# Boggabri Flood Study

Narrabri Shire Council

1599-01-J1, 29 January 2021

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| **Report Title** | Boggabri Flood Study |
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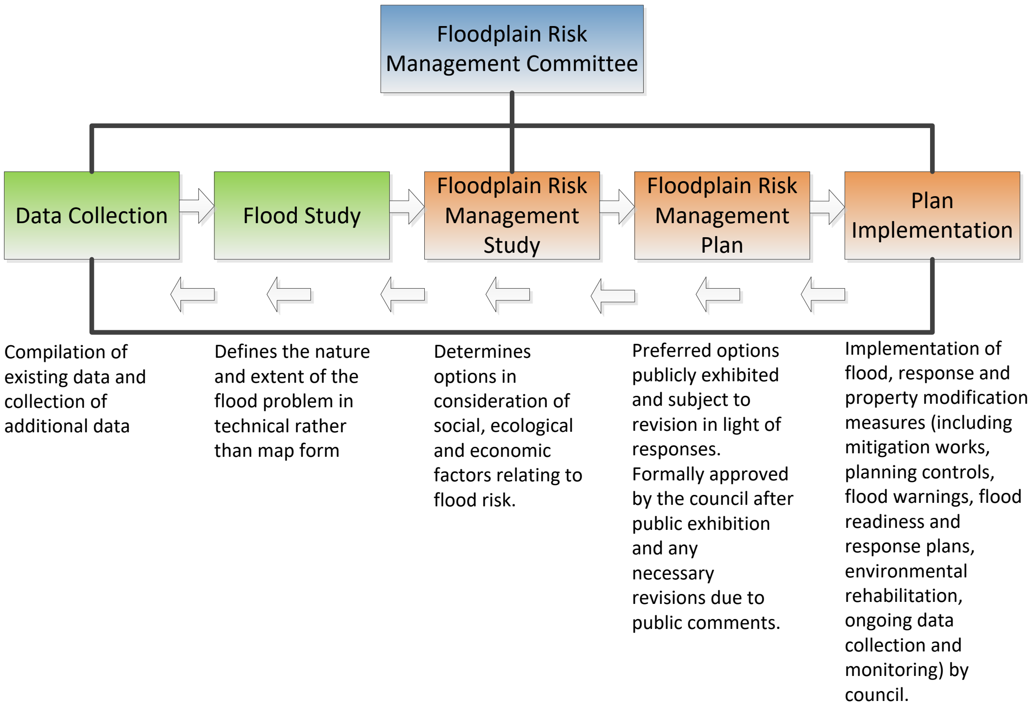
# Foreword

The NSW Government's Flood Prone Land Policy provides a framework for managing development on the floodplain. The primary objective of the policy is to develop sustainable strategies for managing human occupation and use of the floodplain using risk management principles. Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The NSW Government's Floodplain Development Manual (2005) (the Manual) has been prepared to support the NSW Government's Flood Prone Land Policy. The Manual provides Council's with a framework for implementing the policy to achieve the policy's primary objective. The framework is shown below.




The Boggabri Flood Study constitutes the first stage of the Floodplain Risk Management process and assesses the risk of regional flooding from the Namoi River and Coxs Creek. It has been prepared by consultants WRM Water & Environment Pty Ltd for Narrabri Shire Council.

# Acknowledgements and limitations

This project was prepared with financial assistance from the NSW Government's Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

While all due effort has been made to ensure the reliability of flood model results, all models have limitations (Ball et al., 2019). The accuracy of any model is a function of the quality of the data used in the model development including topographical data, drainage structure data and calibration data. Modelling is by nature a simplification of very complex systems and results of flood model simulations should be considered as a best estimate only. There is, therefore, an unknown level of uncertainty associated with all model results that should be considered when utilising the outputs from this study.

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# 1 Introduction

## 1.1 BACKGROUND

The township of Boggabri is located within the Narrabri Shire Council in the northwest of New South Wales (NSW). Narrabri Shire Council has commissioned WRM Water & Environment Pty Ltd (WRM) to prepare a flood study for Boggabri in accordance with the NSW Floodplain Development Manual (DIPNR, 2005). Boggabri sits adjacent to the Namoi River and Coxs Creek. The location of Boggabri and the catchments of the Namoi River and Coxs Creek is shown in Figure 1.1.

The primary objective of the flood study is to improve understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information.

## 1.2 ADOPTED APPROACH

The Boggabri Flood Study involves detailed investigations of both Coxs Creek and the Namoi River and includes:

- identifying key infrastructure and flooding issues;
- reviewing and compiling available flood related data;
- establishing a computer based hydrological model of the Coxs Creek catchment and the Namoi River catchment downstream of Gunnedah and calibrating the model to historical events;
- establishing a computer based hydraulic model (TUFLOW) of the Namoi River and the Coxs Creek floodplain and calibrating the model to historical flood peaks;
- estimating the design flood discharges for the Namoi River and the Coxs Creek from the hydrological model and an annual series flood frequency analysis of the recorded peak flows;
- assessing the sensitivity of flooding behaviour to vegetation changes and potential climate change effects;
- preparing peak flood depth, extent and level maps for a range of design events;
- assessing the provisional hydraulic categories and undertake mapping of provisional hazard and preliminary emergency response planning classifications for Boggabri; and
- assessing flood damage costs for existing conditions.

The hydrological and hydraulic models were calibrated to the recorded rainfall and stream flow data for the 1997, 1998 and 2000 floods, as well as the major historic floods in 1971 and 1955.

## 1.3 REPORT STRUCTURE

The report is structured as follows:

- Section 2 describes the drainage characteristics of the Namoi River and Coxs Creek catchments;
- Section 3 describes the data available for the flood study, including previous flood studies conducted for Boggabri; information on available gauges in the study area; available precipitation data; available ground level data; data on structural assets; and feedback from the community on historic flooding;
- Section 4 describes the development and calibration of the hydrological model;

- Section 5 describes the development and calibration of the hydraulic model;
- Section 6 presents the design discharge estimates for both Namoi River and Coxs Creek;
- Section 7 presents the design event flood mapping and sensitivity analysis;
- Section 8 provides flood damage estimates for existing conditions;
- Section 9 summarises the findings for the study;
- Section 10 is a list of references;
- Appendix A shows the hydrological model calibration result hydrographs;
- Appendix B shows the hydraulic model calibration event mapping;
- Appendix C shows the hydraulic model design event mapping;
- Appendix D shows the provisional hydraulic hazard category maps for the study area based on the NSW Floodplain Management Manual; and
- Appendix E shows the provisional hydraulic hazard category maps for the study area based on the Australian Institute for Disaster Resilience.

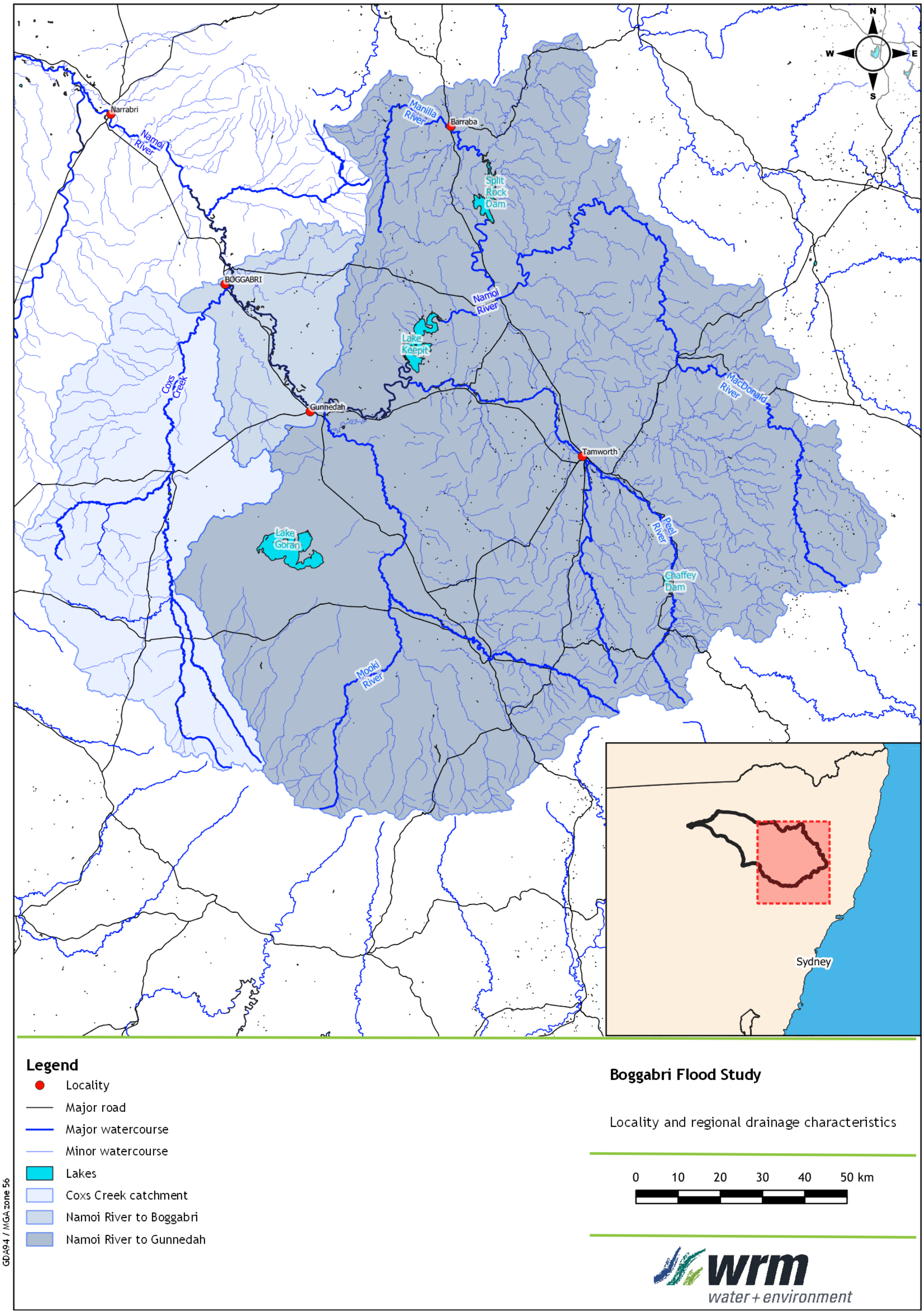


**Figure 1.1 – Locality and regional drainage characteristics**

# 2 Drainage characteristics

## 2.1 CATCHMENT OVERVIEW

The township of Boggabri is located within the Namoi River basin (see Figure 1.1). The Namoi River Basin, a part of the Barwon-Darling River system, extends over an area of 42,000 km$^2$ from the Great Dividing Range in the east to Walgett in the west. The major tributaries upstream of Boggabri include the Macdonald River, Manilla River, Peel River, Mooki River and Coxs Creek.

There are three major water supply dams in the catchment including Chaffey Dam on the Peel River, Split Rock Dam on the Manilla River, and Keepit Dam on the Namoi River. A description of the three dams is as follows:

- Keepit Dam, the largest water supply dam in the catchment, is located about 56 river kilometres upstream of Gunnedah. It was completed in 1960 (following a 20 year construction period) with a capacity of 425,000 ML. The catchment area of Keepit Dam is 5,700 km$^2$, or about 25% of the catchment area of the Namoi River to Boggabri.
- Chaffey Dam was completed in 1979 with a capacity of 69,000 ML. Its capacity was increased to 100,500 ML in 2016. The catchment area draining to Chaffey Dam is only 420 km$^2$ and therefore it does not have a significant impact on flooding at Boggabri. The Peel River drains into the Namoi River downstream of Keepit Dam.
- Split Rock Dam was completed in 1987 and has a capacity of 397,390 ML. The catchment draining to Split Rock Dam is 1,650 km$^2$. The Manilla River drains into the Namoi River upstream of Keepit Dam.

## 2.1 STUDY AREA DRAINAGE

### 2.1.1 Namoi River

Figure 1.1 shows the drainage characteristics of the Namoi River. The Namoi River has a catchment area of 17,100 km$^2$ to Gunnedah and 18,500 km$^2$ to Boggabri (excluding Coxs Creek). Downstream of Gunnedah, the Namoi River channel meanders along the eastern side of the Kamilaroi Highway across a broad floodplain. At Boggabri, the floodplain is approximately 5.5 km wide.

The Namoi River overflows into several flood channels between Gunnedah and Boggabri (see Figure 2.1). The most upstream flood channel is Deadmans Gully, which breaks out of the Namoi River channel about 10 km downstream of Gunnedah. It drains along the western floodplain before draining back into the Namoi River about 3 km upstream of Boggabri. Deadmans Gully, which is likely a remnant, or prior channel of the Namoi River, has little channel capacity or vegetation and is not a significant visual feature of the floodplain. Deadmans Gully also receives flows from Collygra Creek.

The Namoi River overflows to another remnant channel, Gulligal Lagoon, about 16 km upstream of Boggabri. Gulligal Lagoon has a well-defined channel between the Namoi River and the Kamilaroi Highway where it loses channel definition. It has little to no catchment area and only flows when the Namoi River is in flood. It drains back into the Namoi River about 6 km upstream of Boggabri.

Barbers Lagoon, which is also likely a remnant Namoi River channel, breaks out of the eastern side of the Namoi River channel about 6 km upstream of Boggabri. It drains in a northerly direction along a well-defined floodway channel before turning westward back to the Namoi River about 3 km and 7 km downstream of Boggabri via separate flood channels. Several minor watercourses including Bollol Creek and Driggle Draggle Creek drain into Barbers Lagoon from the east.

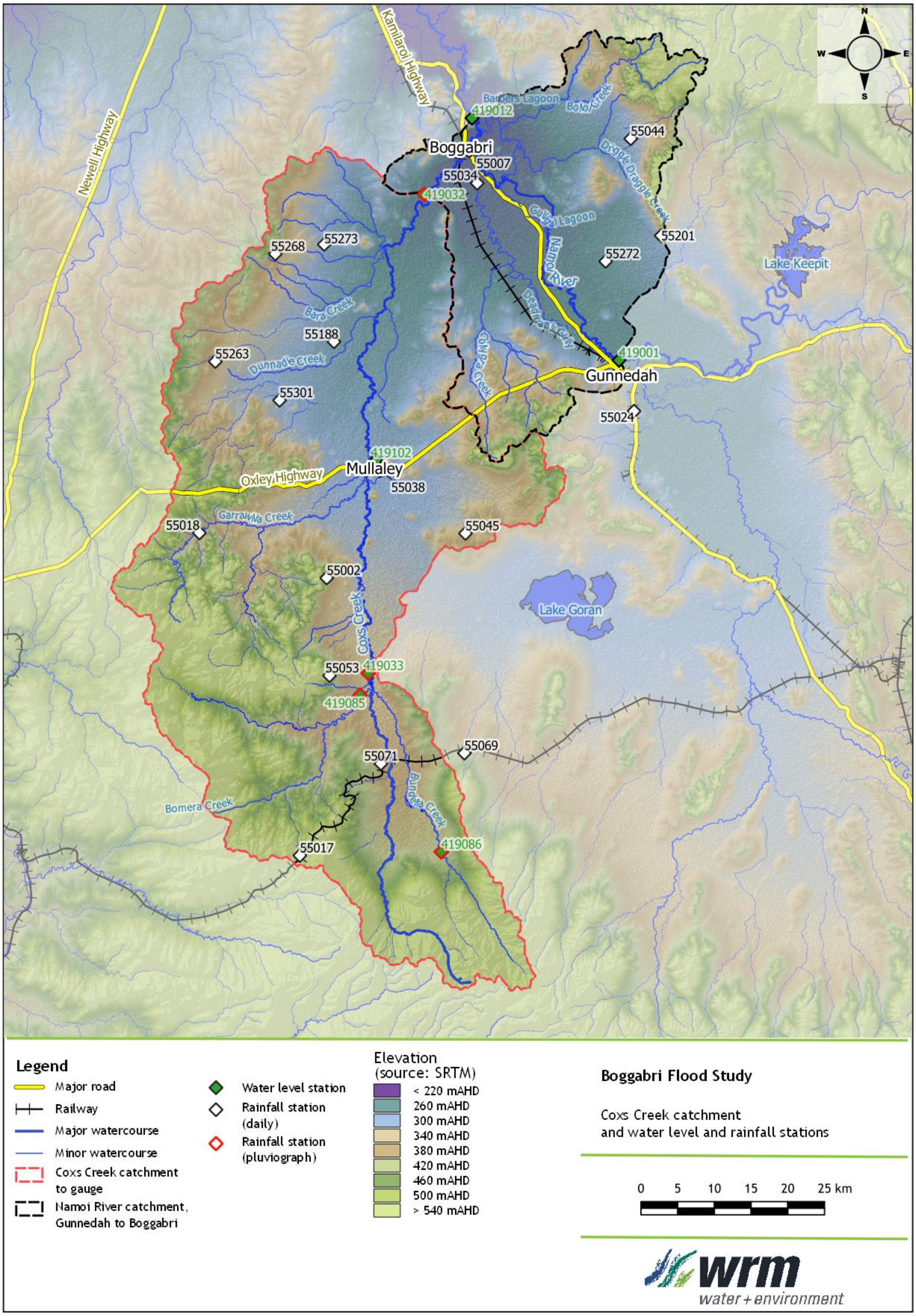


**Figure 2.1 – Study area catchment and locations of rainfall and water level gauges**

The floodplain narrows to about 1 km wide downstream of Barbers Lagoon due to a large rock formation known as Gins Leap, or Cooloobindi. This narrowing of the floodplain forms a significant constriction to flood flows.

The Namoi River floodplain is used extensively for crop irrigation with many farm paddocks laser levelled and protected from flooding by earthen levees. These levees are managed under The Floodplain Management Plan for the Upper Namoi Valley Floodplain 2019 (plan), which commenced on 7 June 2019. The plan includes management zones, rules and assessment criteria for granting or amending approvals for flood works within the plan area.

### 2.1.2 Coxs Creek

Figure 2.1 shows the layout of the Coxs Creek catchment. It includes the major tributaries of Bundella Creek, Bomera Creek and Garrawilla Creek upstream of Mullaley and Dunnadie and Barra Creek downstream of Mullaley. The total area drained by the Coxs Creek to Boggabri is 3,878 $km^2$.

The catchment commences about 120 km to the south of Boggabri at a peak elevation of around 1,100 mAHD before draining into flat agricultural land as it gets closer to Mullaley at 315 mAHD. The floodplain downstream of Mullaley is very flat at a slope of 0.1%. The floodplain is extensively cropped with several paddocks containing flood protection levees. These levees are managed under the Lower Coxs Creek Floodplain Management Plan.

# 3 Available data

## 3.1 OVERVIEW

Available data for the calibration of the hydrological and hydraulic models consist of:

- previous reports;
- recorded water levels at the stream gauging stations and at surveyed locations across the floodplain;
- stream gauging station rating curves and recorded stream gaugings that convert recorded water levels to stream flows;
- recorded rainfall (daily and instantaneous pluviograph data);
- topographic data; and
- data on structural assets.

In addition, a questionnaire was sent to the community to provide information on historical flooding to assist with model calibration. A summary of the available data including the previous assessments at the site is outlined below.

## 3.2 PREVIOUS FLOOD STUDIES

A number of studies relating to flooding and drainage in and around Boggabri have been undertaken since the 1960's. A brief description of these studies is given below.

### 3.2.1 Carroll to Boggabri Flood Study and Compendium of data (SMEC, 2003)

The SMEC (2003) study was prepared to support the development of the Carroll to Boggabri Floodplain Management Plan (FMP) (DNR, 2006). Available data on recorded flood discharges and levels were reported and hydraulic modelling of the Namoi River floodplain was undertaken using the MIKE11 hydrodynamic modelling package. The model was calibrated to the 1955 and 1998 historical flood events and validated against 1984 and 2000 flood data. The estimated SMEC (2003) discharges for the 1955 event at Gunnedah has been used for model calibration in this study. Peak flood level data surveyed for the 1998 and 1955 flood were also used (see Section 5.3).

The report includes references to numerous historical studies and calculation folders prepared for the Namoi River of relevance to this study. Initial discussions with the Department of Environment, Energy and Science (DEES) indicates that these reports are not available.

### 3.2.2 Upper Coxs Creek Floodplain Management Plan (DNR, 2005)

This report was prepared to assess the community-owned strategies to manage flood risk and flood management issues and support the natural function of the floodplain environment. It is concerned with the floodplain of the Coxs Creek between Bundella and Mullaley and provides a framework for improving the drainage of the floodplain system, as well as resolving landuse management issues.

### 3.2.3 Background document to the Floodplain Management Plan for the Upper Namoi Valley Floodplain 2019 (NSW Dept of Industry, 2019)

This report was prepared to support the development of the Upper Namoi Valley Floodplain Management Plan, which replaced the Carroll to Boggabri Floodplain Management Plan. No additional data was provided in this report in relation to flooding at Boggabri. The hydraulic modelling of the Namoi River floodplain developed for the SMEC (2003) study was used for this study.

### 3.2.4 Boggabri Sewage Treatment Plant Flood Impact Assessment (Lyall & Associates, 2018)

This report was prepared for Narrabri Shire Council to determine peak flood levels at the Boggabri Sewage Treatment Plant. A TUFLOW hydraulic model was developed for the study. The model was calibrated to historical peak flood level data for the 1955 flood, which was obtained from a flood inundation photo provided by the Water Resources Commission (DNR, 2007). The 1955 flood photograph is shown in Figure 3.1. Flood marks shown in the photograph have been used to assist in model calibration in this study.

### 3.2.5 Additional reports

Data for model development and calibration was also obtained from a flood study undertaken for Boggabri Coal (WRM, 2009) and for the Narrabri Flood Study (Kinhill, 1991).

## 3.3 STREAM FLOW GAUGING STATION DATA

Stream water levels have been recorded in the study area at various locations by WaterNSW (and other government agencies) since 1891. Table 3.1 summarises the water level recording stations within the study area. The commencement date, highest gauged level and recorded peak level is also shown. The locations of the water level stations are shown in Figure 1.1.

**Table 3.1 – Stream gauges within the study area**

| Station name | Station number | Commence -ment date | Highest gauged level (mAHD) | Date of highest gauging | Peak recorded level (mAHD) | Date of peak level |
|---|---|---|---|---|---|---|
| **Namoi River** | | | | | | |
| Gunnedah | 419001 | Nov 1891[a] - | 263.585 | Jul 1998 | 263.867 | Feb 1971[c] |
| Boggabri | 419012 | Nov 1911[b] - | 239.524 | Nov 2000 | 241.366 | Feb 1955[c] |
| **Coxs Creek** | | | | | | |
| Boggabri | 419032 | Jun 1965 - | 248.039 | Nov 2000 | 248.216 | Nov 2000 |
| Tambar Springs | 419033 | Jun 1965 - | 341.586 | Feb 1992 | 343.086 | Jan 1996 |
| Tambar-Premer Road (Bomera Ck) | 419085 | Jun 1995 - | 343.628 | Jan 1996 | 349.623 | Jul 1998 |
| Bundella (Bundella Ck) | 419086 | Dec 1995 - | 420.736 | Jan 1996 | 423.014 | Jan 1996 |
| Tourable | 419102 | Aug 2010 - | 289.458 | Jan 2013 | 290.107 | Dec 2010 |

[a] – Historical water level available for the 1864 event
[b] – Predicted peak discharge data only available post 1937, partially derived based on historic rating curves
[c] – SMEC (2003) reports higher peak flood levels occurred

The following is of note:

- The Coxs Creek at Boggabri gauge (GS419032), located approximately 9 km upstream of the Coxs Creek and Namoi River confluence, would represent the total Coxs Creek catchment flows. It is located within the study area and is the primary stream gauge to represent historical discharges and to determine design discharges at Boggabri from Coxs Creek. The catchment area to the gauge is shown in Figure 2.1.


**Figure 3.1 – Inundation map of the February 1955 flood**

- The Namoi River at Boggabri gauge (GS419012), located approximately 4 km downstream of Boggabri, would represent the total discharge draining to Boggabri from both the Namoi River and Coxs Creek. It is located within the study area and is the primary stream gauge to represent historical and design discharges at Boggabri from the Namoi River including Coxs Creek.
- The Namoi River at Gunnedah gauge (GS419001), located approximately 37 km upstream of Boggabri, represents the catchment flows from the Namoi River catchment upstream of Gunnedah.

The four remaining Coxs Creek gauges (GS419033, GS419085, GS419086 and GS419102) are in the upper headwaters of Coxs Creek and have been used to assist in the calibration of the hydrological model.

Stream flows at each gauging station are derived from the recorded water level and a water level-discharge rating curve. The rating curve has been developed from historical stream flow measurements (gaugings). The rating curve at a station provides a reliable estimate of stream flow in the range of water levels that have stream flow gaugings. The reliability is lower in the range of water levels with no or few stream gaugings, which usually occur at higher water levels (as flood events are infrequent). Above the highest gauged level, the rating curve would be the least reliable as it relies on an extrapolation of the curve using limited ground level data and analysis. Table 3.1 shows that the highest recorded peak water level is generally well above the highest gauged water level at all stations except for the Coxs Creek at Boggabri.

WaterNSW would create a new rating curve for a station when stream flow measurements indicate a change has occurred. These changes are mostly due to changes at low flows due to sedimentation/aggradation of the bed. However, high flow ratings are also altered when flood gaugings have been taken above or near the previous highest stream gauging. WaterNSW do not update the historical flood peaks in the dataset using the updated rating curves.

### 3.3.1 Namoi River at Gunnedah

Figure 3.2 shows the WaterNSW rating curve (Table 330.02) and historical stream flow measurements (gaugings) for the Namoi River at Gunnedah gauge. The six highest historical flood peaks at the gauge are also shown. A total of 930 gaugings have been undertaken over the period of record with the highest gauging undertaken in July 1998 at a gauge height of 8.7 mRL (263.585 mAHD).

The highest recorded water level (available on the WaterNSW website) occurred in February 1971 at 8.982 mRL (263.867 mAHD). A review of the SMEC (2003) report suggests that flood peaks in 1864 (9.84 mRL), 1908 (9.65mRL), 1910 (9.4mRL) and 1955 (9.6mRL) exceeded the 1971 flood peak. Further, SMEC (2003) suggest that all the historical peak flood discharges prior to 1998 were predicted to be much higher than what is provided on the WaterNSW website (WaterNSW, 2020). The predicted 1955 flood peak discharge from SMEC (2003), which is shown on Figure 3.2, is some 3.5 times larger than the next highest recorded flood peak.

Figure 3.2 also shows the rating curves used to derive the 1971 (Table 150) and 1984 (Table 285) events. It is of note that the 1984 peak discharge had a similar peak water level to the 1997 event but has a much lower peak discharge. The high flow rating after this time was adjusted following the July 1998 high flow gauging but the historical flood peak discharges were not readjusted. The 1984 and 1971 historical peak discharges have been adjusted using the latest high flow rating (Table 330.02) for model calibration. The SMEC (2003) estimate of the 1955 flood peak of 9,000 $m^3/s$ does not fit on any of the WaterNSW rating curves. It is expected there is considerable uncertainty with this estimate. An interpolated high flow curve that would be required to achieve the SMEC (2003) estimate of the 1955 event is also shown in Figure 3.2.

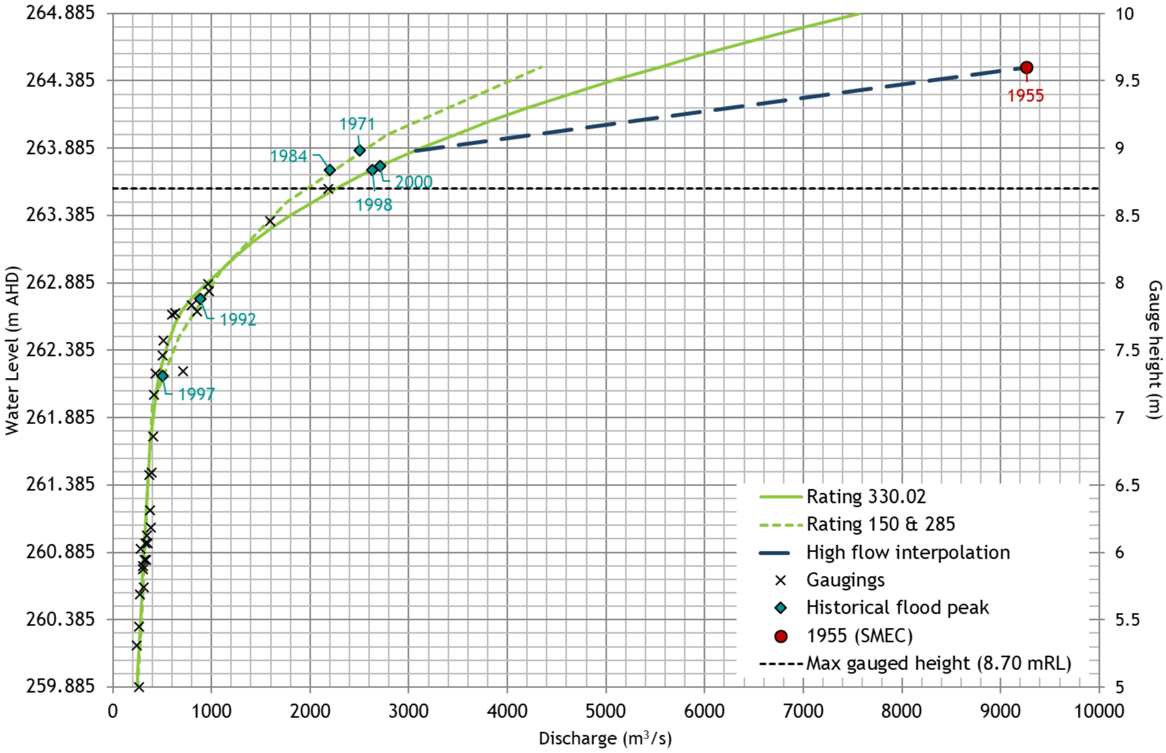


**Figure 3.2 - Rating curve and gauging history for Namoi River at Gunnedah (GS419001)**

The highest gauging at the Namoi River at Gunnedah gauge was 2,187 $m^3/s$. The rating curve relies on extrapolated estimates above these flow rates. The reliability of the current rating and historical flood peaks for the very large events at the Gunnedah gauge is poor.

### 3.3.2 Namoi River at Boggabri

Figure 3.3 shows the latest WaterNSW rating curve (Table 137) and historical stream flow measurements (gaugings) for the Namoi River at the Boggabri stream gauge. The six highest historical flood peaks at the gauge are also shown. A total of 721 gaugings have been undertaken over the period of record with the highest gauging undertaken in November 2000 at a gauge height of 8.674m mRL (239.524 mAHD).

Five of the historical flood peaks are higher than the highest stream gauging and are therefore within the extrapolated section of the rating curve. Further, the 1971 and 1955 flood peaks do not lie on the extrapolated curve; the peak discharge for these events was derived using earlier curves (Table 54 and Table 85). The rating curve derived using the hydraulic model, at the gauge is also shown in Figure 3.3. Further discussion on how this rating was derived is given in Section 5. However, this curve suggests that the 1971 and 1955 peak discharges are much higher than what was derived using the using earlier curves (Table 54 and Table 85). For the subsequent analysis, these historical discharges were shifted using the TUFLOW derived extension to the latest rating curve.

Some gaps in the data meant the record was not complete. Large flood peaks prior to 1971 consisted of peak flows only, which were derived using the earlier (incorrect) rating curves. Peak water level data was not available. To overcome this problem, the historical peak water levels for the large floods were derived from their associated rating curves and the latest rating curve (or TUFLOW derived curve) was then applied to determine the adjusted historical discharge.

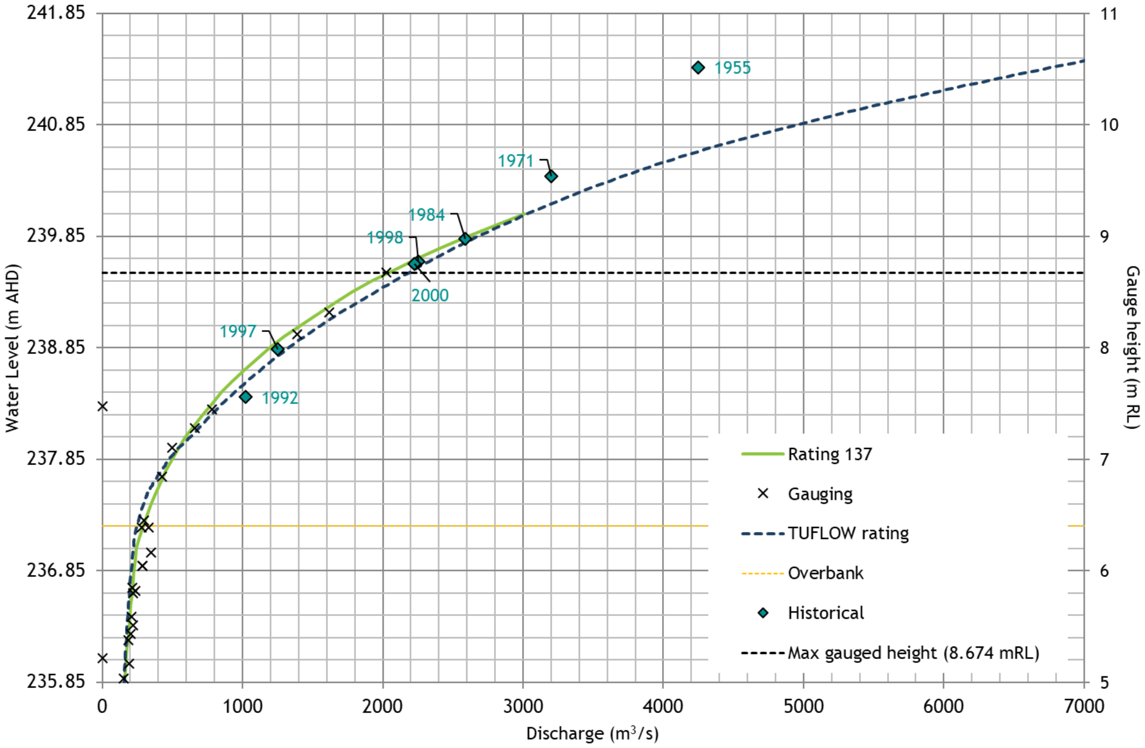


**Figure 3.3 - Rating curve and gauging history for Namoi River at Boggabri (GS419012)**

### 3.3.3 Coxs Creek at Boggabri

Figure 3.4 shows the latest WaterNSW rating curve (Table 126) and historical stream flow measurements (gaugings) for the Coxs Creek at Boggabri stream gauge. A total of 280 gaugings have been undertaken over the period of record with the highest gauging undertaken in November 2000 at a gauge height of 7.96 mRL (248.039 mAHD). The highest recorded water level occurred in the same month at 8.137 mRL (248.216 mAHD).

