (email) which are sent to Council and SES staff via Enviromon. Presently there are no rainfall or water level stations in the upper catchment, but a new

rain gauge is planned to be installed in the catchment headwaters in 2023. Whilst the Porters Creek Dam rain gauge is located just outside the Lake Conjola catchment, this gauge is representative of rainfall in the south-western catchment headwaters.

- Realtime rainfall and water level information is available from Councils Fishermans Paradise and Porters Creek Dam rainfall gauges and Conjola Creek water level gauges. These gauges are currently operated with automatic alert messages (email) which are sent to Council and SES staff via Enviromon.

The FRMS&P provides the following assessment of the limitations of the current warning arrangements:

> *"At present, the only warnings available for Lake Conjola are generic, and automatically generated* [based on model weather forecasts] *by the Bureau of Meteorology in response to severe weather warnings. Water levels are monitored at the water level gauge located in the entrance channel. Being located right at the downstream end of the system, the use of realtime water level data at the gauge to issue flood warnings provides for little effective warning and response time. Furthermore, the time from the onset of rain to the point at which floodwaters become hazardous can be a matter of hours in some locations, particularly in the more extreme events. This means that any realistic warnings would need to be disseminated to a large number of people very rapidly." P67-68*

2.1.1.7 Flood warning improvement

Improving flood warning was reported as one of the priority measures for flood risk management in the Lake Conjola FRMS&P (BMT WBM, 2013b). Recommended actions relevant to improving flood warning included:

Develop flood prediction capability with cooperation of Council, the Bureau and SES

- Provide water level forecasting for Lake Conjola gauge based on realtime and forecast rainfall products from the Bureau of Meteorology. The FRMS&P notes this forecast would "*provide a local reference for the Conjola community as well as the SES to gauge the imminent flood risk, and respond accordingly"*; P87
- Consideration of additional telemetered gauges for Conjola Creek to provide indication of upstream water levels prior to confluence with the lake system; It is noted that Council have installed a water level gauge on Conjola Creek at Fishermans Paradise.

Develop and implement methods/systems for improved Flood Warning communication

- Development of improved Flood Warning System for Lake Conjola (covering Catchment and Ocean Flooding), including effective broadcasting of warnings and relevant information through a range of methods such as automated messaging, door knocking (dependant on warning time, available resources, and the number of impacted catchments), multimedia, community information hubs, social media channels, internet postings and telephone warning. It is expected that mobile phone-based SMS warnings could also be developed for registered message recipients;

Update Local Flood Plan

- Improved local flood intelligence needs updated with the flood level data derived from the flood study and linked to the property databases established in the FRMS&P.

Additional during-flood measures including flood warning considerations are outlined in the FRMS&P and noted in Table 2.3.

The fundamental importance of successful implementation of a Total Flood Warning System in the Floodplain Risk Management process is strongly noted:

> *"When integrated with community education, the development of a complete Flood Warning System for Lake Conjola forms the cornerstone of this Floodplain Risk Management Plan. With improved warning of an approaching flood, the community will hopefully be able to respond in a more responsible and appropriate manner. Clearly the earlier the warnings are given then the more time communities have to respond."* P 86

Although not noted in previous floodplain risk management studies, development of a flood warning system and improved lake level intelligence in each of these catchments may also have potential benefits to help inform pre-flood entrance management procedures which is outside the scope of the present study.

Table 2.3: During-flood response measures Lake Conjola FRMS&P

From BMT WBM (2013b)

During a Flood	FRMS&P Comments
Improved flood warning system, based on integrated rainfall and river level gauging, and realtime radar	A total flood warning system can buy extra time for appropriate flood response if the information can get to the community in time. The system needs to be locally specific and not generic. A system is very acceptable to the community, but can lead to a false sense of security.
Automated voice and text messaging for notification of flood warnings	One possible method of disseminating flood warning information. Multiple methods would be required.
Multi-media bulletins for notification of flood warnings	Urgency of disseminating flood warnings is critical to providing the community with as much preparation time as possible. This should extend to all radio and TV channels, not just local ABC.
Social media channels, such as Twitter and Facebook	Much of the flood information that was distributed and accessed during the 2011 floods across Queensland, NSW, Victoria and WA was via social media (Facebook, Twitter) and internet sites. Emergency services set up direct feeds to these channels with latest updates and information. Communities were able to supplement the information with first-hand knowledge (thus making sure the information was as current as possible).
Flood markers indicating problem areas	Flood markers indicate flood depths – historical and design possible flood events

2.1.2 Burrill Lake

2.1.2.1 Flood risk

Flooding in Burrill Lake predominantly occurs due to three main mechanisms (including combinations of) (BMT WBM, 2013a):

- Catchment flooding occurs as a result of intense rainfall of a few hundred of millimetres over periods of typically 1-2 days (typically in excess of 150 mm/day). The catchment has a critical design storm duration of 18 hours. The lake storage itself provides for some flood attenuation with typically several hours between the onset of heavy rainfall to rising levels in the lower lake system. Rate of rise of lake level during a flood depends on the temporal distribution of rainfall over the catchment and can reach the order of 0.1 m/hour.
- Oceanic inundation occurs with open entrance conditions during coastal events with high ocean tides, storm surge, tidal anomalies and large swell at the entrance (e.g., king tides and the 1974 event). When coinciding with catchment flooding, these events can result in worsened flooding to low-lying areas.
- Low-level persistent flooding, occurring through a gradual and prolonged increase in lake levels during periods of entrance closure when the trigger levels for entrance opening have not yet been reached. Low-level persistent flooding predominantly impacts public foreshore areas including boat ramps and jetties, situated at elevations of less than 1.2 m AHD. An Interim Entrance Management Policy (Peter Spurway & Associates Pty Limited, 2008) was developed to help alleviate low-lying flooding by opening the entrance when the water level reaches the trigger levels of:
    - Lake water level at or exceeding **1.20 m AHD** initiates an immediate entrance opening at any time on the first available high tide;
    - If the lake reaches and stabilises at a level between **1.10 m and 1.20 m AHD**, a planned opening shall be made under suitable defined conditions;
    - If the lake level reaches and stabilises at a level between **1.00 m and 1.10 m AHD** and it is within one month prior to or at the time of the Christmas or Easter holiday periods, a planned opening shall be made under suitable defined conditions.

Flooding of building floor levels and property ground levels are shown in Figure 2.3 (BMT WBM, 2013a). Low-lying areas typically begin flooding at lake levels (Burrill Lake Gauge) of 1.1 to 1.2 m AHD and include areas of Kendall Crescent, Thistleton Drive, Balmoral Drive and also regions of public foreshore areas become inundated, particularly around Rackham Crescent, Ireland Street and MacDonald Parade.

Habitable flood levels (Burrill Lake Gauge) at which inundation occurs at tourist parks are:

- 1.2 m AHD at Big 4 Bungalow Pk on Burrill Lake;
- 1.5 m AHD at Burrill Lake Holiday Park; and
- 1.8 m AHD at Dolphins Point Tourist Park.

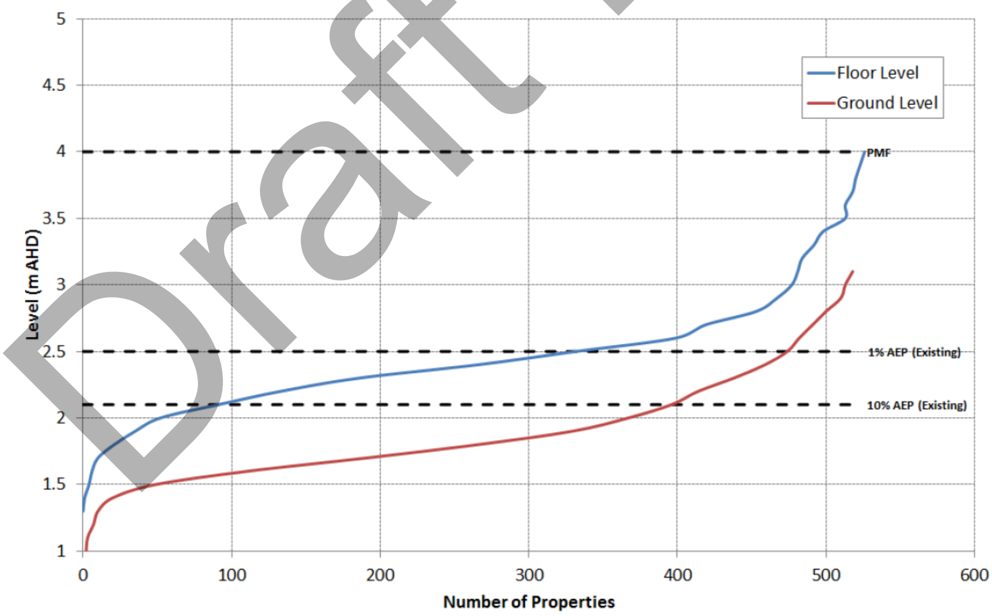
Sewer pumps at Burrill Lake are impacted by flooding at 1.5 m AHD (Station B2) and 2.0 m AHD (Stations B3, B5, B6, B7). Sewer pumps at Kings Point are impacted by flooding at 1.96-2.01 m AHD.

BMT WBM (2013a) found the number of properties impacted by flooding above habitable floor levels (i.e., excluding non-habitable buildings) for existing conditions at the time of the study to be the following:

- 70 for a 10% AEP flood event (approx. 2.1 m AHD);
- 318 for a 1% AEP flood event (approx. 2.5 m AHD); and
- 510 for a PMF event (approx. 4.0 m AHD)

Modelled peak design flood levels for catchment and oceanic flood events are shown in Table 2.4. Catchment flooding was undertaken for closed entrance conditions. Sensitivity analysis undertaken in the Burrill Lake Flood Study found differences in peak flood levels of 0.25-0.3 m between closed and open entrance conditions, and may vary in reality depending on coinciding ocean conditions.

Flood damages from the Burrill Lake FRMS&P (BMT WBM, 2013a) are also shown in Table 2.4. Annual average damages due to flood impacts in Burrill Lake are estimated to be $1.9M and are expected to increase with sea level rise to $5.6M by 2050 and $11.1M by 2100 (BMT WBM, 2013a).



From BMT WBM (2013a)

Figure 2.3: Burrill Lake building and property inundation at nominal water levels.

Table 2.4: Burrill Lake modelled peak design flood levels for catchment and oceanic flood events.

From BMT WBM (2007a, 2013a)

Flood event	Peak design flood levels (m AHD)				Flood Damages from FRMS&P ($M)**
	Princes Hwy Causeway (near Burrill Lake gauge)		Northern Basin		
	Catchment flooding*	Oceanic flooding[#]	Catchment flooding*	Oceanic flooding[#]	
20% AEP	2.0	1.95	2.1	2.05	$2.2
10% AEP	2.1	2.15	2.2	2.2	$4.4
5% AEP	2.25	2.3	2.35	2.35	$8.9
2% AEP	2.4	2.45	2.55	2.55	$17.2
1% AEP	2.45	2.6	2.6	2.65	$21.3
PMF	4.05	-	4.3	-	$59.1
				Annual Average Damages	***$1.9***

** Obtained from design flood hydrographs in Figures 8-4 and Figures 8-5 from Burrill Lake Flood Study (2007). Assumes initially closed entrance berm at 1.2m AHD*

[#] *Obtained from design flood hydrographs in Figures 8-6 and Figures 8-7 from Burrill Lake Flood Study (2007).*

** *Annual Average Damages (BMT WBM, 2013a) is based on an envelope of the highest modelled water level between two design flood scenarios, considering a "the most restricted entrance" scenario and "the least restricted entrance" scenario as outlined in the Burrill Lake Flood Study (BMT WBM, 2007a).*

2.1.2.2 Evacuation access

Inundation levels of key access roadways are shown in Table 2.5. Properties in the Bungalow Park Village, on the western side of the Princes Hwy are particularly susceptible to isolation to low-lying road levels. In major floods, Burrill Lake may become isolated from Ulladulla due to the closure of the Princes Highway at Racecourse Creek.

Table 2.5: Inundation levels of key access roadways

From SES (2022)

Inundation level - Burrill Lake Gauge (m AHD)	Road
From 1.1	Roadways in the Bungalow Park Village area including Kendall Crescent, Thistleton Drive, Balmoral Drive, Rackham Crescent, Ireland Street, Commonwealth Avenue and MacDonald Parade.
1.8	Dolphin Point Rd
2.6	Northern approach to Burrill Lake Bridge Princes Hwy

2.1.2.3 *Emergency response*

Evacuation procedures for Burrill Lake rely upon realtime water level monitoring at the Burrill Lake gauge and Severe Thunderstorm Warnings or Severe Weather Warnings that may lead to flash flooding issued by the Bureau (See Section 2.1.2.6). Evacuation of residents and caravan parks in the low-lying areas subject to inundation is considered in conjunction with local knowledge of the flood behaviour, if floodwaters are expected to reach 1.3 m AHD at the Burrill Lake gauge and weather forecasts indicate further rises (BMT WBM, 2013a).

The Burrill Lake FRMS&P also notes a number of existing limitations for SES emergency response deployment at Burrill Lake during the rapid onset of flooding (BMT WBM, 2013a):

- The SES is principally a volunteer organisation and the time required to mobilise personnel could exceed the warning time available;
- A major flood event in Burrill Lake is likely to coincide to major flooding in other catchments within the Shoalhaven Local Government Area further stretching already limited emergency response resources;
- Many of the principal roads within the Local Government Area are cut early in major floods making access difficult for mobilising or responding; and
- There is generally insufficient time and resources to undertake tasks such as sandbagging or evacuation to reduce impacts on property or people.

Noting these limitations, the Burrill Lake FRMS&P recommended a “Community Flood Emergency Response Plan” to equip local residents and the community to take appropriate actions to protect themselves and property during flood events with information regarding evacuation routes, refuge areas, what to do/not to do during a flood event etc. Successful implementation of such a plan on a community level was noted to have the potential to help strengthen self-sufficiency in terms of flood response and maximise potential for effective emergency response and a non-reliance on formal emergency services (BMT WBM, 2013a).

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for the catchment.

2.1.2.4 *Flood awareness*

The Burrill Lake FRMS&P (BMT WBM, 2013a) undertook community engagement to better understand the level of flood awareness in the community. The findings include:

- Lack of lived experience through major flood events in the community over recent decades and resulting potential unawareness of flood risk;
- A significant proportion of the community were unaware if their property was at risk flooding at all, unaware of any flood warning procedures or available flood information, and generally indicated a low-level of flood preparedness in terms of personal flood emergency response; and
- High tourist population during holiday periods with lower level of flood risk awareness and preparedness than that of the resident community.

The FRMS&P recommended ongoing community engagement initiatives to improve flood awareness such as an ongoing flood awareness program, media releases, SES community education training, additional brochures targeting sectors of the community, flood risk workshops with community groups, tourist park owners, and businesses.

2.1.2.5 Warning time

Flood warning time categories for Burrill Lake were documented in FRMS&P (BMT WBM, 2013a) and are presented in Table 2.6. Short warning time can mean that SES on-ground assistance can be limited rapid flooding onset and the community requires to be largely self-reliant during an event. However, agencies do have an important role to play in helping to inform community decisions during floods, provision of flood warning infrastructure to support community led emergency response, development of flood emergency planning provisions, and flood preparedness programs in the community before the event. Adequate warning time is important to allow residents to safely move valuable goods and evacuate to higher ground.

In the case of widespread regional flooding (including regional lakes and rivers), adequate warning time for emergency response will varying depending on the availability of competing emergency resources that may be spread across the broader Ulladulla SES unit area of responsibility.

Table 2.6: Burrill Lake flood warning time categories.
From BMT WBM (2013a)

Category	Warning time	Description
No effective warning	<1 hr	No time for pro-active and systematic organisation of flood mitigation, evacuation, emergency response etc. Individuals would be self-directed in regards to emergency response.
Minimal warning	1-6 hrs	Limited assistance and direction likely from emergency services. Measures requiring minimal time for implementation may be appropriate for flood management.
Moderate warning	6-12 hrs	Potential assistance and direction from emergency services, depending on time of day. Measures requiring moderate time, or less, for implementation may be appropriate for flood management.
Good warning	12+ hrs	Significant assistance and direction from emergency services may be available, including assistance with evacuation. Most measures requiring some form of on-demand implementation would be appropriate for flood management.

2.1.2.6 Existing flood warning arrangements

There is no site-specific flood warning system for Burrill Lake. Council and SES emergency response to flood events currently rely upon on the following information sources:

- Bureau of Meteorology Warning Services:
  - Severe Thunderstorm Warnings - typically provide 0.5 to 2 hours notice. These short-range forecasts are based upon radar, data from field stations, reports from storm spotters as well as synoptic forecasts; and

    - Severe Weather Warnings - for synoptic scale events that cause a range of hazards, including flooding. Examples of synoptic scale events are the deep low pressure systems off the NSW coast.
- Water level information is provided by Manly Hydraulics Laboratory and Council at the gauge location just upstream of the Princes Hwy as listed in Table 3.2. The Council gauge is currently operated with automatic alert messages (email) which are sent to Council and SES staff via Enviromon. Presently there are no rainfall or water level stations in the upper catchment.

The FRMS&P provides the following assessment of the limitations of the current warning arrangements:

> *"At present, the only warnings available for Burrill Lake are generic, and automatically generated* [based on model weather forecasts] *by the Bureau of Meteorology in response to severe weather warnings. Water levels are monitored at the water level gauge just upstream of the Causeway. Being located right at the downstream end of the system, the use of realtime water level data at the gauge to issue flood warnings provides for little effective warning and response time. Furthermore, the time from the onset of rain to the point at which floodwaters become hazardous can be a matter of hours in some locations, particularly in the more extreme events. This means that any realistic warnings would need to be disseminated to a large number of people very rapidly." P71*

2.1.2.7 Flood warning improvement

Improving flood warning was reported as one of the priority measures for flood risk management in the Burrill Lake FRMS&P (BMT WBM, 2013a). Recommended actions relevant to improving flood warning included:

Develop flood prediction capability with cooperation of Council, the Bureau and SES

- Provide water level forecasting for Burrill Lake gauge based on realtime and forecast rainfall products from the Bureau of Meteorology. The FRMS&P notes this forecast would - "*provide a local reference for the Burrill Lake community as well as the SES to gauge the imminent flood risk, and respond accordingly*"; P87
- Consideration of additional telemetered gauges for Stony Creek to provide indication of upstream water levels prior to confluence with the lake system;

Develop and implement methods/systems for improved Flood Warning communication

- Development of improved Flood Warning System for Burrill Lake (covering Catchment and Ocean Flooding), including effective broadcasting of warnings and relevant information through a range of methods such as automated messaging, door knocking (dependant on warning time, available resources, and the number of impacted catchments), multimedia, community information hubs, social media channels, internet postings and telephone warning. It is expected that mobile phone-based SMS warnings could also be developed for registered message recipients;

Update Local Flood Plan

- Improved local flood intelligence needs updated with the flood level data derived from the flood study and linked to the property databases established in the FRMS&P.

Additional during-flood measures including flood warning considerations are outlined in the FRMS&P and noted in Table 2.7.

The fundamental importance of successful implementation of a Total Flood Warning System in the Floodplain Risk Management process is strongly noted:

> *"When integrated with community education, the development of a complete Flood Warning System for Burrill Lake forms the cornerstone of this Floodplain Risk Management Plan. With improved warning of an approaching flood, the community will hopefully be able to respond in a more responsible and appropriate manner. Clearly the earlier the warnings are given then the more time communities have to respond."* P 89

Although not noted in previous floodplain risk management studies, development of a flood warning system and improved lake level intelligence in each of these catchments may also have potential benefits to help inform pre-flood entrance management procedures which is outside the scope of the present study.

Table 2.7: During-flood response measures Burrill Lake FRMS&P

From BMT WBM (2013a)

During a Flood	**FRMS&P Comments**
Improved flood warning system, based on integrated rainfall and river level gauging, and realtime radar	A total flood warning system can buy extra time for appropriate flood response if the information can get to the community in time. The system needs to be locally specific and not generic. A system is very acceptable to the community, but can lead to a false sense of security.
Automated voice and text messaging for notification of flood warnings	One possible method of disseminating flood warning information. Multiple methods would be required.
Multi-media bulletins for notification of flood warnings	Urgency of disseminating flood warnings is critical to providing the community with as much preparation time as possible. This should extend to all radio and TV channels, not just local ABC.
Social media channels, such as Twitter and Facebook	Much of the flood information that was distributed and accessed during the 2011 floods across Queensland, NSW, Victoria and WA was via social media (Facebook, Twitter) and internet sites. Emergency services set up direct feeds to these channels with latest updates and information. Communities were able to supplement the information with first-hand knowledge (thus making sure the information was as current as possible).
Flood markers indicating problem areas	Flood markers indicate flood depths – historical and design possible flood events

2.1.3 Tabourie Lake

2.1.3.1 Flood risk

Flooding in Tabourie Lake predominantly occurs due to three main mechanisms (including combinations of) (Cardno, 2016):

- Catchment flooding occurs as a result of intense rainfall typically in excess of 100 mm over several hours. The catchment has a critical design storm duration of 9 hours, with peak flow typically occurring within 7 – 10 hours from the onset of rainfall.
- The rate of rise of lake level during a flood depends on the temporal distribution of rainfall over the catchment. Rate of rise information is detailed in the Tabourie Lake Entrancement Policy (Cardno, 2019) using design flood modelling from the FRMS&P (Cardno, 2016). For a 1% AEP event rates of rise were reported to reach 0.5 m/hour, with a three-hour window where the average rate of rise is over 0.4 m per hour. This poses a significant hazard to residents, as access to and from properties and along local roads is quickly inundated, with little or no warning. For a 20% AEP, event rates of rise were reported to reach up to 0.3 m/hour. Analysis of different design events found that the rate of rise of lake water levels above a 1.17 m AHD level (former entrance management trigger level) were:
    - 45 to 60 minutes to reach 1.50 m AHD;
    - 60 to 90 minutes to reach 1.80 m AHD;
    - 90 to 120 minutes to reach 2.0 m AHD.

  The findings highlight the rapid response of the catchment to flooding and limited warning time available based on lake level gauge alerts.
- Oceanic inundation occurs with open entrance conditions during coastal events with high ocean tides, storm surge, tidal anomalies and large swell at the entrance (e.g., king tides and the 1974 event). When coinciding with catchment flooding, these events can result in worsened flooding to low-lying areas.
- Low-level persistent flooding, occurring through a gradual and prolonged increase in lake levels during periods of entrance closure when the trigger levels for entrance opening have not yet been reached. An Interim Entrance Management Policy (Cardno, 2019) was developed to help alleviate low-lying flooding by opening the entrance when the water level reaches the trigger levels of:
    - If the lake water level is at or exceeding 1.3 m AHD - then the lake shall be mechanically opened as soon as conditions permit.
    - If the lake water level stabilises after rainfall at a level between 1.0 m and 1.3 m AHD, then:
        - If heavy rain is predicted and lake water levels are likely to exceed 1.3 m AHD overnight; or
        - If a period of over two months has elapsed since attaining a level of 1.0 m AHD; and
        - If it is non-breeding season for threatened shorebirds, or clearance from NPWS has been obtained (the breeding period typically extends from late August to March in any year).

At lake levels (Tabourie Creek gauge) of 1.0 m AHD, at least four houses along the Princes Hwy may experience some minor flooding of yards . These properties along the Princes Hwy receive stormwater runoff directly from the Princes Hwy. At levels of 1.3 to 1.4 m AHD, lake levels are close to some non-habitable garages and outbuildings (e.g., sheds and laundries). At 1.7 m AHD the Lake Tabourie Holiday Park access road will be inundated at low points. At 2.0 m AHD, flooding above habitable floor level is experienced at 2 houses. The number of properties with flooding above floor levels increases to 42 houses for the 1% AEP event as shown in Table 2.8.

Tabourie Child Care Centre experiences flooding of property grounds at lake levels less than 2.4 m AHD and above floor flooding at 4.2 m AHD. Lake Tabourie Holiday Park loses access to the Princes Hwy at 2.0 m AHD with inundation of grounds (SES, 2022).

Modelled peak design flood levels and flood damages are shown in Table 2.8. Annual average damages due to flood impacts in Tabourie Lake are estimated to be $0.6M. Properties experiencing above floor flooding in a 1% AEP event is expected to increase with future sea level rise is expected to increase by an additional 39 properties in 2050 and 56 in 2100 (Cardno, 2016). High risk locations include the Tabourie Child Care Centre, Lake Tabourie Tourist Park and evacuation of high tourist populations during holiday periods.

The magnitude of flooding in Tabourie Lake is particularly sensitive to the natural build-up of sand at the entrance berm with typical accreted sand levels of approximately +2 m AHD. Differences in open and closed entrance conditions prior to flooding are noted in the Tabourie Lake Flood Study (BMT WBM, 2010), however, in reality depend on prevailing ocean conditions (i.e., swell, tides, storm surge).

Table 2.8: Burrill Lake modelled peak design flood levels for catchment and oceanic flood events.

From BMT WBM (2007, 2013)

Flood event	Peak flood level at Tabourie Creek gauge (m AHD)	Properties with flooding above floor level	Flood damages ($M)
50% AEP	-	0	$0
20% AEP	2.0	2	$0.5
5% AEP	2.36	12	$2.0
2% AEP	2.62	41	$4.9
1% AEP	2.66	42	$5.5
PMF	4.25	176	$27.5
		Annual Average Damages	$0.6

2.1.3.2 *Evacuation access*

Inundation levels of properties along key roadways are shown in Table 2.9. Properties along Princes Hwy and Oaks Ave are particularly susceptible to isolation to low-lying road levels. Lake Tabourie may become isolated when the Princes Highway closes on the east of the Tabourie Creek Bridge at lake levels of 2.4 m AHD. Off the Princes Highway, local roads may also be cut by flooding at 2.4 m AHD including:

- Portland Way potentially isolating properties on Portland Way and Lulworth Crescent;
- Centre Street potentially isolating residents in the Lake Tabourie Village to the east of Lemon Tree Creek.
- At 1.7 m AHD the Lake Tabourie Holiday Park access road will be inundated at low points.

Table 2.9: Inundation levels of key access roadways

From Cardno (2016) and SES (2022)

Inundation level – Lake Tabourie gauge (m AHD)	Water depth on road (m)	Location
2.0	0.22	Caravan Park Access Road
2.4	0.15	Princes Hwy closure east of Tabourie Creek Bridge
2.4	0.21	Portland Way, North
2.4	0.22	Portland Way, South
2.4	0.27	Centre St and Oak Ave intersection
2.4	0.19	Centre St and Dermal St intersection
2.4	0.40	Lyra Rd and River Rd intersection
2.4	-	Dermal Street, Beach Street and Portland Way
2.6	0.36	Lyra Rd and Venus Ave intersection
2.6	-	Weymouth Road, Bridge Street, Short Street and River Road
4.25	-	South Street, Surf Street, Saturn Avenue and Torquay Drive

2.1.3.3 *Emergency response*

Evacuation procedures for Tabourie Lake rely upon realtime water level monitoring at the Lake Tabourie gauge and weather warning services by the Bureau (see Section 2.1.3.6). The flash flooding nature of Lake Tabourie limits available response time to 1-2 hours, or in many cases sub-hourly. Regional evacuation led by the SES may take 5 hours or more and is limited by:

- Time required to notify a flood-affected region;
- Forecast and actual rainfall monitoring: There is inadequate flood forecasting tools in place for forecasting to be used to inform flood evacuation. Instead actual rainfall monitoring is the only feasible warning system. This type of system requires heavy rainfall to be observed before an alert is issued; and

- The time required for mobilisation of the SES in response to a flood event.

The Tabourie Lake FRMS&P notes that localised evacuation, led by the community on a smaller scale, provides the primary evacuation response during flooding. However, at present the community does not have sufficient warning time to allow evacuation, and any communication of potential flooding occurs when access to/from the property may be already cut off by floodwaters. In addition to construction of designated flood refuges in the community, the Tabourie Lake Flood Study (Cardno, 2007) also notes the importance of improving flood warning:

> *"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 an hour would give residents sufficient time to relocate some household objects, pack some belongings, and walk to the refuge centre. This warning could be provided by a warning linked to the water level gauge in Tabourie Creek."* P48.

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for the catchment.

2.1.3.4 Flood awareness

The Tabourie Lake FRMS&P (Cardno, 2016) undertook community engagement to better understand the level of flood readiness in the community. The findings include:

- Approximately 20% of respondents were living in the area during major flooding in 1988;
- Many residents are aware of the natural variability of the lake entrance and how flood behaviour can change due to changing entrance conditions;
- Residents underestimated the risks of potential future flooding perhaps due to the long period since a major event;
- Flood awareness relatively consistent across the catchment; and
- High tourist population during holiday periods with lower level of flood risk awareness and preparedness than that of the resident community.

The FRMS&P recommended ongoing public awareness and education initiatives to improve flood readiness.

2.1.3.5 Warning time

The critical storm duration for the Tabourie Lake is the 9-hour event, with peak flows occurring in the catchment within 7 – 10 hours from the start of rainfall. Given the potential for rapid rates of rise in floodwaters and notice of potential flooding available, effective warning time for residents to undertake safety response measures is limited in some case to less than one hour. Flood warning of one hour is considered sufficient for residents to evacuate safely to local refuges in the township. A six-hour warning would allow sufficient time for residents to move valuable household items to higher levels and evacuate to flood free refuges, such as flood-free properties with family and friends in the township or an official evacuation centre outside of the township.

2.1.3.6 *Existing flood warning arrangements*

There is no site-specific flood warning system for Tabourie Lake. Emergency response to flood events currently rely upon on the following information sources:

- Bureau of Meteorology Warning Services:
    - Severe Thunderstorm Warnings - typically provide 0.5 to 2 hours' notice. These short-range forecasts are issued by the Bureau's severe weather team and are based upon radar, data from field stations, reports from storm spotters as well as synoptic forecasts; and
    - Severe Weather Warnings - for synoptic scale events that cause a range of hazards, including flooding. Examples of synoptic scale events are the deep low-pressure systems off the NSW coast.
- Water level information is provided by Manly Hydraulics Laboratory (MHL) and Council at the Lake Tabourie gauge at Tabourie Creek causeway as listed in Table 3.2. The MHL gauge is currently operated with automated alert messages (SMS and email) are sent to designated Council recipients when rising flood levels exceed 0.85, 1, 1.3, 1.8 and 2.1 m AHD. The Council gauge is currently operated with automatic alert messages (email) which are sent to Council and SES staff via Enviromon. Presently there are no rainfall or water level stations in the upper catchment, but a new rain gauge is planned to be installed in the catchment headwaters in 2023.
- This information is used to inform SES issuing the following warnings to the community:
    - 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 the SES SEZ Region Headquarters which will issue SES Livestock and Equipment Warnings; and
    - Evacuation Warnings by radio, doorknocks and telephone.

Inadequate warning time under existing arrangements are noted to limit the ability of the SES and community to respond proactively during flood events.

