Flood Study for the Towns of Urana, Morundah, Boree Creek, Oaklands and Rand

Federation Council

Flood Study Report for Rand

IA055600 | FINAL

November 2017

Flood Study for the Towns of Urana, Morundah, Boree Creek, Oaklands and Rand

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Cover photo: Four Corners Road bridge over Billabong Creek, looking upstream

Document history and status

Revision	Date	Description	By	Review	Approved
1	26/08/2015	Model Calibration and Verification Report	MR	AH	AH
2	6/05/2016	Rand Design Flood Estimation Report	MR	AH	AH
3	17/8/2017	Flood Study Report (Draft)	MR/AH	AH	AH
4	25/9/2017	Draft Flood Study Report (Public exhibition)	MR/AH	AH	AH
5	9/11/2017	Final Flood Study Report	AH	A Hossain	A Hossain

Contents

Foreword

The primary objective of the New South Wales Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods, wherever possible. Under the Policy, the management of flood prone land remains the responsibility of local government.

The policy provides for a floodplain management system comprising the following five sequential stages:

1.	**Data Collection**	Involves compilation of existing data and collection of additional data
2.	**Flood Study**	Determines the nature and extent of the flood problem
3.	**Floodplain Risk Management Study**	Evaluates management options in consideration of social, ecological and economic factors relating to flood risk with respect to both existing and future development
4.	**Floodplain Risk Management Plan**	Involves formal adoption by Council of a plan of management for the floodplain
5.	**Implementation of the Plan**	Implementation of flood, response and property modification measures (including mitigation works, planning controls, flood warnings, flood preparedness, environmental rehabilitation, ongoing data collection and monitoring by Council

Federation Council proposes to develop a Floodplain Risk Management Plan for the townships of Boree Creek, Morundah, Oaklands, Rand and Urana to address the existing, future and continuing flood problems, in accordance with the NSW Floodplain Development Manual (2005).

This report documents data collection and flood study for Rand.

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to undertake a flood study for Rand within Federation Council (formerly, Urana Shire), located in New South Wales in accordance with the scope of services set out in the contract between Jacobs and Federation Council (the Client). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client, third parties, and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

All topographic data used in this study were sourced from a LiDAR survey and a ground survey which were undertaken by third parties. Undertaking independent checks on the accuracy of the topographic data was outside Jacobs's scope of work for this study.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

Rand is located within Federation Council, approximately 40km southeast of Urana and 17km northwest of Walbundrie. It has a population of 204 people (2016 census) and is located adjacent to Billabong Creek (refer **Figure 1-1**). The creek runs along the south-western edge of the village and under Four Corners Road. The village on the upstream side of this crossing is located on high ground and is generally free from flooding in Billabong Creek. Downstream of the Four Corners Road crossing, the village area near Rand Hotel is serviced by an earth embankment levee along the western side of Mahonga Road, almost to Five Mile Road. The levee is approximately 900mm high with a crest less than 1m wide.

Flooding in Rand occurs primarily from Billabong Creek and the village has experienced several major floods including June-July 1870, July 1891, October 1917, June-July 1931, July 1956, October 1974, September 1983, and most recently October 2010, February 2011 and March 2012. The highest flood for this reach of the Billabong Creek was the 1931 flood. During the 2012 flood, about 8 properties were affected by inundation and houses were threatened, but there were no residences with above-floor flooding in Rand. Access to Rand, however, was cut off in the 2010, 2011 and 2012 flood events. Intense storm events may cause nuisance flooding in the village.

1.1 Objectives

The primary objective is to define the nature and extent of flood behaviour in and adjacent to Rand village. The study will produce information on flood levels, velocities, flows, hydraulic categories and provisional hazard categories for 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% annual exceedance probability (AEP) events and the probable maximum flood (PMF) event.

1.2 Structure of the Report

This report describes the up-to-date progress on the Flood Study for Rand. This report has been divided into the following sections:

Section 1: introduces the study

Section 2: provides details on the initial investigations undertaken for the study including review of the available data and community consultation

Section 3: details catchment hydrology including the development of a hydrologic model for the catchment area of interest to this study

Section 4: details development of a hydraulic model for the study area

Section 5: provides details on calibration and verification of the hydrologic and the hydraulic models and sensitivity analysis

Section 6: details on the input data used in the estimation of design flood

Section 7: discusses modelled flood behaviour for the design events

Section 8: provides conclusions on the study

Section 9: provides acknowledgements for this study

Section 10: provides details on references citied in this report

Section 11: provides a glossary of terms used in this report

Legend

- Rand levee
- Cadastre
- Railway
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Study Area
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR	PROJECT # IA055600
CHECK AH	DATE 1/08/2017

FIGURE 1-1

Appendix A: provides further details on the available data

Appendix B: contains the Newsletter and Questionnaire sent to residents

Appendix C: details on hydrologic modelling

Appendix D: details on hydraulic modelling

Appendix E: contains modelling results and flood maps for the design flood events

2. Available Data

2.1 Site Inspection

A site inspection was carried out on 28 October 2014 to gain an overall appreciation of the study area, including flood behaviour. Information gained from the site reconnaissance was utilised to define the scope of the topographic survey for this study and to determine modelling parameters such as Manning's roughness coefficients for channels and floodplains located within the study area.

2.2 Data Collection and Review

Council and a number of government agencies including NSW Office of Environment and Heritage (OEH), DPI Water (formerly, NSW Office of Water), State Emergency Services (SES) and the Bureau of Meteorology, were contacted to collect information on flooding, topographic data and flood evacuation etc. DPI Water advised Jacobs to use the latest version of PINNEENA (a surface water and groundwater monitoring database published by DPI Water). A summary of the information relevant to Rand is presented in the following sections.

2.2.1 Available Reports

- **Culcairn, Henty and Holbrook Flood Studies, Final Report, September 2013, (WMAwater 2013)**
  The report was prepared by WMAwater for Greater Hume Shire Council (GHSC) to document flood behaviours for the full range of flood events for three townships. The period from 2010 to 2012 is the wettest on record throughout the GHSC region with Culcairn, Henty and Holbrook all experiencing record or near record floods. The largest of these events occurred in October 2010 and March 2012, however numerous other floods were also experienced during this period. Prior to this, the most notable flood event occurred during June 1931 and this event caused significant flooding and damage throughout the region.

  Flooding in Culcairn is primarily caused by flooding in Billabong Creek which at Culcairn has a catchment area of 1,800 km^2. Flooding in the other two towns is caused by creeks which have significantly smaller catchment areas (less than150 km^2).

  A global hydrologic model using WBNM was set up for the catchment area of Billabong Creek at Culcairn and a TUFLOW hydraulic model using 5m grid was set up for the flood study area. Both models were calibrated and validated in tandem against observed flood events of October 2010 and March 2012 respectively. An initial loss of 70 mm was applied to the October 2010 calibration event with a continuing loss of 2.8 mm/hr. For the March 2012 validation event an initial loss of 150 mm was applied and a continuing loss of 2.3 mm/hr. The WBNM model slightly overestimated peak flow (modelled 615 m^3/s; gauged 555 m^3/s) in Billabong Creek at Culcairn for the 2010 flood event and produced almost the same peak flow (modelled 450 m^3/s; recorded 447 m^3/s) for the 2012 flood event. The flood event of 2010 was similar to the 1% AEP event and the flood event of 2012 was similar to the 5% AEP event.

- **Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood, Final Report, June 2013, (Yeo 2013)**
  This report, produced by the SES is a valuable document to understand flood behaviour in Federation Council. The report contains general information about the floods in the region, including rainfall data, information about flood behaviour (levels, timing, depth, velocity, extent, history, etc.) and its consequences (buildings, yards, road affected, evacuations, etc). The key findings from the report on the village of Rand are provided below:
  - The highest recorded flood at the Walbundrie, Cocketgedong and Jerilderie gauges was the 1931 flood.
  - Flood heights at Rand appear to be naturally regulated by the effluent flows that remove water from Billabong Creek between Walbundrie and Rand. These flows are diverted towards Nowranie and Wangamong Creeks and result in suppressed flood heights at Rand. For example, the difference in flood heights at Rand between the 2011 and 2012 events was only 0.15m, despite there being a difference of over 1m at Walbundrie. This produces a very 'flat' hydrograph at Rand.
  - The peak flood travel time between Walbundrie and Rand is estimated to be 6-9 hours.

- Flood depths on the Billabong Creek floodplain are generally shallow with low velocities.
- Flood heights at the Rand staff gauge are provided for the 2010, 2011 and 2012 flood events along with local resident reports of flood behaviour for the 2012 event, and several photographs of the 2010 flood event.

- **Billabong Creek Floodplain Management Plan (Bewsher 2002)**

  Bewsher Consulting was engaged by the NSW Department of Land & Water Conservation in 1999 to undertake a floodplain management plan for Billabong Creek in two phases. The available data and the flood behaviour were reviewed in the first phase and a report entitled "Phase A – Data Review and Flood Behaviour, Main Report" was produced as the outcome of Phase A. The scope of the Phase A activities included community consultation; review of planning and environmental aspects; review of flood hydrology including review of rainfall records, streamflow records and flood extents; undertaking flood frequency analysis and formulation, calibration and verification of a hydraulic computer model using MIKE11. The MIKE11 model was calibrated against flood events of 1981 and 1970 and verified against flood events of 1974, 1983 and 1995. The MIKE11 model was subsequently used in the Phase 2 of the study to estimate flow distribution in the floodways for a range of floodplain management options.

2.2.2 Topographic Data

2.2.2.1 LiDAR Data

LiDAR data for Rand was provided by OEH which was originally captured by NSW Land and Property Information (LPI) between 11 July and 25 November 2013 and also processed by LPI. OEH provided 1m square, 5m square and 10m square grid data for the ground surface. The full LiDAR point cloud was classified to Level 3 by LPI. The spatial horizontal accuracy of the LiDAR data was 0.8m @ 95% CI and the vertical accuracy of the LiDAR data was 0.3m @ 95% CI with a minimum point density of one laser return per square metre. A Digital Elevation Model (DEM) was created using the 1m grid data and is shown in **Figure 2-1**.

2.2.2.2 SRTM Data

The Shuttle Radar Topography Mission (SRTM) data was collected during a 10 day NASA Space Shuttle mission in February 2000. It was processed to produce a 1 arc second digital surface model covering most of the earth's landmass. The 1 second (30m) DEM is a national elevation data product derived from the SRTM data. Seven (7) SRTM tiles covering the local government area were provided by OEH. The SRTM data was utilised to delineate catchment boundaries for Billabong Creek which are located beyond the extent of the LiDAR data.

2.2.2.3 Aerial Photography

Aerial photography was obtained from Council. Rand is covered by the 'Walbundrie' tile. It was captured in 2010. It has a 50cm resolution and was provided as a geo-referenced raster. Aerial flood photography was also provided for the October 2010 flood over the region. This is provided as a false colour image over Rand showing the extent of flooding.

2.2.2.4 Stormwater Details

A CAD file for Rand was provided by Council (shown in **Appendix A**). This outlines the boundaries and features in Rand including roads, buildings and culverts. It does not provide any culvert details (such as size). The drawing was compiled in February 2008.

2.2.2.5 Additional Topographic Data

Additional topographic features, such as stream networks, road and rail networks, and cadastral boundaries were held in-house and utilised for this study.

2.2.3 Rainfall Data

Rainfall data used in this study was for a calibrated RORB model of Billabong Creek to Walbundrie. The details of the rainfall data used are contained in the following sections.

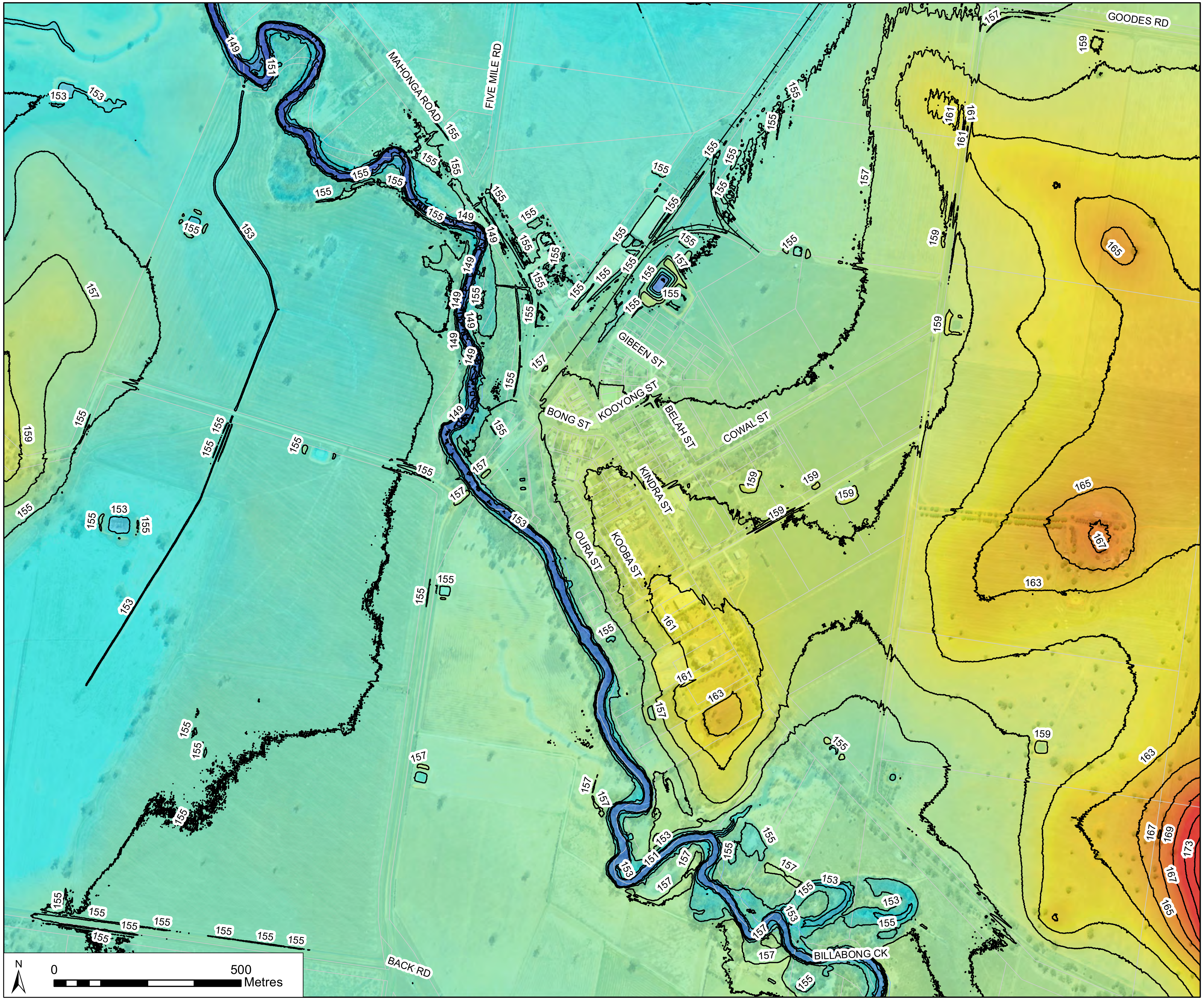
2.2.3.1 Daily Rainfall

The Bureau of Meteorology (BoM) maintains a network of daily rainfall gauges and there are a number of them located in and adjacent to the Billabong Creek catchment. Data for 15 sites was obtained from the Bureau's website. A summary of the rainfall stations used is tabulated in **Table 2-1** and their location is displayed in **Figure 2-2**.

Table 2-1 Daily rainfall gauge data used for Rand

Gauge number	Gauge name	Start Date	End Date	Length of record (years)	Completeness (%)
072019	Holbrook (Glenfalloch)	1/01/1909	31/12/2014	106.1	98.9
072037	Holbrook (Narrawa)	1/01/1952	31/12/2014	63.0	75.3
072058	Noonbah (Yammacoona)	1/01/1958	4/03/2015	57.2	87.4
072078	Garryowen (Yallock)	1/02/1965	6/03/2015	50.1	93.3
072081	Holbrook (Moorak)	1/01/1967	31/12/2011	45.0	81.6
072101	Holbrook (Narrabilla)	1/08/1969	6/03/2015	45.6	99.8
072142	Holbrook (Croft St)	1/05/2000	31/01/2015	14.8	97.2
072144	Tabletop (Tabletop (Eastgate)	1/01/1966	31/05/2013	47.4	94.8
072171	Woomargama Post Office	1/07/2009	6/03/2015	5.7	92.7
074053	Henty Post Office	1/02/1901	6/03/2015	114.2	96.0
074115	Walbundrie (Crediton Street)	1/2/1882	31/01/2015	133.1	82.5
074117	Walla Walla Post	1/01/1925	31/12/2014	90.1	98.5

Gauge number	Gauge name	Start Date	End Date	Length of record (years)	Completeness (%)
	Office				
074188	Culcairn Bowling Club	1/01/1912	2/03/2015	103.2	99.2
074263	Alma Park (Albaringa)	1/01/1997	6/03/2015	18.2	98.7
074264	Mangoplah (Forest Vale)	1/11/2002	6/03/2015	12.4	92.9



Legend

- 2m contours
- Railway
- Watercourses
- Cadastre

Rand DEM

Elevation (m AHD)

High : 170

Low : 145

GDA 1994 MGA Zone 55
Scale: A3

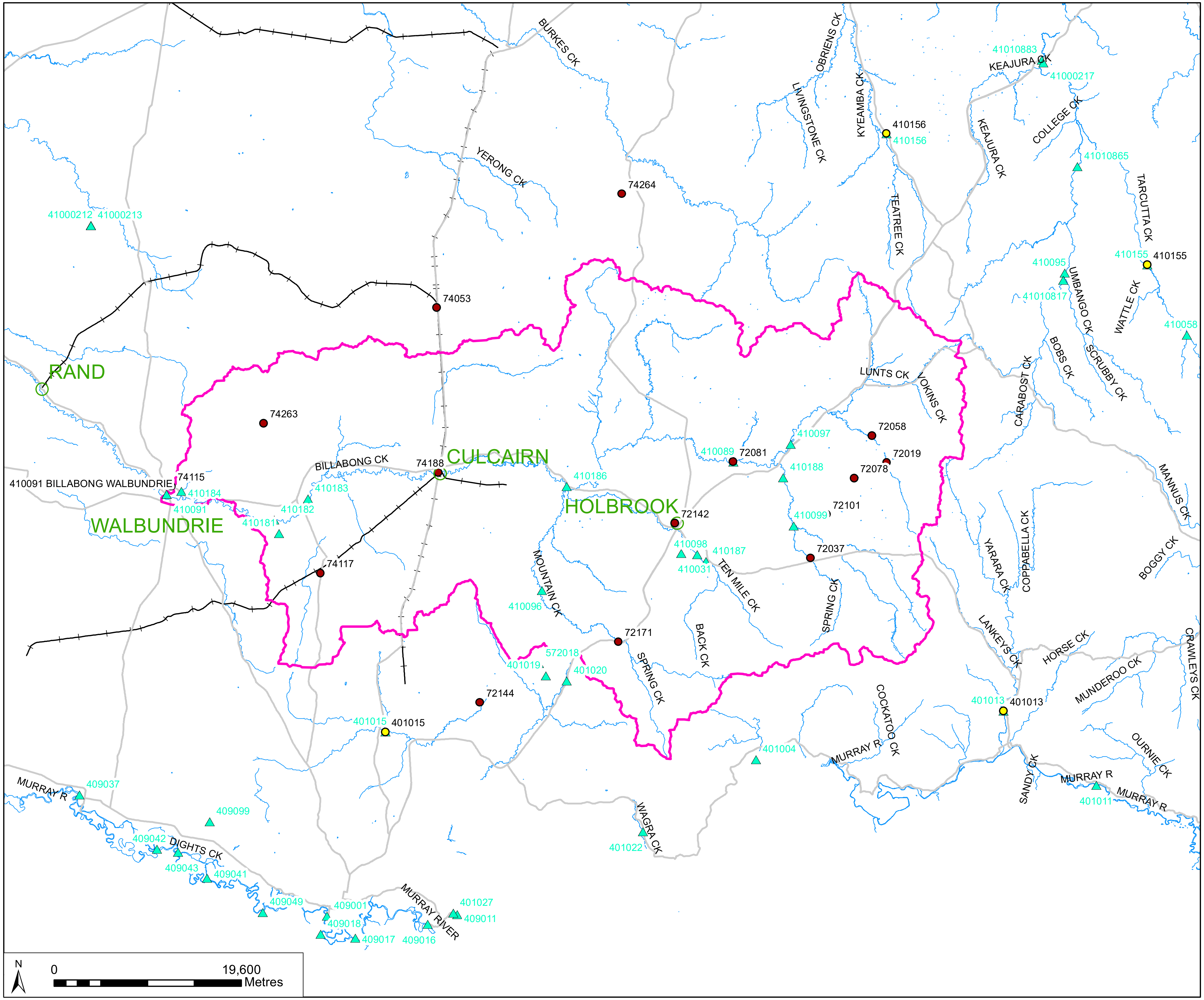
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Digital Elevation Model
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 2-1
CHECK AH	DATE 1/08/2017	



Legend

- Locality
- Official daily rainfall gauges
- Pluviograph stations
- Stream gauges
- Study Catchment
- Railway
- Major Roads
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Gauging Stations
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 2-2
CHECK AH	DATE 25/09/2017	

2.2.3.2 Pluviograph

The DPI Water holds pluviograph data in catchments adjacent to Billabong Creek. No sub-daily rainfall data exists within the Billabong Creek catchment upstream of Rand. Data for 4 pluviograph stations was obtained and are outlined in **Table 2-2**. These stations are also shown in **Figure 2-2**. Cumulative rainfall graphs are also provided for the 2010, 2011 and 2012 storm events in **Figure 2-3**, **Figure 2-4** and **Figure 2-5** respectively.