The five highest historical flood peaks are also shown in Figure 3.4. Three of these (1997, 1998 and 2000) recorded higher flood peaks than the highest stream gauging and therefore the predicted peak discharges are within the extrapolated section of the rating curve with a low level of reliability. It is of note that the 1984 peak discharge had a similar peak water level to the other three events but has a much lower recorded peak discharge. The high flow rating after this time was adjusted following the July 1998 high flow gauging but the historical flood peak discharges were not readjusted. The rating curve used to define the 1984 flood peak (Table 100) is also shown in Figure 3.4.

### 3.3.4 Coxs Creek at Tambar Springs

Figure 3.5 shows the latest WaterNSW rating curve (Table 244.02) and historical stream flow measurements (gaugings) for the Coxs Creek at Tambar Springs gauge. A total of 268 gaugings have been undertaken over the period of record with the highest gauging undertaken in February 1992 at a gauge height of 7.1 mRL (341.586 mAHD). The curve is extrapolated above this level. The highest recorded flood peak (that is available from the WaterNSW website) occurred in January 1996 at a level of 8.6mRL (343.086 mAHD), some 1.5 m above the highest recorded gauging. It would be expected that the reliability of historical peak discharges above a gauge level of 7.1 mRL would be poor.

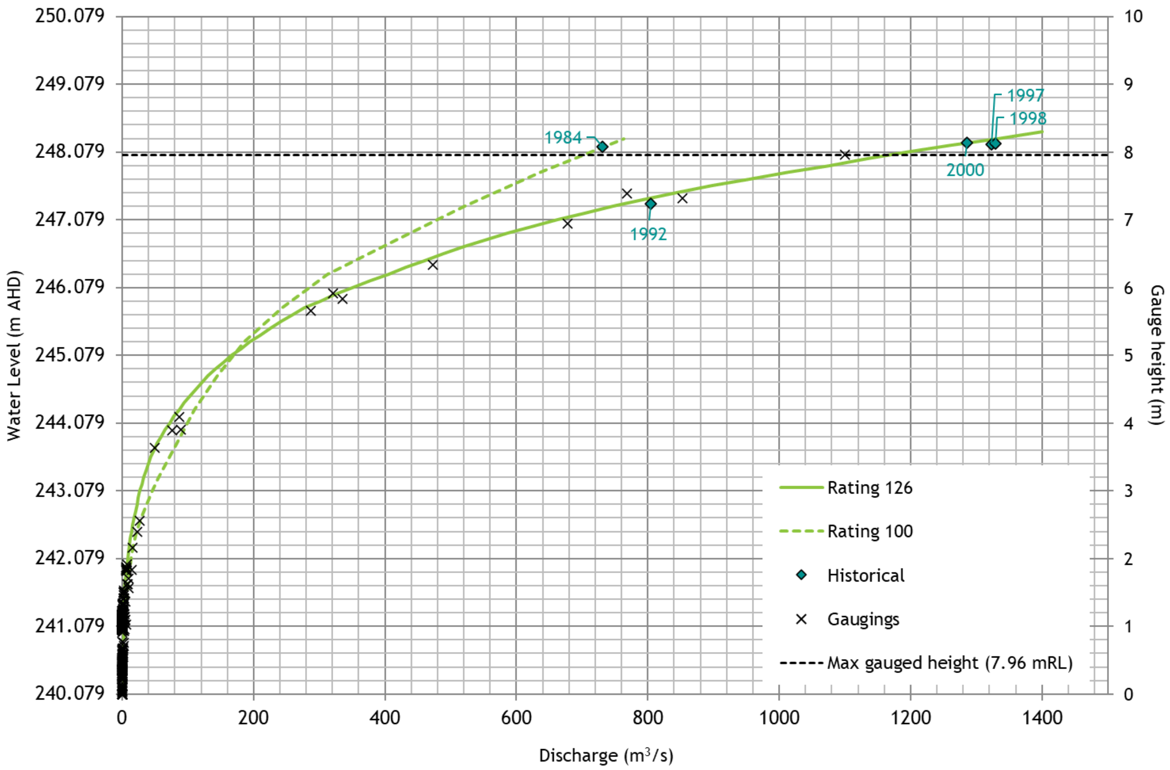


**Figure 3.4 - Rating curve and gauging history for Coxs Creek at Boggabri (GS419032)**

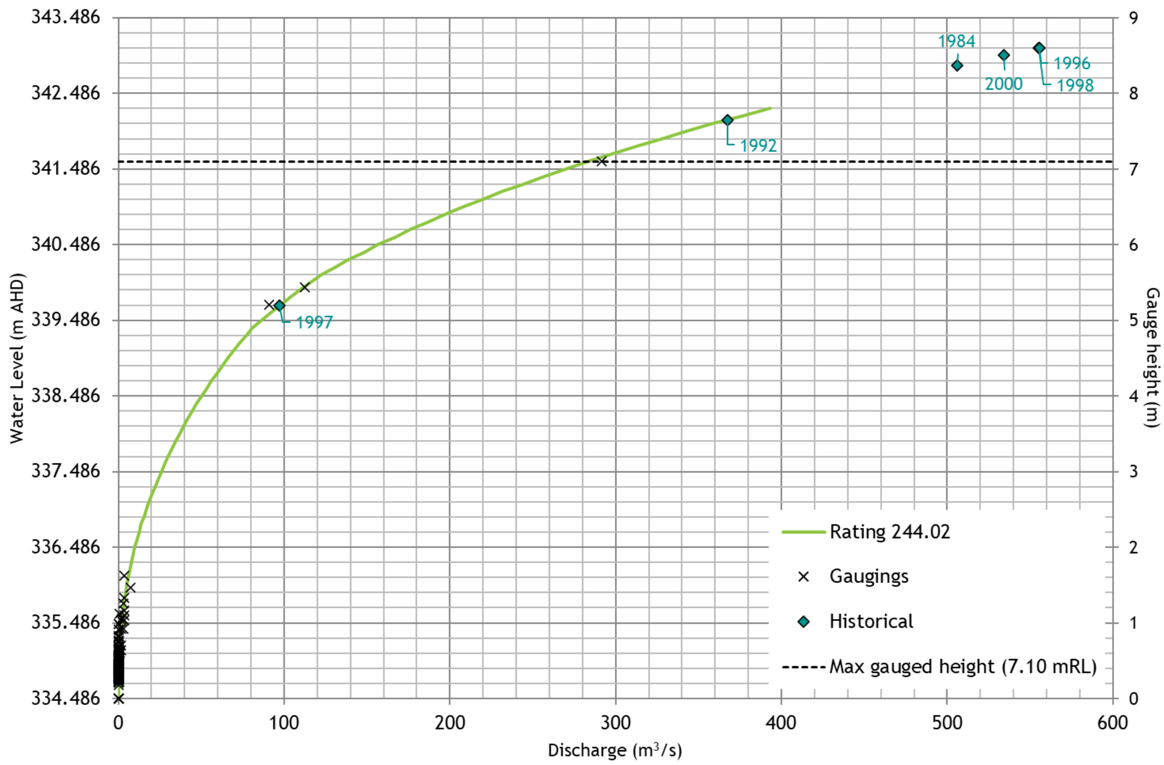


**Figure 3.5 - Rating curve and gauging history for Coxs Creek at Tambar Springs (GS419033)**

### 3.3.5 Bomera Creek at Tambar-Premer Road

Figure 3.6 shows the latest WaterNSW rating curve (Table 28) and historical stream flow measurements (gaugings) for the Bomera Creek at Tambar Premer Road gauge. A total of 97 gaugings have been undertaken over the period of record with the highest gauging undertaken in January 1996 at a gauge height of 2.97 mRL (346.628 mAHD). The curve is extrapolated above this level. The highest recorded flood peak occurred in July 1998 at a level of 5.965mRL (349.623 mAHD), some 3 m above the highest recorded gauging. It would be expected that historical peak discharge estimates for this site would be poor.

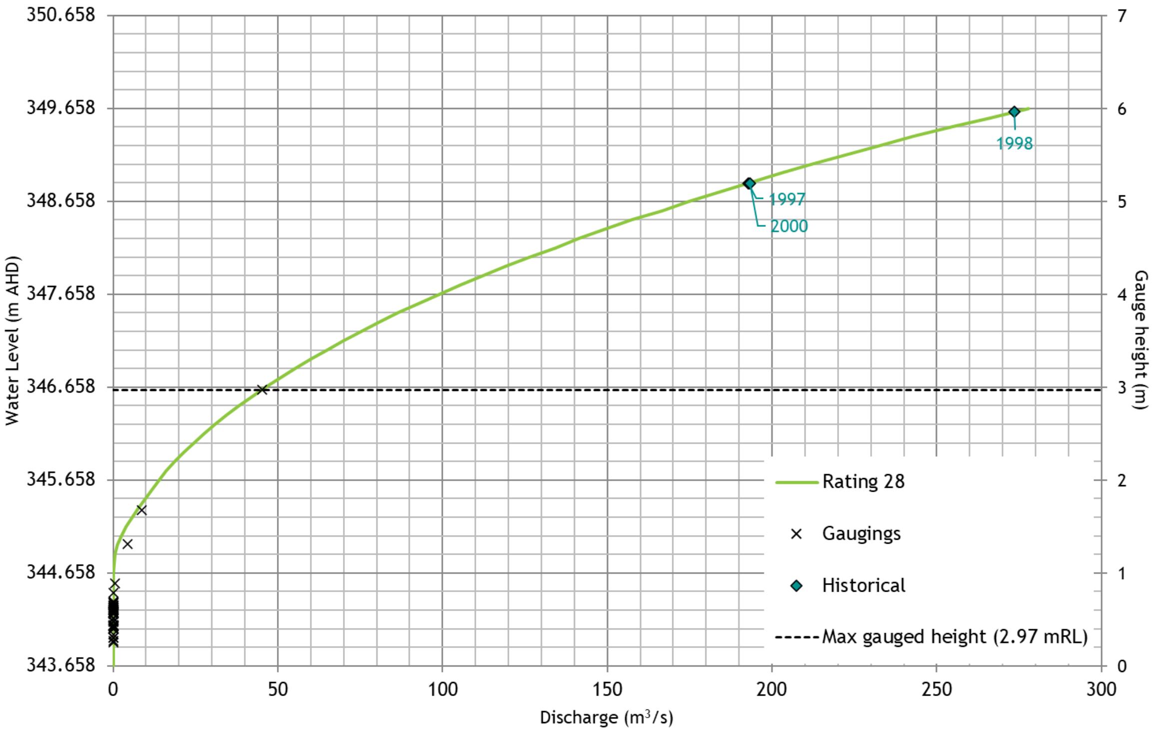


**Figure 3.6 - Rating curve and gauging history for Bomera Creek at Tambar Premer Road (GS419085)**

### 3.3.6 Bundella Creek at Bundella

Figure 3.7 shows the latest WaterNSW rating curve (Table 30) and historical stream flow measurements (gaugings) for the Bundella Creek at Bundella gauge. A total of 102 gaugings have been undertaken over the period of record with the highest gauging undertaken in January 1996 at a gauge height of 1.384 mRL (420.736 mAHD). The curve is extrapolated above this level. The highest recorded flood peak occurred in January 1996 at a level of 3.662mRL (423.014 mAHD), some 2.3 m above the highest recorded gauging. It would be expected that historical peak discharge estimates for this site would be poor.

### 3.3.7 Coxs Creek at Tourable

Figure 3.8 shows the latest WaterNSW rating curve (Table 6) and historical stream flow measurements (gaugings) for the Coxs Creek at Tourable gauge. A total of 47 gaugings have been undertaken over the period of record with the highest gauging undertaken in January 2013 at a gauge height of 5.398m mRL (289.458 mAHD). The curve is extrapolated above this level. The highest recorded flood peak occurred in December 2010 at a level of 6.047mRL (290.107 mAHD). This gauge was only installed in 2010 and no significant flood events occurred in the catchment since this time for use in model calibration.

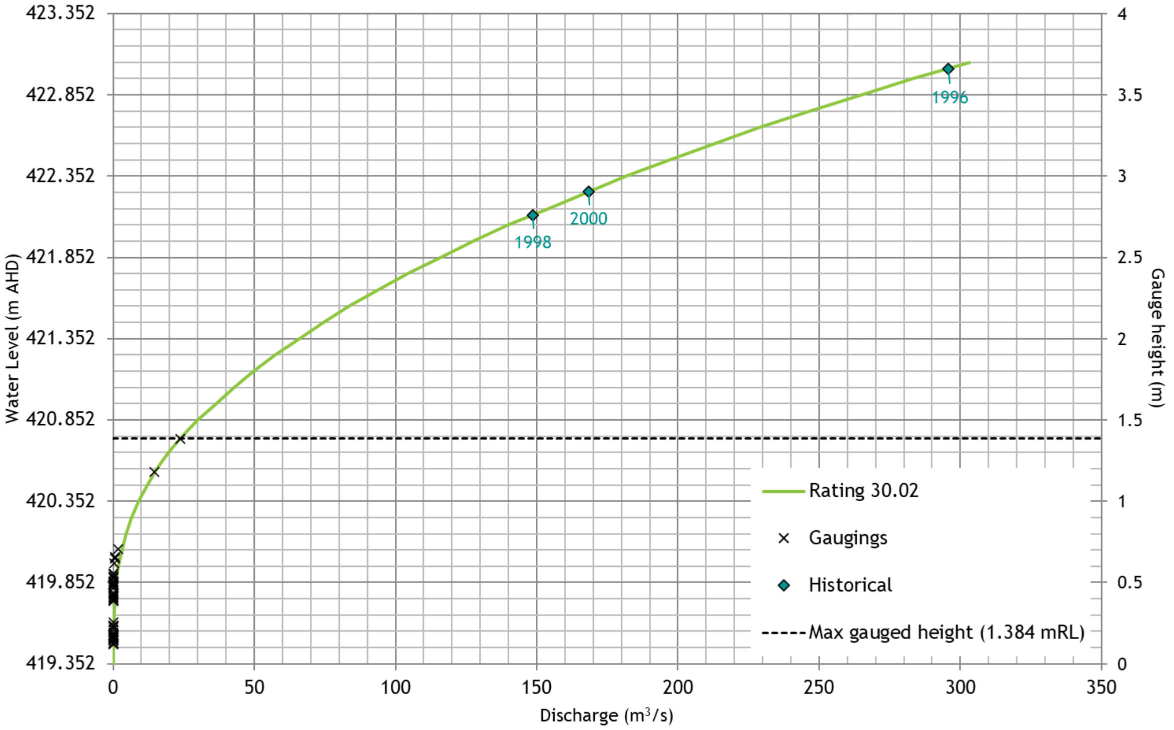


**Figure 3.7 – Rating curve and gauging history for Bundella Creek at Bundella (GS419086)**

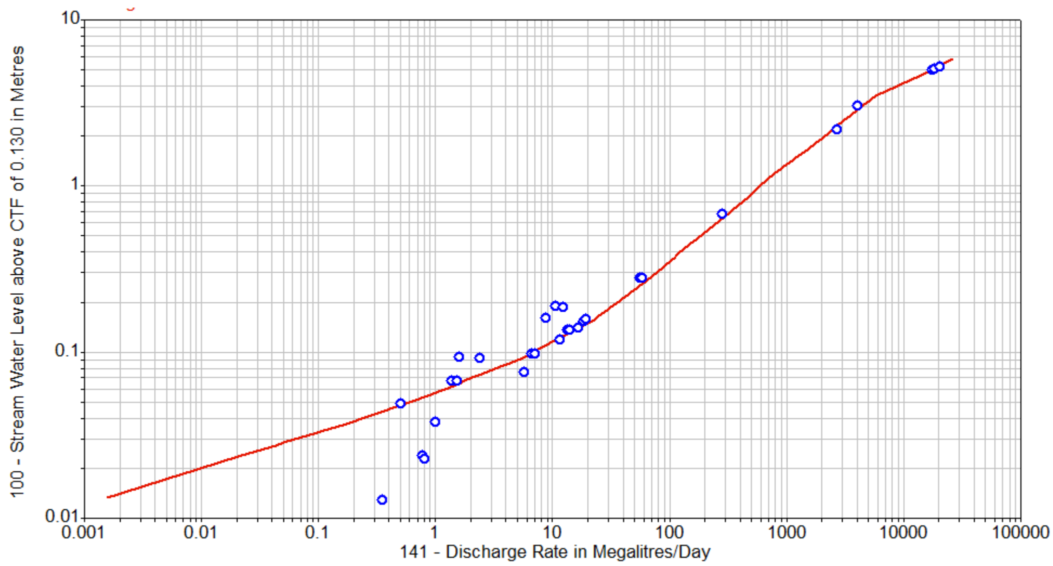


**Figure 3.8 – Rating curve and gauging history for Coxs Creek at Tourable (GS419102)**

## 3.4 RAINFALL DATA

Table 3.2 lists the available rainfall stations in the study area with data available for the highest historical flood events and the calibration events. The locations of the rainfall stations are shown in Figure 2.1. WaterNSW (2020) provided the sub-daily instantaneous tip data for four stations. The Commonwealth Bureau of Meteorology (BOM, 2019) provided daily rainfall for the other BOM stations.

**Table 3.2 – Rainfall data availability for highest historical flood events**

| Station No. | Station name | Observ. Interval | 1955 | 1971 | 1984 | 1992 | 1997 | 1998 | 2000 |
|---|---|---|---|---|---|---|---|---|---|
| 419032 | Coxs Creek at Boggabri | instant | | | | | ✓ | ✓ | ✓ |
| 419033 | Coxs Creek at Tambar Springs | instant | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 419085 | Bomera Creek at Tambar-Premer Road | instant | | | | | ✓ | ✓ | ✓ |
| 419086 | Bundella Creek at Bundella | instant | | | | | ✓ | ✓ | ✓ |
| 55024 | Gunnedah Resource Centre | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55002 | Mullaley (Bando) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55007 | Boggabri Post Office | daily | ✓ | ✓ | ✓ | ✓ | C | C | ✓ |
| 55017 | Premer (Eden Moor) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55018 | Mullaley (Garrawilla) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55020 | Ghoolendaadi | daily | ✓ | ✓ | | | | | |
| 55021 | Goolhi | daily | ✓ | | | | | | |
| 55029 | Lignum | daily | ✓ | ✓ | ✓ | | | | |
| 55033 | Mayfield | daily | ✓ | ✓ | ✓ | | | | |
| 55034 | Boggabri (Milchengowrie) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55038 | Mullaley Post Office | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55044 | Boggabri Retreat | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | i |
| 55045 | Curlewis (Pine Cliff) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55053 | Tambar Springs PO | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55059 | Wandobah | daily | ✓ | ✓ | | | | | |
| 55069 | Yannergee (Dobroyd) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55071 | Premer Post Office | daily | | ✓ | ✓ | ✓ | ✓ | C | ✓ |
| 55185 | Wongarina | daily | | ✓ | | | | | |
| 55188 | Mullaley (Derwentville) | daily | | | | | | | ✓ |
| 55201 | Kelvin (Kahana) | daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55263 | Mullaley (Keigho) | daily | | ✓ | ✓ | ✓ | C | C | ✓ |
| 55268 | Boggabri (Be-Bara) | daily | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55271 | Balmoral | daily | | ✓ | ✓ | ✓ | | | |
| 55272 | Gunnedah (Colstoun South) | daily | | ✓ | ✓ | ✓ | | | ✓ |
| 55273 | Boggabri (Neotsfield) | daily | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55281 | Brentwood | daily | ✓ | | | | | | |
| 55301 | Mullaley (Kirkbright) | daily | | ✓ | ✓ | ✓ | ✓ | C | ✓ |

C - includes cumulative values, excluded from analysis
I - incomplete series, excluded from analysis

## 3.5 GROUND LEVEL SURVEY

Figure 3.9 shows the location and extent of the available ground level data.

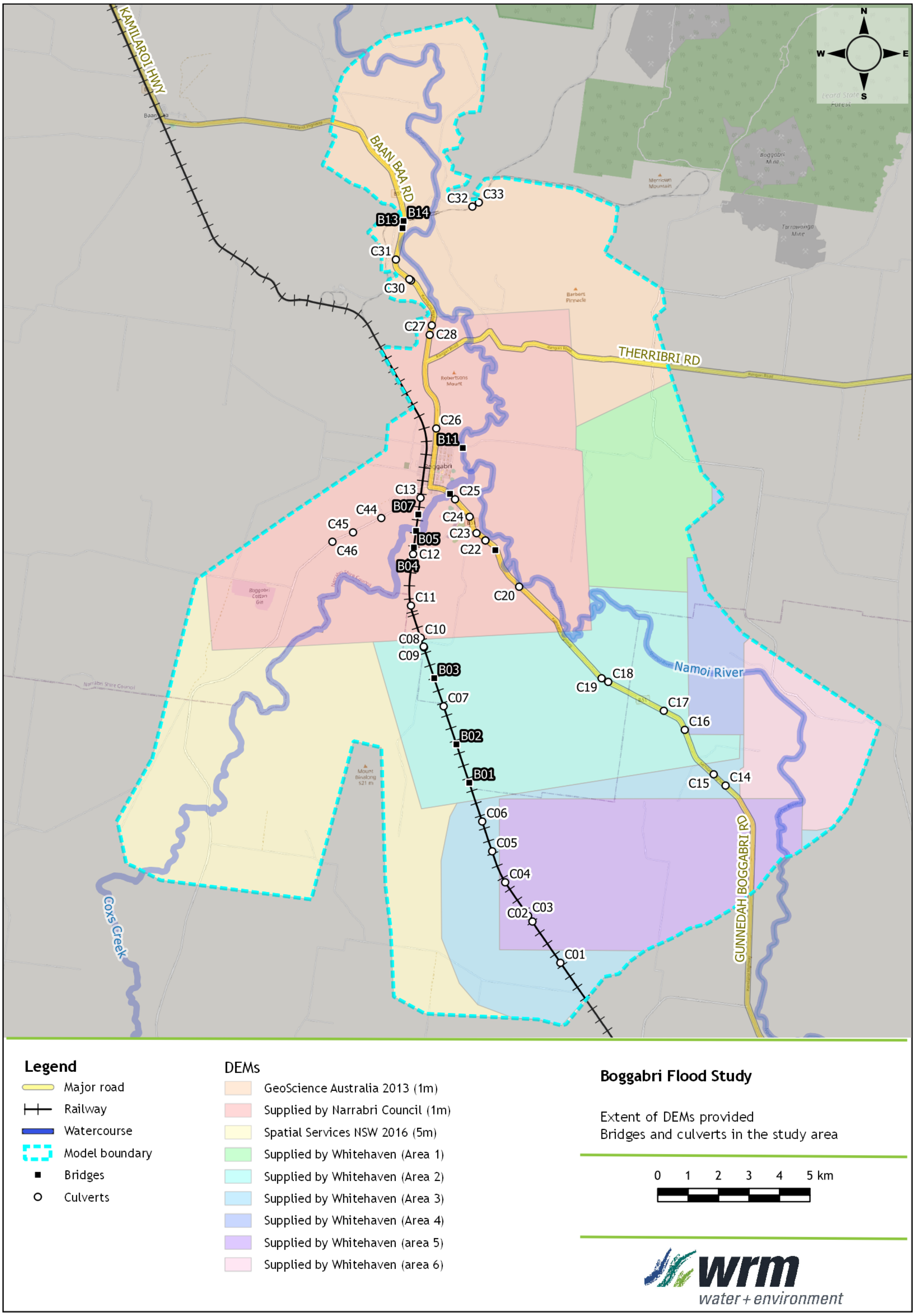


**Figure 3.9 – Overview of ground data availability, bridges and culverts in the study area**

A description of the data is as follows:

- The Narrabri Shire Council data was derived from LiDAR (Light Detection and Ranging) from an ALS50 (Airborne Laser Scanner) flown on 22 January 2014. It has an accuracy of 0.3 m (95% confidence limit (CI)) vertical and 0.8 m (95% CI) horizontal and was provided as an ESRI grid with a 1 m resolution.
- The Geoscience Australia data (sourced from the ICSM platform "Elevation and Depth – Foundation Spatial Data" (ELVIS, 2019)) was derived from LiDAR flown between September and October 2013. It has an accuracy of 0.3 m (95% CI)) vertical and 0.8m (95% CI) horizontal and was provided as an ESRI grid with a 1 m resolution.
- The NSW Spatial Services data was derived from photogrammetry flown between July and August 2011 and obtained from ELVIS (2019). It has an accuracy of 0.9 m (95% CI)) vertical and 1.25 m (95% CI) horizontal and was provided as an ESRI grid with a 5 m resolution. This data tends to overestimate the elevation compared to the other data sources by approximately 0.4 m, on average. The use of this data will not impact on the estimation of flood levels at Boggabri because it is located upstream. However, the data provides the only coverage of ground levels at the Coxs Creek at Boggabri stream gauge, which means it would not be reliable for use in hydraulic model calibration.
- Whitehaven Coal Limited kindly provided six sets of data:
  - Area 1 was provided without metadata as a Geotif file on a 1 m grid. The file was labelled as September 2015.
  - Area 2 was derived from LiDAR flown in November 2016. It has an accuracy of 0.15 m (95% CI)) vertical and 0.8 m (95% CI) horizontal and was provided as an ECW file with 0.25 m resolution.
  - Area 3 was provided without metadata as a DXF file with points at 25 m spacing and 3D lines to represent breaks in the topography, converted to a grid with a 5 m resolution. It was flown in February 2011.
  - Area 4 was provided without metadata as a DXF file with points at 20 m spacing and 3D lines to represent breaks in the topography, converted to a grid with a 1 m resolution. The file was labelled as January 2012.
  - Area 5 and Area 6 were provided without metadata as text files with points spaced at irregular intervals. The files were labelled as September 2019 and May 2019, respectively, and were converted to grids with a 1 m resolution.

The 2014 Narrabri Council and 2014 Geoscience Australia data was given preference over the other datasets because the confidence limits are known. A review of the overlapping areas showed these two datasets and the Whitehaven Area 1, Area 2, Area 5 and Area 6 data matched well and are therefore suitable and given preference next. There were minor differences in the overlapping Whitehaven areas, likely due to the different collection methodologies (LiDAR versus photogrammetry). Although the differences were minor, the Whitehaven Area 3 and Area 4 were given a lower preference. The NSW Spatial Services data was given the lowest preference, given its lower accuracy. This data was only used in the upper reaches of Cox Creek and therefore should not impact on the estimation of peak flood levels at Boggabri but would impact on the hydraulic calibration at the Coxs Creek at Boggabri stream gauge.

## 3.6 BRIDGE AND CULVERT DETAILS

A total of 62 relevant structures were identified in the study area. Table 3.3 summarises the key features of each structure and the respective data source. Figure 3.9 shows the locations of all structures excluding those at Boggabri, while the structures in Boggabri are shown in Figure 3.10.

Table 3.3 – Bridge and culvert details

| ID | Structure type | Dimensions (m) (h-height, w-width, L-length, D-diameter) | U/S invert (mAHD) | D/S invert (mAHD) | Source | Location/ reference |
|---|---|---|---|---|---|---|
| **B01** | Bridge | 1 x 0.8h x 3.2w x 5.2L | - | - | ARTC | Western rail line |
| **B02** | Bridge | 1 x 0.8h x 3.2w x 5.2L | - | - | ARTC | Western rail line |
| **B03** | Bridge | 2 x 1.1h x 3.2w x 7.6L | - | - | ARTC | Western rail line |
| **B04** | Bridge | 1 x 1.6h x 3.2w x 3.5L | - | - | estimated | Western rail line |
| **B05** | Bridge | 2 x 2.2h x 4w x 7.6L | - | - | ARTC | Western rail line |
| **B06** | Bridge | 13 x 5.85h x 3.66w x 156L | - | - | ARTC | Coxs Creek viaduct |
| **B07** | Bridge | 10 x 3.07h x 3.66w x 88L | - | - | ARTC | Coxs Creek overflow |
| **B08** | Bridge | 3 x 1.7h x 10w x 35L | - | - | estimated | Kamilaroi Highway |
| **B09** | Bridge | 4 x 2.3h x 8.73w x 40.7L | - | - | RMS | Deadman's Gully |
| **B10** | Bridge, | 13 x 5.1h x 11.1w x 261L | - | - | RMS | Bridge over Coxs Creek |
| **B11** | Bridge | 4 x 6.69h x 3.2w x 60L | - | - | RMS | Boston Street bridge |
| **B12** | Bridge | 3 x 3.3h x 5w x 130L | - | - | estimated | Iron Bridge |
| **B13** | Bridge | 3 x 6.5h x 8w x 54L | - | - | RMS | Kamilaroi Highway |
| **B14** | Bridge | 3 x 6.5h x 8w x 72L | - | - | estimated | Kamilaroi Highway |
| **B15** | Bridge | 25 x 6.5h x 4w x 1020L | - | - | estimated | Northern rail |
| **B16** | Bridge | 2 x 7.1h x 10w x 54L | - | - | estimated | North |
| **C01** | BC | 1 x 2.2h x 4.5w x 7L | 251.50 | 251.10 | estimated | Western rail line |
| **C02** | BC | 1 x 2.2h x 4.5w x 7L | 249.40 | 249.00 | estimated | Western rail line |
| **C03** | BC | 5 x 2.2h x 5w x 7L | 249.00 | 248.90 | estimated | Western rail line |
| **C04** | BC | 1 x 1.8h x 4.5w x 7L | 248.35 | 248.20 | estimated | Western rail line |
| **C05** | BC | 1 x 1.8h x 4.5w x 7L | 248.00 | 247.50 | estimated | Western rail line |
| **C06** | CBC | 1 x 0.9h x 6w x 5.2L | 247.30 | 247.10 | ARTC | Western rail line |
| **C07** | SPC | 20 x 1.5h x 2.7w x 8.3L | 245.35 | 245.30 | ARTC | Western rail line |
| **C08** | SPC | 3 x 0.9D x 8.2L | 245.70 | 245.60 | ARTC | Western rail line |
| **C09** | SPC | 2 x 0.9D x 7.7L | 245.50 | 245.40 | ARTC | Western rail line |
| **C10** | SPC | 3 x 1.4D x 10.6L | 245.10 | 245.00 | ARTC | Western rail line |
| **C11** | CBC | 2 x 0.9h x 1.2w x 5L | 244.50 | 244.40 | ARTC | Western rail line |
| **C12** | PC | 1 x 0.5D x 12L | 242.05 | 241.96 | estimated | Western rail line |
| **C13** | CBC | 1 x 0.9h x 1.8w x 17L | 247.10 | 247.00 | ARTC | Western rail line |
| **C14** | BC | 1 x 0.45h x 0.75w x 24.5L | 250.00 | 249.90 | estimated | Kamilaroi Highway |
| **C15** | BC | 2 x 0.45h x 0.75w x 20L | 249.90 | 249.65 | estimated | Kamilaroi Highway |
| **C16** | BC | 2 x 0.45h x 0.75w x 20L | 248.45 | 248.40 | estimated | Kamilaroi Highway |
| **C17** | BC | 4 x 1.83h x 3.16w x 25L | 246.00 | 245.50 | estimated | Kamilaroi Highway |
| **C18** | CBC | 3 x 0.91h x 2.44w x 8.1L | 244.60 | 244.40 | RMS | Kamilaroi Highway |
| **C19** | CBC | 3 x 1.82h x 2.74w x 8.9L | 243.80 | 243.40 | RMS | Kamilaroi Highway |
| **C20** | RCBC | 1 x 0.3h x 0.7w x 41L | 242.30 | 242.20 | RMS | Kamilaroi Highway |
| **C21** | RCBC | 2 x 1.51h x 2.48w x 18L | 241.63 | 241.49 | RMS | Kamilaroi Highway |
| **C22** | RCP | 2 x 0.9D x 18L | 241.63 | 241.49 | RMS | Kamilaroi Highway |
| **C23** | RCP | 1 x 0.36D x 13L | 242.80 | 242.20 | RMS | Kamilaroi Highway |
| **C24** | RCP | 1 x 0.375D x 14L | 242.45 | 242.40 | RMS | Kamilaroi Highway |
| **C25** | RCP | 1 x 1.75D x 10L | 242.10 | 242.00 | RMS | Kamilaroi Highway |
| **C26** | CBC | 4 x 0.91h x 1.82w x 9.3L | 242.70 | 242.40 | RMS | Kamilaroi Highway |
| **C27** | RCP | 2 x 0.45D x 15L | 238.60 | 238.30 | RMS | Kamilaroi Highway |
| **C28** | RCP | 1 x 0.75D x 19L | 237.80 | 237.60 | RMS | Kamilaroi Highway |
| **C29** | CBC | 3 x 0.92h x 1.81w x 6L | 237.30 | 237.00 | RMS | Kamilaroi Highway |

| ID | Structure type | Dimensions (m) (h-height, w-width, L-length, D-diameter) | U/S invert (mAHD) | D/S invert (mAHD) | Source | Location/ reference |
|---|---|---|---|---|---|---|
| **C30** | CBC | 4 x 0.91h x 2.43w x 10.6L | 237.30 | 237.20 | RMS | Kamilaroi Highway |
| **C31** | CBC | 3 x 1.21h x 2.43w x 8L | 238.50 | 238.45 | RMS | Kamilaroi Highway |
| **C32** | PC | 1 x 0.5D x 18L | 237.50 | 236.80 | estimated | North |
| **C33** | PC | 1 x 0.5D x 17L | 237.20 | 237.19 | estimated | North |
| **C34** | BC | 3 x 0.6h x 2.6w x 13.7L | 242.40 | 242.25 | WRM | Boggabri |
| **C35** | BC | 3 x 0.75h x 1.8w x 12.8L | 243.40 | 243.30 | WRM | Boggabri |
| **C36** | BC | 1 x 0.3h x 0.9w x 23.1L | 243.00 | 242.90 | WRM | Boggabri |
| **C37** | BC | 1 x 0.3h x 0.9w x 23.2L | 243.55 | 243.38 | WRM | Boggabri |
| **C38** | BC | 1 x 0.45h x 0.9w x 17L | 241.40 | 241.32 | WRM | Boggabri |
| **C39** | BC | 1 x 0.45h x 0.9w x 12.1L | 241.60 | 241.53 | WRM | Boggabri |
| **C40** | BC | 1 x 0.45h x 0.9w x 20.7L | 241.70 | 241.60 | WRM | Boggabri |
| **C41** | BC | 1 x 0.3h x 0.45w x 6.5L | 241.70 | 241.65 | WRM | Boggabri |
| **C42** | BC | 1 x 0.3h x 0.9w x 17.2L | 242.06 | 242.02 | WRM | Boggabri |
| **C43** | BC | 2 x 0.3h x 0.9w x 15.5L | 242.06 | 242.00 | WRM | Boggabri |
| **C44** | PC | 1 x 1D x 18L | 244.40 | 242.40 | estimated | West of Boggabri |
| **C45** | PC | 1 x 0.5D x 14L | 244.40 | 244.30 | estimated | West of Boggabri |
| **C46** | PC | 1 x 0.5D x 10L | 244.20 | 244.10 | estimated | West of Boggabri |

BC: box culvert; ICBC: (reinforced) concrete box culvert;
PC: pipe culvert; SPC: steel pipe culvert; RCP: reinforced concrete pipe culvert

## 3.7 COMMUNITY RESPONSE

The local community were sent a letter to advise them of the purpose of the study. A questionnaire was also given to gain an understanding of the community priorities with respect to flooding. It also provided an opportunity to collect anecdotal data on historical flood behaviour. At the time of reporting, 14 responses to the community survey were received. Data on historical flooding was not provided.


