Data Collection, Review and Flood Study for West Coonamble, Gulargambone and Quambone

COONAMBLE SHIRE COUNCIL

Gulargambone Flood Study Report

FINAL

October 2016

COONAMBLE SHIRE COUNCIL

JACOBS

Gulargambone Flood Study Report

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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

Coonamble Shire Council intends to develop a Floodplain Risk Management Plan for the Village of Gulargambone to address the existing, future and continuing flood problems, in accordance with the NSW Floodplain Development Manual (2005). This report represents the first and the second stages of the management process and has been prepared for Council by Jacobs (Sinclair Knight Merz merged with Jacobs in December 2013). It documents the nature and flooding extents within the Study Area for Gulargambone and is an essential resource for the subsequent stages of the floodplain management process.

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to prepare a flood study report for the village of Gulargambone in accordance with the scope of services set out in the contract between Jacobs and Coonamble Shire Council (hereafter Council). That scope of services, as described in this report, was developed with the Council.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Council 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 Council (if any) 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' scope of work for this study.

This report has been prepared on behalf of, and for the exclusive use of, Council, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and Council. 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

The village of Gulargambone (population approximately 367 according to 2011 census) is situated on the Castlereagh Highway approximately 50km north of Gilgandra and 45km south of Coonamble in the central west of NSW. The village is located in the Castlereagh River Catchment and is the local centre of a rich and diversified pastoral and agricultural area with the major industries being wheat, cattle and sheep. These industries are supported by an array of professional and specialist services such as a rural transaction centre, rural supplies, mechanical repairs, workshops and fuel outlets and skilled tradespeople.

The study area for Gulargambone (refer **Figure 1-1**), shows that the central village area is a typical grid pattern running in a north-south and east-west direction. The Castlereagh River (catchment area 7,000 km^2 upstream of Gulargambone Bridge) runs along the western and the north-western boundary of the village and Gulargambone Creek (600 km^2) runs along the north and the eastern boundary of the village. Gulargambone Creek joins the Castlereagh River at the northern boundary of the village. Due to the close proximity of two major waterways and the relatively flat terrain of the village, the village has experienced in excess of 12 flood events since 1950 with local overland flows causing flooding in low lying areas. Hence there is a need to define the extent of flooding and to determine appropriate development controls and to develop a Floodplain Risk Management Plan for the village of Gulargambone.

Sinclair Knight Merz (operating as Jacobs since December 2013) was engaged by Coonamble Shire Council in May 2013 to undertake a flood study for the study area in Gulargambone.

1.1 Objectives

Objectives of this study are to:

- Define the extent of flooding within Gulargambone village and to highlight problem areas for a range of flood events;
- Determine the potential impact of overland flooding;
- Identify interim development controls to minimise any future impact on private and public assets; and
- Prepare an interim flood planning area map for inclusion into the Coonamble LGA - LEP 2011.

The overall study is being undertaken in two major phases:

Stage 1 Initial Investigations

- Undertake a comprehensive site inspection with nominated Council staff, authorised representatives and nominated local residents as arranged by Council.
- Review of all relevant documents, data and available reports.
- Undertake a comprehensive consultation with the local community, Council and relevant agencies.
- Collate and assess all data and information required to satisfy the objectives.
- Identify any gaps in the available data including surveys required to complete the study and update all information as required with the approval of the Council.

Stage 2 Flood Study

- Establish appropriate hydrologic and hydraulic/ hydrodynamic models to include riverine and overland flooding for the village of Gulargambone for use in the estimation of design floods. The events of interest include the 0.5%, 1% and 5% annual exceedance probability (AEP) events, together with the Probable Maximum Flood (PMF) / or relevant extreme flood event.

Legend

- Study Area
- Cadastre
- Daily Read Rain Gauge
- Stream Gauge
- Water Course

SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	Study Area
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council
DRAWN	AH
PROJECT #	EN04190
MAP #	FIGURE 1-1
REV	1
VER	1
CHECK	AH
DATE	11/03/2016

GIS MAP file: EN04190_G_Fig 1-1 Study Area_Solar

- Following the above, establish appropriate hydraulic categories including floodways, flood storages, flood fringes, etc. and provisional hazard categories along with the mapping of the Flood Planning Area for residential developments (1% AEP event flood level +0.5 m freeboard – considered to be the flood planning level for residential development) as described in Planning Directions for NSW.

1.2 Structure of the Report

This report describes the outcomes from Gulargambone Flood Study. 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 hydrologic assessment undertaken for this study

Section 4: details hydraulic assessment, flood behaviour and flood mapping

Section 5: discusses stormwater drainage issues for the area around Wilga Street

Section 6: provides conclusions and recommendations on the study

Section 7: provides acknowledgements for this study

Section 8: provides details on references citied in this report

Section 9: provides the glossary of terms

Appendix A: contains the Newsletter and Questionnaire sent to residents

Appendix B: provides topographic survey details

Appendix C: details on hydrologic modelling

Appendix D: details on hydraulic modelling

2. Initial Investigations

2.1 Site Inspection

A site inspection was carried out on 5 June 2013 to gain an overall appreciation of the study area, including flood behaviour. Information gained from the site reconnaissance was utilised to define the scope of the topographic survey for this study and to determine modelling parameters such as Manning's roughness coefficients for channels and floodplains located within the study area.

2.2 Data Collection and Review

Council and a number of government agencies including NSW Office of Environment and Heritage (OEH), NSW Department of Primary Industries (DPI) Water, State Emergency Services (SES) and the Bureau of Meteorology, were contacted to collect information on flooding, topographic data and flood evacuation etc. However, very limited information was available from the agencies.

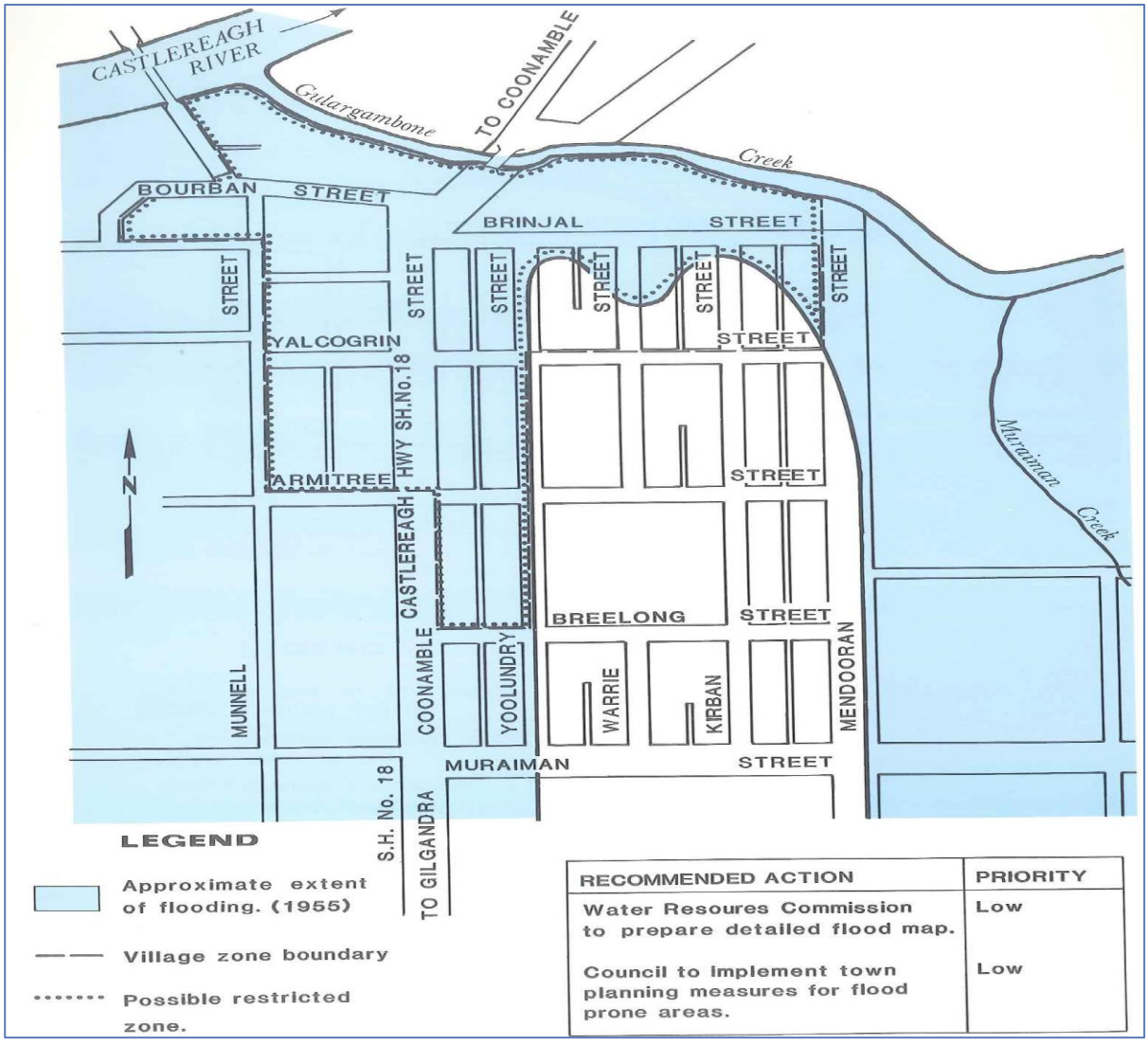
2.2.1 Available Reports

- **Coonamble Shire Flood Emergency Sub Plan (2013)** – The plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Coonamble Shire Council area. The plan covers all levels of flooding within the Council area. The plan (provided to Jacobs by Council) does not include any flood intelligence. However, Lyall & Associates in their report covering the Dec 2010 flood event at Gulargambone identifies that SES Local Flood Plan includes flood intelligence for Gulargambone. The plan identifies that the following locations may be suitable for use as flood evacuation centres in Gulargambone:
  - Gulargambone Central School, Yalcogrin Street;
  - Memorial Hall, Bourbah Street;
  - Sports Ground, Munnell Street;
  - Bowling Club, Coonamble Street; and
  - Golf Club, Muraiman Street.
- **Flood Intelligence Report Castlereagh Valley December 2010 Flood, Draft Report, February 2013 (Lyall & Associates)** The draft report documents flood behaviour for the December 2010 flood event in the Castlereagh Valley on the basis of data collected on the impacts of the December 2010 flood in four urban centres which include Mendooran, Gilgandra, Gulargambone and Quambone. Key findings from the report on the village of Gulargambone are provided below:
  - The December 2010 flood reached a peak of 4.85 m at the Gulargambone Gauge (Station No. 10168) on the Castlereagh River, which was between 1.0 - 1.5 m higher than the level reached during three recent floods, the peaks of which occurred on 24 December 2007 (3.48 m), 28 December 2009 (3.30 m) and 4 January 2010 (3.82 m). The December 2010 flood peak at Gulargambone was 200 mm lower than the level reached during the 1974 flood (5.05 m) and almost a metre lower than the level reached during the 1971 flood (5.79 m). However, according to Rankine & Hill (1983) the 1971 flood reached a gauge height of 5.4m which is 0.39m lower than the gauge height identified by Lyall & Associates. The 1955 flood peaked 3.65 m higher than the level that was reached during the December 2010 flood at 8.5 m on the Gulargambone Gauge.
  - Whilst the village was not affected by mainstream flooding during the December 2010 flood, SES were required to pump water from Nos. 3, 5, 7, 9, 11 and 13 Wilga Street. Water was also observed in Nos. 20, 22 and 24 Coonamble Street. Flooding is believed to be as a result of local catchment runoff which ponded in these properties on 1st and 3rd December 2010, several days prior to the arrival of the flood peak in the Castlereagh River.

- The travel time of the flood wave between Gilgandra and Gulargambone for the two flood peaks was between 16 - 18 hours, which equates to an average flow velocity of between 3.5 - 4.0 km/hr.

- **New South Wales Inland Rivers Flood Plain Management Studies - Castlereagh Valley (Rankine & Hill 1983) –** The report includes a map which represents the area of Gulargambone village affected by the February 1955 flood. The report identifies the February 1955 flood is the only flood to have caused any problems within the village. The Castlereagh River reached a peak stage of 8.5m on the gauge located on the road bridge over the Castlereagh River at Gulargambone, while in 1971 it reached a peak of 5.4m. The 1955 caused extensive damages in Gulargambone, particularly in the area between Yoolundry Street and Castlereagh River on the western side where properties were inundated up to depths of 1m. Flood damages for the 1955 flood were estimated at $50,000. The report did not recommend any structural flood mitigation measures for Gulargambone where flooding were extremely rare. However, the report recommended Council to implement planning measures to control existing and future development in the flood prone portions of the village shown in **Figure 2-1**.

- **Figure 2-1 Approximate 1955 flood extent and zonings (source: Figure 9.5 Rankin & Hill, 1983)**



2.2.2 Flood Planning and Development Control Plans

- **Clause 6.6 of Coonamble Local Environment Plan (LEP, 2011)**

  1. The objectives of this clause are as follows:
     - to minimise the flood risk to life and property associated with the use of land,
     - to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,
     - to avoid significant adverse impacts on flood behaviour and the environment.
  2. This clause applies to land at or below the flood planning level.
  3. Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:
     - is compatible with the flood hazard of the land, and
     - is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and
     - incorporates appropriate measures to manage risk to life from flood, and
     - is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and
     - is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.
  4. A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0), published in 2005 by the NSW Government, unless it is otherwise defined in this clause.
  5. In this clause, flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

- **Fencing Policy (1999)**: The current fencing policy applies to the village of Gulargambone. The policy does not consider impact of fencing on flood behaviour.
- **Section 149 Certificate**: Coonamble Shire Council issues Section 149 (2) Planning Certificate and Section 149 (2) & (5) Planning Certificate. Information on flood risk is not included on in these Certificates.

2.2.3 Bridge Drawings

Coonamble Shire Council provided work as executed drawings(WAE Drawing Nos. 11614-S01, 11614-S02 dated 16 Nov 2009) prepared by Barnson for Fulton Hogan for the new Gulargambone Bridge. Key features of the new bridge as shown of the drawings are summarised below:

- The 100 year ARI flood level at the bridge is RL 224.05m;
- Deck levels for the old bridge and the new bridge are shown as RL 221.65m and RL 223.85m respectively;
- The clear waterway area for the old bridge and the new bridge being 237m^2 and 503 m^2 respectively; and
- The 13 span old timber bridge was 129m long and the new concrete bridge is 135m long and it has 9 spans.

