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

Federation Council

Flood Study Report for Oaklands

IA055600 | FINAL

November 2017

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

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Cover photo: Nowranie (South) Creek near Oaklands

Document history and status

Revision	Date	Description	By	Review	Approved
1	26/08/2015	Oaklands Calibration and Verification Report	MR	AH	AH
2	12/05/2016	Oaklands Design Flood Estimation Report	MR	AH	AH
3	1/08/2017	Draft Flood Study Report	MR	AH	AH
4	25/09/2017	Draft Flood Study Report (Public exhibition)	MR	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 (formerly Urana Shire 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 Oaklands.

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 Oaklands 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' 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

Oaklands is located within the local government area of Federation Council, approximately 27km south of Urana and 46km southeast of Jerilderie. It has a population of 349 people (2016 census) and is located adjacent to Nowranie (South) Creek (refer **Figure 1-1**).

Nowranie Creek is a flood runner of Billabong Creek which receives breakout flows from Billabong Creek downstream of Walbundrie. Once past Oaklands, Nowranie Creek flows north and northwest until it joins with Billabong Creek to the west of Lake Urana. The village is located approximately 2km south of Nowranie Creek at an elevation around 20m above the creek bed, on a small hill on the floodplain. The town has not been impacted by riverine flooding in the past, but may be impacted by local runoff flooding from severe storm events. There are three mechanisms of flooding that are investigated: flooding due to the Nowranie Creek flood runner, flooding due to the Nowranie Creek local catchment and local catchment flooding around Oaklands itself.

1.1 Objectives

The primary objective of this study is to define the nature and extent of flood behaviour in and adjacent to the township of Oaklands. 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 Oaklands. 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

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

- 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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

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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 flood maps for the design flood events

Appendix F: contains extracts from the Rand Flood Study Report (Jacobs 2017)

2. Available Data

2.1 Site Inspection

A site inspection was carried out on 29 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), 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. A summary of the information relevant to Oaklands is presented in the following sections.

2.2.1 Available Reports

- **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). While flooding in Oaklands was not reported, the document contains information regarding flooding in Billabong Creek and its floodplain (including Nowranie Creek).

- **Billabong Creek Floodplain Management Plan (DNR 2006, 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.

  The Billabong Creek Floodplain Management Plan (DNR 2006) identifies a network of floodways across the Billabong Creek floodplain that need to be kept clear of obstructions, such as levees or other flood control works to ensure the free flow of floodwater within Billabong Creek and across the floodplain. The design flood selected in the Plan (DNR 2006) is a combination of two historical flood events. The 1983 event (25 year average recurrence interval) was adopted for the upper floodplain and the 1974 flood (32 year average recurrence interval) was chosen for the lower floodplain. The 1983 event was the design flood adopted for Nowranie Creek corresponding to a peak flow of 2,400 ML/day (approximately 27.8 m^3/s).

2.2.2 Topographic Data

2.2.2.1 LiDAR Data

LiDAR data for Oaklands was provided by OEH which was originally captured by NSW Land and Property Information (LPI) on 9 July 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% confidence interval (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

Shuttle Radar Topography Mission (SRTM) data was provided by OEH. The SRTM data is a 30m DEM (1 second). Raw DEM data from 2000 was provided with a horizontal accuracy of 7.2m (90% CI) and an absolute vertical accuracy of 7.2m at the 95th percentile. This data covers the entire catchment area of interest.

2.2.2.3 Aerial Photography

Aerial photography was obtained from Council. Oaklands is covered by the 'Buraja' tile. It was captured in 2010. It has a 50cm resolution and was provided as a georeferenced raster. Aerial flood photography was also provided for the October 2010 flood over the region. This is provided as a false colour image over Oaklands showing almost no flooding in Oaklands.

2.2.2.4 Stormwater Details

A CAD file for Oaklands was provided by Council (shown in **Appendix A**). This outlines the boundaries and features in Oaklands including roads, culverts and the stormwater network. It does not provide stormwater details (such as culvert or underground pipe sizes). The drawing was updated in July 2014.

2.2.2.5 Additional Topographic Data

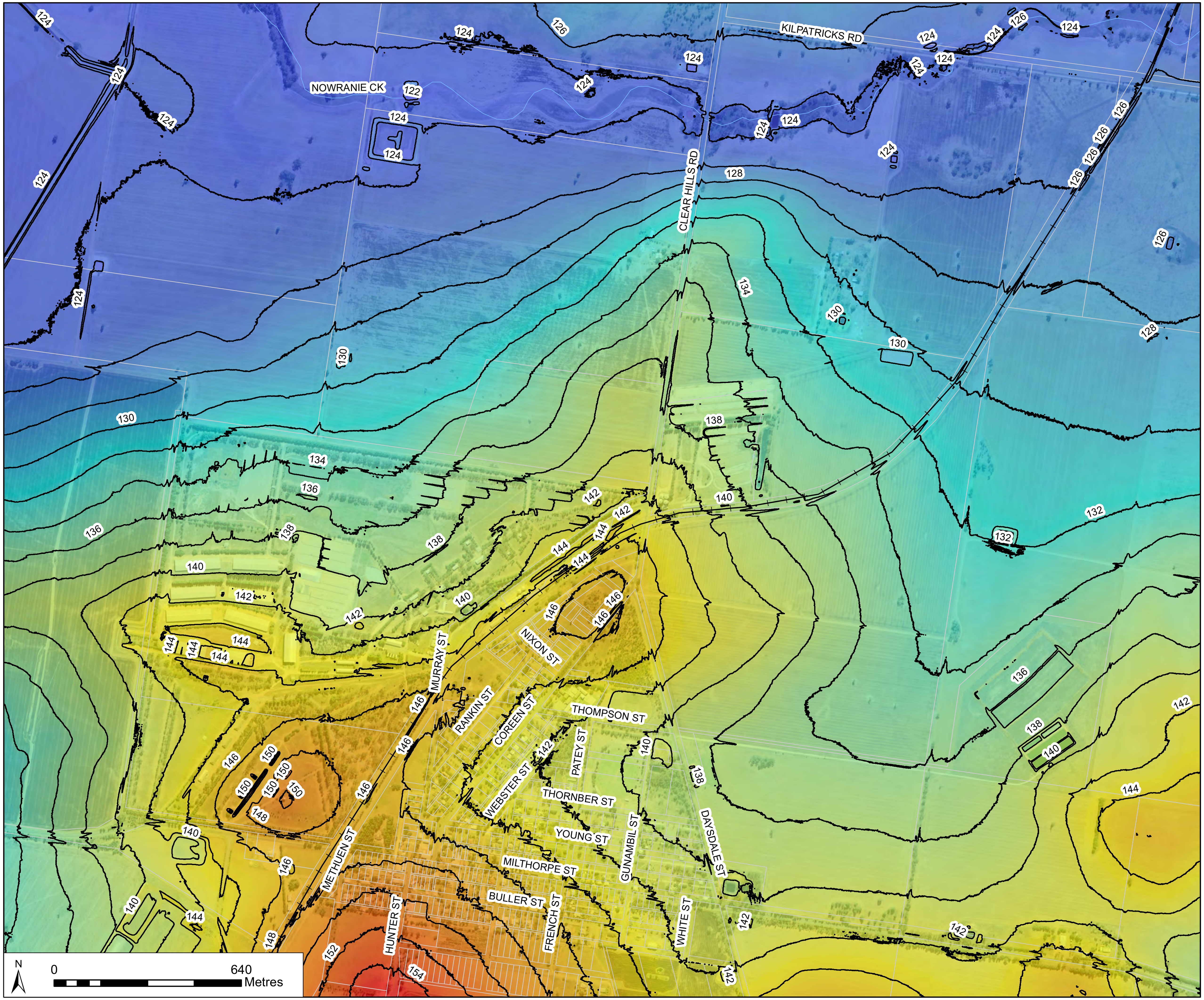
Additional topographic features, such as stream networks, road and rail networks, and cadastral boundaries were held in-house and utilised for this study.

2.2.3 Rainfall Data

Rainfall data used in this study includes the Billabong Creek catchment (to estimate breakout flows to Nowranie Creek) and in the vicinity of Nowranie Creek / Oaklands village. 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 the Billabong Creek and Nowranie Creek catchments and in the vicinity of Oaklands. Data for 19 sites was obtained from the Bureau's website. A summary of the rainfall stations in the vicinity of Oaklands (4 sites) is tabulated in **Table 2-1**. Details on the available rainfall data for Billabong Creek (15 sites) are presented **Appendix F**. The location of the gauged data from **Table 2-1** can be found in **Figure 2-2** for Nowranie Creek/Oaklands.



Legend

- 2m contours
- Cadastre
- Railway
- Watercourses

Oaklands DEM

Elevation (m AHD)

High : 155

Low : 120

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

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FIGURE 2-1

Table 2-1 Daily rainfall gauge data for Nowranie Creek / Oaklands

Gauge number	Gauge name	Start Date	End Date	Length of record (years)	Completeness (%)
74131	Rand Post Office	1/06/1954	6/08/2011	57.2	99.0
74065	Mahonga	1/01/1937	30/06/1954	17.5	100.0
74038	Daysdale (Dennison St)	1/11/1914	31/03/2013	98.5	97.1
74088	Oaklands General Store	1/2/1886	31/01/2015	129.1	71.8

2.2.3.2 Pluviograph

The DPI Water holds pluviograph data and details on the available pluviograph data for flood events of 2010, 2011 and 2012 are presented in **Appendix F.**

2.2.4 Streamflow Data

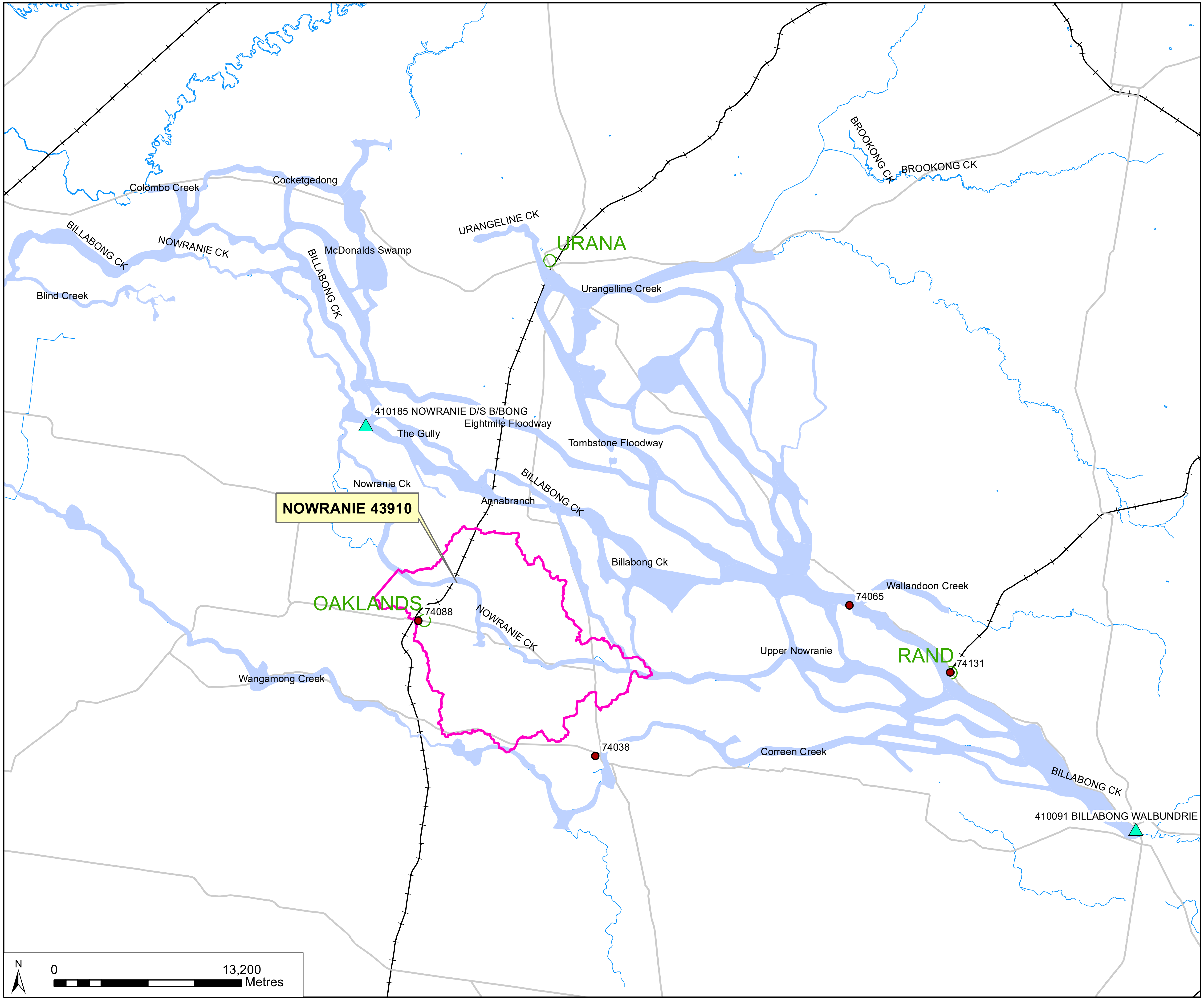
Streamflow data exists for Nowranie Creek, at Nowranie Creek at D/S Offtake Billabong Creek (410185). PINNEENA v10.2 shows the gauge has recorded water level data from January 2001 to December 2013, and is approximately 88.7% complete. The location of this gauge can be seen in **Figure 2-2**. A rating curve is not available for this gauge, and hence no discharge data is available.

Details on the additional available streamflow data are presented in **Appendix F**.

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**. 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 discharges in Billabong Creek (near Walbundrie) and Nowranie Creek in the vicinity of Oaklands are summarised in **Table 2-2**. A review of modelling results from Bewsher 2002 study indicates the modelled peak flows in Nowranie Creek in the vicinity of Oaklands are not impacted by the various scenarios investigated.

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 in Nowranie Creek for the flood events are shown in **Table 2-2**.



Legend

- Official daily rainfall gauges
- Stream gauges
- Nowranie local catchment
- Billabong Creek FMP Floodway
- Major Roads
- 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	Gauging Stations for Nowranie Creek
TOWN	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	MR	PROJECT #	IA055600	FIGURE 2-2
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Table 2-2 Flow distributions from the MIKE-11 model for the flood events

Flood event	Source	Billabong Creek at Walbundrie (m^3/s)	Modelled Discharge at 'Nowranie Ck 43910' (m^3/s)
1970	Bewsher 2002	296	9
1974	Bewsher 2002	407	21
1981	Bewsher 2002	185	2
1983	Bewsher 2002	444	27
1995	Bewsher 2002	307	7
2010	This study	554	44
2011	This study	264	4
2012	This study	446	21

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

There were no residents in Oaklands that responded to the questionnaire, which indicates flooding may not be a significant issue for Oaklands.

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 details of four crossings of Nowranie Creek (Maxwelton Rd culverts, drainage canal, Urana-Oaklands Rd culverts, abandoned railway bridge abutments) to Jacobs. Details for the culverts included culvert invert levels, lengths, diameters, number of cells and blockages along with photographs. Ground levels defining other features were also provided in a drawing file.

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 Oaklands is presented in **Appendix A**.

3. Catchment Hydrology

3.1 Catchment Description

Oakland is located at the apex of a hill and local catchments around Oaklands are shown in **Figure 3-1**. Intense rainfall on the local catchments has the potential to cause nuisance flooding in isolated areas of the village.

Nowranie (South) Creek is a small creek located north of Oaklands which runs in a north westerly direction approximately 1km north of Oaklands. Nowranie Creek traverses land that is cleared rural land, being used predominantly for grazing and dryland cropping and horticulture. The area is generally wide and open floodplain. The creek is constricted between two areas of high ground where Oaklands is situated before the floodplain opens up again.

Nowranie Creek is a flood runner of Billabong Creek which rejoins Billabong Creek upstream of Jerilderie. Flows in Billabong Creek, downstream of Walbundrie and upstream of Rand, break out and flow along Nowranie and Wangamong Creeks. Two major breakouts of Nowranie Creek are located upstream of Urana- Corowa Road which re- join Billabong Creek downstream of Oaklands Railway line. The floodways defined in the Billabong Creek Floodplain Management Plan (Bewsher 2002) can be seen in **Figure 2-2**. Due to the interflows between Nowranie Creek, Wangamong Creek and Billabong Creek, there is only a small defined catchment for Nowranie Creek of approximately 160km^2 that flows to Oaklands, as shown in **Figure 2-2**. Rainfall runoff generated from the relatively smaller catchment area of Nowranie Creek is unlikely to be a major source of flooding in the village which is located over 1km away from the creek.

