APPENDIX A

Site Inspection Details

Rocky Hall
Community Hall and Fire Shed located close to river bank but elevated. No farm houses or structures appeared to be at risk of flooding. Big Jack Mountain Rd near Stockyard Creek set low, likely to get overtopped in large flood. Inspected new bridge at Stockyard Creek and low level crossing at Orchard Rd.

Wyndham
Houses wiithin the township set at higher elevations than Creek. Mount Darragh Rd Bridge over Mataganah Creek represent downstream hydraulic control.

New Buildings
RMS currently doing maintenance work on bridge. River bed wide and sandy at this location. Some locations along New Buildings Road may be inundated during large floods. No other structures or buildings appears to be at risk of flooding.

Burragate
Debris from previous floods along river bank noted at low level crossing.
Inspections of overland flow paths at Burragate Road were inspected. Council advised of overland flooding issues associated with one particular property.

Eden and Lake Curalo
Flow paths were noted as generally well defined, with flow accumulating in small creeks which were piped in some locations, leading to flood risk when capacity of pipes exceeded.
Some development very close to waterways (e.g. commercial properties on Government Road).
Dense vegetation noted in most waterways.
Cocora Lagoon entrance closed at time of inspections.

Shadrachs Creek
Estuary entrance was closed at time of inspections. Creek bank erosion noted along caravan park. Princes Highway bridge high above creek level. No flood risk identified upstream of Princes Highway.

Towamba
Buildings on lefthand bank appear to be set on the fringe of the floodplain.
Buildings within the township generally located outside of the floodplain.
Significant sand deposits noted in River bed.
Low point at Pericoe Rd crossing of Bens Creek appears to be at risk of flooding from Towamba River and local flows within Bens Creek.
Dense vegetation noted within the riparian areas.

Nullica River
Wide sandy entrance to river, open at time of inspections. No flood risk to Prinec Highway or approaches. Low level timber crossing of tributary on Nullica Short Cut Road.

Boydtown
Low lying area around Seahorse Inn could be at risk from coastal flooding.
Boydtown Creek entrance to Twofold Bay closed at time of inspection. Significant vegetation noted growing in berm.
Residential dwellings along southern side of creek appear to be located above the floodplain. May be issues associated with flooding of Juno Drive.

N
W E
S

Figure A1
Site Inspections
4 - 6 October 2017

Legend

- Detailed Inspections

Scale : 1:123000@A3
Date : January 2018
Revision : A
Created by : ERM
Coordinate System : Map Grid of Australia 94

Rhelm

APPENDIX B

Rainfall and Flow Data

Rainfall Data

There is an extensive network of rainfall gauges (current and discontinued) across the study area operated by the Bureau of Meteorology (BoM). A list of gauges for the area surrounding the catchment is shown in **Table B1,** together with key information on whether they are pluviometer or daily gauges. The suitability of these gauges for use in calibrating / validating the identified historical storms is shown in **Table B2**. The locations of these gauges are shown in **Map 304**.

Further discussion on recorded rainfall data for historical events is presented with the calibration and validation of the models developed for the study in **Section 5.5**.

The Wyndham gauge within the catchment area has an extensive daily record of rainfall depths, covering 128 years, and including the 2011 event.

Table B1 Bureau of Meteorology Rain Gauges

ID	Station Name	Commenced	Closed	Daily	Pluvio
69009	Boyd East State Forest	1938	31-Dec-46	Y	
69011	Wyndham (Nyumbani)	1960	1-Jun-2010	Y	
69066	Wyndham (Post Office)	1890	Ongoing	Y	
69012	Burragate Post Office	1900	31-Dec-74	Y	
69015	Eden (Marine Rescue)	1869	Ongoing	Y	Y (1965 – 1966)
69019	Cathcart (mount Darragh)	1924	Ongoing	Y	
69026	Rocky Hall Post Office	1890	31-Dec-76	Y	
69055	Green Cape Light House	1967	1-May-2002	Y	Y (1967 - 2002
69057	Towamba Lower	1962	31-Dec-74	Y	
69066	Wyndham Post Office	1890	Ongoing	Y	Y (1993 – 2013)
69073	Towamba (Nungatta St)	1976	Ongoing	Y	
69078	Nethercote	1902	31-Dec-43	Y	
69080	Towamba (Pericoe)	1897	31-Dec-71	Y	
69096	Eden (Chip Mill)	1971	31-Dec-74	Y	
69109	Boyd East (Edrom)	1947	31-Dec-47	Y	
69137	Green Cape Aws	2002	1-Oct-2012	Y	Y (2002-2012)
69152	Cathcart (Mount Darragh)	1995	Ongoing	Y	
70106	Cathcart (old Post Office)	1899	Ongoing	Y	
70167	Rockton (wog Wog)	1963	31-Dec-69	Y	

Table B2 Operation of BoM Gauge Data for Identified Historical Events

ID	Name	Pluvio	Historical Events						
			Jun-2016	Mar-2011	Feb-2010	Jun-1998	Jun-1978	Feb-1971	Mar-1919
69009	Boyd East State Forest		No	No	No	No	No	No	No
69011	Wyndham (Nyumbani)		No	No	Yes	Yes	Yes	Yes	No

69012	Burragate Post Office		No	No	No	No	No	Yes	No
69015	Eden (Marine Rescue)	Yes (1965 to 1966)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
69019	Cathcart (mount Darragh)		Yes	Yes	Yes	Yes	Yes	Yes	No
69026	Rocky Hall Post Office		No	No	No	No	No	Yes	No
69055	Green Cape Light House	Yes (1967 to 2002)	No	No	No	Yes	Yes	Yes	No
69057	Towamba Lower		No	No	No	No	No	Yes	No
69066	Wyndham Post Office	Yes (1993 to 2013)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
69073	Towamba (Nungatta St)		Yes	Yes	Yes	Yes	Yes	Yes	No
69078	Nethercote		No	No	No	No	No	No	No
69080	Towamba (Pericoe)		No	No	No	No	No	Yes	No
69096	Eden (Chip Mill)		No	No	No	No	No	Yes	No
69109	Boyd East (Edrom)		No	No	No	No	No	No	No
69137	Green Cape Aws	Yes (2002 to 2012)	No	Yes	Yes	No	No	No	No
69152	Cathcart (Mount Darragh)		Yes	Yes	Yes	Yes	No	No	No
70106	Cathcart (old Post Office)		Yes	Yes	Yes	Yes	Yes	Yes	Yes
70167	Rockton (Wog Wog)		No	No	No	No	No	No	No

A frequency assessment was undertaken on the 24-hour rainfall totals for the Wyndham gauge to determine estimates of the 24-hour rainfall intensities for a range of recurrence intervals. Peak annual maxima were extracted from each gauge, with these peaks put through the TUFLOW FLIKE software which generates a probability curve for the data.

The estimates derived from FLIKE were then compared to both the ARR2016 and ARR87 24-hour rainfall intensities. The results are shown in **Figure B1** and summarised in **Table B3**.

Table B3 24-hour rainfall intensity comparison at Wyndham Gauge (mm)

AEP	FLIKE Estimate	FLIKE Confidence Limits	ARR2016	ARR87
10% AEP	184	169 – 201	183	195
5% AEP	215	196 – 239	218	232
2% AEP	255	229 – 289	268	286
1% AEP	285	252 – 329	309	326

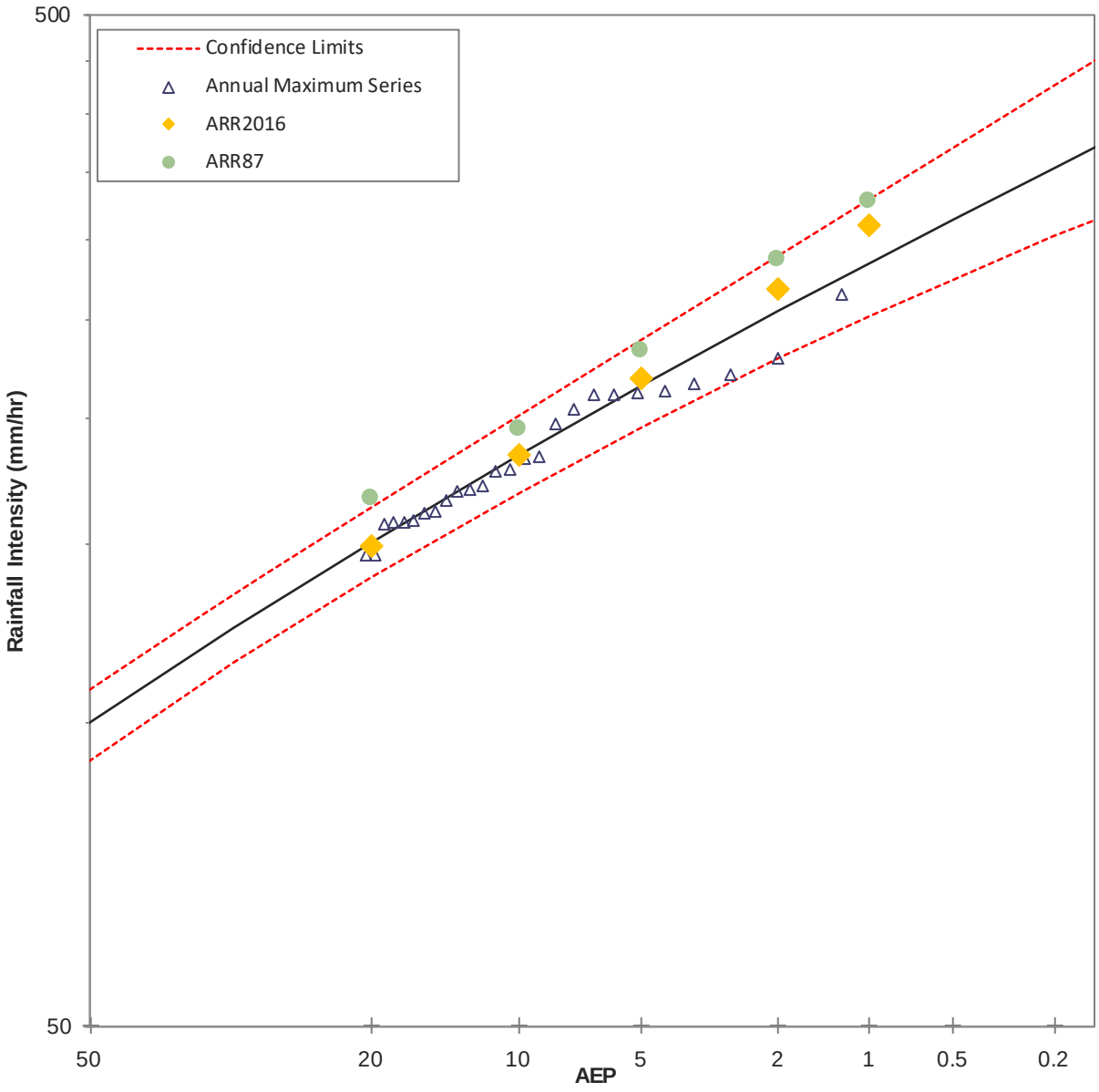


Figure B1 Wyndham 24-hour rainfall intensity probability plot

The results show that the estimates from both ARR2016 and ARR87 align well with the estimates from the probability assessment and are within the confidence intervals. The ARR2016 intensities show a better match, trending closer to the FLIKE estimate. The ARR87 intensities were higher than the 2016 estimates by 5 – 10%.

This assessment provides some confidence in the rainfall intensities adopted from ARR2016. However, it is also likely that given the rainfall record, that the ARR2016 rainfall intensities were based on rainfall data from Wyndham.

Flow Data

There are three flow gauges within the catchment (both active and discontinued). There is an active flow gauge on the Towamba River at Towamba (ID 220004). This gauge has been in operation from April 1970 and covers the full set of identified historical events, save March 1919.

Water for NSW provided further data for two closed gauging stations at New Buildings and Rocky Hall. These gauges provided flow data for the 1971 and 1978 events.

No other suitable gauges were identified in the catchment. There is no flow data for Eden or the other catchments draining into Twofold Bay.

The gauge data provided included both water level and flow time series. The gauge itself records water levels, with the flow data being generated from these level recordings based on the rating curve of the gauge. While the water level recordings are considered relatively robust (unless noted in the gauge data) the flow data requires calibration and validation of the rating curve, which requires operators to visit the gauge during flood events to record the flows, and to extrapolate estimates to flows above those observed. As such, there is much more confidence in the lower "gauged" flows, than in the higher, given that it is uncommon for operators to visit the gauges during extreme flood events. Each gauge includes the level to which it has been validated. Beyond this, flows are extrapolated, and estimates are less reliable.

An initial flood frequency analysis (FFA) was undertaken for each of the three gauges. The assessment was undertaken using the TUFLOW FLIKE software, which fits a probability curve to the gauge flows to determine flow estimates for various recurrence intervals.

The results of the FFA are presented in **Table 3-9**. The table demonstrates that the 1% AEP levels are significantly above the gauged level. Further, Rocky Hall for example has higher flows at the 1% AEP than New Buildings, even though the catchment is significantly smaller than the New Buildings catchment.

Table B4 Flow Gauge Heights

Location	Maximum Gauge Level (m)	1% AEP Level from FFA (m)
Towamba	2.069	8.88
New Buildings	1.845	3.91
Rocky Hall	0.85	3.55

Table B5 Initial FFA Design Flow Estimates

AEP	Towamba (m^3/s)	New Buildings (m^3/s)	Rocky Hall (m^3/s)
10% AEP	1,955	475	274
5% AEP	2,672	609	505
2% AEP	3,437	746	993
1% AEP	3,873	823	1,546

Based on the relatively low maximum gauge level relative to the 1% AEP level, the rating curves of the gauges was reviewed.

The rating curves for each gauge were revised based on a Manning's formula.

For the Rocky Hall gauge and the Towamba gauge, the river cross sections at the gauge location were included in the gauge data set provided by the Water for NSW. For New Buildings, a cross section at the gauge was extracted from the drone survey undertaken for this project.

River channel slopes were determined from the available satellite terrain or survey (for New Buildings), by determining the fall in the river from 50m upstream of the gauge to 50m downstream.

Manning's roughness values were determined based on aerial photography and site photography.

As noted above, the gauges have a height level to which they have been validated, and for which flow estimates can be considered reasonable. In order to ensure that the Manning's values adopted were suitable, the calculations were checked against the flows at this level. Roughness values were then adjusted to ensure that the flows were generated similar to the gauge. This ensures that the suitable portion of the rating curve is retained, and also provides a measure of calibration by ensuring that the roughness values adopted generate appropriate discharges.

Once the roughness values had been calibrated for lower flows, a revised rating curve was established for the higher flows estimating the roughness for the banks and sides of the channel. These new rating curves, as well as the previous, original curves, are shown in **Figures B2** to **B4**.

