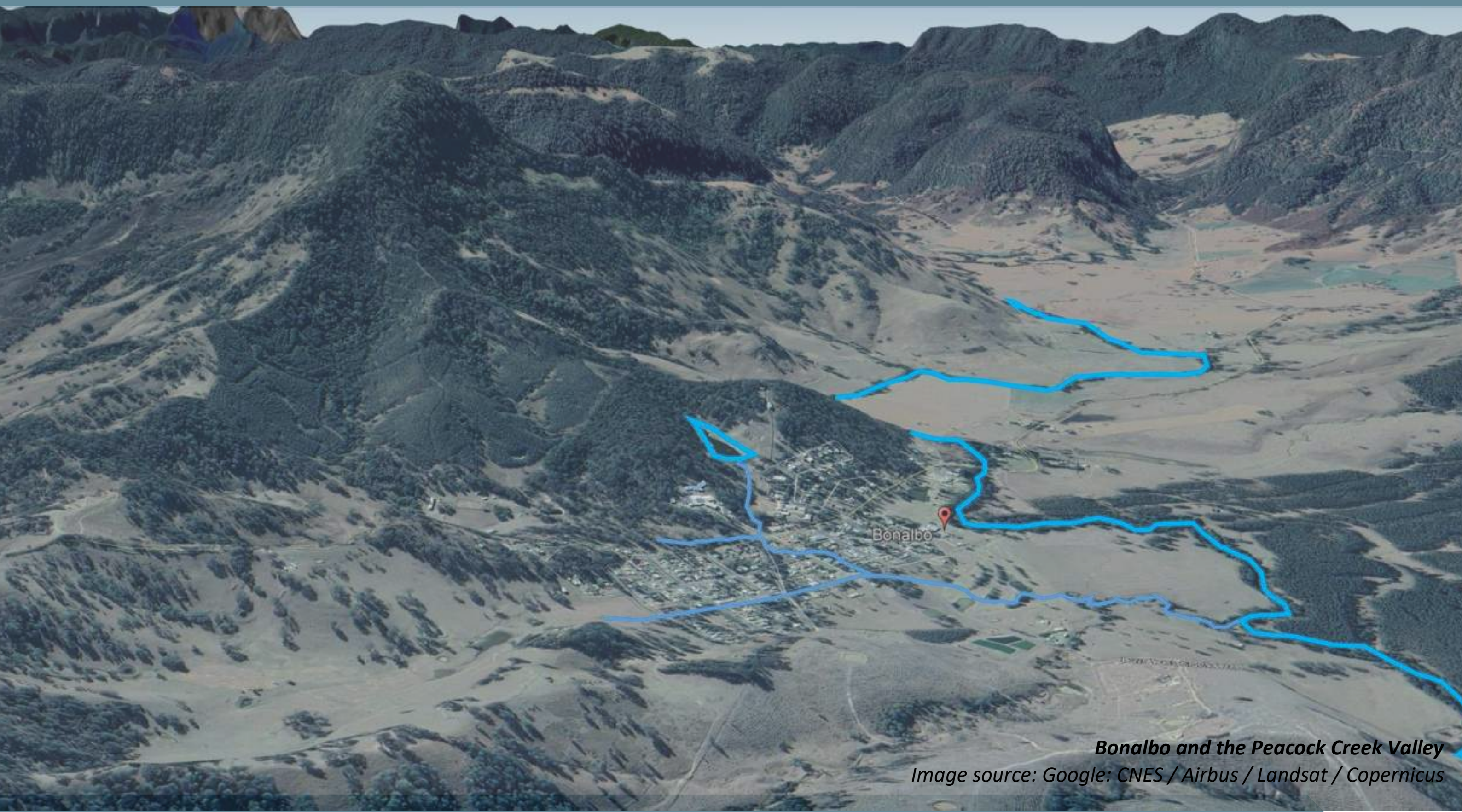



***Bonalbo and the Peacock Creek Valley***
*Image source: Google: CNES / Airbus / Landsat / Copernicus*

# BONALBO
# FLOOD STUDY

KYOGLE COUNCIL

ISSUE / Public Exhibition Report
CLIENT / Kyogle Council
DATE / 28/07/2021
BG&E PROJECT NO / S20095

www.bgeeng.com

# CONTENTS

# APPENDICES

## Document *Control*

| Revision | Date | Description | Prepared | Reviewed | Approved |
|---|---|---|---|---|---|
| A | 28/06/2021 | Draft for Comment | S Mortimer | L Baxter | L Baxter |
| B | 28/07/2021 | Public Exhibition Report | S Mortimer | L Baxter | L Baxter |
| | | | | | |

# GLOSSARY AND ABBREVIATIONS

| | |
|---|---|
| **1d** | 1-dimensional – in flood modelling this typically refers to models where flow moves perpendicular to given cross sections. In these study 1d elements have been embedded in the 2d model to represent drainage. |
| **2d** | 2-dimensional – in flood modelling this typically refers to the modelling of a gridded elevation surface (DEM) over which runoff can move in all direction on a 2-dimenasional plane eg left, right, backward, forwards. |
| **AEP** | Annual Exceedance Probability – the chance of a flood of a given size or larger occurring in any one year, usually expressed as a percentage. |
| **AHD** | Australian Height Datum |
| **AIDR** | Australian Institute for Disaster Resilience |
| **ARI** | Average Recurrence Interval – the long term average number of years between the occurrence of a flood as larger as or larger than the selected event. |
| **ARR2019** | Australian Rainfall and Runoff 2019 (Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019). A national guideline used for flood estimation across Australia. |
| **ARR87** | Australian Rainfall and Runoff 1987 (Institution of Engineers Australia, 1987). A national guideline to flood estimation now updated with ARR2019. |
| **BoM** | Bureau of Meteorology |
| **Catchment** | Land area draining to a given point |
| **Cumec** | Cubic metre per section also expressed as $m^3/s$. |
| **DCP** | Development Control Plan |
| **DEM** | Digital Elevation Model |
| **DFE** | The Defined Flood Event (DFE) is selected by council for floodplain risk management purposes for an area/catchment, generally through the FRM process outlined in the Floodplain Development Manual. DFEs form the basis for determining the level of exposure to flooding and associated risks to life and property damage. The manual identifies the 1% AEP flood event, or an equivalent historic flood, as an appropriate starting point for determining the DFE for development controls |
| **Discharge** | The rate of flow of water typically measures in volume per unit of time, for example $m^3/s$ |
| **DPIE** | Department of Planning, Industry and Environment |
| **Effective warning time** | The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions. |

| | |
|---|---|
| **EY** | Exceedances per Year |
| **FDM** | Floodplain Development Manual 2005 |
| **FFA** | Flood Frequency Analysis – a statistical means of establish the Annual Exceedance Probability of flood based on gauged data records. |
| **Flash flooding** | Flooding which is often sudden and can be unexpected. Usually caused by localised intense rainfall. Often defined as flooding which peaks within six hours of the causative rain (Floodplain Development Manual: the management of flood liable land, April 2005). |
| **Flood fringe** | The remaining area of flood prone land after floodway and flood storage areas have been defined. |
| **Flood prone land** | Land subject to flooding up to and including the Probable Maximum Flood (PMF) extent. |
| **Flood storage area** | Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. |
| **Floodway** | Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels. |
| **FPA** | Flood Planning Area is land at or below the Flood Planning Level (FPL) |
| **FPL** | Flood Planning Level is a combination of the flood level from the defined flood event (DFE) and freeboard selected for flood risk management purposes. |
| **Freeboard** | Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the Flood Planning Level (FPL) is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the Flood Planning Level. |
| **FRM** | Flood Risk Management |
| **FRMC** | Floodplain Risk Management Committee |
| **FSL** | Full Supply Level – refers to the top design water level in a dam. |
| **ha** | hectares |
| **Habitable Room** | In a residential situation: a living or working area such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom<br>In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood. |
| **Hazard** | A source of potential harm or a situation with a potential to cause loss. |
| **Hydrograph** | A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood. |

| | |
|---|---|
| **Hydrology** | Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods. |
| **ICM** | InfoworksICM – a hydrology and hydraulic modelling software. For this study ICM has been used as the rainfall routing model. |
| **LEP** | Local Environmental Plan |
| **Local overland flooding** | Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam. In this study, local overland flooding refers to flooding caused by the local catchments and rainfall within the Bonalbo township area. |
| **Mainstream flooding** | Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. In this study mainstream flooding refers to flooding from Peacock Creek. |
| **ML** | megalitre |
| **NSW** | New South Wales |
| **PMF** | Probable Maximum Flood - the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. |
| **PMP** | Probable Maximum Precipitation - the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation. |
| **Rainfall routing model** | A hydrology models which converts rainfall depths over time to a flow hydrograph. |
| **RFFE** | Regional Flood Frequency Estimation |
| **Risk** | Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood e.g. AEP |
| **Runoff** | Rainfall which actually ends up as streamflow. |
| **SES** | State Emergency Services |
| **TUFLOW** | Hydraulic modelling software for flood, urban drainage, estuarine and coastal assessments. |

# TERMINOLOGY

Australian Rainfall and Runoff 2019, referred to as ARR2019, describes terminology for describing the frequency of flooding which has been adopted in this Flood Study report.

| Frequency Descriptor | EY | AEP (%) | AEP (1 in x) | ARI |
|---|---|---|---|---|
| Very Frequent | 12 | | | |
| | 6 | 99.75 | 1.002 | 0.17 |
| | 4 | 98.17 | 1.02 | 0.25 |
| | 3 | 95.02 | 1.05 | 0.33 |
| | 2 | 86.47 | 1.16 | 0.5 |
| | 1 | 63.21 | 1.58 | 1 |
| Frequent | 0.69 | 50 | 2 | 1.44 |
| | 0.5 | 39.35 | 2.54 | 2 |
| | 0.22 | 20 | 5 | 4.48 |
| | 0.2 | 18.13 | 5.52 | 5 |
| Rare | 0.11 | 10 | 10 | 9.49 |
| | 0.05 | 5 | 20 | 19.5 |
| | 0.02 | 2 | 50 | 49.5 |
| Very Rare | 0.01 | 1 | 100 | 99.5 |
| | 0.005 | 0.5 | 200 | 199.5 |
| | 0.002 | 0.2 | 500 | 499.5 |
| | 0.001 | 0.1 | 1000 | 999.5 |
| Extreme | 0.0005 | 0.05 | 2000 | 1999.5 |
| | 0.0002 | 0.02 | 5000 | 4999.5 |
| | | | ↓ | |
| | | | PMP/ PMP Flood | |

*Preferred terminology indicated in blue. Source ARR2019*

**Figure T-1-1: ARR2019 Terminology (Preferred terminology indicated in blue)**

# EXECUTIVE SUMMARY

## Report Status

This report has been prepared for Public Exhibition. Prior to Public Exhibition the report has been reviewed by Kyogle Council and DPIE with feedback from NEW SES.

## Purpose of the Bonalbo Flood Study

The Bonalbo Flood Study has been prepared under the Floodplain Risk Management Process to develop a detailed understanding of the flood behaviour at Bonalbo from both Peacock Creek (mainstream flooding) and from the local catchment drainage though the township.

Detailed hydrologic analysis and hydraulic modelling has been undertaken to map the predicted flood extents, levels, depths, velocities and hazards associated with a range of design flood events; 20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events. Predicted effects of climate change on flood behaviour are also presented.

The information in this Flood Study will be used to inform the subsequent Floodplain Risk Management Study and Plan which will set out flood risk management measures to minimise the risk and consequences of future flooding.

## Flooding in Bonalbo

Bonalbo is subject to two types of flooding; mainstream flooding from Peacock Creek and overland flows from local catchments draining through the town. At the southern end of the town flooding is dominated by mainstream flooding from Peacock Creek. Peacock Creek is a winding creek system with approximately 121 $km^2$ catchment size as it passes Bonalbo.

The local catchment for Bonalbo is quite small in comparison to the catchment of Peacock Creek; approximately 5 $km^2$. Catchments are characterised by steep upper slopes with the town located on the flatter areas. The town is located at the bottom of these catchments and receives flows from these ranges. The town itself has two major channels running through it, Capeen Street drain and one parallel to Bonalbo Street from the hospital catchment. Both channels hydraulic capacity can be exceeded in large storm events cutting road access in the town.

## Community Consultation and Public Exhibition

In preparing the Flood Study information was sought from the community via a community questionnaire to understand the community's experiences of flooding. This community information has been used in validating the findings of the flood modelling against actual event-based data.

Prior to adopting the Bonalbo Flood Study, a period of Public Exhibition will be held during which the community and key stakeholders will be invited to provide further comment on the study findings. This report comprises that Public Exhibition report.

# 1 INTRODUCTION

## 1.1 The Floodplain Risk Management Framework

The NSW Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, April 2005) and Australian Institute for Disaster Resilience's Handbook 7 (Managing the Floodplain; A Guide to Best Practice in Flood Risk Management in Australia, 2017), sets out the floodplain risk management process and provides guidance to local councils for the development of flood studies to lead to the development and implementation of floodplain risk management plans.

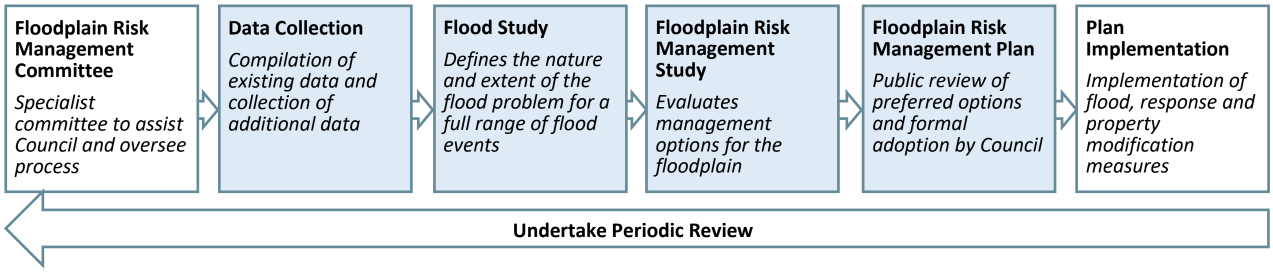



**Figure 1-1: Floodplain Risk Management Framework**

This is typically overseen by a Floodplain Risk Management Committee (FRMC) comprising representatives from Council and other interested parties including NSW State Emergency Services (NSW SES), Department of Planning, Industry and Environment (DPIE) any other key stakeholders.

For the Bonalbo area, few studies have been undertaken in the past and those that have had focused on dam failure and water supply. The Bonalbo Flood Study provides opportunity for Council and other interested stakeholders to understand, in detail, the flood behaviour in the area and allows, though the later Floodplain Risk Management Study and Plan, to improve safety of the community through flood related development controls and evacuation and warning, provisions of cost-effective flood mitigation measures and improved community awareness.

## 1.2 Purpose of the Bonalbo Flood Study

The Bonalbo Flood Study has been prepared to provide a detailed understanding of the precited flood behaviour at Bonalbo from Peacock Creek (mainstream flooding) and also from the local catchments (local overland flows). The findings of the Flood Study will inform a later Floodplain Risk Management Study and Plan which will investigate options for flood mitigation to minimise future losses due to flooding including flood planning development controls and options such as drainage upgrades, flood protection levees etc. The Flood Study is also important to inform emergency planning and has been prepared to address the Floodplain Risk Management Guideline SES Requirements from the Flood Risk Management Process (Department of Environment and Climate Change, 2007).

# 2 BACKGROUND

## 2.1 The Study Area

The project study (refer Figure 2-1) includes the township of Bonalbo and Clarence Way / Woodenbong Road area around Peacock Creek.

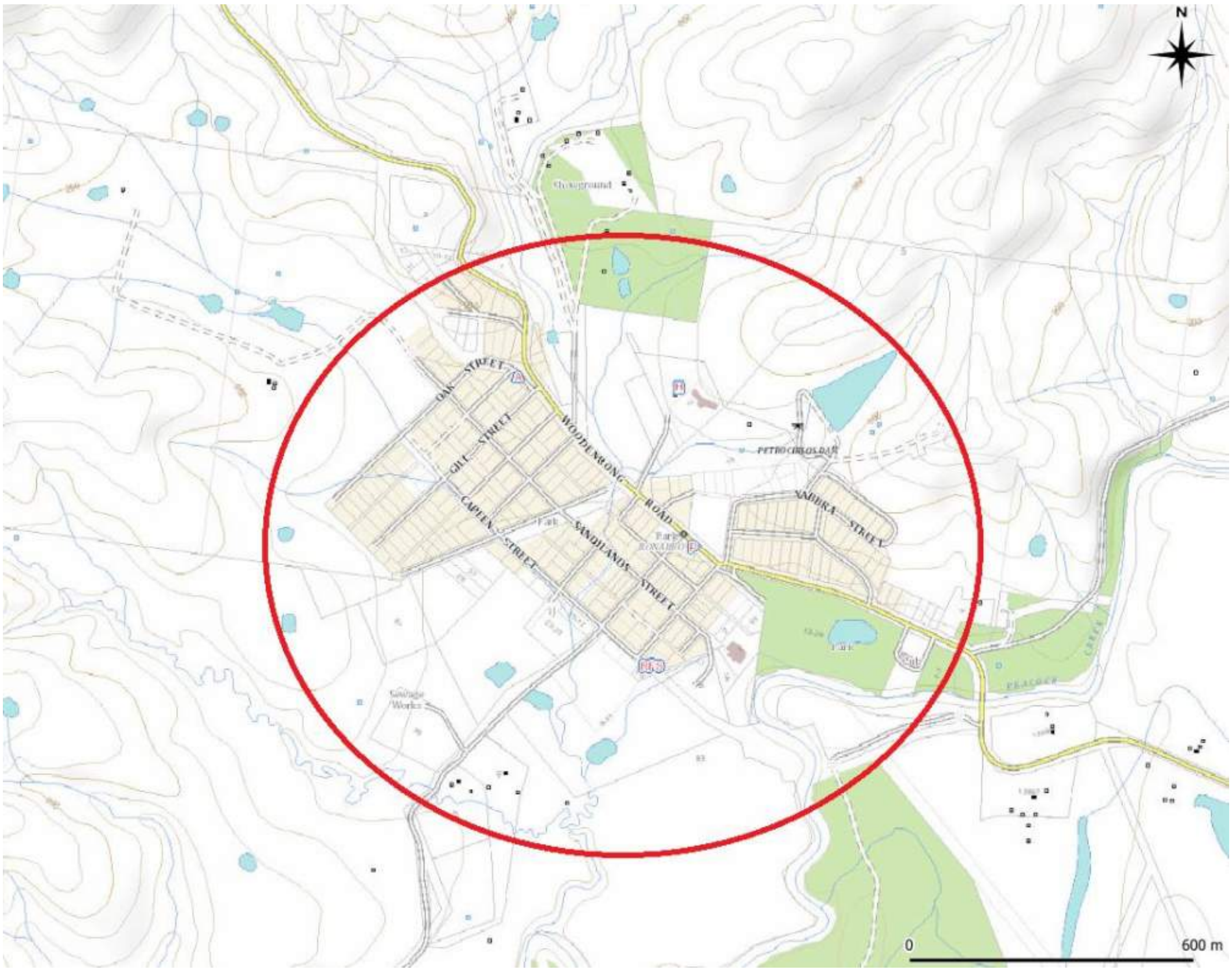



**Figure 2-1: The study area**

The township of Bonalbo is founded on undulating land north-west of Peacock Creek. Bonalbo is affected by flooding from two sources; Peacock Creek to the east of the township and from flooding of local catchment which run through the town as overland flows and via a series of drains towards Peacock Creek. Stormwater drains from the urban catchment through the existing stormwater network and discharges into two natural detention basins on the downstream side of the village.

In recent years no significant mainstream flooding has been reported and recent inundation reported though the community consultation has typically been from overland flows.

Bonalbo township becomes frequently isolated from the wider community. During events in the last 10 years including 2010 and 2011, roads such as the Clarence Way between Urbenville and Bonalbo were cut by floodwaters while much of the town remained unaffected by direct flooding. While the focus of the Bonalbo Flood Study is on the township, it is important to also consider the periods of isolation in floodplain risk management planning.

The Bonalbo Dam (Petrochilos Dam) is located upstream of the town and used for water supply. The dam comprises an earth embankment and piped outlet spillway and bywash overflow channel. Water is pumped to the dam from an intake well from Peacock Creek and a groundwater bore adjacent to the creek.

## 2.2 The Catchment Area

To the Clarence Way Bridge at Bonalbo Peacock Creek has a catchment area of 121 km$^2$. The catchment comprises two large catchments of Peacock Creek and Gorge Creek which each have an area of about 105 m$^2$ to their confluence. A river gauge is located on Peacock Creek about 7 km upstream of the confluence and gauges a catchment area of about 48 km$^2$. The Gorge Creek catchment drains about 45 km$^2$.

A number of smaller sub-catchments of Peacock Creek drain an area of about 5 km$^2$ through the town.

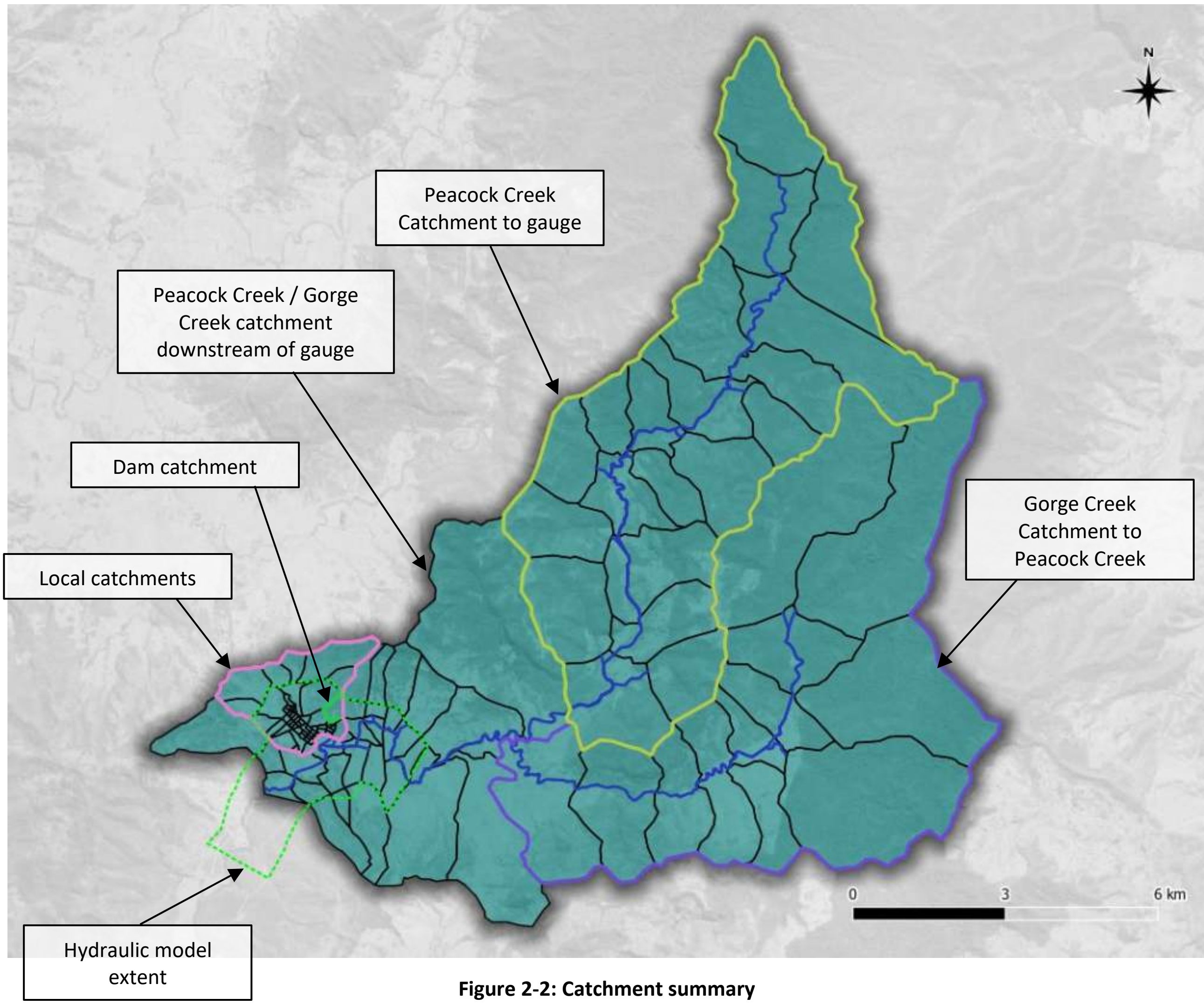



**Figure 2-2: Catchment summary**

## 2.3 Historic Flooding at Bonalbo

Major flooding affecting the town from Peacock Creek occurred in 1967; the event was estimated as about a 1% AEP event. Events in the 1950s washed away the Woodenbong Road / Clarence Way bridge crossing on Peacock Creek and damaged a replacement bridge. Other than these events, there has not been major flooding from Peacock Creek in recent years.

