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

Federation Council

Flood Study Report for Morundah

IA055600 | FINAL

November 2017

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

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Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Level 7, 177 Pacific Highway
North Sydney NSW 2060 Australia
PO Box 632 North Sydney
NSW 2059 Australia
T +61 2 9928 2100
F +61 2 9928 2500
www.jacobs.com

Cover photo: Yamma Road Bridge over Colombo Creek, looking downstream

Document history and status

Revision	Date	Description	By	Review	Approved
1	12/02/2016	Model Calibration and Verification Report	MR	AH	AH
2	10/6/2016	Design Flood Estimation Report	MR	AH	AH
3	30/8/2017	Flood Study Report (DRAFT)	MR	AH	AH
4	22/9/2017	Flood Study Report (Public Exhibition)	MR	AH	AH
5	8/11/2017	Final Flood Study Report	AH	A Hossain	A Hossain

Contents

Foreword

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

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

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

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

This report documents data collection and flood study for Morundah.

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 Morundah, located in New South Wales in accordance with the scope of services set out in the contract between Jacobs and Federation Council (formerly, Urana Shire Council) (the Client). That scope of services, as described in this report, was developed with the Client.

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

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

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

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

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

1. Introduction

Morundah is located within Federation Council, approximately 31km southwest of Narrandera and 44km north of Urana. It is located on the Newell Highway and has a population of 69 (2016 census). The village is located on the left bank of Colombo Creek, which is an effluent of Yanco Creek (refer **Figure 1-1** and Figure 2-3). Exchange of water occurs between the two creeks, regulated at Tarabah Weir (approximately 6km north of Morundah village) and occurring naturally along the floodplain. Morundah is protected by a low earthen levee approximately 3.2km long. The topography around Morundah is relatively flat, though runoff from the north and east drain towards the village. There are several bridge and culvert crossings of the Colombo/Yanco Creek system west of the village by Yamma Road, Newell Highway and the disused Narrandera-Tocumwal railway line.

Flooding in Morundah occurs from Colombo Creek flows overtopping the levee and also overland flows from local catchment runoff. Morundah has experienced several major floods including June 1889, July 1891, June 1931, April 1950, June 1952 and March 2012. In the recent March 2012 event, the town was flooded initially by heavy rain over the local catchment resulting in local overland flows with one house being inundated. Approximately a week later Colombo Creek peaked and just overtopped the Morundah levee at nine locations with water seeping into the racecourse area. The water level at Morundah remained high for the week following the flood.

1.1 Objectives

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

1.2 Structure of the Report

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

Section 1: introduces the study

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

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

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

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

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

Section 7: discusses modelled flood behaviour for the design events

Section 8: provides conclusions on the study

Section 9: provides acknowledgements for this study

Section 10: provides details on references citied in this report

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

Legend

- Levee
- Railway
- Watercourses
- Cadastre

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 1-1
CHECK AH	DATE 30/08/2017	

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

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

2.2.1 Available Reports

- **Sturt Highway Upgrade West of Narrandera, Flood Study Review and Impact Assessment of Highway Upgrade Options, May 2015, (Lyall & Associates)**

The report, prepared for the NSW Roads and Maritime Services, details findings of an investigation into the impact of the proposed upgrade of a 30 km section of the Sturt Highway, west of Narrandera, on flood behaviour on the floodplain of the Murrumbidgee River. The study was undertaken in two phases. The flood study review and update carried out undertaken in Phase 1 and flood impact assessment of Highway upgrade options was undertaken in Phase 2. Two hydraulic models were developed for a 140 km reach of the Murrumbidgee River between Wagga Wagga and downstream of Narrandera using TUFLOW GPU and TUFLOW classic modelling systems. The hydraulic models were calibrated against the flood events of September 1974, December 2010 and March 2012 and the study updated design flood estimates for the Murrumbidgee River @ Narrandera gauge (GS 410005) for the full range of flood events between 20% AEP and extreme flood events.

Modelled discharge hydrographs breaking out from the Murrumbidgee River into the Yanco Creek system in the vicinity of Narradera for the modelled flood events were available to this study.

- **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 Urana Shire (currently Federation Council). The report contains general information about the floods in the region, including rainfall data, information about flood behaviour (levels, timing, depth, velocity, extent, history, etc.) and its consequences (buildings, yards, road affected, evacuations, etc). The key findings from the report on the village of Morundah are provided below:

- The March 2012 flood (gauge height 2.975m) is most likely the third highest on record at the Colombo Creek gauge at Morundah (GS 410014) following the June 1931 (gauge height 2.997m) and July 1952 (gauge height 2.997m) floods.

- The data for Colombo Creek suggests a small flood height range, with five historic floods in the range of 2.9-3.0m. This may be due to the very wide floodplain.

- The lowest height of the levee (at the time of the March 2012 flood) protecting Morundah is estimated to correspond to a gauge height of 2.93m.

- Detailed information regarding the March 2012 flood event is presented in the report including timings throughout the flood event, photographs and observations about the flood behaviour.

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

Bewsher Consulting was engaged by the NSW Department of Land & Water Conservation in 1999 to undertake a floodplain management plan for Billabong Creek in two phases. The available data and the flood behaviour were reviewed in the first phase and a report entitled “Phase A – Data Review and Flood Behaviour, Main Report” was produced as the outcome of Phase A. The scope of the Phase A activities included community consultation; review of planning and environmental aspects; review of flood hydrology including review of rainfall records, streamflow records and flood extents; undertaking flood frequency analysis and formulation, calibration and verification of a hydraulic computer model using MIKE11. The study included a flood frequency analysis for Colombo Creek at Morundah. The highest flood on record is the 1952 flood with a peak flow of 5680ML/day. The rating table is considered good and the highest annual flows from 1913 to 1998 were used to generate the flood frequency analysis.

2.2.2 Topographic Data

2.2.2.1 LiDAR Data

LiDAR data for Morundah was provided by OEH which was originally captured by NSW Land and Property Information (LPI) between 10 February and 11 February 2014 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**.

LiDAR data along Yanco Creek was also provided by OEH in two segments (Block D and E). This provides a corridor of information from the Lowbidgee to Morundah along Yanco and Colombo Creeks. The data was captured between 28 August and 13 September 2007, and on 10 January 2008 by AAMHatch for a ’Water for Rivers’ project. The expected accuracy of the data is 0.15m in the vertical and <0.5m in the horizontal (68% CI). The data is projected in MGA55 with the GDA94 datum. LiDAR data was also provided by OEH for the Lowbidgee region around Narrandera and downstream along the Murrumbidgee. This data has little metadata associated with it, but is assumed to be of similar quality to the other DEMs, also being a 1m grid.

2.2.2.2 SRTM Data

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

2.2.2.3 Aerial Photography

Aerial photography was obtained from Council. Morundah is covered by the ‘Yanco’ tile. It was captured in 2008. It has a 50cm resolution and was provided as a geo-referenced raster.

2.2.2.4 Stormwater Details

A CAD file for Morundah was provided by Council (shown in **Appendix A**). This outlines the boundaries and features in Morundah including roads, buildings, railway, Colombo Creek, levee and culverts. It does not provide any culvert details (such as size). The drawing was compiled in September 2007.

2.2.2.5 Levee Survey

A survey of the Morundah levee crest was undertaken by NSW Public Works, completed in February 2015. The AutoCAD files for the survey were provided including the horizontal and vertical alignment of the levee, features such as tracks and culverts crossing the levee along with thirteen cross sections (see **Appendix A**). Through discussions with Council Officers, it was identified in March 2017 that the survey completed in February 2015 represents the levee after the reconstruction works completed following the flood event of 2012.

In March 2017, Federation Council provided observation data for the Colombo Creek 2012, an AutoCAD file dated 2012 and two appendices from the report which is titled ‘Levee Survey 2013’. An attempt was made to align the levee surveyed in 2012 and 2015 as the 2012 survey was not based on geographical coordinates. An approximate comparison of crest levels along the two surveys (refer to **Figure 2-2**) shows that the reconstructed levee is approximately 0.8m to 1.0m higher than the levee surveyed in 2012.

2.2.2.1 Additional Topographic Data

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

2.2.3 Rainfall Data

Rainfall data used in this study was for an XP-RAFTS hydrologic model of the local catchment draining to Morundah. 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 is one located in the Morundah local catchment. Data for this site was obtained from the Bureau’s website. A summary of the rainfall station is tabulated in **Table 2-1** and its location is displayed in **Figure 2-3**.

Table 2-1 Daily rainfall gauge data used for Morundah

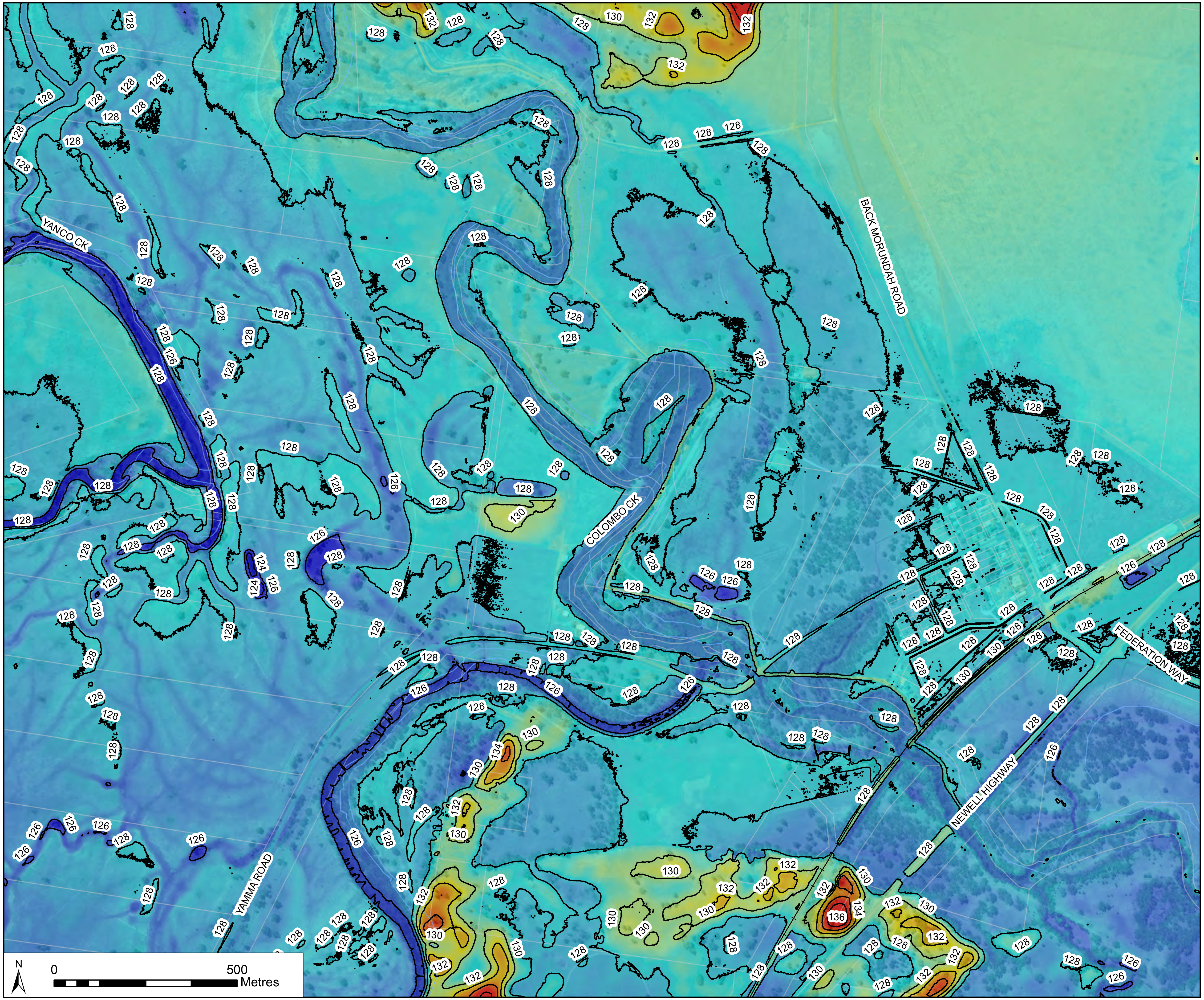
Gauge number	Gauge name	Start Date	End Date	Length of record (years)	Completeness (%)
074162	Morundah Hotel	1/11/1886	24/02/2015	128.4	21.8

2.2.3.1 Pluviograph

BoM holds the closest pluviograph station to the Morundah local catchment. No sub-daily rainfall data exists within the Morundah local catchment. Data for one pluviograph station was obtained and is outlined in **Table 2-2**. The station is also shown in **Figure 2-3**. Cumulative rainfall graphs are also provided for the 2010 and 2012 storm events in **Figure 2-4** and **Figure 2-5** respectively.

Table 2-2 Pluviograph data used for Morundah

Gauge number	Gauge name	Source	Resolution	Storm events with data available
074037	Yanco Agricultural Institute	BoM	6 minute	Dec 2010, Mar 2012



Legend

- 2m contours
- Railway
- Watercourses
- Cadastre

Morundah DEM

Elevation (m AHD)

High : 135

Low : 125

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

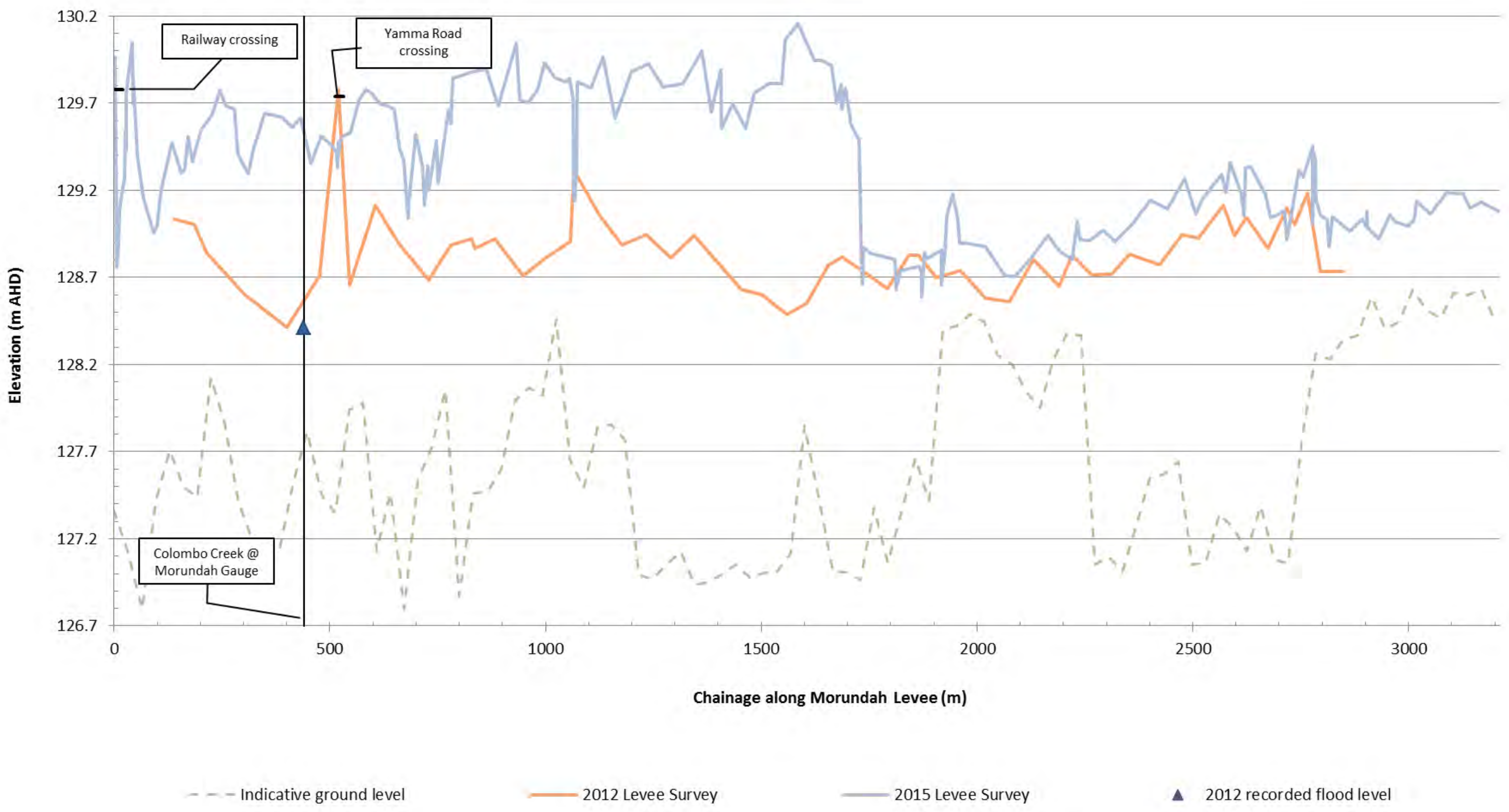
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

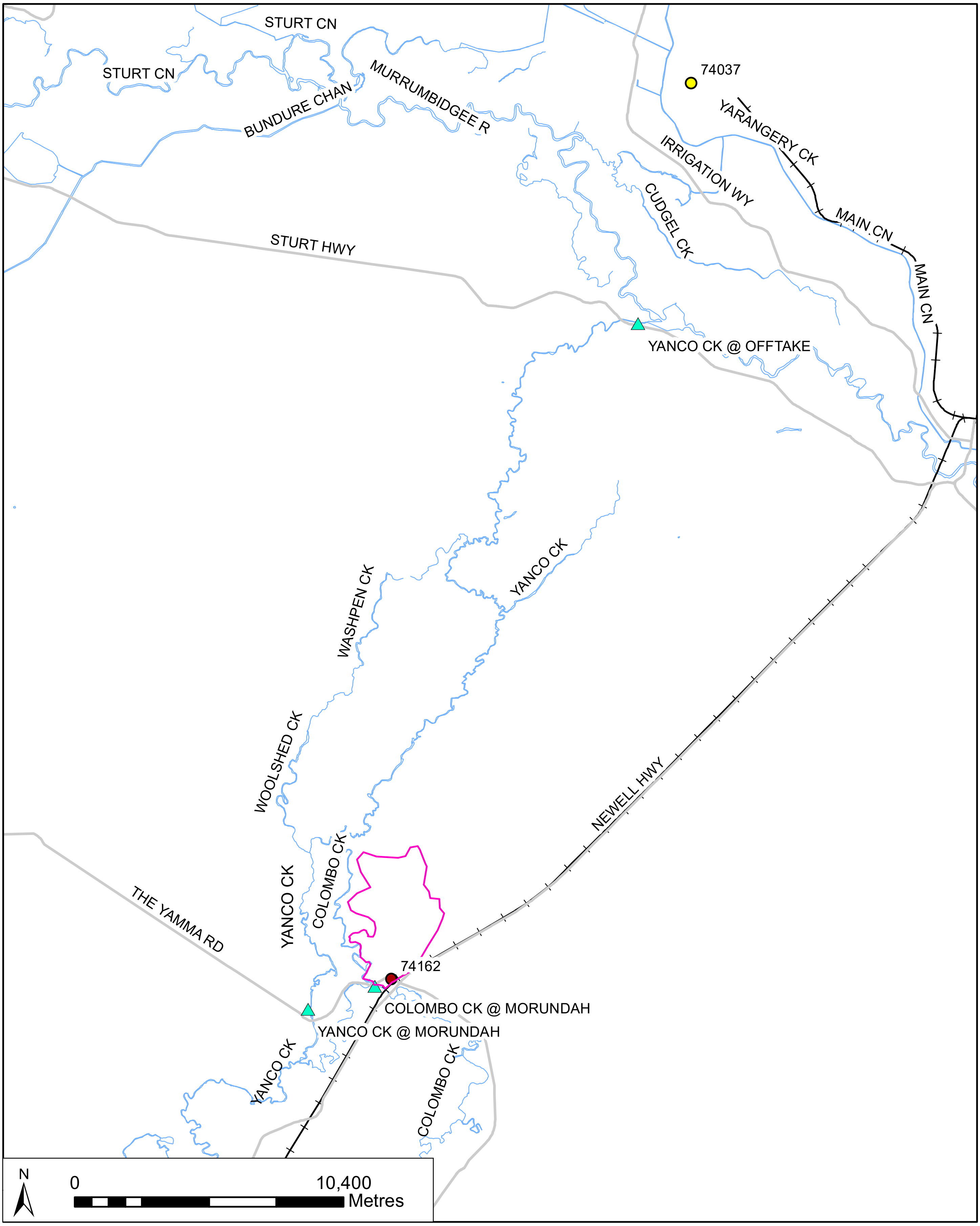
JACOBS

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

DRAWN MR	PROJECT # IA055600	FIGURE 2-1
CHECK AH	DATE 30/08/2017	

■ **Figure 2-2 Crest levels along Morundah levee**





Legend

- Local catchment
- Official daily rainfall gauges
- BOM pluviograph stations
- Stream gauges
- Major Roads
- Railway
- Watercourses

JACOBS

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, 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.

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

DRAWN	PROJECT #	
MR	IA055600	FIGURE 2-3
CHECK	DATE	
AH	8/11/2017	

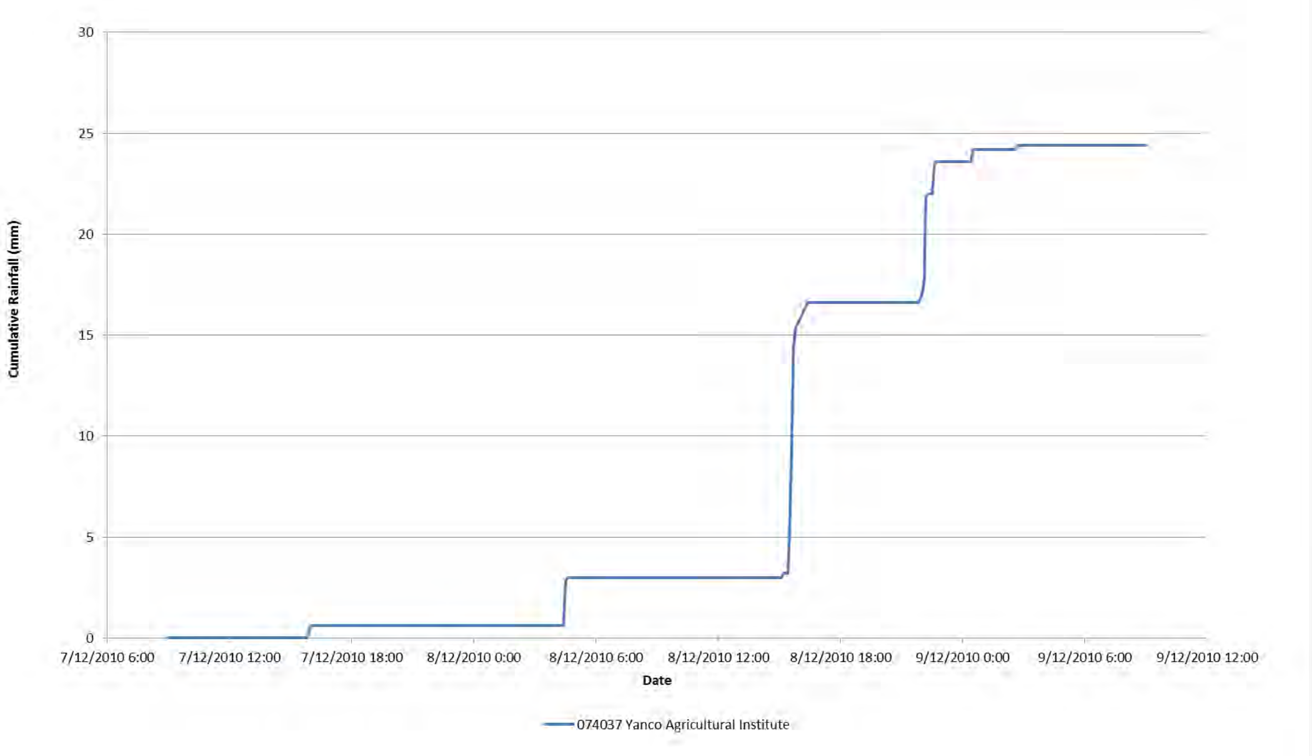


Figure 2-4 Cumulative pluviograph rainfall for the December 2010 event

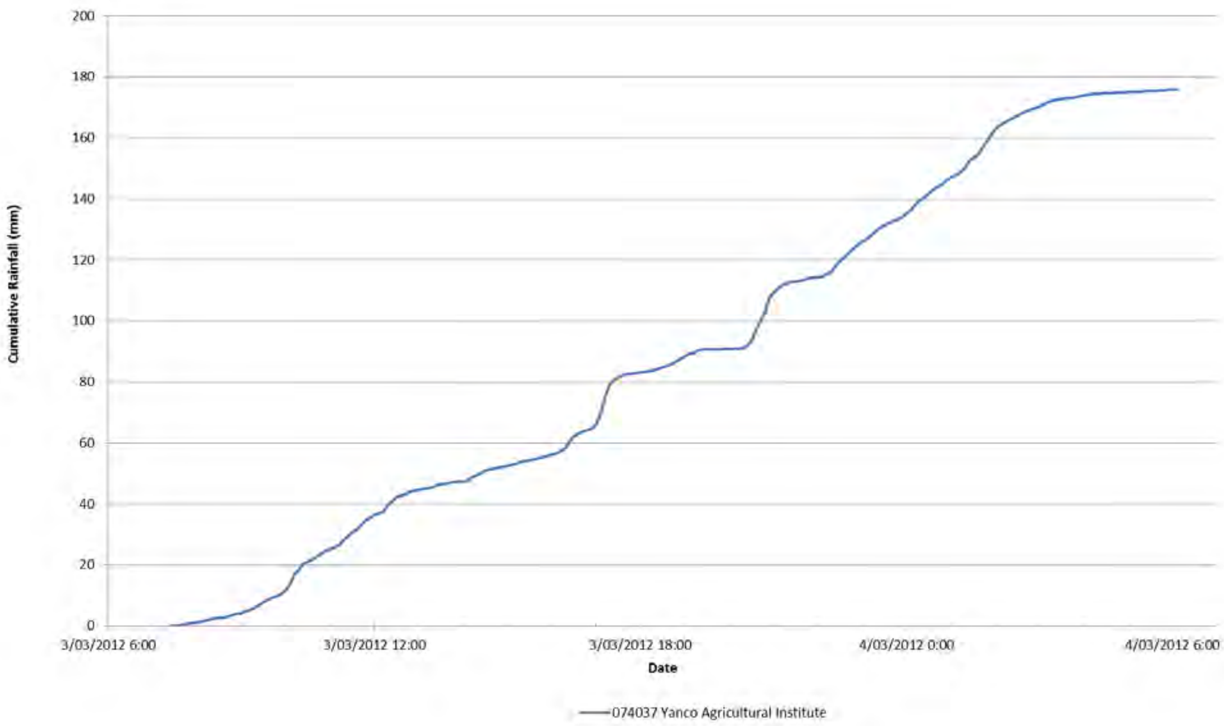


Figure 2-5 Cumulative pluviograph rainfall for the March 2012 event

2.2.4 Streamflow Data

Streamflow data exists for several sites along the Yanco/Colombo Creek system. PINNEENA v10.2 has data for these gauges and their location is shown in **Figure 2-3**. There is a gauge located on Yanco Creek at the Murrumbidgee offtake (GS 410007), approximately 28km north-northeast from Morundah. Gauging commenced in 1918 and both water level and discharge data is available. At Morundah, there are two gauging stations – Yanco Creek @ Morundah (GS 410015) and Colombo Creek @ Morundah (GS 410014). Both of these gauges commenced in 1912 and water level and discharge data are available in PINNEENA for both gauges for the period 1978 to 2013.

Hydrographers from DPI Water were contacted to collect the latest streamflow data for the Murrumbidgee River in the vicinity of Narrandera and it was advised that DPI Water updated the rating table No. 165 for the Murrumbidgee River @ Narrandera gauge (GS 410005) in August 2014 based on flow gaugings undertaken during 2010 and 2012 flood events. It was further advised that the updated streamflow data is available in http://realtimedata.water.nsw.gov.au/water.stm.

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.

Residency status (Question 1-2)

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

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

The respondent lived in the study area for 7 years and owned a business for 5 years.

Experiences of Flooding (Questions 6-12)

The respondent had experienced flooding at their residence, with the depth reaching an estimated 400mm. The flooding was observed to occur ‘everywhere’ however there was no damage to their property.

The access was cut off to the respondent’s property, though no emergency assistance was required from the SES.

Flood Evidence (Questions 13, 15)

The respondent did not indicate any evidence of past flooding.

Flood Affects to properties due to works (Questions 14)

The respondent did not indicate if any works had impacted on flooding.

Intention of Respondents for further development (Question 16)

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

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

The respondent indicated that commercial, residential and critical utilities were the greatest priority on protecting from flooding. Other development types were of lower priority.

Priority for flood mitigation measures (Question 18)

The respondent indicated that protecting residential buildings was of the greatest priority followed by commercial buildings and maintaining an emergency flood free access. Flood signage and flood warning were lower priorities with support from the SES being of least priority.

Further comments (Question 19)

The respondent indicated some ways to alleviate the flooding problem including extending the upgraded levee along the old levee on Colombo Creek and the installation of a culvert under the road near the railway line to prevent damming on the northeast side of the road.

Wanting to be kept informed (Question 20)

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

Contact details for respondents (Question 21)

The respondent provided contact details.

2.3.3 Personal Communication

In addition to the community questionnaire, personal communication was sought from Council and the community. Two people were contacted by phone and email to obtain additional information regarding flooding in Morundah. A Council officer provided information regarding the use of pumps during the 2012 flood event. The officer provided information on the type of pumps and their approximate duration of operation. The owner of the Morundah Hotel was also contacted for information regarding the 2012 flood event and the owner provided information on the extent of inundation during the 2012 flood event and provided indicative locations where the levee was overtopped, the levee blowout, the Tarabah Homestead and the location and type of pumps installed. The owner of the hotel also clarified that the house flooded on Milvain Drive was a result of overland flooding and was separate to the inundation due to the overtopping of the levee.

2.4 Topographic Survey

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

- Details of eight bridge structures (small bridge over Colombo Creek 1.5km north of Morundah, Yamma Road over Colombo Creek, two railway bridges over Colombo Creek and an effluent stream, Newell Highway over Colombo Creek and an effluent stream, Yamma Road and the old Yamma Road over Yanco Creek). Details included deck and underside levels, length, width, railing height, location and width of piers and photographs;

- Details of three culvert structures (under Yamma Road between Colombo and Yanco Creeks, under Yamma Road near Colombo Creek and under Yarrabee Street at the edge of the village). Details included location and invert levels of the outlet and inlet, length, number of cells, blockage and photographs;

- Details of Tarabah Weir and Yanco Weir (including gate locations, invert levels, top levels, gate size, number of gates and photographs);

- Details of the gauging station at Tarabah Weir, Yanco Weir and on Yanco Creek at Morundah (gauge 0 referenced to AHD and photographs); and

- Details of Spiller's Regulator on Back Creek just downstream from Yanco Creek and Molly's Regulator (including gate locations, invert levels, top levels, gate sizes, number and type of gates and photographs),

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 Morundah is presented in **Appendix A**.

3. Catchment Hydrology

3.1 Sources of Flooding and Flood Behaviour

The village of Morundah is located on Colombo Creek, which is an effluent of Yanco Creek. Yanco Creek originates from the Murrumbidgee River where flows are regulated by Yanco Weir west of Narrandera. Yanco Creek has a relatively flat gradient and meanders over a length of 258km. Colombo Creek commences at Tarabah Weir, just upstream of Morundah and flows south-east through open plains to join Billabong Creek upstream of Jerilderie. The weir controls the distribution of water between Yanco Creek and Colombo Creek. Colombo Creek is 148km long and has a relatively steep gradient and has intermittent patches of natural woody vegetation along its banks. Hence the mainstream flood behaviour in Morundah, to a large extent, is controlled by the volume, frequency and duration of breakouts from the left bank of the Murrumbidgee River which discharge into Yanco and Colombo Creeks. In the vicinity of Morundah, the flow split between the Colombo and Yanco Creek governs the magnitude of flooding in Morundah.

There is also a local catchment that drains to Morundah. The catchment is bounded by the Narrandera-Tocumwal railway line to the south-east and the Morundah levee to the south-west and extents to high ground in the north. The catchment covers an area of approximately 1,270ha and is predominately cleared rural land used for grazing and dryland cropping and horticulture. Rainfall runoff generated from the catchment alone impacted properties during the 2012 flood event.

3.2 Flood Frequency Analysis

Two flood frequency analyses were undertaken using the available annual peak flows for Colombo Creek @ Morundah gauge (GS 410014) and Yanco Creek @ Morundah gauge (GS 410015). Available annual peak flows for the period 1913 to 2012 were used to undertake the flood frequency analysis for Colombo Creek @ Morundah gauge and the available annual peak flows for the period 1913 to 2012 were used to undertake the flood frequency analysis for Yanco Creek @ Morundah gauge. The flows were sourced from PINNEENA where available and the completeness and accuracy of the data was analysed. For Colombo Creek @ Morundah (GS 410014), flows were only available in PINNEENA from 1979 onwards. Flows prior to this were obtained from Bewsher's flood frequency analysis (2002). Combined there was 95 years of data available. The highest flood recorded at the station was the 1952 flood, which had an estimated peak flow of 5,680ML/day. The station has been gauged on 607 occasions, the largest being in March 2012 where a peak flow rate of 3,132ML/day was recorded. The rating table for the station is considered good. For Yanco Creek @ Morundah (GS 410015), there was 96 years of available data. The largest flood recorded at the station was the 1974 flood, which had an estimated peak flow of 20,250ML/day. The station has been gauged on 615 occasions, the largest being in December 2010 where a peak flow rate of approximately 2,780ML/day was recoded.

TUFLOW's FLIKE (BMT WBM 2015) program was then used to undertake both flood frequency analyses on the data. A Log Pearson Type III distribution was fitted to the data annual maximum flow data for the two gauges using a Bayesian inference. The results are presented in **Figure 3-1** and **Figure 3-2** and a comparison of flood frequency results is shown in **Table 3-1**. It is to be noted that the flood frequency analysis undertaken by Bewsher (2002) for Colombo Creek @ Morundah gauge was based on annual peak flow data for the period 1913 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 20% AEP and 5% AEP are very similar to estimates made by Bewsher (2002). However, peak flows estimated in this study for both 2% and 1% AEP events are higher than Bewsher (2002).

Table 3-1 Flood frequency results

Annual Exceedance Probability	Peak Flow (m^3/s) Colombo Creek @ Morundah gauge	Peak Flow (m^3/s) Yanco Creek @ Morundah gauge
20%	22 *(23)*	40
10%	33 *(33)*	64
5%	48 *(45)*	95
2%	74 *(63)*	149
1%	101 *(78)*	202

(23) Bewsher (2002) estimate

It is to be noted that Colombo Creek @ Morundah gauge did not record flood height above 3.0m since the gauge was installed over 100 years ago implying the limited flood range at the gauge.