2.1.3.7 *Flood warning improvement*

Improving flood warning was reported as one of the priority measures for flood risk management in the Tabourie Lake FRMS&P (Cardno, 2016). Recommended actions relevant to improving flood warning included:

Flood Warning System

Installation of a flood warning system, tied to local rainfall and water level gauges, to provide residents with advance warning of potential flood events. Recommendations include:

- Consideration of installing potential additional water level gauges in the upper catchment to improve flood warning time to approximately 6 hours. These gauges would not improve warning time for ocean flooding;

- Automated alerting from the existing Tabourie Creek gauge to provide a warning time of one hour.

Flood Warning Signs at Critical Locations

Provision of flood warning signs in public places with high hazard flooding in a 1% AEP event including:

- Caravan Park;
- Tabourie Creek boardwalk;
- Tabourie beach;
- Local parks and open space along Tabourie Creek; and
- River Road / Centre Road over Saltwater Creek.

These signs may contain information on flooding issues or be depth gauges to inform residents of the flooding depth over roads and paths.

It was also recommended that additional depth markers be installed at road crossings which are subject to inundation in frequent events. Depth markers were recommended at the low points on the Caravan Park access road, Centre Road, River Road and Beach Street. However, it is important that communities are informed never to drive through floodwaters.

Preparation of Local Flood Plan

Preparation of a local flood plan for Tabourie Lake and its surrounding areas and update the Shoalhaven DISPLAN document with specific information for Tabourie Lake and its surrounding areas.

Although not noted in previous floodplain risk management studies, development of a flood warning system and improved lake level intelligence in each of these catchments may also have potential benefits to help inform pre-flood entrance management procedures which is outside the scope of the present study.

2.2 Initial stakeholder questionnaire

This section summarises findings from initial stakeholder and community questionnaire distributed for completion in May-June 2023 during the commencement of the present study. This forms an initial engagement stage upon which the project will continue to work with stakeholders and the community in subsequent project stages to discuss flood warning options and develop required detail of a preferred total flood warning system.

2.2.1 NSW SES – Ulladulla SES Unit

Flood warning and the role of SES

Flood warning information is critical for the Ulladulla SES Unit to prepare for and respond to flooding in their area of responsibilities. Potential for flash flooding and limited lead times in the catchments of Lake Conjola, Burrill Lake and Tabourie Lake make timely warning of most assistance to SES operations.

The decisions required of SES Incident Management Team, regarding warnings for the communities, to consider evacuations, to pe-locate response teams and an understanding of the possible depths and velocities of flood water are based on flood intelligence and warning information available.

Types of flood warning information that were noted by SES to assist their operations included:

- Predicted and current rainfall in the catchments;
- Current water levels both within the lakes and upstream;
- Entrance configuration of each of the ICOLLs;
- Possible/probable swell levels and the possibility of East Coast Low pressure systems which may impact predicted tide heights and elevate lake levels; and
- Indication of local and tourist populations throughout the year in locations of impact to inform planning and evacuations.

Preferred flood warning alerts or information formats for SES: SMS message, Email message, Flood warning system web portal for Council and SES with realtime flood information, Mobile phone or tablet flood warning app.

Messaging formats are to conform to the Australian Warning System format (Australian Institute for Disaster Resilience).

Desired flood warning measures or initiatives

Continued interaction with the Council Flood Engineers and SES members in attempts to develop systems by which SES and Council Staff are better prepared to respond, safely and efficiently, in attempts to keep their communities safe and better prepared, reduce damage to property and Council Assets and reduce the impact of flooding.

Other comments

This initiative will enable the Ulladulla SES Unit to be better prepared to assist their communities. The incorporation of a range of data inputs would provide an overview of possible flooding across the three ICOLL catchments. This evidence base will extend the possible warning and set-up times, generating an improved response to the possible flooding and planning for updating Flood Intelligence.

2.2.2 Shoalhaven City Council

Flood warning is equally important for Lake Conjola, Burrill Lake and Tabourie Lake catchments.

Flood forecast and warning information would support Councils management of the Lake Conjola, Burrill Lake and Tabourie Lake ICOLL entrances in accordance with the adopted Entrance Management Policies. This would allow increased warning time by forecasting lake levels based on forecast and/or actual rainfall in each catchment. This could lead to future updates of Entrance Management Policies (and associated Crown Land Licences) to include additional triggers based on predicted lake levels. This information would also assist Council to understand when and where roads may need to be closed during a flood event.

Ideal flood warning information would comprise a TFWS that predicts lake levels with a reasonable accuracy based on forecast and actual rainfall, the initial lake level, sea conditions and the ICOLL entrance condition. This would also include additional gauging to improve the accuracy of the forecasts and have integrated alerting.

Flood waning alerts would ideally be received by SMS, email and a flood warning system web portal for Council and SES with real-time flood information. The TFWS would ideally convey information directly to Council and the SES and then be disseminated to the wider community.

2.3 Initial community consultation questionnaire

In May-June 2023 an initial consultation questionnaire was distributed to the Lake Conjola, Burrill Lake and Tabourie Lake communities. The survey and combined summary results are provided in Appendix A. The questionnaire covered topics of flood risk perception, flood preparedness, preferred flood information sources, and preferred mechanisms for flood warning messaging.

In total, 123 people completed the community survey, with 32% of respondents from Lake Conjola, 41% from Burrill Lake and 27% from Tabourie Lake. The majority of respondents had residential property in the catchments that was owner occupied (69%) with a notable portion of holiday homes (25%) and smaller number of rentals (5%).

Key findings from the community survey relevant to the development of a flood warning system are summarised below:

- A high proportion of residential holiday home and caravan parks is noted amongst respondents indicating potential for high transient populations during holiday seasons. Flood warning system design should cater for visiting populations to the area and those who might be less informed and prepared during flood emergencies;
- A majority of respondents (54%) have lived in the area for more than 10 years however a number of respondents have lived in the area for less than 5 years (31%). Approximately 51% of respondents had lived in the area during a flood. Given more significant flooding is reported to have occurred in earlier decades in these catchments (e.g., major events in 1971, 1975, 1988 and 1991; BMT WBM 2010), it is likely that a substantial proportion of the population have not experienced a major flood event for some time. Respondents in Lake Conjola are likely to have experienced flooding in February 2020;
- The majority (70%) of respondents perceived a low to no risk of flooding to the main buildings on their property with 30% perceiving a moderate to high risk. Approximately 54% of respondents perceived a low to no risk of flooding to the property (land, backyard, front yard, driveway, etc) with 46% perceiving a moderate to high risk. Similar results were noted for perceived future risk. More detailed floor level and property assessment would be required to determine the degree of accuracy of perceived flood risk held in the community in comparison to quantified hazards in flood studies. Given a lack of major flooding in recent decades perceived risk may potentially be underestimated;
- The majority (65%) of respondents did not have a flood emergency plan for their home with 35% having a flood emergency plan. Development of a flood warning system should work closely with the community to inform and improve community and household emergency response;
- Approximately 15% of respondents have household members who require care (e.g., infants, elderly or has a disability), 25% indicated they would need help from others in the event of a flood and 13% perceive a moderate to high risk to their personal safety from flooding. Latest Census data also indicates a high proportion of the population aged 65 years or older. Development of a flood warning system and emergency response procedures are to provide sufficient assistance particularly to vulnerable

populations within the communities. It is likely that most of this assistance would come from community members and neighbours, given a significant proportion (83%) of respondents indicating they are willing to help others during a flood;

- The top five sources of information to find out what to do before, during and after a flood were (% of total votes):
    1. Neighbours (13%)
    2. SES website (11%)
    3. Council website (10%)
    4. Radio (10%)
    5. Flood meeting/forum, speaking with SES, family friends (7%)

  The results indicate the importance of a collaborative effort involving community, SES and Council to effectively disseminate flood safety information.

- The top five preferences for ways to receive flood warning messaging were (% of total votes):
    1. SMS messages (30%)
    2. Flood warning or hazards near me phone app (14%)
    3. Radio messages (13%)
    4. Door knocking (12%)
    5. Phone calls (10%)

  The results indicate the importance of providing a variety of mechanisms to communicate flood warning messaging to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues). Respondents noted the importance of in-person communication, particularly for elderly community members. Some respondents also recommended the bushfire alerting system as a potential model to use as example of hazard notification (more recently integrated into the Hazards Near Me app).

Respondents were asked if they have other comments, questions, or concerns regarding a flood warning system for the community. Key themes from the comments relevant to the scoping and implementation of a flood warning system include:

- Importance of disseminating early flood warning and flood hazard areas, particularly potential road closures and congestion (with some respondents indicating preference for automated road signage);
- Ability to include ocean-driven (high seas, tides, tsunamis etc) flood warning during open entrance conditions;
- Alternative communication mechanisms in case of unreliable mobile or phone systems during flood emergencies;
- Importance of accurate and consistent warning messaging to help inform community

response; and

- Strong interest in entrance management, pre-flood entrance management procedures and flood response associated with open/closed entrance conditions. It is noted in the present study, that the development of a flood warning system and improved lake level intelligence in each of these catchments may also have potential benefits to help inform pre-flood entrance management procedures.

Stakeholder feedback was also received from caravan park managers who noted the importance of early flood warning and lake level updates to assist in managing bookings and take appropriate action to ensure the safety of the caravan park guests and park operations.

Ongoing consultation with the community and stakeholder groups throughout subsequent stages of the study will be undertaken to discuss flood warning system options and detail of a preferred flood warning system design.

2.4 Summary

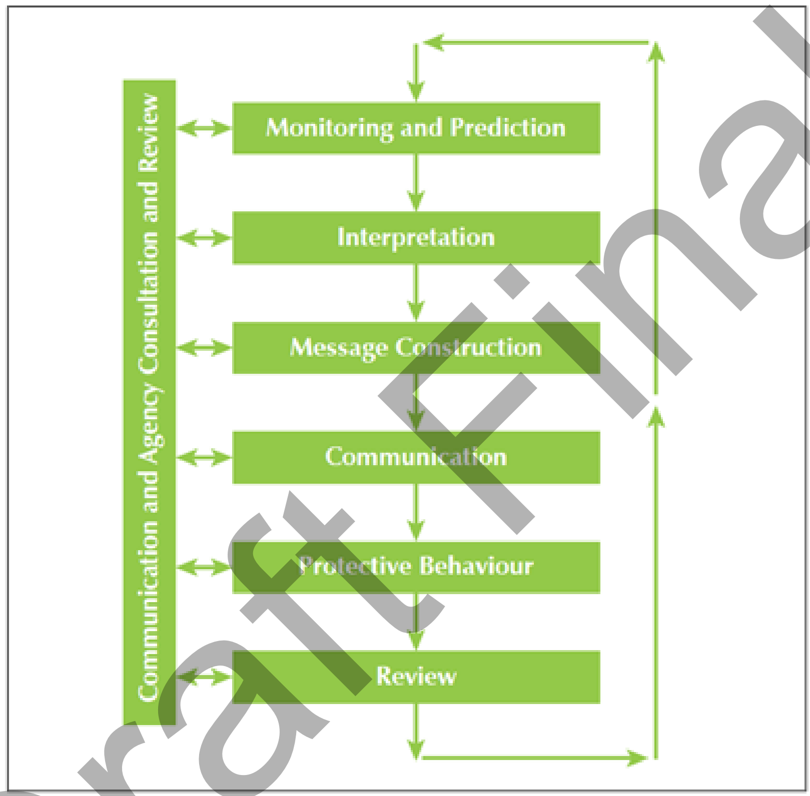
The review of previous flood studies indicates the present and future flood risk of low-lying settlements in the Lake Conjola, Burrill Lake and Tabourie Lake catchment areas. Key flood information has been summarised from the study areas to help inform development of trigger levels for warnings and flood levels for key assets. This information for each catchment shall be reviewed in subsequent project stages during the detailing of a preferred flood warning system. Existing flood warning arrangements are noted to provide insufficient warning time to both SES and community during flood events.

In all flood risk management studies, the fundamental importance of successful implementation of a Total Flood Warning System is noted as a priority action to reduce risk to life during flood events. The following section details and assesses potential component design options to improve flood warning in Lake Conjola, Burrill Lake and Tabourie Lake.

3 Flood warning system component design options

3.1 Total Flood Warning System (TFWS)

In Australia, best practice guidelines for flood warning system design are described in Australian Emergency Manual 21 – Flood Warning (AIDR, 2009). This manual sets out a framework for the Total Flood Warning System as shown in Figure 3.1.



From AIDR (2009)

Figure 3.1: The Total Flood Warning System

The Total Flood Warning System (TFWS) includes six (6) components with an overarching consultation and review process which should be integrated into all other components. The components are:

1. Monitoring & Prediction – physical and predictive infrastructure which determines the level and timing of flooding. The physical infrastructure could consist of realtime rainfall and/or water level gauges, streamflow gauges, moisture detectors, cameras, rain radar, predictive meteorological models, or similar. The predictive elements take those observations and estimates the level of flooding at key locations. These techniques include trigger levels, local knowledge, rainfall-runoff relationships, hydrological modelling, direct-rainfall modelling, etc.

2. Interpretation – determine the likely impact of flooding given a prediction. This takes the observed or predicted data from the first component and uses understanding of the local topography, community, traffic requirements as well as flood behaviour to determine the likely impacts on the ground.
3. Message Construction – devise persuasive messages which encourage those at risk to take action. This component takes the data created in the Interpretation phase and turns it into information which those at risk can use to make decisions about their own safety. This includes such things as severity and estimated timing of flooding (noting accuracy of estimates are subject to changing rainfall, entrance and ocean conditions), location and evacuation routes, contact points and hotlines, evacuation priorities. The format of this messaging must also be appropriate to the method of communication in the next Stage.
4. Communication – getting the message out to those who need it. This component involves leveraging from as many communication avenues as appropriate to ensure that *everyone* who is at risk has been warned of the potential threat. These include such methods as SMS messaging, the Bureau and NSW SES warnings, radio and tv announcements, phone calls, door knocking, sirens, etc.
5. Protective Behaviour – generating appropriate and timely actions and behaviours from the agencies involved and from the threatened community. In NSW this involves coordination from the NSW SES and local community members to ensure that those that need help have it where possible (in consideration of available resources and the extent and magnitude of the flood event), that everyone remains safe, and where possible, that the impact of the flooding is reduced. All of this work should be underpinned by a strong community engagement program to build resilience to ensure the community understands the threat and can plan and undertake actions proactively.
6. Review – post-event audit of the TFWS, overall performance, successes and opportunities for improvement. This component requires honest and transparent assessment of the system with focus primarily directed towards the safety of those at risk and what areas could be improved to ensure the risk to life is further reduced. This should involve all agencies with a stake in the TFWS, including the local community, and be a collaborative effort to implement learnings and tackle inefficiencies in the system.

It is critical to the TFWS that all components of the system are addressed and treated holistically. Ignoring or omitting one component undermines the strength of the framework and reduces the effectiveness of the flood response. The TFWS is most beneficial if those at risk have ownership of the system, feel that it is developed to benefit them, and are therefore involved in the design and review of the system. An aware and engaged community is key to any system and empowering people to help and teach each other reduces pressure on emergency services. This greatly improves the efficacy of the system.

Every community is different: varying in population, demographics, lived flood experience and risk perspectives, all of which inform the response to a flooding emergency. Additionally, every catchment is slightly different, with location, area, shape, steepness and vegetation all changing the behaviour of the flood. Furthermore, the inherent uncertainty in rainfall intensity, location and timing, as well as catchment preconditions mean that no two floods are the same even within a single catchment, let alone in different villages or regions. Therefore, no two flood warning systems should be designed to be the same and instead should be tailored to the specifics of the localised flood hazard. Given this tailored approach, there are many component options for the design of any given flood warning system and some constraints must be applied to form a manageable set of options which can be feasibly reviewed.

MHL has taken information from the individual Flood Studies and the Floodplain Risk Management Studies and Plans (FRMS&P) to form an initial set of constraints. The aim was to identify those components which are most appropriate to the physical conditions of the respective catchments.

The component design options presented below for each catchment, only include options that are practically and physically feasible, given the flood characteristics at Lake Conjola, Burrill Lake and Tabourie Lake. Due to the scope of design choices, component options are grouped according to the TFWS to make analysis easier and facilitate ongoing discussion. Component options are labelled with a number following the TFWS prefix, e.g., M.3 for the 3rd monitoring option, P.2 for the 2nd prediction option, etc. A preferred detailed design of a TFWS may incorporate a combination of component design options.

For each catchment these components were assessed using multi-criteria analysis to develop a preliminary list of flood warning system options.

3.2 Multi-criteria analysis

Multi-Criteria Analysis (MCA), sometimes referred to as Multi-Criteria Decision Analysis, is a non-monetary decision-making framework which is often used in environmental decision making (Janssen, 2001). It's main advantage over a more traditional Cost-Benefit Analysis (CBA) is that it is able to account for a range of intangible values (or significance) as one does not need to quantify all values in terms of dollars. Additionally, it can accommodate differing or conflicting priorities more transparently than a CBA by integrating them into a rational decision-making framework. The MCA process aims to:

> *"help decision makers learn about the problem situation, about their own and other's values and judgements, and through organisation, synthesis and appropriate presentation of information to guide them in identifying, often through extensive discussion, a preferred course of action"*
>
> (Belton & Stewart, 2002)

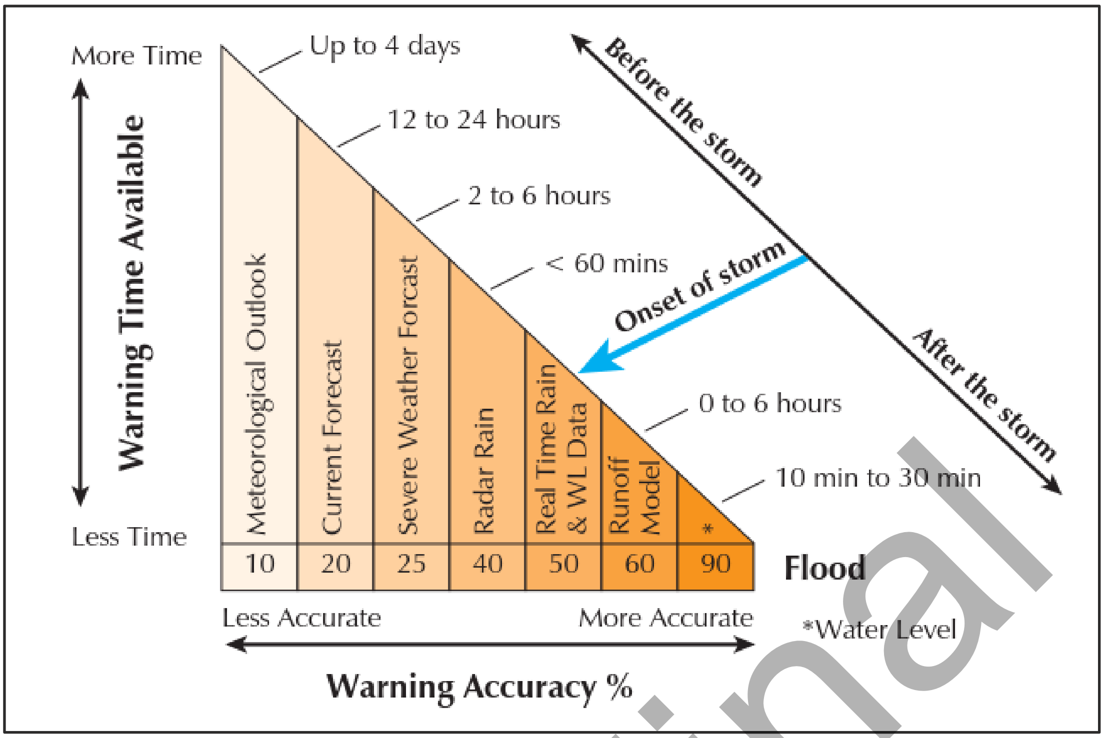
MCA does this through a selection of criteria which aim to cover all the important factors, or dimensions, of the problem from the point-of-view of each stakeholder group or concerned party. Following this selection, the MCA process involves assessment and discussion of the options against the selected criteria and includes weighting of criteria and sensitivity analysis around the proposed decision. This process, then, can help to complement and challenge intuition, make use of relevant experience and lead to more considered and justifiable decision-making (Belton & Stewart, 2002).

MHL has opted to use an MCA framework in this options assessment primarily for its ability to act as a tool for initiating and directing discussion among the Shoalhaven ICOLL flood warning system stakeholders and for the easy comparison of the relevant factors in developing a rational and justifiable outcome. The MCA framework will be used to assess all the TFWS components and then create a short list of options to be reviewed further. In this way, stakeholders will be able to assess a manageable subset of options rather than needing to deal with all the permutations of the system.

3.2.1.1 Criteria selection

When it comes to alerting those at risk of a potential flood, current best practice indicates that the TFWS for the Shoalhaven ICOLLs should employ a tiered solution. This warning system will need to provide advanced heads up and explicit updates to both the public and relevant authorities as the storm develops as well as communicating the relationship between the accuracy of the prediction and the lead time (Figure 3.2).

The criteria used to assess the flood warning options, therefore, need to be able to determine which options are suitable for different tiers of warning as well as their overall viability. The criteria selected for this assessment were collected from prior MHL studies and discussions with the technical working group. These are presented in Table 3.1. Assessment criteria were given equal weighting. All component options were assessed relative to the existing case except for capital and maintenance costs.



From AIDR (2009)

Figure 3.2: Warning Time vs. Warning Accuracy

Benefit to flood warning lead time refers to the additional length of time (relative to the existing case) that a component provides between information being collected and action needing to take place based on that information. As discussed in Section 2.1, the lead time can be short for each ICOLL catchment and, hence, maximising what time is available is critical to the design of the TFWS.

Costs criterion for component options have been assessed against estimated capital cost to install the system ($) and maintenance costs to continue operation ($/year). Cost estimates are preliminary and for comparative purposes only, and are subject to change during detailed component design in subsequent stages.

Benefit for emergency response refers to the added value (relative to the existing case) of a component option to supporting SES operations and decision-making. This includes how much easier, or more difficult, the NSW SES's job becomes with the component in place. Will they require additional resources to interact with that component or does it let them know when there's a potential issue to address? These kinds of questions are addressed through this criterion.

Benefit to accuracy of prediction refers to the degree of improvement (relative to the existing case) in accurately predicting flood behaviour associated with a component option. Component options that provide information that is important to accurately predicting ICOLL flooding are scored higher than component options where sufficient information may be already available, or its implementation is expected to provide little improvement in flood prediction. Prediction accuracy is deemed sufficient in the context of flood warning. For example, while it may not be critical to know if the flood is going to be at 2.1 m AHD or 2.15 m AHD , it is certainly important to know if 10 houses on the edge of the floodplain are going to be underwater or not.

The technical feasibility criterion was chosen with the understanding that some components can fulfil their role perfectly on paper but that implementing them can be much more difficult or complex. The simpler a component is to implement, the higher its technical feasibility. This also includes consideration of the legislative requirements of a component option and whether it is legally possible to implement or if there are regulations which say that a particular component *must* be in place (e.g., NSW SES responsible for flood warning message dissemination and initiating evacuation orders).

Table 3.1: MCA Criteria

Item	Weighting	Score				
		1	2	3	4	5
		Negative / Limited perfomance				Positive / High performance
Benefit to flood warning lead time	5	+1 hour of improved warning	+1 to 3 hours of improved warning	+3 to 6 hours of improved warning	+6 to 12 hours of improved warning	Greater than 12 hours improved warning
Capital cost of component	5	Very high (>$50,000)	High ($30,000 - $50,000)	Moderate ($15,000 - $30,000)	Low ($5,000 - $15,000)	Very low (<$5,000)
Maintenance cost of component ($ per year)	5	Very high (>$10,000)	High ($6,000 - $10,000)	Moderate ($3,000 - $6,000)	Low ($1,000 - $3,000)	Very low (<$1,000)
Benefits for emergency response	5	No benefit to SES operations and decision making	Little benefit to SES operations and decision making	Moderate benefit to SES operations and decision making	Major benefit to SES operations and decision making	Signficant benefit to SES operations and decision making
Benefit to accuracy of prediction	5	Does not improve flood prediction accuracy	Limited prediction accuracy	Moderately improves prediction accuracy	Majorly improves prediction accuracy	Significantly improves prediction accuracy
Technical Feasibility	5	Very high level of difficulty and complexity to implement	High level of difficulty and complexity to implement	Moderate level of difficulty and complexity to implement	Low level of difficulty and complexity to implement	Very low level of difficulty and complexity to implement

3.2.1.2 Component assessment

When performing the MCA each component is assessed against these criteria based on the defining statement. A score from one to five (1-5) is assigned to each criterion based on the degree to which it conforms to the assessment criteria in Table 3.1.

When all the scores for all the options have been tallied, a weighting is assigned to each criterion based on its relative importance to the outcome. The final result is a total of the weighted values for each criterion, presented as a score which allows direct comparison of options against one another to determine order of preference and relative desirability. The component items with the highest scores have been used to generate a set of possible options for a total flood-warning system for consideration by the Shoalhaven ICOLL stakeholders. The preliminary MCA results are presented in the following sections for the Lake Conjola, Burrill Lake and Tabourie Lake catchments. Finalised results will be available after the consultation process with each community.

3.3 Lake Conjola TFWS

3.3.1 Component Options

3.3.1.1 Monitoring

Current monitoring in Lake Conjola is undertaken via existing rainfall and water level gauges detailed in Table 3.2 and Figure 3.3. All listed rainfall and water level stations are automatic with data telemetered at Council owned gauges via Event-reporting Radio Telemetry System (ERTS) and mobile network at DPE BCD owned gauges. Council are also currently planning the installation of a new rainfall gauge at the George Boyd Lookout Area in the upper Conjola catchment. Also listed in Table 3.2 are existing rainfall gauges in regional areas surrounding the catchment as well as an ocean tide (Ulladulla Harbour) and wave monitoring station (Batemans Bay) situated within the region.

Table 3.3 summarises different monitoring design options for development of a flood warning system. A TFWS may include one or a combination of those listed. Options for potential installation of new water level and rainfall gauges are: an additional water level at Conjola Creek (Princes Hwy) situated upstream beyond the tidal limit of the estuary to provide better indication of lake inflows; and/or an additional rain gauge at Conjola Creek (Princes Hwy) to improve rain gauge coverage.

Site specifications for installation and maintenance of additional gauging is to be undertaken during detailed design of the flood warning system (Stage 4). Review of additional gauging requirements will also be undertaken during detailed design of a preferred flood warning system (Stage 4).

Another monitoring component of flood warning system design for the Lake Conjola catchment is the ability to incorporate dynamic entrance channel and ocean conditions into flood level estimates. Entrance berm surveys are currently undertaken by Council at Lake Conjola via:

- Monthly entrance berm surveys when the channel is closed to the ocean
- Entrance berm survey within the week prior to a potential flood event where possible
- Entrance monitoring (daylight hours)

Manly Hydraulics Laboratory provides realtime tidal harmonic analysis (M2 constituent) of water levels at Lake Conjola as a proxy for how open the entrance is to the ocean (i.e., how much tidal signal is prevalent in the lake water level record). This information could also be incorporated into a flood warning system to better represent prevailing entrance conditions.

Also included in the monitoring component options is the potential installation of a remotely operated and automatic entrance monitoring station to provide live entrance berm and channel opening conditions to support flood prediction.

Many Hydraulics Laboratory also maintains an automatic ocean tide gauge in Ulladulla Harbour and a wave buoy (wave height, direction and period) offshore of Batemans Bay. Flood warning system design is recommended to incorporate the latest entrance and ocean conditions from such information sources to help improve flood level estimation and warning accuracy.

Table 3.2: Lake Conjola and surrounds - existing rainfall and water level gauges

Catchment (including surrounds)	Station	Station No.		Type		Ownership	Maintenance	Comms	Alerting	Live Data Available
		AWRC	BoM	Level	Rain					
Lake Conjola	Lake Conjola Downstream	216420D	-	✓ (including tidal harmonic M2 analysis)	✓	DPE BCD	MHL	Mobile 3G/4G (IP)	No	https://www.mhl.nsw.gov.au/Station-216420D https://mhl.nsw.gov.au/users/ShoalhavenCityCouncil-LakeConjolaM2
	Lake Conjola	216420	568182	✓	✓	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/fwo/IDN60234/IDN60234.568182.plt.shtml http://www.bom.gov.au/fwo/IDN60234/IDN60234.568182.plt.shtml
	Fishermans Paradise, Conjola Creek	-	569044	✓	-	Council	Council	ERTS	No	http://www.bom.gov.au/fwo/IDN60234/IDN60234.569044.plt.shtml
	Fishermans Repeater	-	568201		✓	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	Jerrawangala	-	568204	-	✓ *	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	Porters Creek Dam	-	568212	✓ *	✓ *	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	George Boyd Lookout Area	-	-	-	✓	Planned future Council rain gauge installation				
Ocean Conditions	Ulladulla	216471	569039	Ocean Tide *		DPE BCD	MHL	Mobile 3G/4G (IP)	No	https://www.mhl.nsw.gov.au/Station-216471
	Batemans Bay	BATBOW		Ocean Wave *		DPE BCD	MHL	Radio	No	https://www.mhl.nsw.gov.au/Station-BATBOW

* Station located outside of catchment area but useful for regional rainfall monitoring or ocean conditions

Figure 3.3

Lake Conjola - Existing and Proposed Gauges

Legend

▭ Catchment Boundary
— Waterways

Gauges

● Existing Rain Gauge
■ Existing Water Level Gauge
▲ Existing Water Level & Rain Gauge
● Planned Future Rain Gauge
● Potential Rain Gauge
▲ Potential Additional Water Level & Rain Gauge
◆ Ocean Tide
✦ Ocean Wave

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Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study: Stages 1 to 3 Review and Flood Warning System Options

NSW GOVERNMENT

Manly Hydraulics Laboratory

Table 3.3: Lake Conjola - Summary of monitoring options

Component Option	Option Name	Summary
Existing base case		• No additional monitoring infrastructure will be installed; • Continued maintenance of existing gauges and installation of planned gauge at George Boyd Lookout Area as per Table 3.2; • Continued maintenance of basic alerting from Council's rainfall gauges through Enviromon; • No flood warning integration of entrance and ocean condition information.
M.1	Additional automatic water level station upstream at Conjola Creek Princes Hwy	• Improved warning of upstream water level rises beyond the tidal estuary limit to provide better indication of lake inflows; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.2	Additional automatic rainfall station upstream at Conjola Creek Princes Hwy	• Additional rainfall gauge coverage in the Conjola Creek catchment; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.3	Integrate entrance channel data from latest Council surveys and Lake Conjola M2 tidal analysis	Improved use of entrance condition information for flood prediction via: • Integration of latest entrance conditions from Council existing entrance monitoring program including entrance berm surveys at monthly intervals when closed, entrance berm surveys within the week prior to an event where possible, and entrance monitoring cameras; • Realtime tidal harmonic analysis at Lake Conjola, also provides indication of trends in entrance behaviour and may supplement entrance condition monitoring; • Likely further benefits to pre-flood entrance management procedures.
M.4	Installation of remote entrance berm monitoring station at Lake Conjola Entrance	Improved monitoring of entrance conditions for flood prediction via: • Installation of a remotely operated and automatic station to monitor the condition of the entrance throat channel and entrance berm; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new station; • Likely further benefits to pre-flood entrance management procedures.
M.5	Integrate ocean wave and tide data	Improved understanding of ocean conditions for flood prediction via: • Integration of available ocean water level data from Ulladulla tide gauge (216471); • Integration of available ocean wave conditions from Batemans Bay Wave Buoy (BATBOW), transformed into nearshore water depths at entrance.