Table 2-2 Pluviograph data used for Rand

Gauge number	Gauge name	Source	Resolution	Storm events with data available
401013	Jingellic Creek at Jingellic	DPI Water	Every 0.2mm	Oct 2010, Feb 2011, Mar 2012
401015	Bowna Creek at Yambla	DPI Water	Every 0.2mm	Oct 2010, Feb 2011, Mar 2012
410155	Tarcutta Creek at Belmore Bridge	DPI Water	Every 0.2mm	Oct 2010, Feb 2011, Mar 2012
410156	Kyeamba Creek at Book Book	DPI Water	Every 0.2mm	Feb 2011, Mar 2012

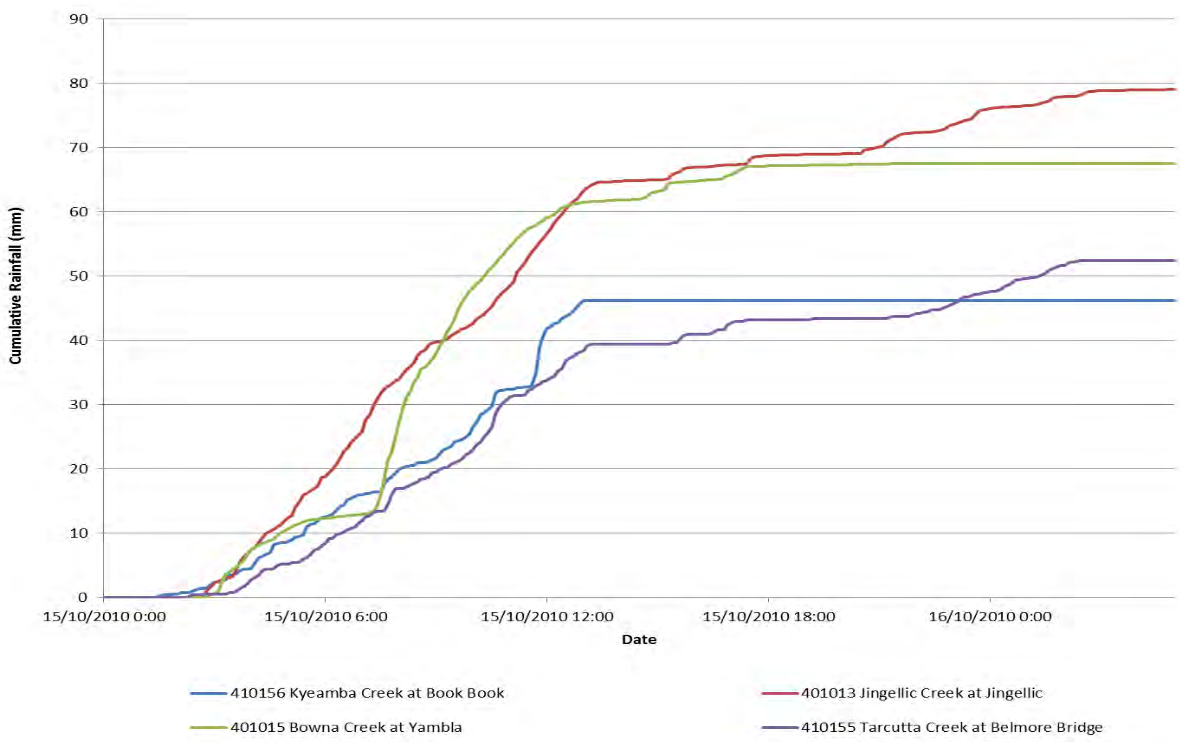


Figure 2-3 Cumulative pluviograph rainfall for the October 2010 event

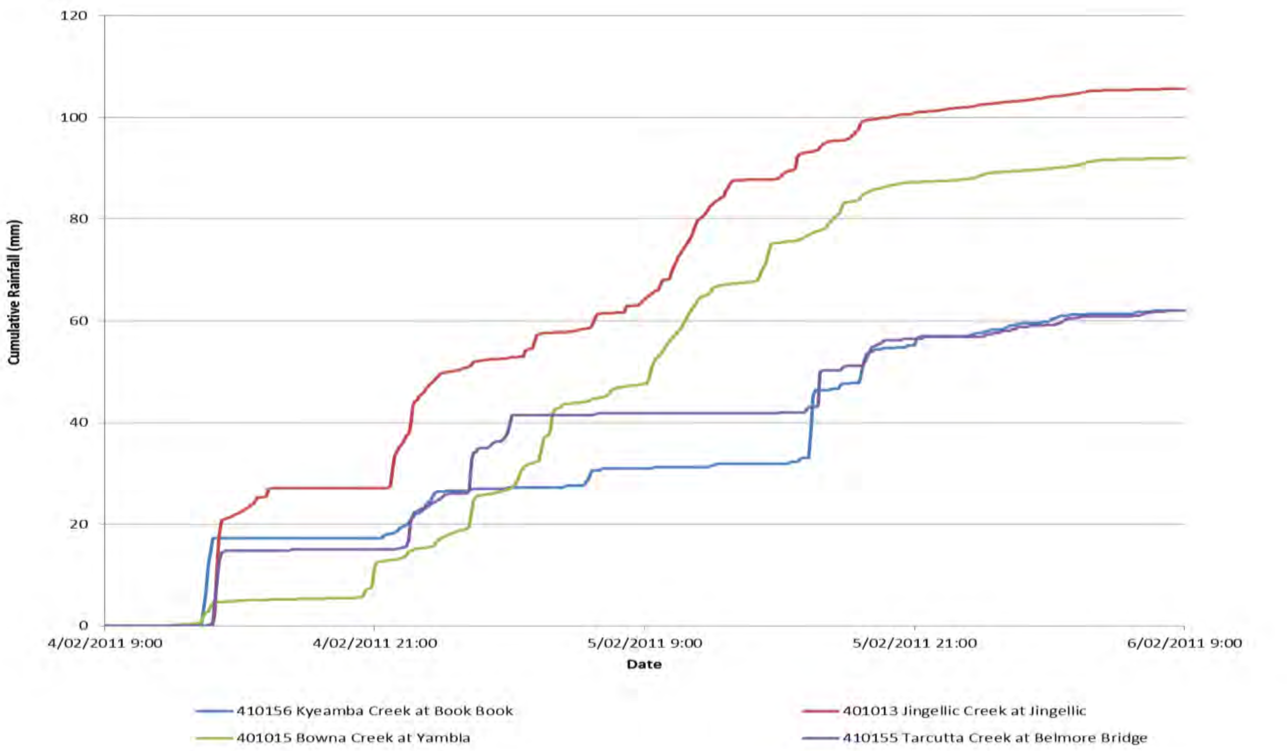


Figure 2-4 Cumulative pluviograph rainfall for the February 2011 event

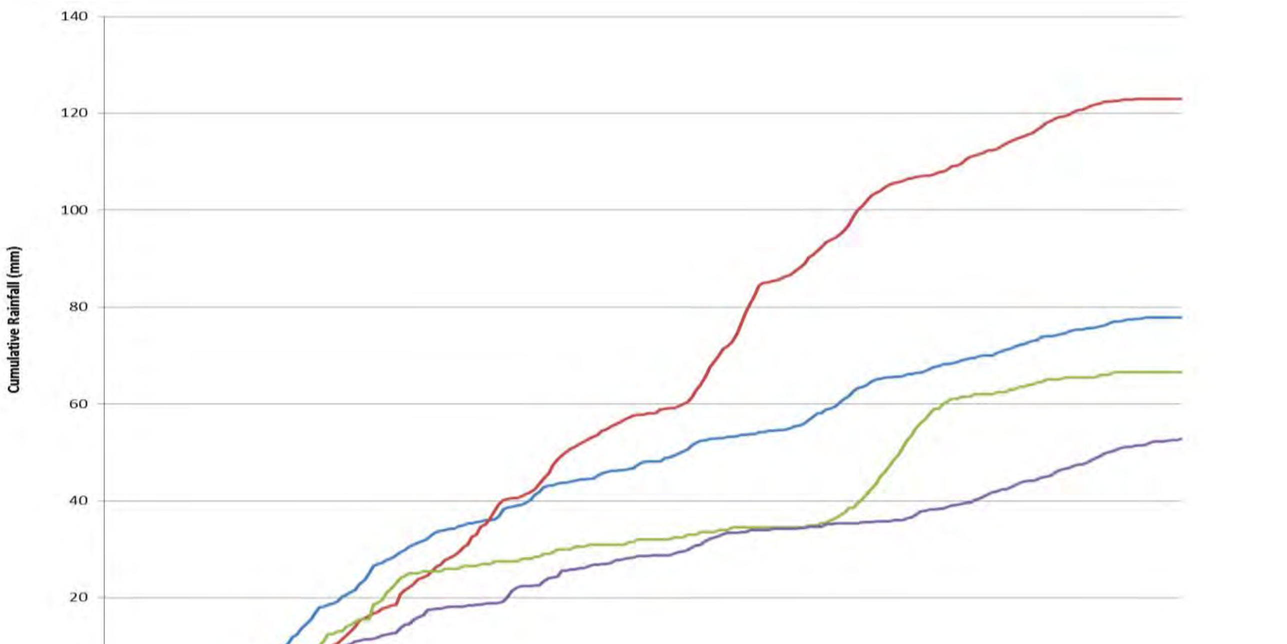


Figure 2-5 Cumulative pluviograph rainfall for the March 2012 event

2.2.4 Streamflow Data

Streamflow data exists for a number of sites along Billabong Creek. For the flood study for Rand, the gauge on the Billabong Creek at Walbundrie (station number 410091) is the closest recording station. It is located approximately 30km upstream of Rand. PINNEENA v10.2 shows that the gauging station opened in 1965 and has mean daily flows recorded up to 1982, and instantaneous flows to the current date. The dataset is 98.6% complete.

PINNEENA also shows that 317 flow gaugings were undertaken at this station between 1965 and 2013 and the highest gauged flow was 557m^3/s (48,125 ML/day) corresponding to a gauge height of 9.113m observed on 17 October 2010. The gauge reached a peak height of 9.117m on the same day. The rating table for this station is considered to be good. It has been reported that the 1931 flood reached a level equivalent to 9.65m on this gauge (Bewsher 2002) and the peak flow corresponding to this gauge height was estimated at 579m^3/s (50,000 ML/day).

2.2.5 Flood Modelling Data

The MIKE11 modelling data from the Bewsher 2002 study was collected by Jacobs from NSW Office of Environment and Heritage for use in this study. The MIKE11 model was developed using version 2000 of MIKE11. A schematic of the MIKE11 model is presented in **Appendix D**.1. The model uses 1D flowpaths with link channels to represent a quasi-2D flood behaviour. MIKE11 cross sections are not geo-referenced within the model, however, a list of each cross section and its location is reported. Modelled peak discharge in Billabong Creek near Walbundrie and upstream of Rand are summarised in **Table 2-3**. A review of modelling results from Bewsher 2002 study indicates the modelled peak flows in Billabong Creek upstream of Rand were not impacted by the various scenarios investigated.

Table 2-3 Flow distributions from the MIKE11 model for the flood events

Flood event	Source	Billabong Creek at Walbundrie (m^3/s)	Modelled Discharge at 'BILLABONG CK 36862.5'[1] (m^3/s)
1970	Bewsher 2002	296	238
1974	Bewsher 2002	407	272
1981	Bewsher 2002	185	164
1983	Bewsher 2002	444	297
1995	Bewsher 2002	307	226
2010	This Study	554	347
2011	This Study	264	206
2012	This Study	446	282

[1] refer to **Appendix D.1** for location of MIKE11 cross section "BILLABONG CK 36862.5"

The MIKE11 model for the 1974 event was run in version 2014 of MIKE11 and a comparison modelled flows indicated no significant changes in flows between Bewsher 2002 study and this study. The MIKE11 model was run for 2010, 2011 and 2012 flood events using recorded inflows for Billabong Creek @ Walbundrie gauge. Modelled peak flows for the flood events are shown in **Table 2-3**.

2.3 Community Consultation

2.3.1 Flood Questionnaire

A community consultation process was initiated to obtain flood information for past events. This involved sending a newsletter and a questionnaire (refer to **Appendix B**) to residents and landowners within the study area. The newsletter introduced the floodplain management process to the residents of the village, described the purpose of the questionnaire and provided the residents with contacts for their responses. The questionnaire was prepared in consultation with Council to help identify flooding issues for the study area and to provide reliable flood information to assist in the validation of the hydrologic and hydraulic computer models.

The flood information that was requested included:

- General information, such as:
  - Residents from the Study Area
  - Ownership of the residence
  - How long residents lived at the property
- Specific flood information, such as:
  - Experience on flooding in residence and/or at work
  - Location and depth of flood water in the worst flood experienced
  - Duration of flooding
  - Flood damages to residence and business
  - Disruption to vehicular access to residence during flooding
  - Assistance required by residents from SES
  - Flooding to residence made worse by works on other properties or by construction of roads or other structures
  - Identify information (eg. flood photographs, newspaper clippings, flood marks etc) that can be provided to Consultant
  - Residents intention for further development on their lands
  - Ranking of development types for protection against flooding
  - Ranking of potential flood mitigation measures
  - Any comments on any other issues associated with this study.

2.3.2 Summary of Responses to Flood Questionnaire

In total, one (1) response was received from the community to the questionnaire. A summary of the response is provided in the following paragraphs details on the consultation undertaken by the SES following the flood event of March 2012 are included in the report (Yeo, 2013).

Residency status (Question 1-2)

The respondent was a resident of the study area, owning the residence.

Length of Residency in Rand and Business Activity (Questions 3-5)

The respondent lived in the study area for 49 years and does not manage a business in Rand.

Experiences of Flooding (Questions 6-12)

The respondent had experienced flooding at their residence in 2010. The depth was estimated at 2 feet (61cm). The respondent estimated that the duration of flooding was 3 days.

There was moderate damage to the respondent's yard. The access was cut off to the respondent's property, though no emergency assistance was required from the SES.

Flood Evidence (Questions 13, 15)

The respondent indicated that they did not have evidence from past flooding.

Flood Affects to properties due to works (Questions 14)

The respondent was unsure whether works on other properties had impacted on flooding at their property. One respondent located outside the study area identified that the public road aggravated flooding to the property.

Intention of Respondents for further development (Question 16)

The respondent did not intend to undertake further works on their property.

Priority for protecting different types of developments from flooding (Question 17)

The respondent did not indicate their thoughts on this question.

Priority for flood mitigation measures (Question 18)

The respondent did not indicate their thoughts on this question.

Further comments (Question 19)

The respondent did not provide any further comments.

Wanting to be kept informed (Question 20)

The respondent wished to be kept informed of the progress of the flood study.

Contact details for respondents (Question 21)

The respondent provided contact details.

2.4 Topographic Survey

A topographic survey was undertaken as part of this study to collect additional data to satisfy the scope of the study. The scope of the topographic survey was identified by Jacobs, with Council engaging T J Hinchcliffe & Associates to undertake the ground survey. T J Hinchcliffe & Associates provided the following results from the ground survey to Jacobs:

- Details for the bridge (Four Corners Road / Kindra Road crossing Billabong Creek). Details included deck and underside levels, length, width, railing height, location and width of piers and photographs;
- Details of the Rand levee (including spot heights along its 520m length, details of a culvert crossing the levee and photographs; and
- Levels of the manual gauge located upstream of the Four Corners Road / Kindra Road bridge. The 4m mark on one gauge is at 152.74 mAHD and the 6m mark on the other is at 154.87 mAHD. This indicates a difference of 0.13m between the two gauges which are located approximately 5m apart.

Details on the topographic survey are presented in the Urana Flood Study Survey Report prepared by T J Hinchcliffe & Associates. The relevant topographic survey information collected by T J Hinchcliffe & Associates for Rand is presented in **Appendix A**.

3. Catchment Hydrology

3.1 Catchment Description

The village of Rand is located along Billabong Creek and the creek is the main source of flooding for the village. Billabong Creek drains a catchment area of approximately 2,620km^2 to Walbundrie, where a gauging station is located. The creek then flows for a further 30km in a north-westerly direction to Rand. The creek runs along the south-western edge of the village and under Four Corners Road. Billabong Creek then continues along the southern side of Mahonga Road where it is then joined by Wallandoon Creek. The creek continues to flow north-westerly, passing Lake Urana. Just west of Lake Urana, Colombo Creek, Cocketgedong Creek and Nowranie Creek all join Billabong Creek, which then continues westward to its confluence with the Edward River, before joining the Murray River.

The catchment is predominantly cleared rural land, with the majority of land being used for grazing with some areas being used for dryland cropping and horticulture. The catchment's highest elevation is approximately 880m AHD. Billabong Creek rises in the east of the catchment and flows westward to an elevation of approximately 175m AHD at Walbundrie and then flows in a north-westerly direction to Rand, at an elevation of approximately 150m AHD.

During flood events, water from Billabong Creek can breakout in between Walbundrie and Rand, flowing south toward Nowranie and Wangamong Creeks. This effluent acts as a natural regulator to suppress maximum flood heights at Rand (Yeo 2013).

3.2 Flood Frequency Analysis

A flood frequency analysis was undertaken using the available annual peak flows for Billabong Creek @ Walbundrie gauge (GS 410091) in PINNEENA for the period 1965 to 2014. Data prior to 1990 has not been assigned a quality code, while data from 1990 is of a good quality. There are several periods with missing data during 1969, 1981, 1997, 2009 and 2013. By using other gauges on Billabong Creek (both upstream and downstream) or gauges in adjacent catchments, an analysis was undertaken to see if the captured data for the year is likely to include the annual maximum flow. In most cases the recorded data covered the annual peak flow. The exception was 1997, where it was ambiguous as to whether the gauged data captured the annual peak. This year was removed from the dataset. TUFLOW's FLIKE (BMT WBM 2015) (a program for undertaking flood frequency analysis) was then used to undertake a flood frequency analysis on the data. A Log Pearson Type III (LP3) distribution was fitted to the data annual maximum flow data using a Bayesian inference for two scenarios without and with censoring of the peak flow on record for the 1931 event (Bewsher 2002). The results are presented in **Figure 3-1** and **Figure 3-2** and a comparison of flood frequency results between this study and Bewsher 2002 study is shown in **Table 3-1**. It is to be noted that the flood frequency analysis undertaken by Bewsher (2002) was based on peak flow data for the period 1965 to 1998 and a Log Pearson Type III distribution was fitted to annual maximum flow data possibly by the method of moments. A comparison of results presented in **Table 3-1** shows that peak flows estimated in this study between 10% AEP and 1% AEP events are higher than Bewsher 2002 study.

Table 3-1 Comparison of flood frequency results for Billabong Creek @ Walbundrie

Annual Exceedance Probability	Peak Flow (m^3/s) This Study[1]	Peak Flow (m^3/s) Bewsher 2002
20%	220 (240)	223
10%	341 (388)	325
5%	450 (533)	418
2%	568 (704)	525
1%	639 (814)	594

[1] Peak flow with 1931 as censored flow is shown within ()

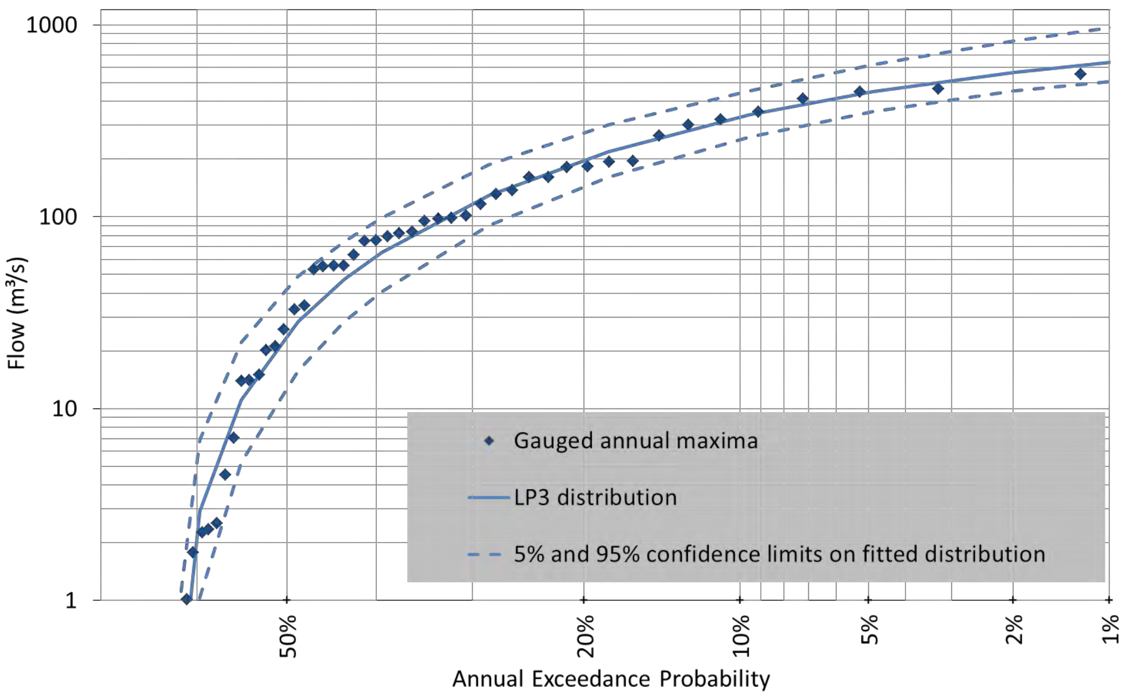


Figure 3-1 Flood Frequency Curve for Billabong Creek @ Walbundrie (GS 410091) 1965-2014

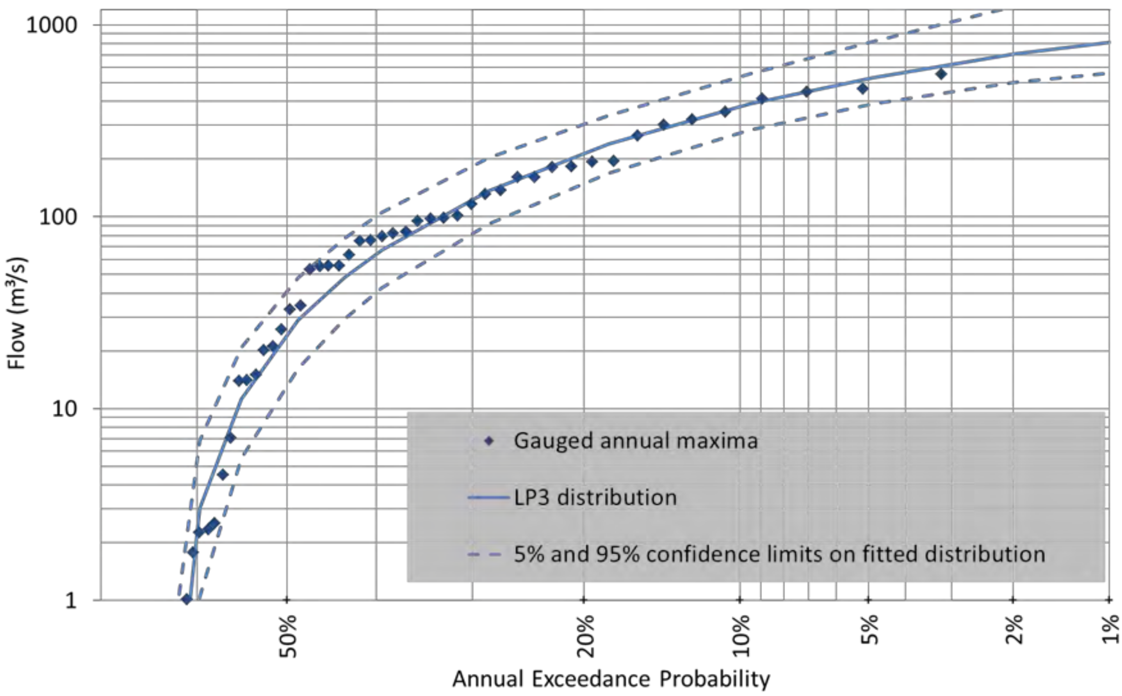


Figure 3-2 Flood Frequency Curve for Billabong Creek @ Walbundrie (GS 410091) 1965-2014 with Censored 1931 Flood

3.3 Catchment modelling

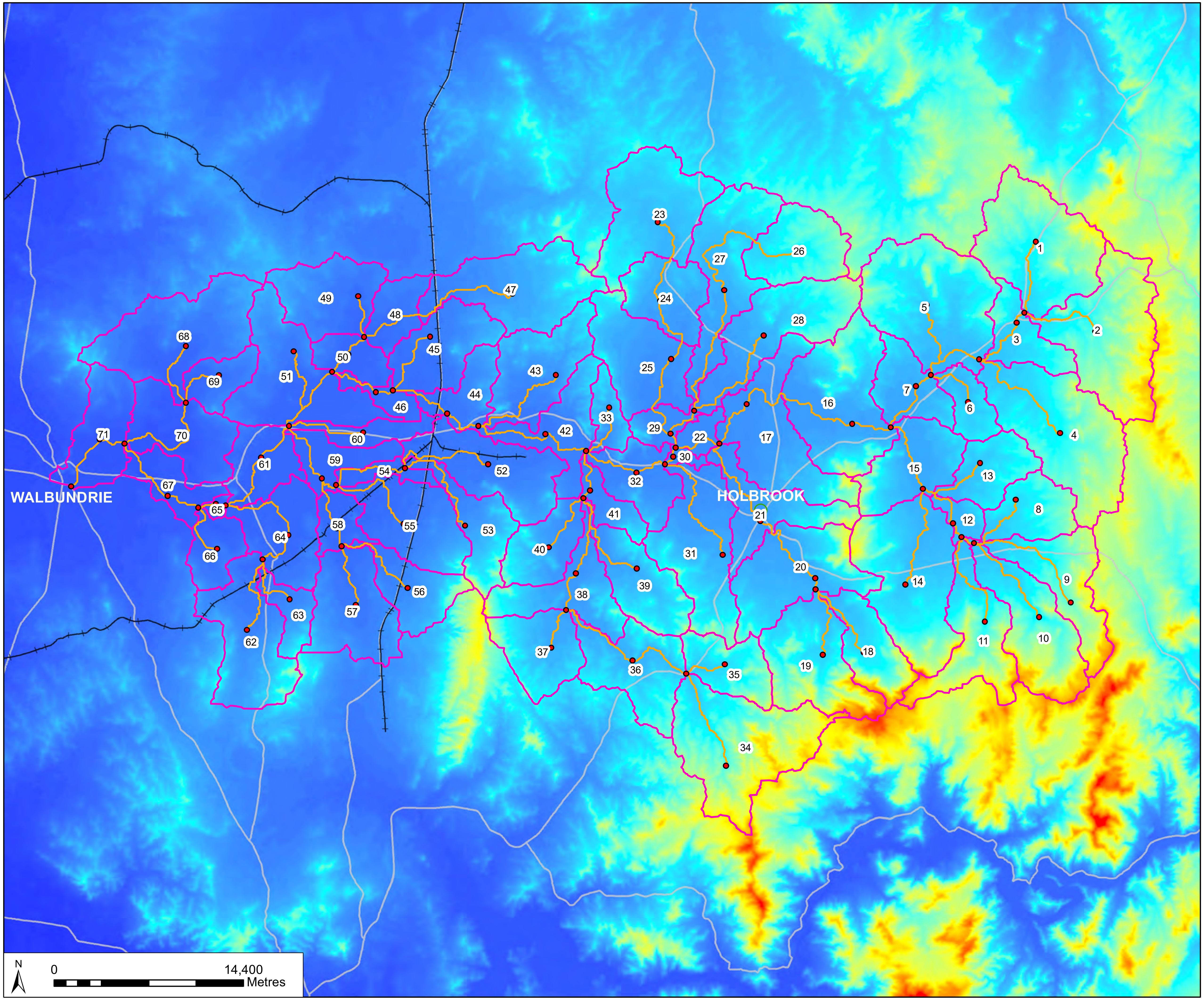
Whilst adequate recorded streamflow data is available in PINNEENA for Billabong Creek @ Walbundrie gauge for calibration and verification of a hydraulic model for the flood study of Rand, a hydrologic model will be required to estimate design catchment runoff for the full range of flood events up to and including the PMF.