Figure 3-1 Flood Frequency Curve for Colombo Creek @ Morundah (GS 410014) 1913-2012

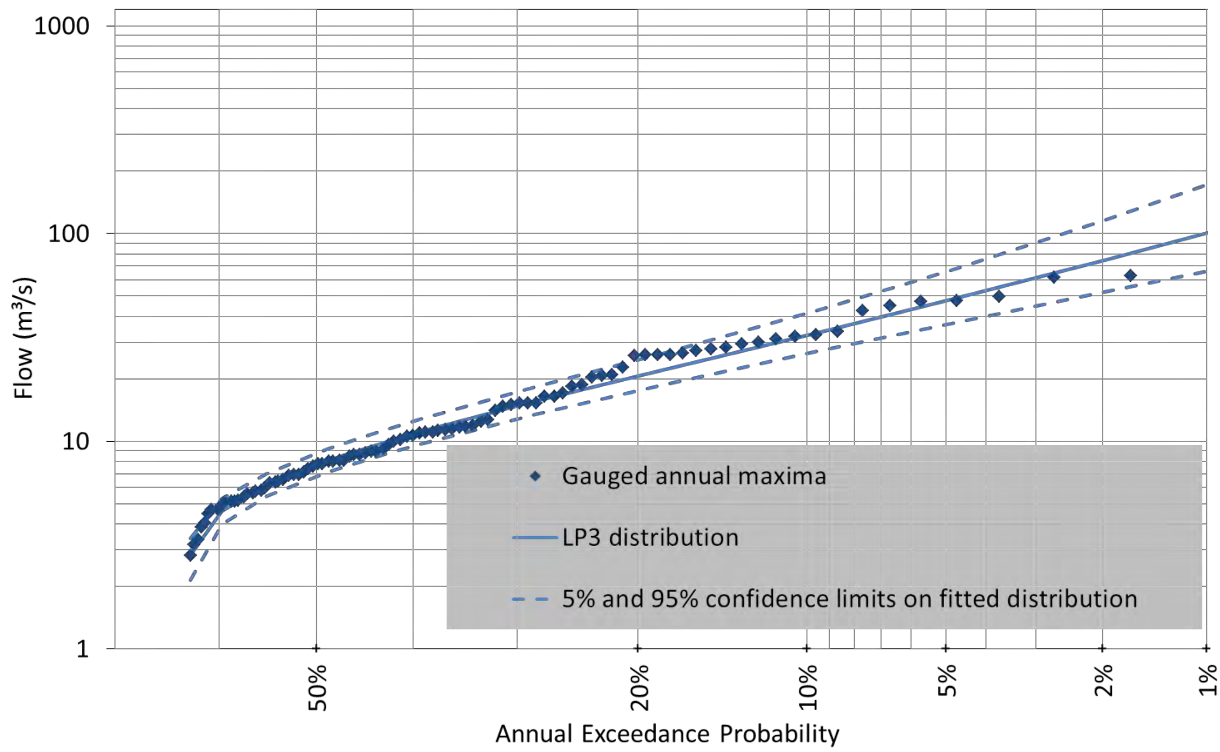
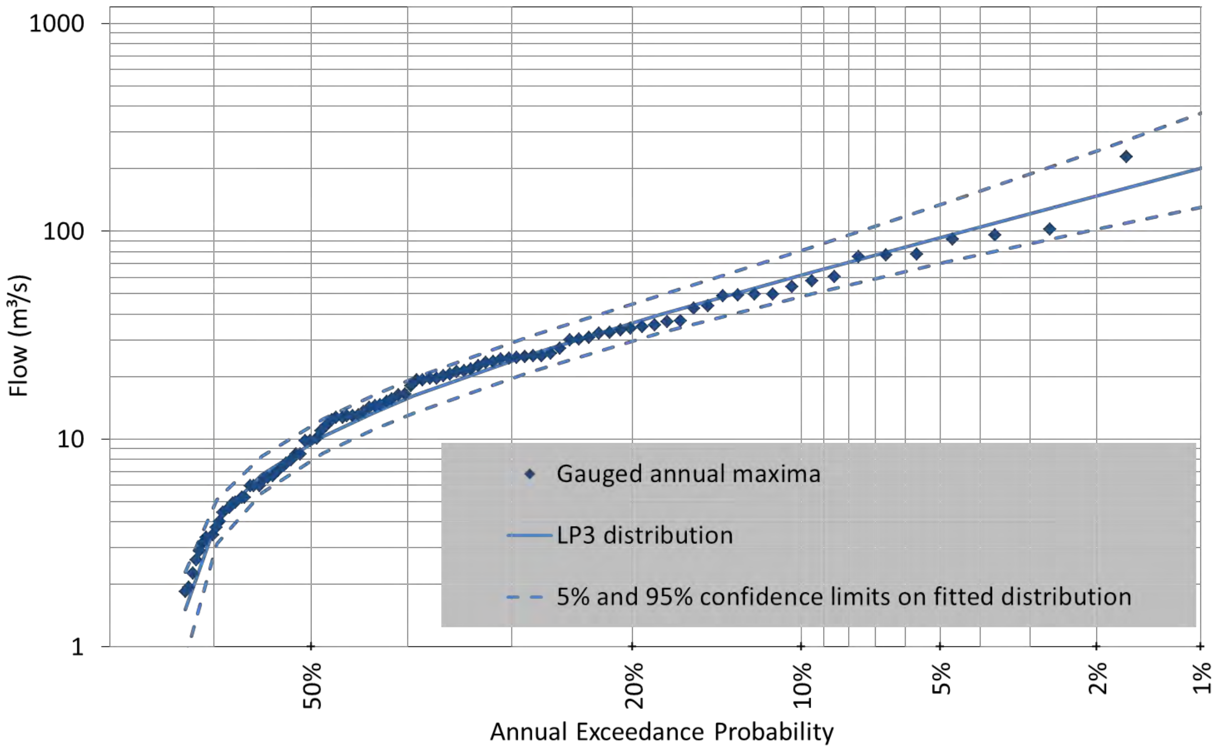


Figure 3-2 Flood Frequency Curve for Yanco Creek @ Morundah (GS 410015) 1913-2013



3.3 Catchment Modelling

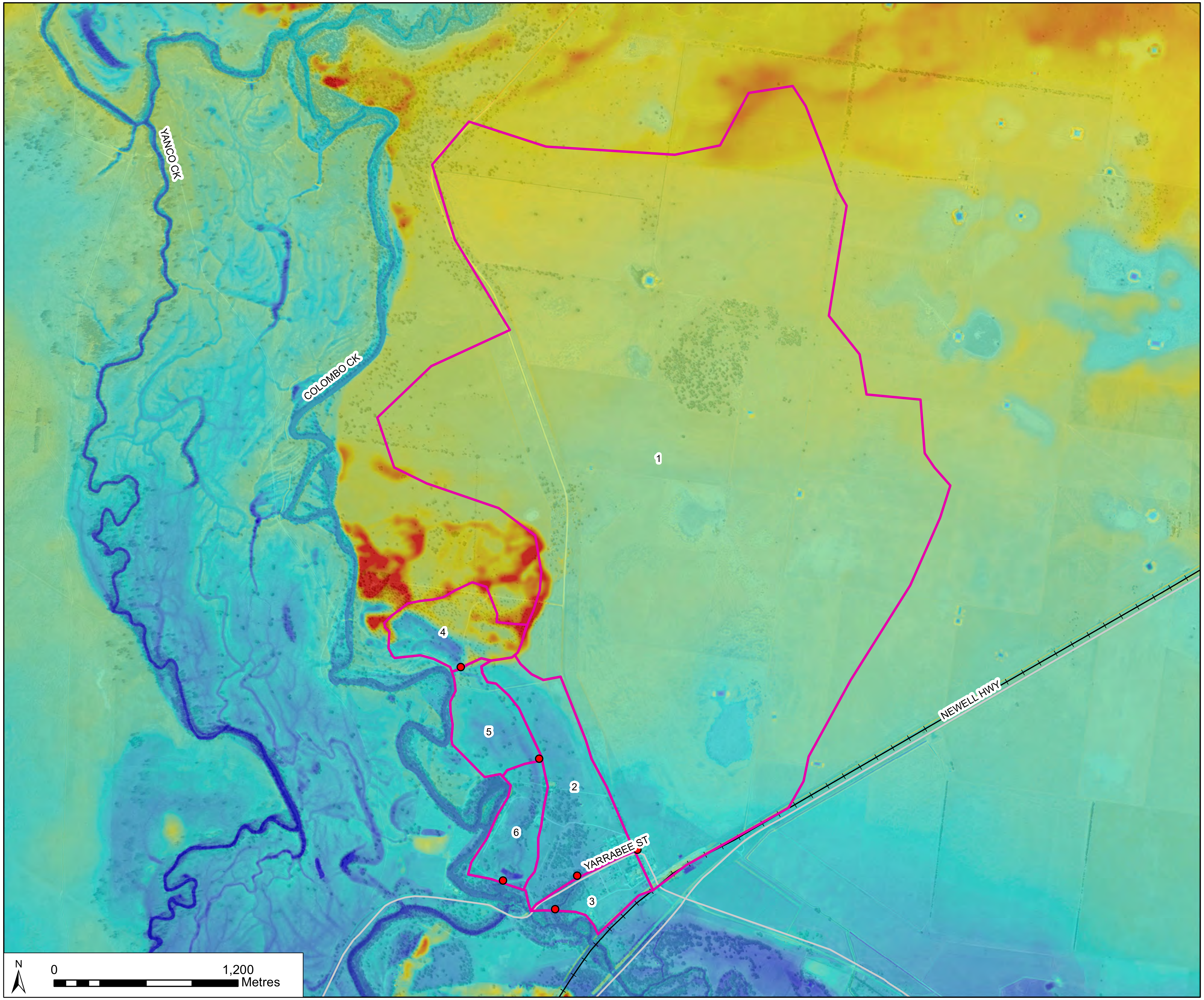
Whilst adequate recorded streamflow data is available in PINNEENA for both Yanco and Colombo Creeks for calibration and verification of a hydraulic model for the mainstream flooding at Morundah, a hydrologic model is required to estimate the local catchment runoff which is also a major source of flooding for the village.

3.3.1 Methodology

The local catchment draining to Morundah village was modelled using XP-RAFTS (2013 version), a robust runoff routing program (XP Software 2013). XP-RAFTS is commonly used across Australia to simulate both urban and rural catchment runoff hydrographs. XP-RAFTS has the ability to simulate sub-catchments of varying sizes and the routing of flows between them, and it was considered the most suitable modelling platform. Both total and local sub-catchment flows are able to be obtained from the model for inclusion in the hydraulic model.

3.3.2 XP-RAFTS Model Configuration

The Morundah local catchments were delineated based on the 1m LiDAR DEM, which covered the entire catchment to be modelled. A total of 6 sub-catchments were delineated, covering an area of 1,276ha. An outline of the XP-RAFTS catchments is shown in **Figure 3-3**. Catchment roughness values were estimated based on the aerial imagery (set between 0.04 and 0.05) and slopes were obtained from the 1m LiDAR DEM. A nominal impervious fraction of 5% was used for rural sub-catchments and impervious fractions for sub-catchments in and around Morundah village were estimated using the aerial imagery. The runoff generated from each individual catchment was used directly in the hydraulic model (i.e. routing was not applied within XP-RAFTS). Further details on the XP-RAFTS model are provided in **Appendix C**.



Legend

- RAFTS Nodes
- RAFTS Subcatchments
- Major Roads
- Railway
- Watercourses

Morundah DEM

Elevation (m AHD)

High : 135

Low : 125

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

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

JACOBS

TITLE	RAFTS Model Setup
TOWN	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 3-1
CHECK AH	DATE 30/08/2017	

4. Hydraulic Modelling

4.1 Model Selection

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydrodynamic model has been developed for Morundah. 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.

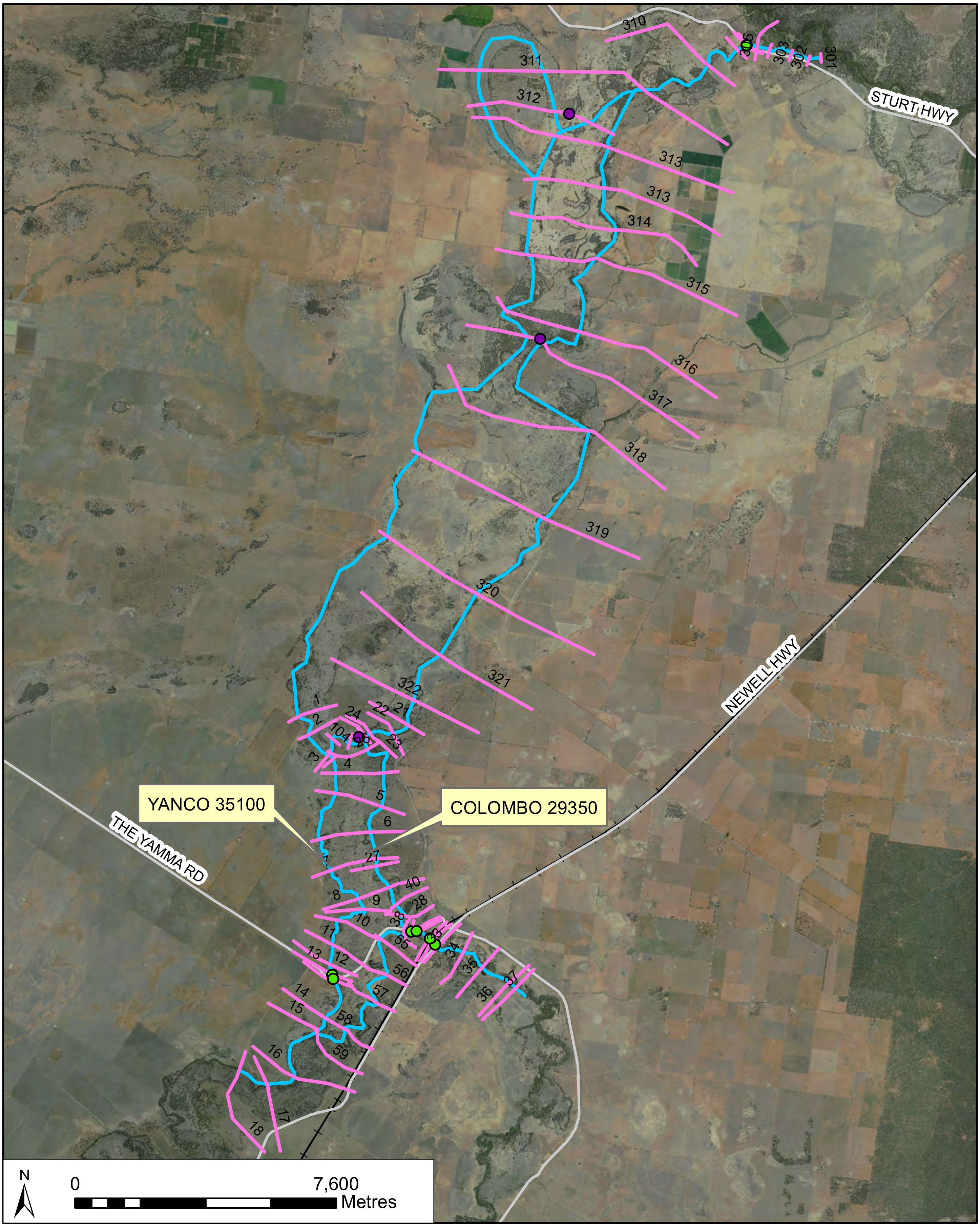
In order to route the diverted flows from the Murrumbidgee River and determine the distribution of flows between Yanco and Colombo Creeks downstream of Tarabah Weir, a one-dimensional (1D) MIKE11 hydraulic model was set up. Danish Hydraulic Institute's (DHI) MIKE11 program allows flow to occur along one-dimensional flowpaths (must be identified by the modeller), which can be linked in a network to represent quasi two-dimensional flow behaviour experienced on floodplains. Being one-dimensional in nature, MIKE11 is able to route flows over a large distance efficiently. The software is also capable of representing culverts, bridges and other hydraulic structures including regulators and their operation.

4.2 MIKE11 Model Configuration

The MIKE11 model configuration consists of identified flow paths (along the main creek lines) and cross sections. The model setup can be seen in **Figure 4-1**. The model includes Yanco Creek, from the Murrumbidgee offtake to approximately 6.5km downstream of Morundah, and Colombo Creek, from its bifurcation with Yanco Creek to approximately 3.5km downstream of Morundah. Woolshed Creek (also known as Washpen Creek), an anabranch of Yanco Creek running parallel to it, was also included in the model. Link channels between these main flowpaths were also included in the model to simulate the interchange of water across the floodplain.

Cross sections were cut from the LiDAR data provided by OEH for Yanco Creek. In some areas the LiDAR data did not extend into Washpen Creek, but this will not significantly affect the results at Morundah since the small creek rejoins Yanco Creek just downstream of the Colombo Creek distributary.

A Manning's n roughness value was applied to the cross sections based on a review of the aerial imagery and a global value of 0.075 was adopted for the floodplain. Hydraulic structures and obstructions were represented in the MIKE11 model including road crossings, railway crossings, weirs and regulators. This information was based on the topographical survey data. Stage-discharge relationships were used as the downstream boundaries for Yanco and Colombo Creeks based on a normal depth.



Legend

- MIKE-11 culverts
- MIKE-11 regulators
- MIKE-11 cross sections
- MIKE-11 flow paths
- Major Roads
- Railway

JACOBS

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, 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.

TITLE	MIKE-11 Model Setup
TOWN	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	FIGURE 4-1
CHECK AH	DATE 30/08/2017	

4.3 TUFLOW Model Configuration

4.3.1 Extent and Structure

The Morundah TUFLOW model is comprised of:

- A 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use
- A 2D representation of the bridge structures in the vicinity of Morundah (both road and railway) over Colombo Creek and Yanco Creek
- Obstructions to flow are represented as 2D objects, including existing buildings.

Refer to the following report sections for details on these features. The locations of various features in the TUFLOW model are shown in **Figure 4-2**.

4.3.2 Model Topography

The topography of the catchment is represented in the model using an 8m grid. The grid size was selected to optimise model run time and to achieve a level of precision required for adequate representation of flood behaviour within the study area. The basis of the topographic grid used in the TUFLOW model is the LiDAR data set for Morundah (**Figure 2-1**). Due to the reasonably large grid size, road crests crossing the floodplain and smaller channels were included with break lines using elevations obtained from the 1m DEM. The Colombo Creek bed was also approximated to be 1m deep as sections of the creek had standing water when the LiDAR data was captured. The Morundah levee was added in based on the survey undertaken of the levee in 2015 (see **Appendix A** for further details) representing the existing levee.

4.3.3 Bridges and Culverts

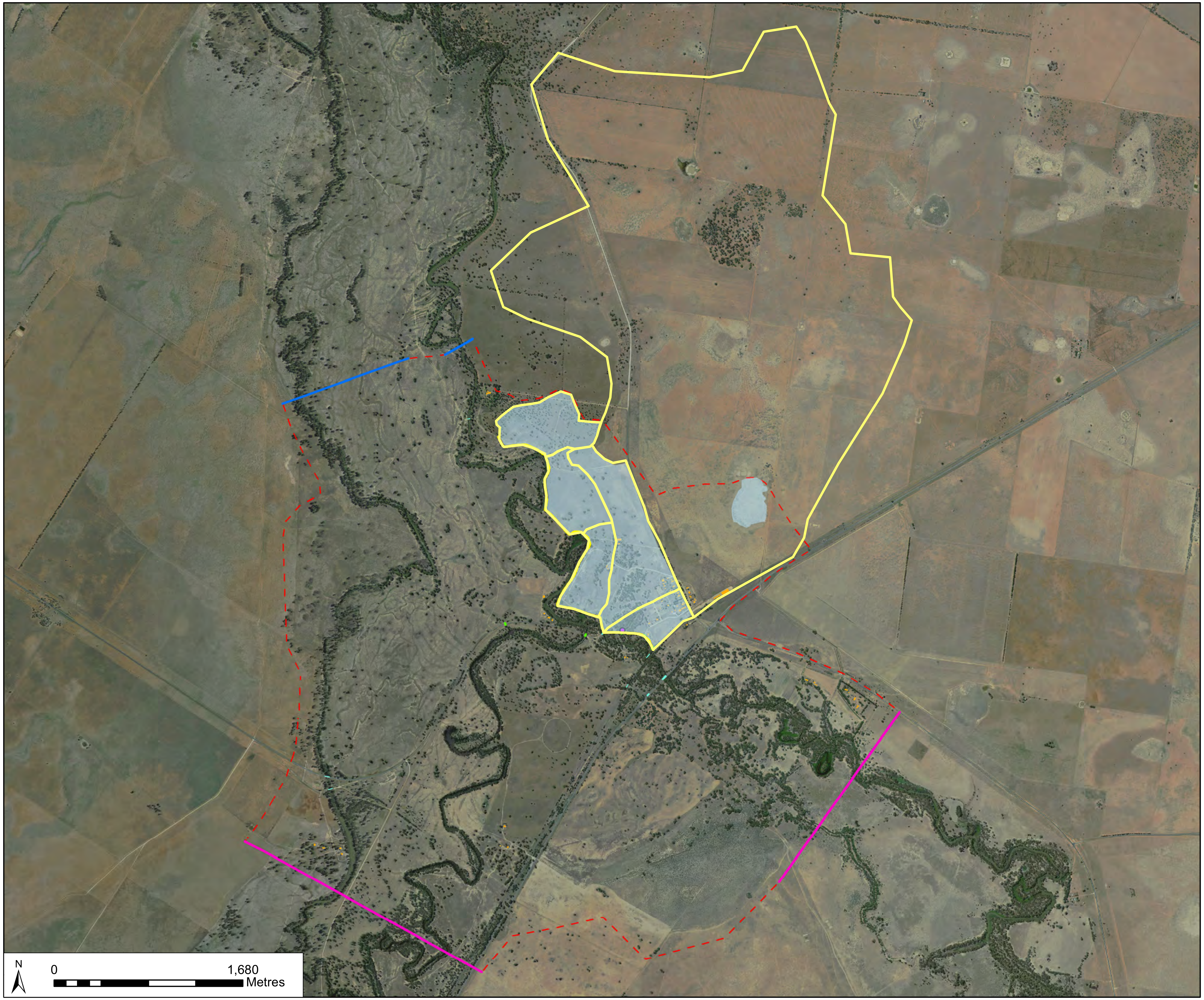
There were a total of eight bridges crossing Colombo and Yanco Creeks in the vicinity of Morundah. These were surveyed for this study by TJ Hinchcliffe & Associates in 2015 and the data was used to represent the structures as 2D elements on the floodplain. The underside, deck and railing levels were included in the model along with a blockage and form loss factor for each layer. Additional culvert structures (including 3 culverts through the levee, two under Yamma Road and one at the edge of Morundah village) were represented as 1D elements and included details such as culvert dimensions, length and upstream and downstream invert levels.

4.3.4 Building Polygons

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

4.3.5 Property Fencelines

Fencelines were not been represented in the model and floodwaters were 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 was assumed that these fences did not cause any significant obstruction to the flow.



Legend

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

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

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

JACOBS

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

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 30/08/2017

FIGURE 4-2

4.3.6 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

4.3.7 Flood Pump

Morundah has a permanent 8 inch diameter pump that pumps water from the village side of the levee to the creek side. This was also included in the TUFLOW model. Exact details of this pump were not available at the time of the study, so some general assumptions were made regarding the pump capacity and operation.

4.4 Boundary Conditions

4.4.1 Model Inflows

Hourly flow data for Yanco Creek @ Offtake gauge were extracted from PINNEENA 10.2 for the flood events of 2010 and 2012. The extracted flow hydrographs for the flood events were used in the MIKE11 model for Colombo and Yanco Creeks and the model was run for the two flood events. Simulated flows at MIKE11 cross section YANCO 35100 and COLOMBO 29350 for the two flood events that were used as inflows into the TUFLOW model. The modelled hydrographs were adopted as upstream inflow hydrograph in the TUFLOW model for Morundah. Since the duration of the MIKE11 model was quite long (for example the 2010 event was modelled over almost 100 days), the rising limb and receding limb of the hydrograph was truncated for the TUFLOW model as the peak of the hydrograph is the primary interest. These truncated hydrographs are shown in **Figure 4-3** and **Figure 4-4** for the 2010 and 2012 flood events, respectively.

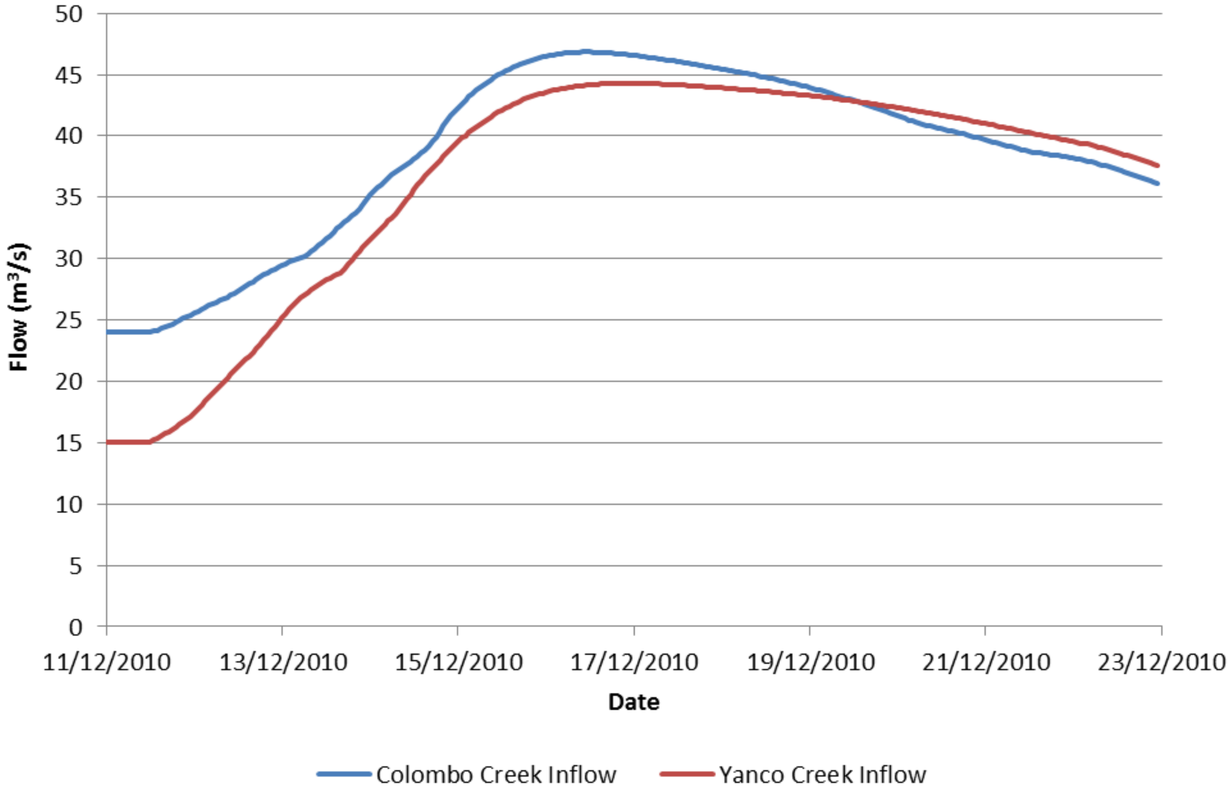


Figure 4-3 Modelled flow for input into the Morundah TUFLOW model for the 2010 event

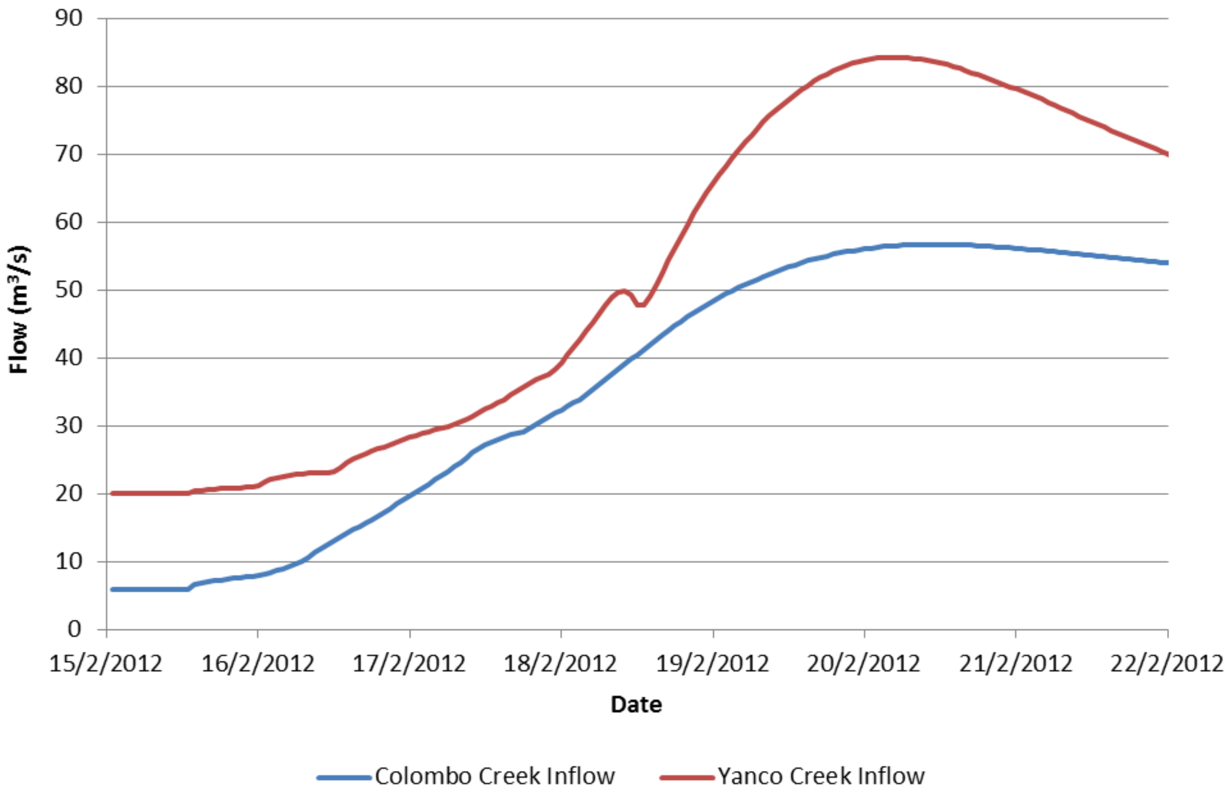


Figure 4-4 Modelled flow for input into the Morundah TUFLOW model for the 2012 event

4.4.2 Tailwater Conditions

The TUFLOW model for Morundah incorporated two downstream boundaries, separated into Colombo and Yanco Creeks. The boundaries are located approximately 2km 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 these boundaries.

4.4.3 Initial Conditions

Small flows were assumed representing dry floodplain conditions.

5. Calibration and Verification

5.1 Selection of Calibration and Verification Events

There have been a number of floods that have impacted Morundah, most recently the 2010 and 2012 flood events. These flood events have the most reliable flood data associated with them and as such, they were selected for model calibration and verification. An attempt was made to calibrate both the MIKE11 and TUFLOW hydraulic models to the March 2012 flood event and verify the models against the December 2010 flood event.

The MIKE11 model was calibrated to the gauged flows in Yanco Creek at Morundah and Colombo Creek at Morundah using the recorded flows at the Yanco Creek Offtake as the inflow. Once this model was calibrated, the flows were applied to the TUFLOW inflow boundaries and the model was calibrated with the local catchment flows also. A joint calibration was undertaken with the XP-RAFTS hydrologic model and TUFLOW hydraulic model for the local catchment flows. The models were calibrated using the gauged flows in Yanco Creek at Morundah and Colombo Creek at Morundah as well as flood photography and other observations. The results are presented in the sections below, with further results presented in **Appendix D**.

5.2 Hydrologic Modelling

5.2.1 2012 Event

The Morundah local catchment XP-RAFTS model was calibrated for the 2012 event through a joint calibration process with the TUFLOW hydraulic model. The available Morundah Hotel rainfall gauge (**Section 2.2.3.1**) was used to obtain a representative rainfall depth across the catchment. The temporal pattern from the Yanco Agricultural Institute pluviograph station (**Section 2.2.3.1**) was used for the timing and temporal distribution of the rainfall event. Since there was limited flood height information to calibrate the local catchment flows to, reasonable estimates of the model parameters were made. The adopted rainfall loss parameters were 25mm initial loss and 2.0mm/hr continuing loss. This is consistent with the rainfall loss parameters that were selected in the Flood Study for Boree Creek (Jacobs 2017) and other studies in the region for the 2012 rainfall event. The rainfall event produced just over 100mm of rain recorded on the 4th March 2012.

5.2.2 2010 Event

The Morundah local catchment XP-RAFTS model was also calibrated to the 2010 event through a simultaneous calibration process with the TUFLOW hydraulic model. The available Morundah Hotel rainfall gauge (**Section 2.2.3.1**) was used to obtain a representative rainfall depth across the catchment. The temporal pattern from the Yanco Agricultural Institute pluviograph station (**Section 2.2.3.1**) was used for the timing and temporal distribution of the rainfall event. Since there was limited flood height information to calibrate the local catchment flows to, reasonable estimates of the model parameters were made. The adopted rainfall loss parameters were 8mm initial loss and 2mm/h continuing loss. The 2010 event at Morundah was primarily a result of flooding from Colombo Creek. The local catchment did not contribute a significant flow. The Morundah Hotel gauge only recorded 16mm on 9th December 2010.

5.3 Hydraulic Modelling

5.3.1 2012 Event

5.3.1.1 MIKE11 Model

The MIKE11 model was calibrated to the 2012 event using the gauged inflows at the Yanco Creek Offtake and comparing the simulated flows at the Yanco Creek @ Morundah and Colombo Creek @ Morundah gauges. The routed flow was the primary interest. Calibration results at the two gauges are presented in **Figure 5-1** and **Figure 5-2**. The model is reasonable at simulating the peak flow in both Yanco and Colombo Creeks, however the rising limb of the hydrographs is markedly different. The recorded hydrographs display a sharp increase in flow to the flood peak that is not replicated by the MIKE11 model. This could be due to the sudden local catchment inflows from Woolshed Creek (Yeo 2013) or perhaps the operation of Tarabah weir and other regulators along Yanco Creek. The flow in Colombo Creek is slightly underestimated while the flow in Yanco Creek is slightly overestimated.

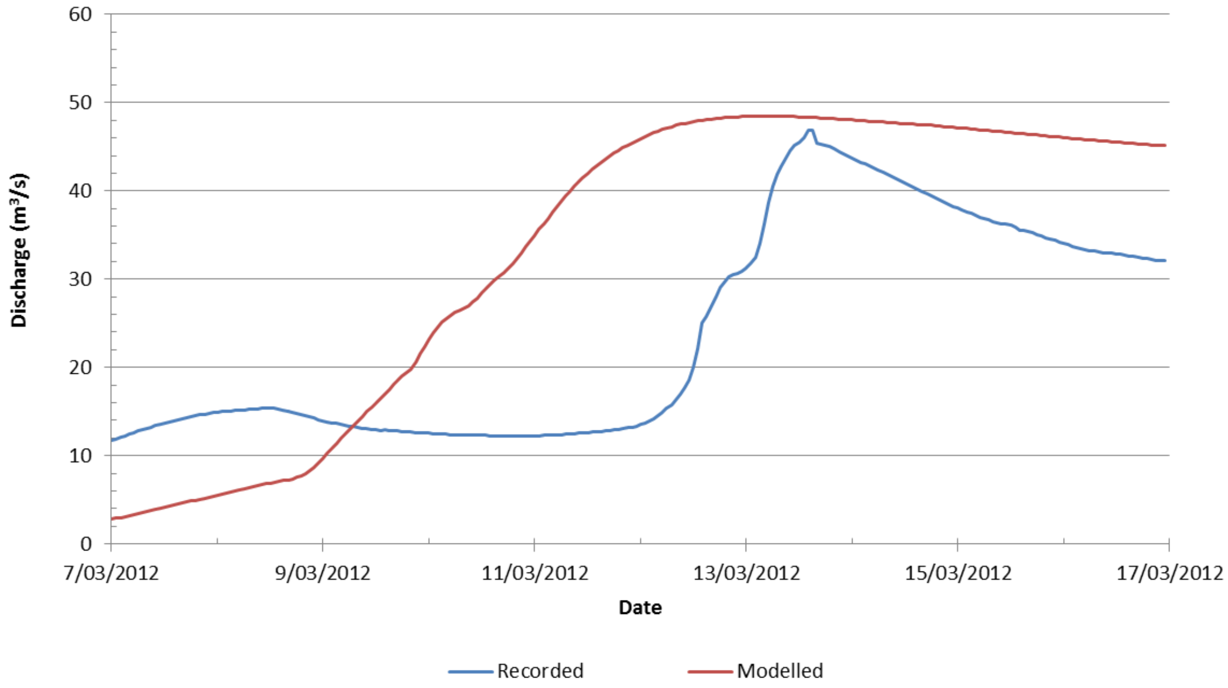


Figure 5-1 MIKE11 calibration results for flows in Colombo Creek at Morundah for the 2012 event

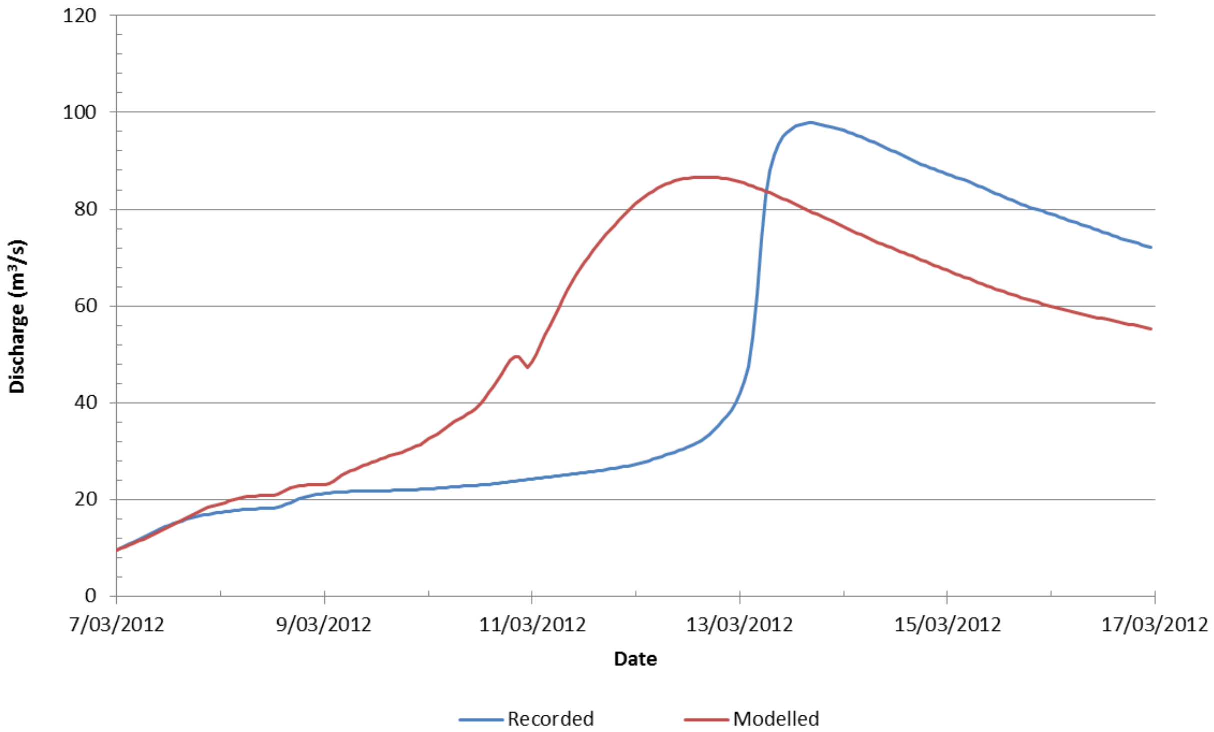


Figure 5-2 MIKE11 calibration results for flows in Yanco Creek at Morundah for the 2012 event

The flow hydrograph simulated by the MIKE11 model for this flood event was used as the upstream boundary conditions for the Morundah TUFLOW model. The model results show that the floodplain is active and there is an exchange of water between Yanco and Colombo Creeks downstream of Tarabah Weir.