MCA Assessment

Results of the MCA assessment for monitoring component options are shown in Table 3.4. Installation of an additional automatic water level station upstream at Conjola Creek Princes Hwy (M.1) will likely improve warning of upstream water level rises beyond the estuary tidal limit and lake inflows. The installation of this new gauge is considered a Priority 1 installation.

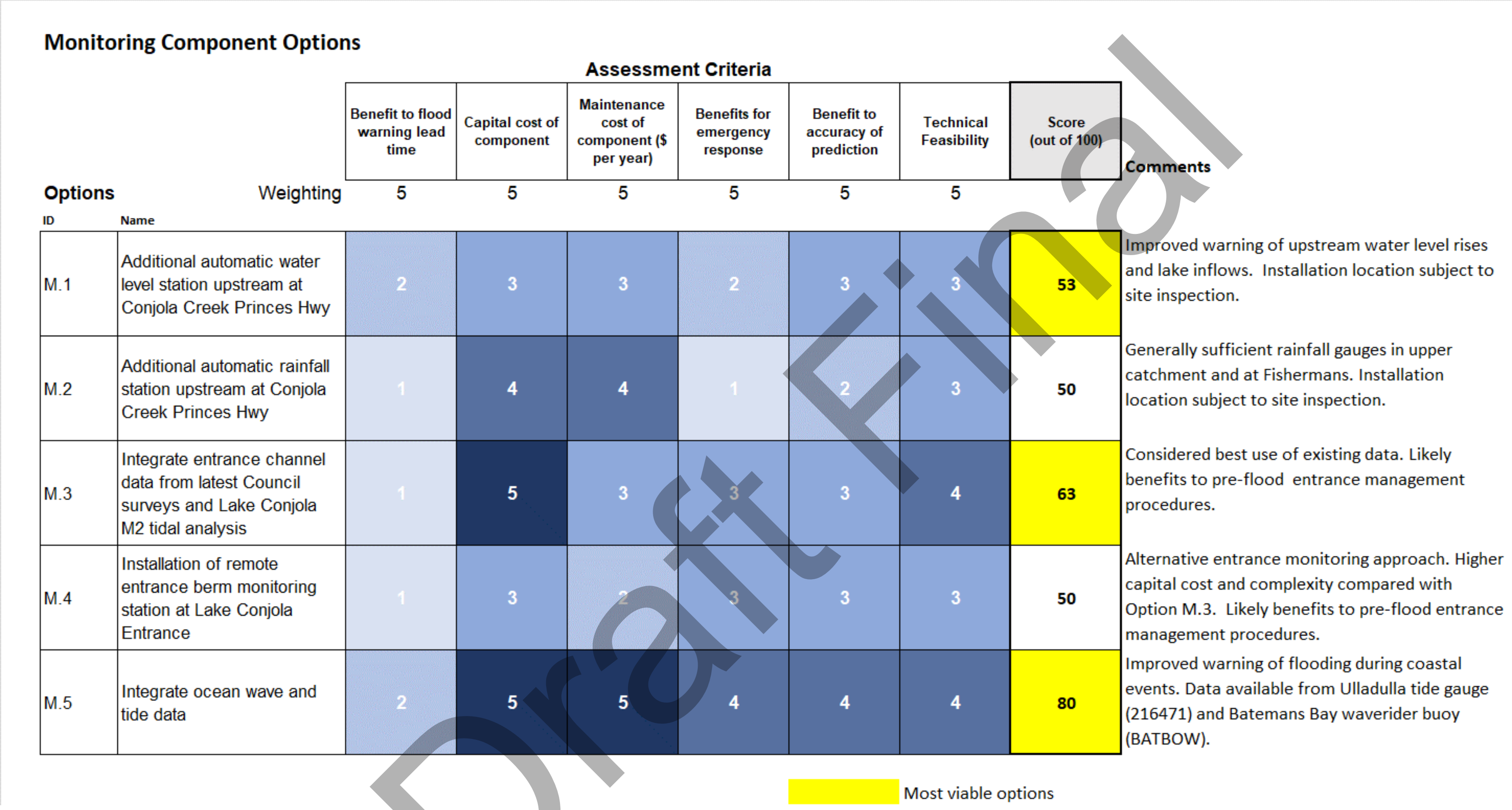
Installation of an additional automatic rainfall station upstream at Conjola Creek Princes Hwy (M.2) is considered to be of slightly lower priority given the generally sufficient coverage of rainfall gauges in the catchment under the existing case (listed in Table 3.2). The installation of this new gauge is considered a Priority 2 installation.

Provision of entrance channel information for flood warning is considered best achieved through integration of entrance data from latest Council surveys and the existing Lake Conjola M2 tidal analysis (M.3). This option provides best use of available information in comparison to installation of a remote berm entrance monitoring station (M.4) with higher capital cost and installation complexities.

Integration of ocean wave and tide data (M.5) was scored the highest of all component options. This also make best use of available information providing realtime ocean conditions to support flood prediction accuracy at Lake Conjola.

The results indicate that a combination of monitoring options is likely viable for design of a TFWS at Lake Conjola, incorporating available entrance and ocean monitoring information with options for improved water level and rain gauge coverage.

Table 3.4: Lake Conjola - Monitoring Component Options MCA Results



Monitoring Component Options

Assessment Criteria

ID	Name	Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
Options	Weighting	5	5	5	5	5	5		
M.1	Additional automatic water level station upstream at Conjola Creek Princes Hwy	2	3	3	2	3	3	**53**	Improved warning of upstream water level rises and lake inflows. Installation location subject to site inspection.
M.2	Additional automatic rainfall station upstream at Conjola Creek Princes Hwy	1	4	4	1	2	3	**50**	Generally sufficient rainfall gauges in upper catchment and at Fishermans. Installation location subject to site inspection.
M.3	Integrate entrance channel data from latest Council surveys and Lake Conjola M2 tidal analysis	1	5	3	3	3	4	**63**	Considered best use of existing data. Likely benefits to pre-flood entrance management procedures.
M.4	Installation of remote entrance berm monitoring station at Lake Conjola Entrance	1	3	2	3	3	3	**50**	Alternative entrance monitoring approach. Higher capital cost and complexity compared with Option M.3. Likely benefits to pre-flood entrance management procedures.
M.5	Integrate ocean wave and tide data	2	5	5	4	4	4	**80**	Improved warning of flooding during coastal events. Data available from Ulladulla tide gauge (216471) and Batemans Bay waverider buoy (BATBOW).

🟨 Most viable options

3.3.1.2 Prediction

Currently there is no formalised procedure or mechanism to provide realtime flood level predictions during a flood event for Lake Conjola. Current methods are described in Section 2.1 and rely upon realtime gauge information, Bureau weather warning services and limited rate-of-rise information where available from technical studies.

Potential options to improve flood prediction are listed in Table 3.5. These include flood predictions based on (including combinations of) rate-of-rise analysis and gauge trigger levels (informal prediction), realtime hydrology modelling, realtime hydrodynamic modelling, realtime simplified lake hydraulic modelling, incorporation of Bureau rain forecast products (MetEye, Rainfields), entrance channel scour predictions and ocean water level predictions. A TFWS may include one or a combination of those listed.

Prediction options have differing levels of complexities, accuracy and effort associated with each approach. Realtime flood models differ in calibration complexity, model setup, computing power and runtime requirements. Realtime hydrology models (P.2) take observed and predicted rainfall and converting it an inflow into the lake storage system. Outputs from a hydrology model can be readily applied in a realtime simplified lake hydraulic model (P.4) to provide lake level predictions based on lake and floodplain bathymetry, and entrance configuration. These models may be run very quickly (in the order of seconds) and are able to, generally, provide a good level of accuracy of downstream prediction as compared to trigger level predictions (P.1) when combined with sufficient entrance channel and ocean representation (P.6 and P.7). Hydrology models require realtime data to provide the best results, need to run automatically in a dedicated computing environment which in some cases can be complicated and expensive to operate, and often require experienced personnel to interpret the results they provide. Catchment pre-conditions are another factor which is difficult to account for in a realtime hydrological model and could have impact on the prediction accuracy.

At the most complex and expensive end of the prediction options is the running of a realtime 2D direct-rainfall hydrodynamic model (P.3). These models are the same type as those used to perform flood studies and floodplain risk management plans, however they need to be configured to run in a flood forecasting capacity. These forecasting systems are just starting to become available in NSW and can require large amounts of computational power, are costly to setup and maintain, and can take hours to run. It is unlikely that given the short lead-time for flooding in the respective catchments and the available resources of Council that this option will be viable, however it has been included for completeness.

In order to drive predictions, the Bureau have provided a number of forecast products for consideration in this report. P.5 consists of utilising the Bureau's MetEye forecast products which, for the purposes of flood forecasting, provides a number of gridded (6km) probabilistic rainfall forecasts (10%, 25% and 50% chance of exceedance) at 3-hour intervals. This gridded data can be used to drive predictions from any of the other prediction options to estimate the likely flooding up to 7-days in the future. The MetEye forecast services are based on regional climate models with limited spatial and temporal resolution. P.5 also includes use of the Bureau's new Rainfields rainfall forecast which is based on rain radar nowcasting. This provides much better resolution both across space (100's of metres to kilometres) and time (6-minute time interval) and is designed to improve short-term rain predictions for thunderstorm-scale flood forecasting.

Table 3.5: Lake Conjola - Summary of prediction options

Component Option	Option Name	Summary
Existing base case		- As per existing flood warning arrangement utilising as outlined in Section 2.1.1.6; - Relies heavily upon manual interpretation of realtime gauge data, BoM weather warning services and knowledge of flood behaviour; - No formalised procedure or mechanism to provide realtime flood level predictions during a flood event.
P.1	Rate-of-rise and trigger level based predictions	- Flooding predictions are estimated using recorded rainfall, water level trigger levels and rate-of-rise information from flood modelling analysis; - Simplistic and preliminary technique to flood prediction with limited accuracy.
P.2	Realtime hydrology modelling	- Flooding predictions are based on realtime hydrology modelling of observed and predicted rainfall; - Simple model to setup and run.
P.3	Realtime direct-rainfall hydrodynamic modelling	- Flooding predictions are based on realtime direct-rainfall hydrodynamic model of observed and predicted rainfall; - Complex model to setup and run.
P.4	Realtime simplified lake hydraulic modelling	- Flooding predictions are based on simplified lake hydraulic modelling incorporating inflows from hydrology modelling (P.2), lake bathymetry and entrance representation.; - Simple model to setup and run.
P.5	Utilise Bureau rainfall forecast services (Rainfields and Meteye)	- Use BoM rain radar predictive model (Rainfields) to inform short-term (e.g., Thunderstorms) predictions - Use BoM Australian Digital Forecasting Database (ADFD; MetEye) to inform predictions
P.6	Entrance channel predictions	- Improvement of flood predictions via integration of a predictive entrance model that incorporates latest entrance observations and predictive entrance breakout/scour during flooding. - Based on knowledge of entrance scour behaviour.
P.7	Ocean water level predictions	- Integration of forecast ocean conditions at the entrance to improve flood level predictions. Forecast services include the NSW Nearshore Wave Tool (utilising AUSWAVE), astronomical tide and ocean anomaly forecasts.

Representation of the entrance channel (including latest conditions and scour induced by flooding) and forecasted ocean conditions at the entrance (waves, tides, anomalies, etc) throughout an imminent flood event is also an important component of accurate flood level prediction. Realtime entrance prediction (P.6) considers latest entrance observations and characteristic scour behaviour during flooding and is calibrated against historical flood events.

P.7 involves taking into consideration forecast ocean conditions in flood predictions. The NSW Nearshore Wave Tool is also available to provide wave height forecasts (based on AUSWAVE) into nearshore locations (10m water depth) fronting the entrance. Tidal and ocean anomaly forecast services are also available to inform of ocean tailwater conditions.

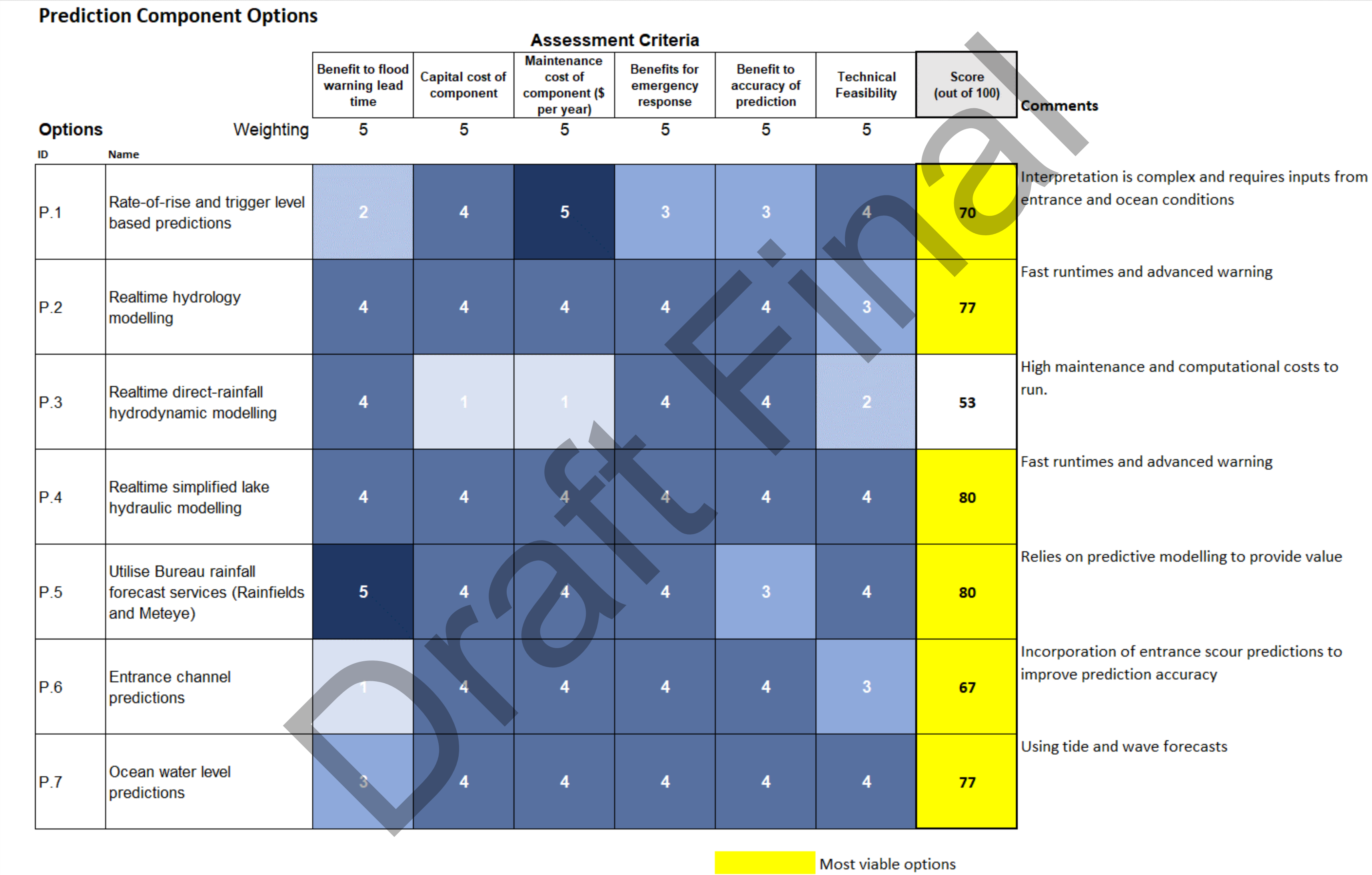
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.6. The provision of predictive capabilities to the design of a TFWS at Lake Conjola is estimated to extend flood warning lead time by 6-12 hours or more.

Prediction component options range in differing degrees of complexity, setup effort and cost. Realtime two-dimensional direct-rainfall hydrodynamic modelling (P.3) was deemed not a viable design options given its high setup effort, cost and longer model run times. All other options (including combinations of) are considered viable including incorporation of latest forecast information services from the Bureau to improve flood predictions.

Given the dynamic nature of the entrance and ocean conditions, it is considered important that flood warning design incorporate recent entrance observations, entrance scour behaviour, ocean condition monitoring data (waves and tides), and forecast ocean conditions to improve accuracy of flood level predictions.

Table 3.6: Lake Conjola - Prediction Component Options MCA Results



Prediction Component Options

Options ID	Name	Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
	Weighting	5	5	5	5	5	5		
P.1	Rate-of-rise and trigger level based predictions	2	4	5	3	3	4	70	Interpretation is complex and requires inputs from entrance and ocean conditions
P.2	Realtime hydrology modelling	4	4	4	4	4	3	77	Fast runtimes and advanced warning
P.3	Realtime direct-rainfall hydrodynamic modelling	4	1	1	4	4	2	53	High maintenance and computational costs to run.
P.4	Realtime simplified lake hydraulic modelling	4	4	4	4	4	4	80	Fast runtimes and advanced warning
P.5	Utilise Bureau rainfall forecast services (Rainfields and Meteye)	5	4	4	4	3	4	80	Relies on predictive modelling to provide value
P.6	Entrance channel predictions	1	4	4	4	4	3	67	Incorporation of entrance scour predictions to improve prediction accuracy
P.7	Ocean water level predictions	3	4	4	4	4	4	77	Using tide and wave forecasts

Assessment Criteria

🟨 Most viable options

3.3.1.3 Interpretation

Effective flood interpretation is required to translate flood predictions to an understanding of who is at risk from flooding and what the appropriate response should be. Currently the NSW SES take rainfall and weather forecast services the Bureau and utilise flood information gained from flood studies and historical observed data to determine the most effective response based on the information at hand.

Table 3.7 summarises interpretation component options for TFWS design at Lake Conjola. A TFWS may include one or a combination of those listed.

Interpretation of flood prediction information can be undertaken through known inundation impacts at defined trigger levels (I.1) based on historical flood impacts and technical studies. When a predicted flood level is available, information is readily at hand to interpret that likely inundation impacts associated with that level and determine an appropriate emergency response.

To assist proactive emergency response during hazardous flood events, a detailed flood evacuation plan (I.2) could be formulated by Council and SES in collaboration with the Lake Conjola community. This could consist of meetings or workshops where residents were guided through the creation of their own flood evacuation plan, including where to go, what route to take, what to do with belongings and pets, etc. Workshops of this nature would also help to improve local awareness of flood risk and could be integrated into a yearly review cycle. Following the completion of this project and potential implementation of a TFWS, the SES will identify the most appropriate emergency management flood response arrangements for the Lake Conjola catchment.

Web-based platforms (I.3) can also be developed to provide customised interpretation of flood predictions and realtime information in a central location to support the decision-making needs of Council, SES and community during flood emergencies. Tailored emergency management decision support from flood predictions can include information such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined (“what-if”) scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall Intensity-Frequency-Duration analysis etc.

MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.8 Interpretation options were assessed to be all viable and a flood warning system design could include a combination of the approaches listed. Information delivered from a flood warning system is to be tailored to the decision-making needs of different end-users (e.g., Council, SES and community) and best allow for ease of interpretation. Some users may require more detailed level of information whereas others may require more prescriptive information. Integration of message interpretation into an emergency response plan for each catchment is important.

Table 3.7: Lake Conjola - Summary of interpretation options

Component Option	Option Name	Summary
Existing base case		• NSW SES use the outcomes from completed flood investigations, additional resources and local knowledge to determine likely impacts of flooding.
I.1	Trigger levels for known flood impacts	• Interpretation through known inundation impacts at defined trigger levels based on historical flood information and technical studies.
I.2	Detailed flood evacuation plan	• Use available flood data to provide community with property-specific flood evacuation plans; • Disseminate to the community.
I.3	Web based platforms to provide tailored decision support from flood predictions	• Utilise live web-based platforms to provide tailored decision support using realtime model outputs and flood predictions. This may include different level of information and flood intelligence tools customised to the need of different user groups (i.e., Community or Council/SES). • Tailored emergency management decision support from flood predictions can include information such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall Intensity-Frequency-Duration analysis etc.

Table 3.8: Lake Conjola – Interpretation Component Options MCA Results

Interpretation Component Options

		Assessment Criteria							
		Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
Options	Weighting		5	5	5		5		
ID	**Name**								
I.1	Trigger levels for known flood impacts	**n/a**	4	4	4	**n/a**	3	**75**	Interpretation through known inundation impacts at defined trigger levels
I.2	Detailed flood evacuation plan	**n/a**	2	3	5	**n/a**	4	**70**	Interpretation through documented flood behaviour in detailed flood evacuation plan
I.3	Web based system to provide tailored decision support	**n/a**	3	2	5	**n/a**	4	**70**	Interpretation through various web-based decision support tools

🟨 Most viable options

3.3.1.4 Message construction

The content of any warning message is highly dependent on the intended recipients of the messaging as well as the means through which the message is communicated. For this reason, NSW SES in conjunction with Council and the community will develop pre-defined warning messages which are appropriate and useful for those at risk. This process will take place during the subsequent stage of the flood warning system detailed development and, therefore, no explicit options will be presented for this component in this report.

Message construction formats will be consistent with the Australian Warning System, Australian Institute for Disaster Resilience (2021) as outlined in Section 3.6.

3.3.1.5 Communication

The NSW SES are the agency responsible for communicating flood warning messaging to the community. Currently the SES use pre-defined channels to communicate flood warning information including EA phone calls, radio and television alerts, door knocking (where possible) and postings on their website, social media and Hazards Near me phone app.

A summary of communication options for a TFWS at Lake Conjola is shown in Table 3.9. A TFWS should automatically alert SES with timely flood prediction information for the SES to then effectively communicate to the community the imminent flood-risk and appropriate course of action. Alerting can also be sent to delegated Council representatives. An integrated system with automatic alerting can be direct from gauge trigger levels (C.1) or direct from predictive flood modelling when a certain water level threshold is predicted to exceed (C.2). The latter provides additional warning time compared to the gauge trigger level approach.

As a further step, automated alerting can by directly tied into SES procedures for constructing flood warning messaging and disseminating to the community (C.3). This approach would aim to help streamline SES procedures with automated real-time flood prediction information based on the latest alerts.

Another communication option to provide an additional avenue of support is to engage a third party to monitor data in the area and manually send alerts if a trigger level is exceeded (C.4). Trigger levels and associated messages would need to be pre-defined and a list of message recipients developed for each trigger. Some of these services offer 24-hour support and can send alerts in a range of formats including SMS messages, emails and phone calls through an electronic dialler. Any such service would not, necessarily, provide any additional warning time, but could be used as another mechanism to alert residents to potential flooding via SMS messages.

For all options, the TFWS is to utilise a variety of mechanisms to communicate flood warning messaging are to be adopted to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages). These may include SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.

Importantly, communication formats for flood warning are to be clear, concise and consistent with the Australian Warning System format (See Section 3.6).

Table 3.9: Lake Conjola - Summary of communication options

Component Option	Option Name	Summary
Existing base case		• NSW SES use pre-defined channels of communication including EA phone calls, radio and television alerts, doorknocking (where possible) and postings on their website, social media and Hazards Near Me app.
C.1	Integrated alerting system based on gauge trigger levels to Council & SES	• Direct SMS (or email) alerting to Council and SES from monitoring infrastructure indicating current conditions; • SES is the agency responsible for disseminating flood warning messaging to community. • Requires trigger levels P.1.
C.2	Integrated alerting system based on predictive flood modelling to Council & SES	• Direct SMS (or email) alerting to Council and SES from realtime predictive flood modelling indicating potential flooding based on latest forecast information. • SES is the agency responsible for disseminating flood warning messaging to community. • Requires predictive flood model.
C.3	Tie automated alerting into procedures for warning messaging for SES to disseminate to community.	• Integrated automated alerting into SES procedures for issuing flood warning messaging to community; • SES is the agency responsible for disseminating flood warning messaging to community.
C.4	Third party to issue warning messaging to individual community members, Council & SES	• Engage 24-hr monitoring service to initiate warning communications; • SMS/email/phone calls available; • Third party responsible for disseminating flood warning messaging to community • Requires trigger levels P.1.
C.5	Flood warning message dissemination via a range of mechanisms	• To be undertaken for all options. • Mechanisms for dissemination such as SMS, radio, door knocking, phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app. • Allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages).

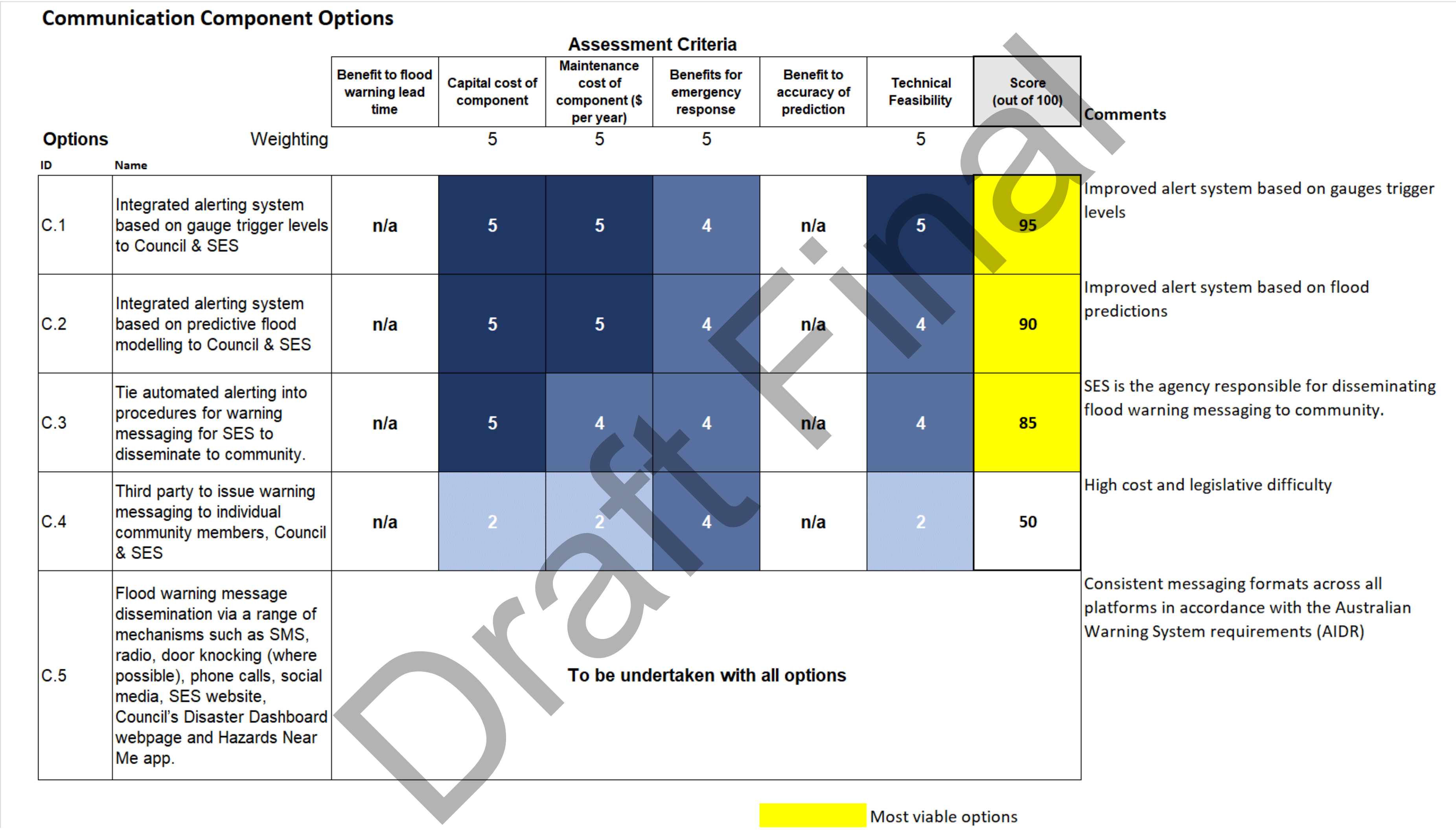
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.26.

All communications options were assessed to be viable except for third party issuing of warning messaging to community (C.4). C.4 was deemed not viable due to high costs associated with implementation and maintenance as well as conflicts with legislation requiring SES to be the responsible authority for issuing flood warning messages to the community. The *National Arrangements for Flood Forecasting and Warning* (BoM, 2018) require local warning dissemination to be undertaken in accordance with jurisdictional emergency management arrangement, namely the roles and responsibilities outlined in *NSW State Flood Plan* (SES, 2021) and *Shoalhaven City Flood Emergency Sub Plan* (SES, 2022).

Flood warning communication is to be issued by the SES through a range of avenues such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app. SES procedures are to be informed by realtime flood information alerts from gauges and/or predictive models. Consistent messaging formats is to be adopted across all communications platforms in accordance with consistent with the Australian Warning System requirements (AIDR).

Table 3.10: Lake Conjola – Communication Component Options MCA Results



Communication Component Options

		Assessment Criteria							
Options		**Benefit to flood warning lead time**	**Capital cost of component**	**Maintenance cost of component ($ per year)**	**Benefits for emergency response**	**Benefit to accuracy of prediction**	**Technical Feasibility**	**Score (out of 100)**	**Comments**
	Weighting		5	5	5		5		
ID	**Name**								
C.1	Integrated alerting system based on gauge trigger levels to Council & SES	**n/a**	5	5	4	**n/a**	5	**95**	Improved alert system based on gauges trigger levels
C.2	Integrated alerting system based on predictive flood modelling to Council & SES	**n/a**	5	5	4	**n/a**	4	**90**	Improved alert system based on flood predictions
C.3	Tie automated alerting into procedures for warning messaging for SES to disseminate to community.	**n/a**	5	4	4	**n/a**	4	**85**	SES is the agency responsible for disseminating flood warning messaging to community.
C.4	Third party to issue warning messaging to individual community members, Council & SES	**n/a**	2	2	4	**n/a**	2	**50**	High cost and legislative difficulty
C.5	Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	**To be undertaken with all options**							Consistent messaging formats across all platforms in accordance with the Australian Warning System requirements (AIDR)

🟨 Most viable options

3.3.1.6 Protective behaviour

The current flood emergency response relies heavily upon ad-hoc protection by the respective communities with limited warning time and is not a serious consideration for protective behaviour. SES driven response is noted to be constrained by limited warning time and resources available during flood emergencies. The FRMS&Ps in all three catchments recommend a more collaborative approach between the NSW SES and community residents.