3.3.1 Methodology

It is to be noted that no information was available on the WBNM hydrology model (WMAwater 2013) for Billabong catchment at the beginning of this study and hence it was necessary to set up a new hydrology model as part of this study. The Billabong Creek catchment to Walbundrie was modelled using RORB (version 6.18), a runoff routing program (Laurenson et al 2010). RORB is one of the most widely used models of its type in Australia, and consequently there is substantial information available on the value of the model parameters for a wide range of catchments. The model has the capability to simulate both linear and non-linear catchment behaviour, and exhibits many desirable modelling features, such as areally distributed inputs, flexible reservoir-routing options and the ability to model flows at a number of points throughout the catchment.

3.3.2 RORB Model Configuration

The Billabong Creek sub-catchments were delineated based on the 30m SRTM DEM, which covers the entire catchment to be modelled. A total of 71 sub-catchments were delineated to Walbundrie, covering an area of 2,620km^2. An outline of the RORB catchments is shown in **Figure 3-3**. Catchment routing channels followed overland flow paths and elevations were obtained from the SRTM DEM. The model was developed using MiRORB. A nominal impervious fraction of 5% was used across the catchment. Further details on the RORB model are provided in **Appendix C**.



Legend

- RORB nodes
- RORB links
- RORB subcatchments
- Railway
- Major Roads

SRTM DEM

Elevation (m AHD)

High : 900

Low : 100

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	RORB Model Setup
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE 3-3
CHECK	DATE	
AH	25/09/2017	

4. Hydraulic Modelling

4.1 Model selection

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydrodynamic model has been developed for Rand. TUFLOW is an industry-standard flood modelling platform, which was selected for this assessment as it has:

- Capability in representing complex flow patterns on the floodplain, including flows through street networks and around buildings and on flat terrain where flow patterns may not be concentrated or well defined
- Capability in accurately modelling flow behaviour in 1D channel, bridge and culvert structures and interflows with adjacent 2D floodplain areas
- Easy interfacing with GIS and capability to present the flood behaviour in easy-to-understand visual outputs

The model was developed and run in TUFLOW version 2013-12-AD-w64, in double-precision mode.

4.2 TUFLOW Model Configuration

4.2.1 Extent and structure

The Rand TUFLOW model is comprised of:

- A 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use
- A 2D representation of the Rand bridge over Billabong Creek
- Obstructions to flow are represented as 2D objects, including existing buildings.

Refer to the following report sections for details on these features. The locations of various features in the TUFLOW model are shown in **Figure 4-1**.

4.2.2 Model Topography

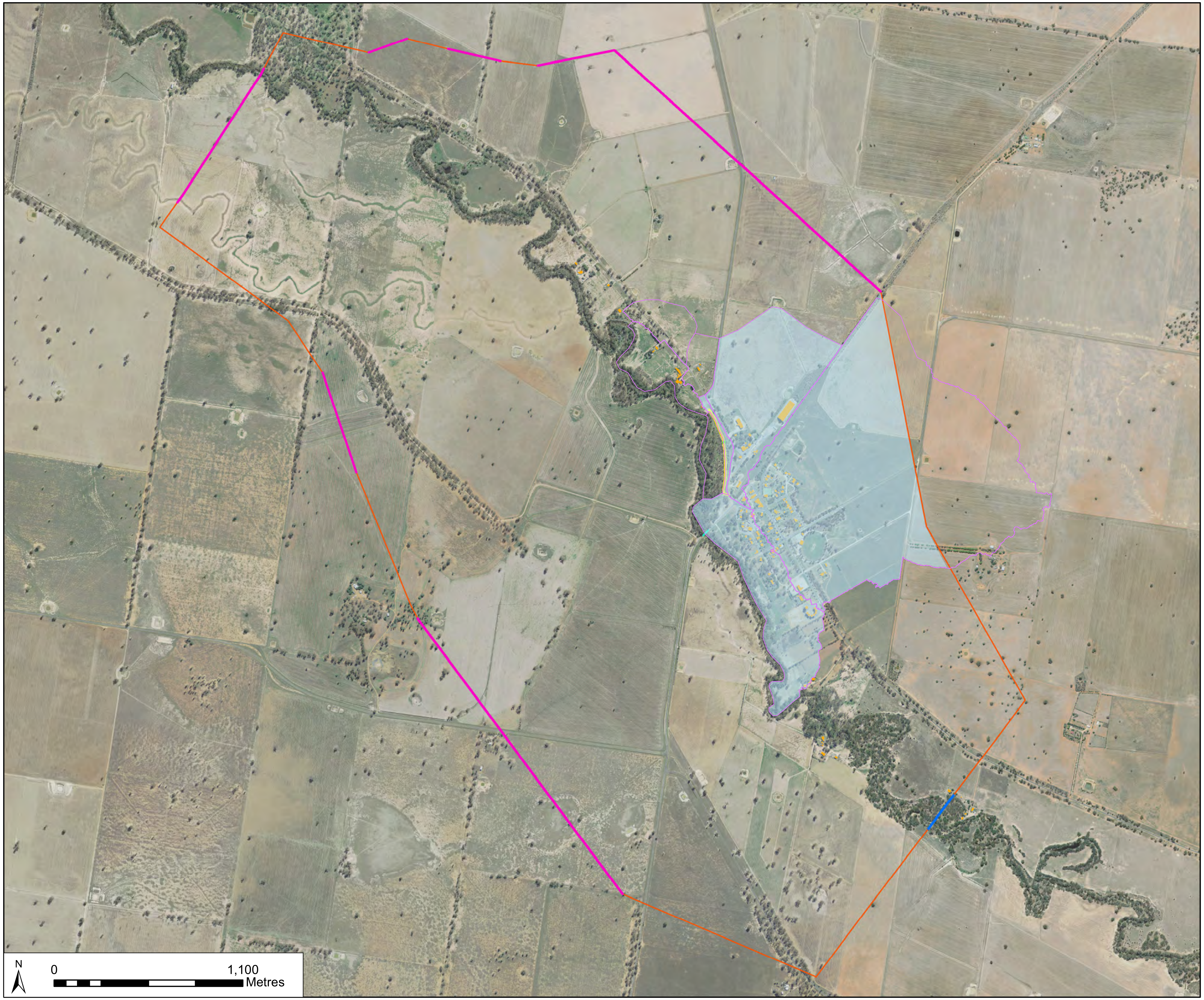
The topography of the catchment is represented in the model using a 5m grid. The grid size was selected to optimise model run time and to achieve a level of precision required for adequate representation of both mainstream and overland flood behaviour within the study area. Local catchments draining the town into Billabong Creek have smaller areas and relatively flatter topography and hence a 5m grid is considered a reasonable representation of major overland flow paths within the TUFLOW model. The basis of the topographic grid used in the TUFLOW model is the LiDAR data set for Rand (**Figure 2-1**).

4.2.3 Bridges

The main bridge in Rand, Four Corners Road crossing Billabong Creek, was modelled as a 2D structure. The details of the bridge were obtained from the topographic survey undertaken for this study by TJ Hinchcliffe & Associates in 2015. The underside, deck and railing levels were included in the model along with a blockage and form loss factor for each layer.

4.2.4 Building Polygons

This study considers buildings as solid objects on the floodplain. This means that buildings form impermeable boundaries within the model and while water can flow around buildings, it cannot flow across their footprint. The building polygons were superimposed on the model grid to make model computational cells under the footprints inactive. This will reduce the availability of temporary floodplain storage, however, this will be negligible in comparison to the overall flood volume and is considered a conservative approach.



Legend

- XP-RAFTS sub-catchment
- TUFLOW XP-RAFTS Inflow
- 1D culverts
- Levee
- Inflow boundary
- Outflow boundary
- Buildings
- 2D Bridge
- Model Extent

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	TUFLOW Model Setup
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE 4-1
CHECK	DATE	
AH	1/08/2017	

4.2.5 Property Fencelines

Fencelines have not been represented in the model and floodwaters are allowed to flow across them freely. Although fences may obstruct overland flood flows in some parts of the catchment, experience indicates that representing fences in the hydraulic model requires making invalidated assumptions about depths at which fences overflow or fail. The dominant type of rural fencing consists of wooden posts and barbed wire, which allows floodwaters to pass through. It has been assumed that these fences do not cause any significant obstruction to the flow.

4.2.6 Surface Roughness

All parts of the study area within the TUFLOW model were assigned hydraulic roughness values according to areas defined based on aerial photography. These are based on engineering experience and typical values used in previous flood studies undertaken in Western NSW by Jacobs and other consultants. These are provided in **Table 4-1** below.

Table 4-1 TUFLOW model grid hydraulic roughness values

Land Use Type	Manning's n
Low density residential areas	0.08
Open rural areas	0.045
Dense vegetation	0.12
Roads and paved areas	0.02
Railway	0.05
Creeks	0.045

4.3 Boundary Conditions

4.3.1 Model Inflows

Hourly flow data for Billabong Creek @ Walbundrie gauge were extracted from PINNEENA 10.2 for the flood events of 2010, 2011 and 2012. The extracted flow hydrographs for the three flood events were used in the MIKE11 model for Billabong Creek and the model was run for the three flood events. Simulated flows at MIKE11 cross section "BILLABONG CK 36862.5" (refer **Appendix D.1**) for the three flood events are shown in **Figure 4-2** to **Figure 4-4**. Modelled peak flows in Billabong Creek upstream of Rand for flood events of 2010, 2011 and 2012 were 347 m^3/s, 206 m^3/s and 282 m^3/s respectively. The modelled hydrographs were adopted as upstream inflow hydrograph in the TUFLOW model for Rand.

Figure 4-2 : Modelled Flow in Billabong Creek upstream of Rand for 2010 Flood

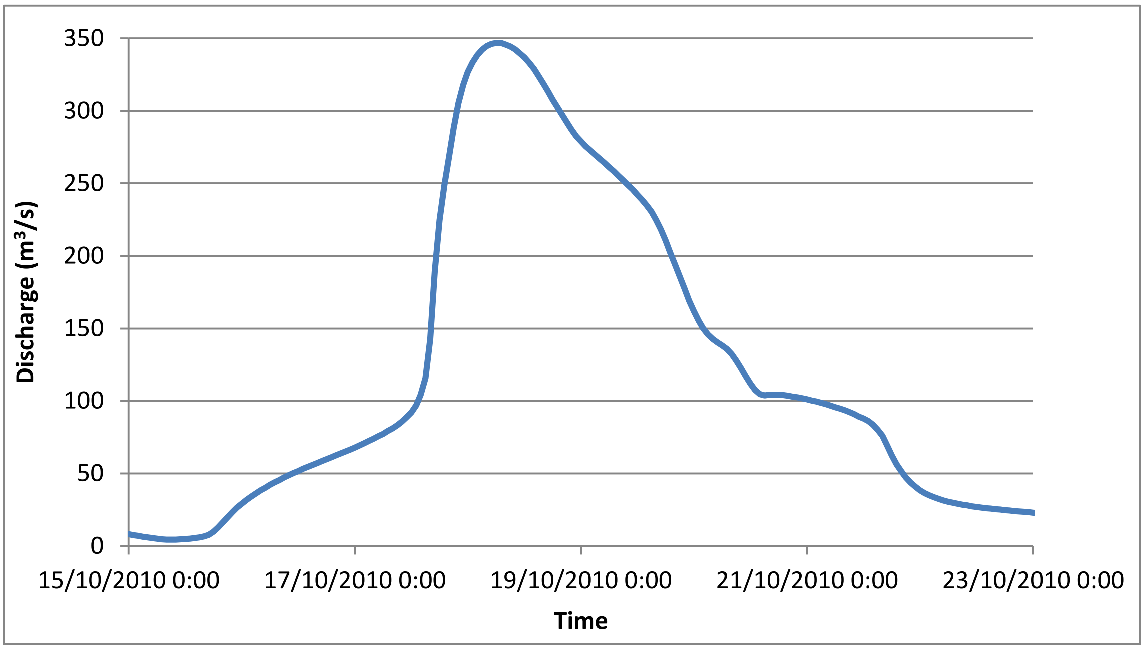


Figure 4-3 : Modelled Flow in Billabong Creek upstream of Rand for 2011 Flood

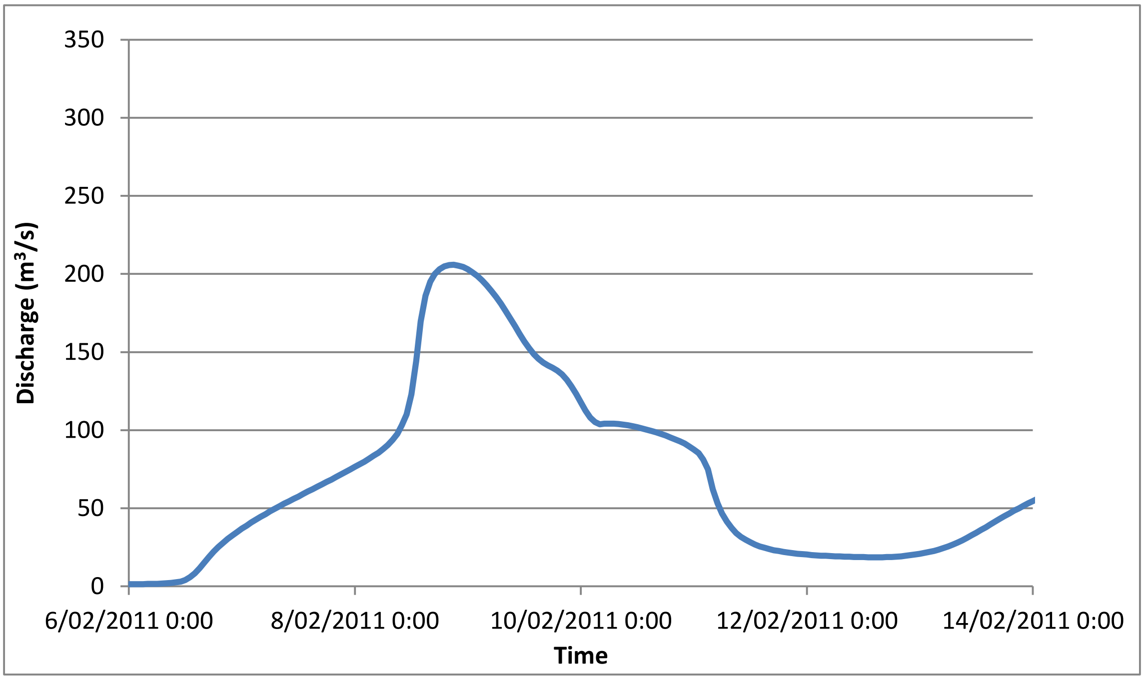
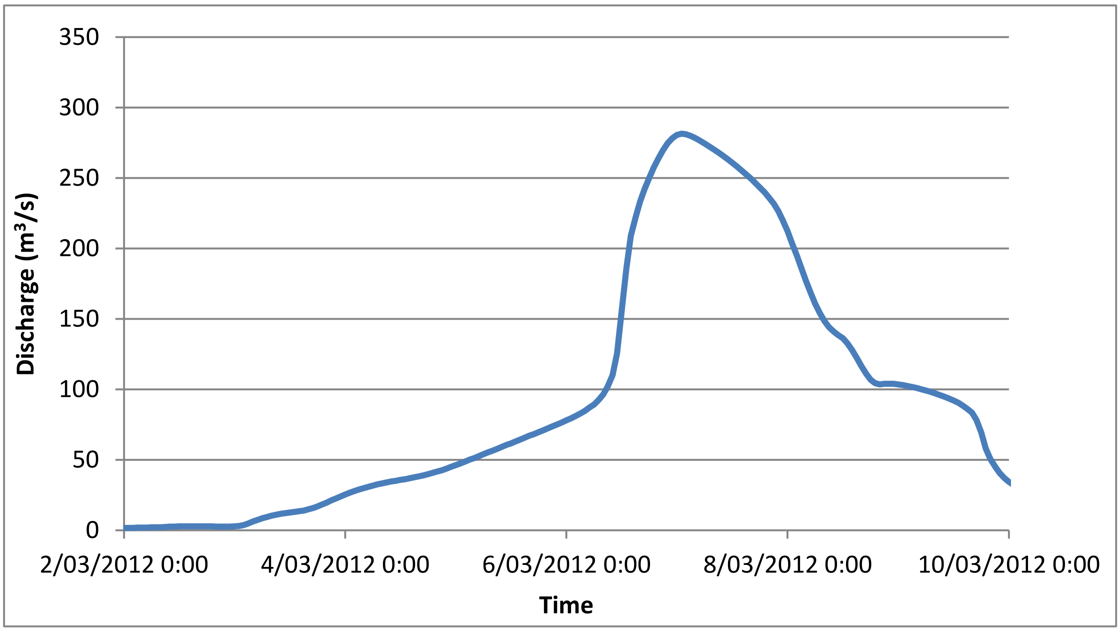


Figure 4-4 : Modelled Flow in Billabong Creek upstream of Rand for 2012 Flood



4.3.2 Tailwater Conditions

The TUFLOW model for Rand incorporated three downstream boundaries, including the main channel, overbank flow and a secondary channel. The boundary was located approximately 3.5km downstream of the village to eliminate the potential influence of the boundary conditions on flood levels in the study area. Seven additional breakout boundaries were defined. These are located where floodwaters break out of Billabong Creek. Three boundaries are located on the south-western edge of the model to receive flows breaking out towards Nowranie Creek, and four boundaries were defined along the northern edge of the model boundary to receive flows breaking out downstream of the Rand levee. These boundaries are located at least 1.2km away from the village. A normal depth condition was applied to the downstream and breakout boundaries.

4.3.3 Initial Conditions

A small flow was assumed at the start of the model run for each event.

5. Calibration and Verification

5.1 Selection of Calibration and Verification Events

There have been a number of floods that have impacted Billabong Creek, most notably the 1974 flood. Due to availability of accurate flood level data, however, the most recent flood events of 2010, 2011 and 2012 were selected for model calibration and verification. The RORB hydrologic model was calibrated to the 2010 and 2012 events, verified against the 2011 event. It is to be noted that estimated design flows simulated by the RORB model will be validated against at-site flood frequency analysis results.

The TUFLOW hydraulic model was calibrated to the recorded peak flood levels at the staff gauge on Rand Bridge for the two largest events (in terms of flow at Walbundrie), 2010 and 2012, with the 2011 event being used for verification.

5.2 Hydrologic Modelling

5.2.1 2010 Event

The Walbundrie RORB model was calibrated to the 2010 flood event. A review of the recorded streamflow and pluviograph data was undertaken to select the duration of the storm be modelled. The available daily rainfall gauges (**Section 2.2.3.1**) were used to obtain the spatial distribution of rainfall depth across the catchment for the period 15-16 October 2010 which is consistent with the spatial distribution adopted by WMAwater (2013). The temporal pattern from the nearby pluviograph stations (**Section 2.2.3.2**) was used for the timing and temporal distribution of the rainfall. The RORB model was calibrated to the recorded gauge flows at Walbundrie (410091). The baseflow was removed from the recorded data using a manual graphing method to obtain the rainfall excess runoff. The value of m (catchment linearity) was retained at the recommended 0.8 while other parameter values were changed. The peak runoff was matched by the RORB model. The model, however, simulated a quicker time to peak than was observed. This could be due to the fact that there was one pluviograph gauge that was discarded due to missing data, or the pluviograph records to not accurately represent the storm over the Walbundrie catchment (since they are located outside the catchment area). The calibrated parameters and results are summarised in **Table 5-1** for hydrographs shown in **Figure 5-1**.

Table 5-1 2010 event Walbundrie RORB calibration summary

Calibrated Parameters	Value	
Initial loss (mm)	32	
Continuing loss (mm/hr)	2.1	
Kc	122	
m	0.8	
Calibration Results	**Recorded (excluding baseflow)**	**Modelled**
Peak discharge (m^3/s)	522.4	512.3
Time to peak (hrs)	54.2	42.0

Volume (m^3) - over the simulation period of approximately 90 hours	8.10×10^7	9.12×10^7

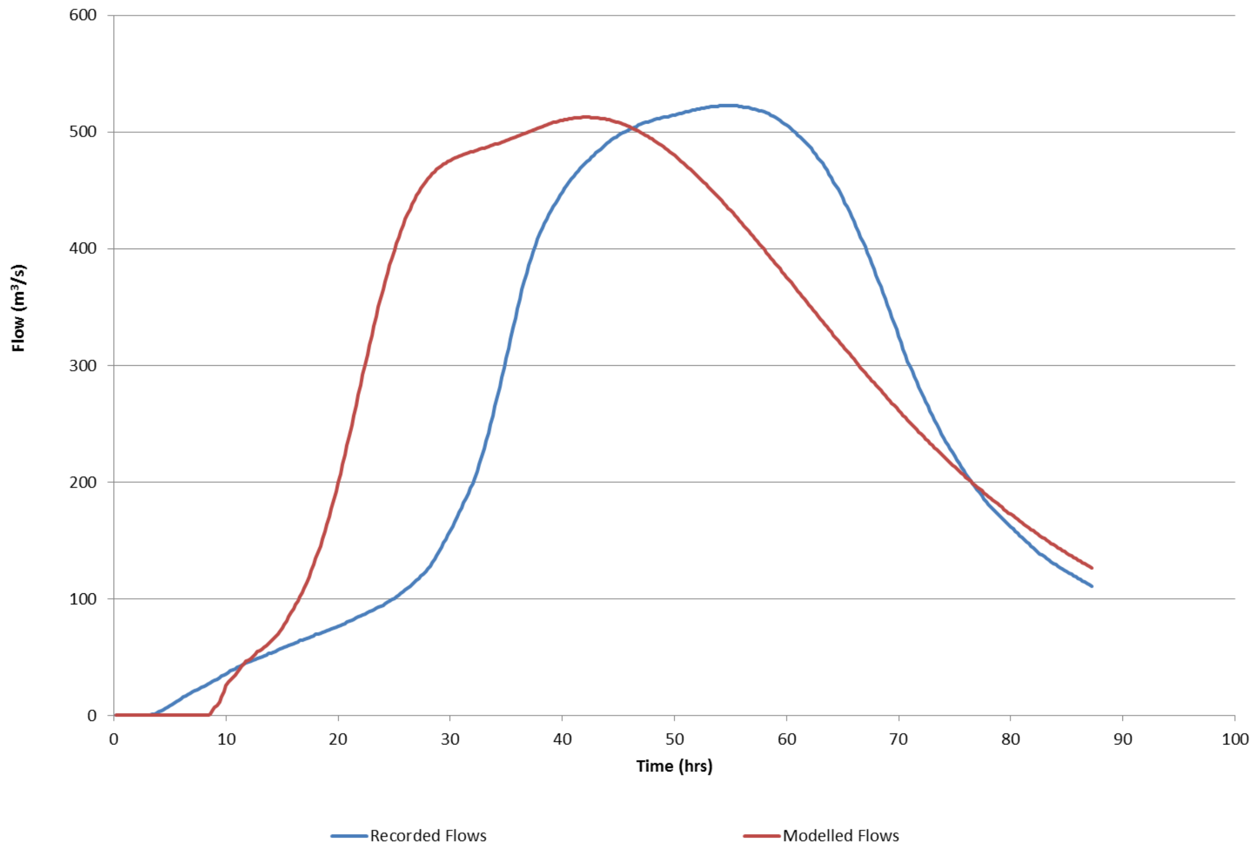


Figure 5-1 2010 event Walbundrie RORB calibration hydrograph

5.2.2 2012 Event

The Walbundrie RORB model was also calibrated to the 2012 flood event. A review of the recorded streamflow and pluviograph data was undertaken to select the duration of the storm be modelled. The available daily rainfall gauges (**Section 2.2.3.1**) were used to obtain the spatial distribution of rainfall depth across the catchment for the period 3-4 March 2012. The spatial distribution is consistent with the spatial distribution adopted by WMAwater (2013). The temporal pattern from the nearby pluviograph stations (**Section 2.2.3.2**) was used for the timing and temporal distribution of the rainfall. The RORB model was calibrated to the recorded gauge flows at Walbundrie (410091). The baseflow was removed from the recorded data by a manual graphing method to obtain the rainfall excess. The value of m (catchment linearity) was retained at the recommended 0.8 while other parameter values were changed. The runoff peak was matched by the RORB model and the timing of the peak was replicated. The model overestimated the volume of the event, with the rising and receding limbs of the hydrograph having a more gradual increase. The calibrated parameters and results are summarised in **Table 5-2** for hydrographs shown in **Figure 5-2**.