Billabong Creek drains a catchment area of approximately 2,620km^2 to Walbundrie, where a gauging station is located. 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 a flood event, water that breaks the bank of Billabong Creek downstream of Walbundrie flow south towards Nowranie and Wangamong Creeks. Billabong Creek is considered a major source of flooding in Nowranie Creek near Oaklands.

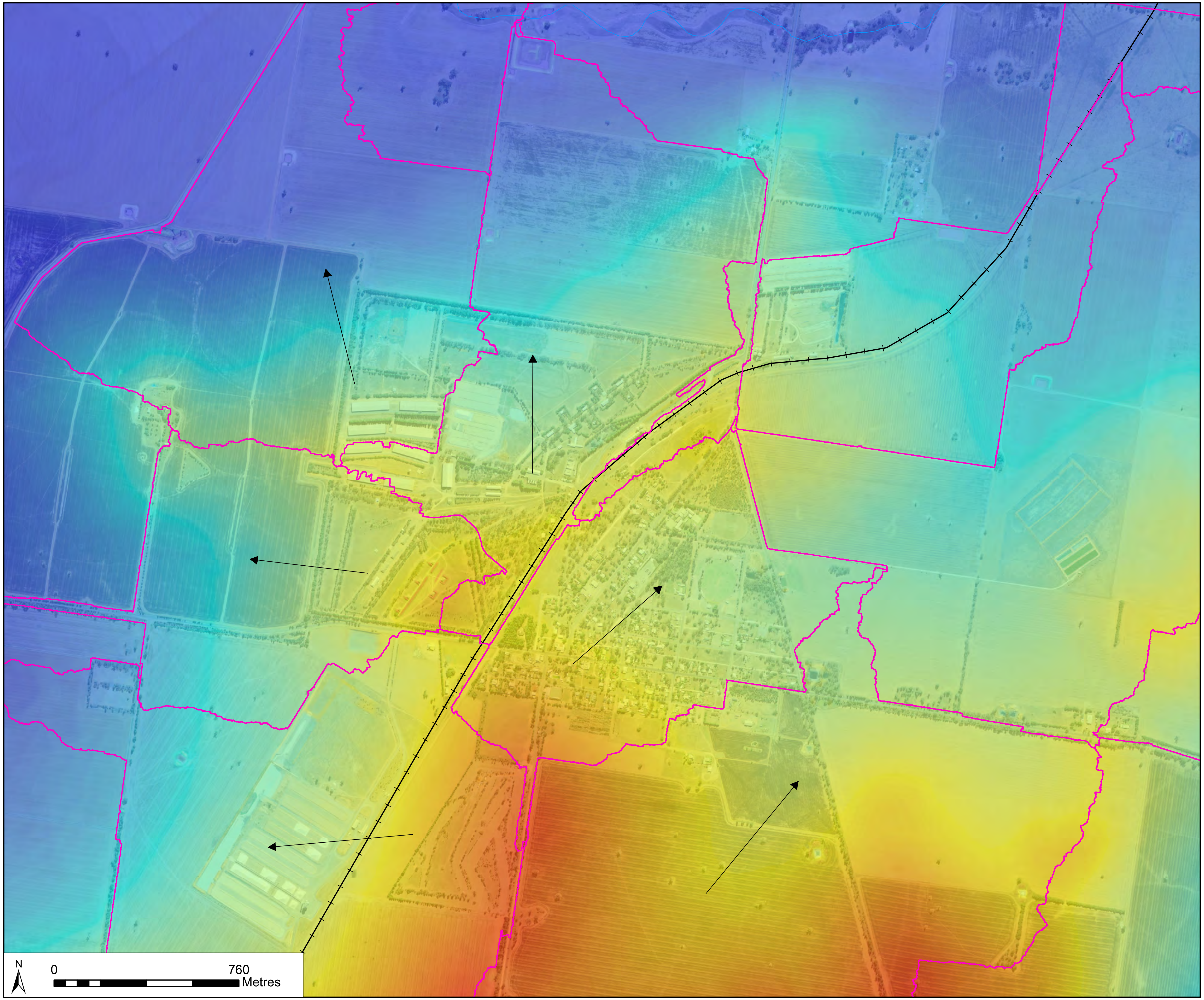
3.2 Flood Frequency Analysis

Adequate recorded streamflow data is not available to undertake a flood frequency analysis for Nowranie Creek. Details on the flood frequency analysis for Billabong Creek @ Walbundrie gauge are provided in the Flood Study Report for Rand (Jacobs 2017) and relevant extracts from the report are included in **Appendix F**.

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 Oaklands, a hydrologic model will be required to estimate design catchment runoff for the full range of flood events up to and including the PMF. This flow can then be used in the MIKE-11 model to estimate the breakout flows from Billabong Creek to Nowranie Creek. It is not expected that the additional catchment flows from the local Nowranie Creek catchment will influence flood behaviour significantly. The local catchment draining through Oaklands has also not been included in the modelling due to the lack of calibration data at Oaklands. The purpose of this calibration is to observe the impact that Billabong Creek breakout has on flooding in Oaklands.

A RORB hydrologic model has been developed for the catchment area of Billabong Creek @ Walbundrie gauge as part of the Flood Study Report for Rand (Jacobs 2017) and details on model development and modelling results are provided in **Appendix F**.



Legend

- Oaklands local catchments
- Railway
- Watercourses

Oaklands DEM
Elevation (m AHD)
High : 160
Low : 120

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	Oaklands local catchments and flow directions
TOWN	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 3-1
CHECK AH	DATE 1/08/2017	

4. Hydraulic Modelling

4.1 Model Selection

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydrodynamic model has been developed for Oaklands to assess riverine flooding from Nowranie Creek. 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. Additional information regarding hydraulic modelling can be found in **Appendix D**.

4.2 TUFLOW Model Configuration

4.2.1 Extent and Structure

The Oaklands TUFLOW model is comprised of:

- A 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use
- 1D representation of the culvert crossings
- Obstructions to flow are represented in the 2D terrain, including the abandoned railway abutments.

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**. It is to be noted that details on the stormwater pits and pipes within the township were not available to this study and consequently pits and pipes were not represented in the TUFLOW model.

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. In addition, due to the sparse nature of the existing development, typically wide road corridors and no reported overland flooding problems, a 5m grid was considered adequate. The basis of the topographic grid used in the TUFLOW model is the LiDAR data set for Oaklands (see **Figure 2-1**).

4.2.3 Culverts

There are two main crossings of Nowranie Creek in the vicinity of Oaklands - Maxwelton Road and Clear Hills Road. These crossings each consist of 4 x 900mm diameter culverts which were represented as 1D structures in the TUFLOW model. The details of the culverts, including invert levels and lengths were obtained from the topographic survey undertaken for this study by TJ Hinchcliffe & Associates in 2015. A nominal 5% blockage was applied to these culverts.

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

Legend

- Local Catchment Inflow
- 1D culverts
- Railway embankment
- Inflow boundary
- Outflow boundary
- 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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 2/08/2017

FIGURE 4-1

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. There were no significant buildings located on the floodplain so none have been modelled for Oaklands.

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 for the flood events of 2010 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 two flood events. Simulated flows at MIKE11 cross section "NOWRANIE 43910" for the two flood events are shown in **Figure 4-2** and **Figure 4-3** respectively. Modelled peak flows in Nowranie Creek upstream of Oaklands for flood events of 2010 and 2012 were 44 m^3/s and 21 m^3/s respectively. Due to the long duration of the hydrograph and the relatively small flow, the model was run in "steady state", taking the peak flow from the hydrographs and adopting this as a steady inflow in the TUFLOW model for Oaklands.

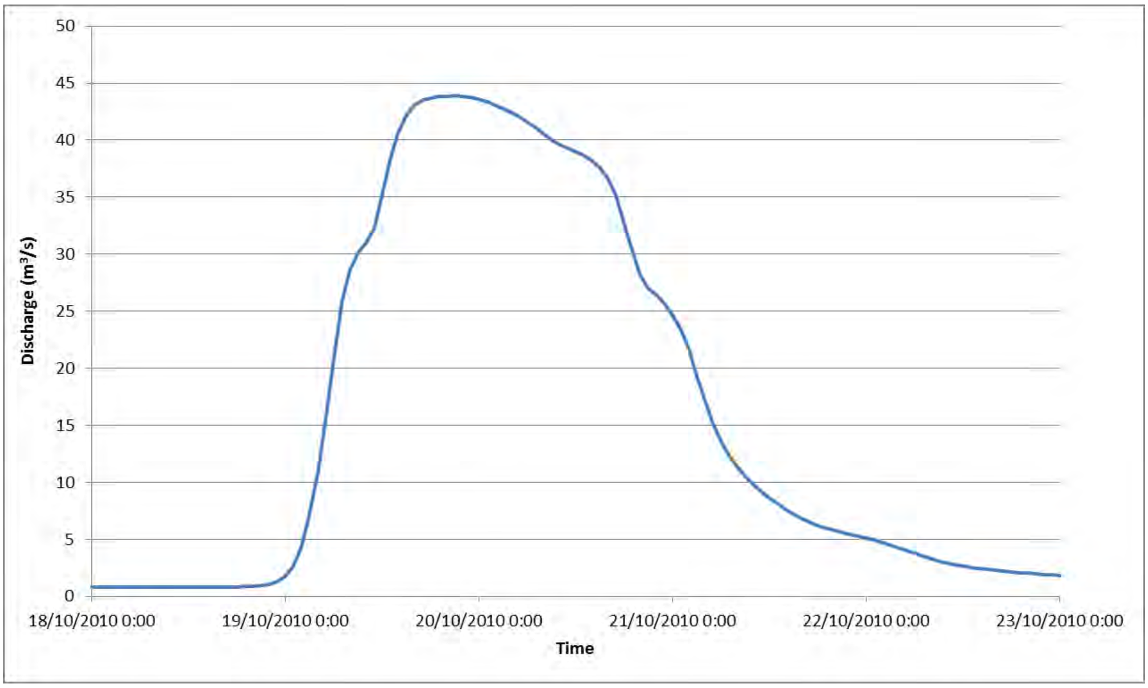


Figure 4-2 : Modelled Flow in Nowranie Creek upstream of Oaklands for 2010 Flood

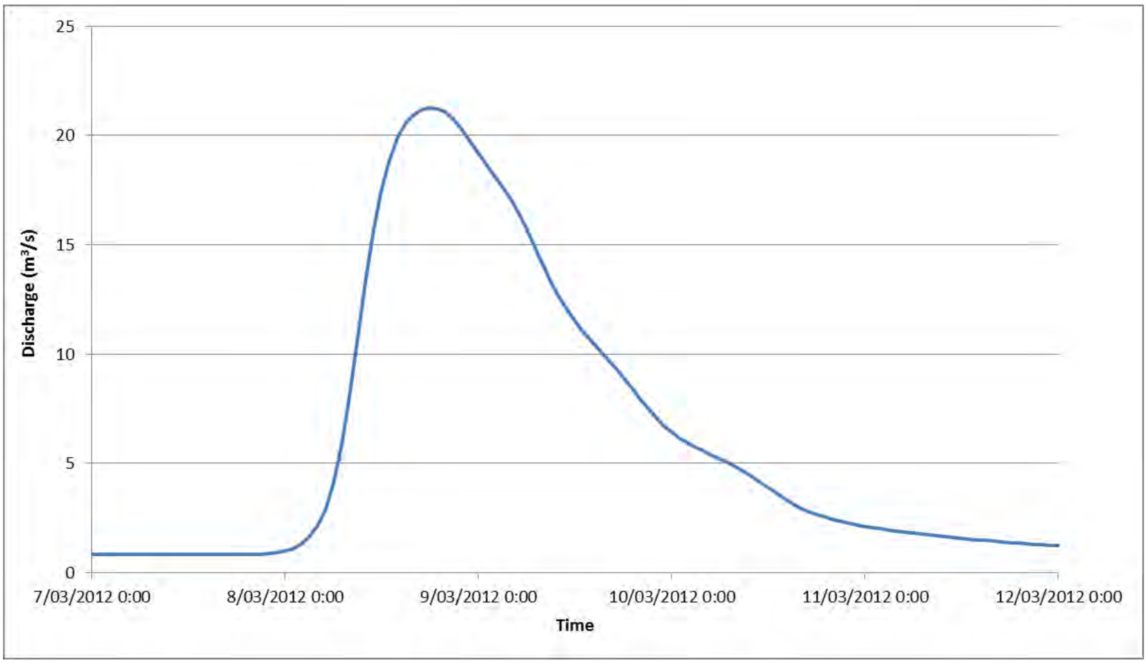


Figure 4-3 : Modelled Flow in Nowranie Creek upstream of Oaklands for 2012 Flood

4.3.2 Tailwater Conditions

The TUFLOW model for Oaklands incorporated a single downstream boundary. The boundary was located approximately 2.5km downstream of the village to eliminate the potential influence of the boundary conditions on flood levels in the study area. A normal depth condition was applied to the downstream boundary.

4.3.3 Initial Conditions

Small inflow was assumed at the start of the model runs.

5. Calibration and Verification

5.1 Selection of Calibration and Verification Events

Flood events in the Billabong Creek catchment were investigated since Nowranie Creek is a flood runner of Billabong Creek. There have been a number of floods that have impacted Billabong Creek, most notably the 1974 flood. Due to availability of data, however, the most recent flood events of 2010, 2011 and 2012 have been used for calibration and verification.

There are no recorded flood levels in Oaklands so typical hydraulic parameter values have been used in the TUFLOW model and a sensitivity analysis has been undertaken to assess sensitivity of key model parameter values on the flood behaviour.

Details on the calibration of the RORB hydrologic model for Billabong Creek are provided in **Appendix F** and details on the calibration and verification of the TUFLOW model are discussed in the following sections.