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for the catchment.

3.3.1.7 Review

The review stage of the TFWS is vital for maintaining long-term maintenance and efficacy of the system. Since extreme flooding happens only rarely and is unpredictable, it is important to maintain awareness of the TFWS to ensure that the system runs as intended despite the potential years between events. The review process, like the message construction, will be highly dependent on the type of flood warning system which is developed and will therefore need to be developed alongside it. As such, no explicit review options will be presented in this report. Whatever the flood warning system developed, however, it will be important to have the community involved in the ongoing maintenance and review process. Toward this goal it is proposed that an annual community event is organised around the flood warning system to incentivise members of the community to be involved and act as a regular refresher about what to do in case of a flooding emergency. It is envisaged that this event could be delivered by the Council and NSW SES in partnership.

3.3.2 Preliminary TFWS Options

Preliminary flood warning system options have been developed for the Lake Conjola catchment based on outcomes of the component design options assessment (Section 3.3.1). This section provides an outline of each option, summary of advantages and disadvantages, preliminary cost estimates and a summary of community/stakeholder engagement outcomes (including public exhibition).

3.3.2.1 Option 1: Predictive flood warning and decision support (utilising present gauge network)

This option consists of flood warning system design based on realtime predictive flood modelling and decision support and utilising the present gauge network as outlined in Table 3.11.

This option involves no new rainfall or water level gauge installations other than planned rainfall gauges identified in Table 3.2. Rain and water level data from the existing gauge network, with entrance condition information from the latest Council surveys and Lake Conjola M2 tidal analysis, and ocean tide and wave data are to be integrated into a predictive flood warning system.

The predictive flood warning system is to be composed of a realtime catchment hydrology model and a realtime simplified lake hydraulic model with entrance channel prediction to estimate a predicted flood level timeseries in the lake. Inputs to the realtime models will include latest rainfall forecast services from the Bureau (Meteye and Rainfields), latest entrance configuration information and forecast ocean wave and tide conditions.

Interpretation of flood predictions will utilise known inundation impacts for pre-defined trigger levels, detailed flood evacuation plan and a customised web portal accessed by SES and Council to support flood emergency management decision making. A web-based platform will be used to provide tailored decision support from flood predictions such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined (“what-if”) scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall IFD analysis etc.

Communication of flood warning messaging to the community is to be undertaken by the SES. The TFWS will support the communication process by providing delegated SES and Council representatives with automated alerting direct from rainfall and water level instruments as well as flood model predictions. An integrated alerting system would be built into SES procedures to support communication mechanisms of flood emergency information.

For all options, the TFWS is to utilise a variety of mechanisms to communicate flood warning messaging are to be adopted to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages). These may include SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council’s Disaster Dashboard webpage and Hazards Near Me app.

Importantly, communication formats for flood warning are to be clear, concise and consistent with the Australian Warning System format (See Section 3.6).

3.3.2.2 Option 2: Predictive flood warning and decision support with priority 1 gauge installation works

Option 2 consists of the same components as Option 1 with the additional installation of a water level station (Priority 1) at Conjola Creek, Princes Hwy as outlined in Table 3.11. This additional gauge is to provide improved water level monitoring upstream of the estuary tidal limit and help to provide early indication of high lake inflows.

Also included in Option 2 is a secondary redundancy flood prediction mechanism (in case of realtime flood model failure) utilising rate-of-rise information and trigger levels for different entrance and ocean conditions.

3.3.2.3 Option 3: Predictive flood warning and decision support with priority 2 gauge installation works

Option 3 consists of the same components as Options 1 and 2 with the addition of a rainfall station at Conjola Creek Princes Hwy (Priority 2) and a remote entrance berm monitoring station at Lake Conjola entrance (Priority 2), as outlined in Table 3.11. This additional rainfall is to provide improved rain gauge coverage in the Conjola Creek catchment and redundancy in case of failure of the nearby Fishermans rain gauge. Remote entrance berm monitoring at the entrance is to utilise innovative technologies to provide realtime entrance channel and berm information to support flood warning predictions. Entrance berm monitoring would be undertaken on an automated program via remote operation. This provides an alternative to undertaking an entrance survey in-person that can be constrained by suitable weather conditions, limited pre-flood timing, safety considerations and Council staff availability.

Advantages and disadvantages of each of the above options are listed in Table 3.12.

Table 3.11: Lake Conjola - Flood warning system preliminary options

Flood warning system options	Monitoring	Prediction	Interpretation	Message construction	Communication	Protective behaviour
Option 1 - Predictive flood warning and decision support (utilising present gauge network)	Maintain operation of existing rain and water level gauge network with the following: • M.3 Integrate entrance channel data from latest Council surveys and Lake Conjola M2 tidal analysis; • M.5 Integrate ocean wave and tide data.	Realtime flood level predictions using: • P.2 Realtime; hydrology modelling • P.4 Realtime simplified lake hydraulic modelling; • P.5 Utilise Bureau rainfall forecast services (Rainfields and Meteye); • P.6 Entrance channel predictions; • P.7 Ocean water level predictions.	• I.1 Trigger levels for known flood impacts; • I.2 Detailed flood evacuation plan; • I.3 Web based system to provide tailored decision support.	*To be determined during next phase of detailed flood warning system design*	• C.1 Integrated alerting system based on gauge trigger levels to Council & SES; • C.2 Integrated alerting system based on predictive flood modelling to Council & SES; • C.3 Tie automated alerting into procedures for warning messaging for SES to disseminate to community; • C.5 Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	*Emergency Management Flood Response Arrangements to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS.*
Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	As per Option 1 with addition of: • M.1 Additional automatic water level station upstream at Conjola Creek Princes Hwy	As per Option 1 with addition of: • P.1 Rate-of-rise and trigger level based predictions (as backup prediction mechanism)	As per Option 1		As per Option 1	
Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works	As per Option 1 & 2 with addition of: • M.2 Additional automatic rainfall station upstream at Conjola Creek Princes Hwy • M.4 Installation of remote entrance berm monitoring station at Lake Conjola Entrance.	As per Option 1 & 2.	As per Option 1		As per Option 1	

Table 3.12: Lake Conjola - Advantages and disadvantages of options

Flood warning system options	Advantages	Disadvantages
Option 1 - Predictive flood warning and decision support (utilising present gauge network)	• Improved potential lead time (6-12+ hours) to provide earlier warning and better inform Council, SES and community of potential flooding; • Range of potential flood prediction outputs to inform emergency decision-making such as predicted lake level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, etc; • Utilises best available forecast services from Bureau of Meteorology; • Utilises available technology and computer models with fast runtimes; • Inclusion of representative entrance behaviour and ocean conditions to improve flood prediction; • Potential benefits to help inform pre-flood entrance management procedures; • Supports a proactive pre-flood emergency response for Council, SES and Community; • Lower cost option.	• Prediction accuracy subject to rainfall forecast accuracy limitations (including spatial and temporal uncertainty), model assumptions and limitations; • Successful communication and implementation of protective behaviour dependant on strong and effective collaboration between SES, Community and Council.
Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	As per Option 1 with addition of: • Improved warning of upstream water level rises at Conjola Creek beyond the tidal estuary limit to provide better indication of lake inflows • Prediction redundancy utilising rate-of-rise and trigger level based predictions;	As per Option 1 with addition of: • Limited warning improvement (particularly for flash flooding) associated with new water level gauge at Conjola Creek • Additional expense to install and maintain new gauge. • Predictions based on rate of rise information and trigger levels are subject to inaccuracies and may not represent prevailing entrance and ocean conditions.
Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works	As per Option 1 & 2 with addition of: • Improved rain gauge coverage and redundancy in the Conjola Creek catchment. • Utilises new technologies to provide innovative realtime entrance berm condition monitoring. • Entrance berm condition monitoring can be undertaken readily and remotely and is not limited by weather conditions, timing constraints or Council staff availability. • Likely benefits to pre-flood entrance management procedures and environmental monitoring.	As per Option 1 & 2 with addition of: • Higher capital and maintenance costs with additional new rainfall gauge and remote entrance berm monitoring station. • Potential site location limitations and constraints associated with installation of a remote entrance monitoring station.

3.3.1 Preliminary cost estimates

Preliminary cost estimates for the TFWS options at Lake Conjola are shown in Table 3.13. Cost estimates are preliminary and may vary depending on site constraints for gauge locations and client requirements. Costs include installation of the planned rainfall gauge at George Boyd Lookout Area.

Table 3.13: Lake Conjola - Preliminary cost estimates associated with TFWS options

Catchment	Option 1 - Predictive flood warning and decision support (utilising present gauge network)	Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works
Lake Conjola	$50,000 - 60,000	$90,000 - 120,000	$120,000 - 160,000

***** Costs do not include potential upgrades to existing gauge network to improved flood warning reliability and redundancy, SES fees associated with dissemination of flood warning information, development of detailed flood evacuation and emergency response plans, establishment of Emergency Management Flood Response Arrangements, establishment awareness and training of SES and community.

Maintenance costs for a predictive flood warning system typically range from $5,000 - $15,000 per year. Typical maintenance costs for a rainfall or water level station range from $3,000 - $10,000 per station per year. Flood warning networks with numerous gauges can have high annual maintenance costs to maintain.

3.3.2 Community and stakeholder engagement

This section will be completed following Public Exhibition and Stakeholder feedback of this draft report with the Lake Conjola community.

3.4 Burrill Lake TWFS

3.4.1 Component Options

3.4.1.1 Monitoring

Current monitoring at Burrill Lake is undertaken via existing rainfall and water level gauges detailed in Table 3.14 and Figure 3.4. All listed rainfall and water level stations are automatic with data telemetered at Council owned gauges via Event-reporting Radio Telemetry System (ERTS) and mobile network at DPE BCD owned gauges. Also listed in Table 3.14 are existing and planned rainfall gauges in regional areas surrounding the catchment as well as an ocean tide (Ulladulla Harbour) and wave monitoring station (Batemans Bay) situated within the region.

Table 3.15 summarises different monitoring design options for development of a flood warning system at Burrill Lake. A TFWS may include one or a combination of those listed. Options for potential installation of new water level and rainfall gauges are: a water level at Stony Creek (Woodstock Rd) situated upstream beyond the tidal limit of the estuary to provide better indication of lake inflows; a rain gauge at Stony Creek (Woodstock Rd) to improve rain gauge coverage in the Stony Creek catchment; and or a rain gauge at Woodstock Creek to improve rain gauge coverage in the upper Woodstock Creek catchment.

Site specifications for installation and maintenance of additional gauging is to be undertaken during detailed design of the flood warning system (Stage 4). Review of additional gauging requirements will also be undertaken during detailed design of a preferred flood warning system (Stage 4).

Another potential monitoring component of flood warning system design for the Burrill Lake catchment is the ability to incorporate entrance channel configuration and ocean conditions into flood level estimates. Entrance berm surveys are currently undertaken by Council at Burrill Lake via:

- Monthly entrance berm surveys when the channel is closed to the ocean
- Entrance berm survey within the week prior to a potential flood event where possible
- Entrance monitoring (daylight hours)

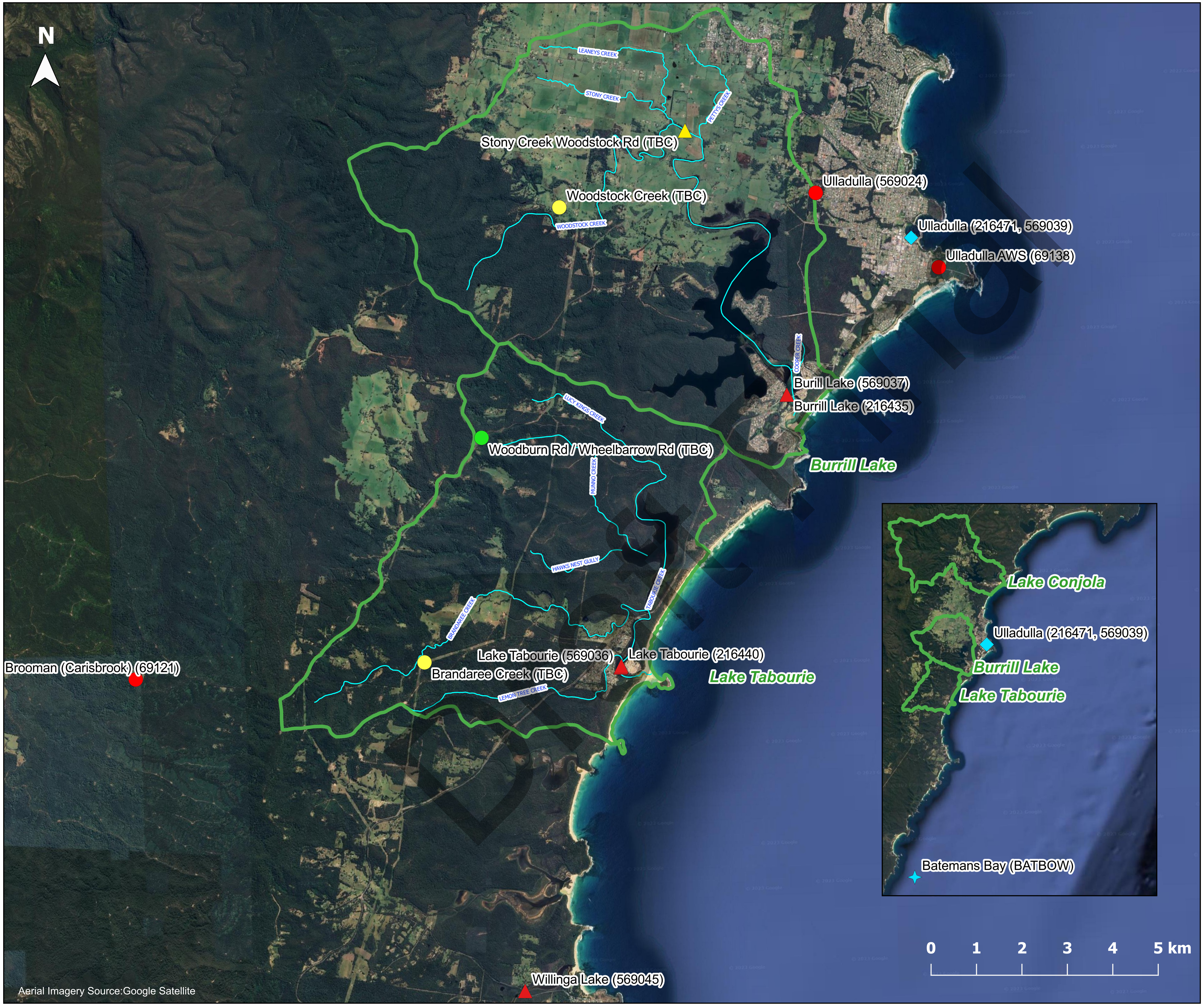
Also included in the monitoring component options is the potential installation of a remotely operated and automatic entrance monitoring station to provide live entrance berm and channel opening conditions to support flood prediction.

Many Hydraulics Laboratory also maintains an automatic ocean tide gauge in Ulladulla Harbour and a wave buoy (wave height, direction and period) offshore of Batemans Bay. Flood warning system design is recommended to incorporate entrance configuration estimates and ocean conditions from such information sources to help improve flood level estimation and warning accuracy.

Table 3.14: Burrill Lake and surrounds - existing rainfall and water level gauges

Catchment (including surrounds)	Station	Station No.		Type		Ownership	Maintenance	Comms	Alerting	Live Data Available
		AWRC	BoM	Level	Rain					
Burrill Lake	Burrill Lake	216435	-	✓	✓	DPE BCD	MHL	Mobile 3G/4G (IP)	No	https://www.mhl.nsw.gov.au/Station-216435
	Burrill Lake	-	569037	✓	✓	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html http://www.bom.gov.au/fwo/IDN60234/IDN60234.569037.plt.shtml
	Ulladulla	-	569024	-	✓	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	Ulladulla AWS	-	69138	-	✓ *	BoM	BoM	ERTS	No	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	Woodburn Rd / Wheelbarrow Rd	-	-	-	✓ *	Planned future Council rain gauge installation				
Ocean Conditions	Ulladulla	216471	569039	Ocean Tide *		DPE BCD	MHL	Mobile 3G/4G (IP)	No	https://www.mhl.nsw.gov.au/Station-216471
	Batemans Bay	BATBOW		Ocean Wave *		DPE BCD	MHL	Radio	No	https://www.mhl.nsw.gov.au/Station-BATBOW

* Station located outside of catchment area but useful for regional rainfall monitoring or ocean conditions



Aerial Imagery Source:Google Satellite

Figure 3.4

Burrill Lake and Tabourie Lake - Existing and Proposed Gauges

Legend

- 🟩 Catchment Boundary
- — Waterways

Gauges

- ● Existing Rain Gauge
- ■ Existing Water Level Gauge
- ▲ Existing Water Level & Rain Gauge
- ● Planned Future Rain Gauge
- ● Potential Rain Gauge
- ▲ Potential Additional Water Level & Rain Gauge
- ◆ Ocean Tide
- ✦ Ocean Wave

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Table 3.15: Burrill Lake - Summary of monitoring options

Component Option	Option Name	Summary
Existing base case		• No additional monitoring infrastructure will be installed; • Continued maintenance of existing gauges and installation of planned rain gauge at Morton (Woodburn / Wheel Barrow Rd) as per Table 3.14; • Continued maintenance of basic alerting from Council's rainfall gauges through Enviromon; • No flood warning integration of entrance and ocean condition information.
M.1	Additional automatic water level station upstream at Stony Creek Woodstock Rd	• Improved warning of upstream water level rises beyond the tidal estuary limit to provide better indication of lake inflows; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.2	Additional automatic rainfall station upstream at Stony Creek Woodstock Rd	• Additional rainfall gauge coverage in the Stony Creek catchment; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.3	Additional automatic rainfall station upstream at Woodstock Creek upper catchment	• Additional rainfall gauge coverage in the Woodstock Creek catchment; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.4	Integrate entrance channel data from latest Council surveys	Improved use of entrance condition information for flood prediction via: • Integration of latest entrance conditions from Council existing entrance monitoring program including entrance berm surveys at monthly intervals when closed, entrance berm surveys within the week prior to an event where possible, and entrance monitoring cameras;
M.5	Installation of remote entrance berm monitoring station at Burrill Lake Entrance	Improved monitoring of entrance conditions for flood prediction via: • Installation of a remotely operated and automatic station to monitor the condition of the entrance throat channel and entrance berm; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new station.
M.6	Integrate ocean wave and tide data	Improved understanding of ocean conditions for flood prediction via: • Integration of available ocean water level data from Ulladulla tide gauge (216471); • Integration of available ocean wave conditions from Batemans Bay Wave Buoy (BATBOW), transformed into nearshore water depths at entrance.

MCA Assessment

Results of the MCA assessment for monitoring component options are shown in Table 3.16. Installation of an additional automatic water level station upstream at Stony Creek Woodstock Rd (M.1) will likely improve warning of upstream water level rises beyond the estuary tidal limit and lake inflows. The installation of this new gauge is considered a Priority 1 installation.

Installation of an additional automatic rainfall station upstream at Stony Creek Woodstock Rd (M.2) is considered to be value to improving rainfall coverage in the Stony Creek catchment. The installation of this new gauge is also considered a Priority 1 installation.

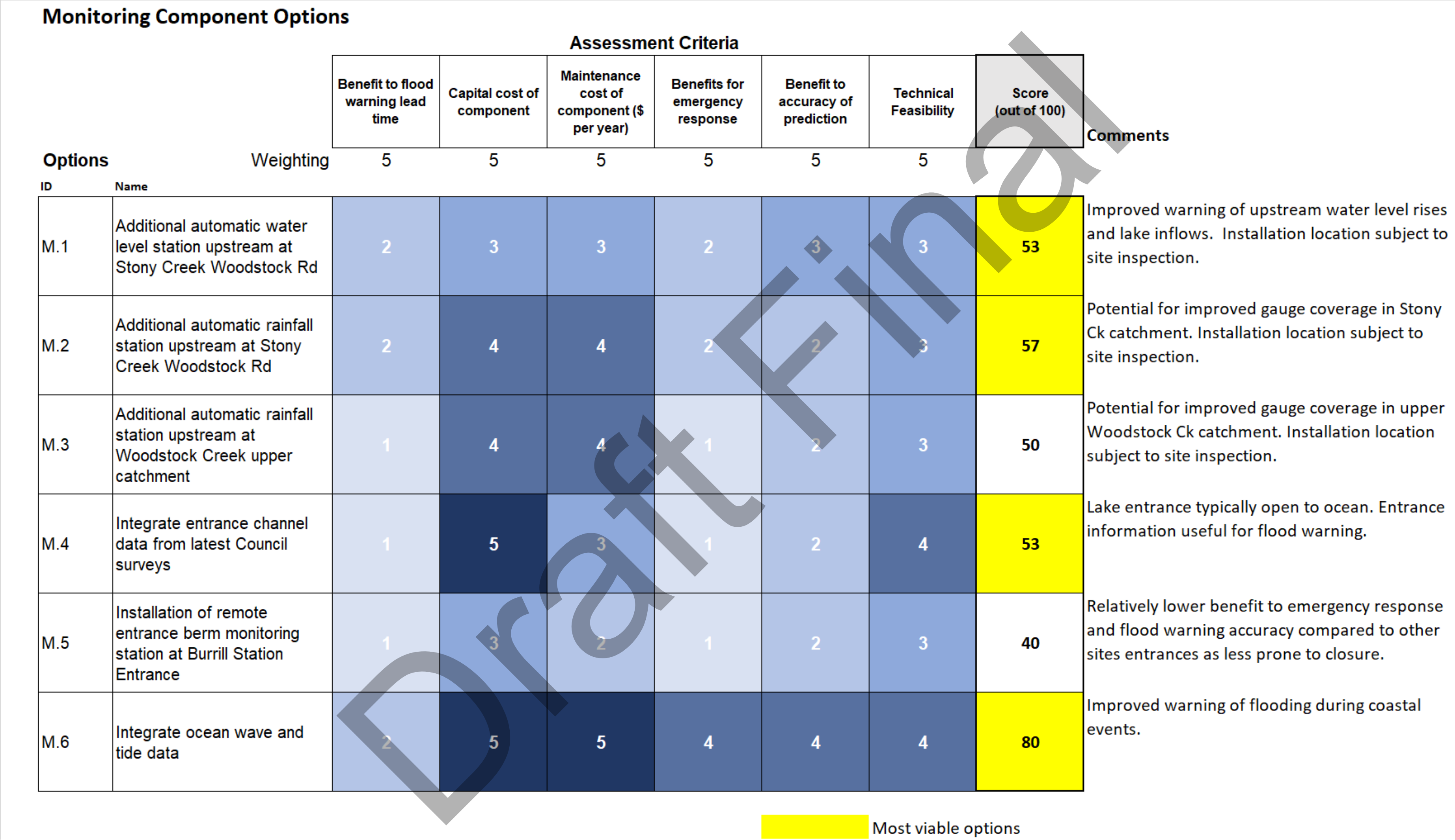
Installation of an additional automatic rainfall station upstream at Woodstock Creek (M.3) is of slightly lower priority given the generally sufficient coverage of rainfall gauges in the region under the existing case (listed in Table 3.15). The installation of this new gauge is considered a Priority 2 installation.

Provision of entrance channel information for flood warning is considered best achieved through integration of entrance data from latest Council surveys (M.4). Given the entrance is generally open to the ocean, flood predictions are likely to be less sensitive to entrance conditions in comparison to prevailing ocean conditions at this location. Remote entrance berm monitoring (M.5) is not recommended at this location given the low frequency of entrance closure.

Integration of ocean wave and tide data (M.6) was scored the highest of all component options. This also make best use of available information providing realtime ocean conditions to support flood prediction accuracy at Burrill Lake.

The results indicate that a combination of monitoring options is likely viable for design of a TFWS at Burrill Lake, incorporating entrance configuration estimates with available ocean monitoring data and options for improved water level and rain gauge coverage.

Table 3.16: Burrill Lake - Monitoring Component Options MCA Results



Monitoring Component Options

Assessment Criteria

ID	Name	Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
Options	Weighting	5	5	5	5	5	5		
M.1	Additional automatic water level station upstream at Stony Creek Woodstock Rd	2	3	3	2	3	3	53	Improved warning of upstream water level rises and lake inflows. Installation location subject to site inspection.
M.2	Additional automatic rainfall station upstream at Stony Creek Woodstock Rd	2	4	4	2	2	3	57	Potential for improved gauge coverage in Stony Ck catchment. Installation location subject to site inspection.
M.3	Additional automatic rainfall station upstream at Woodstock Creek upper catchment	1	4	4	1	2	3	50	Potential for improved gauge coverage in upper Woodstock Ck catchment. Installation location subject to site inspection.
M.4	Integrate entrance channel data from latest Council surveys	1	5	3	1	2	4	53	Lake entrance typically open to ocean. Entrance information useful for flood warning.
M.5	Installation of remote entrance berm monitoring station at Burrill Station Entrance	1	3	2	1	2	3	40	Relatively lower benefit to emergency response and flood warning accuracy compared to other sites entrances as less prone to closure.
M.6	Integrate ocean wave and tide data	2	5	5	4	4	4	80	Improved warning of flooding during coastal events.

🟨 Most viable options

3.4.1.2 Prediction

Currently there is no formalised procedure or mechanism to provide realtime flood level predictions during a flood event for Burrill Lake. Current methods are described in Section 2.1 and rely upon realtime gauge information, Bureau weather warning services and limited rate-of-rise information where available from technical studies.

Potential options to improve flood prediction are listed in Table 3.17. These include flood predictions based on (including combinations of) rate-of-rise analysis and gauge trigger levels (informal prediction), realtime hydrology modelling, realtime hydrodynamic modelling, realtime simplified lake hydraulic modelling, incorporation of Bureau rain forecast products (MetEye, Rainfields), entrance channel scour predictions and ocean water level predictions. A TFWS may include one or a combination of those listed.

Prediction options have differing levels of complexities, accuracy and effort associated with each approach. Realtime flood models differ in calibration complexity, model setup, computing power and runtime requirements. Realtime hydrology models (P.2) take observed and predicted rainfall and converting it an inflow into the lake storage system. Outputs from a hydrology model can be readily applied in a realtime simplified lake hydraulic model (P.4) to provide lake level predictions based on lake and floodplain bathymetry, and entrance configuration. These models may be run very quickly (in the order of seconds) and are able to, generally, provide a good level of accuracy of downstream prediction as compared to trigger level predictions (P.1) when combined with sufficient entrance channel and ocean representation (P.6 and P.7). Hydrology models require realtime data to provide the best results, need to run automatically in a dedicated computing environment which in some cases can be complicated and expensive to operate, and often require experienced personnel to interpret the results they provide. Catchment pre-conditions are another factor which is difficult to account for in a realtime hydrological model and could have impact on the prediction accuracy.

At the most complex and expensive end of the prediction options is the running of a realtime 2D direct-rainfall hydrodynamic model (P.3). These models are the same type as those used to perform flood studies and floodplain risk management plans, however they need to be configured to run in a flood forecasting capacity. These forecasting systems are just starting to become available in NSW and can require large amounts of computational power, are costly to setup and maintain, and can take hours to run. It is unlikely that given the short lead-time for flooding in the respective catchments and the available resources of Council that this option will be viable, however it has been included for completeness.

In order to drive predictions, the Bureau have provided a number of forecast products for consideration in this report. P.5 consists of utilising the Bureau’s MetEye forecast products which, for the purposes of flood forecasting, provides a number of gridded (6km) probabilistic rainfall forecasts (10%, 25% and 50% chance of exceedance) at 3-hour intervals. This gridded data can be used to drive predictions from any of the other prediction options to estimate the likely flooding up to 7-days in the future. The MetEye forecast services are based on regional climate models with limited spatial and temporal resolution. P.5 also includes use of the Bureau’s new Rainfields rainfall forecast which is based on rain radar nowcasting. This provides much better resolution both across space (100’s of metres to kilometres) and time (6-minute time interval) and is designed to improve short-term rain predictions for thunderstorm-scale flood forecasting.

Table 3.17: Burrill Lake - Summary of prediction options

Component Option	Option Name	Summary
Existing base case		• As per existing flood warning arrangement utilising as outlined in Section 2.1.2.6; • Relies heavily upon manual interpretation of realtime gauge data, BoM weather warning services and knowledge of flood behaviour; • No formalised procedure or mechanism to provide realtime flood level predictions during a flood event.
P.1	Rate-of-rise and trigger level based predictions	• Flooding predictions are estimated using recorded rainfall, water level trigger levels and rate-of-rise information from flood modelling analysis; • Simplistic and preliminary technique to flood prediction with limited accuracy.
P.2	Realtime hydrology modelling	• Flooding predictions are based on realtime hydrology modelling of observed and predicted rainfall; • Simple model to setup and run.
P.3	Realtime direct-rainfall hydrodynamic modelling	• Flooding predictions are based on realtime direct-rainfall hydrodynamic model of observed and predicted rainfall; • Complex model to setup and run.
P.4	Realtime simplified lake hydraulic modelling	• Flooding predictions are based on simplified lake hydraulic modelling incorporating inflows from hydrology modelling (P.2), lake bathymetry and entrance representation.; • Simple model to setup and run.
P.5	Utilise Bureau rainfall forecast services (Rainfields and Meteye)	• Use BoM rain radar predictive model (Rainfields) to inform short-term (e.g., Thunderstorms) predictions • Use BoM Australian Digital Forecasting Database (ADFD; MetEye) to inform predictions
P.6	Entrance channel predictions	• Improvement of flood predictions via integration of a predictive entrance model that incorporates latest entrance observations and predictive entrance breakout/scour during flooding. • Based on knowledge of entrance scour behaviour.
P.7	Ocean water level predictions	• Integration of forecast ocean conditions at the entrance to improve flood level predictions. Forecast services include the NSW Nearshore Wave Tool (utilising AUSWAVE), astronomical tide and ocean anomaly forecasts.

Representation of the entrance channel (including scour induced by flooding) and forecasted ocean conditions at the entrance (waves, tides, anomalies, etc) throughout an imminent flood event is also an important component of accurate flood level prediction. Realtime entrance prediction (P.6) considers latest entrance observations and characteristic scour behaviour during flooding and is calibrated against historical flood events.

P.7 involves taking into consideration forecast ocean conditions in flood predictions. The NSW Nearshore Wave Tool is also available to provide wave height forecasts (based on AUSWAVE) into nearshore locations (10m water depth) fronting the entrance. Tidal and ocean anomaly forecast services are also available to inform of ocean tailwater conditions.