5.3.1.2 TUFLOW Model

The TUFLOW modelled flood level hydrograph on Colombo Creek was compared with the recorded hydrograph in order to calibrate the model, as seen in **Figure 5-3**. For the 2012 flood event, the modelled flood levels were 0.23m lower than the recorded flood level. The modelled hydrograph shows a flat profile, indicating that there is a control which is regulating the peak flood level in Colombo Creek at Morundah. It could be that the Yamma Road Bridge, which is just upstream of the gauge, regulates the flow and diverts excess water to Yanco Creek. The recorded hydrograph shows a significant jump in water level which is not replicated in the model. This sharp increase may be due to the operation of Tarabah Weir or the influence of local inflows from Woolshed Creek into Yanco Creek which have not been modelled.

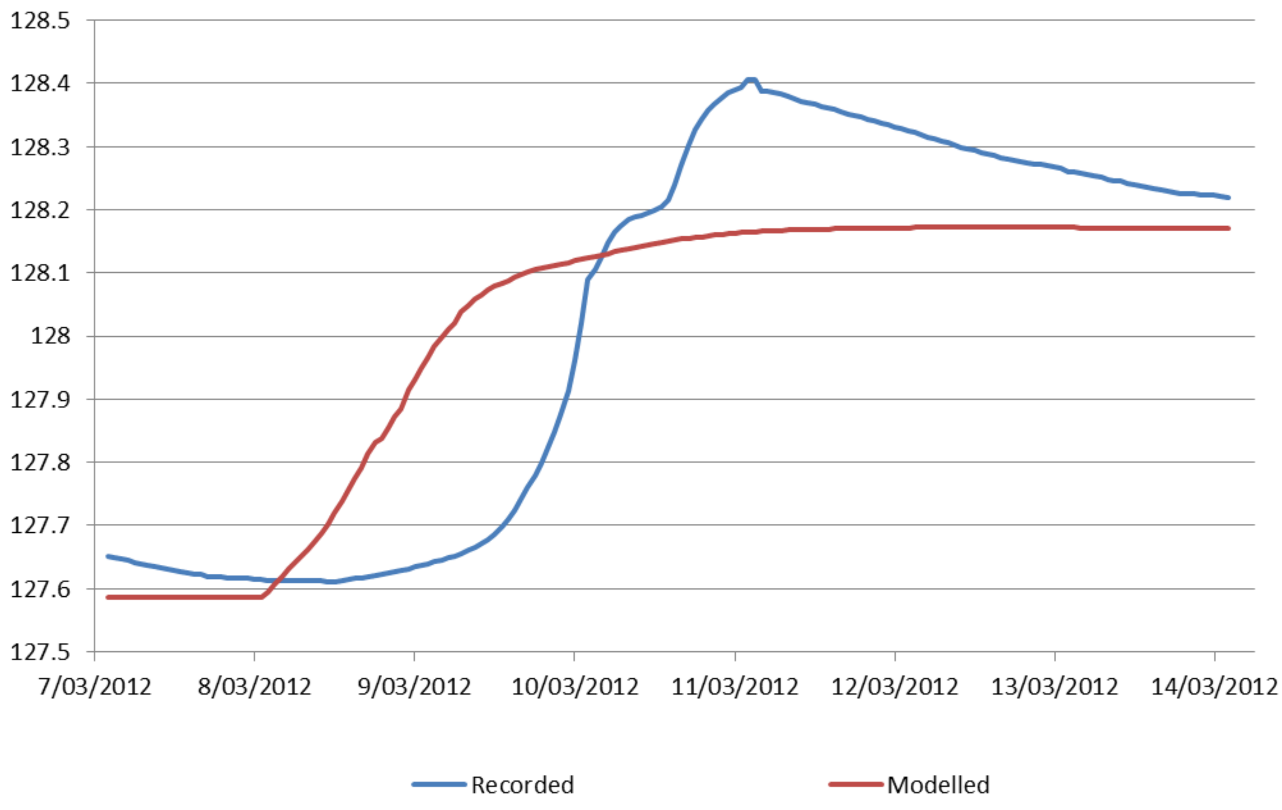


Figure 5-3 Water level hydrographs for Colombo Creek at Morundah for the 2012 calibration event

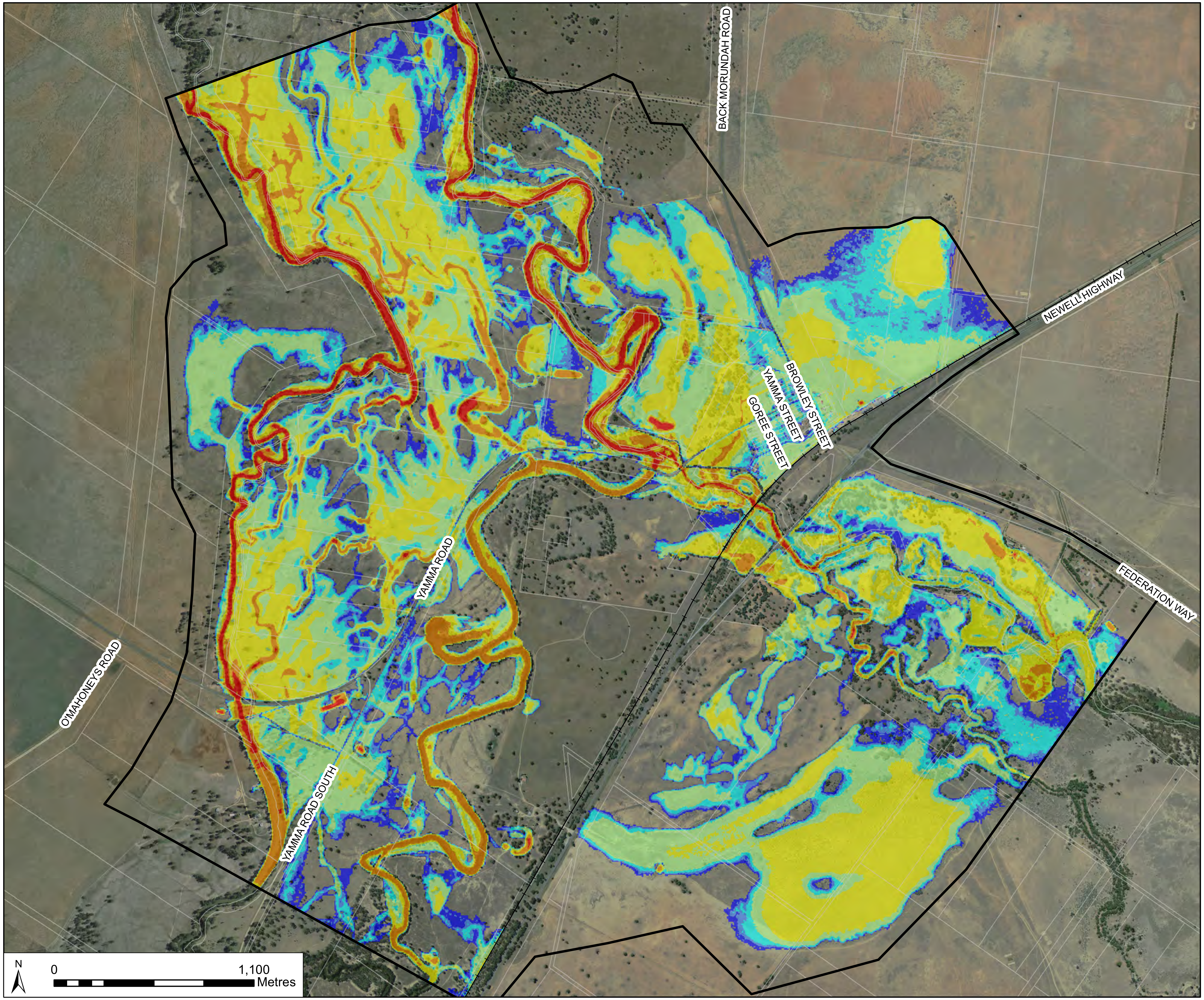
The flood map for the 2012 event is presented in **Figure 5-4**. Modelled peak water level profile for the 2012 flood event along Colombo Creek near Morundah is presented in **Figure 5-5** which shows that the model underestimates the peak water level profile along the levee as the levee (2012 survey) is close to overtopping only at two locations. Modelled flood levels at the upstream and the downstream end of the levee is approximately 0.7m only.

Local catchment flooding was also a major issue during the 2012 flood, with one house on Milvain Drive being inundated. The modelled flood depths in this location are approximately 0.3-0.4m. This is a reasonable depth to cause slight inundation of a house. It should be noted that the other three houses on Milvain Drive, while being exposed to the same overland flow, were not inundated. Floodwaters run through most of the town at shallow depth (<0.5m) and accumulate behind the levee. The modelled results are consistent with the photographs taken when the overland flooding from the local catchment was occurring. Two unnamed local roads (to the west of Back Morundah Road) which were cut during the 2012 event were modelled to have depths ranging from 0.35m to 0.75m. During the 2012 flood event, the permanent 8 inch pump was run 20 hours per day for a duration of 10 weeks (John Geppert, pers. comm.). Additionally, Council placed two portable 4-inch pumps and hired one 6-inch pump which were run for approximately 20 hours per day for a period of approximately 2 weeks (in 2 segments starting 12 March and 26 March 2012). These pumps were assumed to have the capacities outlined below in **Table 5-1**. The pumps were modelled as a single pump with a combined capacity of 250L/s and were run continuously in the model during the 2012 calibration event. The small culverts and flood pumps did little to alleviate the large volume of water that builds up behind the levee over the model duration (1 week).

Table 5-1 Assumed pump capacities

Pump Type	Assumed capacity (L/s)
8 inch permanent	100
6 inch portable	70
4 inch portable	40

It can be concluded that the TULOW model was unable to represent the observed flood behaviour in Colombo Creek at Morundah for the 2012 flood event. However, the TUFLOW model represented overland flooding within the township for the same flood event satisfactorily. It is to be noted that the overland flooding resulted from intense rainfall on the local catchment was independent of the flooding in Colombo Creek in Morundah.



Legend

TUFLOW Model Extent
Railway
Cadastre

2012 flood depth (m)

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

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

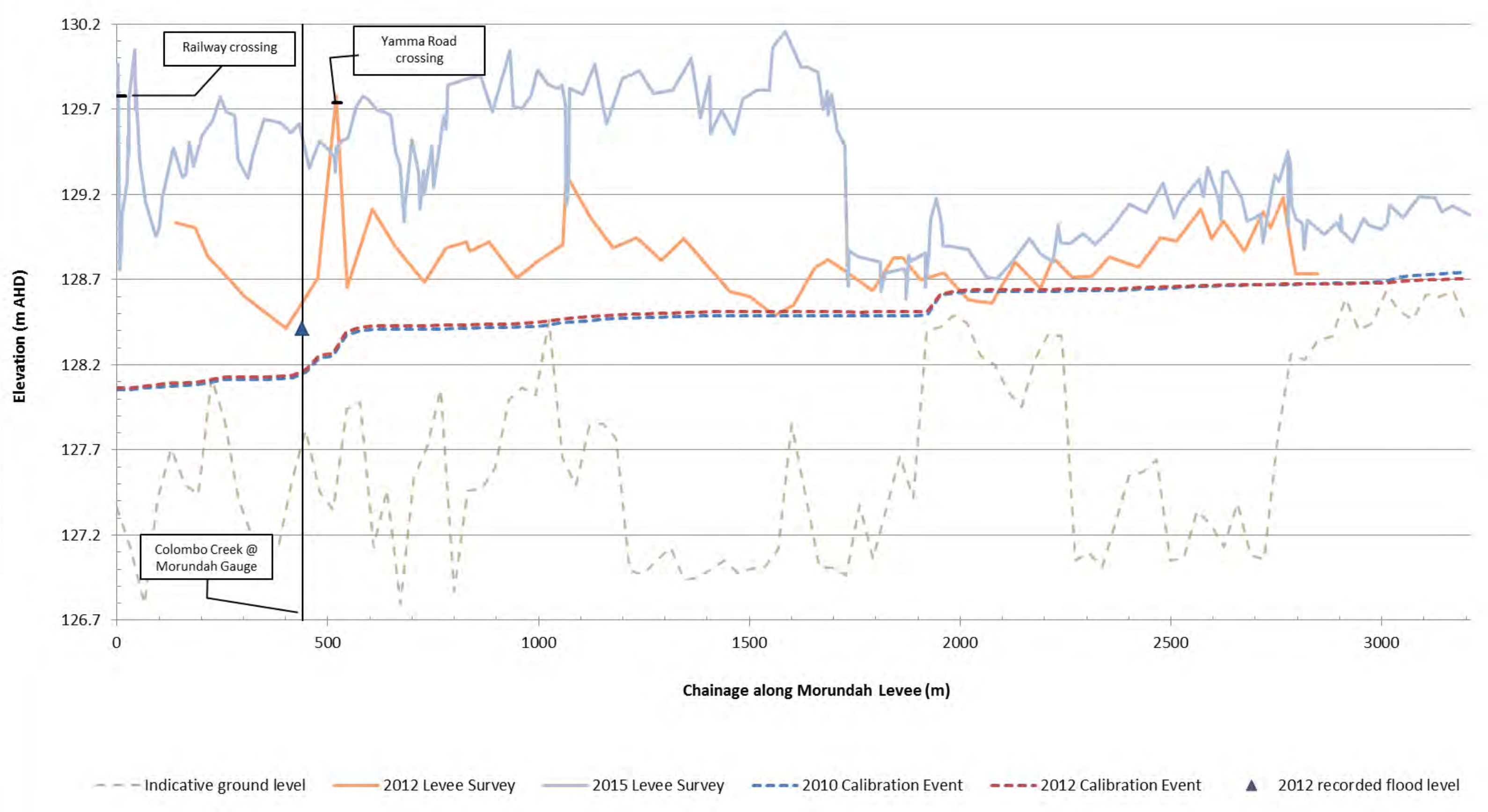
LIMITATIONS: This mapping is based on data and assumptions identified in the Urana Shire Flood Study Reports prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

JACOBS

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

DRAWN MR	PROJECT # IA055600	FIGURE 5-4
CHECK AH	DATE 25/09/2017	

Figure 5-5 Peak Water Level Profile along Colombo Creek at Morundah for calibration events



5.3.2 2010 Event

5.3.2.1 MIKE11 Model

The MIKE11 model was calibrated to the 2010 event using the gauged inflows at the Yanco Creek Offtake and comparing the simulated flows at the Yanco Creek @ Morundah and Colombo Creek @ Morundah gauges. The routed flow was the primary interest. The results for the calibration to the Colombo Creek and Yanco Creek gauges are presented in **Figure 5-6** and **Figure 5-7** respectively. The results for Yanco Creek are very good, with the rising limb and flood peak consistent with the gauged flows, and only a minor change in the phase of the flood peak. The flow in Colombo Creek, however, is substantially overestimated.

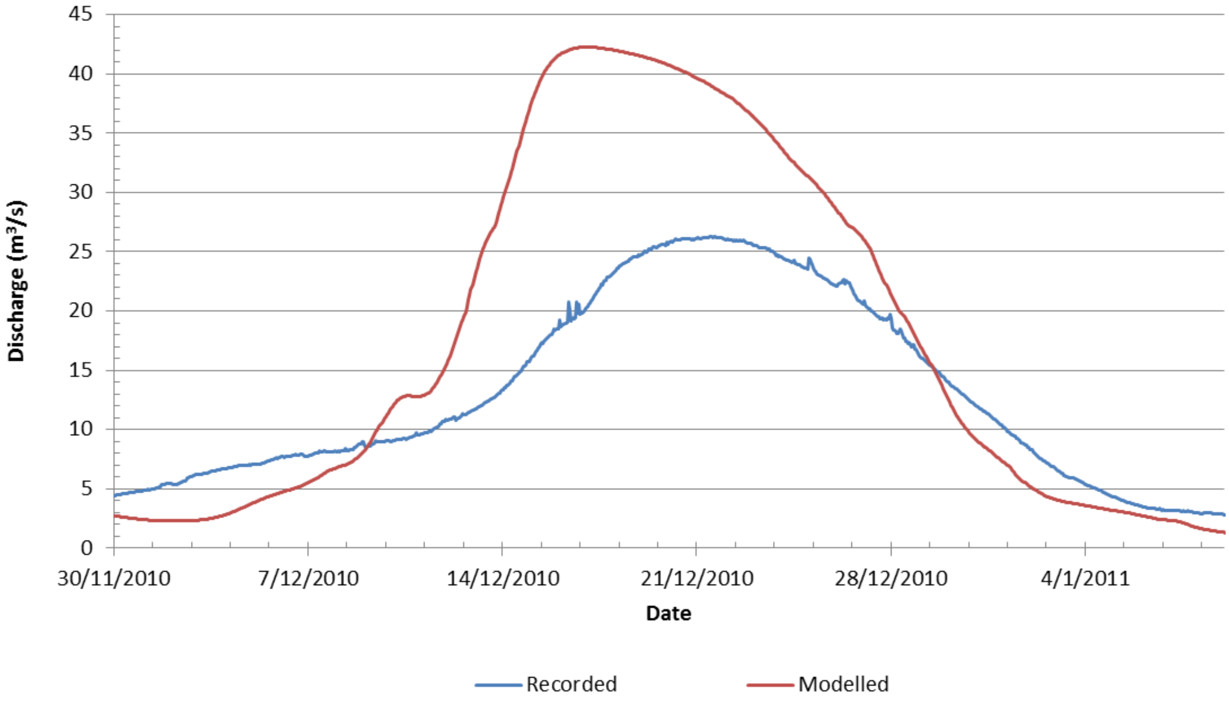


Figure 5-6 MIKE11 calibration results for flows in Colombo Creek at Morundah for the 2010 event

5.3.2.2 TUFLOW Model

The flow hydrograph simulated by the MIKE11 model for this flood event was used as the upstream boundary conditions for the Morundah TUFLOW model. The model results show that the floodplain is active and there is an exchange of water between Yanco and Colombo Creeks downstream of Tarabah Weir. Flow from Colombo Creek comes close to overtopping the Morundah levee (within 1m), but it does not overtop the levee. There is little information available on this flood event to calibrate the model to except for the gauge located on Colombo Creek at Morundah. A comparison of the modelled and recorded water level hydrographs at this gauge are shown in **Figure 5-8**. The modelled peak water level is 0.04m above the recorded peak water level. Again, the modelled stage hydrograph shows a flat profile indicating the flows in Colombo Creek are being controlled.

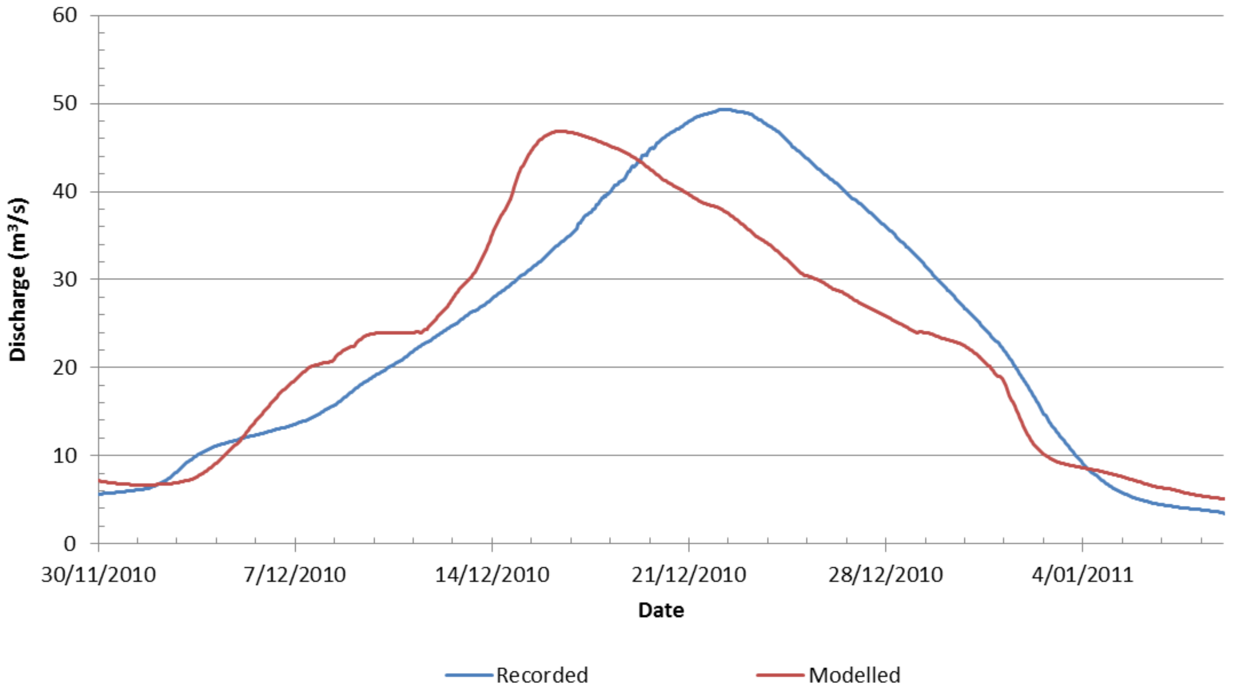


Figure 5-7 MIKE11 calibration results for flows in Yanco Creek at Morundah for the 2010 event

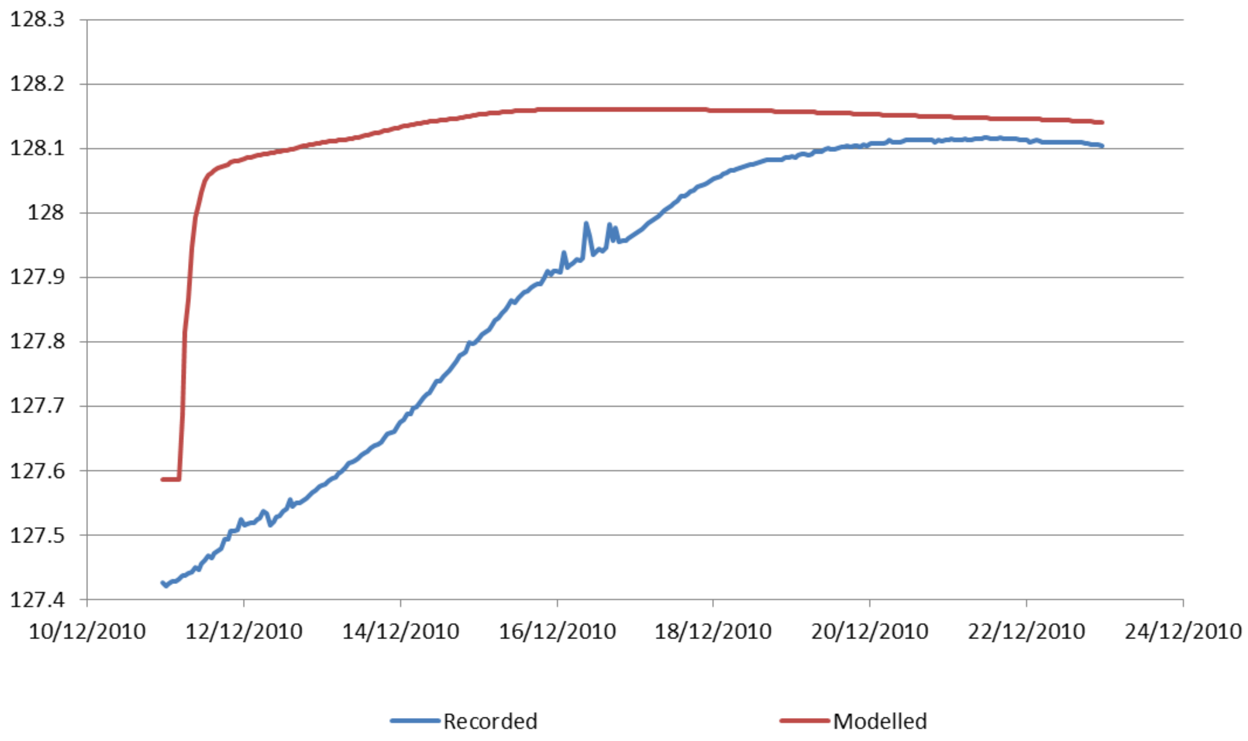
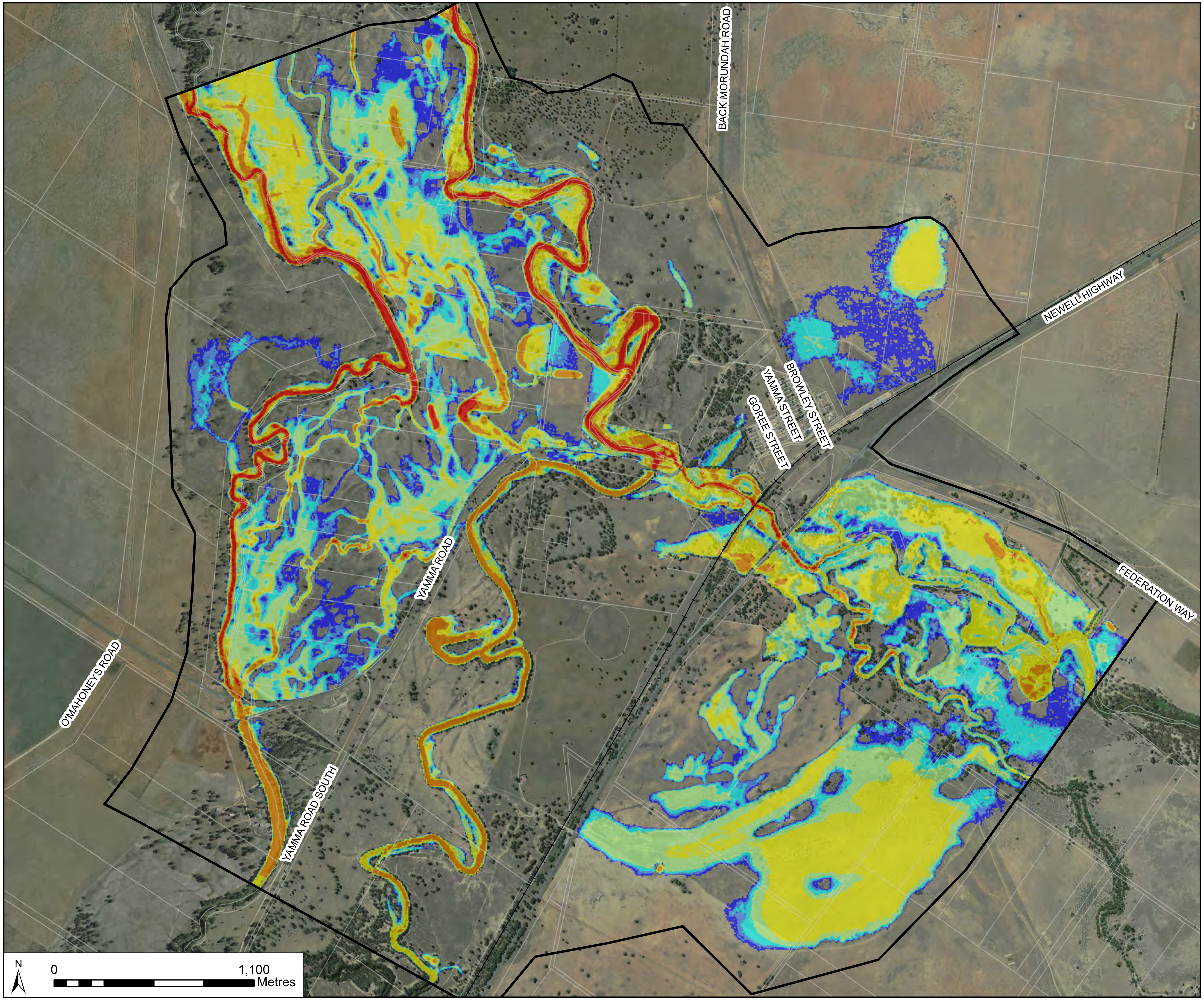


Figure 5-8 Water level hydrographs for Colombo Creek at Morundah for the 2010 calibration event

The TUFLOW modelled peak water level profile along Colombo Creek near Morundah is presented in **Figure 5-5** which is almost similar to the modelled 2010 profile. The modelled flood map for the 2010 event can be seen in **Figure 5-9**.



Legend

- TUFLOW Model Extent
- Railway
- Cadastre

2010 flood depth (m)

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

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

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

JACOBS

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

DRAWN MR | PROJECT # IA055600
CHECK AH | DATE 25/09/2017

FIGURE 5-9

5.4 Sensitivity Analysis (2012 Flood Event)

A sensitivity analysis was conducted using the 2012 flood event. The following hydrologic and hydraulic model parameters were changed: initial losses, inflows, Manning's n roughness, blockage of structures and the downstream boundaries. Each of these is addressed in the sections below and further details on the results from the sensitivity analysis are provided in **Appendix D**.

5.4.1 Initial Losses

The adopted initial rainfall loss in the hydrologic model for the 2012 event was 25mm. This was adjusted by +/-20%, i.e. becoming 30mm and 20mm. Increasing or decreasing the initial loss resulted in a negligible change in peak water level in and adjacent to Morundah (at selected locations), being within ±0.03m. This change was most prominent at the flood pump location, and minor in the village itself.

5.4.2 Manning's n

The Manning's n roughness values adopted (**Table 4-1**) were adjusted by +/-20% in both the MIKE11 and TUFLOW hydraulic models. Increasing the Manning's roughness values resulted in water levels increasing by up to 0.1m. This change was most prominent in Yanco Creek, with only minor changes observed in Colombo Creek. The conveyance of flow was reduced by up to 20% in some locations. Decreasing the Manning's roughness values resulted in a decrease in flood levels of up to 0.18m. Again, the largest changes occurred in Yanco Creek. Decreases in the order of 0.01m were typically seen in Colombo Creek.

5.4.3 Blockage of Structures

The structures located on the floodplain are typically road and rail bridges that cross Colombo and Yanco Creeks. A total of eight bridges were contained in the TUFLOW model as 2D structures. The blockage of these structures was considered in the sensitivity analysis rather than the smaller culverts. A 50% and 100% blocked scenarios were run. The 50% blockage scenario resulted in water levels remaining roughly similar, within ±0.09m at the selected locations. The change in flow also fluctuated depending on the location. The 100% blocked scenario resulted in water levels being increased by up to 0.6m and would be expected to be higher upstream of the structures. The flow was significantly reduced at locations where the blockage was applied.

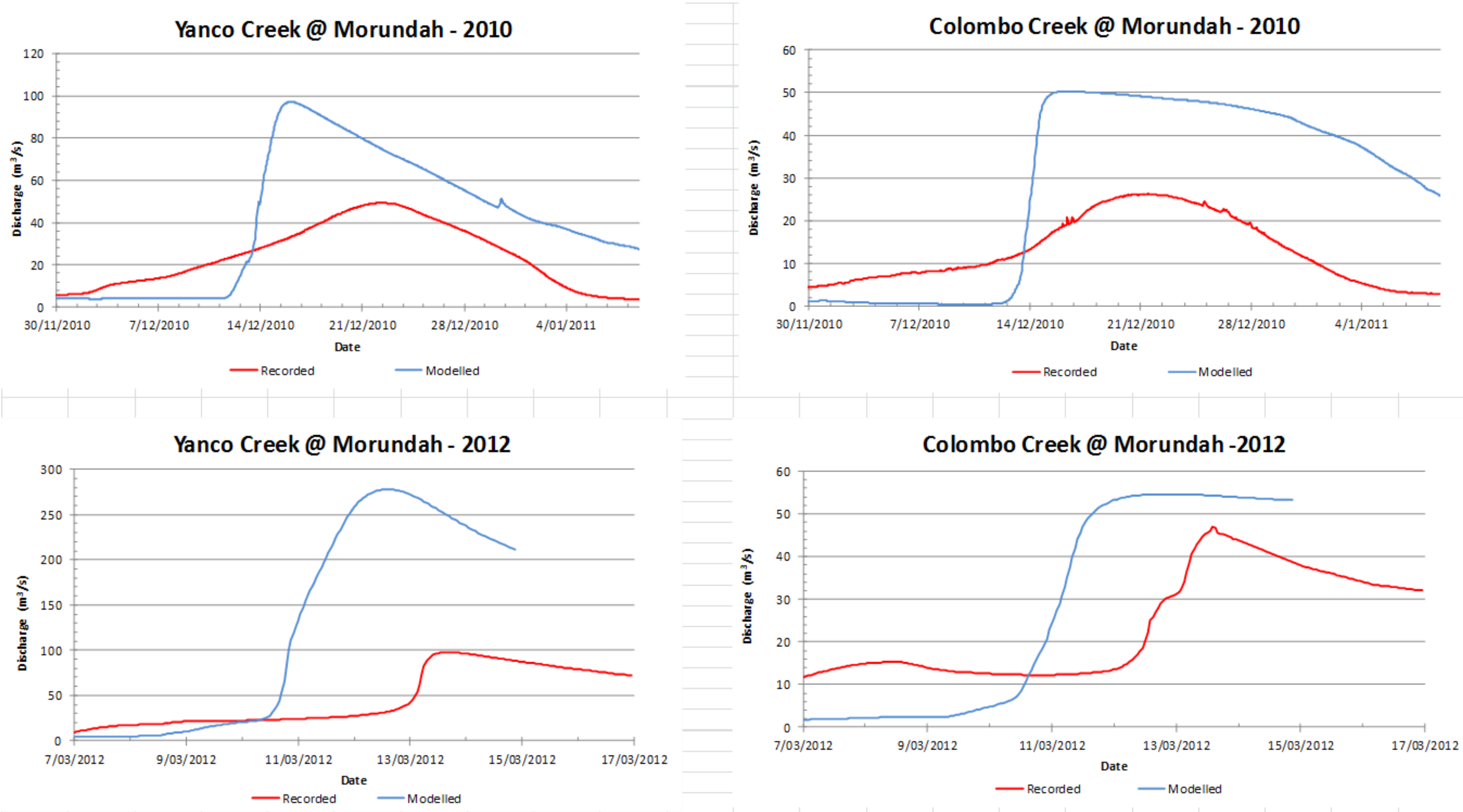
5.4.4 Downstream Boundary

A normal water depth was used at the downstream boundaries for both Yanco and Colombo Creeks. A sensitivity analysis was conducted by changing the tailwater levels by +/-0.5m. There was no change in the flows and negligible change (<±0.01m^3/s) in the flows when the tailwater level was adjusted. This indicates that the outflow boundaries are located far enough downstream to not impact the modelled flood behaviour in the vicinity of the village.

5.4.5 Inflow Hydrographs Provided by Lyall (2015)

Inflow hydrographs provided by Lyall & Associates for the 2010 and 2012 flood event representing breakouts from the left bank of the Murrumbidgee River in the vicinity of Narrandera were used in the MIKE11 model. Modelled water level and discharge hydrographs are compared against observed data for Colombo Creek @ Morundah gauge and Yanco Creek @ Morundah gauge in **Figure 5-10**. **Figure 5-10** does not show any improvement in MIKE11 calibration results using modelled inflow hydrographs provided by Lyall & Associates. It is to be noted that the hydraulic model used by Lyall & Associates was not calibrated against observed data for Yanco Creek or Colombo Creek.

Figure 5-10 MIKE11 Calibration Results using Inflow hydrographs provided by Lyall & Associates (2015)



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.

The XP-RAFTS model was used to simulated catchment runoff for the design events for Morundah. The simulated runoff hydrographs were used as inflow boundaries for the TUFLOW model for Morundah.

A relationship was established between hourly observed discharges in the Murrumbidgee River at Narrandera gauge and Yanco Creek at Offtake gauge for the flood event of March 2012. The relationship was applied to the modelled discharge hydrographs for the design flood events adopted in the Narrandera Floodplain Risk Management Study (SKM 2009). The estimated hydrographs for the design events at Yanco Creek Offtake were routed through the MIKE11 model developed in this study to generate inflow hydrographs in Colombo and Yanco Creek for use in the TUFLOW hydraulic model for Morundah. The TUFLOW model was utilised to simulate flood behaviour within the study area for the design events.

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 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	19.63
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	44.6
12 hour 50 year ARI mm/hr	6.83
72 hour 50 year ARI mm/hr	1.63

Data Description	XP-RAFTS model
Skewness G	0.13
Geographical factor 2 year ARI F2	4.34
Geographical factor 50 year ARI F50	15.25

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).

6.1.3 Model Parameter Values

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 XP-RAFTS model for Zone 2. The temporal pattern for the PMP event was sourced from BoM (2003).

6.1.5 Design Rainfall Losses

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

6.1.6 Design Discharges

6.1.7 XP-RAFTS Model

The XP-RAFTS model for Morundah was run for a range of storm durations for the selected design flood events to estimate design inflow hydrographs. Results from the XP-RAFTS model were reviewed to identify storm durations which produced peak discharges for each sub-catchment.