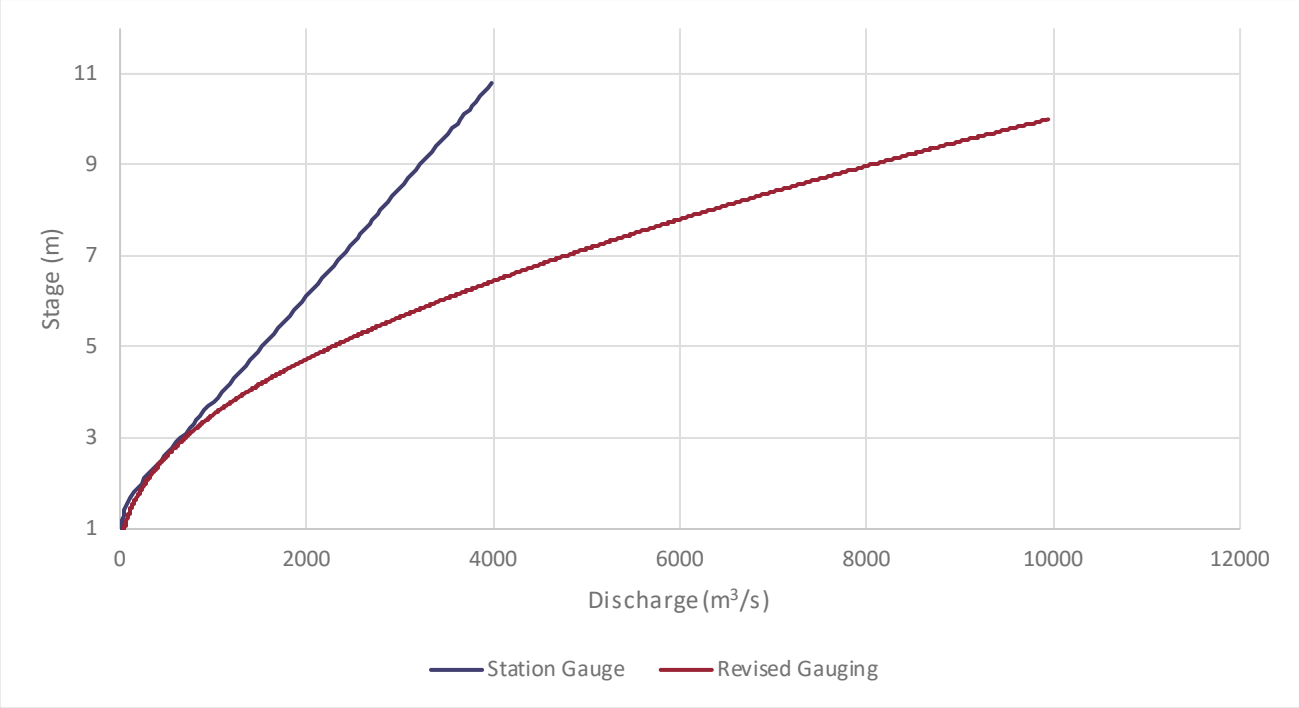


Figure B2 Towamba Rating Curves

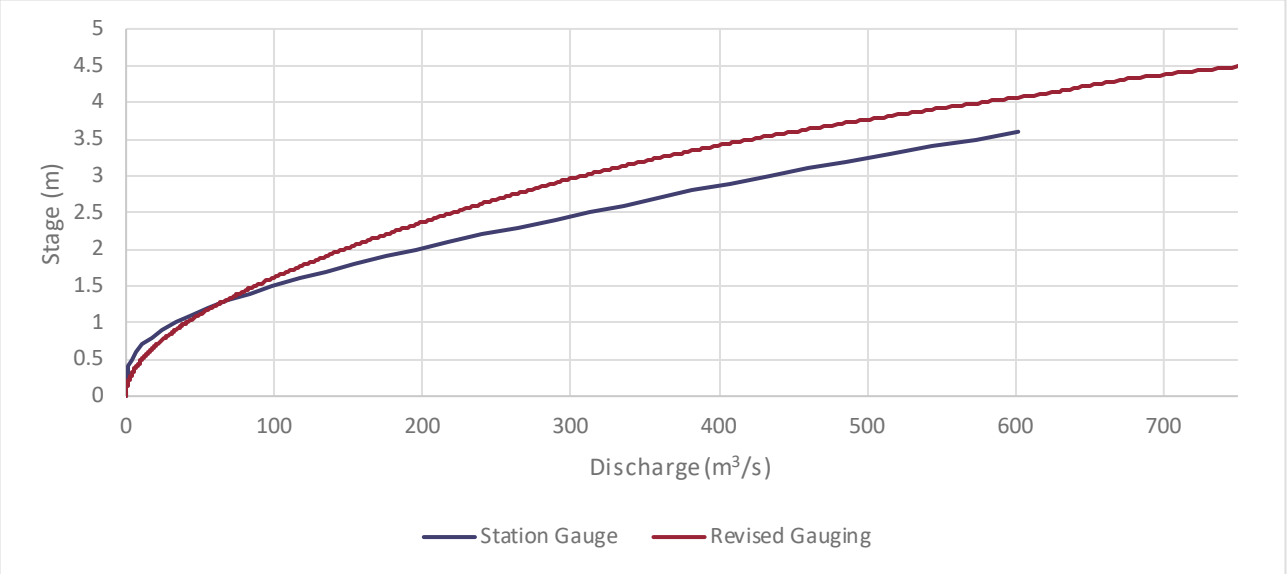


Figure B3 New Buildings Rating Curves

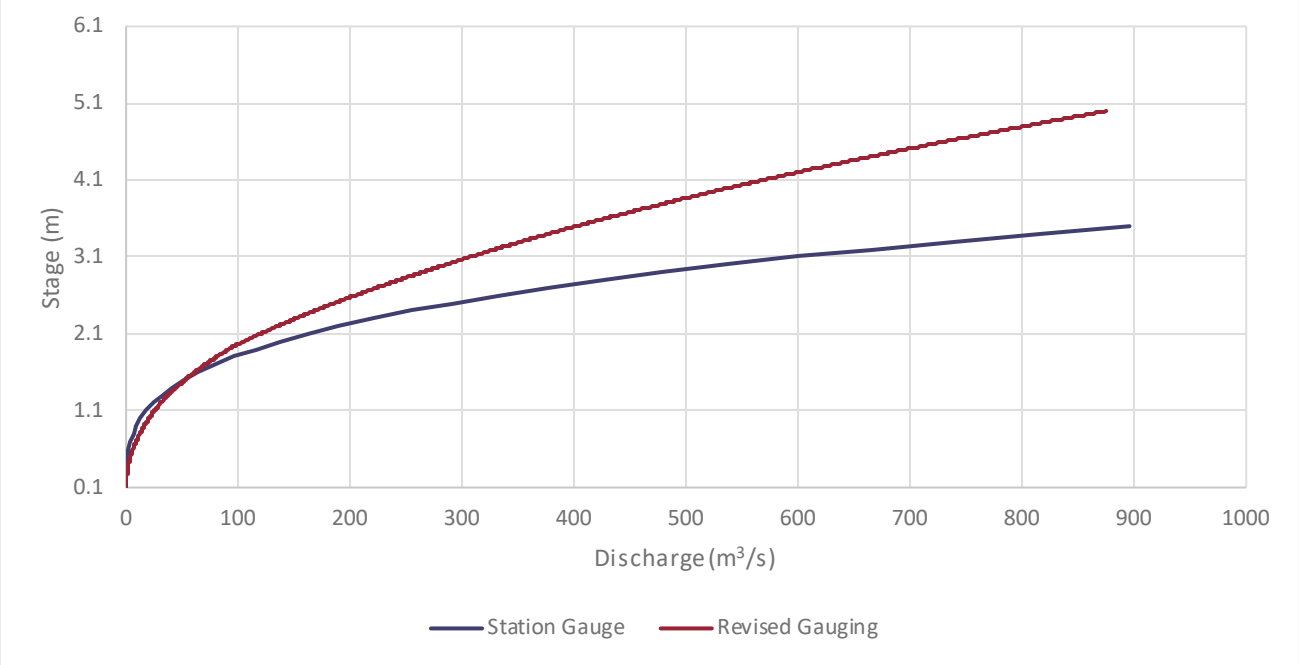


Figure B4 Rocky Hall Rating Curves

It can be seen that there were varying degrees of difference for the gauges.

Both the New Buildings and Rocky Hall gauges were revised downwards, such that lower flows are now estimated for a given level. It is interesting to note that Rocky Hall saw the greatest reduction given that the initial FFA appeared to be overestimating gauge flows at Rocky Hall.

The Towamba gauge had the largest change, resulting in significantly higher flows being associated with a given level in the more extreme events. As discussed in **Section 5.5.3**, this gauge is still under review and revisions may be made in a future version of the report.

Some validation was able to be undertaken on the revised curves for New Buildings by running a steadily increasing hydrograph through the New Buildings 2D hydraulic model (refer **Section 5.5.4** for further details). The water level and flow results were then extracted from the gauge location in the model to generate a rating curve based on the hydraulic model results. This was only possible at New Buildings, as the Rocky Hall and Towamba gauges were located outside of the drone survey extents.

The rating curve extracted from the hydraulic model is shown against the revised and original rating curves in **Figure B5**.

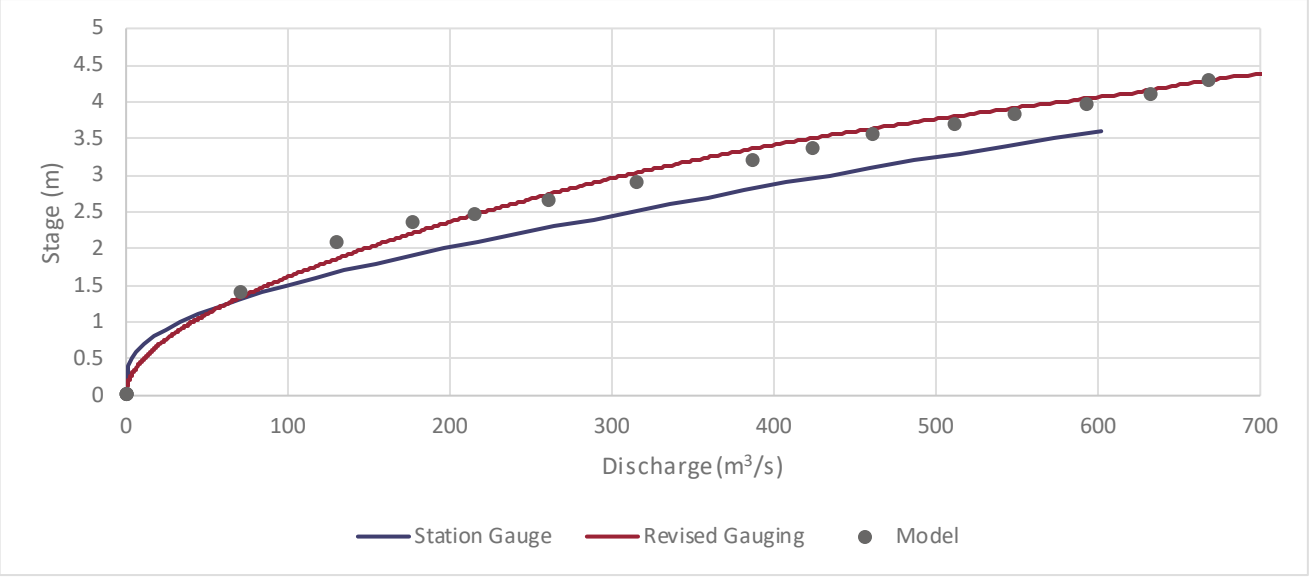


Figure B5 Comparison of Calculated and Modelled Rating Curves at New Buildings

The figure shows that the hydraulic model resulted in a similar stage-discharge relationship as that from the Manning's calculation. This provides a further check to ensure that assumptions on slope and backwater were relevant. Further, the Mannings calculation did not explicitly include the effects of the bridge, which is located a short distance downstream of the gauge.

Following the validation of the new rating curves, the flows for the FFA were updated using the new rating curves. The results of the revised FFA are summarised in **Table B6**. The FFA plots are shown in **Figure B6** to **Figure B8**. For the Towamba gauge, the flood record for 1971 was removed from the assessment. On reviewing the gauge data, it was found that the gauge was missing data for this event, and that the gauge had filled in the missing values with a nominal 10m level. As such, this peak was removed from the FFA assessment.

As expected, based on the new rating curves, the flow estimates for the Towamba gauge have increased significantly, and those for Rocky Hall have dropped. The estimates for Rocky Hall are now lower than New Buildings, which is a more reasonable result that the original FFA. Further analysis is still being undertaken on the Towamba Gauge and these values may be revised in a future report.

A comparison of these flow estimates with the XP-RAFTS model is provided in **Section 5.5.3**, following the discussion on the development of the XP-RAFTS model.

Table B6 Revised FFA Design Flow Estimates

AEP	Towamba (m^3/s)	New Buildings (m^3/s)	Rocky Hall (m^3/s)
10% AEP	1,002	519	193
5% AEP	1,770	706	276
2% AEP	3,378	954	409
1% AEP	5,214	1138	526

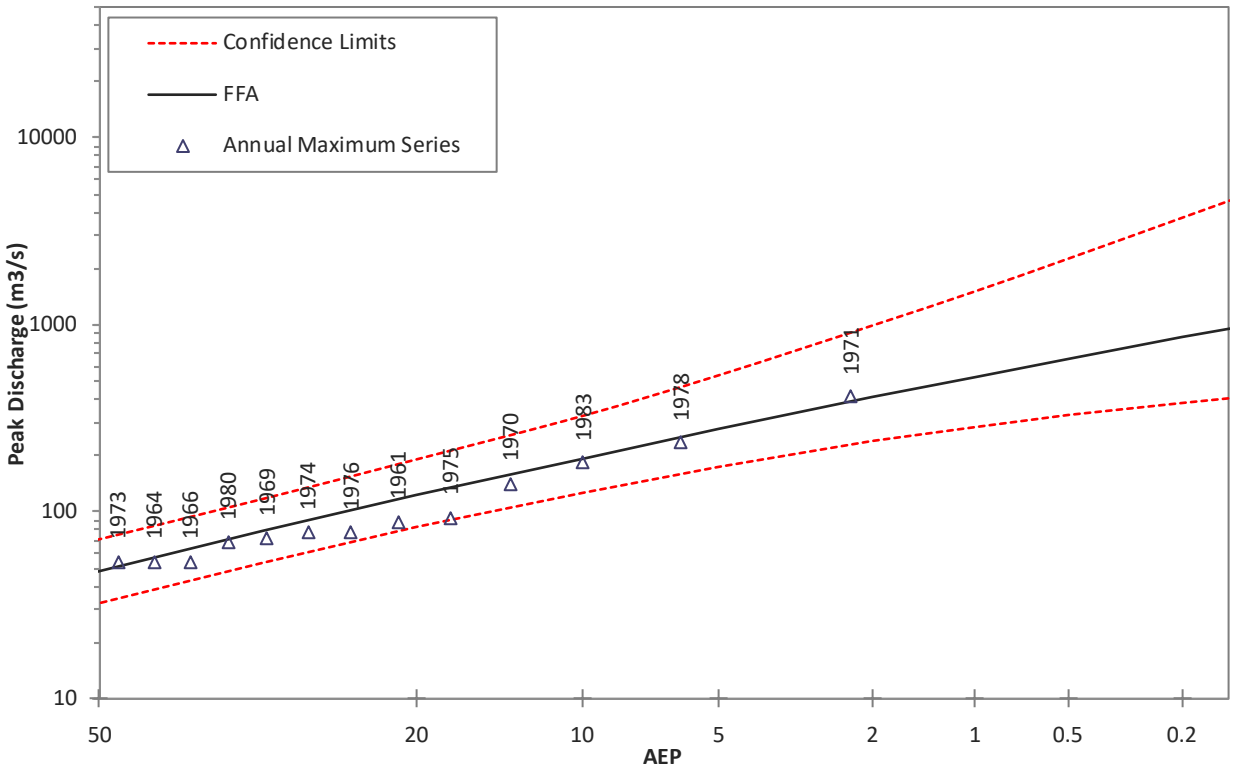


Figure B6 Rocky Hall FFA Comparison

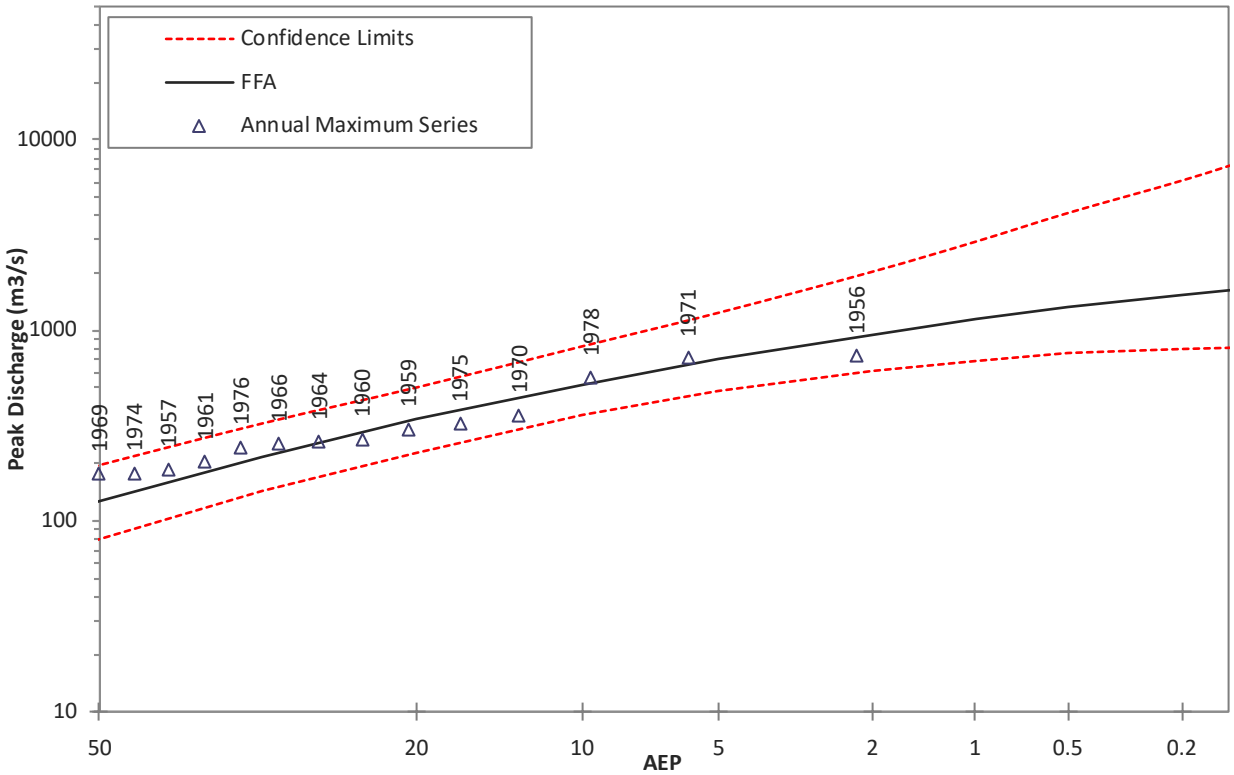


Figure B7 New Buildings FFA Comparison

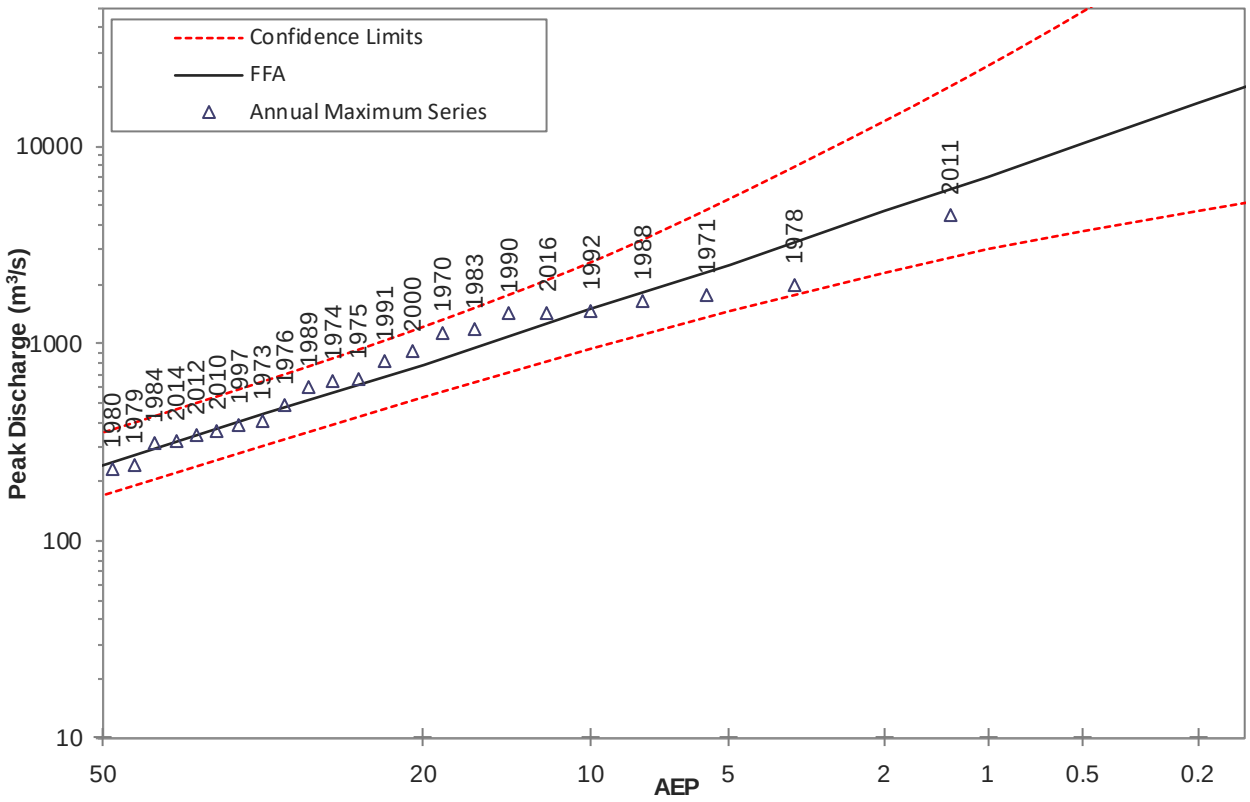


Figure B8 Towamba FFA Comparison

APPENDIX C

Community and Stakeholder Engagement

Consultation Strategy

The consultation strategy outlined in **Table C1** describes the approach to consultation in accordance with the IAP2 framework and the requirements of the NSW Governments Floodplain Development Manual (2005).

Table C1 Consultation Strategy Outline

IAP2 Engagement Strategy Guide	Flood Study for Eden, Towamba and Surrounds
Context *The internal and external drivers, pressures and other background information that is of relevance to the consultation strategy, and in particular how these may influence how the community receives and responds to the consultation program.*	The context of the consultation will be defined by the following: • Floodplain Development Manual • Council's policies. • Flood behaviour (e.g. ocean storms, wave direction, riverine flooding and overland flow and the coincidence of these). • Past flooding experiences and local, regional and national media on flooding. • Council's contact with flood impacted residents following previous flood events. • Consultation undertaken as part of previous related studies (it is important to build on this rather than just repeat or supersede it). The consultation approach, breadth and outcomes of relevant project will be reviewed prior to finalising the consultation program and materials. This will include the Eden Wharf EIS, The Curalo Lagoon Entrance Management Policy and the consultation currently being undertaken as part of the Coastal Management Programs.
Scope *The scoping statements are based on the project context and articulate why the consultation is being undertaken for this project, what the desired outcomes would be, and what the limitations of the engagement are.*	The scope of the consultation strategy is to engage with stakeholders and the community to better understand the flood risks within the study area and to develop community understanding and ownership of the study outcomes.
Stakeholders *This section provides an overview of the different categories of stakeholders, and their relative level of interest, influence and impact.* *This process is useful in identifying the level of engagement under the IAP2 Consultation Spectrum that may be suitable for different types of stakeholders.*	A stakeholder matrix has been provided in Table C2. This informs the selection of appropriate consultation methods.
Purpose *The purpose relates to the purpose of the consultation not the overall project. Stakeholders will be linked to each purpose and the goals within each purpose for each stakeholder will be identified.*	The purpose of the consultation is to: Inform the community and stakeholders of the study; Gain an understanding of the community and stakeholders' concerns relating to flooding in the study area; Obtain historical flood information; Gather information from the community by participation;

	Obtain feedback on the Draft Flood Study; and Develop and maintain community confidence and collaboration with the study results.
Methods	The method selection and associated goals is provided in **Table 4-3**.