Recent flooding has not been as significant as the events in the 1950s and 1960s. Following events in 2008, 2010, 2012, 2020, as well as others, flash flooding in streets was reported in local news and social media. Flash flooding has also been described in the community consultation responses.

The summer months of December to March typically receive the highest rainfall. Flooding on Peacock Creek and some of the largest events (1954, 1976, 2008) have all occurred during these summer months with the exception of the 1967 event which occurred in June.

*Sydney Morning Herald 24 March 1953*

The Sydney Weather Bureau last night issued warnings of gales and serious floods on the North Coast.

Floodwaters from a cloudburst yesterday swept away a bridge on the main road between Bonalbo and Casino.

The cloudburst deposited three inches of rain in less than an hour.

The water raced down Peacock Creek in an eight-foot high wall, which tore out the 80-foot span of the bridge.

"NO TRACE"

"The bridge disappeared like a ship sinking," said an eyewitness. "There just is no trace of it."

*The Daily Telegraph 29 December 2010*

The Daily Telegraph

News › NSW › Lismore

### Council's action saves town

BONALBO was spared inundation from floodwaters after Kyogle Council conducted works on a drain running behind the town.

BONALBO was spared inundation from floodwaters after Kyogle Council conducted works on a drain running behind the town just in the nick of time, according to residents.

Bonalbo Hardware owner Greg Dollin was on his way to Tweed Heads on Boxing Day when he got the call at 11pm to turn around because Bonalbo was about to flood.

Mr Dollin returned home to prepare his store for the worst. The State Emergency Service had delivered sandbags, which he planned to use to block water from entering his store.

However, almost miraculously, the deluge never came.

"The rain was powering down," Mr Dollin said. "I believe it was the council's good works that saved the town."

Mr Dollin said the council had recently cleared out and improved a large drain which ran along the western edge of the town, near the golf course.

According to Mr Dollin, the drain had become silted with debris.

In previous floods, water from the drain had backed up into the township, he said.

In January 2008, Mr Dollin's store was inundated with 15cm of flood-water, which resulted in a section of the store's floor being so badly damaged it had to be replaced.

*Northern Star 8 February 2012*

### Downpour floods Bonalbo streets

BONALBO'S streets have been turned into rivers after a sudden downpour brought flash-flooding to the town.

less than 2 min read February 8, 2012 - 6:29PM Northern Star

Picture: The Northern Star

BONALBO'S streets have been turned into rivers after a sudden downpour brought flash-flooding to the town.

Resident Eve Sinton, who grabbed these pictures, said she had never seen such intense flooding in her three years living in the town - including last year when the Northern Rivers' western regions were hit relatively hard by flooding.

Ms Sinton said she wasn't aware of any damage caused by the downpour, which began shortly before 6pm, or the flash flood that followed.

**Figure 2-3: Extracts from News Articles**

**Figure 2-4: The old bridge at Bonalbo, Peacock Creek during a flood event in the 1950s. Source: Marj Bob Glasby, Facebook**

# HEAVY TOLL AT BONALBO

**BONALBO, Thursday. — The flood in Bonalbo and district was the biggest ever experienced and untold damage has been done to roads, bridges, homes, property and crops.**

At Capeen Mill, at the head of Upper Duck Creek, the home of Mr. Harold Keys was swept away by the raging waters and was a complete loss. Salvage of stray items of the home's contents was made at Old Bonalbo, 11 miles away.

All bridges in the Bonalbo area have been damaged. For three days Bonalbo was completely isolated. The approaches to bridges on the only roads of access were washed away.

One, that at Peacock Creek, (w)as the approach to the (B)ailey Bridge, which was the (r)eplacement of the timber (b)ridge swept away in the pre(v)ious flood.

After shire employees, aided (b)y Bonalbo Timber Co. bull(d)ozer, had worked over the (w)eekend both bridges are now (t)rafficable.

In Bonalbo itself eight homes (w)ere evacuated and one garage (w)as washed away. The butter (f)actory was flooded and it (p)artly entered the Bonalbo (T)imber Mill.

A Greyhound bus with six (p)assengers was stranded here (a)nd owing to no telephone (c)ommunications these passen(g)ers were unable to reassure (t)heir relatives of their safety. They left for Brisbane today.

There is no telephone communication other than to Old Bonalbo and Grange Hill (Bottle Creek). Electricity was switched on today. Mail goes out tomorrow.

The only news from the outside world was received by persons working battery radio sets.

After working over the weekend to repair flood damage the Norco factory is now operating.

The contour of the "Oasis" swimming pool at Gorge Creek has been severely changed by boulders and silt.

Whilst cleaning up debris after the flood, Mr. Vic Wade, of Capeen Creek, was bitten on the finger by a black snake.

Bonalbo-Mallanganee gravel road at Bottle Creek is badly washed out, but is trafficable.

**Figure 2-5: Article from Northern Star Newspaper (Lismore, NSW), Friday 26 February 1954**

## 2.4 Flood Behaviour

Bonalbo is subject to two forms of flooding, mainstream flooding from Peacock Creek which it is located next to, and overland flows from the smaller catchments which drain though the town. Peacock Creek meanders near the town and in high flow events is prone to exceeding its channel capacity into the surrounding floodplain. There is a small distance between the creek and surrounding properties of less than 100 m in areas.

In the town there are two major channels; Capeen Street Drain and another from the hospital catchment and Bonalbo Dam. These receive the flows from the local catchments of the town. In large storm events both of these channels are subject to the channel capacity becoming exceeded and overtopping roads cutting the town in half.

Parallel to Oak street a levee has been built to direct flows from the catchment to the north west into the Capeen Street Drain. Runoff from the catchments to the north flows down the hills and can build up behind Woodenbong Road. Even in more frequent events such as the 20% AEP, floodwaters have the potential to cross Woodenbong Road and flow across properties along Lunar Lane. The rest of the flows from these catchments continues along Woodenbong Road to the channel that runs parallel to Bonalbo Street. This is also seen in the results from the 2008 calibration event.

Flows and ponding of water near to the Bowling Club and sporting fields along Tooloom Street affects properties at the south-eastern end of the town. In the more frequent events this area is subject to inundation from the local catchments north of Woodenbong Road as flows move south west towards a tributary to Peacock Creek. In the 1% AEP event and greater, flows from Peacock Creek spill into the floodplain and flow through this area exacerbating flooding further.

In larger flooding events such as the 1% AEP and onwards the flooding from the Creek is dominant on the south eastern edges of the town. When the creek spills out into the floodplain it inundates areas of the town along Woodenbong Road and Peacock Street.

The remainder of the town is typically affected by shallow overland flows. However, localised areas of high hazard floodways can develop near to the two town channels and where the channels are exceeded and also where road cross drainage is exceeded. This can cause streets to become unsafe for people and vehicles.

As part of this study the 20%, 5%, 1%, 0.2% AEP and PMF were hydrologically and hydraulically modelled. The flood models were calibrated against the 2008 historical event which occurred at Bonalbo.

## 2.5 Relevant Policies, Legislation and Guidance

Flood planning at Bonalbo is governed by local government legislation and policies as well as several NSW and Australia wide Guidance Documents.

### 2.5.1 Kyogle Local Environmental Plan 2012

The LEP is the principal planning document for the LGA. Recent NSW Government changes through the Flood Prone Land Package meant that the LEP clause regarding flooding was repealed and replaced in July 2021 to a compulsory standard clause.

Part 5, Clause 5.21, requires that councils consider the compatibility of new development to the flood behaviour and flood hazard as well as impact of any development on other properties. It also requires consideration of climate change, risk to life and safe evacuation of people.

Council also have an option to opt-in for Special Flood Considerations. This allows councils to adopt additional controls for sensitive and hazardous development which may require additional consideration of flooding for land above the FPL but below the PMF. At this time there is no Special Flood Considerations clause in the LEP.

### 2.5.2 Kyogle Development Control Plan 2014

The Kyogle DCP provides controls to manage development within the LGA and is prepared to be consistent with the objectives and provisions of the LEP. With regard to flooding the DCP sets out a number of controls (performance criteria) and acceptable solutions which vary slightly depending on the development type.

Typically development controls require that:

- Buildings, structures and persons on a development site are not exposed to unacceptable risk from flooding including overland flow.
- Rural subdivisions maintain stock access to flood free land and lot layouts maintain access for flood refuge areas.
- Buildings are not located in flood prone land where possible and where a building envelope is proposed on land mapped or known to be flood prone, floor levels of at a least the 1% AEP plus 0.5 m freeboard is achieved.
- Stormwater to be managed so that it does not contribute to flooding or nuance on adjoining properties.

### 2.5.3 Guidance Documents

The following key guidance documents are considered in this Flood Study:

- NSW Floodplain Development Manual (2005)
- Australian Rainfall and Runoff 2019 (ARR2019)
- AIDR Handbook Series
- Floodplain Risk Management Guidelines series published by DECC and OEH (now DPIE)

# 3 REVIEW AND ANALYSIS OF AVAILABLE DATA

## 3.1 Previous Studies

Several studies have been completed for the area although most focus on the Bonalbo Dam rather than flood risk from Peacock Creek or local overland flows.

### 3.1.1 Bonalbo Dam Probable Maximum Flood Study, (NSW Department of Public Works and Services, November 2001)

The study used the Generalised Short Duration (GSDM) method for deriving Probable Maximum Precipitation (PMP) which is limited to up to a six-hour duration storm. A RORB rainfall-routing model was developed for the dam catchment and also for the Peacock River catchment to Bonalbo.

The dam drains a catchment of about 14 ha and has a storage capacity of about 55 megalitres (ML) at Full Supply Level (FSL). The report states the FSL as 194.15 m RL and the embankment crest as 195.67 m RL.

The study found that a 0.5 hour PMP event typically produced the greatest peak inflow and a one hour PMP event would produce the peak outflow. The study concluded that in a PMF event the dam embankment would overtop by 40 mm. However, this was superseded by an updated report in 2015 (refer section 3.1.3).

To develop concurrent flood estimates a RORB model of the Peacock Creek catchment was developed. The RORB model was not available for use in this study however output hydrographs for the PMF on Peacock Creek at various locations were available in the report.

### 3.1.2 Bonalbo Dam Dambreak Study, (NSW Department of Public Works, August 2004) and Bonalbo Dam Dambreak Study Addendum (NSW Department of Public Works and Services, 2005)

The study was prepared to assess the consequences of a sunny day and PMF flood failure of the Bonalbo Dam embankment. This study was based on the original design drawings for the construction of the dam, and limited floor level survey. The original design drawings are now outdated in relation to the bywash spillway, with a subsequent report in 2015 (NSW Public Works, April 2015).

The Dambreak Study developed a Mike11 hydraulic model based on cross section survey completed by Council. The MIKE 11 model was not available, however the cross-section survey has been made available. These cross sections were used to spot check against LiDAR and provided similar sections once the datums had been adjusted (refer Section 3.3.2).

The study mapped the area predicted to be affected by the PMF (refer Figure 3-1) and noted that the PMF flood was predicted to be 2.4 m above the Clarence Way crossing of Peacock Creek and 4.8 m above the top of river bank level nearer the town.

The study found that the dambreak wave travel time to the populated area is in the order of five minutes which gives no time for warning and evacuation. An addendum report (NSW Department of Public Works and Services, 2005) re-assessed the consequence categories for the various dambreak cases. The dam failure consequence was defined as "High C" for both Sunny Day Dambreak Consequence Category (SDCC) and Incremental Flood Consequence Category (IFCC). The Addendum report suggests 46 properties downstream of the dam would be affected in the PMF event with a Population At Risk (PAR) of 124, increasing to 51 in a dam failure scenario with a PAR of 138.

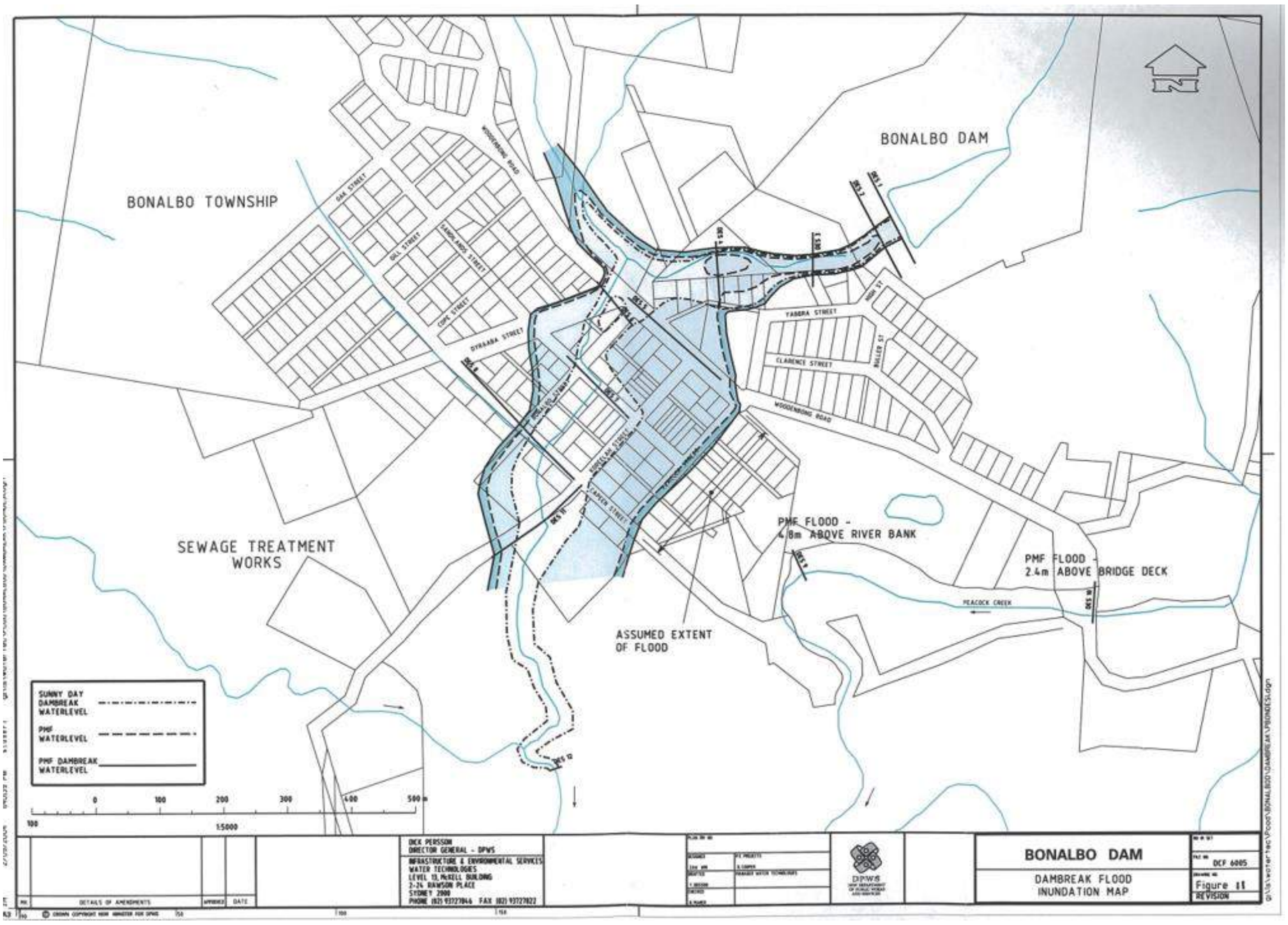



**Figure 3-1: PMF and PMF dam failure flood extents from Bonalbo Dambreak Study**

### 3.1.3 Bonalbo Dam Addendum to Flood Study (NSW Public Works, April 2015)

The 2015 addendum refers to updated flood routing studies undertaken in 2011 between the publication of the Bonalbo Dam Probable Maximum Flood Study (November 2001) and this 2015 study. The 2015 addendum further refined the assessment using 2014 survey data. The report refers to works to the spillway prior to 2014 which “flattened” the spillway.

The addendum study did not make any changes to the PMF catchment hydrology but assessed changes in the assumed dam geometry based on more recent survey data to revise the dam outflow. The assessment indicated that the peak flood level in a PMF would be RL 100.13 which is below to the crest level (RL 100.20). The peak PMF inflow was adopted as 22.4 $m^3/s$ and the outflow was estimated to be 15.7 m3/s. The addendum identified that the PMF outflow can be passed safely through the dam without overtopping the crest although freeboard is limited.

### 3.1.4 Bonalbo Dam Piping Risk Assessment (Public Works Advisory, July 2017)

The report describes that the biggest risk of dam failure is from piping failure (internal erosion caused by seepage) rather than flood failure as the dam spillway has the capacity to convey the PMF without overtopping the dam crest. The PMF flood level in the dam was stated to be RL 100.13m or 195.93m AHD based on previous studies. The report provides additional details including levels of the full supply level (FSL), dam crest and spillway and the discharge, rainfall and dam levels over time. The FSL was stated to be RL 98.3m or 194.15m AHD and the raised dam crest level as RL 100.2m or 196.00m AHD.

#### 3.1.5 Bonalbo Long Term Water Supply and Drought Strategy (Department of Commerce, July 2015),

The report focusses largely on water supply but notes that frequency nuisance flash flooding occurs in the urban area of Bonalbo. The formation of the drainage system in Bonalbo village is one where stormwater is transported along the roads by grass swales and some kerb and gutter to side entry and grated pits, whereupon it enters the drainage network. Many of the roads within Bonalbo have only a central sealed strip with gravel shoulders, allowing overland flow to occur.

#### 3.1.6 Kyogle Flood Study (WBM Oceanics Australia, February 2004) and Floodplain Risk Management Plan (BMT WBM, April 2009)

The Kyogle Flood Study and Floodplain Risk Management Plan were adopted in 2009. While the study area does not cover the Bonalbo area, the study and plan provide useful information on the historic rainfall events including the 2008 event.

The study used Australian Rainfall and Runoff 1987 (ARR87) methods and Flood Frequency Analysis (FFA) to determine design event flood behaviour and calibrated the modelling to historic events. The report refers to major flooding around 20 February 1954 as well as smaller flooding in 1974, 1976, 1978, 1980, 1987, 1989,1996, 2001 and 2008. The study found that that the January 2008 event to affect Kyogle was approximately a 2% AEP event.

#### 3.1.7 Tabulam Flood Study (Jacobs, March 2019) and Floodplain Risk Management Study and Plan (Jacobs, December 2019)

Although the study area of the Tabulam Flood Study and Floodplain Risk Management Study and Plan does not cover Bonalbo, the studies provide some insights into historic flooding in the Kyogle LGA noting significant flood events in 1967 and 2011. The study notes that the 1967 event was considerably larger than the 2011 event.

The Tabulam Flood Study used FFA (using ARR2016 procedures) to determine design event flood behaviour. The January 2011 event was approximated as a between a 2% AEP and 5% AEP event for the local area. It is noted that this is different to the Peacock Creek event and that is largely due to the patterns of rainfall near to and across the respective catchments.

### 3.2 Historic Data

Historic data was obtained through the community consultation (refer Section 4), data supplied by Kyogle Council and a search of old media reports. This was used to supplement river and rainfall gauge data to develop an understanding flood behaviour and also for calibrating and validating the hydrology and hydraulic flood models (refer Section 7).

#### 3.2.1 River Gauges

Only one river gauge is located within the study area on Peacock Creek about 1.7 km upstream of the confluence with Gorges Creek and about 7 km upstream of Bonalbo town (refer Figure A 1). A catchment area of about 48 $km^2$ drains to the gauge. The gauge is managed by WaterNSW and provides instantaneous recorded flows and flood levels derived from rating tables. Data is available from 1960 to the current day.

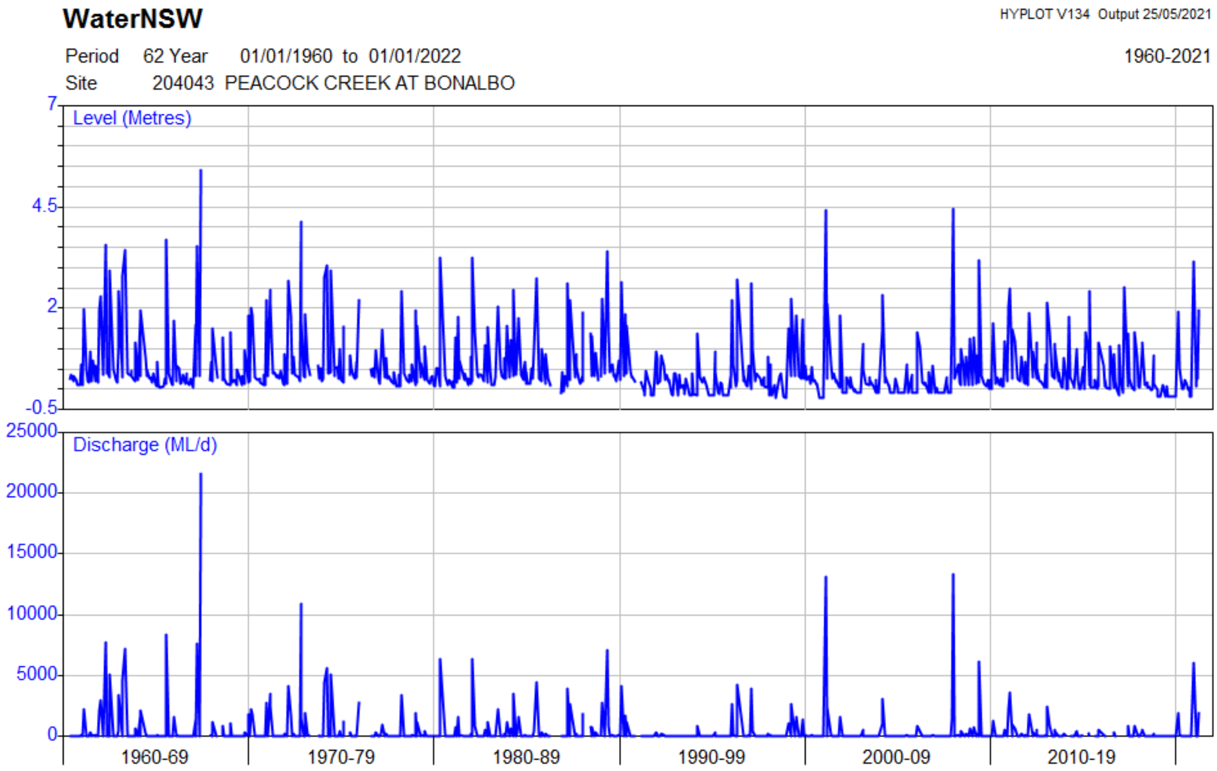



**Figure 3-2: Gauged levels and discharge at Peacock Greek gauge**

Consultation was undertaken with WaterNSW to understand the reliability of the gauge for use in flood frequency analysis. The maximum gauged level recording is 1.314 m taken on 15/01/1974 with a flow of 704.6 ML/s (8.1 $m^3/s$). Other flow measurements have been taken but the second highest was about 300 ML/d. Based on the FFA (refer section 5.2) these flow/level recording would have an AEP of about 75% and 85% (equivalent to 1.5 Exceedances per Year (EY) and 2 EY events). Above these values the rating curve appears to have been extrapolated on a log/log line to a flow of about 28,000 ML/d (level of about 6.3 m RL and therefore any levels above 1.3 m (related to gauge datum) has poor confidence limits.

WaterNSW advised that the gauge has never been related back to mAHD. An arbitrary datum of 23.67 m had been adopted each time the channel cross section had been surveyed but there is no conversation factor to obtain AHD for the site.

The greatest three peak hights recorded were in 1967, 2001 and 2008:

- 12 June 1967 – Stage 5.447 m
- 2 February 2001 – Stage 4.424 m
- 5 January 2008 - 4.453 m

By comparison the highest gauged level recording taken in 1974 was 1.314 m RL which indicates a low level of confidence in events larger than this.

### 3.2.2 Rain Gauges

Rainfall data was obtained from Bureau of Metrology (BoM). Within the catchment to the study area there is only one rainfall gauge at Bonalbo Post Office (57003). The gauge is a daily-read gauge with records back to 1913. Other daily read gauges are sparsely located outside of the catchment area (refer Figure A 3). The nearest pluviometry gauges are more than 20 km from the study area. Availability of additional daily-read and sub-daily (pluviograph) gauges are summarised in Table 3-1. Further analysis of the flood events used for calibration is provided in section 7.