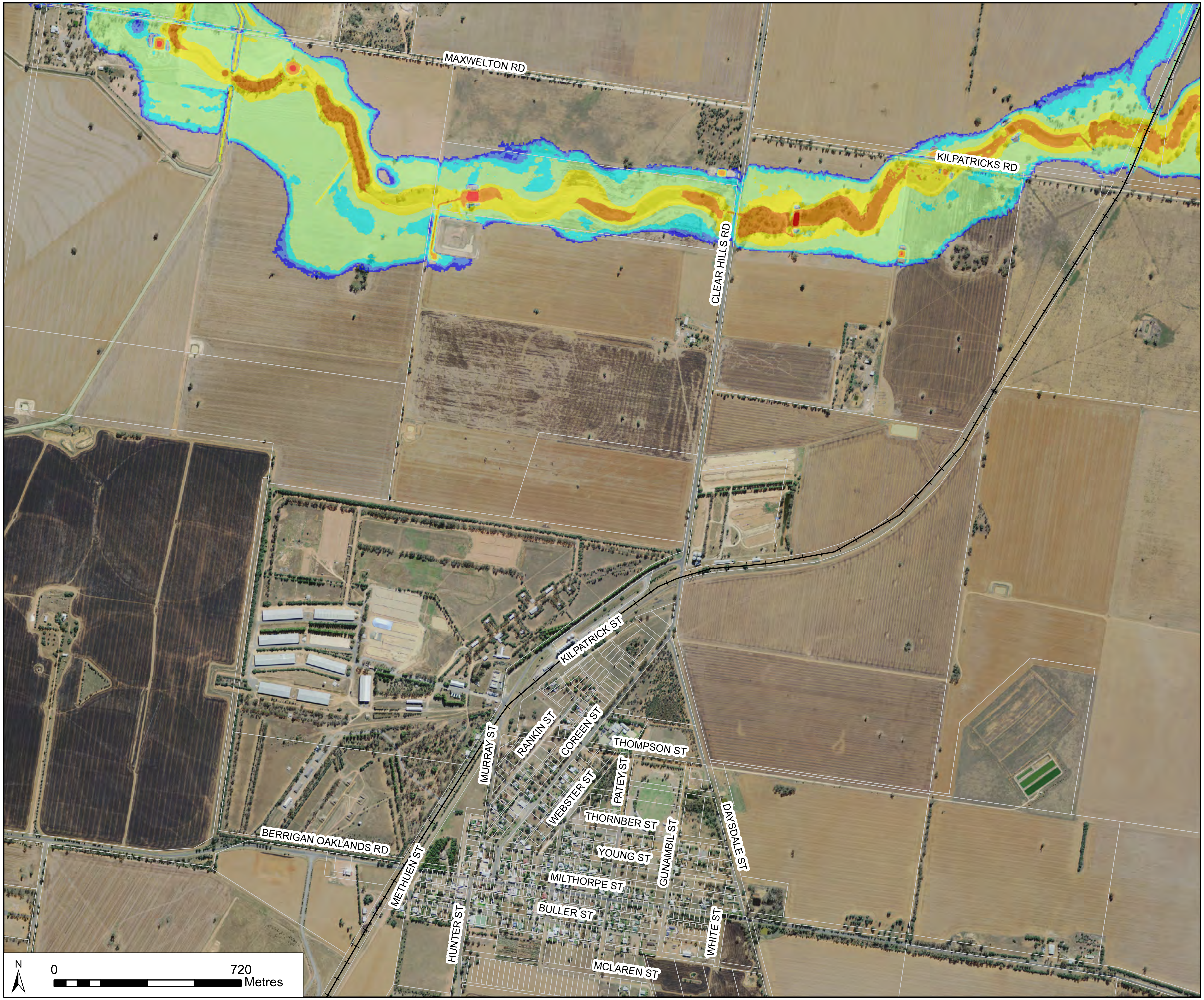
5.2 Hydraulic Modelling

5.2.1 2010 Event

The breakout flows along Nowranie Creek simulated by the MIKE11 model for this flood event were used as the upstream boundary conditions for the Oaklands TUFLOW model. The flows are relatively small, with a peak flow of 44m^3/s entering the model. The flows are restricted to a flow path up to 300m wide in the vicinity of the town (just upstream of Clear Hills Road). Control points along the floodplain include the railway embankment and road crossings. The flow, however, remains approximately 1.5km from the village, and there is no impact on Oaklands from Nowranie Creek. The flood map for the 2010 event can be seen in **Figure 5-1**. The modelled peak water level profile along Nowranie Creek near Oaklands can be seen in **Figure 5-2**. It is to be noted that an approximately 40m section of the railway is located at ground level (RL 124.3 mAHD) and the crest level of Maxwelton Road in the vicinity of the road culvert is the highest. Hence, a section of the railway and a section Maxwelton Road is subject to flooding during this flood event.

5.2.2 2012 Event

The flows simulated by the MIKE11 model for this flood event were used as the upstream boundary conditions for the Oaklands TUFLOW model. The flows are relatively small, with a peak flow of 21m^3/s entering the model. The flows are restricted to a flow path up to 300m wide in the vicinity of the town (just upstream of Clear Hills Road). Control points along the floodplain include the railway embankment and road crossings. The flow, however, remains approximately 1.5km from the village, and there is no impact on Oaklands from Nowranie Creek. The flood map for the 2012 event can be seen in **Figure 5-3**. The modelled peak water level profile along Nowranie Creek near Oaklands can be seen in **Figure 5-2**. It is to be noted that an approximately 40m section of the railway is located at ground level (RL 124.3 mAHD) and the crest level of Maxwelton Road in the vicinity of the road culvert is the highest. Hence, a section of the railway and a section Maxwelton Road is subject to flooding during this flood event.



Legend

- Cadastre
- Railway

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-1
CHECK AH	DATE 26/09/2017	

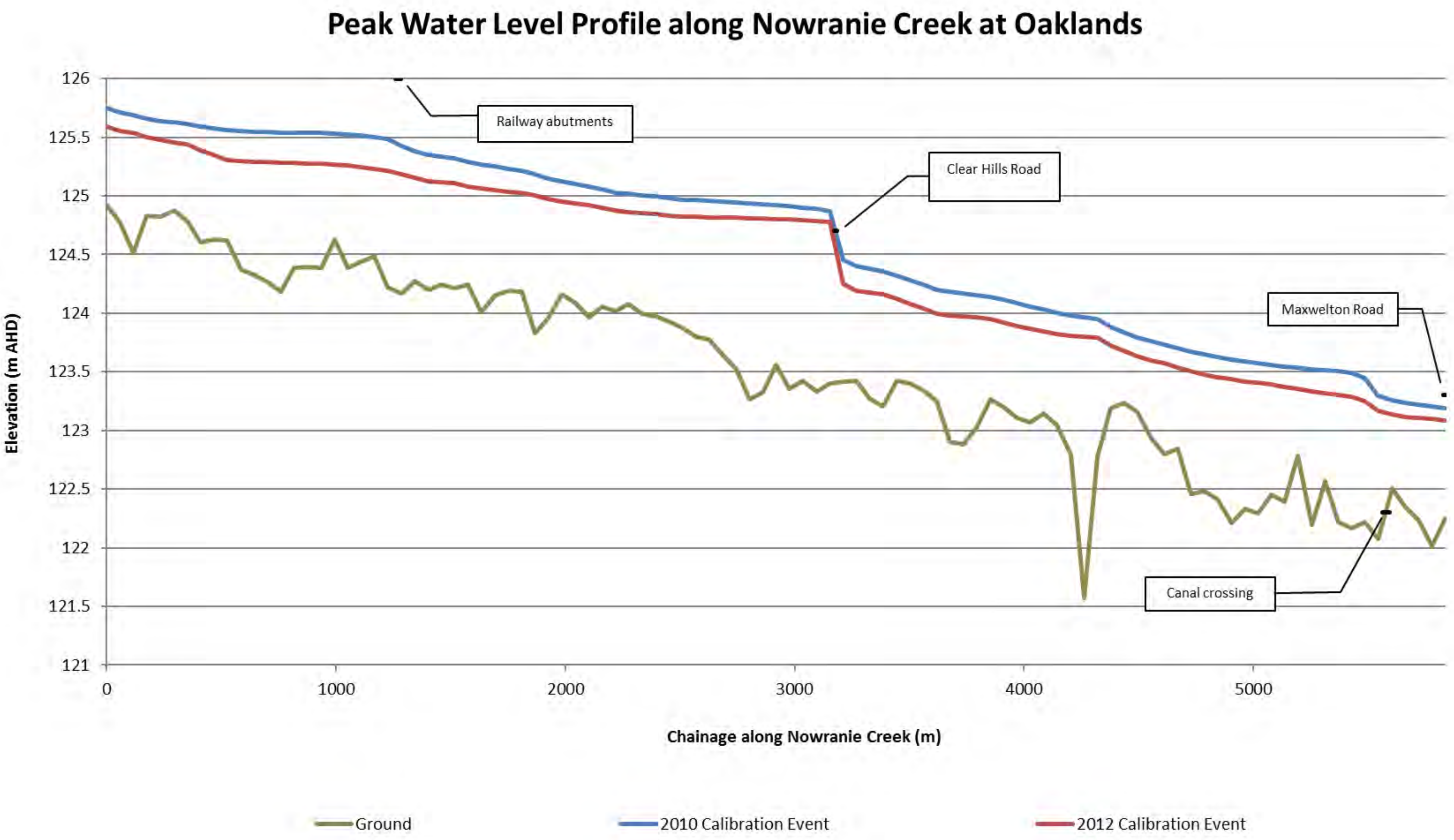
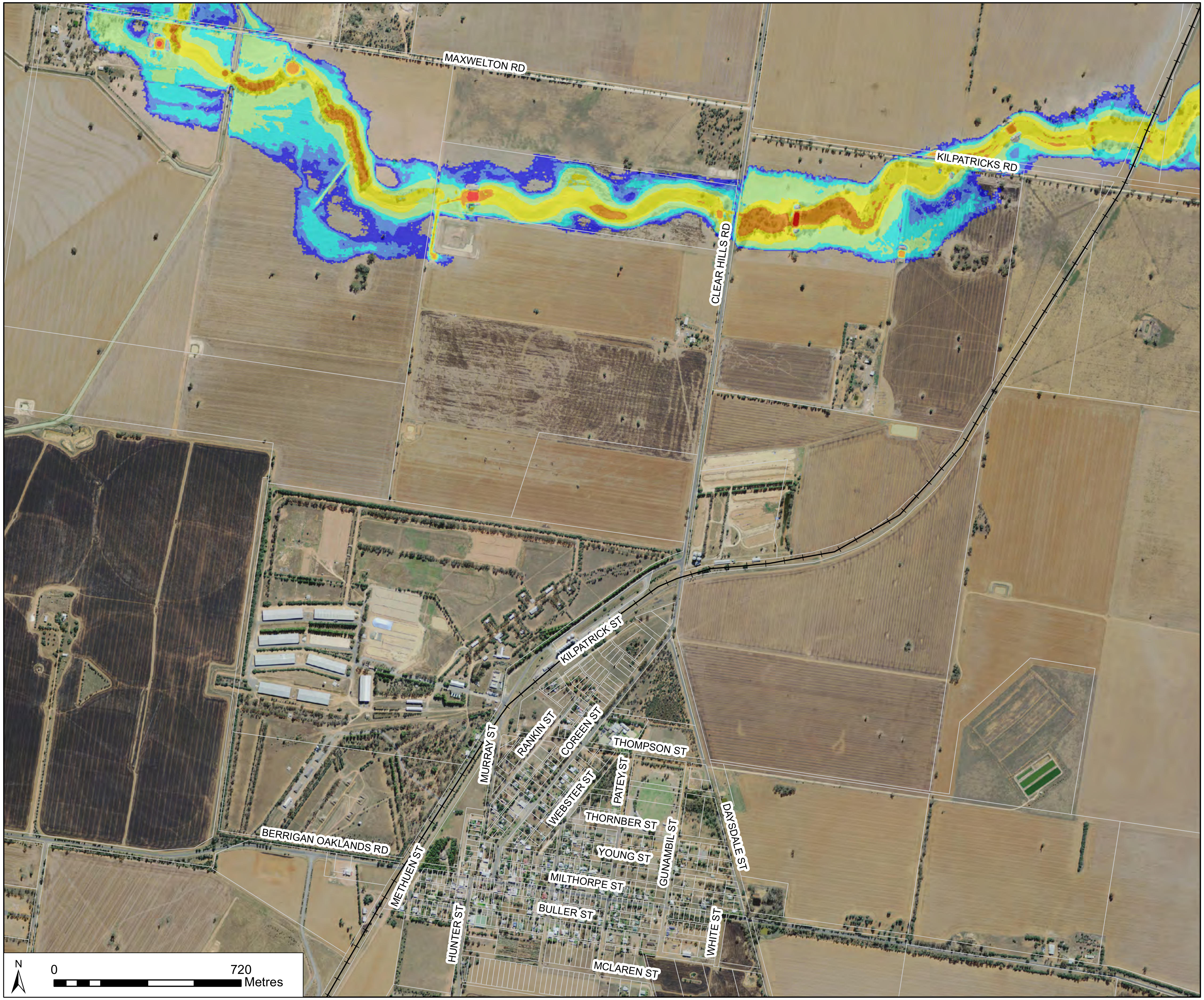


Figure 5-2 Peak Water Level Profile along Nowranie Creek at Oaklands for calibration events



Legend

- Cadastre
- Railway

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 5-3	
CHECK AH	DATE 26/09/2017		

5.3 Sensitivity Analysis (2010 Flood Event)

A sensitivity analysis was conducted using the 2010 flood event. Since the floodwater does not impact the village, a sensitivity analysis was only undertaken for the inflows. Adjusting the Manning's roughness, blockage of structures and downstream boundary will have no impact on flooding in Oaklands. The sensitivity of the inflows is addressed below and further details on the results from the sensitivity analysis are provided in **Appendix C**.

The steady-state inflow hydrograph was increased by 20%, from a peak flow of 44m^3/s to 53m^3/s. This resulted in a slightly larger flood extent and the increase in flow was carried through the model. There was some minor overtopping of the railway embankment north of the opening where a secondary flow path tries to cross the railway. The flood levels were increased by up to 0.08m at the upstream end and 0.03m at the downstream end.

Further to this analysis, the recorded peak flow at Walbundrie for the 2010 flood event was applied at the model inflow boundary. This assumes that all flow in Billabong Creek is diverted through Nowranie Creek. The peak flow is in the order of 10 times that of the modelled breakout flow for Nowranie Creek in the MIKE-11 model. The results show that the flow is less than 500m wide when it contracts in the vicinity of Oaklands. A cross section is provided in **Figure 5-4** which shows a section along Clear Hills Road with the modelled 2010 flood event and the 2010 Walbundrie flows applied. Even the significantly higher Walbundrie flows do not come close to encroaching on the village and hence Oaklands is not affected by flooding from Nowranie Creek.

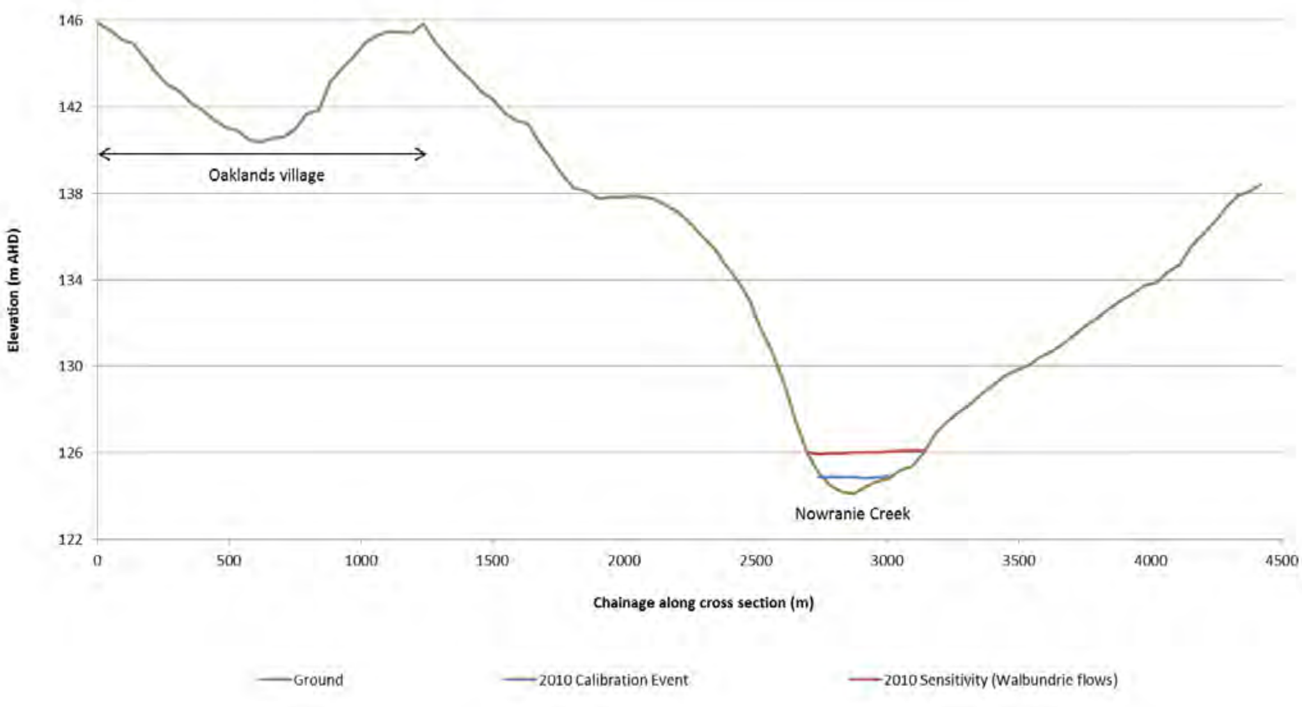


Figure 5-4 Cross section of flood levels along Clear Hills Road

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 Oaklands developed as part of this study) were utilised in the estimation of design flood for Oaklands. 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 to define flood behaviour for the study area.

6.1 Input Data for Hydrologic Modelling

Details on the RORB modelling for Billabong Creek and the estimation of discharge hydrographs for the design events using the RORB model are provided in **Appendix F**.

An XP-RAFTS hydrology model was developed for a total catchment area of 668ha 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 and impervious areas represented in the XP-RAFTS model for the sub-catchments varied between 5% and 40%.