Stakeholder Matrix

A stakeholder matrix was developed at the project inception to provide an overview of the different categories of stakeholders, and their relative level of interest, influence and impact on the Flood Study. The type of consultation to be undertaken with each stakeholder was based on the IAP2 consultation spectrum, conceptualised in **Figure C1**.

Figure C1 IAP2's Public Participation Spectrum

Table C2 Preliminary Stakeholder Matrix

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Impacted Agency Stakeholders				
Bega Valley Shire Council	High	High	High	Empower
Office of Environment and Heritage	High	High	High	Empower
Technical Working Group (TWG)	High	High	High	Collaborate
Floodplain Risk Management Focus Group	High	High	High	Collaborate
State Emergency Service	High	High	Moderate	Collaborate
Roads and Maritime Service	High	High	Moderate	Collaborate
NSW Port Authority	High	High	Moderate	Collaborate

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Interested Agency Stakeholders				
Representatives from Council's Engineering, Planning and Environmental Departments	Moderate	Moderate	Moderate	Involve
Bega Valley Shire Coastal Planning and Management Committee	Moderate	Moderate	Moderate	Involve
NSW DPI – Crown Lands	Moderate	Moderate	Low	Consult
NSW DPI – Water	Moderate	Moderate	Low	Consult
Department of Defence – Royal Australian Navy	Low	Low	Low	Consult
Impacted Community Stakeholders				
Flood affected property owners	High	High	Low	Consult
Flood affected residents	High	High	Low	Consult
Flood affected business owners	High	High	Low	Consult
Residents and owners of properties not affected by flooding but within the study area (e.g. impacted by flood access)	Moderate	Moderate	Low	Consult
Users of the area (e.g. impacted by flood access)	Moderate	Low	Low	Consult
Interested Community Stakeholders				
Towamba Community Progress Association Inc.	Low	Moderate	Low	Consult
Port of Eden Marina Inc.	Low	Moderate	Low	Consult
Eden Killer Whale Museum	Low	Low	Low	Consult
Eden Chamber of Commerce Inc.	Low	Moderate	Low	Consult

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Allied Natural Wood Exports	Low	Low	Low	Consult
General community	Low	Low	Low	Consult

Engagement Methods Selection

A list of engagement methods was developed at the project inception based on the project requirements, the objectives of the consultation (identified in the consultation strategy outline) and the level of consultation identified for each of the stakeholders (in the stakeholder matrix). The key goals of each method are also provided.

Table C3 Engagement Methods Selection

Method	Stakeholders	Goals	Timing	Details
Media and social media updates.	All stakeholders. Wider community.	To inform stakeholders of the study. To increase engagement with survey and feedback on draft documents. To capture stakeholders (e.g. visitors and users of the area) not targeted by other consultation methods.	Project inception. Prior to newsletter and survey release. Prior to and during public exhibition.	Council will use their own Facebook page to distribute key project information and invitations to community sessions. Media releases will also be published at key project milestones.
Letter of introduction to the study and follow up phone call.	All agency stakeholders. Community groups.	To inform stakeholders of the study. To identify any additional relevant documents or data sets to be included in the data analysis and review.	Project inception.	Rhelm would prepare a letter of introduction to be sent to relevant agency and community stakeholders to inform them of the purpose of the study and how they can provide input. Each letter would be tailored for the recipient. Follow up will be undertaken by Rhelm by email or by phone as required.
Project Website	Public	To inform the public of the study. To provide additional information to interested stakeholders and community. To provide information of how stakeholders can provide input.	For entire project duration.	Council will use their own website to distribute key project information and invitations to community sessions. A permanent webpage will also be provided to host the project details following project completion.
Newsletter and questionnaire	All flood impacted land owners, business owners and residents. Wider community	Inform. Gain interest and improve likelihood of participation during the public exhibition period.	Project inception	Rhelm to draft newsletter and questionnaire for Council review. The questionnaire will be finalised based on a single set of Council comments.

Method	Stakeholders	Goals	Timing	Details
		Gather input on flood risk concerns and historical flood data.		Council to print and distribute to flood impacted landowners, businesses and residents. Newsletter and questionnaire also to be made available on the project website including an online version of the survey. If Council would prefer this component to be provided through their "Have Your Say" page, a link to this will be provided on the project website. Council will receive and compile the responses. Rhelm will analyse the responses and undertake follow up calls to ascertain the details of available data or other information.
Public Exhibition Period	All stakeholders	Provide an opportunity for feedback on the Draft Study.	Following completion of the Draft Study.	Rhelm to provide documents and posters and provide input to media releases regarding the public exhibition period. Council to provide for all other arrangements.
Public workshops for community consultation	Impacted Community Stakeholders. Interested Community Stakeholders.	Provide an overview of the study purpose, methodology and outcomes. Provide location specific information to attendees (via one on one sessions). Provide an opportunity for feedback on the Draft Study.	During Stage 1 (data collation and review). Following completion of the Draft Study.	Community information sessions will be facilitated by Rhelm with input from Council and DPIE. Community information sessions will be held within the Towamba River Catchment and Eden Township.
Project Meetings	Council's Floodplain Risk Management (FRM) technical sub-committee and	Inform the committee of the study scope, objectives, methodology and outcomes.	Four meetings have been allowed for. The timing of these meetings have been included in the proposed	Rhelm to prepare the materials for discussion, and facilitate and participate in discussions. Council to organise meetings logistics.

Method	Stakeholders	Goals	Timing	Details
	steering committee (FRM Focus Group)	Receiving feedback and clarifying technical matters.	project schedule, however, this will be confirmed with Council at the inception meeting.	
Councillor Briefing (if required)	Councillors	Inform Councillors of the final Flood Study Review and outcomes. Gain approval for adoption of the Flood Study.	Prior to public exhibition	Rhelm will prepare and deliver the presentation to the Councillors. Rhelm will also respond to any queries raised during the presentation. Council to organise meetings logistics.

MEDIA RELEASE

Contact: communications@begavalley.nsw.gov.au
www.begavalley.nsw.gov.au/news
P. 02 6499 2222

Information sought for Eden, Twofold Bay and Towamba River Flood Study

Tuesday, 28 November 2017

Bega Valley Shire Council has appointed consultants, Rhelm, to undertake a flood study for Eden, Twofold Bay and Towamba River. The study seeks to define the current and future flood behaviour of the catchments and ocean storms impacting Twofold Bay.

Community participation is critical to the study's success, particularly when it comes to collecting historical flood information. Council and the consultants Rhelm are eager to hear from anyone who resides the study area or who has historical information on floods in the area.

Council's Asset Management Coordinator, Gary Louie said residents can participate in a number of ways.

"An online survey is available on Council's website, with a hardcopy mailed to residents in the study area, or residents can attend one of the scheduled drop-in sessions", Mr Louie said.

"Residents' and business owners' local knowledge and personal experience of flooding in this area is an invaluable source of data.

"We are specifically interested in any historical records that residents and businesses might hold such as photographs, videos, flood marks or observations." Mr Louie said.

The drop-in sessions will be held on Wednesday, 6 December between 3.00pm and 5.00pm at Towamba Community Hall and on Thursday, 7 December between 10.00am and 12.00pm and also 3.30pm and 5.30pm at Eden Gardens Country Club.

Council is also calling for expressions of interest for representatives on its Floodplain Risk Management Focus Group to assist with the project. Two vacancies currently exist for people living in the Towamba River, Eden and Twofold Bay catchments.

Acting Director Transport and Utilities, Ian Macfarlane said "the primary objective of the focus group is to reduce the potential impacts of flooding, including the private and public financial losses that can result".

"The end result will allow us to make informed decisions on the best way to invest in flood mitigation and better manage the risks posed by floods. While we are primarily looking to reduce property and public risks, this work will also provide essential information to the State Emergency Service and enable effective responses to flood emergencies," Mr Macfarlane said.

Visit Council's website www.begavalley.nsw.gov.au/haveyoursay to complete the survey by 15 December 2017. Contact Council's Asset Management Coordinator, Gary Louie on 02 6499 222 for more information on the focus group.

Photograph: Towamba Bus Shelter, March 2011

END

MEDIA RELEASE

Contact: communications@begavalley.nsw.gov.au
www.begavalley.nsw.gov.au/news
P. 02 6499 2222

Encouraging response to flood study

11 December 2017

Council staff and consultants Rhelm have been very encouraged by the community's enthusiastic response to the flood study for Eden, Twofold Bay and the Towamba River.

The study seeks to define the current and future flood behaviour of the catchment for communities along the Towamba River and ocean storms impacting Eden, Boydtown and Twofold Bay.

Council's Asset Management Coordinator, Gary Louie, said the workshops held last week in Towamba and Eden were well attended, with some very good conversations, stories, recollections and valuable flood information shared.

"The Towamba session was a particularly lively evening, with people coming from all over the catchment despite the wet weather to contribute their information. It proved a real community event, with many people also sharing their information and experiences with each other," Mr Louie said.

"The Eden workshops also yielded some very good information through people's past recollections of storm events in and around the town and the coastal impacts on Twofold Bay.

"Community participation remains critical to the study's success and an online survey is available on Council's website. A hardcopy of the survey has been mailed to residents in the study area.

"We (Council) are also calling for expressions of interest for representatives on the Floodplain Risk Management Focus Group to assist with the project. Two vacancies currently exist for people living in the Towamba River, Eden and Twofold Bay catchments.

"The overall objective of the study is to allow us to make informed decisions on the best way to invest in flood mitigation and better manage the risks posed by floods. While we are primarily looking to reduce property and public risks, this work will also provide essential information to the State Emergency Service and enable effective responses to flood emergencies," Mr Louie said.

Visit Council's website www.begavalley.nsw.gov.au/haveyoursay to complete the survey by 15 December 2017. Contact Council's Asset Management Coordinator, Gary Louie on 6499 2222 for more information on the focus group and existing vacancies.

Council wishes to acknowledge the financial and technical assistance being provided by the NSW Government Floodplain Management Program through the NSW Office of Environment and Heritage and the Minister for Police and Emergency Services.

Photograph: Some valuable historical information has been provided on Twofold Bay.

END

Towamba River

- Stream gauge installed upstream of town (off the map) in the 80s or 90s.
- Wog Wog drive (off map) contributes significant runoff to Towamba River.
- Since 2011/12 event noticed increased level of vegetation affecting flow.
- 1971 the river was clearer with less vegetation.
- Sand under bridge has built up. There is an old photo of someone standing on a horse back not able to touch the underside of the bridge. However, it is also noted that until recent floods the old bridge footings were covered in sand, so some recent reduction in bed levels may have also occurred.
- 1919 bridge washed away in flood.
- Local historian supplied a CD of photos.
- Pericoe Forest Road provides alternative access during a flood, Adds 1.5 hours to the journey to Eden. Relatively good condition unsealed road.
- Towamba River is noted by some to be the fastest rising and fastest flowing river in NSW.
- Typically 2-3 days of steady rain will overtop bridge.
- Bridge overtopped in 2014, cut off for 3-4 days. 2 days due to water over bridge, another 1-2 days for debris clean up.
- 2011 isolation partly due to poor communication. Not many people knew that Towamba was cut off.
- 2011 velocity stripped bitumen off road approaches to bridge. Northern approach still needs repair.
- Residents would like to see road closed signs installed in Eden and at end of Towamba Road when Towamba Bridge is under.
- Road to Eden is mostly flood free now that Mitchell Creek crossing has been upgraded. Only low point is just downstream of town.
- Several locations along the snake track that go under water from backwater. One low point near Ivy Farm that is flooded from river flow (not backwater).
- Residents adjacent to Stoney Creek crossing are concerned about the sediment runoff from unsealed approaches to crossing. In last big event, the deep dams on their property almost completely filled with sediment washed down from the road. They feel that road sealing should be prioritised near waterways to protect downstream waterways. Possibly run sensitivity modelling of tributaries filling with sediment. May be a task for the FRMS.
- Debris still present along river from 2011 event. Poses a fire hazard.
- There was a Towamba River Dam study done by State Government.
- The groundwater flow from Cathcart contributed to the flood in 1971. 2011 event was very similar.
- Local resident has rainfall records from his house near the bus stop at Towamba and from his farm.
- Towamba Post office took rainfall records.
- In 1965 the current bridge over the Towamba River at Kiah was built to replace the previous low level timber bridge. The river came about 0.5m below the soffit in 1971.
- Significant flood events noted in Towamba River in 1971, 78, 87, 2011 and 2016. Biggest were 1971 and 2011.
- Significant impacts on farms in Kiah as a result of the 2011 flood. This was mostly due to the lack of warning. There was very little rain in Kiah, most of the rain fell in the upper catchment. The flood came in the night. No time to move cattle and pumps.

- Local Kiah resident has contacted Council to voice her concerns about Kiah not being included in the study area. Provided photos of 2011 event.
    - 2011 flood caused a lot of erosion and flooded cattle. Event caught property owners by surprise. 3am at the river bank, 6:30am onto the flats, but 11am (ish) river had broken through the berm at the northern end. There was a sudden rise in water between 6:30am and 11am, possibly as a result of Rocky Hall rainfall.
    - 2016 event not as big.
    - Flow from Towamba to Kiah takes about 12 hours.
    - Most people don't build on river flats. Newer residents not as flood aware. Flood mapping could assist in better property management.
    - There should be some controls of farming on river flats.
    - Floods knock out fences, this is an issue when farmed deer escape.
    - 1971 water came close to going over the Kiah Bridge.

Eden

- Local resident has a residential property at Imlay St. Has issues with drainage at driveway. Council and OEH representative visited the site. Council representative advised that there is a design plan for this location to deal with the drainage issues.
- Council, OEH and Rhelm representative visited the industrial area on 7/12/17 and inspected the channel at the rear of the properties. Very dense vegetation. Large trees growing in the channel.
- Golf Course creek erosion has resulted in silting up of the culvert under highway.
- Highway at golf course went under by about 200mm in 2011 and maybe 2016.
- Flow that used to drain to Cattle Bay is now diverted the other way across Imlay Street and then towards Bupa and Lake.
- Mailing Street floods, only one lintel near the Men's Shed.
- At Freshwater Creek – old wooden bridge was too low. DMR replaced the bridge in 1980s. The new bridge no longer goes under but the adjacent properties do.

Twofold Bay

- Rock has been in place at Quarantine Bay, but the area still overtops during a coastal event.
- Low level crossing on Nullica Short Cut Road goes under water.

Rocky Hall

Wyndham

New Buildings

Burragate

S Sketon has photo 2011 looking this way

S Sketon has photo here.

Towamba

Twofold Bay, Eden and Lake Curralo

River cuts this bend in big events (2011 and 1971)

Bridge is tidal limit - noted by Stephanie Skelton

C. McMahon

Errol

N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

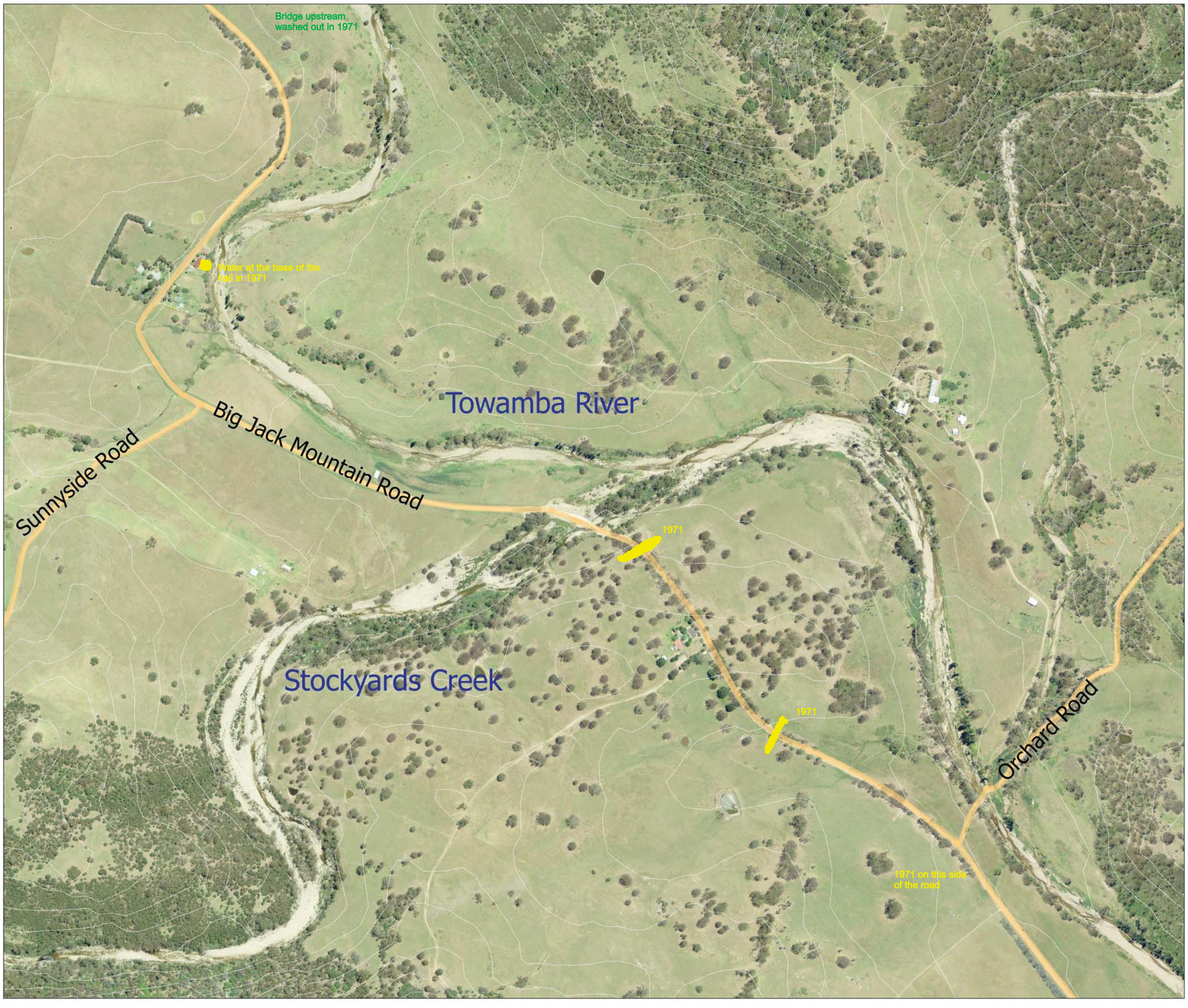
STUDY AREAS MAP FOR CONSULTATION

1000 0 1000 2000 3000 4000 5000 m

File: G0029-ConsultationMap_Study Area
Scale : 1:60000@A1
Date : 22 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm



N
W E
S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

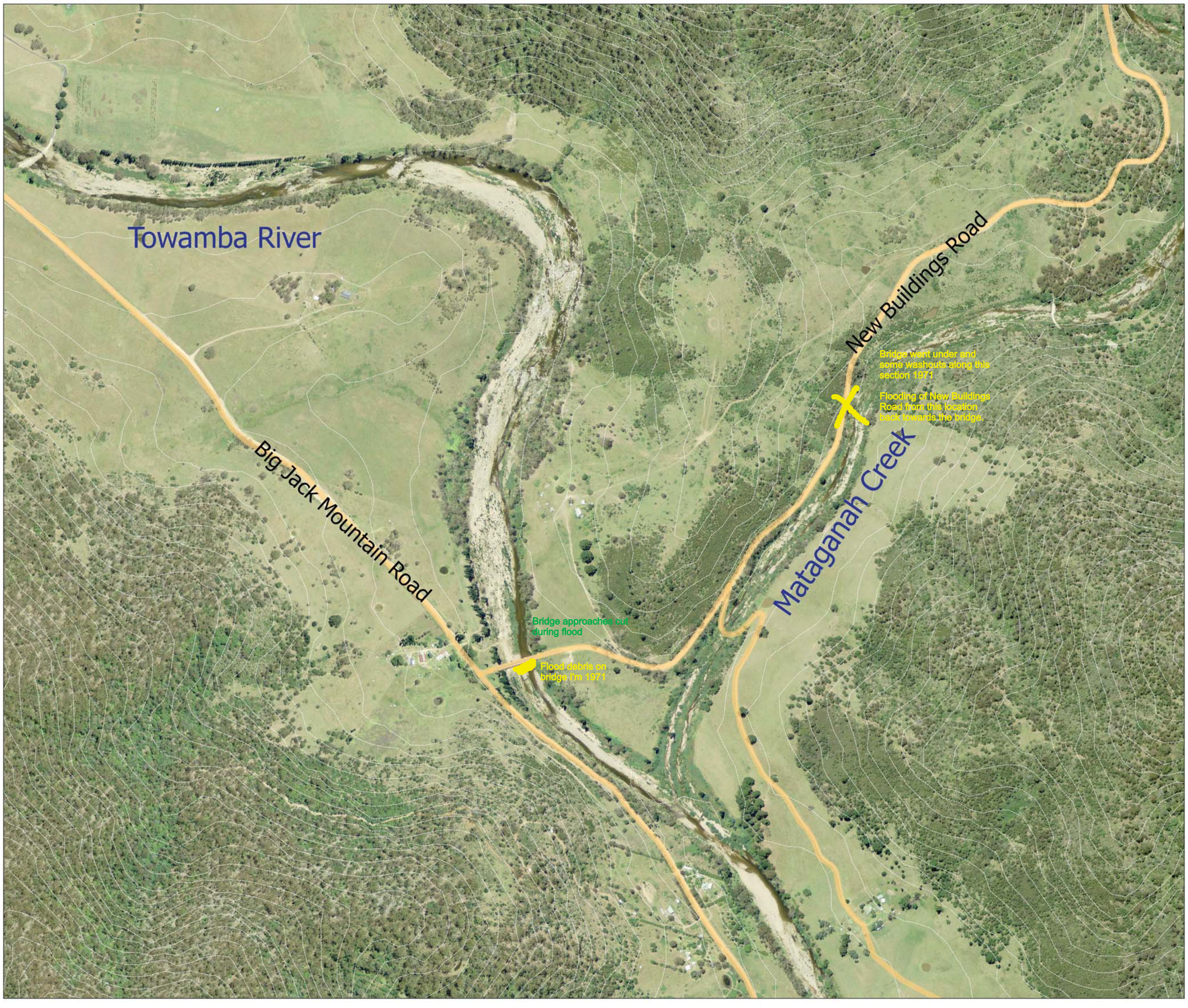
ROCKY HALL
MAP FOR CONSULTATION

Comments on this map provided by Edith Ormond.