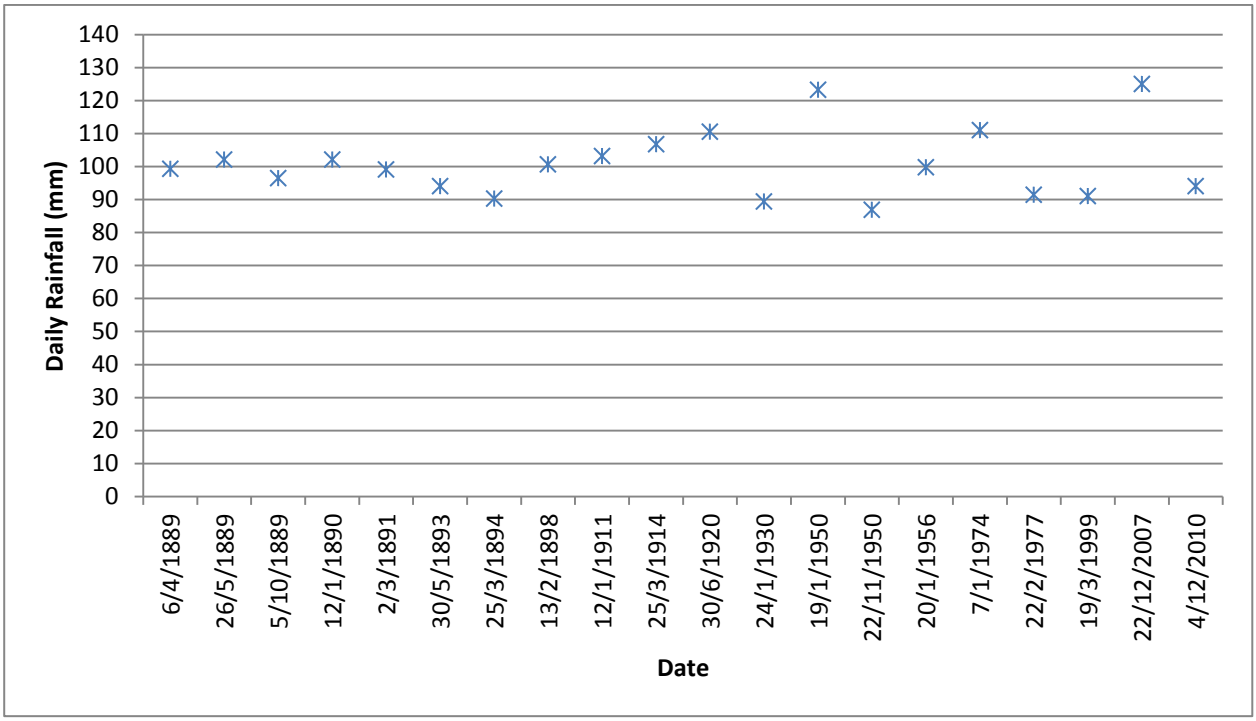
Information compiled by Lyall & Associates (2013) on the December 2010 flood event, indicates that Gulargambone Bridge on the Castlereagh River was overtopped during the flood event of December 2010. The AEP of the December 2010 flood at Gilgandra Town gauge is similar to a 10% AEP event.

2.2.4 Rainfall Data

High rainfall in the upper catchment area of the Castlereagh River is considered to be the key source flooding in Gulargambone. A search was conducted on the Bureau of Meteorology's website to locate rainfall stations in the close proximity of Gulargambone to define the rainfall in the village. The daily read rain gauge located (refer to **Figure 1-1**) at Gulargambone (Yalcogrin St) Station (No. 051022) is the nearest rainfall gauge. The gauge was commissioned in 1886 and it is still in operation.

The twenty (20) highest one-day (9 AM to 9 AM) rainfall events recorded at rain gauge No. 051022 are shown in **Figure 2-2**. This shows that the maximum one-day rainfall recorded at the gauge was 125mm, which occurred on 22 December 2007, and the second highest rainfall (123.2mm) occurred on 19 January 1950. The gauge recorded 37.8mm, 83.8mm, 56.6mm and 10.4mm of rainfall on 23, 24, 25 and 26 February 1955, respectively, which is considered the highest flood on record in the village. It is to be noted that the recorded rainfall on 24 February 1955 is not included in the twenty highest 1-day rainfall shown in **Figure 2-2**.

- **Figure 2-2 Twenty Highest 1-Day Rainfall Recorded at Gulargambone (Yalcogrin St) Rain Gauge (051022)**



2.2.5 Streamflow Data

A review of PINNEENA version 9.3 (a surface water database released by NSW DPI Water) shows that no available streamflow gauging stations are located in the vicinity of the village of Gulargambone. Rankine & Hill (1983) identifies that the staff gauge located on the road bridge on the Castlereagh River at Gulargambone is operated by the SES during flood times and records are taken by the SES. Recorded heights at the gauge during the December 2010 event for example was captured by the SES as reported in the Lyall & Associates Report 2013. Limited information is available on the history of the gauge.

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 A) 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, twelve (12) responses were received from the community to the questionnaire. A summary of responses is provided in the following paragraphs.

Residency status (Question 1)

All respondents were residents of the study area.

Length of Residency in Gulargambone and Business Activity (Questions 2-4)

Respondents lived in the Study Area between 1 to 60 years with an average residency of 25 years. Three (3) respondents managed business located within the study area.

Experiences of Flooding (Questions 5-12)

One respondent experienced flooding in the property in 2010, which caused major damages to garden, lawn and backyard and the duration of flooding was longer than three days and access to the property was cut off.

Another respondent experienced flooding in the property located outside the study area. Flooding cut off access to the property, damaged a car ($2,000) and residents of the property required assistance from the SES during the flood.

Flood Affects to properties due to works (Questions 13 - 14)

One respondent located outside the study area identified that the public road aggravated flooding to the property.

Intention of Respondents for further development (Question 15)

One respondent was expecting to undertake minor extensions to the property.

Priority for protecting different types of developments from flooding (Question 16)

Respondents were asked to rank different types of development for protection against flooding. One respondent gave the highest priority for protection of residences against flooding.

Priority for flood mitigation measures (Question 17)

Maintaining an emergency flood free access was given the highest priority by two respondents and one respondent gave the highest priority to providing flood warning.

Willingness to provide additional information (Question 18)

Respondents did not provide additional information.

Contact details for respondents (Question 19)

Two respondents provided their contact details.

2.4 Topographic Survey

Very limited topographic data was available for the village of Gulargambone to undertake this flood study. A LiDAR (Light Detection And Ranging) survey supplemented with ground survey was considered to be the most feasible option of collecting the required topographic data for this flood study. All topographic data available to this study are to be provided to Council after completion of the flood study.

2.4.1 LiDAR Survey

Fugro Spatial Solutions Pty Ltd was engaged by Council to provide topographic survey data based on a LiDAR survey of the study area and accordingly, the LiDAR survey was undertaken on 21 March 2014. Fugro provided 1m square, 2m square and 10m square grid data and 0.5m contour data for the ground surface. The full LiDAR point cloud was classified to Level 3 according to NSW Land and Property Information (LPI) requirements. The spatial horizontal accuracy of the LiDAR data was 0.19m @ 67% CI and the vertical accuracy of the LiDAR data was 0.09m @ 67% CI.

A Digital Elevation Model (DEM) was created using the 1m square grid data provided by Fugro and is shown in **Figure 2-3**.

2.4.2 Ground Survey

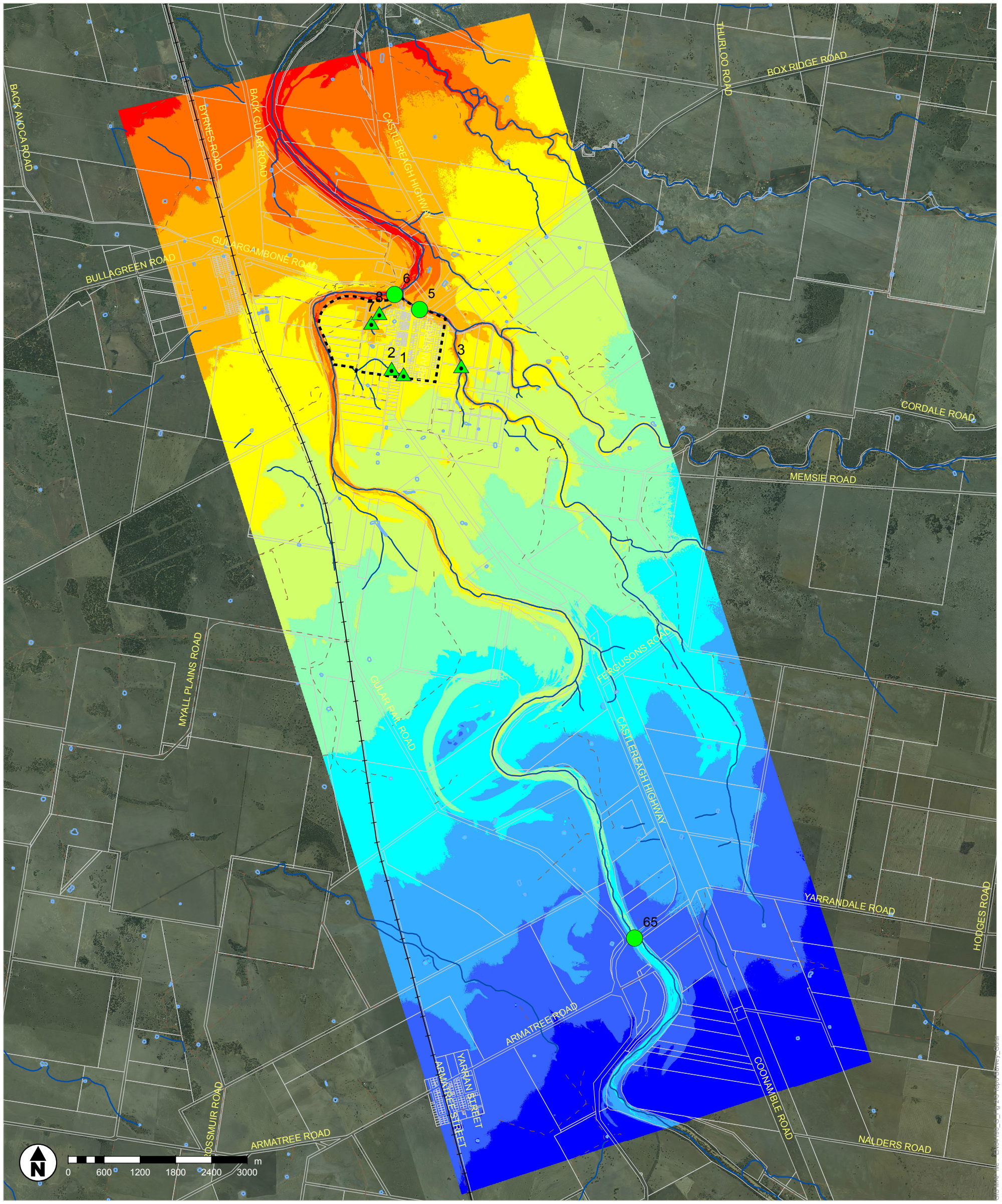
The scope of the ground survey was identified by Jacobs, with Council engaging Geolyse Pty Ltd to undertake the ground survey. Geolyse provided the following results from the ground survey to Jacobs:

- Details (eg. size, shape, invert level, top of road level etc) for 5 culverts;
- Details for 3 bridges; and
- Fifteen (15) items identified in **Table 2-1** including the gauge zero for .the staff gauge on the Castlereagh River @ Gulargambone Bridge.

Location of surveyed culverts and bridges is shown in **Figure 2-3** and details on the other surveyed features are provided in **Appendix B**. It is to be noted that fourteen (14) flood marks were identified by residents during the community consultation process. However, during the ground survey residents were unavailable or unable to locate twelve (12) flood marks and subsequently floor levels of 12 buildings were surveyed. The gauge zero for the staff gauge on the Castlereagh River @ Gulargambone Bridge was estimated at 219.46 mAHD.

Table 2-1 Other features surveyed

Item No.	Item	Location	RL (m AHD)	Description
1	Floor Level	13 Wilga St	226.644	
2	Floor Level	25 Munnell St	226.398	
3	Floor Level	54 Munnell St	226.563	
4	Floor Level	5 & 7 Wilga St	226.365	
5	Floor Level	23 Munnell St	226.133	
6	Floor Level	7-19 Skuthorpe Lane	226.249	
8	Floor Level	76 Munnell St	227.129	
9	Floor Level	61 Munnell St	226.395	
10	Floor Level	63 Munnell St	225.945	
11	Floor Level	65 Munnell St	226.023	
12	Floor Level	2-6 Bourbah St	225.933	
13	Floor Level	4 Evelyn Simpson Ave	226.021	
15	Flood Mark	Church, Armitree St	226.243	
16	Flood Marks	Gulargambone Road	225.44, 225.84	Two bolts on a tree
17	Gauge Zero	Gulargambone Bridge	219.46	Castlereagh River Gauge



Legend

- Study Area
- Cadastre
- Surveyed Bridge
- Surveyed Culvert

LiDAR Data

m AHD

- 212.8 - 219.9
- 220 - 222.5
- 222.6 - 225
- 225.1 - 227.8
- 227.9 - 230.7
- 230.8 - 233.8
- 233.9 - 237
- 237.1 - 240
- 240.1 - 242.9
- 243 - 248.2

Data Sources: LPI, Council.

SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	Surveyed Features
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council
DRAWN	AH
PROJECT #	IA013100
MAP #	FIGURE 2-3
REV	1
VER	1
CHECK	AH
DATE	26/03/2016

3. Catchment Hydrology

3.1 Sources of Flooding

The study area is located at the confluence of the Castlereagh River and Gulargambone Creek. The Castlereagh River (catchment area 7,000 km^2 upstream of Gulargambone Bridge) runs along the western and the north-western boundary of the study area and Gulargambone Creek (600 km^2) runs along the north and the eastern boundary of the study area. Gulargambone Creek joins the Castlereagh River at the northern boundary of the study area. Hence the Castlereagh River and Gulargambone Creek are major sources of flooding for the study area. However, limited information was available to this study on the relative timing of floods between the Castlereagh River and Gulargambone Creek.

3.2 Estimation of Design Discharges for the Castlereagh River

In the absence of long-term recorded streamflow data for the Castlereagh River @ Gulargambone gauge (catchment area 7,000 km^2), the flood frequency results for the Castlereagh River @ Gilgandra gauge (catchment area 6,350 km^2) adopted in the Gilgandra Floodplain Management Study (Lyall & Macoun 1996) were scaled up to estimate design discharges in the Castlereagh River @ Gulargambone gauge using the following equation:

$$Q_{Gulargambone} = Q_{Gilgandra} \times (A_{Gulargambone} / A_{Gilgandra})^{0.7}$$

where, Q is discharge (m^3/s) and A is catchment area (km^2).

The adopted design discharges in the Castlereagh River at Gilgandra gauge and Gulargambone gauge are shown in **Table 3-1**. The gauge at Gulargambone is located upstream of the junction of the Castlereagh River and Gulargambone Creek.

Table 3-1 Adopted design discharges

AEP	Castlereagh River at Gilgandra (6,350 km^2)	Castlereagh River at Gulargambone (7,000 km^2)
5%	1870	2000
2%	3000	3210
1%	4050	4340
0.5%	5265	5640

3.3 Estimation of Design Discharges for Gulargambone Creek

Gulargambone Creek is the waterway adjacent to the village of Gulargambone. The creek originates approximately 50km east of Gulargambone and flows in a westerly direction towards Gulargambone. There are a number of minor tributaries which join the creek before it joins with the Castlereagh River just north of Gulargambone Village. Gulargambone Creek, at the village of Gulargambone, drains a catchment area of approximately 600km^2. The average slope of the catchment is approximately 0.3% and the general land use within the catchment area of Gulargambone Creek upstream of Gulargambone is rural/natural. The banks are

lined with River Red Gums and Grey Box while the floodplain is covered by Poplar open woodland and open grassland, cleared for grazing.

No recorded streamflow data were available for Gulargambone Creek or its tributaries. Moreover, the method recommended in Australian Rainfall & Runoff (IEAust, 2001) for estimation of peak discharges for undulating and hilly regions in western NSW using the Probabilistic Rational Method is only applicable up to 250km^2 and the 5% AEP event. Hence, it was necessary to develop a rainfall runoff model to estimate design discharges for Gulargambone Creek and for a range of flood events for use in this study. The following sections describe details on the methodology adopted in the estimation of design discharges.

3.3.1 Selection of the Rainfall Runoff Model

The runoff routing model that was selected for this study is the RORB model version 6.18 (Laurenson et al 2010). RORB is one of the most widely used models of its type in Australia, and consequently there is substantial information available on the value of the model parameters for a wide range of catchments. The model has the capability to simulate both linear and non-linear catchment behaviour, and exhibits many desirable modelling features, such as areally distributed inputs, flexible reservoir-routing options and the ability to model flows at a number of points throughout the catchment.