6.1.8 Estimation of Inflow Hydrographs at Yanco Creek Offtake

Hourly flow data for the flood event of March 2012 were extracted from PINNEENA for Murrumbidgee River @ Narrandera gauge and Yanco Creek Offtake gauge (refer **Figure 6-1**). The following two relationships were developed between the two gauges for this flood event:

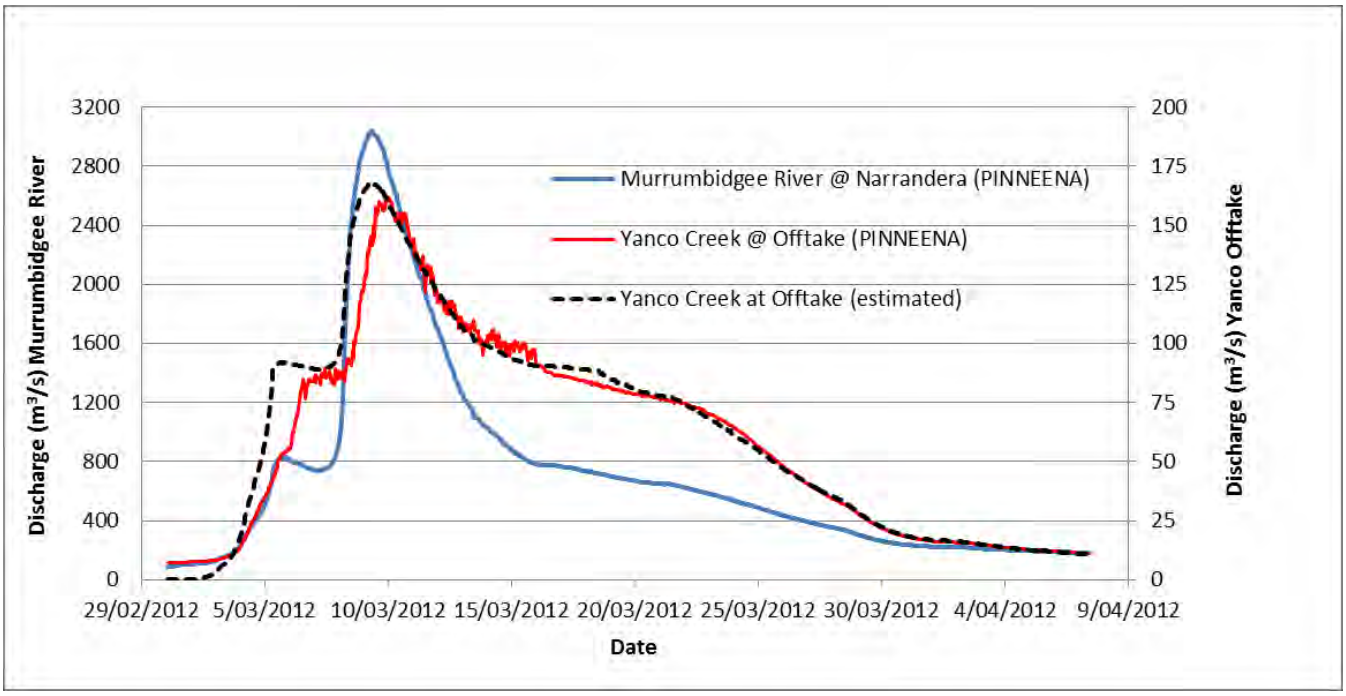
$Y = 0.1434 \times M - 1325.7$ for $M < 62{,}000$; and

$Y = 0.0344 \times M + 5496.8$ for $M >= 62{,}000$

- Where, M is the flow in the Murrumbidgee River @ Narrandera gauge in Ml/day; and Y is the flow in Yanco Creek at offtake gauge in Ml/day.

The derived relationships between the two gauges were then applied to modelled hydrographs in the SKM 2009 study for the Murrumbidgee River @ Narrandera gauge to obtain the resulting discharge hydrographs at Yanco Creek Offtake (refer **Figure 6-2**).

Figure 6-1 Discharge Hydrographs for March 2012 flood event



6.2 Hydraulic Model Parameters for Design Events

6.2.1 MIKE11 Inflows

The calibrated MIKE11 model was run for 20%, 10%, 5%, 2% and 1% AEP events and an extreme event equivalent to 3 times the 1% AEP event to estimate discharge hydrographs in Yanco Creek and Colombo Creek for use in the TUFLOW model. Discharge hydrographs simulated by the MIKE11 model in Yanco Creek and Colombo Creek for the design events are shown in **Figure 6-3** and **Figure 6-4** respectively.

6.2.2 Local Catchment Inflows

Discharge hydrographs simulated by the XP-RAFTS model for all sub-catchments 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 design events for the sub-catchments generally varied between 45 minutes (for the probable maximum precipitation event) and 6 hours for the 5% AEP event. However, the 72 hour storm was the critical duration for both the 20% and 10% AEP events. The lag time between flooding from the local catchment and flooding resulting from the Murrumbidgee River for the flood event of March 2012 was more than one week and hence flooding from the two sources is considered independent.

Figure 6-2 Adopted Design Discharge Hydrographs for Yanco Creek Offtake

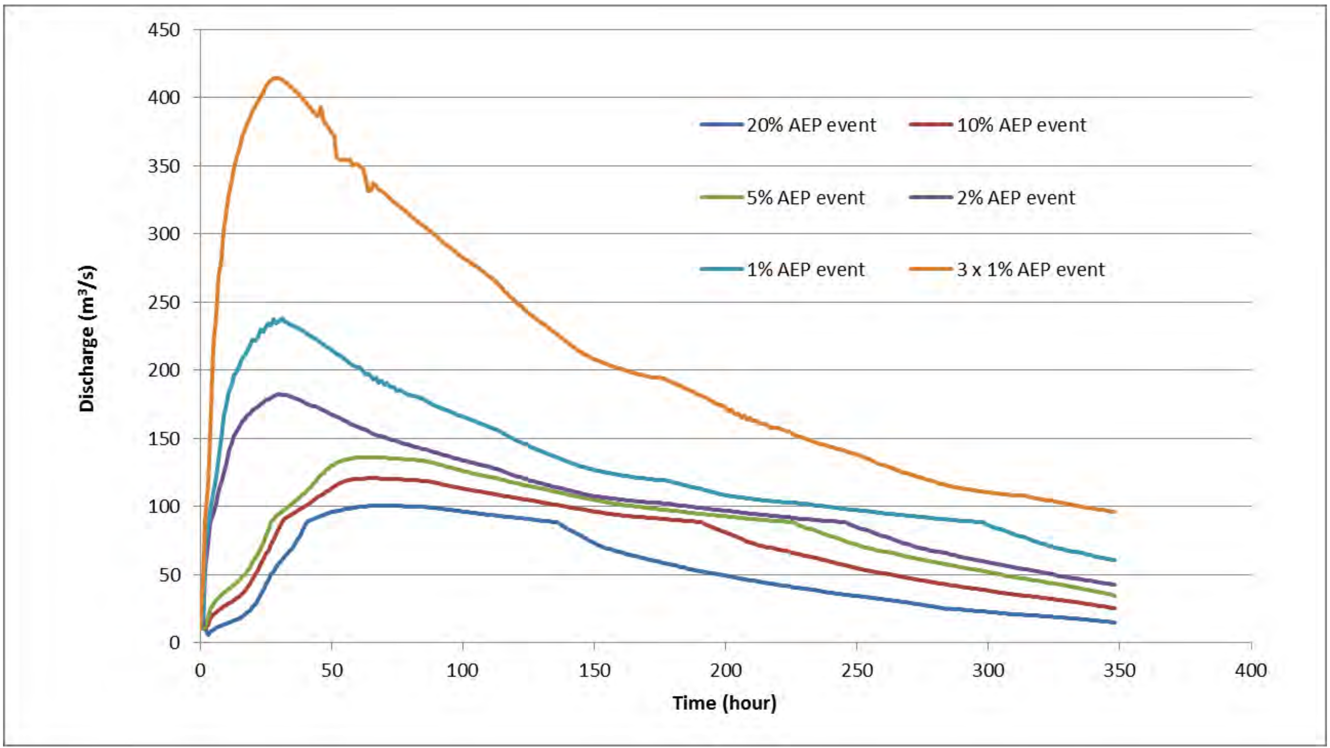


Figure 6-3 Modelled Design Discharge Hydrographs in Yanco Creek at Cross section "YANCO 35100"

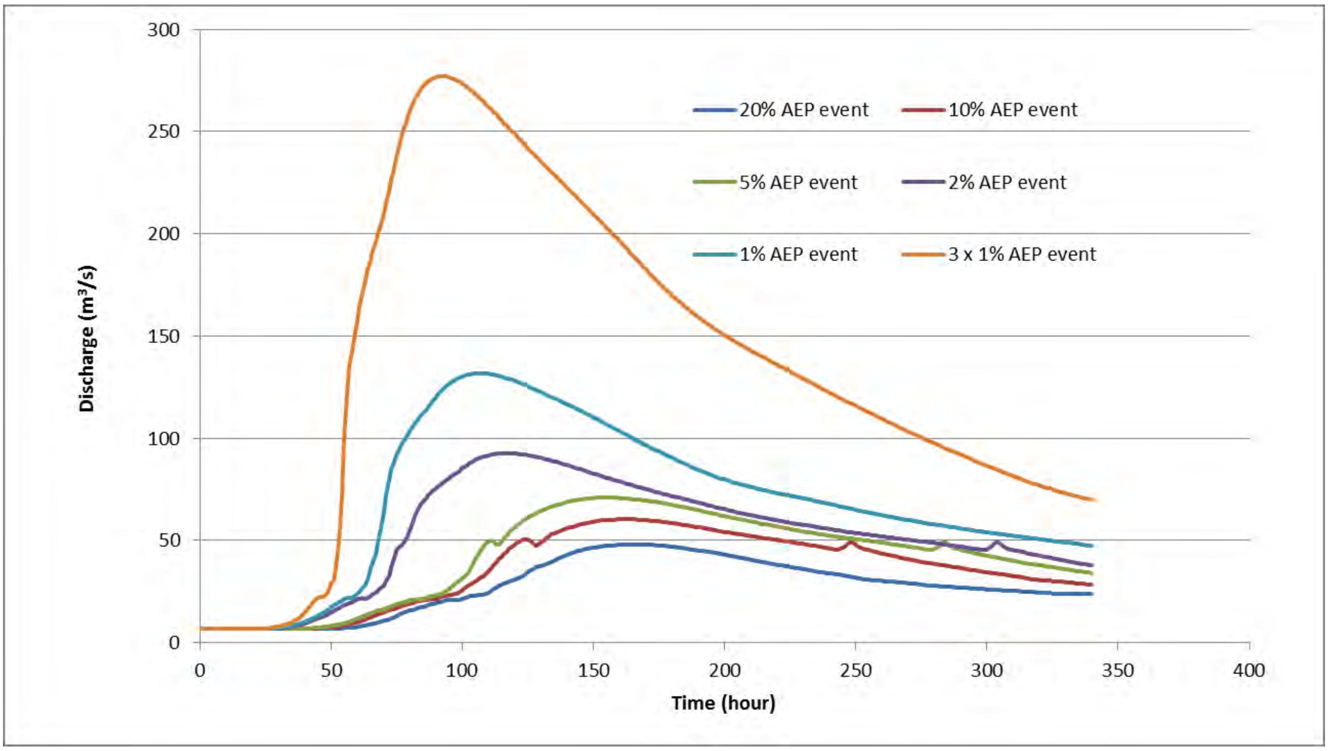
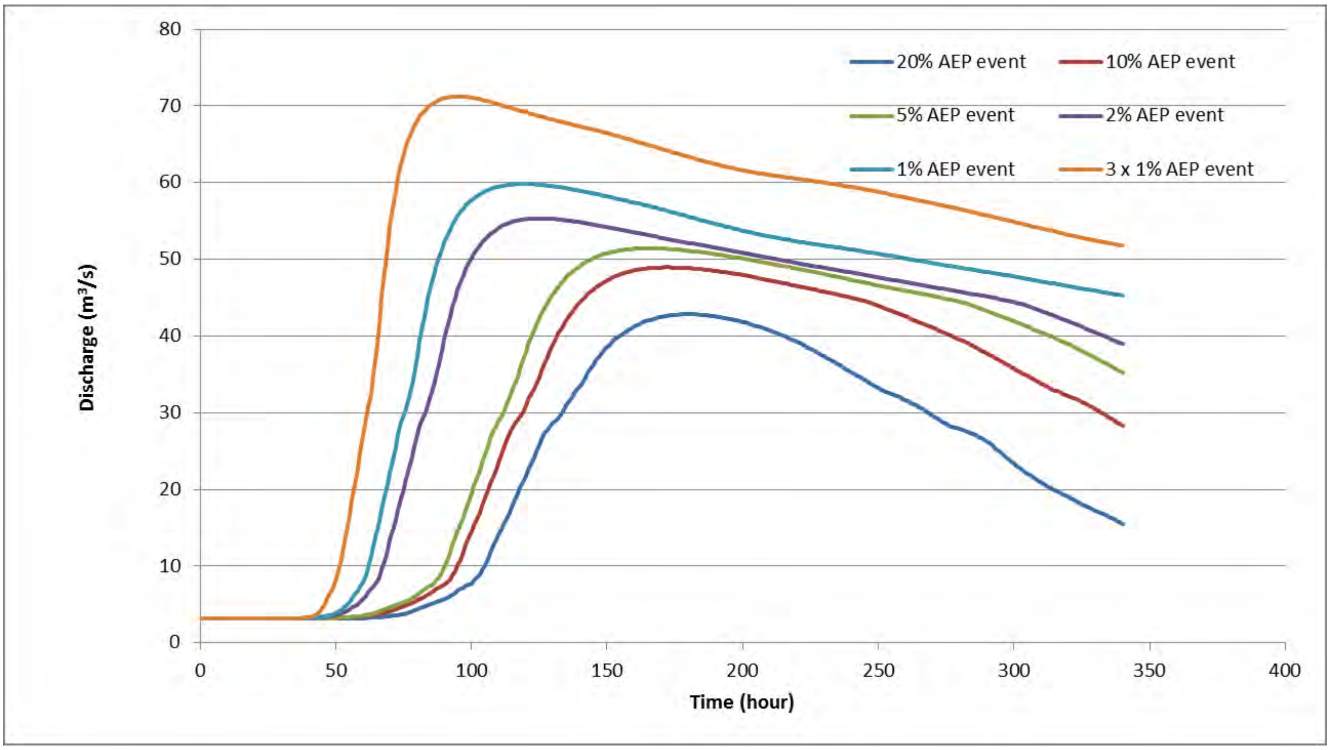


Figure 6-4 Modelled Design Discharge Hydrographs in Colombo Creek at Cross section "COLOMBO 29350"



The 0.5% and 0.2% AEP events were not assessed in the SKM 2009 study report and considering the small flood height range in Morundah, the MIKE11 modelled hydrographs for the 1% AEP event were scaled up to estimate discharge hydrographs in Yanco and Colombo Creeks for these two events. The scaled hydrographs were subsequently used in the TUFLOW model to define flood behaviour in Morundah for the 0.5% and 0.2% AEP events.

6.2.3 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.

6.2.4 Initial Conditions

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

6.2.5 Simulated Design Events

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

7. Flood Behaviour for Design Flood Events

7.1 Flood Depth Mapping

The maximum envelope of flood depth mapped for all design events are included in **Appendix E**. The following observations are made from the flood depth maps (refer **Figure E-1** to **Figure E-8**):

- In the 20% AEP event, properties located along the eastern side of Milvain Drive are subject to up to 0.5m depth of flooding due to local catchment runoff and Milvain Drive is generally flood free;
- Sections of Milvain Drive and a number of properties located along north-west of Goree Street and Yamma Street are subject to shallow flooding in the 5% AEP event; and
- The majority of the developed areas in Morundah are subject to shallow flooding in the 1% AEP event and the majority of the developed areas are subject to up to 0.5m flood depth in the 0.2% AEP event and all developed areas in Morundah are subject to more than 1m depth of flooding in the PMF event.

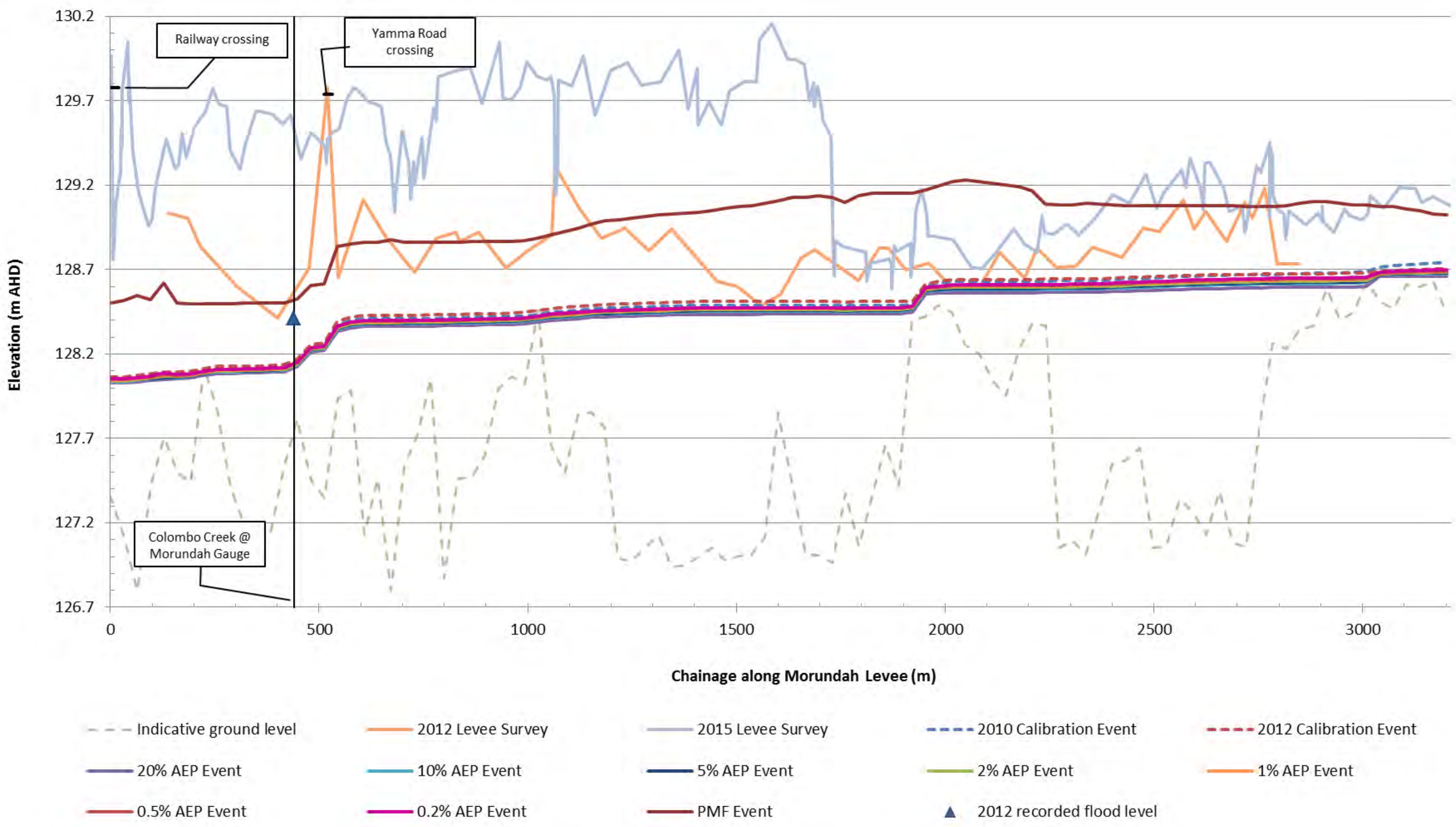
7.2 Flood Surface Profiles

The peak flood surface profiles are plotted in **Figure 7-1** for Colombo Creek located within the study area. **Figure 7-1** shows that the flood profiles for all modelled events are generally uniform and the Yamma Road Bridge impedes flood flow for all modelled events to some degree. However, the bridge is not overtopped in the PMF event. The maximum difference in peak water level for the 20% AEP and 0.2% AEP flood event is only 0.11m which is consistent with the observed small flood height range for historic flood events. The existing Morundah levee (2015 survey) is overtopped in the PMF event only. It is to be noted that the TUFLOW model underestimated the observed flood level at the gauge for the 2012 flood event and hence modelled flood profiles for the design events along the levee are also expected to be underestimated. Modelled flood profiles along the levee may need to be raised uniformly if the flood levels are to be used in any assessment involving the Morundah levee. **Table 7-1** shows the peak water levels at modelled waterway crossings.

Table 7-1 Modelled Peak Water Levels at Waterway crossings

Waterway Crossing	**Soffit Level** (mAHD)	**Deck Level** (mAHD)	**Peak Water Levels** (mAHD)				
			20% AEP	5% AEP	1% AEP	0.5% AEP	PMF
Colombo Ck - Yamma Road	128.59	129.74	128.34	128.35	128.36	128.37	128.84
Colombo Ck -Railway	129.08	129.78	128.01	128.02	128.03	128.03	128.46
Colombo Ck – Newell Hwy	128.98	129.48	127.91	127.91	127.92	127.92	128.20
Yanco Ck - Yamma Road	127.80	128.52	126.62	126.97	127.40	127.45	127.76
Yanco Ck - Local Road	127.42	127.92	126.40	126.77	127.19	127.25	127.63
Tributary of Colombo Ck - Railway	128.65	129.60	127.83	127.84	127.84	127.85	128.34
Tributary of Colombo Ck - Newell Hwy	128.47	129.52	127.83	127.84	127.84	127.85	128.27

Figure 7-1 Peak Water Level Profiles – Colombo Creek



7.3 Summary of Peak Flows

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

7.4 Provisional Flood Hazard Mapping

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

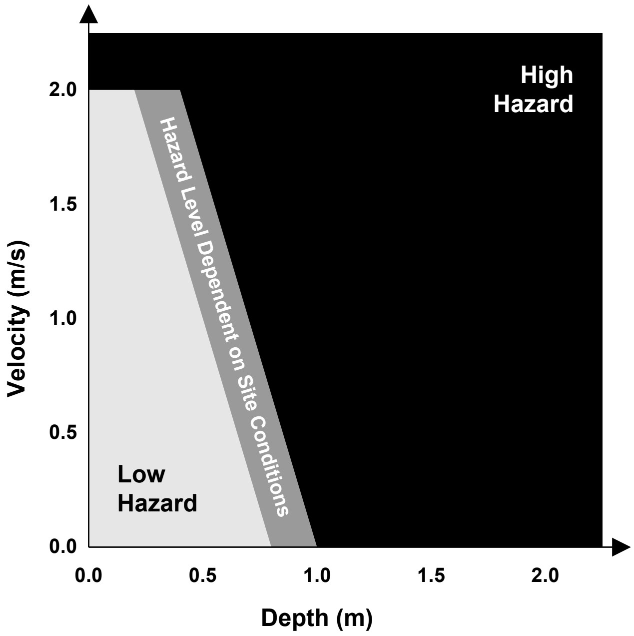


Figure 7-2 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)

Hazard categories delineated in this study are based on depths and velocities of floodwaters and do not consider evacuation, isolation, flood damages and social impacts of flooding, hence, these categories are considered provisional. The provisional flood hazard mapping is presented in **Figure E-9** to **E-11** in **Appendix E**. The figures show than the flood hazard is low in the developed areas in Morundah and hazard categories outside the town are approximate only.

7.5 Hydraulic Categories Mapping

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

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

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

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

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

Floodways estimated based on the above criteria are shown in **Appendix E** (**Figure E-12**). The area flooded in the 5% event is considerably more extensive than floodways identified using the other three criteria. Also the high hazard area in the 1% AEP event is more extensive than the other two criteria. An encroachment analysis was undertaken using the floodway defined by the four criteria. A final encroachment analysis was undertaken to ensure no increase in flood levels in excess of 0.1m. It is to be noted that the encroachment analysis was undertaken for the existing catchment and floodplain conditions. The flood hydraulic categories are mapped and presented in **Appendix E** (**Figure E-13**). It is to be noted that the hydraulic categories defined for the township (ie. bounded by Morundah levee) is reliable. However, the hydraulic categories defined for the area outside the township is approximate due to limited calibration of the TUFLOW model.

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 Morundah is included in **Appendix E** (**Figure E-14**). It is to be noted that the flood planning area defined for the township (ie. bounded by Morundah levee) is reliable. However, the flood planning area defined outside the township is approximate due to limited calibration of the TUFLOW model.

7.7 Flood Intelligence

Currently no flood intelligence card exists for the Colombo Creek @ Morundah gauge and a draft outline of the flood intelligence card is provided in Yeo, 2013.

7.8 Flood Emergency Response

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

Almost the entire village is impacted by flooding in the PMF event (refer to **Figure E-8**) with flood depths being greater than 1m deep. Access to the village is expected to be cutoff in the 1% AEP event and a number of roads within the village would be subject to up to 0.5m flooding in the 1% AEP event.

8. Conclusions

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

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

The available LiDAR survey for Morundah 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 the road and rail bridges that traverse the Yanco/Colombo Creek floodplain. The 2102 and 2015 survey undertaken by NSW Public Works of the Morundah Levee was also available.

Recent flood events of 2010 and 2012 were selected for calibration and verification of hydrologic and hydraulic models. The flood event of 2012 is the seventh largest flood on record in Colombo Creek @ Morundah gauge. SES undertook a detailed flood investigation on the impact of the recent flood events at Morundah.

A hydrologic model using XP-RAFTS was set up for the local catchment draining to Morundah to estimate overland flows for the 2010 and 2012 flood events. Gauged flows in Yanco Creek @ Offtake were used to estimate the mainstream flow in Yanco and Colombo Creeks at Morundah. A MIKE11 model was developed to route the gauged flows from the Murrumbidgee River to Morundah.

The TUFLOW hydraulic model for Morundah was developed utilising an 8m grid based on a 1m LiDAR DEM. The model included breaklines for the road and levee crests and included the surveyed bridges. Buildings were modelled as solid obstructions to the flow. The flows estimated in both Yanco and Colombo Creeks at Morundah from the MIKE11 model were used as inflows into a TUFLOW model for the 2010 and 2012 flood events. The peak flood levels modelled were within 0.23m of the gauge on Colombo Creek @ Morundah for the 2012 event and within 0.04m for the 2010 event. The modelled overland flows were consistent with the photographs, reports and other anecdotal evidence available for the 2012 flood event. These results confirm that the hydraulic model was reasonably calibrated. The TUFLOW model can be used to simulate design events with confidence within the town only.

A sensitivity analysis was undertaken to assess sensitivity in flood behaviour for the 2012 event due to the adopted rainfall losses, Manning's n values, blockage of structures and tailwater boundary conditions. A sensitivity analysis was undertaken using modelled inflow hydrographs provided by Lyall & Associates to improve MIKE11 calibration results. However, the hydrographs did not improve calibration results and consequently hydrographs provided for the design events were not utilised for simulation of design flood events.

Outcomes from the hydrologic and hydraulic model calibration and verification are considered reasonable for estimation of overland flood behaviour for the full range of design events for Morundah. Representation of flood behaviour due to mainstream flooding for the calibration and verification events is generally limited due to the complex flood behaviour, paucity of observed streamflow data and information on the operation of regulating structures during flood events. It is expected that the mainstream flood behaviour for Morundah would be reviewed and updated as part of the floodplain risk management study for Morundah.

The calibrated and verified XP-RAFTS, MIKE11 and TUFLOW models were utilised to define flood behaviour for the design flood events of 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events and the PMF. Outcomes from the flood modelling for the design events have been utilised to prepare flood extent maps, provisional hazard maps, flood hydraulic categories (ie. floodway, flood storage and flood fringe areas) and a flood planning area map. Modelling results were interrogated to identify major hydraulic controls in Morundah. Yamma Road Bridge on Colombo Creek is a significant hydraulic control in Morundah. Properties in the township are subject flooding due to rainfall runoff generated from the local catchments which drain through the town. Properties located along the eastern side of Milvain Drive are subject to up to 0.5m depth of flooding in the 20% AEP event. The entire town is subject to more than 1m depth of flooding in the PMF event. The entire town is located below 1% AEP flood level plus 0.5m freeboard (provisional flood planning level).

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 Morundah
- Federation Council
- Office of Environment and Heritage
- SES
- DPI Water

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11. Glossary

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

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

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

MGA	MGA is a metric grid system (i.e. east and north) and the unit of measure is the metre. It is a Cartesian coordinate system based on the Universal Transverse Mercator projection and the Geocentric Datum of Australia (GDA) 1994.
MIKE11	A computer program used for analysing behaviour of unsteady flow in open channels and floodplains.
MiRORB	A tool which uses the geographical information system MapInfo^{TM} 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: Survey of the Morundah Levee by NSW Public Works
- A4: Morundah 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.

Image 30 shows structure 10 facing upstream.

Image 30: Structure 10 facing upstream.

Morundah

11: Bridge

Structure 11 is a small bridge over Colombo creek 1.5km north of Morundah

Table 11 shows the pertinent physical information about the structure.

Bridge 11

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	434454.73	6135627.49	434475.66	6135630.51
Levels	Start	Middle	End	
Deck	129.83	129.89	129.84	
Underside	129.07	129.13	129.08	
Length	21.15			
Width	4.30			
Height Rails/Barriers	0.00			

Table 11: Structure 11 details.

Image 31 shows structure 11 facing downstream.

Image 31: Structure 11 facing downstream.

Image 32 shows the structure 11 facing upstream.

Image 32: Structure 11 facing upstream.

12: Culvert

Structure 12 is a Culvert under the Yamma Road 1.2km west of Morundah.

Table 12 shows the pertinent physical information about the structure.

Culvert 12

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	434787.65	6133816.36	434792.19	6133804.35
Length	12.84			
Dimensions (HxW)	0.62x2.05			
Number of Cells	2			
	Cell 1		Cell 2	
	Upstream	Downstream	Upstream	Downstream
Invert Levels (AHD m)	126.22	126.08	126.20	126.06
Blockage %	5	5	0	0

Table 12: Structure 12 details.

Image 33 shows structure 12 facing downstream.

Image 33: Structure 12 facing downstream.

Image 34 shows structure 12 facing upstream.

Image 34: Structure 12 facing upstream.

13: Culvert

Structure 13 is a culvert under Yamma Road 500m west of Morundah. Despite little recent rain this culvert was flowing under pressure. No other culverts were flowing during this survey. It would seem this culvert is a significant control structure in the flow of Yanco Creek.

Table 13 shows the pertinent physical information about the structure. The blockage could not be ascertained as the culvert was under pressurised flow. The authors assume blockage would be minimal due to large consistent flow rate but this could not be confirmed.

Culvert 13

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	435505.49	6133717.58	435500.66	6133704.32

Length	14.10	
Dimensions (Diameter)	0.600	
Number of Cells	1	
	Cell 1	
	Upstream	Downstream
Invert Levels (AHD m)	125.57	125.52
Blockage %	N/A	N/A

Table 13: Structure 13 details.

Image 35 shows structure 13 facing downstream.

Image 35: Structure 13 facing downstream.

Image 36 shows structure 13 facing upstream.

Image 36: Structure 13 facing upstream.

14: Bridge

Structure 14 is a bridge over Colombo Creek 300m west of Morundah.

Table 14 shows the pertinent physical information about the structure.

Bridge 14

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	435657.96	6133731.81	435649.55	6133723.07
Levels	Start		End	
Deck	129.72		129.76	
Underside	128.57		128.61	
Length	12.10			
Width	5.80			
Height Rails/Barriers	0.85			

Table 14: Structure 14 details.

Image 37 shows the structure 14 facing downstream.

Image 37: Structure 14 facing downstream.

Image 38 shows structure 14 facing upstream.

Image 38: Structure 14 facing upstream.

15: Culvert

Structure 15 is a mostly blocked culvert under Yabtree Street on the Western edge of Morundah.

Table 15 shows the pertinent physical information about the structure.

Culvert 15

	Inlet		Outlet	
	Easting	Northing	Easting	Northing
Coordinates	435966.74	6133949.46	435973.06	6133938.66
Length	12.50			
Dimensions (Diameter)	0.375			
Number of Cells	1			
	Cell 1			
	Upstream	Downstream		
Invert Levels (AHD m)	126.82	126.66		
Blockage %	90	20		

Table 15: Structure 15 details.

Image 39 shows structure 15 facing downstream.

Image 39: Structure 15 facing downstream.

Image 40 shows structure 15 facing upstream.

Image 40: Structure 15 facing upstream.

16: Bridge

Structure 16 is a dilapidated rail bridge crossing the Colombo Creek south of Morundah. This bridge is in a bad state of disrepair. Much of the lower course of sleepers have disintegrated and most of the bridge bourne balast is gone.

Table 16 shows the pertinent physical information about the structure.

Bridge 16

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	436041.47	6133511.10	436075.94	6133539.09
Levels	Start	Middle	End	
Deck	129.78	129.76	129.79	
Underside	129.08	129.06	129.09	
Length	44.40			
Width	3.90			
Height Rails/Barriers	0.00			

Table 16: Structure 16 details.

Image 41 shows the structure 16 facing downstream.

Image 41: Structure 16 facing downstream.

Image 42 shows the structure 16 facing upstream.

Image 42: Structure 16 facing upstream.

17: Bridge

Structure 17 is a substantial road bridge on the Newell Highway over the Colombo Creek.

Table 17 shows the pertinent physical information about the structure.

Bridge 17

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	436184.81	6133316.02	436218.18	6133352.07
Levels	Start	Middle	End	
Deck	129.51	129.48	129.44	
Underside	129.01	128.98	128.94	
Length	45.62			
Width	11.00			
Height Rails/Barriers	1.00			

Table 17: Structure 17 details.

Image 43 shows the structure 17 facing downstream.

Image 43: Structure 17 facing downstream.

Image 44 shows the structure 17 facing upstream.

Image 44: Structure 17 facing upstream.

18: Bridge

Structure 18 is a rail bridge that crosses the Colombo Creek flood plain just to the southwest of the Colombo Creek North West of the Newell Highway Newell Highway.

Table 18 shows the pertinent physical information about the structure.

Bridge 18

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	435866.45	6133247.08	435880.95	6133271.81
Levels	Start	Middle	End	
Deck	129.65	129.58	129.58	
Underside	128.70	128.63	128.63	
Length	28.66			
Width	3.70			
Height Rails/Barriers	0.00			

Table 18: Structure 18 details.

Image 45 shows the structure 18 facing downstream.

Image 45: Structure 18 facing downstream.

Image 46 shows the structure 18 facing upstream.

Image 46: Structure 18 facing upstream.

19: Bridge

Structure 19 is a bridge that crosses the Colombo Creek flood plain just to the southwest of the Colombo Creek along the Newell Highway Newell Highway.

Table 19 shows the pertinent physical information about the structure.

Bridge 19

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	436051.12	6133171.10	436066.27	6133187.46
Levels	Start	Middle	End	
Deck	129.49	129.59	129.48	
Underside	128.44	128.54	128.43	
Length	22.30			
Width	11.10			
Height Rails/Barriers	1.00			

Table 19: Structure 19 details.

Image 47 shows structure 19 facing downstream.

Image 47: Structure 19 facing downstream.

Image 48 shows the structure 19 facing upstream.

Image 48: Structure 19 facing upstream.

20: Bridge

Structure 20 is a relatively new bridge that crosses the Yanco Creek along the Yamma Road.

Table 20 shows the pertinent physical information about the structure.

Bridge 20

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	433189.21	6132455.72	433229.95	6132446.93
Levels	Start	Middle	End	
Deck	128.53	128.52	128.50	
Underside	127.81	127.80	127.78	
Length	41.67			
Width	8.80			
Height Rails/Barriers	0.82			

Table 20: Structure 20 details.

Image 49 shows structure 20 facing downstream.

Image 49: Structure 20 facing downstream.

Image 50 shows the structure 20 facing upstream.

Image 50: Structure 20 facing upstream.

21: Bridge

Structure 21 is a bridge crossing Yanco Creek on the old Yamma Road.

Table 21 shows the pertinent physical information about the structure.

Bridge 21

	Start Centreline		End Centreline	
	Easting	Northing	Easting	Northing
Coordinates	433224.78	6132340.38	433251.07	6132348.22
Levels	Start	Middle	End	
Deck	127.81	127.92	128.04	
Underside	127.31	127.42	127.54	
Length	27.43			
Width	4.45			
Height Rails/Barriers	0.47			

Table 21: Structure 21 details.

Image 51 shows the structure 21 facing downstream.

Image 51: Structure 21 facing downstream.

Image 52 shows the structure 21 facing upstream.

Image 52: Structure 21 facing upstream.

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

Morundah

Tarabah Weir

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

Table 44 shows the pertinent details about Tarabah Weir.

Tarabah Weir

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

Table 44: Tarabah Weir

Image 124 shows Tarabah Weir facing downstream.

Image 124: Tarabah Weir facing downstream.

Image 125 shows Tarabah Weir facing upstream.

Image 125:Tarabah Weir facing upstream.

Gauging Station 41000213

Gauging Station 41000213 is located north of Tarabah Weir.

Table 45 shows the pertinent details about Gauging Station 41000213.