**Table 3-1: Rain gauge data availability**

| Name | BOM Gauge ID | Year Opened | Year Closed | Gauge Type | Distance to Bonalbo (km) | Historic Storm Captured |
|---|---|---|---|---|---|---|
| Peacock Creek at Bonalbo | 204043 | 1960 | Open | Discharge / Water Level | 5.0 | 1967, 2008 |
| Bonalbo Post Office | 57003 | 1913 | Open | Rainfall | 0 | 1967, 2008 |
| Old Bonalbo Post Office | 57015 | 1915 | Closed - 2010 | Rainfall | 9.6 | 1967, 2008 |
| Tunglebung (Wingfield) | 57027 | 1952 | Closed - 1971 | Rainfall | 10.6 | 1967 |
| Old Bonalbo (Alcheringa) | 57085 | 1910 | Open | Rainfall | 19.0 | 2008 |
| Woolners Arm | 58220 | 1927 | Open | Rainfall | 21.6 | 2008 |
| Mummulgum (Bingeebeera) | 58004 | 1936 | Open | Rainfall | 15.2 | 1967, 2008 |
| Theresa Creek (Roseview) | 58134 | 1968 | Closed 1976 | Rainfall | 14.4 | n/a |
| Upper Mongogarie (Marangaroo) | 58192 | 1987 | Closed 2017 | Pluviograph | 37.5 | 2008 |
| Casino Airport AWS | 58208 | 2011 | Open | Minuetly Rainfall | 45.8 | 2008 |
| Unumgar (Summerland Way) | 58016 | 2000 | Open | Pluviograph | 37 | 2008 |
| Lismore Airport AWS | 58214 | 2002 | Open | Pluviograph | 63 | 2008 |
| Green Pigeon (Morning View) | 58113 | 1978 | Open | Pluviograph | 53.9 | 2008 |
| Nimbin Post Office | 58044 | 1963 | Open | Pluviograph | 60.7 | 1967, 2008 |
| Tabulam (Muirne) | 57095 | 1969 | Closed - 2016 | Pluviograph | 16.9 | 2008 |

### 3.2.3 Anecdotal Flood Information

Anecdotal evidence included responses from the community questionnaire and information provided by Kyogle Council. Community consultation responses are summarised in Appendix D and typically relate to the overland flow flooding within the town.

### 3.2.4 Summary of Flood History at Bonalbo

Some of the key flood events affecting the study are summarised in Table 3-2. The AEP has either been estimated from the FFA for the Peacock Creek gauge if available, or from the rainfall data obtained for this study.

**Table 3-2: Historic Flood Events**

| Date | Description | AEP estimate (if known) |
|---|---|---|
| 1967 | | 1% AEP (FFA) |
| January 2008 | • Approximated as 2% AEP event (Kyogle Council based on Kyogle Flood Study) though data at Peacock Creek and Bonalbo Gauges, this was estimated as an approximate 5% AEP at Bonalbo.<br>• Level of 166.930 m at Butter Factory and assumed level of 100.81 m at Preschool with about 400 mm of above floor flooding (Kyogle Council)<br>• Bonalbo Hardware store on Sandilands Street affected by some 150 mm of floodwater (Northern Star, 29 December, 2010)<br>• Mapped flood extent provided by Council shows flooding reaching the south side of Woodenbong Road / Clarence Way and inundated properties at the eastern end of Sandilands street east of Peacock Street and also properties on Capeen Street (refer Figure 3-3). | 5% AEP (FFA and Bonalbo Post Office daily-read gauge) |
| 2010 | • Council's prior clearing of a drain either side of Farm Road and through the golf course and bowling club successfully reduced flooding (Northern Star, 29 December, 2010) | 50% AEP |
| January 2020 | • Approximated as a 50% AEP<br>• 300 mm depths at Woodenbong Road Bridge and Sandilands Street Bridge<br>• Flooding over Farm Road<br>• 300 mm of water in front yard of 1A Sandliands Street | 50% AEP |
| Unknown | • 167.820 mAHD at Butter Factory (Kyogle Council) | |

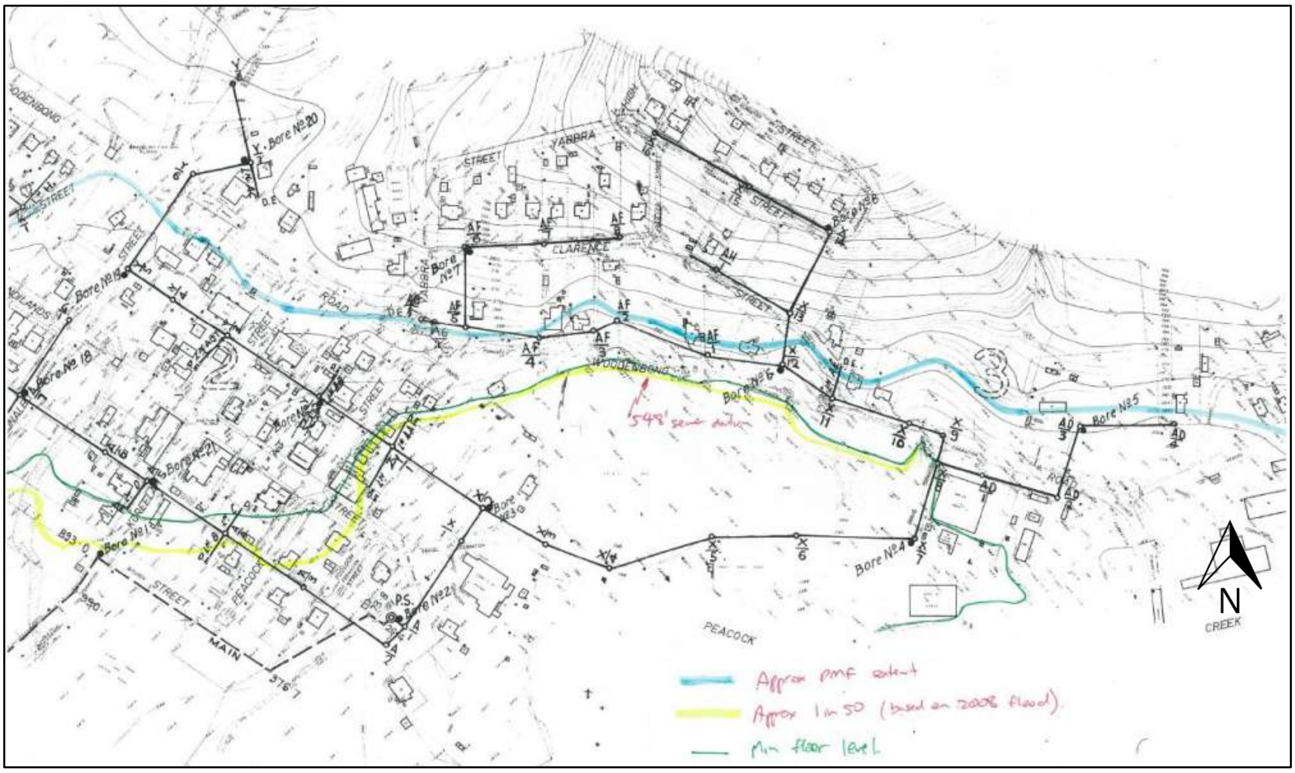


**Figure 3-3: 2008 Flood extent (yellow line) (provided by Kyogle Council)**

## 3.3 Topographic and Aerial Survey and Imagery

### 3.3.1 Topographic Data

Aerial imagery was used from Bing Aerial Imager, SixMaps WMS link, and Google Maps Hybrid. Multiple sources were used as the detail of each was varying in quality.

### 3.3.2 LiDAR

A 2m resolution LiDAR DEM data is available for the Bonalbo township study area from elevation.fsdf.org.au (ELVIS, 2020). Data was flow in 2017 and the DEM has a 2m grid resolution. The LiDAR DEM is not hydrologically enforced. The data used to create this DEM has an accuracy of 0.3m (95% Confidence Interval) vertical and 0.8m (95% Confidence Interval) horizontal. This is typical of Classification 3 LiDAR obtained in this way and is considered suitable for flood modelling in rural areas (DFSI Spatial, May 2015).

Checks were made against the LiDAR DEM and inverts from MIKE11 sections used in Bonalbo Dam Dambreak Study (2004). At the locations of the Mike11 cross sections elevations between the LiDAR and Mike11 sections were compared. The LiDAR and Mike11 sections showed the same profiles across the cross sections. The Mike 11 sections elevations have been recorded as relative levels. Using the conversion from Bonalbo Dam Addendum to Flood Study (NSW Public Works, April 2015), there were consistent elevation differences of 1.3 m. When the Mike 11 sections were lowered by 1.3 m, the cross sections were consistent matches with each other.

### 3.3.3 Survey Data – Watercourses

No survey of the watercourse was available and therefore LiDAR data has been adopted. LiDAR does not typically pick up channel dimensions as the LiDAR beam does not typically penetrate water and therefore the cross sections of the channel itself may not be well represented in the flood modelling.

Although this is a limitation of the flood modelling, the effect of this is that peak flood levels may be conservative, particular in the smaller magnitude flood events. For the flood events assessed in this Flood Study (20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events) there is typically a large percentage of out of bank flow and therefore the effect is unlikely to be significant and within the typical accuracies of flood modelling.

### 3.3.4 Survey Data – Hydraulic Structures

No survey data was available for the Clarence Way crossing of Peacock Creek. Council advised that the bridge comprises steel girders and a concrete deck and has two piers in the watercourse, each about one metre wide. A GIS database of the storm water network was provided from Council however no invert levels were included.

### 3.3.5 Survey Data – Bonalbo Dam

The spillways and embankment of the dam were taken from the 2014 survey used in the Bonalbo Dam Addendum to Flood Study (NSW Public Works, April 2015).

### 3.3.6 Survey Data – Other Features

Other features such as the levee at Oak Street were identified from LiDAR data. Kyogle Council were able to provide some survey data of the Capeen Street drain. After converting the survey from the relative datum to mAHD, in comparison to the LiDAR values in Capeen Street drain it was found that the survey was significantly higher than the LiDAR. In some cross sections this difference in elevations ranged greater than a metre. Therefore as the data was uncertain, the Capeen Street drain was enforced with a Z line based off the LiDAR values.

## 3.4 GIS data

Kyogle Council provided GIS data including cadastre, land use zoning, and details of the drainage network in the town. The data did not include invert levels or pipe sizes at all locations and therefore assumptions were made (refer Table 6-1).

## 3.5 Data Gap Analysis

A data Gap Analysis reviewed data suitability for use in the study and noted limitations of any assumptions. For some hydraulic structures, such as the Woodenbong Road Bridge crossing of Peacock Creek no survey or work-as-executed drawings or similar was available as assumptions had to be made in the flood modelling.

The data used is considered to be sufficient for the purposes of the Flood Study. Recommendations for additional data to be obtained for the future Floodplain Risk Management Study and Plan are detailed in Table 3-3.

**Table 3-3: Data Gap Analysis and Recommendations for Further Data at Later Stages**

| Issue | Comment | Recommendations to be completed at Floodplain Risk Management Study Stage |
|---|---|---|
| **Watercourse cross sections** | Watercourse has been based on LiDAR as previously surveys sections and models were not available. | Undertake watercourse survey in areas identified for assessment of potential flood mitigation options. |

| Issue | Comment | Recommendations to be completed at Floodplain Risk Management Study Stage |
|---|---|---|
| **Capeen Street Drain Survey** | Could not be adjusted to tie in with LiDAR data. | Survey to be obtained to confirm drain capacity and inverts. |
| **Features in the floodplain** | Based on LIDAR data. | Obtain survey if in critical flood areas to be reviewed at FRMS stage. |
| **Drainage network** | The urban stormwater GIS data was missing invert information. Cross drainage pipes were assumed to have invert levels from the LiDAR. Suitable cover was adopted in areas where LiDAR levels were not appropriate. | For areas where drainage is critical in terms of flood behaviour, or areas where floodplain risk mitigation options are to be considered detailed survey should be obtained. |
| **River Gauge Data** | Gauge data is considered to have poor confidence limits especially for large flood events. However, this is the best available data for this area and will be used. | n/a |
| **Floor levels** | The Flood Study identified properties flooded based on LiDAR DEM ground levels. Over floor flooding will require survey and will be assessed in the next stage; the Floodplain Risk Management Study and Plan.<br>Some floor level information was available in the 2005 Dambreak Addendum report however the datum was unclear compared to the LiDAR information. | Obtain floor level survey. |
| **Peacock Creek Bridge** | Has been modelled based on advice from Council. | Bridge survey. |
| **Bridge Downstream of Farm Road** | There was a bridge observed downstream of Capeen Street drain after the Farm Road culverts. There were no bridge details available for the model. | Bridge survey. |

# 4 COMMUNITY CONSULTATION

## 4.1 Community Consultation Program

A community consultation program included newsletters, a questionnaire, and a project website. Community information sessions will be held during the Public Exhibition period.

## 4.2 Project Website

A project website is available at www.bgeeng.com/FloodStudies/Bonalbo. The website is being maintained for the duration of the project and provides updates to the community and contact details.

The project website is being updated at key milestones throughout the project and includes:

- Summary of study objectives
- Map of the study area
- Link to online questionnaire
- Contact details for residents to obtain further information or provide flood information for use in the study

During the Public Exhibition period the website will be updated to include:

- Information about community information session dates and times
- Copies of draft report for download during Public Exhibition
- Mapping of predicted flood behaviour and flood planning areas
- Feedback form for Public Exhibition submissions and general enquires

## 4.3 Community Questionnaire and Newsletter

A community newsletter and questionnaire were mailed to 280 residents in September 2020 and was also made available online. The findings of the questionnaire are useful to understand the community's experiences of past flooding, the level of flood awareness, highlight areas for flood mitigation and allow residents to provide flood information for use in calibration of the flood models. A project email address was also created to allow people to email photographs and addition information.

A detailed analysis of the findings is provided in Appendix D.

A total of one response were received online and 26 responses by mail which equates to a 9.5% response rate. This was considered to be a reasonable response rate. Response rates to surveys such as these tend to be more skewed to those who have experienced or are concerned with flooding.

59% of respondents indicated that their property had flooded before with a further 15% acknowledging that their property was flood affected but it had not flooded before to their knowledge.

Over 80% of the of the respondents were from residential properties. The majority of respondents were located within the Bonalbo town area. Residents were asked to identify areas where they had observed flooding and areas where they thought flood mitigation was required. The responses are mapped in Appendix D and include:

- Sandilands Street – 10 people mentioned this area including flooding to residential properties. Flooding is both from Peacock Creek (at the eastern end of the street) and from overland flows (other areas).
- Woodenbong Road – 5 people mentioned this area. Concerns included flash flooding from runoff from around the hospital area.
- Clarence Street – 4 people mentioned poor drainage in this area.

Details on historic flooding were requested for use in flood model calibration and validation (refer Section 7). Most residents recalled flooding in January 2020 including at the locations above.

## 4.4 Community Information Sessions

A community information session will be held during the Public Exhibition period.

# 5 HYDROLOGIC ANALYSIS

## 5.1 Hydrologic Assessment Approach

The hydrologic assessment considers the gauged Peacock Creek catchment (refer section 3.2.1) to upstream of Gorge Creek, the larger ungauged catchment and the local catchments which flow through Bonalbo township. As the gauged catchment comprises about only half of the total upstream catchment draining towards the study area, additional methods are necessary to define the flows to input into the hydraulic model of the Bonalbo Flood Study area.

An approach was adopted which used a rainfall routing model for the entire catchment. ICM was adopted for this purpose. ICM is the successor software to XP-RAFTS which has typically been used for similar studies in the past (Kyogle Flood Study) but essentially provides the same functions and calculations.

The purpose of the rainfall routing modelling is to determine the input flows into the hydraulic (TUFLOW) model by converting rainfall depths to hydrographs. Design rainfall data in input from Intensity-Frequency-Duration (IFD) data which has been developed by BoM for the whole of Australia. Parameters such as catchment area, slope, vegetation cover (roughness), initial and continuing losses and lag times and routing parameters are input into the hydrologic model.

For the gauged portion of the catchment, Flood Frequency Analysis (FFA) was also undertaken using the Peacock Creek gauge (ID 204043). FLIKE software was used to assist in the analysis.

## 5.2 Flood Frequency Analysis (FFA)

For the gauged catchment a FFA was undertaken using the recommended procedures of ARR2019. The gauge has a 60-year data recorded with less than 2% of data marked as “missing” which is typically acceptable for FFA. However, WaterNSW have advised that the accuracy of the rating curve is limited as gauged flows have only been undertaken in relatively low flow situations (refer section 3.2.1).

Annual Maximum (AM) series was used as it provides a more robust estimate of low AEP floods and the flood peaks are likely to be more independent than the alternative Peaks over Threshold series (POTs).

For a valid frequency analysis, the data used, should comprise a random sample of independent values over a homogenous data set. A review of the gauged data was undertaken to identify annual peaks that may not be independent of each other (for example two floods in succession before flood levels have reduced to average flow) and examine the record for homogeneity. No peaks were removed in this way.

Given the forested and rural nature of the catchment, it is not expected that there have been significant upstream changes in the Peacock Creek catchment in the last 60 years that would significantly affect the homogeneity of the dataset. The pumping offtake from Peacock Creek to Bonalbo Dam is downstream of the gauge and therefore would not affect the FFA.

The Generalized Extreme Value (GEV) and Log Pearson III (LP III) distributions typically fit most AM series reasonably and both were reviewed for goodness-of-fit to the gauged data. The LP III distribution was found to provide the best fit.

A multiple Grubbs-Beck test was undertaken to define a threshold for censoring minor discharges, this removes smaller annual maximum discharges which may not less than full bank flow and runs the risk of low representative peak flows.

Results of the FFA gave a 1% AEP peak flood level at the Peacock Creek stream gauge of 249 $m^3/s$ (refer Figure 5-1).

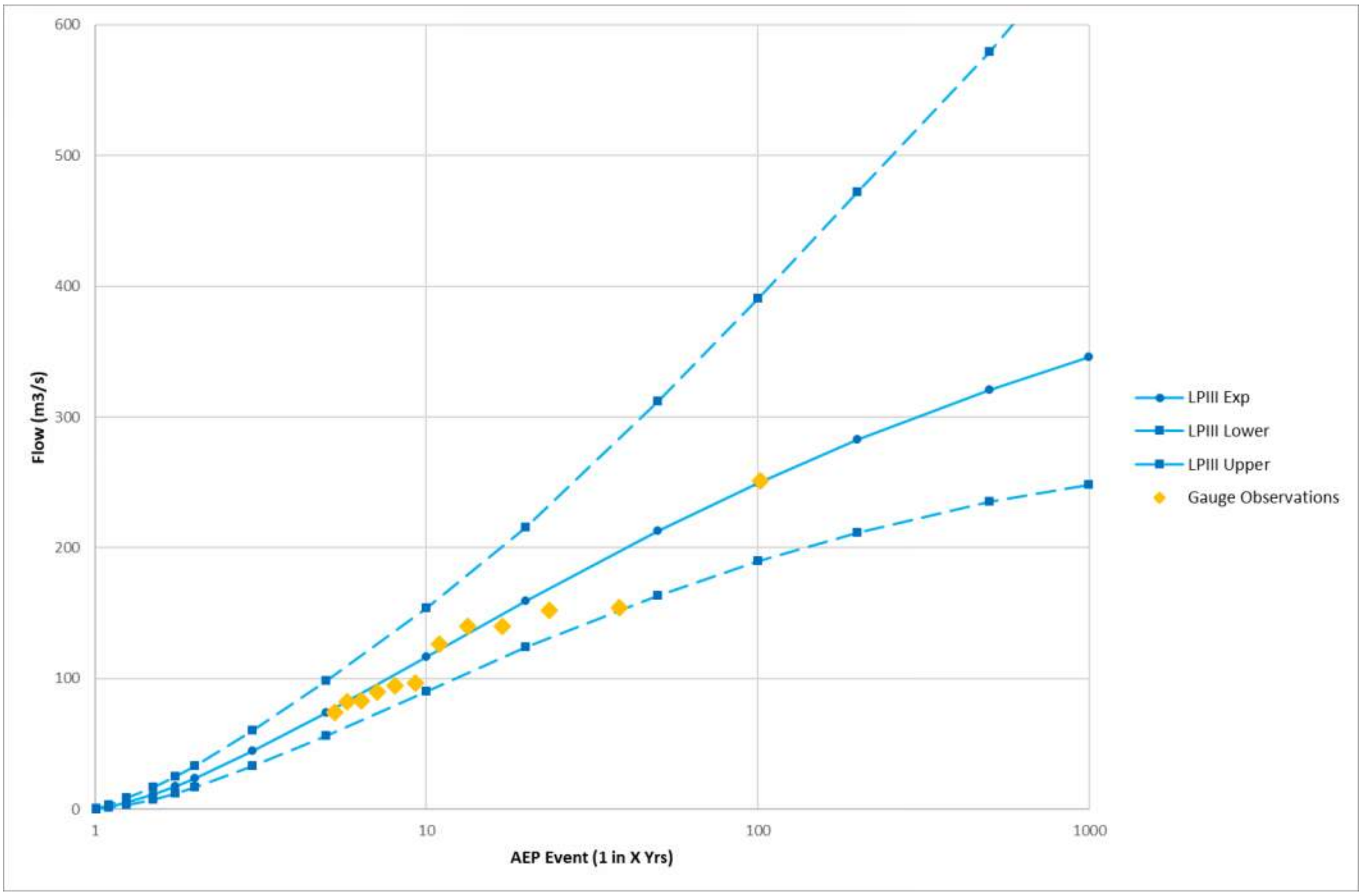



**Figure 5-1: Flood Frequency Analysis for Peacock Creek at gauge 204043**

### 5.2.1 Comparison of FFA to Regional Flood Frequency Estimation (RFFE) at Peacock Creek Stream Gauge

ARR2019 recommend that at least two hydrologic methods are used in determines peak flows to assess uncertainties. The Regional Flood Frequency Estimation (RFFE) method allows for design flood estimates on ungauged catchments based on data from a number of nearby gauged catchments and/or gauged catchments with similar characteristics. RFFE is an estimation tool and is not appropriate for the detailed assessment of design events but can be used as a check that results from FFA and rainfall routing models are within reasonable expected bounds.

The results of the FFA analysis was compared to the RFFE outputs. The results of the RFFE model are used in this study only to indicate potential confidence limits on the flows derived from the FFA and runoff-routing model. RFFE outputs are shown in Figure 5-2. The 1% AEP flow is estimated as 429 $m^3/s$. The 5% to 95% confidence limits give peak flows of 115 $m^3/s$ and 1570 $m^3/s$ and indicate the typical uncertainties of peak flow estimation.

A comparison of the FFA and RFFE peak flows is presented in Table 5-1. The results show that the FFA is within the bounds of the RFFE. This is to be expected as the RFFE analysis also used the Peacock Creek stream gauge in its calculations.

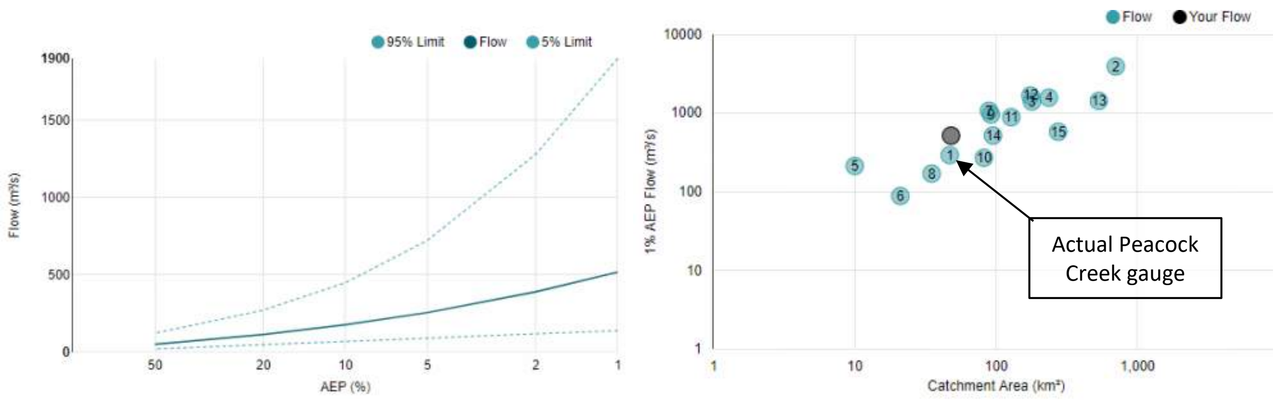



**Figure 5-2: Results from RFFE modelling for the Peacock Creek catchment to the gauge location (left) and comparison of 1% AEP flow with nearest 15 gauged catchments (right)**

The confidence limits of RFFE are considerably larger than the FFA estimate. This is to be expected where ungauged catchment flows are derived from alternative catchments. However, for Peacock Creek, the FFA confidence limits are more realistic given that at site data has been used.