3.3.2 Configuration of the RORB Model

The best available topographic data for the Gulargambone Creek catchment was 10m contour data and the LiDAR survey. Combined with a GIS layer of watercourses and satellite imagery, sub-areas for the RORB model were delineated. The sub-areas within the RORB model were defined to coincide with watershed boundaries and stream junctions. The resulting sub-areas of the RORB model are shown in Appendix C.

The RORB model consisted of 17 nodes and 16 links. Out of the 17 nodes, 13 represent sub-catchments, 3 were stream junctions and the remaining one was the outlet. At the catchment scale, the proportion of imperviousness represented by houses and roads were considered negligible and therefore was not included in the model. All links were defined as natural channel type. Sub-areas for the RORB model and channel lengths were measured in MapInfo using the MiRORB tool.

3.3.3 Input Data for Design Flood Estimation

Rainfall Depths

The rainfall design data necessary for this study was generated from the Bureau of Meteorology's website (BoM 2014). The derivation of the rainfall intensity, frequency and duration (IFD) relationship within RORB was based on data presented in **Table 3-2**.

Table 3-2 Data used to estimate design rainfall IFD

Parameter	Value
Zone	2
1 hour 2 year ARI (mm/hr)	29.31
12 hour 2 year ARI (mm/hr)	4.89
72 hour 2 year ARI (mm/hr)	1.31
1 hour 50 year ARI (mm/hr)	58.18
12 hour 50 year ARI (mm/hr)	10.03

Parameter	Value
72 hour 50 year ARI (mm/hr)	2.65
Skewness G	0.29
Geographical factor 2 year ARI F2	4.32
Geographical factor 50 year ARI F50	15.69

Areal Reduction Factors

Areal reduction factors (ARF) were applied based on the Siriwardena and Weinmann formulation (IEAust 2013) for the NSW GTSMR region. These factors were applied to events up to, and including, the 1% AEP event. Adopted ARF in this study for the 18 hour storm is 0.86 and the ARF from AR&R 1987 for the same storm duration is 0.91.

Temporal Patterns

Temporal patterns for all events storm durations up to, and including, the 1% AEP event were sourced using the 'filtered' pattern approach contained in RORB.

Initial and Continuing Rain Losses

Initial losses were varied based upon the AEP of the event. These losses were based on the research conducted by Walsh (1991). Continuing losses were set to the recommended 2.5mm/h for all events. A summary of the rain losses used can be seen in **Table 3-3**.

Table 3-3 Initial and continuing losses used

Rain Loss	5% AEP	1% AEP	0.5% AEP
Initial loss (mm)	25	15	15
Continuing loss (mm/hr)	2.5	2.5	2.5

K_c and m Parameters

A fixed value of 0.8 was adopted for m. This is the recommended value to use provided there is minimal information about catchment behaviour or gauge data to calibrate against (Laurenson et al, 2010). It is a common practice to estimate the value of k_c using Kleemola (1987) for ungauged catchments located in eastern NSW and Lipp (1983) for catchments located in western NSW. Kleemola (1987) gives a k_c= 23 and Lipp (1983) gives k_c = 50 (approximately) for the catchment area of Gulargambone Creek. The catchment area of Gulargambone Creek lies between the regions where the relationships for the estimation of k_c values were developed by Kleemola (1987) and Lipp (1983). In this study Pearse et. al. (2002) (i.e. $k_c = 1.14 \times D_{av}$) was used to estimate the value of k_c. Pearse et. al. (2002) gives k_c = 37.4 which lies between Kleemola (1987) and Lipp (1983) estimates and the adopted value of k_c is considered a reasonably sound estimate.

3.4 Validation of Design Discharges

The 18 hour storm produced the peak discharge for all the events run (5% to 0.5% AEP) for Gulargambone Creek. A comparison of design discharges estimated by the RORB model and the regional peak flow estimates for Western NSW is shown in **Table 3-4**. Table **3-4** shows reasonable agreement between RORB and regional estimates for Gulargambone Creek for the less frequent rainfall events. The RORB model underestimates the peak discharge for events up to and including the 5% AEP event, and shows good agreement with the 2% AEP estimate. Considering the paucity of recorded pluviograph and streamflow data, parameter values adopted in the RORB model were not refined further.

Table 3-4 Comparison of design discharges (m^3/s)

AEP	Gulargambone Creek at Gulargambone	
	RORB	PRM for Western NSW
5%	265	310
2%	480	470

4. Hydraulic Modelling

4.1 Approach

Whilst the hydrologic analysis and modelling were undertaken to design discharges for the Castlereagh River and Gulargambone Creek, a hydraulic model is required to translate the design discharges into water levels and velocities which are critical elements in defining the flood risk.

4.2 The Hydrodynamic Modelling Software

The hydrodynamic model selected for use in this study is the Danish Hydraulic Institute's MIKE11 modelling system. MIKE11 is a one-dimensional, finite difference modelling system for rivers and floodplains using the full Saint Venant Equations of momentum and continuity for unsteady flow. The modelling system allows flow to occur in one-dimensional flow paths (must be identified by the modeller), which can be linked in a network to represent quasi two-dimensional flow behaviour experienced on floodplains. It has the ability to model hydraulic structures, weirs and floodplain storages. MIKE11 has been extensively used in flood studies and floodplain management studies in Australia and overseas for the last 25 years.

MIKE11 has the following data requirements:

- Topographic data: as channel and floodplain cross sections;
- Bed resistance for cross sections;
- Obstructions to flow: details of hydraulic structures such as levees, culverts, bridges and weirs;
- Inflows to the model at appropriate locations; and
- Downstream boundary conditions in the form of water levels or stage-discharge rating curves.

The first step in developing a MIKE11 model involves schematising the floodplain into discrete topological elements. Important topological elements are stream channels, floodplains and hydraulic structures including bridges, culverts, weirs, levees, causeways, etc. These elements are usually represented by cross sections orthogonal to the direction of flow.

The second step in constructing a MIKE11 model is to designate links between each of the topologic elements. The links indicate the direction of flow assigned in the model and show the inter-connected network of flow paths.

The third step involves transforming the topologic data into hydraulic parameters for use in the solution of the momentum and continuity equations. This includes vertical integration of cross sectional area, hydraulic radius, width and bed resistance.

In the fourth step, hydrologic inputs such as inflows and outflows to the model are defined. Generally, inflows are defined by inflow hydrographs, whereas outflows are defined by water level hydrographs or stage-discharge rating curves (a curve that shows relationship between flood flows and flood levels at a specified location in a stream channel).

In the fifth step, the model is run to simulate flooding conditions for the selected flood events. If adequate data is available the model is calibrated and once the model is calibrated, the performance of the model is validated against flood events not used in model calibration.

4.3 Model Formulation

4.3.1 Schematisation

Details on the topographic data available for this study are discussed in Section 2.4 and it is to be noted that both the Castlereagh River and Gulargambone Creek were dry when the LiDAR data was captured. A digital terrain model (DTM) was created using the 1m DEM provided by Fugro. The DTM was used to identify the main flow paths along the Castlereagh River (24.3 km reach) and Gulargambone Creek (4.4 km reach). In addition, the DTM was used to define the following major breakouts (refer **Figure 4-2**):

- A breakout is located on the eastern bank of the Castlereagh River approximately 500m upstream of the Castlereagh Highway Bridge. Flood flows escaping the river in the vicinity of MIKE11 cross section "CASTLEREAGH 2720" cross Yarrandale Road and flows into Muraiman (Mariemon) Creek which runs almost parallel to the Castlereagh Highway and joins Gulargambone Creek (in the vicinity of MIKE11 cross section "GULAR 3320") east of Mendooran Street. An 11.9 km long flow path called "MURAIMAN" was defined in the MIKE11 model to represent the breakout and the reach of Muraiman Creek.

- A 1.76 km long flow path called "OF_1" was defined in the MIKE11 model to represent a breakout on the eastern bank of the Castlereagh River at cross section "CASTLEREAGH 17180". Flood flows escaping the breakout cross two unsealed roads via pipe culverts (single cell 0.375m diameter pipe at the unnamed road crossing and single cell 0.25m diameter pipe at Skuthorpe Road crossing) and join the Castlereagh River upstream of Gulargambone Road Bridge in the vicinity of MIKE11 cross section "CASTLEREAGH 19680.

- A 2.09 km long flow path called "OF_2" was defined in the MIKE11 model to represent a breakout on the western bank of Muraiman Creek in the vicinity of MIKE11 cross section "MURAIMAN 11050" Flood flows escaping the breakout cross Coonamble Street via a single 0.45m diameter pipe culvert and Munnell Street via two 0.45m diameter pipe culverts and join the MIKE11 flow path OF_1 in the vicinity of cross section "OF_1 1120".

In total, eighty four (84) cross sections were cut from the DTM developed using the LiDAR data to represent the identified flow paths in the MIKE11 model. Significant hydraulic controls represented in the MIKE11 model include two road bridges over the Castlereagh River, one road bridge over Gulargambone Creek, two culvert crossings along flow path OF_1, two culvert crossings for flow path OF_2 and one culvert crossing for Muraiman Creek. Details on the MIKE11 model schematic are shown in **Appendix D**.

4.3.2 Manning's 'n'

Bed resistance in the MIKE11 model was defined in terms of Manning's n using information collected from a range of sources including a site reconnaissance, photographs captured by the surveyors, available literature etc. Typical Manning's n values adopted for the various surfaces are given in **Table 4-1**.

- **Table 4-1 Adopted Manning's n Values**

Surface	Manning's n
Main Channel	0.05
Road Surface	0.015 – 0.02
Floodplain (light brush)	0.05
Floodplain (medium brush)	0.07
Floodplain (dense brush)	0.10

4.3.3 Boundary Conditions

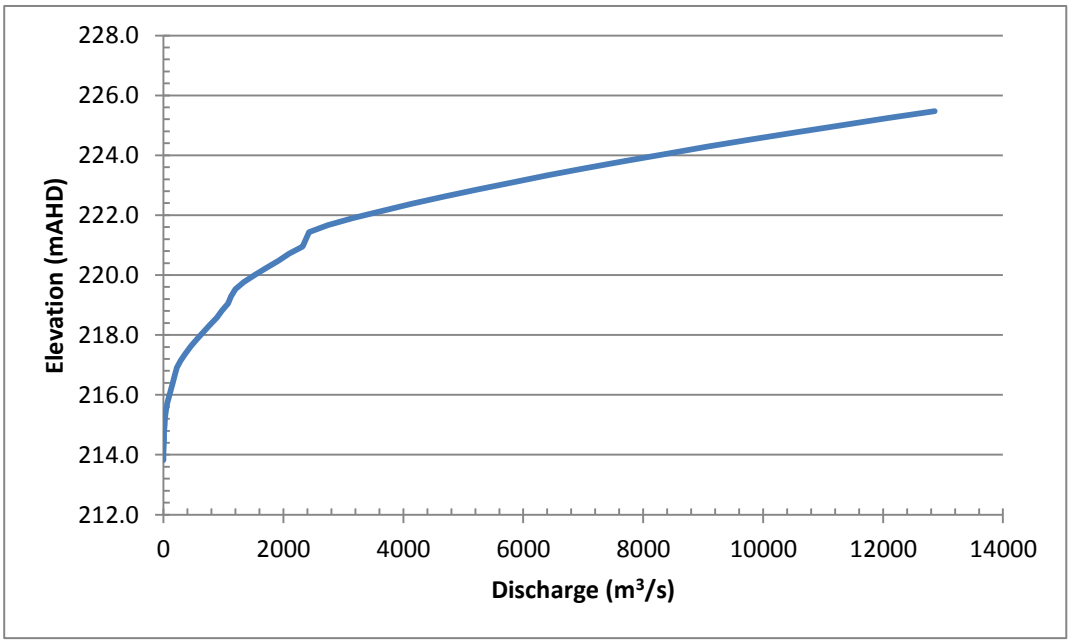
Considering the large catchment areas of both the Castlereagh River and Gulargambone Creek and the small floodplain being modelled, steady inflows were used in the MIKE11 model for the 0.5%, 1% and 5% AEP events. An extreme event, being 3 times the peak flow in the 1% AEP event, was also modelled. Considering the fact that the catchment area of Gulargambone Creek is approximately 10% of the catchment area of the Castlereagh River at Gulargambone and limited information is available on the nature of coincident flooding in the village of Gulargambone, a typical combination of coincidental flooding was adopted in this study. The adopted coincidental flooding for the selected design flood events are shown in **Table 4-2**.

- **Table 4-2 Adopted coincident inflows**

Flood Event	Castlereagh River	Gulargambone Creek
5% AEP	5% AEP (2,002 m^3/s)	20% AEP (75 m^3/s)
	20% AEP (1,040 m^3/s)	5% AEP (263 m^3/s)
1% AEP	1% AEP (4,336 m^3/s)	5% AEP (263 m^3/s)
	5% AEP (2,002 m^3/s)	1% AEP (646 m^3/s)
0.5% AEP	0.5% AEP (5,637 m^3/s)	2% AEP (478 m^3/s)
	2% AEP (3,212 m^3/s)	0.5% AEP (850 m^3/s)
Extreme	Extreme (13,000 m^3/s)	1% AEP (646 m^3/s)
	1% AEP (4,336 m^3/s)	Extreme (1,938 m^3/s)

A stage-discharge relationship was defined to represent the downstream boundary of the MIKE11 model. The stage-discharge relationship was calculated within MIKE11 at cross section "CASTLEREAGH 24300" (located approximately 4600m downstream of Gulargambone Bridge) assuming a constant friction slope of 0.001 and a Manning's n of 0.05. The adopted stage-discharge relationship is presented in **Figure 4-1**.

- **Figure 4-1 Downstream stage-discharge relationship**



4.4 Flood Behaviour

The MIKE11 model was run for the 0.5%, 1%, 5% AEP events and an extreme flood event for the coincident flood events shown in **Table 4-2**. Modelled peak water levels, discharge and velocities are presented in Appendix D.

4.4.1 Flow Distribution

Peak inflows and outflows for the modelled flowpaths for flood events dominated by the Castlereagh River inflows (ie. coincident flooding based on a rarer inflow in the Castlereagh River and a relatively smaller flood in Gulargambone Creek) are shown in **Table 4-3** as a percentage of the corresponding modelled outflow from the Castlereagh River at the downstream boundary of the MIKE11 model. An example on the flow distribution for the extreme event shown in **Table 4-3** is shown in **Figure 4-2**.

Following observations are made from **Table 4-3**:

- The Castlereagh River does not breakout upstream of the Castlereagh Highway Bridge in the 5% AEP event. In the case of flood events larger than the 5% AEP event, this breakout (ie. inflows for "MURAIMAN" flowpath) conveys up to 20% of the corresponding modelled outflow for the Castlereagh River (ie. "CASTLEREAGH").

- Inflows in Gulargambone Creek are only 3% to 7% of the corresponding modelled Castlereagh River outflows. However, outflows from Gulargambone Creek can be as high as 32% of the corresponding modelled outflow for the Castlereagh River.

- The breakout "OF_1" conveys 12% to 18% of the outflows for the Castlereagh River for the modelled flood events. In combination with the outflows from flowpath "OF_2", the peak outflow from flowpath "OF_1" is 26% of the corresponding modelled outflow for the Castlereagh River.