File: G0022-ConsultationMap_RockyHall
Scale : 1:3500@A4
Date : 21 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm



N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

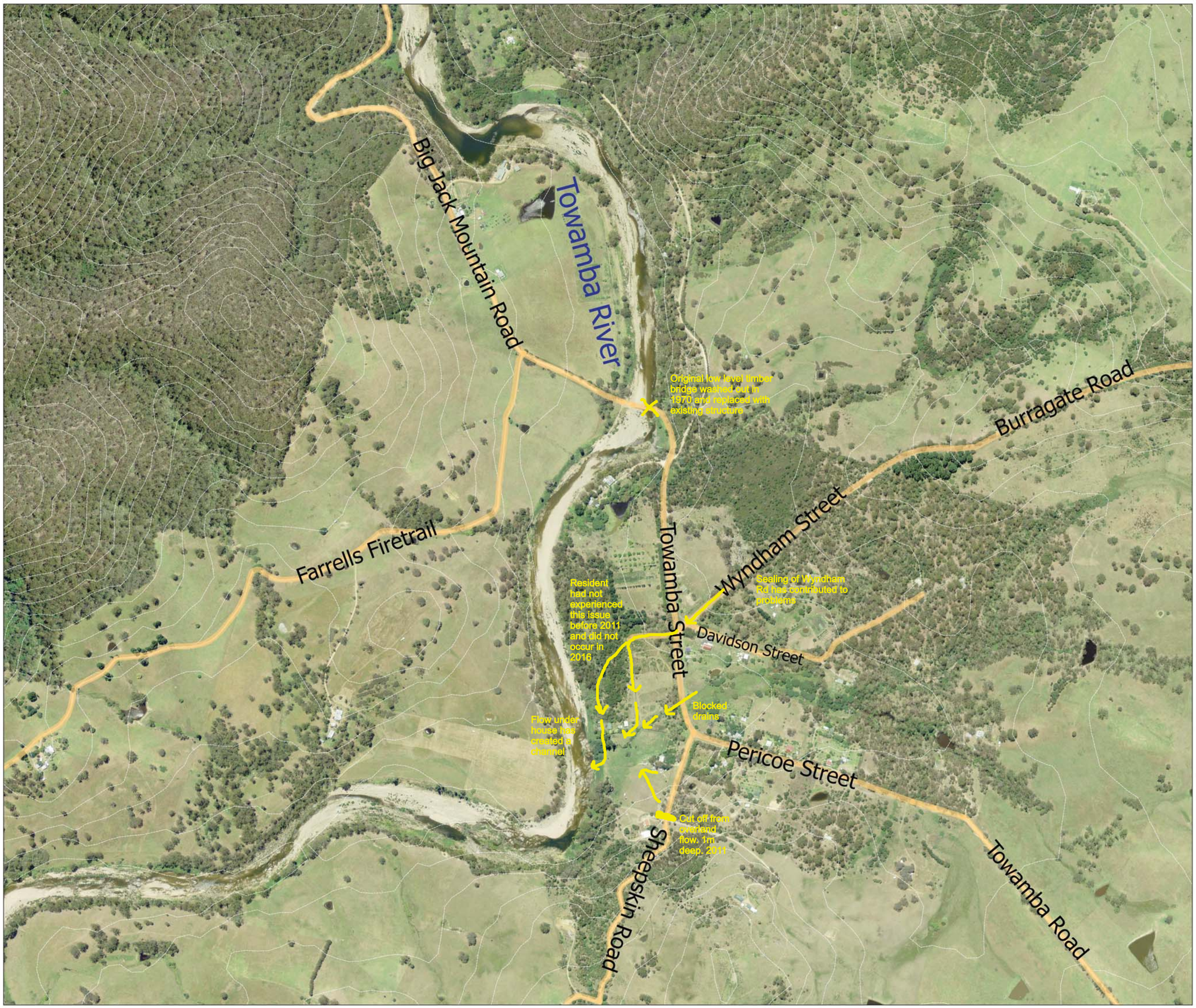
NEW BUILDINGS MAP FOR CONSULTATION

50 0 50 100 150 200 250 m

File: G0022-ConsultationMap_NewBuildings
Scale : 1:3500@A1
Date : 21 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm



N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

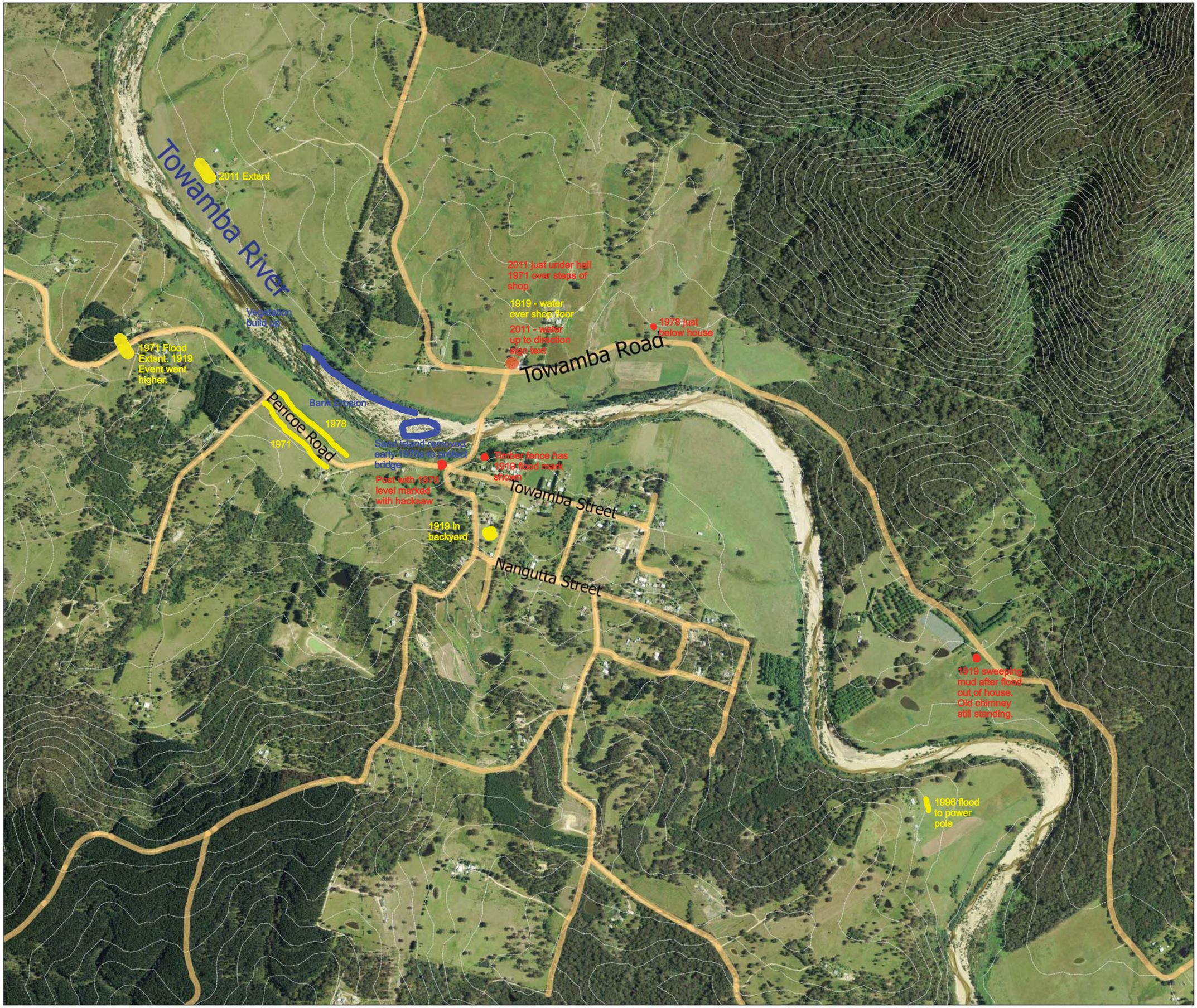
BURRAGATE
MAP FOR CONSULTATION

50 0 50 100 150 200 250 m

File: G0024-ConsultationMap_Burragate
Scale : 1:4000@A1
Date : 21 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm



N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

TOWAMBA
MAP FOR CONSULTATION

100 0 100 200 300 400 500 m

File: G0025-ConsultationMap_Towamba
Scale : 1:6000@A1
Date : 21 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm

Access to private properties cut off by Palestine Creek. Alternative access is steep and access onto Highway dangerous.

Bridges on Palestine Creek destroyed in 1978 flood

Government Road

Should be labelled Government Street (not Road)

1978 event destroyed bridge. Upgraded road crossing has not gone under yet.

Channel at rear of Government Rd business lots is dense with vegetation and debris. Scour of banks noted during large flow events.

Radar was given permission by Council in the 80s to excavate the channel and line with gravel. No maintenance of the channel has been undertaken since that time.

Storey Avenue

Princes Highway

Lake levels observed near but not over footpath

Lake Curalo

Lake opened here in 1978

Reservoir Street

1978 Lake Level

Barclay Street

1978 Lake Level

Curalo Street

N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

EDEN NORTH MAP FOR CONSULTATION

100 0 100 200 300 m

File: G0029-ConsultationMap_EdenNorth
Scale : 1:4600@A1
Date : 22 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm

low point floods

1978 erosion at southern end of cemetery. Consistent with the recent coastal hazards study.

Curalo Street

Princes Highway

Calle Calle Street

Imlay Street

Old cannery used to flood from overland flow

Cocora Street

High tide breakout in heavy rain

1978 foam crossed the road on the high tide.

2006/7 high tide & storm surge back water came up through drian into Marine Discovery Centre building & flooded carpet.

N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

EDEN SOUTH
MAP FOR CONSULTATION

100 0 100 200 300 m

File: G0028-ConsultationMap_Eden
Scale : 1:4000@A1
Date : 21 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm

Shadrachs Creek

Quarantine Bay

Snug Cove

Anne Felton has photos of 2004 and 2010 events

Debris from landslide used as fill for Bupa Site

Nullica River

Princes Highway

Anne Felton has photos of 1990/91 storm event on this beach

Boydtown

Boydtown Creek

Breaks cut here is large events. Adjacent rock influences the breakout

Kiah Inlet

1971 Breakout

In 1971 the chip boat lines were cut to release it due to tides, rain and floods

Jews Head

Munganno Point

Towamba River

N

W E

S

EDEN, TWOFOLD BAY AND TOWAMBA RIVER FLOOD STUDY

TWOFOLD BAY MAP FOR CONSULTATION

200 0 200 400 600 800 m

File: G0026-ConsultationMap_TwofoldBay
Scale : 1:10000@A4
Date : 21 November 2017
Revision : 0
Created by : ERM
Coordinate System : Map Grid of Australia 94

bega valley shire council

Rhelm

Towamba River

- Stream gauge installed upstream of town (off the map) in the 80s or 90s.
- Wog Wog drive (off map) contributes significant runoff to Towamba River.
- Since 2011/12 event noticed increased level of vegetation affecting flow.
- 1971 the river was clearer with less vegetation.
- Sand under bridge has built up. There is an old photo of someone standing on a horse back not able to touch the underside of the bridge. However, it is also noted that until recent floods the old bridge footings were covered in sand, so some recent reduction in bed levels may have also occurred.
- 1919 bridge washed away in flood.
- Local historian supplied a CD of photos.
- Pericoe Forest Road provides alternative access during a flood, Adds 1.5 hours to the journey to Eden. Relatively good condition unsealed road.
- Towamba River is noted by some to be the fastest rising and fastest flowing river in NSW.
- Typically 2-3 days of steady rain will overtop bridge.
- Bridge overtopped in 2014, cut off for 3-4 days. 2 days due to water over bridge, another 1-2 days for debris clean up.
- 2011 isolation partly due to poor communication. Not many people knew that Towamba was cut off.
- 2011 velocity stripped bitumen off road approaches to bridge. Northern approach still needs repair.
- Residents would like to see road closed signs installed in Eden and at end of Towamba Road when Towamba Bridge is under.
- Road to Eden is mostly flood free now that Mitchell Creek crossing has been upgraded. Only low point is just downstream of town.
- Several locations along the snake track that go under water from backwater. One low point near Ivy Farm that is flooded from river flow (not backwater).
- Residents adjacent to Stoney Creek crossing are concerned about the sediment runoff from unsealed approaches to crossing. In last big event, the deep dams on their property almost completely filled with sediment washed down from the road. They feel that road sealing should be prioritised near waterways to protect downstream waterways. Possibly run sensitivity modelling of tributaries filling with sediment. May be a task for the FRMS.
- Debris still present along river from 2011 event. Poses a fire hazard.
- There was a Towamba River Dam study done by State Government.
- The groundwater flow from Cathcart contributed to the flood in 1971. 2011 event was very similar.
- Local resident has rainfall records from his house near the bus stop at Towamba and from his farm.
- Towamba Post office took rainfall records.
- In 1965 the current bridge over the Towamba River at Kiah was built to replace the previous low level timber bridge. The river came about 0.5m below the soffit in 1971.
- Significant flood events noted in Towamba River in 1971, 78, 87, 2011 and 2016. Biggest were 1971 and 2011.
- Significant impacts on farms in Kiah as a result of the 2011 flood. This was mostly due to the lack of warning. There was very little rain in Kiah, most of the rain fell in the upper catchment. The flood came in the night. No time to move cattle and pumps.

- Local Kiah resident has contacted Council to voice her concerns about Kiah not being included in the study area. Provided photos of 2011 event.
    - 2011 flood caused a lot of erosion and flooded cattle. Event caught property owners by surprise. 3am at the river bank, 6:30am onto the flats, but 11am (ish) river had broken through the berm at the northern end. There was a sudden rise in water between 6:30am and 11am, possibly as a result of Rocky Hall rainfall.
    - 2016 event not as big.
    - Flow from Towamba to Kiah takes about 12 hours.
    - Most people don't build on river flats. Newer residents not as flood aware. Flood mapping could assist in better property management.
    - There should be some controls of farming on river flats.
    - Floods knock out fences, this is an issue when farmed deer escape.
    - 1971 water came close to going over the Kiah Bridge.

Eden

- Local resident has a residential property at Imlay St. Has issues with drainage at driveway. Council and OEH representative visited the site. Council representative advised that there is a design plan for this location to deal with the drainage issues.
- Council, OEH and Rhelm representative visited the industrial area on 7/12/17 and inspected the channel at the rear of the properties. Very dense vegetation. Large trees growing in the channel.
- Golf Course creek erosion has resulted in silting up of the culvert under highway.
- Highway at golf course went under by about 200mm in 2011 and maybe 2016.
- Flow that used to drain to Cattle Bay is now diverted the other way across Imlay Street and then towards Bupa and Lake.
- Mailing Street floods, only one lintel near the Men's Shed.
- At Freshwater Creek – old wooden bridge was too low. DMR replaced the bridge in 1980s. The new bridge no longer goes under but the adjacent properties do.

Twofold Bay

- Rock has been in place at Quarantine Bay, but the area still overtops during a coastal event.
- Low level crossing on Nullica Short Cut Road goes under water.

Flood Risk Management Focus Group Meeting Minutes

Held at BVSC Conference Room at 04:00pm on Thursday, 5 October 2017

Present:

Gary Louie – BVSC

John Murtagh – (OEH) – by teleconference

Clr Liz Seckold - BVSC

Emma Maratea (Rhelm)

Rhys Thomson (Rhelm)

Luke Evans – (Cardno) – by teleconference

1. Apologies

Clr Mitchell Nadin

Tim Whitaker (Community representative)

Kirra Waine – SES

Yvette Ringland – SES

Jason Deller – BVSC

Daniel Murphy – BVSC

Rob Quick – BVSC

Michael Fiedler - BVSC

2. Confirmation of minutes

Confirmation of minutes of the Floodplain Risk Management Focus Group meeting held on 20/6/2016

3. Business arising from last meeting

The Merimbula and Back Lake Flood Study at Merimbula and surrounds has now been completed.

4. New business

4.1 Introductions and new Councillor Representatives

Introductions were completed and the group was advised of Council's 2 new councillor representatives Clr Seckold and Clr Nadin.

4.2 Twofold Bay, Lake Curalo, and Towamba River Flood Study inception meeting – Rhelm

Rhelm gave a project overview. See attached presentation slides for reference - attachment 4.2

Potential initial community consultation workshops and dates were discussed.

Eden proposed late November, however, OEH unavailable 20-23 and 27-29 Nov

Target date for initial workshops likely to be 1st week December 2017

4.3 Bega and Brogo Rivers Floodplain Risk Management Study and Plan progress – Cardno

Cardno gave a project update.

The data collection and flood study is now complete. This stage builds on work from the previous Bega and Brogo Rivers Flood Study.

The current floodplain risk management study (FRMS) focused on Bega downstream to Mogareeka and at the village of Candelo.

The aim is to identify the mitigation options and strategies to reduce flood risk for the community. These options are broadly grouped into structural options, property modification options and emergency management options.

- Typical examples of structural options are detention basins, levees and vegetation management.
- Typical examples of property modifications are aimed at altering building response and resilience usually through material specifications, planning controls and house raising.
- Typical examples of emergency management options are aimed at improving community response, can include flood warning systems and community education.

Part of the FRMS project outcomes will be a dataset handover to SES

The floodplain risk management plan (FRMP) will be for council's consideration for adoption of the recommendations.