**Table 5-1: RFFE Results at Peacock Creek Gauge**

| AEP (%) | RFFE Discharge ($m^3/s$) | RFFE Lower Confidence Limit (5%) ($m^3/s$) | RFFE Upper Confidence Limit (95%) ($m^3/s$) | FFA Discharge ($m^3/s$) | FFA Discharge Lower Limit (5%) ($m^3/s$) | FFA Discharge Upper Limit (95%) ($m^3/s$) |
|---|---|---|---|---|---|---|
| 50 | 42.3 | 17.3 | 103 | 23.6 | 16.8 | 33.0 |
| 20 | 95.2 | 40.6 | 226 | 73.7 | 56.0 | 98.3 |
| 10 | 147 | 57.9 | 373 | 116 | 90.0 | 154 |
| 5 | 212 | 75.3 | 599 | 159 | 124 | 216 |
| 2 | 323 | 98.5 | 1060 | 213 | 164 | 311 |
| 1 | 429 | 115 | 1570 | 249 | 190 | 391 |

## 5.3 (IFD) Data Review

There is some variation in the IFD across the catchment as shown in refer Figure 5-3. Higher intensity rainfalls are likely in the upper catchment areas where the steeper hillslopes are likely to have orographic effects on rainfall patterns. Rainfall at Bonalbo town is likely to be less intense than across other areas of the catchment.

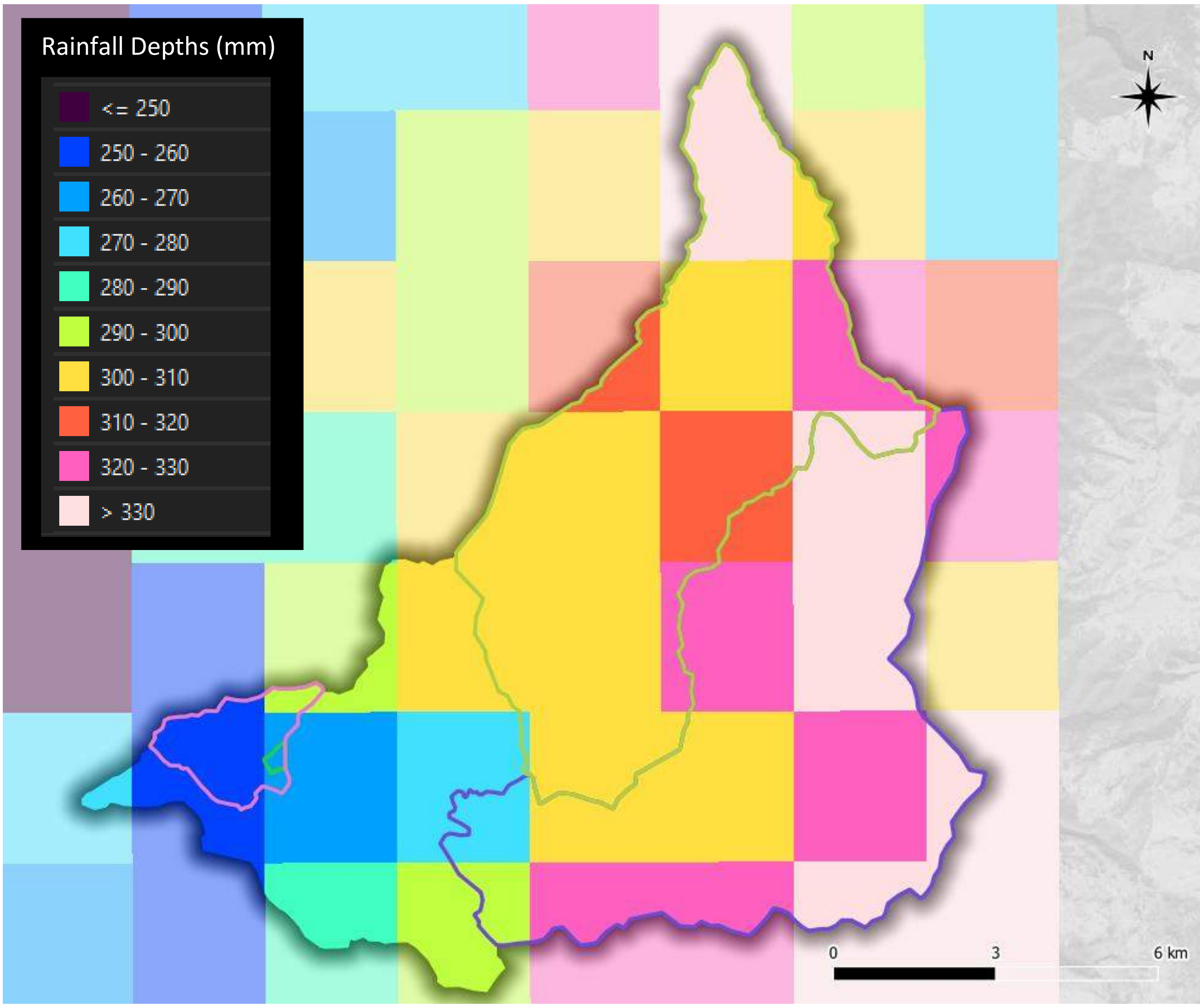



**Figure 5-3: Gridded IFD data – Depths – 1% AEP event 24 hours (source: BOM)**

A comparison of the IFD data and at-site gauge data is typically desirable for flood studies as a check on the BoM IFD data. However for the Bonalbo Flood Study catchment, there are no sub-daily gauges within the catchment area and only one daily read gauge (refer Section 3.2.2).

At site IFD data was generated based on the daily gauge at Bonalbo Post Office (57003). The gauge has a record of 108 years and will therefore give a reasonable IFD estimate of a range of AEP rainfall events. However, this analysis can only be undertaken for durations of 24 hours and longer as the gauge is daily read. Furthermore, it is possible that the Bonalbo gauge could underestimate the 24 hour total rainfall as the observed 24 hour rainfall totals are limited to rainfall recorded in the 24 hour period to 0900 hours each day. Should the rainfall event occur either side of this, it would be recorded over a 48 hour period and thus under estimate the 24 hour total.

A comparison of the point IFD data at the same location and gauge derived IFD is presented in Figure 5-4. The IFD depths at Bonalbo gauge are higher than the point IFD from ARR 2019. It should be noted that the dominating rainfall event that is being used in the Bonalbo gauge IFD is from February 1954, this may lack accuracy in comparison to a rainfall event that occurred later.

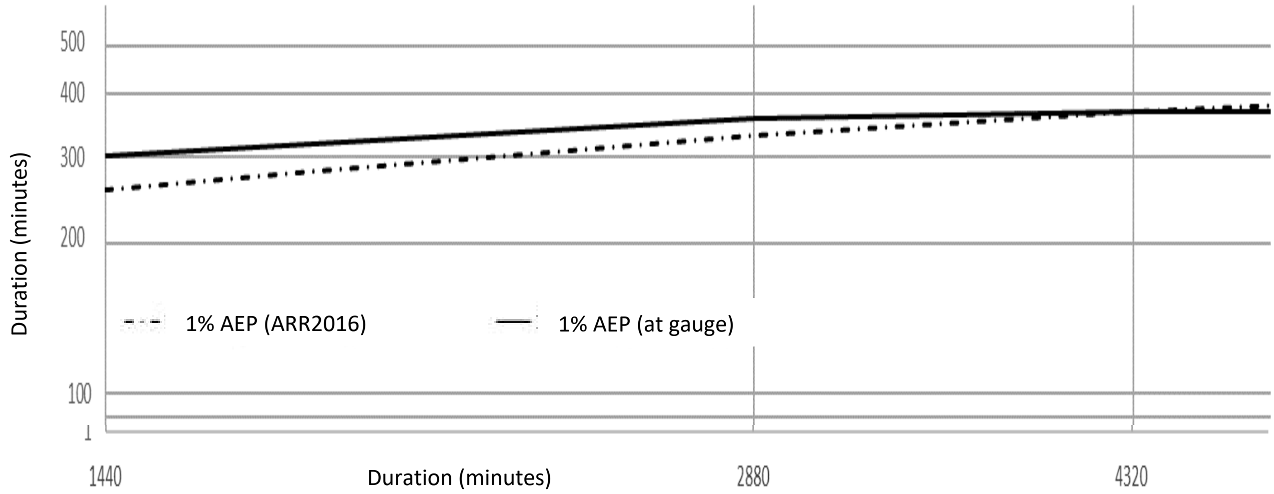



**Figure 5-4: Bonalbo Post Office (57003) and ARR2019 point IFD Comparison**

## 5.4 Rainfall routing model (ICM)

A rainfall routing model was developed for the catchment to the study area using ICM software. ICM is the successor software for XP-RAFTS which is no longer supported by the developer.

The rainfall routing model comprised 117 sub-catchments each with catchment specific parameters applied (refer Figure A 4). Catchment parameters such as percentage impervious, slope, were be determined using GIS methods, aerial and topographic data and are summarised in Table 5-2.

### 5.4.1 Model Parameter Selection

**Table 5-2: ICM Model Setup and Adopted Parameters**

| Parameter | Comment |
|---|---|
| Catchment delineation | Catchments were delineated in GIS using the 2017 2m LiDAR DEM |
| Slope | Catchments equal area slopes were calculated using the 2017 2m LiDAR |
| % impervious | Impervious areas of the catchments were estimated using aerial imagery. |
| Roughness | Manning's n was applied to the catchments based off the impervious, pervious nature of the catchment. A Manning's n of 0.04 was adopted for pervious areas and 0.025 for impervious areas. |
| Lag time | Lag times were varied depending on the slope and distance of the watercourse between catchments and a typical flow velocity for similar watercourse systems. The velocity within the watercourses were estimated between 1 and 2 m/s dependent on the slope. |
| Losses | NSW-FFA reconciled losses were adopted from the ARR19 data hub with IL: 49.7 mm and CL 3.26 mm/hr. These losses had been calibrated against the Peacock Creek stream gauge and were given a good quality rating. These losses were applied for the entire study area due to the vicinity of the sub-catchments and similarity of terrain to the rest of the catchment. Impervious losses were adopted as IL: 1 mm and CL: 0 mm. |

### 5.4.2 Spatial Distribution of Rainfall

The BOM provides gridded IFD data at a resolution of about 6.25 $km^2$. The catchment size for the study area is 127.1 $km^2$ and therefore, spatially variability of the inputs needed to be considered. For the Peacock Creek catchment to the township, the average design rainfall depth was calculated for each design event as per ARR2019. This involves calculating the IFD depth at each individual catchment and applying a weighted average as per the sub-catchment area to calculate a spatially distributed catchment average. This was applied for each duration and AEP event within the hydrology model.

A comparison of the total catchment weighted average IFD and the IFD at Bonalbo township indicated a difference in estimated rainfall depths. Using the catchment weighted average method, the rainfall depths were overstated at the township. This is due to the distribution of the IFD across the Peacock Creek catchment where higher rainfall depths occur due to the natural geography of the upper catchment (refer Figure 5-3). This effect was more dominant in larger magnitude events.

The Bonalbo township catchment has an area of 5 $km^2$. Therefore, instead of using the catchment average rainfalls, a point IFD was applied for each duration and event within the hydrology model.

### 5.4.3 Pre-Burst Rainfall

The initial loss burst adopted was the Probability Neutral Burst Loss from the ARR data hub. This provides the end result of Storm Loss less Pre-burst rainfall for each AEP event and duration.

### 5.4.4 Temporal Patterns

Due to the area of the catchment Peacock Creek catchment to Bonalbo, areal temporal patterns were applied for the full catchment. Areal temporal patterns are applicable for catchments of 75 $km^2$. For Bonalbo township point temporal patterns were applied. The joint probability of Peacock Creek and the Bonalbo town catchments is addressed in Section 6.2.1.

### 5.4.5 Hydrology Model Calibration

The rainfall runoff routing model was calibrated to the gauged data at the Peacock Creek gauge. Further details are provided in Section 7. The match to the Peacock Creek data was reasonable.

### 5.4.6 ARRR2019 Ensemble Approach for Design Event Flows

The rainfall runoff routing model was run for the 20% AEP, 5% AEP, 1% AEP, 0.2% AEP events using the ARR2019 ensemble approach. A total of five durations were assessed for the Peacock Creek catchment at Bonalbo and 15 durations were assessed at Bonalbo Town.

The temporal pattern producing the upper median storm for each storm duration was identified (rank 5 of 10). For each storm duration assessed, the representative storm for input into the hydraulic TUFLOW model was selected on two criteria:

- The pattern that provides the upper median flow at Woodenbong Road / Clarence Way bridge over Peacock Creek; and
- The pattern that provides the upper median flows through the Bonalbo township from local catchments at the downstream of Capeen Street drain.

Box plots showing the range, median and mean of peak flows for the ensemble are shown in Figure 5-5 and Figure 5-6. For the Bonalbo township the critical duration is the 1-hour event.

For Peacock Creek where the catchment size is larger, the 12 hour event gave the critical duration as the durations become longer. It is noted that this is the shorted duration assessed. Following ARR2019 guidance for catchments greater than 75 km$^2$ areal temporal were used for the Peacock Creek catchment to the town. The 12 hour storm is the smallest duration available while using areal temporal patterns. Due to the size of the Peacock Creek catchment and the ARR2019 approach is it assumed smaller durations would not provide the critical duration for this catchment.

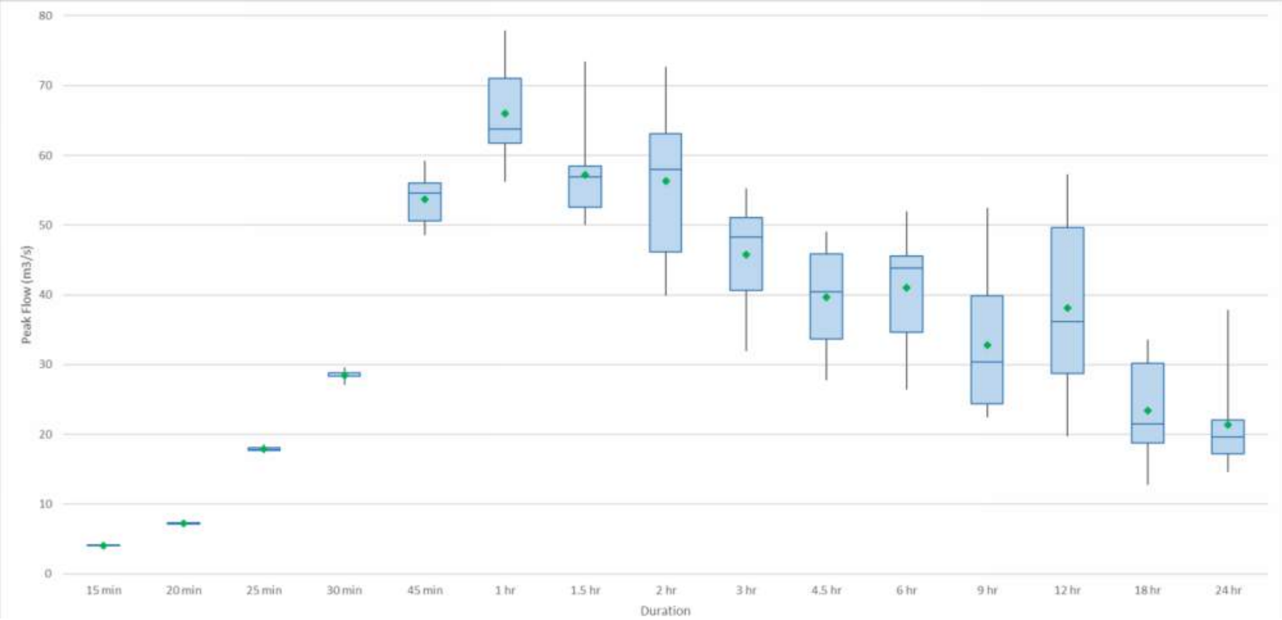



**Figure 5-5: Box Plot for 1% AEP at Bonalbo Township**

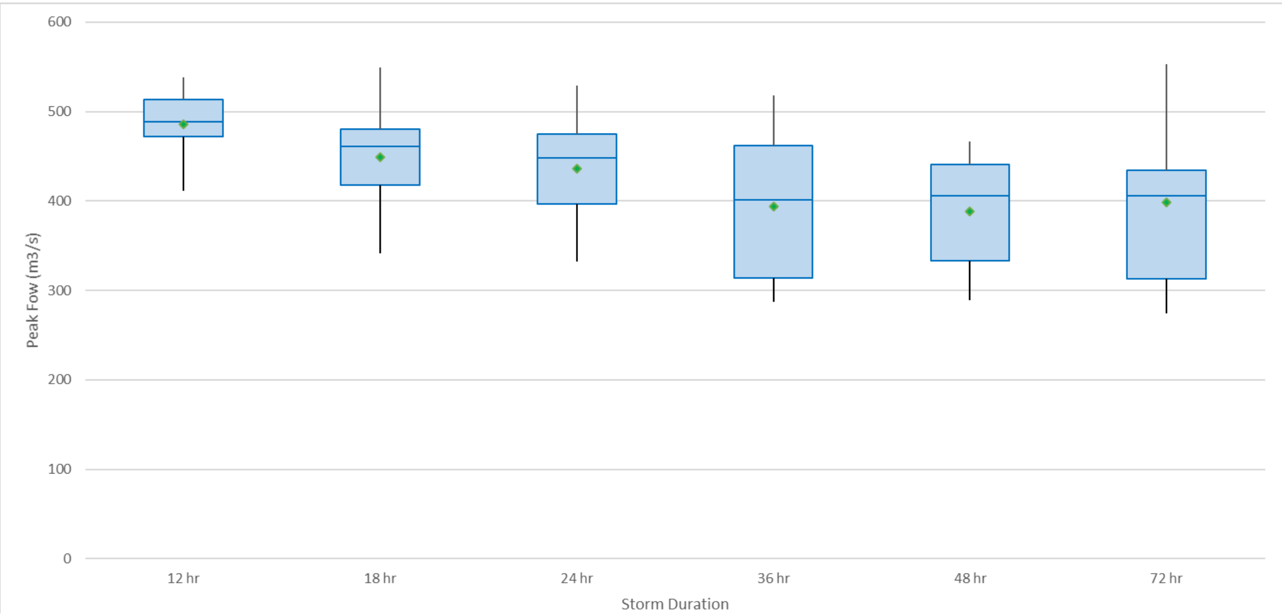



**Figure 5-6: Box Plot for the 1% AEP on Peacock Creek at Woodenbong Bridge**

### 5.4.7 Comparison of Rainfall Routing Model to Flood Frequency Analysis

A probability plot (refer Figure 5-7) shows the comparison of the FFA and the rainfall routing model generated values at the Peacock Creek gauge location. A confidence interval was created from the rainfall routing model values using the different values from the temporal pattern analysis, the upper median temporal pattern being the expected value, the maximum temporal pattern, and the upper minimum temporal pattern. The gauge observations fall within the confidence intervals of both rainfall routing and the FFA. While the rainfall routing model generated expected values fits closely within the FFA expected values with less than 10% difference in the 1% AEP event. This indicates that the rainfall routing model has a good fit to observed gauge data at the catchment draining to the gauged location and is therefore reasonable for use across the wider catchment and study area.

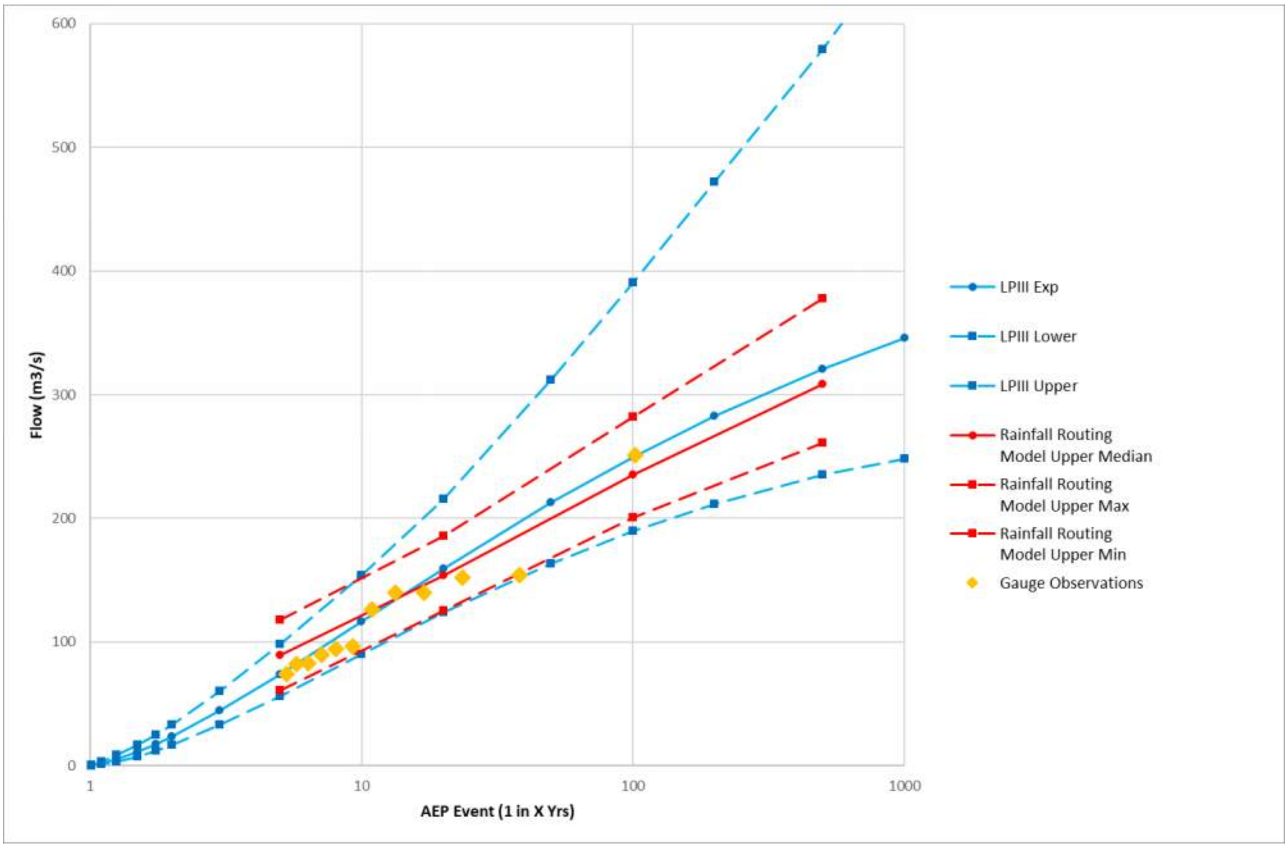



**Figure 5-7: Flood Frequency Analysis for Peacock Creek at gauge 204043**

## 5.5 Probable Maximum Precipitation Flood

Probable Maximum Precipitation (PMP) was calculated for the Bonalbo township catchment and the upstream catchment. The generalised short-duration method (GSDM) (Bureau of Meteorology, 2003) was applied for the catchment of the Bonalbo township. Durations between 15 minutes to 6 hours were assessed and the township catchment found to have a PMP flood critical duration of 45 minutes.

The PMP calculation for the catchment for Peacock Creek to where it passes Bonalbo was undertaken using GSDM for critical durations 15 minutes to 6 hours. The found critical duration using the GSDM approach was the 6 hour. Due to this being the longest duration of the GSDM, the Generalised Tropical Storm Method (GTSM) (Bureau of Meteorology, 2003) approach was also adopted to test longer durations. The 24 hours to 72 hour storms were assessed and a 12 hour storm was iterated from between the rainfall depths of the 24 GTSM and 6 hour GDSM. The application of the rainfall within the rainfall routing model found the critical duration was the 12 hour for Peacock Creek at Woodenbong Bridge.

## 5.6 Australian Rainfall and Runoff 1987

### 5.6.1 Intensity-Frequency-Depth data

A comparison of the ARR87 and 2019 IFD data was undertaken for the point IFD at Bonalbo town and also for the catchment average IFD. The results are summarised in Figure 5-8 and Figure 5-9.