Table 5-2 2012 event Walbundrie RORB calibration summary

Calibrated Parameters	Value	
Initial loss (mm)	60	
Continuing loss (mm/hr)	2.1	
Kc	122	
M	0.8	
Calibration Results	**Recorded (excluding baseflow)**	**Modelled**
Peak discharge (m^3/s)	374.9	375.6
Time to peak (hrs)	61.4	61.0
Volume (m^3) - over the simulation period of approximately 90 hours	4.16×10^7	4.74×10^7

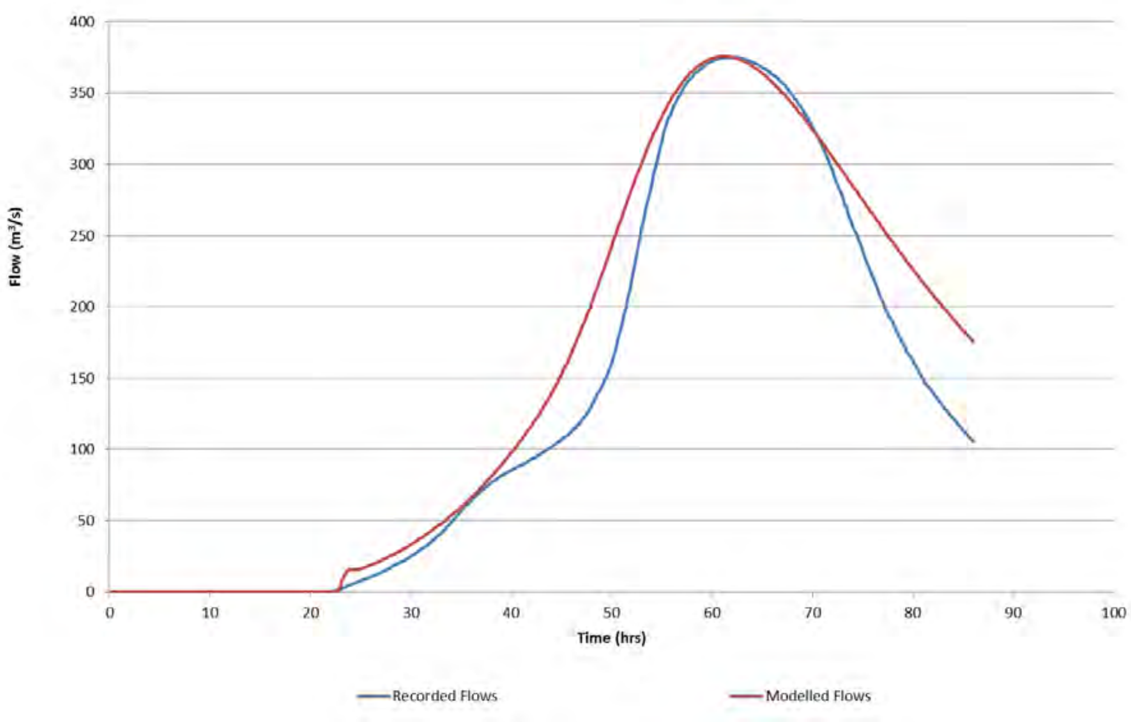


Figure 5-2 2012 event Walbundrie RORB calibration hydrograph

5.2.3 2011 Event

The Walbundrie RORB model was verified with the 2011 flood event. A review of the recorded streamflow and pluviograph data was undertaken to select the duration of the storm be modelled. The available daily rainfall gauges (**Section 2.2.3.1**) were used to obtain the spatial distribution of rainfall depth across the catchment for the period 5-6 February 2011. The temporal pattern from the nearby pluviograph stations (**Section 2.2.3.2**) was used for the timing and temporal distribution of the rainfall. The RORB model was verified against the recorded gauge flows at Walbundrie (410091). The baseflow was removed from the recorded data by a manual graphing method to obtain the rainfall excess runoff. The RORB parameters (m and Kc) were obtained from the calibration runs. The initial loss was adjusted accordingly. The high initial loss used was due to a rainfall burst that occurred prior to the main storm burst. The observed peak runoff was matched by the RORB model. The timing of the peak was also replicated, however, the overall volume of the storm was overestimated. The calibrated parameters and results are summarised in **Table 5-3** for hydrographs shown in **Figure 5-3**.

Table 5-3 2011 event Walbundrie RORB verification summary

Calibrated Parameters	**Value**	
Initial loss (mm)	83	
Continuing loss (mm/hr)	2.1	
Kc	122	
m	0.8	
Calibration Results	Recorded (excluding baseflow)	Modelled
Peak discharge (m^3/s)	232.1	230.7
Time to peak (hrs)	73.6	73.2
Volume (m^3) - over the simulation period of approximately 90 hours	3.07×10^7	4.17×10^7

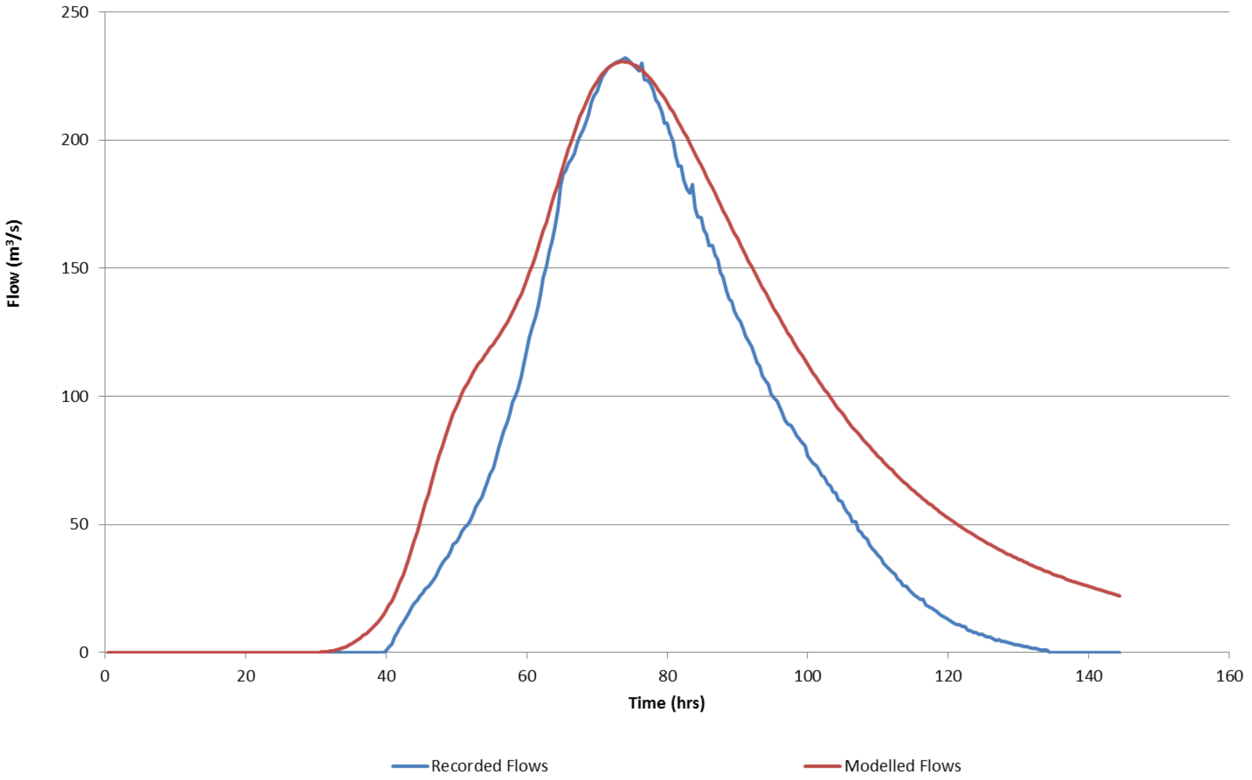
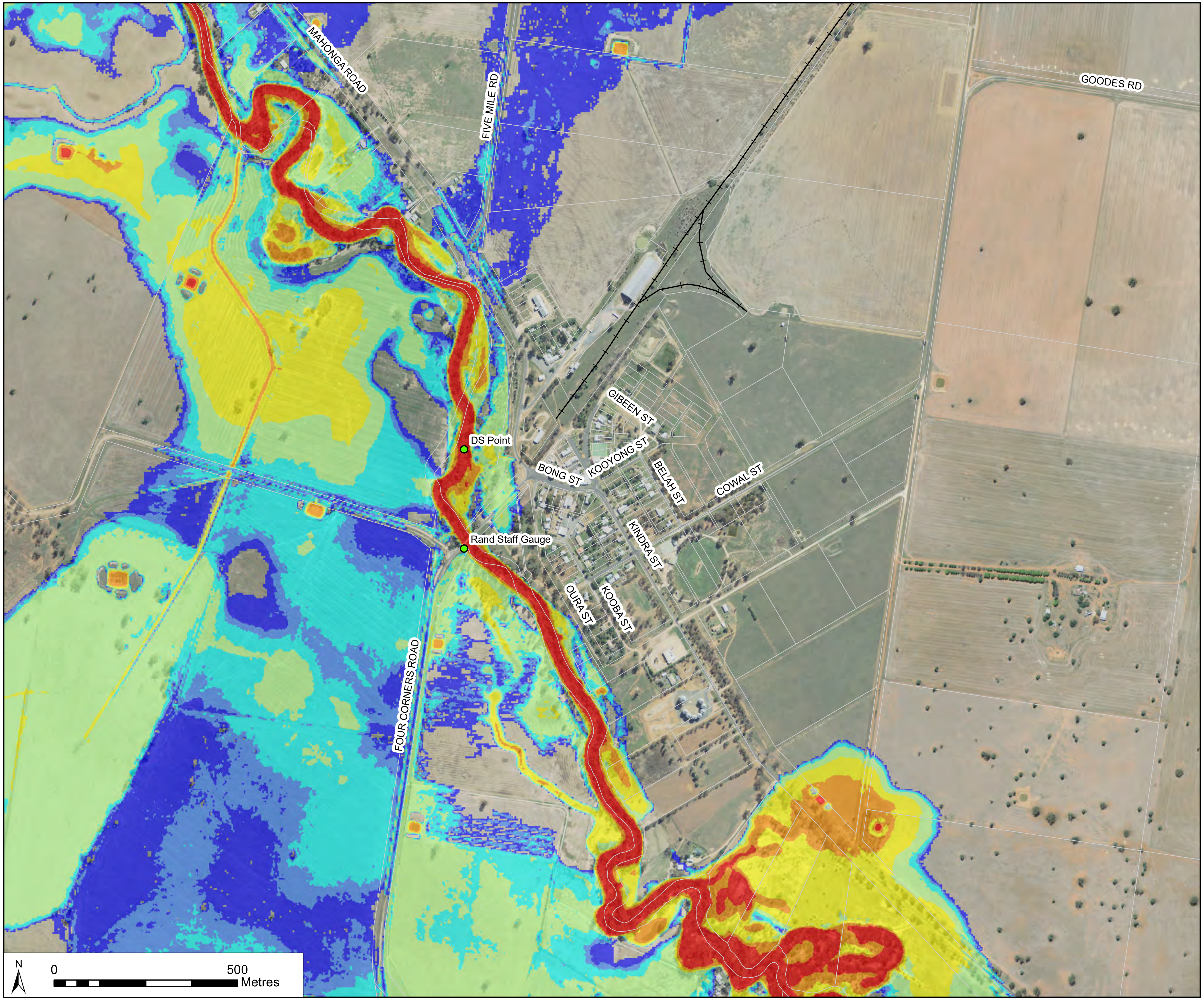


Figure 5-3 2011 event Walbundrie RORB verification hydrograph

5.3 Hydraulic Modelling

5.3.1 2010 Event

The flow hydrograph simulated by the MIKE11 model for this flood event was used as the upstream boundary conditions for the Rand TUFLOW model. The peak flow exceeded the in-bank capacity of Billabong Creek. Overflows break out to the south and south west, towards Nowranie and Wangamong Creeks, beyond the hydraulic model extent. Of the 347m^3/s peak flow entering the model, only 195m^3/s continues past the village, with the bridge conveying 189m^3/s. No properties are impacted upstream of the bridge within the village. The levee is not overtopped, although downstream of the levee, floodwater breaks out across Mahonga Road to the north. Floodwater encroaches on properties along Mahonga Road, downstream of the levee. The modelled flood level at the Rand staff gauge was the same as the recorded level (gauge height 7.1m). The flood map for the 2010 event can be seen in **Figure 5-4**. The modelled peak water level profile along Billabong Creek near Rand can be seen in **Figure 5-5**.



Legend

- Recorded flood level location
- Railway
- Cadastre

2010 flood depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	2010 Calibration Event Flood Depth Map
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-4
CHECK AH	DATE 18/08/2017	

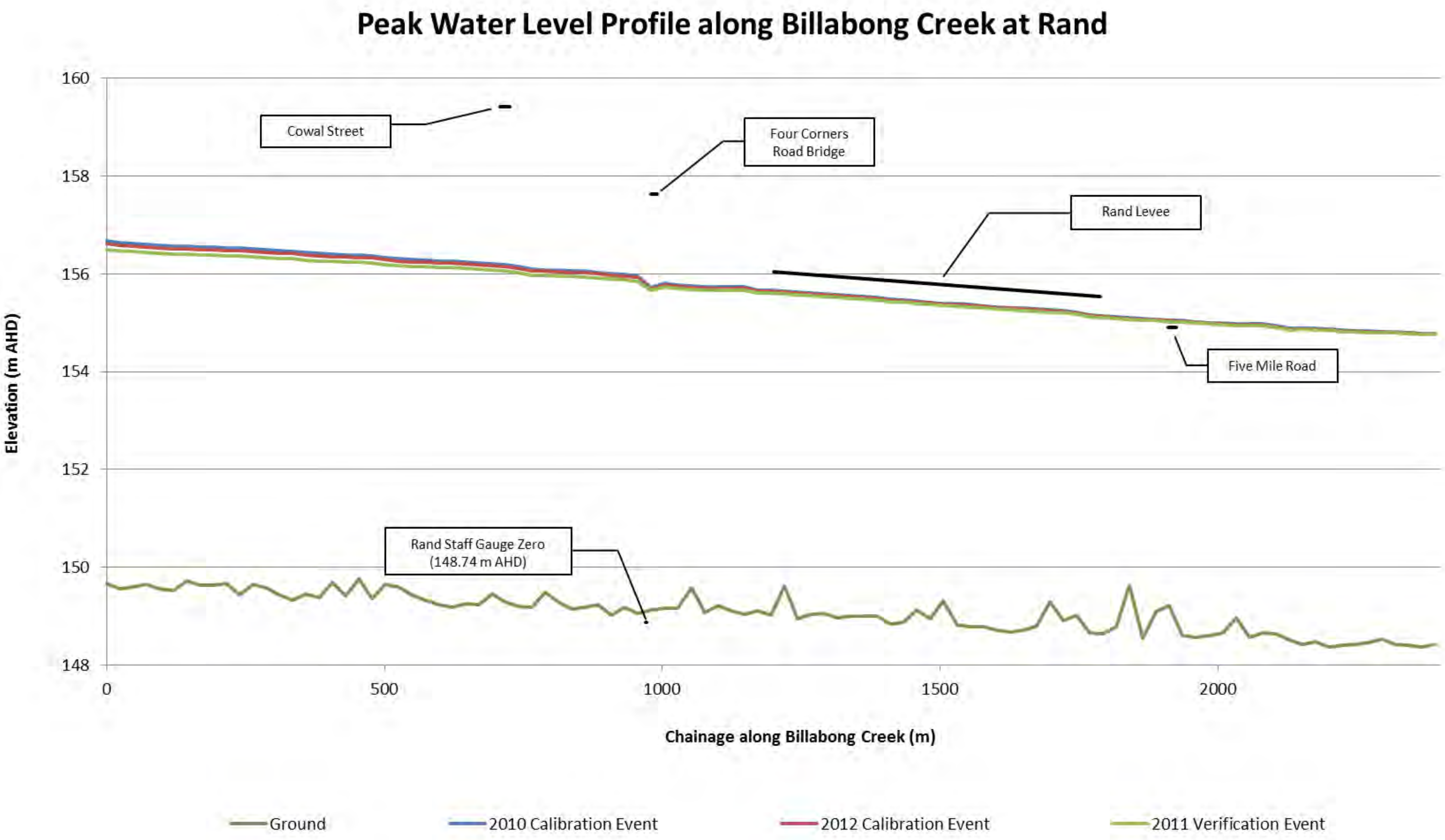
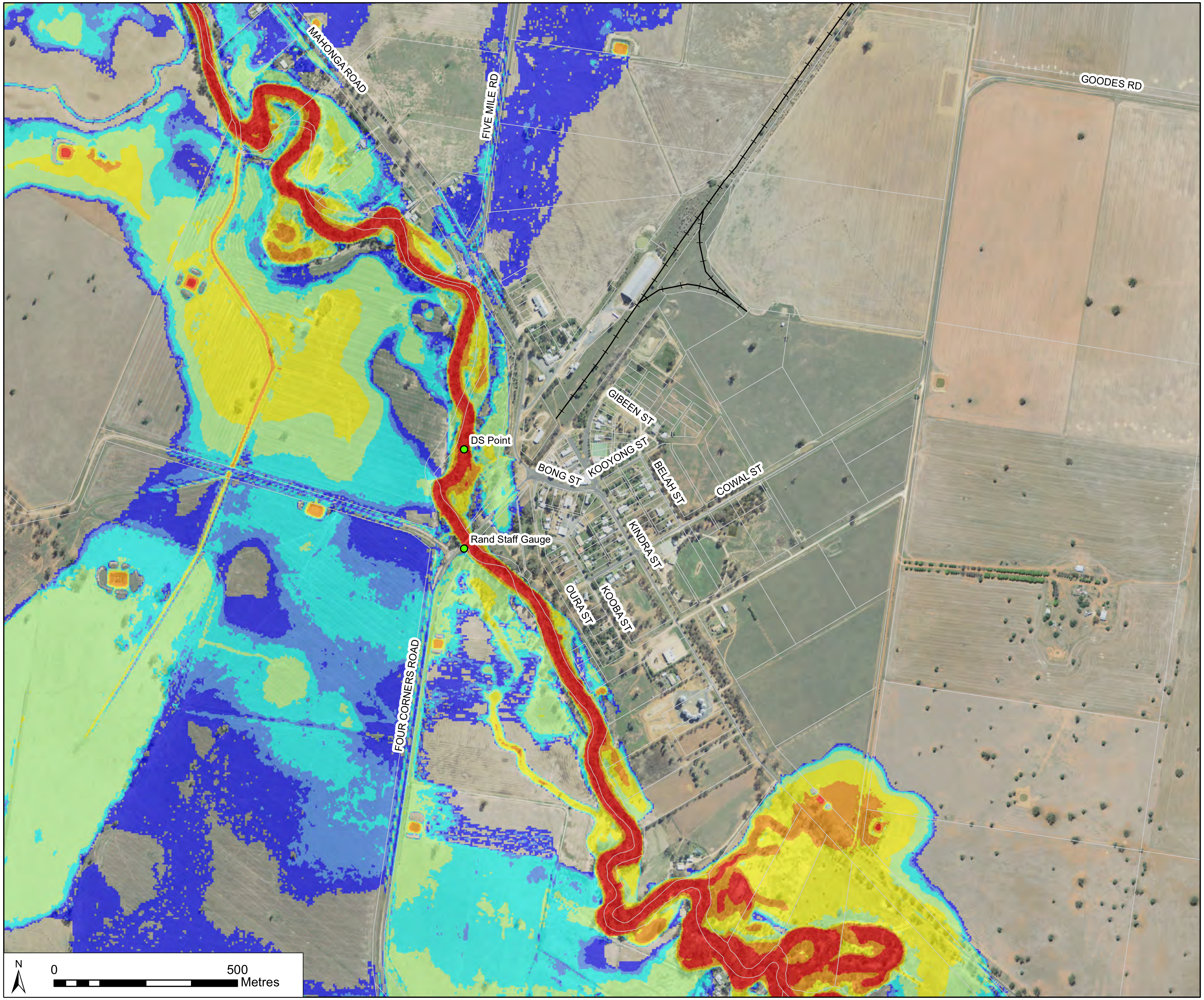


Figure 5-5 Peak Water Level Profile along Billabong Creek at Rand for calibration events

5.3.2 2012 Event

The flow hydrograph simulated by the MIKE11 model for this flood event was used as the upstream boundary conditions for the Rand TUFLOW model. The peak flow breaks out the bank of Billabong Creek and overflows break out to the south and south west, towards Nowranie and Wangamong Creeks, beyond the hydraulic model extent. Of the 282m^3/s peak flow entering the model, only 188m^3/s continues past the village, with the bridge conveying 183m^3/s. No properties are impacted upstream of the bridge within the village. The levee is not overtopped, although downstream of the levee, floodwater breaks out across Mahonga Road to the north. Floodwater encroaches on properties along Mahonga Road, downstream of the levee. This is consistent with reports of flooding contained in Yeo 2013. The modelled flood level at the Rand staff gauge (gauge height 6.95m) was within 0.12m of the recorded level. The modelled peak water level profile along Billabong Creek near Rand can be seen in **Figure 5-5**. The flood map for the 2012 event can be seen in **Figure 5-6**.