Broadly, structural options are limited due to the volume of flow and depth. Some options may be suitable for levees but not the town as a whole.

Emergency management response options are more effective. Flood warning infrastructure can be of benefit and also community education programmes.

The options that were more effective at managing risk were evaluated against a multi-criteria analysis.

Community engagement is now key including the public exhibition of drafts to seek feedback from community regarding available options.

Hoping to finalise study by end of year

Clr Seckold raised a question whether the Bega pioneer museum part of FRMS data collection. Cardno advised that the Musuem was part of the original Flood Study consultation that the current project is built on.

Availabilities of different stakeholders were discussed ahead of the public exhibition period:

Cardno availability good over next 4 weeks, 2 weeks notice would be useful for booking flights

OEH unavailable 23 and 25 October to advise other availability

Actions:

Council to confirm public exhibition period and community workshop dates

OEH to advise other availability

4.4 Council issues

Current focus is complete the public exhibition period for the Bega and Brogo FRMS/FRMP as there is an end of year deadline to deliver the project materials to OEH.

Action

Council will forward comments and submissions regarding Bega FRMS/FRMP project to Cardno as they are received to expedite evaluation of any submissions.

4.5 OEH issues

OEH availability outlined previously

4.6 SES issues

SES unavailable no update given.

Action

OEH to supply contacts

Council to supply meeting minutes and inform SES of the public exhibition

4.7 Community representative issues

Community representative unavailable, no update given.

Clr Seckold advised that she is on a separate committee with the community representative and that he has changed jobs recently.

Action

Clr Seckold to update Tim Whitaker on proceedings and confirm any new contact details.

Council to distribute meeting minutes

5. General business

Nil

6. Closure

Next meeting will be following close of submissions for Bega and Brogo rivers FRMS and FRMP Public Exhibition.

Meeting date to be advised, likely early-mid November.

Floodplain Risk Management Focus Group

MINUTES

HELD AT **Eden Amateur Fishermans Club, Quarantine Bay, 11.45 am 22/2/2019**

Present:

Emma Maratea – Rhelm (consultant)

Derek van Bracht – BVSC Environmental reprsentative

Clr Liz Seckold - BVSC

Gary Louie – BVSC Assets and Operations representative

Clr Mitchell Nadin - BVSC

John Murtagh - OEH

Joanne Humphries – SES Regional

Patricia Daly – SES Eden

Clyde Thomas – Community representative

Colin Walder – Community guest

1 Apologies:

Yvette Ringland – SES Local Commander

Sophie Thomson – BVSC Planning representative

2 Endorsement of guest attendance

Colin Walder was endorsed unaminously by the Focus Group as a guest attendee for the purposes of supervising use of the Eden Amateur Fishermans Club facility but also as a knowledgeable long time local resident of the Towamba River catchment.

3 Confirmation of minutes

The Minutes of the 20/11/2017 Committee were taken as read.

Moved – Gary Louie BVSC

Seconded – Emma Maratea Rhelm

4 Business arising from last meeting

No business arising

New business

5.1 Eden Twofold Bay Towamba River Flood Study progress update

A project overview of the Eden Twofold Bay Towamba River Flood Study was given by Rhelm. Refer to the attachment for details.

An overview of the Floodplain Risk Management process was given and the relationship between Flood Study (FS) and Floodplain Risk Management Study and Plan (FRMSP) projects.

Some questions and discussions were then raised about the availability of flood information to insurance companies and erosion.

Derek commented that the effects of erosion have been considered in the Coastal Hazard study. Rhelm commented that insurance companies typically rely on their own information to price premiums but FS information can on occasion assist in reducing premiums. The aim of the FS is to define where it floods. The information then helps to identify relevant mitigation options later. OEH commented that FS information is typically made public when Council adopts and publishes the final FS. However, interpretation of the information in the public arena is variable and is not controlled or contained.

Some further discussion was then had regarding the differences between section 10.7 part 2 and part 5 certificates (previously section 149 certificates) and their relationship to development and planning controls.

Derek commented that the s10.7 part 2 certificate typically outlines the planning and development controls associated with a parcel of land whereas the s10.7 part 5 certificate details additional information of relevance. OEH commented that the part 2 is issued when land sale occurs in NSW. A part 5 is an optional document can be secured. Derek then commented that Council is indemnified under s733 of the Local Government Act if it issues relevant information in 'good faith' as indicated on the s10.7 certificates. It is important to have the best available and current information referenced on the certificates to ensure Council operates within the Act to effect indemnity provisions.

Further discussion was then had on the relation between FS/FRMSP and planning instruments like Council's Local Environmental Plan (LEP) and Development Control Plan (DCP).

OEH commented that the LEP and DCP will reference information from adopted studies as inputs. The LEP and DCP then typically assist and guide planning decisions.

Action: *Planning to verify the existing s10.7 certificates and LEP and DCP provisions are suitable to effect indemnity provisions where Council have adopted studies and plans in place and report back next meeting.*

Rhelm then outlined how multiple models have been used to address differing flooding mechanisms occurring within the catchment. There are 6 areas of specific interest within the study area. Refer attachment.

Rhelm then outlined why Kiah was not included originally as part of the project due to the lower risk to life and lack of population in the flood affected area. During the course of the community engagement, it became apparent that advance warning to residents was important in the Kiah area so that stock and pumps could be moved. There is scope to include Kiah as part of the FRMSP now that the FS is in a well advanced stage. A likely recommendation of the FS may be to include consideration of Kiah in the FRMSP stage. Gary then commented that Council's flood damage data

from 2010 did not substantial damage or incidences in the area and thus the area was not included as part of the original project scope due to budget considerations.

Action: *Rhelm to consider appropriate recommendations regarding Kiah in production of the final study outcomes.*

Rhelm then outlined the project timeline and activities completed to date and activities yet to occur. Stage 1 and 2 have now been completed and the project is now nearing end of Stage 3. Refer attachment.

Rhelm then discussed the signficance of rainfall intensity and daily gauges. A daily gauge can only determine the total rainfall but not intensity of rainfall. A pluviometer can provide intensity data as readings are taken more frequently typically at 15min intervals. The model is not calibrated due to a lack of available calibration data but rather the model is 'validated' since it correlates well with community information supplied. The upper catchment around Towamba and Rocky Hall had flow gauges, pluviometers and daily gauges available. The lower catchment around Eden and Twofold Bay had less data available. OEH then commented that Bureau of Meteorology daily gauges are only read once per 24 hours at 9am each day.

Flood terminology was then discussed. Rhelm outlined that older terminology of the 1 in 100 year flood is referred to as the 1% AEP event (Annual Exceedance Probability). This means that an event has a 1% chance of occurring in any one year rather than once every 100 years as was commonly misconstrued. PMF means Probable Maximum Flood, a very very rare flood. In anecdotal terms, the 'Noah Flood'.

Rhelm then commented that the level of catchment development can be a factor contributing to flood impacts and how this is typically accounted for in modelling. Roughness parameters are used as proxies for the level of development. Undeveloped catchments are 'rougher' and developed catchments are 'less rough'. The preliminary 1% AEP maps were then presented for comment and some examination of the area around Lake Curalo occurred. Further discussion was then had regarding the difference between coastal and catchment effects and how boundary conditions apply.

SES then discussed the key issues locally for them. The BUPA facility was typically an issue within Eden compared to other locations. Some discussion was then had about sensitive infrastructure and how the final flood study information can be used. Clyde Thomas then commented that he used to own the land that BUPA was built on and outlined the original construction process. Refer Clyde for further details.

Action: *Rhelm to follow up with Clyde Thomas regarding BUPA local knowledge to validate any findings.*

Rhelm then outlined the interaction between the coastal and lagoon model and how the information is of use. Some discussion regarding the sediment in the lake was had and a previous sediment study project was discussed.

Rhelm then outlined the next steps of the process. The public exhibition and Stage 4 activities are likely to occur around August – September 2019 with a project end date submission to Council and OEH still on target for end of the year.

Action: *All to promote the upcoming public exhibition through private and professional networks so that broad community feedback can be garnered to provide ownership over the final outcome.*

5.2 Merimbula Lake and Back Lake Floodplain Risk Management Study and Plan progress update

A project overview of the Eden Twofold Bay Towamba River Flood Study was given by Rhelm. Refer to the attachment for details.

The previous engagement process was discussed. The Flood Study identified from flooding and overland flow issues. From a review of preliminary information, Council has no apparent planning controls in place to deal with overland flow at the moment.

A copy of the community engagement brochure used in the initial drop-in sessions was circulated for information.

Clr Nadin commented that the Back Lake Estuary east of the bridge was treeless in the 1960s and also noted about the location of a powerpole on Merimbula Creek in the Berrambool Sports complex. It would be good to include some recommendations in the Floodplain Risk Management Study and Plan to assist future grant applications for environmental management.

OEH commented that environmental management options can be applied in the floodplain management programme at 2:1 funding if flood mitigation benefits arise. Otherwise, application can be made to the coastal hazard programme which is at 1:1 funding.

Rhelm then summarised that the Stage 1 activities are now virtually complete and then outlined the remaining activities to occur.

5.3 SES issues

Joanne Humphries briefly introduced herself and outlined that the SES have mandatory requirements from the Floodplain Risk Management process and inquired whether these were previously provided to Rhelm.

Rhelm confirmed that the requirements have been provided by OEH.

Local SES Eden advised that a recent issue following heavy rains at the Killer Whale Museum location has now been resolved. It was also advised that the BUPA site is highly represented in emergency responses.

Regional SES also commented that they could be available to assist with community engagement with appropriate notice.

Action: *Council to consider inviting SES to participate in the next round of public exhibition workshops for the draft Eden Twofold Bay Towamba River FS and Merimbula and Back Lake FRMSP.*

5.4 Council issues

5.4.1 Councillor issues

Clr Seckold reported that Wallagoot Lake with its small catchment, closed mouth and warming water reducing oxygen leading to fish kill are of concern to her.

Action: *Rhelm to note in development of FRMSP*

Clr Nadin reported that environmental issues are of concern to him citing a past incident in Mirador and Merimbula Creek. The other key interest is having relevant information available to secure external funding.

Action: *Rhelm to note in development of FRMSP*

Clr Seckold then reported that weed control and revegetation following the Tathra fires is now in progress.

5.4.2 Current deferred matters and other issues – Planning staff

A brief of relevant BVSC Planning interests was given by Derek van Bracht in the absence of Planning staff.

Council currently has a Rural Living Strategy on exhibition for the Towamba and Kiah areas.

There are no large scale releases identified in the study area but a current Planning Proposal exists for the locality of Boydtown.

Emblem Street, Eden is an issue to consider in detail and also the BUPA facility location.

Action: *Rhelm to verify whether the locations have been considered as part of the modelling process and report back next meeting.*

5.4.3 Current identified grant projects – Asset and Operations staff

Council's broad strategy of floodplain risk management projects was outlined. Council Council uses a risk based methodology based on areas of population, an older strategic flood risk assessment and whether a catchment has an existing flood study to target flood study grant applications and projects. When a flood study has been prepared and adopted in accordance with the 2005 NSW Floodplain Development Manual, Council prefers to make grant application to OEH to secure funds to complete a subsequent Floodplain Risk Management Study and Plan. Once a Floodplain Risk Management Plan has been adopted, Council will then again make application to OEH for an implementation grant. Some areas will be lower priority according to a lack of population, a lack of flood damages or according to the priorities of the previous strategic assessment.

A number of grant applications are now being prepared for the current grant round.

Clr Nadin then verified the major catchments within the LGA for potential projects.

Action: *Asset and Operations to verify that Wallaga Lake and Wonboyn River are part of the forward programme and include if not.*

5.4.4 Environmental issues – Environmental Services Staff

Lake Curalo is the main area of focus for gaining additional information.

Derek then left the meeting early.

5.5 OEH issues

The current round of Floodplain Management and Floodplain Risk Management grants are now open and closing 20th March 2019.

OEH has been working with Council regarding strategic priorities for both agencies in formulating grant applications.

Action: *Council to progress grant application submissions for the current grant round.*

5.6 Community issues

Clyde will think through some different ideas for improving community engagement in conjunction with the Eden Twofold Bay Towamba River Flood Study project.

Clyde's previous professional career involved diving and has seen many practical examples of erosion and scour he can contribute to the conversation.

Clyde Thomas left the meeting early.

Action: *Clyde to report back on community engagement concepts at next meeting.*

5.7 General Business

Colin Walder gave some local background history to the Cathcart upper catchment area that includes Mt. Darragh, Coolangubra and Cathcart.

Twin landslides occurred in the upper catchment that banked water up and then broke. The current sediment load is probably from the previous event working down. The Towamba river appears to be going back to its rock base from the 1971 event.

Mt. Darragh/Cathcart controls the water in the BVSC LGA stemming up to Brown Mountain. In 1971, the upper catchment was heavily forested. Subsequent die back led to be debris being washed down.

Colin then outlined his association with the Tathra bridge construction at Mogareeka.

Many timber bridges survived following the 1971 event whereas concrete structures did not. The timber structures flexed with the floodwaters. The piles at Mogareeka went down 140 feet before hitting solid ground. Floodwaters reached the top of the powerpoles across Jellat Jellat. In 1971, the floodwaters went to the Fish and Chip shop on Andy Poole Drive opposite the caravan park. Gary then commented that these were probably not the current powerpoles as they are higher than the normal 11m above ground standard poles.

Colin also added that in 1971, floodwaters also got to the 2nd step of the first pub in Pambula and that the 'Oaks' was under about 30 feet of water at the time.

In Eden, the bottom of the Palestine school was inundated and the road was cut at the Golf Club and the Fountain caravan park. Government Road was underwater in 1975 and also in 1965 after an offshore underwater landslip near the first drop off generated a 60 foot wave. The water crossed the Highway near Quarantine Bay.

Action: *Rhelm to note information and validate against current model outputs and follow up with Colin for any other local knowledge of use.*

Closure

The meeting was declared closed at 2.15 pm.

Next meeting

The next meeting is to be held at a date and venue to be determined nearing the time of public exhibition of the draft Eden Twofold Bay Towamba River Flood Study in the 2nd half of 2019.

Eden Twofold Bay Towamba River Flood Study – technical sub-committee meeting

MINUTES

HELD AT 1 pm 16/10/2018 **BVSC GMs Conference Room**

Present:

John Murtagh – OEH	Luke Evans – Rhelm (via teleconference)	Emma Maratea - Rhelm
Sean Garber – Baird Australia (via teleconference)	Gary Louie - BVSC	Rhys Thomson - Rhelm
Yvette Ringland - SES		

Apologies:

Derek van Bracht - BVSC

Progress Update – Rhelm

Rhelm gave a progress update of the stage 2 work completed as per the draft stage 2 report.

Council's comments were discussed regarding the draft Stage 2 report and figures as provided through OneDrive. Some issues regarding the commentary and figures required some attention.

OEH's comments regarding the draft reports were regarding the flood frequency analysis and calibration at Towamba mostly.

Rhelm recognised that a good executive summary will be required to the substantive technical material to be reported.

The scope of the project and study area was recapped for the benefit of SES.

Initial model runs used an open downstream boundary without tidal effects as a starting point to test model operation.

There are 2 models in Eden. A model for the Lake Curalo lagoon to determine tidal impacts and another for the Eden township to determine overland flows. TUFLOW is being used to define the floodplain impacts and Delft3d to drive the entrance conditions and water level boundary.

Rhelm are considering running a suite of durations through the models. Alternatively, a static boundary condition could be used. Council's preference is for a time series dynamic analysis.

Baird outlined some of their modelling technique thus far.

Entrance condition assumptions are important. At the start of runs, use an open entrance condition based on 2016 bed levels. A closed condition of between 0.1-0.6 MSL was also used to test lake volume impacts. An open entrance was used to test the tidal exchange and propagation of storm tide effects associated with the June 2016 ECL.

Before breakout, typically an inflow event at 0.6 – 0.7m MSL was observed for the starting water level. The 1% event referred to in coastal modelling is the 1% exceedance at any point in time rather than based on an annual series. To calibrate the breakout process in the lagoon, the November 2013 event was used. This examined sediment transport to produce a realistic opening scenario. Broken entrance characteristics at Curalo corresponds well to other similar work Baird have done at other sites along the NSW coast.

Rhelm added that other ICOLLS within the study area were examined less rigorously due to lower populations surrounding them. The Juno Drive culvert at Boydtown needs more examination. This will tested in Delft3d to determine any overtopping potential.

The Nullica grid may be refined to a smaller cell size in the upper creek catchment to resolve some resolution issues there.

Shadrach's Caravan Park was noted to be impacted significantly in the 20% AEP event. Some extension of model on other side of highway may be needed to assess private road access impacts.

The breakout level is assumed to be at the managed entrance level. A conservative approach is to adopt the lake water level prior to breakout.

OEH offered that work by Hanslow may have some probabilistic berm height data at Curalo available.

OEH also added that a local developer had contacted a number of ministers regarding flooding/insurance in the Boydtown area and that OEH is investigating on behalf of the relevant minister.

If no better data can be sourced, then the managed level for berm height can be used.

Baird to check sensitivity on berm height based on 20% and 1% AEP events.

Rhelm added impacts of lake water level v. highest daily rainfall events could be used as another check measure.

Council added that contours of water levels in some figures will be useful for the final report.

Rhelm to incorporate.

Baird left the meeting and Rhelm continued to discuss the Towamba River catchment model hydrology.

Rhelm outlined that from the data review, good flow data was available but pluvio data was rarer. A number of disparate daily rainfall gauges were available but temporal effects will be difficult to determine due to a lack of pluvio data. The available data was used to try and get the temporal patter correct.

The hydrology fit is good at new Buildings and Rocky Hall, less so at Towamba. The Towamba model will test the calibration of travel time/routing.

Flood frequency analysis (FFA) is available at the 3 locations above. The Towamba FFA had good correlation at 10% AEP flows but the 2011 event was an issue when using the FLIKE model. Originally the Log-Pearson III (LPIII) distribution was used to test fit and also the Generalised Extreme Variable (GEV) but the fits were not very good. Later log-normal distributions were used that omitted the 2011 event and a better fit was achieved. Accordingly, 2011 appears an outlier and some examination of causes is needed.

There is approximately 2m difference in levels between the 2011 and 1978 events. The 2011 event was higher than 1978.

The cross section at the Towamba gauge location needs some examination to test model impacts and verification for validity as the gauge is some km upstream from the village.

OEH issues

No other issues were raised.

SES issues

No other issues were raised.

Council issues

Council added that the end products can be submitted into the NSW Flood Portal.

Immediately, work can continue to resolve technical issues around calibration. The issues can be resolved through a series of working papers in teleconference with key technical sub-committee members.

Rhelm to note.

General Business

Nil

Closure

The meeting was declared closed at 2.10pm.

Next meeting

The next meeting is to be held at BVSC date and time TBA.

Rhelm

engineering | environmental | economics | engagement

APPENDIX D

Calibration & Validation

Model Calibration

The data review process has allowed for the identification of appropriate calibration events through review of rainfall and water level data and consultation with the community. A summary of key catchment and coastal events is provided in **Table D-1**. Further discussion on these events is provided in **Section D.2**. Calibration events did not necessarily require all models to be run, the models run for each of the events is noted in **Table D-1**Table 5-4.

Discussion on the calibration and validation modelling undertaken is presented in below. No calibration data was available for Boydtown Creek, Nullica River, Shadrach Creek or Cocora Lagoon.