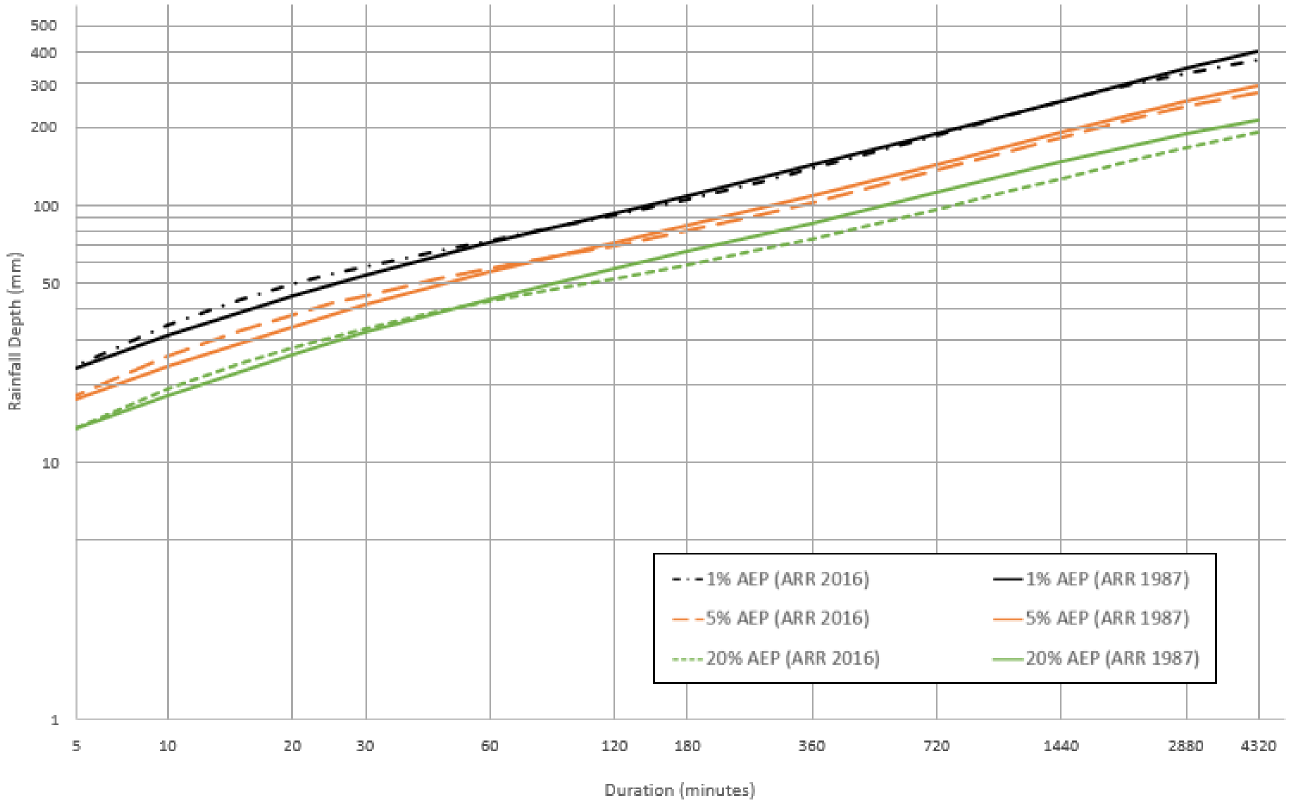



**Figure 5-8: ARR87 and ARR2019 Point IFD Comparison – Bonalbo town**

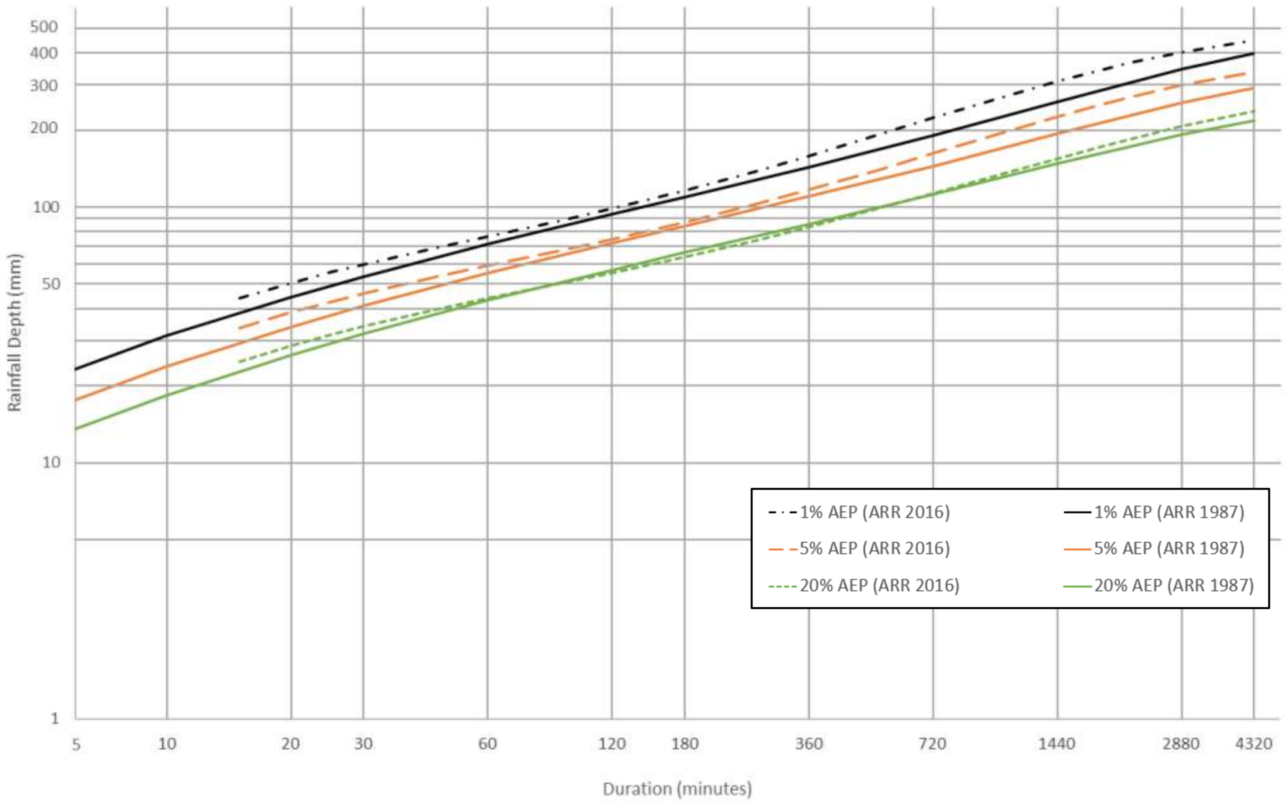



**Figure 5-9: ARR87 and ARR2019 Catchment Average Weighted IFD Comparison**

For shorter duration events (typically less than one hour) the ARR2019 IFD gives a higher rainfall depth while for longer duration events, the rainfall depth of a given AEP is typically reduced when comparing the 2019 IFD to the ARR87 IFD. This indicates that, when compared to the ARR 87 IFD, the revised 2019 IFD may lead to shorter critical durations for short duration flash flooding type events but lower flood levels for longer duration events.

### 5.6.2 ARR87 and ARR2019 Losses

The conversion of rainfall depths to runoff is also affected by other factors such as the application of losses. Losses adopted for this study used the FFA reconciled losses for NSW (refer section 5.4). A comparison of ARR87 and ARR2019 losses is provided in Table 5-3.

On first inspection the ARR87 losses in comparison to the NSW-FFA reconciled losses are significantly different and the ARR2019 losses are much higher than the ARR87 losses. The ARR87 approach does not consider pre-burst rainfall before the major storm burst as ARR2019 does. With the application of pre-burst losses which are varied for each event and duration, the storm loss that is modelled in the hydrology model is the initial loss less the pre-burst. An example of this can be seen in the 1% AEP 12 hour storm in Table 5-3. Through the application of pre-burst the storm losses applied are varied and more accurate than the ARR87 one size fits all approach.

**Table 5-3: Comparison of ARR87 and ARR2019 losses**

| | Initial loss (mm) | Continuing Loss (mm/hr) |
|---|---|---|
| ARR87 | 10 | 2.5 |
| ARR2019 | 49.7 | 3.26 |
| 1% AEP 12 hour Storm Loss | 3.6 | 3.26 |

### 5.6.3 Hydrology Assessment

The 5% AEP and 1% AEP events were run through the rainfall routing model using ARR87 procedures. A comparison of the hydrographs for the Peacock Creek catchment and Bonalbo town catchments is presented in Figure 5-11 and Figure 5-10.

For the 5% and 1% AEP events the revised ARR2019 method produces shorter duration critical storms. For the Bonalbo catchment the ARR2019 methods also result in higher peak flows as a result of the higher rainfall depths in the ARR2019 IFD for durations less than 60 minutes (refer Figure 5-8).

For the Peacock Creek catchment, the ARR2019 procedures result in reduced peak flows. As the catchment average 2019 IFD rainfall depths are actually higher than the catchment average 1987 IFD depths (refer Figure 5-8) the cause of the lower peak flows can be attributed to a combination of the greater losses and also the approach of running an ensemble of storms and adopting the upper median temporal pattern. While ARR87 adopts a single temporal pattern, the introduction of 10 varying temporal patterns in the ARR2019 ensemble approach gives more variation in rainfall distribution and hydrograph shape. For the case of the Peacock Creek catchment the temporal pattern that leads to the critical peak flows in the 1% AEP is storm 9.

In the 1% AEP event the comparison of ARR87 and ARR2019 methods gives similar results to the 5% AEP event. For the smaller local town catchment the peak flow is increased and the critical duration is reduced from 9 hours in ARR87 to 1 hour in ARR2019. For the larger Peacock Creek catchment at Bonalbo the peak flow is reduced, and the critical duration reduced from 36 to 12 hours.

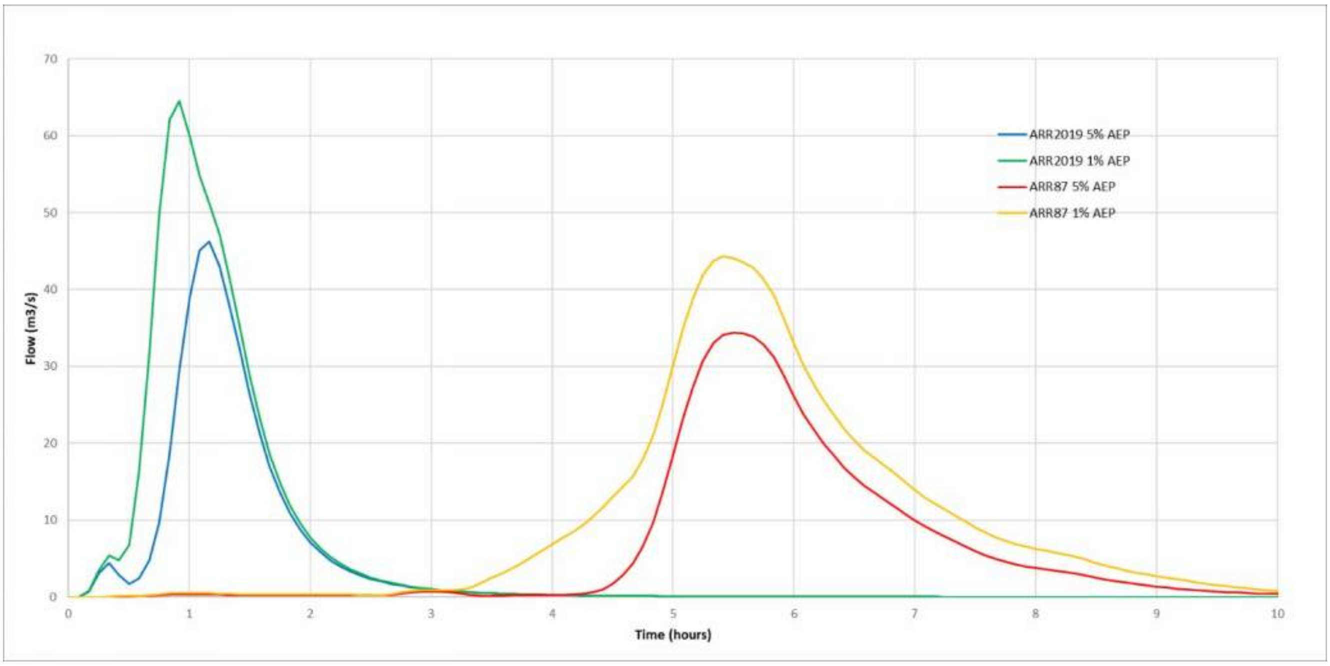



**Figure 5-10: ARR87 and ARR2019 Hydrograph Comparison – Bonalbo town catchments at the outlet of Capeen Street Drain**

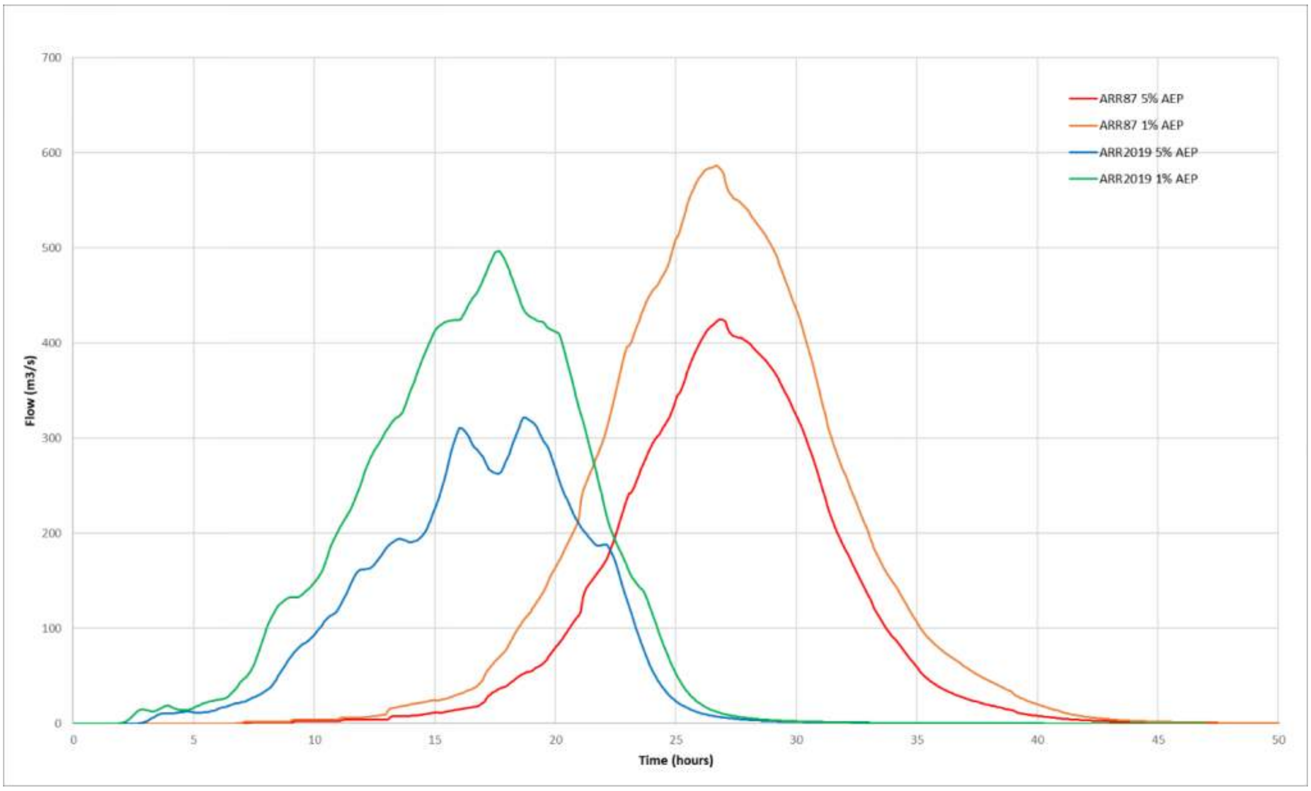



**Figure 5-11: ARR87 and ARR2019 Hydrograph Comparison – Peacock Creek at Woodenbong Road Bridge**

# 6 HYDRAULIC ANALYSIS

## 6.1 Hydraulic Modelling

Hydraulic modelling was undertaken using TUFLOW. This modelling package allows effective linking of both 1d and 2d modelling methods. The 2d modelling is grid based, but with the inclusion of 1d elements embedded into the 2d domain, allows for representation of finer details such as narrow waterways, the drainage network, and detailed hydraulic structures.

The model setup is summarised in Table 6-1 and also in Figure A 5.

**Table 6-1: TUFLOW Model Setup and Adopted Parameters**

| Parameter | Comment |
|---|---|
| Model Version | 2020-01-AB |
| Adopted grid cell size | A 2m model grid size was adopted for all model runs. |
| Model Extent | Refer in Figure A 5. Upstream model extent is approximately 2.6 km upstream of the Woodenbong Bridge crossing of Peacock Creek, and the downstream extent is 3 km south west of the Bonalbo town. The whole Bonalbo township is included in the model extent. The model extent was set larger than the study area so that any boundary conditions effects have no effect of flood behaviour within the flood study area. |
| Digital Elevation Model (DEM) | Developed from 2 m resolution 2017 LiDAR from NSW Spatial Services. LiDAR sourced from NSW Spatial services flown in 2017 has Horizontal Spatial Accuracy: +/-0.80 @95% Confidence Interval and Vertical Spatial Accuracy: +/-0.30 @95% Confidence Interval.<br>Areas in the model terrain which influence hydraulic behaviour such as Capeen Street channel, areas of raised or lowered land, features have been digitised using break lines so that the hydraulic effect of crest levels and depressions is considered. |
| Manning's roughness values | Based on aerial photography using Manning's 'n' Ranges for Different Land Use Types outlined in ARR2016 ARR Project 15: Two Dimensional Simulations in Rural and Urban Floodplains. |
| Upstream inflow boundaries | Catchment boundary conditions for the model has been determined at various locations based on discharge hydrographs established during the hydrologic analysis. The rainfall-runoff routing model (ICM) was used to determine inflows from external catchments. The representative hydrographs from the calibrated ICM rainfall runoff routing model was used to input hydrographs into the hydraulic model. |
| Internal flow boundaries | For local catchments and catchments internal to the TUFLOW model extent flows have been determined from the rainfall-runoff routing model and input as point inflows at suitable location into the TUFLOW model. |
| Downstream boundary | An automatically generated HQ (level-flow) boundary based on terrain slope was used. Sensitivity has been undertaken to ensure no boundary effects on the modelled flood behaviour in the study area. |
| Hydraulic structures – Peacock Creek | Woodenbong Bridge was assumed based on LiDAR data to determine deck height and advice provided from Council (2x 1m width piers in creek). The deck depth was assumed as 1.5 m, and railing height of 1m. The bridge is modelled as a 2d layered flow constriction layer using form losses determined through (Bradley, March 1978). |

| Parameter | Comment |
|---|---|
| Stormwater drainage network | Based on Council GIS data and incorporated as 1d elements. Invert levels were not provided for the network. Pipe inverts were set to ground level using the terrain. Where drainage was not present but was visible from the aerials and LiDAR a diameter was set according to the drainage size in the surrounding area. Pipes less than 375 mm in diameter were assumed to be blocked providing a conservative approach to overland flow assessment, except for pipes that provided transverse drainage under road crossings to keep connectiveness of flow paths.<br><br>For culverts crossing Woodenbong Road to the east of the town no data was available and culvert sizes were assumed based on typical engineering standards and a suitable level of cover from the LiDAR data. |
| Capeen Street Drain | Capeen Street Drain was incorporated into the model using the form of z lines and z points. The survey provided by council when compared to LiDAR values gave an unrealistic step up at each of the road crossings. Due to this LiDAR values were enforced along the drain. Deck levels were used to set the height of the road crossings along Capeen Street Dain where LiDAR was unavailable for the crossings. The Bridges across Capeen Street Drain are modelled in 2d. |
| Bonalbo Dam | The dam spillway, crest level and full supply level were input using the December 2014 survey and the Bonalbo Dam addendum to Flood Study report. The catchment flows draining to the were applied upstream of the dam wall in the hydraulic model. The dam was assumed to be at Full Supply Level (FSL) at the start of the storm. |
| Oak Street levee | Oak Street levee has been captured in the 2017 2m LiDAR DEM and performed as expected of the levee without any necessary treatment of the DEM. |
| Buildings | Buildings within the model extent were digitised from aerial imagery and blocked out of the model extent; ie assume no flow would pass through buildings. Buildings were digitised to make sure that flow paths were maintained around buildings. |
| Blockage | All pipes smaller 375 mm were excluded from the model (unless where connecting larger upstream and downstream systems) and effectively assumed as 100% blocked. This provides a conservative of overland flows, particularly in the smaller magnitude events.<br><br>For other pipes, due to the surrounding terrain lack of well-defined streams leading to the township, no blockage was applied to the storm water networks within the township. No blockage has been applied to the stormwater outside of the township catchment as all pipes and culverts sizes were assumed.<br><br>At Woodenbong Bridge due to the size of the spans being 22.5 m it was assumed there would be no debris from the upstream areas that would be significant enough of length to cause additional significant blockage. This provides a conservative approach to downstream areas allowing more flow to pass.<br><br>Blockage sensitivity was also undertaken (refer section 8.6). |
| Shallow drains / depressions | Drainage features, or natural depressions which convey flow, were incorporated as a gully (or minimum) line in the flood model. This ensure that flows continue from one cell to the next without artificial obstruction due to grid size. The Capeen Street drainage channel has been incorporated this way and so has the major flow path from Hospital Road through the town. |

## 6.2 Modelling Design Events

The flood model was run for the 20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events. Results are presented in section Appendix B.

### 6.2.1 Joint Probability Approach

Given the relative catchment sizes between the Peacock Creek catchment (121 $km^2$) at Bonalbo and the local catchments (5.3 $km^2$ to Peacock Creek) an event of a given magnitude may not occur on both catchments the same time. In addition, the temporal pattern and storm duration that produces the representative storm for the larger catchment is unlikely to be the same for the local catchments.

Therefore, a joint probability approach was adopted based on the Floodplain Risk Management Guide (OEH, November 2015) and as per Table 6-2.

**Table 6-2: Combinations of Catchment Probability for Determining Design Event Flood Behaviour**

| Design AEP | Scenario | Peacock Creek catchment | Bonalbo town catchments |
|---|---|---|---|
| 20% | 1 | 12 hour 20% AEP Temporal Pattern 3 | |
| | 2 | Creek full | 2 hour 20% AEP Temporal Pattern 6. |
| 5% | 1 | 12 hour 5% AEP Temporal Pattern 10 | |
| | 2 | Creek full | 1 hour 5% AEP Temporal Pattern 3. |
| 1% | 1 | 12 hour 1% AEP Temporal Pattern 9 | 1 hour 5% AEP Temporal Pattern 3 |
| | 2 | 12 hour 5% AEP Temporal Pattern 10 | 1 hour 1% AEP Temporal Pattern 1 |
| 0.2% | 1 | 12 hour 0.2% AEP Temporal Pattern 2 | 1 hour 1% AEP Temporal Pattern 1 |
| | 2 | 12 hour 1% AEP Temporal Pattern 9 | 1 hour 0.2% AEP Temporal Pattern 8 |
| PMF | 1 | 1 hour PMF | |
| | 2 | 12 hour PMF | |

For each of the AEP design events the design flood was determined by enveloping two scenarios to extract the maximum values. The critical durations and temporal patterns adopted for the TUFLOW hydraulic model had been determined in the hydrologic modelling (refer section 5).

# 7 MODEL CALIBRATION AND VALIDATION

## 7.1 Data for Model Calibration and Validation

The 1967 and 2008 events are considered the largest to have affected Bonalbo and were identified with potential for flood model calibration.

Within the Bonalbo and Peacock Creek catchment there are only two gauges available for model calibration and validation. The Bonalbo Post Office gauge (Gauge ID: 57003) has daily rainfall readings of rainfall from 1913 to present day and on Peacock Creek there is a stream gauge with 60 years of data. No sub-daily rainfall gauges exist with the Peacock Creek catchment although the surrounding catchments there are pluviometer gauges with varying years of record (refer section 3.2). Figure 7-1 shows the gauge locations within and outside the catchment.

For model calibration, as well as rainfall and stream gauge data, observed flood marks are useful so that the flood behaviour in the modelling can be calibrated to actual event-based data. Calibration data was collected thought the community consultation (refer Appendix D). Little data was available for the 2008 and 1967 events with most residents recalling flooding in January 2020. Although anecdotal evidence was available the 2020 event was not selected for flood model calibration. Rainfall gauge analysis indicates that this 2020 event had an AEP of about 50% AEP around Bonalbo, and while this caused overland flow flooding in the town, creek flooding was relatively minor. Given the relatively frequent AEP of the event and the fact that most flood marks were anecdotal rather than actual recorded flood depths it was not considered to be suitable for model calibration.

Kyogle Council provided a flood extent line for the 2008 event (refer Figure 3-3) although there were no community comments regarding this event. Reasonable rainfall and stream gauge data exists for the 2008 event (refer section 7.4) and therefore this has been selected for model calibration.