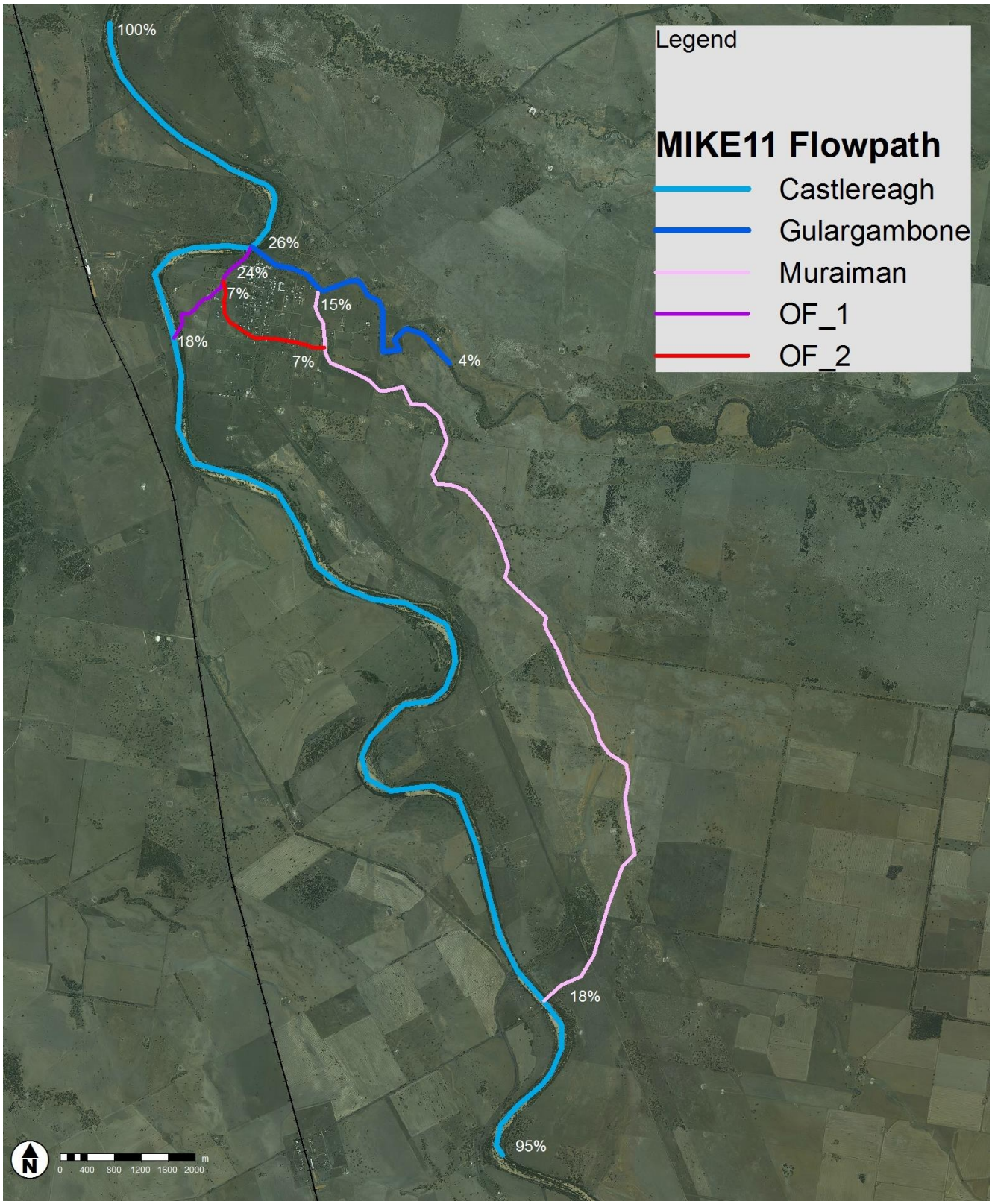
- The breakout "OF_2" does not operate in the 5% AEP event. For the remaining three flood events, the breakout conveys up to a maximum 8% of the corresponding modelled peak outflow for the Castlereagh River.

Table 4-3 Flow distribution for flood events dominated by the Castlereagh River inflows

MIKE11 Flowpath	Flow*	Flood Event			
		5% AEP	1% AEP	0.5% AEP	Extreme
CASTLEREAGH	Inflow	96%	94%	92%	95%
	Outflow	100%	100%	100%	100%
GULAR	Inflow	3%	5%	7%	4%
	Outflow	4%	26%	32%	26%
MURAIMAN	Inflow	0%	15%	20%	18%
	Outflow	0%	21%	24%	15%
OF_1	Inflow	12%	18%	18%	18%
	Outflow	12%	21%	26%	24%
OF_2	Inflow	0%	3%	8%	7%
	Outflow	0%	3%	8%	7%

* expressed as a percentage of the modelled outflow at the downstream boundary of the MIKE11 model.

Figure 4-2 : Example on Flow Distribution for the Extreme Event (refer Table 4-3)



Peak inflows and outflows for the modelled flowpaths for flood events dominated by Gulargambone Creek inflows (ie. coincident flooding based on a rarer inflow in Gulargambone Creek and a relatively smaller flood in the Castlereagh River) are shown in **Table 4-4** as a percentage of the corresponding modelled outflow from the Castlereagh River. **Table 4-4** shows that whilst inflows and outflows are increased in Gulargambone Creek, inflows and outflows for all breakouts (ie. flowpaths "MURAIMAN", "OF_1" and "OF_2") are considerably reduced. Hence, the flood behaviour in the upper reaches of Gulargambone Creek is dominated by inflows generated from the catchment area of Gulargambone Creek and flood behaviour elsewhere within the modelled floodplain is donated by inflows in the Castlereagh River upstream of the Castlereagh Highway Bridge.

Table 4-4 Flow distribution for flood events dominated by Gulargambone Creek inflows

MIKE11 Flowpath	Flow*	Flood Event			
		5% AEP	1% AEP	0.5% AEP	Extreme
CASTLEREAGH	Inflow	80%	76%	79%	69%
	Outflow	100%	100%	100%	100%
GULAR	Inflow	18%	22%	19%	28%
	Outflow	20%	24%	30%	41%
MURAIMAN	Inflow	0%	0%	6%	11%
	Outflow	2%	2%	11%	14%
OF_1	Inflow	1%	10%	15%	15%
	Outflow	1%	10%	16%	22%
OF_2	Inflow	0%	0%	1%	7%
	Outflow	0%	0%	1%	7%

* expressed as a percentage of the modelled outflow at the downstream boundary of the MIKE11 model

4.4.2 Peak Water Level Profiles

Modelled peak water levels based of the two coincident flood scenarios at each cross section were used to plot peak water level profiles along the Castlereagh River and Gulargambone Creek. Modelled peak water level profiles along the Castlereagh River are shown in **Figure 4-3** which shows the following:

- Peak water level profiles along the Castlereagh River for the modelled reach are generally consistent for all design flood events;
- The Castlereagh Highway Bridge (Chainage approximately 3200m) is not overtopped in the 5% AEP event. However, the bridge is overtopped by flood events larger than the 5% AEP event.
- The Gulargambone Bridge is overtopped by all modelled flood events. The bridge is subject to 2.4m depth of inundation in the 5% AEP event implying that the bridge is a significant hydraulic restriction. The 1% AEP event is approximately 1.5m higher than the 5% AEP event at the bridge. However, the 0.5% AEP event is only 0.45m higher than the 1% AEP event at the bridge.

Peak water level profiles along Gulargambone Creek are shown in **Figure 4-4** which shows the following flood behaviour:

- Peak water profiles along the creek are flatter approximately 2km upstream of the Castlereagh Highway Bridge due to backwater flooding from the Castlereagh River. It is to be noted that in the case of larger flood events, flow conditions are dominated by flows in Gulargambone Creek.
- The Castlereagh Highway Bridge is overtopped by all modelled flood events.

4.4.3 Peak Velocities

Modelled peak velocities based on the two coincident flood scenarios were used to plot peak velocity profiles along the Castlereagh River and Gulargambone Creek are shown in **Figure 4-5** and **Figure 4-6** respectively.