Table D-1 Calibration Events

Event	Calibration / Validation Undertaken			Comments
	Towamba River Models	Eden Overland Flow Model	Coastal Models	
February 1919 Towamba River Catchment Event				One survey mark near Towamba. No rainfall or flow data available for calibration.
February 1971 Towamba River Catchment Event				The community were able to identify several flood levels and extents around Towamba, Rocky Hall and New buildings, but there were periods of missing data in the gauge record, preventing calibration to this event.
1978 Catchment and Coastal Event	Calibration	Validation of 20% and 1% AEP runs		The community were able to identify several flood levels and extents around Towamba. General observations were collected of flooding in Eden.
June 1998 East Coast Low				Listed in Council's brief but no significant water levels were recorded for this event.
February 2010 Towamba River Catchment Event				No reliable flood observations available.
March 2011 Towamba River Catchment Event	Calibration			Majority of flood recollections provided for Kiah area. One calibration mark surveyed in Towamba for this event.
March 2012 Coastal Event			Calibration	It is one of the largest water level events associated with an entrance breakout. Event allows for the calibration of the entrance breakout of Lake Curalo.
September 2013 Coastal Event				It is largest water level event associated with an entrance breakout. Rainfall was modest, but lake levels were already

Event	Calibration / Validation Undertaken			Comments
				elevated behind a closed entrance prior to the event. However, missing Lake Curalo water level data resulted in no calibration being undertaken.
June 2016 East Coast Low			Calibration	Lake Curalo entrance was open (i.e. Lake was tidal) during June 2016 ECL. Exact entrance condition at that time is unknown. Event allows for the calibration of the interaction of rainfall runoff and storm surge in the lake. This will be limited by the availability of rainfall data.

Twofold Bay Hydrodynamic Model

Baird's NSW Tasman Sea Model, developed for the coastal inundation component of the ECL multi hazard study encompasses Twofold Bay and has been calibrated and validated against tides and storm surges at selected ports along the NSW coastline, including Eden.

The ECL dataset is derived from a combination of data analysis/interpolation and numerical modelling. The modelling captures the tidal variation along the coast, while measured data was used to derive empirical relationships between storm intensity and storm surge (based on 1127 events). This relationship is then applied to the stochastic ECL event track database to derive a long-term population (1000 year) of storm tide events.

Table 5-6 presents a summary of the water level calibration statistics for full NSW Tasman Sea model. The values in Table 5-6 are calibration metrics for modelled astronomical tides over a 12 months period.

Table D-2: Comparison of measured and modelled water levels (m MSL) for selected ports in the Delft3D NSW Tasman Sea Model.

Location	Bias (m)	Skill	RMS error (m)
Tweed Heads	0.001	0.997	0.049
Coffs Harbour	0.002	0.998	0.037
Port Macquarie	0.001	0.970	0.131
Crowdy Heads	0.001	0.999	0.029
Sydney	0.001	0.999	0.026
Port Kembla	0.001	0.999	0.024
Batemans Bay	0.001	0.999	0.023
Eden	0.001	0.999	0.026

Lake Curalo Hydrodynamic Model

For the calibration of the ICOLL model setups, historical calibration events were run out on the Lake Curalo model as there was water level data available from the MHL gauge within Lake Curalo. The model was calibrated against a historical ECL (June 2016) and a breakout event (March 2012). The calibration periods are as follows

- ECL: June 2016: 31st May 2016 – 16th June 2016
- Breakout: March 2012: 24th Feb 2012 – 7th March 2012

The June 2016 event provides water level information to define an ECL event driven by coastal water levels with an open lagoon entrance condition whereas the 2012 event was used in the calibration of a breakout event at Lake Curalo driven by catchment flooding. Measured water levels from the Eden tide gauge and wave parameters from the Eden and Batemans Bay wave buoys were extracted during the calibration periods to provide coastal water level boundary conditions.

Measured water levels at the Eden tide gauge were used as the coastal boundary conditions for the two periods, see **Figure D-1**. Similarly, the inflow data from the catchment model (XP-RAFTS) applied to the Delft3D model were also derived from measured rainfall during the two events.

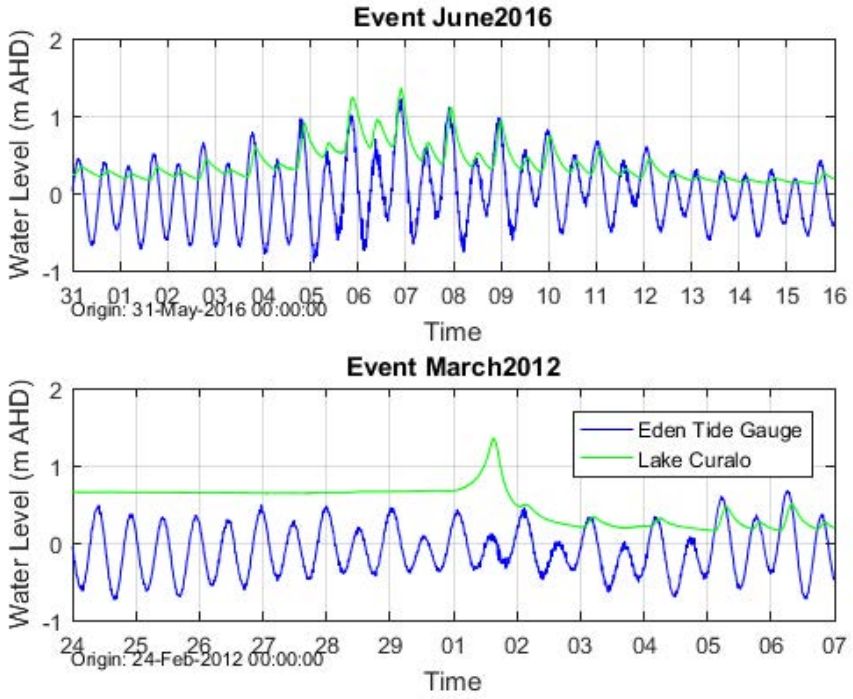


Figure D-1 **Water levels at Eden Tide gauge used as coastal boundary conditions in the Lake Curalo model**

June 2016 ECL Event

The June 2016 ECL event occurred when the lake entrance was open. As the lake survey was undertaken with a closed entrance, the entrance condition needed be assumed and an open lake entrance schematised in the model. Lake depths were modified using satellite imagery as a reference to replicate the entrance dimensions,

orientation and depths within Lake Curalo. Further, sensitivity analysis was undertaken with roughness values through the lake entrance area.

Measured water levels within Lake Curalo were used to compare the modelled outputs and the bathymetry and entrance conditions adjusted to replicate the tidal range and tidal phase for the pre-storm open entrance conditions. **Figure D-2** shows that the modelled lake water level, with the schematised open entrance bathymetry, matched well with the measured tidal range and phase within the lake prior to and after the ECL event, indicating that the entrance dimensions and orientation are a good representation of the open entrance condition during that event.

Phasing of the peak water levels during the event are well replicated by the model and are principally driven by astronomical tide and storm surge, however the peak water level is underpredicted. Water levels within the lake peaked at 1.35m AHD, above the storm tide level in Two-fold Bay of 1.1m AHD, hence there is a contribution from catchment inflows. Catchment inflows were provided by the Eden catchment model and were added at suitable locations around the lakes boundary. However, the inclusion of catchment inflows did not improve the comparisons against the measured water levels with the timing of the discharge being out of phase with the observed lake water level response. It is expected that this is a result of having to adopt the pluvio data from Merimbula (as no pluviometer data was available at Eden for this storm), with the rainfall depths factored to Eden based on the Eden and Merimbula daily totals. This highlights the limitations of deriving accurate catchment inflows with limited site-specific rainfall data. Further analysis of the timing and discharge rates of peak catchment inputs would improve the representation of the peak water levels within the lake. As it stands, the model schematisation of an open entrance condition has been validated against the observed water level records in the lake.

March 2012 Lake Breakout Event

The entrance breakout event that occurred in March 2012 was used to calibrate the entrance breakout process in the Lake Curalo model. As for the previous validation case, the exact entrance condition (berm level) was not known and hence water level data from within Lake were used to infer the berm level prior to the breakout event. The sediment transport module of Delft3D was used to dynamically model the March 2012 entrance breakout. Being a closed entrance condition, the rate of change in measured water levels prior to breakout is controlled by the rate of discharge from the seven catchment inflow inputs. Hence, the critical calibration parameters for the timing of the breakout were the initial berm level and the difference in lake volume before the event to breakout, which were both inferred from measured lake levels and associated lake volumes.

The measured and modelled peak water levels within Lake Curalo during the March 2012 breakout event are 1.35 and 1.42 m AHD respectively with the phasing of the modelled breakout matching the measurements to within 15 minutes.

The rate of change in lake water levels post breakout was a critical calibration parameter. The rate at which the water level recedes within the ICOLL following an entrance breakout is an important factor in the flood analysis of the lake surrounds as the catchment inflows at this stage of the event are still large. Sensitivity analysis was undertaken with roughness values, discharge inputs, initial sediment layer thickness and initial berm level being the calibration parameters with the most influence on the rate of change in lake levels after the breakout.

The largest uncertainty for this event is with the inflow discharges from the catchment as the quality of the measured rainfall during this period are low. Due to a lack of pluviometer data within the Eden catchment area, it was necessary to source pluviometer data from the nearest operating gauge, located in Merimbula. Rainfall depths were factored to Eden based on a comparison of daily rainfall totals in Eden and Merimbula. Merimbula is located approximately 25km from Eden, so while both locations would have experienced rainfall, it is likely the distribution will have been different. Initial estimates of the catchment flows resulted in a more gradual increase in the lake water level than what was observed, indicating limitations with the catchment inflow estimates. These were subsequently modified to better reflect the rate of rise in the lake water level (while maintaining the same total volume of catchment inflow). **Figure D-3** shows measured water levels within Lake Curalo dropped at a rate of -0.15 m/hr over the 6 hours following the entrance breakout. With modified inflows, this was well replicated by the model with a rate of -0.14 m/hr. The resulting channel through entrance had a width of 10m and a bed level of +0.2mMSL which is a realistic channel dimension for ICOLL entrance breakouts.

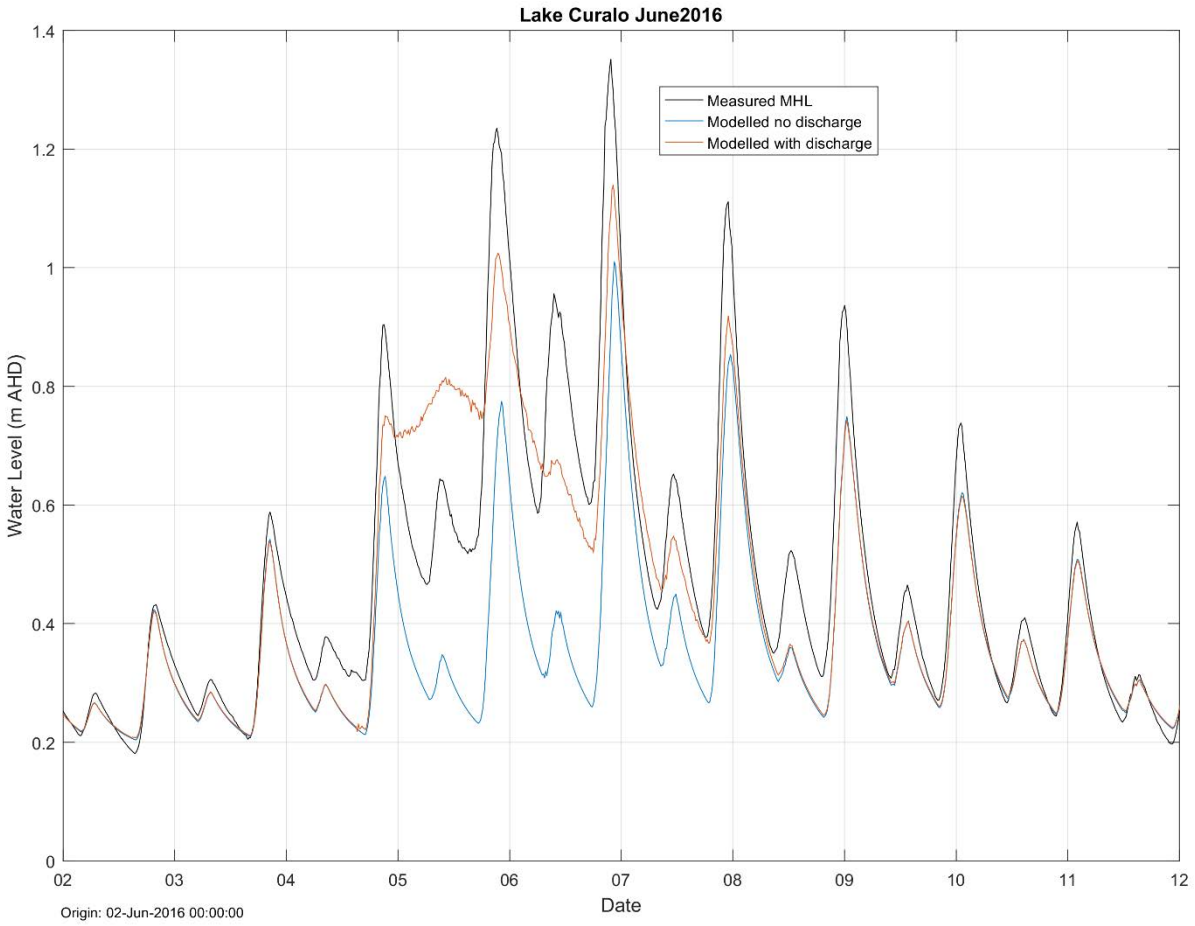


Figure D-2 Comparison of modelled lake water levels with the measured water levels from the MHL gauge within Lake Curalo for the June 2016 ECL event.

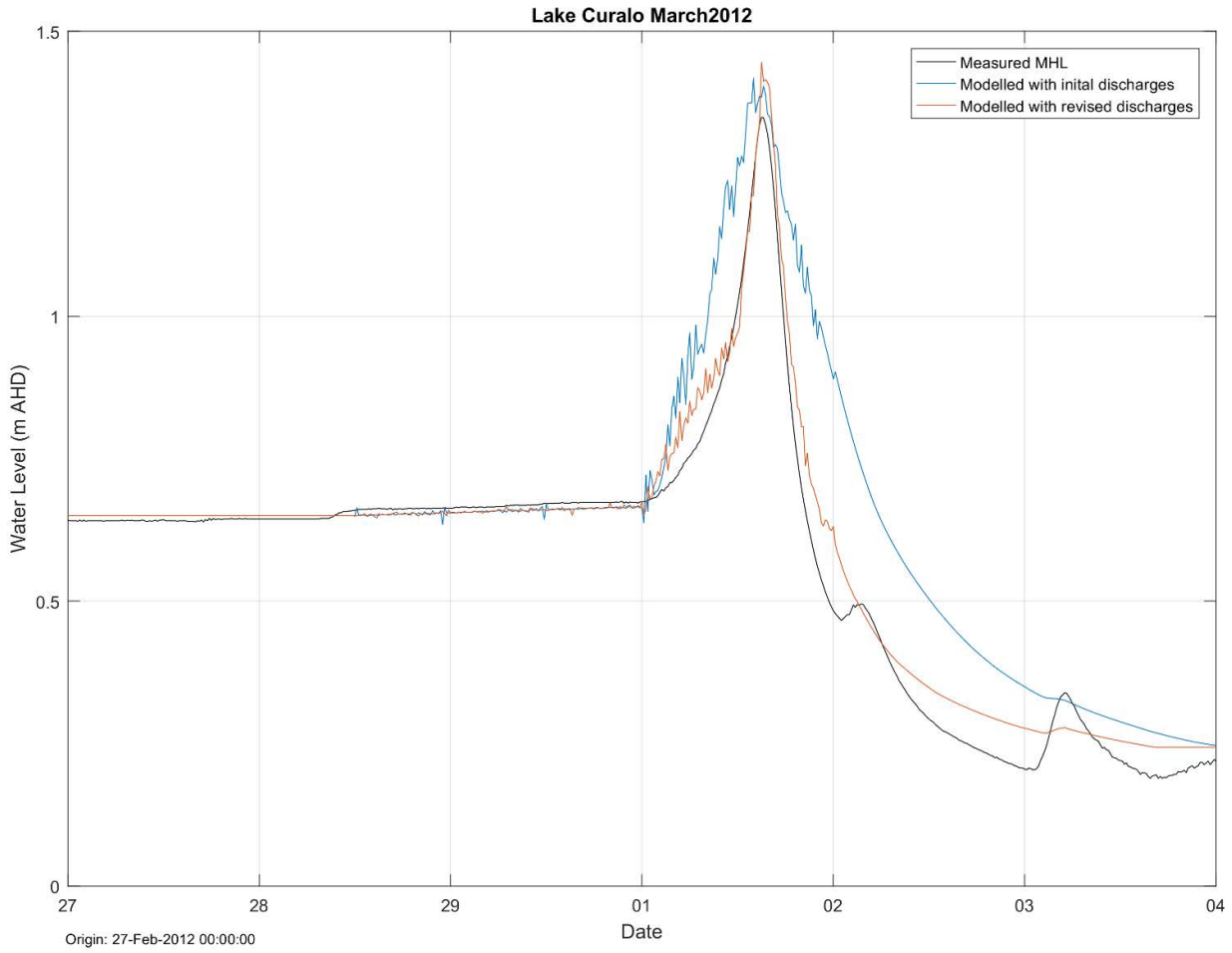


Figure D-3 Comparison of modelled lake water levels with the measured water levels from the MHL gauge within Lake Curalo for the March 2012 breakout event.

Coastal Connected Area Models (ICOLLs)

No calibration data was available for Cocora Lagoon, Shadrachs Creek and Nullica River and Boydtown Creek. Instead, the models were 'tested' using example design flood scenarios with the model domain extending out to the 5 m AHD contour.

Towamba River Catchment Hydrological Models

Calibration to Historical Gauge Record

The hydrological model was calibrated to one historical event which occurred within the gauge record. The 2011 event, which was only recorded at the Towamba gauge. This event is approximately a 1 in 80 year event based on the FFA.

Unfortunately, the rainfall data associated with this event was minimal. The initial review of the rainfall data suggested that the 2011 event should have been recorded at two pluvio-stations within the catchment at Towamba and Wyndham. However, on receiving the rainfall data, the pluvio-station at Towamba was found

not to be working during the 2011 event. Therefore, only Wyndham could be used to represent the temporal pattern. This gauge is north east of the catchment. It may be reflective of the rainfall in the Wyndham and New Buildings part of the catchment, but it is uncertain on changes to the temporal pattern moving south through the catchment, and in the steeper upper reaches of the catchment.

The rainfall data from the Wyndham gauge was factored across the Towamba catchment based on the daily rainfall totals sourced from the gauges at Cathcart and Towamba (refer Figure 3-5). The daily totals at each gauge were compared, and the rainfall from Wyndham increased or decreased in line with this factor. The daily totals and the factor for each are summarised in **Table D-3.** The Wyndham rainfall was factored for each 24 hour period (9am to 9am) based on the relative value of the daily totals at the three gauges.

As sufficient pluvio data to define the storm movement was no available, a review was undertaken of the BoM rainfall radar to gain an indication of how the storm through the catchment area. The radar data from the Canberra radar gauge (which was the closest to the study area) was sourced from The Weather Chaser website (http://www.theweatherchaser.com), which provide historic rainfall radar images. The radar images showed that the storm moved in a southerly direction across the catchment, with the centre of the storm taking approximately 1.5 hours to move from the top of the catchment to the bottom. To account for this, the rainfall depths across the catchment were shifted accordingly, so that the peak of the rainfall occurred 1.5 hours later at the bottom of the catchment compared to the top.

Table D-3: Towamba Rainfall Factoring

Location	21/3/2011	22/3/2011	23/3/2011
Rainfall Depths			
Cathcart	35	378	41.2
Wyndham	22	340.8	26
Towamba	13.6	215	61.2
Rainfall Factors			
Cathcart	1.6	1.1	1.6
Wyndham	1	1	1
Towamba	0.6	0.6	2.4

The 1978 event was also investigated, which is estimated to be approximately a 1 in 30 year event. However, for this event the only pluviometer data that was available was from Green Cape, which is located south east of Twofold Bay and only the coast. It is a significant distance from the part of the catchment which drives the flood behaviour for Towamba, Rocky Hall and New Buildings where the gauges are located, which would also be affected by the mountainous terrain in this area. Therefore, this event was not used for the calibration of the hydrological model.