No observed flood markers were available for the 1967 event nor suitable rainfall data. Only the Bonalbo daily read gauge appeared to cover this period sufficiently.

## 7.2 Rainfall Analysis

### 7.2.1 Bonalbo Post Office Gauge

Analysis of the Bonalbo Post Office Daily gauge was undertaken to identify large rainfall events with potential for use in model calibration and validation. Figure 7-1 shows the daily recorded data at Bonalbo Post Office.

The 2008 and 1967 events are the two largest and most recent events to occur in a single day. The events that occurred in November and February 2001 occurred over 11 and 2 days respectively and therefore the totals shows in Figure 7-1 are totals over several days.

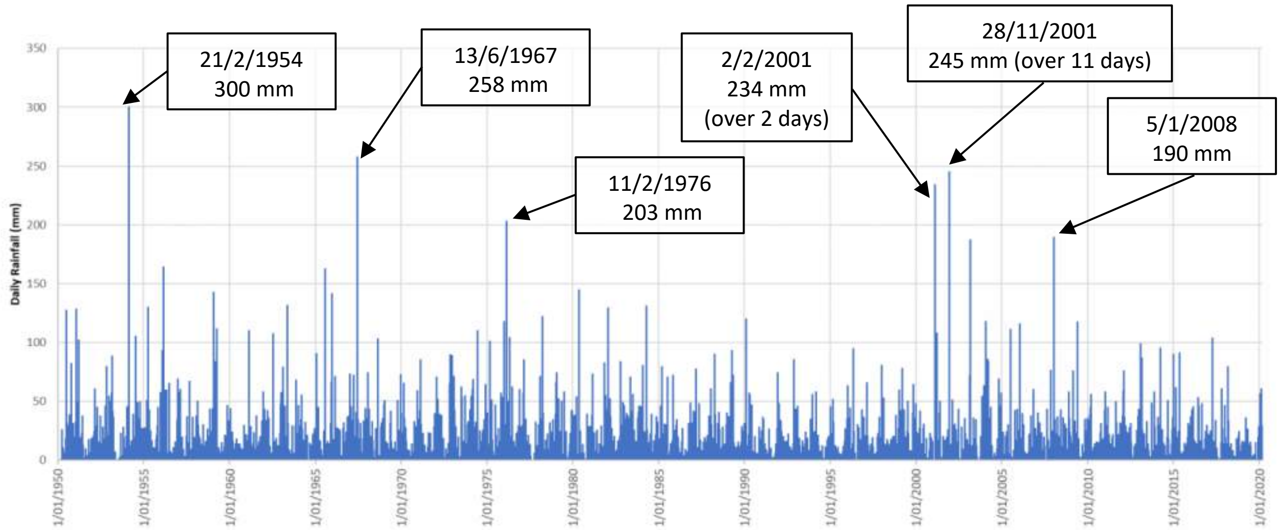



**Figure 7-1 Daily Rainfall Data Recorded at Bonalbo Post Office Gauge since 1950**

### 7.2.2 Sub-daily read gauges

There are no sub-daily read gauges within the catchment and therefore a combination of gauges outside of the catchment and RADAR data was used to establish input rainfall for the calibration events. For the 1967 event at this time of record there was no data available other than Nimbin, in the 2008 event there was data available for Tabulam, Unumgar, Nimbin, Green Pigeon and Upper Monogogarie.

## 7.3 June 1967 Event

For the June 1967 event the only additional data outside of the Peacock Creek water level gauge and Bonalbo Post Office daily rainfall gauge was the Nimbin pluviometer which is approximately 60 km from the Bonalbo Post Office gauge (refer Figure A 3).

An analysis of the data available seen below in Table 7-1, shows the June 1967 rainfall event was approximately a 1% AEP event at Bonalbo. The discharge recorded at the water level gauge at Peacock Creek corresponds to a 1% AEP event (based on the FFA outcomes). The Bonalbo Post Office rainfall gauge recorded a 1% AEP rainfall depth in a 24 hour period.

By comparison, the largest storm captured by the Nimbin pluviometer gauge was an about 10% AEP over a 12 hour duration. This difference in AEPs is due to the large spatial variability in rainfall due to the distance between the two gauges.

**Table 7-1: Gauges available for the 1967 Historical event**

| Gauge | Gauge Type | Peak AEP and Duration |
|---|---|---|
| Bonalbo Post Office (57003) | Daily Rainfall | 1% 24 hour Event |
| Nimbin (58044) | Pluviometer Rainfall | 9.4% 12 hour Event |
| Peacock Creek (204043) | Flow | 1% |

As there is not suitable sub-daily rainfall data over the catchment for the 1967 event, and a lack of observed flood markers the event was not used for flood model calibration.

## 7.4 January 2008 Event

For the January 2008 event a number of gauges captured data for the storm. From the daily read gauge at Bonalbo Post Office and stream gauge at Peacock Creek, the January 2008 event is estimated to have been approximately a 5% AEP at the township (based on 24 hours rainfall and ARR2019 IFD data) and slightly more frequent over the Peacock Creek catchment (based on Stream gauge data and FFA).

Pluviometers in the surrounding catchments vary in the estimated AEP of the storm. The rarest rainfall observed was a 3.3% AEP rainfall event experienced at Green Pigeon and the most frequent rainfall event was a 28.2% AEP event observed at Upper Monogogarie. These are 53 and 37 km away from the Bonalbo Post Office gauge respectively and in different catchments.

As the Bonalbo Post Office gauge is daily read and will capture the 24 hour period from 0900 to 0900, it may underestimate the AEP of the storm where the rainfall fell within a different 24 hour period.

**Table 7-2 Gauged Data Available for the 2008 Event**

| Gauge | Gauge Type | AEP for a 24 hour event | Peak AEP and Duration |
|---|---|---|---|
| Bonalbo Post Office (57003) | Daily Rainfall | 4.8% | 4.8% 24 hour Event |
| Tabulam (57095) | Pluviometer Rainfall | 20.8% | 7.8% 6 hour Event |
| Unumgar (58016) | Pluviometer Rainfall | 19.1% | 9.3% 7 Day Event |
| Nimbin (58044) | Pluviometer Rainfall | 32.7% | 4.8% 7 Day Event |
| Green Pigeon (58113) | Pluviometer Rainfall | 16.3% | 3.3% 6 Day Event |
| Upper Monogogarie (58192) | Pluviometer Rainfall | 37.3% | 28.2% 7 Day Event |
| Peacock Creek (204043) | Flow | Peak flow slightly less than a 5% Event | |

Historical RADAR images sourced from BOM (refer Figure 7-2), show the spatial variability in the January 2008 storm as the storm front approached from the coast north east of Bonalbo. This spatial variability accounts for why Green Pigeon experienced the most severe storm as it is the closest to the front.


**Figure 7-2: 2008 RADAR image and Storm Direction**

Using the rainfall observed at the pluviometer gauges in the surrounding catchments, the January 2008 storm was simulated in the rainfall runoff routing model. The rainfall was applied to each individual catchment within the model using thiessen polygons weighted around each rainfall gauge.

The storm rainfall peak over the Peacock Creek catchment occurred was on the 5th January and the storm was simulated to run between the 4th January to the 6th January to capture the full hydrograph. The flows at Peacock Creek have been compared in Figure 7-3 with the flows observed at the Peacock Creek stream gauge and the flows generated in the rainfall routing model.

The peak flow estimated from the rainfall routing model of 155 $m^3/s$ matches well to the observed peak flow of 154 $m^3/s$ at the Peacock Creek stream gauge.

The timing of the hydrographs are offset, with the rainfall routing model being later than the Peacock Creek. This is due in part to the rainfall distribution applied in rainfall routing model. The majority of catchments are weighted by the Tabulam rainfall gauge which observed the rainfall later in the storm than gauges to the north west due to the direction of the storm front. This therefore results in a lag between the measured and generated hydrographs. This is seen in the hyetographs (rainfall over time graphs) of Green Pigeon and Tabulam in Figure 7-3 which are 69.5 km apart. Green Pigeon experiences its peak rainfall at an earlier time than Tabulam, as the storm front moves across from the north east in a south westerly direction. However, as the peak flows are similar between the observed gauged data and the rainfall routing model, it could be expected that the hydraulic flood model would produce similar peak flood levels to the 2008 event.

The general shape of the hydrographs is captured in the rainfall routing model with some variability. There is a minor peak before the major peak in both and a minor uplift after the main peak. The size of the minor peaks are not captured in the flood. This is most likely due to the difference in rainfall losses, as the January event experienced a large run in of precipitation before the major storm. There was no rainfall gauge within the Peacock Creek catchment was used meaning there was the potential for some unaccounted spatial variability in the rainfall event.

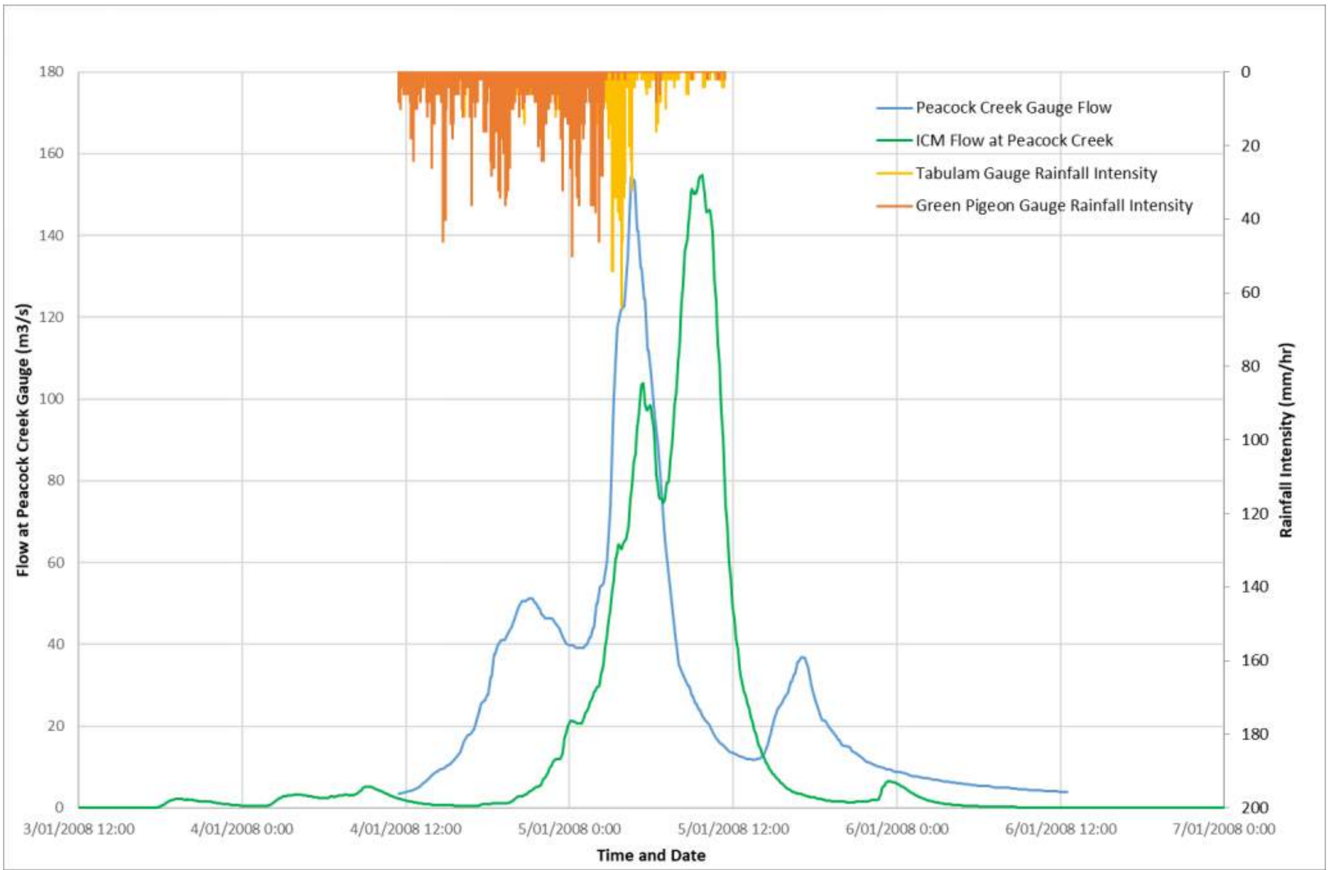



**Figure 7-3 January 2008 Calibration Event**

## 7.5 Model Validation

### 7.5.1 2008 Event

As shown in Figure 7-3 the modelled 2008 flood peak in the rainfall runoff model matches well to observed data. Flood depths and level mapping of for the modelled 2008 event output from the hydraulic model is shown in Appendix B. A comparison of the model and observed flood markers is summarised in Table 7-3.

A mapped flood extent provided by Council shows flooding reaching the south side of Woodenbong Road and inundated properties at the eastern end of Sandilands Street east of Peacock Street and also properties on Capeen Street (refer Figure 3-3). The modelled Peacock Creek flood extent compares well to the 2008 flood mapped outline.

A comparison of the flood model with observed 2008 flood levels is summarised in Table 7-3. After adjustment of the datum the flood model matches well with observed level at the Butter Factory.

**Table 7-3 Comparison of 2008 event Observed Flood Behaviour and Flood Model Results**

| Location | 2008 Flood Observations | 2008 Event Model Result |
|---|---|---|
| Butter Factory (1 Sandilands Street) | Approximate level of 166.930 mAHD provided on sketches form Kyogle Council. This flood level was based on a datum adjustment of 66.52 m as per the provided sketches. A drawing of the proposed works at the Butter Factory site indicated a ground level of 166.97 mAHD. However, LiDAR data gives levels around 165.25 mAHD which is some 1.7 m lower. By adjusting the estimated flood level also by 1.7 m gives a flood level of 165.3 mAHD. | In the 2008 modelled scenario, flood depths are about 150 mm in front of the Butter factory, this equates to flood levels of about 165.2 m AHD.<br>This is within 100 mm of the estimated flood levels and considered a reasonable calibration. |
| Pre-School | Assumed flood level of RL 100.81 m at Preschool with about 400 mm of above floor flooding (Kyogle Council). Applying the amended datum adjustment above results in an estimated flood level of about 165.6 mAHD and floor level of 165.2 mAHD. | The modelled flood level of 165.3 mAHD is about 300 mm lower than the assumed flood level at the school. There are several possible reasons for this:<br>• Local rainfall patterns were different from the observed sub-daily rain gauge data used in the assessment (no local sub-daily rainfall data is available).<br>• The DEM is poor at this location. Survey is recommended at the Floodplain Risk Management Study and Plan stage to validate the LiDAR DEM.<br>• The accuracy of the observed flood level may be low, also noting that is has been adjusted based on an assumed datum adjustment from drawings at the Butter Factory. |

In the first flood model of the 2008 event the pre-school remained dry during the 2008 event. Knowing that this was not the case and the pre-school had flooded during 2008, the DEM was reviewed in the area surrounding the school. The DEM was found to have localised high area which may have been caused by poor development of the LiDAR DEM from the flown ground strikes.

The DEM was manually adjusted to better represent the on-ground situation and the model was rerun. This resulted in a flood level of 165.3 mAHD at the pre-school and showed water surrounding the building. In doing this exercise it was noted that the local flood levels are sensitive to the assumed ground levels in the area and changes in ground level at one location can affect flood levels at a nearby location.

Overall, the adjusted DEM resulted in the model results being more representative of the observed flood behaviour and therefore this DEM adjustment was also adopted for the design event modelling.

### 7.5.2 Validation Against Anecdotal Evidence

No detailed flood level markers were available for further model calibration and therefore a model validation approach has been undertaken against anecdotal evidence provided by the community. As many of the comments provided did not include actual dates, times or recorded depths it is difficult to compare directly with the model outputs. A comparison of community comments against the results of the flood modelling has been undertaken to validate that the flood model is reasonably replicating actual flood behaviour.

As shown in Table 7-4, generally the model matches well to the anecdotal evidence with key areas replicating similar flood behaviour in the model to what has been reported e.g. inundation in particular areas.

**Table 7-4 Comparison of Flood Model Results and Anecdotal Flooding Evidence from the Community Consultation**

| Address | Date Observed | Comment | 2008 Event Model Result |
|---|---|---|---|
| 16, 18 and 20 Clarence Street | Frequent | 0.2 m depths from overland flow from High/Yabbra intersection | Poor match to observed data.<br>Flood model shown 0.03 m depths sheeting down the hill in the 2008 event (equivalent to a 5% AEP event). Advice from Kyogle Council suggest that continuous 0.2 mm depths of overland flow are unlikely. It is likely that where the reported 0.2 mm depths occurred this would be contained within drainage routes and not affected properties. |
| 6 Sandilands Street | No Date | 0.74 m depth in stormwater drain across rear fence boundary. | A reasonable match to overserved data within typically model limits.<br>0.5 m depths in stormwater drain in the flood model. Depths may differ from anecdotal advice as data of operation is unknown. Drain is also based on LiDAR data (with enforce gully line) and therefore invert level may differ slightly from on site. |
| 37 Sandilands Street | No Date | 0.4 m depth of floodwaters in open drainage channel at back of residence. | A reasonable match to overserved data within typically model limits.<br>0.1 m depths of floodwater in the drainage channel in the 2008 event food model. As above, depths may differ from anecdotal advice as data of operation is unknown. Drain is also based on LiDAR data (with enforce gully line) and therefore invert level may differ slightly from on site. |
| 61 Woodenbong Road | No Date | Flooding of open drainage channel adjacent to Bonalbo Street | Reasonable match to observed data.<br>The flood model replicates this behaviour. |

| Address | Date Observed | Comment | 2008 Event Model Result |
|---|---|---|---|
| 49 Capeen Street | No Date | Channel full in front or property | Reasonable match to observed data.<br>The flood model replicates this behaviour. |

# 8 MODEL RESULTS

## 8.1 Summary of Flood Behaviour

Bonalbo is subjected to flooding from both the local overland flows and mainstream Peacock Creek. For events up to an including 5% AEP Peacock Creek flows typically stay within the Creek. For these events, flooding in the town is dominated by local overland flows from the local catchments and the Capeen Street and hospital and dam catchment drains being exceeded.

At the southern end of the town local catchments from north on Bonalbo Road pass over the road and through the open area and properties at the lower end of Sandilands Street and adjacent streets. Flows follow a route which is a natural flood runner of the creek in larger magnitude events.

In the town the critical duration storm is relatively short; typically one hour. However, in the more frequent events the Bowling Club and sports field areas area affected by longer duration events as flatter areas act as flood storage.

For Creek flooding the critical duration storm is longer given the larger catchment areas. In larger events such as the 1% AEP and greater Peacock Creek spills into the floodplain downstream of the Woodenbong Bridge at the Bowling Club and Tourist Park and Camping ground following the natural flood runner and becomes the dominant source of flooding at the south-eastern end of the town. Individual maps for each AEP can be seen in Appendix B.

### 8.1.1 20% AEP event

In the 20% AEP event flows from Peacock Creek typically remain in channel and the majority of flooding within the Bonalbo township is from the overland flows coming from the town catchment. Depths are typically shallow and less than 300 mm however some localised areas of high hazard and floodways can occur in particular on Koreelah Street between Sandilands and Capeen Streets.

Some flooding from occurs near the Bonalbo Bowling Club and sports field from local catchments and the small catchments north of Woodenbong Road. Flows move towards the drain near Tooloom Streets and towards the tributary to Peacock Creek at the south of the town.

### 8.1.2 5% AEP event

Flooding behaviour in the 5% AEP event is similar to the 20% AEP event. The creek exceeds its main channel but does not extend significant into the floodplain. The town flooding is dominated by the local catchment flooding.

### 8.1.3 1% AEP event

In the 1% AEP event flows from Peacock Creek spill into the floodplain and contributes to flooding within the town. Areas east of Peacock Street and south of Woodenbong Road are dictated by overbank flooding of Peacock Creek. Flows move through the flood run from the Bowling Club area forming a floodways towards the tributary and back to the creek at downstream of the town.

In the town area affected by overland flood depths are typically less than 0.5m with the exception of localised areas where flooding from the drainage or exceedance of cross drainage structures occurs. With the exception for these areas flood hazard is typically H1 and H2 (refer section 8.3).

### 8.1.4 0.2% AEP event

In the 0.2% AEP event the flood behaviour is similar to the 1% AEP event in terms of areas affected by Creek and overland flow flooding. Flood depths are increased, in particular at the south-eastern portion of the town where the creek flows have the greater influence on the flood levels.

### 8.1.5 PMF event

In the PMF event the Peacock Creek flooding is main driver for peak flood levels up to about Dyraaba street. Floodwaters from Peacock Creek extent slightly north of Woodenbong Road, and south of Sandilands street and east of Dyraaba street and east of Peacock Street. Depths become significant in this area and are in excess of 1 m up to more than 5 m south of the town. High velocity and high hazard flows affect most of study area.

## 8.2 Design Peak Levels and Flows

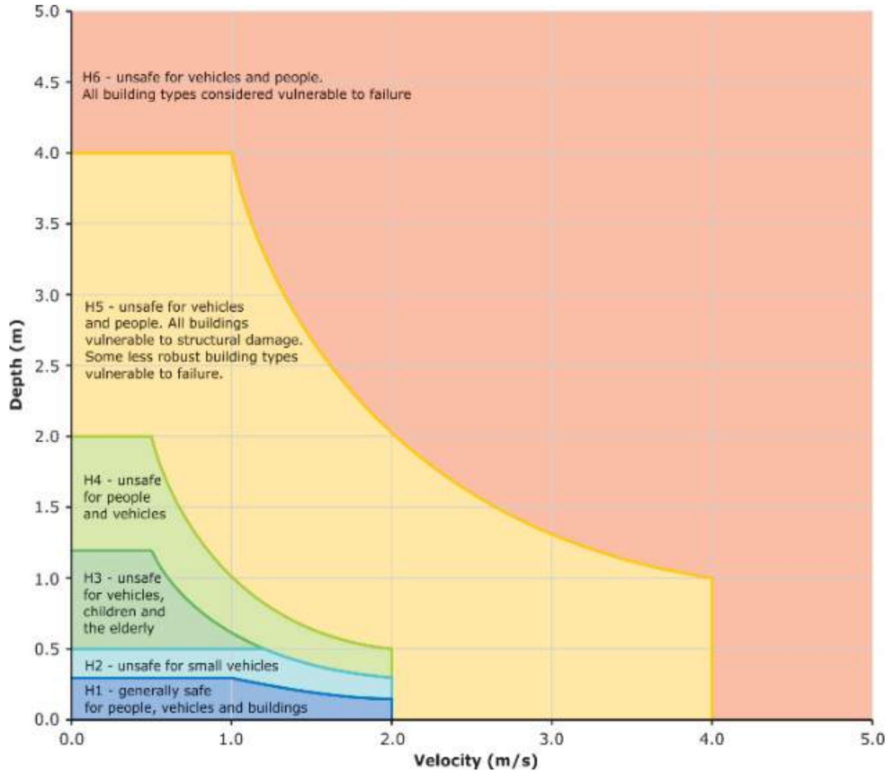
Table 8-1 shows the corresponding calculated flow at the gauge at Peacock Creek and the associated water level experienced at the town downstream of Woodenbong Bridge behind the Bowling Club.

**Table 8-1: Flow and Levels in Peacock Creek**

| AEP Event (%) | Peacock Creek Gauge Flow ($m^3/s$) | Water Level in Peacock Creek near Bonalbo Bowling Club, downstream of Woodenbong Bridge (m AHD) |
|---|---|---|
| 20% | 75 | 164.2 (within channel) |
| 5% | 160 | 165.1 (within channel) |
| 1% | 250 | 166.1 (outside of channel) |
| 0.02% | 320 | 166.4 (outside of channel) |
| PMF | 1453 | 168.1 (outside of channel) |

## 8.3 Flood Hazard

Mapping of flood hazard for is included in Appendix B. Flood hazard classifications described in ARR 2016 (Book 6, Chapter 7: Safety Design Criteria) have been adopted for the Bonalbo Flood Study as they it provide a greater range of hazard classifications than the provisional hazard categories described in the Floodplain Development Manual 2005. The ARR2019 hazard classifications are in line with AIDR Guideline 7-3 Flood Hazard (Australian Institute for Disaster Resilience (AIDR), 2017).




H1 – Generally safe for vehicles, people and buildings.

H2 – Unsafe for small vehicles.

H3 – Unsafe for vehicles, children and the elderly.

H4 – Unsafe for vehicles and people.

H5 – Unsafe for vehicles and people. All buildings vulnerable to
structural damage. Some less robust buildings subject to failure.

H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

**Figure 8-1: ARR2019 / AIDR General Flood Hazard Curves**

In the 20% and 5% AEP there are typically no areas of high hazard across the town with the exception of alongside Capeen Street drain and the drain that runs parallel to Bonalbo Street. A localised area of H3 hazard occurs on Sandilands Street at the drain crossing where the capacity of the cross drainage is limited.