Figure 4-3 Peak water level profiles along the Castlereagh River

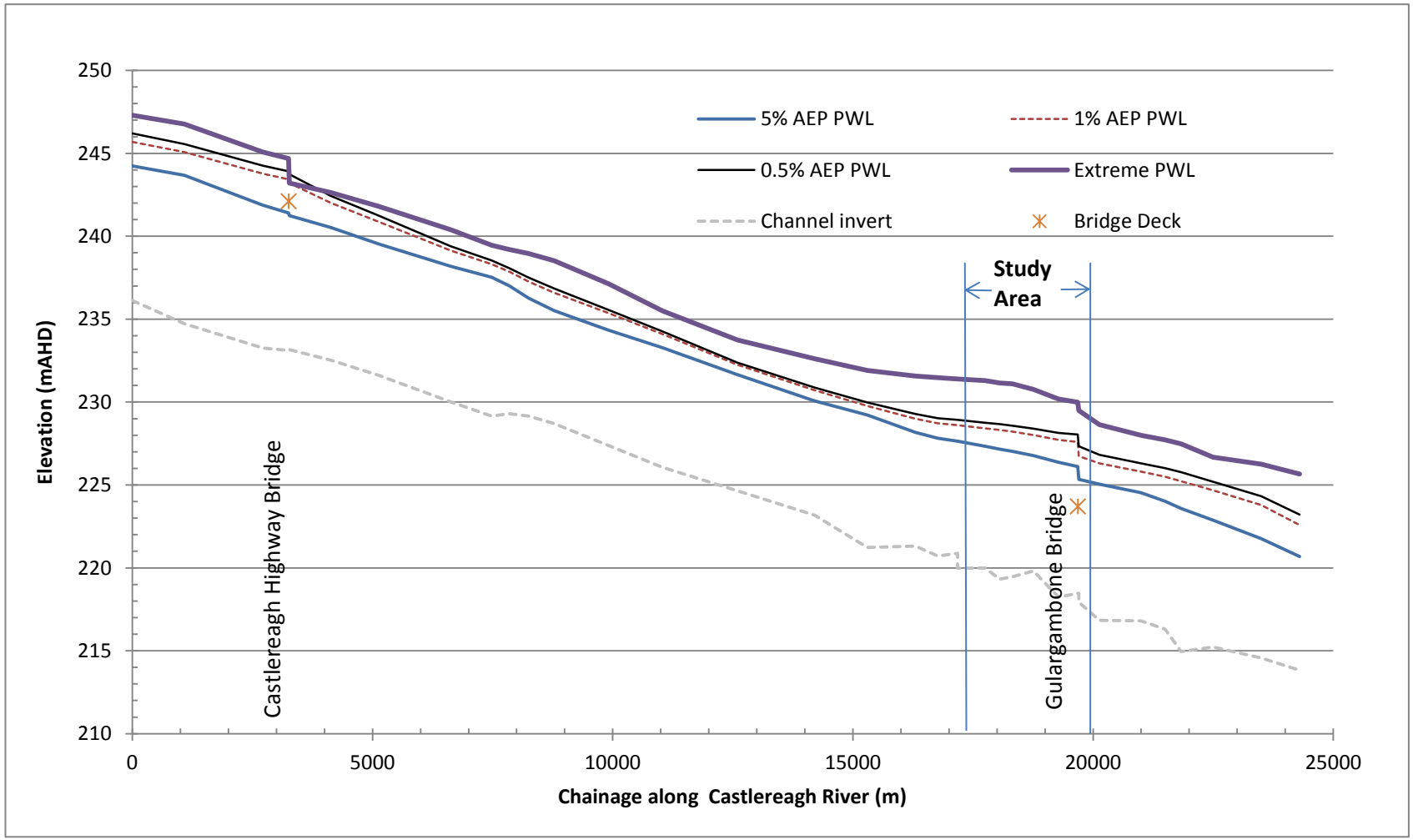


Figure 4-4 Peak water level profiles along Gulargambone Creek

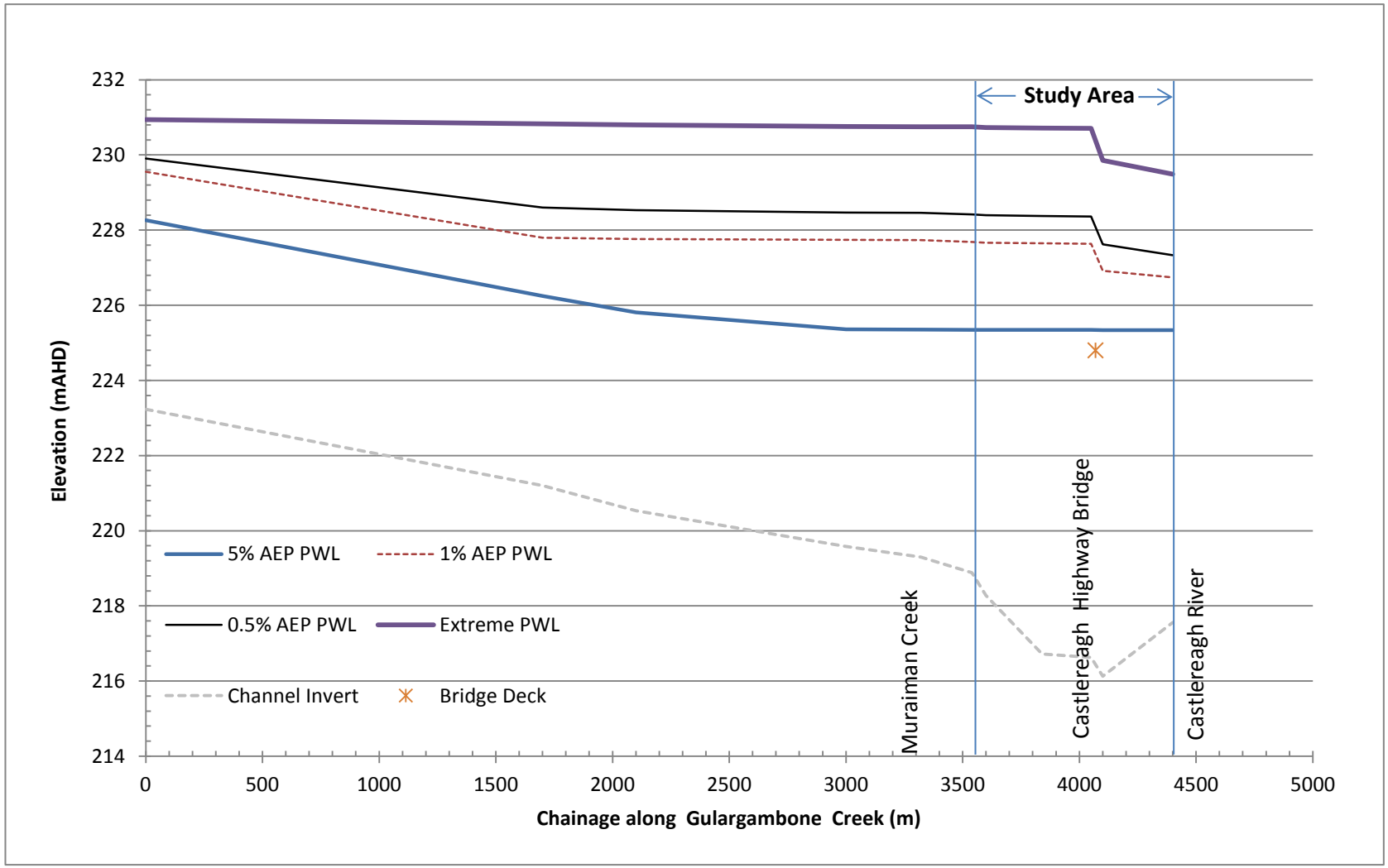


Figure 4-5 Peak velocity profiles along the Castlereagh River

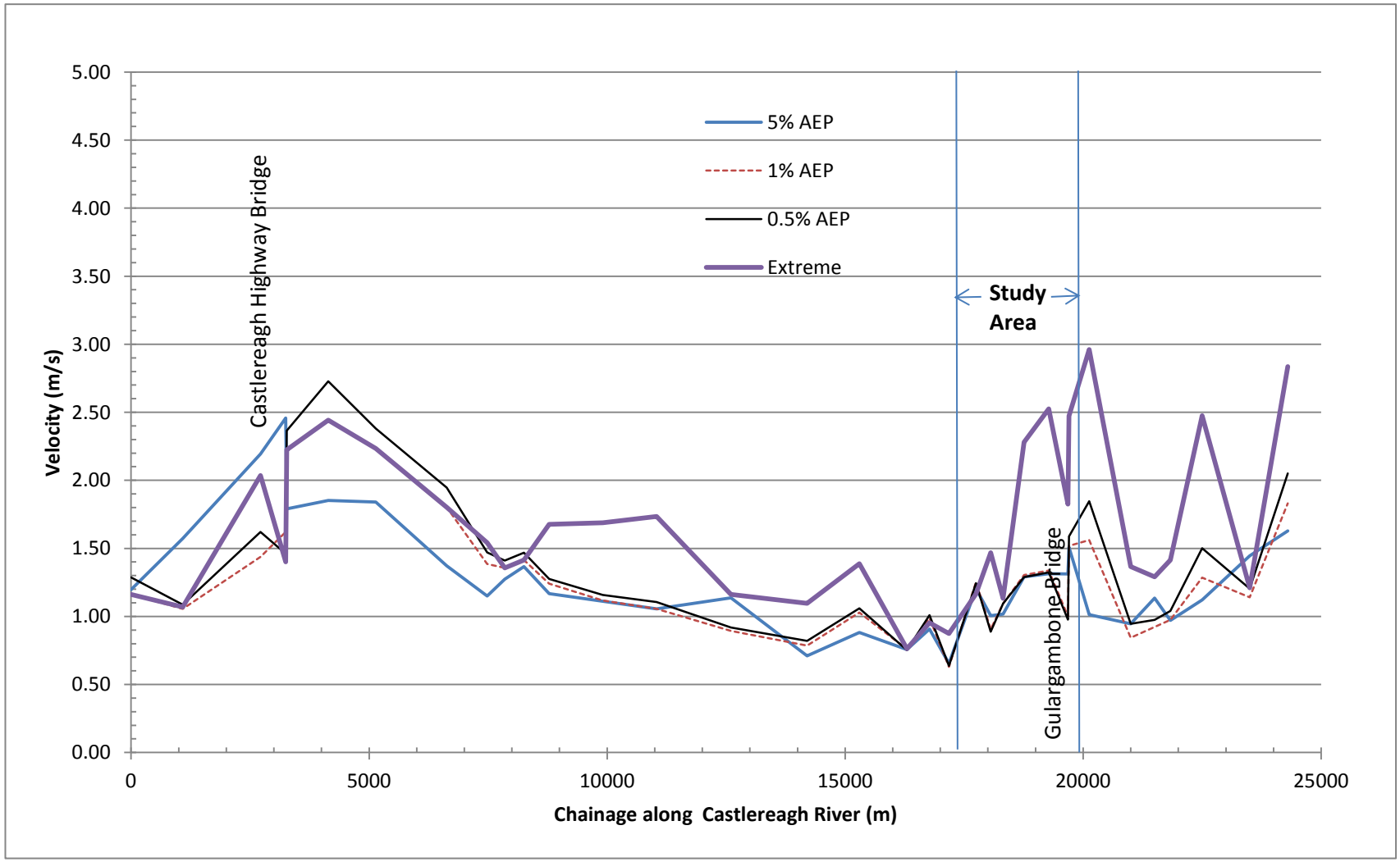
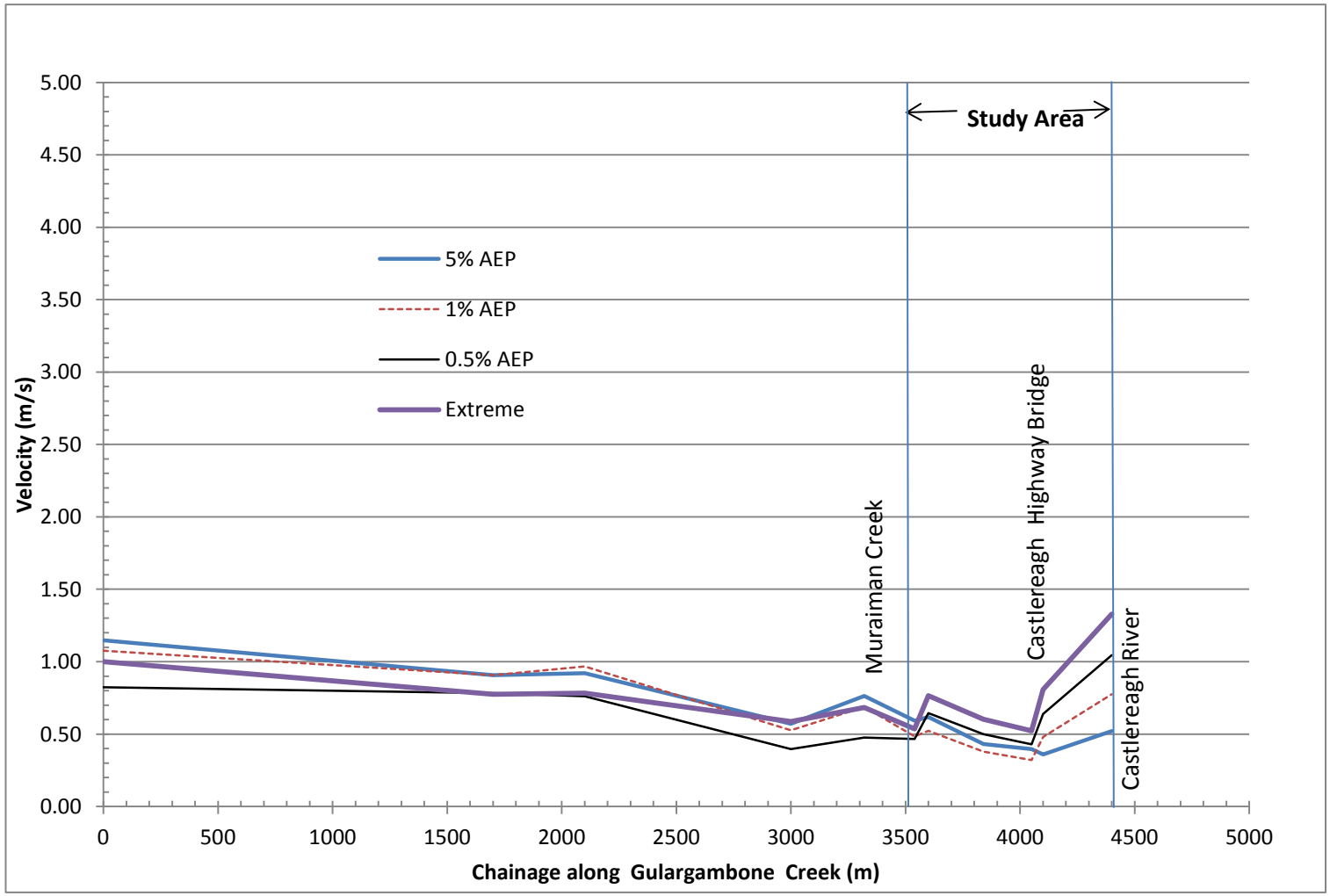


Figure 4-6 Peak velocity profiles along Gulargambone Creek



Peak velocities in the Castlereagh River vary between 0.7m/s and 3m/s and peak velocities are generally higher at waterway crossings. Peak velocities are generally low in Gulargambone Creek and vary between 0.6 m/s and 1.3 m/s for the modelled scenarios.

4.5 Sensitivity Analysis

A sensitivity analysis was undertaken to assess changes in peak water levels for the 1% AEP event due to changes in the adopted design discharges, Manning's n values and downstream boundary conditions.

The adopted design discharges for the 1% AEP event were increased and decreased by 10% to assess their sensitivity on the resulting peak water levels. The sensitivity of peak water levels to adopted Manning's n values was assessed by changing Manning's n values by 20%. The sensitivity of the 1% AEP peak water level profile on the adopted downstream boundary condition was assessed by lowering and raising the downstream boundary condition by 0.5m.

Outcomes from the sensitivity analysis on the 1% AEP peak water levels within the study area are summarised in **Table 4-5**.

Table 4-5 Changes in 1% AEP peak water levels within the study area

MIKE11 Flowpath	Design Discharge		Manning's n		Downstream Boundary	
	10% less	10% more	20% less	20% more	0.5m lower	0.5m higher
CASTLEREAGH	-0.2	0.2	-0.5	0.4	0.0	0.0
GULAR	-0.4	0.3	-0.7	0.4	0.0	0.0
MURAIMAN	-0.4	0.3	-1.2	0.5	0.0	0.0
OF_1	-0.2	0.2	-0.2	0.2	0.0	0.0
OF_2	-0.3	0.2	-1.0	0.4	0.0	0.0

The flowing observations are made from the sensitivity analysis:

- A 10% reduction in the adopted design flow results in up to 0.4 m lower 1% AEP flood levels within the study area. However, a 10% increase in design flow results in up to 0.3 m higher 1% AEP flood levels. Peak water levels in the Castlereagh River are relatively less sensitive to changes in flows in the flood runners.
- A 20% reduction in the adopted Manning's n values results in up to 1.2m reduced 1% AEP flood levels in the flood runner "MURAIMAN" and up to 1m reduced flood levels in flood runner "OF_2" which is a breakout of "MURAIMAN". Due to reduced Manning's n, the Castlereagh River conveys more flows and hence less flow breakout the river resulting lower flood levels in the flood runners. A 20% increase in Manning's n increases 1% AEP flood levels up to a maximum of 0.5m.
- A 0.5m change in the adopted downstream boundary condition has negligible impacts on 1% AEP flood levels within the study area.

The sensitivity analysis indicates that modelled peak water levels within the study area are sensitive to the adopted Manning's n values and a 20% increase in the adopted Manning's n values results in up to a maximum 0.5m increase in modelled peak water levels. It is to be noted that a 0.5m freeboard is generally added to the 1% AEP peak water level to define the flood planning level for residential development. Either a 10% increase design discharge for the 1% AEP event or a 20% increase in Manning's value is not considered unrealistic. Hence the appropriateness of adopting a freeboard higher than 0.5m needs to be considered critically in the Floodplain Risk Management Study stage. It is recommended that the flood model is to be verified against significant flood events as part of the Floodplain Risk Management Study to enhance confidence on modelled flood levels.

4.6 Flood Extent Mapping

The modelled peak water levels for the 1% AEP event and 1% AEP event plus 0.5m freeboard at MIKE11 model cross sections were used to create a flood surface for each event which was then intersected with the DTM representing the ground surface to delineate the flood extent for that event. The flood mapping was undertaken using the available routines in ArcMap. The entire study area is flooded in the 1% AEP event as shown in and hence SES needs to consider appropriate location for flood shelters outside the study area. A comparison between 1% AEP modelled flood extent and the 1955 flood extent is discussed in

4.7 Comparison of Observed and Modelled Flood Behaviour

- **Castlereagh River @ Gulargambone Bridge** – Modelled peak water levels at the bridge and the corresponding gauge heights are shown in **Table 4-6**. Peak water levels recorded at the gauge for the major flood events of 1955, 1971 and 1974 are 227.96 mAHD (gauge height 8.50m), 225.25 mAHD (gauge height 5.79m) and 224.51 mAHD (gauge height 5.05m). Although the modelled 1% AEP peak water level at the bridge is very similar to the 1955 recorded level, it to be noted that the flood behaviour in the village are influenced by two bridges on the Castlereagh River and the bridge on Gulargambone Creek on the Castlereagh Highway and coincidental inflows in the Castlereagh River and Gulargambone Creek. All three timber bridges which were present during the 1955 flood were replaced at different times with concrete bridges. The Work as Executed drawing signed by Fulton Hogan Pty Ltd on 16 November 2009 for Gulargambone Bridge on the Castlereagh River provided by Council includes the info "*Waterway area, Existing: 237 sq m, proposed: 503 sq m, areas are approximated clear waterway area*". The information presented on the WAE drawing clearly indicates a major change in waterway area between the old timber bridge and the new concrete bridge.
- **1955 flood extent** - The 1955 flood extent shown in **Figure 2-1** is less extensive than the modelled flood extent for the 1% AEP event shown in . In particular, **Figure 2-1** shows that the area within the village bounded by Mendooran Street to the east, Muraiman Street to the south, Coonamble Street to the west and Yalcogrin Street to the south is flood free. However, the entire village is flooded in the 1% AEP event as shown in . It is expected that replacement of timber bridges may have altered flood behaviour within the study area.
- **1955 flood levels** – Apart from the Castlereagh River @ Gulargambone Bridge gauge, two 1955 flood marks were identified by the community. One flood mark was located on a tree (the top bolt RL 225.84 mAHD) and the other flood mark (RL 226.24 mAHD) was located inside the Church on Armitree Street. Both flood marks are located at least, 1.7m lower than the 1955 peak water level recorded at the gauge. Hence, it is concluded that both flood marks are not related to the 1955 flood event.

Table 4-6 Modelled Peak Water Levels - Castlereagh River @ Gulargambone Gauge

Flood Event	Peak Water Level (mAHD)	Gauge Height (m)**
5% AEP	226.11	6.65
2% AEP	227.60	8.14
1% AEP	228.04	8.58
Extreme	229.99	10.53

** Gauge zero at 219.46 mAHD.

Note: Flood extent outside the study area are indicative only

Legend

- Study Area
- Cadastre
- 1% AEP Flood

Data Sources: LPI, Council.

LIMITATIONS: This mapping is based on data and assumptions identified in the Gulargambone Flood Study Report (2016) prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

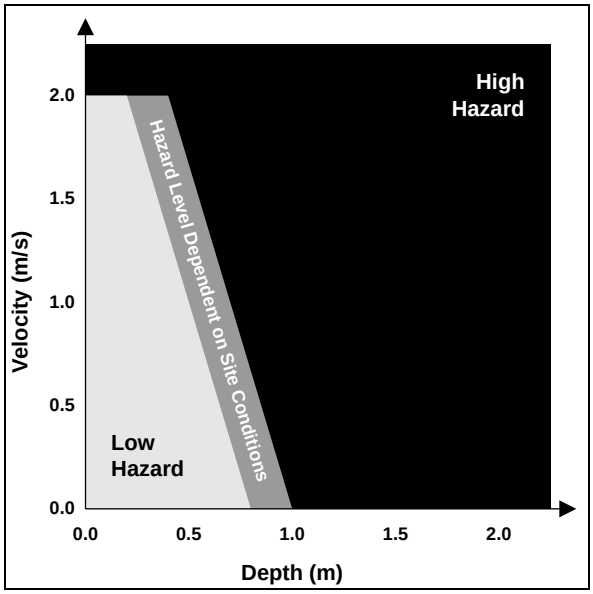
SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	1% AEP Flood Extent
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council

DRAWN	PROJECT #	MAP #	REV	VER
AH	IA013100	FIGURE 4-7	1	1
CHECK	DATE			
AH	23/05/2016			

4.8 Mapping of Hazard and Hydraulic Categories

The MIKE11 modelling results for the 1% AEP event were used in ArcMap to delineate the flood hazard areas for the study area based on the hydraulic hazard category diagram presented in the *Floodplain Development Manual* (DECC, 2005), shown in **Figure 4-8**. The resulting high and low flood hazard areas for the 1% AEP event are shown in **Figure 4-9**. It is to be noted that high hazard areas results from either the depth of flooding is 1m or greater or the product of flood depth and velocity equal to or greater than 1. The flood extent for the 5% AEP event is also shown in **Figure 4-9** which indicates that the flood extent for the 5% AEP event is similar to the identified high flood hazard areas for the 1% AEP event.