Gauging Station 41000213	
Height of Gauge Measured	3
AHD	129.5
Gauge 0 AHD	126.5
Office of Water AHD	N/A

Table 45: Gauging Station 41000213.

Image 126 shows Gauging Station 41000213.

Image 126: Gauging Station 41000213.

Gauging Station 41000212 is downstream from Tarabah Weir and is on the same datum.

Gauging Station 410015

Table 46 shows the pertinent details about Gauging Station 410015.

Gauging Station 410015	
Height of Gauge Measured	4.1
AHD	127.66
Gauge 0 AHD	123.56
Office of Water AHD	123.58

Table 46: Tarabah Weir

Image 127 shows Gauging Station 410015.

Image 127: Gauging Station 410015.

Yanco (South)

Yanco Weir

Yanco Weir is a substantial Weir on the Murrumbidgee River just downstream (west) from the Junction with Yanco Creek.

Table 47 shows the pertinent details about Yanco Weir.

Yanco Weir

	Easting	Northing
Start Gate	446607.15	6159687.2
End Gate	446615.22	6159698.27
Gates	2	
Gate Invert	134.05	
Gate Top	141.7	
Spill Size (HxW)	7.65x12	
Gate Size (HxW)	3.3x12	
Automatic/Manual	2/0	
Level Below Spillgate	132.5	

Table 47: Yanco Weir.

Image 128 shows Yanco Weir facing downstream.

Image 128: Yanco Weir facing downstream.

Image 129 shows Yanco Weir facing upstream.

Image 129: Yanco Weir facing upstream.

Old Yanco Weir

The Old Yanco Weir has been shut down and blocked since the establishment of the (new) Yanco Weir. The Old Yanco Weir now serves as a spillway. The method for blocking the weir was to block the gates and shutes, as such it is a consistent spillway that has been mapped and included in the associated dxf.

Table 48 shows the pertinent details about The Old Yanco Weir.

Old Yanco Weir

Spill Length	75.5
Spill Crest AHD	137.11

Table 48: The Old Yanco Weir

Image 130 shows The Old Yanco Weir as it used to operate

Image 130: The Old Yanco Weir.

Gauging Station 41010981

Gauging Station 41010981 is located just upstream of the Yanco Weir.

Table 49 shows the pertinent details about Gauging Station 41010981.

Gauging Station 41010981	
Height of Gauge Measured	5
AHD	139.01
Gauge 0 AHD	134.01
Office of Water AHD	134.09

Table 49: Gauging Station 41010981.

Image 131 shows Gauging Station 41010981.

Image 131: Gauging Station 41010981.

Regulators

Spiller's Regulator

Spiller's Regulator is on Back Creek just downstream from Yanco Creek. This old regulator is rarely maintained and verbal advice from Water NSW is that the gate is not adjusted with low flow allowed under the gate continually.

Table 50 shows the pertinent details about Spiller's Regulator.

Spiller's Regulator

	Easting	Northing
Start Gate	439307.68	6150947.58
Gates	1	
Type	Vertical	
Gate Invert	131.85	
Gate Top	133.09	
Gate Size (HxW)	1.24x1.80	
Automatic/Manual	0/1	

Table 50: Spiller's Regulator.

Image 132 shows Spiller's Regulator facing downstream.

Image 132: Spiller's Regulator facing downstream.

Image 133 shows Spiller's Regulator facing upstream.

Image 133: Spiller's Regulator facing upstream.

Molley's Regulator

Molley's Regulator controls the flow from/to Molley's Lagoon. It is relatively new.

Table 51 shows the pertinent details about Molley's Regulator.

Molley's Regulator

	Easting	Northing
Start Gate	441029.71	6156621.8
Gates	1	
Type	Radial	
Gate Invert	135.67	
Gate Top	137.31	
Gate Size (HxW)	1.64x1.56	
Automatic/Manual	0/1	

Table 51: Molley's Regulator.

Image 134 shows Molley's Regulator facing downstream.

Image 134: Molley's Regulator facing downstream.

Image 135 shows Molley's Regulator facing upstream.

Image 135: Molley's Regulator facing upstream.

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/bridges surveyed
- Railway
- Watercourses

GDA 1994 MGA Zone 55
Scale: A3

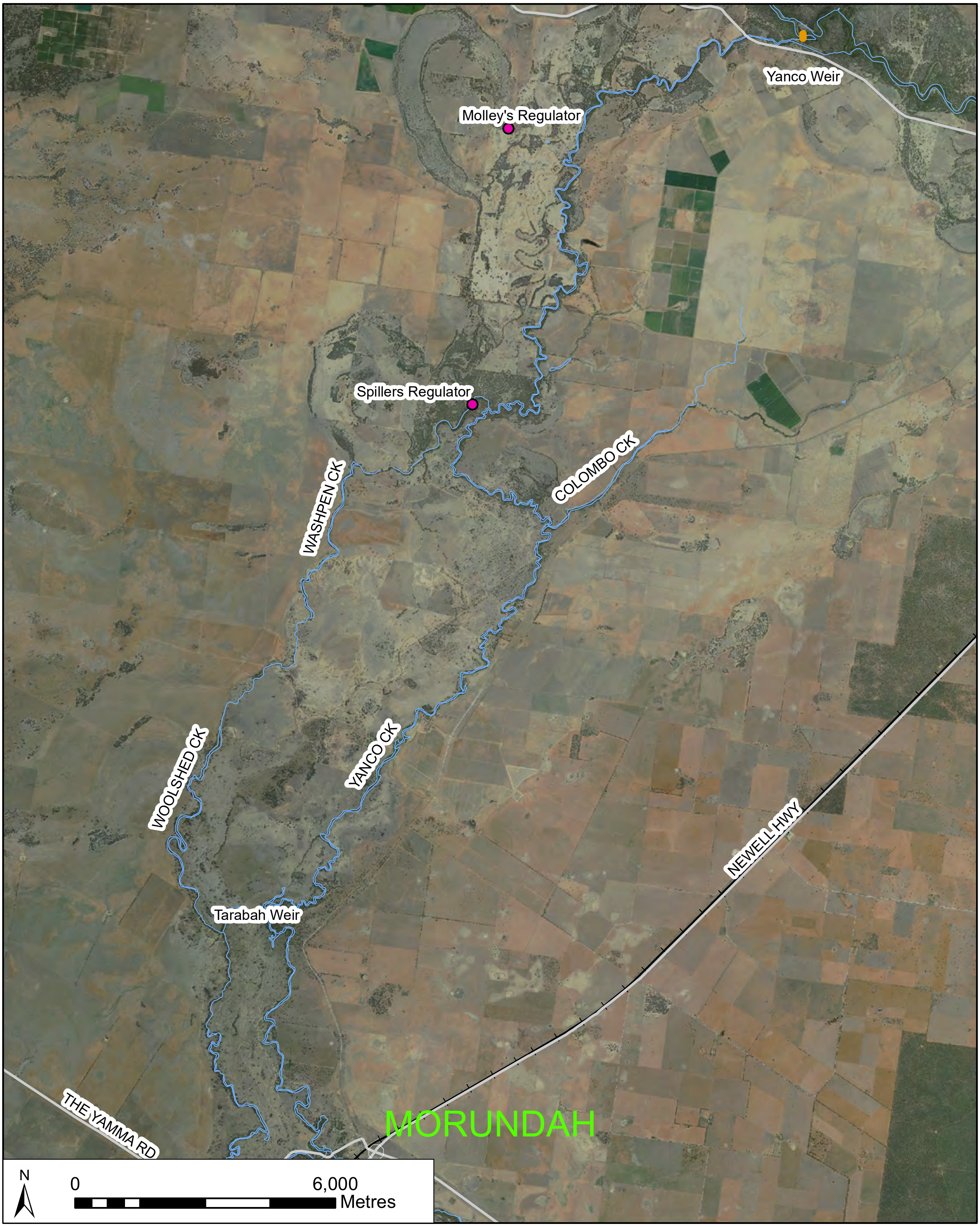
Data Sources: LPI, OEH, Council

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 Sheet 1
TOWN	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN	MR	PROJECT #	IA055600	APPENDIX A-2
CHECK	AH	DATE	30/08/2017	



Legend

- Weirs surveyed
- Regulators surveyed
- Major Roads
- Railway
- Watercourses

JACOBS

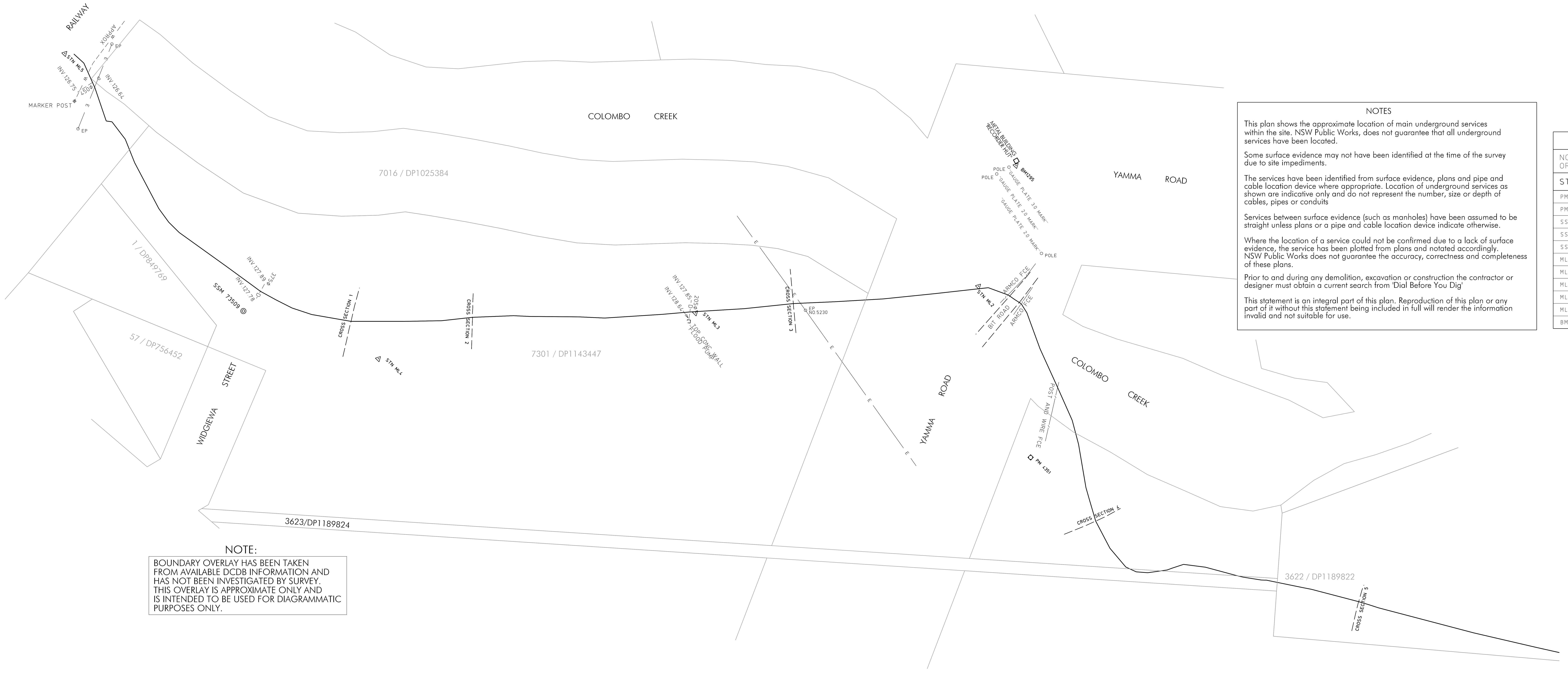
GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, 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.

TITLE	Topographic Survey Sheet 2
TOWN	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN MR	PROJECT # IA055600	APPENDIX A-2
CHECK AH	DATE 30/08/2017	



NOTE:
BOUNDARY OVERLAY HAS BEEN TAKEN FROM AVAILABLE DCDB INFORMATION AND HAS NOT BEEN INVESTIGATED BY SURVEY. THIS OVERLAY IS APPROXIMATE ONLY AND IS INTENDED TO BE USED FOR DIAGRAMMATIC PURPOSES ONLY.

NOTES

This plan shows the approximate location of main underground services within the site. NSW Public Works, does not guarantee that all underground services have been located.

Some surface evidence may not have been identified at the time of the survey due to site impediments.

The services have been identified from surface evidence, plans and pipe and cable location device where appropriate. Location of underground services as shown are indicative only and do not represent the number, size or depth of cables, pipes or conduits

Services between surface evidence (such as manholes) have been assumed to be straight unless plans or a pipe and cable location device indicate otherwise.

Where the location of a service could not be confirmed due to a lack of surface evidence, the service has been plotted from plans and notated accordingly. NSW Public Works does not guarantee the accuracy, correctness and completeness of these plans.

Prior to and during any demolition, excavation or construction the contractor or designer must obtain a current search from 'Dial Before You Dig'

This statement is an integral part of this plan. Reproduction of this plan or any part of it without this statement being included in full will render the information invalid and not suitable for use.

STATION CO-ORDINATE SCHEDULE

NOTE GRID BASED ON M.G.A CO-ORDINATE ADOPTED FOR PM4351
ORIENTATION OF GRID PM4351 TO PM4352 BEARING 208° 24′ 07″

STATION	EASTING	NORTHING	HEIGHT	DESCRIPTION
PM4351	435666.406	6133816.888	127.747	PIN IN METAL BOX FD
PM4352	433076.621	6129027.590	126.458	PIN IN METAL BOX FD
SSM2673	437043.011	6134076.733	128.170	BRASS PLAQUE SET IN CONC FD
SSM2674	434417.410	6133544.347	127.578	BRASS PLAQUE SET IN CONC FD
SSM73509	436034.095	6133711.381	128.315	BRASS PLAQUE SET IN CONC FD
ML1	433779.875	6132146.953	126.436	DUMPY
ML2	435683.387	6133733.111	129.450	PEG
ML3	435819.165	6133732.872	129.633	PEG
ML4	435972.070	6133740.237	128.145	PEG
ML5	436107.313	6133580.805	130.000	CLOUT IN RAILWAY SLEEPER
BM1295	435660.036	6133677.374	127.489	IRON ROD IN METAL BOX FD

ZERO GAUGE PLATE = HT.125.451

LEGEND

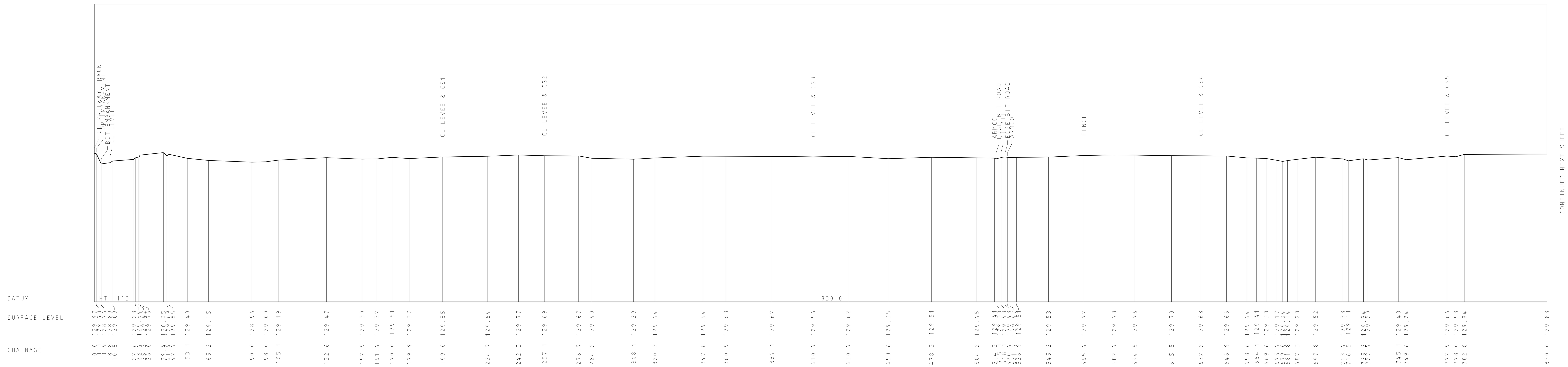
UNDERGROUND SERVICES — ABOVEGROUND SERVICES

- W — WATER — W
- T — TELECOMMUNICATION — T
- S — SEWER — S
- D — DRAINAGE — D
- E — ELECTRICITY — E
- DISH DRAIN
- GRATE
- FS — FIRE — FS
- F — FUEL — F
- G — GAS — G
- I — IRRIGATION — I

STOP VALVE; HYDRANT; WATER METER; WPIT WATER PIT; SMH SEWER MANHOLE; SWGRATE STORMWATER GRATE; SWPIT STORMWATER PIT; TEL PIT TELSTRA PIT; EJ TELSTRA ELEVATED JOINT; EP ELECTRICITY POLE; LP LIGHT POLE; TOP OF BANK; BOTTOM OF BANK

AIR VALVE; DOUBLE AIR VALVE; ELECTRICAL METER; GAS METER; GULLY PIT STORMWATER GULLY PIT; I/O INSPECTION OPENING; MANHOLE; PUMP STATION; INACCESSIBLE PIT

MGA NORTH



CREST LEVEL - MORUNDAH LEVEE

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

SERVICE DETAILS
A) visual evidence is shown to survey accuracy
B) inverts & diameters are shown where reasonable access was obtained
C) direction of services shown have been derived from visual evidence and when in agreement with Service Authority WAE drawings
D) direction of services NOT SHOWN is due to an uncertainty when comparing visual location with service diagrams
E) service details should be confirmed with the relevant Service Authorities during design and prior to construction

CAUTION
THIS SURVEY HAS BEEN CARRIED OUT FOR THE PRODUCTION OF PLANS AT A REDUCTION RATIO OF 1:1000H 200V FOR THE PURPOSE OF DESIGN AND SHOULD NOT BE USED FOR ANY OTHER PURPOSE. DISTANCES SCALED MAY BE INACCURATE

0 10 20 40 60 80 100
HORIZONTAL REDUCTION RATIO 1:1000 METRES
0 2 4 8 12 16 20
VERTICAL REDUCTION RATIO 1:200 METRES

DATUM AHD
ORIGIN OF LEVELS PM4351 HT.127.747
AZIMUTH
FOLDER B5002 LB FB
L.G.A. URANA
SURVEYOR D.BURNETT
SURVEY DATE 19/22-01-2015 FILE
CADD D.D.P

SURVEYING & SPATIAL INFORMATION SERVICES
LEVEL 14 McKELL BUILDING
2 - 24 RAWSON PLACE, SYDNEY NSW 2000
TEL: (02) 9372 7980 FAX: (02) 9372 7922

VERIFIED D.BURNETT 9/02/2015
VALIDATED A.VEERSEMA 11/02/2015
APPROVED MANAGER S.SAUNDERS 11/02/2015

NSW GOVERNMENT Public Works

URANA SHIRE COUNCIL N.S.W. 1906

MORUNDAH LEVEE
CREST LEVEL SURVEY

ROUTE PLAN LONGITUDINAL SECTION
CH.0.0 - CH.830.0

PLAN RM NO 57288
NO IN SET 6
SCALES HOR1:1000 VER 1:200 @B1
SHEET NO 1
DESIGNED DATE
DRAFTED VERIFIED

NOTES

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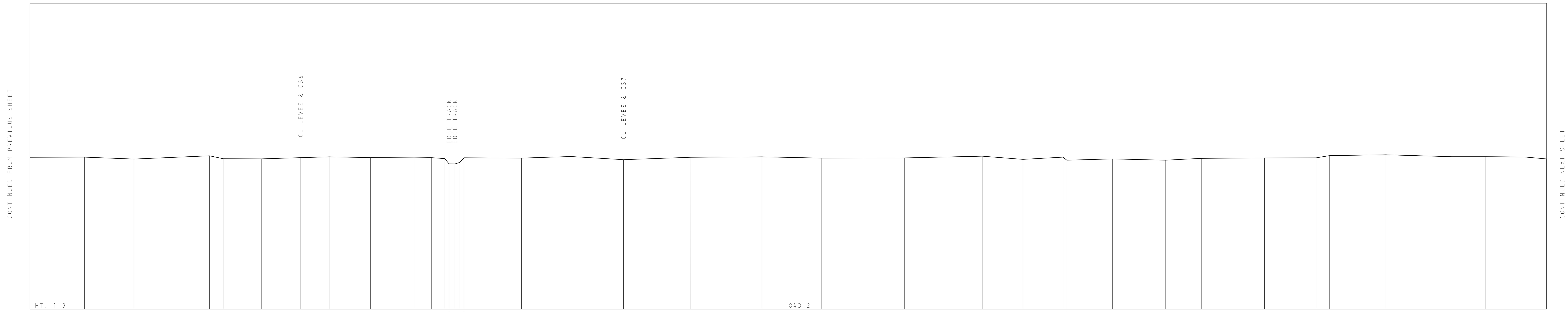

DATUM HT. 113 — 843.2

CHAINAGE	SURFACE LEVEL
830.0	129.88
860.3	129.90
887.8	129.69
929.8	130.04
937.5	129.72
958.8	129.71
980.5	129.84
996.4	129.93
1019.3	129.85
1043.6	129.82
1053.2	129.84
1060.6	129.73
1063.0	129.15
1066.3	129.14
1069.0	129.31
1071.3	129.82
1103.3	129.79
1130.7	129.97
1160.0	129.62
1197.4	129.88
1237.0	129.93
1270.0	129.79
1316.2	129.81
1359.5	130.00
1382.1	129.65
1404.3	129.89
1406.5	129.56
1431.9	129.70
1461.3	129.56
1481.3	129.76
1516.4	129.81
1545.1	129.82
1552.6	130.06
1583.9	130.16
1620.5	129.94
1639.4	129.95
1660.8	129.91
1673.2	129.70

CREST LEVEL - MORUNDAH LEVEE

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

SERVICE DETAILS
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CAUTION
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0 10 20 40 60 80 100
HORIZONTAL REDUCTION RATIO 1:1000 METRES
0 2 4 8 12 16 20
VERTICAL REDUCTION RATIO 1:200 METRES

DATUM AHD
ORIGIN OF LEVELS PM4351 HT.127.747
AZIMUTH MGA ZONE 55
FOLDER B5002 LB FB
L.G.A. URANA
SURVEYOR D.BURNETT
SURVEY DATE 19/22-01-2015 FILE
CADD D.D.P

SURVEYING & SPATIAL INFORMATION SERVICES
LEVEL 14 McKELL BUILDING
2 - 24 RAWSON PLACE, SYDNEY NSW 2000
TEL: (02) 9372 7980 FAX: (02) 9372 7922

VERIFIED D.BURNETT 9/02/2015
VALIDATED A.VEERSEMA 11/02/2015
APPROVED MANAGER S.SAUNDERS 11/02/2015

NSW GOVERNMENT Public Works

URANA SHIRE COUNCIL N.S.W.

MORUNDAH LEVEE
CREST LEVEL SURVEY

ROUTE PLAN LONGITUDINAL SECTION
CH.830.0 - CH.1673.2

PLAN RM NO 57288
SCALES HOR1:1000 VER 1:200 @B1
DESIGNED | DATE
DRAFTED | VERIFIED
NO IN SET 6
SHEET NO 2

12:19:47 PM11/02/2015 piccolod

NOTES

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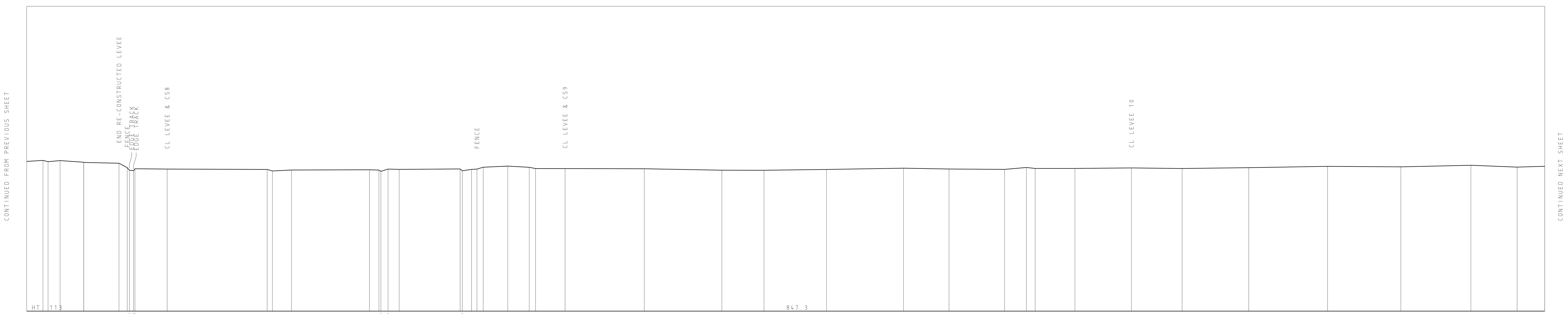

CHAINAGE	SURFACE LEVEL
1673.2	129.70
1682.3	129.81
1685.1	129.66
1691.8	129.79
1705.0	129.60
1724.7	129.49
1729.3	129.01
1730.5	128.72
1732.8	128.66
1733.6	128.87
1751.6	128.84
1807.4	128.80
1810.3	128.63
1821.0	128.74
1864.5	128.76
1869.8	128.73
1870.9	128.59
1874.9	128.84
1881.1	128.81
1915.1	128.86
1916.3	128.65
1921.5	128.80
1924.5	128.84
1928.0	129.05
1941.7	129.18
1953.7	129.04
1957.2	128.90
1973.7	128.90
2017.9	128.88
2061.2	128.71
2084.7	128.71
2119.6	128.80
2162.6	128.94
2188.0	128.85
2219.0	128.80
2231.2	129.02
2236.1	128.92
2258.3	128.91
2289.8	128.97
2318.1	128.91
2355.3	129.00
2399.3	129.14
2440.2	129.09
2479.3	129.27
2505.1	129.06
2520.5	129.16

CREST LEVEL - MORUNDAH LEVEE

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

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0 10 20 40 60 80 100
HORIZONTAL REDUCTION RATIO 1:1000 METRES
0 2 4 8 12 16 20
VERTICAL REDUCTION RATIO 1:200 METRES

DATUM AHD
ORIGIN OF LEVELS PM4351 HT.127.747
AZIMUTH MGA ZONE 55
FOLDER B5002 LB FB
L.G.A. URANA
SURVEYOR D.BURNETT
SURVEY DATE 19/22-01-2015 FILE
CADD DDP

SURVEYING & SPATIAL INFORMATION SERVICES
LEVEL 14 MCKELL BUILDING
2 - 24 RAWSON PLACE, SYDNEY NSW 2000
TEL: (02) 9372 7980 FAX: (02) 9372 7922

VERIFIED D.BURNETT 9/02/2015
VALIDATED A.VEERSEMA 11/02/2015
APPROVED MANAGER S.SAUNDERS 11/02/2015

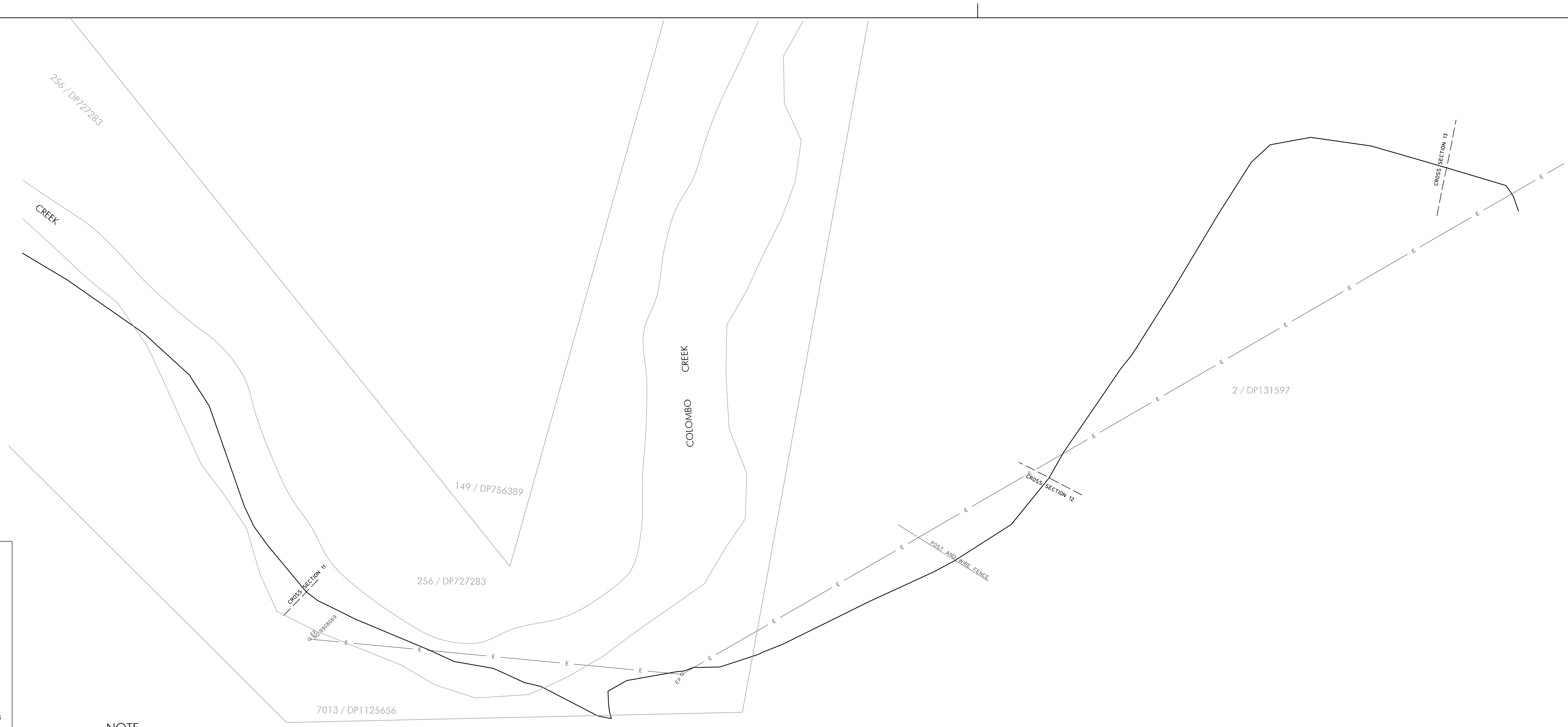
NSW Public Works

URANA SHIRE COUNCIL N.S.W.

MORUNDAH LEVEE CREST LEVEL SURVEY

ROUTE PLAN LONGITUDINAL SECTION
CH.1673.2 - CH.2520.5

PLAN RM NO 57288
NO IN SET 6
SCALES HOR1:1000 VER 1:200 @B1
DESIGNED DATE
DRAFTED VERIFIED
SHEET NO 3



LEGEND

UNDERGROUND SERVICES		ABOVEGROUND SERVICES
W	WATER	W
T	TELECOMMUNICATION	T
S	SEWER	S
D	DRAINAGE	D
E	ELECTRICITY	E
	DISH DRAIN	
	GRATE	
FS	FIRE	FS
F	FUEL	F
G	GAS	G
I	IRRIGATION	I

	STOP VALVE		AIR VALVE
	HYDRANT		DOUBLE AIR VALVE
	WATER METER		ELECTRICAL METER
WPIT	WATER PIT		GAS METER
SMH	SEWER MANHOLE		GULLY PIT STORMWATER GULLY PIT
SWGRATE	STORMWATER GRATE	I/O	INSPECTION OPENING
SWPIT	STORMWATER PIT		MANHOLE
TEL PIT	TELSTRA PIT		PUMP STATION
EJ	TELSTRA ELEVATED JOINT		
EP	ELECTRICITY POLE		INACCESSIBLE PIT
LP	LIGHT POLE		
	TOP OF BANK		
	BOTTOM OF BANK		

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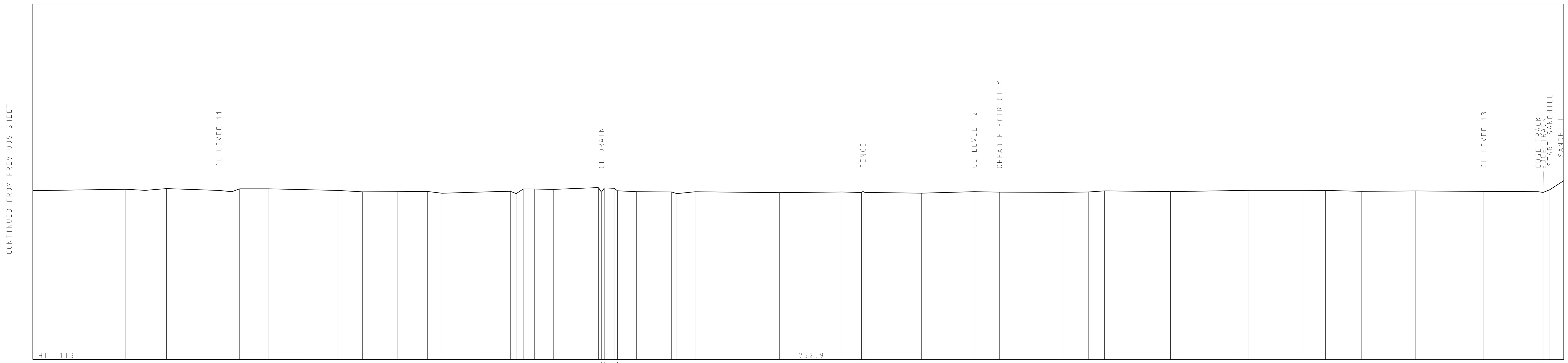

DATUM

CHAINAGE	SURFACE LEVEL
2520.5	129.16
2565.1	129.29
2574.4	129.19
2584.6	129.36
2609.7	129.18
2615.9	129.06
2619.6	129.33
2633.3	129.34
2666.6	129.18
2678.4	129.04
2695.1	129.06
2709.5	129.08
2716.5	128.91
2743.4	129.08
2749.2	129.09
2752.0	128.88
2755.4	129.32
2760.8	129.32
2769.8	129.28
2791.4	129.45
2792.8	129.01
2794.9	129.42
2798.9	129.38
2800.5	129.14
2809.6	129.06
2826.4	129.03
2828.9	128.88
2837.7	129.05
2878.0	128.97
2908.0	129.03
2917.3	128.98
2918.0	129.08
2918.9	128.99
2946.0	128.92
2971.2	129.06
2983.4	129.02
3013.8	129.00
3025.9	129.03
3033.6	129.14
3065.2	129.07
3102.7	129.19
3128.6	129.18
3139.4	129.18
3156.7	129.10
3182.4	129.13
3215.2	129.09
3241.2	129.06
3243.6	128.99
3246.8	129.25
3253.4	130.11

CREST LEVEL - MORUNDAH LEVEE

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0 10 20 40 60 80 100
HORIZONTAL REDUCTION RATIO 1:1000 METRES
0 2 4 8 12 16 20
VERTICAL REDUCTION RATIO 1:200 METRES

DATUM AHD
ORIGIN OF LEVELS PM4351 HT.127.747
AZIMUTH MGA ZONE 55
FOLDER B5002 LB FB
L.G.A. URANA
SURVEYOR D.BURNETT
SURVEY DATE 19/22-01-2015 FILE
CADD D.D.P

SURVEYING & SPATIAL INFORMATION SERVICES
LEVEL 14 McKELL BUILDING
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TEL: (02) 9372 7980 FAX: (02) 9372 7922

VERIFIED D.BURNETT 9/02/2015
VALIDATED A.VEERSEMA 11/02/2015
APPROVED MANAGER S.SAUNDERS 11/02/2015

NSW GOVERNMENT | Public Works

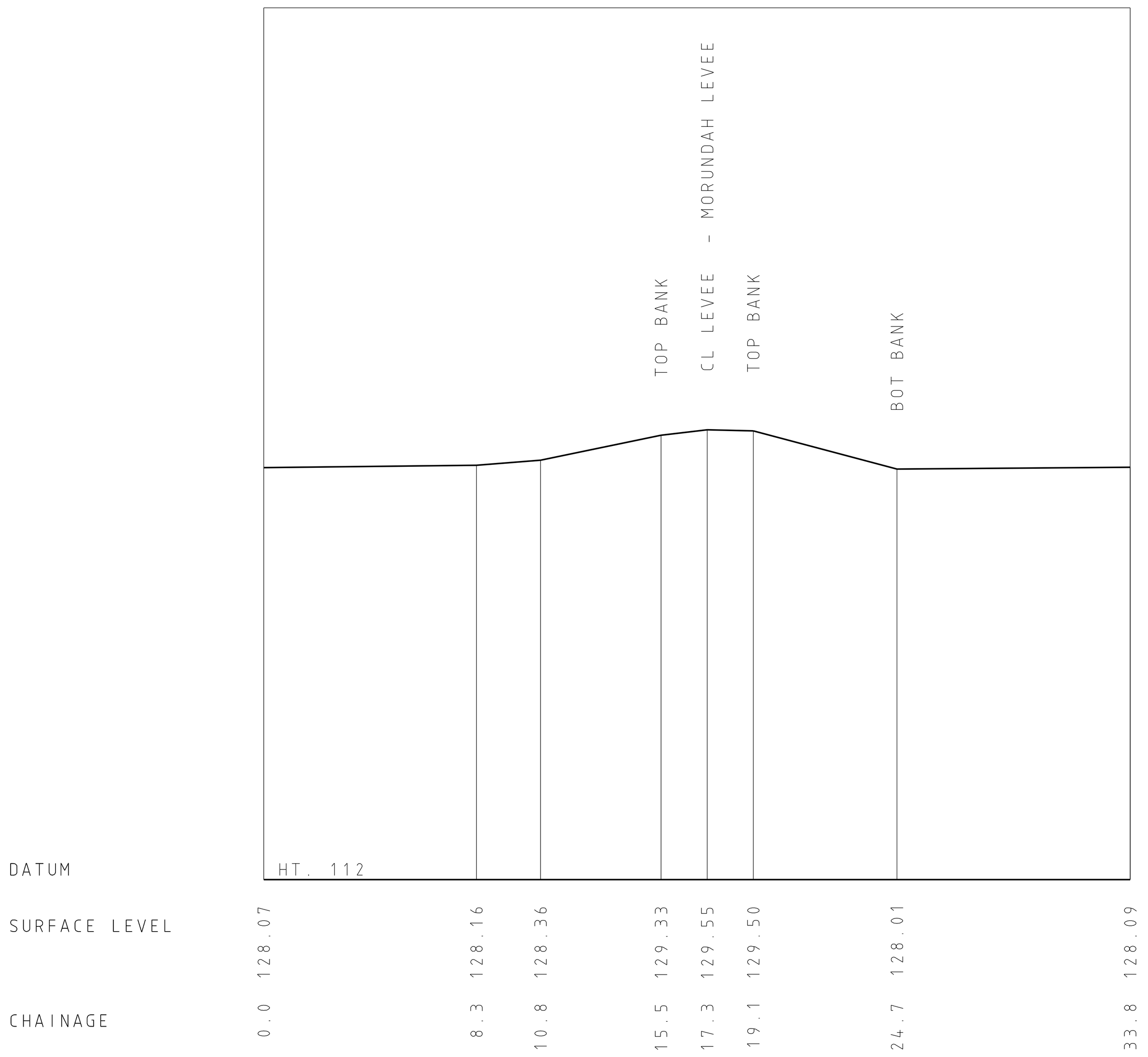
URANA SHIRE COUNCIL N.S.W.