**Figure 3.10 – Overview of bridges and culverts in central Boggabri**

# 4 XP-RAFTS model development

## 4.1 OVERVIEW

Flood discharges at Boggabri were estimated using:

- the recorded flows at the Namoi River at Gunnedah stream gauge (GS419001) to estimate upper Namoi River catchment flows; and
- an XP-RAFTS rainfall runoff model (Innovyze, 2019) of the Coxs Creek catchment and the residual catchment downstream of Gunnedah to Boggabri.

XP-RAFTS is a computer model that predicts flood discharge hydrographs from a catchment by routing rainfall excess (the part of rainfall that does not infiltrate into the soil) through a representation of catchment storage. Catchment storage is determined by both surface runoff from a subcatchment as well as linear storage along a channel. The use of subcatchments also allows for the accounting of the areal distribution of rainfall, land use and stream characteristics.

The Laurenson non-linear runoff routing procedure was used to develop a subcatchment runoff hydrograph from recorded rainfall time series data. Catchment parameters such as area, slope, percentage impervious and roughness are used to determine a storage delay coefficient for each subcatchment to produce a discharge hydrograph from the excess rainfall. An initial and continuing rainfall loss model (determined from model calibration) was used to define the rainfall excess. The Muskingum method, which uses a weighting factor and a routing time in hours, was used to determine the channel storage and routing.

This section describes the development and calibration of the XP-RAFTS model. The recorded rainfall and streamflow data outlined in Section 3 was used to calibrate the model. The XP-RAFTS model parameters were determined by matching as closely as possible the recorded and predicted discharge hydrographs at the stations along the Namoi River and Coxs Creek.

## 4.2 MODEL CONFIGURATION

Figure 4.1 shows the subcatchment and routing link configuration of the XP-RAFTS model. The catchments were delineated by analysing a digital elevation model (DEM) derived from 1 arc second satellite data (SRTM) obtained from Geoscience Australia, as well as satellite imagery. Details of the adopted XP-RAFTS subcatchment and link parameters are given in Table 4.1 and Table 4.2 respectively. These parameters were determined through model calibration as described in Section 4.3. The following is of note:

- A total of 21 subcatchments, ranging in size from 33 km$^2$ to 104 km$^2$, have been used to represent the waterways and local catchment runoff within the residual catchment area between Gunnedah and Boggabri along the Namoi River;
- A total of 38 subcatchments, ranging in size from 34 km$^2$ to 152 km$^2$, have been used to represent the drainage of Coxs Creek;
- The Namoi River at Gunnedah (419001) gauge discharge hydrograph was incorporated as a direct inflow to the model at node “Namoi”;
- The XP-RAFTS fraction impervious in each subcatchment was assumed to be zero for all subcatchments, except in catchments B50 and B57, which contain Boggabri;
- The township of Boggabri was assumed to be 50% impervious, resulting in a fraction impervious of 0.46% and 0.55% for subcatchments B50 and B57, respectively;
- The catchment slope was determined using the equal area method from SRTM 1 second topographic data;

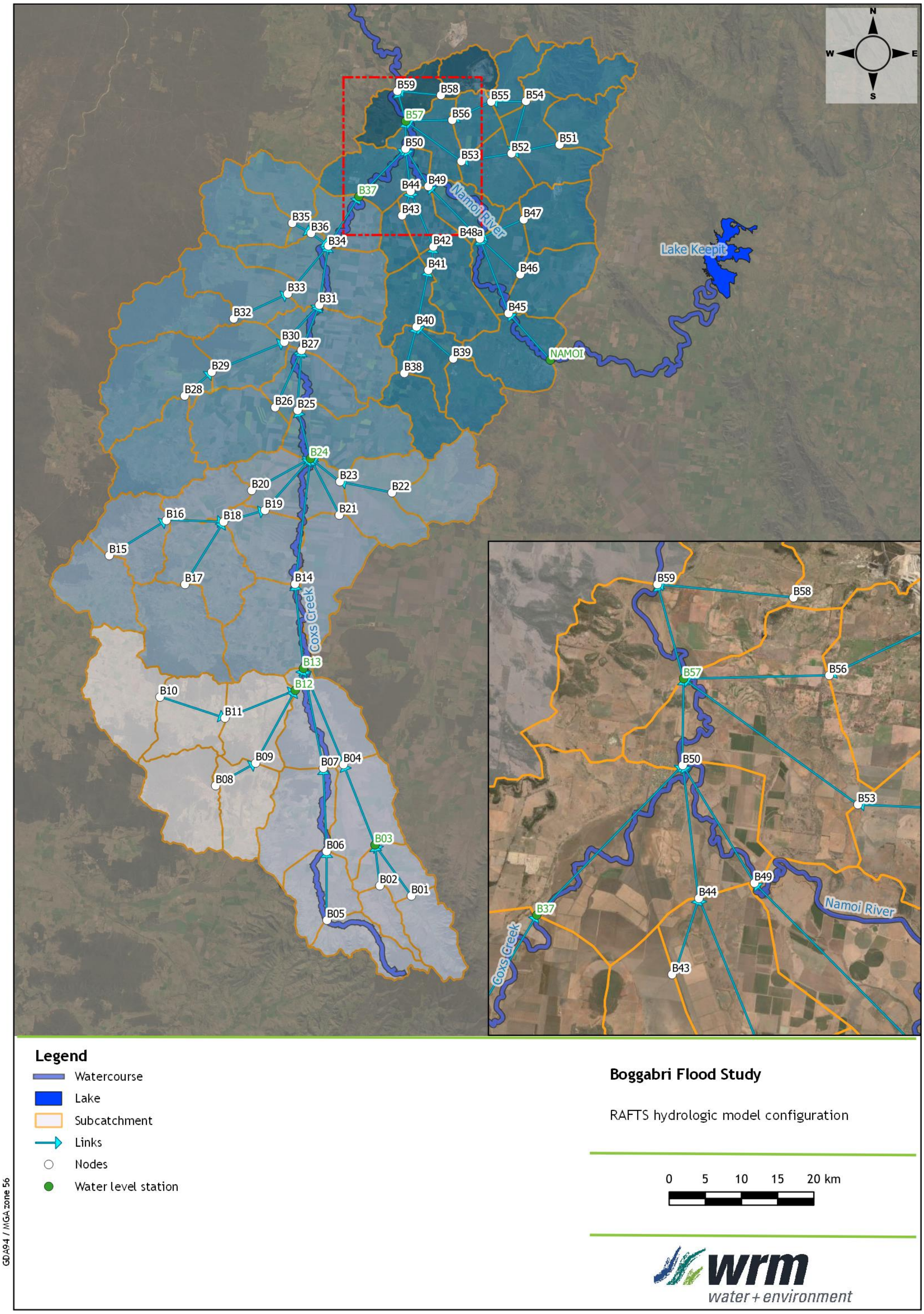


**Figure 4.1 – XP-RAFTS model configuration**

Table 4.1 – Adopted XP-RAFTS model subcatchment parameters

| ID | Area (km²) | Slope (%) | PERN | ID | Area (km²) | Slope (%) | PERN |
|---|---|---|---|---|---|---|---|
| **B01** | 71 | 1.94 | 0.020 | **B31** | 124 | 0.23 | 0.035 |
| **B02** | 34 | 3.33 | 0.020 | **B32** | 105 | 0.45 | 0.035 |
| **B03** | 60 | 1.26 | 0.020 | **B33** | 109 | 0.52 | 0.035 |
| **B04** | 111 | 0.30 | 0.040 | **B34** | 147 | 0.18 | 0.035 |
| **B05** | 69 | 2.61 | 0.020 | **B35** | 97 | 0.66 | 0.035 |
| **B06** | 85 | 1.02 | 0.020 | **B36** | 70 | 0.34 | 0.035 |
| **B07** | 120 | 0.75 | 0.040 | **B37** | 65 | 0.30 | 0.035 |
| **B08** | 123 | 0.98 | 0.020 | **B38** | 68 | 0.84 | 0.040 |
| **B09** | 89 | 1.48 | 0.020 | **B39** | 61 | 0.91 | 0.040 |
| **B10** | 140 | 0.60 | 0.020 | **B40** | 62 | 0.78 | 0.040 |
| **B11** | 97 | 1.26 | 0.020 | **B41** | 66 | 0.32 | 0.040 |
| **B12** | 104 | 0.36 | 0.040 | **B42** | 89 | 0.18 | 0.040 |
| **B13** | 130 | 0.29 | 0.040 | **B43** | 33 | 0.14 | 0.040 |
| **B14** | 127 | 1.36 | 0.040 | **B44** | 40 | 0.03 | 0.040 |
| **B15** | 100 | 1.06 | 0.040 | **B45** | 105 | 0.14 | 0.040 |
| **B16** | 93 | 0.80 | 0.040 | **B46** | 86 | 0.22 | 0.040 |
| **B17** | 136 | 0.87 | 0.040 | **B47** | 83 | 1.02 | 0.040 |
| **B18** | 120 | 0.41 | 0.040 | **B48** | 0 | 1.00 | 0.040 |
| **B19** | 87 | 1.10 | 0.035 | **B48a** | 77 | 0.04 | 0.040 |
| **B20** | 59 | 0.30 | 0.040 | **B49** | 55 | 0.14 | 0.040 |
| **B21** | 117 | 0.16 | 0.035 | **B50** | 96 | 0.18 | 0.040 |
| **B22** | 105 | 0.59 | 0.035 | **B51** | 61 | 1.42 | 0.040 |
| **B23** | 109 | 0.24 | 0.035 | **B52** | 91 | 0.46 | 0.040 |
| **B24** | 108 | 0.01 | 0.035 | **B53** | 65 | 0.43 | 0.040 |
| **B25** | 120 | 0.22 | 0.035 | **B54** | 84 | 1.01 | 0.040 |
| **B26** | 117 | 0.49 | 0.035 | **B55** | 49 | 0.62 | 0.040 |
| **B27** | 82 | 0.04 | 0.035 | **B56** | 42 | 0.51 | 0.040 |
| **B28** | 118 | 0.68 | 0.040 | **B57** | 63 | 0.05 | 0.040 |
| **B29** | 152 | 0.66 | 0.035 | **B58** | 44 | 0.61 | 0.040 |
| **B30** | 86 | 0.22 | 0.035 | **B59** | 68 | 0.39 | 0.040 |

- the following PERN adaption factors, used to introduce the effect of pervious catchment roughness, were assigned:
  - 0.02 was adopted for the steep subcatchments in the upper reach of Coxs Creek (B01-B03, B05-B06, B08-B11);
  - 0.035 was adopted for the predominantly cropped midland catchments (B19, B21-B27, B29-B37); and
  - 0.040 was adopted for the remaining catchments containing light brush and trees.
- channel routing adopted a constant weighting factor ‘X’ of 0.20 for the drainage lines draining catchment B50 and a constant weighting factor ‘X’ of 0.25 for all other catchments; and

Table 4.2 – XP-RAFTS routing link parameters

| U/S node | D/S node | Link length (km) | Channel velocity (m/s) | Channel routing K (hrs) | U/S node | D/S node | Link length (km) | Channel velocity (m/s) | Channel routing K (hrs) |
|---|---|---|---|---|---|---|---|---|---|
| **B01** | **B03** | 10.2 | 1.60 | 1.77 | **B31** | **B34** | 11.5 | 1.04 | 3.07 |
| **B02** | **B03** | 9.1 | 1.60 | 1.57 | **B32** | **B33** | 9.2 | 1.04 | 2.45 |
| **B03** | **B04** | 17.7 | 1.60 | 3.07 | **B33** | **B34** | 10.9 | 1.04 | 2.90 |
| **B04** | **B13** | 20.5 | 1.60 | 3.56 | **B34** | **B37** | 13.3 | 1.04 | 3.56 |
| **B05** | **B06** | 12.7 | 1.60 | 2.20 | **B35** | **B36** | 4.0 | 1.04 | 1.08 |
| **B06** | **B07** | 17.5 | 1.60 | 3.03 | **B36** | **B34** | 6.7 | 1.04 | 1.79 |
| **B07** | **B13** | 19.9 | 1.60 | 3.45 | **B37** | **B50** | 13.4 | 0.60 | 6.19 |
| **B08** | **B09** | 6.9 | 1.60 | 1.20 | **B38** | **B40** | 8.3 | 1.00 | 2.31 |
| **B09** | **B12** | 18.5 | 1.60 | 3.21 | **B39** | **B40** | 7.5 | 1.00 | 2.09 |
| **B10** | **B11** | 12.3 | 1.60 | 2.14 | **B40** | **B41** | 9.8 | 1.00 | 2.73 |
| **B11** | **B12** | 18.2 | 1.60 | 3.16 | **B41** | **B42** | 7.5 | 1.00 | 2.08 |
| **B12** | **B13** | 6.6 | 1.60 | 1.14 | **B42** | **B44** | 15.0 | 1.00 | 4.16 |
| **B13** | **B14** | 17.7 | 1.60 | 3.07 | **B43** | **B44** | 4.3 | 1.00 | 1.19 |
| **B14** | **B19** | 25.5 | 1.04 | 6.80 | **B44** | **B50** | 8.3 | 0.60 | 3.85 |
| **B15** | **B16** | 12.8 | 1.60 | 2.22 | **B45** | **B48** | 18.9 | 1.00 | 5.24 |
| **B16** | **B18** | 10.3 | 1.60 | 1.78 | **B46** | **B48** | 7.7 | 1.00 | 2.13 |
| **B17** | **B18** | 15.4 | 1.60 | 2.68 | **B47** | **B48** | 7.3 | 1.00 | 2.02 |
| **B18** | **B24** | 8.5 | 1.04 | 2.28 | **B48** | **B48a** | 0.0 | 1.00 | 0.00 |
| **B19** | **B24** | 15.2 | 1.04 | 4.07 | **B48** | **B49** | 0.0 | 1.00 | 0.00 |
| **B20** | **B24** | 10.7 | 1.04 | 2.86 | **B49** | **B50** | 9.6 | 0.60 | 4.45 |
| **B21** | **B24** | 13.0 | 1.04 | 3.46 | **B50** | **B57** | 7.9 | 1.00 | 2.18 |
| **B22** | **B23** | 8.3 | 1.04 | 2.21 | **B51** | **B52** | 7.1 | 1.00 | 1.98 |
| **B23** | **B24** | 10.3 | 1.04 | 2.75 | **B52** | **B53** | 10.5 | 1.00 | 2.92 |
| **B24** | **B25** | 10.0 | 1.04 | 2.68 | **B53** | **B57** | 21.1 | 1.00 | 5.87 |
| **B25** | **B27** | 14.2 | 1.04 | 3.79 | **B54** | **B55** | 6.7 | 1.00 | 1.85 |
| **B26** | **B27** | 10.0 | 1.04 | 2.68 | **B55** | **B56** | 7.3 | 1.00 | 2.03 |
| **B27** | **B31** | 8.7 | 1.04 | 2.32 | **B56** | **B57** | 15.4 | 1.00 | 4.28 |
| **B28** | **B29** | 5.9 | 1.04 | 1.59 | **B57** | **B59** | 7.2 | 1.00 | 1.99 |
| **B29** | **B30** | 14.0 | 1.04 | 3.74 | **B58** | **B59** | 8.5 | 1.00 | 2.36 |
| **B30** | **B31** | 8.9 | 1.04 | 2.38 | **NAMOI** | **B45** | 12.0 | 1.00 | 3.33 |

- channel routing adopted the following average channel velocities:
  - 1.60 m/s for the upstream Coxs Creek catchments (B1-B18, B20, B28);
  - 1.04 m/s for the downstream Coxs Creek catchments upstream of Boggabri (B19, B21-B37);
  - 0.60 m/s in catchment B50 to account for the slowing effect of the Coxs Creek merging with the Namoi River; and
  - 1.00 m/s for the remaining catchments along the Namoi River in which water tends to extend over the wide floodplain (B38-B49, B51-B59).

## 4.3 MODEL CALIBRATION DATA

The XP-RAFTS model was used to simulate five historic rainfall events:

- February 1955;
- February 1971;
- February 1997;
- July 1998; and
- November 2000.

The purpose of the model calibration was to match as closely as possible the predicted and recorded flood discharges for all historic events using a single set of model parameters (except for losses).

Both short duration and daily rainfall stations in and near the catchment were used for model calibration (see Table 3.2). The locations of these rainfall stations are shown in Figure 2.1. Each XP-RAFTS subcatchment was assigned the total daily rainfall recorded at the nearest rainfall station and distributed to hourly data using the nearest pluviograph. For the 1955 and 1971 events, short duration rainfall data was not available and therefore daily rainfall equally distributed across the day was used.

Details of the rainfall event simulation periods are given in Table 4.3.

**Table 4.3 – Rainfall event and simulation periods**

| Rainfall event | Simulation period |
|---|---|
| 1955 | 22 Feb (0900 hours) – 28 Feb (0900 hours) |
| 1971 | 26 Jan (0900 hours) – 6 Feb (0900 hours) |
| 1997 | 12 Feb (0900 hours) – 16 Feb (2300 hours) |
| 1998 | 19 July (2300 hours) – 24 July (2300 hours) |
| 2000 | 13 Nov (0900 hours) – 24 Nov (0900 hours) |

### 4.3.1 February 1955 event

Table 4.4 shows the daily rainfalls recorded at the 18 rainfall stations in the vicinity of the study area over the six days to 0900 hours on 28 February 1955. The highest total rainfalls occurred in the upper Coxs Creek catchments for this event, with the highest daily rainfall recorded in the 24 hours to 0900 hours on 23 February at Premer Eden Moor (55017) at 134.1 mm. Antecedent rainfall conditions were wet prior to the event, with 20 to 30 mm recorded at several stations and several rainfall events in the previous weeks suggesting a saturated catchment.

Figure 4.2 shows the discharge hydrographs for the Namoi River at Gunnedah (410001) and Boggabri (419012) and the Coxs Creek at Boggabri (419032) gauges over the simulation period. The predicted RAFTS discharge hydrographs at the Boggabri gauges, which are discussed further in Section 4.6, are also shown.

The Gunnedah data was obtained from the SMEC (2003) hydraulic model but the timing was shifted forward by 9 hours to match the recorded peak timing from the Pinneena database. The Boggabri data was obtained from the Pinneena database obtained from WaterNSW but with the peak discharge adjusted to the TUFLOW rating curve shown in Figure 3.3. The Boggabri data was recorded once per day only. The data suggests that two flood peaks occurred for the 1955 event with the largest peak predominantly generated from the Namoi River upstream of Gunnedah. It also suggests that there was a significant attenuation of the Namoi River flood peak between the two gauges.

Table 4.4 – Recorded daily rainfalls for the February 1955 event

| Station name | Station No. | Daily rainfall (mm) to 0900 hours | | | | | | Total rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| | | 23/02 | 24/02 | 25/02 | 26/02 | 27/02 | 28/02 | |
| Gunnedah Resource Center | 55024 | 16 | 91.9 | 25.1 | 36.6 | 6.4 | 0 | 176 |
| Mullaley (Bando) | 55002 | 38.6 | 132.1 | 43.9 | 2.5 | 5.6 | 3.8 | 226.5 |
| Boggabri Post Office | 55007 | 19.6 | 42.7 | 20.6 | 30 | 0 | 0.3 | 113.2 |
| Premer (Eden Moor) | 55017 | 134.1 | 96.8 | 18.5 | 4.6 | 2 | 0 | 256 |
| Mullaley (Garrawilla) | 55018 | 69.1 | 47.5 | 53.3 | 41.7 | 9.4 | 0 | 221 |
| Ghoolendaadi | 55020 | 17.5 | 47.2 | 9.7 | 0 | 28.7 | 4.8 | 107.9 |
| Goolhi | 55021 | 45.7 | 76.2 | 29.2 | 13.2 | 12.7 | 0 | 177 |
| Lignum | 55029 | 38.9 | 81.3 | 34.3 | 21.1 | 3.8 | 5.3 | 184.7 |
| Mayfield | 55033 | 0 | 19.3 | 0 | 0 | 19.1 | 0 | 38.4 |
| Boggabri (Milchengowrie) | 55034 | 16.5 | 53.6 | 0 | 46.7 | 0 | 0 | 116.8 |
| Mullaley Post Office | 55038 | 19.3 | 59.4 | 20.1 | 18 | 0 | 0.8 | 117.6 |
| Boggabri Retreat | 55044 | 15.2 | 51.8 | 49.5 | 55.9 | 29.7 | 0 | 202.1 |
| Curlewis (Pine Cliff) | 55045 | 18.8 | 78 | 27.2 | 20.3 | 1 | 7.6 | 152.9 |
| Tambar Springs Post Office | 55053 | 27.9 | 180.3 | 66 | 14 | 4.6 | 1.3 | 294.1 |
| Wandobah | 55059 | 70.6 | 17.5 | 24.4 | 1 | 0 | 0 | 113.5 |
| Yannergee (Dobroyd) | 55069 | 27.9 | 108 | 42.4 | 21.1 | 2.5 | 0 | 201.9 |
| Kelvin (Kahana) | 55201 | 63.2 | 42.2 | 43.9 | 29.5 | 0 | 0 | 178.8 |
| Brentwood | 55281 | 108.5 | 56.4 | 8.1 | 5.8 | 6.1 | 55.9 | 240.8 |

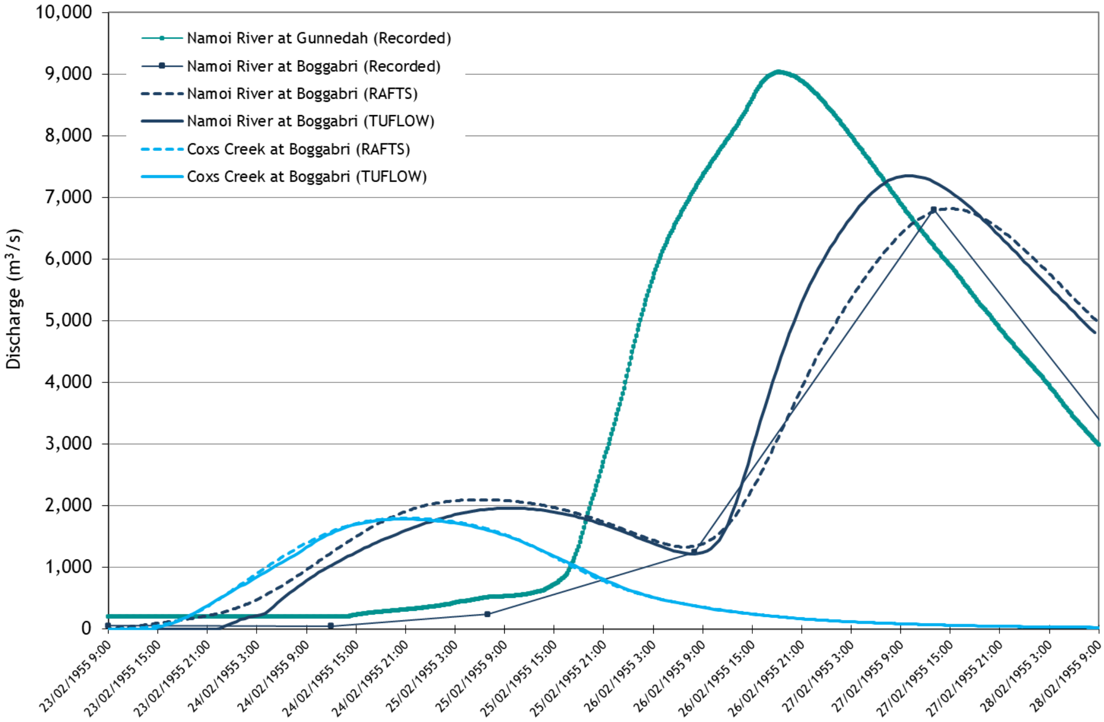


**Figure 4.2 – Recorded Namoi River at Gunnedah and Boggabri and predicted Namoi River at Boggabri discharge hydrographs, February 1955 event**

### 4.3.2 February 1971 event

Table 4.5 shows the daily rainfalls recorded at the 22 rainfall stations in the vicinity of the study area over the 11 days to 0900 hours on 6 February 1971. Another flood peak occurred soon after this date, but it was lower than the initial peak and therefore not simulated. The highest total rainfalls occurred in the upper Coxs Creek catchments for this event, with the highest daily rainfall recorded in the 24 hours to 0900 hours on 31 January at Tambar Springs Post Office (55053) at 133.1 mm. Antecedent rainfall conditions were dry prior to the event, with rainfall only recorded at the Kelvin Kahana (55201) station.

Figure 4.3 shows the discharge hydrographs for the Namoi River at Gunnedah (410001) and Boggabri (419012) and the Coxs Creek at Boggabri (419032) gauges over the simulation period. The predicted RAFTS discharge hydrographs at the Boggabri gauges, which are discussed further in Section 4.6, are also shown. The Gunnedah data was obtained from the Pinneena database obtained from WaterNSW but with the discharges adjusted using the latest WaterNSW rating curve (Table 330.02) (see Figure 3.2). The Boggabri data was also obtained from the Pinneena database but with the peak discharges adjusted to the TUFLOW rating curve shown in Figure 3.3. Only one reading per day was available for the event at Boggabri.

The data suggests that the Namoi River and Coxs Creek peaks for the 1971 event may have occurred within a few hours of each other because the Namoi River at Boggabri peak was much higher than that recorded at Gunnedah. No data was available at the Coxs Creek gauge to confirm this.

Table 4.5 - Recorded daily rainfalls for the February 1971 event

| Station name | Station No. | Daily rainfall (mm) to 0900 hours | | | | | | | | | | | Total rainfall (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 27/ 01 | 28/ 01 | 29/ 01 | 30/ 01 | 31/ 01 | 01/ 02 | 02/ 02 | 03/ 02 | 04/ 02 | 05/ 02 | 06/ 02 | |
| Gunnedah | 55024 | 4.3 | 0.8 | 42.7 | 18.8 | 38.9 | 69.1 | 0 | 0 | 0.5 | 4.8 | 30.5 | 210.4 |
| Mullaley (Bando) | 55002 | 0 | 0 | 109.2 | 12.2 | 57.4 | 90.7 | 3.8 | 0 | 8.1 | 23.1 | 28.2 | 332.7 |
| Boggabri Post Office | 55007 | 0 | 0 | 64.8 | 44.7 | 38.1 | 59.7 | 0 | 0 | 0.5 | 18.8 | 14.5 | 241.1 |
| Premer (Eden Moor) | 55017 | 0 | 32.3 | 0 | 0 | 44.5 | 61 | 0 | 10.2 | 0 | 2.5 | 39.4 | 189.9 |
| Mullaley (Garrawilla) | 55018 | 0 | 0 | 0 | 72.1 | 55.9 | 3 | 0 | 3 | 21.3 | 41.4 | 15 | 211.7 |
| Ghoolendaadi | 55020 | 42.9 | 0 | 45.7 | 25.7 | 39.6 | 0 | 0 | 20.3 | 0 | 38.1 | 35.6 | 247.9 |
| Mayfield | 55033 | 0 | 0 | 65.3 | 36.6 | 19.3 | 82 | 0 | 0 | 2.5 | 0 | 51.3 | 257 |
| Boggabri (Milchengowrie) | 55034 | 20.3 | 0 | 59.7 | 33.8 | 35.8 | 57.9 | 0 | 0 | 0 | 9.9 | 14.2 | 231.6 |
| Mullaley Post Office | 55038 | 0 | 0 | 30 | 25.4 | 92.7 | 0 | 0 | 0 | 9.4 | 2.3 | 26.7 | 186.5 |
| Boggabri Retreat | 55044 | 2 | 68.1 | 27.7 | 16.5 | 0 | 86.4 | 0 | 0 | 0 | 10.9 | 15 | 226.6 |
| Curlewis (Pine Cliff) | 55045 | 2 | 0 | 32.5 | 39.1 | 52.8 | 84.6 | 0 | 0 | 9.7 | 12.7 | 19.3 | 252.7 |
| Tambar Springs PO | 55053 | 0 | 0 | 50.3 | 6.1 | 133.1 | 4.1 | 0 | 9.7 | 35.3 | 0 | 0 | 238.6 |
| Wandobah | 55059 | 0 | 7.6 | 35.6 | 58.4 | 87.6 | 62.2 | 0 | 7.6 | 19.1 | 20.3 | 0 | 298.4 |
| Yannergee (Dobroyd) | 55069 | 0 | 0 | 89.9 | 3.8 | 34.3 | 57.7 | 5.6 | 0 | 11.9 | 10.2 | 8.9 | 222.3 |
| Premer Post Office | 55071 | 0 | 0 | 47 | 5.8 | 76.7 | 56.9 | 0 | 0 | 3.6 | 23.1 | 20.6 | 233.7 |
| Kelvin (Kahana) | 55201 | 13.7 | 43.2 | 44.7 | 28.7 | 93.5 | 0 | 0 | 2.8 | 0 | 17.8 | 16.3 | 260.7 |
| Mullaley (Keigho) | 55263 | 5.6 | 0 | 17 | 18.3 | 60.5 | 58.4 | 0 | 0 | 8.1 | 38.9 | 14 | 220.8 |
| Boggabri (Be-Bara) | 55268 | 5.6 | 0 | 39.4 | 34.3 | 48.3 | 77 | 0 | 0 | 3.6 | 10.7 | 28.7 | 247.6 |
| Balmoral | 55271 | 0 | 0 | 14.2 | 14.7 | 79.2 | 42.4 | 5.8 | 0 | 15.2 | 0 | 25.1 | 196.6 |
| Gunnedah (Colstoun Sth) | 55272 | 0 | 0 | 41.9 | 21.6 | 28.2 | 81.3 | 0 | 0 | 0 | 0 | 33.5 | 206.5 |
| Boggabri (Neotsfield) | 55273 | 5.1 | 0 | 47.5 | 17.5 | 50.5 | 101.6 | 0 | 0 | 2.5 | 8.1 | 39.4 | 272.2 |
| Mullaley (Kirkbright) | 55301 | 0 | 0 | 19.1 | 30.5 | 35.3 | 70.9 | 0 | 0 | 0 | 10.7 | 27.4 | 193.9 |

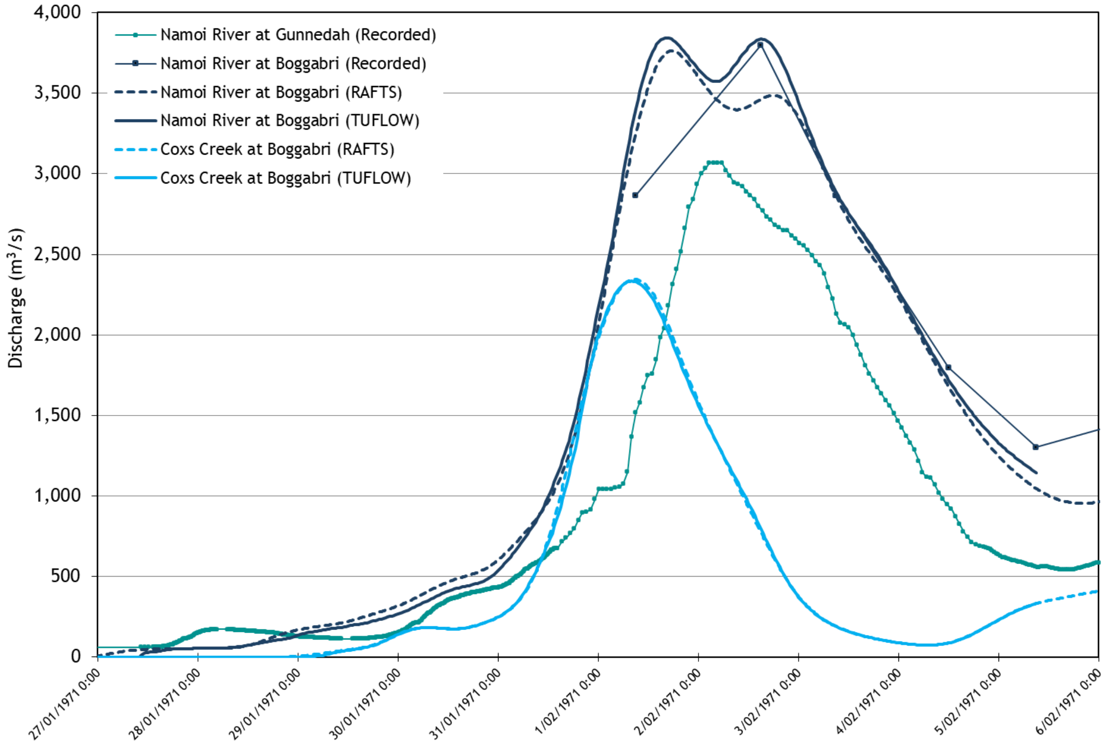


**Figure 4.3 – Recorded Namoi River at Gunnedah and Boggabri and predicted Namoi River at Boggabri discharge hydrographs, February 1971 event**

### 4.3.3 February 1997 event

Table 4.6 shows the daily rainfalls recorded at 19 rainfall stations in the vicinity of the study area over the three days to 0900 hours on 14 February 1997. Significant rainfalls were recorded over this period with the highest rainfalls occurring in the Mullaley area. Much lower rainfalls occurred around Boggabri and in the upper headwaters of the catchment. Rainfall conditions prior to the February 1997 event were generally dry with only 4.5 mm recorded at the Mullaley (Kirkbright) station and only 0.56 mm recorded at the Bundella Creek at Bundella station in the two days prior to 12 February, and no rainfall recorded at the Coxs Creek at Boggabri gauge.