Legend

- Recorded flood level location
- Railway
- Cadastre

2012 flood depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

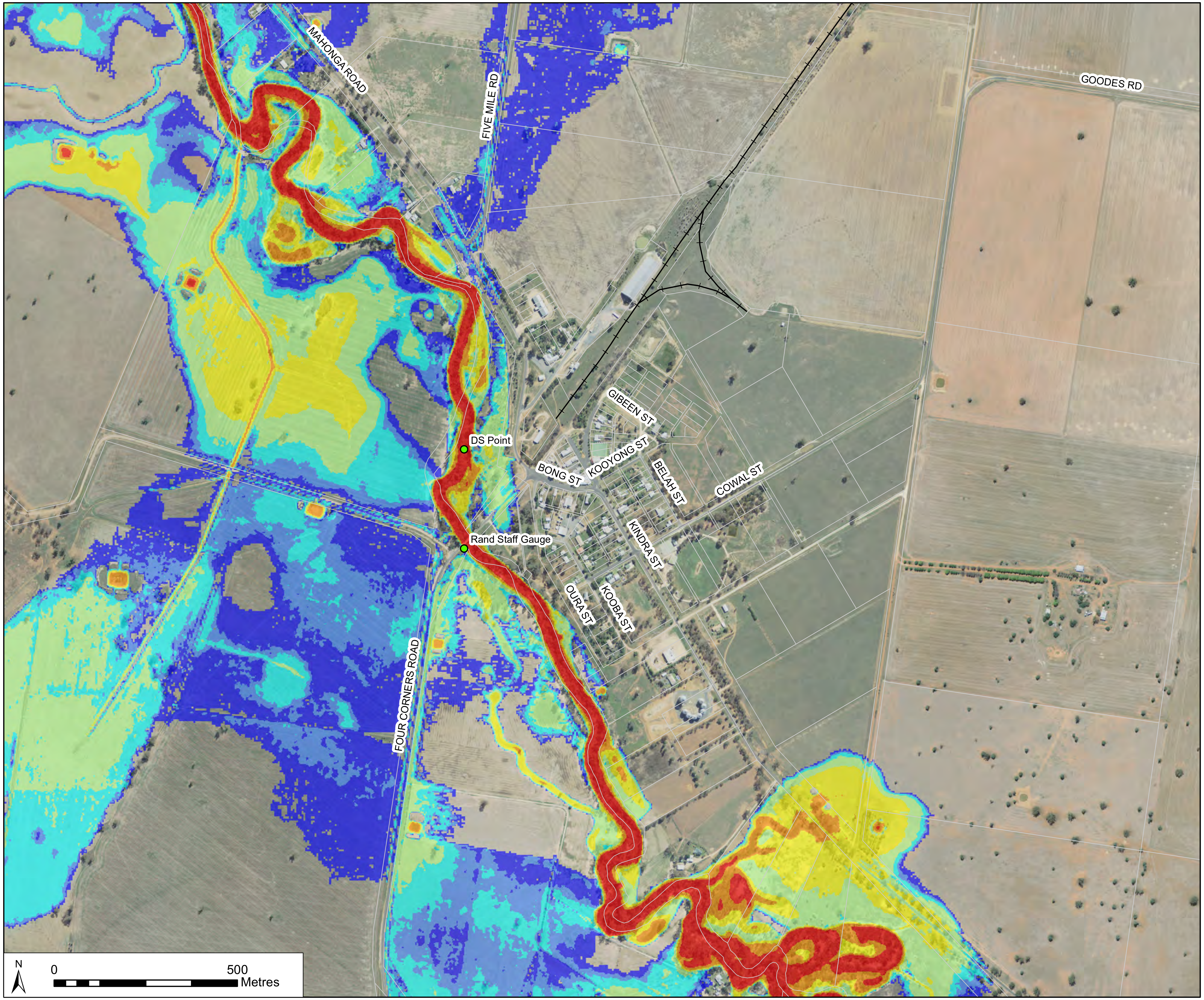
JACOBS

TITLE	2012 Calibration Event Flood Depth Map
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE 5-6
CHECK	DATE	
AH	18/08/2017	

5.3.3 2011 Event

The flow hydrograph simulated by the MIKE11 model for this flood event were used as the upstream boundary conditions for the Rand TUFLOW model. The peak flow overtops banks of Billabong Creek and overflows break out to the south and south west, towards Nowranie and Wangamong Creeks, beyond the hydraulic model extent. Of the 206m^3/s peak flow entering the model, 175m^3/s continues past the village, with the bridge conveying 174m^3/s. No properties are impacted upstream of the bridge within the village. The levee is not overtopped, although downstream of the levee, floodwater just breaks out across Mahonga Road to the north. Floodwater encroaches on properties along Mahonga Road, downstream of the levee. The modelled flood level at the Rand staff gauge was within 0.04m of the recorded level (gauge height 6.95m). The modelled peak water level profile along Billabong Creek near Rand can be seen in **Figure 5-5**. The flood map for the 2011 event can be seen in **Figure 5-7**.



Legend

- Recorded flood level location
- Railway
- Cadastre

2011 flood depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	2011 Verification Event Flood Depth Map
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR; CHECK AH	PROJECT # IA055600; DATE 18/08/2017

FIGURE 5-7

5.4 Sensitivity Analysis (2010 Flood Event)

A sensitivity analysis was conducted using the 2010 flood event. The following hydraulic model parameters were changed: inflows, Manning's n roughness, blockage of structures and the downstream boundaries. Each of these is addressed in the sections below and further details on the results from the sensitivity analysis are provided in **Appendix D**.

5.4.1 Inflows

The inflow hydrographs used (from the MIKE-11 model) were increased and decreased by 20%. Increasing the flows by approximately 70m^3/s, resulted in a large proportion of this breaking out to the south of the village, with only an additional 5m^3/s being modelled through the Rand bridge. The peak water levels were only increased by up to 0.025m in the vicinity of the village. When the inflows were reduced, a similar (reverse) trend was found, where the flow only decreased by approximately 6m^3/s through the Rand bridge, with water levels reducing by approximately 0.03m. The flow in Billabong Creek adjacent to Rand is heavily controlled by the breakout flows towards Nowranie Creek, as suggested in the SES Flood intelligence Report (Yeo 2013).

5.4.2 Manning's n

The Manning's n roughness values adopted (**Table 4-1**) were adjusted by +/-20%. Increasing the Manning's roughness values resulted in flows being approximately 8% less through the Rand bridge and an increase in the flows that break out to the south of Rand. The flood level upstream of the Rand bridge increases by approximately 0.01m and the flood level downstream increases by 0.02m. Decreasing the Manning's roughness values resulted in more flow breaking out upstream of Rand, with a reduction in flows being conveyed by the main channel through past Rand. The flow is reduced by approximately 6%. The flood levels, both upstream and downstream of the bridge are reduced by up to 0.2m.

5.4.3 Blockage of Structures

The bridge at Rand (Four Corners Road crossing Billabong Creek) had a 50% blockage factor applied to the 2D structure for the 2012 calibration event. The effect of 0% blockage and 100% blockage was modelled. In the 0% blockage scenario, the flow through the bridge only increased by approximately 3% and the flood level decreased by approximately 0.07m. The water level downstream of the bridge increased by approximately 0.02m. In the 100% blocked scenario, the water level increased by 0.82m on the upstream side and decreased by approximately 2.7m on the downstream side as a result of some water being diverted around to the right of the bridge and rejoining the main channel, while a significant portion is diverted to the left of the bridge and flows to the breakout boundary. Flows diverted to the right of the bridge result in some minor overtopping of the levee. The flow in Billabong Creek downstream of the bridge is approximately half that under the base case scenario.

5.4.4 Downstream Boundary

A normal water depth was used at the downstream and breakout boundaries. A sensitivity analysis was conducted by changing the tailwater levels by +/-0.5m. There was no change in the flows or flood levels in reducing the tailwater level at reporting locations identified in **Appendix D.4**. There was also no change in flood levels when the tailwater was increased, and negligible (<0.01m^3/s) in the flows. This indicates that the outflow boundaries are located far enough downstream to not impact the modelled flood behaviour in the vicinity of the village.

6. Estimation of Design Flood

The scope of the study included flood modelling for 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP events and the PMF event. Details on the input data used in hydrologic and hydraulic modelling for the design events are discussed in this section.

Two hydrologic models developed as part of this study (a RORB for the regional catchment area of Billabong Creek and an XP-RATFS hydrologic model developed for the local sub-catchments areas of the township) and two hydraulic models (an existing MIKE11 model for Billabong Creek and a TUFLOW model for Rand developed as part of this study) were utilised in the estimation of design flood for Rand. Initially, the calibrated and verified RORB model for Billabong Creek was run to estimate inflow hydrographs for the required design flood events which were then utilised in the MIKE11 model for Billabong Creek. Inflow hydrographs simulated by the MIKE11 model were then extracted and in combination with inflow hydrographs simulated by the XP-RAFTS model were subsequently utilised as inflow boundaries for the TUFLOW model.

6.1 Input Data for Hydrologic Modelling

An XP-RAFTS hydrology model was developed for a total catchment area of 287ha for the township and details on the XP-RAFTS model are provided in **Appendix C**.

6.1.1 Land Use

Hydrologic modelling was undertaken for the existing land use.

6.1.2 Rainfall Depths

The rainfall design data for this study for events up to and including the 0.2% AEP was generated within the RORB model applying the rainfall intensity, frequency and duration (IFD) relationship based on data presented in **Table 6-1**.

- Table 6-1: Data Used to Estimate Rainfall IFD

Data Description	RORB model	XP-RAFTS model
Zone	2	2
1 hour 2 year ARI mm/hr	20.54	19.11
12 hour 2 year ARI mm/hr	3.73	3.5
72 hour 2 year ARI mm/hr	1.05	0.92
1 hour 50 year ARI mm/hr	42.79	42.19
12 hour 50 year ARI mm/hr	6.97	6.78
72 hour 50 year ARI mm/hr	1.78	1.65
Skewness G	0.20	0.17
Geographical factor 2 year ARI F2	4.31	4.32
Geographical factor 50 year ARI F50	**15.32**	**15.25**

Areal reduction factors (ARF) built within RORB model based on Siriwardena & Weinmann (1996) were applied to the estimated design rainfall depths for events up to, and including, the 0.5% AEP event. The adopted ARF corresponding to 18 hour, 24 hour and 30 hour storm events were 0.80, 0.83 and 0.85 respectively. However, in the case of the XP-RAFTS model an ARF of 1 was adopted considering smaller sub-catchment areas.

Estimates of the Probable Maximum Precipitation (PMP) for the study catchment up to 3 hours duration were prepared using the procedures given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BoM, 2003). Estimates of the PMP for longer duration storms were prepared using the *Guidelines to the Estimation of Probable Maximum Precipitation: Generalised Southeast Australia Method* (BoM, 2006).

6.1.3 Model Parameter Values

The adopted value of k_c and m were 122 and 0.8 respectively on the basis of calibration results. In the XP-RAFTS model for the township, the adopted value of Bx was 1.0.

6.1.4 Temporal Patterns

Temporal patterns for all events storm durations up to, and including, the 0.2% AEP event were sourced from the RORB and XP-RAFTS model for Zone 2. The temporal pattern for the PMP event was sourced from BoM (2003 and 2006).

6.1.5 Design Rainfall Losses

An initial loss of 5mm was adopted for events up to and including the 2% AEP event, and an initial loss of 10mm was adopted for events between 1% and 0.2% AEP. An initial loss of 0mm was adopted for the PMP event. A continuing loss of 2.5mm/hr was adopted for all design events up to and including the 0.2% AEP event and a continuing loss of 1mm/hr was adopted for the PMP event.

6.2 Design Discharges

The RORB model for Billabong Creek catchment was run for a range of storm durations for the selected design flood events to estimate design inflow hydrographs. Results from the RORB model were reviewed to identify storm durations which produced peak discharges for each sub-catchment and at the catchment outlet. The estimated design discharges for the modelled events and storm duration which produced the peak discharge are shown in **Table 6-2**.

- Table 6-2 Peak Discharges (m^3/s) for Billabong Creek

Event	RORB Model - This Study At Walbundrie gauge	Culcairn (WMAwater 2013) (catchment area 1,847 km^2)
20% AEP	291 (24 hr)	248
10% AEP	359 (18 hr)	315
5% AEP	478 (18 hr)	424
2% AEP	634 (18 hr)	553
1% AEP	695 (18 hr)	687
0.5% AEP	853 (18 hr)	812
0.2% AEP	1085 (18 hr)	-
PMF	13181 (24 hr)	7306

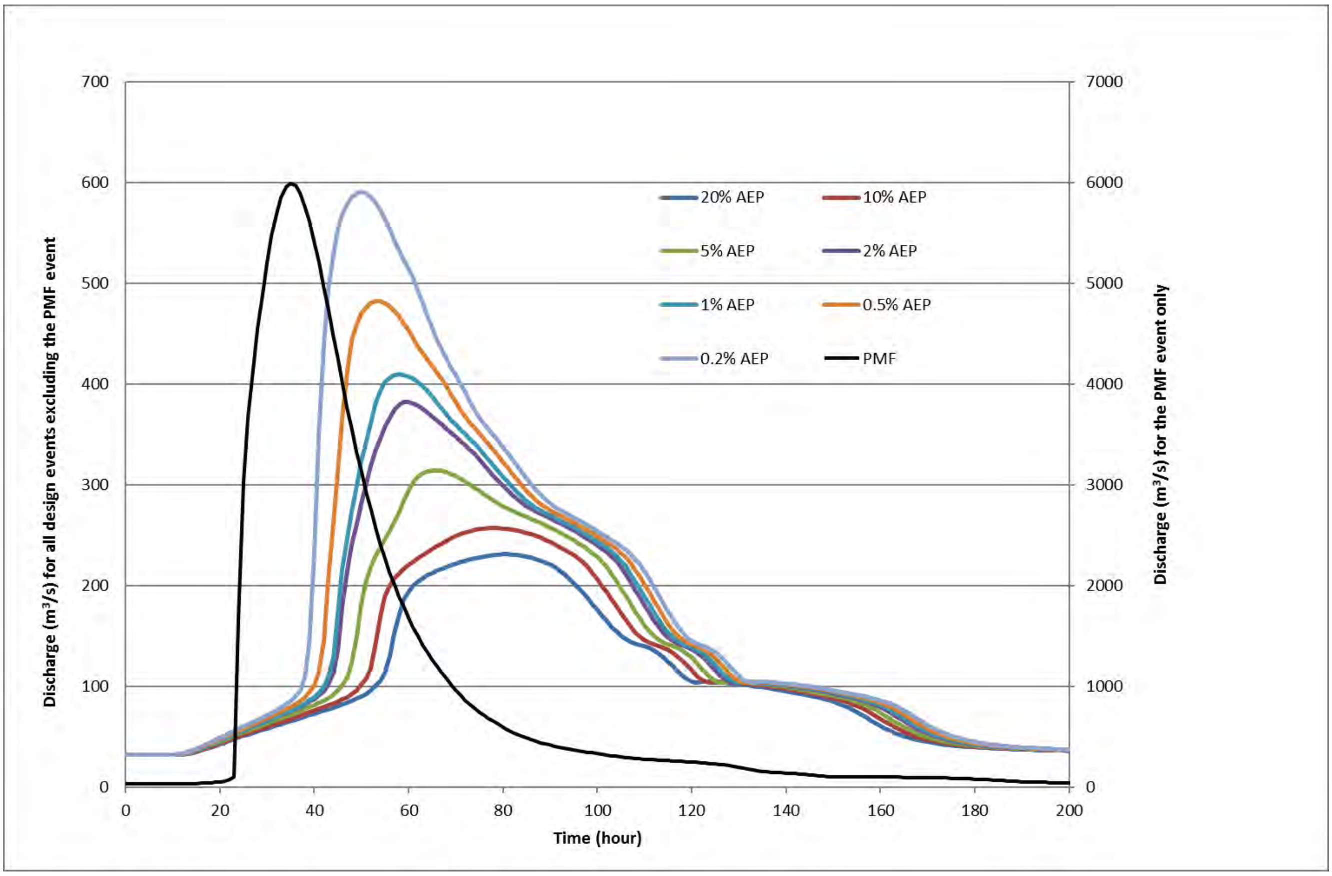
A comparison of design discharges estimated in this study and design discharges adopted for Culcairn in the Culcairn, Henty, Holbrook Flood Studies (WMAwater 2013) is shown in **Table 6-2**, which shows that design discharges estimated in this study for 20% AEP to 0.5% AEP events agree closely with discharges adopted in the Culcairn, Henty, Holbrook Flood Studies Report (WMAwater 2013). However, in the case of the PMF event, the peak flow estimated in this study is almost twice the magnitude of the peak flow adopted for Culcairn. An independent check undertaken using Cooperative Research Centre for Catchment Hydrology (1996) provides a peak flow estimate of 16,580 m^3/s for the PMF for Billabong Creek at Walbundrie gauge.

6.3 Hydraulic Model Parameters for Design Events

6.3.1 MIKE11 Inflows

Critical inflow hydrographs simulated by the RORB model for the design events were used as input in the MIKE11 model Billabong Creek and the model was run for all design events. Discharge hydrographs generated by the MIKE11 model at cross section “BILLABONG CK 36862.5” (refer **Appendix D.1**) were extracted for use in the TUFLOW model. Discharge hydrographs simulated by the MIKE11 model for the design events are shown in **Figure 6-1**.

Figure 6-1 Discharge Hydrographs Simulated by MIKE11 model at cross section “BILLABONG CK 36862.5”



6.3.2 Local Catchment Inflows

Discharge hydrographs simulated by the XP-RAFTS model for sub-catchments 1, 3, 4 and 5 (refer to **Figure C-2**) for the design events were included in the TUFLOW model. Design storm events producing peak discharges from these sub-catchments were included in the TUFLOW model in combination with discharge hydrographs generated by the MIKE11 model. The critical storm duration for all design events for the four sub-catchments varied between 15 minutes (for the probable maximum precipitation event) and 3 hours (for 20% to 5% AEP events).

6.3.3 Tailwater Conditions

The downstream model boundary was located some distance downstream of the township, to eliminate the potential influence of the boundary conditions on flood behaviour in the study area. A normal depth condition has been assumed at the boundary.

6.3.4 Initial Conditions

The model was assumed to be dry at the start of the model runs.

6.4 Simulated Design Events

The storm durations assessed for all design events were selected based on runs undertaken using the MIKE11 and the XP-RAFTS model to capture the critical storm durations throughout the study area.

7. Flood Behaviour for Design Flood Events

7.1 Flood Depth Mapping

The maximum envelope of flood depth mapped for all design events are included in **Appendix E**. The maps show flood envelope resulting from both Billabong Creek and local catchments draining into Billabong Creek at Rand. It is to be noted that peak runoff generated from the smaller local catchments draining into Billabong Creek are very unlikely to coincide with the peak flooding in Billabong Creek. Hence, the two mechanisms of flooding are can be considered almost independent. Flood extents are clipped to 150mm to exclude shallow depth of flooding on floodplains due to local catchment flooding.

The following observations are made from the flood depth maps (refer **Figure E-1** to **Figure E-8**):

- A section of Urana Road near the intersection with Western Road is cut-off in the 20% AEP event;
- Areas located north-east of Gibbens Street are subject to shallow flooding from local catchment runoff in the 20% AEP event;
- A number of properties located along Billabong Creek west of Mahonga Road from its intersection with Five Mile Road are subject to shallow flooding from the creek in the 1% AEP event.
- Although the township would be cut-off from the adjoining towns in the PMF event, the majority of residential properties located within township are not subject to flooding in the PMF event.

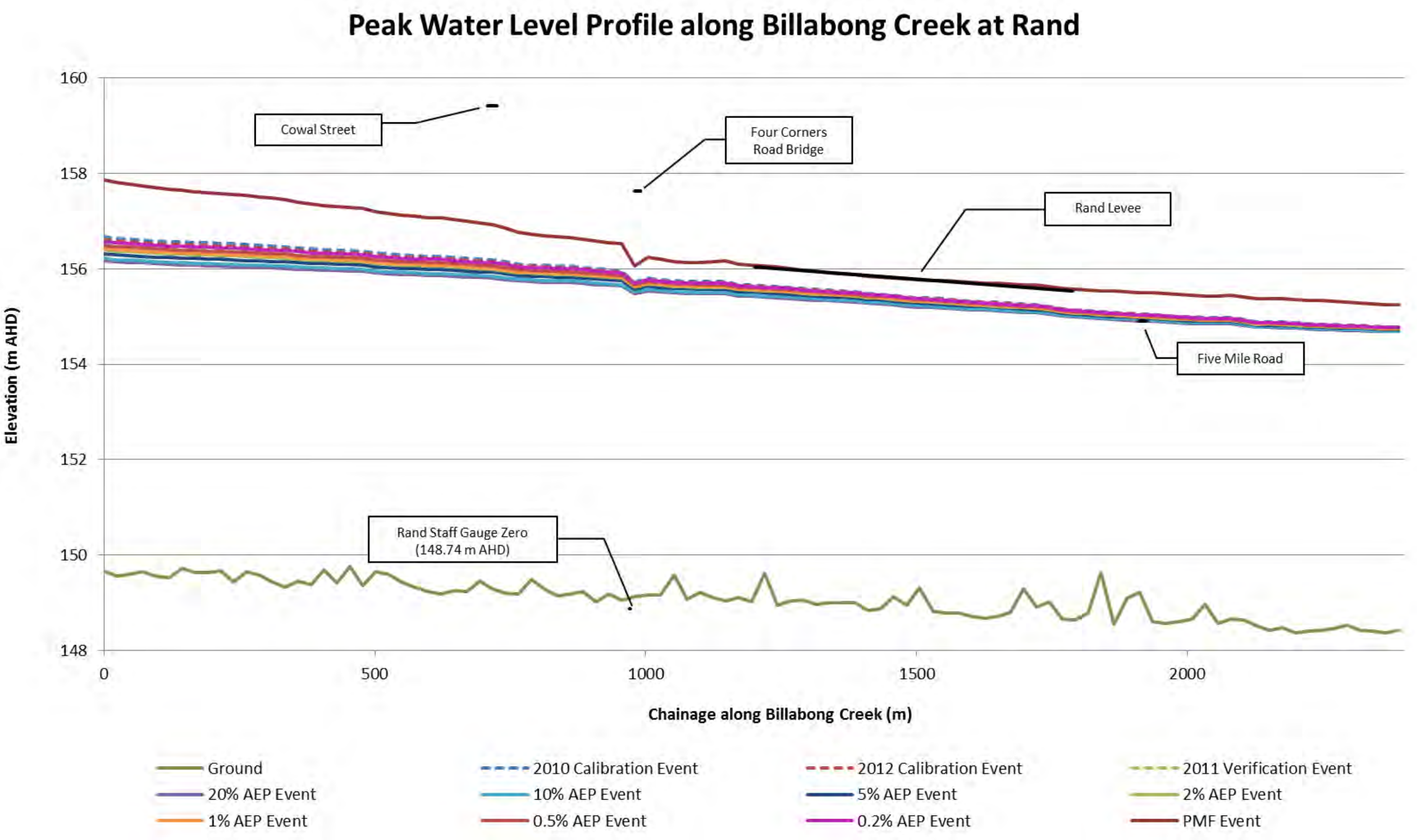
7.2 Flood Surface Profiles

The peak flood surface profiles are plotted in **Figure 7-1** for Billabong Creek located within the study area. **Figure 7-1** shows that the flood profiles for all modelled events are generally uniform. The Four Corners Road Bridge impedes flood flow for all modelled events to some degrees. However, the bridge is not overtopped in the PMF event. The informal Rand levee is overtopped in the PMF event only. The informal levee may fail during major flood events due to improper construction and poor maintenance. An audit on the structural integrity of the levee and an assessment of potential impacts due to failure of the levee needs to be undertaken. **Table 7-1** shows the peak water levels at Four Corners Road Bridge.

Table 7-1 Modelled Peak Water Levels at Waterway crossings

Waterway Crossing	Soffit Level (m AHD)	Deck Level (m AHD)	Peak Water Levels (mAHD)				
			20% AEP	5% AEP	1% AEP	0.5% AEP	PMF
Four Corners Road Bridge	156.55	157.6	155.49	155.58	155.64	155.67	156.06

Figure 7-1 Peak Water Level Profiles – Billabong Creek



7.3 Summary of Peak Flows

Peak overland flows are tabulated for selected locations as detailed in **Appendix D** for the modelled design flood events.

7.4 Provisional Flood Hazard Mapping

The TUFLOW modelling results were used to delineate the preliminary flood hazard areas for the study area from interpretation of the 5%, 1% and 0.5% AEP event results, based on the hydraulic hazard category diagram presented in the *Floodplain Development Manual* (NSW Government 2005), shown in **Figure 7-2**. The TUFLOW model calculates the hazard rating at each cell and computational time step, rather than calculating the rating based on the peak depth and peak velocity, since these may occur at different times.

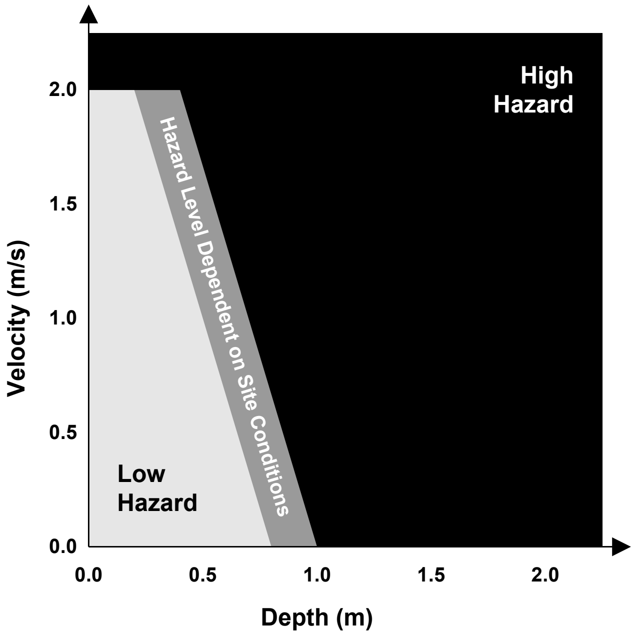


Figure 7-2 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)

Hazard categories delineated in this study are based on depths and velocities of floodwaters and do not consider evacuation, isolation, flood damages and social impacts of flooding, hence, these categories are considered provisional. The provisional flood hazard mapping is presented in **Figure E-9** to **E-11** in **Appendix E**.