MORUNDAH LEVEE CREST LEVEL SURVEY

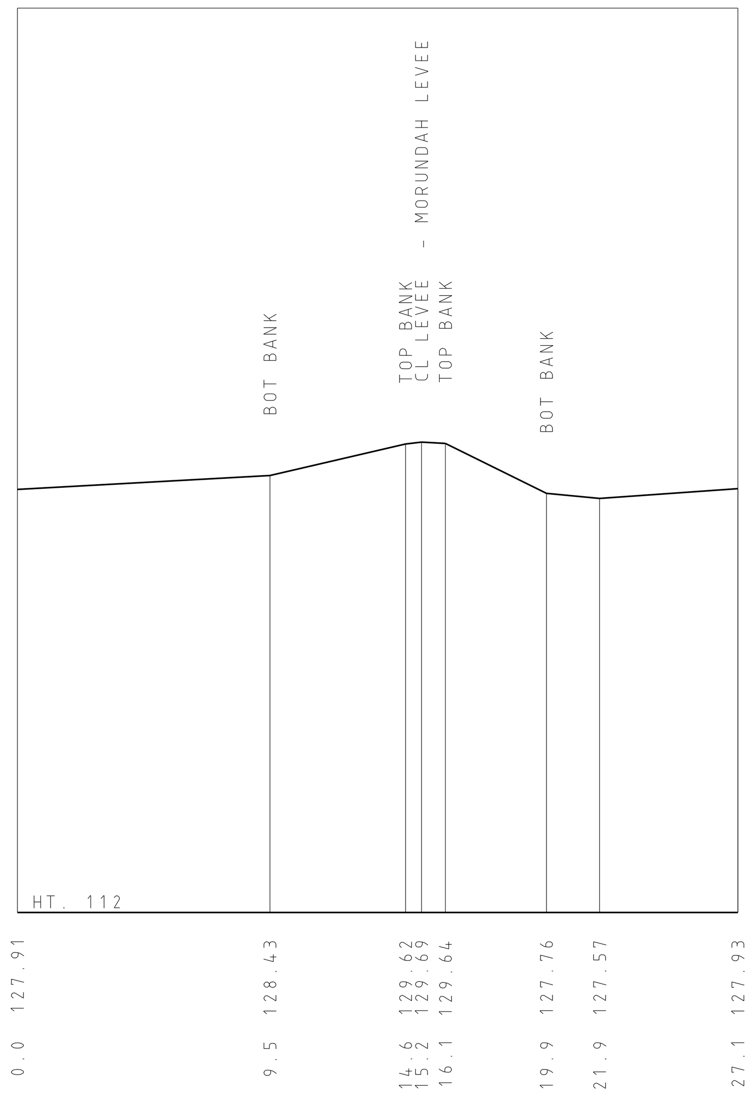
ROUTE PLAN LONGITUDINAL SECTION
CH.2520.5 - CH.3253.4

PLAN RM NO 57288
SCALES HOR1:1000 VER 1:200 @B1
DESIGNED | DATE
DRAFTED | VERIFIED
NO IN SET 6
SHEET NO 4

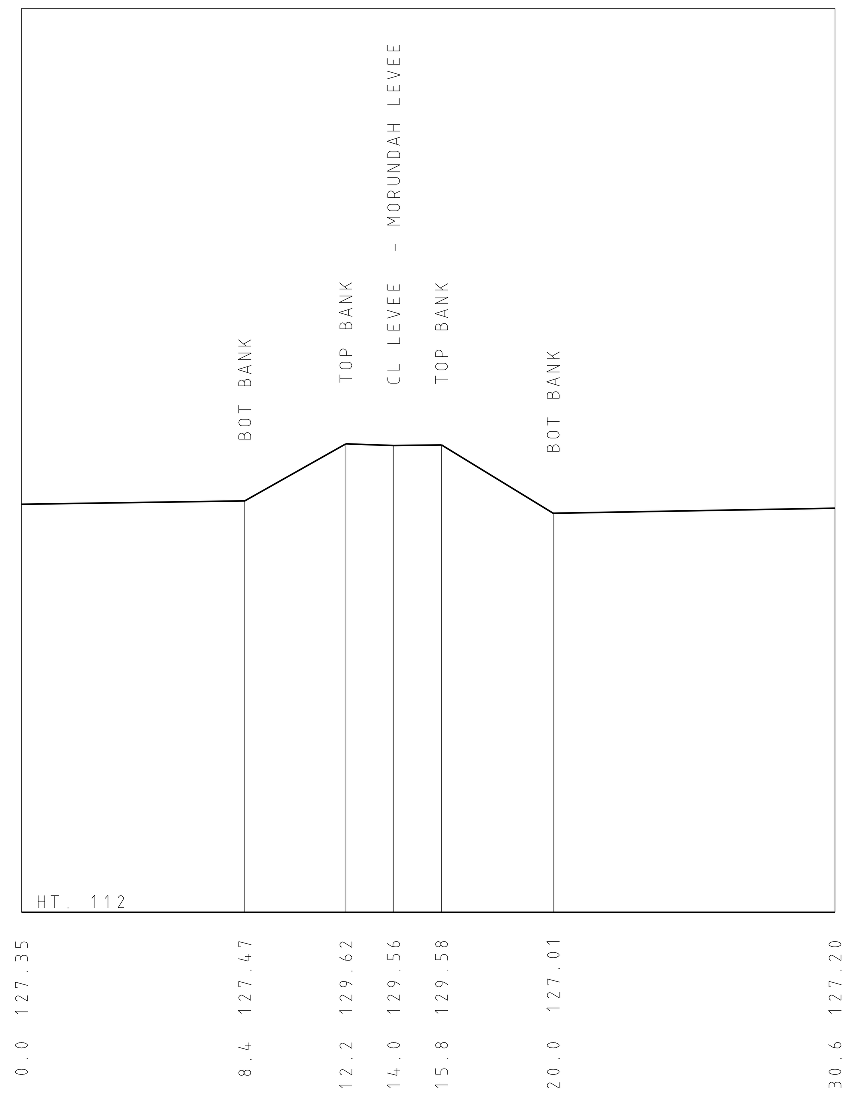
12:21:18 PM 11/02/2015 piccolod



CS1



CS2



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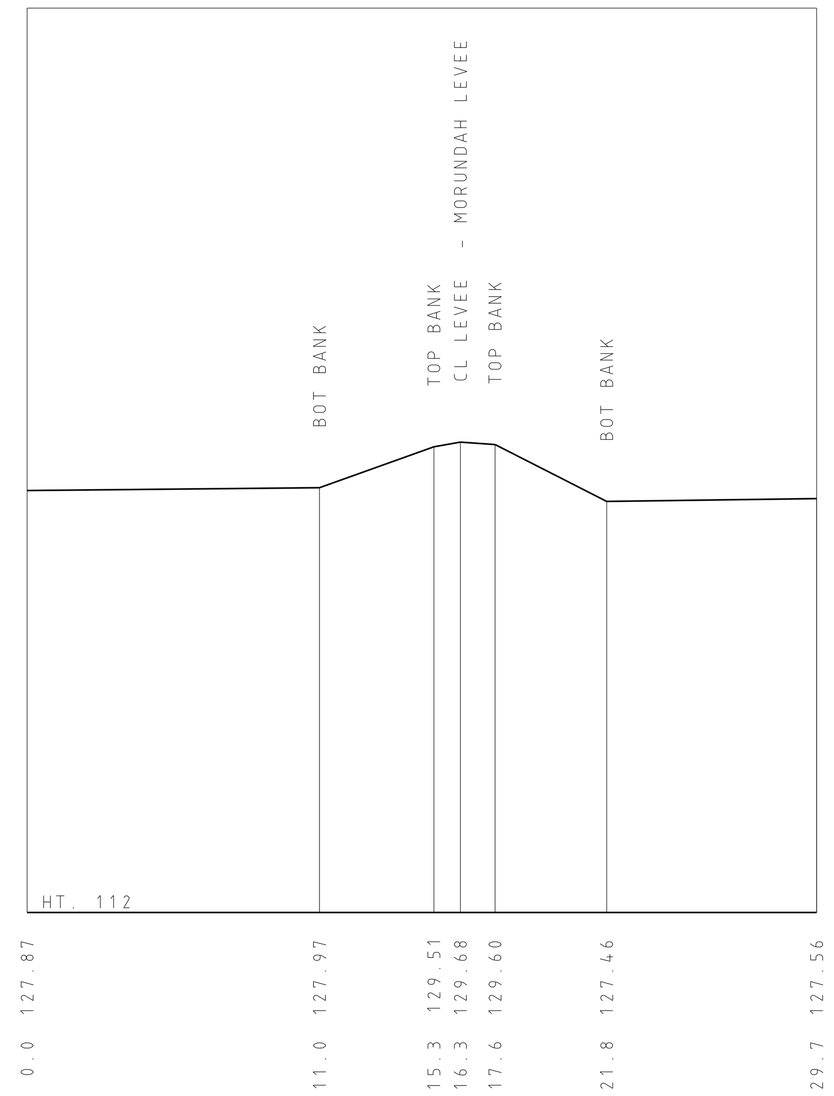

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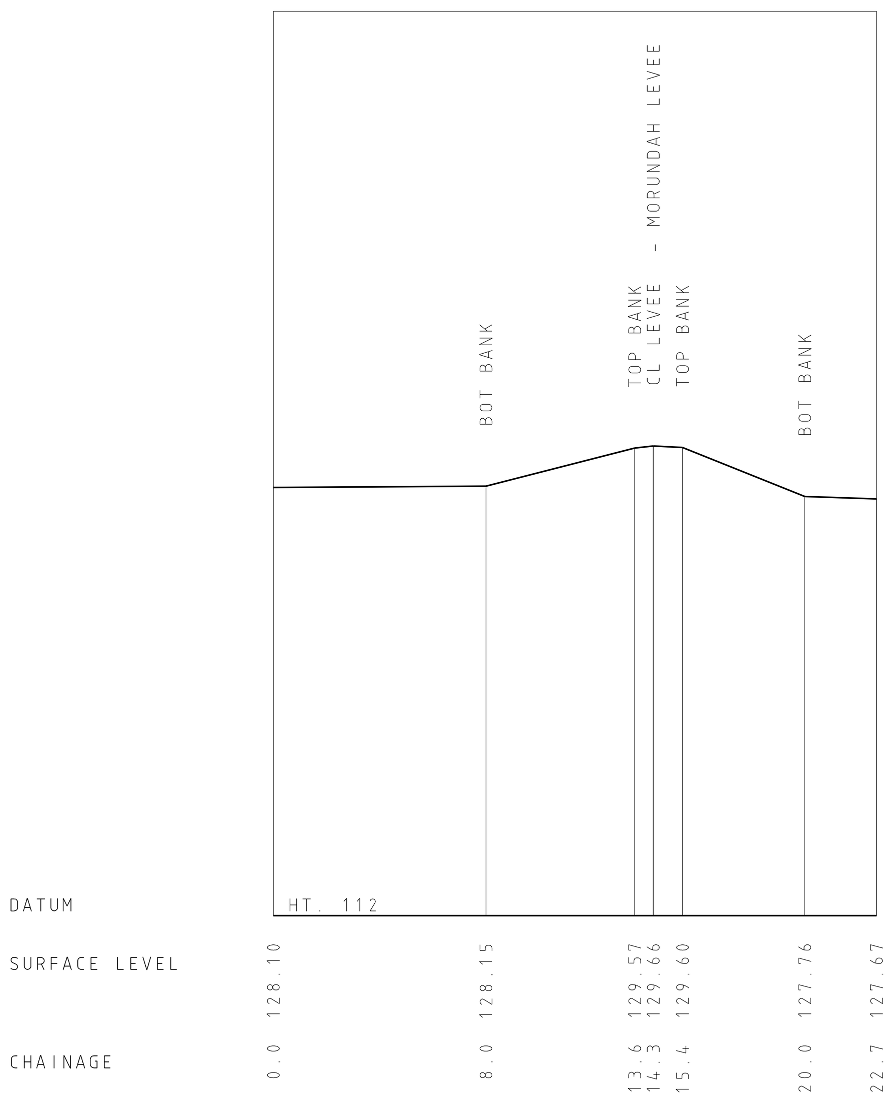
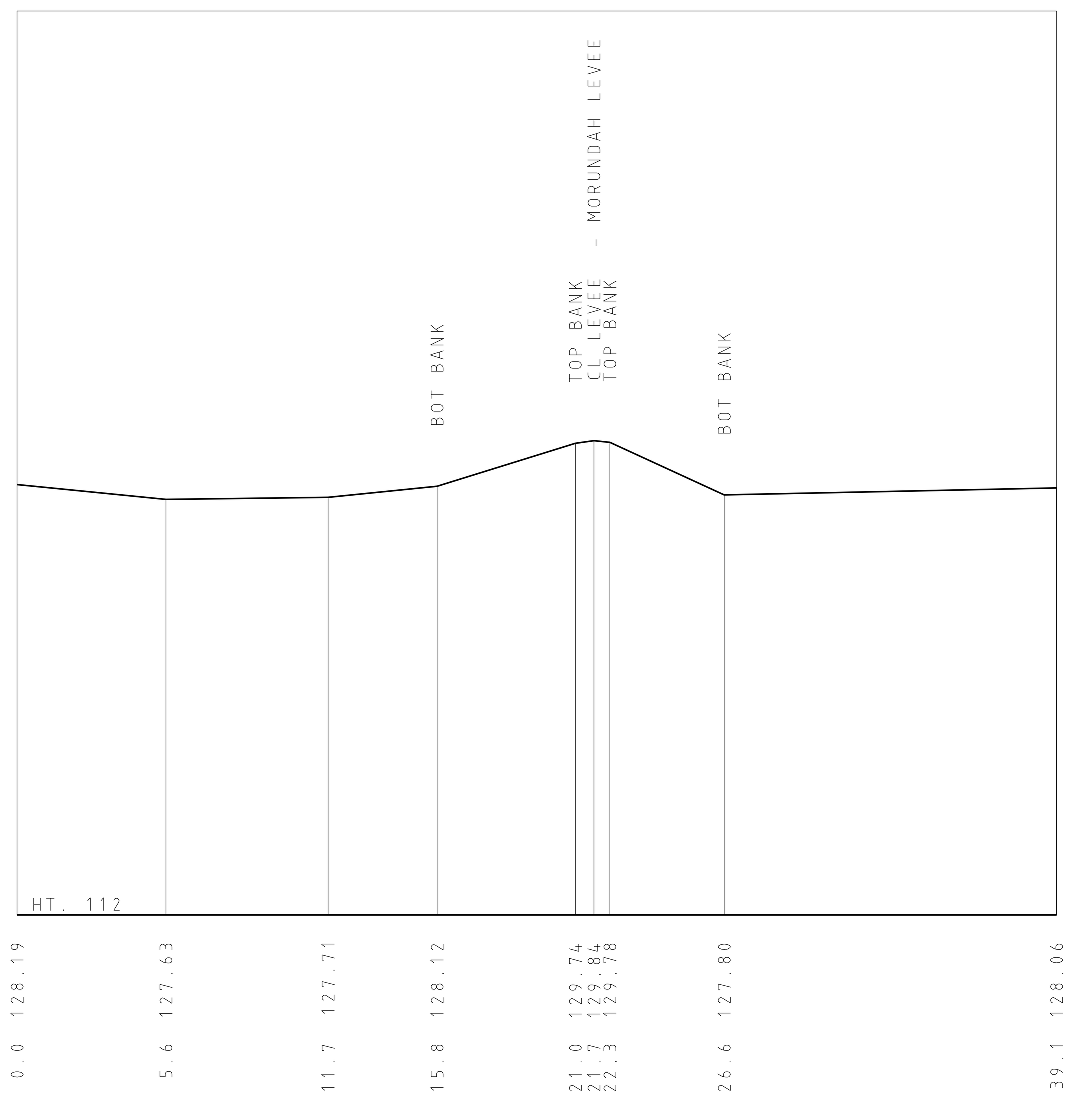
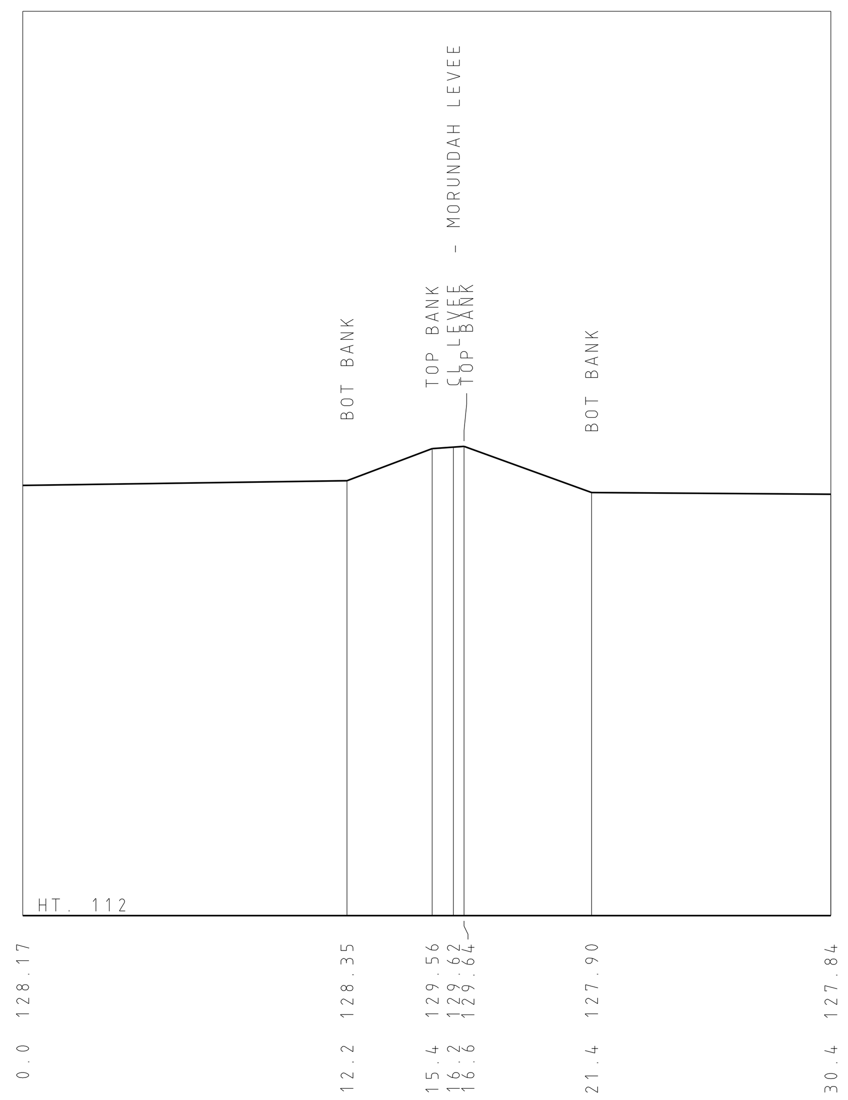


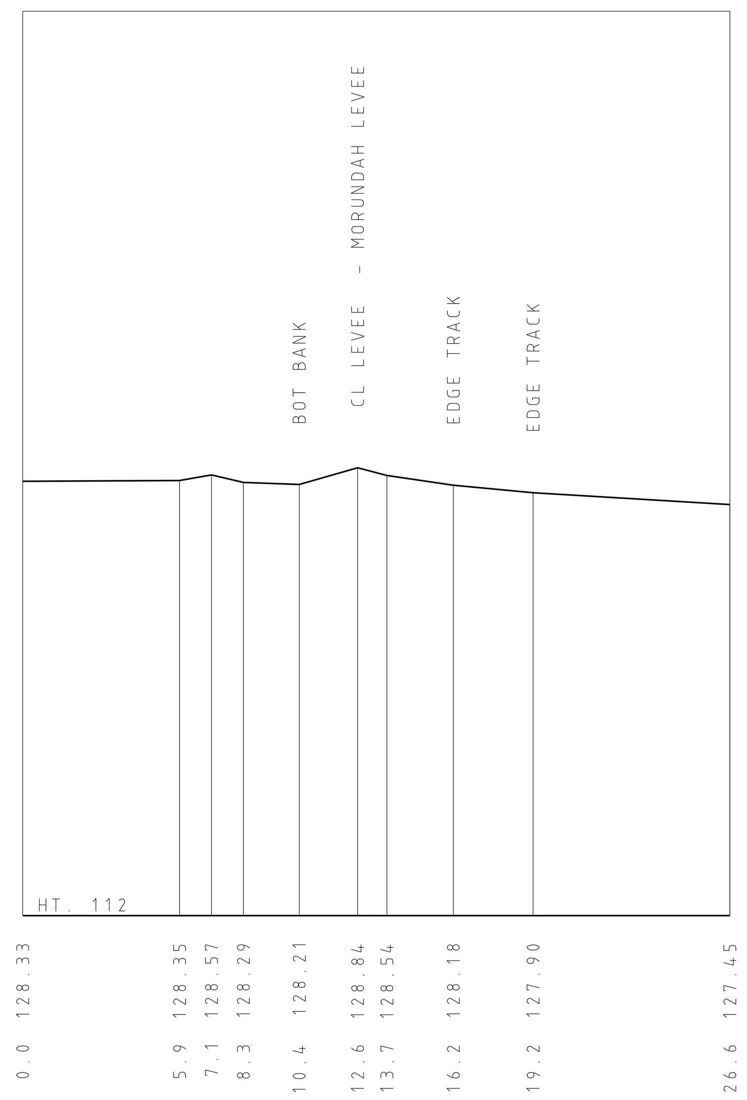
CS5



CS6



CS7



CS8

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0 2 4 8 12 16 20
REDUCTION RATIO 1:200 METRES

DATUM AHD
ORIGIN OF LEVELS PM4351 HT.127.747
AZIMUTH MGA ZONE 55
FOLDER B5002 LB FB
L.G.A. URANA
SURVEYOR D.BURNETT
SURVEY DATE 19/22-01-2015 FILE
CADD ODP

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TEL: (02) 9372 7980 FAX: (02) 9372 7922

VERIFIED D.BURNETT 9/02/2015
VALIDATED A.VEERSEMA 11/02/2015
APPROVED MANAGER S.SAUNDERS 11/02/2015

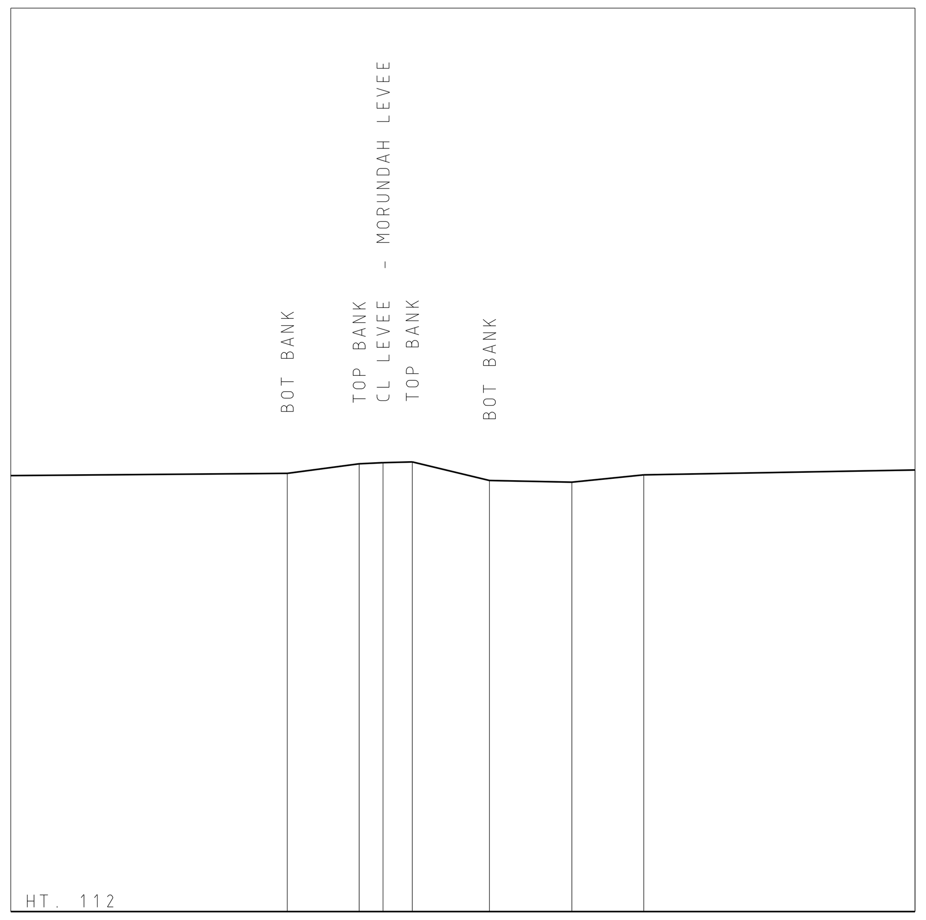
NSW Public Works

URANA SHIRE COUNCIL N.S.W.

MORUNDAH LEVEE CREST LEVEL SURVEY

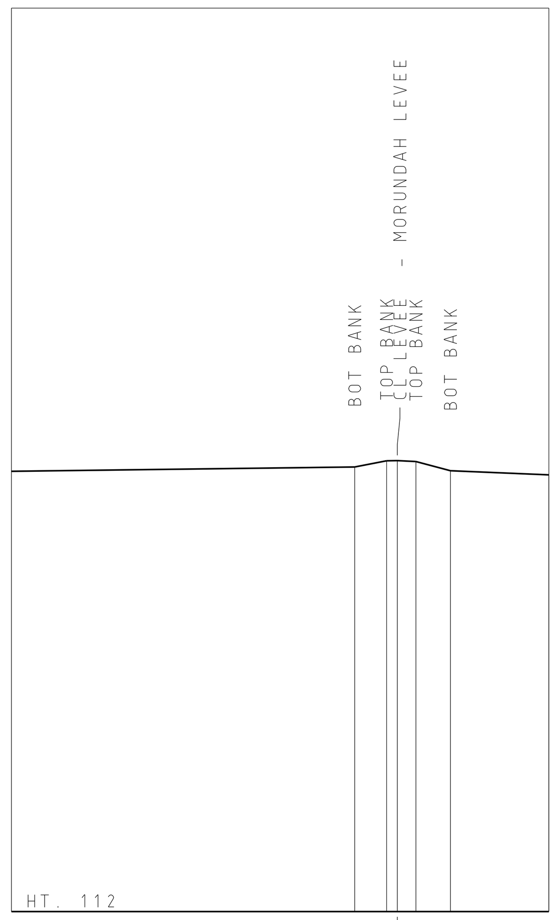
CROSS SECTIONS

PLAN RM NO 57288
NO IN SET 6
SCALES HOR1:200 VER 1:200 @B1
SHEET NO 5
DESIGNED
DATE
DRAFTED
VERIFIED



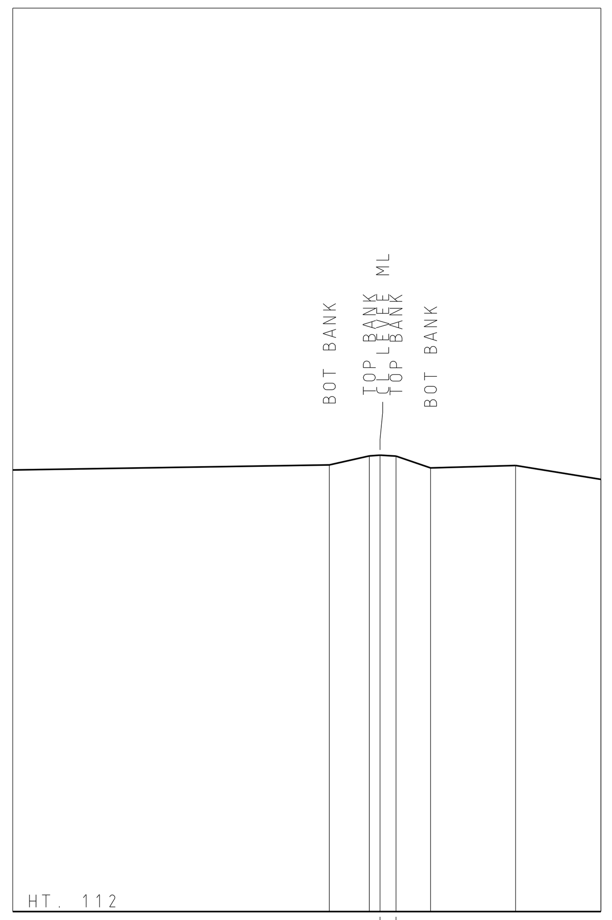
DATUM	HT. 112								
SURFACE LEVEL	128.41	128.50	128.85	128.90	128.92	128.22	128.16	128.44	128.62
CHAINAGE	0.0	10.4	13.1	14.0	15.1	18.0	21.1	23.8	34.0

CS9



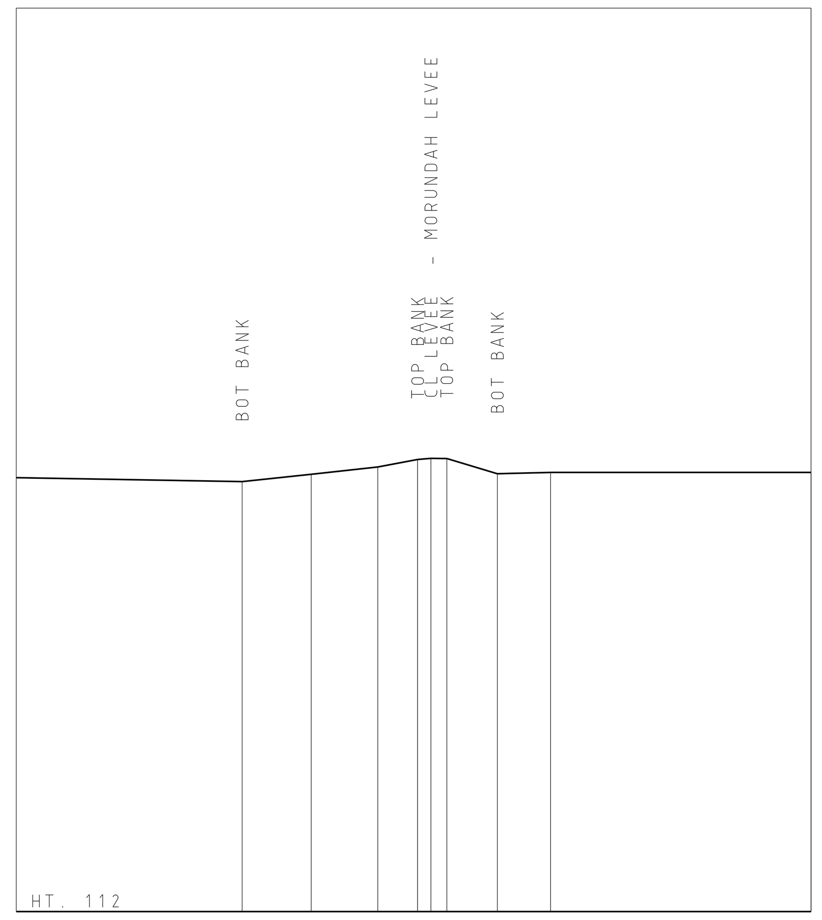
DATUM	HT. 112						
SURFACE LEVEL	128.57	128.73	128.97	128.97	128.94	128.59	128.44
CHAINAGE	0.0	12.9	14.1	14.5	15.2	16.5	20.2

CS10



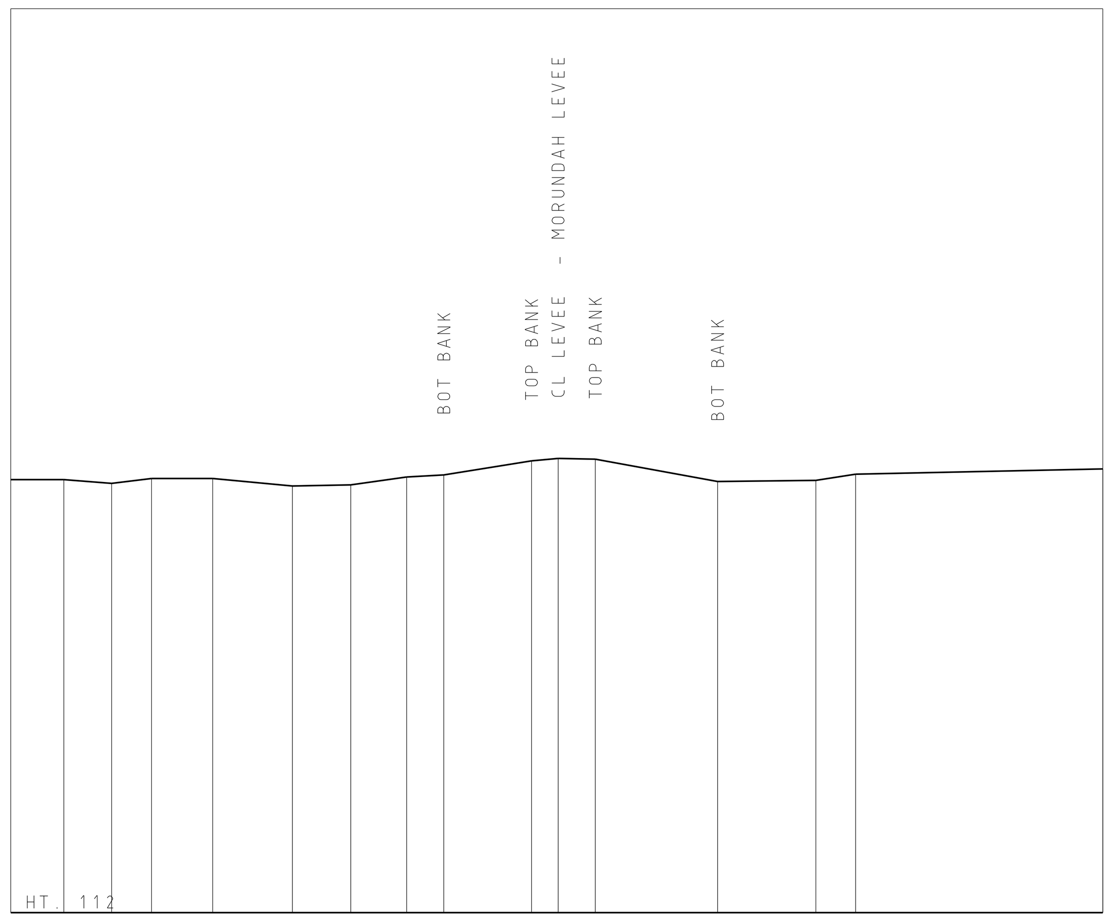
DATUM	HT. 112							
SURFACE LEVEL	128.62	128.81	129.15	129.18	129.14	128.70	128.79	128.27
CHAINAGE	0.0	11.9	13.4	13.8	14.4	15.7	18.9	22.1

CS11



DATUM	HT. 112									
SURFACE LEVEL	128.33	128.19	128.46	128.73	129.02	129.06	129.05	128.48	128.53	128.53
CHAINAGE	0.0	8.5	11.1	13.6	15.1	15.6	16.2	18.1	20.1	29.9