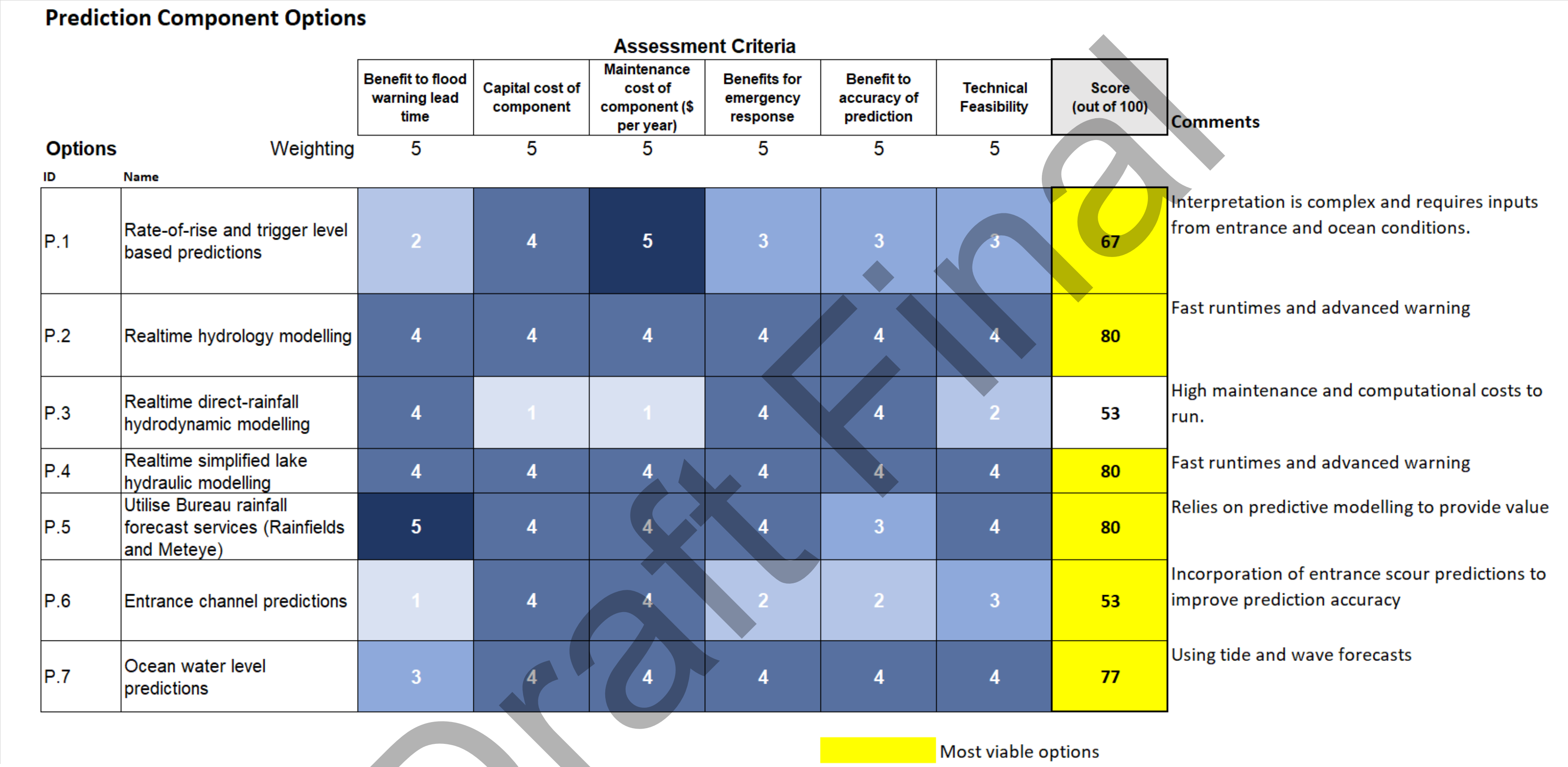
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.18. The provision of predictive capabilities to the design of a TFWS at Burrill Lake is estimated to extend flood warning lead time by 6-12 hours or more.

Prediction component options range in differing degrees of complexity, setup effort and cost. Realtime two-dimensional direct-rainfall hydrodynamic modelling (P.3) was deemed not a viable design options given its high setup effort, cost and longer model run times. All other options (including combinations of) are considered viable including incorporation of latest forecast information services from the Bureau to improve flood predictions.

It is considered important that flood warning design incorporate representative entrance conditions, ocean condition monitoring data (waves and tides), and forecast ocean conditions to improve accuracy of flood level predictions.

Table 3.18: Burrill Lake - Prediction Component Options MCA Results



Prediction Component Options

Options		Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
	Weighting	5	5	5	5	5	5		
ID	Name								
P.1	Rate-of-rise and trigger level based predictions	2	4	5	3	3	3	67	Interpretation is complex and requires inputs from entrance and ocean conditions.
P.2	Realtime hydrology modelling	4	4	4	4	4	4	80	Fast runtimes and advanced warning
P.3	Realtime direct-rainfall hydrodynamic modelling	4	1	1	4	4	2	53	High maintenance and computational costs to run.
P.4	Realtime simplified lake hydraulic modelling	4	4	4	4	4	4	80	Fast runtimes and advanced warning
P.5	Utilise Bureau rainfall forecast services (Rainfields and Meteye)	5	4	4	4	3	4	80	Relies on predictive modelling to provide value
P.6	Entrance channel predictions	1	4	4	2	2	3	53	Incorporation of entrance scour predictions to improve prediction accuracy
P.7	Ocean water level predictions	3	4	4	4	4	4	77	Using tide and wave forecasts

Assessment Criteria

🟨 Most viable options

3.4.1.3 Interpretation

Effective flood interpretation is required to translate flood predictions to an understanding of who is at risk from flooding and what the appropriate response should be. Currently the NSW SES take rainfall and weather forecast services the Bureau and utilise flood information gained from flood studies and historical observed data to determine the most effective response based on the information at hand.

Table 3.19 summarises interpretation component options for TFWS design at Burrill Lake. A TFWS may include one or a combination of those listed.

Interpretation of flood prediction information can be undertaken through known inundation impacts at defined trigger levels (I.1) based on historical flood impacts and technical studies. When a predicted flood level is available, information is readily at hand to interpret that likely inundation impacts associated with that level and determine an appropriate emergency response.

To assist proactive emergency response during hazardous flood events, a detailed flood evacuation plan (I.2) could be formulated by Council and SES in collaboration with the Burrill Lake community. This could consist of meetings or workshops where residents were guided through the creation of their own flood evacuation plan, including where to go, what route to take, what to do with belongings and pets, etc. Workshops of this nature would also help to improve local awareness of flood risk and could be integrated into a yearly review cycle. Following the completion of this project and potential implementation of a TFWS, the SES will identify the most appropriate emergency management flood response arrangements for the Burrill Lake catchment.

Web-based platforms (I.3) can also be developed to provide customised interpretation of flood predictions and realtime information in a central location to support the decision-making needs of Council, SES and community during flood emergencies. Tailored emergency management decision support from flood predictions can include information such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined (“what-if”) scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall Intensity-Frequency-Duration analysis etc.

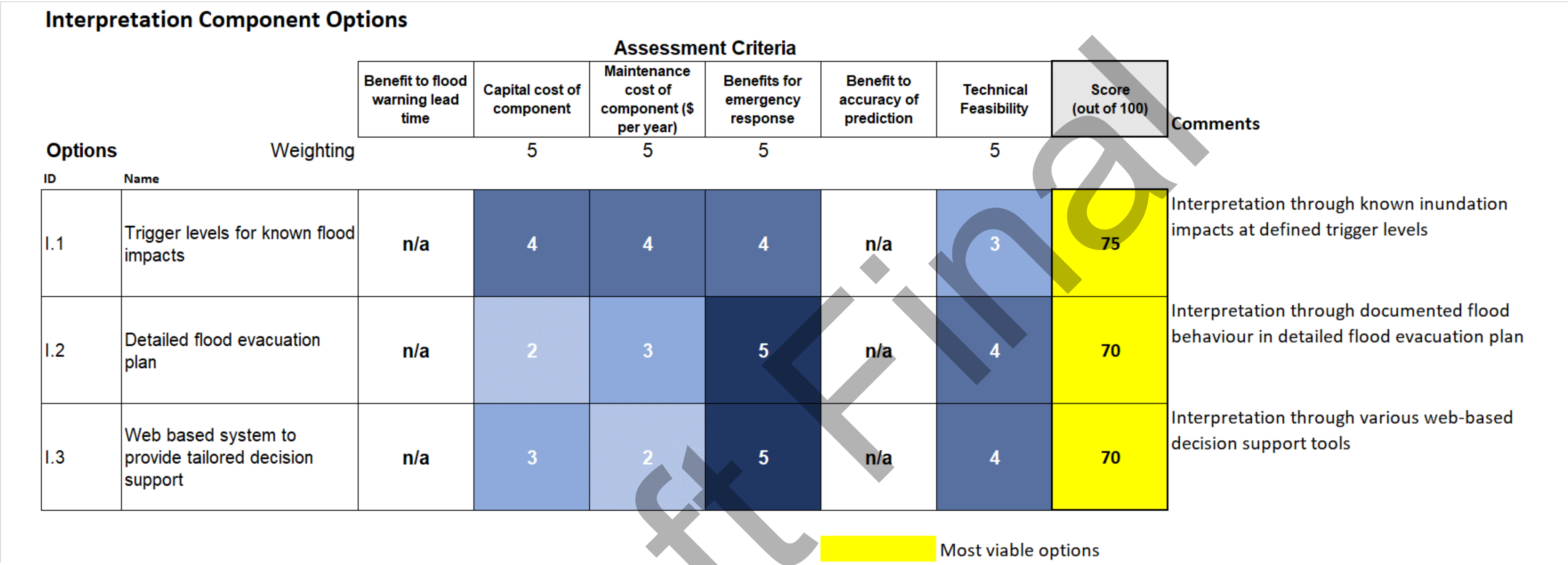
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.20. Interpretation options were assessed to be all viable and a flood warning system design could include a combination of the approaches listed. Information delivered from a flood warning system is to be tailored to the decision-making needs of different end-users (e.g., Council, SES and community) and best allow for ease of interpretation. Some users may require more detailed level of information whereas others may require more prescriptive information. Integration of message interpretation into an emergency response plan for each catchment is important.

Table 3.19: Burrill Lake - Summary of interpretation options

Component Option	Option Name	Summary
Existing base case		• NSW SES use the outcomes from completed flood investigations, additional resources and local knowledge to determine likely impacts of flooding.
I.1	Trigger levels for known flood impacts	• Interpretation through known inundation impacts at defined trigger levels based on historical flood information and technical studies.
I.2	Detailed flood evacuation plan	• Use available flood data to provide community with property-specific flood evacuation plans; • Disseminate to the community.
I.3	Web based platforms to provide tailored decision support from flood predictions	• Utilise live web-based platforms to provide tailored decision support using realtime model outputs and flood predictions. This may include different level of information and flood intelligence tools customised to the need of different user groups (i.e., Community or Council/SES). • Tailored emergency management decision support from flood predictions can include information such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall Intensity-Frequency-Duration analysis etc.

Table 3.20: Burrill Lake – Interpretation Component Options MCA Results



Interpretation Component Options

Assessment Criteria

Options ID	Name	**Benefit to flood warning lead time**	**Capital cost of component**	**Maintenance cost of component ($ per year)**	**Benefits for emergency response**	**Benefit to accuracy of prediction**	**Technical Feasibility**	**Score (out of 100)**	**Comments**
Weighting			5	5	5		5		
I.1	Trigger levels for known flood impacts	**n/a**	4	4	4	**n/a**	3	**75**	Interpretation through known inundation impacts at defined trigger levels
I.2	Detailed flood evacuation plan	**n/a**	2	3	5	**n/a**	4	**70**	Interpretation through documented flood behaviour in detailed flood evacuation plan
I.3	Web based system to provide tailored decision support	**n/a**	3	2	5	**n/a**	4	**70**	Interpretation through various web-based decision support tools

🟨 Most viable options

3.4.1.4 Message construction

The content of any warning message is highly dependent on the intended recipients of the messaging as well as the means through which the message is communicated. For this reason, NSW SES in conjunction with Council and the community will develop pre-defined warning messages which are appropriate and useful for those at risk. This process will take place during the subsequent stage of the flood warning system detailed development and, therefore, no explicit options will be presented for this component in this report.

Message construction formats will be consistent with the Australian Warning System, Australian Institute for Disaster Resilience (2021) as outlined in Section 3.6.

3.4.1.5 Communication

The NSW SES are the agency responsible for communicating flood warning messaging to the community. Currently the SES use pre-defined channels to communicate flood warning information including EA phone calls, radio and television alerts, door knocking (where possible) and postings on their website, social media and Hazards Near me phone app.

A summary of communication options for a TFWS at Burrill Lake is shown in Table 3.21. A TFWS should automatically alert SES with timely flood prediction information for the SES to then effectively communicate to the community the imminent flood-risk and appropriate course of action. Alerting can also be sent to delegated Council representatives. An integrated system with automatic alerting can be direct from gauge trigger levels (C.1) or direct from predictive flood modelling when a certain water level threshold is predicted to exceed (C.2). The latter provides additional warning time compared to the gauge trigger level approach.

As a further step, automated alerting can by directly tied into SES procedures for constructing flood warning messaging and disseminating to the community (C.3). This approach would aim to help streamline SES procedures with automated real-time flood prediction information based on the latest alerts.

Another communication option to provide an additional avenue of support is to engage a third party to monitor data in the area and manually send alerts if a trigger level is exceeded (C.4). Trigger levels and associated messages would need to be pre-defined and a list of message recipients developed for each trigger. Some of these services offer 24-hour support and can send alerts in a range of formats including SMS messages, emails and phone calls through an electronic dialler. Any such service would not, necessarily, provide any additional warning time, but could be used as another mechanism to alert residents to potential flooding via SMS messages.

For all options, the TFWS is to utilise a variety of mechanisms to communicate flood warning messaging are to be adopted to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages). These may include SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council’s Disaster Dashboard webpage and Hazards Near Me app.

Importantly, communication formats for flood warning are to be clear, concise and consistent with the Australian Warning System format (See Section 3.6).

Table 3.21: Burrill Lake - Summary of communication options

Component Option	Option Name	Summary
Existing base case		- NSW SES use pre-defined channels of communication including EA phone calls, radio and television alerts, doorknocking (where possible) and postings on their website, social media and Hazards Near Me app.
C.1	Integrated alerting system based on gauge trigger levels to Council & SES	- Direct SMS (or email) alerting to Council and SES from monitoring infrastructure indicating current conditions; - SES is the agency responsible for disseminating flood warning messaging to community. - Requires trigger levels P.1.
C.2	Integrated alerting system based on predictive flood modelling to Council & SES	- Direct SMS (or email) alerting to Council and SES from realtime predictive flood modelling indicating potential flooding based on latest forecast information. - SES is the agency responsible for disseminating flood warning messaging to community. - Requires predictive flood model.
C.3	Tie automated alerting into procedures for warning messaging for SES to disseminate to community.	- Integrated automated alerting into SES procedures for issuing flood warning messaging to community; - SES is the agency responsible for disseminating flood warning messaging to community.
C.4	Third party to issue warning messaging to individual community members, Council & SES	- Engage 24-hr monitoring service to initiate warning communications; - SMS/email/phone calls available; - Third party responsible for disseminating flood warning messaging to community - Requires trigger levels P.1.
C.5	Flood warning message dissemination via a range of mechanisms	- To be undertaken for all options. - Mechanisms for dissemination such as SMS, radio, door knocking, phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app. - Allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages).

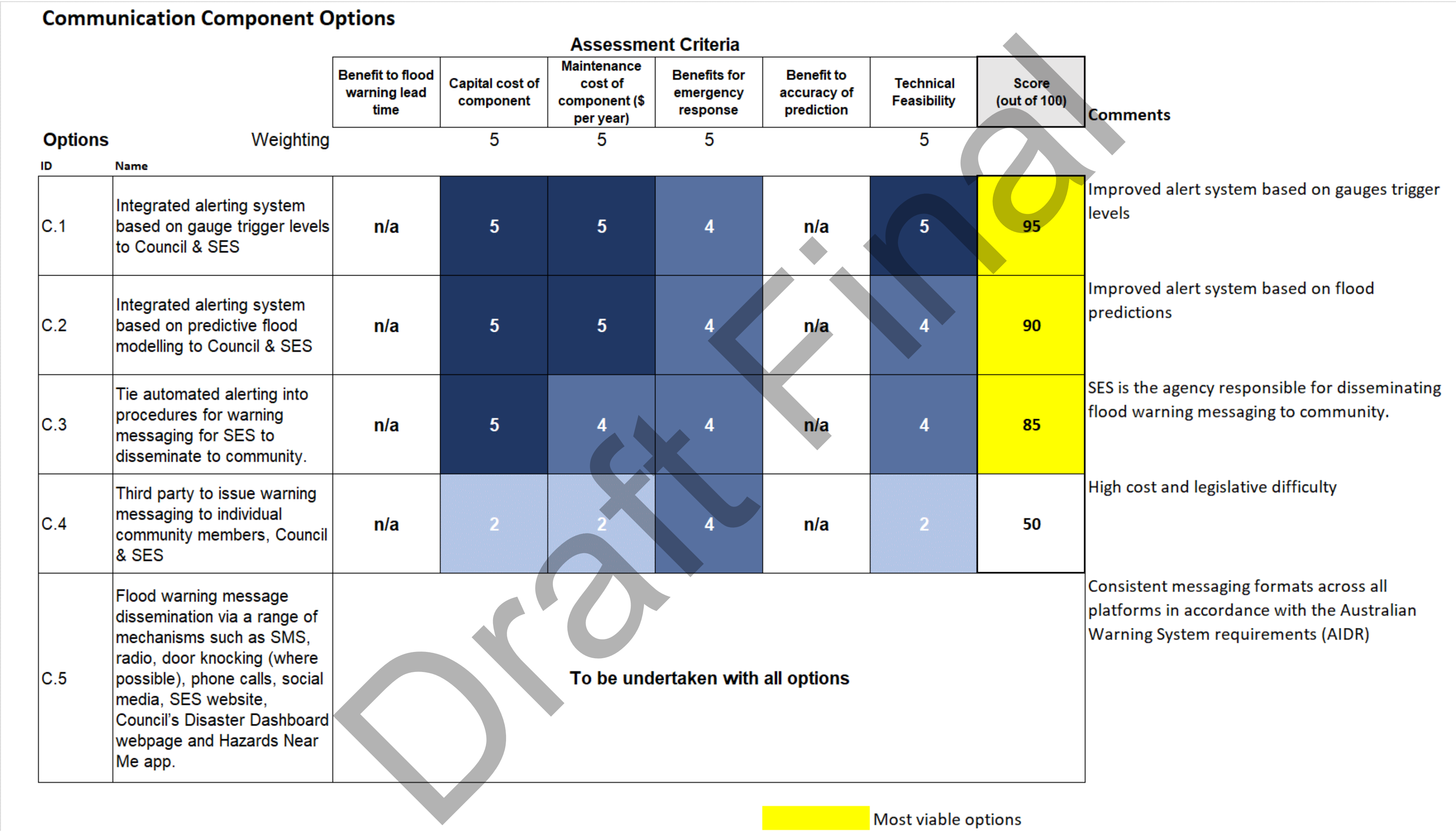
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.22.

All communications options were assessed to be viable except for third party issuing of warning messaging to community (C.4). C.4 was deemed not viable due to high costs associated with implementation and maintenance as well as conflicts with legislation requiring SES to be the responsible authority for issuing flood warning messages to the community. The *National Arrangements for Flood Forecasting and Warning* (BoM, 2018) require local warning dissemination to be undertaken in accordance with jurisdictional emergency management arrangement, namely the roles and responsibilities outlined in *NSW State Flood Plan* (SES, 2021) and *Shoalhaven City Flood Emergency Sub Plan* (SES, 2022).

Flood warning communication is to be issued by the SES through a range of avenues such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council’s Disaster Dashboard webpage and Hazards Near Me app. SES procedures are to be informed by realtime flood information alerts from gauges and/or predictive models. Consistent messaging formats is to be adopted across all communications platforms in accordance with consistent with the Australian Warning System requirements (AIDR).

Table 3.22: Burrill Lake – Communication Component Options MCA Results



Communication Component Options

		Assessment Criteria							
		Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
Options	Weighting		5	5	5		5		
ID	**Name**								
C.1	Integrated alerting system based on gauge trigger levels to Council & SES	**n/a**	5	5	4	**n/a**	5	**95**	Improved alert system based on gauges trigger levels
C.2	Integrated alerting system based on predictive flood modelling to Council & SES	**n/a**	5	5	4	**n/a**	4	**90**	Improved alert system based on flood predictions
C.3	Tie automated alerting into procedures for warning messaging for SES to disseminate to community.	**n/a**	5	4	4	**n/a**	4	**85**	SES is the agency responsible for disseminating flood warning messaging to community.
C.4	Third party to issue warning messaging to individual community members, Council & SES	**n/a**	2	2	4	**n/a**	2	**50**	High cost and legislative difficulty
C.5	Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	**To be undertaken with all options**							Consistent messaging formats across all platforms in accordance with the Australian Warning System requirements (AIDR)

🟨 Most viable options

3.4.1.6 Protective behaviour

The current flood emergency response relies heavily upon ad-hoc protection by the respective communities with limited warning time and is not a serious consideration for protective behaviour. SES driven response is noted to be constrained by limited warning time and resources available during flood emergencies. The FRMS&Ps in all three catchments recommend a more collaborative approach between the NSW SES and community residents.

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for the catchment.

3.4.1.7 Review

The review stage of the TFWS is vital for maintaining long-term maintenance and efficacy of the system. Since extreme flooding happens only rarely and is unpredictable, it is important to maintain awareness of the TFWS to ensure that the system runs as intended despite the potential years between events. The review process, like the message construction, will be highly dependent on the type of flood warning system which is developed and will therefore need to be developed alongside it. As such, no explicit review options will be presented in this report. Whatever the flood warning system developed, however, it will be important to have the community involved in the ongoing maintenance and review process. Toward this goal it is proposed that an annual community event is organised around the flood warning system to incentivise members of the community to be involved and act as a regular refresher about what to do in case of a flooding emergency. It is envisaged that this event could be delivered by the Council and NSW SES in partnership.

3.4.2 Preliminary TFWS Options

Preliminary flood warning system options have been developed for the Burrill Lake catchment based on outcomes of the component design options assessment (Section 3.4.1). This section provides an outline of each option, summary of advantages and disadvantages, preliminary cost estimates and a summary of community/stakeholder engagement outcomes (including public exhibition).

3.4.2.1 Option 1: Predictive flood warning and decision support (utilising present gauge network)

This option consists of flood warning system design based on realtime predictive flood modelling and decision support and utilising the present gauge network as outlined in Table 3.23.

This option involves no new rainfall or water level gauge installations other than planned rainfall gauges identified in Table 3.14. Rain and water level data from the existing gauge network, with entrance condition information from the latest Council surveys, and ocean tide and wave data are to be integrated into a predictive flood warning system.

The predictive flood warning system is to be composed of a realtime catchment hydrology model and a realtime simplified lake hydraulic model with entrance channel prediction to estimate a predicted flood level timeseries in the lake. Inputs to the realtime models will include latest rainfall forecast services from the Bureau (Meteye and Rainfields), latest entrance configuration information and forecast ocean wave and tide conditions.

Interpretation of flood predictions will utilise known inundation impacts for pre-defined trigger levels, detailed flood evacuation plan and a customised web portal accessed by SES and Council to support flood emergency management decision making. A web-based platform will be used to provide tailored decision support from flood predictions such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined (“what-if”) scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall IFD analysis etc.

Communication of flood warning messaging to the community is to be undertaken by the SES. The TFWS will support the communication process by providing delegated SES and Council representatives with automated alerting direct from rainfall and water level instruments as well as flood model predictions. An integrated alerting system would be built into SES procedures to support communication mechanisms of flood emergency information.

For all options, the TFWS is to utilise a variety of mechanisms to communicate flood warning messaging are to be adopted to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages). These may include SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council’s Disaster Dashboard webpage and Hazards Near Me app.

Importantly, communication formats for flood warning are to be clear, concise and consistent with the Australian Warning System format (See Section 3.6).

3.4.2.2 Option 2: Predictive flood warning and decision support with priority 1 gauge installation works

Option 2 consists of the same components as Option 1 with the additional installation of a rainfall and water level station (Priority 1) at Stony Creek Woodstock Rd as outlined in Table 3.23. The additional water level gauge will provide improved water level monitoring upstream of the estuary tidal limit and help to provide early indication of high lake inflows. The additional rain gauge will improve rainfall gauge coverage in the Stony Creek catchment.

Also included in Option 2 is a secondary redundancy flood prediction mechanism (in case of realtime flood model failure) utilising rate-of-rise information and trigger levels for different entrance and ocean conditions.

Installation of an additional automatic rainfall station upstream at Stony Creek Woodstock Rd (M.2) is considered to be value to improving rainfall coverage in the Stony Creek catchment. The installation of this new gauge is also considered a Priority 1 installation.

Installation of an additional automatic rainfall station upstream at Woodstock Creek (M.3) is of slightly lower priority given the generally sufficient coverage of rainfall gauges in the region under the existing case (listed in Table 3.14). The installation of this new gauge is considered a Priority 2 installation.

Provision of entrance channel information for flood warning is considered best achieved through integration of entrance data from latest Council surveys (M.4). Given the entrance is generally open to the ocean, flood predictions are likely to be less sensitive to entrance conditions in comparison to prevailing ocean conditions at this location. Remote entrance berm monitoring (M.5) is not recommended at this location given the low frequency of entrance closure.

3.4.2.3 Option 3: Predictive flood warning and decision support with priority 2 gauge installation works

Option 3 consists of the same components as Options 1 and 2 with the addition of a rainfall station at Woodstock Creek (Priority 2) as outlined in Table 3.23. This additional rainfall is to provide improved rain gauge coverage in the upper Woodstock Creek catchment and redundancy in case of failure of the Stony Creek rain gauge.

Advantages and disadvantages of each of the above options are listed in Table 3.24.

Table 3.23: Burrill Lake - Flood warning system preliminary options

Flood warning system options	Monitoring	Prediction	Interpretation	Message construction	Communication	Protective behaviour
Option 1 - Predictive flood warning and decision support (utilising present gauge network)	Maintain operation of existing rain and water level gauge network with the following: • M.4 Integrate entrance channel data from latest Council surveys • M.6 Integrate ocean wave and tide data.	Realtime flood level predictions using: • P.2 Realtime; hydrology modelling • P.4 Realtime simplified lake hydraulic modelling; • P.5 Utilise Bureau rainfall forecast services (Rainfields and Meteye); • P.6 Entrance channel predictions; • P.7 Ocean water level predictions.	• I.1 Trigger levels for known flood impacts; • I.2 Detailed flood evacuation plan; • I.3 Web based system to provide tailored decision support.	*To be determined during next phase of detailed flood warning system design*	• C.1 Integrated alerting system based on gauge trigger levels to Council & SES; • C.2 Integrated alerting system based on predictive flood modelling to Council & SES; • C.3 Tie automated alerting into procedures for warning messaging for SES to disseminate to community; • C.5 Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	*Emergency Management Flood Response Arrangements to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS.*
Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	As per Option 1 with addition of: • M.1 Additional automatic water level station upstream at Stony Creek Woodstock Rd • M.2 Additional automatic rainfall station upstream at Stony Creek Woodstock Rd	As per Option 1 with addition of: • P.1 Rate-of-rise and trigger level based predictions (as backup prediction mechanism)	As per Option 1		As per Option 1	
Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works	As per Option 1 & 2 with addition of: • M.3 Additional automatic rainfall station upstream at Woodstock Creek.	As per Option 1 & 2.	As per Option 1		As per Option 1	

Table 3.24: Burrill Lake - Advantages and disadvantages of options

Flood warning system options	Advantages	Disadvantages
Option 1 - Predictive flood warning and decision support (utilising present gauge network)	• Improved potential lead time (6-12+ hours) to provide earlier warning and better inform Council, SES and community of potential flooding; • Range of potential flood prediction outputs to inform emergency decision-making such as predicted lake level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, etc; • Utilises best available forecast services from Bureau of Meteorology; • Utilises available technology and computer models with fast runtimes; • Inclusion of representative entrance behaviour and ocean conditions to improve flood prediction; • Potential benefits to help inform pre-flood entrance management procedures; • Supports a proactive pre-flood emergency response for Council, SES and Community; • Lower cost option.	• Prediction accuracy subject to rainfall forecast accuracy limitations (including spatial and temporal uncertainty), model assumptions and limitations; • Successful communication and implementation of protective behaviour dependant on strong and effective collaboration between SES, Community and Council.
Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	As per Option 1 with addition of: • Improved warning of upstream water level rises at Stony Creek beyond the tidal estuary limit to provide better indication of lake inflows • Improved rain gauge coverage and redundancy in the Stony Creek catchment. • Prediction redundancy utilising rate-of-rise and trigger level based predictions;	As per Option 1 with addition of: • Additional expense to install and maintain new gauges. • Predictions based on rate of rise information and trigger levels are subject to inaccuracies and may not represent prevailing entrance and ocean conditions.
Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works	As per Option 1 & 2 with addition of: • Improved rain gauge coverage and redundancy in the Woodstock Creek catchment.	As per Option 1 & 2 with addition of: • Additional expense to install and maintain new gauge.

3.4.3 Preliminary cost estimates

Preliminary cost estimates for the TFWS options at Burrill Lake are shown in Table 3.25. Cost estimates are preliminary and may vary depending on site constraints for gauge locations and client requirements. Costs do not include installation of the planned rainfall gauge at Morton (Woodstock and Wheelbarrow Rd) as this is considered as part of the Tabourie Lake TFWS cost estimates.

Table 3.25: Burrill Lake - Preliminary cost estimates associated with TFWS options

Catchment	Option 1 - Predictive flood warning and decision support (utilising present gauge network)	Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works
Burrill Lake	$40,000 - 50,000	$90,000 - 120,000	$110,000 - 140,000

***** Costs do not include potential upgrades to existing gauge network to improved flood warning reliability and redundancy, SES fees associated with dissemination of flood warning information, development of detailed flood evacuation and emergency response plans, establishment of Emergency Management Flood Response Arrangements, establishment awareness and training of SES and community.

Maintenance costs for a predictive flood warning system typically range from $5,000 - $15,000 per year. Typical maintenance costs for a rainfall or water level station range from $3,000 - $10,000 per station per year. Flood warning networks with numerous gauges can have high annual maintenance costs to maintain.

3.4.4 Community and stakeholder engagement

This section will be completed following Public Exhibition and Stakeholder feedback of this draft report with the Burrill Lake community.

3.5 Tabourie Lake TWFS

3.5.1 Component Options

3.5.1.1 Monitoring

Current monitoring at Tabourie Lake is undertaken via the existing rainfall and water level gauges detailed in Table 3.26 and Figure 3.5. All listed rainfall and water level stations are automatic with data telemetered at Council owned gauges via Event-reporting Radio Telemetry System (ERTS) and mobile network at DPE BCD owned gauges. Council are also currently planning the installation of a new rainfall gauge at the intersection of Woodstock and Wheelbarrow Rd at Morton in the upper Tabourie Lake catchment. Also listed in Table 3.26 are existing rainfall gauges in regional areas surrounding the catchment as well as an ocean tide (Ulladulla Harbour) and wave monitoring station (Batemans Bay) situated within the region.