7.5 Hydraulic Categories Mapping

The three flood hydraulic categories identified in the *Floodplain Development Manual* (NSW Government 2005) are:

- Floodway, where the main body of flow occurs and blockage could cause redirection of flows. Generally characterised by relatively high flow rates; depths and velocities;
- Flood storage, characterised by deep areas of floodwater and low flow velocities. Floodplain filling of these areas can cause adverse impacts to flood levels in adjacent areas; and
- Flood fringe, areas of the floodplain characterised by shallow flows at low velocity.

There is no firm guidance on hydraulic parameter values for defining these hydraulic categories, and appropriate parameter values may differ from catchment to catchment. In this study, the floodway was delineated first and then the remaining floodplain was classified into flood storage or flood fringe on the basis of flood depth. If the flood depth is greater than 0.5m then the floodplain is classified as flood storage area otherwise the floodplain is classified as flood fringe.

Initially, an encroachment analysis was undertaken to identify potential floodway areas for the 1% AEP event on the basis of following considerations:

- VxD > 0.25 m^2/s and V > 0.25 m/s; or V >1.0 m/s (Howells et al 2004);
- VxD > 0.50 m^2/s and V > 0.5 m/s; or V >1.0 m/s (Thomas and Golaszewski, 2012);
- High hazard area in the 1% AEP event; and
- Area flooded in the 5% AEP event.

Floodway estimated based on the above criteria and the floodway defined in the Billabong Creek Floodplain Management Plan (FMP) are shown in **Appendix E** (**Figure E-12**). It is to be noted that the floodway defined in the Billabong Creek FMP in the vicinity of Rand was based on the flood event of 1983 the floodway was delineated using coarse topographic data. Also the area flooded in the 5% AEP event is more extensive than the other three criteria. An encroachment analysis was undertaken using the floodway defined by the three criteria. A final encroachment analysis was undertaken to ensure no increase in flood levels in excess of 0.1m. It is to be noted that the encroachment analysis was undertaken for the existing catchment and floodplain conditions. The flood hydraulic categories are mapped and presented in **Appendix E** (**Figure E-13**).

7.6 Provisional Flood Planning Area

The provisional flood planning area is defined by the extent of the area below the flood planning level (usually the 1% AEP flood plus 0.5m freeboard) and delineates the area and properties where flood planning controls are proposed, for example minimum floor levels to ensure that there is sufficient freeboard of building habitable floor levels above the 1% AEP flood. The provisional flood planning area map for Rand is included in **Appendix E** (**Figure E-14**). The flood planning level and the flood planning area will be adopted in the floodplain risk management plan for Rand.

7.7 Flood Intelligence

Information on the flood intelligence card is provided in Section 11.4 (Yeo, 2013). The card is to be updated with information presented in the following sections.

There are two staff gauges in the vicinity of Four Corners Bridge which are located approximated 5m apart. The 4m mark (lower gauge) and the 6m mark (one the upper gauge) were connected to AHD as part of this study. Details on the gauges are provided in Table 7-2.

- Table 7-2: Details on the Staff gauges located near Four Corners Bridge

Gauge	Easting (m)	Northing (m)	RL (m AHD)	Gauge Zero (m AHD)
4m mark	461538	6060909	152.742	148.742
6m mark	461533	6060905	154.867	148.867

Recent flood history for Rand is provided in Table 11.1 (Yeo 2013) which shows that the reported gauge heights varied between 6.38m and 7.1m. Modelled flood levels in the vicinity of the gauge for the observed and design flood events are provided in Table 7-3.

- Table 7-3: Modelled Peak Flood Levels in the vicinity of the gauges

Flood Event	Peak Flood Level (m AHD)
2010	155.97
2011	155.86
2012	155.94
20% AEP	155.64
5% AEP	155.75
1% AEP	155.82
0.5% AEP	155.85
PMF	156.51

7.8 Flood Emergency Response

Flood emergency response is an important outcome of the Floodplain Risk Management Process. The New South Wales State Emergency Service (SES) will use the information contained in the report to update the Federation Council Local Flood Plan.

Urana Road (Rand-Walbundrie Road), Four Corners Road (Rand – Corowa Road) and Mahonga Road are three main access roads for Rand and all three roads are subject to inundation in the 20% AEP event. Whilst properties within the town centre are not impacted by flooding in the PMF event, properties located along Billabong Creek are subjected to flooding during the PMF. Hence properties impacted in the PMF event need to be evacuated. Flood forecast for an extreme flood event in Billabong Creek at Walbundrie is to be used as the trigger for evacuation of the low lying properties in Rand.

8. Conclusions

In accordance with NSW Government Policy, Federation Council is committed to preparing a Floodplain Risk Management Plan for its local government area including the Township of Rand. This report documents the up-to date progress on preparing the first two stages of the process of preparing the Plan – that is, the preparation of a flood study report.

A community consultation process was undertaken to collect information on flooding from the community and only one response was received on the questionnaire.

The available LiDAR survey for Rand undertaken by LPI was supplemented with a ground survey to capture the required topographic data for this flood study. The ground survey captured details of a bridge for which adequate information was not available to this study. The ground survey collected crest levels along Rand levee and connected a staff gauge to the Australian Height Datum.

Recent flood events of 2010, 2011 and 2012 were selected for calibration and verification of hydrologic and hydraulic models. The flood event of 2010 is the highest flood on record in Billabong Creek @ Walbundrie gauge. SES undertook a detailed flood investigation on the impact of the recent flood events at Rand.

A flood frequency analysis was undertaken for Billabong Creek @ Walbundrie gauge based on observed flow data for 1965 to 2014 including the flood event of 1931 which is considered as the largest flood in Billabong Creek @ Walbundrie gauge.

A hydrologic model using RORB was set up for Billabong Creek @ Walbundrie gauge to estimate design inflow hydrographs for a range of flood events up to and including the PMF. The RORB model was calibrated against 2010 and 2012 flood events and verified against 2011 flood event.

An existing hydraulic model for Billabong Creek (Walbundrie to Jerilderie) developed as part of the Billabong Creek Floodplain Management Study (Bewsher 2002) was available to this study. The hydraulic model developed using MIKE11 modelling system was upgraded from v2000 to v2014 for use in this study. Observed flows for Billabong Creek @ Walbundrie gauge were routed through the MIKE11 model to estimate flows in Billabong Creek upstream of Rand.

A TUFLOW hydraulic model for Rand was developed utilising a 5m grid based on a 1m LiDAR DEM. The model included the surveyed bridge at Rand and buildings were modelled as obstructions to the flow. Modelled inflows for the calibration and verification events in Billabong Creek upstream of Rand were used to model flood behaviour for the flood events of 2010, 2011 and 2012 flood events. The flood levels modelled were within 0.12m of the recorded level at the Rand staff gauge. These results confirm that the hydraulic model was reasonably calibrated and verified. The TUFLOW model can be used to simulate design events with confidence.

A sensitivity analysis was undertaken to assess sensitivity in flood behaviour for the 2010 event due to the adopted modelled flows, Manning's n values and tailwater boundary conditions.

The calibrated and validated RORB, MIKE11 and TUFLOW models were utilised to define flood behaviour for the design flood events of 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events and the PMF. An XP-RAFTS model was developed to estimate rainfall runoff from the local catchments draining through the township into Billabong Creek. Rainfall losses and other input utilised in the estimation of design flood events are similar to that adopted in the Flood Study Report for Culcairn, Hently and Holbrook (WMAwater 2013) and there is a reasonable agreement between peak discharges for the design events.

Outcomes from the flood modelling for the design events have been utilised to prepare flood extent maps, provisional hazard maps, flood hydraulic categories (ie. floodway, flood storage and flood fringe areas) and a flood planning area map. Modelling results were interrogated to identify major hydraulic controls in Rand. However, no major hydraulic controls were identified. Although the township would be cut-off from the neighbouring towns, the majority of the residential developments within the township are located above the

PMF. The Four Corners Road Bridge impedes flood flow for all modelled events to some degrees. However, the bridge is not overtopped in the PMF event. The informal Rand levee is overtopped in the PMF event only. The informal levee may fail during major flood events due to improper construction and poor maintenance. An audit on the structural integrity of the levee and an assessment of potential impacts due to failure of the levee needs to be undertaken soon.

The flood intelligence and flood emergency response for Rand are to be updated by NSW SES using information presented in this study and outcomes from the study are considered appropriate for undertaking a floodplain risk management study leading to the development of a floodplain risk management plan for Rand.

9. Acknowledgements

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A number of organisations and individuals have contributed both time and valuable information to this study. The assistance of the following in providing data and/or guidance to the study is gratefully acknowledged:

- Residents of Rand
- Federation Council
- Office of Environment and Heritage
- SES
- DPI Water

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11. Glossary

Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. It is to be noted that design rainfalls used in the estimation of design floods up to and including 200 year ARI (ie. 0.5% AEP) events was derived from 1987 Australian Rainfall and Runoff. Hence the flowing relationship between AEP and ARI applies to this study. 20% AEP = 5 year ARI; 5% AEP = 20 year ARI; 1% AEP = 100 year ARI; 0.5% AEP = 200 year ARI
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital Elevation Model (DEM)	A specialised three dimensional dataset that represents the surface topography using points of known elevations.
Development	Is defined in Part 4 of the EP&A Act <u>In fill development</u>: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. Eg. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. Eg. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.

Effective Warning Time	The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood liable land	Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area)
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designated flood" or the “flood standard” used in earlier studies.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.
Flood readiness	Readiness is an ability to react within the effective warning time.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

	Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
GDA	Geocentric Datum of Australia is a coordinate system for Australia which is used to keep track of locations.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m AHD	Metres Australian Height Datum (AHD)
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
MGA	MGA is a metric grid system (i.e. east and north) and the unit of measure is

	the metre. It is a Cartesian coordinate system based on the Universal Transverse Mercator projection and the Geocentric Datum of Australia (GDA) 1994.
MIKE11	A computer program used for analysing behaviour of unsteady flow in open channels and floodplains.
MiRORB	A tool which uses the geographical information system MapInfo™ to generate input data for use with RORB.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Overland flowpath	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flowpaths can occur through private property or along roads.
PINNEENA	PINNEENA is a surface water and groundwater monitoring database released by the NSW Government on DVD/CD.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RORB	RORB is a general runoff and streamflow routing computer program used to calculate flood hydrographs from rainfall and other channel inputs.
Runoff	The amount of rainfall which actually ends up as a streamflow, also known as rainfall excess.
Stage	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
Watershed Bounded Network Model (WBNM)	WBNM converts rainfall to runoff for both natural and urban catchments. WBNM is similar to RORB.
XP-RAFTS	XP-RAFTS is a computer program which is used to convert rainfall into runoff. XP-RAFTS is used for hydrologic analysis of stormwater drainage and conveyance systems. XP-RAFTS simulates both urban and rural

catchments ranging in size between a single house allotment up to thousands of square kilometre river systems.

Appendix A. Available Data

- A1: Extracts from the ‘Urana Flood Study Survey – Report’ by TJ Hinchcliffe & Associates
- A2: Map showing the locations of the surveyed features
- A3: Rand village drawing with stormwater features (Council)

Urana Flood Study Survey – Report

For Urana Shire Council and Jacobs

By TJ Hinchcliffe & Associates: Chris Ryan

Table of Contents

Introduction

This report has been written to outline and describe the survey informaiton collected and prepared by TJ Hinchcliffe & Asssociates to aid in the Urana Flood Study being performed by Jacobs in the Urana Shire Council Local Governemnt Area.

The data contained within this report has been prepared to be used in conjunction with Lidar data in computer models that calculate water flow through a system.

Each structure identified by a number is listed and described in sequence. Following the structure reports are a series of sections describing the; Urana Dam, Urana Levee, Urana Stormwater System, Rand Levee.

35: Bridge (Rand)

Structure 35 Is a bridge on Kindra Road over the Billabong Creek. There is a Staff Gauge at the site.

Table 35 shows the pertinent physical information about the structure.

Bridge 35

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	461526.08	6060914.26	461559.91	6060948.61
Levels	Start	Middle	End	
Deck	157.60	157.79	157.69	
Underside	156.55	156.74	156.64	
Length	48.20			
Width	7.40			
Height Rails/Barriers	0.92			

Table 35: Structure 35 details.

Images 77-79 shows structure 35 facing downstream.

Image 77: Structure 35 facing downstream.

Image 78: Structure 35 facing downstream.

Image 79: Structure 35 facing downstream.

Image 80 shows structure 35 facing upstream.

Image 80: Structure 35 facing upstream.

36: Bridge

Structure 36 is an old bridge. The only remaining parts of it are the abutments (missing a lot of timber) and the rails (which are suspended through the void of the old bridge). The ground surface at this control point has been mapped and is included in the associated dxf file.

Table 36 shows the pertinent physical information about the structure.

Rand

Rand Levee Bank

Rand Levee Bank runs along the North-Western edge of Rand for about 520m. It separates the town of Rand from the Billabong Creek. The levee is a small one. It is crossed by a 600mm round concrete pipe with a drop board. The following images 117-123 show the general nature of the Rand Levee Bank.

Image 117: Rand Levee Bank, southern end.

Image 118: Rand Levee Bank, southern end.

Image 119: Rand Levee Bank, northern end.

Image 120: Rand Levee Bank, northern end.

Image 121: Rand Levee Bank, middle.

Image 122: Rand Levee Bank, 600mm rcp inlet.

Image 123: Rand Levee Bank, 600mm rcp outlet.

Morundah

Tarabah Weir

Tarabah is a small weir over Yanco Creek just downstream from Colombo Creek.

Table 44 shows the pertinent details about Tarabah Weir.

Tarabah Weir

	Easting	Northing
Start Gate	433947.39	6139366.17
End Gate	433957.5	6139361.57
Gates	7	
Gate Invert	127.64	
Gate Top	128.74	
Gate Size (HxW)	1.1x1.68	
Automatic/Manual	6/1	
Level Below Spillgate	127.16	

Table 44: Tarabah Weir

Image 124 shows Tarabah Weir facing downstream.

Lidar Test Points

Lidar test points were observed at various points around the survey area. While 10 points were required in the survey brief additional points have been included. The additional points are redundancies in case the initial points were obstructed at time of Lidar observation.

Lidar Test Points

Surface	Easting	Northing	AHD
Urana			
Bitumen	432875.94	6090092.28	116.73
Bitumen	433325.78	6089951.76	116.60
Bitumen	433452.70	6090004.57	116.82
Bitumen	433366.80	6089767.71	116.12
Oaklands			
Bitumen	425129.30	6066389.74	137.63
Bitumen	424337.79	6064799.09	147.25
Bitumen	424347.65	6064798.39	147.28
Bitumen	425332.06	6067753.44	127.55
Rand			
Bitumen	461715.76	6061111.65	157.06
Bitumen	461563.40	6061683.34	155.05
Morundah			
Bitumen	436328.52	6134113.76	128.39
Bitumen	435878.19	6135720.34	129.75
Boree Creek			
Bitumen	464520	6114905.52	146.97
Bitumen	464020.51	6114603.81	146.07
Bitumen	464036.17	6114602.82	146.05
Bitumen	465086.23	6114577.02	147.46

Legend

- Bridge surveyed
- Staff gauge surveyed
- Levee surveyed
- Railway
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

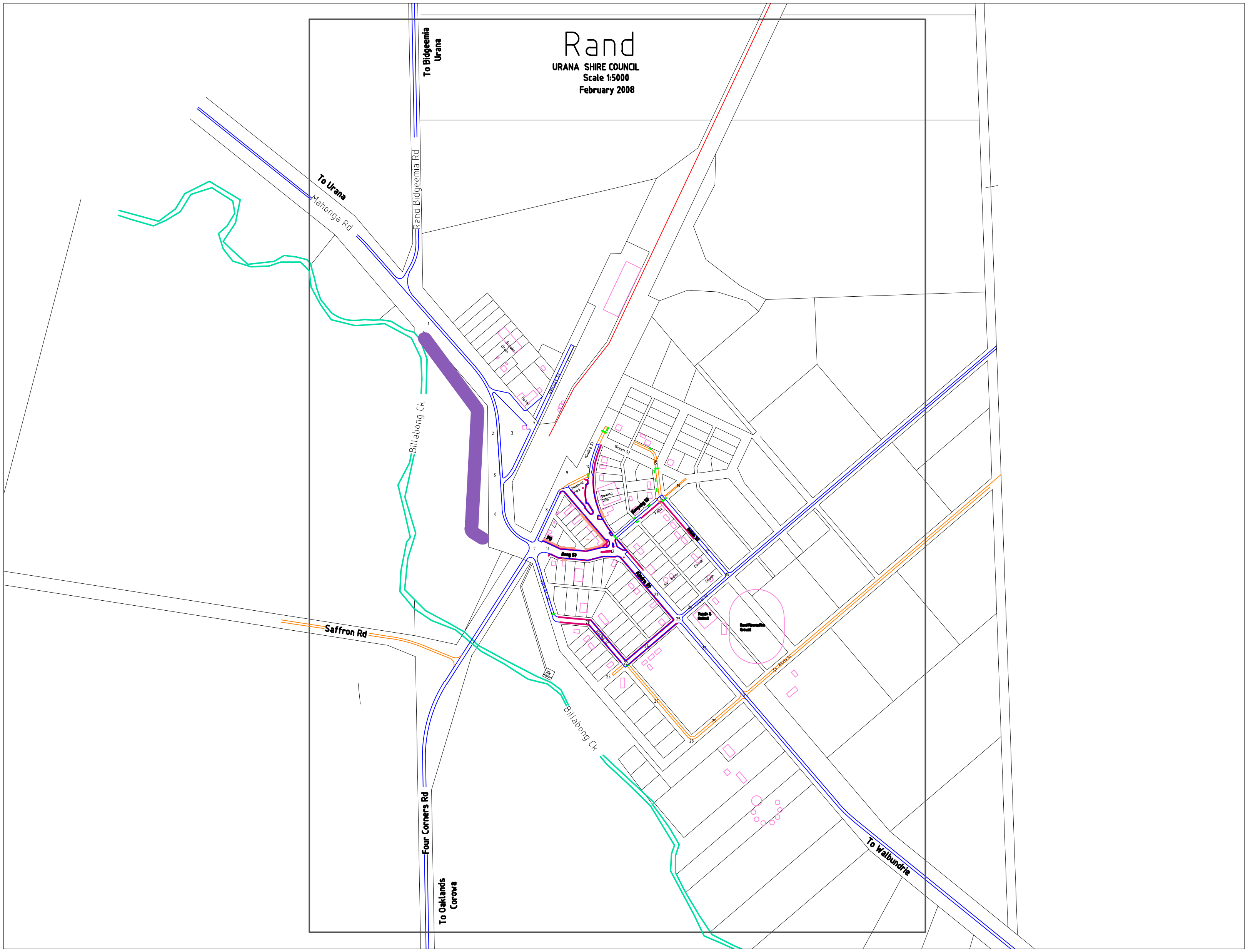
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Topographic Survey
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	APPENDIX A-2
CHECK	DATE	
AH	1/08/2017	



Rand
URANA SHIRE COUNCIL
Scale 1:5000
February 2008
To Bidgeemia
Urana
Rand Bidgeemia Rd
To Urana
Mahonga Rd
Billabong Ck
Saffron Rd
Billabong Ck
Four Corners Rd
To Oaklands
Corowa
To Walbundrie

Appendix B. Questionnaire

Urana Shire Flood Study Questionnaire (February 2015)

Rand

Urana Shire Council has contracted the Consultant, Jacobs, to undertake a flood study for five towns in the Shire: Morundah, Urana, Boree Creek, Oaklands and Rand. Council is seeking the community's input in providing historical data for the flood study in order to understand the behaviour of floods within Rand. The flood study area is shown in the map on Page 6.

The study is aimed at addressing the flooding impacts due to both riverine and overland flooding. Jacobs would like to receive feedback from the community on a number of issues and topics already highlighted by the Council with regard to flooding in Rand. This questionnaire provides an opportunity for your input into the flood study.

Please print the questionnaire and if you cannot answer any question in the questionnaire, or do not wish to answer a question, then leave it unanswered and proceed to the next question. **Your input to this important study will be greatly appreciated.** If you need additional space, please add sheets. **Please scan all pages of the questionnaire (including additional pages) filled in by you and send the scanned document** (preferably in PDF) **by email** to Akhter.Hossain@jacobs.com **by 27 March 2015**.

Alternatively, you could drop off your response to the questionnaire at Council's Reception Desk, 30-32 William Street, Urana by 27 March 2015.

If you would prefer to send your response to the questionnaire by mail, this would also be welcomed. Contact details of the Jacobs' Project Manager are provided below:

Akhter Hossain
P O Box 164
St Leonards, NSW 1590
Email: Akhter.Hossain@jacobs.com

Place a tick or write the answer in the relevant box as per instructions.