6.1.2 Rainfall Depths

The rainfall design data was generated within the XP-RAFTS 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	XP-RAFTS model
Zone	2
1 hour 2 year ARI mm/hr	18.5
12 hour 2 year ARI mm/hr	3.38
72 hour 2 year ARI mm/hr	0.87
1 hour 50 year ARI mm/hr	42.26
12 hour 50 year ARI mm/hr	6.78
72 hour 50 year ARI mm/hr	1.61
Skewness G	0.14
Geographical factor 2 year ARI F2	4.33
Geographical factor 50 year ARI F50	15.21

Estimates of the Probable Maximum Precipitation (PMP) for XP-RAFTS model up to 3 hour storm duration were prepared using the procedures given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BoM, 2003).

6.1.3 Model Parameter Values

The adopted value of Bx was 1.0 in the XP-RAFTS model.

6.1.4 Temporal Patterns

Temporal patterns for all storm durations were sourced from the XP-RAFTS model for Zone 2.

6.1.5 Design Rainfall Losses for Pervious Areas

An initial loss of 15mm was adopted for events up to and including the10% AEP event and an initial loss of 10mm was adopted for events between 5% 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

Details on the estimated design discharges for Billabong Creek are provided in **Appendix F**. Peak discharges estimated by the XP-RAFST model for the design events are provided in **Appendix C**.

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 “NOWRANIE 43910” were extracted for use in the TUFLOW model. Discharge hydrographs simulated by the MIKE11 model for the 20% AEP to 0.2% AEP are shown are shown in **Figure 6-1** and the discharge hydrograph for the PMF event is shown in **Figure 6-2**. **Figure 6-1** shows that peak flows for the 2% and 1% AEP events are very similar which can be attributed to significant attenuation of peak flows due to flat floodplain and limited size of waterway crossings. The peak flow for the PMF event is more than 50 times the peak flow for the 1% AEP event. This is due to the fact that the MIKE11 model cross sections do not cover the full extent of the floodplain for the PMF event and consequently there is limited attenuation of the peak flow for the PMF event.

Figure 6-1 Discharge Hydrographs for 20% AEP to 0.2% AEP event in Nowranie Creek

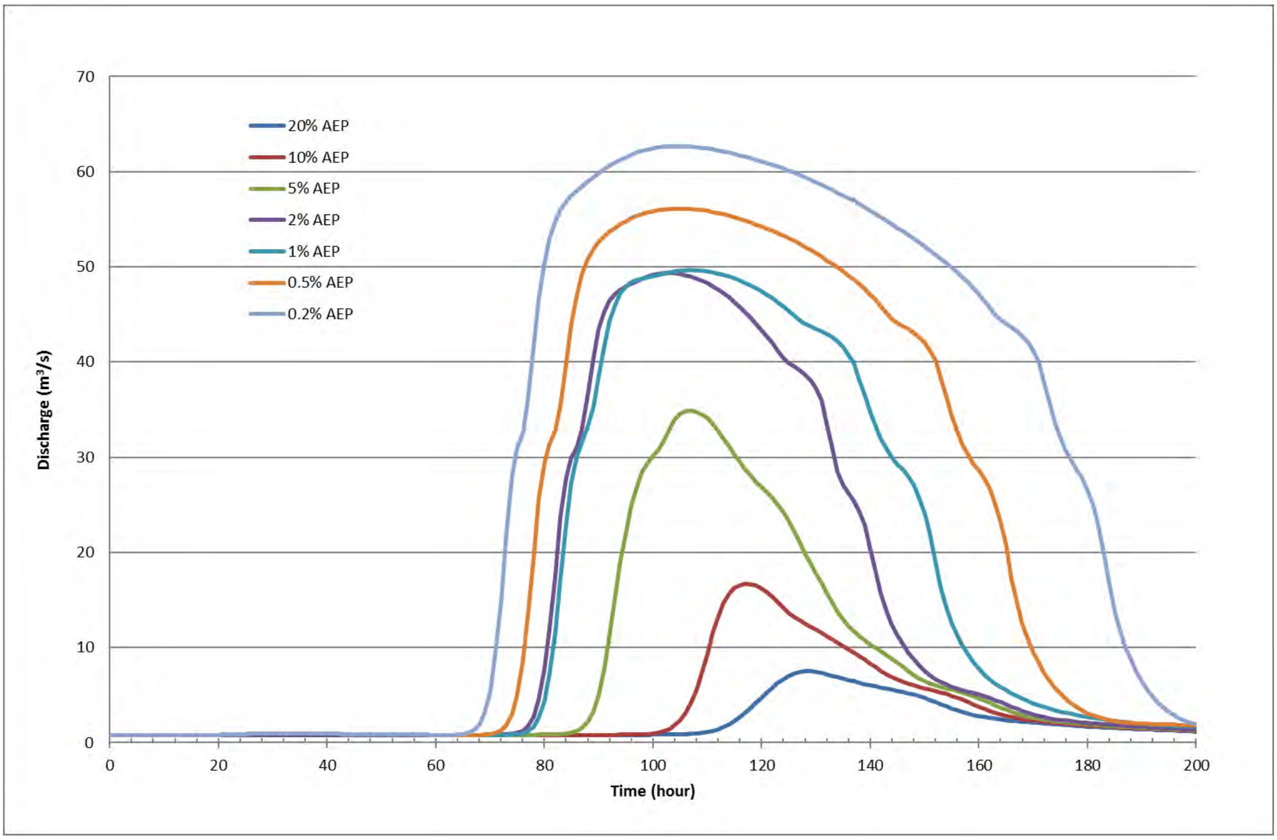
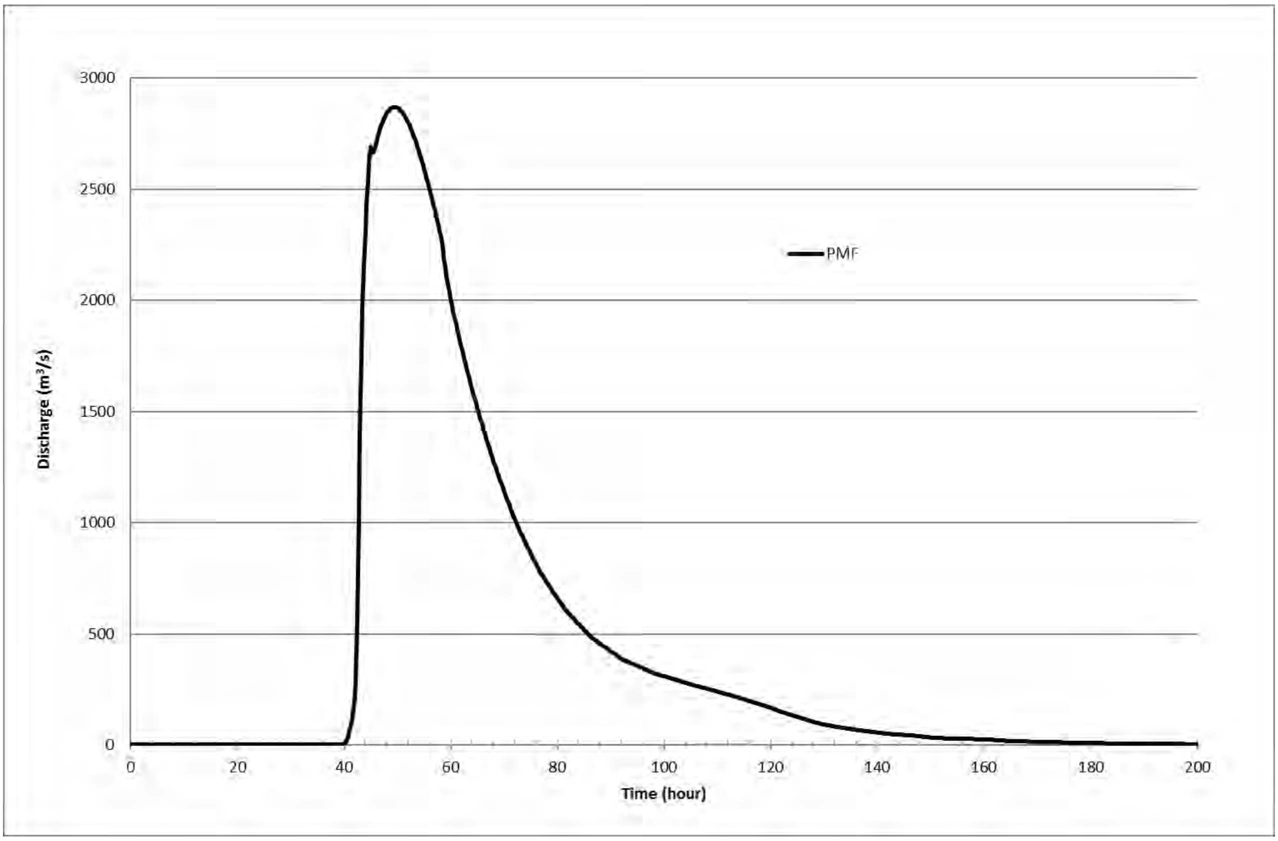


Figure 6-2 Discharge Hydrograph for the PMF event in Nowranie Creek



6.3.2 Local Catchment Inflows

Discharge hydrographs simulated by the XP-RAFTS model for the design events were included in the TUFLOW model (refer **Figure 4-1**) on the basis of the critical storm durations for sub-catchments 1A to 1F. For all these sub-catchments the 15 minute PMP event was the critical one and the 1 hour storm was critical for all design events between 2% and 0.2% AEP events. The 3 hour storm was critical for 20%, 10% and 5% AEP events. Runoff hydrographs simulated by the XP-RAFTS model for all sub-catchments for the critical storm duration were included in the TUFLOW model in combination with the discharge hydrograph generated by the MIKE11 model for the critical storm duration.

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

A small inflow was assumed at the start of the model runs.

6.4 Simulated Design Events

The storm durations assessed for all design events were selected based on MIKE11 model results and the XP-RAFTS hydrologic model to capture the critical storm durations throughout the study area. Inflow hydrographs for the critical storm events were routed through the TUFLOW model for Oaklands to simulate both mainstream and overland flooding for the study area.

7. Flood Behaviour for Design Flood Events

7.1 Flood Depth Mapping

One TUFLOW model was used to simulate both mainstream and overland flooding for the study area. The maximum envelope of flood depth mapped for all design events are included in **Appendix E** (refer **Figure E-1** to **Figure E-8**). These maps show that the township of Oaklands is not subject to flooding due to flooding in Nowranie Creek for the full range of flood events assessed in this study.

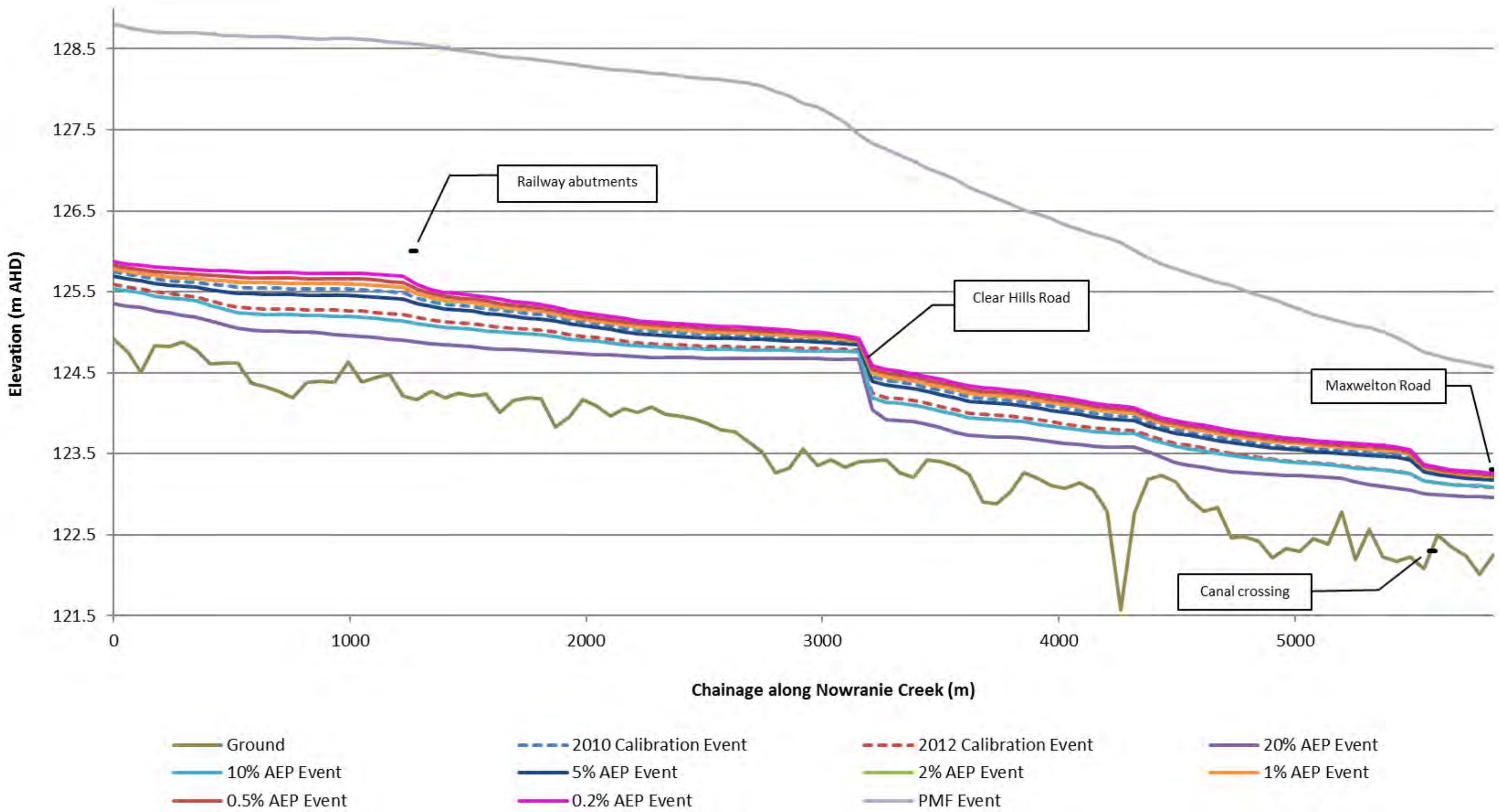
A number of small isolated areas within the township are subject to up to a maximum flood depth of 0.5m in the 1% AEP event due to rainfall runoff generated from sub-catchments located within the township. The open space located west of Daysdale Street between Thompson Street and Thornber Street is subject to up to 0.5m depth of flooding in the 1% AEP event. Sections of a number of roads within the town are impassable in the PMF event including Daysdale Road, Gunambil Street, Patey Street, Websters Street, Gaffney Street and Thompson Street.

Historic information on flooding for the township is not available. It is expected that the community, Council and NSW SES would monitor flooding in the township during future flood events to validate the flood behaviour for the township.

7.2 Flood Surface Profiles

The peak flood surface profiles are plotted in **Figure 7-1** for Nowranie Creek near Oaklands. **Figure 7-1** shows that the flood profiles for all modelled events are generally uniform between 20% and 0.2% AEP event. Clear Hills Road is a major hydraulic control. The peak water level profile for the PMF event is approximately 1.5m to 3m higher than the water level profile for the 0.2% AEP event. Given that the flow distribution was simulated by a MIKE11 model with limited number of cross sections and extents, the flow distribution for the PMF event may be not be highly reliable. However, the township is not subject to flooding due to the mainstream PMF event.

Figure 7-1 Peak Water Level Profiles – Nowranie Creek near Oaklands



7.3 Summary of Peak Flows

Peak 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.

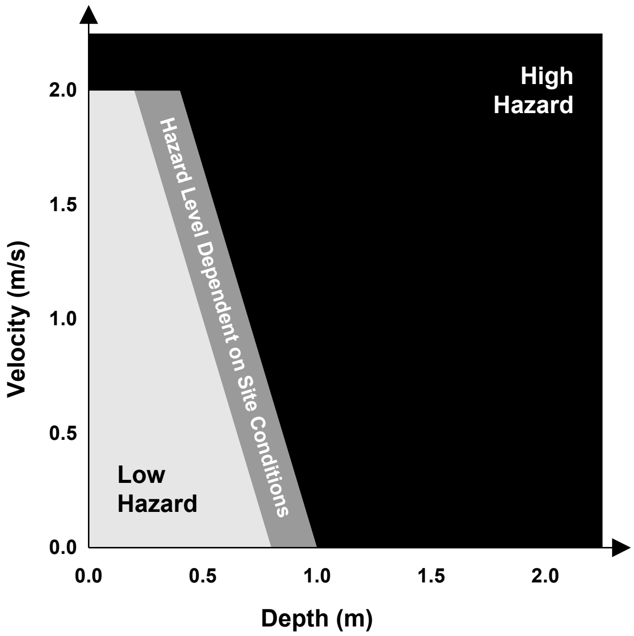


Figure 7-2 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)

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.** These maps show high hazard areas located along Nowranie Creek and no high hazard areas within the township.