Figure 4.4 shows the recorded subdaily rainfalls, redistributed to hourly intervals, at the four gauges with short duration data (see Section 3.4). The recorded discharge hydrographs at the Namoi River at Gunnedah (419001) and Namoi River at Boggabri (419012) gauges as well as the Coxs Creek at Boggabri (419032) gauge during the event are also shown. Figure 4.4 shows that the February 1997 event was mostly a Coxs Creek flood.

### 4.3.4 July 1998 event

Table 4.7 shows the daily rainfalls recorded at 17 rainfall stations in the vicinity of the study area over the three days to 0900 hours on 22 July 1998. Rainfalls were generally evenly distributed across the catchment for this event with the highest rainfalls occurring in the 24 hours to 0900 hours on 21 July 1998. Rainfall conditions prior to the July 1998 event were wet with 34 mm recorded at the Coxs Creek at Tambar Springs station, 41 mm recorded at the Bundella Creek at Bundella station and 21.5 mm recorded at the Coxs Creek at Boggabri gauge in two days prior to 20 July.

**Table 4.6 – Recorded daily rainfalls for the February 1997 event**

| Station name | Station No. | Daily rainfall (mm) to 0900 hours | | | Total rainfall (mm) |
|---|---|---|---|---|---|
| | | 12/02 | 13/02 | 14/02 | |
| Coxs Creek at Boggabri | 419032 | 2.5 | 32.0 | 24.5 | 59.0 |
| Coxs Creek at Tambar Springs | 419033 | 7.0 | 47.5 | 20.5 | 75.0 |
| Bomera Creek at Tambar-Premer Road | 419085 | 6.5 | 43.5 | 23.5 | 73.5 |
| Bundella Creek at Bundella | 419086 | 10.0 | 25.0 | 12.5 | 47.5 |
| Gunnedah Resource Center | 55024 | 0.0 | 40.4 | 30.4 | 70.8 |
| Mullaley (Bando) | 55002 | 10.6 | 53.0 | 71.0 | 134.6 |
| Premer (Eden Moor) | 55017 | 13.0 | 21.0 | 17.0 | 51.0 |
| Mullaley (Garrawilla) | 55018 | 10.2 | 80.4 | 80.8 | 171.4 |
| Boggabri (Milchengowrie) | 55034 | 0.0 | 51.2 | 21.4 | 72.6 |
| Mullaley Post Office | 55038 | 8.1 | 65.6 | 62.6 | 136.3 |
| Boggabri Retreat | 55044 | 0.0 | 17.4 | 14.2 | 31.6 |
| Curlewis (Pine Cliff) | 55045 | 11.8 | 64.0 | 84.2 | 160.0 |
| Tambar Springs Post Office | 55053 | 9.4 | 31.6 | 34.0 | 75.0 |
| Yannergee (Dobroyd) | 55069 | 12.8 | 24.6 | 36.6 | 74.0 |
| Premer Post Office | 55071 | 10.6 | 25.0 | 35.8 | 71.4 |
| Kelvin (Kahana) | 55201 | 24.2 | 35.5 | 0.0 | 59.7 |
| Boggabri (Be-Bara) | 55268 | 4.0 | 14.4 | 9.0 | 27.4 |
| Boggabri (Neotsfield) | 55273 | 2.6 | 15.8 | 3.4 | 21.8 |
| Mullaley (Kirkbright) | 55301 | 10.5 | 25.0 | 98.5 | 134.0 |

Figure 4.5 shows the recorded subdaily rainfalls, redistributed to hourly intervals, at the four gauges with short duration data (see Section 3.4). The recorded discharge hydrographs at the Namoi River at Gunnedah (419001) and Namoi River at Boggabri (419012) gauges as well as the Coxs Creek at Boggabri (419032) gauge during the event are also shown. The rainfall was generally confined to a 31 hour period to 1100 hours on 21 July for this event. Two flood peaks occurred at Boggabri, the first peak from Coxs Creek and the second and larger peak from the Upper Namoi River catchment.

### 4.3.5 November 2000 event

Table 4.8 shows the daily rainfalls recorded at 21 rainfall stations in the vicinity of the study area over the eight days to 0900 hours on 20 November 2000. Significant rainfalls were recorded over most days for this event. Rainfall conditions prior to the November 2000 event were moderately wet with 7.5 mm recorded at the Coxs Creek at Tambar Springs station, 8.5 mm recorded at the Bundella Creek at Bundella station, and 7 mm recorded at the Coxs Creek at Boggabri gauge in the day prior to 13 November.

Figure 4.6 shows the recorded subdaily rainfalls, redistributed to hourly intervals, at the four gauges with short duration data (see Section 3.4). The recorded discharge hydrographs at the Namoi River at Gunnedah (419001) and Namoi River at Boggabri (419012) gauges as well as the Coxs Creek at Boggabri (419032) gauge during the event are also shown. The flood event was produced by multiple smaller storm bursts in the Coxs Creek catchment followed by a larger Namoi River flood.

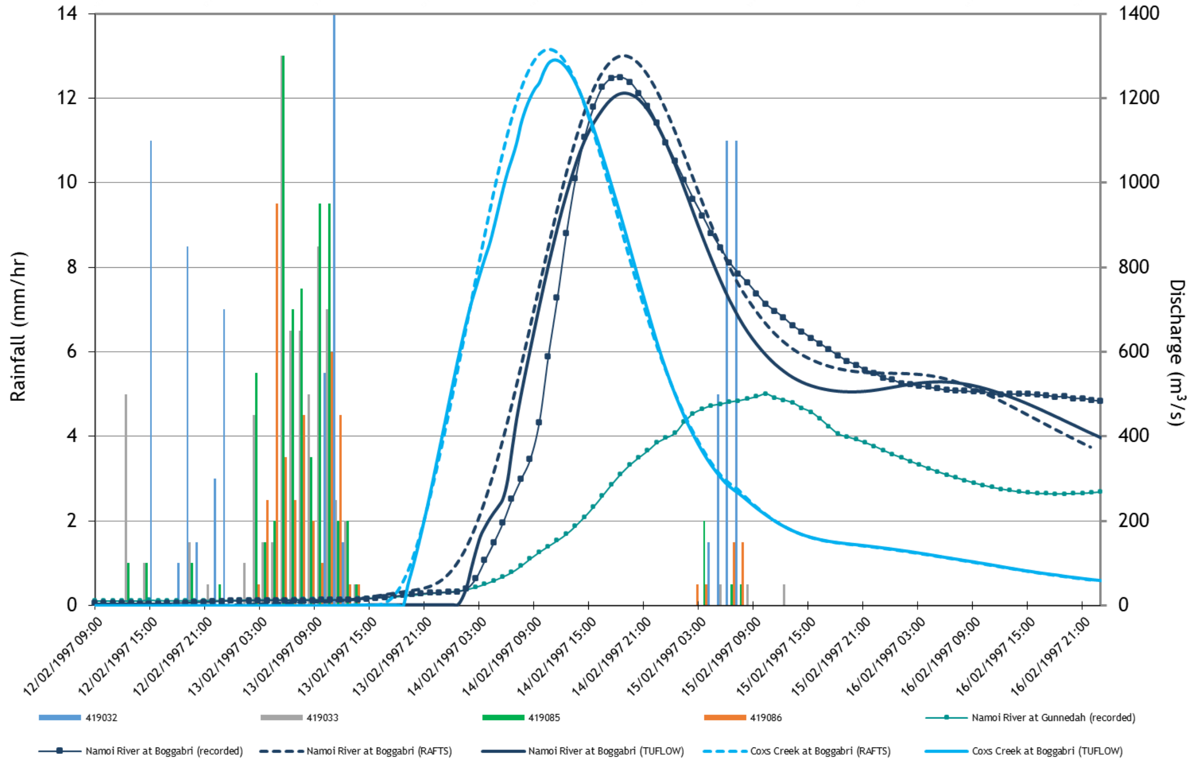


**Figure 4.4 – Recorded hourly rainfalls and discharge hydrographs, February 1997 event**

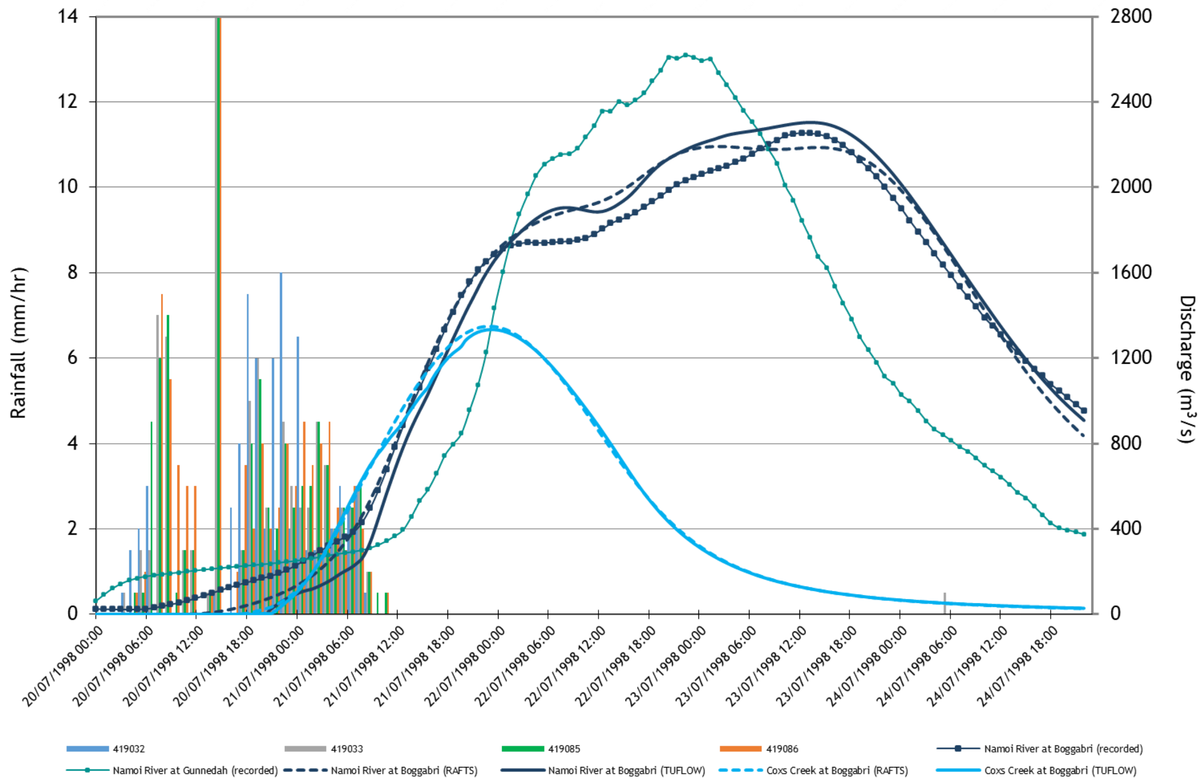


**Figure 4.5 – Recorded hourly rainfalls and discharge hydrographs, July 1998 event**

Table 4.7 – Recorded daily rainfalls for the July 1998 event

| Station name | Station No. | Daily rainfall (mm) to 0900 hours | | | Total rainfall (mm) |
|---|---|---|---|---|---|
| | | 20/07 | 21/07 | 22/07 | |
| Coxs Creek at Boggabri | 419032 | 7 | 60.5 | 0 | 67.5 |
| Coxs Creek at Tambar Springs | 419033 | 17 | 67 | 0 | 84 |
| Bomera Creek at Tambar-Premer Road | 419085 | 18.5 | 65.5 | 1 | 85 |
| Bundella Creek at Bundella | 419086 | 15 | 75.5 | 0.5 | 91 |
| Gunnedah Resource Center | 55024 | 12.4 | 66.4 | 1.6 | 80.4 |
| Mullaley (Bando) | 55002 | 12.4 | 70 | 0 | 82.4 |
| Premer (Eden Moor) | 55017 | 6 | 67 | 5 | 78 |
| Mullaley (Garrawilla) | 55018 | 53.2 | 41.8 | 26.6 | 121.6 |
| Boggabri (Milchengowrie) | 55034 | 3.4 | 79 | 12 | 94.4 |
| Mullaley Post Office | 55038 | 13.2 | 67.4 | 3.6 | 84.2 |
| Boggabri Retreat | 55044 | 0 | 45 | 6.2 | 51.2 |
| Curlewis (Pine Cliff) | 55045 | 15.4 | 79.2 | 3.4 | 98 |
| Tambar Springs Post Office | 55053 | 12.4 | 85 | 2.2 | 99.6 |
| Yannergee (Dobroyd) | 55069 | 15.2 | 69 | 2.8 | 87 |
| Kelvin (Kahana) | 55201 | 2 | 55 | 12.6 | 69.6 |
| Boggabri (Be-Bara) | 55268 | 10.4 | 74.2 | 3.4 | 88 |
| Boggabri (Neotsfield) | 55273 | 6.6 | 66.4 | 3.4 | 76.4 |

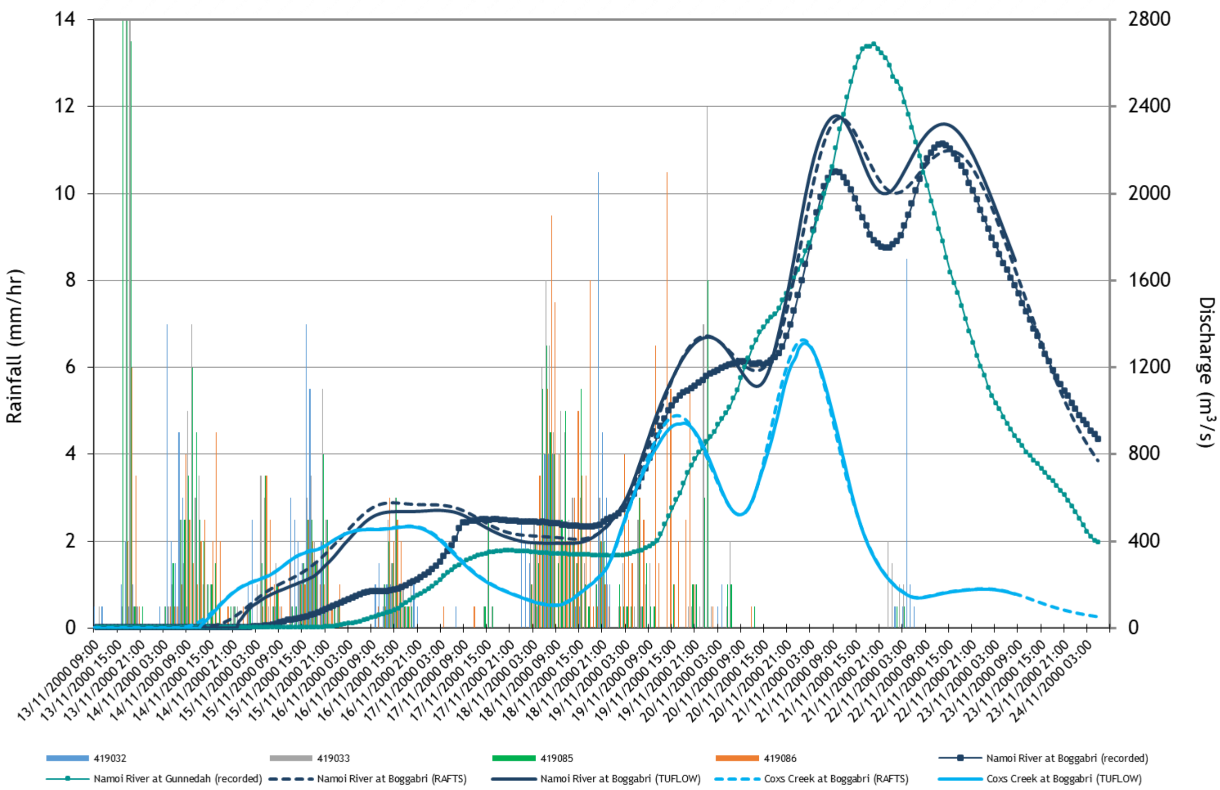


Figure 4.6 – Recorded hourly rainfalls and discharge hydrographs, November 2000

Table 4.8 – Recorded daily rainfalls for the November 2000 event

| Station name | Station No. | Daily rainfall (mm) to 0900 hours | | | | | | | | Total rainfall (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 13/11 | 14/11 | 15/11 | 16/11 | 17/11 | 18/11 | 19/11 | 20/11 | |
| Coxs Creek at Boggabri | 419032 | 13.5 | 21.5 | 7.0 | 27.5 | 8.5 | 14.5 | 24.5 | 1.5 | 117.5 |
| Coxs Creek at Tambar Springs | 419033 | 27.9 | 69.5 | 33.0 | 23.5 | 11.0 | 30.5 | 39.0 | 27.0 | 257.5 |
| Bomera Creek at Tambar-Premer Road | 419085 | 23.8 | 78.0 | 32.0 | 18.5 | 10.0 | 24.5 | 36.5 | 18.5 | 238 |
| Bundella Creek at Bundella | 419086 | 33.8 | 14.8 | 31.0 | 16.2 | 12.0 | 24.5 | 59.0 | 36.5 | 223 |
| Gunnedah Resource Centre | 55024 | 20.6 | 8.8 | 18.6 | 30.8 | 12.6 | 19.4 | 20.6 | 16.8 | 148.2 |
| Mullaley (Bando) | 55002 | 40.0 | 13.2 | 60.4 | 42.0 | 13.2 | 28.0 | 51.6 | 104.2 | 352.6 |
| Boggabri Post Office | 55007 | 16.5 | 12.8 | 7.0 | 39.0 | 8.6 | 8.0 | 25.4 | 2.0 | 119.3 |
| Premer (Eden Moor) | 55017 | 29.0 | 12.0 | 25.0 | 15.0 | 11.0 | 8.0 | 61.0 | 99.0 | 260 |
| Mullaley (Garrawilla) | 55018 | 21.6 | 14.2 | 51.2 | 32.2 | 11.4 | 39.0 | 37.0 | 73.0 | 279.6 |
| Boggabri (Milchengowrie) | 55034 | 20.2 | 4.4 | 9.2 | 39.4 | 10.6 | 2.4 | 30.2 | 4.2 | 120.6 |
| Mullaley Post Office | 55038 | 22.2 | 5.4 | 27.4 | 31.0 | 11.0 | 18.2 | 36.2 | 30.8 | 182.2 |
| Boggabri Retreat | 55044 | 10.5 | 18.0 | 0.0 | 35.5 | 10.0 | 6.0 | 15.0 | 3.0 | 98 |
| Curlewis (Pine Cliff) | 55045 | 29.6 | 5.6 | 23.4 | 28.4 | 12.6 | 18.2 | 37.6 | 78.2 | 233.6 |
| Tambar Springs Post Office | 55053 | 42.0 | 55.0 | 42.0 | 35.0 | 15.0 | 28.2 | 65.6 | 45.0 | 327.8 |
| Yannergee (Dobroyd) | 55069 | 45.6 | 18.6 | 43.0 | 24.6 | 13.8 | 16.4 | 50.8 | 15.4 | 228.2 |
| Premer Post Office | 55071 | 12.0 | 26.0 | 30.0 | 25.2 | 12.0 | 25.0 | 52.0 | 8.2 | 190.4 |
| Kelvin (Kahana) | 55201 | 14.2 | 11.6 | 12.6 | 34.6 | 10.6 | 10.0 | 18.4 | 8.4 | 120.4 |
| Mullaley(Keigho) | 55263 | 14.0 | 19.6 | 36.6 | 46.0 | 10.4 | 40.8 | 19.8 | 42.0 | 229.2 |
| Boggabri (Be-Bara) | 55268 | 22.0 | 14.0 | 21.0 | 41.0 | 11.0 | 33.0 | 24.0 | 5.0 | 171 |
| Boggabri (Neotsfield) | 55273 | 17 | 24.8 | 10 | 28 | 9 | 17.8 | 39.8 | 7.4 | 153.8 |
| Mullaley (Kirkbright) | 55301 | 10 | 4 | 42 | 37 | 12.5 | 32 | 22 | 35.5 | 195 |

## 4.4 TRANSMISSION LOSSES

During model calibration, it was not possible to match the recorded Namoi River at Boggabri discharge hydrograph using the recorded Namoi River at Gunnedah discharge hydrograph without the inclusion of a transmission loss. Apart from the 1971 event, where the Namoi River and Coxs Creek peaks appear to coincide at Boggabri, the Namoi River at Boggabri peak is lower than at Gunnedah even including the Coxs Creek flows. The peak at Boggabri is 14% lower than the Gunnedah peak for the 1998 event, 17% lower for the 2000 event and 25% lower for 1955.

To match the recorded peak at the Boggabri gauge, 8% of the Namoi River flow was diverted from XP-RAFTS model nodes at B45, B48 and B49 (see Figure 4.1). These locations are approximately 25%, 50% and 75% of the distance along the Namoi River between Gunnedah and Boggabri. These flows were assumed to soak into the underlying aquifer and not report back to the river.

## 4.5 RAINFALL LOSSES

Table 4.9 shows the rainfall losses adopted in the XP-RAFTS model for each calibration event. The rainfall losses were adjusted to match the recorded flood peak and volume (shape) at all stream gauges. A higher priority was given to matching the Coxs Creek at Boggabri gauge data given its relevance to flooding in Boggabri and the fact that the upstream gauges are generally poorly rated (see Section 3.3).

**Table 4.9 - Calibrated initial and continuing rainfall losses, calibration events**

| Event | Initial loss (mm) | Continuing loss (mm/hr) |
|---|---|---|
| February 1955 | 25 | 1.3 |
| February 1971 | 60 | 0.4 |
| February 1997 | 52 | 1 |
| July 1998 | 15 | 1[a] |
| November 2000 | 30 | 2 |

[a] 2.2mm/hour adopted for the catchment upstream of Mullaley

## 4.6 MODEL CALIBRATION RESULTS

Figure A 1 to Figure A 15 in Appendix A show the recorded and predicted discharge hydrographs along the Coxs Creek at the three upstream stream gauges Bomera Creek at Tambar-Premer Road (419085), Coxs Creek at Tambar Springs (419033) and Bundella Creek at Bundella (419086) as well as the two downstream gauges Coxs Creek at Boggabri (419032) and Namoi River at Boggabri (419012) for the five calibration events. Data is only available at the Namoi River at Boggabri gauge for the 1955 and 1971 events.

The hydrologic model was able to replicate the hydrographs for the upstream gauges (Bundella Creek at Bundella (419086), Bomera Creek at Tambar-Premer Road (419085), and Coxs Creek at Tambar Springs (419033)) reasonably well. A good agreement was achieved at the Coxs Creek at Tambar Springs (419033) gauge for the 1998 and 2000 events. The match for the 1997 event at this station is poor due to the low discharges. This event was generated mostly from the catchment downstream of this gauge.

The timing, peak and flood volume of the recorded and predicted hydrographs at the Coxs Creek at Boggabri gauge (419032) are in good agreement for the 1997, 1998 and 2000 calibration events, suggesting the rainfall losses and channel routing parameters adopted for the Coxs Creek catchment are reasonable.

At the Namoi River at Boggabri (419012) gauge, the recorded and predicted discharge hydrographs are in reasonable agreement for the 1955, 1997, 1998 and 2000 events which suggests that the adopted transmission and routing losses between Gunnedah and Boggabri are sound for these events.

Two flood peaks are predicted for the 1971 event, with the first peak associated with the Coxs Creek and the rising limb of the Namoi River flood and the second associated with the Namoi River peak and the falling limb of the Coxs Creek flood. The second peak is marginally lower than the recorded flood peak. Recorded data is not available for the first peak.

# 5 Hydraulic model development

## 5.1 OVERVIEW

The two-dimensional TUFLOW hydrodynamic model (BMT, 2020) was used to simulate the flow behaviour of Coxs Creek and Namoi River and their tributaries in the vicinity of Boggabri.

TUFLOW represents hydraulic behaviour on a fixed grid by solving the full two-dimensional depth-averaged momentum and continuity equations for free surface flow (BMT, 2018). The model automatically calculates breakout points and flow directions within the study area. An adaptive time step is used by the computational engine to maintain simulation stability. A grid size of 10 m was adopted for this study.

A description of the development and calibration of the TUFLOW model that has been used to estimate design flood levels at Boggabri is outlined below.

## 5.2 MODEL CONFIGURATION

Figure 5.1 shows the extent of the hydraulic model. The model includes:

- a digital elevation model (DEM) of the available topographic data;
- Manning's 'n' roughness values for surfaces within the study area;
- a global soil type to account for infiltration losses;
- inflow and outflow boundaries; and
- road and rail culvert and bridge data.

Descriptions of these are given in the following sections.

### 5.2.1 Topographic data

The LiDAR/DEM datasets were merged into a single DEM. Based on the metadata information on vertical accuracy (see Section 3.4), the following preference order (best to poorest) was adopted:

1. data supplied by Narrabri Council, 2014;
2. data from GeoScience Australia, 2014;
3. area 2 supplied by Whitehaven, 2016;
4. area 1 supplied by Whitehaven, 2015;
5. area 4 supplied by Whitehaven, 2012;
6. area 5 supplied by Whitehaven, 2019;
7. area 6 supplied by Whitehaven, 2019;
8. area 3 supplied by Whitehaven, 2011; and
9. data from NSW Spatial Services, 2011.

### 5.2.2 Bathymetric data

The project DEM represents the water level in the Namoi River at the time of the survey rather than the watercourse bed. A review of the Namoi River at Boggabri (419012) gauge cease-to-flow level showed that the depth of water at was about 2.3 m above the bed. This level was supported by the overlapping areas from the 2019 lidar data provided by Whitehaven, which was taken when there was no flow in the Namoi River.

To account for this, the bed level of the Namoi River has been lowered by 2.3 m over a constant width of 25 m for the entire length of the model area. No changes were made to the Coxs Creek bed as it has no water on the bed at time of survey.

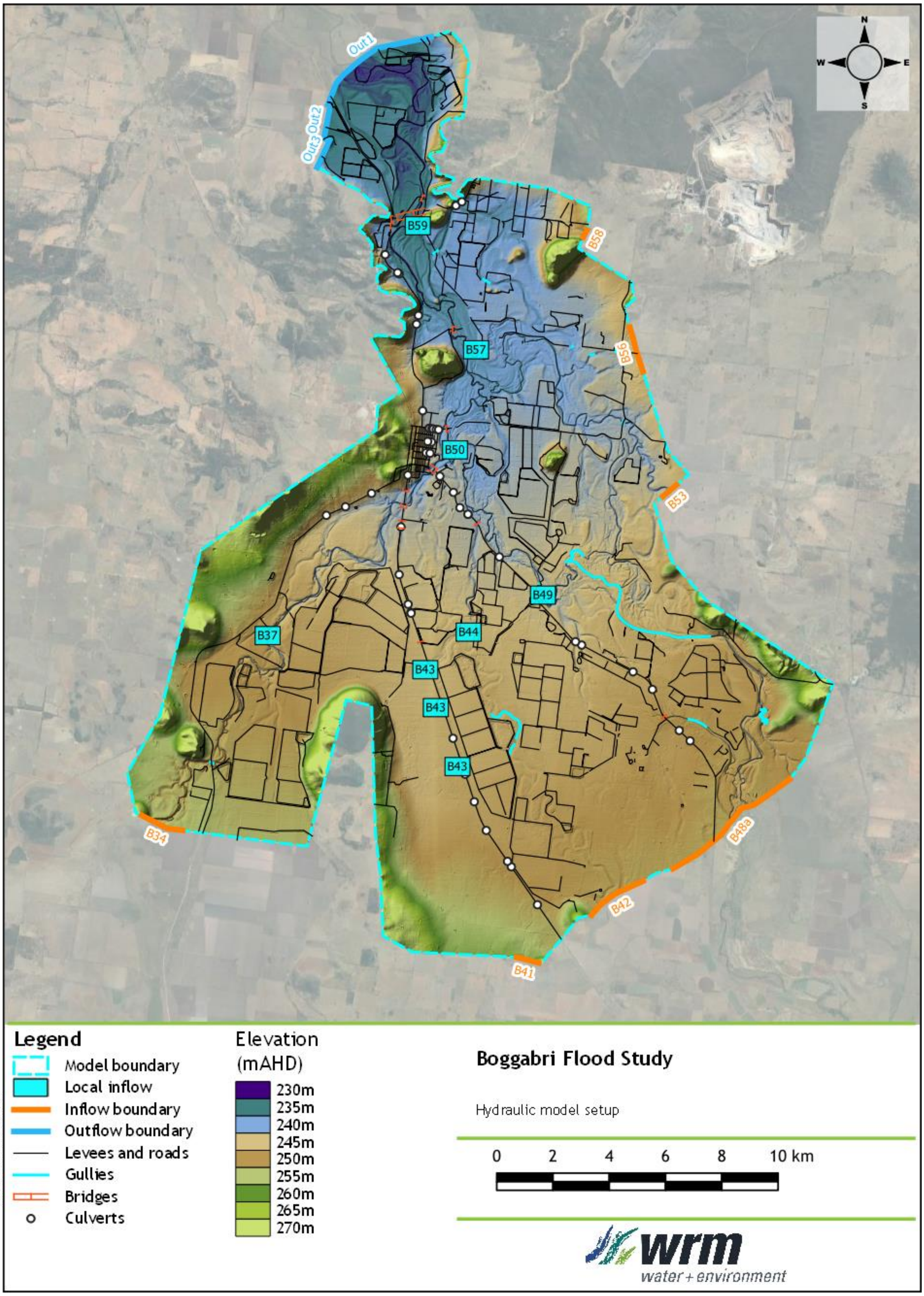


**Figure 5.1 – TUFLOW model configuration, general overview**

### 5.2.3 Manning's 'n' values

The model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). Discrete regions of continuous vegetation types and land uses were mapped, and appropriate roughness values assigned to each region. Vegetation and land use mapping were based on Google Satellite and ESRI Satellite imagery as well as the project DEM. The Manning's 'n' values were selected during model calibration and were applied to all model scenarios.