Question No.	Question and Answer
1.	**Do you live (reside), or have lived, in the study area shown on the Map (p6)?** A Yes (Please provide your address and put an 'X' on the relevant map) .... B No (Go to Question 4) ***If you are not sure whether you are in the map or not, please provide address
2.	**Do you own or rent your residence in the study area shown on the Map?** A Own B Rent

Question No.	Question and Answer
3.	**How long have you lived in the study area?** (Please write number of years) ……………………
4.	**Do you own or manage a business in the study area?** A Yes, For how many years? ………………………… B No (go to Question 6)
5.	**What kind of business is yours?** A Home based business B Shop/commercial premises C Light industrial D Heavy industry E Others, please write type of business ………………………………………………………
6.	**Have you had any experience of flooding (due to riverine and/or storm events as well) in and around where you live or work?** A Yes B No (Go to Question 16)
7.	**How deep was the floodwater (from riverine and/or storm water as well) in the worst flood/storm event that you experienced?** Please estimate the depth …………………………… What was the year of this flood?……………………… Where was this flood? A At your house? B At work? C Elsewhere? Please provide the street address for this flood? ……………………………………………………
8.	**How long did the floodwaters stay up?** A Less than 2 hours B Less than 6 hours C Greater than 6 hours, how long?
9.	**What damage resulted from this flood in your residence?** (Please indicate either “none”, "minor", "moderate" or "major". A Damage to garden, lawns or backyard B Damage to external house walls C Damage to internal parts of house (floor, doors, walls etc) D Damage to possessions (fridge, television etc) E Damage to car F Damage to garage G Other damage, please list………………………………………. H What was the cost of the repairs, if any?……………………........
10.	**What damage resulted from this flood in your business?** (Please indicate either "none", "minor", "moderate" or "major".) A Damage to surroundings B Damage to building C Damage to stock D Other damages, please list……………………………… E What was the approximate cost of the repairs, if any?………………….
11.	**Was vehicle access to/from your property disrupted due to floodwaters during the worst**

Question No.	Question and Answer
	flooding/storm event? A Not affected B Minor disruption (roads flooded but still driveable) C Access cut off
12.	**Did you or members of your family require assistance from SES during flood events?** A No B Yes, Please specify how many times (in total) assistance was required?
13.	**What information can you provide on past floods/storm events that created flooding?** (You can tick more than one item). Please write any descriptions at the end of the questionnaire A No information B Information on extent or depth of floodwater at particular locations, newspaper clippings or other images on the past floods C Marks indicating maximum flood level for particular floods D Recollections of flow directions, depth or velocities
14.	**Do you consider that flooding of your property has been made worse by works on other properties, or by the construction of roads or other structures?** A Yes (please provide further details and attach extra pages if necessary. Please provide a sketch if possible). B Unsure C No
15.	**Do you have any photographs of past floods that would be useful for the study to help understand the flood behaviour and are you willing to provide copies?** If possible please attach the photographs (with dates and location) which will be copied and returned. A Yes (either attach or the consultant will contact you to arrange for a copy to be made and returned) B No
16.	**Do you expect to undertake any further development on your land in the future?** A No B Minor extensions C New building D Unsure E Other (please specify) …………………………………………………………..
17.	**Please rank the following development types according to what you consider should be assigned greatest priority in protecting from flooding** (1 = greatest priority to 7 = least priority). **Please identify specific items if necessary**. A Commercial …………………………………………………………………………………… B Heritage items, please specify …………………………………………………………………… C Residential …………………………………………………………………………………… D Community facilities (schools, halls, etc.) …………………………………………………. E Critical utilities (power substations, telephone exchanges, etc.) ………………………… F Emergency facilities (Hospital, Police Station, etc.) ………………………………………… G Recreation areas and facilities ……………………………………………………………...
18.	**Please rank the following by placing numbers from 1 to 6 (1 = greatest priority to 6 = least priority) next to A, B, C, D, E and F.** A Protecting residential buildings from flooding

Question No.	Question and Answer
	B Protecting commercial buildings from flooding C Maintaining an emergency flood free access D Providing flood signage for public safety E Support from SES F Providing flood warning
19.	**Do you wish to comment on any other issues associated with this study? Please add comments at the end of the questionnaire or please indicate your willingness to answer questions over the phone?** ______________________________ ______________________________ ______________________________ ______________________________ ______________________________
20.	**Do you wish to remain on the mailing list for further details, newsletters etc?** A Yes (please provide contact details, see next question) B No
21.	If you would like, please provide details of where you live and how we can contact you if we need to follow up on some details or seek additional comment. **Name:** ________________________ **Address:** ________________________ ________________________ **Telephone:** ________________________ **Fax:** ________________________ **Email**: ________________________
Additional comment	**Space for additional comments** ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________

Question No.	Question and Answer

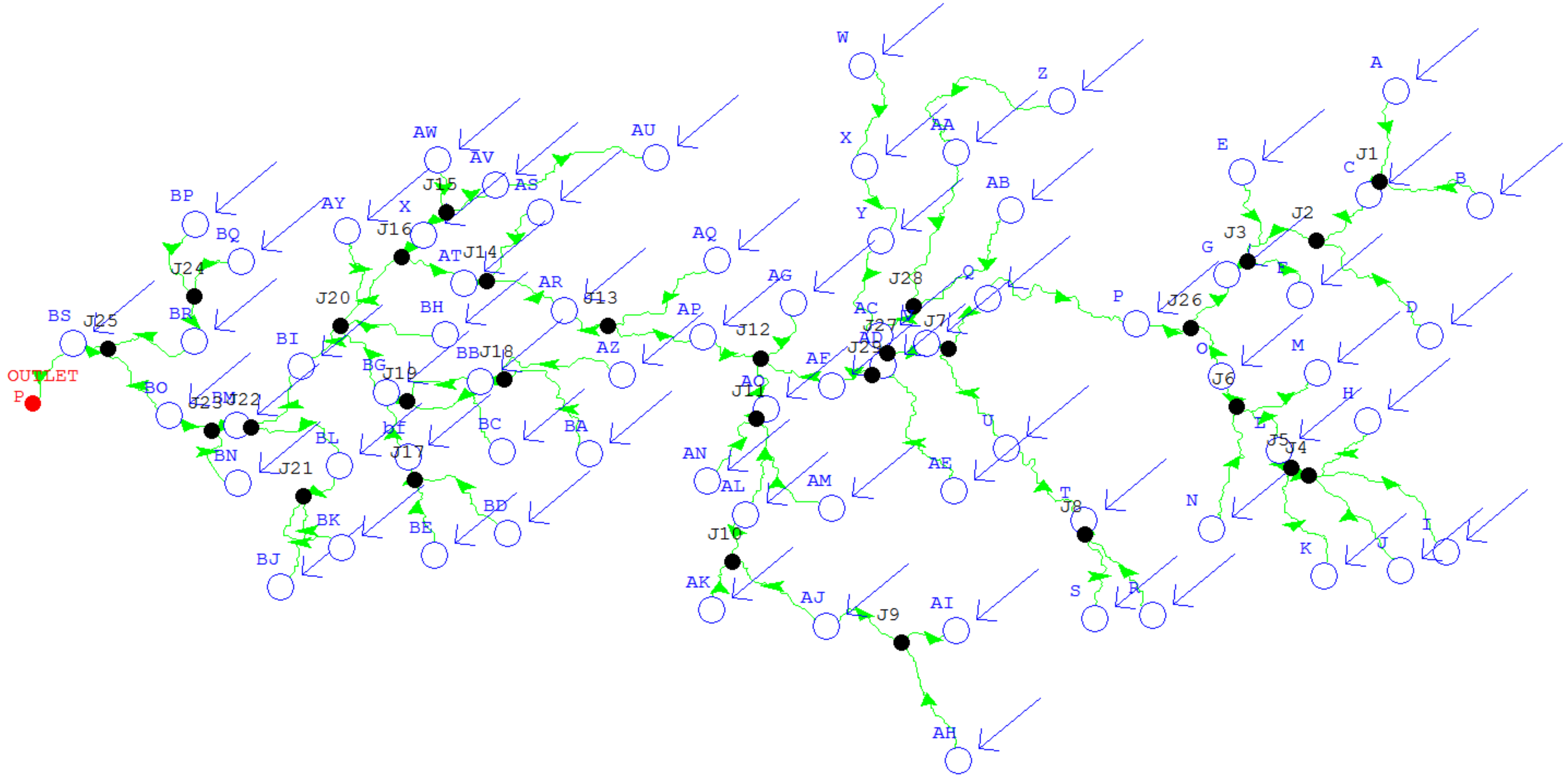
Thank you for your assistance

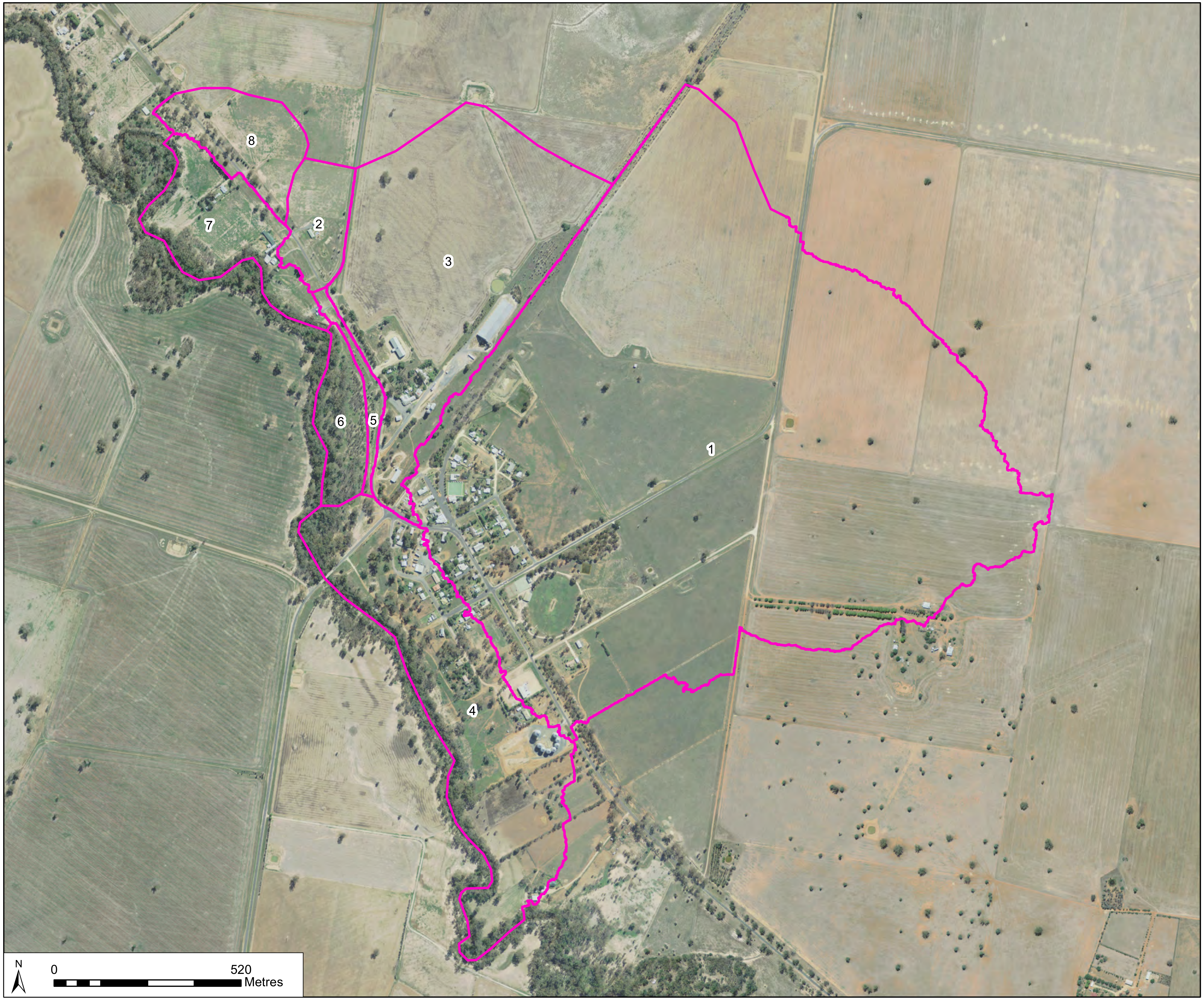
Map – Study Area for Rand

Appendix C. Hydrologic Modelling

- Figure C-1: RORB model configuration for Billabong Creek
- Figure C-2: XP-RAFTS model configuration for local sub-catchments
- Table C-1: RORB model sub-catchment data for Billabong Creek
- Table C-2: XP-RAFTS model sub-catchment data for Billabong Creek

- Figure C-1: RORB Model Configuration for Billabong Creek





Legend

RAFTS local catchments

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE RAFTS Local Catchments

TOWN Rand

PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN MR
PROJECT # IA055600
CHECK AH
DATE 9/05/2016

FIGURE C-2

JACOBS

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Table C-1: RORB Model sub-catchment data for Billabong Creek

Node Number	Sub-catchment Name	Area (km^2)	Impervious fraction
1	A	69.5	0.05
2	B	72.0	0.05
3	C	23.8	0.05
4	D	77.4	0.05
5	E	79.7	0.05
6	F	16.7	0.05
7	G	27.0	0.05
8	H	27.2	0.05
9	I	40.9	0.05
10	J	51.1	0.05
11	K	44.9	0.05
12	L	8.8	0.05
13	M	26.5	0.05
14	N	75.1	0.05
15	O	38.2	0.05
16	P	69.3	0.05
17	Q	58.6	0.05
18	R	30.3	0.05
19	S	52.7	0.05
20	T	55.5	0.05
21	U	35.3	0.05
22	V	8.0	0.05
23	W	60.1	0.05
24	X	31.8	0.05
25	Y	47.3	0.05
26	Z	36.2	0.05
27	AA	54.4	0.05
28	AB	54.9	0.05

29	AC	11.3	0.05
30	AD	3.2	0.05
31	AE	58.4	0.05
32	AF	28.6	0.05
33	AG	13.3	0.05
34	AH	78.5	0.05
35	AI	26.6	0.05
36	AJ	44.7	0.05
37	AK	33.8	0.05
38	AL	36.5	0.05
39	AM	36.1	0.05
40	AN	27.9	0.05
41	AO	13.7	0.05
42	AP	33.8	0.05
43	AQ	44.9	0.05
44	AR	21.7	0.05
45	AS	38.0	0.05
46	AT	9.4	0.05
47	AU	58.4	0.05
48	AV	18.7	0.05
49	AW	39.5	0.05
50	X	16.6	0.05
51	AY	61.8	0.05
52	AZ	49.2	0.05
53	BA	29.0	0.05
54	BB	9.0	0.05
55	BC	45.7	0.05
56	BD	28.1	0.05
57	BE	46.0	0.05
58	bf	14.0	0.05
59	BG	20.0	0.05

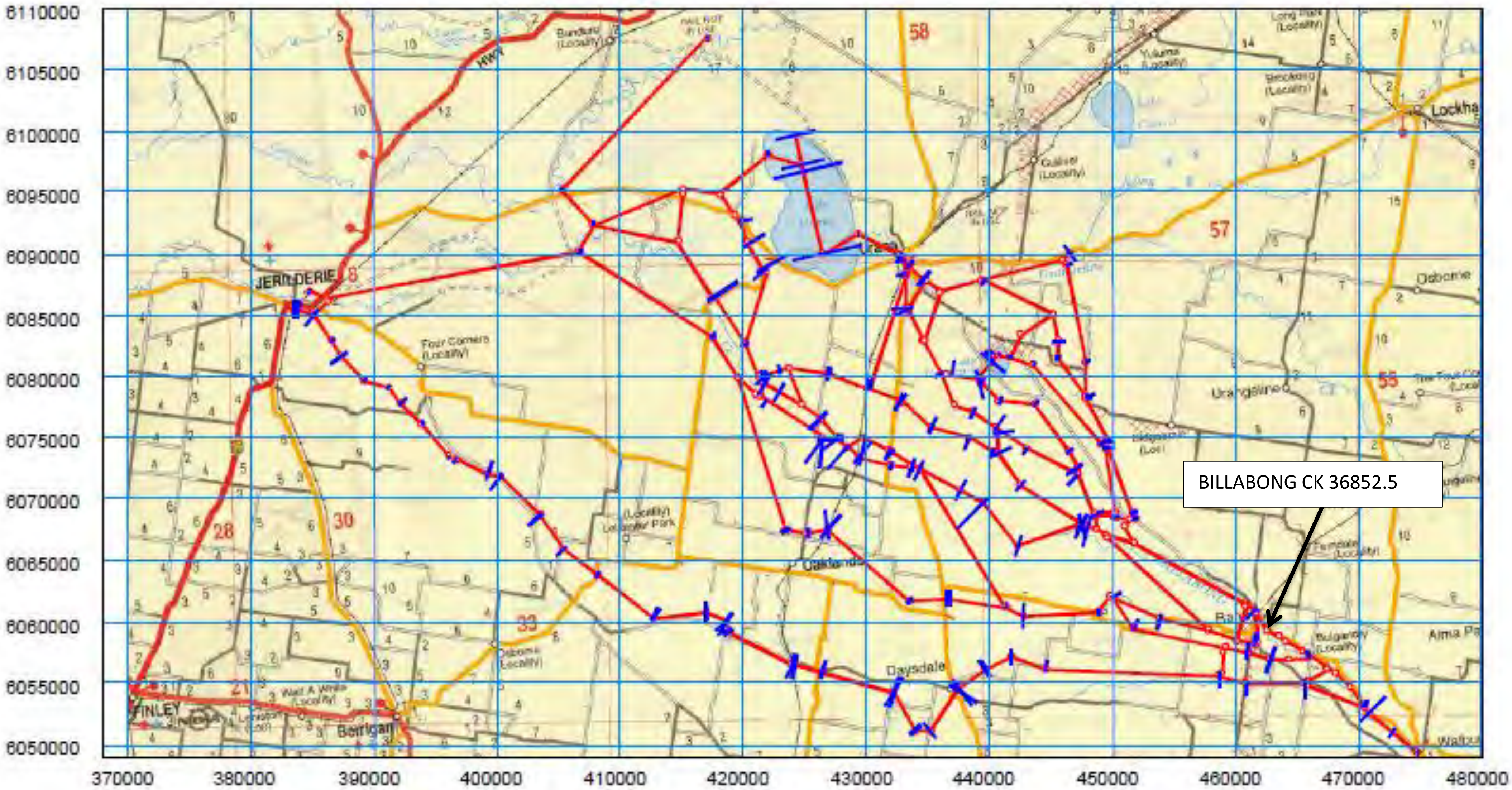
60	BH	14.5	0.05
61	BI	26.7	0.05
62	BJ	53.8	0.05
63	BK	15.0	0.05
64	BL	37.8	0.05
65	BM	2.4	0.05
66	BN	19.2	0.05
67	BO	20.5	0.05
68	BP	67.2	0.05
69	BQ	17.04	0.05
70	BR	41.0	0.05
71	BS	35.4	0.05

Table C-2: XP-RAFTS sub-catchment characteristics for Rand

Node_no	Area (ha)	Imperviousness (%)	Slope (%)	Roughness(n)
1	177.5	10	0.80	0.04
2	5.5	5	0.61	0.04
3	43.2	10	0.46	0.04
4	34.3	20	3.14	0.06
5	1.9	5	0.27	0.04
6	5.3	5	1.43	0.08
7	11.4	5	1.14	0.05
8	8.1	5	0.36	0.04

Appendix D. Hydraulic Modelling

- D1: MIKE-11 model network diagram (Bewsher 2002)
- D2: Map showing reporting locations of flows and flood levels for TUFLOW model
- D3: Reporting tables for the 2010, 2011 and 2012 flood events
- D4: Reporting tables for the sensitivity runs
- D5: Peak discharges for design events



LEGEND

Model Cross Section Location

Appendix D1: MIKE11 Model Schematic for Billabong Creek

Source: Bewsher 2002

Legend

Flood Level Locations
Flow Lines

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	TUFLOW Model Reporting Locations
TOWN	Rand
PROJECT	Urana Shire Flood Study
CLIENT	Urana Shire Council

DRAWN MR	PROJECT # IA055600	APPENDIX D-2
CHECK AH	DATE 9/05/2016	

Appendix D3 – Calibration Results

- Modelled flows for the 2010, 2011 and 2012 calibration events

Flow line	2010 Flow (m^3/s)	2011 Flow (m^3/s)	2012 Flow (m^3/s)
F01	346.7	205.6	281.3
F02	135.7	27.9	86.3
F03	22.2	2.8	11.6
F04	194.8	175.3	187.5
F05	3.5	1.6	2.4
F06	210.9	176.9	194.8
F07	188.8	173.5	182.9
F08	0.0	0.0	0.0
F09	0.4	0.2	0.3
F10	188.2	172.6	182.7
F11	154.0	150.3	152.6
F12	34.2	22.3	30.0
F13	34.0	22.1	29.8
F14	138.2	136.4	137.6

Appendix D4 – Sensitivity Results

- Flood level differences (m) for the sensitivity runs (2010 event)

Base = Base case

Flow = Inflows (+/-20%)

n = Manning's n (+/-20%)

B = Blockage factor (0%, 100%)

TWL = Tailwater level (+/- 0.5m)

Mark	Base	+Flow	-Flow	+n	-n	B0	B100	+TWL	-TWL
Rand Staff Gauge[1]	155.965	+0.024	-0.029	+0.013	-0.194	-0.066	+0.821	0.000	0.000
DS Point[2]	155.602	+0.017	-0.023	+0.025	-0.145	+0.020	-2.699	0.000	0.000

1 Chosen as the point upstream of the bridge to compare flood levels at the village

2 Chosen as a point downstream of the bridge to compare flood levels where the levee commences

- Flow differences (m^3/s) for the sensitivity runs (2010 event)

Flow line	Base	+Flow	-Flow	+n	-n	B0	B100	+TWL	-TWL
F01	346.7	69.4	-69.3	0.1	-8.7	0.0	0.1	0.0	0.0
F02	135.7	49.9	-52.4	8.8	31.9	-1.7	20.1	0.0	0.0
F03	22.2	14.6	-11.0	5.8	-22.0	-2.1	91.0	0.0	0.0
F04	194.8	6.3	-7.8	-14.2	-17.0	2.9	-35.8	0.0	0.0
F05	3.5	0.9	-1.1	0.3	-2.7	-0.4	4.3	0.0	0.0
F06	210.9	19.1	-17.0	-9.0	-33.1	1.7	-20.1	0.0	0.0
F07	188.8	4.9	-6.3	-14.1	-11.1	4.9	-184.0	0.0	0.0
F08	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
F09	0.4	0.1	-0.1	0.0	-0.4	0.1	-0.2	0.0	0.0

F10	188.2	4.5	-5.9	-14.9	-11.6	3.7	-95.0	0.0	0.0
F11	154.0	0.9	-1.5	-13.5	9.1	1.0	-102.5	0.0	0.0
F12	34.2	3.5	-4.5	-1.3	-20.7	2.6	1.6	0.0	0.0
F13	34.0	3.5	-4.5	-1.4	-20.6	2.6	1.8	0.0	0.0
F14	138.2	0.3	-0.7	-12.9	11.4	0.3	-89.5	0.0	0.0

Appendix D5 – Peak Flows (m^3/s) for Design Events

Flow line	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
F01	227	252	305	370	397	468	573	5856
F02	86	109	158	213	235	291	370	3372
F03	0	0	0	5	8	20	43	1792
F04	144	148	156	164	166	173	180	485
F05	0	0	0	1	1	1	2	61
F06	145	148	157	168	174	191	220	2562
F07	146	149	157	164	167	173	179	303
F08	0	0	0	0	0	0	0	4
F09	3	4	6	8	10	13	18	146
F10	145	149	157	164	166	173	181	686
F11	141	142	146	148	149	150	152	401
F12	4	6	11	16	17	23	28	248
F13	4	6	11	15	17	23	28	267
F14	132	132	134	135	136	136	137	265

Appendix E. Flood Mapping for Design Events

Legend

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	20% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-1
CHECK AH	DATE 10/29/2015	

Legend

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	10% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-2
CHECK AH	DATE 10/29/2015	

Legend

Railway

Cadastre

flood depth (m)

0.15 - 0.3

0.3 - 0.5

0.5 - 1.0

> 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	5% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-3
CHECK AH	DATE 10/29/2015	

Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	2% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN AG / CHECK AH	PROJECT # IA055600 / DATE 10/29/2015
	FIGURE E-4

Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-5
CHECK AH	DATE 10/29/2015	

Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	0.5% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-6
CHECK AH	DATE 10/29/2015	

Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

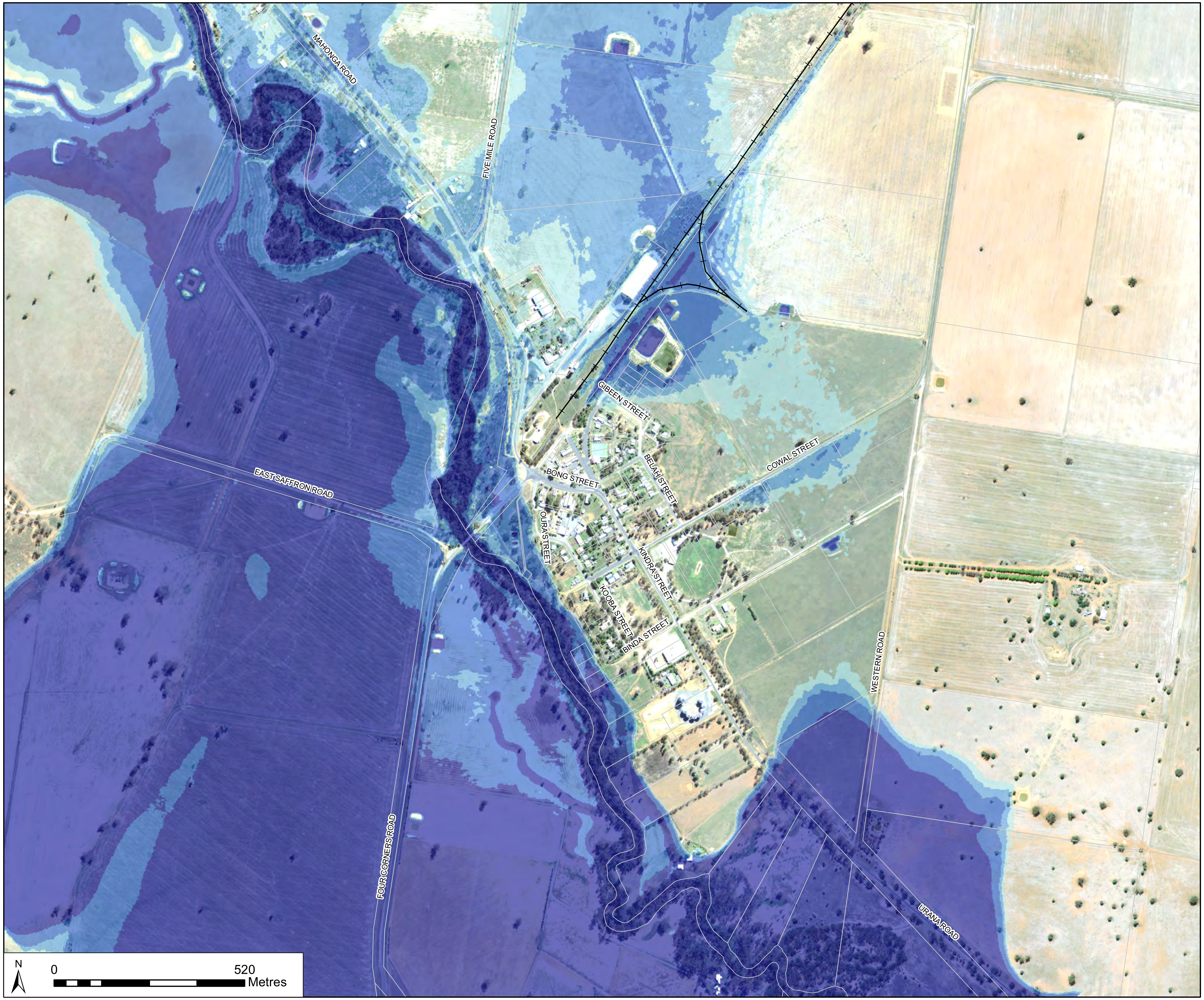
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	0.2% AEP Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-7
CHECK AH	DATE 10/29/2015	