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.

The township of Oaklands is not subject to flooding due to flooding in Nowranie Creek for the full range of flood events assessed in this study. Moreover, areas within the township are not subject to high hazard for flood events up to and including the 0.5% AEP event. Considering the fact that there is no firm guidance on hydraulic parameter values for defining hydraulic categories and the low flood risk for the township of Oaklands, no hydraulic categories were delineated as part of the study.

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 Oaklands is included in **Appendix E** (**Figure E-12**). The flood planning level and the flood planning area will be adopted in the floodplain risk management plan for Oaklands.

7.7 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.

Oaklands is located at the apex of a hill and accessible by Corowa Road, Jerilderie Oaklands Road, Clear Hills Road and Wangamong Road. However, road access to Oaklands can be cutoff by flooding in Nowranie Creek and Wangamong Creek which are flood runners of Billabong Creek. After road closure, the only access to Oaklands would be by boat or by aircraft and hence Oaklands is to be classified as High Flood Island during major flooding in Billabong Creek.

Sections of a number of roads within the town are impassable due to rainfall runoff generated from local catchments located within the town for the PMF event. Sections of Daysdale Road,Gunambil Street, Patey Street, Websters Street, Gaffney Street and Thompson Street are impassable in the PMF event. Due to the short duration of the PMF, it may be problematic to evacuate residents to a flood evacuation centre prior to the PMF. However, Oaklands Central School could be considered as a flood evacuation centre if necessary.

The focus of this study has been limited to flooding from Nowranie Creek and local catchment areas within the township. Due to the extensive floodplain of Billabong Creek around the township, the community, NSW SES and Council need to monitor road access to the township during major flood events.

8. Conclusions

In accordance with NSW Government Policy, Federation Council is committed to preparing a Floodplain Risk Management Plan for the township of Oaklands. 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 no responses on the questionnaire were received from residents of Oaklands. This indicates that flooding is not a significant issue for the community of Oaklands.

The available LiDAR survey for Oaklands 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 culvert crossings on Nowranie Creek for which adequate information was not available to this study. The ground survey collected abutment details of the railway crossing and a canal crossing under the creek.

A calibrated and validated RORB hydrologic model and an available MIKE11 hydraulic model were utilised to estimate inflow hydrographs in Nowranie Creek in the vicinity of Oaklands for the flood events of 2010 and 2012. Details on the hydrologic and hydraulic model are provided in the Flood Study Report for Rand (Jacobs 2017).

A TUFLOW hydraulic model for Oaklands was developed utilising a 5m grid based on a 1m LiDAR DEM. The model included the surveyed culverts crossing Nowranie Creek and other obstructions to flow including the railway embankment. Modelled inflows for the calibration events in Nowranie Creek upstream of Oaklands were used to model flood behaviour for the flood events of 2010 and 2012 flood events. The results indicate that during these events, floodwaters were around 1.5km from the town. Due to the lack of information regarding flooding in Oaklands, this is considered the best calibration possible.

A sensitivity analysis was undertaken to assess sensitivity in flood behaviour for the 2010 event due to the adopted modelled flows by increasing them by 20% and adopting the peak gauged flow from Walbundrie (approximately 10 times the modelled peak inflow in Nowranie Creek for the 2010 event). These results indicate that Oaklands is not impacted by flooding from Nowranie Creek.

Outcomes from the hydrologic and hydraulic model calibration and verification are considered adequate for estimation of flood behaviour for the full range of design events for Oaklands.

An XP-RAFTS hydrologic model was developed to simulate rainfall-runoff generated from sub-catchments located within the township which drain into Nowranie Creek. The XP-RAFTS model was utilised to simulate rainfall runoff from the sub-catchments for the design flood events assessed in this study.

The calibrated and validated RORB and MIKE11 models were utilised to define inflow hydrographs for Nowranie Creek in the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP design events and the PMF. Design inflow hydrographs for Nowranie Creek in combination with the corresponding rainfall-runoff hydrographs estimated using the XP-RAFTS model were routed through the TUFLOW model for Oaklands to simulate flood behaviour for the design flood 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. These maps show that the township of Oaklands is not subject to flooding due to flooding in Nowranie Creek for the full range of flood events assessed in this study. A number of small isolated areas within the township are subject to up to a maximum flood depth of 0.5m in the 1% AEP event due to rainfall-runoff generated from sub-catchments located within the township. Sections of a number of roads within the town are impassable in the PMF event including Daysdale Road, Gunambil Street, Patey Street, Websters Street, Gaffney Street and Thompson Street.

9. Acknowledgements

This study was undertaken by Jacobs on behalf of Federation Council. Federation Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

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 Oaklands
- Federation Council
- Office of Environment and Heritage
- NSW 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: Oaklands 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.

Oaklands

32: Culvert

Structure 32 is a culvert at the crossing of Nowrannie Creek by Maxwelton Road.

Table 32 shows the pertinent physical information about the structure.

Culvert 32

	Inlet		Outlet					
	Easting	Northing	Easting	Northing				
Coordinates	423135.15	6068080.51	423136.11	6068087.39				
Length	6.85							
Dimensions (Diameter)	0.900							
Number of Cells	4							
	Cell 1		Cell 2		Cell 3		Cell 4	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	121.87	121.86	121.85	121.83	121.87	121.82	121.87	121.82
Blockage %	5	0	5	0	5	0	5	0

Table 32: Structure 32 details.

Image 71 shows the structure 32 inlet.

Image 71: Structure 32 inlet.

Image 72 shows the structure 32 outlet.


Image 72: Structure 32 outlet.

33: Earthworks

Structure 33 has no culvert or bridge. It is formed land between two headwalls that force an irrigation channel underground. The crosssection of this 20m wide 'structure' is included in the georeferenced image. The structure is approximately 1.5m depth and 60m wide.

Table 33 shows the pertinent physical information about the structure.

Structure 33

Width approx	60m
Depth approx	1.5m
Length approx	20m

Table 33: Structure 33 details.

Image 73 shows the structure 33 facing north-west.

Image 73: Structure 33 facing north west.

Image 74 shows the structure 33 facing south west.

Image 74: Structure 33 facing south west.

34: Culvert

Structure 34 is a culvert on the main road to Urana alongthe Nowranie Creek.

Table 34 shows the pertinent physical information about the structure.

Culvert 34

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	425279.80	6067348.66	425268.84	6067350.31
Length	11.10			
Dimensions (Diameter)	0.900			
Number of Cells	4			
	Cell 1		Cell 2	
	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	123.29	123.29	123.29	123.27
Blockage %	5	5	5	5
	Cell 3		Cell 4	
	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	123.26	123.25	123.25	123.25
Blockage %	5	5	5	5

Table 34: Structure 34 details.

Image 75 shows the structure 34 inlet.

Image 75: Structure 34 inlet.

Image 76 shows the structure 34 outlet.

Image 76: Structure 34 outlet.

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.

Earthworks	
Height (approx)	1.6
Length	47
Width	8.00

Table 36: Structure 36 details.

Image 81 shows the structure 36 facing North.

Image 81: Structure 36 facing North.

Image 82 shows the structure 36 facing South.

Image 82: Structure 36 facing south.

37: Bridge

Bridge 37 is a structure spanning the Yanco Creek on the Sturt Highway just upstream from its junction with the Murrumbidgee River.

Table 37 shows the pertinent details about the structure.

Bridge 37

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	445240.71	6159537.05	445282.35	6159499.15
Levels	Start	Middle	End	
Deck	141.88	141.78	141.78	
Underside	141.33	141.23	141.23	
Length	66.10			
Width	10.00			
Height Rails/Barriers	0.93			

Table 37: Bridge over Yanco Creek at the Sturt Highway.

Image 83 shows structure 37 from the North.

Image 83: Structure 37 facing South.

Image 84 shows structure 38 from the South.

Image 84: Structure 37 facing North.

Other Structures

Flood Depth Indicator/Flood Marks

The flood depth indicators in this report are all located near major structures previously mentioned in the report. The following tables and images identify each and show it in relation to the surrounding environment.

Table 37 and Table 38 show the pertinent information about the Flood Depth Indicators at Structure 35 in Rand.

Flood Depth Indicator 6m mark		
South East of Structure 35		
	Easting	Northing
Coordinates	461533.65	6060905.41
AHD height	154.87	

Flood Depth Indicator 4m mark		
South East of Structure 35		
	Easting	Northing
Coordinates	461538.64	6060909.56
AHD height	152.74	

Table 37 and Table 38: Flood Depth Indicator Details.

Image 85 shows two Flood depth indicators South East of Structure 35.

Image 85: Flood depth Indicators near bridge 35, Rand.

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

- Culverts/features 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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

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

Appendix B. Questionnaire

	# *Urana Shire Flood Study Questionnaire (February 2015)* Oaklands

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 Oaklands. 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 Oaklands. 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** ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

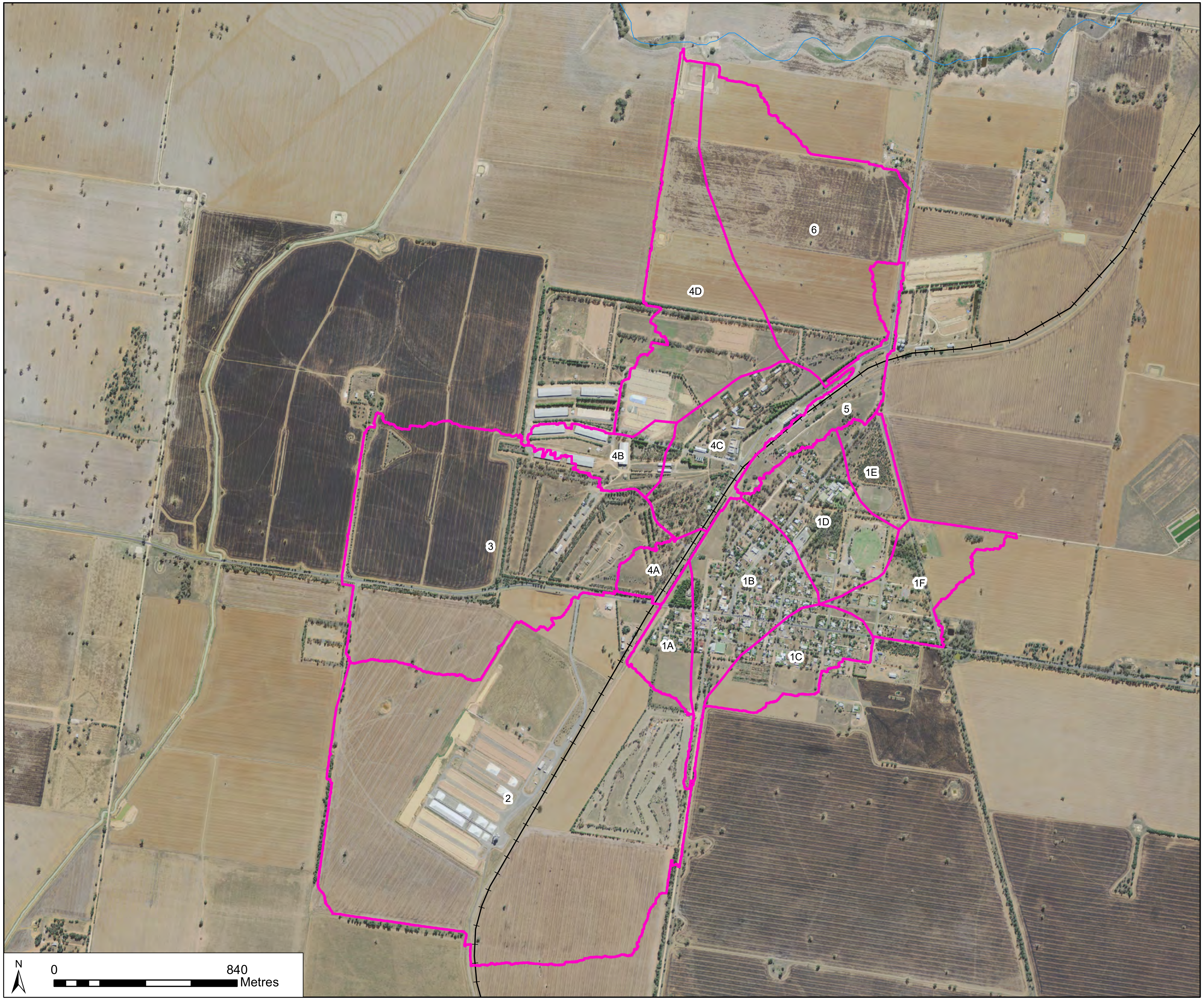
Question No.	Question and Answer

Thank you for your assistance

Map – Study Area for Oaklands

Appendix C. Hydrologic Modelling

- C1: Map showing XP-RAFTS Sub-catchments
- C2: Table showing sub-catchment characteristics
- C3: Reporting table for modelled peak discharges for the design events



Legend

- Oaklands local catchments
- 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	XP-RAFTS Sub-catchments
TOWN	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

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

Appendix C2

- XP-RAFT**S** sub-catchment characteristics

Sub-catchment	Area (ha)	Imperviousness (%)	Slope (%)	Roughness(n)
1A	11.20	20	1.42	0.03
1B	33.23	40	1.41	0.025
1C	20.48	30	1.46	0.025
1D	28.24	30	0.83	0.03
1E	9.92	10	1.48	0.05
1F	22.60	20	0.01	0.04
2	218.53	15	1.53	0.035
3	119.19	15	1.27	0.035
4A	7.24	10	0.52	0.04
4B	13.83	50	1.20	0.02
4C	31.33	35	1.24	0.04
4D	56.38	5	0.38	0.04
5	16.96	10	1.23	0.04
6	79.31	5	1.40	0.04
Total	**668.4**			