Table 3.27 summarises different monitoring design options for development of a flood warning system. A TFWS may include one or a combination of those listed. Options for potential installation of new water level and rainfall gauges are: an additional water level at Brandaree Creek situated upstream beyond the tidal limit of the estuary to provide better indication of lake inflows; and/or an additional rain gauge at Brandaree Creek to improve rain gauge coverage.

Site specifications for installation and maintenance of additional gauging is to be undertaken during detailed design of the flood warning system (Stage 4). Review of additional gauging requirements will also be undertaken during detailed design of a preferred flood warning system (Stage 4).

Another monitoring component of flood warning system design for the Tabourie Lake catchment is the ability to incorporate dynamic entrance channel and ocean conditions into flood level estimates. Entrance berm surveys are currently undertaken by Council at each location via:

- Monthly entrance berm surveys when the channel is closed to the ocean
- Entrance berm survey within the week prior to a potential flood event where possible
- Entrance monitoring (daylight hours)

Also included in the monitoring component options is the potential installation of a remotely operated and automatic entrance monitoring station to provide live entrance berm and channel opening conditions to support flood prediction.

Many Hydraulics Laboratory also maintains an automatic ocean tide gauge in Ulladulla Harbour and a wave buoy (wave height, direction and period) offshore of Batemans Bay. Flood warning system design is recommended to incorporate the latest entrance and ocean conditions from such information sources to help improve flood level estimation and warning accuracy.

Table 3.26: Tabourie Lake and surrounds - existing rainfall and water level gauges

Catchment (including surrounds)	Station	Station No.		Type		Ownership	Maintenance	Comms	Alerting	Live Data Available
		AWRC	BoM	Level	Rain					
Tabourie Lake	Lake Tabourie	216440	-	✓	✓	DPE BCD	MHL	Mobile 3G/4G (IP)	Yes (MHL)	https://www.mhl.nsw.gov.au/Station-216440 https://mhl.nsw.gov.au/users/ShoalhavenCityCouncil-TabourieLake
	Lake Tabourie	-	569036	✓	✓	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	Woodburn Rd / Wheelbarrow Rd	-	-	-	✓	Planned future Council rain gauge installation				
	Brooman (Carisbrook)	-	69121	-	✓ *	BoM	BoM	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html
	Brooman (Clyde River)	216002	569018	✓ *	✓ *	WaterNSW	WaterNSW	ERTS	No	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60171.html http://www.bom.gov.au/fwo/IDN60234/IDN60234.569018.plt.shtml
	Willinga Lake	-	569045	✓	✓ *	Council	Council	ERTS	Yes (Enviromon)	http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDN60155.html http://www.bom.gov.au/fwo/IDN60234/IDN60234.569045.plt.shtml
	Burrill Lake	216435	-	✓	✓ *	DPE BCD	MHL	Mobile 3G/4G (IP)	No	https://www.mhl.nsw.gov.au/Station-216435
Ocean Conditions	Ulladulla	216471	569039	Ocean Tide *		DPE BCD	MHL	Mobile 3G/4G (IP)	No	https://www.mhl.nsw.gov.au/Station-216471
	Batemans Bay	BATBOW		Ocean Wave *		DPE BCD	MHL	Radio	No	https://www.mhl.nsw.gov.au/Station-BATBOW

* Station located outside of catchment area but useful for regional rainfall monitoring or ocean conditions

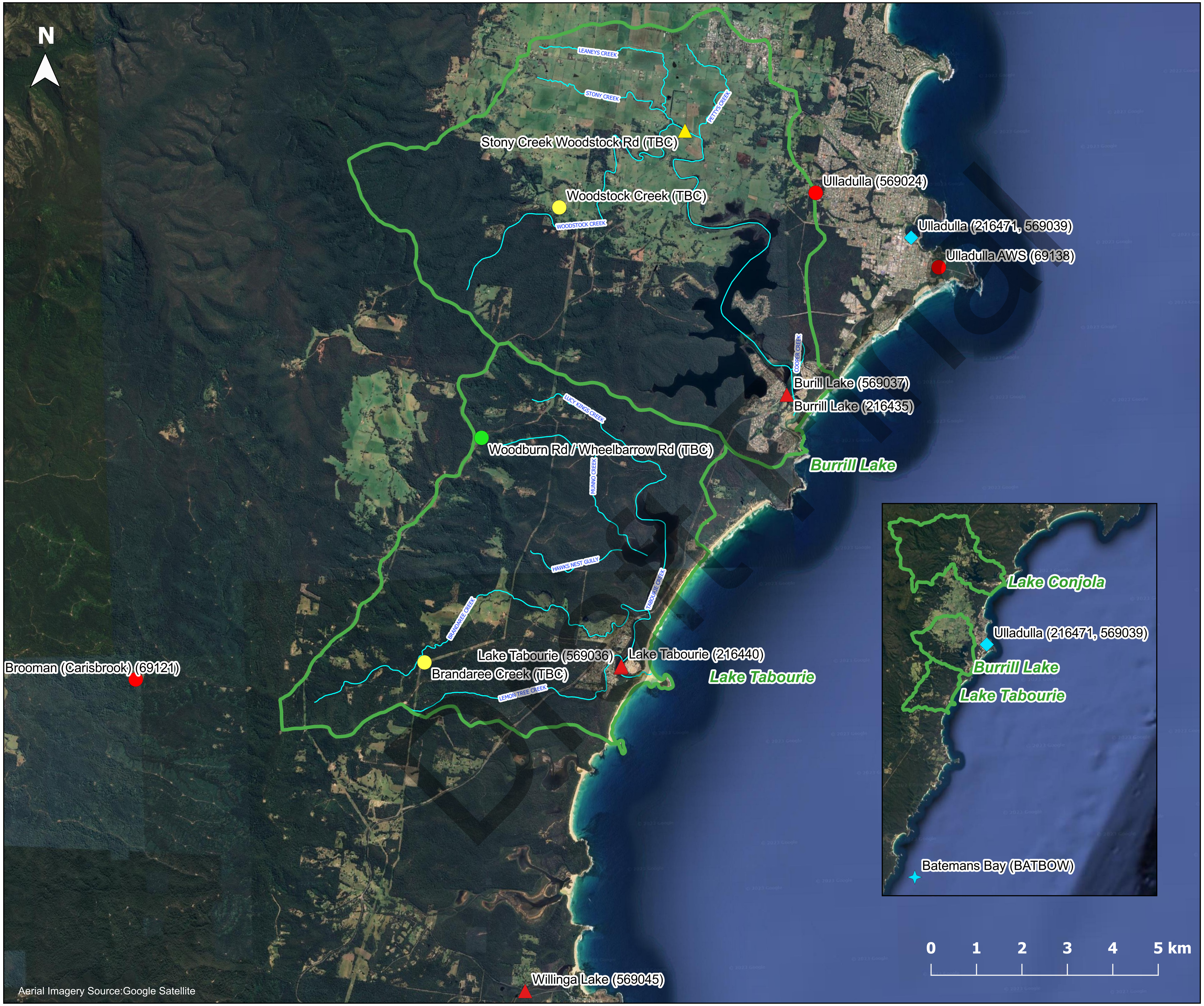


Figure 3.5

Burrill Lake and Tabourie Lake - Existing and Proposed Gauges

Legend

🟩 Catchment Boundary
— Waterways

Gauges

● Existing Rain Gauge
■ Existing Water Level Gauge
▲ Existing Water Level & Rain Gauge
● Planned Future Rain Gauge
○ Potential Rain Gauge
△ Potential Additional Water Level & Rain Gauge
◆ Ocean Tide
✦ Ocean Wave

Report MHL2969

Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study: Stages 1 to 3 Review and Flood Warning System Options

NSW GOVERNMENT
Manly Hydraulics Laboratory

Table 3.27: Tabourie Lake - Summary of monitoring options

Component Option	Option Name	Summary
Existing base case		• No additional monitoring infrastructure will be installed; • Continued maintenance of existing gauges and installation of planned gauge at Morton (Woodstock/Wheelbarrow Rd) as per Table 3.26; • Continued maintenance of basic alerting from Council's rainfall gauges through Enviromon; • Continued maintenance of water level trigger alerts at the Tabourie Lake gauge through MHL. • No flood warning integration of entrance and ocean condition information.
M.1	Additional automatic water level station upstream at Brandaree Creek	• Improved warning of upstream water level rises beyond the tidal estuary limit to provide better indication of lake inflows; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.2	Additional automatic rainfall station upstream at Brandaree Creek	• Additional rainfall gauge coverage in the Brandaree Creek catchment; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new site.
M.3	Integrate entrance channel data from latest Council surveys.	Improved use of entrance condition information for flood prediction via: • Integration of latest entrance conditions from Council existing entrance monitoring program including entrance berm surveys at monthly intervals when closed, entrance berm surveys within the week prior to an event where possible, and entrance monitoring cameras; • Likely further benefits to pre-flood entrance management procedures.
M.4	Installation of remote entrance berm monitoring station at Tabourie Lake Entrance	Improved monitoring of entrance conditions for flood prediction via: • Installation of a remotely operated and automatic station to monitor the condition of the entrance throat channel and entrance berm; • Scoping of potential location is performed with installation location subject to site inspection; • Company is engaged for installation and maintenance of the new station; • Likely further benefits to pre-flood entrance management procedures.
M.5	Integrate ocean wave and tide data	Improved understanding of ocean conditions for flood prediction via: • Integration of available ocean water level data from Ulladulla tide gauge (216471); • Integration of available ocean wave conditions from Batemans Bay Wave Buoy (BATBOW), transformed into nearshore water depths at entrance.

MCA Assessment

Results of the MCA assessment for monitoring component options are shown in Table 3.28. Installation of an additional automatic water level station upstream at Brandaree Creek (M.1) will likely have limited benefit to flood warning due to potential fast rate of lake level rise and is not considered a viable option to improving flood warning.

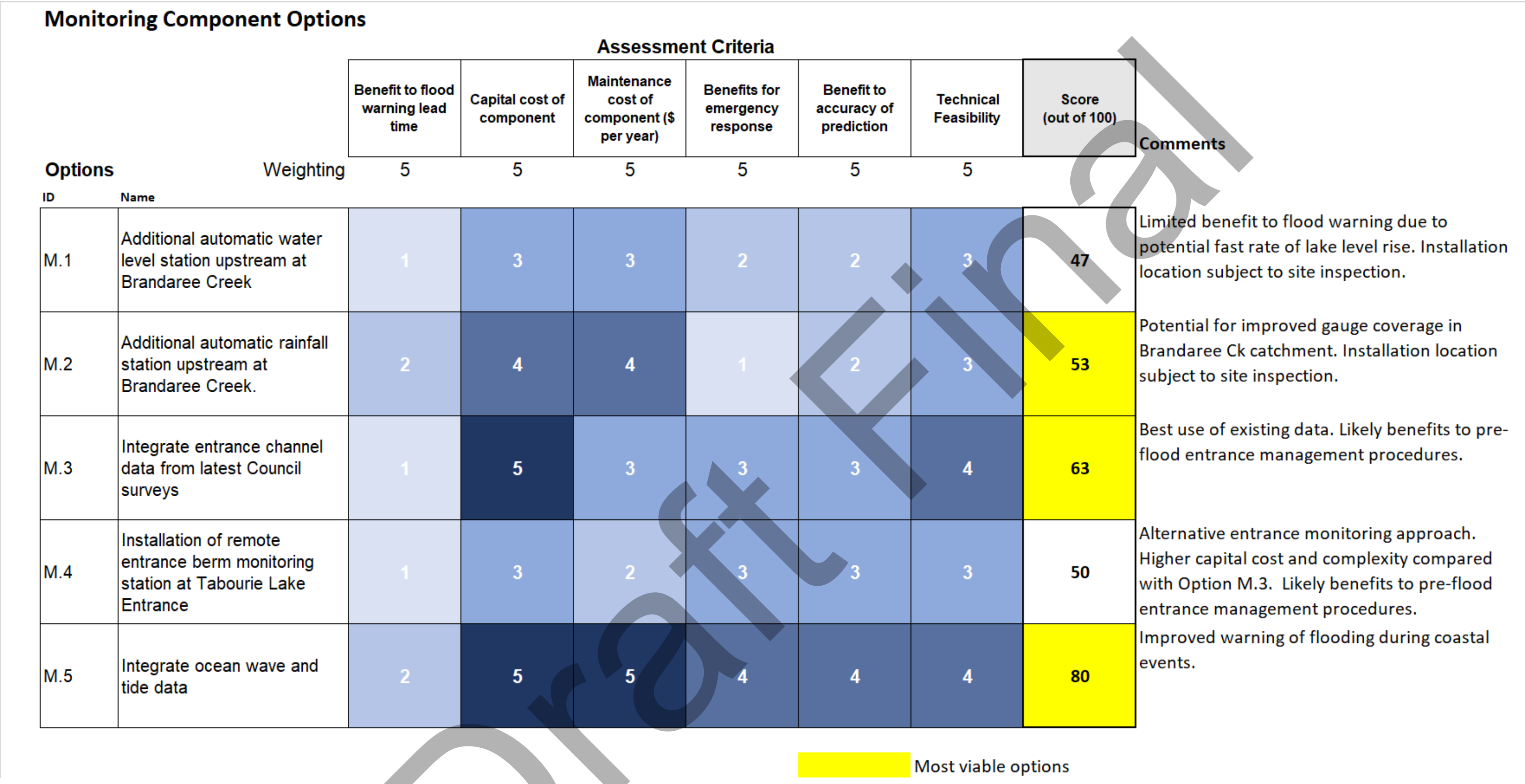
Installation of an additional automatic rainfall station upstream in the Brandaree Creek catchment (M.2) is considered to be of higher priority given the improved benefit to lead time and generally poor coverage of rainfall gauges in this area of catchment under the existing case (listed in Table 3.26). The installation of this new gauge is considered a Priority 1 installation.

Provision of entrance channel information for flood warning is considered best achieved through integration of entrance data from latest Council surveys (M.3). This option provides best use of available information in comparison to installation of a remote berm entrance monitoring station (M.4) with higher capital cost and installation complexities.

Integration of ocean wave and tide data (M.5) was scored the highest of all component options. This also make best use of available information providing realtime ocean conditions to support flood prediction accuracy at Tabourie Lake.

The results indicate that a combination of monitoring options is likely viable for design of a TFWS at Tabourie Lake, incorporating available entrance and ocean monitoring information with options for improved rain gauge coverage.

Table 3.28: Tabourie Lake - Monitoring Component Options MCA Results



Monitoring Component Options

Assessment Criteria

Options ID	Name	Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
	Weighting	5	5	5	5	5	5		
M.1	Additional automatic water level station upstream at Brandaree Creek	1	3	3	2	2	3	47	Limited benefit to flood warning due to potential fast rate of lake level rise. Installation location subject to site inspection.
M.2	Additional automatic rainfall station upstream at Brandaree Creek.	2	4	4	1	2	3	53	Potential for improved gauge coverage in Brandaree Ck catchment. Installation location subject to site inspection.
M.3	Integrate entrance channel data from latest Council surveys	1	5	3	3	3	4	63	Best use of existing data. Likely benefits to pre-flood entrance management procedures.
M.4	Installation of remote entrance berm monitoring station at Tabourie Lake Entrance	1	3	2	3	3	3	50	Alternative entrance monitoring approach. Higher capital cost and complexity compared with Option M.3. Likely benefits to pre-flood entrance management procedures.
M.5	Integrate ocean wave and tide data	2	5	5	4	4	4	80	Improved warning of flooding during coastal events.

🟨 Most viable options

3.5.1.2 Prediction

Currently there is no formalised procedure or mechanism to provide realtime flood level predictions during a flood event for Tabourie Lake. Current methods are described in Section 2.1 and rely upon realtime gauge information, Bureau weather warning services and limited rate-of-rise information where available from technical studies.

Potential options to improve flood prediction are listed in Table 3.29. These include flood predictions based on (including combinations of) rate-of-rise analysis and gauge trigger levels (informal prediction), realtime hydrology modelling, realtime hydrodynamic modelling, realtime simplified lake hydraulic modelling, incorporation of Bureau rain forecast products (MetEye, Rainfields), entrance channel scour predictions and ocean water level predictions. A TFWS may include one or a combination of those listed.

Table 3.29: Tabourie Lake - Summary of prediction options

Component Option	Option Name	Summary
Existing base case		• As per existing flood warning arrangement utilising as outlined in Section 2.1.3.6; • Relies heavily upon manual interpretation of realtime gauge data, BoM weather warning services and knowledge of flood behaviour; • No formalised procedure or mechanism to provide realtime flood level predictions during a flood event.
P.1	Rate-of-rise and trigger level based predictions	• Flooding predictions are estimated using recorded rainfall, water level trigger levels and rate-of-rise information from flood modelling analysis; • Simplistic and preliminary technique to flood prediction with limited accuracy.
P.2	Realtime hydrology modelling	• Flooding predictions are based on realtime hydrology modelling of observed and predicted rainfall; • Simple model to setup and run.
P.3	Realtime direct-rainfall hydrodynamic modelling	• Flooding predictions are based on realtime direct-rainfall hydrodynamic model of observed and predicted rainfall; • Complex model to setup and run.
P.4	Realtime simplified lake hydraulic modelling	• Flooding predictions are based on simplified lake hydraulic modelling incorporating inflows from hydrology modelling (P.2), lake bathymetry and entrance representation.; • Simple model to setup and run.
P.5	Utilise Bureau rainfall forecast services (Rainfields and Meteye)	• Use BoM rain radar predictive model (Rainfields) to inform short-term (e.g., Thunderstorms) predictions • Use BoM Australian Digital Forecasting Database (ADFD; MetEye) to inform predictions
P.6	Entrance channel predictions	• Improvement of flood predictions via integration of a predictive entrance model that incorporates latest entrance observations and predictive entrance breakout/scour during flooding. • Based on knowledge of entrance scour behaviour.
P.7	Ocean water level predictions	• Integration of forecast ocean conditions at the entrance to improve flood level predictions. Forecast services include the NSW Nearshore Wave Tool (utilising AUSWAVE), astronomical tide and ocean anomaly forecasts.

Prediction options have differing levels of complexities, accuracy and effort associated with each approach. Realtime flood models differ in calibration complexity, model setup, computing power and runtime requirements. Realtime hydrology models (P.2) take observed and predicted rainfall and converting it an inflow into the lake storage system. Outputs from a hydrology model can be readily applied in a realtime simplified lake hydraulic model (P.4) to provide lake level predictions based on lake and floodplain bathymetry, and entrance configuration. These models may be run very quickly (in the order of seconds) and are able to, generally, provide a good level of accuracy of downstream prediction as compared to trigger level predictions (P.1) when combined with sufficient entrance channel and ocean representation (P.6 and P.7). Hydrology models require realtime data to provide the best results, need to run automatically in a dedicated computing environment which in some cases can be complicated and expensive to operate, and often require experienced personnel to interpret the results they provide. Catchment pre-conditions are another factor which is difficult to account for in a realtime hydrological model and could have impact on the prediction accuracy.

At the most complex and expensive end of the prediction options is the running of a realtime 2D direct-rainfall hydrodynamic model (P.3). These models are the same type as those used to perform flood studies and floodplain risk management plans, however they need to be configured to run in a flood forecasting capacity. These forecasting systems are just starting to become available in NSW and can require large amounts of computational power, are costly to setup and maintain, and can take hours to run. It is unlikely that given the short lead-time for flooding in the respective catchments and the available resources of Council that this option will be viable, however it has been included for completeness.

In order to drive predictions, the Bureau have provided a number of forecast products for consideration in this report. P.5 consists of utilising the Bureau’s MetEye forecast products which, for the purposes of flood forecasting, provides a number of gridded (6km) probabilistic rainfall forecasts (10%, 25% and 50% chance of exceedance) at 3-hour intervals. This gridded data can be used to drive predictions from any of the other prediction options to estimate the likely flooding up to 7-days in the future. The MetEye forecast services are based on regional climate models with limited spatial and temporal resolution. P.5 also includes use of the Bureau’s new Rainfields rainfall forecast which is based on rain radar nowcasting. This provides much better resolution both across space (100’s of metres to kilometres) and time (6-minute time interval) and is designed to improve short-term rain predictions for thunderstorm-scale flood forecasting.

Representation of the entrance channel (including scour induced by flooding) and forecasted ocean conditions at the entrance (waves, tides, anomalies, etc) throughout an imminent flood event is also an important component of accurate flood level prediction. Realtime entrance prediction (P.6) considers latest entrance observations and characteristic scour behaviour during flooding and is calibrated against historical flood events.

P.7 involves taking into consideration forecast ocean conditions in flood predictions. The NSW Nearshore Wave Tool is also available to provide wave height forecasts (based on AUSWAVE) into nearshore locations (10m water depth) fronting the entrance. Tidal and ocean anomaly forecast services are also available to inform of ocean tailwater conditions.

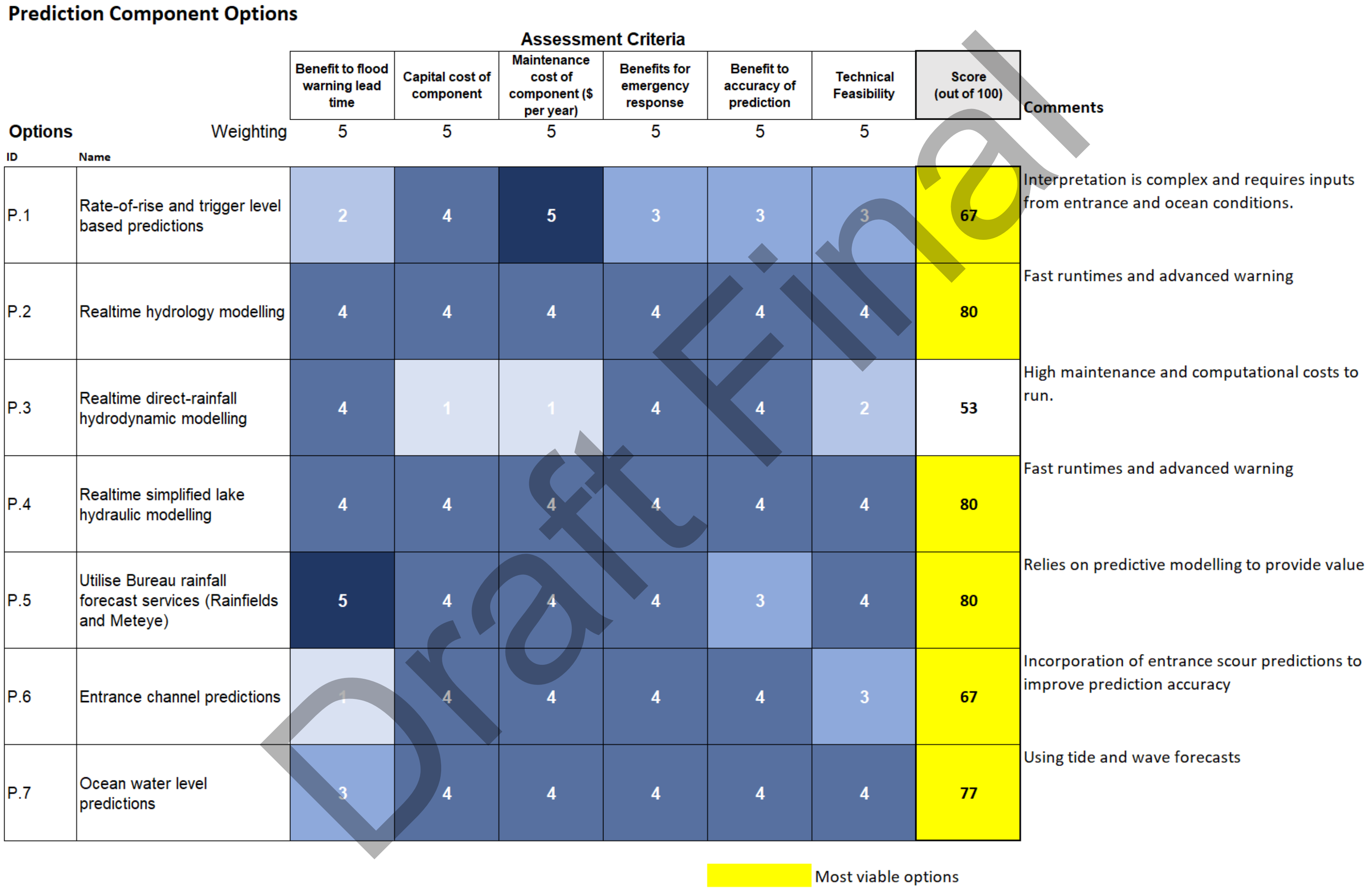
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.30. The provision of predictive capabilities to the design of a TFWS at Tabourie Lake is estimated to extend flood warning lead time by 6-12 hours or more.

Prediction component options range in differing degrees of complexity, setup effort and cost. Realtime two-dimensional direct-rainfall hydrodynamic modelling (P.3) was deemed not a viable design options given its high setup effort, cost and longer model run times. All other options (including combinations of) are considered viable including incorporation of latest forecast information services from the Bureau to improve flood predictions.

Given the dynamic nature of the entrance and ocean conditions, it is considered important that flood warning design incorporate recent entrance observations, entrance scour behaviour, ocean condition monitoring data (waves and tides), and forecast ocean conditions to improve accuracy of flood level predictions.

Table 3.30: Tabourie Lake - Prediction Component Options MCA Results



Prediction Component Options

Options		Assessment Criteria							
		Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
	Weighting	5	5	5	5	5	5		
ID	Name								
P.1	Rate-of-rise and trigger level based predictions	2	4	5	3	3	3	67	Interpretation is complex and requires inputs from entrance and ocean conditions.
P.2	Realtime hydrology modelling	4	4	4	4	4	4	80	Fast runtimes and advanced warning
P.3	Realtime direct-rainfall hydrodynamic modelling	4	1	1	4	4	2	53	High maintenance and computational costs to run.
P.4	Realtime simplified lake hydraulic modelling	4	4	4	4	4	4	80	Fast runtimes and advanced warning
P.5	Utilise Bureau rainfall forecast services (Rainfields and Meteye)	5	4	4	4	3	4	80	Relies on predictive modelling to provide value
P.6	Entrance channel predictions	1	4	4	4	4	3	67	Incorporation of entrance scour predictions to improve prediction accuracy
P.7	Ocean water level predictions	3	4	4	4	4	4	77	Using tide and wave forecasts

🟨 Most viable options

3.5.1.3 Interpretation

Effective flood interpretation is required to translate flood predictions to an understanding of who is at risk from flooding and what the appropriate response should be. Currently the NSW SES take rainfall and weather forecast services the Bureau and utilise flood information gained from flood studies and historical observed data to determine the most effective response based on the information at hand.

Table 3.31 summarises interpretation component options for TFWS design at Tabourie Lake. A TFWS may include one or a combination of those listed.

Interpretation of flood prediction information can be undertaken through known inundation impacts at defined trigger levels (I.1) based on historical flood impacts and technical studies. When a predicted flood level is available, information is readily at hand to interpret that likely inundation impacts associated with that level and determine an appropriate emergency response.

To assist proactive emergency response during hazardous flood events, a detailed flood evacuation plan (I.2) could be formulated by Council and SES in collaboration with the Tabourie Lake community. This could consist of meetings or workshops where residents were guided through the creation of their own flood evacuation plan, including where to go, what route to take, what to do with belongings and pets, etc. Workshops of this nature would also help to improve local awareness of flood risk and could be integrated into a yearly review cycle. Following the completion of this project and potential implementation of a TFWS, the SES will identify the most appropriate emergency management flood response arrangements for the Tabourie Lake catchment.

Web-based platforms (I.3) can also be developed to provide customised interpretation of flood predictions and realtime information in a central location to support the decision-making needs of Council, SES and community during flood emergencies. Tailored emergency management decision support from flood predictions can include information such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall Intensity-Frequency-Duration analysis etc.

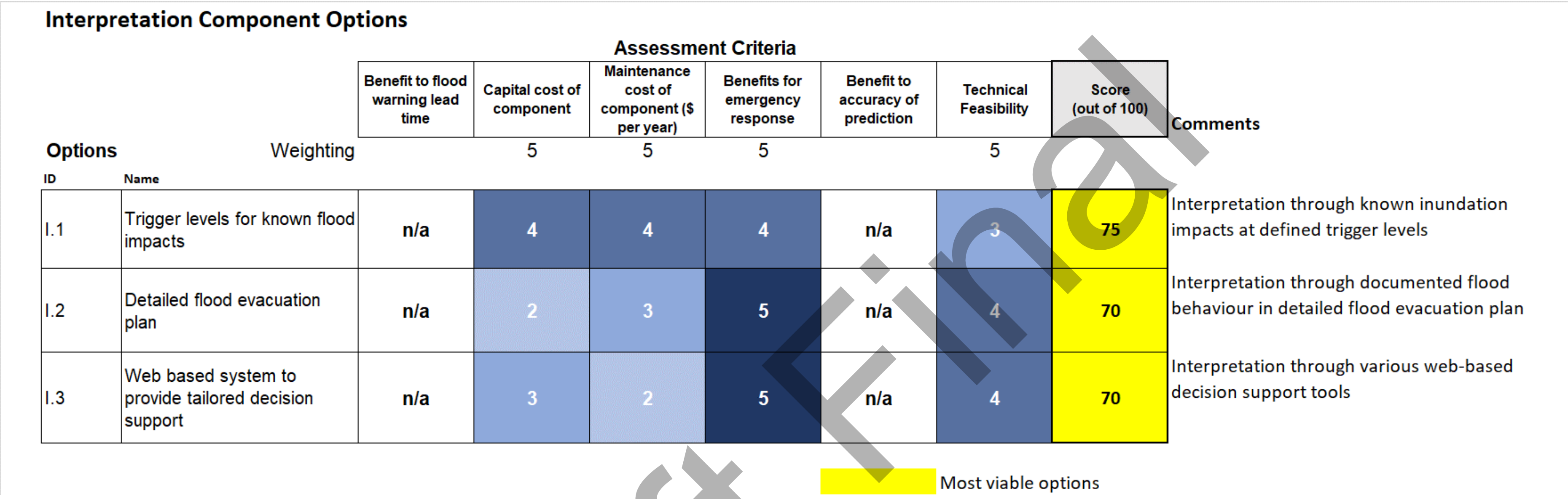
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.32. Interpretation options were assessed to be all viable and a flood warning system design could include a combination of the approaches listed. Information delivered from a flood warning system is to be tailored to the decision-making needs of different end-users (e.g., Council, SES and community) and best allow for ease of interpretation. Some users may require more detailed level of information whereas others may require more prescriptive information. Integration of message interpretation into an emergency response plan for each catchment is important.