Typically up to the 0.2% AEP event most of the residential area is considered H1 Hazard. However localised areas of significant haphazard occur near to the main drainage channels and areas where cross drainage capacity may be exceeded. In the 1% AEP and greater areas on Sandilands Street, Woodenbong Road and Bonalbo Street are subject to H5 Hazard and classified as unsafe for vehicles as waterways overtop onto the roads. These flow paths effectively can cut the town in half and people can become isolated unless evacuated prior to this.

At the eastern end of the town, east of Peacock Street areas of high hazard occur through the residential streets such as Peacock Street and Tooloom street as the Peacock Creek flows pass through the area. In this large events Woodenbong Road is also classified as H4 being unsafe for vehicles. A number of properties within the township are surrounded by floodwaters that are unsafe for people, children and the elderly.

## 8.4 Flood Function

Hydraulic categories were determined in accordance with the Floodplain Risk Management Guideline Floodway Definition and the Floodplain Development Manual definitions. The following criteria was used to establish the provisional flood function based on Howells et al. (2004) and is mapped in Appendix B:

Floodway:

- Velocity x Depth must be greater than 0.25 $m^2/s$ AND velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s

All other areas were determined as Flood Storage, and where flood depths were less than 200 mm was classified as Flood Fringe.

Floodways are areas important for conveyance of water flows during floods. These areas are typically naturally defined channels. Flood storage is areas of large depths but slower velocities. These areas are typically overbank flow from the defined channels and creeks and if filled would cause adverse effects on flood behaviour elsewhere. Flood fringe considered as areas of shallow depths and slow velocities.

In the 20% AEP the floodways occur in the main channels such as Capeen Street drain, the drainage channel from the hospital area and Peacock Creek. In the 1% AEP event floodways form along some of the streets within the town as the drainage channels are exceeded. Although depths are typical shallow, velocities are high and this would make evacuation difficult for some.

There is an overbank flow path from Peacock Creek which occurs through the eastern end of the town where flows exceed the channel of Peacock Creek and join local catchment flows south of Woodenbong Road. This is seen to cut through the Bowling Club and playing field area and affects the properties along Tooloom Street.

In the PMF even the Township is covered by floodway as the depths and velocities are significantly high.

## 8.5 Climate Change

Assessment of the potential effects of climate change allows for Council to understand the implications of on flood planning into the future, for example, if the flood planning area need to be extended or flood planning levels increased.

ARR2019 recommends the application of percentage increases in rainfall based on climate scenarios assessed by CSIRO. Through the ARR Data Hub, Interim Climate Change Factors are provided with percentage increase in rainfall to be applied to a range of future years. ARR2019 recommends the use of RCP4.5 and RCP 8.5 values. For Bonalbo this equates to an increase of 11.5% and 19.7% to 2090.

As per the project brief, a comparison of the 0.2% AEP event to the 1% and AEP event has been used as a proxy to assessment of climate change and also the recommendations of ARR2019. Figure 8-2 shows the difference in peak water levels between the 1% AEP and 0.5% AEP events.

On Peacock Creek the peak flow upstream of the Woodenbong Road Bridge increases from 500 $m^3/s$ in the 1% AEP event to 640 $m^3/s$ in the 0.5% AEP event. This is a 28% increase in peak flows. While a percentage increase in rainfall does not directly equate to the same percentage increase in peak flows, adopting 0.5% AEP as a proxy for climate change is likely to be a conservative estimate in the potential effects of climate change to 2090.

An increase in flood extents of flooding from Peacock Creek can be seen in the Was Wet Now Dry sections in Figure 8-2. Within the town, the extent of flooding does not increase significantly, although depths may increase by up to 120 mm in the residential areas, on average these increases are by 40 mm.

Increases of up to 290 mm occur within Capeen Street drain and the channel alongside Hospital Road is subject to increases of up to 240 mm. Within Peacock Creek and on the creek floodplain the increases in peak flood levels are greater than within the town. In Peacock Creek adjacent to the bowling club there are increases of up to 600 mm. Where the creek flows out of bank through the Bowling Club and the floodplain where there is more flood storage available the depths increase over 500 mm in areas.

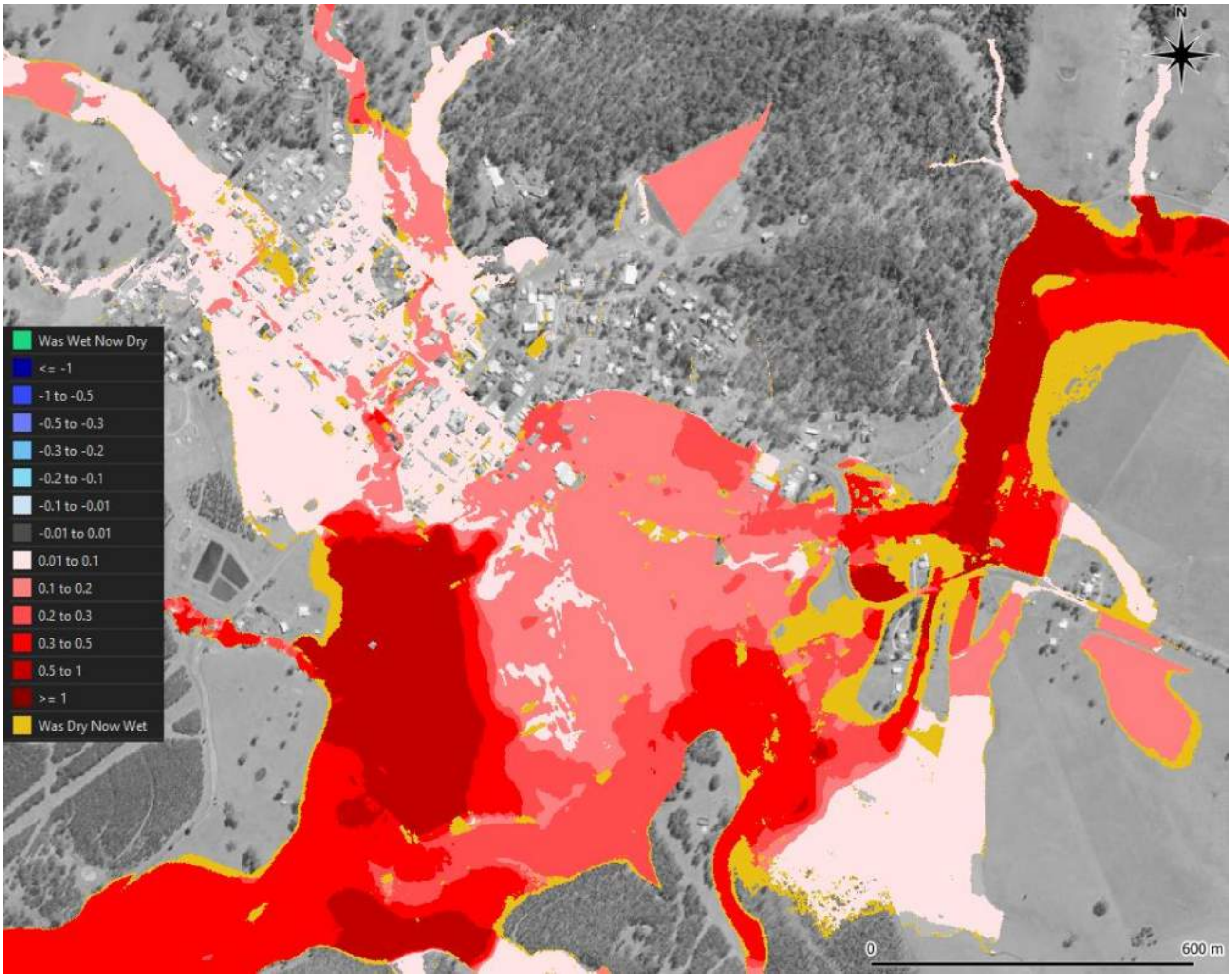



**Figure 8-2 Water Level Difference between 0.2% and 1% AEP**

## 8.6 Blockage Analysis

A sensitivity was undertaken with blockage analysis with the blockage increased 10% at the Woodenbong Road Bridge and 50% for other stormwater networks within the model for the 1% AEP. Based on the ARR2019 blockage procedures, this corresponds to Medium potential for the 1% AEP for the stormwater network and High potential for Woodenbong Bridge.

The results from the sensitivity test showed a decrease in flood levels in the channels and creek downstream of key structures. Decreases up to 50 mm occurring in Capeen Street Drain due to floodwaters being held at upstream entry points through the town. In Peacock Creek there was minor decreases downstream of Woodenbong Road Bridge less than 10 mm. Upstream of the bridge the 10% blockage lead to a 2 mm increase in flood levels directly upstream.

Increases in peak flood levels occur along Gill Street, Lunar Lane and Sandilands Street where water is ponding upstream of cross drainage. These increases are on average 10 – 20 mm and are up to as much as 40 mm in areas and shows the importance of drainage maintenance. This is seen in Figure 8-3.

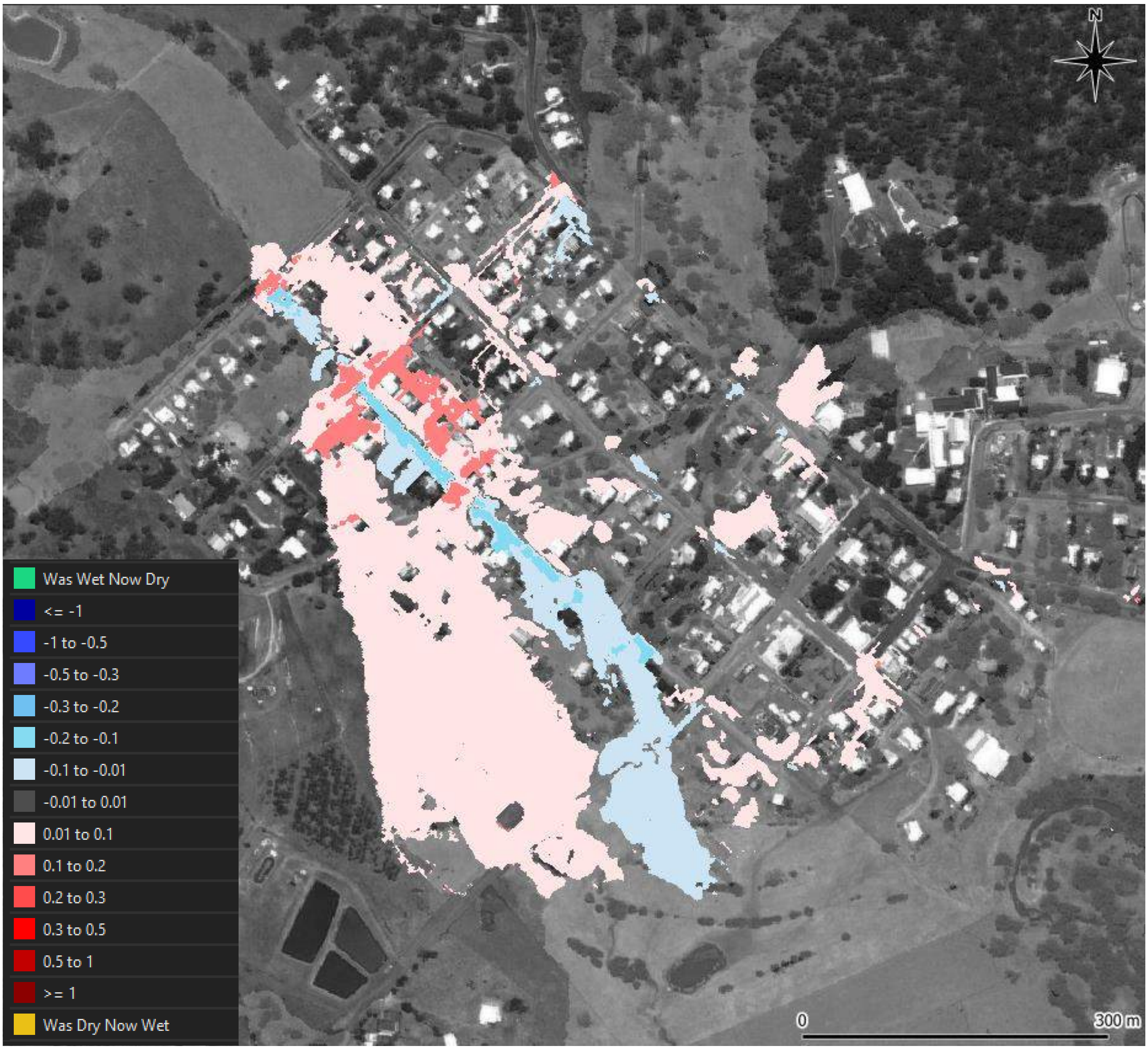


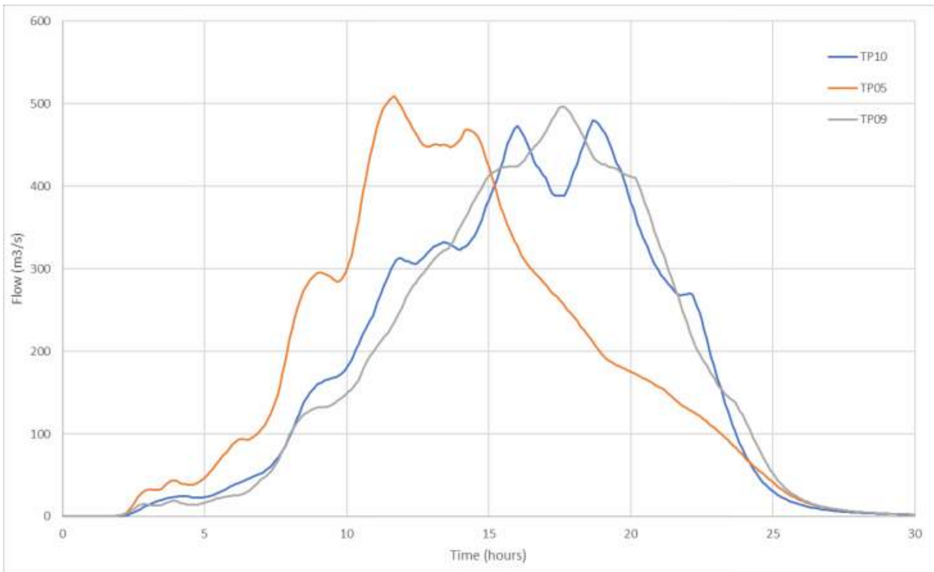

**Figure 8-3 Blockage Analysis Differences – Higher Blockage Less Design**

## 8.7 Sensitivity Analysis

Sensitivity analysis has been undertaken to observe the influence of model parameters on the predicted flood behaviour. Sensitivity was undertaken by adjusting relevant parameters in both the hydrologic rainfall routing model (ICM) and hydraulic (TUFLOW) models and assessed against the 5% AEP and 1% AEP design events.

**Table 8-2: Model Sensitivity Assessment**

| Parameter and Sensitivity Assessment | Outcomes |
|---|---|
| Initial and Continuing losses<br>a) Adopt ARR19 Losses: IL to 35.3 mm and CL to 3.5 mm/hr | NSW FFA losses applied in the hydrology model are IL 49.7 mm and CL 3.26 mm/hr. As a sensitivity these have been decreased to ARR datahub values for the region of IL 35.3 mm and CL 3.5 mm/hr. In the Peacock Creek catchment, at Woodenbong Bridge this sensitivity has only a negligible impact on the peak flow in the 5% AEP and 1% AEP events lowering peak flow by less than 5 $m^3/s$. Due to the size of the catchment and using areal temporal patterns the minimum applicable duration is 12 hours. The difference in the initial loss (14.4 mm) becomes small in storm with a total of 223 mm, and the continuing increase from 3.26 to 3.5 mm/hr cause a slight decrease of flows.<br>For Bonalbo town catchment there is more increase in peak flow, from 64.5 to 74.9 $m^3/s$. The Bonalbo town catchment has critical duration of 1 hour and a rainfall depth 73.6 mm. The shorter duration events are more sensitive to the initial loss. |
| Hydraulic roughness<br>a) Increase of 20%<br>b) Decrease of 20% | Increasing the Mannings 'n' roughness slows down the floodwater velocities within the model extent and typically creates higher flood depths. By increasing the roughness by 20% within the model there is an increase of flood levels across the model. At properties within the town there is maximum increases of 10 mm. Within defined channels the increases are higher with an average increase of 40 mm and maximum increases of 100 mm, within Peacock Creek there is increases of on average 450 mm.<br>Decreasing the roughness by 20% has the opposite effect, increasing flood velocities and lowering flood depths. Within the town there are decreases in flood levels of typically 15 mm, in well-defined channels within the town there are decreases of up to 100 mm. In Peacock Creek there are decreases on average of 450 mm within the creek.<br>While the model has some sensitivity to hydraulic roughness, the differences are within the expected model tolerances. |
| Structure losses at Woodenbong Road bridge over Peacock Creek<br>a) Increase by 10%<br>b) Decrease by 10% | Increasing the form losses at Woodenbong Road bridge has no significant result in Peacock Creek in the 5% or 1% AEP events. In the 1% AEP event it results in 10 mm increases in flood levels in the floodplain upstream of Woodenbong Road bridge.<br>Decreasing the structural losses at Woodenbong Road bridge has no significant result in the creek in the 5% AEP event or the 1% AEP event. In the 1% AEP event it results in a 10 mm decrease in flood levels in the floodplain upstream of the Woodenbong Road Bridge. |
| Downstream boundary conditions<br>a) Increase slope by 20%<br>b) Decrease slope by 20% | Downstream boundary sensitivity is undertaken to ensure that the model extends suitably downstream so that boundary affects to dot influence the predicted flood behaviour in the study area.<br>By increasing the slope on the downstream boundary the flood levels are reduced by at least 10 mm up to 1200 m upstream of the boundary. This is still significantly far from the township to have no impact on flood levels within the town.<br>Decreasing the slope by 20% increases flood levels by at least 10 mm up to 1500 m upstream of the boundary. This is still significantly far from the township to have no impact on flood levels within the town. |

| Parameter and Sensitivity Assessment | Outcomes |
|---|---|
| Temporal Patterns | Sensitivity to temporal patterns assists in understanding flood response times to rainfall and available warning times for flood emergency response and will be considered further in the Floodplain Risk Management Study and Plan.<br><br>The upper median temporal pattern (rank 5), the pattern that is the closest highest neighbor to the median has been chosen for each design event from the 10 potential temporal patterns as per ARR2019. For sensitivity testing the temporal pattern which produces the peak flow either side of this has been assessed in the rainfall routing model.<br><br>In Peacock Creek at Woodenbong Bridge the upper median temporal pattern selected (TP9) has a peak flow of 496.5 $m^3/s$. TP10 the temporal below the median value has a peak flow of 480 $m^3/s$ and TP05 the next TP above the median has a peak flow of 508 $m^3/s$. While this will have some effect on peak flood levels it is not likely to be significant and is considered within the accuracies and limitations of flood estimation.<br><br>The hydrographs of the three different temporal patterns are seen below. TP9 and TP10 are both rear loaded storms and show similarities. TP05 (one rank above the upper median) is a front loaded storm and creates a higher peak flow at Woodenbong Road Bridge.<br><br>TP05 is also likely to lead to a faster rate of rise in Peacock Creek. It is worth considering this further in regard to flood emergency response.<br><br> |

# 9 CONSEQUENCES OF FLOODING ON THE COMMUNITY

## 9.1 Flood Emergency Reponses Classification of Communities

The Flood Emergency Response Classification of Communities (DECC, 2007) is defined to assist in managing flood evacuation and response. Areas are broadly classified based on the flood affection to the area and to the local evacuation routes before the flood peak.

The Flood Emergency Response Classification is mapped in Appendix C. Much to the town is considered to have Rising Road Access where people can evacuate via vehicle before the peak of the flood (subject to sufficient warning). However, although areas have Rising Road or Overland Escape Route access, often this is to areas which are considered to be High Trapped Perimeter due to the natural topography and hillslopes.

The southern portion of the town is considered as Low Flood Island where if people are not evacuated before the surrounding areas are inundated, they would become trapped and eventually inundated. This is a priority area for evacuation.

Areas on the west and north-east of town become High Trapped Perimeter areas meaning that although above the PMF, the areas could be cut from vehicular or overland on foot access to areas of safety. The showground is considered as High Trapped Perimeter as while above the PMF can become isolated. Indirectly affected areas on the periphery of the residential properties to the north; although not flooded in the PMF access road become cut and the areas is effectively isolated. Table 9-1 shows the number lots in each FERP category.

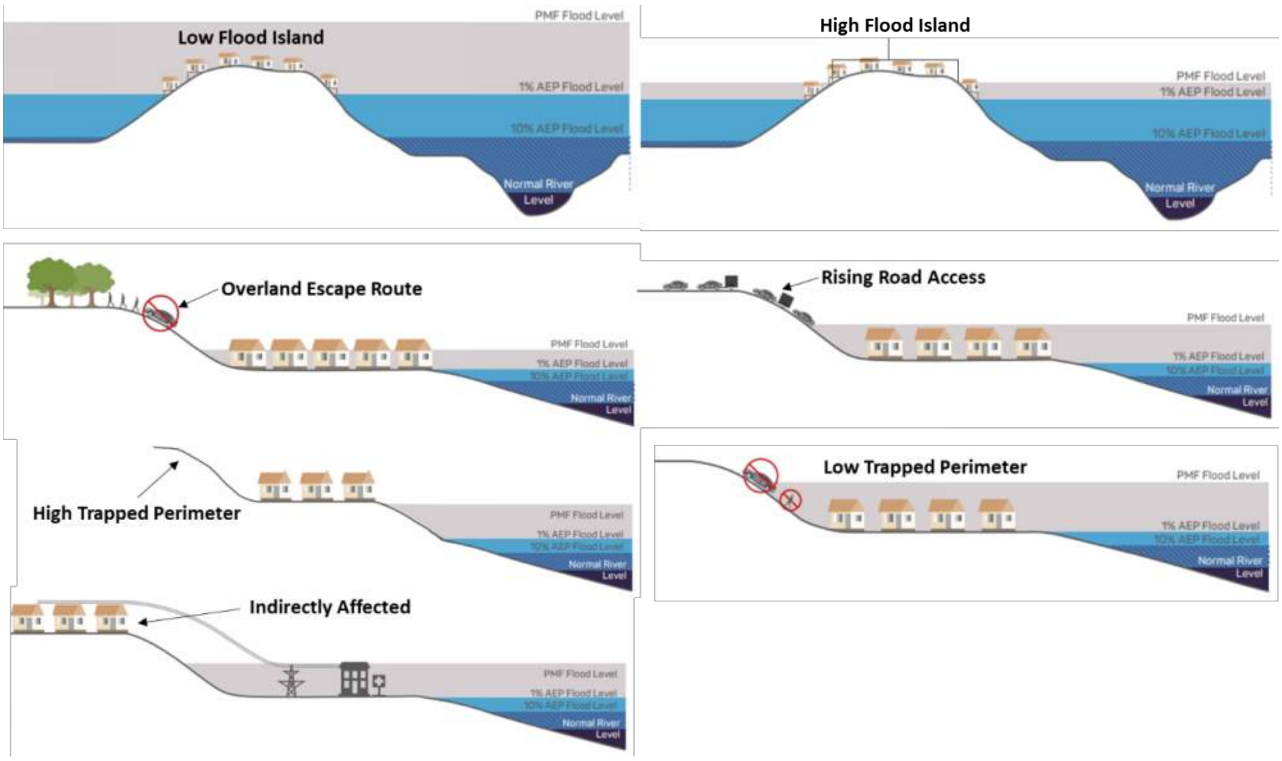



**Figure 9-1: Schematic of FERP Classifications (adapted from Guideline 7-2; Flood Emergency Response Classification of the Floodplain (Australian Institute for Disaster Resilience (AIDR), 2017))**

Within Low Flood island and Rising Road Access, the first areas to be cut-off are the properties south of Peacock Street when Peacock Creek breaks it banks and goes across the flood runner. These areas would be priority for evacuation. For areas subject to overland flows, the short duration of the critical storms mean that flooding is flash flooding type and the areas can be cut suddenly. For minor local storms most properties (with the exception of those towards the south of Bonalbo town) would remain safe within their homes. Floor level survey at the Floodplain Risk Management Study stage will be sought to further identify affected properties.

**Table 9-1 Number of Lots in FERP Category**

| Classification | Number of Lots |
|---|---|
| Low Flood Island | 50 |
| Rising Road Access | 183 |
| Overland Escape Route | 47 |
| High Trapped Perimeter | 30 |

## 9.2 Dam Break Assessment

Kyogle Council is responsible, under the Dam Safety Act, for preparing and maintaining a Dam Safety Management System and associated Dam Safety Emergency Plan (DSEP) for the Bonalbo (Petrochilos) Dam as it is a Prescribed Dam under this Act. The DSEP is finalised in consultation with the SES and updated regularly.