CS12



DATUM	HT. 112															
SURFACE LEVEL	128.29	128.29	128.15	128.33	128.33	128.05	128.09	128.39	128.47	128.99	129.09	129.06	128.22	128.26	128.49	128.69
CHAINAGE	0.0	2.0	3.8	5.3	7.6	10.6	12.8	14.9	16.3	19.6	20.6	22.0	26.6	30.3	31.8	41.1

CS13

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0 2 4 8 12 16 20

REDUCTION RATIO 1:200 METRES

DATUM AHD
ORIGIN OF LEVELS PM4351 HT.127.747
AZIMUTH MGA ZONE 55
FOLDER B5002 LB FB
L.G.A. URANA
SURVEYOR D.BURNETT
SURVEY DATE 19/22-01-2015 FILE
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APPROVED MANAGER S.SAUNDERS 11/02/2015

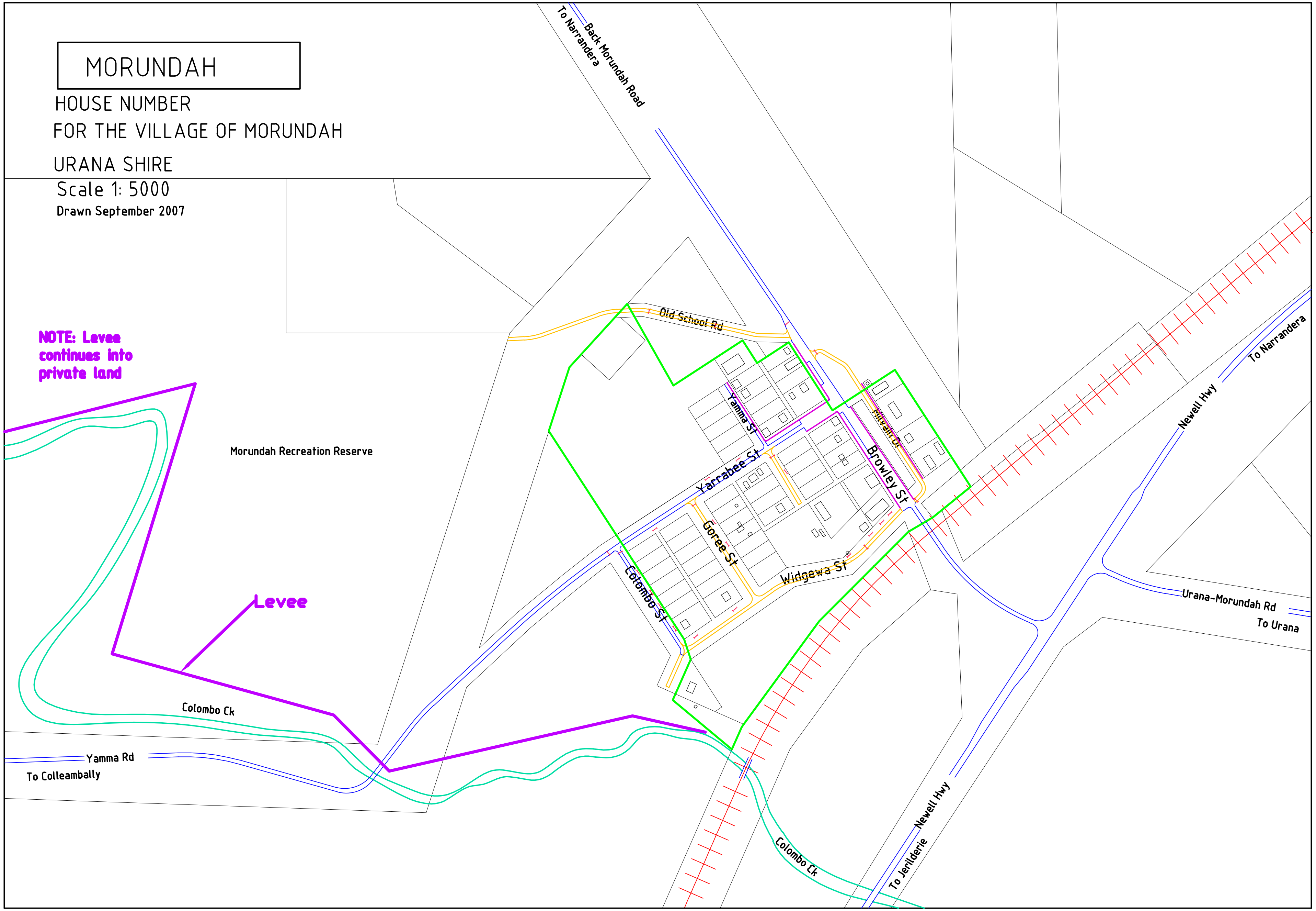
NSW GOVERNMENT | Public Works

URANA SHIRE COUNCIL N.S.W. 1906

MORUNDAH LEVEE CREST LEVEL SURVEY

CROSS SECTIONS

PLAN RM NO	NO IN SET
57288	6
SCALES HOR1:200 VER 1:200 @B1	SHEET NO 6
DESIGNED / DATE	
DRAFTED / VERIFIED	


MORUNDAH
HOUSE NUMBER
FOR THE VILLAGE OF MORUNDAH
URANA SHIRE
Scale 1: 5000
Drawn September 2007
NOTE: Levee continues into private land
Morundah Recreation Reserve
Levee
Colombo Ck
Yamma Rd
To Colleambally
To Narrandera
Back Morundah Road
Old School Rd
Yamma St
Milvain Dr
Browley St
Yarrabee St
Goree St
Colombo St
Widgewa St
Newell Hwy
To Narrandera
Urana-Morundah Rd
To Urana
Newell Hwy
To Jerilderie
Colombo Ck

Appendix B. Questionnaire

Urana Shire Flood Study Questionnaire (February 2015)

Morundah

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 Morundah. 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 Morundah. 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

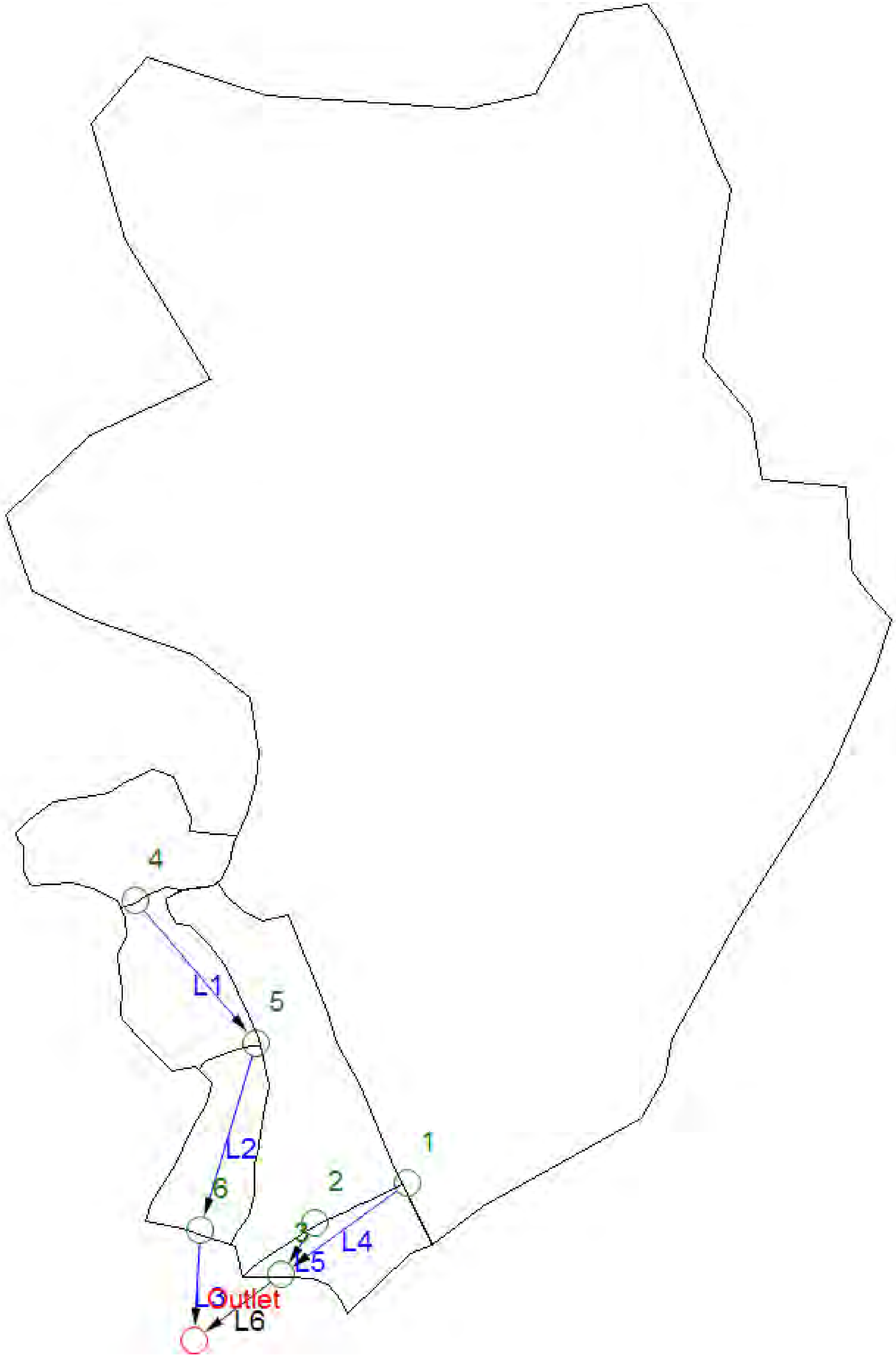
Thank you for your assistance

Map – Study Area for Morundah

Appendix C. Hydrologic Modelling

- C1: Figure showing XP-RAFTS model configuration for Morundah
- C2: Table showing XP-RAFTS model sub-catchment data for Morundah

- C1: XP-RAFTS Model Configuration for Morundah local catchments

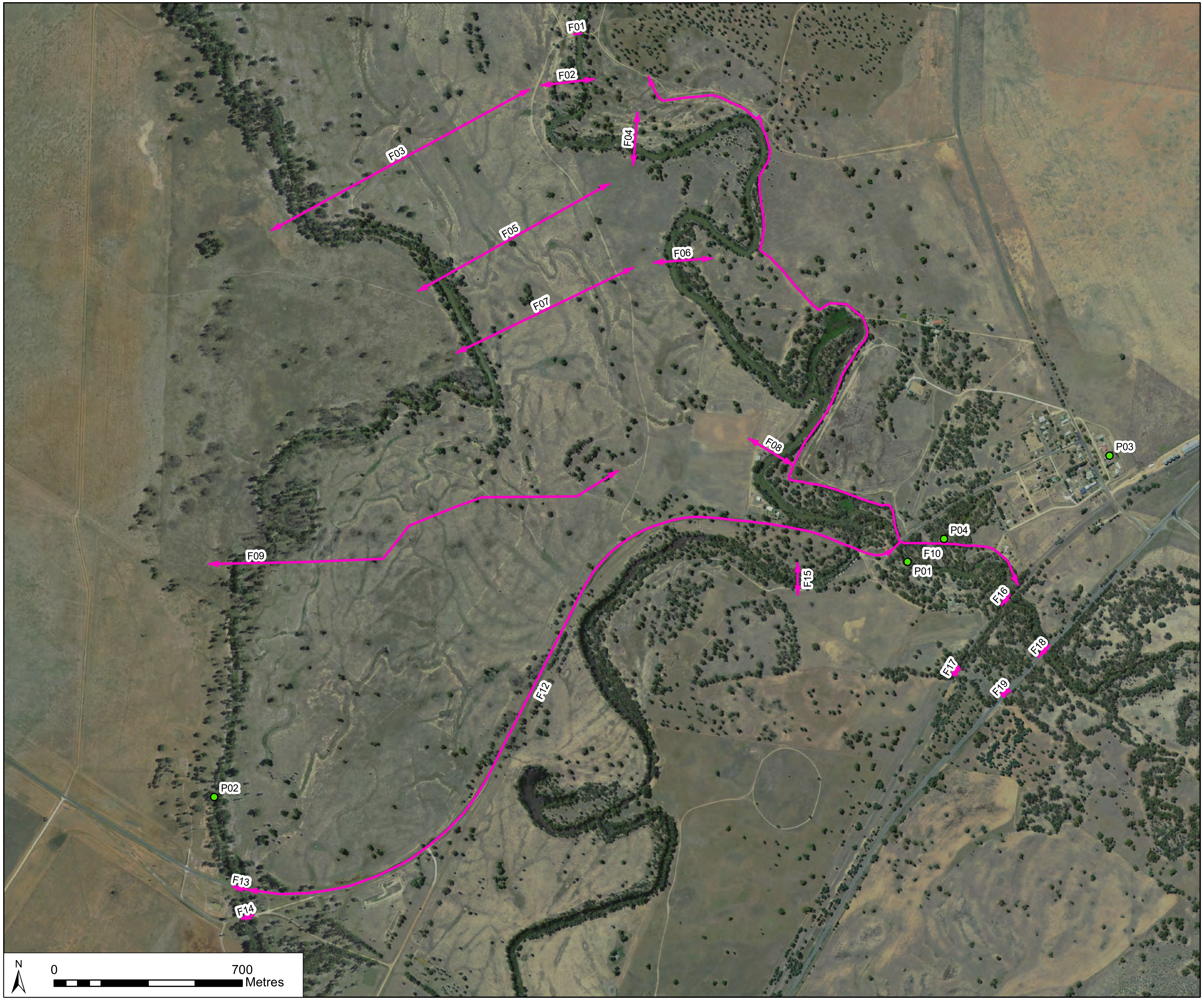


- C2: XP-RAFTS Model sub-catchment data for Morundah local catchments

Node number	Area (ha)	Impervious fraction (%)	Slope (%)	Manning's n Roughness
1	1103.72	5	1.0	0.045
2	61.94	8	0.1	0.050
3	18.44	20	0.3	0.040
4	32.94	5	1.0	0.050
5	28.05	5	0.1	0.045
6	24.55	5	0.1	0.045

Appendix D. Hydraulic Modelling

- D1: Map showing reporting locations of flows and flood levels for TUFLOW model
- D2: Reporting tables for the 2010 and 2012 flood events
- D3: Reporting tables for the sensitivity runs
- D4: Peak discharges for design flood events



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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN MR	PROJECT # IA055600
CHECK AH	DATE 30/08/2017

APPENDIX D-1

Appendix D2 – Calibration Results

- Modelled flows for the 2010 and 2012 calibration events

Flow line	2010 Flow (m^3/s)	2012 Flow (m^3/s)
F01	41.1	45.2
F02	45.3	51.1
F03	45.8	89.7
F04	31.8	34.2
F05	59.0	106.3
F06	29.9	31.3
F07	60.5	108.6
F08	29.6	30.5
F09	61.4	110.2
F10	0.0	0.0
F11	26.1	26.7
F12	2.6	15.0
F13	55.3	93.4
F14	55.3	88.7
F15	1.2	1.1
F16	26.0	26.8
F17	0.0	0.1
F18	23.1	23.7
F19	3.0	3.2

Appendix D3 – Sensitivity Results

- Flood level differences (m) for the sensitivity runs (2012 event)

Base = Base case

IL = Initial rainfall loss (+/-20%)

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

B = Blockage factor (50%, 100%)

TWL = Tailwater level (+/- 0.5m)

Location	Base	+IL	-IL	+n	-n	B50	B100	+TWL	-TWL
P01	128.17	0.00	0.00	0.00	-0.02	-0.04	+0.03	0.00	0.00
P02	127.22	0.00	0.00	+0.08	-0.16	+0.09	+0.60	0.00	0.00
P03	128.61	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
P04	128.25	-0.02	+0.03	0.00	0.00	0.00	0.00	0.00	0.00
F01	128.85	0.00	0.00	-0.03	-0.06	0.00	+0.06	0.00	0.00
F02	128.79	0.00	0.00	-0.03	-0.05	0.00	-0.02	0.00	0.00
F03	128.30	0.00	0.00	+0.05	-0.09	+0.01	+0.05	0.00	0.00
F11	128.24	0.00	0.00	0.01	-0.03	-0.07	-0.11	0.00	0.00
F13	127.01	0.00	0.00	+0.10	-0.18	0.00	-0.14	0.00	0.00
F14	126.77	0.00	0.00	+0.10	-0.17	+0.07	+0.34	0.00	0.00
F16	128.02	0.00	0.00	0.00	-0.01	-0.01	+0.58	0.00	0.00
F17	127.84	0.00	0.00	0.00	-0.01	+0.02	+0.49	0.00	0.00
F18	127.89	0.00	0.00	0.00	-0.01	-0.01	+0.32	0.00	0.00
F19	127.82	0.00	0.00	0.00	-0.01	-0.01	+0.50	0.00	0.00

- Flow differences (m^3/s) for the sensitivity runs (2012 event)

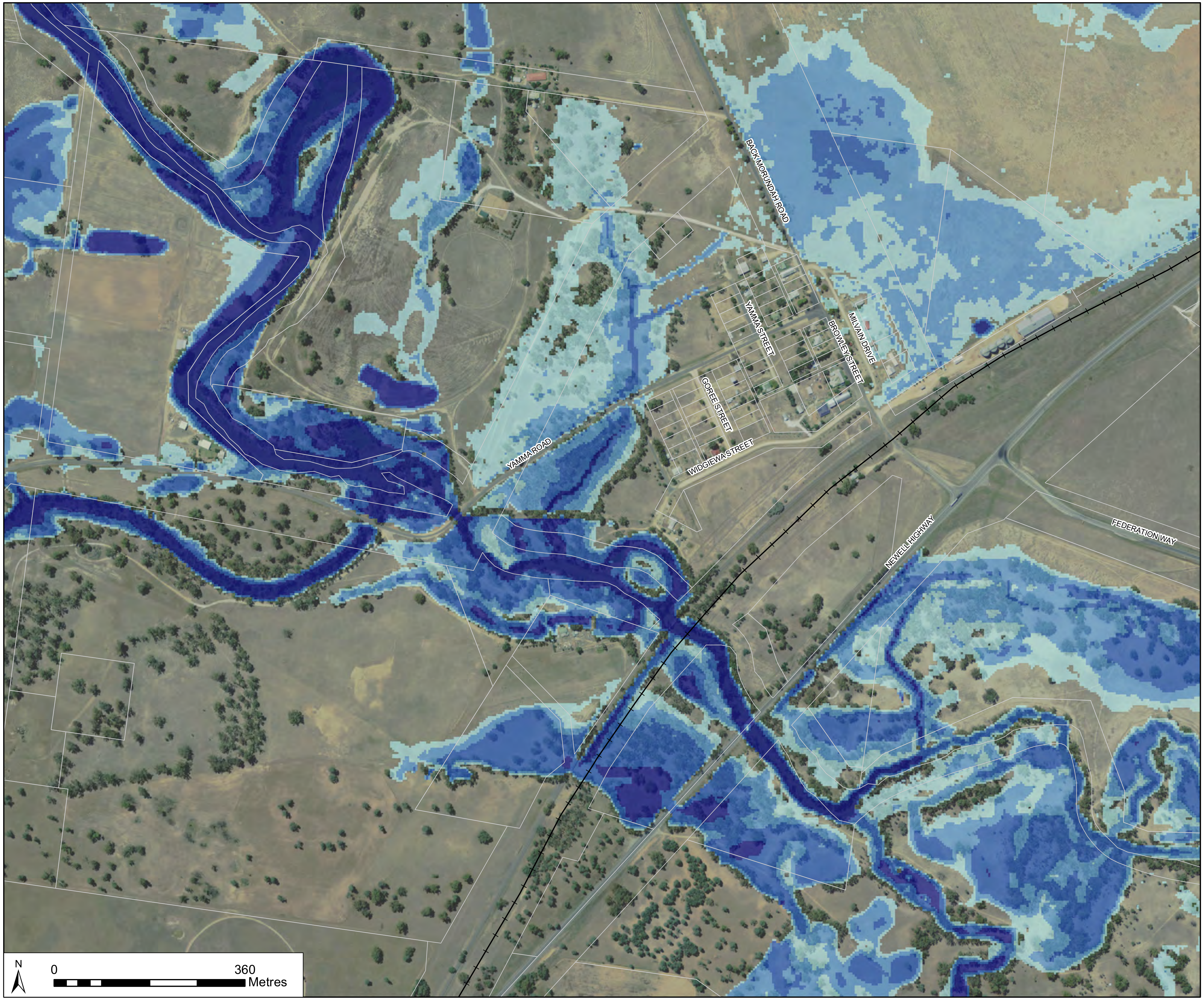
Flow line	Base	+IL	-IL	+n	-n	B50	B100	+TWL	-TWL
F01	45.17	0.00	0.00	-8.30	+2.08	-0.68	-18.02	0.00	0.00
F02	51.13	0.00	0.00	-10.31	+0.87	-0.19	-7.25	0.00	0.00
F03	89.67	0.00	0.00	+2.14	-4.55	+0.19	+7.00	0.00	0.00
F04	34.19	0.00	0.00	-5.91	+2.60	-0.77	-6.75	0.00	0.00
F05	106.33	0.00	0.00	-2.24	-6.36	+0.76	+6.64	0.00	0.00
F06	31.29	0.00	0.00	-4.80	+3.26	-1.46	-9.18	0.00	0.00
F07	108.56	0.00	0.00	-3.11	-6.93	+1.27	+8.60	0.00	0.00
F08	30.55	0.00	0.00	-4.45	+3.56	-2.35	-15.43	0.00	0.00
F09	110.15	0.00	0.00	-4.05	-7.72	+2.35	+15.44	0.00	0.00
F10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F11	26.75	0.00	0.00	-3.52	+3.15	-4.30	-26.66	0.00	0.00
F12	15.01	0.00	0.00	-0.34	-5.30	+2.13	+121.25	0.00	0.00
F13	93.43	0.00	0.00	-4.24	-3.03	+2.39	-86.82	0.00	0.00
F14	88.69	0.00	0.00	-6.75	+1.55	-3.56	-86.44	0.00	0.00
F15	1.13	0.00	0.00	-0.03	+0.06	+0.01	+0.25	0.00	0.00
F16	26.82	0.00	0.00	-3.45	+3.23	-4.29	-26.40	0.00	0.00
F17	0.06	0.00	0.00	-0.03	-0.04	-0.05	-0.04	0.00	0.00
F18	23.68	0.00	0.00	-2.87	+2.67	-4.63	-23.59	0.00	0.00
F19	3.15	0.00	0.00	-0.59	+0.50	+0.39	-3.12	0.00	0.00

Appendix D4 – Peak Flows (m^3/s) for Design Flood Events

Flow line	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
F01	38	42	43	45	46	47	48	48
F02	42	47	48	50	53	54	55	56
F03	49	62	74	97	139	153	178	292
F04	30	32	33	34	35	35	36	37
F05	60	76	89	114	156	171	196	288
F06	29	30	31	31	32	32	32	47
F07	61	78	91	116	158	173	198	287
F08	29	30	30	30	31	31	31	118
F09	61	79	92	117	160	175	201	301
F10	0	0	0	0	0	0	0	0
F11	26	26	27	27	27	27	27	48
F12	2	6	10	17	36	48	71	183
F13	55	70	80	99	124	128	132	138
F14	55	70	80	92	102	103	103	105
F15	1	1	1	1	1	1	1	15
F16	26	26	26	27	27	27	27	47
F17	0	0	0	0	0	0	0	19
F18	23	23	23	23	24	24	24	59
F19	3	3	3	3	3	3	3	17

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: 1% AEP floodway outlines
- Figure E-13: 1% AEP hydraulic categories map
- Figure E-14: 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

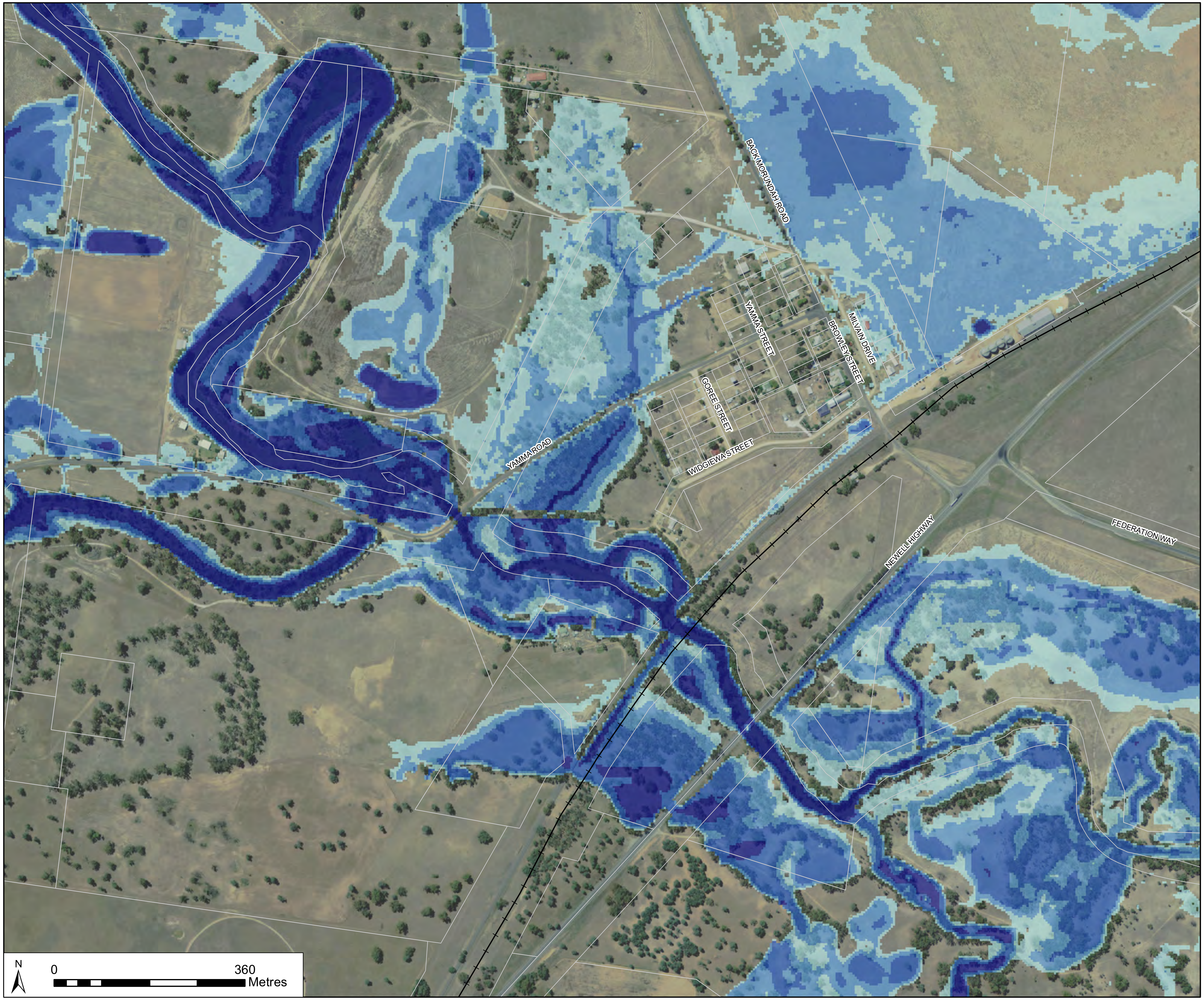
GDA 1994 MGA Zone 55
Scale: A3

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN AG / CHECK AH	PROJECT # IA055600 / DATE 5/25/2016
	FIGURE E-1



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

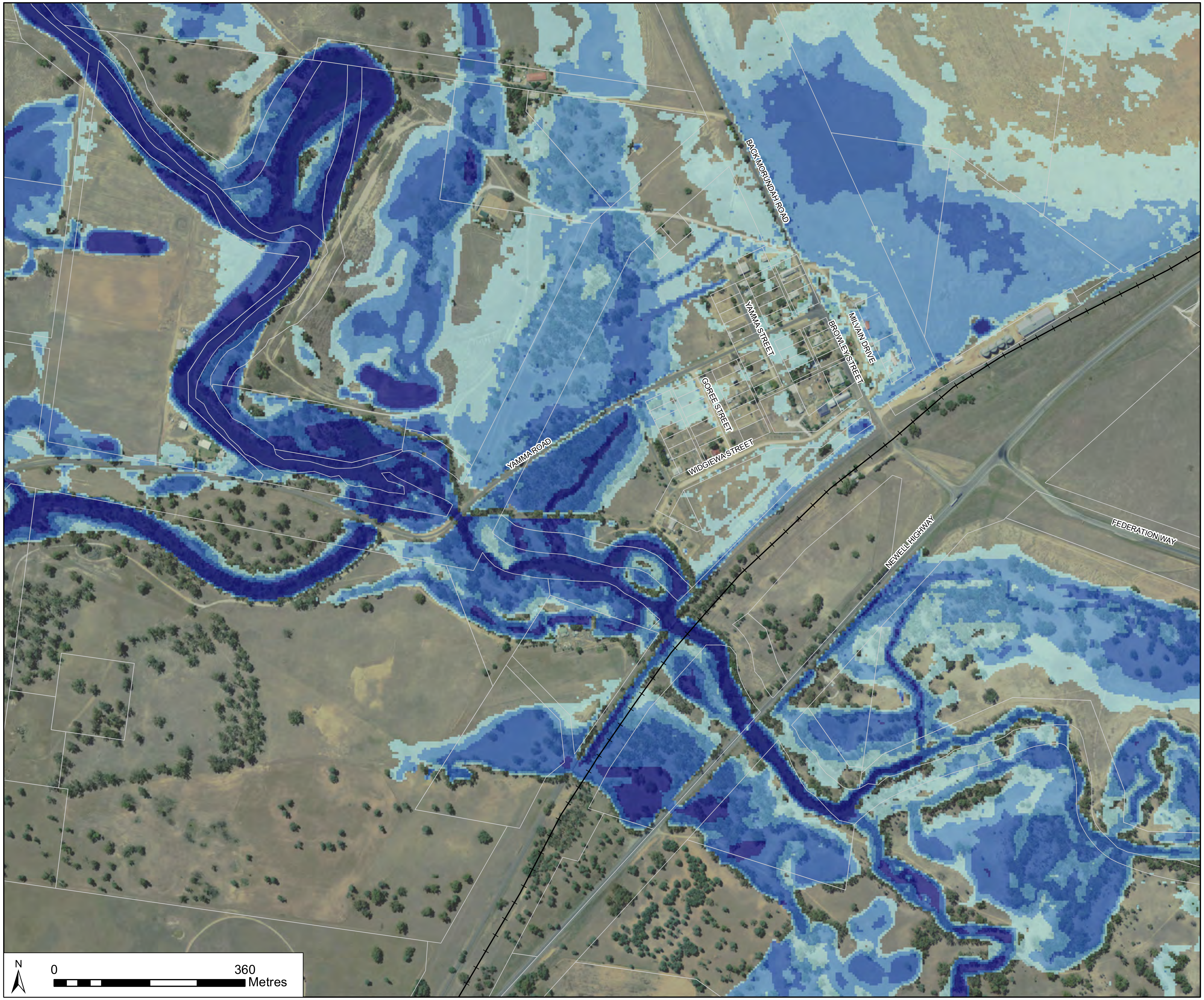
GDA 1994 MGA Zone 55
Scale: A3

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN AG / CHECK AH	PROJECT # IA055600 / DATE 5/25/2016
	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