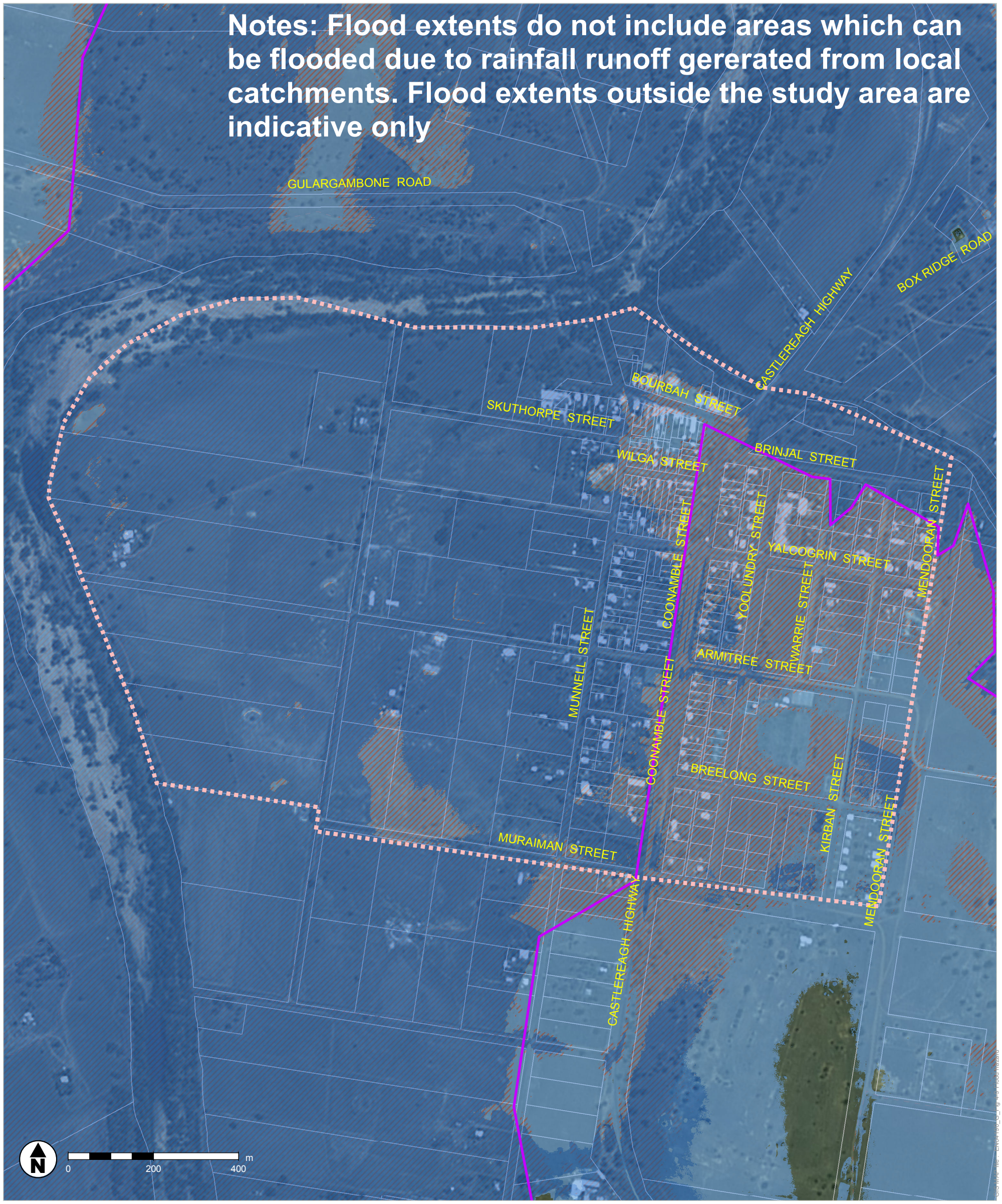
- **Figure 4-8 Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual*)**



The delineation of hydraulic categories is important with the adoption of merit based flood policy. This is because the NSW Government's Floodplain Development Manual (2005) recognises three hydraulic categories of flood prone land (floodway, flood fringe and flood storage). Definition of floodways, flood storage and flood fringe, as given in the Manual, are presented below:

- Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flows or areas where higher velocities occur.
- Flood Storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
- Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

After reviewing the nature of riverine flooding in the study area and considering the definition of floodways in the Floodplain Development Manual, a provisional floodway has been defined for the study area which is shown in **Figure 4-9**. The portion of the study area bounded by Brinjal Street, Coonamble Street, Mendooran Street and Muraiman Street is located outside the provisional floodway and the remaining of the study area is located within the provisional floodway. It is recommended that the portion of the study area bounded by Brinjal Street, Coonamble Street, Mendooran Street and Muraiman Street be classified as flood fringe. It is further recommended that the provisional hazard categories be based on hazard categories shown in **Figure 4-9**.



Legend

- Study Area
- Cadastre
- Low Hazard (1% AEP)
- High Hazard (1% AEP)
- 5% AEP Flood Extent
- Provisional Floodway

Data Sources: LPI, Council.

LIMITATIONS: This mapping is based on data and assumptions identified in the Gulargambone Flood Study Report (2016) prepared by Jacobs. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	Provisional 1% AEP Flood Hazard
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council

DRAWN	PROJECT #	MAP #	REV	VER
AH	IA013100	FIGURE 4-9	1	1
CHECK	DATE			
AH	23/05/2016			

5. Drainage Issues

The study area was not affected by mainstream flooding during the flood event of December 2010. The recorded peak water level in the Castlereagh River @ Gulargambone gauge in December 2010 is 1.8m below the modelled flood level at the gauge for the 5% AEP event. However, SES was required to pump water from properties located on Nos. 3, 5, 7, 9, 11 and 13 Wilga Street on 1st and 3rd December 2010, several days prior to the arrival of the flood peak in the Castlereagh River. Water was also observed in properties 20, 22 and 24 Coonamble Street. Stormwater drainage problem in this area is believed to be as a result of catchment runoff in combination with inadequate stormwater drainage works. The topography of this area is flat and the general slope of the land is towards north-west of Wilga Street. Minor works (eg. earthworks, fencing, roads etc) on the floodplain have the potential to alter the drainage characteristics of the area.

A site specific drainage assessment is required to improve the stormwater drainage for this area. Council and SES could monitor drainage patterns in this area during large storm events so that impediments to stormwater drainage could be identified and appropriate mitigation measures could be undertaken to improve drainage. It is expected that stormwater drainage improvement would result in negligible improvement in riverine flooding for this area.

6. Conclusions and Recommendations

In accordance with NSW Government Policy, Coonamble Shire Council is responsible for managing flood risk within its local government area, which includes the Village of Gulargambone. This report documents the first two stages of the process of preparing the Floodplain Risk Management Plan – that is, the preparation of a Flood Study.

6.1 Conclusions

A community consultation process was undertaken to collect information on flooding from the community. Maintaining an emergency flood free access and providing flood warning were given higher priority by the community to address the existing flood risk for the village of Gulargambone.

LiDAR and ground surveys were undertaken to capture the required topographic data for this flood study. The topographic data was used in the development of a hydrologic model and a hydraulic computer model. Both models were used to assess flood behaviour in the study area for the 0.5%, 1% and 5% AEP events and an extreme flood event (i.e. 3 times 1% AEP event).

Modelled peak water levels for the 1% and 5% AEP events were utilised to create flood extent maps. The flood map shows that the study area is cut-off from neighbouring towns in the 5% AEP event and the entire study area is subject to flooding in the 1% AEP event. This means that the study area is not suitable for locating flood evacuation centres. In addition, the Castlereagh Highway is flooded in the 5% AEP event both in the north and in the south of the village.

A provisional hydraulic flood hazard map was prepared for the 1% AEP event, which shows that a significant portion of the study area is classified as hydraulic high hazard area.

6.2 Recommendations

The scope of the study did not include undertaking an encroachment assessment to define the floodway and to provide detailed information to satisfy the requirements of the SES. It is recommended that Council undertakes these tasks at the Floodplain Risk Management Study stage.

The following specific recommendations are made for consideration by Council:

- Council adopts this Flood Study and updates the flood policy;
- Council and SES monitor future floods and capture photographs with a date stamp; and
- The monitoring data are to be used in the verification of the flood model in the future and in the development of effective mitigation measures to improve stormwater drainage for the study area.

7. Acknowledgements

This study was undertaken by Jacobs on behalf of Coonamble Shire Council. Coonamble Shire 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 the study area
- Coonamble Shire Council
- Office of Environment and Heritage

8. References

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9. 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.
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.
Development	Is defined in Part 4 of the EP&A Act In fill development: 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.
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 "cusecs". 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.
MIKE11	A computer program used for analysing behaviour of unsteady flow in open channels and floodplains.
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.
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.

Appendix A. Questionnaire

Flood Study for Gulargambone - Questionnaire

Coonamble Shire Council has contracted the Consultant, Sinclair Knight Merz (SKM), to undertake a flood study for the village of Gulargambone. The flood study area for Gulargambone is shown in the attached Map 1.

The objective of this study is to define the riverine as well as overland flooding behaviour within the study area. The study will produce information on flood levels, velocities and flows for a range of flood events under existing catchment conditions. Outcomes from the study would assist Council to apply appropriate development controls as a management measure in the floodplain risk management process, as it is believed to be most feasible management option for Council's consideration at this stage.

The Consultant 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 the study area.

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 send your response to this questionnaire directly to the Consultant **before 28 June 2013** at the address provided below.

Akhter Hossain
P O Box 164
St Leonards, NSW 1590
or
email: ahossain@globalskm.com

Place a tick or write a number in the relevant box as per instruction or write answers.

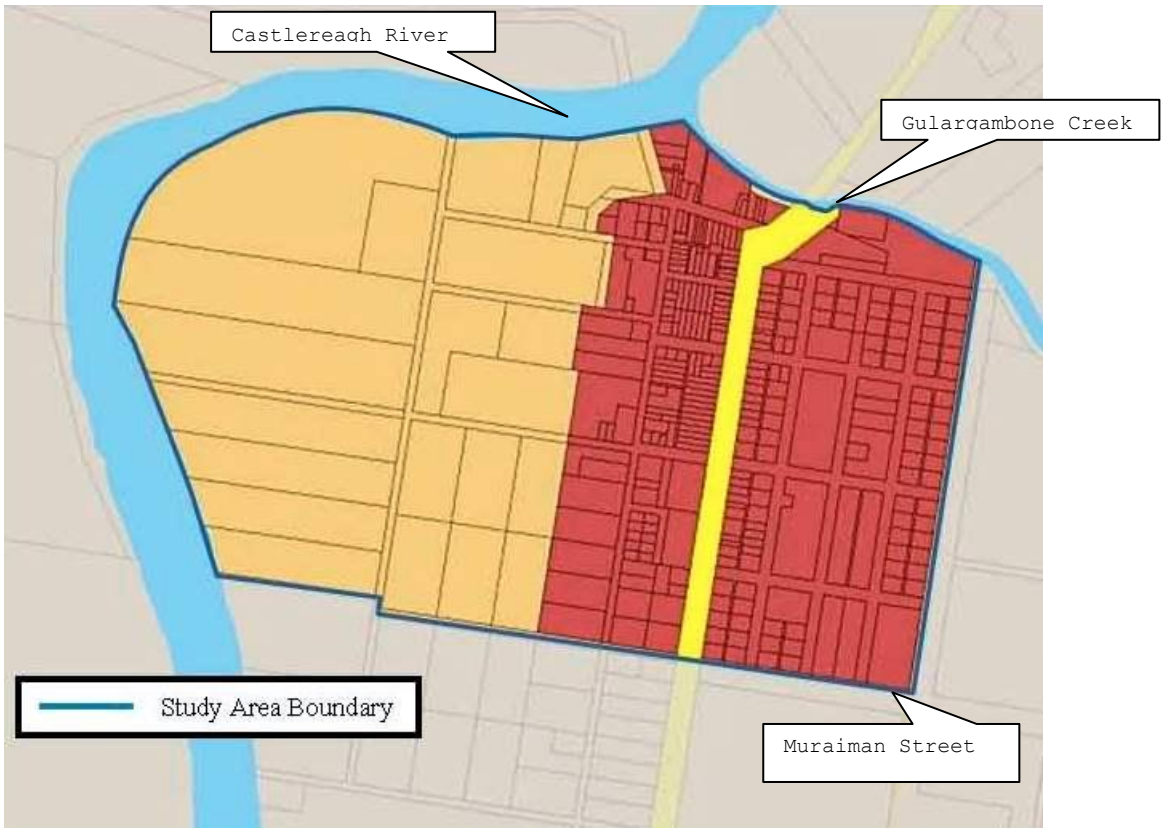
Question No.	Question and Answer
1.	**Do you live (reside) or have lived in the study area shown on Map 1?** A ☐ Yes (Please provide your address and put an 'X' on the relevant map) .... B ☐ No (Go to Question 3)
2.	**Do you own or rent your residence in the study area shown on Map 1?** A ☐ Own B ☐ Rent C How long have you lived in the study area? (Please write number of years)……..... ***If you are not sure whether you are in the map or not, please provide address
3.	**Do you own or manage a business in the study area?** A ☐ Yes, For how many years? ……. B ☐ No (go to Question 5)

Quest-ion No.	Question and Answer
4.	**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 ……
5.	**Have you had any experience of flooding (due to the Castlereagh River, Gulargambone Creek and storm events as well) in and around where you live or work?** A □ Yes B □ No (Go to Question 15)
6.	**How deep was the floodwater (from the Castlereagh River, Gulargambone Creek and 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? …….....
7.	**How long did the floodwaters stay up?** A □ Less than 6 hours B □ Approximately 1 day C □ More than 3 days
8.	**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?…….....
9.	**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 cost of the repairs, if any?…….
10.	**Was vehicle access to/from your property disrupted due to floodwaters during the worst flooding/ storm event?** A □ Not affected

Quest-ion No.	Question and Answer
	B Minor disruption (roads flooded but still driveable) C □ Access cut off
11.	**Were you or members of your family required assistance from SES during flood events?** A □ No B Yes, Please specify how many times (in total) members of your family required assistance? .....
12.	**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 □ Any permanent marks indicating maximum flood level for particular floods D □ Memory of flow directions, depth or velocities
13.	**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
14.	**Do you have any photographs of past floods that would be useful for the consultant to help him understand the area flooded or other flood effects 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
15.	**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) _____
16.	**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 _____

Quest-ion No.	Question and Answer
17.	**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 residents/business from flooding B □ Protecting land of residents/businesses from flooding C □ Maintaining an emergency flood free access D □ Providing flood signage for public safety E □ Support from SES F □ Providing flood warning
18.	**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?** _____ _____ _____ _____
19.	**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
20.	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:…….....**
	Space for additional comments _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