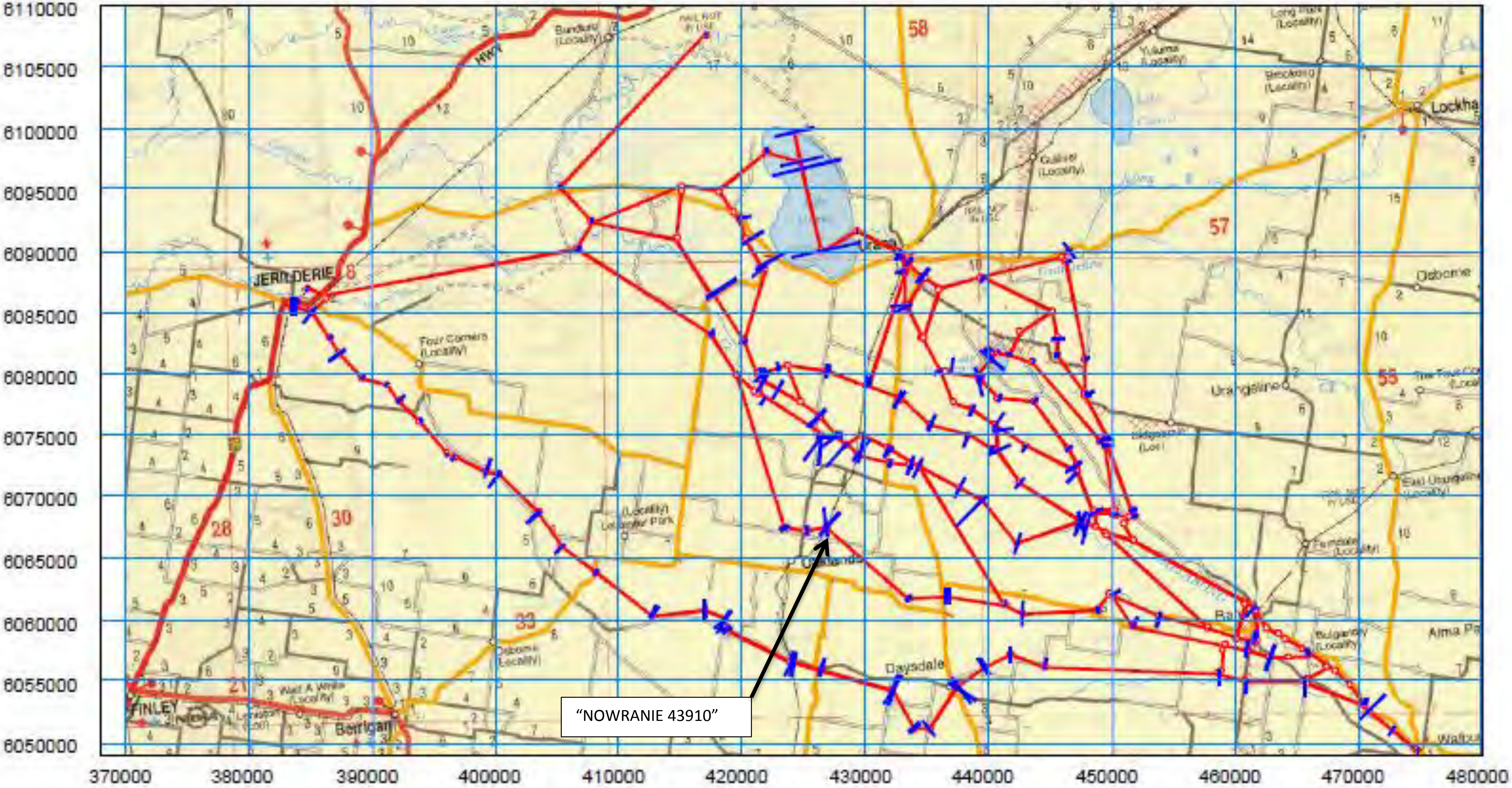
Appendix C3

- XP-RAFTS Modelled peak discharges (m^3/s) for design events

Sub-catchment	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1A	0.3	0.5	0.8	1.2	1.6	2.1	3.0	18.3
1B	1.2	2.0	3.1	4.4	5.6	7.4	10.7	61.5
1C	0.7	1.2	1.9	2.6	3.4	4.4	6.5	37.6
1D	0.7	1.1	1.8	2.6	3.4	4.5	6.7	40.7
1E	0.2	0.3	0.4	0.6	0.8	1.1	1.6	8.9
1F	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.8
2	2.9	4.5	6.8	9.2	12.5	17.0	25.8	122.6
3	1.6	2.6	3.8	5.3	7.2	9.6	14.7	71.7
4A	0.1	0.2	0.2	0.3	0.4	0.6	0.9	4.5
4B	0.7	1.3	1.9	2.5	3.4	4.4	5.8	29.5
4C	0.8	1.3	2.0	3.0	3.9	5.3	7.7	46.8
4D	0.3	0.5	0.8	0.8	1.2	1.6	2.5	11.0
5	0.3	0.4	0.7	1.0	1.3	1.8	2.7	14.5
6	0.9	1.4	2.1	2.6	3.5	4.9	7.7	34.9

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 and 2012 flood events
- D4: Reporting tables for the sensitivity runs
- D5: Map showing reporting locations of design flows for TUFLOW model
- D6: Reporting flows for design flood events

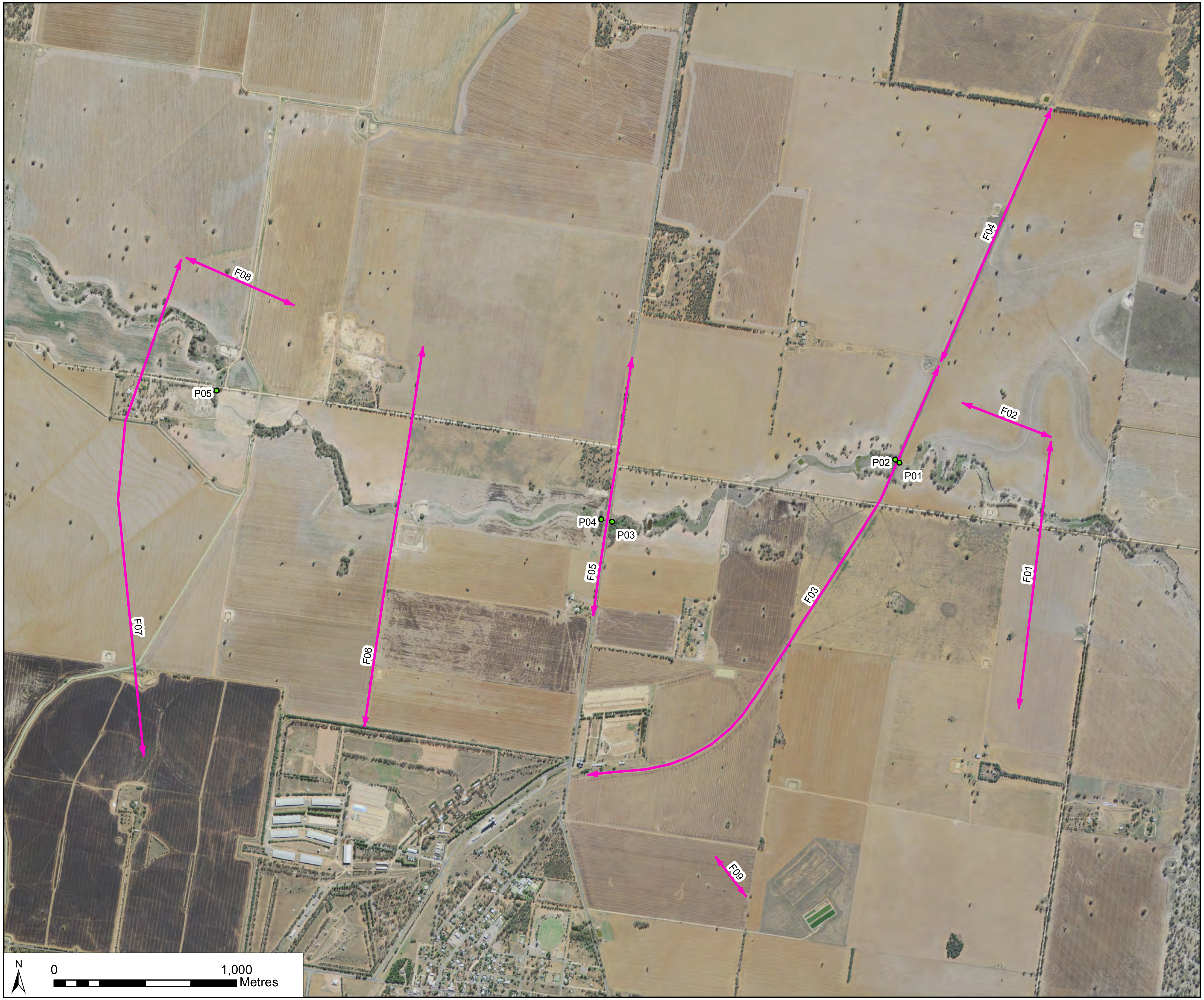


LEGEND

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

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

Appendix D3 – Calibration Results

- Modelled flows for the 2010 and 2012 calibration events

Flow line[1]	2010 Flow (m^3/s)	2012 Flow (m^3/s)
F01	35.0	18.8
F02	5.8	1.8
F03	40.5	20.5
F04	0.0	0.0
F05	35.0	14.9
F06	39.2	19.6
F07	36.2	11.6

[1] refer to Figure D-2

Appendix D4 – Sensitivity Results

- Flood level differences (m) for the sensitivity runs (adjusting flows)

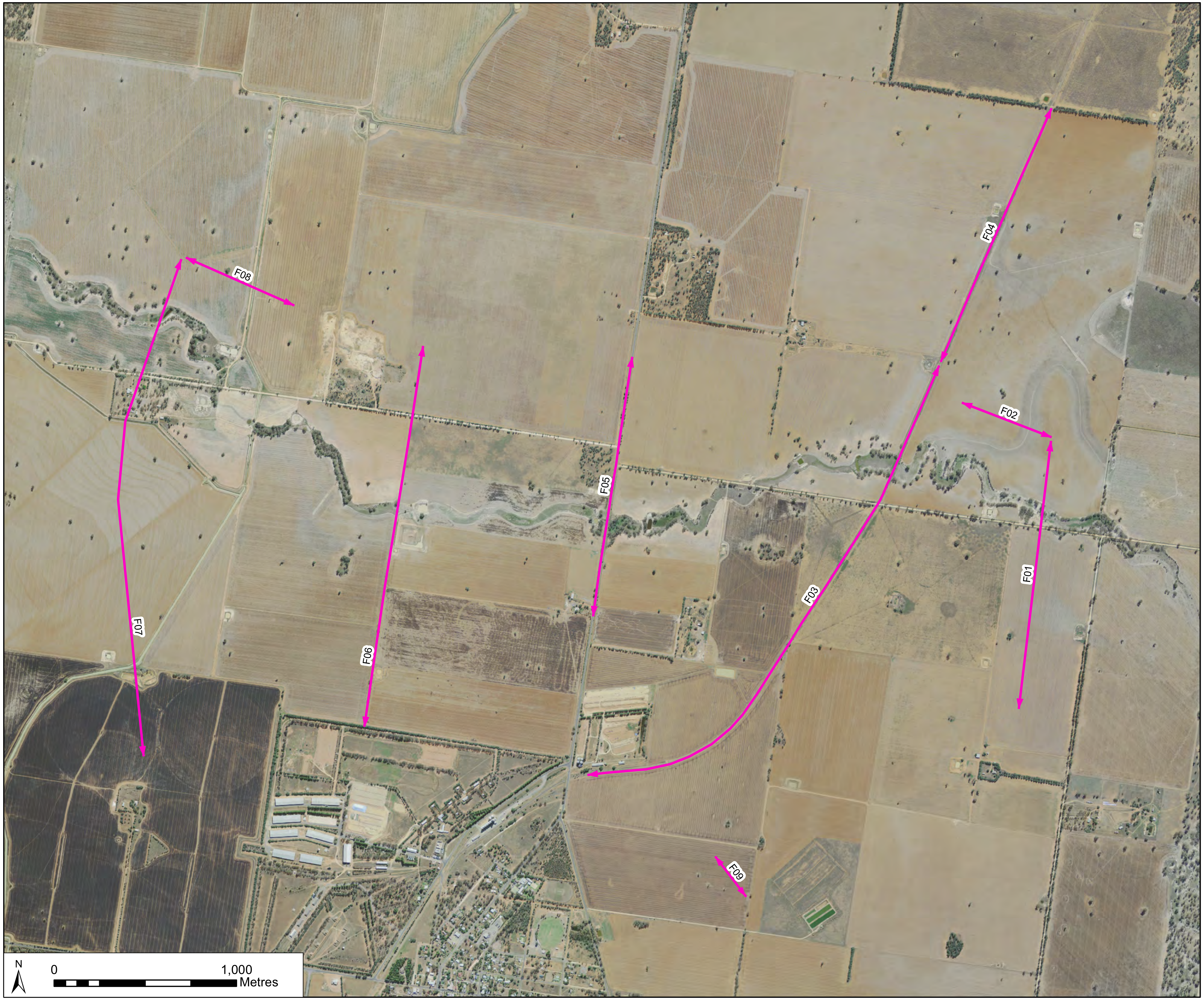
Mark[1]	2010 Calibration	2010 +20% Flow	2010 Walbundrie Flow
P01	125.45	+0.08	+1.49
P02	125.40	+0.06	+1.52
P03	124.87	+0.02	+1.17
P04	124.46	+0.05	+1.49
P05	123.19	+0.03	+0.86

[1] refer to Figure D-2

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

Flow line[1]	2010 Calibration	2010 +20% Flow	2010 Walbundrie Flow
F01	35.0	6.5	196.8
F02	5.8	-0.2	122.3
F03	40.5	6.5	408.0
F04	0.0	1.0	97.5
F05	35.0	6.6	510.7
F06	39.2	6.6	502.6
F07	36.2	7.7	489.8

[1] refer to Figure D-2



Legend

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 Reporting Locations Design Events

TOWN Oaklands

PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 12/05/2016

APPENDIX D-5

Appendix D6 – Results for Design Flood Events

- Modelled peak flows (m^3/s)

Flow line[1]	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
F01	7.5	15.5	28.7	39.3	39.5	44.5	49.5	2620.8
F02	0.0	0.9	5.0	6.0	6.0	7.3	8.4	20.0
F03	7.4	16.5	33.8	45.3	45.7	51.4	57.6	1990.0
F04	0.0	0.0	0.0	2.5	2.6	3.6	4.8	313.5
F05	1.8	11.0	28.7	40.9	41.4	47.2	54.2	1950.4
F06	7.1	16.5	33.5	45.7	46.2	51.8	58.2	1835.1
F07	5.4	15.9	33.2	45.6	45.8	51.2	56.8	1504.3
F08	0.0	0.2	0.8	0.9	0.9	1.0	1.1	96.8
F09	0.3	0.8	1.6	1.8	3.0	4.8	8.6	103.9

[1] refer to Figure D-5

Appendix E. Flood Mapping for Design Events

- Figure E-1: 20% AEP flood depth map
- Figure E-2: 10% AEP flood depth map
- Figure E-3: 5% AEP flood depth map
- Figure E-4: 2% AEP flood depth map
- Figure E-5: 1% AEP flood depth map
- Figure E-6: 0.5% AEP flood depth map
- Figure E-7: 0.2% AEP flood depth map
- Figure E-8: PMF flood depth map
- Figure E-9: Provisional 5% AEP flood hazard map
- Figure E-10: Provisional 1% AEP flood hazard map
- Figure E-11: Provisional 0.5% AEP flood hazard map
- Figure E-12: Provisional flood planning area map

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

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

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600 | CHECK AH | DATE 1/08/2017

FIGURE E-2

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 1/08/2017

FIGURE E-3

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 1/08/2017

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE E-5
CHECK	DATE	
AH	1/08/2017	

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

FIGURE E-6

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE E-7
CHECK	DATE	
AH	1/08/2017	

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

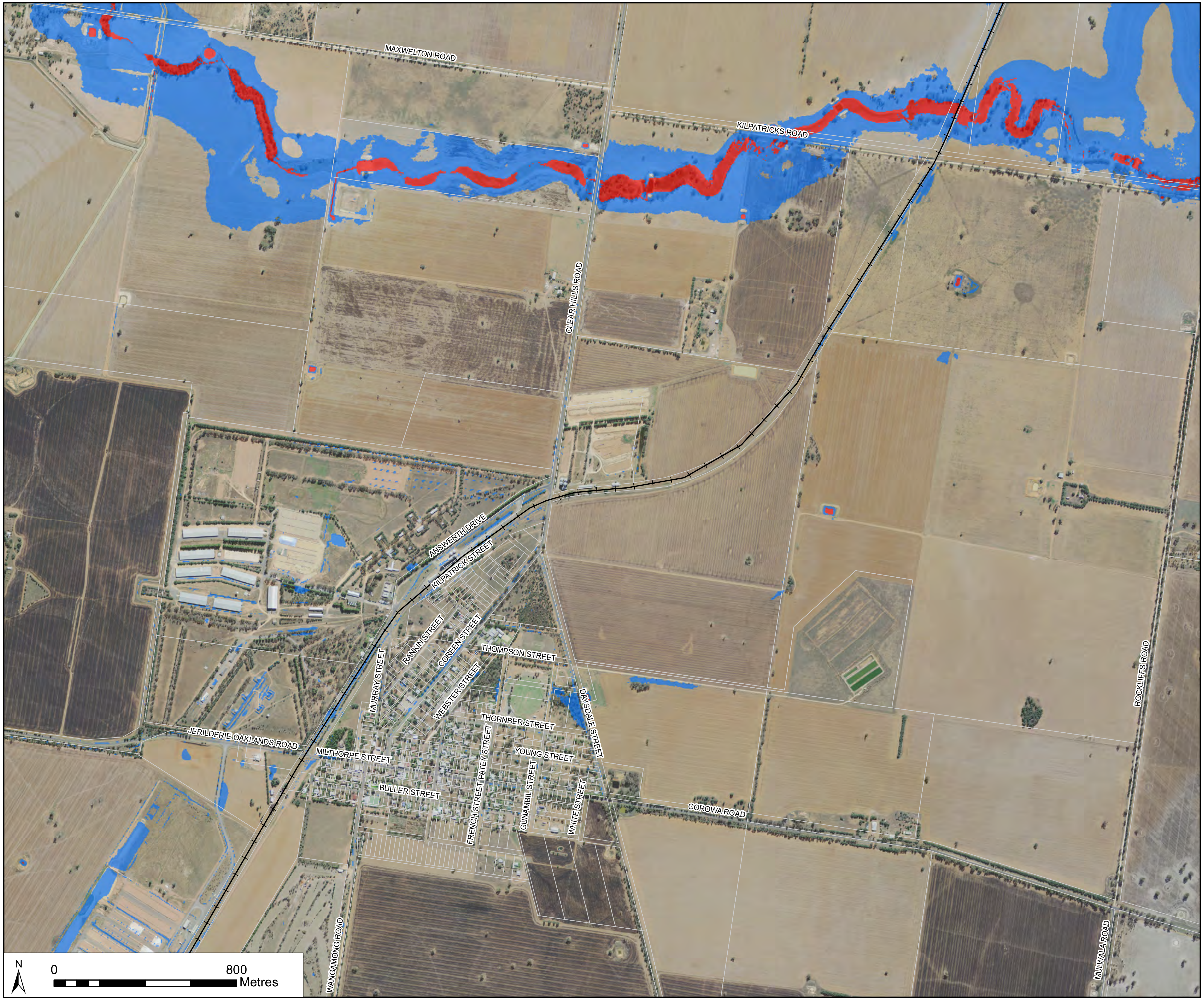
Data Sources: LPI, OEH, Council

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE E-8
CHECK	DATE	
AH	1/08/2017	



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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 1/08/2017

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-10
CHECK AH	DATE 1/08/2017	

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	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE E-11
CHECK AH	DATE 1/08/2017	

Legend

Cadastre

Railway

Flood Planning Area

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 Flood Planning Area
TOWN	Oaklands
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR	PROJECT # IA055600
CHECK AH	DATE 2/08/2017

FIGURE E-12

Appendix F. Extracts from Rand Flood Study Report (Jacobs 2017)

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.