Table 5.1 shows the Manning's 'n' values adopted for use in the hydraulic model. Figure 5.2 shows the discrete regions where specific Manning's 'n' values have been applied. The dominant land use in the area of interest is for crops and has been applied for any area not discretely mapped otherwise.

**Table 5.1 – Manning's 'n' parameters**

| Region | Manning's 'n' value |
|---|---|
| Floodplain (crops) | 0.040 |
| Channel | 0.030 |
| Overbank | 0.050 |
| Vegetation | 0.070 |
| Road/rail | 0.025 |

### 5.2.4 Model boundaries

Figure 5.1 shows the locations of the inflow and outflow boundaries of the hydraulic model. Seven inflow boundaries were used to represent the Namoi River and the Coxs Creek as well as several minor watercourses draining the model. A further seven local subcatchment inflows were used within the hydrodynamic model boundary. Due to the uncertainty of the exact drainage lines in local catchment B43, the local inflow boundaries B43 were configured to proportionally distribute the inflows along the rail line. The inflow hydrographs were derived using the XP-RAFTS hydrological model described in Section 4.

Three outflow boundaries have been assigned across the Namoi River floodplain approximately 18.8 km downstream of the "Namoi River at Boggabri" (GS419012) gauge (measured along the Namoi River centreline). The outflow boundaries were specified as TUFLOW generated discharge-head (Q-H) relationships based on the tailwater slopes assigned as I = 0.01% for all outflow boundaries.

A sensitivity analysis using a downstream tailwater slope of 0.03% showed the impacts at to be negligible at the Namoi River at Boggabri gauge.

### 5.2.5 Infiltration losses

As described in Section 4.4, it was not possible to match the recorded Namoi River at Boggabri discharge hydrograph using the recorded Namoi River at Gunnedah discharge hydrograph without the inclusion of a transmission loss. To match the recorded peak, 8% of the Namoi River flow was diverted from XP-RAFTS model nodes at B45, B48 and B49 (see Figure 4.1). The TUFLOW model upstream boundary corresponds to Node B48, which means that two XP-RAFTS transmission losses of 8% have occurred prior to the flows entering the TUFLOW model.

To incorporate the remaining transmission loss in the TUFLOW model to match the third XP-RAFTS model transmission loss, the Green-Ampt infiltration model inbuilt into TUFLOW was applied. This infiltration model assumes a variation of the infiltration rate over time as a result of soils saturating at a wetting front and is based on the soil's hydraulic conductivity, suction, porosity and initial soil moisture content.

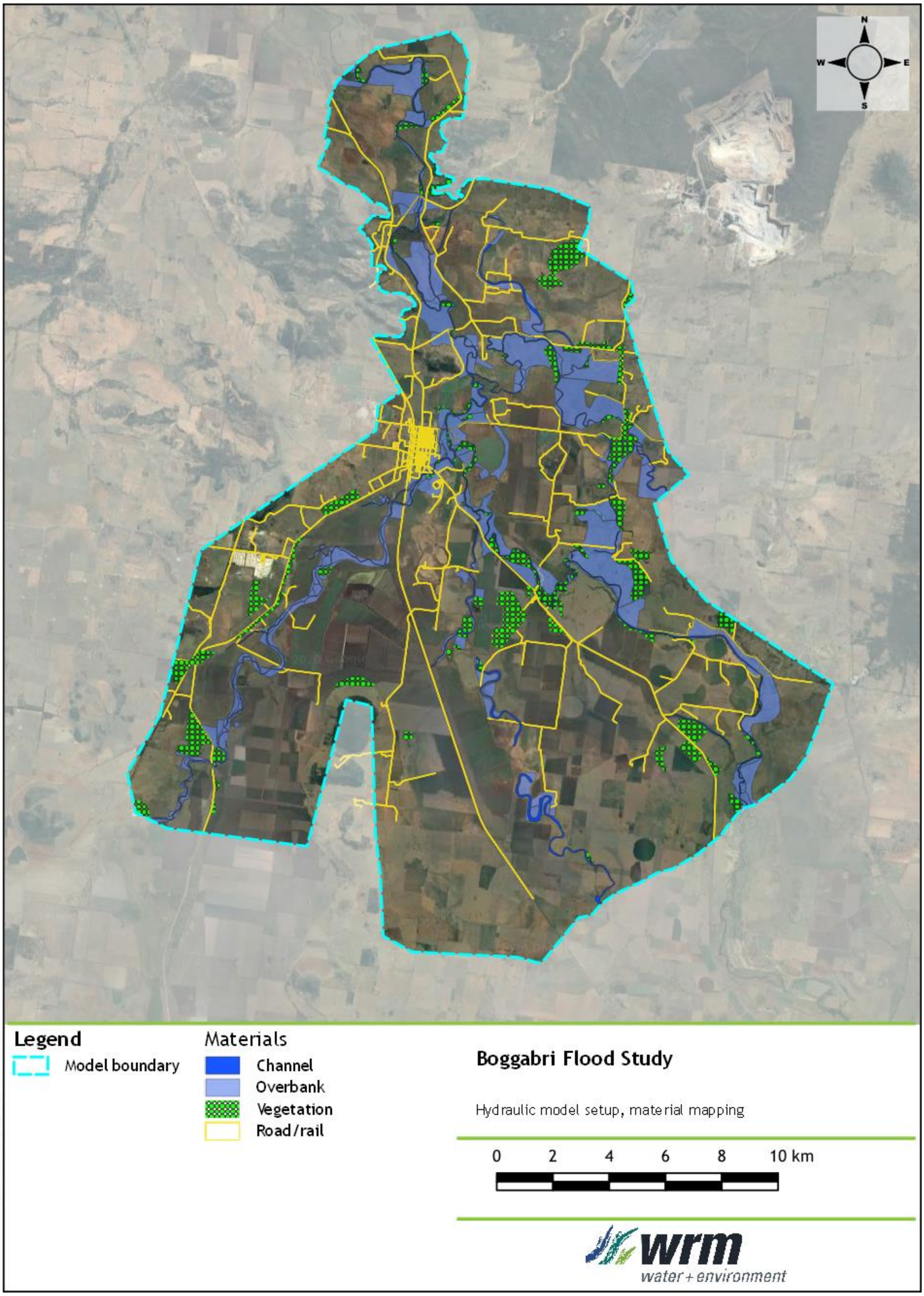


**Figure 5.2 – TUFLOW model configuration, material mapping**

According to the NSW SEED datahub (SEED, 2019), the prevailing soil type in the study area are vertosol soils with a clay content of 35%. The “clay loam” soil type as predefined by the United States Department of Agriculture (USDA), as outlined in Table 5.2, was applied to the model as a global parameter. The initial moisture content, i.e. the fraction of the soil that is initially wet, was assumed to be 0.

**Table 5.2 - Green-Ampt infiltration parameters, USDA ‘clay loam’ soil type**

| Suction (mm) | Hydraulic conductivity (mm/hr) | Porosity (fraction) |
|---|---|---|
| 208.8 | 1.0 | 0.309 |

### 5.2.6 Bridge, culvert and levee structures

Section 3.6 describes the locations and details of the bridge and structures in the study area. Culverts were modelled as 1D structures assuming a roughness value of 0.015, entry and exit loss coefficients of 0.5 and 1 respectively. Rectangular structures were modelled with height and width contraction coefficients of 0.7 and 1 respectively.

Bridge structures were modelled as layered flow constrictions within the 2D domain. Layer 1 represents the bridge piers and underside of the bridge. Layer 2 represents the bridge structure and is 100% blocked and Layer 3 represents the hand rail. Details of the modelled bridge structures is given in Table 5.3.

**Table 5.3 - Bridge structure losses**

| ID | Width (m) | Length (m) | Layer 1 (underside of bridge) | | Layer 2 (bridge structure) | | Layer 3 (handrail) | |
|---|---|---|---|---|---|---|---|---|
| | | | Obvert (mAHD) | % blockage | Structure depth (m) | % blockage | Depth (m) | % blockage |
| B01 | 3.2 | 5.2 | 247.5 | | 0.80 | 100 | | |
| B02 | 3.2 | 5.2 | 246.7 | | 0.80 | 100 | | |
| B03 | 3.2 | 7.6 | 247 | 10.5 | 0.40 | 100 | | |
| B04 | 3.2 | 3.5 | 243.9 | | 0.40 | 100 | | |
| B05 | 4 | 7.6 | 243.6 | 10.5 | 0.80 | 100 | | |
| B06 | 3.66 | 156 | 244.1 | 6.15 | 0.80 | 100 | | |
| B07 | 3.66 | 88 | 243.07 | 8.2 | 1.43 | 100 | | |
| B08 | 10 | 35 | 249.7 | 4.6 | 0.80 | 100 | 0.5 | 50 |
| B09 | 8.73 | 40.7 | 242.8 | 5.9 | 0.80 | 100 | 0.5 | 50 |
| B10 | 11.1 | 260.6 | 244.4 to 245.18 | 3.7 | 0.80 | 100 | 1 | 50 |
| B11 | 3.2 | 60 | 242.19 | 4 | 0.50 | 100 | 3 | 15 |
| B12 | 5 | 130 | 239.8 | 1.25 | 0.80 | 100 | 2 | 50 |
| B13 | 8 | 54 | 245.6 to 246.1 | 3 | 1.00 | 100 | 2 | 10 |
| B14 | 8 | 72 | 243.8 | 2.3 | 2.00 | 100 | 3 | 45 |
| B15 | 4 | 1020 | 243.8 to 244.5 | 1.9 | 2.00 | 100 | 1 | 15 |
| B16 | 10 | 54 | 235.8 | 2 | 0.80 | 100 | | |

Where the height of a structure was provided, this value added to the ground level was assumed as the obvert level of a structure (L1 obvert). Where this information was not supplied, a depth of the overlying layer (L2 depth) of 0.8 m was assumed. Bridge form loss coefficients for the bridge opening (layer 1), the bridge deck (layer 2) and the rail guards (layer 3) were assumed as 0.1, 1.56 and 0.5, respectively.

Gullies, elevated road and railways as well as levee structures in the project area were modelled as a TUFLOW Z-shape polyline with the crest or invert levels defined from the underlying DEM.

For the 1955 and 1971 calibration events, the levees were removed from the topography as it was understood they were constructed post 1971.

The Boggabri/Maules Creek rail bridge and embankment are recent developments that were not represented in the topographic data. The ground elevation has been adjusted manually to account for these changes for the post 1971 analyses.

## 5.3 MODEL CALIBRATION

Appendix B shows the flood depths, extents, and levels across the study area for the 1955, 1971, 1997, 1998 and 2000 flood event. A discussion of the model calibration for each event is given below.

### 5.3.1 February 1955 event

Figure 5.3 shows the recorded and predicted peak water level hydrographs at the Namoi River at Boggabri gauge. Table 5.4 show comparisons of TUFLOW predicted flood levels at the surveyed peak flood level locations across the floodplain for the 1955 flood. The source of the surveyed flood peaks is also shown. The locations of the surveyed points are shown in Appendix B.

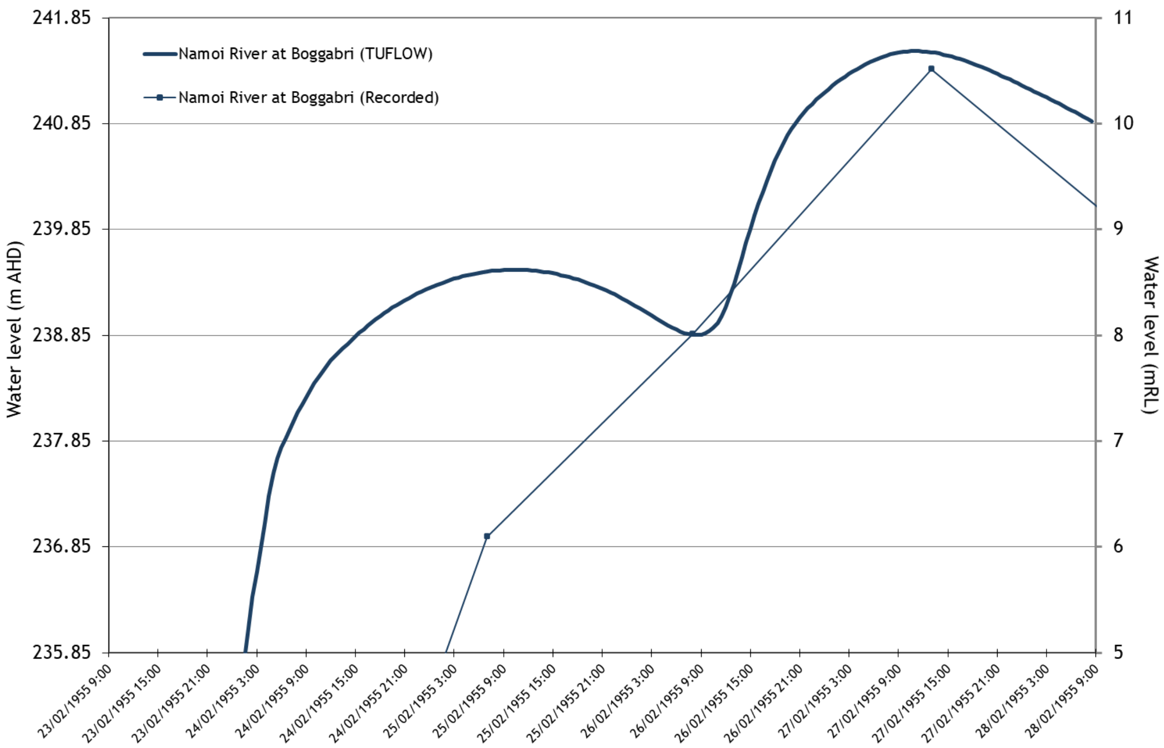


**Figure 5.3 – Recorded and predicted Namoi River at Boggabri water level hydrographs, February 1955 event**

Table 5.4 – Comparison between surveyed and predicted peak flood levels, 1955 event

| ID | Location | Source | Surveyed level (mAHD) | Predicted flood level (mAHD) | Difference (m) |
|---|---|---|---|---|---|
| 419012 | Gauge | G | 241.37 | 241.54 | 0.17 |
| A | Rail line | D | 243.65 | 243.80 | 0.15 |
| B | Derby Street | D | 243.50 | 243.54 | 0.04 |
| C | Frome Street | D | 243.45 | 243.44 | -0.01 |
| D | Grantham Street | D | 243.35 | 243.17 | -0.19 |
| E | Clare Street | D | 243.30 | 243.13 | -0.17 |
| F | Caxton Street | D | 243.20 | 243.07 | -0.13 |
| G | Brent Street | D | 243.10 | 243.07 | -0.03 |
| H | Dalton Street | D | 242.90 | 242.88 | -0.02 |
| I | Boston Street | D | 242.50 | 242.64 | 0.14 |
| J | Floodplain east | D | 243.73 | 243.83 | 0.10 |
| K | Floodplain U/S | S | 248.54 | 248.99 | 0.45 |
| L | Floodplain U/S | S | 249.96 | 250.37 | 0.41 |
| M | Floodplain U/S | S | 250.92 | 251.36 | 0.44 |
| N | Floodplain U/S | S | 249.64 | 250.41 | 0.77 |
| O | Floodplain U/S | S | 246.32 | 246.73 | 0.41 |
| P | Floodplain D/S | S | 240.30 | 240.67 | 0.37 |
| Q | Floodplain D/S | S | 239.30 | 239.58 | 0.28 |
| R | Floodplain D/S | S | 239.24 | 239.58 | 0.34 |
| S | Floodplain D/S | S | 240.80 | 240.93 | 0.13 |
| T | Floodplain D/S | S | 240.00 | 239.34 | -0.66 |

G - Gauge, D - DNR, 2007 (flood map), S - SMEC, 2003,

Data available for the calibration includes intermittent (manually read) peak flood levels at the Namoi River at Boggabri gauge as well as at 10 flood marks surveyed throughout Boggabri (see Figure 3.1) sourced from survey conducted by the then NSW Water Resources Commission (year unknown). An additional 11 peak flood levels were sourced from the SMEC (2003) study and a flood study prepared for Boggabri Coal (WRM,2009).

A good calibration was achieved for the 1955 event. At the Namoi River at Boggabri gauge, the predicted flood peak from Coxs Creek was much higher than what was recorded, likely due to the use of daily rainfalls to estimate discharges. A reduction of the model inflows at Gunnedah of approximately 10% would be required in order to meet the level at gauge.

However, the predicted and recorded Namoi River flood peak from Gunnedah, which occurred some 48 hours later, matches reasonably well. The predicted peak flood levels at Boggabri, identified by flood points A to J, vary from 0.145 m high to 0.185 m low when compared to the surveyed levels. However, the peak flood extent matches very well with Figure 3.1. Conversely, the predicted peak flood levels across the Namoi River floodplain are generally higher than the surveyed levels. While levees have been removed from the model for the 1955 calibration, changes in ground levels that have not been accounted for may also have occurred in the area, affecting the flood levels.

### 5.3.2 February 1971 event

Figure 5.4 shows the recorded and predicted peak water level hydrographs at the Namoi River at Boggabri gauge for the 1971 event. Table 5.5 show comparisons of the predicted peak flood levels and the surveyed peak flood at the gauge and another location identified on the 1955 flood map. The location of the gauge and the surveyed peak level are shown in Appendix B.

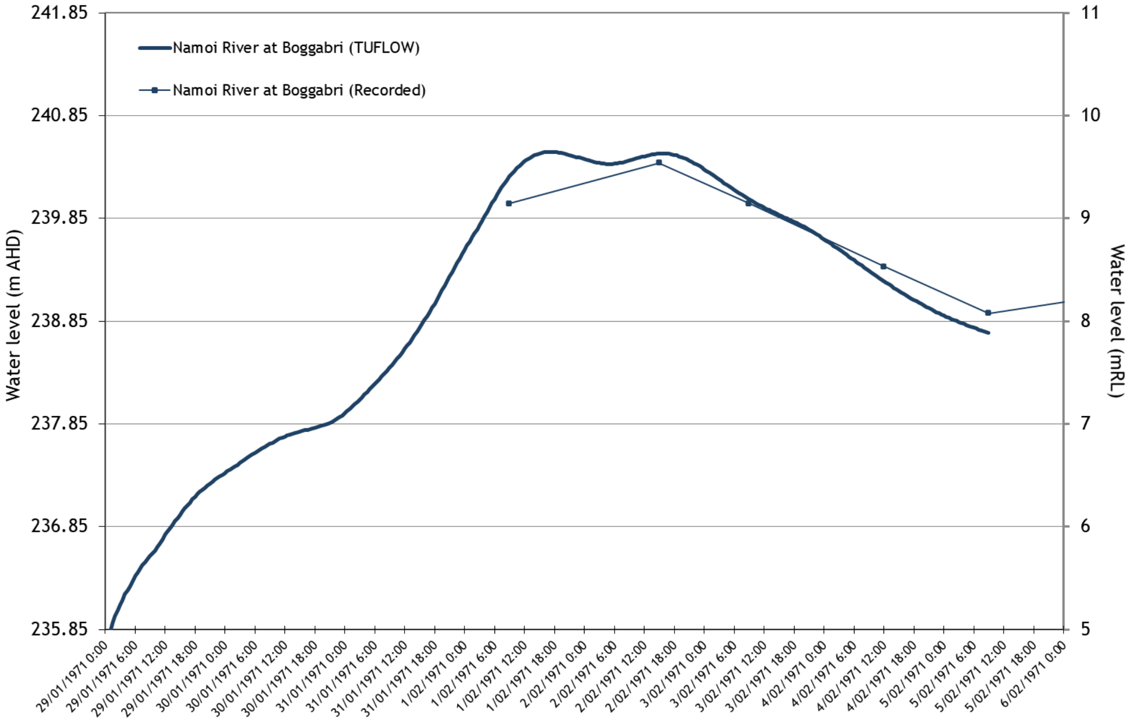


**Figure 5.4 - Recorded and predicted Namoi River at Boggabri water level hydrographs, February 1971 event**

**Table 5.5 - Comparison between surveyed and predicted peak flood levels,1971 event**

| Surveyed point | Source | Surveyed level (mAHD) | Predicted flood level (mAHD) | Difference (m) |
|---|---|---|---|---|
| 419012 | Gauge | 240.39 | 240.50 | +0.11 |
| A-71 | 1955 flood map | 242.04 | 242.93 | +0.89 |

Two flood peaks were predicted at the gauge with the first peak (from Coxs Creek) approximately equal with the second peak from the upper Namoi River. There was less than 24 hours between peaks for this event with Coxs Creek flows significantly contributing to the second Namoi River flood peak.

The calibration to the A-71 peak flood level is poor. It would appear that this level is not associated with the flood peak. Based on the notes supplied with the 1955 flood map, the flood extent shown on the 1955 flood map was taken of the 1971 event when the flood level at the Boggabri gauge was 0.4 m below the peak. The predicted flood level and flood extent corresponds very well with the surveyed flood peak and flood extent at this time.

### 5.3.3 February 1997 event

Figure 5.5 shows the recorded and predicted peak water level hydrographs at the Namoi River at Boggabri gauge for the 1997 event. The predicted water level peak is within 0.02 m of the recorded peak for this event.

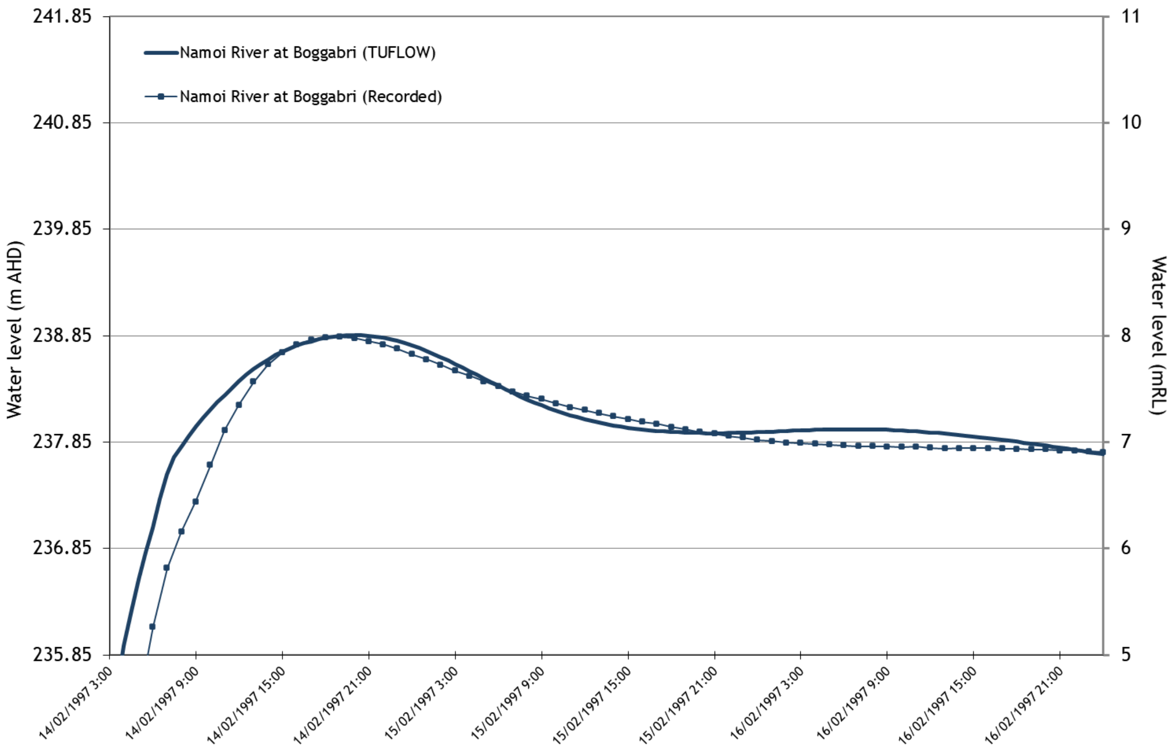


**Figure 5.5 - Recorded and predicted Namoi River at Boggabri water level hydrographs, February 1997 event**

### 5.3.4 July 1998 event

Figure 5.6 shows the recorded and predicted peak water level hydrographs at the Namoi River at Boggabri for the 1998 event. Table 5.6 show comparisons of TUFLOW predicted flood levels and the surveyed peak flood across the floodplain for the event. The source of the surveyed flood peaks is also shown. The locations of the surveyed points are shown in Appendix B.

**Table 5.6 - Comparison between surveyed and predicted peak flood levels for the 1998 event**

| Surveyed point | Source | Surveyed level (mAHD) | Predicted flood level (mAHD) | Difference (m) |
|---|---|---|---|---|
| 419012 | Gauge | 239.63 | 239.71 | 0.08 |
| A | SMEC, 2003 | 250.58 | 250.62 | 0.04 |
| B | SMEC, 2003 | 248.90 | 248.81 | -0.09 |
| C | SMEC, 2003 | 245.77 | 245.83 | 0.06 |
| D | SMEC, 2003 | 243.48 | 242.45 | -1.03 |
| E | SMEC, 2003 | 242.12 | 242.43 | 0.31 |
| F | SMEC, 2003 | 242.02 | 242.39 | 0.37 |
| G | SMEC, 2003 | 240.04 | 240.75 | 0.71 |
| H | SMEC, 2003 | 239.66 | 240.74 | 1.08 |

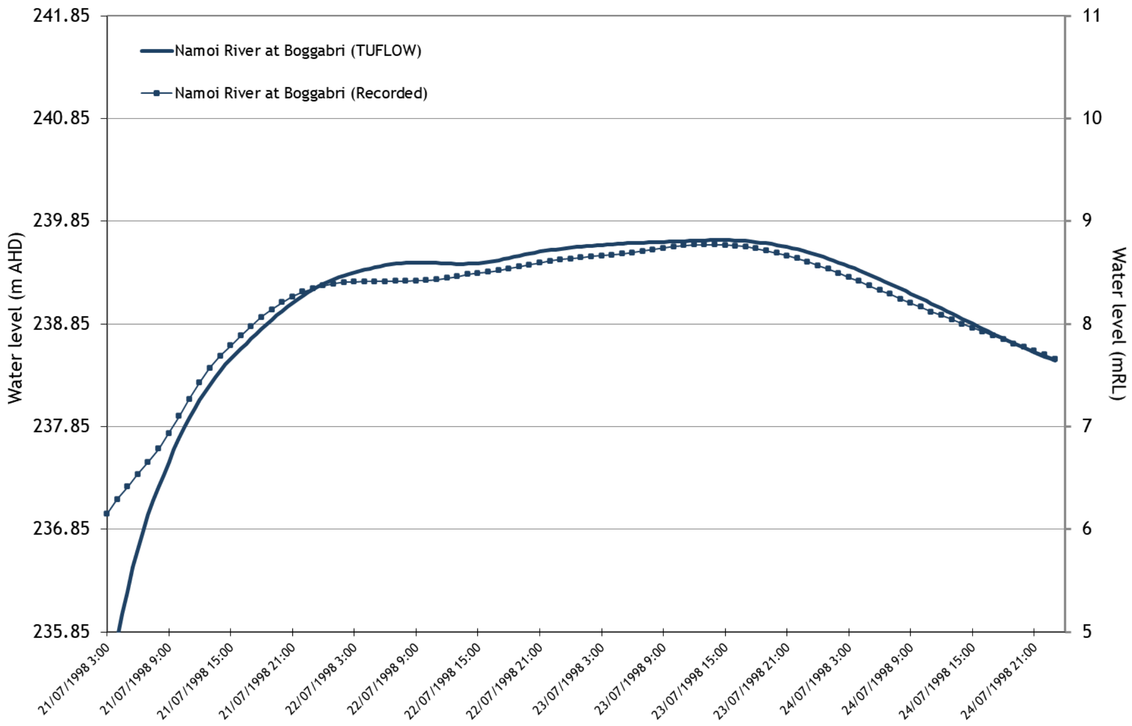


**Figure 5.6 – Recorded and predicted Namoi River at Boggabri water level hydrographs, July 1998 event**

A good calibration was achieved for the 1998 flood with predicted timings and peak flood levels in excellent agreement with the recorded values at the Namoi River at Boggabri gauge.

### 5.3.5 November 2000 event

Figure 5.7 shows the recorded and predicted peak water level hydrographs at the Namoi River at Boggabri gauge for the 2000 event. The predicted water level peak is within 0.12 m of the recorded peak for this event.

### 5.3.6 Summary

Overall, a good calibration was achieved using a single set of model parameters for all design events using both the XP-RAFTS and TUFLOW models. As shown in Table 5.7, the predicted peak discharges using the XP-RAFTS corresponds well to the recorded data, which suggests that the adopted transmission losses for the flows between Gunnedah and Boggabri are reasonable.

The predicted Namoi River at Boggabri Gauge discharges using the TUFLOW model are moderately higher than the recorded data, particularly for the 1955 event, but still reasonable. There is a high level of uncertainty surrounding the adopted peak discharge at Gunnedah for the 1995 event. The models are expected to be suitably calibrated to estimate design discharges at Boggabri.

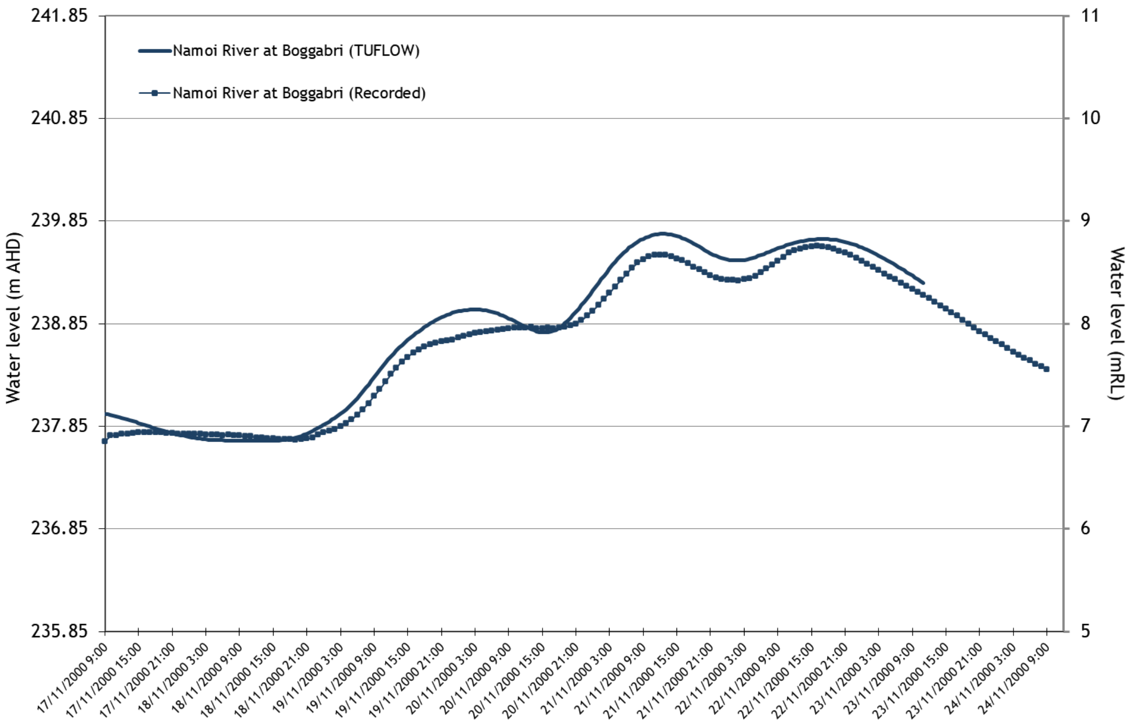


**Figure 5.7 - Recorded and predicted Namoi River at Boggabri water level hydrographs, November 2000 event**

**Table 5.7 - Historical peak discharge comparison for Namoi River at Boggabri (419012), recorded, XP-RAFTSs and TUFLOW**

| Event | Peak discharge ($m^3/s$) | | |
|---|---|---|---|
| | Recorded | XP-RAFTS | TUFLOW |
| 1955 | 6,774[a] | 6,819 (0.7%) | 7,355 (7.9%) |
| 1971 | 3,712[b] | 3,762 (1.3%) | 3,844 (3.4%) |
| 1997 | 1,253 | 1,301 (3.7%) | 1,212 (-3.4%) |
| 1998 | 2,256 | 2,191 (-3.0%) | 2,305 (2.1%) |
| 2000 | 2,227 | 2,349 (5.2%) | 2,360 (5.6%) |

[a] adjusted from 4,247 using WRM rating (see Figure 3.3)
[b] adjusted from 3,199 using WRM rating (see Figure 3.3)

# 6 Estimation of design discharges

## 6.1 FLOOD FREQUENCY AND TERMINOLOGY

In this report, the frequency of floods is referred to in terms of their Annual Exceedance probability (AEP). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (ARI). The relationship between AEP and ARI is given in Table 6.1.