Map 1 – Study Area for Gulargambone



Appendix B. Topographic Survey

Legend

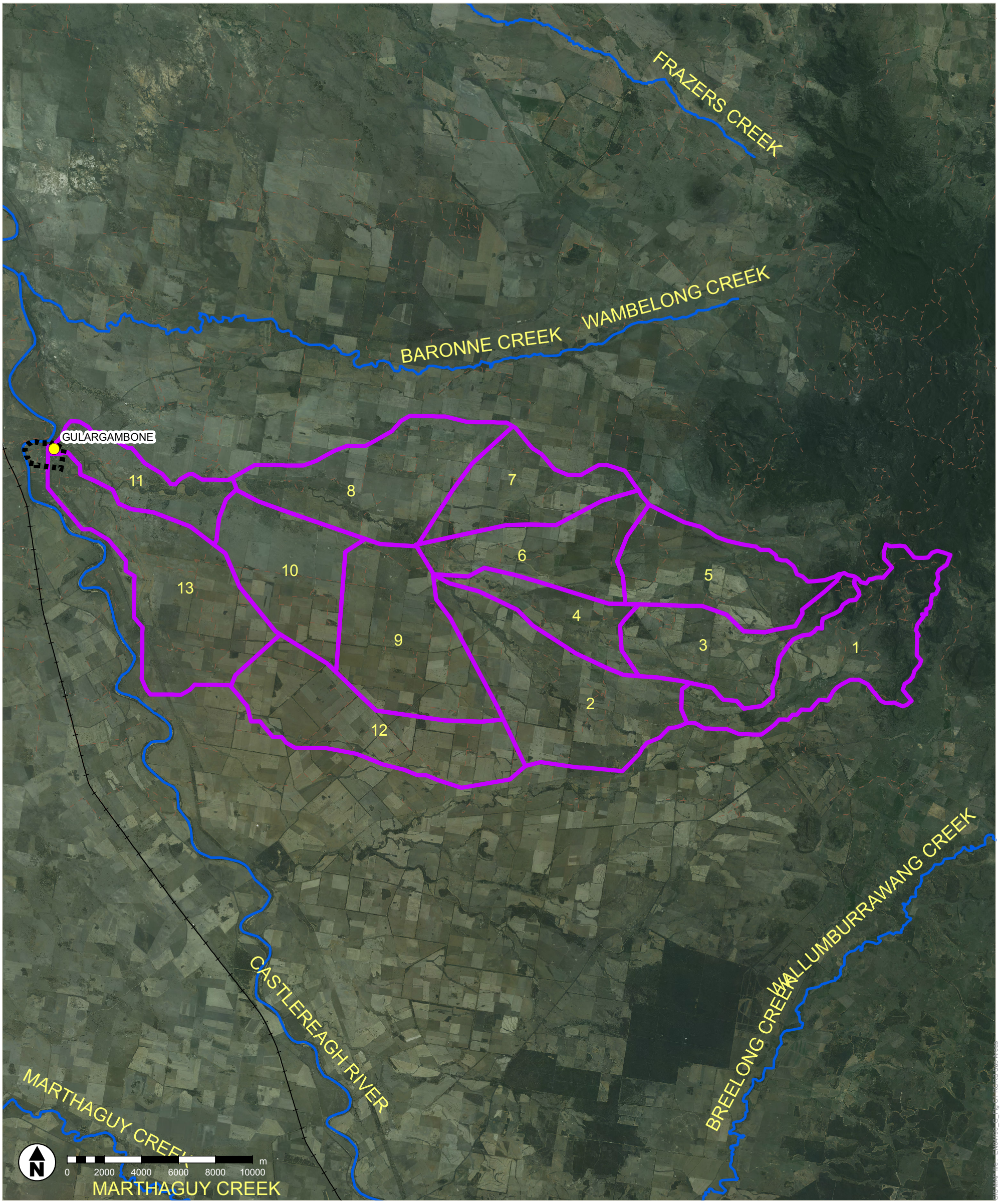
- Study Area
- Cadastre
- Surveyed Features

Data Sources: LPI, Council.

SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	Surveyed Features
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council

DRAWN	PROJECT #	MAP #	REV	VER
AH	IA013100	FIGURE B-1	1	1
CHECK	DATE			
AH	11/03/2016			

Appendix C. Hydrologic Modelling



Legend

- Study Area
- Railway
- RORB Subarea

SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	Subareas of RORB Model
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council
DRAWN AH	PROJECT # IA013100
MAP #	FIGURE C-1
REV	1
VER	1
CHECK AH	DATE 13/02/2015

GIS MAP file : EN04186_G_Fig C1 RORB Sub Areas

Table C-1 RORB Sub-areas

RORB Sub-Area	Catchment Area (km^2)
1	53.2
2	66.5
3	39.0
4	22.5
5	43.5
6	36.9
7	33.2
8	54.9
9	56.8
10	41.7
11	23.9
12	55.8
13	65.0

Appendix D. Hydraulic Modelling

Legend

- Study Area
- Railway
- MIKE11 Cross Section

MIKE11 Flowpath

- Castlereagh
- Gulargambone
- Muraiman
- OF_1
- OF_2

SCALE	A3
SHEET	1 of 1
	GDA 1994 MGA Zone 55
TITLE	MIKE11 Model Schematic
PROJECT	Flood Study for Gulargambone
CLIENT	Coonamble Shire Council
DRAWN AH	PROJECT # IA013100
MAP #	FIGURE D-1
REV	1
VER	1
CHECK AH	DATE 26/03/2016

GIS MAP file : EN04190_G_Fig D-1 MIKE11 Schematic

Table D-1 Modelled Peak Water Level (PWL)

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - PWL (mAHD)				Gulargambone Ck Flood[2] - PWL (mAHD)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
1	Castlereagh 0	244.24	245.69	246.20	247.29	241.72	244.24	245.18	245.69	
2	Castlereagh 1085	243.67	245.08	245.56	246.77	240.69	243.67	244.61	245.08	
3	Castlereagh 2720	241.88	243.78	244.26	245.08	238.25	241.88	243.29	243.78	Joins "Muraiman 0"
4	Castlereagh 3250	241.40	243.44	243.92	244.68	237.43	241.40	242.96	243.44	U/S of Castlereagh Hwy
5	Castlereagh 3270	241.25	243.20	243.74	243.08	239.53	241.25	242.65	243.20	D/S of Castlereagh Hwy
501	Castlereagh 4140	240.52	241.99	242.42	242.63	238.49	240.52	241.55	241.99	
6	Castlereagh 5140	239.51	240.86	241.22	241.79	237.62	239.51	240.47	240.86	
7	Castlereagh 6630	238.19	239.14	239.40	240.40	236.90	238.19	238.87	239.14	
8	Castlereagh 7480	237.53	238.32	238.54	239.45	236.52	237.53	238.09	238.32	
9	Castlereagh 7850	237.01	237.86	238.08	239.20	236.11	237.01	237.62	237.86	
10	Castlereagh 8250	236.27	237.26	237.51	238.96	235.32	236.27	236.99	237.26	
11	Castlereagh 8780	235.52	236.60	236.85	238.52	234.44	235.52	236.31	236.60	
12	Castlereagh 11040	233.28	234.09	234.25	235.50	231.78	233.28	233.91	234.09	
13	Castlereagh 12600	231.64	232.24	232.38	233.74	230.11	231.64	232.08	232.24	
14	Castlereagh 14200	230.08	230.72	230.88	232.61	228.96	230.08	230.55	230.72	
15	Castlereagh 15300	229.22	229.77	229.97	231.91	228.21	229.21	229.58	229.79	
16	Castlereagh 16300	228.18	229.00	229.28	231.56	227.40	228.20	228.74	229.07	
17	Castlereagh 16770	227.82	228.73	229.03	231.48	226.96	227.86	228.46	228.83	
18	Castlereagh 17180	227.65	228.61	228.92	231.39	226.74	227.71	228.34	228.73	Joins "OF_1 0"
19	Castlereagh 17750	227.34	228.42	228.76	231.29	226.11	227.44	228.13	228.57	
20	Castlereagh 18060	227.16	228.32	228.68	231.15	225.80	227.29	228.03	228.49	
21	Castlereagh 18320	227.03	228.22	228.58	231.10	225.61	227.18	227.93	228.40	
22	Castlereagh 18760	226.77	228.01	228.39	230.76	225.30	226.96	227.72	228.23	

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - PWL (mAHD)				Gulargambone Ck Flood[2] - PWL (mAHD)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
23	Castlereagh 19280	226.36	227.73	228.14	230.19	224.78	226.63	227.44	228.01	
24	Castlereagh 19680	226.11	227.60	228.04	229.99	224.31	226.46	227.31	227.92	U/S of Gulargambone Bridge
25	Castlereagh 19700	225.34	226.74	227.33	229.49	224.16	225.77	226.50	227.39	D/S of Gulargambone Bridge
26	Castlereagh 20130	225.04	226.30	226.81	228.63	223.88	225.45	226.08	226.86	
27	Castlereagh 21000	224.53	225.81	226.30	228.00	223.38	224.99	225.58	226.35	
28	Castlereagh 21500	224.02	225.49	226.01	227.71	222.94	224.58	225.23	226.06	
29	Castlereagh 21830	223.58	225.22	225.77	227.48	222.65	224.29	224.95	225.82	
30	Castlereagh 22500	222.87	224.68	225.19	226.67	221.93	223.90	224.49	225.24	
31	Castlereagh 23500	221.76	223.80	224.33	226.25	220.75	223.07	223.61	224.38	
32	Castlereagh 24300	220.69	222.58	223.21	225.66	219.70	221.60	222.34	223.28	D/S Boundary
81	Gular 0	226.49	228.38	229.41	230.91	228.26	229.56	229.91	230.94	
82	Gular 1700	225.49	227.80	228.60	230.83	226.25	227.44	228.20	229.53	
83	Gular 2100	225.42	227.76	228.53	230.80	225.81	226.98	227.94	229.24	
84	Gular 3000	225.36	227.74	228.47	230.76	225.03	226.45	227.70	228.91	
85	Gular 3320	225.35	227.73	228.46	230.75	224.73	226.33	227.65	228.84	
64	Gular 3540	225.35	227.68	228.42	230.75	224.54	226.27	227.59	228.80	
65	Gular 3600	225.35	227.67	228.40	230.73	224.51	226.26	227.57	228.78	
66	Gular 3840	225.35	227.65	228.37	230.72	224.44	226.23	227.55	228.75	
67	Gular 4050	225.35	227.64	228.36	230.71	224.35	226.22	227.54	228.73	U/S of Castlereagh Hwy
68	Gular 4100	225.34	226.92	227.62	229.86	224.29	225.88	226.70	227.80	D/S of Castlereagh Hwy
69	Gular 4400	225.34	226.74	227.33	229.49	224.16	225.77	226.50	227.39	Joins "Castlereagh 19700"
51	Muraiman 0	241.88	243.78	244.26	245.08	238.25	241.88	243.29	243.78	
52	Muraiman 1140	238.21	240.07	240.60	241.13	238.33	238.47	239.56	240.11	
53	Muraiman 3000	234.80	237.80	238.40	238.96	235.06	235.41	236.98	237.91	
54	Muraiman 4800	233.23	235.74	236.36	237.09	233.47	233.70	234.98	235.80	

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - PWL (mAHD)				Gulargambone Ck Flood[2] - PWL (mAHD)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
55	Muraiman 5700	231.37	234.46	235.16	235.84	231.63	231.94	233.71	234.55	
56	Muraiman 7350	228.23	232.61	233.14	233.93	228.73	229.04	231.14	232.68	
57	Muraiman 9280	225.55	230.54	231.21	232.64	225.90	226.72	229.05	230.69	
58	Muraiman 10760	225.36	228.84	229.57	231.73	224.78	226.36	228.09	229.32	
59	Muraiman 11050	225.35	228.37	229.11	231.63	224.75	226.35	227.88	229.06	Joins "OF_2 0"
60	Muraiman 11280	225.35	228.04	228.96	231.61	224.74	226.34	227.72	229.01	U/S Culvert No.3[a]
61	Muraiman 11350	225.35	227.97	228.70	230.84	224.74	226.34	227.71	228.91	D/S Culvert No.3
62	Muraiman 11650	225.35	227.85	228.58	230.80	224.74	226.34	227.68	228.88	
63	Muraiman 11900	225.35	227.73	228.46	230.75	224.73	226.33	227.65	228.84	Joins "Gular 3320"
91	OF_1 320	227.01	228.11	228.60	230.62	226.07	227.08	227.79	228.41	
92	OF_1 620	226.75	227.96	228.47	230.52	225.78	226.85	227.62	228.29	
93	OF_1 710	226.60	227.90	228.43	230.49	225.68	226.74	227.56	228.25	
94	OF_1 770	226.48	227.85	228.39	230.45	225.59	226.66	227.51	228.22	
95	OF_1 940	226.23	227.75	228.30	230.38	224.99	226.53	227.42	228.14	
96	OF_1 1120	226.18	227.75	228.30	230.39	224.70	226.51	227.41	228.15	U/S Culvert No. 7[a]
97	OF_1 1150	226.17	227.74	228.30	230.38	224.33	226.50	227.40	228.14	D/S Culvert No. 7
98	OF_1 1300	226.16	227.73	228.28	230.36	224.32	226.50	227.39	228.12	U/S Culvert No. 8[a]
99	OF_1 1370	226.15	227.72	228.27	230.33	224.31	226.49	227.39	228.12	D/S Culvert No. 8
100	OF_1 1600	226.13	227.67	228.18	230.20	224.31	226.48	227.36	228.04	
101	OF_1 1640	226.12	227.64	228.11	230.04	224.31	226.47	227.34	227.98	
71	OF_2 140	225.39	228.35	229.06	231.63	225.39	226.35	227.88	229.01	
72	OF_2 390	227.22	228.21	228.92	231.12	227.22	227.22	227.74	228.83	
73	OF_2 660	226.58	227.84	228.66	231.10	226.58	226.58	227.43	228.51	
74	OF_2 940	226.18	227.81	228.61	231.09	225.73	226.51	227.42	228.44	U/S Culvert No. 1[a]

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - PWL (mAHD)				Gulargambone Ck Flood[2] - PWL (mAHD)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
75	OF_2 980	226.18	227.80	228.57	230.94	225.53	226.51	227.42	228.41	D/S Culvert No. 1
76	OF_2 1140	226.18	227.79	228.55	230.93	225.45	226.51	227.42	228.39	U/S Culvert No. 2[a]
77	OF_2 1190	226.18	227.78	228.43	230.44	225.45	226.51	227.41	228.28	D/S Culvert No. 2
78	OF_2 1440	226.18	227.76	228.37	230.41	225.44	226.51	227.41	228.21	
79	OF_2 1590	226.18	227.75	228.33	230.39	224.97	226.51	227.41	228.17	

[1] Refer to Figure No. D-1 for location of cross sections

[2] Refer to Table 4-2 for details on coincident flooding

[a] Refer to Figure 2-3

Table D-2 Modelled Peak Discharges (m³/s)

MIKE11 Cross Section	Castlereagh Flood[1] - Peak Discharge				Gulargambone Ck Flood[1] - Peak Discharge				Remarks
	5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
CASTLEREAGH 542.5	2,002	4,336	5,637	13,000	1,040	2,002	3,212	4,336	
CASTLEREAGH 1902.5	2,002	4,336	5,637	13,000	1,040	2,002	3,212	4,336	
CASTLEREAGH 2985	2,002	3,639	4,407	10,572	1,040	2,002	2,982	3,639	
CASTLEREAGH 3260	2,002	3,826	4,407	10,572	1,040	2,002	2,982	3,826	Castlereagh Hwy
CASTLEREAGH 3705	2,002	3,652	4,407	10,572	1,040	2,002	2,982	3,652	
CASTLEREAGH 4640	2,002	3,260	3,715	9,709	1,040	2,002	2,815	3,260	
CASTLEREAGH 5885	2,002	3,263	3,715	9,709	1,040	2,002	2,815	3,263	
CASTLEREAGH 7055	2,002	3,262	3,715	9,709	1,040	2,002	2,815	3,262	
CASTLEREAGH 7665	2,002	3,262	3,715	9,709	1,040	2,002	2,815	3,262	
CASTLEREAGH 8050	2,002	3,262	3,715	9,709	1,040	2,002	2,815	3,262	
CASTLEREAGH 8515	2,002	3,262	3,715	9,709	1,040	2,002	2,815	3,262	
CASTLEREAGH 9345	2,002	3,262	3,715	9,709	1,040	2,002	2,815	3,262	
CASTLEREAGH 10475	2,002	3,262	3,715	9,709	1,040	2,002	2,815	3,262	
CASTLEREAGH 11820	2,002	3,246	3,676	9,187	1,040	2,002	2,813	3,246	
CASTLEREAGH 13400	2,002	3,246	3,676	9,187	1,040	2,002	2,813	3,246	
CASTLEREAGH 14750	2,002	3,246	3,676	9,187	1,040	2,002	2,813	3,246	
CASTLEREAGH 15800	2,002	3,246	3,676	9,187	1,040	2,002	2,813	3,246	
CASTLEREAGH 16535	2,002	3,246	3,676	9,187	1,040	2,002	2,813	3,246	
CASTLEREAGH 16975	2,002	3,246	3,676	9,187	1,040	2,002	2,813	3,246	
CASTLEREAGH 17465	1,758	2,426	2,596	6,760	1,031	1,732	2,188	2,335	
CASTLEREAGH 17905	1,758	2,426	2,596	6,760	1,031	1,732	2,188	2,335	
CASTLEREAGH 18190	1,758	2,426	2,596	6,760	1,031	1,732	2,188	2,335	
CASTLEREAGH 18540	1,758	2,426	2,596	6,760	1,031	1,732	2,188	2,335	
CASTLEREAGH 19020	1,757	2,423	2,592	6,747	1,031	1,730	2,186	2,332	