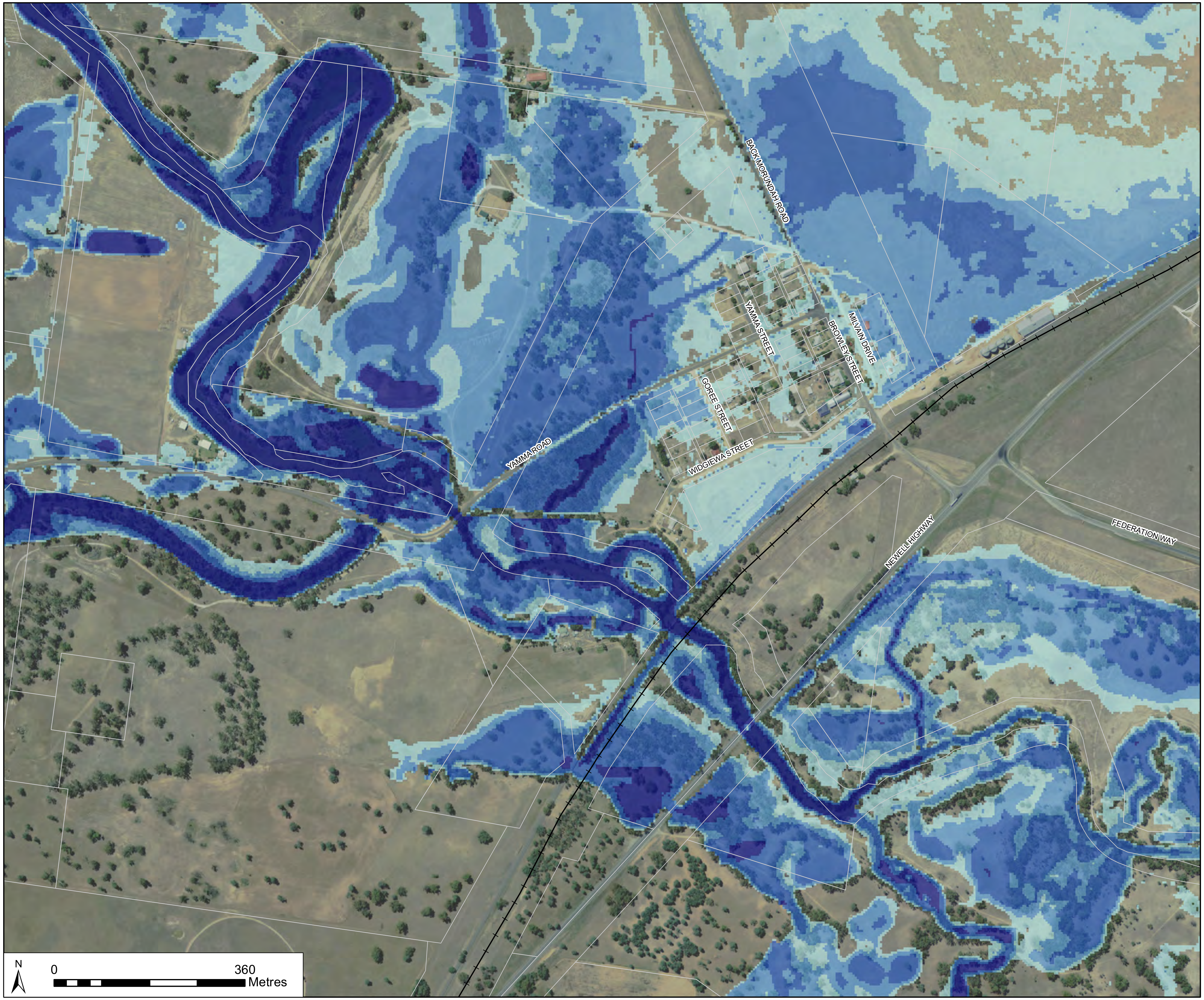
Data Sources: LPI, OEH, Council

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-3
CHECK AH	DATE 5/25/2016	



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

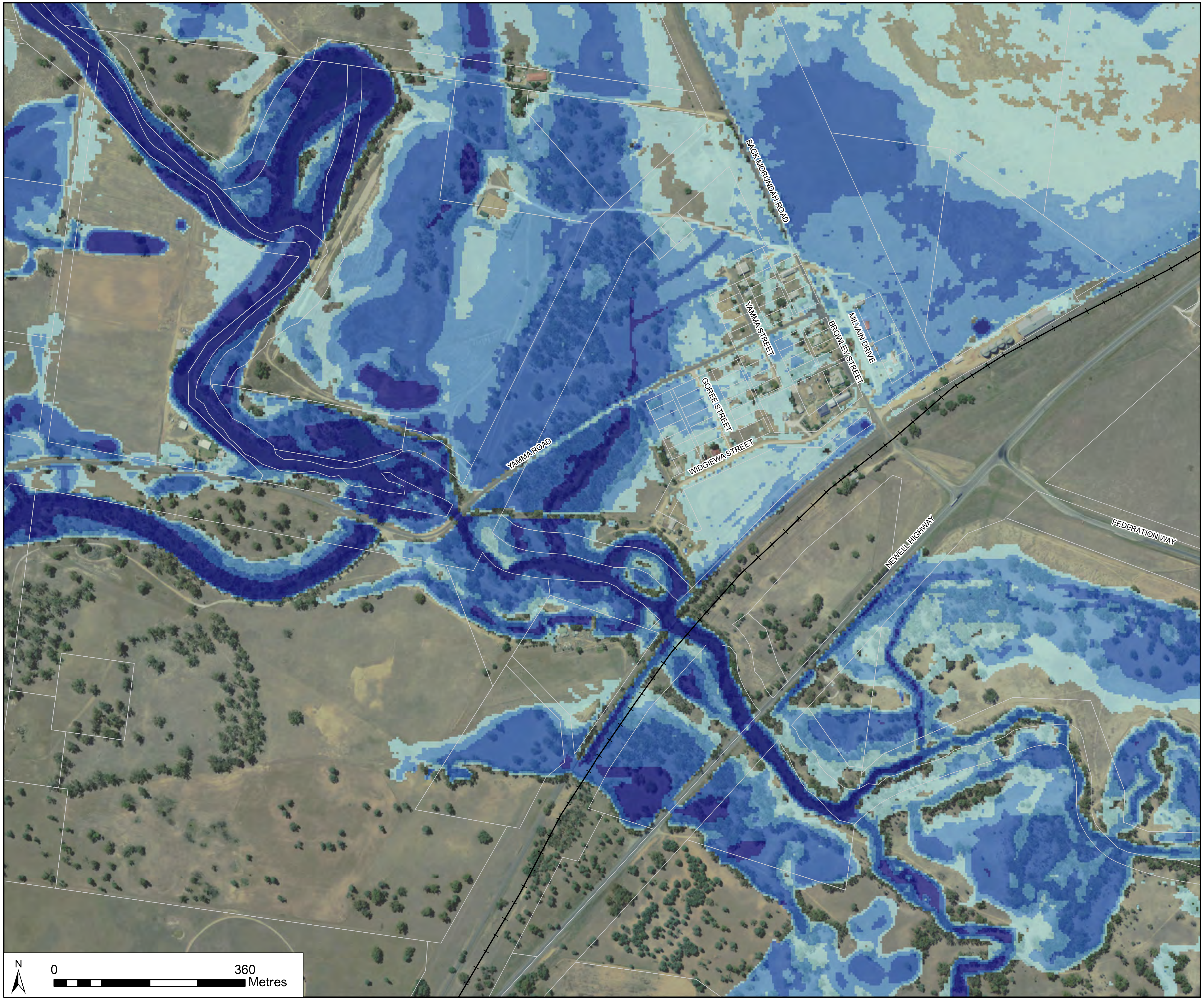
Data Sources: LPI, OEH, Council

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-4
CHECK AH	DATE 5/25/2016	



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

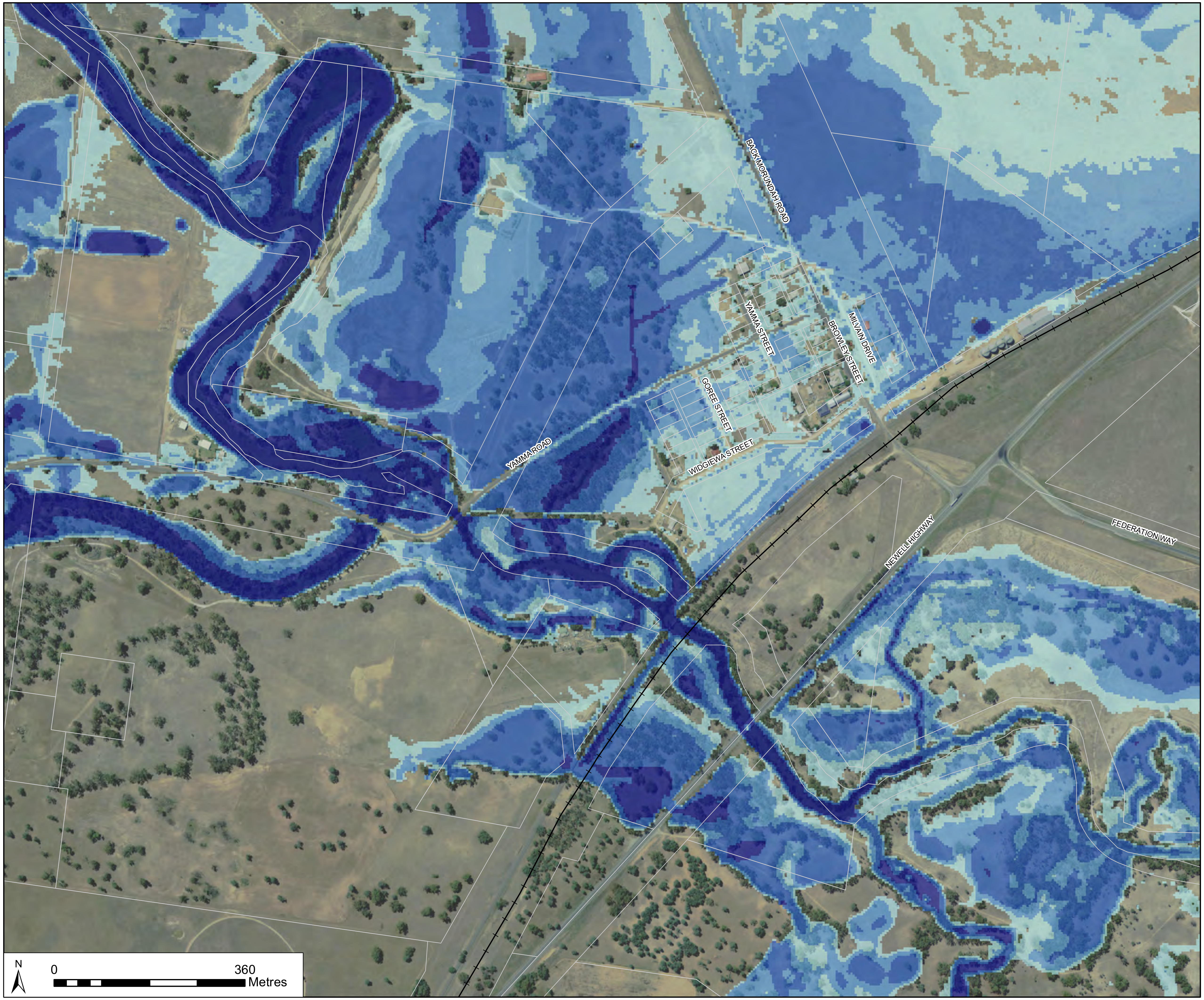
Data Sources: LPI, OEH, Council

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-5
CHECK AH	DATE 5/25/2016	



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 Morundah

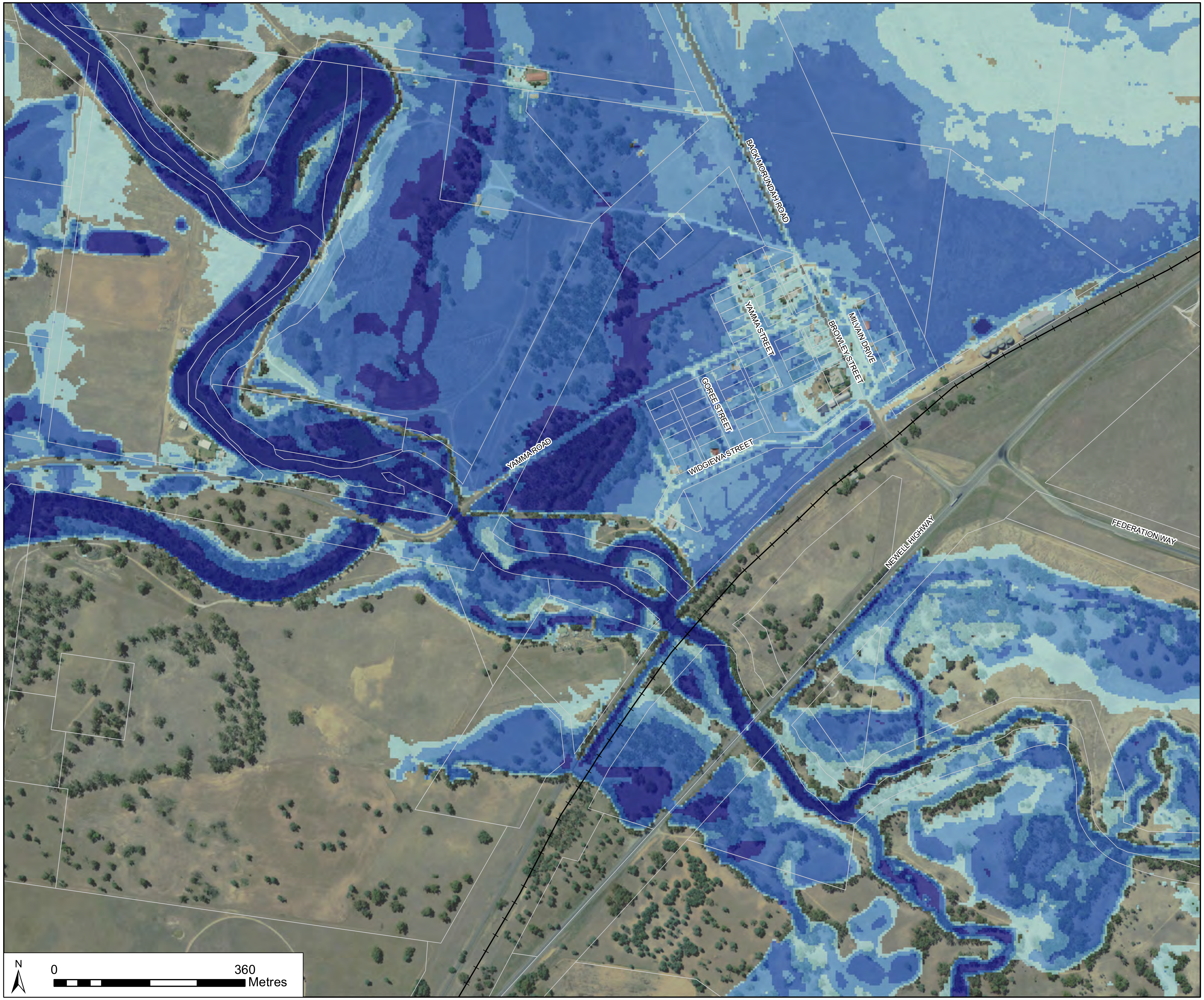
PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN AG PROJECT # IA055600

CHECK AH DATE 5/25/2016

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

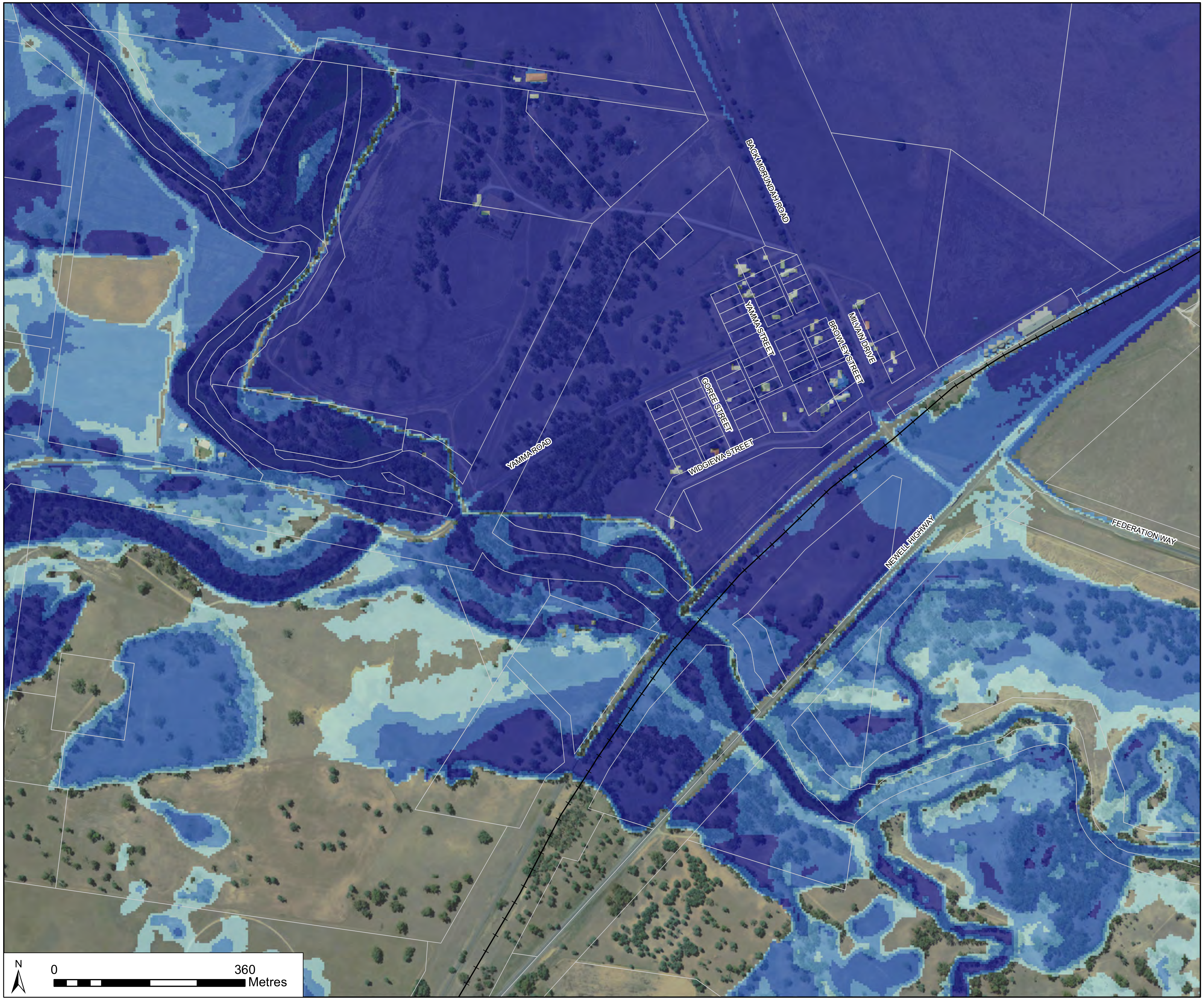
TOWN Morundah

PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN AG | PROJECT # IA055600
CHECK AH | DATE 5/25/2016

FIGURE E-7



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 Morundah

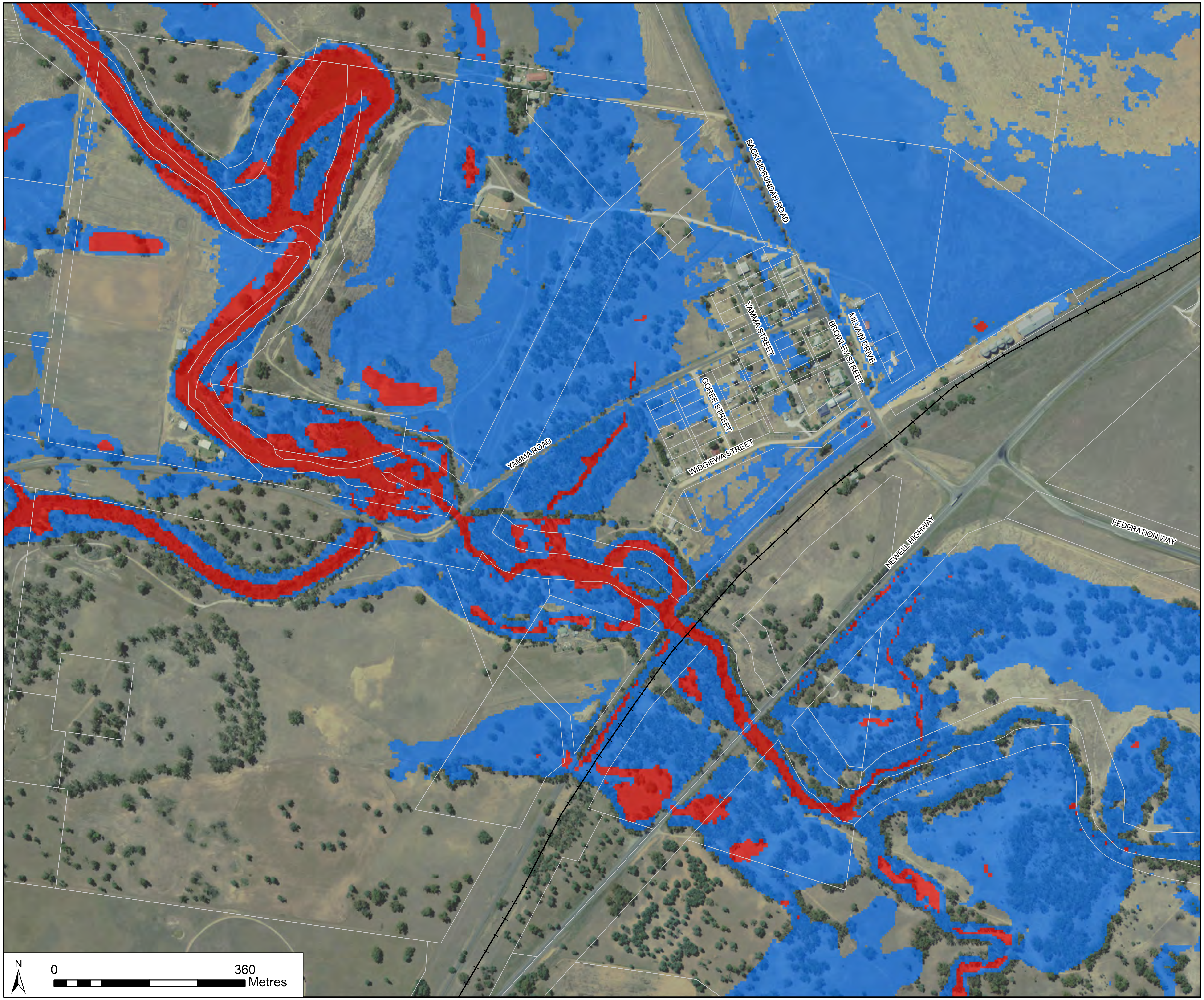
PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN AG | PROJECT # IA055600

CHECK AH | DATE 5/25/2016

FIGURE E-8



Legend

Railway

Cadastre

Provisional hydraulic hazard

Low Hazard

High Hazard

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

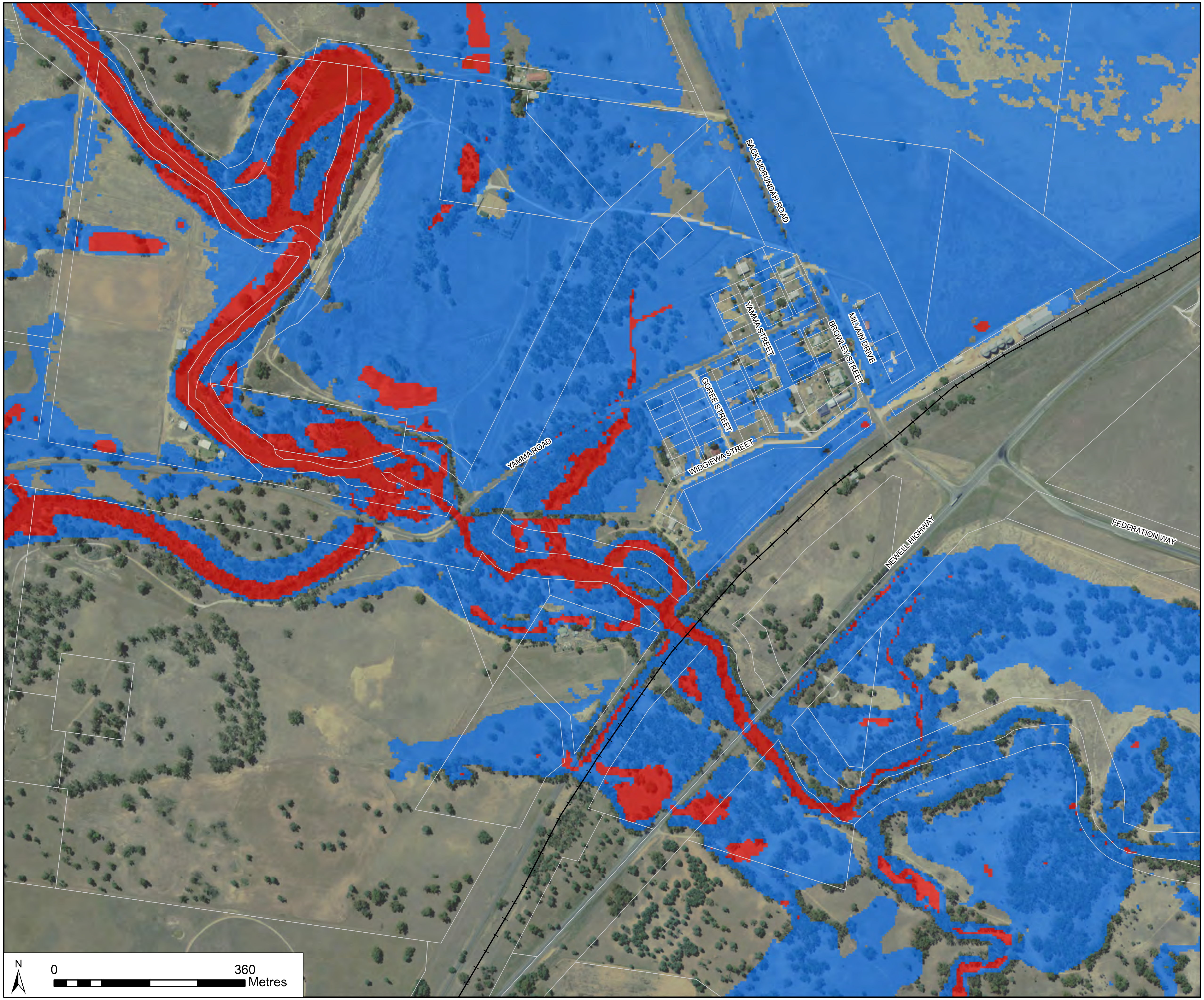
Data Sources: LPI, OEH, Council

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

JACOBS

TITLE	5% AEP Event Provisional Hazard Map
TOWN	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council

DRAWN AG	PROJECT # IA055600	FIGURE E-9
CHECK AH	DATE 5/25/2016	



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

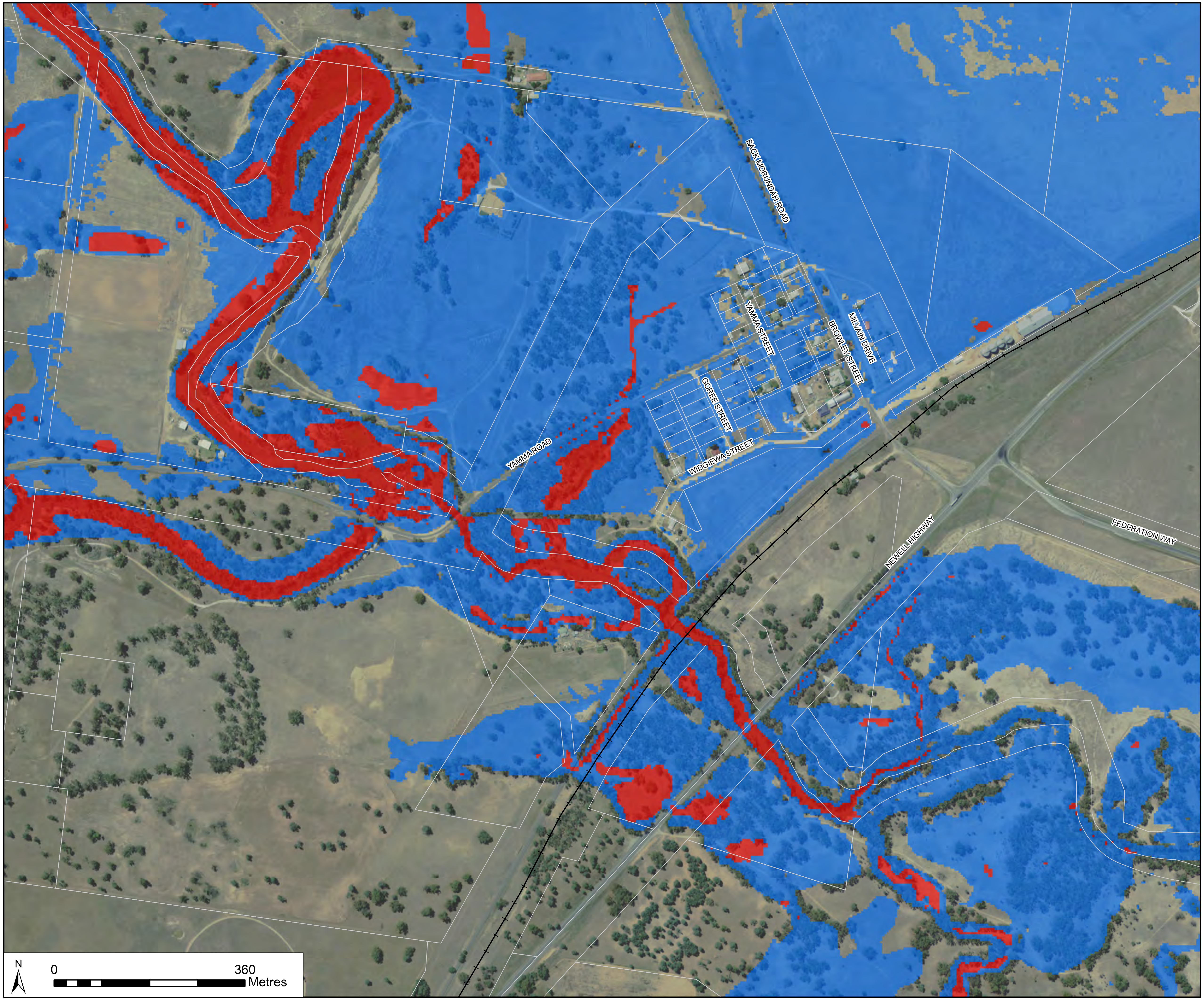
Data Sources: LPI, OEH, Council

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	Morundah
PROJECT	Flood Study for Five Towns
CLIENT	Federation Council
DRAWN AG / CHECK AH	PROJECT # IA055600 / DATE 5/25/2016

FIGURE E-10



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 Morundah

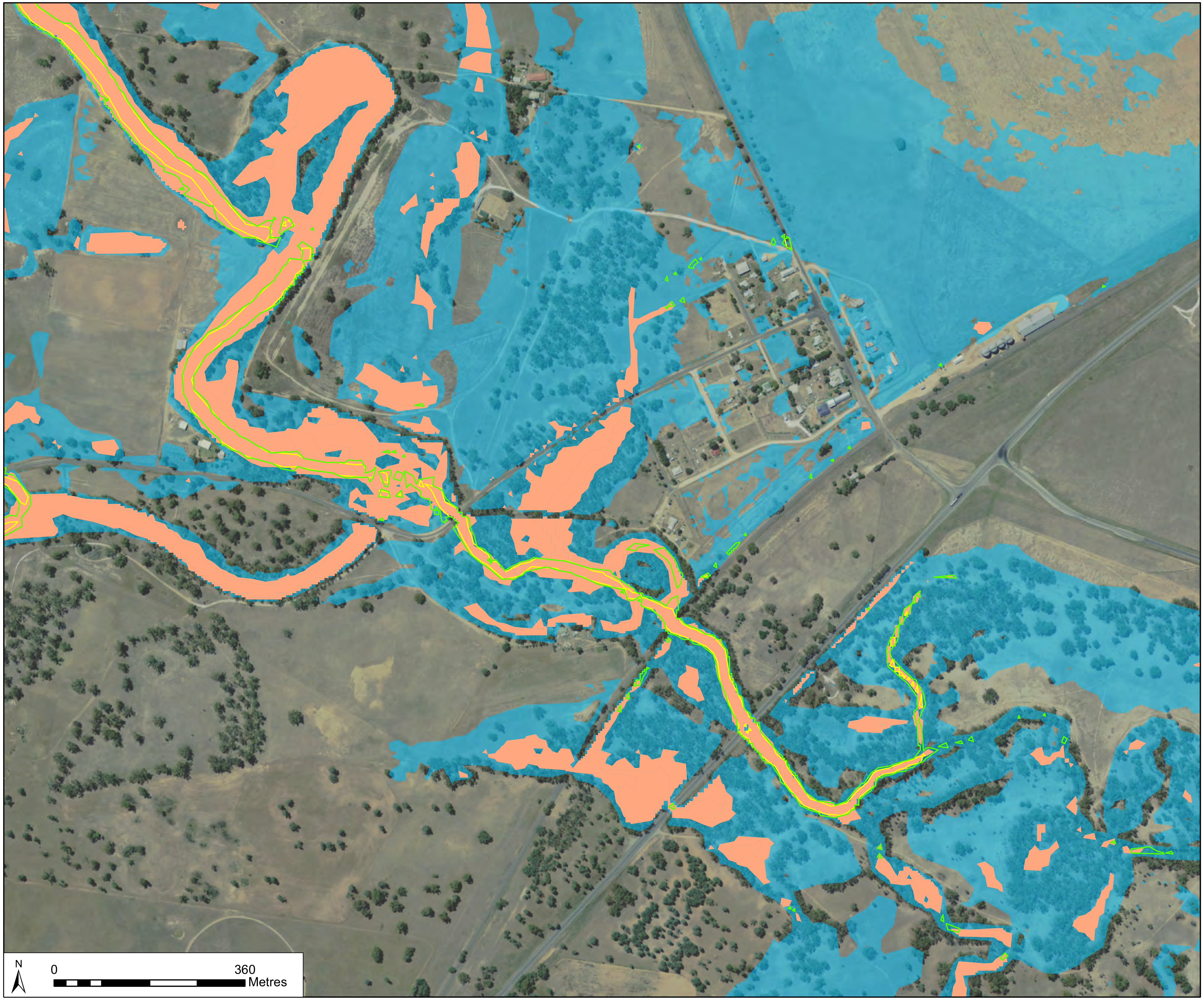
PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN AG | PROJECT # IA055600

CHECK AH | DATE 5/25/2016

FIGURE E-11



Legend

- VD > 0.25
- VD > 0.5
- 1% AEP High Hazard
- 5% AEP Flood Extent

GDA 1994 MGA Zone 55
Scale: A3

Data Sources: LPI, OEH, Council

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

JACOBS

TITLE 1% AEP Floodway Outlines

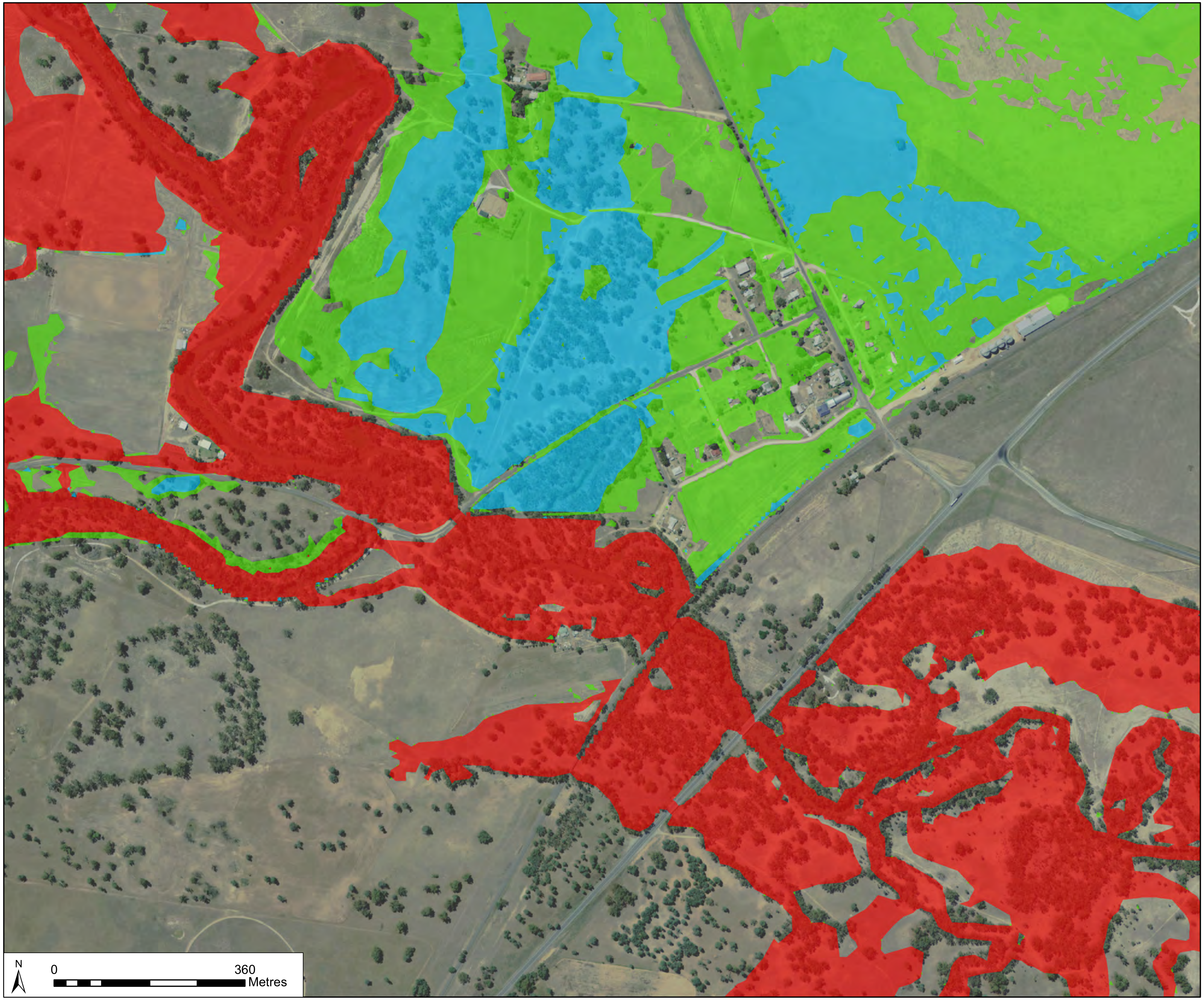
TOWN Morundah

PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN MR PROJECT # IA055600
CHECK AH DATE 9/06/2016

FIGURE E-12



Legend

- Floodway
- Flood Storage
- Flood Fringe

Depths below 150mm have been trimmed from this map

GDA 1994 MGA Zone 55
Scale: A3

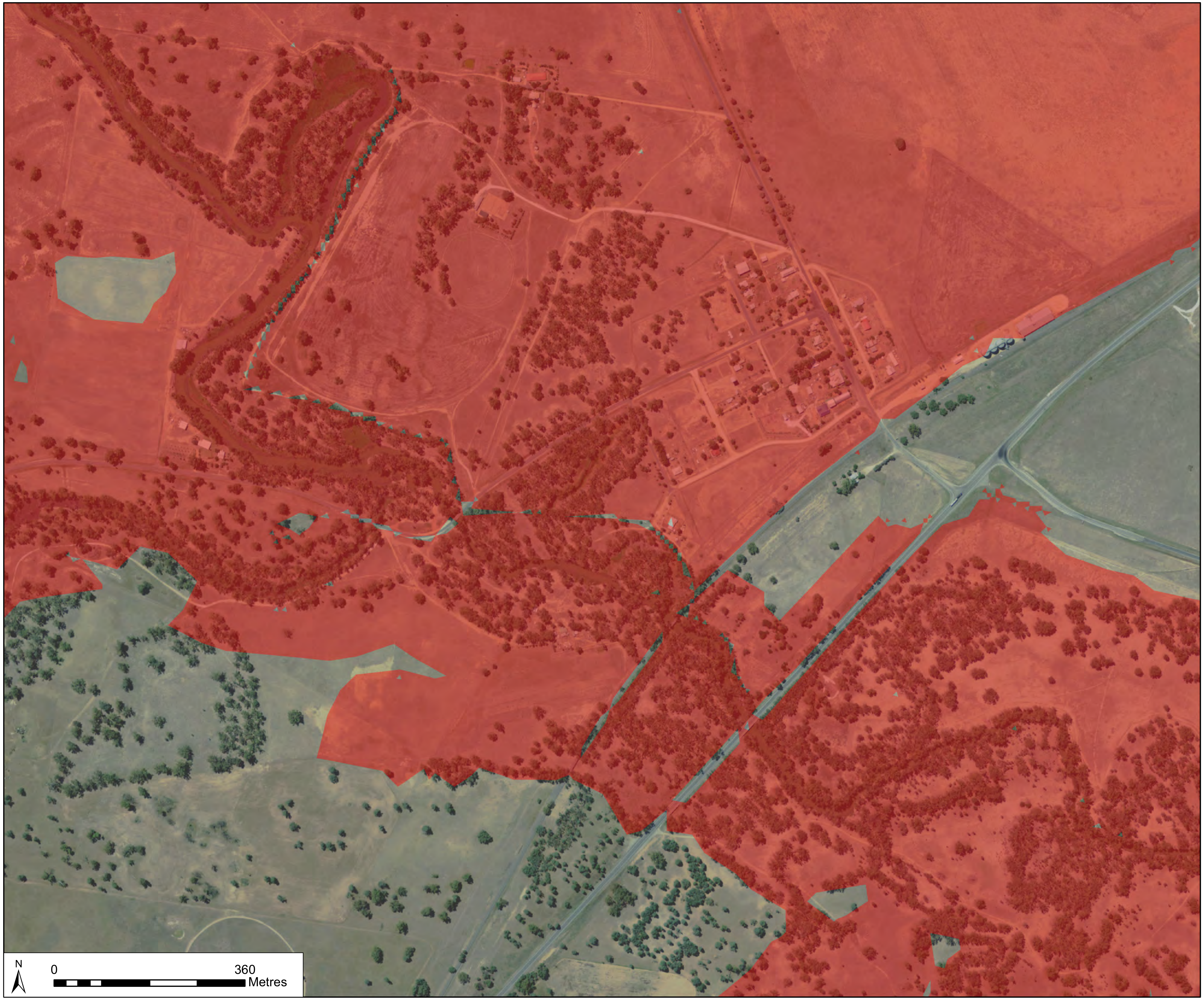
Data Sources: LPI, OEH, Council

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

JACOBS

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

DRAWN MR	PROJECT # IA055600	FIGURE E-13
CHECK AH	DATE 9/06/2016	



Legend

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 Morundah

PROJECT Flood Study for Five Towns

CLIENT Federation Council

DRAWN	PROJECT #	
MR	IA055600	FIGURE E-14
CHECK	DATE	
AH	9/06/2016	