Legend

Railway

Cadastre

flood depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- > 1.0

Depths below 150mm have been trimmed from this map

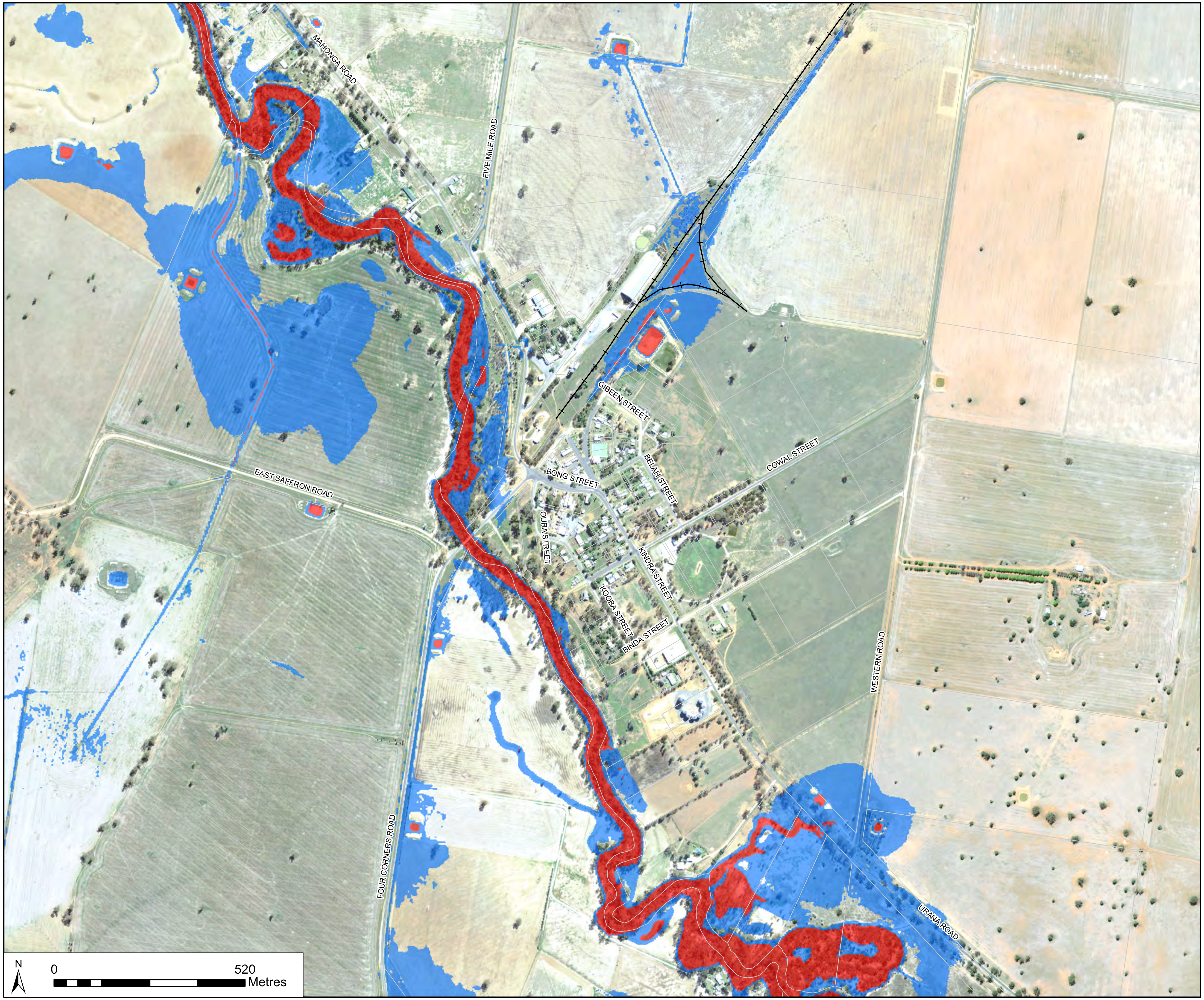
GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	PMF Event Flood Depth Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN AG / CHECK AH	PROJECT # IA055600 / DATE 10/29/2015
	FIGURE E-8



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

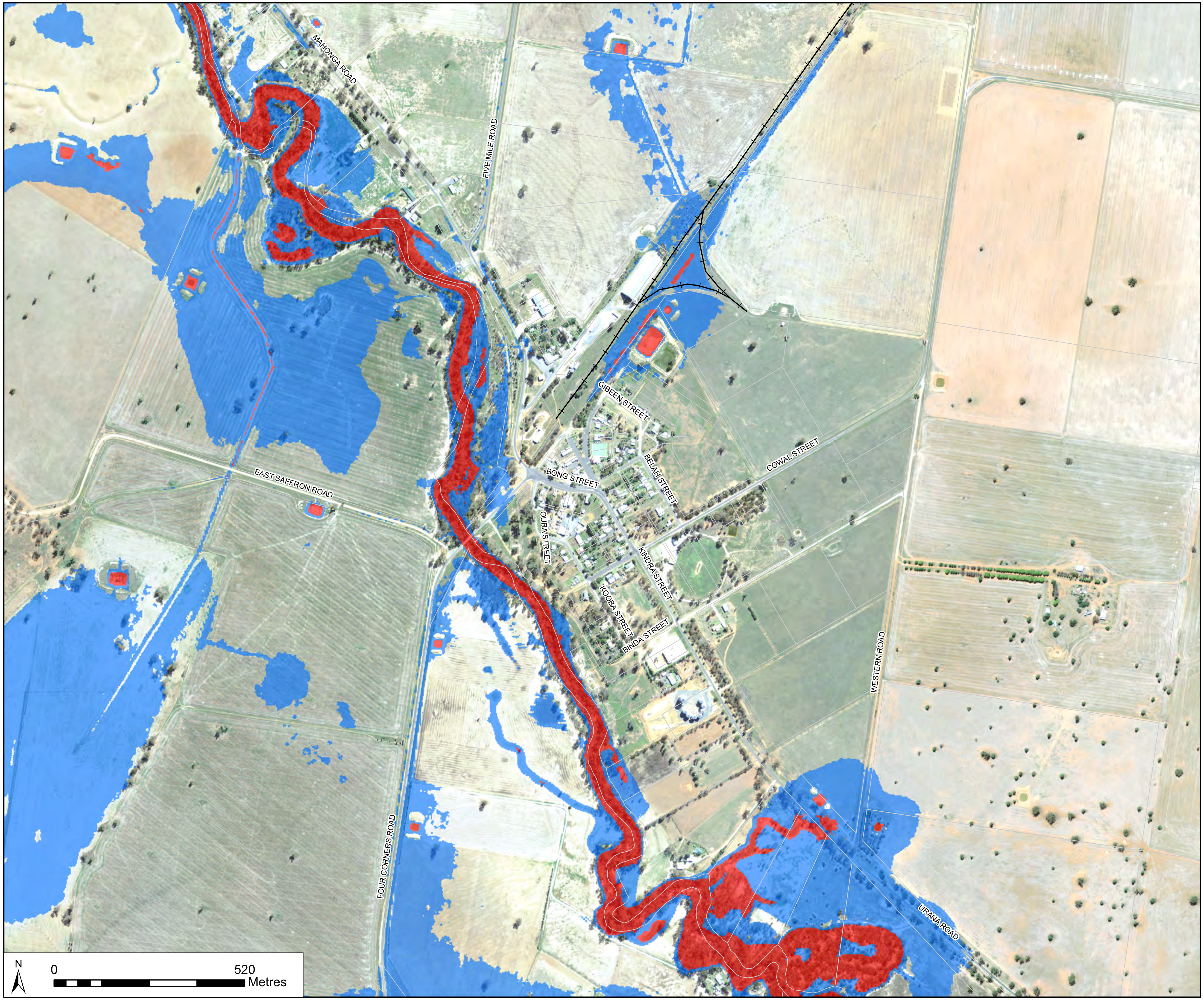
GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	5% AEP Event Provisional Hazard Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN AG / CHECK AH	PROJECT # IA055600 / DATE 10/29/2015 — FIGURE E-9



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

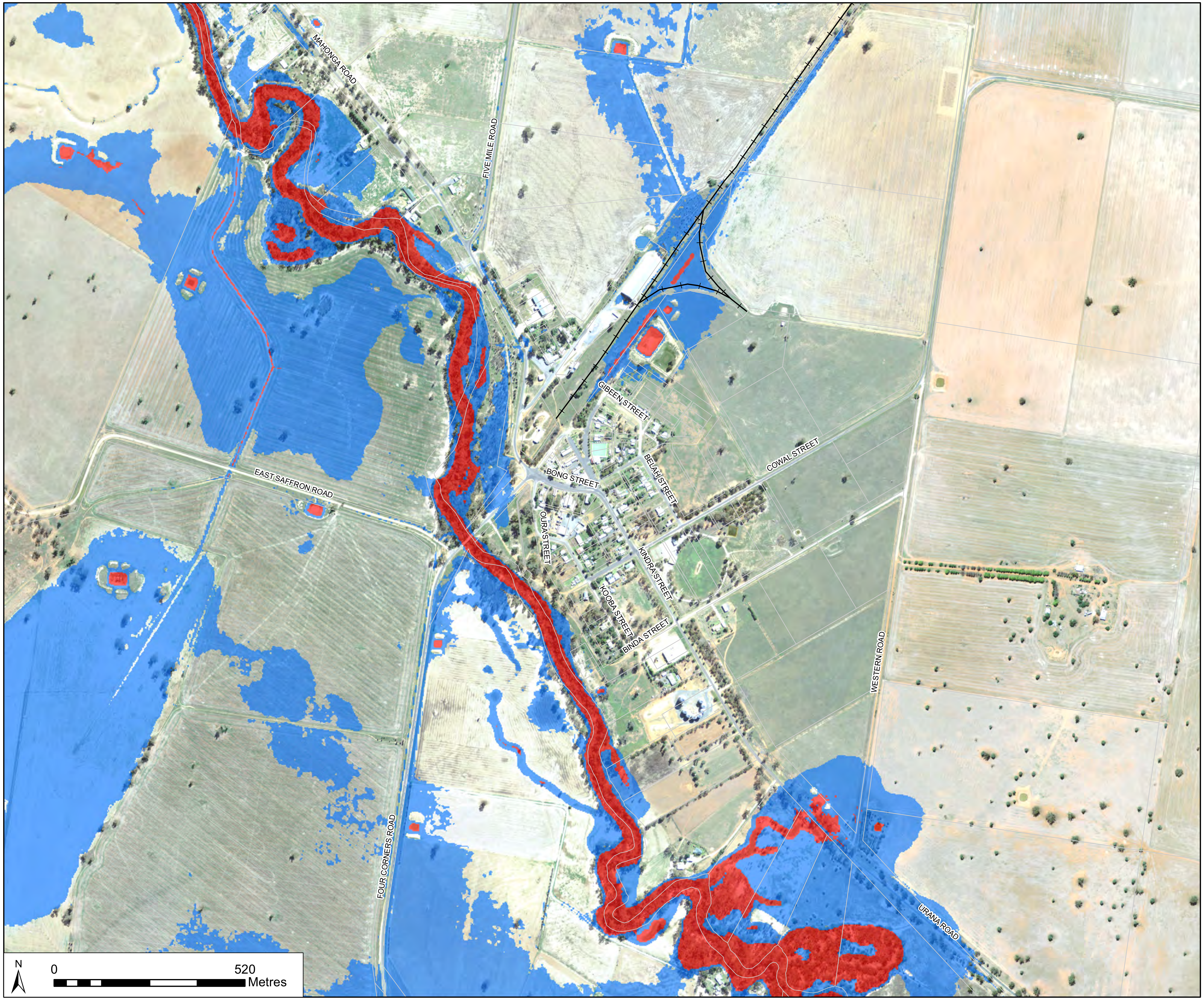
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	1% AEP Event Provisional Hazard Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-10
CHECK AH	DATE 10/29/2015	



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

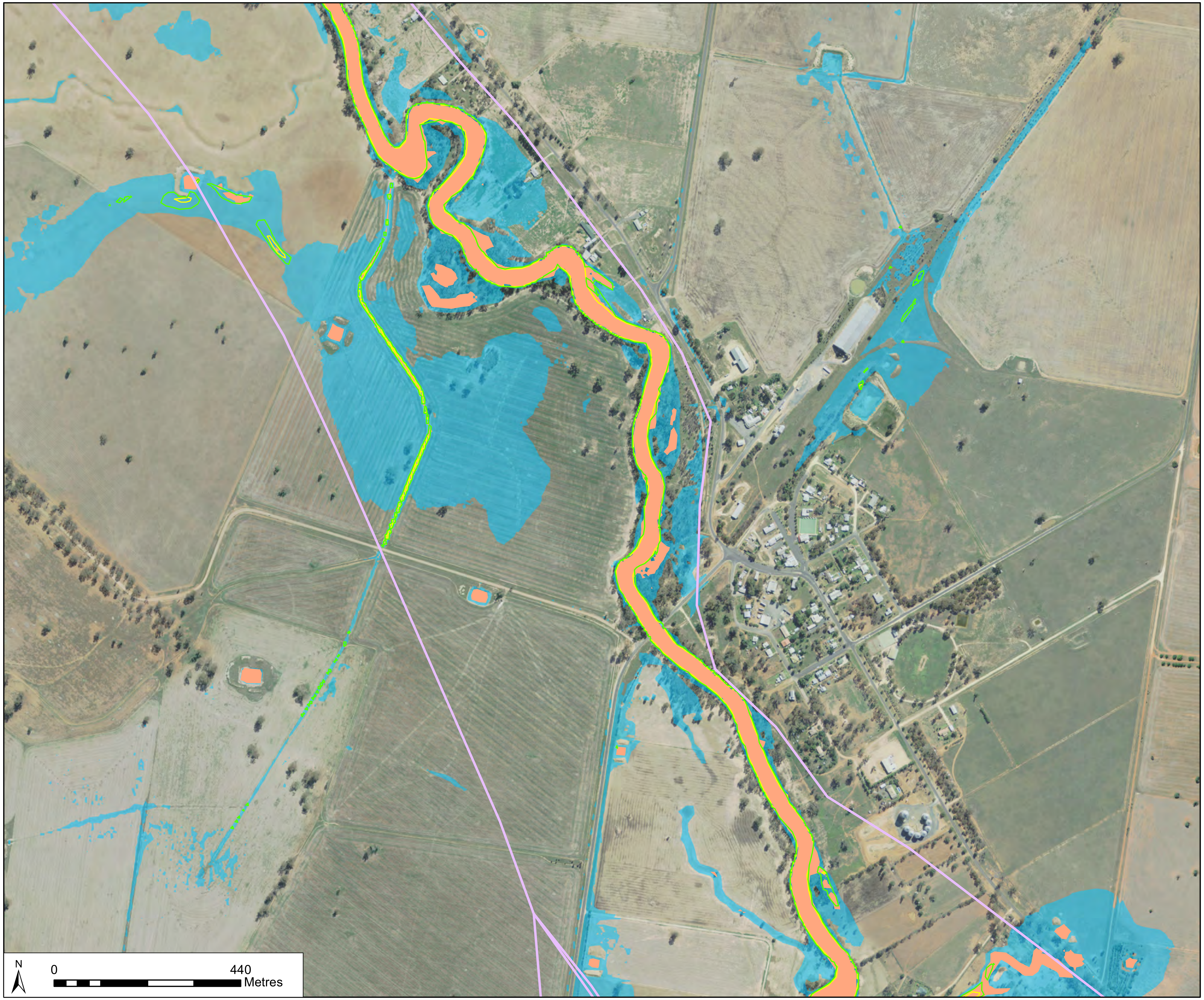
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	0.5% AEP Event Provisional Hazard Map
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-11
CHECK AH	DATE 10/29/2015	



Legend

- Floodway (Billabong Ck FMP)
- VD > 0.25
- VD > 0.5
- 1% AEP High Hazard
- 5% AEP Flood Extent

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE Floodway delineation

TOWN Rand

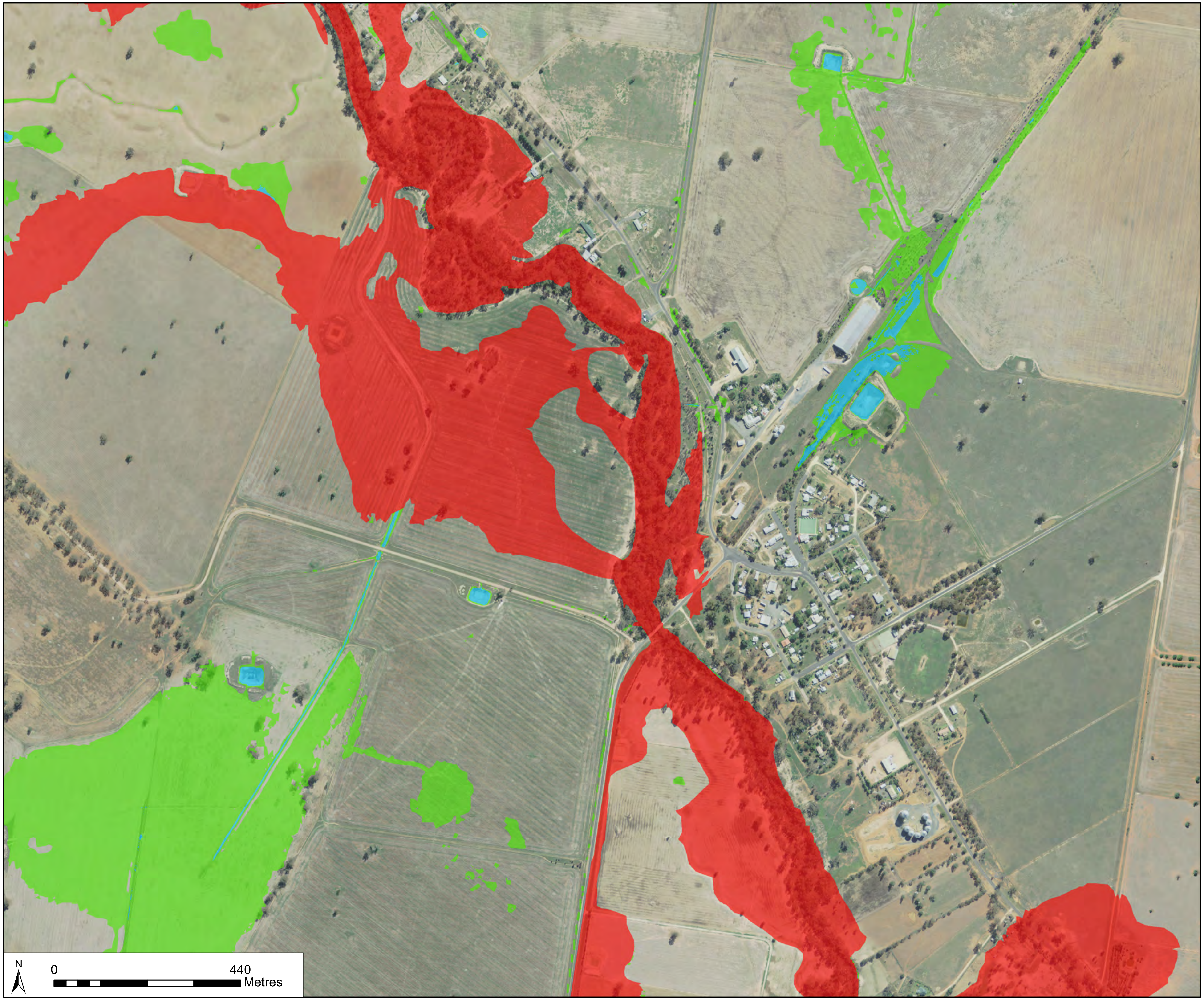
PROJEC Flood Study for Five Towns

CLIENT Federation Council

DRAWN MR | PROJECT # IA055600

CHECK AH | DATE 9/05/2016

FIGURE E-12



Legend

- Floodway
- Flood Storage
- Flood Fringe

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

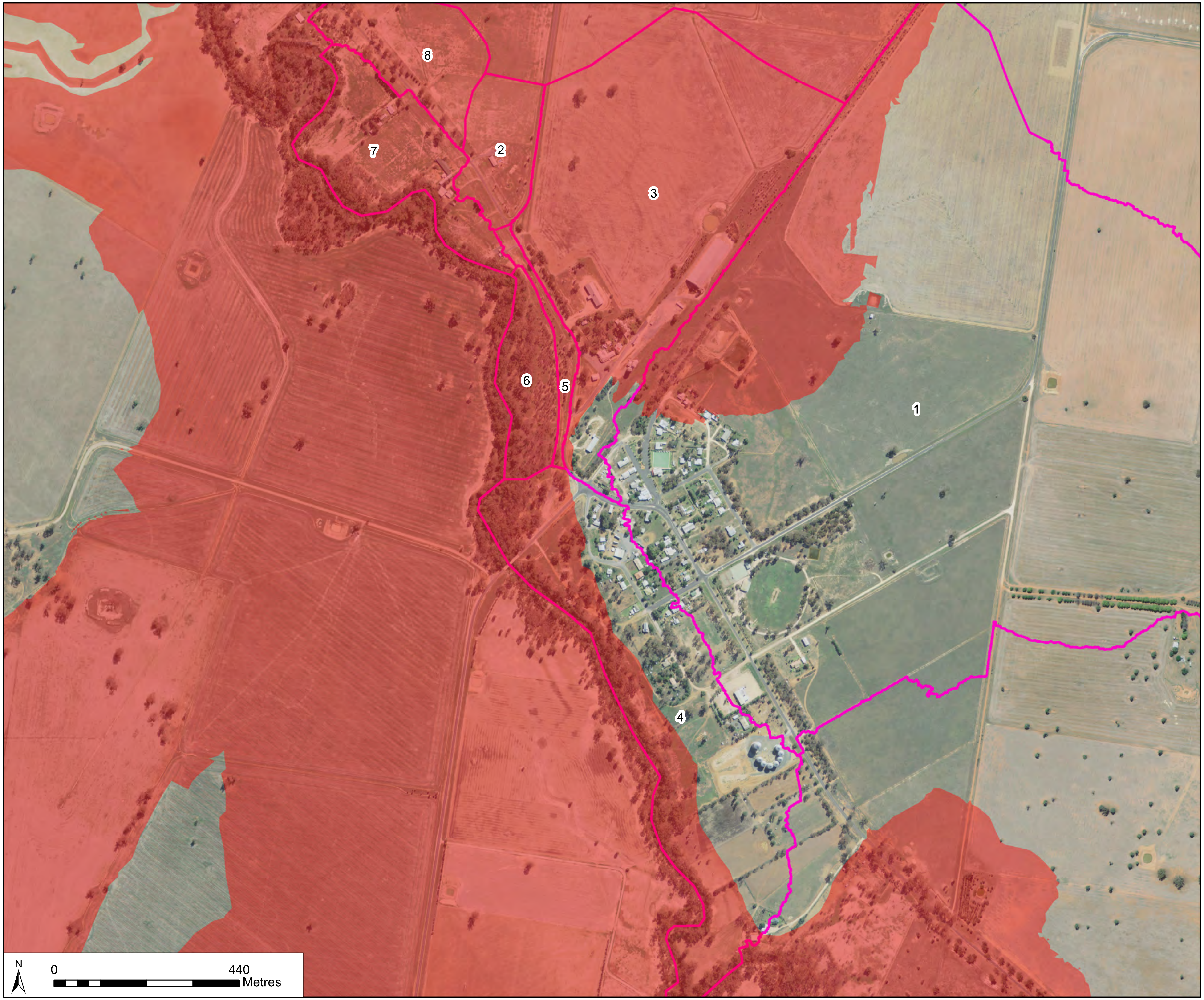
Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Provisional Hydraulic Categories - 1% AEP
TOWN	Rand
PROJEC	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-13
CHECK AH	DATE 9/05/2016	



Legend

- Flood Planning Area
- RAFTS local catchments

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

TITLE	Flood Planning Area
TOWN	Rand
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-14
CHECK AH	DATE 18/08/2017	