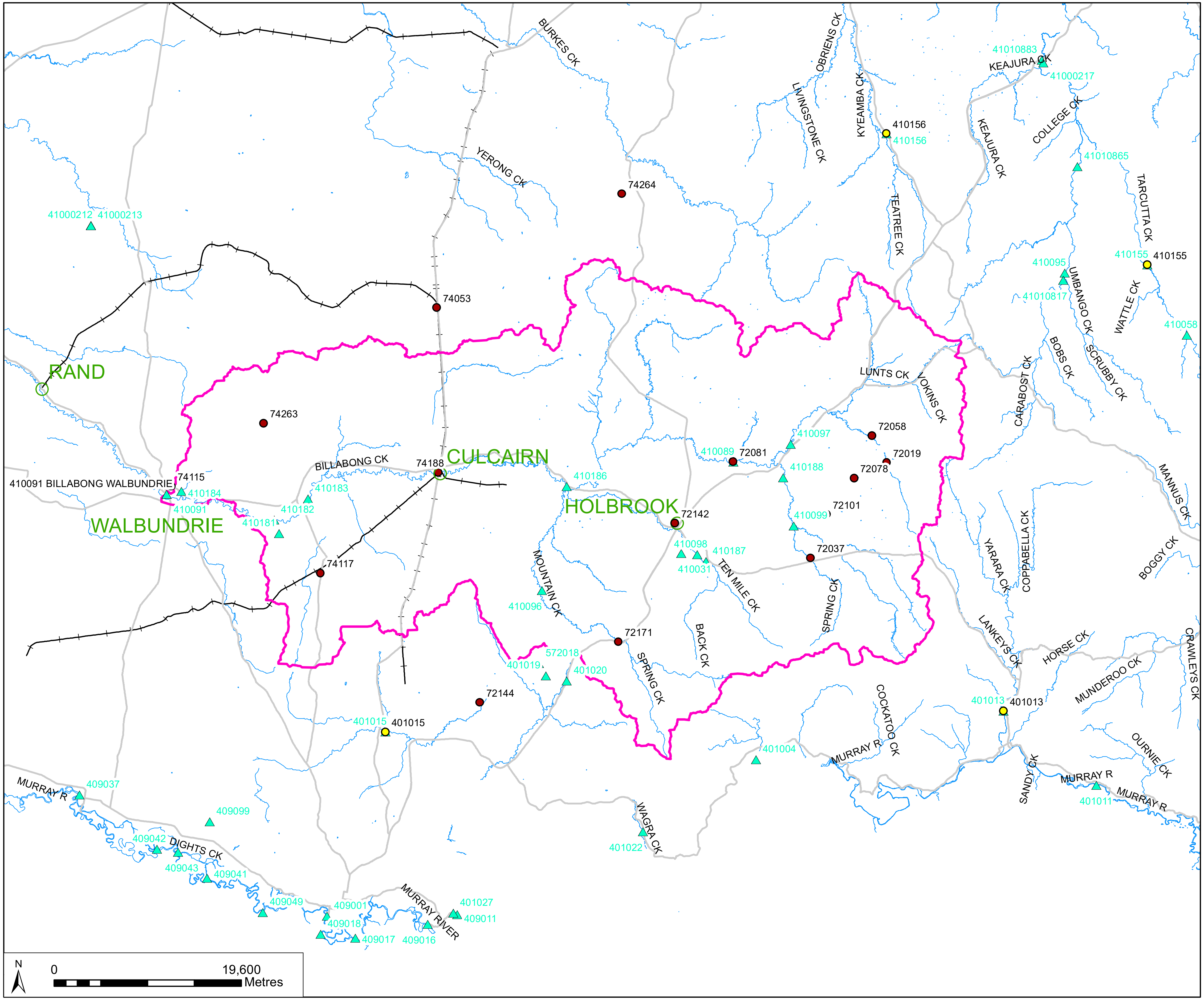
2.2.3.1 Daily Rainfall

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

- 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 / CHECK AH	PROJECT # IA055600 / DATE 25/09/2017

FIGURE 2-2

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

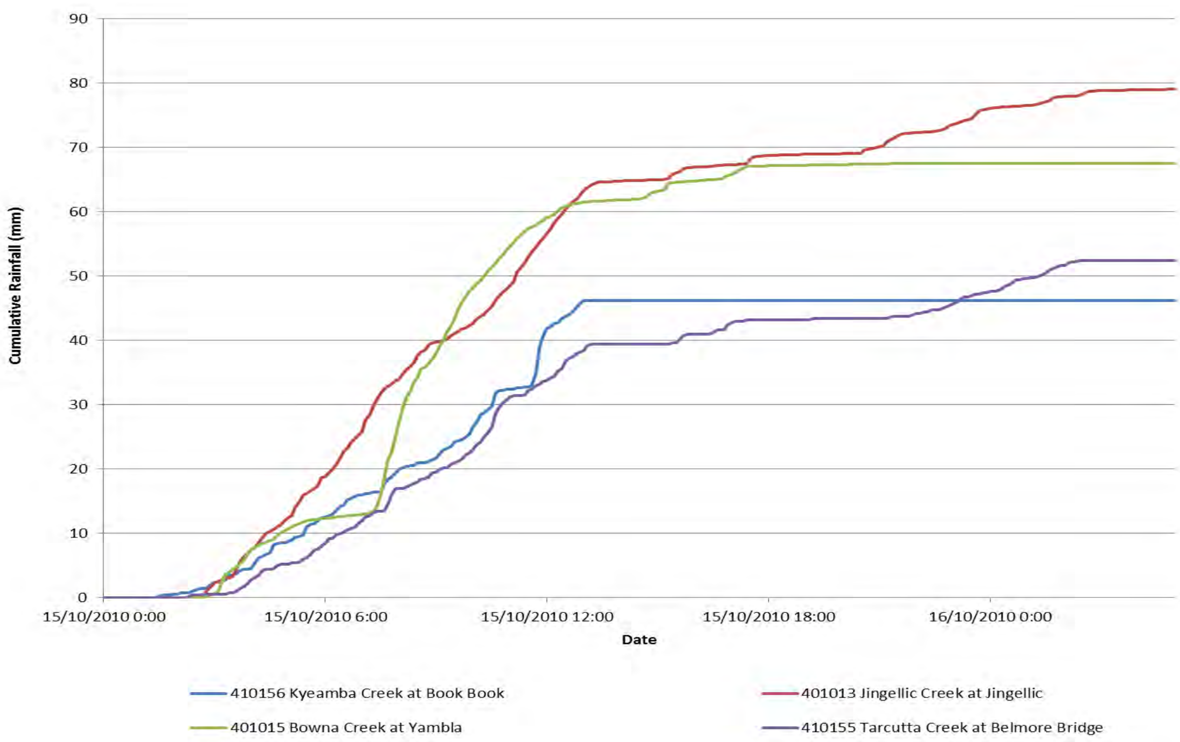


Figure 2-3 Cumulative pluviograph rainfall for the October 2010 event

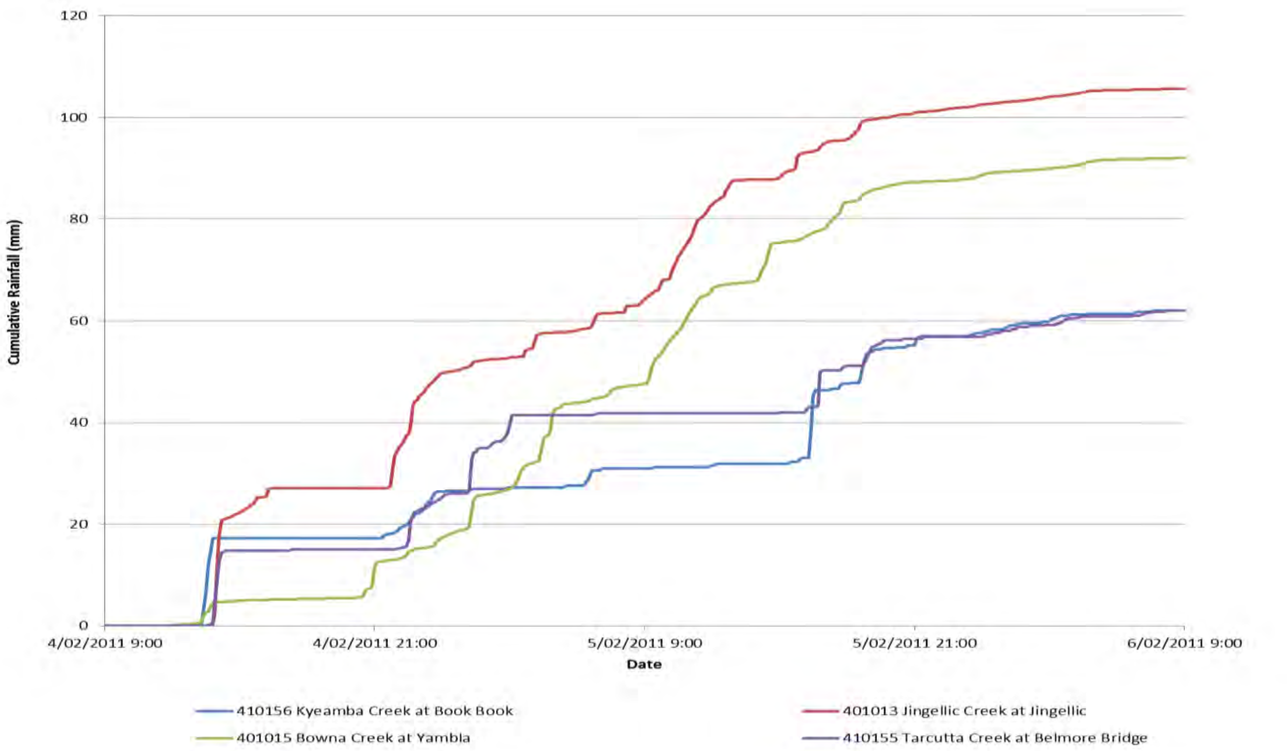


Figure 2-4 Cumulative pluviograph rainfall for the February 2011 event

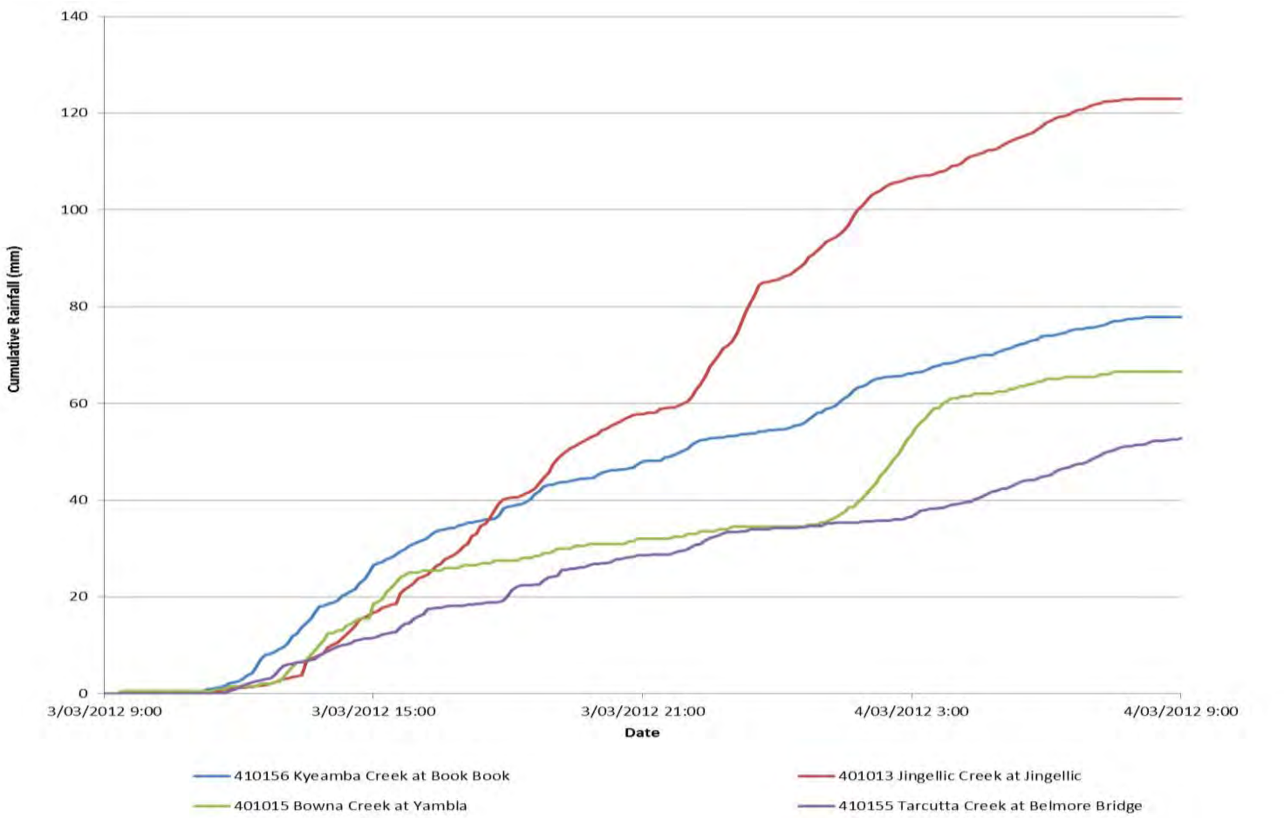


Figure 2-5 Cumulative pluviograph rainfall for the March 2012 event

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)

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 ()