MIKE11 Cross Section	Castlereagh Flood[1] - Peak Discharge				Gulargambone Ck Flood[1] - Peak Discharge				Remarks
	5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
CASTLEREAGH 19480	1,757	2,423	2,592	6,747	1,031	1,730	2,186	2,332	
CASTLEREAGH 19690	2,001	3,389	4,165	10,070	1,040	2,001	2,842	3,704	Gulargambone Bridge
CASTLEREAGH 19915	2,077	4,596	6,111	13,633	1,303	2,646	4,058	6,270	
CASTLEREAGH 20565	2,077	4,596	6,111	13,633	1,303	2,646	4,058	6,270	
CASTLEREAGH 21250	2,077	4,596	6,111	13,633	1,303	2,646	4,058	6,270	
CASTLEREAGH 21665	2,077	4,596	6,111	13,633	1,303	2,646	4,058	6,270	
CASTLEREAGH 22165	2,078	4,599	6,115	13,646	1,303	2,648	4,061	6,273	
CASTLEREAGH 23000	2,078	4,599	6,115	13,646	1,303	2,648	4,061	6,273	
CASTLEREAGH 23900	2,078	4,599	6,115	13,646	1,303	2,648	4,061	6,273	
GULAR 850	68	237	430	581	237	581	764	1,744	
GULAR 1900	68	240	492	1,461	237	581	764	1,696	
GULAR 2550	68	240	492	1,461	237	581	764	1,696	
GULAR 3160	68	240	492	1,461	237	581	764	1,696	
GULAR 3430	76	1,207	1,946	3,563	263	646	1,216	2,566	
GULAR 3570	76	1,207	1,946	3,563	263	646	1,216	2,566	
GULAR 3720	76	1,207	1,946	3,563	263	646	1,216	2,566	
GULAR 3945	76	1,207	1,946	3,563	263	646	1,216	2,566	
GULAR 4070	76	1,207	1,946	3,563	263	646	1,216	2,566	Castlereagh Hwy
GULAR 4250	76	1,207	1,946	3,563	263	646	1,216	2,566	
MURAIMAN 100	0	671	1,230	2,428	0	0	230	671	
MURAIMAN 2070	1	1,078	1,931	3,302	5	12	412	1,109	
MURAIMAN 3900	3	1,083	1,939	3,312	9	23	426	1,141	
MURAIMAN 5250	4	1,086	1,945	3,320	12	31	437	1,165	
MURAIMAN 6525	5	1,089	1,951	3,327	15	38	447	1,188	
MURAIMAN 8315	6	1,110	1,997	3,860	20	49	463	1,237	

MIKE11 Cross Section	Castlereagh Flood[1] - Peak Discharge				Gulargambone Ck Flood[1] - Peak Discharge				Remarks
	5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
MURAIMAN 10020	7	1,114	2,005	3,869	24	59	477	1,267	
MURAIMAN 10905	8	1,113	1,947	2,994	26	64	484	1,331	
MURAIMAN 11165	8	967	1,454	2,100	26	65	452	870	
MURAIMAN 11310	8	967	1,454	2,100	26	65	452	870	Culvert No.3[a]
MURAIMAN 11500	8	967	1,454	2,101	26	65	452	870	
MURAIMAN 11775	8	967	1,454	2,101	26	65	452	870	
OF_1 100	244	820	1,081	2,427	9	270	624	911	
OF_1 470	244	820	1,081	2,427	9	270	624	911	
OF_1 665	244	820	1,081	2,427	9	270	624	911	
OF_1 740	244	820	1,081	2,427	9	270	624	911	
OF_1 855	244	820	1,081	2,427	9	270	624	911	
OF_1 1030	244	820	1,081	2,427	9	270	624	911	
OF_1 1130	244	966	1,573	3,323	9	270	657	1,372	Culvert No. 7[a]
OF_1 1225	244	966	1,573	3,323	9	270	657	1,372	
OF_1 1320	244	966	1,573	3,323	9	270	657	1,372	Culvert No. 8[a]
OF_1 1485	244	966	1,573	3,323	9	270	657	1,372	
OF_1 1620	244	966	1,573	3,323	9	270	657	1,372	
OF_1 1700	244	966	1,573	3,323	9	270	657	1,372	
OF_2 70	0	146	493	896	0	0	32	461	
OF_2 200	0	146	493	896	0	0	32	461	
OF_2 525	0	146	493	896	0	0	32	461	
OF_2 800	0	146	493	896	0	0	32	461	
OF_2 960	0	146	493	896	0	0	32	461	Culvert No. 1[a]
OF_2 1060	0	146	493	896	0	0	32	461	

MIKE11 Cross Section	Castlereagh Flood[1] - Peak Discharge				Gulargambone Ck Flood[1] - Peak Discharge				Remarks
	5% AEP	1% AEP	0.5% AEP	Extreme	5% AEP	1% AEP	0.5% AEP	Extreme	
OF_2 1170	0	146	493	896	0	0	32	461	Culvert No. 2[a]
OF_2 1315	0	146	493	896	0	0	32	461	
OF_2 1515	0	146	493	896	0	0	32	461	
OF_2 1660	0	146	493	896	0	0	32	461	
OF_2 1755	0	146	493	896	0	0	32	461	
OF_2 1835	0	146	493	896	0	0	32	461	
OF_2 1990	0	146	493	896	0	0	32	461	

[1] Refer to Table 4-2 for details on coincident flooding

[a] Refer to Figure 2-3

Table D-2 Modelled Peak Velocities

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - Velocity (m/s)				Gulargambone Ck Flood[2] - Velocity (m/s)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme[2]	5% AEP	1% AEP	0.5% AEP	Extreme	
1	Castlereagh 0	1.0	1.2	1.3	0.8	1.2	1.0	1.0	1.2	
2	Castlereagh 1085	1.1	1.0	1.1	1.1	1.6	1.1	0.9	1.0	
3	Castlereagh 2720	1.4	1.4	1.6	2.0	2.2	1.4	1.2	1.4	Joins "Muraiman 0"
4	Castlereagh 3250	1.6	1.4	1.5	1.4	2.5	1.6	1.3	1.4	U/S of Castlereagh Hwy
5	Castlereagh 3270	1.8	2.2	2.4	0.7	1.3	1.8	2.0	2.2	D/S of Castlereagh Hwy
501	Castlereagh 4140	1.9	2.4	2.7	1.4	1.6	1.9	2.2	2.4	
6	Castlereagh 5140	1.8	2.2	2.4	1.2	1.5	1.8	2.1	2.2	
7	Castlereagh 6630	1.4	1.8	1.9	1.6	1.0	1.4	1.7	1.8	
8	Castlereagh 7480	1.2	1.4	1.5	1.5	1.0	1.2	1.3	1.4	
9	Castlereagh 7850	1.3	1.4	1.4	1.2	1.1	1.3	1.3	1.4	
10	Castlereagh 8250	1.4	1.4	1.5	1.2	1.2	1.4	1.4	1.4	
11	Castlereagh 8780	1.2	1.2	1.3	1.7	1.0	1.2	1.2	1.2	
12	Castlereagh 11040	1.0	1.1	1.1	1.7	1.1	1.0	1.0	1.1	
13	Castlereagh 12600	0.9	0.9	0.9	1.2	1.1	0.9	0.9	0.9	
14	Castlereagh 14200	0.7	0.8	0.8	1.1	0.7	0.7	0.7	0.8	
15	Castlereagh 15300	0.9	1.0	1.1	1.4	0.9	0.9	1.0	1.0	
16	Castlereagh 16300	0.8	0.8	0.8	0.8	0.7	0.7	0.8	0.7	
17	Castlereagh 16770	0.9	1.0	1.0	0.8	0.8	0.9	0.9	1.0	
18	Castlereagh 17180	0.6	0.6	0.6	0.9	0.7	0.6	0.6	0.6	Joins "OF_1 0"
19	Castlereagh 17750	1.2	1.3	1.2	0.9	1.1	1.2	1.2	1.2	
20	Castlereagh 18060	0.9	0.9	0.9	1.5	1.0	0.9	0.9	0.8	
21	Castlereagh 18320	1.0	1.1	1.1	1.1	0.9	1.0	1.0	1.0	
22	Castlereagh 18760	1.3	1.3	1.3	2.3	1.3	1.2	1.3	1.2	
23	Castlereagh 19280	1.3	1.3	1.3	2.5	1.3	1.2	1.3	1.2	

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - Velocity (m/s)				Gulargambone Ck Flood[2] - Velocity (m/s)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme[2]	5% AEP	1% AEP	0.5% AEP	Extreme	
24	Castlereagh 19680	1.1	1.0	1.0	1.8	1.3	1.0	1.0	0.9	U/S of Gulargambone Bridge
25	Castlereagh 19700	1.5	1.5	1.6	2.5	1.3	1.3	1.4	1.4	D/S of Gulargambone Bridge
26	Castlereagh 20130	1.0	1.6	1.8	3.0	1.0	1.1	1.5	1.9	
27	Castlereagh 21000	0.7	0.8	0.9	1.4	0.9	0.7	0.8	1.0	
28	Castlereagh 21500	1.1	0.9	1.0	1.3	1.1	0.9	0.9	1.0	
29	Castlereagh 21830	0.9	1.0	1.0	1.4	1.0	0.8	1.0	1.0	
30	Castlereagh 22500	1.1	1.3	1.5	2.5	1.1	0.9	1.2	1.5	
31	Castlereagh 23500	1.4	1.1	1.2	0.8	1.3	1.0	1.1	1.2	
32	Castlereagh 24300	1.6	1.8	2.1	2.8	1.5	1.5	1.7	2.1	D/S Boundary
81	Gular 0	0.9	1.1	0.7	0.3	1.1	0.8	0.8	1.0	
82	Gular 1700	0.4	0.3	0.3	0.2	0.9	0.9	0.8	0.8	
83	Gular 2100	0.3	0.3	0.3	0.4	0.9	1.0	0.8	0.8	
84	Gular 3000	0.1	0.1	0.2	0.3	0.6	0.5	0.4	0.6	
85	Gular 3320	0.1	0.1	0.2	0.4	0.8	0.7	0.5	0.7	
64	Gular 3540	0.1	0.4	0.5	0.5	0.6	0.5	0.4	0.5	
65	Gular 3600	0.1	0.5	0.6	0.7	0.6	0.5	0.5	0.8	
66	Gular 3840	0.1	0.4	0.5	0.6	0.4	0.4	0.4	0.6	
67	Gular 4050	0.1	0.3	0.4	0.5	0.4	0.3	0.3	0.5	U/S of Castlereagh Hwy
68	Gular 4100	0.1	0.5	0.6	0.8	0.4	0.4	0.5	0.8	D/S of Castlereagh Hwy
69	Gular 4400	0.1	0.8	1.0	1.3	0.5	0.6	0.8	1.3	Joins "Castlereagh 19700"
51	Muraiman 0	0.0	0.1	0.2	0.3	0.1	0.0	0.0	0.1	
52	Muraiman 1140	0.2	0.5	0.6	0.8	0.2	0.3	0.3	0.5	
53	Muraiman 3000	0.2	0.7	0.8	0.9	0.4	0.5	0.6	0.7	
54	Muraiman 4800	0.3	0.8	0.9	1.1	0.4	0.4	0.7	0.8	
55	Muraiman 5700	0.4	1.0	1.1	1.3	0.5	0.7	0.8	1.0	

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - Velocity (m/s)				Gulargambone Ck Flood[2] - Velocity (m/s)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme[2]	5% AEP	1% AEP	0.5% AEP	Extreme	
56	Muraiman 7350	0.4	0.7	0.8	0.8	0.4	0.6	0.9	0.7	
57	Muraiman 9280	0.4	0.8	0.9	0.9	0.7	0.6	1.1	0.8	
58	Muraiman 10760	0.1	1.1	1.5	1.6	0.2	0.2	0.7	1.0	
59	Muraiman 11050	0.0	1.3	1.5	1.1	0.2	0.2	0.8	1.1	Joins "OF_2 0"
60	Muraiman 11280	0.0	0.9	0.8	0.6	0.1	0.2	0.5	0.5	U/S Culvert No.3[a]
61	Muraiman 11350	0.0	0.8	0.8	0.5	0.1	0.1	0.5	0.4	D/S Culvert No.3
62	Muraiman 11650	0.0	0.7	0.8	0.7	0.1	0.1	0.4	0.4	
63	Muraiman 11900	0.0	0.9	1.0	0.9	0.1	0.1	0.4	0.5	Joins "Gular 3320"
91	OF_1 320	0.4	0.6	0.6	0.7	0.2	0.4	0.5	0.5	
92	OF_1 620	0.7	0.8	0.9	1.1	0.3	0.7	0.8	0.8	
93	OF_1 710	0.7	0.8	0.8	1.1	0.2	0.6	0.7	0.8	
94	OF_1 770	0.8	0.9	0.9	1.2	0.3	0.7	0.8	0.8	
95	OF_1 940	0.6	0.8	0.9	1.2	0.7	0.5	0.7	0.8	
96	OF_1 1120	0.2	0.2	0.2	0.6	0.1	0.2	0.2	0.2	U/S Culvert No. 7[a]
97	OF_1 1150	0.2	0.3	0.4	0.5	0.1	0.2	0.2	0.3	D/S Culvert No. 7
98	OF_1 1300	0.2	0.3	0.4	0.5	0.1	0.2	0.2	0.4	U/S Culvert No. 8[a]
99	OF_1 1370	0.2	0.3	0.4	0.5	0.1	0.1	0.2	0.4	D/S Culvert No. 8
100	OF_1 1600	0.4	0.9	1.3	1.8	0.0	0.4	0.7	1.2	
101	OF_1 1640	0.4	1.1	1.6	2.5	0.0	0.4	0.8	1.5	
71	OF_2 140	0.0	0.4	0.7	0.5	0.0	0.0	0.2	0.7	
72	OF_2 390	0.0	0.6	0.8	0.5	0.0	0.0	0.4	0.9	
73	OF_2 660	0.0	0.3	0.4	0.3	0.0	0.0	0.1	0.5	
74	OF_2 940	0.0	0.1	0.3	0.2	0.0	0.0	0.0	0.3	U/S Culvert No. 1[a]
75	OF_2 980	0.0	0.1	0.3	0.2	0.0	0.0	0.0	0.3	D/S Culvert No. 1

Cross Section[1]	MIKE11 Cross Section	Castlereagh Flood[2] - Velocity (m/s)				Gulargambone Ck Flood[2] - Velocity (m/s)				Remarks
		5% AEP	1% AEP	0.5% AEP	Extreme[2]	5% AEP	1% AEP	0.5% AEP	Extreme	
76	OF_2 1140	0.0	0.1	0.3	0.2	0.0	0.0	0.0	0.3	U/S Culvert No. 2[a]
77	OF_2 1190	0.0	0.2	0.5	0.4	0.0	0.0	0.1	0.5	D/S Culvert No. 2
78	OF_2 1440	0.0	0.2	0.5	0.5	0.0	0.0	0.1	0.5	
79	OF_2 1590	0.0	0.2	0.6	0.6	0.0	0.0	0.1	0.6	

[1] Refer to Figure No. D-1 for location of cross sections

[2] Refer to Table 4-2 for details on coincident flooding

[a] Refer to Figure 2-3