An indicative dam break assessment has been completed for the 1% AEP and the PMF event to consider the potential effects of dam break during a flood event. This was done by using a time variable geometry in the TUFLOW hydraulic model to lower the dam embankment at the start of the model run over a five minute period while the dam is at full supply level.

Depth of approximately 1m and 1.5m occur in the dambreak wave in the 1% and PMF events travelling down the hillslopes downstream of dam before dispersing into the town. In the 1% AEP increases in water levels of up to 50 mm on average and up to 500 mm in specific areas within the town. In the PMF event dam failure could cause increases on average of 30 mm and up to 50 mm in areas. There is less increases in the PMF event as the town is already inundated and the additional flow from the dam break is a smaller percentage in comparison to the storm flows through the town.

While a dam failure during the PMF would likely give the highest total flood consequence category, it may not give the highest incremental flood failure category (i.e. the difference between the PMF flood and the PMF dam failure flood could be less than the difference between the 1% AEP flood and the 1% AEP dam failure flood although assumptions on dam capacity prior to the flood also will affect this).

The *2017 Piping Risk Assessment* report suggests that the risk of flood failure is lower than the risk of piping failure (Sunny Day failure) as the dam has the capacity to safely convey the PMF flows without overtopping the embankment crest. Therefore, the worst-case failure scenario in terms of incremental consequence to assess may be a Sunny Day failure. This is outside of the scope of this work as it not directly related to the floodplain risk management but is a recommended for Council's consideration.

## 9.3 Road Inundation

Figure 9-2 shows the flood levels along Woodenbong Road and Clarence Way, Woodenbong Road Bridge is only overtopped in the PMF event and there are localised areas of overtopping in the 1% AEP with shallow depths.

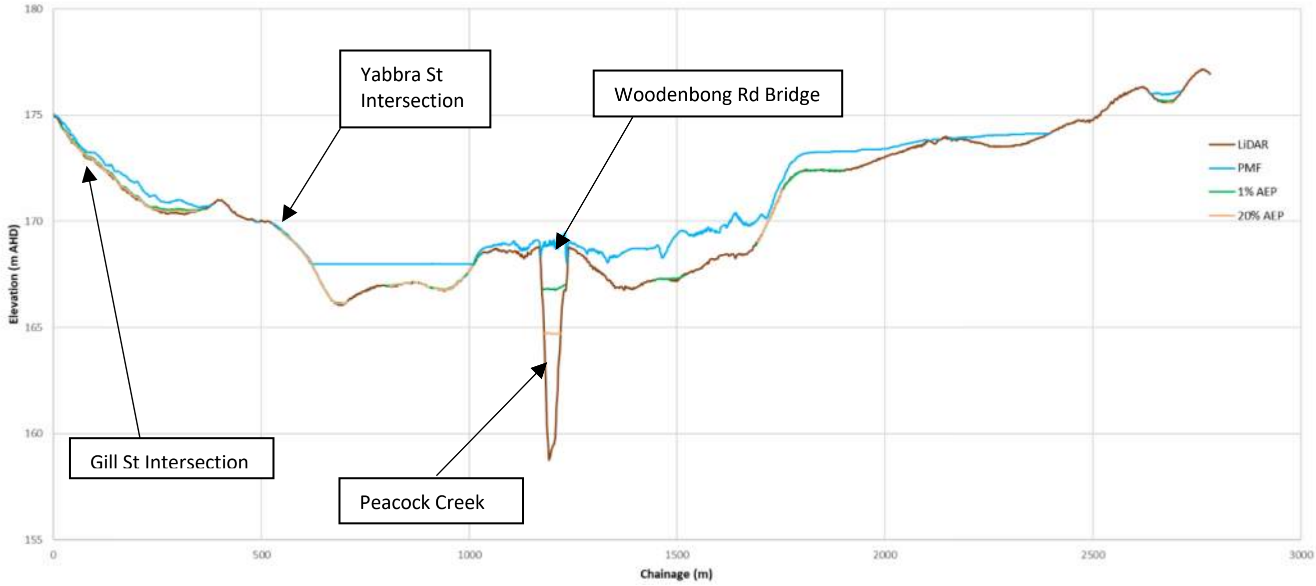



**Figure 9-2: Flood along Woodenbong Road and Clarence Way**

Further investigation at these points of overtopping are seen in Figure 9-3 and Figure 9-4 respectively. At both of these locations there are overland flow paths coming from the hills to Woodenbong Road and Bonalbo. Due to these catchments being relatively small, the response time of each of these catchments is short, with times of inundations at Woodenbong Road being a maximum of 2 hours within the PMF. In smaller events such as the 1% AEP the roads are inundated for a similar period of time however depths of flood waters are less than 200 mm.

Figure 9-5 shows the flood levels at Woodenbong Road Bridge. The PMF is the only overtopping event and only reaches above the deck level for a small amount of time.

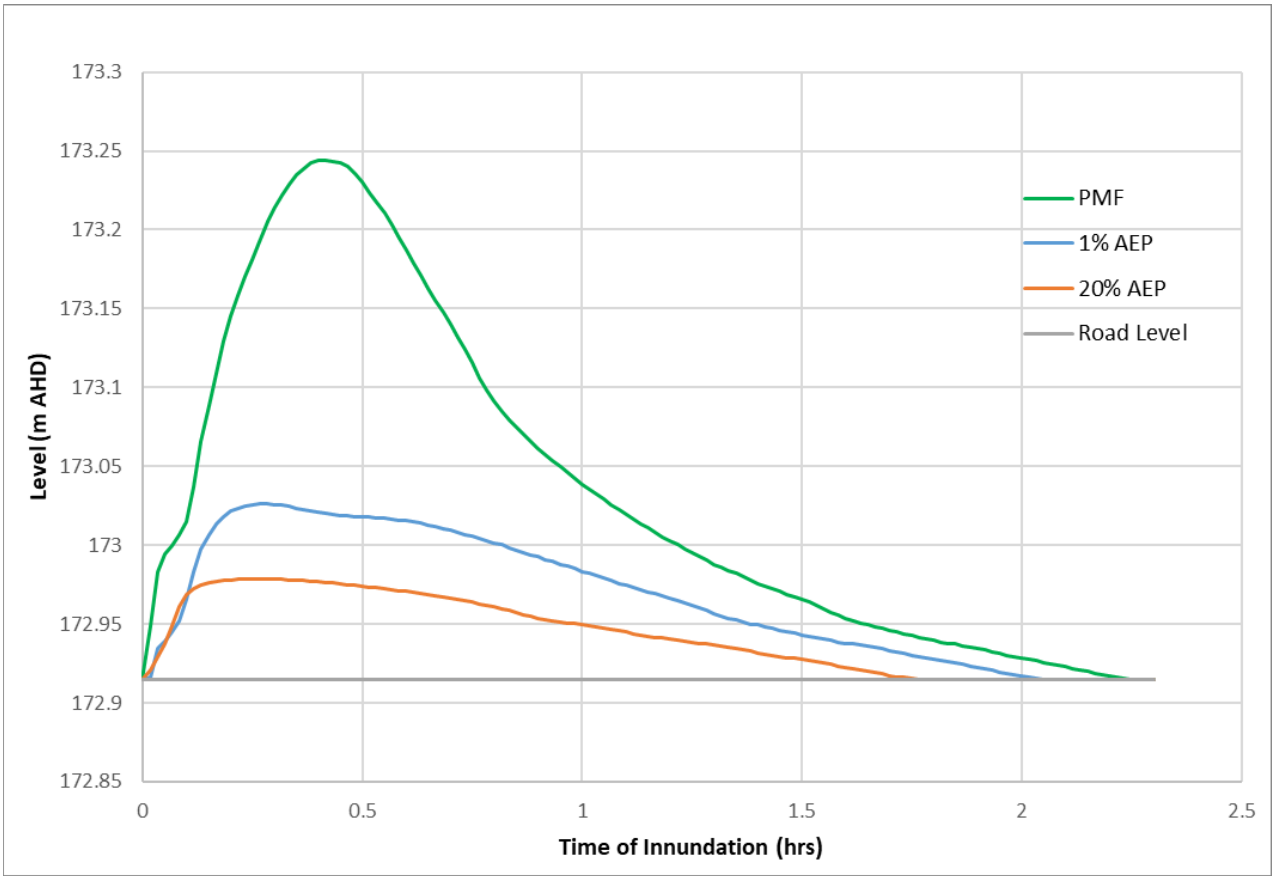



**Figure 9-3: Flood Levels at Woodenbong Road and Cope Street Intersection**

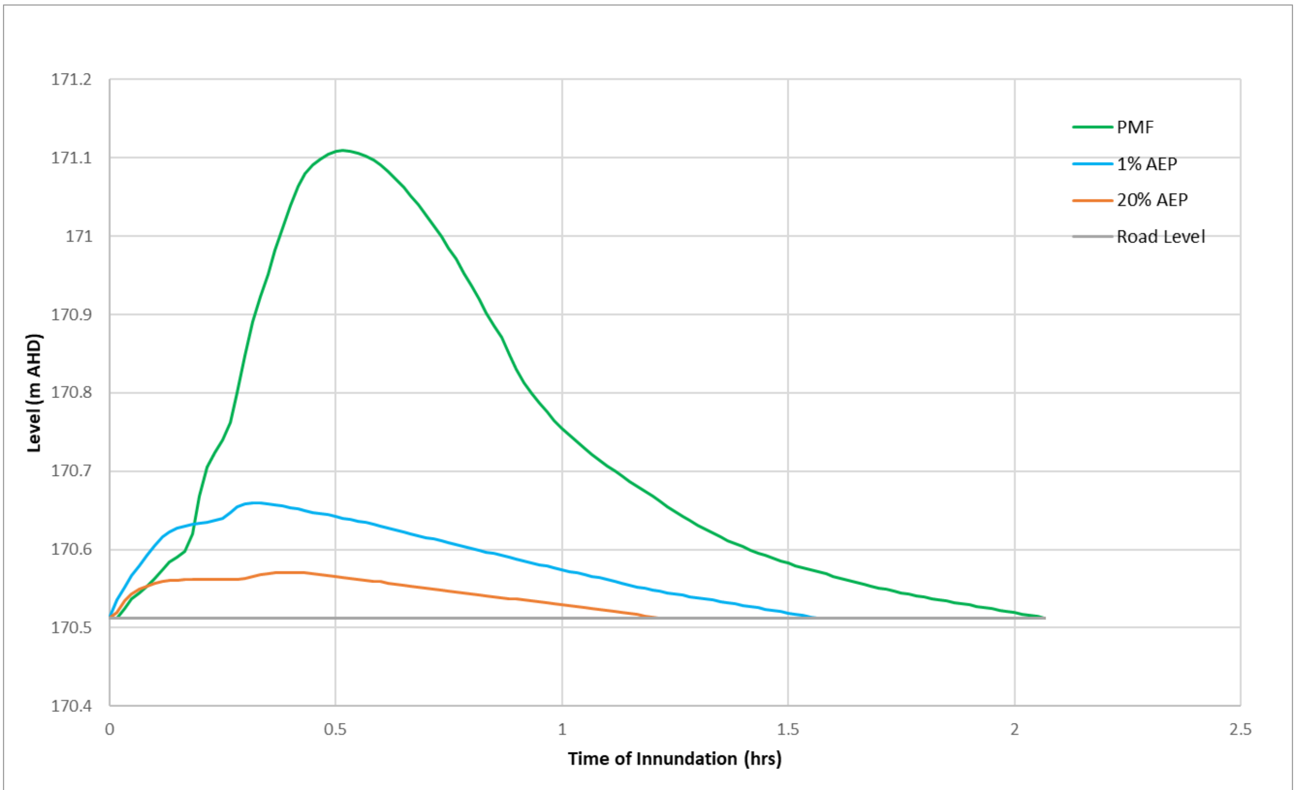



**Figure 9-4: Flood Levels at Hospital Road and Woodenbong Road Intersection**

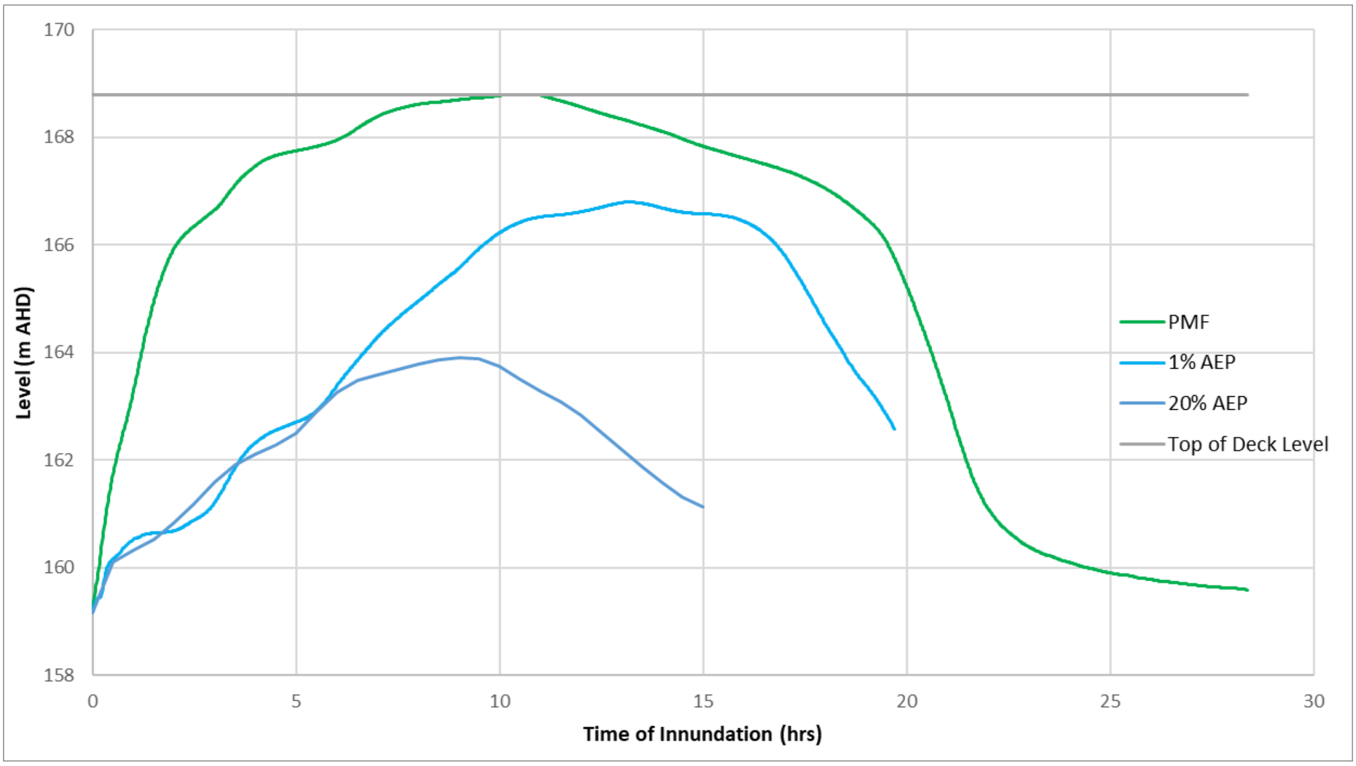



**Figure 9-5: Flood Levels at Woodenbong Road Bridge**

# 10 MANAGING ACTIVITIES IN THE FLOODPLAIN AND FLOOD RISK

## 10.1 Land Use Planning

The town is typically zoned RU5 Village while the surrounding area is RU1 Primary Production. South-east of the town, recreation areas (RE1 Public and RE2 Private) separates Peacock Creek from the RU5 Village area. On the southside of Woodenbong Road / Clarence Way a large area is zoned as R5 Large Lot Residential.

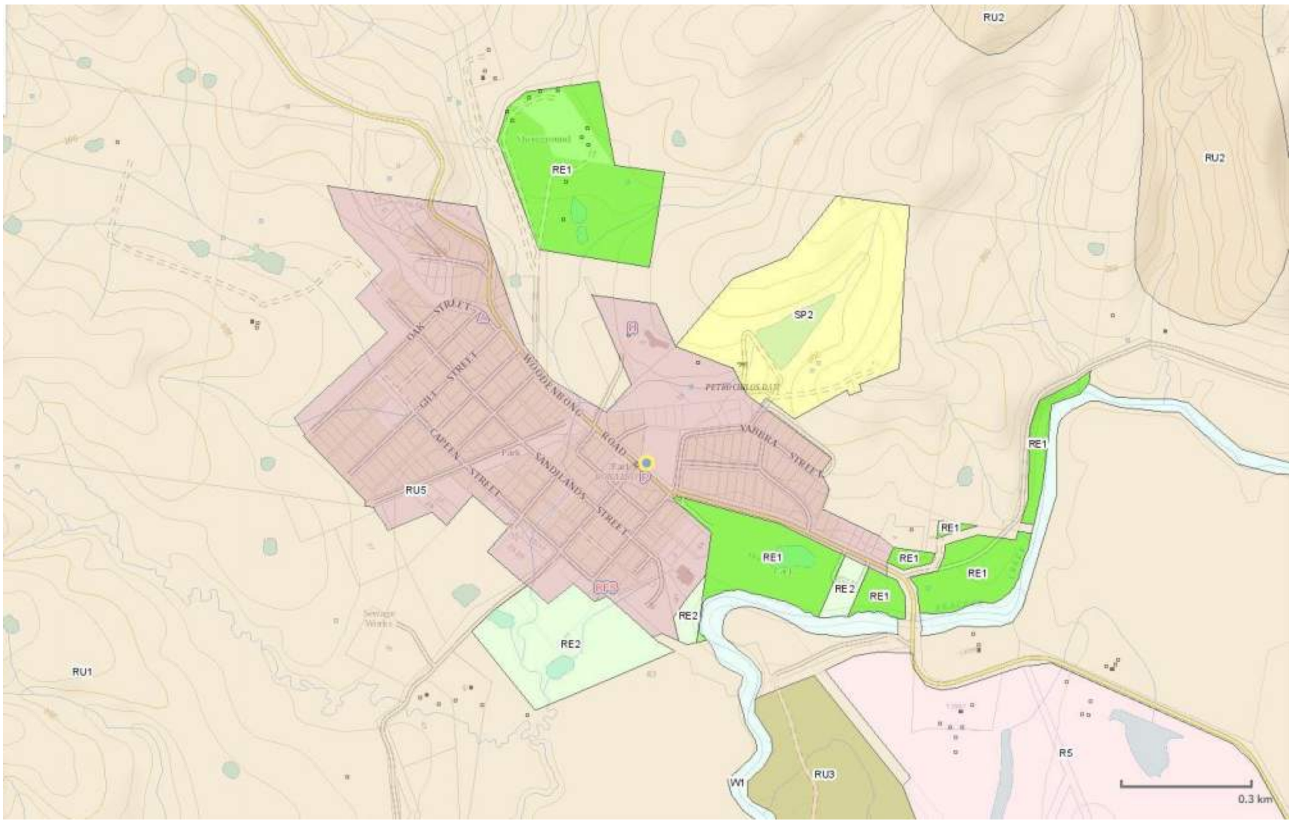



**Figure 10-1: Current Land Use Zoning**

RE1 and RE2 are generally compatible with high hazard and floodway areas, and the immediate area east of Peacock Creek is defined as such.

Where the flood runner of Peacock Creek affects properties at the south-eastern end of Sandilands Street and Tooloom Street, a floodway (refer section 8.4) directly affects several properties in the RU5 land use Zone in the 1% AEP event. It is recommended that the future Floodplain Risk Management Study and Plan consider appropriate land use zoning in this area to restrict further development in the floodway. Subject to further review consideration of Voluntary House Purchase may be appropriate.

In other areas, land use zoning is generally compatible with the flood hazard of the land subject to appropriate development controls.

## 10.2 Flood Planning Levels and Flood Planning Area

As summarised in section 2.5.2, the DCP typically requires floor levels to be at least 500 mm above the 1% AEP flood level. Currently the 1% AEP flood level at Bonalbo is based on anecdotal evidence of historic events. A preliminary Flood Planning Area based on the 1% AEP flood level plus 500 mm is shown in Figure C 2. This results in 271 lots affected by the FPA.

Current guidance makes several recommendations for setting a freeboard for flood planning purposes:

**Table 10-1: Guidance (and Legislation) on Determining of Freeboard, FPAs and FPLs**

| Source | Type | Freeboard / Comment |
|---|---|---|
| Kyogle LEP and DCP | Legislation | • The FPL is typically determined as the 1% AEP flood level plus a 0.5 m freeboard |
| NSW Floodplain Development Manual (2005) | Legislation / Guidance | • Freeboard to FPL typically 0.5 m applied to the 1% AEP flood for residential property unless benefits of a higher FPL eg vulnerable uses such as aged care facilities, hospitals<br>• Consideration should also be given to using the PMF as the FPL when siting and developing emergency response facilities such as police stations, hospitals, SES headquarters, and critical infrastructure, such as major telephone exchanges, if possible.<br>• Potential for commercial and industrial properties to be based on event more frequent than the 1% AEP flood. |
| ARR2019 | Guidance | • No specific freeboard value stated |
| AIDR Handbook 7 (2017) | Guidance | • Freeboard range from 300 mm to 600 mm<br>• 300 mm for shallow floodwater<br>• > 600 mm where flood level estimates are uncertain |
| Queensland Development Code (Queensland Government, 2013) | Interstate | • Minimum floor level for habitable room of 300 mm for all residential building types |
| Queensland Urban Drainage Manual (IPWEAQ, 2017) | Interstate | • Minimum freeboard of 300 m above the defined flood event (typically the 1% AEP event) for minimum floor levels |

The traditional approach for setting the FPA affects the full town of Bonalbo including areas where 1% AEP flood depth are shallow. An alternative approach to setting the FPA where a 0.5 m freeboard is adopted for mainstream flooding (Peacock Creek) and a 0.3 m freeboard was also investigated. Given the steep hillslopes around the town, using a 0.3 m freeboard to set the FPA for areas affected by overland flows results in about only a 2 m reduction in the FPA and did not significantly alter the number of properties affected.

Generally for the Peacock Creek floodplain the PMF extent is larger than the FPA (based on 1% AEP plus 0.5 m freeboard). However, within the town north of about Dryaaba Street the PMF flood levels are greater than the 1% AEP plus 0.5 m level. In this case application of an FPL of the 1% AEP plus 0.5 m level would be above the PMF and can be conservative and a lower freeboard is recommended for these properties.

Therefore, the recommended approach is to:

- Adopt a FPA based on all flood levels plus 0.5 m (as per Figure C 2).
- Adopt variable FPLs based on the source and depth of inundation at properties.

This approach means that properties which only subject to shallow depths are not subject to onerous development controls and that new development is not limited by unrealistic development controls.

During the Floodplain Risk Management Study and Plan further analysis on appropriate freeboard should be considered to define the Flood Planning Area for Bonalbo. In overland flow areas an approach where the greater of the PMF or 1% AEP plus a 0.3 m freeboard may be more appropriate.

# 11 CONCLUSIONS

The Flood Study has developed robust flood modelling to establish the design flood behaviour for the 20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events. Flood modelling has been validated against observed flood marks from the 2008 event and anecdotal evidence obtained for the community during the community consultation.

The study has identified the two main sources of flooding to the town; the local catchments which lead to overland flows, and flooding from Peacock Creek itself. In smaller events the overland flows are the dominant source of flooding. However, in the 1% AEP event and greater as Peacock Creek spills into the floodplain flows from the creek become the dominant source of flooding at the south-eastern end of the town.

The Flood Study has also considered provisional Flood Hazard and Flood Function. Typically, when under overland flow conditions the floodways are limited to the channels and drains with the exception of a few streets. In the larger events a floodway from the creek develops in the flood runner east of the town. This affects a few properties towards the eastern end of Sandilands Street.

Much of the town has Rising Road Access given sufficient warning time, however areas affected by Peacock Creek could become Low Flood Islands due to developing Floodways along streets and channels within the town in larger events. Although areas have Rising Road Access or Overland Escape Routes for properties on the west and north of town these routes lead to High Trapped Perimeter areas where the hillslope terrain can make vehicle access difficult.

For the town area affected by overland flows, flood depths are typically less than 0.5m and therefore adoption of a 0.5 m freeboard above the 1% AEP flood level may be over conservative for flood planning. A reduced freeboard for these areas is recommended.

The next phase of the Flood Study is for Public Exhibition of this document. Following adoption, Council will move to the Floodplain Risk Management stage which will build upon the findings of this flood study to identify options for floodplain risk management.

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