**Table 6.1 – Design events investigated**

| Annual exceedance probability (AEP) % | Average recurrence interval (ARI) years |
|---|---|
| 20% | 4.48 |
| 10% | 9.49 |
| 5% | 20 |
| 2% | 50 |
| 1% | 100 |
| 0.5% | 200 |
| 0.2% | 500 |
| Probable Maximum Flood (PMF) | Theoretical maximum flood |

The AEP of a flood represents the percentage chance of its being equalled or exceeded in any one year. A 1% AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years.

## 6.2 METHODOLOGY

### 6.2.1 Overview

The model calibration showed that Boggabri is prone to flooding from both Coxs Creek and the Namoi River and the highest flood peak can occur for either source. Two flood peaks occurred for most historical floods. For all the historical floods investigated, the peak flood levels along Coxs Creek at Boggabri were dominated by Coxs Creek flows (first flood peak) and not the second peak due to backwater flooding the Namoi River. Therefore, the Coxs Creek design discharges will be determined using the calibrated XP-RAFTS model validated against design discharges estimated from an annual series flood frequency analysis (FFA) of the recorded flows at the Coxs Creek at Boggabri gauge.

Along the Namoi River at Boggabri (to the north of Caxton Street), the peak flood levels were determined by a combination of both. The Namoi River and Coxs Creek flood peaks did not coincide for any of the historical floods investigated. However, the rising limb of the upper Namoi River flood increased the first peak from Coxs Creek and the falling limb of the Coxs Creek flood increased the second Namoi River peak.

A detailed joint probability analysis between the Namoi River and Coxs Creek catchment flood events is required to provide a fully informed relationship between the two flood scenarios. For Boggabri, an annual series flood frequency analysis (FFA) of the recorded flows at the Namoi River at Boggabri gauge provides a direct measure of flood exceedance probabilities taking into consideration both sources of flooding as it is downstream of the confluence. Therefore, the FFA at the gauge provides a suitable proxy for a joint probability analysis and it provides the most appropriate methodology to determine design discharges from the Namoi River at Boggabri.

The methodology used to define the Coxs Creek and Namoi River design discharges at Boggabri is outlined below.

### 6.2.2 Coxs Creek

The calibrated XP-RAFTS model was used to estimate design discharges for Coxs Creek and the residual Namoi River catchment downstream of Gunnedah for the 20%, 10%, 5%, 2% and 1% AEP events and the PMF. The design discharges for the more frequent events were validated against the FFA design discharge estimates for the Coxs Creek at Boggabri gauge.

Design discharges were determined using the ensemble methodology defined in Australian Rainfall & Runoff (ARR) (Ball, et al, 2019). An ensemble of 10 temporal patterns is modelled for each storm duration to derive a range of estimated peak discharges for each location and AEP of interest. For each location and AEP, the storm duration with the highest median peak discharge of the ensemble is selected and the temporal pattern that produces the peak discharge just above the ensemble median is used for design event modelling.

### 6.2.3 Namoi River

The Namoi River design flood discharges were estimated by routing the Gunnedah discharge hydrograph through the XP-RAFTS model (with the Coxs Creek design rainfalls of the same AEP). The design flood discharges at the Gunnedah gauge were determined from an annual series FFA of the recorded flows with the flood hydrograph shape based on the February 1955 discharge hydrograph shape scaled to match the flood peak.

The timing of the Gunnedah flood hydrograph was adjusted within the XP-RAFTS model so that the predicted flood peak at the Namoi River at Boggabri gauge matched the design discharge at the gauge determined from an annual series FFA of the recorded flows. In effect, the flows from falling limb of the Coxs Creek flood hydrograph were used to supplement any short fall in design flows from the upper Namoi River, in a similar manner to what was observed for the calibration events.

### 6.2.4 Namoi River PMF

It is not possible to estimate the Probable Maximum Flood (PMF) using the FFA methodology at Boggabri because the PMF is beyond the credible limit of extrapolation.

The methodology recommended for the estimation of PMF in the ARR guidelines is a rainfall-based procedure. This requires the development of a rainfall runoff routing model of the entire Namoi River catchment. Given that the Namoi River catchment has average annual rainfalls varying between 650 mm and 1,300 mm, elevations varying over a range of 800 m, three large water supply dams, substantial differences in topographic and flow characteristics as well over 20 stream gauges, the development of a rainfall runoff routing model would be a substantial task and is not considered warranted.

Instead, a regression equation developed by Watt et al. (2018) was used to derive an alternative PMF discharge estimate for the Namoi River at Gunnedah, which was then routed down to Boggabri using the methodology described above. The regression equation was based on an analysis of extreme flood estimates for inflows to storages within the Coastal GTSMR region of Queensland and northern New South Wales, with catchment areas varying from less than 10 $km^2$ to over 100,000 $km^2$.

The regression equation from Watt et al. (2018) adopted for the determination of the PMF is as follows:

$$PMF = 226 \times A^{0.586}$$

where A = catchment area ($km^2$)

With a catchment area of 17,655 $km^2$ to the model inflow node at Gunnedah, the estimated PMF discharge is 69,626 $m^3/s$, or some 9.3 times the 1% AEP event at Gunnedah predicted by the FFA.

## 6.3 ANNUAL SERIES FLOOD FREQUENCY ANALYSIS

### 6.3.1 Methodology

A Log-Pearson Type III (LP III) distribution was fitted to the annual series of recorded (and inferred) peak flood discharges at the three gauges using the Bayesian inference methodology recommended in Australian Rainfall and Runoff (AR&R) (Ball et al., 2019) using the FLIKE software. This methodology allows the user to more accurately consider historic data outside the gauged record, as well as allowing the user to censor low flows to improve the fit for the larger events. The FFA was based on a calendar year.

ARR recommends the use of prior information for any FFA involving the LP III distribution unless there is evidence that the regional prior is not applicable to the catchment of interest. The prior information has been developed as part of the Regional Flood Frequency Estimation (RFFE), which calculates the mean, standard deviation and skew of the regional LP III model. The use of prior information in the FFA was found to produce a poor fit to the data and has therefore not been used for any of the gauges.

### 6.3.2 Namoi River at Boggabri gauge

Table 6.2 shows the recorded and inferred annual series data used for the FFA, together with the source of the data. The following is of note regarding the available data:

- WaterNSW website[1] was used to define annual peaks from 1979.
- Peak water levels for the 1955 and 1971 events were obtained from the Pinneena database and translated to discharges using the rating table used at that time or the TUFLOW derived rating curve shown in Figure 3.3.
- Peak annual discharges were obtained from Kinhill (1991) for the period from 1937 to 1978 (excluding 1955 and 1971) as well as the years 1913 and 1914. The recorded water levels over this period could not be obtained from Water NSW. This data was used without modification.
- SMEC (2003) provided an additional peak flood level of 10.66 m for the 1910 event. No information is given on how this data was sourced. However, it is consistent with the recorded data at Gunnedah (419001) and Narrabri (419002 & 419003). The 1910 event was assumed to be the largest event prior to 1937.
- Due to the uncertainty regarding the 1910 value it was included in the FFA as a historical event outside the period of record, exceeding the highest recorded value. Values between 1910 and 1936 were included as censored values.
- Nine low flows below 49 $m^3/s$ were censored from the dataset using the Grubbs Beck test.

Figure 6.1 shows the annual series FFA of the recorded flows at the Namoi River at Boggabri gauge (GS419012). The expected range of design discharges from the FFA is given in Table 6.3.

[1] https://realtimedata.waternsw.com.au/water.stm

**Table 6.2 – Combined data set for peak annual discharges at Namoi River at Boggabri**

| Year | Peak Discharge (m³/s) | Year | Peak Discharge (m³/s) | Year | Peak Discharge (m³/s) | Year | Peak Discharge (m³/s) |
|---|---|---|---|---|---|---|---|
| 1910 | 7,349 [s,a] | 1957 | 37 [k] | 1978 | 604 [k] | 1999 | 338 [p] |
| 1937 | 139 [k] | 1958 | 362 [k] | 1979 | 102 [w] | 2000 | 2,227 [w] |
| 1938 | 201 [k] | 1959 | 126 [k] | 1980 | 40 [w] | 2001 | 71 [w] |
| 1939 | 176 [k] | 1960 | 358 [k] | 1981 | 209 [w] | 2002 | 64 [w] |
| 1940 | 216 [k] | 1961 | 192 [k] | 1982 | 54 [w] | 2003 | 53 [w] |
| 1941 | 793 [k] | 1962 | 1,377 [k] | 1983 | 257 [w] | 2004 | 349 [w] |
| 1942 | 1,192 [k] | 1963 | 436 [k] | 1984 | 2,647 [a] | 2005 | 361 [w] |
| 1943 | 77 [k] | 1964 | 2,014 [k] | 1985 | 327 [w] | 2006 | 42 [w] |
| 1944 | 351 [k] | 1965 | 85 [k] | 1986 | 285 [w] | 2007 | 144 [w] |
| 1945 | 106 [k] | 1966 | 140 [k] | 1987 | 141 [w] | 2008 | 568 [w] |
| 1946 | 106 [k] | 1967 | 92 [k] | 1988 | 202 [w] | 2009 | 54 [w] |
| 1947 | 550 [k] | 1968 | 541 [k] | 1989 | 940 [w] | 2010 | 918 [w] |
| 1948 | 516 [k] | 1969 | 292 [k] | 1990 | 721 [w] | 2011 | 989 [w] |
| 1949 | 654 [k] | 1970 | 325 [k] | 1991 | 636 [w] | 2012 | 1,145 [w] |
| 1950 | 1,863 [k] | 1971 | 3,712 [p,a] | 1992 | 1021 [w] | 2013 | 278 [w] |
| 1951 | 300 [k] | 1972 | 83 [k] | 1993 | 338 [w] | 2014 | 49 [w] |
| 1952 | 1,091 [k] | 1973 | 141 [k] | 1994 | 20 [w] | 2015 | 23 [w] |
| 1953 | 105 [k] | 1974 | 2,234 [k] | 1995 | 158 [w] | 2016 | 436 [w] |
| 1954 | 479 [k] | 1975 | 205 [k] | 1996 | 430 [w] | 2017 | 40 [w] |
| 1955 | 6,774 [p,a] | 1976 | 2,616 [k] | 1997 | 1,253 [w] | 2018 | 41 [w] |
| 1956 | 2,824 [k] | 1977 | 1,366 [k] | 1998 | 2,256 [w] | 2019 | 47 [w] |
| | | | | | | 2020 | 190 [w] |

[S] - SMEC, 2003, [k] - Kinhill, 1991, [W] - WaterNSW, [p] - Pinneena [a] - adjusted value.

**Table 6.3 – FFA design discharge estimates, Namoi River at Boggabri**

| AEP | FFA discharge (m³/s) | | |
|---|---|---|---|
| | Expected parameter quantile | Lower 90% confidence limit | Upper 90% confidence limit |
| 20% | 981 | 734 | 1,318 |
| 10% | 1,825 | 1,337 | 2,530 |
| 5% | 3,026 | 2,126 | 4,539 |
| 2% | 5,313 | 3,406 | 9,227 |
| 1% | 7,701 | 4,527 | 15,463 |
| 0.5% | 10,789 | 5,734 | 25,517 |
| 0.2% | 16,176 | 7,458 | 46,797 |

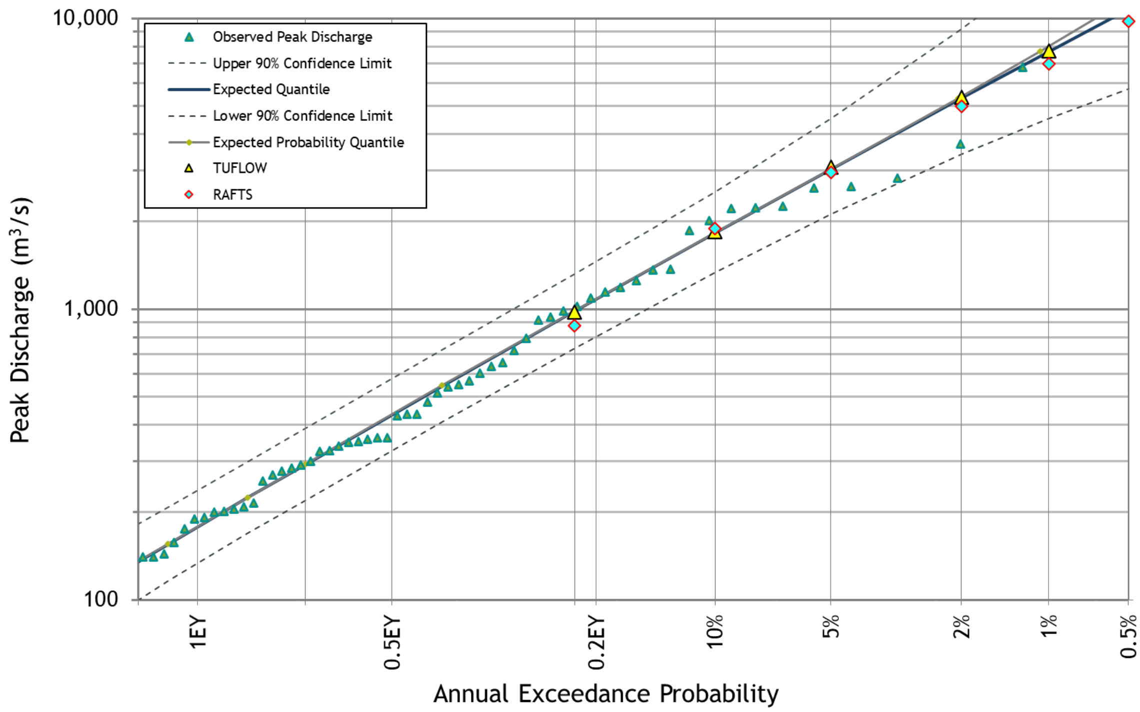


**Figure 6.1 – Namoi River at Boggabri Annual series flood frequency curve, 1937 to 2020 plus 1910**

### 6.3.3 Namoi River at Gunnedah gauge

Table 6.4 shows the recorded and inferred annual series data used for the FFA, together with the source of the data for the Namoi River at Gunnedah gauge. The following is of note regarding the available data:

- WaterNSW website data was used to define annual peaks from 1971 to present except for 1971, 1974, 1976 and 1984.
- The latest WaterNSW rating curve (Table 330.2) and the recorded peak water levels were used to adjust the peak discharges for the 1971, 1974, 1976 and 1984 events. Figure 3.2 shows that the high flow rating adopted by WaterNSW for these historical events has been superseded following more recent flood gaugings.
- Peak discharge data for 1969 and 1970 were obtained from the Pinneena database.
- Between 1893 and 1968, peak water level data supplied by WaterNSW were converted to a peak discharge using the latest WaterNSW rating curve (Table 330.2).
- For years between 1891 and 1968 where no instantaneous flood peaks were recorded, the peak daily discharge volume for each year, obtained from the Pinneena database, was converted to an instantaneous peak using the relationship shown in Figure 6.2. This relationship was determined by plotting the daily peak volume against the instantaneous peak discharge for years where data was available (1969 to 2020). A good fit or $R^2$=0.9955 was achieved for the correlation. The years where instantaneous flood peaks were not available were generally non-flood years.
- WaterNSW provided an additional peak flood level of 9.85 m for the 1864 event. SMEC (2003) note that there is no confirmation of the source of this height given that it was some 30 years prior to the gauge having been installed. With a recorded water level exceeding that of the 1955 event, the 1864 event was included in the analysis as a historical event outside the period of record, exceeding the highest recorded value. Values between 1864 and 1893 were included as censored values.

- One low flow value below 6 $m^3/s$ was censored from the dataset using the Grubbs Beck test.

**Table 6.4 – Combined data set for peak annual discharges, Namoi River at Gunnedah**

| Year | Peak Discharge ($m^3/s$) | Year | Peak Discharge ($m^3/s$) | Year | Peak Discharge ($m^3/s$) | Year | Peak Discharge ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 1893 | 449 [w] | 1925 | 97 [w] | 1957 | 38 [w] | 1989 | 748 [w] |
| 1894 | 376 [w] | 1926 | 100 [w] | 1958 | 442 [w] | 1990 | 706 [w] |
| 1895 | 226 [w] | 1927 | 174 [w] | 1959 | 137 [w] | 1991 | 656 [w] |
| 1896 | 155 [w] | 1928 | 469 [w] | 1960 | 460 [w] | 1992 | 890 [w] |
| 1897 | 338 [w] | 1929 | 258 [w] | 1961 | 193 [c] | 1993 | 117 [w] |
| 1898 | 355 [w] | 1930 | 410 [w] | 1962 | 1,024 [w] | 1994 | 22 [w] |
| 1899 | 201 [w] | 1931 | 1,037 [c] | 1963 | 397 [w] | 1995 | 73 [w] |
| 1900 | 3,000 [w] | 1932 | 159 [w] | 1964 | 2,234 [w] | 1996 | 639 [w] |
| 1901 | 362 [c] | 1933 | 536 [w] | 1965 | 49 [c] | 1997 | 503 [w] |
| 1902 | 117 [c] | 1934 | 680 [w] | 1966 | 141 [c] | 1998 | 2,633 [w] |
| 1903 | 541 [c] | 1935 | 442 [w] | 1967 | 55 [c] | 1999 | 184 [w] |
| 1904 | 367 [c] | 1936 | 422 [w] | 1968 | 594 [w] | 2000 | 2,709 [w] |
| 1905 | 92 [c] | 1937 | 190 [w] | 1969 | 217 [p] | 2001 | 91 [w] |
| 1906 | 35 [c] | 1938 | 261 [w] | 1970 | 386 [p] | 2002 | 118 [w] |
| 1907 | 751 [c] | 1939 | 224 [w] | 1971 | 3,069 [a] | 2003 | 38 [w] |
| 1908 | 5,777 [w] | 1940 | 348 [w] | 1972 | 79 [w] | 2004 | 405 [w] |
| 1909 | 483 [c] | 1941 | 962 [c] | 1973 | 137 [w] | 2005 | 110 [w] |
| 1910 | 4,618 [w] | 1942 | 842 [w] | 1974 | 1,861 [a] | 2006 | 46 [w] |
| 1911 | 398 [c] | 1943 | 387 [w] | 1975 | 243 [w] | 2007 | 169 [w] |
| 1912 | 65 [w] | 1944 | 433 [w] | 1976 | 2,459 [a] | 2008 | 836 [w] |
| 1913 | 449 [w] | 1945 | 354 [w] | 1977 | 997 [w] | 2009 | 23 [w] |
| 1914 | 51 [w] | 1946 | 114 [w] | 1978 | 643 [w] | 2010 | 705 [w] |
| 1915 | 368 [w] | 1947 | 345 [w] | 1979 | 153 [w] | 2011 | 874 [w] |
| 1916 | 528 [w] | 1948 | 418 [w] | 1980 | 41 [w] | 2012 | 987 [w] |
| 1917 | 571 [w] | 1949 | 558 [w] | 1981 | 139 [w] | 2013 | 309 [w] |
| 1918 | 376 [w] | 1950 | 1,863 [w] | 1982 | 79 [w] | 2014 | 55 [w] |
| 1919 | 68 [w] | 1951 | 378 [c] | 1983 | 233 [w] | 2015 | 32 [w] |
| 1920 | 842 [w] | 1952 | 680 [w] | 1984 | 2,636 [a] | 2016 | 436 [w] |
| 1921 | 1,299 [w] | 1953 | 107 [w] | 1985 | 350 [w] | 2017 | 46 [w] |
| 1922 | 126 [w] | 1954 | 477 [w] | 1986 | 338 [w] | 2018 | 48 [w] |
| 1923 | 300 [w] | 1955 | 5,556 [w] | 1987 | 83 [w] | 2019 | 6 [w] |
| 1924 | 410 [w] | 1956 | 2,639 [w] | 1988 | 119 [w] | 2020 | 159 [w] |

[w] – WaterNSW, [p] – Pinneena, [c] – correlation, [a] – adjusted

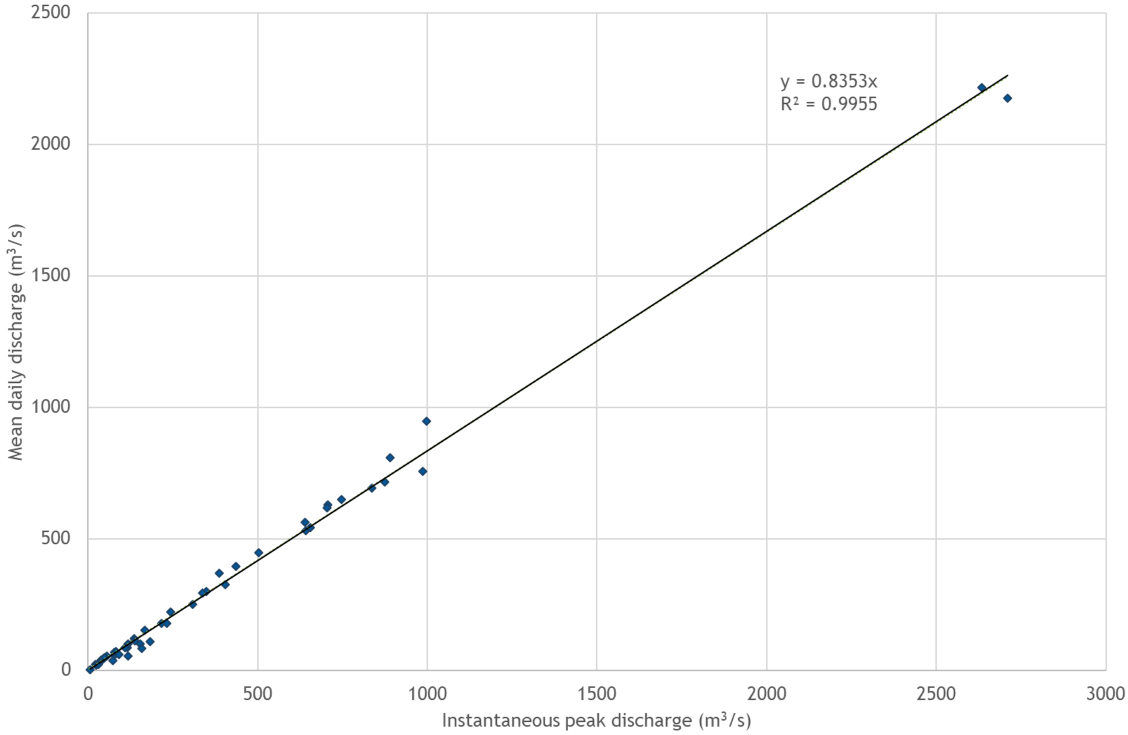


**Figure 6.2 – Namoi River at Gunnedah relationship between instantaneous flood peak discharge and mean daily discharge, 1969 to 2020**

Figure 6.3 shows the annual series FFA of recorded flows at the Namoi River at Gunnedah gauge (GS419001). The expected range of design discharges from the FFA is given in Table 6.5.

**Table 6.5 – FFA design discharge estimates, Namoi River at Gunnedah**

| AEP | FFA discharge ($m^3/s$) | | |
|---|---|---|---|
| | Expected parameter quantile | Lower 90% confidence limit | Upper 90% confidence limit |
| 20% | 943 | 756 | 1,191 |
| 10% | 1,727 | 1,336 | 2,299 |
| 5% | 2,867 | 2,121 | 4,075 |
| 2% | 5,117 | 3,501 | 8,075 |
| 1% | 7,566 | 4,857 | 12,993 |
| 0.5% | 10,860 | 6,515 | 20,371 |
| 0.2% | 16,908 | 9,181 | 35,873 |

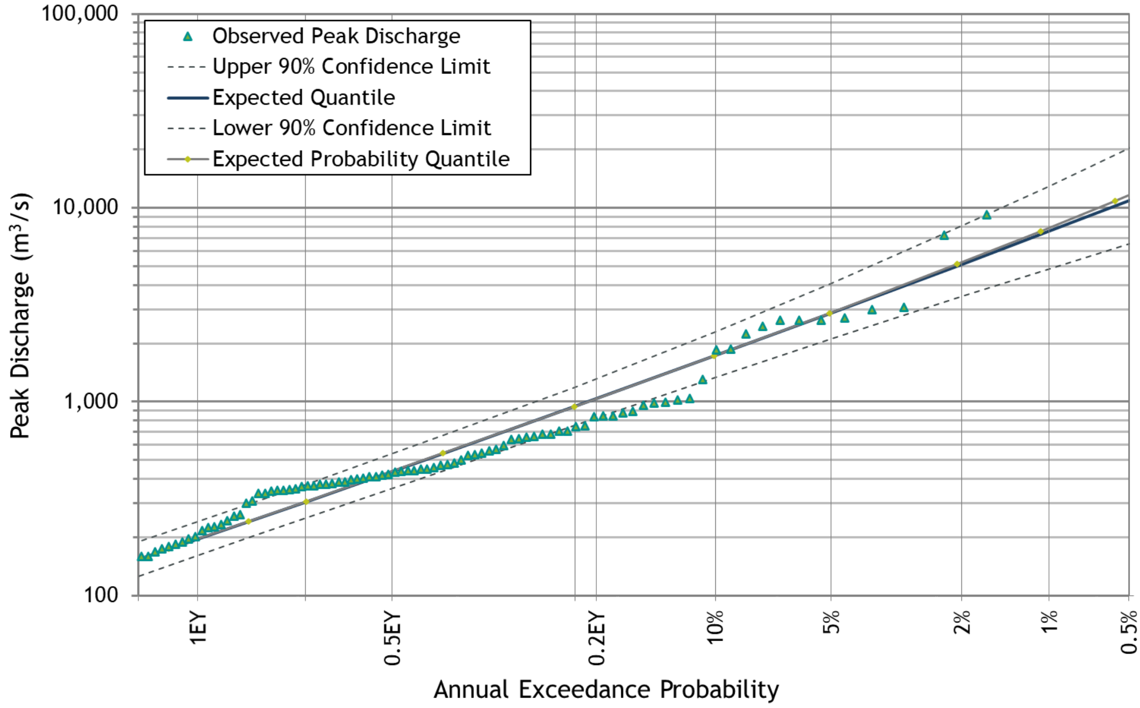


**Figure 6.3 - Namoi River at Gunnedah annual series flood frequency curve, 1891 to 2020 plus 1864**

### 6.3.4 Coxs Creek at Boggabri

Table 6.6 shows the recorded and inferred annual series data used for the FFA, together with the source of the data for the Coxs Creek at Boggabri gauge.

**Table 6.6 - Combined data set for peak annual discharges at Coxs Creek at Boggabri**

| Year | Peak Discharge ($m^3/s$) | Year | Peak Discharge ($m^3/s$) | Year | Peak Discharge ($m^3/s$) | Year | Peak Discharge ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 1965 | 74 [k] | 1979 | 9 [w] | 1993 | 312 [w] | 2007 | 135 [w] |
| 1966 | 35 [k] | 1980 | 4 [w] | 1994 | 5 [w] | 2008 | 58 [w] |
| 1967 | 145 [k] | 1981 | 143 [w] | 1995 | 186 [w] | 2009 | 56 [w] |
| 1968 | 160 [k] | 1982 | 4 [w] | 1996 | 311 [w] | 2010 | 565 [w] |
| 1969 | 182 [k] | 1983 | 187 [w] | 1997 | 1,271 [a] | 2011 | 177 [w] |
| 1970 | 20 [k] | 1984 | 1,246 [a] | 1998 | 1,276 [a] | 2012 | 224 [w] |
| 1971 | 1,545 [k] | 1985 | 44 [w] | 1999 | 318 [w] | 2013 | 368 [w] |
| 1972 | 59 [k] | 1986 | 5 [w] | 2000 | 1,287 [a] | 2014 | 11 [w] |
| 1973 | 114 [k] | 1987 | 137 [w] | 2001 | 6 [w] | 2015 | 0 [w] |
| 1974 | 1,539 [k] | 1988 | 187 [w] | 2002 | 15 [w] | 2016 | 113 [w] |
| 1975 | 78 [k] | 1989 | 609 [w] | 2003 | 11 [w] | 2017 | 0 [w] |
| 1976 | 654 [k] | 1990 | 702 [w] | 2004 | 207 [w] | 2018 | 0 [w] |
| 1977 | 480 [k] | 1991 | 562 [w] | 2005 | 320 [w] | 2019 | 82 [w] |
| 1978 | 128 [w] | 1992 | 804 [w] | 2006 | 0 [w] | 2020 | 199 [w] |

[W] - WaterNSW, [p] - Pinneena, [k] - Kinhill, 1991, [a] - adjusted

The following is of note regarding the available data:

- WaterNSW website data was used to define annual peaks from 1978 to present except for 1984, 1997, 1998 and 2000.
- The latest WaterNSW rating curve (Table 126) and the recorded peak water level were used to adjust the peak discharges for the 1984 event. Figure 3.4 shows that the high flow rating adopted by WaterNSW for this historical event has been superseded following more recent flood gaugings.
- Between 1965 and 1977, peak annual discharges were obtained from Kinhill (1991). The Kinhill (1991) peaks for 1971 and 1974 were adjusted by first converting the discharge to a water level using the rating in place at that time (Table 95) and then reconverting these water levels to a discharge using the latest WaterNSW rating curve (Table 126). The recorded water levels over this period could not be obtained from WaterNSW.
- The 1955 peak discharge was determined by calibrating the flood models to the surveyed floodmarks in Boggabri (shown in Figure 3.1). It was included in the FFA as a historical event outside the period of record, exceeding the highest recorded value. Values between 1955 and 1965 were included as censored values.
- 15 low flows below 35 $m^3/s$ were censored from the dataset using the Grubbs Beck test.

Figure 6.4 shows the annual series FFA of recorded flows at the Coxs Creek at Boggabri gauge (GS419032) The expected range of design discharges from the FFA is given in Table 6.7.

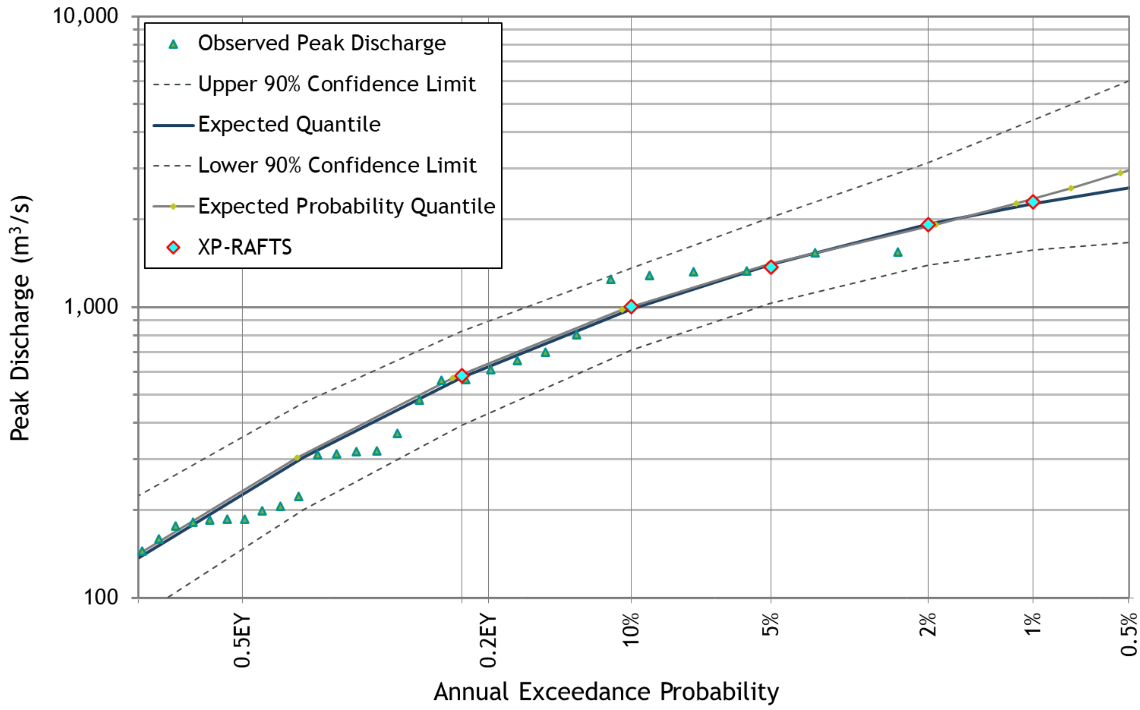


**Figure 6.4 - Coxs Creek at Boggabri annual series flood frequency curve, 1965 to 2020 plus 1955**

Table 6.7 – FFA design discharge estimates, Coxs Creek at Boggabri

| AEP | FFA discharge ($m^3/s$) | | |
|---|---|---|---|
| | Expected parameter quantile | Lower 90% confidence limit | Upper 90% confidence limit |
| 20% | 571 | 392 | 827 |
| 10% | 983 | 713 | 1,361 |
| 5% | 1,405 | 1,033 | 2,038 |
| 2% | 1,924 | 1,391 | 3,134 |
| 1% | 2,268 | 1,568 | 4,407 |
| 0.5% | 2,566 | 1,666 | 6,016 |
| 0.2% | 2,891 | 1,732 | 8,529 |

## 6.4 DESIGN EVENT MODELLING

### 6.4.1 Design rainfalls

Table 6.8 show the design rainfalls for the Coxs Creek to Boggabri catchment. Design rainfall for events up to the 0.2% AEP event were obtained from BOM[2] (2016 design rainfalls) for the centroid of the Coxs Creek catchment (Lat: -31.205, Lon: 149.835) on 1st October 2020.