The XP-RAFTS model hydrographs and the gauge hydrographs for the 2011 event are shown in **Figure D-4**. There was no gauge data available at either Rocky Hall or New Buildings for the 2011 event.

The models had a reasonable calibration with regard to the timing. The start and end of the flood hydrograph from XP-RAFTS corresponds well with the recorded gauge flows. However, the twin peaks of the gauged flows

are not replicated in the modelling. This may be a result of the lack of pluviometer data, making it difficult to represent the change in storm as it moved across the catchment. Further, it is difficult to determine the actual peak of the storm as the rainfall could only be factored based on the daily rainfall, which may differ to sub-daily peaks.

Given the uncertainties with the peak flow estimates for the historical events, the XP-RAFTS model was validated against the FFA using ARR2016 design rainfall intensities and temporal patterns. This provides greater confidence on the peak flow estimates. The 2011 event, by comparison, then provides confidence on the flow routing in the model to ensure that the timing between the rainfall and flow at Towamba is similar.

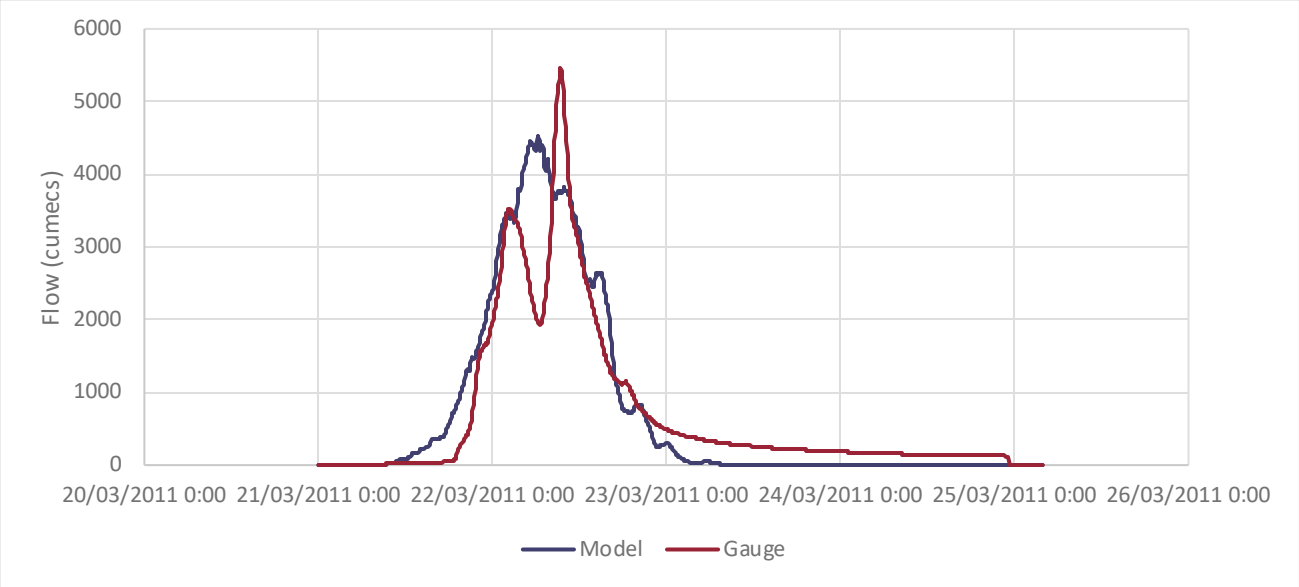


Figure D-4 Comparison of modelled and gauge flows at Towamba, 2011

Validation Against FFA Results

The XP-RAFTS model was used to run the full set of ensemble storms for durations from 12 to 72 hours, for the 10%, 5%, 2% and 1% AEP events. The median storm flow peak was then plotted on the FFA curves to assess how well the design flows aligned with the results of the FFA assessment. These figures are shown in **Figure D-5** to **Figure D-7**.

The figures show that the design flows for both the Rocky Hall gauge and the New Buildings gauge align well with the FFA results, plotting well within the confidence limits and on a similar gradient to the FFA line. Both these gauges are located in the upper catchment where the influence of routing lag parameters is reduced. The good match between the XP-RAFTS model and the FFA at these gauges indicate that the catchment characteristics (roughness and slope) are appropriate.

The Towamba gauge does not show as good a match as the other two gauges. The 10% AEP estimate has a reasonable match against the FFA. However, the larger flows increase at a much slower rate than the FFA probability curve. It is interesting to note that the design flow estimates trend in the same way as the observed flood flows, with the exception of the 2011 event, which sits noticeably higher.

As such, further assessment was undertaken of the Towamba gauge data.

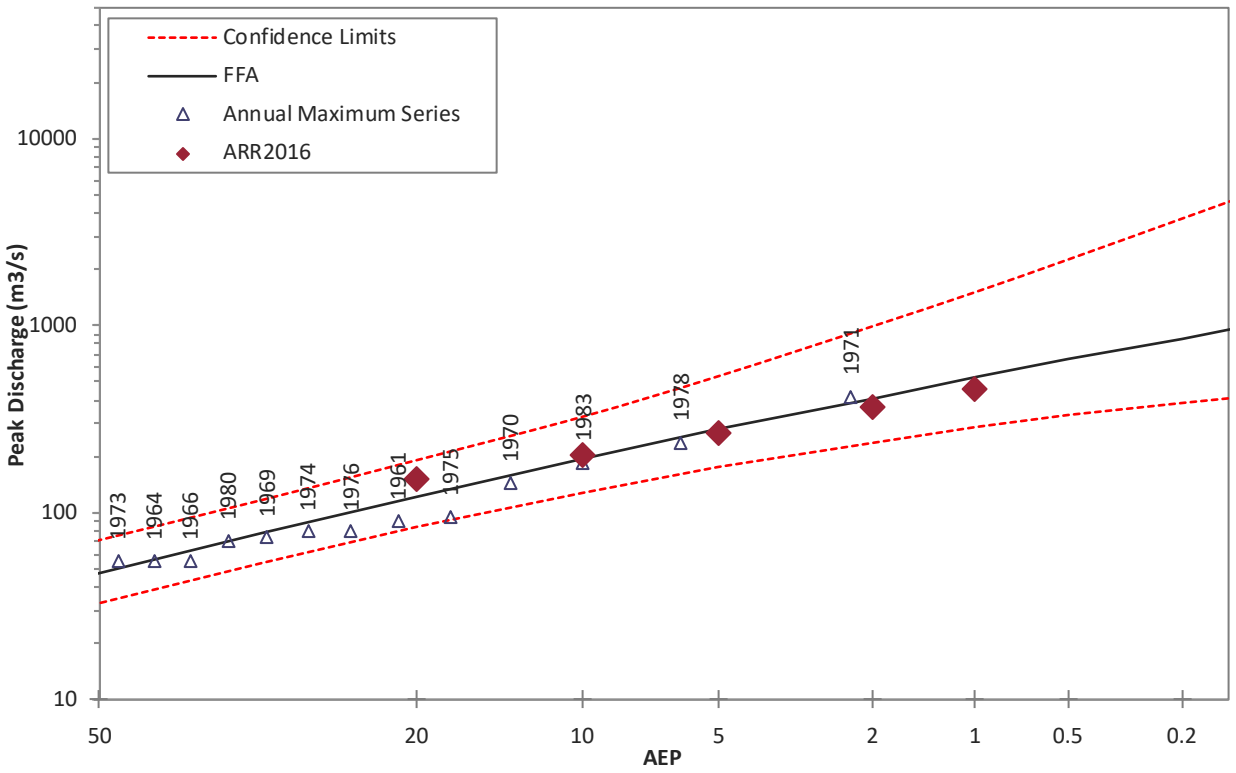


Figure D-5 Rocky Hall FFA Comparison

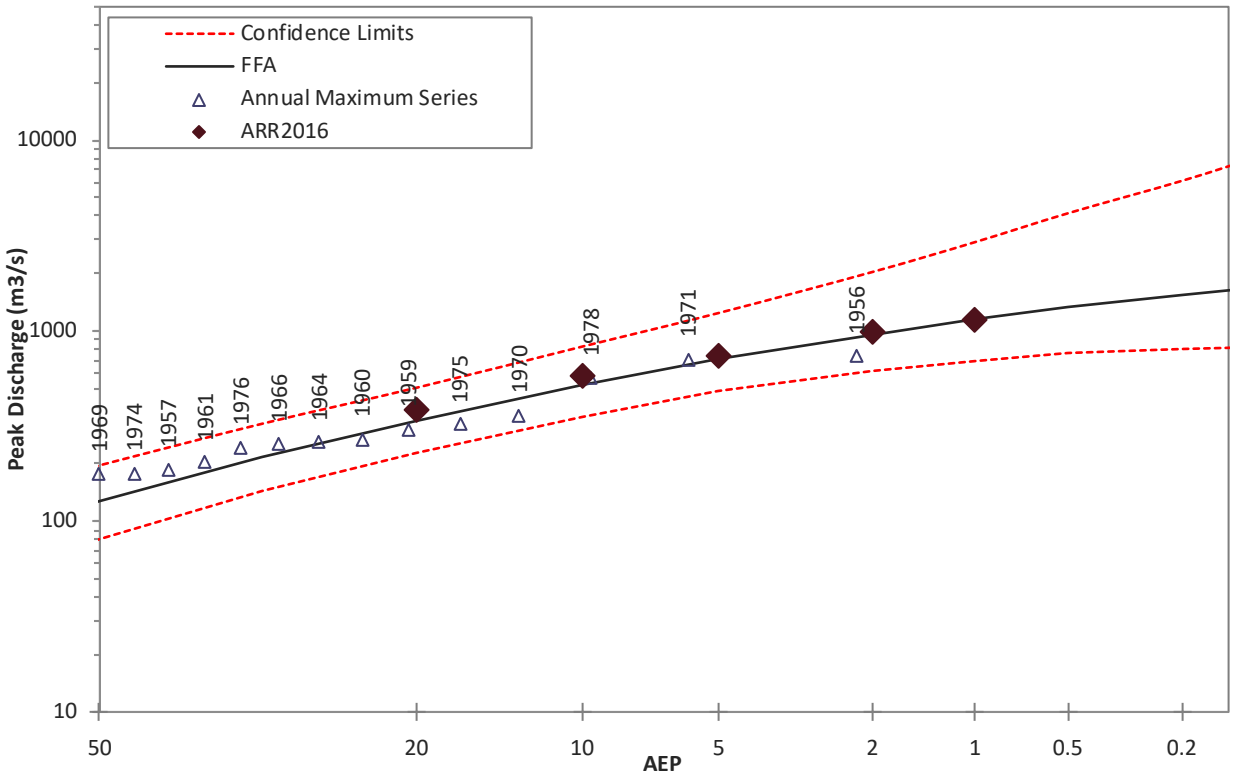


Figure D-6 New Buildings FFA Comparison

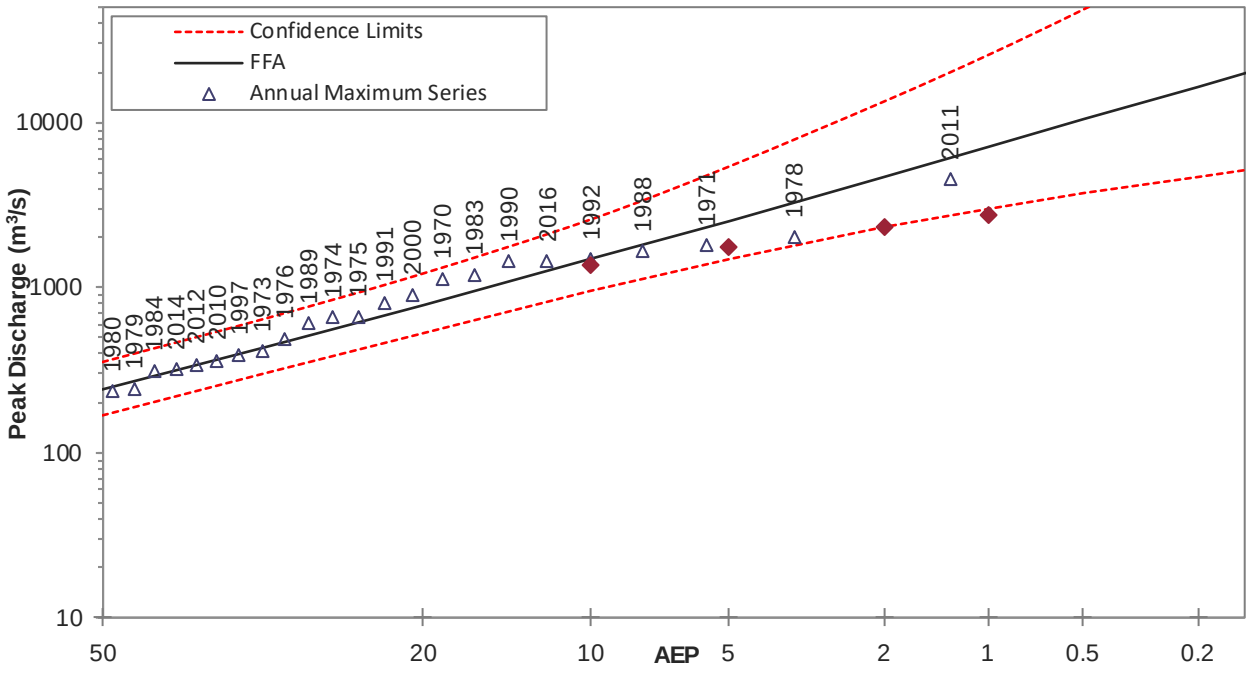


Figure D-7 Towamba FFA Comparison

In the first instance, the frequency and relative size of major floods in the Towamba River was reviewed. This is plotted below in **Figure D-8** below.

The figure shows that before the 2011 event, it had been 19 years (1992) since a 20% AEP event, and 33 years (1978) since anything larger than a 10% AEP event. Further more, in the preceding 10 years (2001 – 2011) there was very little major flow activity in the Towamba River.

Unfortunately the record at Towamba doesn't extend far back beyond the 1978 event, but the 8 years of data available is indicative of a similar pattern for this event as well. The gauge at New Buildings goes back to 1956, and the annual maxima are shown in **Figure D-9**. For New Buildings it shows a large event in 1971 (for which the gauge malfunctioned at Towamba) before which these is a 15 year period with no major floods, until 1956.

It is reasonable to assume that during these intervals, various processes are going to be occurring that will change the conveyance of the system, such as vegetation becoming established throughout the channel, increasing the roughness of the river banks, and the deposition of sand and sediment throughout the river channel, changing the rating curve. Some indications of both of these processes was observed during the visit to the gauge.

In order to take this into account, a second stage-discharge relationship was developed for the channel section, adopting higher roughness values across both banks. Roughness values were increased for both the low shrub areas close to the water, as well as the denser vegetation further up the banks.

Using this higher roughness stage-discharge curve, revised flow estimates were determined for both the 1978 and 2011 events. As would be expected, the higher roughness values resulted in a lower peak discharge for these events, based on the water level recorded by the gauge. This resulted in the 2011 event reducing from 3,570 to 2,620 cumecs, and the 1978 event from 2,960 to 2,200 cumecs, reductions in the order of 25%.

The FLIKE assessment was then undertaken incorporating these reduced flows. Only these two events were changed. The other flows remained the same as the previous assessment, based on the previous rating curve.

The results of this FFA are shown in **Figure D-10**. The general alignment of the FFA with the RAFTS model is good, though the FFA is still estimating higher values.

A second FFA test was also done, which removed both the 1978 and 2011 flows from the assessment. These results are shown in **Figure D-11**. In this case, the FFA and the RAFTS estimates have a very good correlation. The 1978 and 2011 events are still plotted against this result, and it shows them well within the confidence limits but sitting noticeably above the FFA line with respect to the other events.

This assessment indicates the influence that these two events have on the FFA results. This isn't surprising given how much larger they are compared to the other events in the record. It also shows that any uncertainty in these events is going to have a noticeable impact on the FFA results.

Given the data limitations, and no photographic evidence of the gauge prior to either the 2011 and 1978 events, further investigation was not possible. The results in **Figure D-11** show that for the majority of the record, the RAFTS flows are matching well. The differences between **Figures D-10** and **Figure D-11** highlight the influence these two large events have and suggests that there is a factor at play that results in these two events deviating so strongly from the bulk of the data. It is suggested that both bank roughness and sedimentation played a role in elevating the levels of these two events, beyond the 'normal' rating curve of the channel at the gauge, though without photographic evidence it cannot be shown conclusively.

Overall, the results shown in **Figure D-11** (which include the 2011 and 1978 events) are reasonable, and the RAFTS flows are well within the confidence limits of the FFA, indicating the RAFTS model is suitably calibrated.