Table 3.31: Tabourie Lake - Summary of interpretation options

Component Option	Option Name	Summary
Existing base case		• NSW SES use the outcomes from completed flood investigations, additional resources and local knowledge to determine likely impacts of flooding.
I.1	Trigger levels for known flood impacts	• Interpretation through known inundation impacts at defined trigger levels based on historical flood information and technical studies.
I.2	Detailed flood evacuation plan	• Use available flood data to provide community with property-specific flood evacuation plans; • Disseminate to the community.
I.3	Web based platforms to provide tailored decision support from flood predictions	• Utilise live web-based platforms to provide tailored decision support using realtime model outputs and flood predictions. This may include different level of information and flood intelligence tools customised to the need of different user groups (i.e., Community or Council/SES). • Tailored emergency management decision support from flood predictions can include information such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall Intensity-Frequency-Duration analysis etc.

Table 3.32: Tabourie Lake – Interpretation Component Options MCA Results



Interpretation Component Options

		Assessment Criteria							
Options		**Benefit to flood warning lead time**	**Capital cost of component**	**Maintenance cost of component ($ per year)**	**Benefits for emergency response**	**Benefit to accuracy of prediction**	**Technical Feasibility**	**Score (out of 100)**	**Comments**
	Weighting		5	5	5		5		
ID	**Name**								
I.1	Trigger levels for known flood impacts	**n/a**	4	4	4	**n/a**	3	**75**	Interpretation through known inundation impacts at defined trigger levels
I.2	Detailed flood evacuation plan	**n/a**	2	3	5	**n/a**	4	**70**	Interpretation through documented flood behaviour in detailed flood evacuation plan
I.3	Web based system to provide tailored decision support	**n/a**	3	2	5	**n/a**	4	**70**	Interpretation through various web-based decision support tools

🟨 Most viable options

3.5.1.4 Message construction

The content of any warning message is highly dependent on the intended recipients of the messaging as well as the means through which the message is communicated. For this reason, NSW SES in conjunction with Council and the community will develop pre-defined warning messages which are appropriate and useful for those at risk. This process will take place during the subsequent stage of the flood warning system detailed development and, therefore, no explicit options will be presented for this component in this report.

Message construction formats will be consistent with the Australian Warning System, Australian Institute for Disaster Resilience (2021) as outlined in Section 3.6.

3.5.1.5 Communication

The NSW SES are the agency responsible for communicating flood warning messaging to the community. Currently the SES use pre-defined channels to communicate flood warning information including EA phone calls, radio and television alerts, door knocking (where possible) and postings on their website, social media and Hazards Near me phone app.

A summary of communication options for a TFWS at Tabourie Lake is shown in Table 3.33. A TFWS should automatically alert SES with timely flood prediction information for the SES to then effectively communicate to the community the imminent flood-risk and appropriate course of action. Alerting can also be sent to delegated Council representatives. An integrated system with automatic alerting can be direct from gauge trigger levels (C.1) or direct from predictive flood modelling when a certain water level threshold is predicted to exceed (C.2). The latter provides additional warning time compared to the gauge trigger level approach.

As a further step, automated alerting can by directly tied into SES procedures for constructing flood warning messaging and disseminating to the community (C.3). This approach would aim to help streamline SES procedures with automated real-time flood prediction information based on the latest alerts.

Another communication option to provide an additional avenue of support is to engage a third party to monitor data in the area and manually send alerts if a trigger level is exceeded (C.4). Trigger levels and associated messages would need to be pre-defined and a list of message recipients developed for each trigger. Some of these services offer 24-hour support and can send alerts in a range of formats including SMS messages, emails and phone calls through an electronic dialler. Any such service would not, necessarily, provide any additional warning time, but could be used as another mechanism to alert residents to potential flooding via SMS messages.

For all options, the TFWS is to utilise a variety of mechanisms to communicate flood warning messaging are to be adopted to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages). These may include SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council’s Disaster Dashboard webpage and Hazards Near Me app.

Importantly, communication formats for flood warning are to be clear, concise and consistent with the Australian Warning System format (See Section 3.6).

Table 3.33: Tabourie Lake - Summary of communication options

Component Option	Option Name	Summary
Existing base case		• NSW SES use pre-defined channels of communication including EA phone calls, radio and television alerts, doorknocking (where possible) and postings on their website, social media and Hazards Near Me app.
C.1	Integrated alerting system based on gauge trigger levels to Council & SES	• Direct SMS (or email) alerting to Council and SES from monitoring infrastructure indicating current conditions; • SES is the agency responsible for disseminating flood warning messaging to community. • Requires trigger levels P.1.
C.2	Integrated alerting system based on predictive flood modelling to Council & SES	• Direct SMS (or email) alerting to Council and SES from realtime predictive flood modelling indicating potential flooding based on latest forecast information. • SES is the agency responsible for disseminating flood warning messaging to community. • Requires predictive flood model.
C.3	Tie automated alerting into procedures for warning messaging for SES to disseminate to community.	• Integrated automated alerting into SES procedures for issuing flood warning messaging to community; • SES is the agency responsible for disseminating flood warning messaging to community.
C.4	Third party to issue warning messaging to individual community members, Council & SES	• Engage 24-hr monitoring service to initiate warning communications; • SMS/email/phone calls available; • Third party responsible for disseminating flood warning messaging to community • Requires trigger levels P.1.
C.5	Flood warning message dissemination via a range of mechanisms	• To be undertaken for all options. • Mechanisms for dissemination such as SMS, radio, door knocking, phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app. • Allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages).

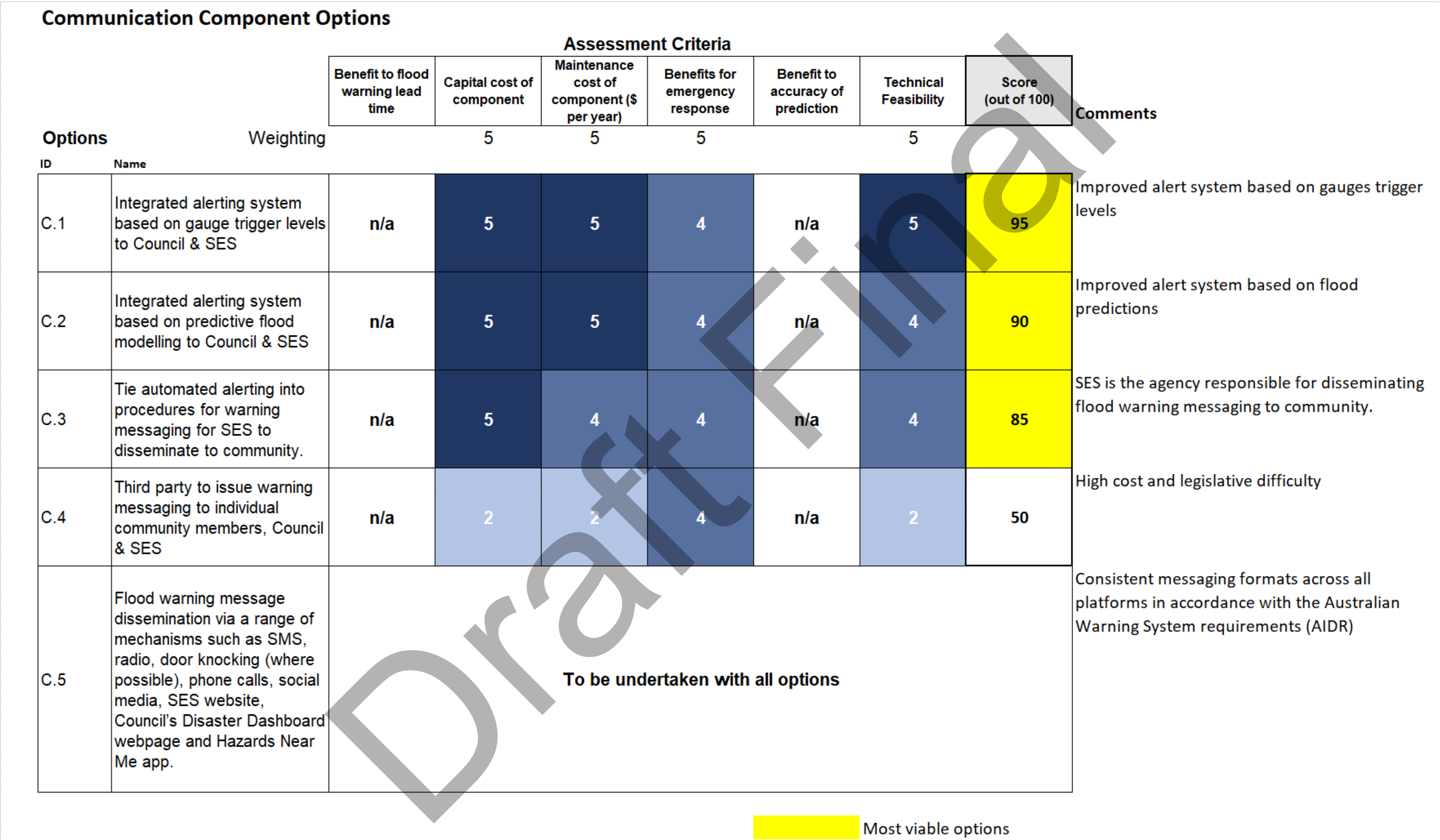
MCA Assessment

Results of the MCA assessment for prediction component options are shown in Table 3.34.

All communications options were assessed to be viable except for third party issuing of warning messaging to community (C.4). C.4 was deemed not viable due to high costs associated with implementation and maintenance as well as conflicts with legislation requiring SES to be the responsible authority for issuing flood warning messages to the community. The *National Arrangements for Flood Forecasting and Warning* (BoM, 2018) require local warning dissemination to be undertaken in accordance with jurisdictional emergency management arrangement, namely the roles and responsibilities outlined in *NSW State Flood Plan* (SES, 2021) and *Shoalhaven City Flood Emergency Sub Plan* (SES, 2022).

Flood warning communication is to be issued by the SES through a range of avenues such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app. SES procedures are to be informed by realtime flood information alerts from gauges and/or predictive models. Consistent messaging formats is to be adopted across all communications platforms in accordance with consistent with the Australian Warning System requirements (AIDR).

Table 3.34: Tabourie Lake – Communication Component Options MCA Results



Communication Component Options

Options		Assessment Criteria							
		Benefit to flood warning lead time	Capital cost of component	Maintenance cost of component ($ per year)	Benefits for emergency response	Benefit to accuracy of prediction	Technical Feasibility	Score (out of 100)	Comments
	Weighting		5	5	5		5		
ID	Name								
C.1	Integrated alerting system based on gauge trigger levels to Council & SES	n/a	5	5	4	n/a	5	95	Improved alert system based on gauges trigger levels
C.2	Integrated alerting system based on predictive flood modelling to Council & SES	n/a	5	5	4	n/a	4	90	Improved alert system based on flood predictions
C.3	Tie automated alerting into procedures for warning messaging for SES to disseminate to community.	n/a	5	4	4	n/a	4	85	SES is the agency responsible for disseminating flood warning messaging to community.
C.4	Third party to issue warning messaging to individual community members, Council & SES	n/a	2	2	4	n/a	2	50	High cost and legislative difficulty
C.5	Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	To be undertaken with all options							Consistent messaging formats across all platforms in accordance with the Australian Warning System requirements (AIDR)

🟨 Most viable options

3.5.1.6 Protective behaviour

The current flood emergency response relies heavily upon ad-hoc protection by the respective communities with limited warning time and is not a serious consideration for protective behaviour. SES driven response is noted to be constrained by limited warning time and resources available during flood emergencies. The FRMS&Ps in all three catchments recommend a more collaborative approach between the NSW SES and community residents.

Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for the catchment.

3.5.1.7 Review

The review stage of the TFWS is vital for maintaining long-term maintenance and efficacy of the system. Since extreme flooding happens only rarely and is unpredictable, it is important to maintain awareness of the TFWS to ensure that the system runs as intended despite the potential years between events. The review process, like the message construction, will be highly dependent on the type of flood warning system which is developed and will therefore need to be developed alongside it. As such, no explicit review options will be presented in this report. Whatever the flood warning system developed, however, it will be important to have the community involved in the ongoing maintenance and review process. Toward this goal it is proposed that an annual community event is organised around the flood warning system to incentivise members of the community to be involved and act as a regular refresher about what to do in case of a flooding emergency. It is envisaged that this event could be delivered by the Council and NSW SES in partnership.

3.5.2 Preliminary TFWS Options

Preliminary flood warning system options have been developed for the Tabourie Lake catchment based on outcomes of the component design options assessment (Section 3.5.1). This section provides an outline of each option, summary of advantages and disadvantages, preliminary cost estimates and a summary of community/stakeholder engagement outcomes (including public exhibition).

3.5.2.1 *Option 1: Predictive flood warning and decision support (utilising present gauge network)*

This option consists of flood warning system design based on realtime predictive flood modelling and decision support and utilising the present gauge network as outlined in Table 3.35.

This option involves no new rainfall or water level gauge installations other than planned rainfall gauges identified in Table 3.26. Rain and water level data from the existing gauge network, with entrance condition information from the latest Council surveys, and ocean tide and wave data are to be integrated into a predictive flood warning system.

The predictive flood warning system is to be composed of a realtime catchment hydrology model and a realtime simplified lake hydraulic model with entrance channel prediction to estimate a predicted flood level timeseries in the lake. Inputs to the realtime models will include latest rainfall forecast services from the Bureau (Meteye and Rainfields), latest entrance configuration information and forecast ocean wave and tide conditions.

Interpretation of flood predictions will utilise known inundation impacts for pre-defined trigger levels, detailed flood evacuation plan and a customised web portal accessed by SES and Council to support flood emergency management decision making. A web-based platform will be used to provide tailored decision support from flood predictions such as predicted flood level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined (“what-if”) scenario flood modelling, latest entrance condition information, realtime and forecast ocean conditions, realtime rainfall IFD analysis etc.

Communication of flood warning messaging to the community is to be undertaken by the SES. The TFWS will support the communication process by providing delegated SES and Council representatives with automated alerting direct from rainfall and water level instruments as well as flood model predictions. An integrated alerting system would be built into SES procedures to support communication mechanisms of flood emergency information.

For all options, the TFWS is to utilise a variety of mechanisms to communicate flood warning messaging are to be adopted to allow for redundancy, varying demographics (differ degrees of familiarity with technologies) and potential communication line failures (e.g., phone reception issues, power outages). These may include SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council’s Disaster Dashboard webpage and Hazards Near Me app.

Importantly, communication formats for flood warning are to be clear, concise and consistent with the Australian Warning System format (See Section 3.6).

3.5.2.2 Option 2: Predictive flood warning and decision support with priority 1 gauge installation works

Option 2 consists of the same components as Option 1 with the additional installation of a rainfall station (Priority 1) at Branderee Creek as outlined in Table 3.35. This additional rainfall is to provide improved rain gauge coverage in the Branderee Creek area and added rainfall gauge redundancy in the Tabourie Lake catchment.

Also included in Option 2 is a secondary redundancy flood prediction mechanism (in case of realtime flood model failure) utilising rate-of-rise information and trigger levels for different entrance and ocean conditions.

3.5.2.3 Option 3: Predictive flood warning and decision support with priority 2 gauge installation works

Option 3 consists of the same components as Options 1 and 2 with the addition of a remote entrance berm monitoring station at Tabourie Lake entrance (Priority 2), as outlined in Table 3.35. Remote entrance berm monitoring at the entrance is to utilise innovative technologies to provide realtime entrance channel and berm information to support flood warning predictions. Entrance berm monitoring would be undertaken on an automated program via remote operation. This provides an alternative to undertaking an entrance survey in-person that can be constrained by suitable weather conditions, limited pre-flood timing, safety considerations and Council staff availability.

Advantages and disadvantages of each of the above options are listed in Table 3.36.

Table 3.35: Tabourie Lake - Flood warning system preliminary options

Flood warning system options	Monitoring	Prediction	Interpretation	Message construction	Communication	Protective behaviour
Option 1 - Predictive flood warning and decision support (utilising present gauge network)	Maintain operation of existing rain and water level gauge network with the following: • M.3 Integrate entrance channel data from latest Council surveys; • M.5 Integrate ocean wave and tide data.	Realtime flood level predictions using: • P.2 Realtime; hydrology modelling • P.4 Realtime simplified lake hydraulic modelling; • P.5 Utilise Bureau rainfall forecast services (Rainfields and Meteye); • P.6 Entrance channel predictions; • P.7 Ocean water level predictions.	• I.1 Trigger levels for known flood impacts; • I.2 Detailed flood evacuation plan; • I.3 Web based system to provide tailored decision support.	*To be determined during next phase of detailed flood warning system design*	• C.1 Integrated alerting system based on gauge trigger levels to Council & SES; • C.2 Integrated alerting system based on predictive flood modelling to Council & SES; • C.3 Tie automated alerting into procedures for warning messaging for SES to disseminate to community; • C.5 Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	*Emergency Management Flood Response Arrangements to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS.*
Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	As per Option 1 with addition of: • M.2 Additional automatic rainfall station upstream at Brandaree Creek	As per Option 1 with addition of: • P.1 Rate-of-rise and trigger level based predictions (as backup prediction mechanism)	As per Option 1		As per Option 1	
Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works	As per Option 1 & 2 with addition of: • M.4 Installation of remote entrance berm monitoring station at Tabourie Lake Entrance.	As per Option 1 & 2.	As per Option 1		As per Option 1	

Table 3.36: Tabourie Lake - Advantages and disadvantages of options

Flood warning system options	Advantages	Disadvantages
Option 1 - Predictive flood warning and decision support (utilising present gauge network)	• Improved potential lead time (6-12 hours) to provide earlier warning and better inform Council, SES and community of potential flooding; • Range of potential flood prediction outputs to inform emergency decision-making such as predicted lake level timeseries, inundation mapping, flood forecast animations, impending asset flood risk, user-defined ("what-if") scenario flood modelling, etc; • Utilises best available forecast services from Bureau of Meteorology; • Utilises available technology and computer models with fast runtimes; • Inclusion of representative entrance behaviour and ocean conditions to improve flood prediction; • Potential benefits to help inform pre-flood entrance management procedures; • Supports a proactive pre-flood emergency response for Council, SES and Community; • Lower cost option.	• Prediction accuracy subject to rainfall forecast accuracy limitations (including spatial and temporal uncertainty), model assumptions and limitations; • Successful communication and implementation of protective behaviour dependant on strong and effective collaboration between SES, Community and Council.
Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	As per Option 1 with addition of: • Improved rain gauge coverage and redundancy in the Brandaree Creek catchment. • Prediction redundancy utilising rate-of-rise and trigger level based predictions;	As per Option 1 with addition of: • Additional expense to install and maintain new gauge. • Predictions based on rate of rise information and trigger levels are subject to inaccuracies and may not represent prevailing entrance and ocean conditions.
Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works	As per Option 1 & 2 with addition of: • Utilises new technologies to provide innovative realtime entrance berm condition monitoring. • Entrance berm condition monitoring can be undertaken readily and remotely and is not limited by weather conditions, timing constraints or Council staff availability. • Likely benefits to pre-flood entrance management procedures and environmental monitoring.	As per Option 1 & 2 with addition of: • Higher capital and maintenance costs with additional new remote entrance berm monitoring station. • Potential site location limitations and constraints associated with installation of a remote entrance monitoring station.

3.5.3 Preliminary cost estimates

Preliminary cost estimates for the TFWS options at Tabourie Lake are shown in Table 3.37. Cost estimates are preliminary and may vary depending on site constraints for gauge locations and client requirements. Costs include installation of the planned rainfall gauge at Morton (Woodstock / Wheelbarrow Rd).

Table 3.37: Tabourie Lake - Preliminary cost estimates associated with TFWS options

Catchment	Option 1 - Predictive flood warning and decision support (utilising present gauge network)	Option 2 - Predictive flood warning and decision support with priority 1 gauge installation works	Option 3 – Predictive flood warning and decision support with priority 2 gauge installation works
Tabourie Lake	$50,000 - 60,000	$70,000 - 90,000	$90,000 -120,000

***** Costs do not include potential upgrades to existing gauge network to improved flood warning reliability and redundancy, SES fees associated with dissemination of flood warning information, development of detailed flood evacuation and emergency response plans, establishment of Emergency Management Flood Response Arrangements, establishment awareness and training of SES and community.

Maintenance costs for a predictive flood warning system typically range from $5,000 - $15,000 per year. Typical maintenance costs for a rainfall or water level station range from $3,000 - $10,000 per station per year. Flood warning networks with numerous gauges can have high annual maintenance costs to maintain.

3.5.4 Community and stakeholder engagement

This section will be completed following Public Exhibition and Stakeholder feedback of this draft report with the Tabourie Lake community.

3.6 Messaging formats

All options are to adopt communication formats consistent with the Australian Warning System requirements (Australian Institute for Disaster Resilience). This includes three levels of flood warning as shown in Figure 3.6, namely:

- **Advice** - an incident has started. Stay up to date in case the situation changes.
    - Stay informed
    - Monitor conditions
    - Reduced threat: return with caution

- **Watch and Act** - conditions are changing and you need to start taking action now to protect you and your family.
    - Do not enter floodwater
    - Prepare to evacuate
    - Prepare to isolate
    - Avoid the area

- **Emergency Warning** - the highest level of warning. You may be in danger and need to take action immediately.
    - Evacuate now / Evacuate before [time]
    - Shelter now
    - Move to higher ground

Figure 3.6: Three warning levels Australian Warning System

Each warning has three components as shown in Figure 3.7, namely:

- **Location + Hazard:** The location and the type of hazard impacting the community (e.g., Lismore flooding);
- **Action statement:** For each warning level there are a range of action statements to guide protective action by the community. These statements evolve as the warning levels increase in severity. Statements range from ‘stay informed’ at the Advice level, to ‘prepare to evacuate’ at the Watch and Act level, to ‘evacuate now’ in the Emergency Warning level. As the situation changes and the threat is reduced, the level of warning will decrease accordingly; and
- **The warning level:** The severity of the natural hazard event based on the consequence to the community.

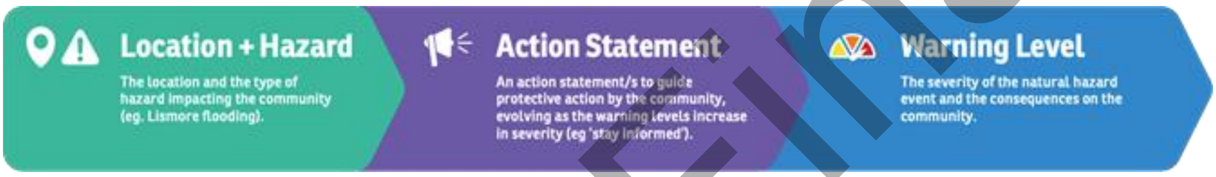


Figure 3.7: Three components of warnings - Australian Warning System

3.7 Roles and Responsibilities

Table 3.38 displays a breakdown of responsibilities for the various components of the TFWS. If Council decides to install additional monitoring infrastructure, they will hold the same responsibilities for that aspect of the TFWS as do MHL for their sites. Further, if any third parties are engaged to provide emergency communications to agencies or residents, they will be responsible for performing due diligence checking of the incoming data, currency of the recipient lists, composition of the messages, sending of those messages, and quality assurance of the methods and contents of all outgoing messaging.

Table 3.38: Assignment of responsibilities associated with TFWS options

✓̲ = Lead stakeholder responsible. ✓= stakeholder involvement

TFWS Component	Stakeholder				
	BoM	DPE EHG	NSW SES	SCC	External Consultant
Monitoring and Prediction					
Flood warning system conceptual design and layout, considering system constraints.		✓	✓	✓	✓̲
Flood warning system detailed design and implementation of preferred approach for each catchment.	✓	✓	✓	✓	✓̲
Nomination of alert thresholds, both real time and forecast/predictive.	✓		✓̲	✓̲	✓
Nomination of warning audience/warning recipients, considering intended response actions to mitigate the effects of the flood.	✓		✓̲	✓	
Maintenance of flood warning system supporting infrastructure including IT systems and platforms.	✓			✓̲	✓
Maintenance of monitoring stations associated with the TFWS.				✓̲	✓
Maintenance and operation of predictive models associated with the TFWS.				✓̲	✓
Testing of the flood warning system; including issuing test alerts to nominated recipients at a regular and defined frequency, and testing forecast/predictive systems.	✓		✓	✓̲	✓
Interpretation					
Interpretation of (near) real time and/or forecast/predicted flood heights at specified locations at particular times, to identify likely consequences within the local area.	✓		✓̲	✓	✓
Development and ongoing review of a detailed flood evacuation plan			✓̲	✓	✓
Initial and ongoing training of use and interpretation of TFWS including decision support tools			✓	✓	✓̲

TFWS Component	Stakeholder				
	BoM	DPE EHG	NSW SES	SCC	External Consultant
Message construction					
Nomination of flood warning system message type, and whether message is automated or semi-automated, considering intended response actions to mitigate the effects of the flood.	✓		✓	✓	
If message is semi-automated, provision of required human support to ensure message delivery.	✓		✓		
Communication					
Integrated alerting system direct from predictive flood modelling and/or gauging.			✓	✓	✓
Incorporation of alerting into procedures for warning messaging for SES to disseminate to community.			✓	✓	✓
SES use pre-defined channels of communication such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.			✓		
Initial and ongoing community awareness and flood emergency and preparedness workshops.			✓		
Protective behaviour					
Determine appropriate Emergency Management Flood Response Arrangements			✓	✓	
Review					
TFWS Review	✓	✓	✓	✓	✓

BoM = Bureau of Meteorology
DPE EHG = NSW Department of Planning and Environment, Environment and Heritage Group
NSW SES = NSW State Emergency Service
SCC = Shoalhaven City Council
External Consultant = TFWS design consultant

4 Conclusions and recommendations

This report summarises outcomes of Stages 1 to 3 of the Shoalhaven ICOLL Catchments Flash Flood Warning System Scoping Study including review of background information, initial community/stakeholder questionnaire findings, and development of fit-for-purpose TFWS preliminary options.

The review of previous flood studies outlines the present and future flood risk of low-lying settlements in the Lake Conjola, Burrill Lake and Tabourie Lake catchment areas. Key flood information has been summarised from the study areas to help inform development of trigger levels for warnings and flood levels for key assets. This information for each catchment shall be reviewed in subsequent project stages during the detailing of a preferred flood warning system.

In all floodplain risk management studies, the fundamental importance of successful implementation of a Total Flood Warning System is noted as a priority action to reduce risk to life during flood events. These previous studies have been undertaken with extensive community consultation. Existing flood warning arrangements are noted to provide insufficient warning time to the SES, Council and community during flood events.

Preliminary fit-for-purpose flood warning system options have been developed based on multi-criteria analysis of a range of component design options. A preferred flood warning system option for each catchment is to be selected in consultation with Council, SES, the Bureau, DPE EHG, and the community.

It is recommended that a predictive flood warning and decision support with priority 1 gauge installation works (Option 2) be considered for the initial development of TFWS design. Components of this option are outlined in Table 4.1 for the Lake Conjola, Burrill Lake and Lake Tabourie catchment areas. Under this approach, predictive flood warning and decision support (Option 1) is to provide the minimal basis for flood warning in each catchment and additional TFWS gauging is undertaken as required to support more robust flood warning operation.

Detailed development of a preferred flood warning system option for each catchment is to be undertaken in subsequent stages. Emergency Management Flood Response Arrangements are to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS for these catchments.

Although not noted in previous floodplain risk management studies, development of a flood warning system and improved lake level intelligence in each of these catchments may also have potential benefits to help inform pre-flood entrance management procedures which is outside the scope of the present study.

Table 4.1: Recommended flood warning system preliminary options

Catchment	Recommended TFWS option for initial development	Monitoring	Prediction	Interpretation	Message construction	Communication	Protective behaviour
Lake Conjola	**Option 2** - Predictive flood warning and decision support with priority 1 gauge installation works	Maintain operation of existing rain and water level gauge network with the following: • M.1 Additional automatic water level station upstream at Conjola Creek Princes Hwy • M.3 Integrate entrance channel data from latest Council surveys and Lake Conjola M2 tidal analysis; • M.5 Integrate ocean wave and tide data.	Realtime flood level predictions using: • P.2 Realtime; hydrology modelling • P.4 Realtime simplified lake hydraulic modelling; • P.5 Bureau rainfall forecast services (Rainfields and Meteye); • P.6 Entrance channel predictions; • P.7 Ocean water level predictions. • P.1 Rate-of-rise and trigger level based predictions (as backup prediction mechanism)	• I.1 Trigger levels for known flood impacts; • I.2 Detailed flood evacuation plan; • I.3 Web based system to provide tailored decision support.	*To be determined during next phase of detailed flood warning system design*	• C.1 Integrated alerting system based on gauge trigger levels to Council & SES; • C.2 Integrated alerting system based on predictive flood modelling to Council & SES; • C.3 Tie automated alerting into procedures for warning messaging for SES to disseminate to community; • C.5 Flood warning message dissemination via a range of mechanisms such as SMS, radio, door knocking (where possible), phone calls, social media, SES website, Council's Disaster Dashboard webpage and Hazards Near Me app.	*Emergency Management Flood Response Arrangements to be identified by the NSW SES following the completion of this project and potential implementation of a TFWS.*
Burrill Lake	**Option 2** - Predictive flood warning and decision support with priority 1 gauge installation works	Maintain operation of existing rain and water level gauge network with the following: • M.1 Additional automatic water level station upstream at Stony Creek Woodstock R; • M.2 Additional automatic rainfall station upstream at Stony Creek Woodstock Rd; • M.4 Integrate entrance channel data from latest Council surveys; • M.6 Integrate ocean wave and tide data.					
Tabourie Lake	**Option 2** - Predictive flood warning and decision support with priority 1 gauge installation works	Maintain operation of existing rain and water level gauge network with the following: • M.2 Additional automatic rainfall station upstream at Brandaree Creek (TBC); • M.3 Integrate entrance channel data from latest Council surveys; • M.5 Integrate ocean wave and tide data.					

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Appendix A Community Survey Results Summary

ICOLL Flash Flood Warning System Scoping Study
Lake Conjola, Burrill Lake and Tabourie Lake
Community Questionnaire

Background

Shoalhaven City Council (Council) has engaged a contractor, Manly Hydraulics Laboratory (MHL), to assist with the preparation of the Intermittently Closed and Open Lake and Lagoon (ICOLL) Catchments Flash Flood Warning System Scoping Study. The study will scope the requirements for a fit for purpose location-based flash flood warning system for the three catchments of Burrill Lake, Lake Conjola and Tabourie Lake to improve the flood warning and evacuation capabilities within the townships in these areas.

Measures to improve flood warning and response through the implementation of a Flood Warning System were identified and adopted for implementation in the individual Floodplain Risk Management Study & Plans (FRMS&P) for each catchment. It was recommended as a suitable measure to reduce flood impacts and the risk to life within these catchments.

Council was successful in receiving grant funding from the Australian Government through the National Recovery and Resilience Agency's Preparing Australian Communities Program – Local Stream to undertake this study to progress the adopted flood mitigation measures. The study will be undertaken in accordance with the NSW Flood Prone Land Policy and in close collaboration with the NSW State Emergency Services (SES), the NSW Department of Planning and Environment (DPE), and other agencies and stakeholders as required.