Table 6.8 - Coxs Creek to Boggabri catchment design rainfalls

| Duration (hrs) | Rainfall depth (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP | PMP |
| 6 | 58.8 | 69.5 | 80.1 | 94.8 | 106 | 119 | 135 | - |
| 9 | 67.6 | 79.5 | 91.4 | 108 | 121 | 135 | 153 | - |
| 12 | 74.7 | 87.8 | 101 | 119 | 133 | 148 | 169 | 615 |
| 18 | 85.9 | 101 | 117 | 137 | 154 | 172 | 196 | - |
| 24 | 94.6 | 112 | 129 | 153 | 172 | 192 | 220 | 730 |
| 30 | 102 | 121 | 140 | 167 | 188 | 210 | 241 | - |
| 36 | 107 | 128 | 150 | 179 | 202 | 227 | 261 | 850 |
| 48 | 117 | 141 | 166 | 199 | 226 | 254 | 294 | 960 |

The probable maximum precipitation (PMP) rainfall depths were estimated using the generalised tropical storm method revised (GTSMR), (BOM, 2003b) from the Bureau of Meteorology (BOM). The parameters used to determine GTSMR rainfalls include:

- Located in the coastal zone;
- Annual Moisture Adjustment Factor, AMAF equals to 0.64;
- Winter Moisture Adjustment Factor, WMAF equals to 0.60;
- Decay Amplitude Factor, DAF equals to 0.82;
- Topographical Adjustment Factor (TAF) equals to 1.25.

2 http://www.bom.gov.au/water/designRainfalls/revised-ifd/

Note that aerial reduction factors are already applied to the PMP rainfalls due to the catchment area already being incorporated into the PMP rainfall estimation methodology. For the storms up to and including the 0.2% AEP event, aerial reduction factors have been applied depending on AEP and duration as outlined in the ARR guidelines (Ball et al., 2019).

### 6.4.2 Selection of appropriate rainfall losses

The NSW Office of Environment and Heritage (OEH) in conjunction with WMA Water (2019) have reviewed the ARR design inputs for use in design flood estimation in NSW. This review was to address concerns raised by practitioners of the underestimation bias in the standard ARR 2016 methodology for deriving design events and to develop advice on any changes needed in the methods or parameters used for flood estimation in NSW.

The study recommended that practitioners use the average of calibration losses from the actual study if available. For Boggabri, the initial losses for the three calibration events with short duration rainfall data (1997,1998 and 2000) ranged from 15 mm to 52 mm and the continuing loss ranged from 1 mm/hr to 2 mm/hr. In comparison, the ARR datahub initial loss for the catchment is 46 mm (excluding pre-burst). The ARR data hub continuing loss is 1.9 mm/hr.

For this study, the rainfall losses have been derived by matching the XP-RAFTS design discharges to the FFA discharges at Coxs Creek at Boggabri gauge (419032). The losses for the 0.5% and 0.2% AEP events were logarithmically interpolated using the methodology described in ARR (Ball et al., 2019), with an AEP of the PMP determined to be 1 in 250,000 based on the Coxs Creek catchment size. The adopted rainfall losses for each event are given in Table 6.9.

**Table 6.9 - Adopted rainfall losses**

| Design event (AEP) | Initial loss (mm) | Continuing loss (mm/hr) |
|---|---|---|
| 20% | 66 | 2.0 |
| 10% | 66 | 2.0 |
| 5% | 66 | 2.0 |
| 2% | 53 | 2.0 |
| 1% | 53 | 2.0 |
| 0.5%* | 30.4 | 1.5 |
| 0.2%* | 14.6 | 1.1 |
| PMF | 0 | 0 |

*interpolated

### 6.4.3 Coxs Creek design discharge comparison

Table 6.10 show the design discharges for the Coxs Creek at Boggabri estimated using the XP-RAFTS model together with the corresponding critical durations and temporal patterns. Comparisons to the FFA design discharge estimates are also shown. The comparisons are shown graphically in Figure 6.4.

The table shows that the two discharge estimates are consistent for the 20%, 10%, 5% and 2% AEP events but the XP-RAFTs discharges are moderately higher for the larger events but are still within the confidence limits of the FFA estimate. Given the limited period of record available, the confidence limits for the extreme event are large due to the high level of uncertainty. On this basis, the XP-RAFTS discharges have been adopted for the assessment of Coxs Creek flows.

Table 6.10 – XP-RAFTS and FFA design discharge comparison, Coxs Creek at Boggabri

| AEP | XP-RAFTS | | | FFA discharge ($m^3/s$) | | |
|---|---|---|---|---|---|---|
| | Design discharge ($m^3/s$) | Critical duration (hours) | Corresponding Temporal Pattern | Expected parameter quantile | Lower 90% confidence limit | Upper 90% confidence limit |
| 20% | 582 | 36 | 8 | 571 | 392 | 827 |
| 10% | 1,003 | 48 | 9 | 983 | 713 | 1,361 |
| 5% | 1,373 | 48 | 9 | 1,405 | 1,033 | 2,038 |
| 2% | 1,920 | 24 | 3 | 1,924 | 1,391 | 3,134 |
| 1% | 2,303 | 24 | 3 | 2,268 | 1,568 | 4,407 |
| 0.5% | 3,480 | 24 | 9 | 2,566 | 1,666 | 6,016 |
| 0.2% | 4,760 | 24 | 5 | 2,891 | 1,732 | 8,529 |
| PMF | 23,670 | 36 | GTSMR | - | - | - |

### 6.4.4 Namoi River at Gunnedah hydrograph

Figure 6.5 shows the shape of the recorded discharge hydrographs at the Namoi River at Gunnedah gauge for five historical events. For ease of comparison, each hydrograph has been scaled to peak at a discharge of one. The results show that the shapes of the top half of the historical floods (0.5 to 1 discharge unit) are relatively similar particularly for the rising limb. There is considerable variation at the lower half of the hydrograph, which is of less relevance for design event modelling. Given that the 1955 flood was the largest recorded flood on record, the 1955 event hydrograph shape was adopted with the flood peak scaled to match the FFA discharges given in Table 6.5.

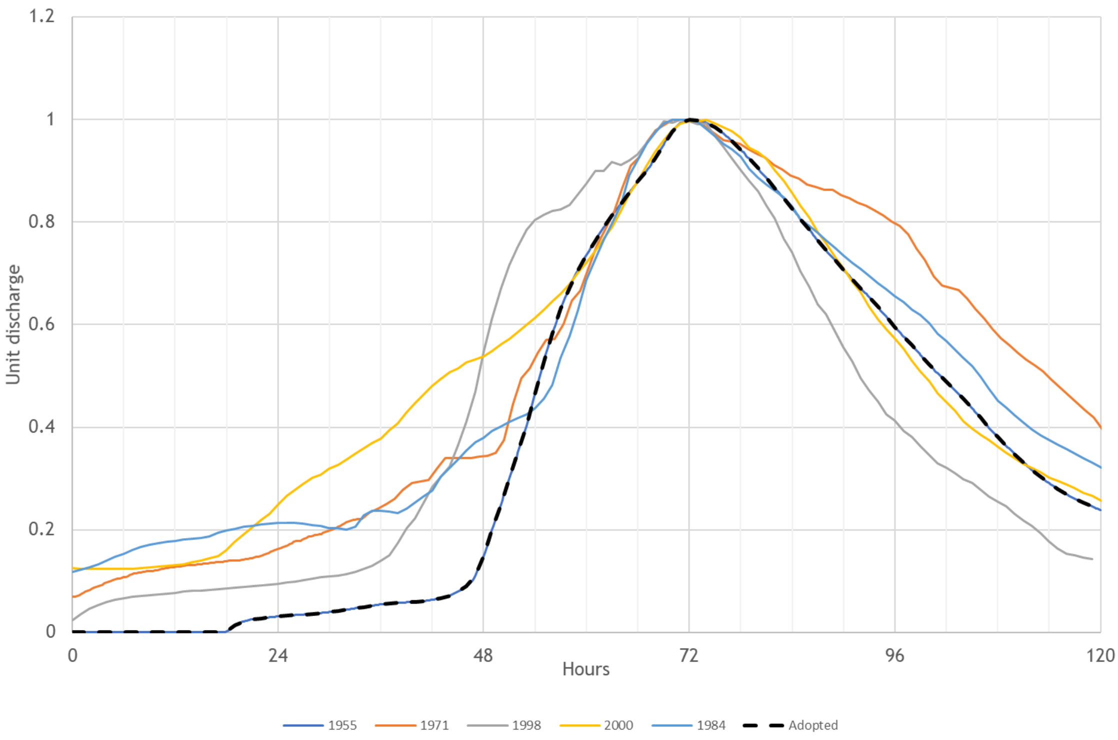


Figure 6.5 – Historical event discharge hydrograph shape, Namoi River at Gunnedah

### 6.4.5 Namoi River at Boggabri design discharge comparison

Table 6.10 shows the design discharges for the Namoi River at Boggabri estimated using the XP-RAFTS model and the TUFLOW model. Comparisons to the FFA design discharge estimates are also shown. The comparisons are shown graphically in Figure 6.1.

The TUFLOW model, which includes more detailed routing and infiltration/transmission losses than the XP-RAFTS model, produces design discharges that are very similar to the FFA for all design events. Overall, the adopted methodology would appear suitable to define flood discharges from both Coxs Creek and the Namoi River at Boggabri.

**Table 6.11 – XP-RAFTS, TUFLOW and FFA design discharge comparison, Namoi River at Boggabri**

| AEP | XP-RAFTS | TUFLOW | FFA discharge ($m^3/s$) | | |
|---|---|---|---|---|---|
| | Design discharge ($m^3/s$) | Design discharge ($m^3/s$) | Expected parameter quantile | Lower 90% confidence limit | Upper 90% confidence limit |
| 20% | 880 | 977 | 981 | 734 | 1,318 |
| 10% | 1,895 | 1,845 | 1,825 | 1,337 | 2,530 |
| 5% | 2,946 | 3,074 | 3,026 | 2,126 | 4,539 |
| 2% | 4,977 | 5,373 | 5,313 | 3,406 | 9,227 |
| 1% | 6,994 | 7,744 | 7,701 | 4,527 | 15,463 |
| 0.5% | 9,758 | 10,760 | 10,789 | 5,734 | 25,517 |
| 0.2% | 14,803 | 16,151 | 16,176 | 7,458 | 46,797 |
| PMF | 72,964 | 71,194 | - | - | - |

# 7 Design event flood mapping

## 7.1 OVERVIEW

The calibrated hydrological and hydraulic models and the design event methodology, described in Section 6.2, has been used to estimate peak depths, levels and extent of flooding for the eight design events from both Namoi River and Coxs Creek.

Predicted flood extents, depths and flood contours for the eight design events are shown in Appendix C.

## 7.2 DESIGN FLOOD LEVELS

Figure 7.1 shows the longitudinal profile along the centre line of Coxs Creek and the Namoi River adjacent to Boggabri for design events ranging from the 20% AEP to the 0.2% AEP. The section commences upstream of the railway on Coxs Creek and extends downstream of Braymont Road. The longitudinal profile for the February 1955 event is also shown.

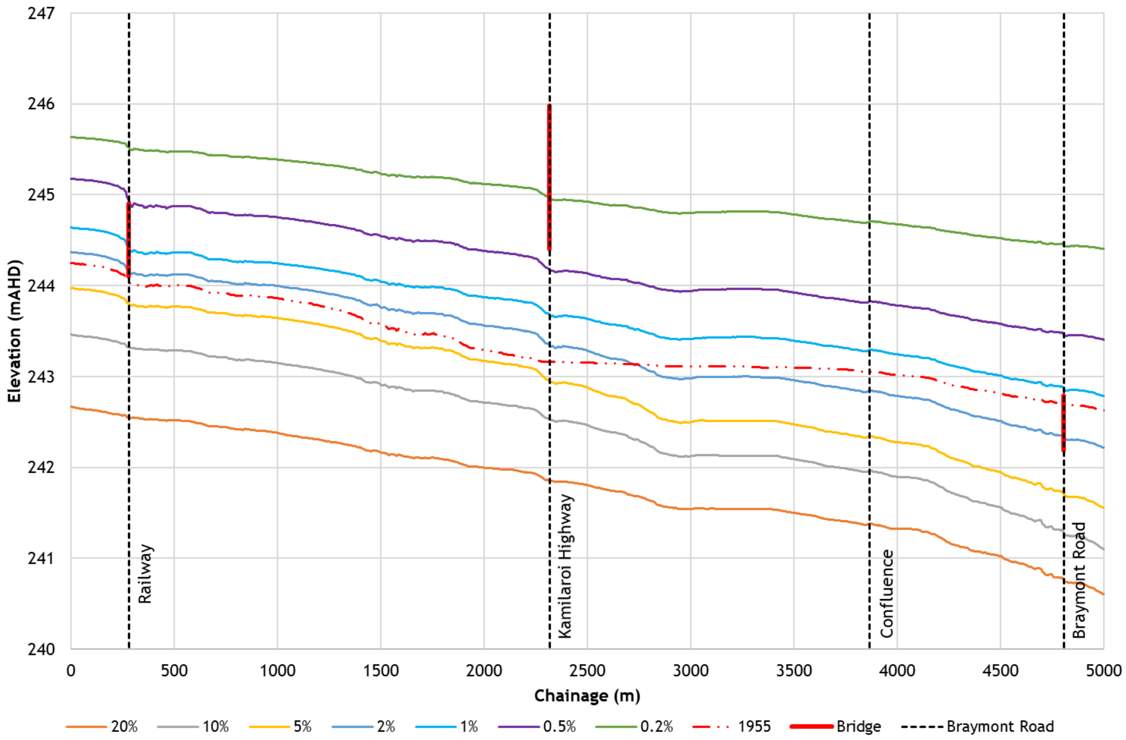


**Figure 7.1 – Design and historical event longitudinal flood profiles, Coxs Creek and Namoi River**

The following is of note:

- The longitudinal sections show that Coxs Creek flows dominate peak flood levels upstream of the Kamilaroi Highway and for about 600 m downstream and the Namoi River flows dominate peak flood levels below this location.
- For the 20%, 10% and 5% AEP events, property inundation in Boggabri is limited to yard flooding of properties on the southern end of Derby Street and Merton Street. The Kamilaroi Highway to Gunnedah would be inundated to shallow depths.

- For the larger events, the peak flows extend into the eastern streets of Boggabri. Properties along the Kamilaroi Highway to the east of Coxs Creek would be inundated.
- Substantial inundation would occur for the PMF with most of the town inundated.

## 7.3 SENSITIVITY ANALYSIS

### 7.3.1 Changes in floodplain roughness

The hydraulic model was used to assess the sensitivity of peak flood levels to changes in floodplain roughness for the 1% AEP event. For the purposes of this assessment the adopted Manning's 'n' values were increased by 25%. The results of the sensitivity analysis showing the increased flood levels for the 1% AEP flood event are shown in Figure 7.2.

The results indicate that a change in floodplain roughness would increase peak 1% AEP flood levels across the study by up to 0.3 m. Note that the floodplain roughness values have been calibrated to five historical floods and as such, this increase would not be expected.

### 7.3.2 Climate change

#### 7.3.2.1 Overview

Climate change projections vary from source to source, with almost all projections agreeing rainfall intensities will increase across much of Australia as time progresses. Changes to rainfall intensity will impact on flooding characteristics in and around Boggabri and these changes need to be considered as part of the flood risk management process.

#### 7.3.2.2 Research

The NSW and ACT Regional Climate Modelling (NARCliM) project is a multi-agency research partnership tasked with providing regional climate projections (NSW Government, 2014). NARCliM modelling has predicted increased maximum and minimum temperatures both in the near future (2020-2039) and far future (2060-2079) for all of NSW (NSW Government, 2014). More hot days are predicted as are extensive seasonal shifts in rainfall (NSW Government, 2014).

Modelling conducted by CSIRO and BOM (2015) predicts the following for Boggabri (Central Slope Region):

1. decreased average winter and spring rainfalls, with changes to summer and autumn rainfalls unclear;
2. increased minimum, mean and maximum temperatures;
3. more hot days and fewer frosts;
4. increased rainfall intensity; and
5. increased potential evapotranspiration across all seasons.

The latest advice on climate change given in Australian Rainfall and Runoff (Ball et al., 2019) recommends adoption of 4.5 and 8.5 representative concentration pathways (RCPs) from the climate futures tool developed by CSIRO. RCP4.5 and RCP8.5 represent low and high projected changes from global climate models. The 2090 planning horizon has RCP4.5 (low) and RCP8.5 (high) projected changes in rainfall intensity for the Central Slopes region of +10.8% and +22.8% respectively (Geoscience Australia, 2019).

#### 7.3.2.3 Approach

The NSW Office of Environment and Heritage (NSW Government, 2019) has produced a guideline for incorporating the latest version of AR&R into NSW floodplain risk management studies. For consideration of climate change this document specifies:

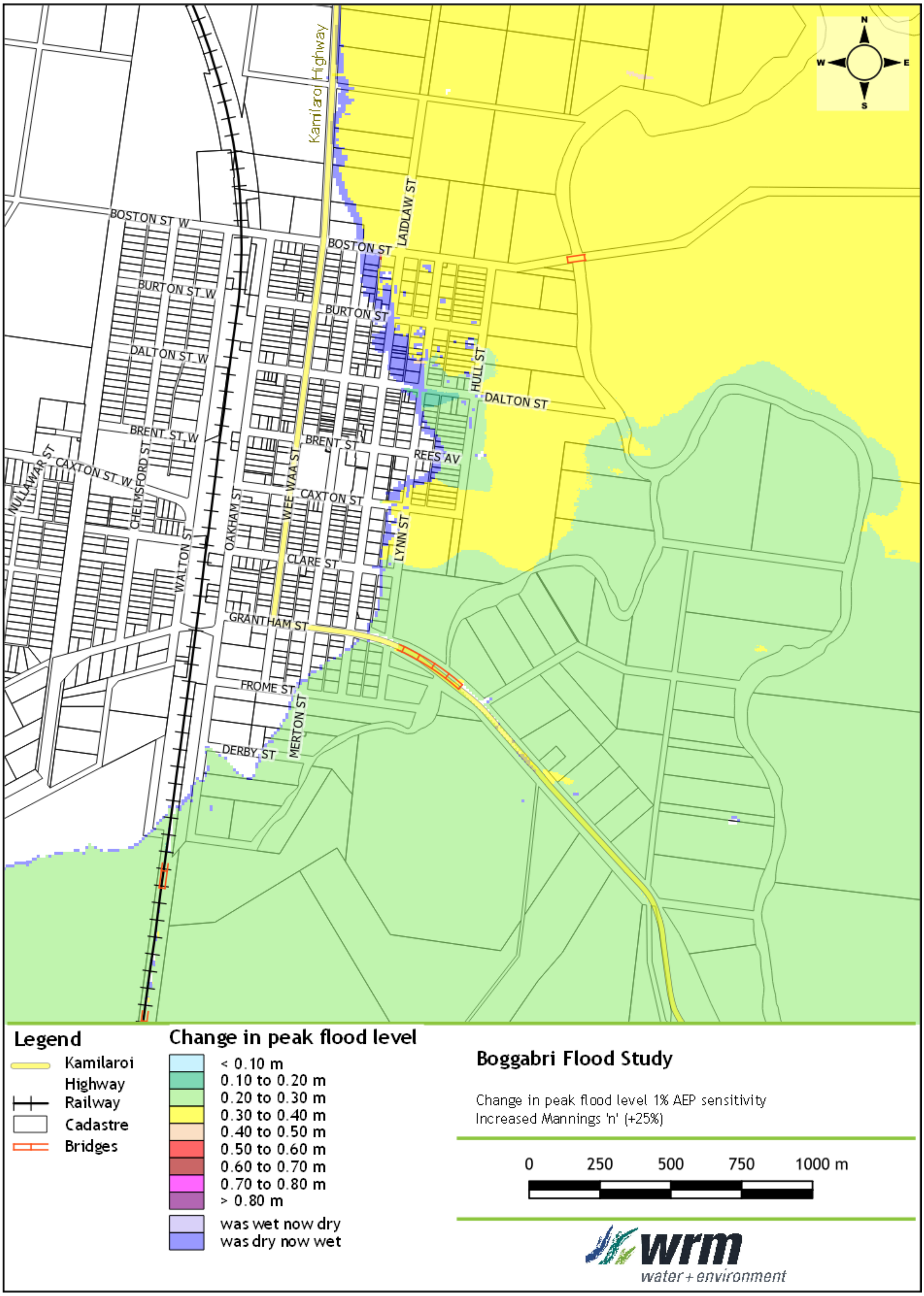


**Figure 7.2 – Hydraulic model sensitivity to a 25% increase in Manning's roughness, 1% AEP event**

*Rather than simulating additional scenarios specifically to consider climate change, the scale of climate change impacts can generally be practically assessed using the 0.5% and 0.2% AEP floods as proxies for the 1% AEP flood, subject to long-term changes in flood-producing rainfall events related to climate change.*

#### 7.3.2.4 Impact on flood levels

The critical duration 0.5% AEP rainfall for the Coxs Creek to Boggabri is approximately 11% higher than the 1% AEP rainfall, while the critical duration 0.2% AEP rainfall is approximately 28% higher than the 1% AEP rainfall. Hence the advice given above from AR&R (Ball et al., 2019) and Geoscience Australia (2019) suggests that the 1% AEP (climate change) rainfall intensities lie somewhere between the 0.5% AEP rainfall (RCP4.5) and the 0.2% AEP rainfall (RCP8.5).

Rainfall intensity is not the only factor affecting flooding. The research reproduced in the preceding section also predicts a hotter climate with greater evapotranspiration meaning that it will be likely to be drier at the onset of flooding rainfalls. These changes mean that initial and continuing losses will likely increase, providing some offset to the increased rainfall intensity.

The peak discharge estimate for the 0.5% AEP regional flood at Boggabri is approximately 39% higher than the 1% AEP peak discharge estimate. The 0.2% AEP peak discharge estimate is approximately 109% higher than the 1% AEP peak discharge, suggesting it is too conservative to represent the 1% AEP climate change scenario.

Considering the above and adopting the NSW Government (2019) methodology, the 0.5% AEP estimate is a reasonable representation of the likely impact of climate change on the 1% AEP event, representative of at least the RCP 4.5 scenario.

The results show that climate change could increase peak 1% AEP flood levels up to 0.5 m throughout much of southern Boggabri and up to 0.6 m in northern Boggabri, as shown in Figure 7.3.

## 7.4 PRELIMINARY FLOOD FUNCTION

Figure D1 to D6 in Appendix D show the provisional hazard categories for 5%, 2% 1%, 0.5%, 0.2% and PMF design events in the study area. Provisional flood hazards have been defined using the depth and velocity of the floodwaters calculated using the flood model determined in accordance with Figure 7.4 as given in Appendix L of the NSW Floodplain Development (NSW Government, 2005).

The flood hazard maps in Appendix D shows that the high hazard floodway areas are generally located on the undeveloped floodplain area and not within the urban areas of Boggabri with the exception of the southern end of Merton Street and eastern end of Derby Street. The extent of high hazard increases along the eastern fringes of Boggabri for lower AEP (larger) events.

The mapping suggests that the floodway areas along Coxs Creek and the Namoi River would likely be defined by the extent of high hazard shown for the 1% AEP event. The remaining areas below the PMF extent would be flood fringe areas.

## 7.5 HYDRAULIC HAZARD

The Australian Disaster Resilience Guideline 7-3 Flood Hazard (AIDR, 2017) recommends grouping the floodplain into six hazard categories using flood depth, flood velocity and the depth-velocity product in accordance with Figure 7.5. This figure closely resembles Figure L1 in the Manual (NSW Government, 2005) but further delineates the floodplain based on recent research undertaken on the trafficability of vehicles and the safety of people during flood events.

Figure E1 to E6 in Appendix E shows the hydraulic hazard for the 5%, 2%, 1%, 0.5%, 0.2% and PMF design events in the study area. The mapping is generally consistent with the flood function mapping with the H5 and H6 areas corresponding to the high hazard areas.

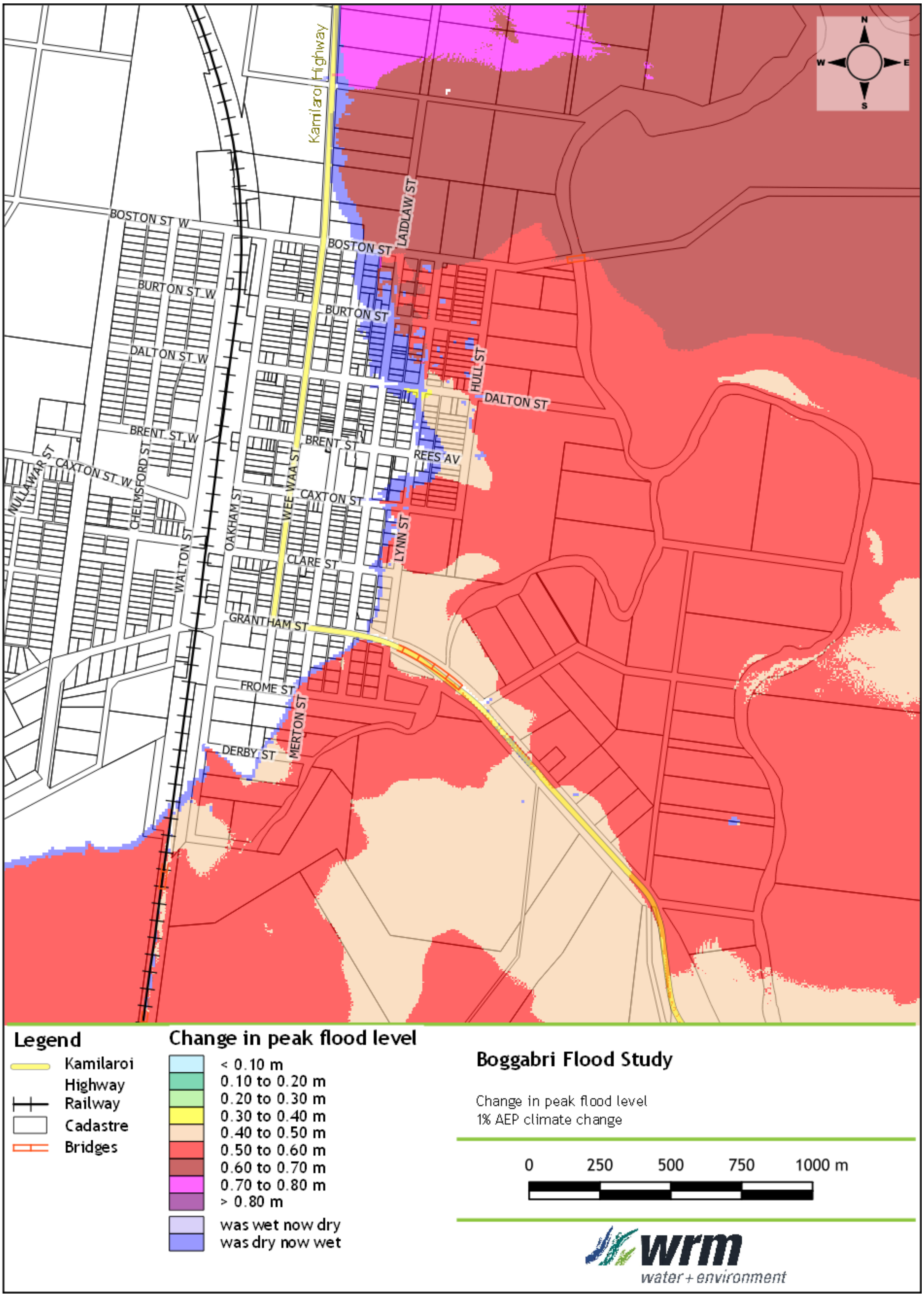


**Figure 7.3 – Comparison of the 1% AEP climate change event to the 1% AEP event**

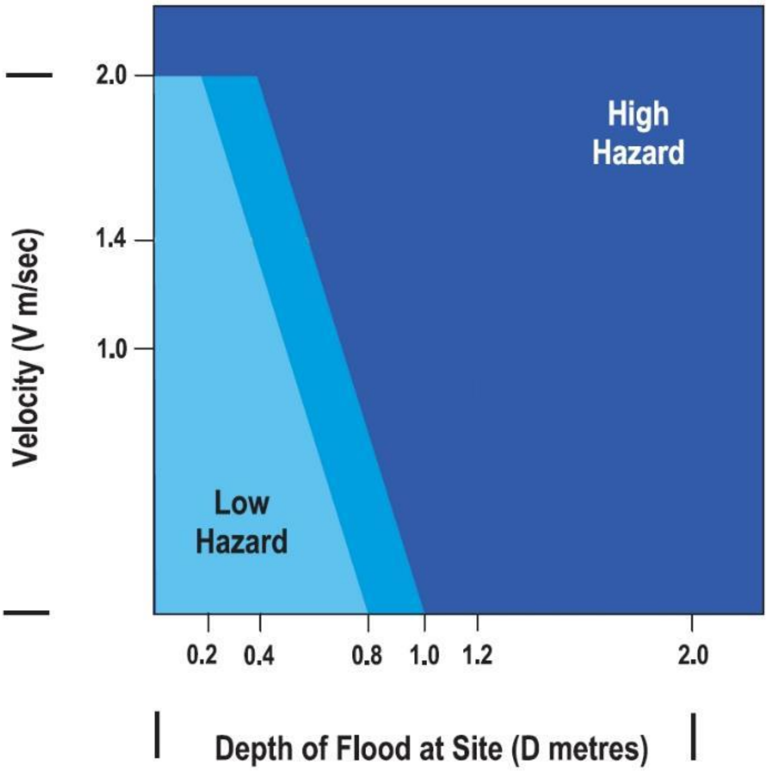


**Figure 7.4 – Provisional hydraulic hazard categories (Source: NSW Government, 2005)**

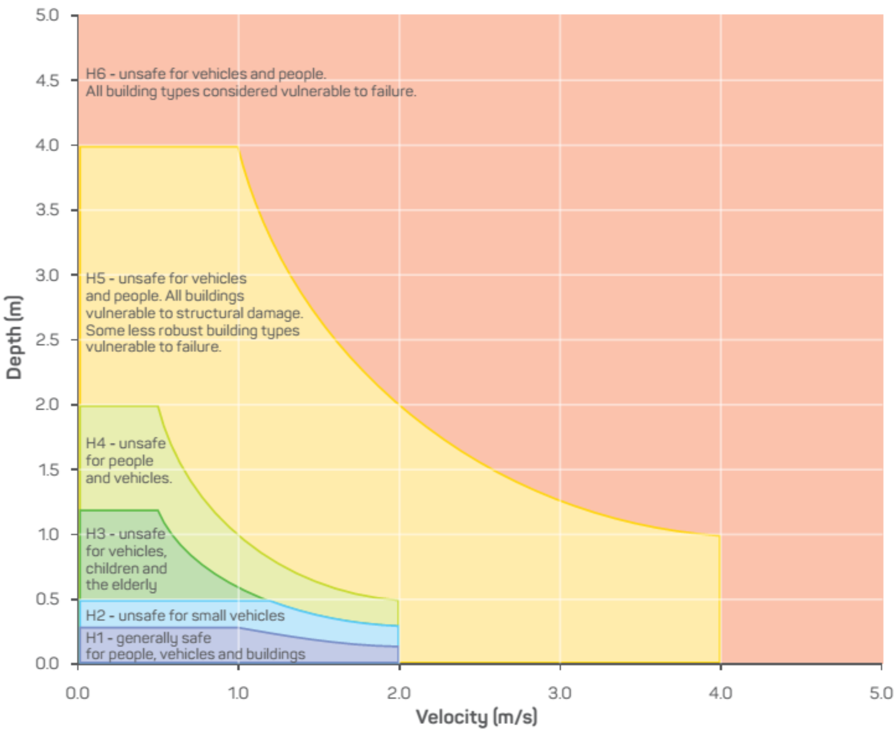


**Figure 7.5 – Flood hazard vulnerability curve (source: AIDR, 2017)**

## 7.6 EMERGENCY RESPONSE PLANNING

The flood mapping shows that all the flood prone urban areas of Boggabri have a rising road exit route, should a flood occur. That is, none of the properties would be cut off from rising floodwater. The rural properties located to the immediate east of the Coxs Creek bridge on the Kamilaroi Highway would also be classified as having a rising road exit route.

## 7.7 FLOOD PLANNING AREA

Figure 7.6 shows the provisional flood planning area for Boggabri. The flood planning area has been defined as the extent of the 0.5% AEP flood, which is generally 0.5 m higher than the 1% AEP flood across Boggabri.