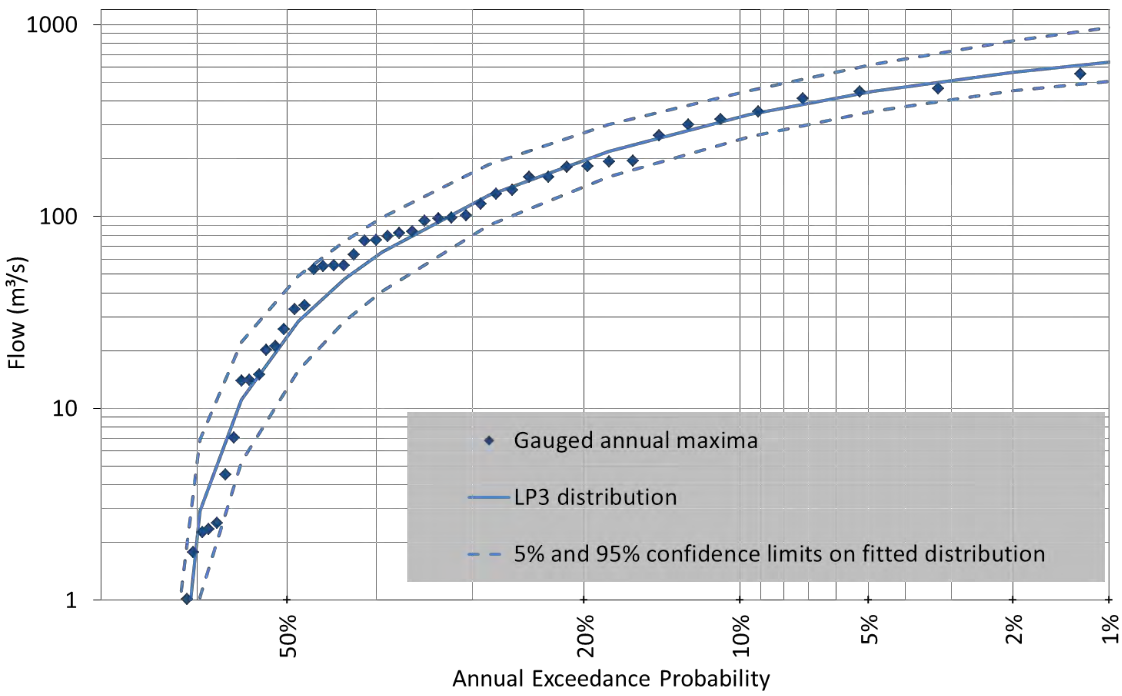


Figure 3-1 Flood Frequency Curve for Billabong Creek @ Walbundrie (GS 410091) 1965-2014

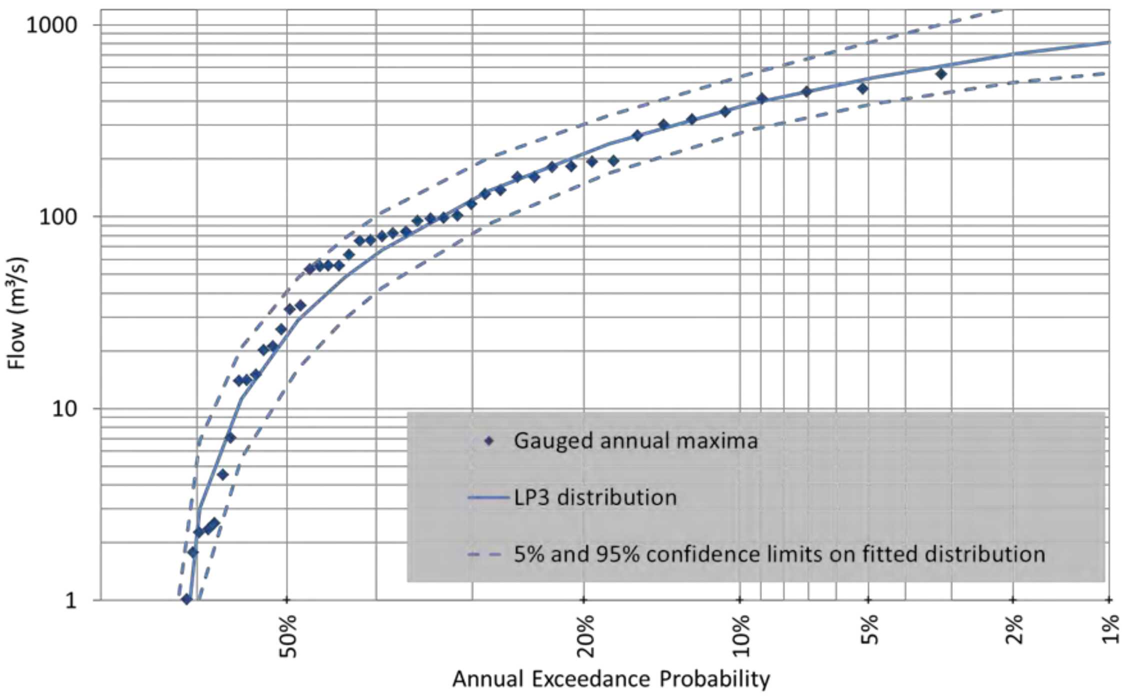


Figure 3-2 Flood Frequency Curve for Billabong Creek @ Walbundrie (GS 410091) 1965-2014 with Censored 1931 Flood

3.3 Catchment modelling

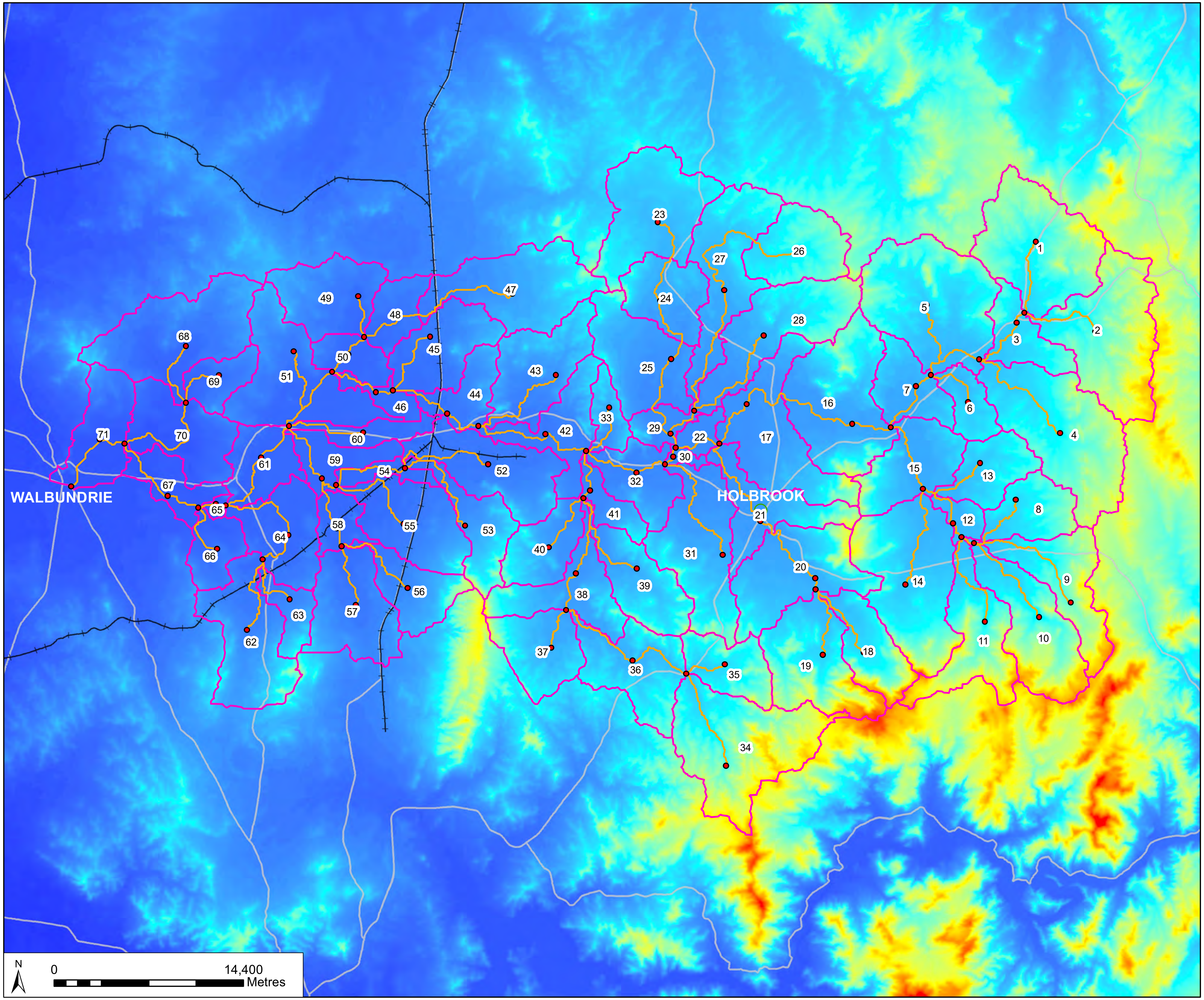
Whilst adequate recorded streamflow data is available in PINNEENA for Billabong Creek @ Walbundrie gauge for calibration and verification of a hydraulic model for the flood study of Rand, a hydrologic model will be required to estimate design catchment runoff for the full range of flood events up to 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 MR	PROJECT # IA055600	FIGURE 3-3
CHECK AH	DATE 25/09/2017	

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

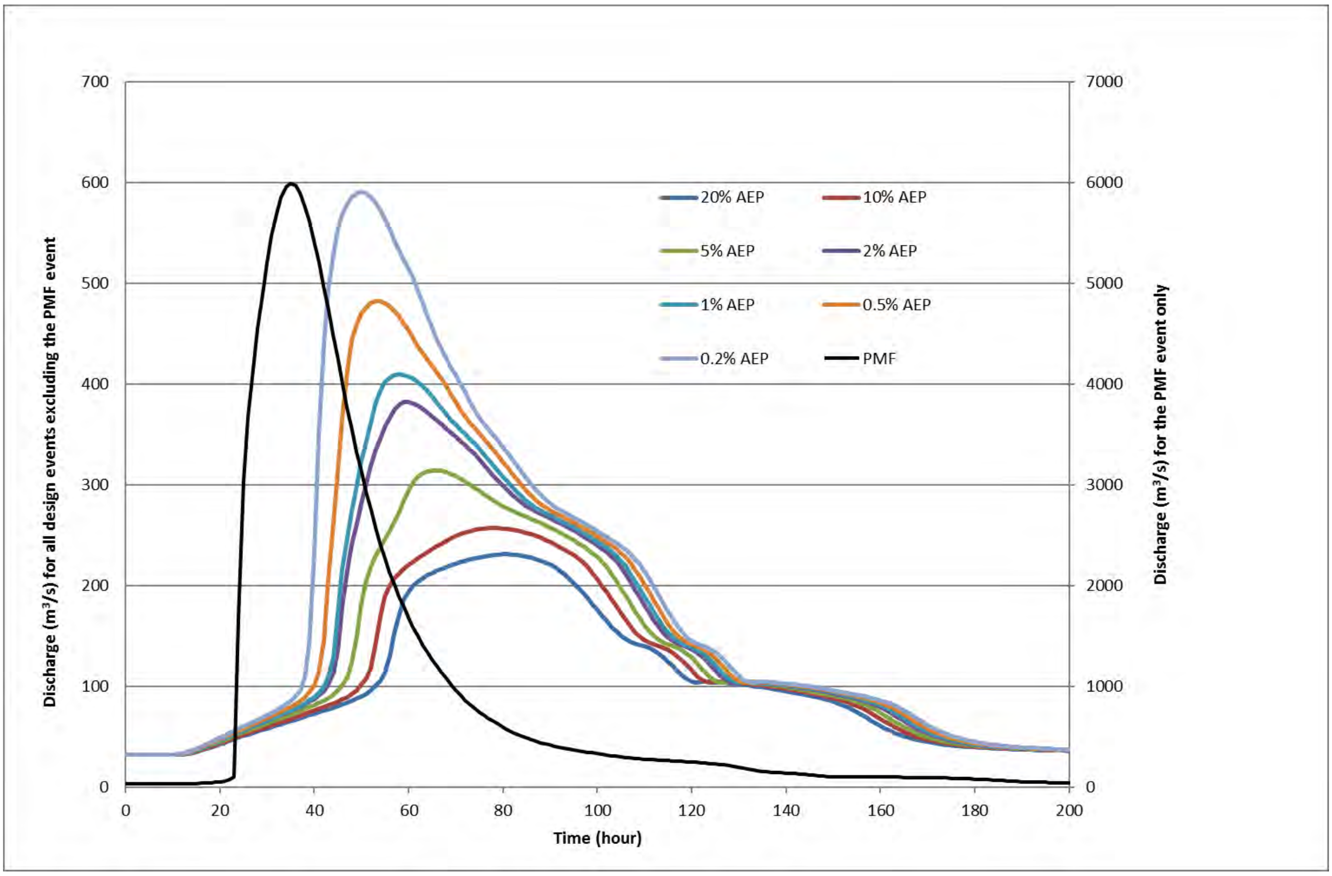
A comparison of design discharges estimated in this study and design discharges adopted for Culcairn in the Culcairn, Henty, Holbrook Flood Studies (WMAwater 2013) is shown in **Table 6-2**, which shows that design discharges estimated in this study for 20% AEP to 0.5% AEP events agree closely with discharges 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).

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

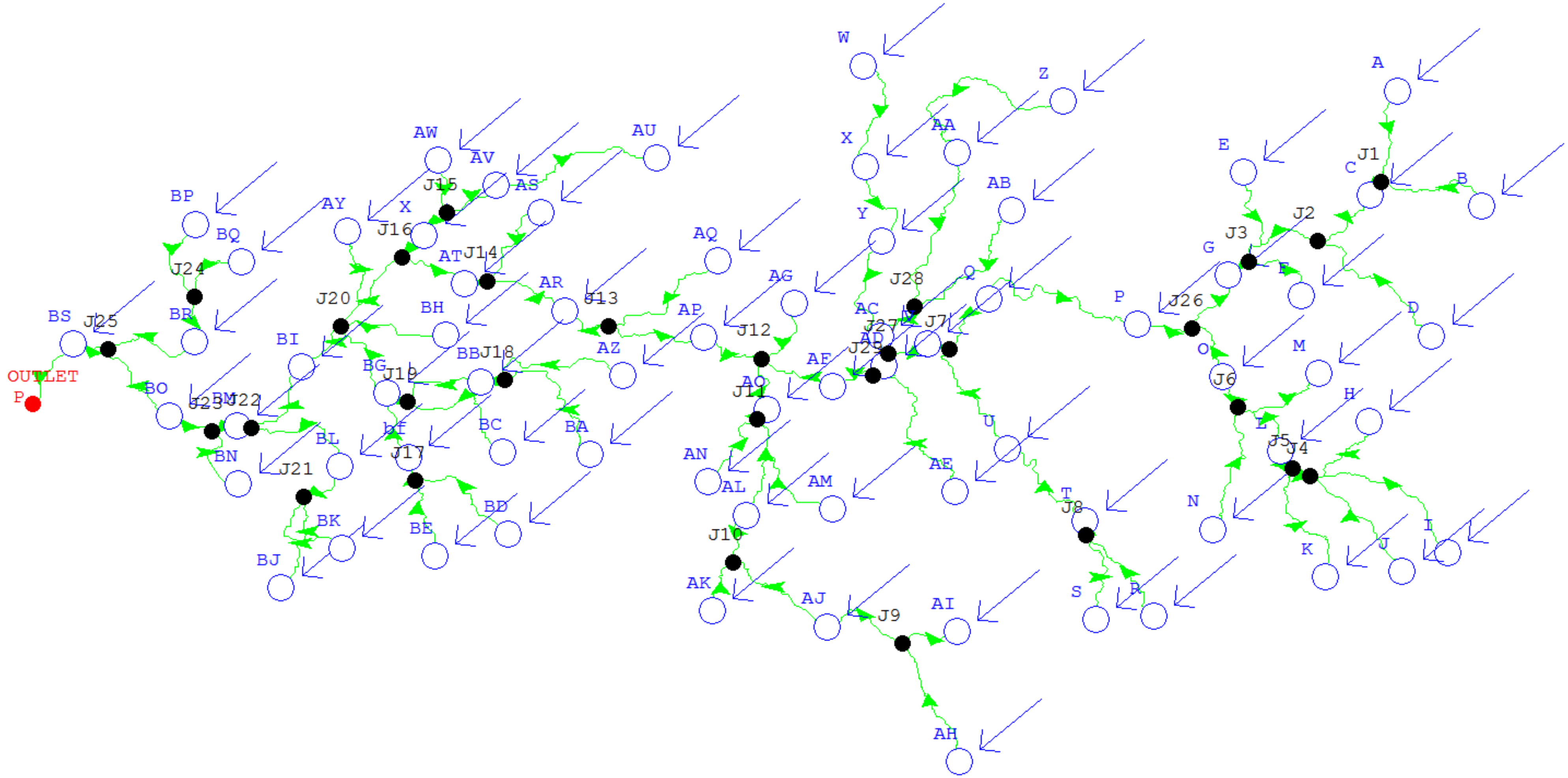


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Table C-1: RORB Model sub-catchment data for Billabong Creek

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