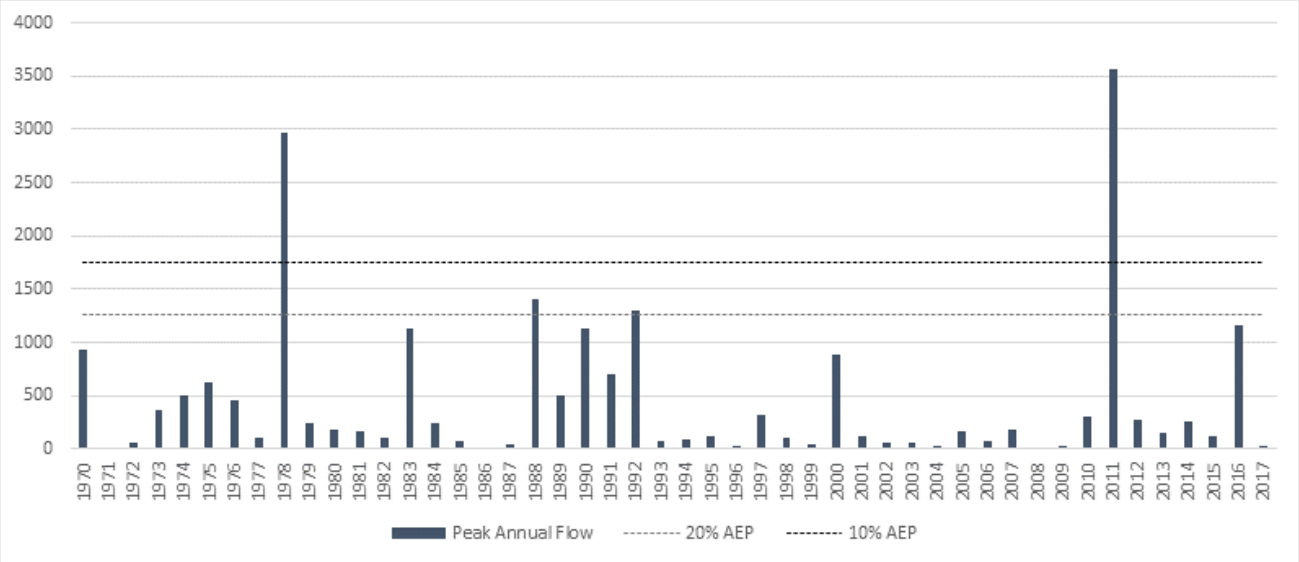


Figure D-8 Towamba Annual Peak Flow

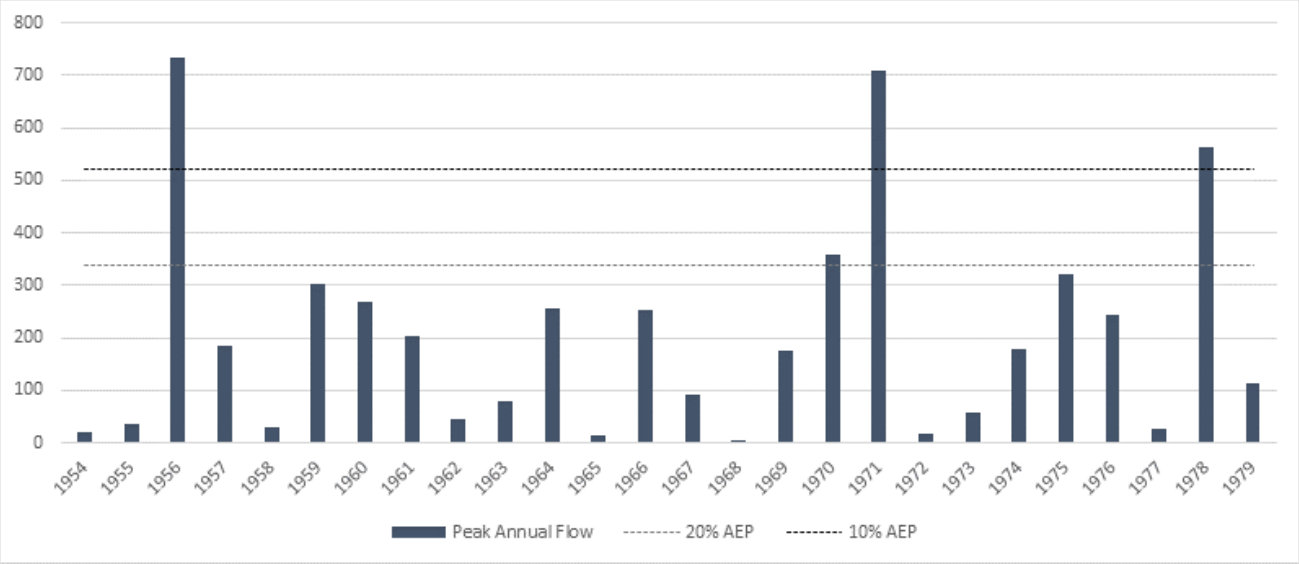


Figure D-9 New Buildings Annual Peak Flow

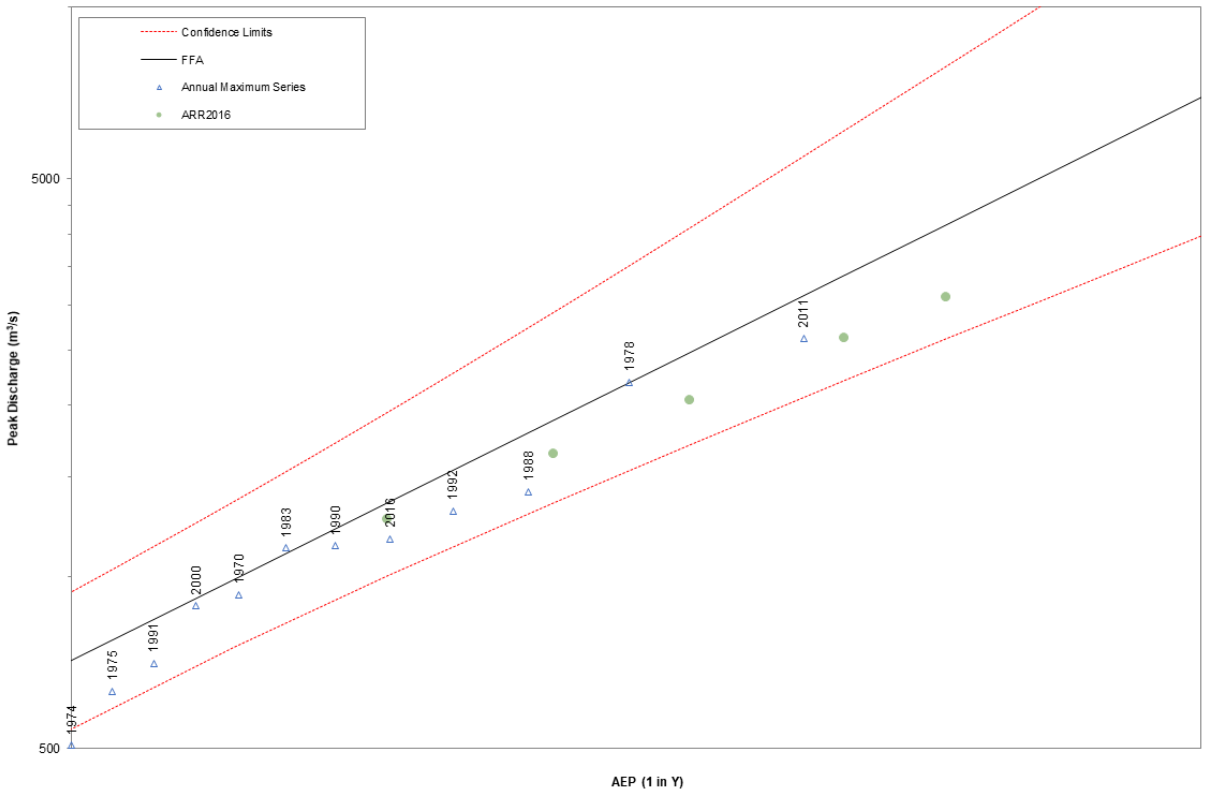


Figure D-10: FFA – 2011 and 1978 updated with a revised rating curve incorporating a higher roughness

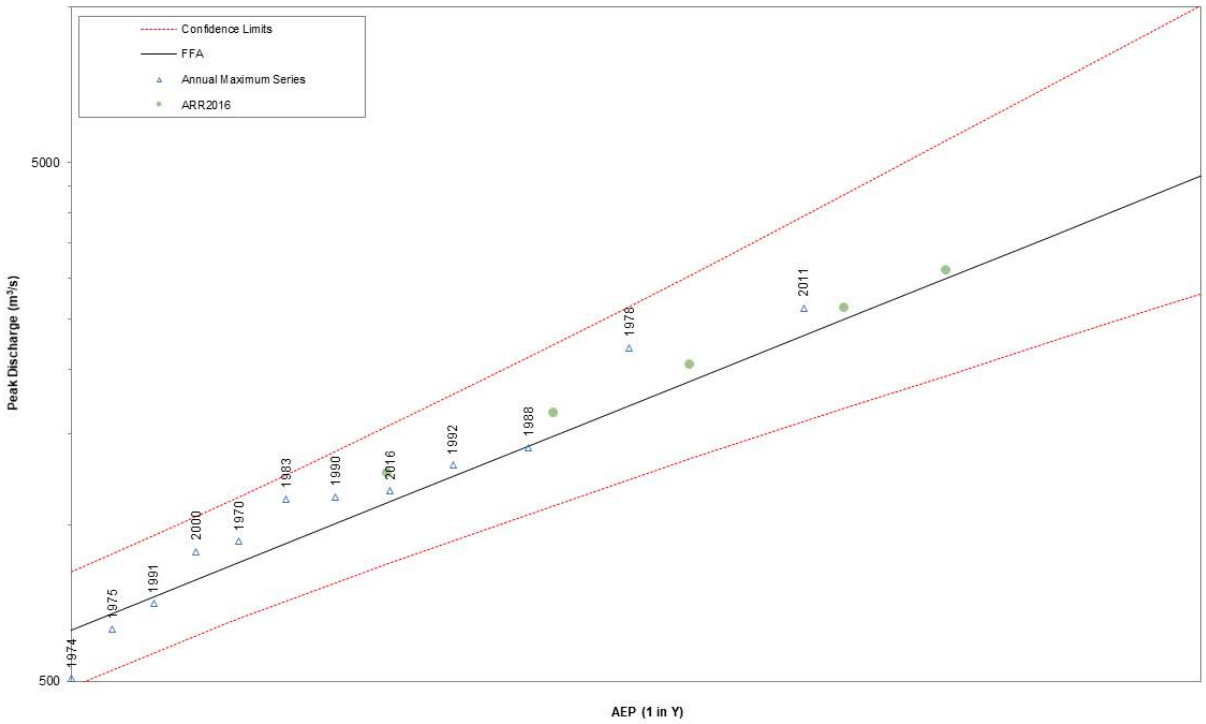


Figure D-11: FFA – 2011 and 1978 excluded with a revised rating curve incorporating a higher roughness

Towamba River Catchment Hydraulic Models

As part of the collection of the additional survey, flood marks from the 2011 and 1978 events were collected in Towamba. Additional observations from the community regarding flood extents were collected as part of the community consultation.

Only the Towamba model was able to be directly calibrated. However, in order to ensure that the Towamba River models are compatible with one another, the hydraulic model parameters determined through the Towamba calibration process will be adopted at the other study areas.

In order to calibrate the Towamba hydraulic model, the revised gauged flows from the 2011 and 1978 events were run through the model. The comparison between modelled results and the survey and community observations are shown in **Map 520** for the 2011 event and **Map 521** for the 1978 event.

The figure shows that the hydraulic model results are producing similar flood levels and extents to those observed by the community.

In the 2011 event, the surveyed flood level in Towamba was 38.34mAHD. The model had a level of 38.54maHD at this location. The comment from the community was that the 2011 flood "reached the text of the sign" at this location, so 0.2m is well within the uncertainty of the survey mark.

Further upstream, community observations placed the flood extant at approximately the 40mAHD contour. The flood level at this location in the model was 39.7mAHD. Given the accuracy of the extent reporting (a community member indicating the flood extent on an A1 map) this is also within the accuracy of the historical reporting.

The community also provided a photo of the local bus shelter in the 2011 event. Two photos showing the flooding of the bus shelter are provided in **Figure D-12**. The photos show that the flood reached to the roof of the shelter. The height of the shelter to the underside of the roof was estimated to be approximately 2.4m, suggesting that the flood height was in the order of 2.5 – 3m. The 2011 flood depth from the model at this location was 2.8m.

The 1978 also had a survey point collected, and an extent marked on the map as part of the community drop in workshops. The historical extent indicated by the community member was that the 1978 event fell approximately 40m short of Pericoe Road. The TUFLOW model calibrates well to this observation, reaching to approximately 50m from Pericoe Road.

The point surveyed for the 1978 event was marked by a hacksaw on a post near the intersection of Yambulla Road and Towamba Street. The point was surveyed as being at 36.52mAHD. The model at this location has a level of 36.39mAHD, 0.13m lower than the survey mark.

Figure D-12 Towamba Bus Shelter Flooding in 2011

Eden Hydraulic Model

No reliable calibration data was available relating to overland and creek flooding within Eden for a specific flood event. However, various general accounts of flood behaviour were collected as part of the community information sessions (**Section 4.5**).

The 20% and 1% AEP design events have been modelled with a stage vs discharge (HQ) downstream boundary to provide an overview of the flood behaviour. The design runs undertaken as part of Stage 3 of the study will adopt a dynamic downstream boundary condition driven by the water levels in the Lake Curalo and Cocora Lagoon Hydrodynamic models.

The results of the model runs are shown in **Map 524 and Map 525** along with the community observations of flooding. Although there are only limited flood observations, the results appear to align with what has been observed in the past.

APPENDIX E

ARR Datahub Output

Results - ARR Data Hub

[STARTTXT]

Input Data Information

[INPUTDATA]

Centroid Latitude,-37.014

Centroid Longitude,149.591

Shapefile filename,Towamba_Catchment_Lat_Long.shp

[END_INPUTDATA]

River Region

[RIVREG]

division,South East Coast (NSW)

rivregnum,20

River Region,Towamba River

per_intersect,0.9943

[RIVREG_META]

Time Accessed,23 July 2018 10:09AM

Version,2016_v1

[END_RIVREG]

ARF Parameters

[LONGARF]

Zone,SE Coast

a,0.06

b,0.361

c,0.0

d,0.317

e,8.11e-05

f,0.651

g,0.0

h,0.0

i,0.0

per_intersect,0.9996

[LONGARF_META]

Time Accessed,23 July 2018 10:09AM

Version,2016_v1

[END_LONGARF]

Storm Losses

[LOSSES]

Storm Initial Losses (mm),19.0

Storm Continuing Losses (mm/h),5.7

[LOSSES_META]

Time Accessed,23 July 2018 10:09AM

Version,2016_v1

[END_LOSSES]

Temporal Patterns

[TP]

code,SSmainland

Label,Southern Slopes (Vic/NSW)

per_intersect,1.0

[TP_META]

Time Accessed,23 July 2018 10:09AM

Version,2016_v2

[END_TP]

Areal Temporal Patterns

[ATP]

code,SSmainland

arealabel,Southern Slopes (Vic/NSW)

per_intersect,1.0

[ATP_META]

Time Accessed,23 July 2018 10:09AM

Version,2016_v2

[END_ATP]

BOM IFD Depths

[BOMIFD]

No data,No data found at this location!

[BOMIFD_META]

Time Accessed,23 July 2018 10:09AM

[END_BOMIFD]

Median Preburst Depths and Ratios

[PREBURST]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),2.0 (0.089),1.5 (0.046),1.2 (0.030),0.9 (0.019),1.9 (0.032),2.6 (0.040),

90 (1.5),5.3 (0.199),4.2 (0.108),3.4 (0.073),2.7 (0.049),4.2 (0.063),5.3 (0.070),

120 (2.0),4.7 (0.156),4.7 (0.110),4.8 (0.091),4.8 (0.078),5.2 (0.071),5.5 (0.067),

180 (3.0),7.9 (0.223),10.8 (0.212),12.8 (0.206),14.6 (0.201),8.9 (0.102),4.5 (0.046),

360 (6.0),9.1 (0.182),17.1 (0.239),22.5 (0.259),27.6 (0.271),27.8 (0.228),27.9 (0.203),

720 (12.0),9.8 (0.137),16.1 (0.155),20.3 (0.160),24.3 (0.162),24.1 (0.133),23.9 (0.116),

1080 (18.0),4.5 (0.050),11.9 (0.092),16.8 (0.106),21.5 (0.115),20.8 (0.090),20.2 (0.077),

1440 (24.0),2.6 (0.025),6.8 (0.045),9.6 (0.052),12.3 (0.056),14.7 (0.055),16.6 (0.053),

2160 (36.0),0.2 (0.002),1.2 (0.007),1.9 (0.009),2.5 (0.010),4.1 (0.012),5.3 (0.014),

2880 (48.0),0.0 (0.000),0.0 (0.000),0.1 (0.000),0.1 (0.000),0.7 (0.002),1.2 (0.003),

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.3 (0.001),0.5 (0.001),

[PREBURST_META]

Time Accessed,23 July 2018 10:09AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST]

10% Preburst Depths

[PREBURST10]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

90 (1.5),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

180 (3.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

360 (6.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

720 (12.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

1080 (18.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

[PREBURST10_META]

Time Accessed,23 July 2018 10:09AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST10]

25% Preburst Depths

[PREBURST25]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

90 (1.5),0.0 (0.001),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

120 (2.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

180 (3.0),0.0 (0.000),0.1 (0.001),0.1 (0.002),0.2 (0.002),0.1 (0.001),0.0 (0.000),

360 (6.0),0.2 (0.005),1.0 (0.014),1.5 (0.017),1.9 (0.019),0.8 (0.007),0.0 (0.000),

720 (12.0),0.2 (0.002),0.6 (0.006),0.9 (0.007),1.2 (0.008),0.5 (0.003),0.0 (0.000),

1080 (18.0),0.0 (0.000),0.3 (0.003),0.6 (0.004),0.8 (0.004),0.5 (0.002),0.3 (0.001),

1440 (24.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

2160 (36.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

2880 (48.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

4320 (72.0),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),0.0 (0.000),

[PREBURST25_META]

Time Accessed,23 July 2018 10:09AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST25]

75% Preburst Depths

[PREBURST75]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),18.9 (0.826),19.2 (0.575),19.3 (0.474),19.5 (0.404),22.7 (0.388),25.1 (0.378),

90 (1.5),31.9 (1.197),32.1 (0.832),32.2 (0.687),32.4 (0.585),32.1 (0.483),32.0 (0.424),

120 (2.0),32.9 (1.102),38.5 (0.894),42.3 (0.808),45.8 (0.746),47.1 (0.639),48.1 (0.578),

180 (3.0),34.5 (0.969),49.4 (0.965),59.2 (0.957),68.7 (0.946),59.0 (0.680),51.8 (0.529),

360 (6.0),32.2 (0.644),52.8 (0.736),66.5 (0.766),79.6 (0.782),91.9 (0.753),101.1 (0.733),

720 (12.0),25.6 (0.354),42.8 (0.410),54.1 (0.426),65.1 (0.435),69.9 (0.386),73.5 (0.356),

1080 (18.0),17.6 (0.197),34.1 (0.263),45.1 (0.284),55.6 (0.296),61.8 (0.269),66.4 (0.252),

1440 (24.0),16.0 (0.156),24.8 (0.165),30.6 (0.166),36.2 (0.165),49.5 (0.184),59.5 (0.192),

2160 (36.0),6.3 (0.051),16.1 (0.089),22.6 (0.101),28.8 (0.108),32.3 (0.098),34.9 (0.091),

2880 (48.0),2.7 (0.020),6.7 (0.033),9.3 (0.037),11.8 (0.039),13.6 (0.036),14.9 (0.035),

4320 (72.0),0.0 (0.000),0.2 (0.001),0.4 (0.001),0.5 (0.002),2.4 (0.006),3.7 (0.008),

[PREBURST75_META]

Time Accessed,23 July 2018 10:09AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST75]

90% Preburst Depths

[PREBURST90]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),63.4 (2.772),71.4 (2.139),76.6 (1.879),81.6 (1.692),88.1 (1.507),92.9 (1.398),

90 (1.5),75.7 (2.842),90.5 (2.346),100.2 (2.136),109.6 (1.982),122.0 (1.833),131.3 (1.742),

120 (2.0),64.8 (2.170),92.5 (2.146),110.8 (2.119),128.4 (2.089),128.0 (1.736),127.7 (1.533),

180 (3.0),63.0 (1.769),103.3 (2.019),130.0 (2.099),155.5 (2.142),140.0 (1.611),128.3 (1.310),

360 (6.0),68.0 (1.361),100.2 (1.397),121.5 (1.400),142.0 (1.397),154.0 (1.262),163.0 (1.181),

720 (12.0),51.6 (0.716),81.9 (0.785),102.0 (0.803),121.2 (0.811),136.2 (0.752),147.5 (0.714),

1080 (18.0),45.0 (0.505),72.6 (0.559),90.8 (0.572),108.3 (0.576),129.6 (0.565),145.6 (0.553),

1440 (24.0),39.7 (0.388),56.9 (0.378),68.3 (0.370),79.2 (0.361),102.9 (0.382),120.7 (0.389),

2160 (36.0),36.3 (0.297),45.1 (0.250),50.9 (0.228),56.5 (0.211),89.7 (0.272),114.5 (0.300),

2880 (48.0),27.3 (0.201),31.8 (0.158),34.9 (0.140),37.8 (0.126),46.7 (0.125),53.4 (0.124),

4320 (72.0),7.9 (0.052),13.7 (0.061),17.5 (0.062),21.2 (0.062),36.1 (0.085),47.2 (0.096),

[PREBURST90_META]

Time Accessed,23 July 2018 10:09AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST90]

Interim Climate Change Factors

[CCF]

2030,0.719 (3.6%),0.739 (3.7%),0.822 (4.1%),

2040,0.925 (4.6%),0.915 (4.6%),1.119 (5.6%),

2050,1.123 (5.6%),1.085 (5.4%),1.449 (7.2%),

2060,1.271 (6.4%),1.294 (6.5%),1.865 (9.3%),

2070,1.394 (7.0%),1.526 (7.6%),2.333 (11.7%),

2080,1.477 (7.4%),1.778 (8.9%),2.776 (13.9%),

2090,1.527 (7.6%),2.009 (10.0%),3.21 (16.1%),

[CCF_META]

Time Accessed,23 July 2018 10:09AM

Version,2016_v1

Note,ARR recommends the use of RCP4.5 and RCP 8.5 values

[END_CCF]

[ENDTXT]