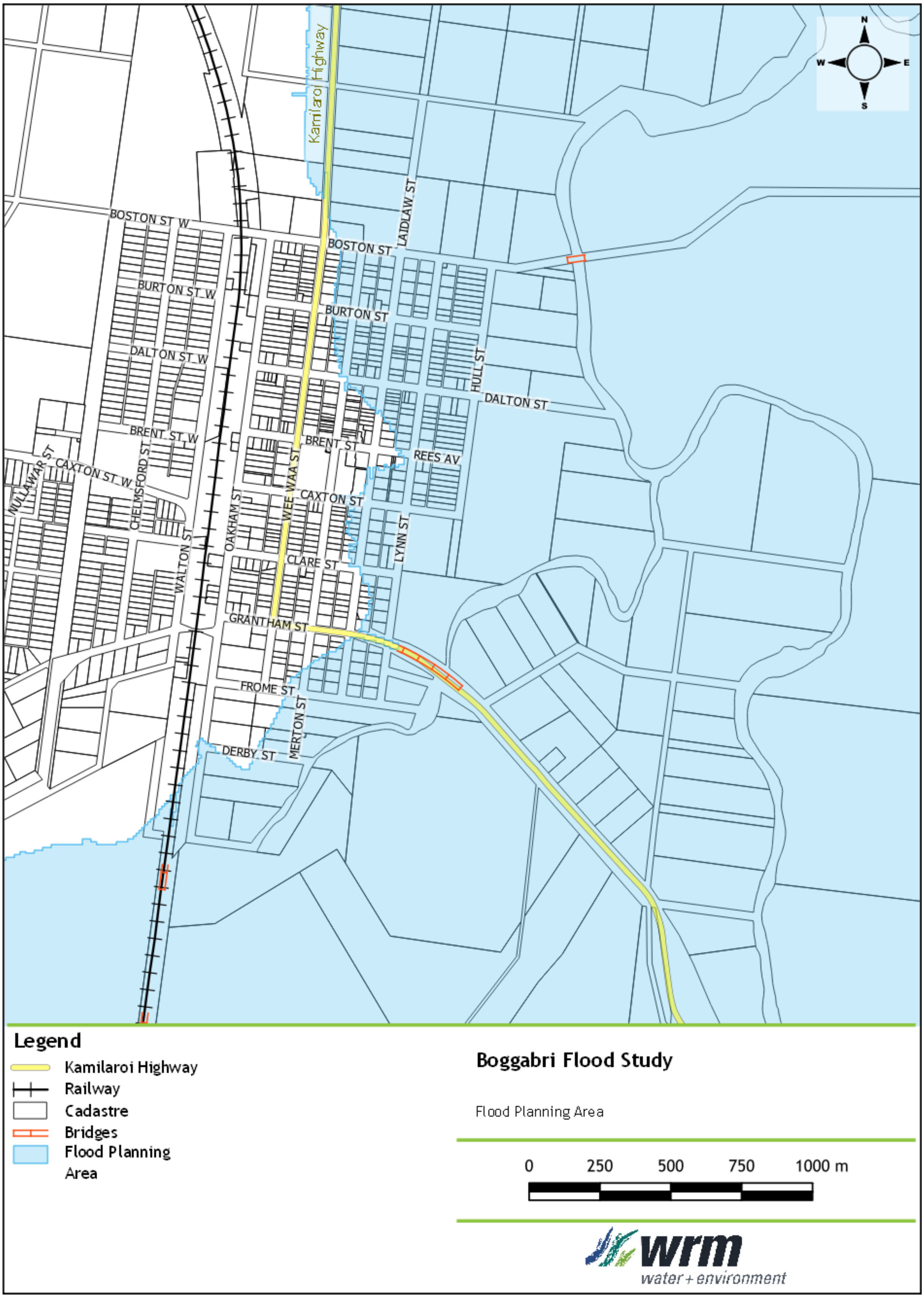


**Figure 7.6 – Boggabri flood planning area**

# 8 Flood damage

## 8.1 TYPES OF FLOOD DAMAGE

The Floodplain Development Manual (NSW Government, 2005) defines the various types of damage caused by flooding, with these damages shown graphically in Figure 8.1. Flood damage can be divided into two major categories: tangible and intangible damages. Tangible damages are the financial costs of flooding and are quantified in dollar terms, while intangible damages are the social and environmental costs of flooding and are reflected in increased levels of emotional stress and psychological and physical illness.

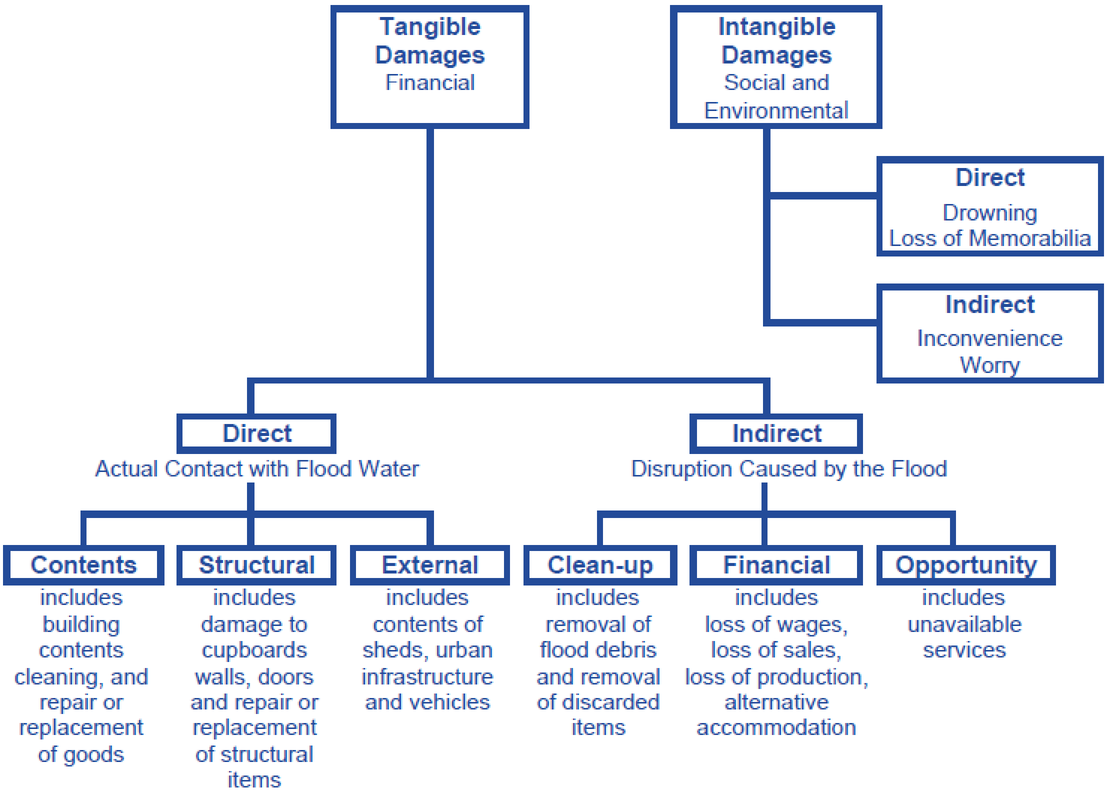


**Figure 8.1 – Types of flood damage (Source: NSW Government, 2005)**

### 8.1.1 Tangible damages

Tangible damages can be separated into two major sub-categories:

- direct damage – the loss in value of an object or piece of property caused by direct contact with floodwater; and
- indirect damage – the loss in production or revenue caused by a flood, e.g. the loss of wages, additional accommodation and living expenses and any other extra outlays that occur as a consequence of flood.

Indirect damages are additional to ordinary pre-flood living costs. Indirect damages are typically incurred in the post-flood recovery phase.

#### 8.1.1.1 Direct damage

Direct damage can be incurred either as:

- a replacement cost if a flood-damaged item is discarded;
- a repair cost if the item is repaired; or
- a loss in value if the item is neither discarded nor repaired (repaired items also suffer a loss in value).

In the first case, the direct damage is either the pre-flood value or the replacement cost of the item. In the second case, the damage is the cost of repairs (plus any loss in value). In the third case, the damage is simply the loss in value.

Direct damage is divided into three categories: contents damage, external damage and structural damage (see Figure 8.1):

- contents damage refers to damage to the contents of the main building(s) on a property;
- external damage refers to damage to items external to the main building, e.g. motor vehicles, fences, gardens, the contents of sheds or outbuildings, etc.; and
- structural damage refers to the damage sustained by the fabric of a building (foundations, floors, walls, doors, windows, etc.) and the damage sustained by permanent fixtures in the building, such as built-in cupboards, benches, etc.

#### 8.1.1.2 Indirect damages

Indirect damage is also divided into three categories:

- indirect financial damage refers to the loss of income or increased expenditure caused by a flood;
- clean-up cost refers to the cost of labour and materials required to clean out a flooded building. Typical clean-up activities include the hosing down of walls and floors to remove silt, the taking up of flooded carpets, the removal and discarding of irreparably damaged items, the drying of rooms, etc.; and
- opportunity costs which arise from direct damage to public assets. Because of this damage, a period elapses when the public is not provided with these services or is provided with a reduced level of service.

It is difficult to realistically evaluate opportunity costs. On the one hand, opportunity costs can be estimated in terms of the total operating cost of the facility (wages, maintenance, interest on capital assets, etc.). Society is prepared to pay this cost to provide the services; thus their absence must be worth a corresponding amount. On the other hand, during the aftermath of a flood, public employees often undertake non-duty tasks useful to society when not providing public services (e.g. clean-up operations). For reasons of convenience, opportunity costs are often estimated as the wages cost over the period public facilities are not operating.

#### 8.1.1.3 Potential versus actual damage

Potential damage refers to the damage that would be sustained if no actions were taken by householders, or others, in an attempt to reduce flood damage, i.e. the damage that would occur if the entire population was absent when a flood occurred.

The actual damage sustained at a property is always less than the potential damage. Notwithstanding the shortness or absence of flood warnings, people will attempt to save items by lifting them onto benches or shelves, by shifting motor vehicles, by evacuating their possessions, etc.

Potential and actual damage costs are the same for structural damage, as it is generally impossible to reduce structural damage to buildings in the onset of a flood.

### 8.1.2 Intangible damages

Intangible damage is difficult to measure and impossible to meaningfully quantify in dollar terms. Nevertheless, it is a very real, significant and often enduring 'cost' that emerges during the recovery phase of a disaster.

The social impacts of flooding include:

- the loss of irreplaceable items, such as family photographs;
- the stress induced by the flood itself;
- temporary evacuation of the home whilst the damage is repaired;
- the disruption caused by the flood to the life of the individual household and to the community as a whole; and
- the effect of floods upon the physical and mental health of those affected.

Research in the past has shown that social impacts can be more important to the victims of floods than the financial losses that they suffer.

## 8.2 TANGIBLE FLOOD DAMAGE ESTIMATION METHODOLOGY

### 8.2.1 Overview

Many factors affect flood damage (e.g. depth of inundation, flow velocity, duration of inundation, time of occurrence, debris/sediment loads, water quality etc.). However, other than the depth of inundation, very little guidance and information is available on how to take the relevant factors into account when estimating flood damage.

In most studies, flood damages are related to only the depth of inundation because the other factors are heterogeneous in space and time, difficult to predict, and there is limited information on their quantitative effects (Merz et al., 2010). As a result, flood stage-damage curves are typically used to estimate flood damages. However, accurate flood damage estimates cannot be made without stage-damage curves that are accurate and locally relevant.

Flood damage estimates made from stage-damage curves require the following information:

- property data;
- floor level data;
- ground level data;
- flood level data; and
- stage-damage curves.

### 8.2.2 Property and floor level data

A property floor level survey was conducted by Fyfe Surveyors early 2020. All properties within Boggabri were surveyed. The floor level survey included relevant property data, such as:

- unique building ID;
- building floor level;
- ground level;
- building coordinates;
- number of floor levels;
- foundation type;
- building type (commercial/residential); and

- miscellaneous comments.

Commercial building sizes were mapped from aerial photographs.

### 8.2.3 Ground level and flood level data

The ground level at each property was included in the survey data. Design flood levels at each property were assigned by inspecting the building coordinates captured during the property survey against flood surfaces produced above.

### 8.2.4 Residential stage-damage curves

Flood stage-damage curves (flood damage curves) relate the depth of flooding at a residential property to an estimate of the corresponding flood damage.

For this study, the residential stage-damage curves described in the Residential Flood Damages flood risk management guideline (NSW Government, 2007) have been used to estimate tangible residential flood damages. The NSW Government approach uses a typical damage curve, which allows damages to be estimated for individual dwellings based on the property type. The use of these curves provides a consistent basis for calculation of flood damage between different projects across NSW whilst allowing consideration for local variation through the scale of a typical house and the value of its contents.

The parameters used to define the residential stage-damage curves are given in Table 8.1. Figure 8.2 graphically shows the residential stage-damage curves adopted for the study.

**Table 8.1 – Residential flood damage curve values, NSW Government method**

| Parameter | Value |
|---|---|
| Regional cost variation factor (from Rawlinsons, 2020) | 1.15 |
| Post late 2001 adjustments (AWE adjustment*) | 1.94 |
| Post flood inflation factor (No. flooded properties > 700) | 1.45 |
| Typical duration of immersion | 26 hours |
| Building damage repair limitation factor | 0.95 |
| Typical house size | 240 $m^2$ |
| Average content relevant to site | $60,000 |
| Contents damage repair limitation factor | 0.85 |
| Level of flood awareness | High |
| Effective warning time | 12 hours |
| Likely time in alternative accommodation | 3 weeks |

*AWE = Average Weekly Earning

### 8.2.5 Commercial and industrial stage-damage curves

Although commercial and industrial damage can be a significant component of overall flood damage, to date there has been limited research on non-residential stage-damage curves other than residential stage-damage curves. A possible reason for this is that it is very difficult to provide accurate estimates given that the costs can vary significantly between each commercial property type and use.

For this study, flood damage curves developed by researchers at Australian National University (CRES, 1992) in the 1980's (ANUFLOOD) have been used. In ANUFLOOD, the commercial and industrial damage is defined on the basis of building size and business type. Three building sizes (small/medium/large) and five classes of building value category (1/2/3/4/5) are combined for a total of fifteen different building categories.

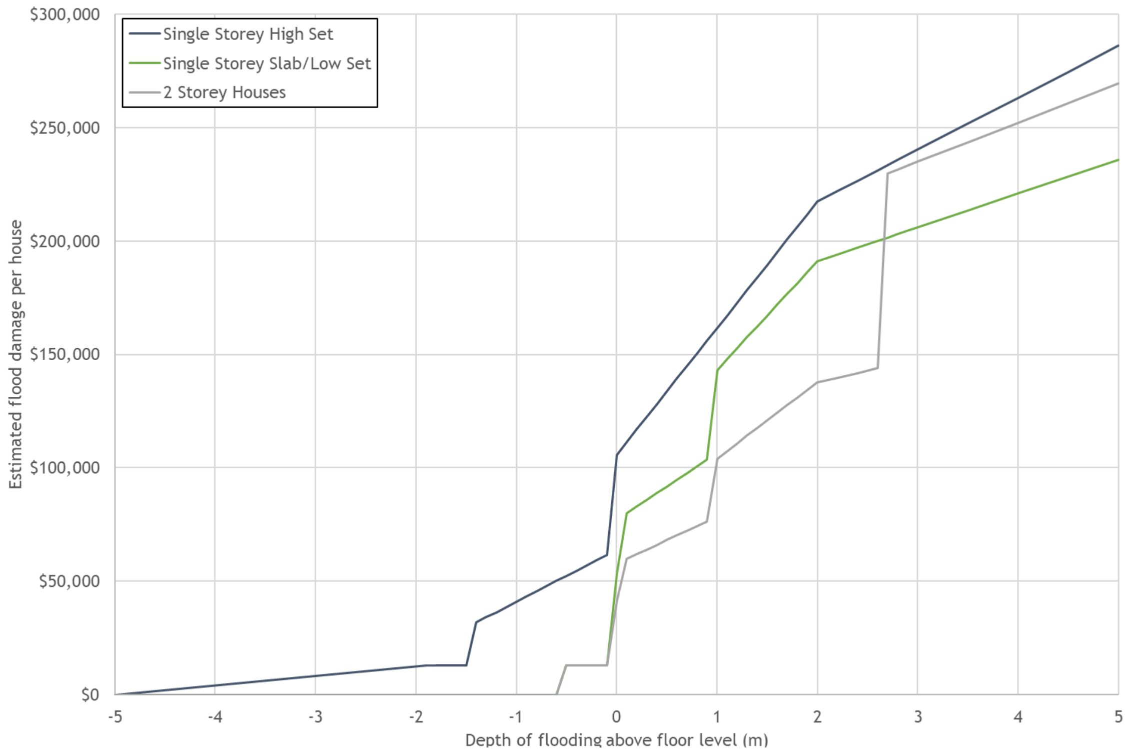


**Figure 8.2 – Residential stage-damage curves**

In applying these curves, the type of business/industry can be defined based on Australia & New Zealand Standard Industrial Classification Code (ANZIC) (ABS, 2013). The ANZIC value class is assessed from 1 (low value) to 5 (high value). The value class is a subjective estimate of the likely loss that would be sustained if the building was inundated by floodwaters.

Table 8.2 shows ANUFLOOD commercial/industrial stage-damage curves updated to March 2020 prices using changes in the Consumer Price Index (CPI). For each non-residential property, damage is also dependent on the size of the building. ANUFLOOD defines three building size ranges:

- small properties (floor area <186m$^2$);
- medium properties (floor area 186 – 650m$^2$); and
- large properties (floor area >650m$^2$).

For small and medium size properties damage is specified in total dollar values. Damage for large properties is specified as a dollar value per unit floor area. It is not clear what damage components are included and/or excluded in the ANUFLOOD damage values. It appears that damage estimates include structural damages. However, it does not appear that these damage curves include external damages.

The stage-damage curves given in Table 8.2 are potential stage-damage curves. The NSW Government methodology used for the residential stage-damage curves converted potential damages to actual damages, hence a similar conversion was required for the commercial stage-damage curves.

Table 8.2 – Stage-damage curves for commercial properties (Source: CRES 1992)

| Depth of Flooding Above Floor Level (m) | Potential Direct Damage (March 2020 Dollar Values) | | | | |
|---|---|---|---|---|---|
| | Value Class | | | | |
| | 1 Very Low | 2 Low | 3 Medium | 4 High | 5 Very High |
| **Small Properties (Floor Area <186m²)** | | | **($)** | | |
| ≤ 0.00 | 0 | 0 | 0 | 0 | 0 |
| 0.25 | 5,115 | 10,232 | 20,461 | 40,921 | 81,845 |
| 0.75 | 12,789 | 25,575 | 51,153 | 102,306 | 204,612 |
| 1.25 | 19,181 | 38,367 | 76,728 | 153,459 | 306,916 |
| 1.75 | 21,313 | 42,626 | 85,255 | 170,510 | 341,018 |
| ≥ 2.00 | 22,591 | 45,186 | 90,370 | 180,739 | 361,479 |
| **Medium Properties (Floor Area 186-650m²)** | | | **($)** | | |
| ≤ 0.00 | 0 | 0 | 0 | 0 | 0 |
| 0.25 | 16,201 | 32,397 | 64,794 | 129,586 | 259,175 |
| 0.75 | 39,217 | 78,433 | 156,869 | 313,738 | 627,473 |
| 1.25 | 59,677 | 119,357 | 238,712 | 477,489 | 954,852 |
| 1.75 | 66,069 | 132,146 | 264,289 | 528,579 | 1,057,158 |
| ≥ 2.00 | 70,334 | 140,673 | 281,340 | 562,681 | 1,125,362 |
| **Large Properties (Floor Area >650m²)** | | | **($/m²)** | | |
| ≤ 0.00 | 0 | 0 | 0 | 0 | 0 |
| 0.25 | 16.26 | 34.84 | 74.33 | 141.7 | 283.4 |
| 0.75 | 90.59 | 181.2 | 357.7 | 715.4 | 1,438 |
| 1.25 | 188.1 | 376.3 | 757.2 | 1,507 | 3,013 |
| 1.75 | 306.6 | 620.2 | 1,238 | 2,474 | 4,945 |
| ≥ 2.00 | 369.3 | 738.6 | 1,477 | 2,954 | 5,911 |

### 8.2.6 Actual to potential damages

For Boggabri, the available warning time is generally in excess of 24 hours for Namoi River floods and at least 12 hours for Coxs Creek. For this study, the ratio of actual to potential flood damages was varied depending on the depth of flooding, the available warning time and level of flood awareness. This methodology is more realistic than a simpler constant ratio methodology and is consistent with the residential stage-damage methodology. The adopted actual to potential damage ratios were based on Figure 8.3 with flood depths of 0.5 m or less assigned an actual to potential damage ratio of 0.4, while flood depths of 2.0 m or greater were assigned a ratio of 0.7, with the ratio for depths in between linearly interpolated.

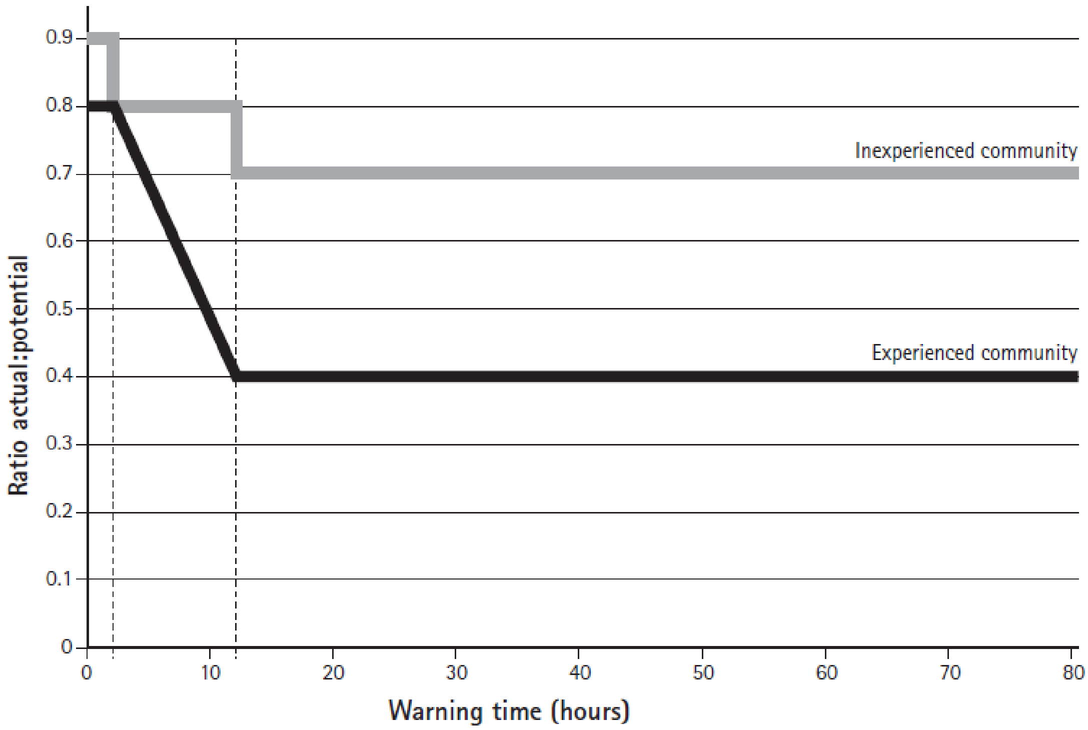


**Figure 8.3 - Actual to potential damage ratio relationship (Source: VDNRE, 2000)**

### 8.2.7 Public authority buildings and public utilities

Direct damage to public and community owned buildings and assets must also be considered when estimating overall flood damage. These include:

- hospitals, schools, police and fire stations, and other government owned buildings;
- parks and recreational facilities;
- sporting facilities; and
- communication, electricity, water supply, sewerage and drainage systems.

Ideally, damage to these properties should be estimated on a case by case basis. In the absence of better data, damage to these properties was evaluated using the stage-damage curves given for commercial/industrial damage in Section 8.2.5.

### 8.2.8 Roads and bridges

Flooding can cause significant damage to roads and bridges. The use of generalised damage rates to calculate road and bridge damage is not applicable as the cost is often closely related to the distance required to travel to access suitable materials (quarries and depots). In the absence of available information, costs due to damage to roads and bridges are not included in this study.

### 8.2.9 Average annual damage

Over a long period of time, a flood liable community will be subject to a succession of floods. In many years, no floods may occur, or the floods may be too small to cause damage. In some years, the floods will be large enough to cause damage, but the damage will generally be small because the floods are of small to medium size. On rare occasions, major floods will occur and cause great damage.

The average annual damage (AAD) is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period (assuming that the population and development situation does not change over the period of analysis). By estimating the damage caused by floods of different severity, e.g. the 20%, 10%, 5%, 2%, 1%, 0.2% and 0.5% AEP and extreme flood events from this study, it is possible to combine the likelihood of a flood occurring, with the damage it causes, and so estimate the AAD.

## 8.3 TANGIBLE FLOOD DAMAGE ESTIMATE

Table 8.3 shows the estimated number of properties flooded above and below floor level and the estimated residential and non-residential building damages for each design flood event (in March 2020 dollar values). The estimated AAD is also shown. A total of 419 buildings were surveyed in the study area. Of the 419 buildings, 346 buildings are residential buildings and the remaining 73 are commercial.

**Table 8.3 - Estimated number of flood affected buildings and flood damage**

| Parameter | Event (AEP) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20% | 10% | 5% | 2% | 1% | 0.5% | 0.2% | PMPF |
| No. residential buildings flooded AGL | - | 1 | 4 | 15 | 45 | 102 | 154 | 343 |
| No. residential buildings flooded AFL | - | 1 | 2 | 5 | 14 | 75 | 135 | 343 |
| Total residential damages ($K) | $0 | $128 | $322 | $1,170 | $3,674 | $10,560 | $21,822 | $92,735 |
| No. non-residential buildings flooded AGL | - | - | - | 4 | 9 | 9 | 16 | 72 |
| No. non-residential buildings flooded AFL | - | - | - | - | 7 | 9 | 16 | 72 |
| Total non-residential damages ($K) | $0 | $0 | $0 | $0 | $38 | $211 | $863 | $10,036 |
| Building average annual damage | **$275,843** | | | | | | | |

AGL – above ground level (count includes buildings flooded above both ground level and floor level)
AFL – above floor level

With respect to the 1% AEP flood, the results show that:

- there would be 54 flood affected properties.
- 14 residential buildings would be inundated above floor level;
- nine non-residential buildings would be inundated above floor level; and
- the total flood damage costs would be in the order of $275,000 (excluding road, bridge and agricultural flood damages).

# 9 Conclusions

This report documents the flood behaviour in the vicinity of the township of Boggabri in New South Wales. It provides information on design flood discharges, flood levels, depths as well as provisional flood hazard categories for a full range of design flood events.

The flood behaviour was defined using computer based hydrological models to convert design rainfall to stream flow hydraulic models convert stream flow to flood levels and depths. The computer models were calibrated to available data for the February 1955, February 1971, February 1997, July 1998, and November 2000 events and recorded discharge data at the Namoi River at Boggabri and the Coxs Creek at Boggabri stream gauges. The following conclusions can be drawn from the flood study;

- The dominant source of flooding at Boggabri is from Coxs Creek adjacent to Coxs Creek (upstream of the Kamilaroi Highway and for about 600 m downstream) and a combination of Namoi River and Coxs Creek flows downstream of the confluence.
- For the 20%, 10% and 5% AEP events, property inundation in Boggabri is limited to yard flooding of properties on the southern end of Derby Street and Merton Street. The Kamilaroi Highway to Gunnedah would be inundated to shallow depths.
- For the larger events, the peak flows extend into the eastern streets of Boggabri. Properties along the Kamilaroi Highway to the east of Coxs Creek would be inundated.
- Substantial inundation would occur for the PMF with most of the town inundated.
- The extent of high hazard for the 1% AEP event would likely define the floodway areas along Coxs Creek and the Namoi River. The remaining areas below the PMF extent would be flood fringe areas.

With respect to the 1% AEP flood:

- there would be 54 flood affected properties.
- 14 residential buildings would be inundated above floor level;
- nine non-residential buildings would be inundated above floor level; and
- the total flood damage costs would be in the order of $275,000 (excluding road, bridge and agricultural flood damages).

# 10 References


| | |
|---|---|
| ABS, 2013 | *'Australian and New Zealand Standard Industrial Classification (ANZSIC)'* (Revision 2) prepared by Brian Pink Australian Bureau of Statistics and Dallas Welch Statistics New Zealand ABS catalogue No. 1292. |
| AIDR, 2017 | *'Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia.'* Commonwealth of Australia 2017 third edition. |
| Ball et al., 2019 | *'Australian Rainfall and Runoff – A Guide to Flood Estimation'*, Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), © Commonwealth of Australia (Geoscience Australia), 2019. |
| BMT, 2018 | *'TUFLOW Classic/HPC User Manual – Build 2018-03-AD'*, BMT WBM, 2018a. |
| BMT, 2020 | TUFLOW (software), BMT, version 2020-01-AB, 2020. |
| BoM 2005 | *'Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method'*, Hydrometeorological Advisory Service, Commonwealth Bureau of Meteorology, September 2005. |
| BOM, 2019 | *'Climate Data Online'*, Commonwealth Bureau of Meteorology, December 2019, <http://www.bom.gov.au/climate/data/>. |
| BOM, 2020 | *'Water Data Online'*, Commonwealth Bureau of Meteorology, July 2020, <http://www.bom.gov.au/waterdata/>. |
| Chow, 1959 | *Open-Channel Hydraulics,* McGraw-Hill Inc., Singapore, 1959. |
| CRES, 1992 | *'ANUFLOOD: A Field Guide'*, Prepared by the Centre for Resources & Environment, Australian National University, Prepared by Smith, D.I. and Greenaway, M.A., 1992. |
| CSIRO & BOM, 2015 | *'Central Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports'*, eds. Ekström, M et al., CSIRO and Bureau of Meteorology, Australia, 2015. |
| DNR, 2005 | *'Upper Coxs Creek Floodplain Management Plan'*, NSW Department of Natural Resources, Sydney NSW, November 2005. |
| DNR, 2006 | *'Carrol to Boggabri Floodplain Management Plan'*, NSW Department of Natural Resources, Sydney NSW, September 2006. |
| DNR, 2007 | *'Lower Coxs Creek Floodplain Risk Management Study'*, NSW Department of Natural Resources, Sydney NSW. |
| ELVIS, 2019 | *'Elevation and Depth – Foundation Spatial Data' (ELVIS)*, Anzlic Committee on Surveying and Mapping (ICSM), Version 0.6.5, December 2019, <https://elevation.fsdf.org.au/>. |
| Geoscience Australia, 2019 | AR&R Data Hub (software), Geoscience Australia, Version 2019_v1, April 2019, <http://data.arr-software.org/>. |
| Innovyze, 2013 | *'XP-RAFTS User Manual'*, XP Software, Australia, 2013. |
| Innovyze, 2019 | XP-RAFTS (software), Innoyvze, Version 2018.1.3, 2019. |
| Kinhill, 1991 | *'Narrabri Flood Study: Final Report'*, Kinhill Engineers Pty Ltd, NSW, May 1991. |

| | |
|---|---|
| Lyall & Associates, 2018 | *'Boggabri Sewage Treatment Plant Flood Impact Assessment'*. Lyall & Associates for Narrabri Shire Council, May 2018. |
| Narrabri Shire Council, 2019 | *'Technical Project Brief for Boggabri Flood Study'* |
| NSW Department of Industry, 2019 | *'Background document to the Floodplain Management Plan for the Upper Namoi Valley Floodplain 2019'*. State of NSW through the Department of Industry. |
| NSW Government, 2005 | *'Floodplain Development Manual – the management of flood liable land'*, New South Wales Government, Department of Infrastructure, Planning and Natural Resources, NSW, April 2005. |
| NSW Government, 2007 | *'Flood Risk Management Guideline: Residential Flood Damages'*, New South Wales Government, Department of Environment and Climate Change, NSW, October 2007. |
| NSW Government, 2014 | *'New South Wales Climate change snapshot'*, New South Wales Government, Office of Environment and Heritage, NSW, November 2014. |
| NSW Government, 2019 | *'Floodplain Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff in studies'*, NSW Government, Office of Environment and Heritage, NSW, January 2019. |
| Rawlinson, 2016 | *'Rawlinsons Australian Construction Handbook'*, Rawlinsons Publishing, Edition 34, 2016. |
| SEED, 2019 | *'The Central Resource for Sharing and Enabling Environmental Data in NSW (SEED)'*, NSW Government, <https://geo.seed.nsw.gov.au>, June 2020. |
| SMEC, 2003 | *'Carroll to Boggabri Flood Study and Compendium of Data'*. SMEC Australia Pty Ltd: Report prepared for the Department of Land and Water Conservation. |
| VDNRE, 2000 | *'Rapid Appraisal Method (RAM) for Floodplain Management'*, Victorian Government, Department of Natural Resources and Environment, VIC, May 2000. |
| WaterNSW, 2020 | *'Real Time Data'*, WaterNSW, July 2020, < https://realtimedata.waternsw.com.au/ >. |
| Watt et al., 2018 | *'A quick method for estimating the Probable Maximum Flood in the Coastal GTSMR Zone'*, 34th Hydrology and Water Resources Symposium (Melbourne). Barton, A.C.T.: Engineers Australia, pp.901-914, S. Watt, D. Sciacca, M. Hughes and P. Pedruco. |
| WMA Water, 2019 | *'Review of ARR design Inputs for NSW Final Report'*, Report prepared for the NSW Office of Environment and Heritage by WMA Water, February 2019 |
| WRM, 2009 | *'Continuation of Boggabri Coal Mine – Namoi River Flood Impact Assessment'* Report prepared for Hansen Bailey on behalf of Boggabri Coal Pty Limited by WRM Water & Environment Pty Ltd, December 2009 |