Project Objectives

The primary objectives of this study are to scope the requirements and determine feasible options for the implementation of a fit for purpose location-based flash flood warning system for the three catchments of Burrill Lake, Lake Conjola and Tabourie Lake to improve the flood warning and evacuation capabilities within the townships in these areas.

We value your feedback!

We would greatly value any feedback from the community as we commence investigating flash flood warning system options for Burrill Lake, Lake Conjola and Tabourie Lake.

This questionnaire is voluntary. If you wish to complete it, it should take approximately 10 minutes. All information provided will be kept confidential and used for the purpose of the study.

For more information about the study and how you can get involved please visit:

https://getinvolved.shoalhaven.nsw.gov.au/icoll-catchments-flash-flood-warning-system-scoping-study

1. **In what location is flood warning information most important to you? (tick all options that apply)**

- ☐ **Lake Conjola**
- ☐ **Burrill Lake**
- ☐ **Tabourie Lake**

2. **What is the street address of your property**

☐

3. **How would you classify your property? (tick all that apply)**

- ☐ **Residential: Rented**
- ☐ **Residential: Owner-occupied**
- ☐ **Residential: Holiday house**
- ☐ **Caravan park owner**
- ☐ **Used for agricultural, business or commercial purposes**
- ☐ **Other (please specify)**

☐

4. **How would you describe the main buildings (e.g., those primarily used, home) on your property? (tick all that apply)**

- ☐ **Two storeys or more**
- ☐ **Raised more than one metre above ground**
- ☐ **Single storey on the ground**
- ☐ **Other (please specify)**

☐

5. **How long have you lived at this address?**

○ **Less than 1 year**

○ **1 to 5 years**

○ **5 to 10 years**

○ **More than 10 years**

○ **Other (please specify)**

6. **How many people live on the property?**

7. **Is there anyone in your household who: (tick all that apply)**

☐ **Require care (e.g. infants, elderly or has a disability)**

☐ **Requires assistance with speaking or reading English**

☐ **None of the above**

8. **In your opinion, what is the risk of flooding to the main buildings (e.g., those primarily used, home) on your property (tick one answer)**

○ **No risk**

○ **Low risk**

○ **Moderate risk**

○ **High risk**

9. **In your opinion, what is the risk of flooding to your property (e.g., land, backyard, frontyard, driveway etc.) (tick one answer)**

- ○ **No risk**
- ○ **Low risk**
- ○ **Moderate risk**
- ○ **High risk**

10. **In your opinion, what is the risk of flooding to your safety (tick one answer)**

- ○ **No risk**
- ○ **Low risk**
- ○ **Moderate risk**
- ○ **High Risk**

11. **Do you think your property may be flooded sometime in the future? (tick one answer)**

- ○ **No**
- ○ **Yes, but only a small part part of my yard/outdoor area**
- ○ **Yes, most of my yard/outdoor area**
- ○ **Yes, my house/office/business could flood over the floor**

12. **Have you ever lived at the property during a flood?**

- ○ **Yes**
- ○ **No**

13. **Out of ten, how would you rate your level of preparedness for flooding?**

0 - Totally unprepared **10 - Very well prepared** ☐

14. **Do you have a flood emergency plan for your home?**

○ **Yes**

○ **No**

15. **If a flood occurred tomorrow, how well do you think you could keep yourself and others in your home safe? (tick one answer)**

○ **Not well**

○ **Fairly well**

○ **Very well**

16. **If your street started to flood, would you help others?**

○ **Yes**

○ **No**

○ **If yes, who would you help?**

☐

17. **If your street started to flood, would you need help from others?**

○ **Yes**

○ **No**

○ **If yes, who would help you?**

☐

18. **How would you learn more about what to do before, during and after a flood? (tick all that apply)**

- ☐ **Community or cultural group**
- ☐ **SES website**
- ☐ **Council website**
- ☐ **Family and friends**
- ☐ **Newspaper**
- ☐ **Speak with the SES in person**
- ☐ **Neighbours**
- ☐ **Social media e.g. Facebook, Twitter**
- ☐ **Speak with Council in person**
- ☐ **Television**
- ☐ **Flood meeting or forum**
- ☐ **Radio**
- ☐ **Police**
- ☐ **Youtube**
- ☐ **Google search**
- ☐ **Other (please specify)**

* 19. **What is your preferred way to receive flood warning messages (Please tick all preferred options)?**

- ☐ **Door knocking**
- ☐ **Social media alerts**
- ☐ **Phone calls**
- ☐ **SMS messages**
- ☐ **Radio messages**
- ☐ **Siren**
- ☐ **Automated Road Signage**
- ☐ **Flood Warning Phone App**
- ☐ **Other (please specify)**

20. **In your opinion, what is the best way(s) to warn your community about imminent flooding?**

21. **Do you have any other comments, questions, or concerns regarding a flood warning system for the community?**

22. If you wish to stay informed about this study, please provide your preferred contact method below

Name:

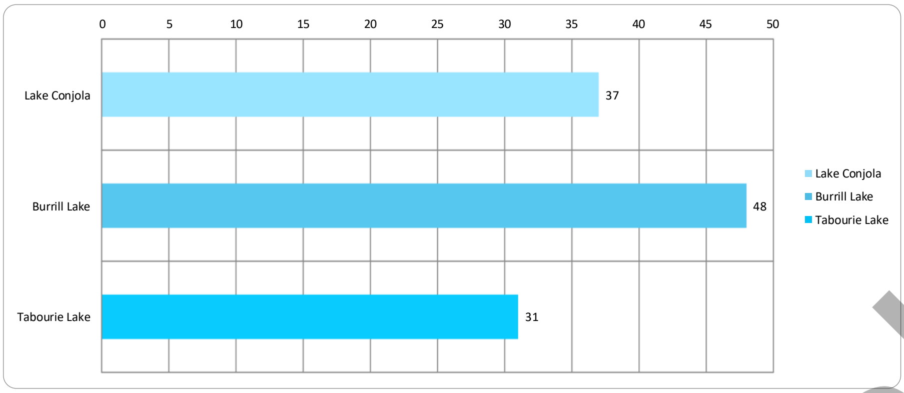
Address:

Telephone/ Mobile:

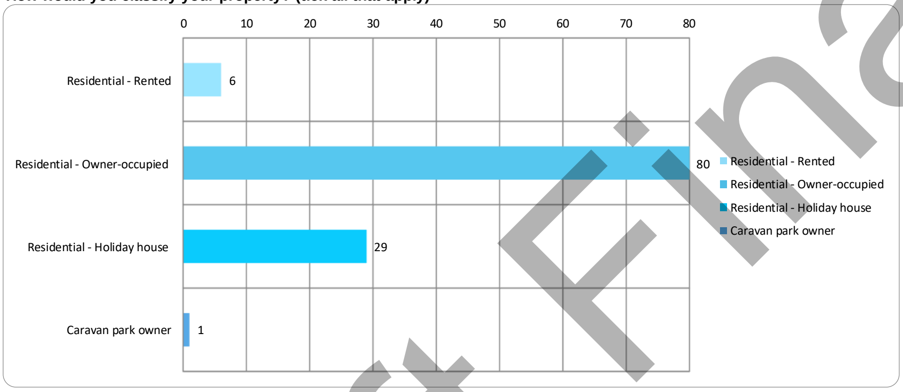
Email:

A.1 Community Survey Results Summary

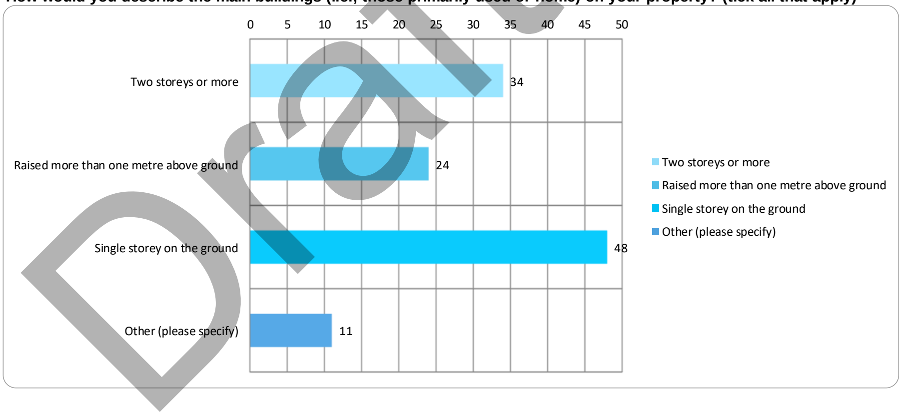
In what location is flood warning information most important to you? (tick all that apply)



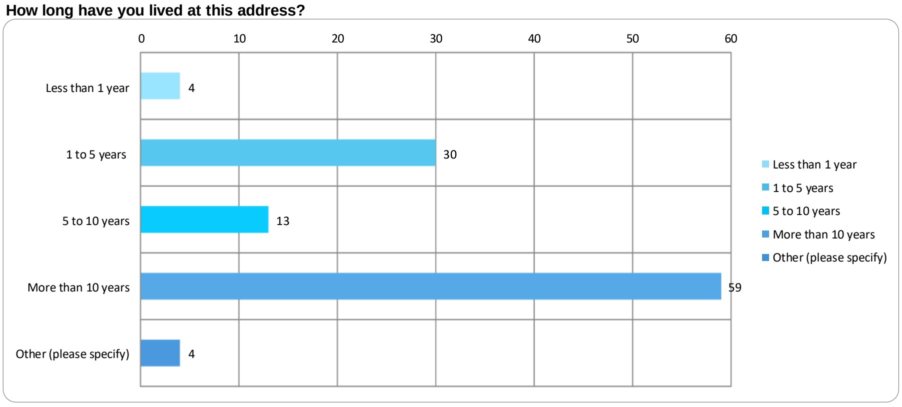
How would you classify your property? (tick all that apply)



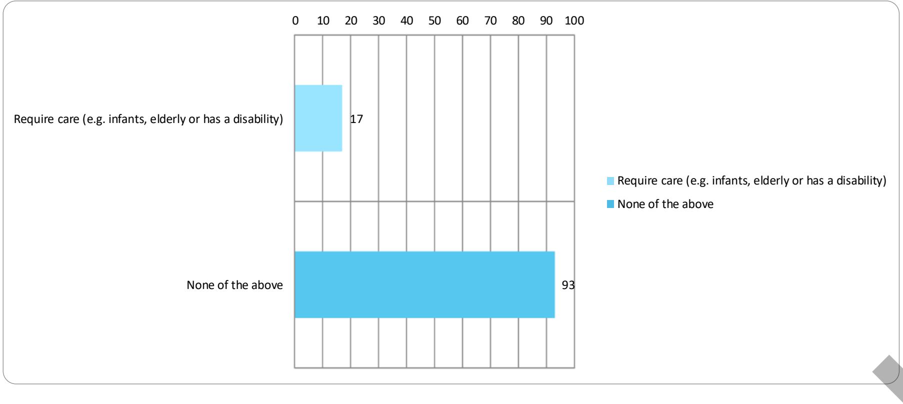
How would you describe the main buildings (i.e., those primarily used or home) on your property? (tick all that apply)



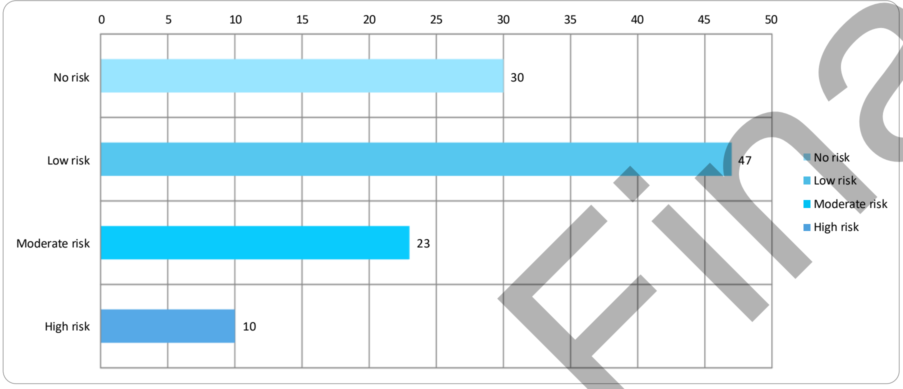
How long have you lived at this address?



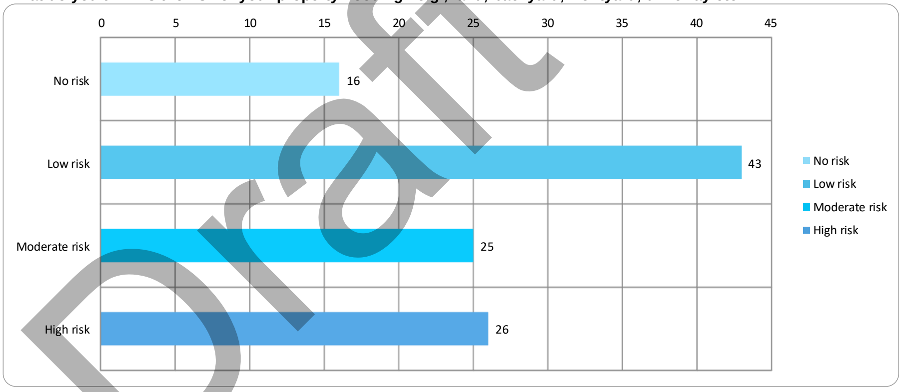
Is there anyone in your household who: (tick all that apply)



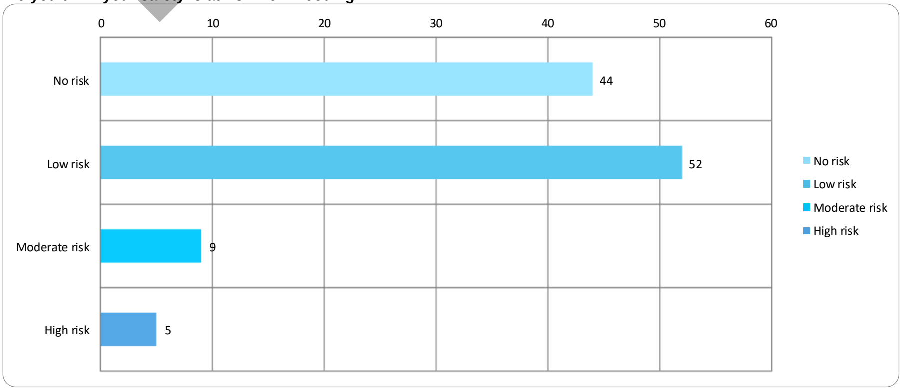
What do you think is the risk of flooding to the main buildings on your property? e.g., those primarily used, home



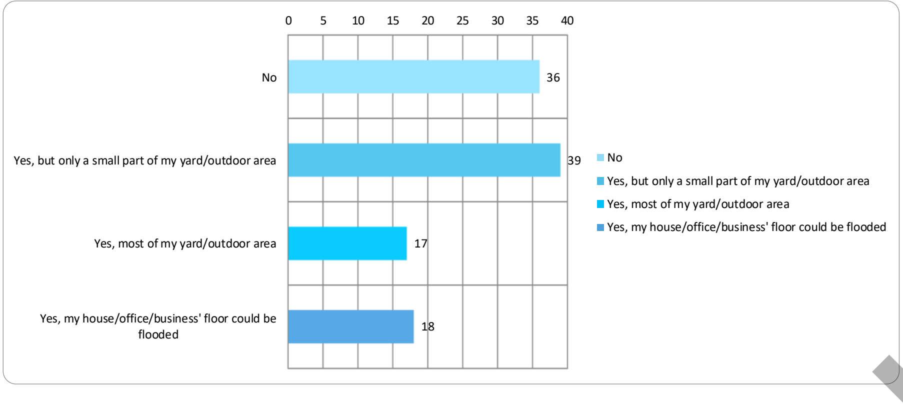
What do you think is the risk of your property flooding? e.g., land, backyard, frontyard, driveway etc.



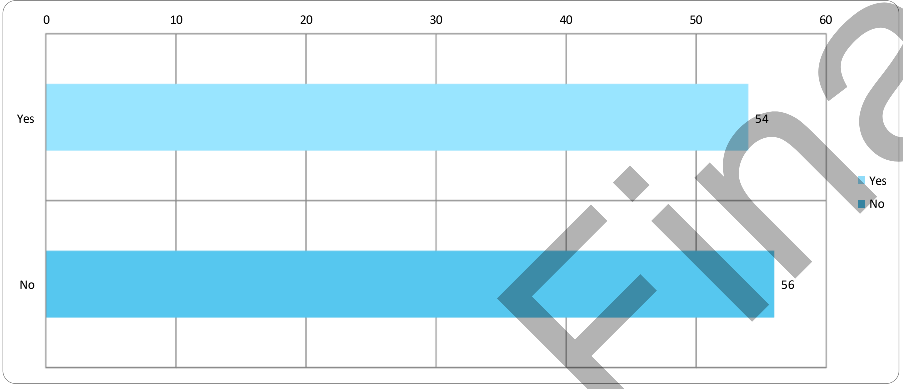
Do you think your safety is at risk from flooding?



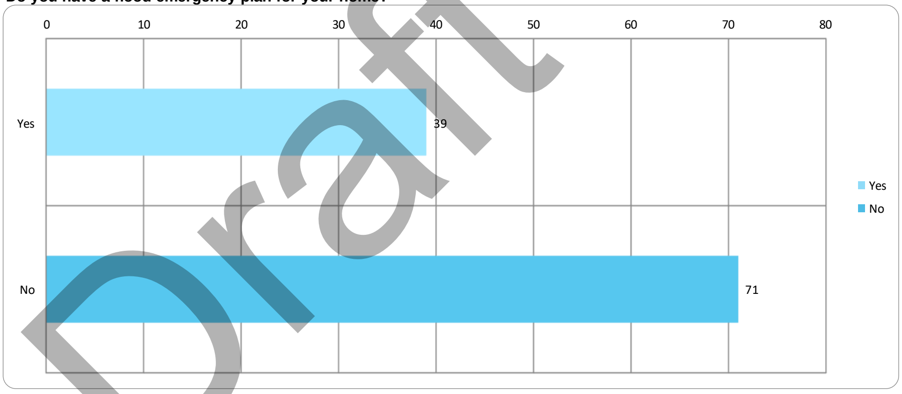
Do you think your property may be flooded in the future?



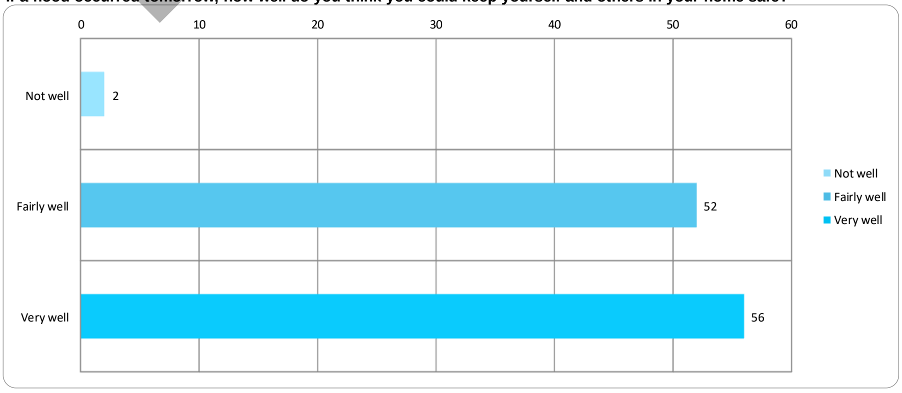
Have you ever lived at the property during a flood?



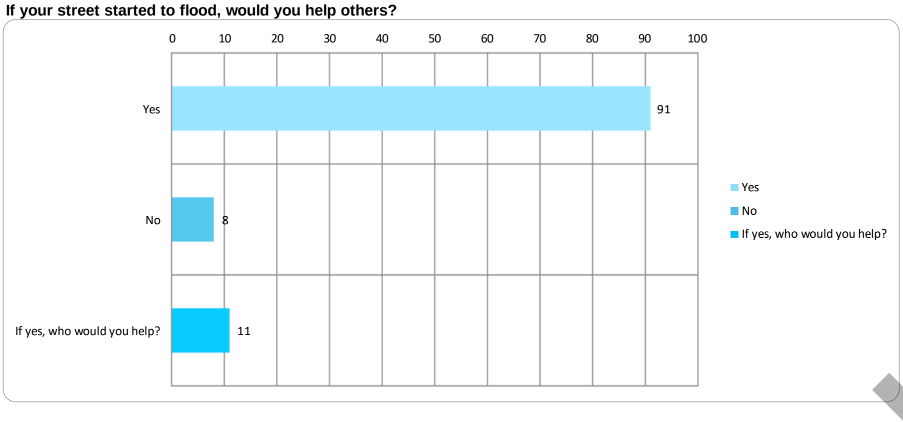
Do you have a flood emergency plan for your home?



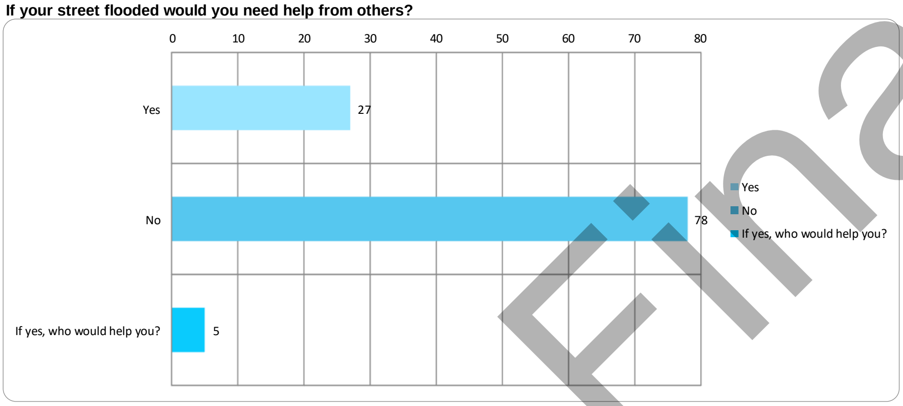
If a flood occurred tomorrow, how well do you think you could keep yourself and others in your home safe?



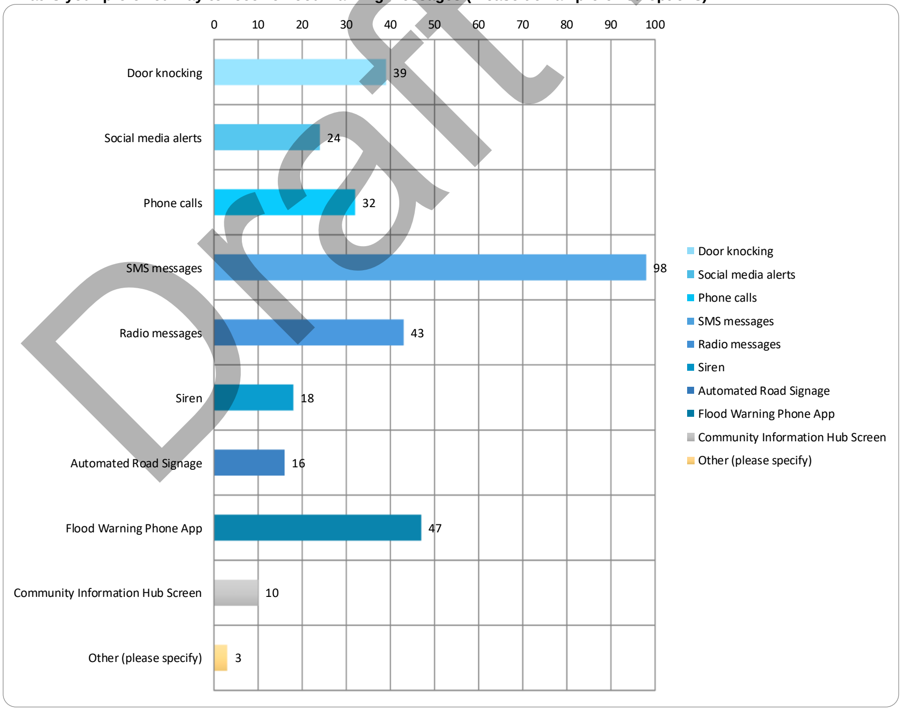
If your street started to flood, would you help others?



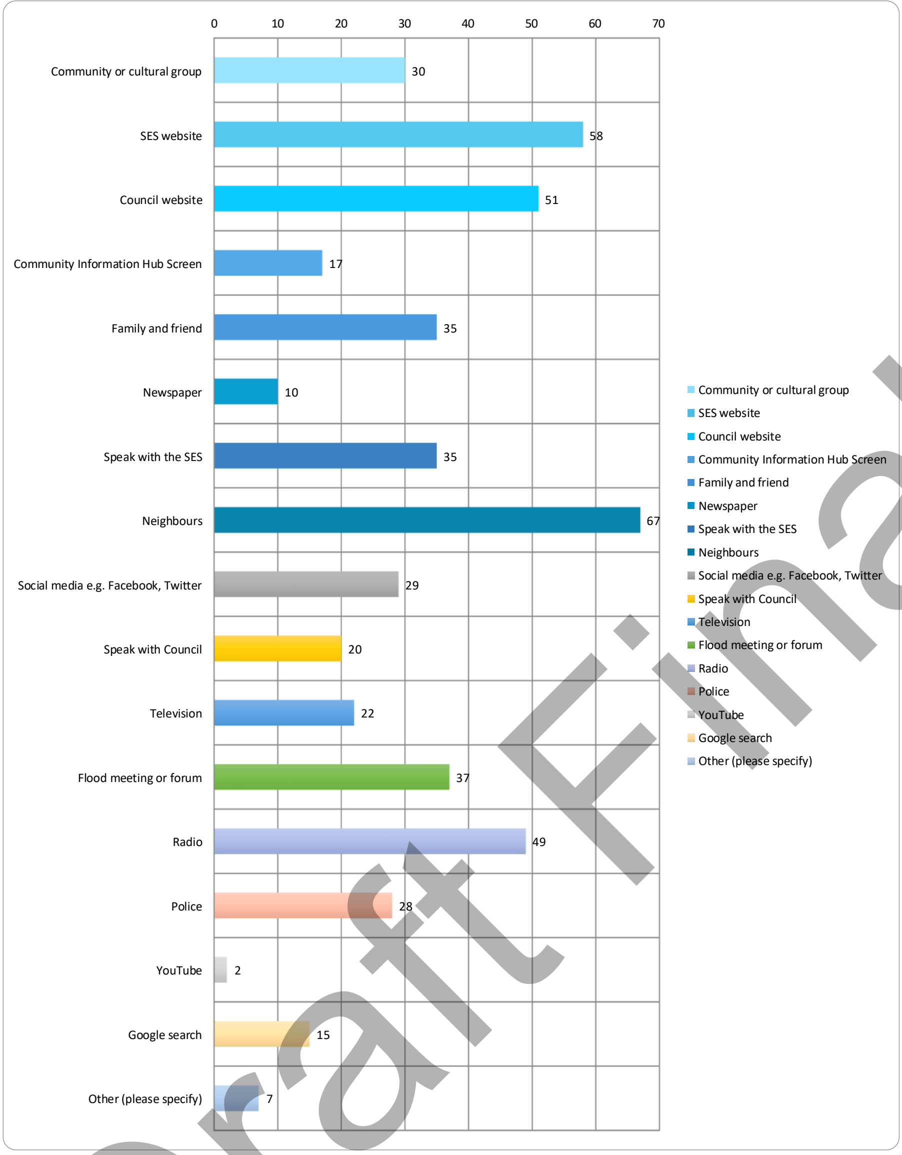
If your street flooded would you need help from others?



What is your preferred way to receive flood warning messages (Please tick all preferred options)?



How would you learn more about what to do before, during and after a flood? (tick all that apply)



Appendix B Stakeholder Survey

ICOLL Flash Flood Warning System Scoping Study

Lake Conjola, Burrill Lake and Tabourie Lake

Stakeholder Questionnaire

Background

Shoalhaven City Council (Council) has engaged a contractor, Manly Hydraulics Laboratory (MHL), to assist with the preparation of the Intermittently Closed and Open Lake and Lagoon (ICOLL) Catchments Flash Flood Warning System Scoping Study. The study will scope the requirements for a fit for purpose location-based flash flood warning system for the three catchments of Burrill Lake, Lake Conjola and Tabourie Lake to improve the flood warning and evacuation capabilities within the townships in these areas.

Measures to improve flood warning and response through the implementation of a Flood Warning System were identified and adopted for implementation in the individual Floodplain Risk Management Study & Plans (FRMS&P) for each catchment. It was recommended as a suitable measure to reduce flood impacts and the risk to life within these catchments.

Council was successful in receiving grant funding from the Australian Government through the National Recovery and Resilience Agency's Preparing Australian Communities Program – Local Stream to undertake this study to progress the adopted flood mitigation measures. The study will be undertaken in accordance with the NSW Flood Prone Land Policy and in close collaboration with the NSW State Emergency Services (SES), the NSW Department of Planning and Environment (DPE), and other agencies and stakeholders as required.

Project Objectives

The primary objectives of this study are to scope the requirements and determine feasible options for the implementation of a fit for purpose location-based flash flood warning system for the three catchments of Burrill Lake, Lake Conjola and Tabourie Lake to improve the flood warning and evacuation capabilities within the townships in these areas.

We value your feedback!

We would greatly value any feedback from our key stakeholders as we commence investigating flash flood warning system options for Burrill Lake, Lake Conjola and Tabourie Lake.

Please complete the questionnaire below. This takes approximately 10 minutes to complete. All information provided will be kept confidential and used for the purpose of the study.

We look forward to working with you over the course of the project.

1. **Contact Information (This will only be used to complete the scoping study)**

Name:

Position/ Role:

Company:

Telephone/ Mobile:

Email:

2. **In what location is flood warning information most important to you? (tick all options that apply)**

☐ **Lake Conjola**

☐ **Burrill Lake**

☐ **Tabourie Lake**

3. **How does flood warning information help to support your position or role? Please specify any key decisions in your role that rely upon flood warning information.**

4. **What flood warning information would help support your position or role?**

5. **What format would you prefer to receive flood warning alerts or information? (please tick all that apply)**

- ☐ **SMS message**
- ☐ **Email message**
- ☐ **Flood warning system web portal for Council and SES with real-time flood information**
- ☐ **Mobile phone or tablet flood warning app**
- ☐ **Phone call**
- ☐ **Face-to-face communication**
- ☐ **Other (please specify)**

6. **What measures or initiatives would you like to see as part of a total flood warning system in the Shoalhaven ICOLL catchments?**

7. **Do you have any other comments, questions, or concerns regarding a total flood warning system for the Shoalhaven ICOLL catchments?**

8. Please keep me informed of stakeholder engagement activities over the course of the scoping study

- ☐ **Yes**
- ☐ **No**

Manly Hydraulics Laboratory

110B King Street

Manly Vale NSW 2093