BLAYNEY SHIRE COUNCIL

BLAYNEY
FLOOD STUDY UPDATE

FEBRUARY 2026

DRAFT REPORT FOR CLIENT REVIEW

Job No: GU595 File: BFSU_V1_Report [Rev 1.0].docx	Date: February 2026 Rev No: 1.0	Principal: SAB Author: SAB/TDR

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FOREWORD

The NSW State Government's Flood Prone Land Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the flood risk management process shown below.

The *Blayney Flood Study Update* is jointly funded by Blayney Shire Council and the NSW Government, via the Department of Climate Change, Energy, the Environment and Water. The Flood Study Update constitutes the first and second stage of the flood risk management process for this area and has been prepared for Blayney Shire Council to define flood behaviour under current conditions.

ACKNOWLEDGEMENT

Blayney 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 Department of Climate Change, Energy, the Environment and Water.

TABLE OF CONTENTS

Page No.

Continued Over

TABLE OF CONTENTS (Cont'd)

APPENDICES

LIST OF MAIN REPORT FIGURES
(BOUND IN VOLUME 2)

NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (**AEP**) or Average Recurrence Interval (**ARI**). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of greater magnitude each year. As another example, for a flood having a 5 year ARI, there will be floods of equal or greater magnitude once in 5 years on average. The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) (%)	Average Recurrence Interval (ARI) (years)
0.2	500
0.5	200
1	100
2	50
5	20
10	10
20	5

The report also refers to the Probable Maximum Flood (**PMF**). This flood occurs as a result of the Probable Maximum Precipitation (**PMP**). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using computer models which simulates the conversion of rainfall to runoff. The PMF is defined as the limiting value of floods that could reasonably be expected to occur. It is an extremely rare flood, generally considered to have a return period greater than 1 in 10^6 years.

NOTE ON QUOTED LEVEL OF ACCURACY

Peak flood levels have on occasion been quoted to more than one decimal place in the report in order to identify minor differences in values. For example, to demonstrate minor differences between peak heights reached by both historic and design floods and also minor differences in peak flood levels which will result from, for example, a partial blockage of hydraulic structures. It is not intended to infer a greater level of accuracy than is possible in hydrologic and hydraulic modelling.

ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
AMC	Antecedent Moisture Condition
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff
AWS	All Weather Station
BoM	Bureau of Meteorology
Council	Blayney Shire Council
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEM	Digital Elevation Model
FRMM	Flood Risk Management Manual (NSW Government, 2023)
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMS&P	Flood Risk Management Study and Plan
GSDM	Generalised Short Duration Method
GS	Gauging Station
IFD	Intensity-Frequency-Duration
LiDAR	Light Detecting and Ranging (type of aerial based survey)
NSW SES	New South Wales State Emergency Service
PFL	Peak Flow Location
PFLL	Peak Flood Level Location
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
TUFLOW	A true two-dimensional hydrodynamic computer model which has been used to define flooding patterns as part of the present study.

Chapter 8 of the report contains definitions of flood-related terms used in the study.

SUMMARY

S.1 Study Objective

The objective of the study was to define the nature of the following two types of flooding that are experienced at the township of Blayney for flood frequencies ranging between 50 and 0.2 per cent Annual Exceedance Probability (**AEP**), together with the Probable Maximum Flood (**PMF**):

- **Main Stream Flooding** which occurs when floodwater surcharges the inbank area of the Belubula River and its tributaries. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater but can include shallower and slower moving floodwater on the overbank of the aforementioned creeks.
- **Major Overland Flow**, which is experienced during periods of heavy rain and is generally characterised by relatively shallow and slow-moving floodwater that is conveyed overland in an uncontrolled manner toward the inbank area of the Belubula River and its tributaries.

The findings of the study will be used as the basis for preparing the future *Blayney Flood Risk Management Study and Plan* (***Blayney FRMS&P***) which will assess options for flood mitigation and prepare a plan of works and measures for managing the existing, future and continuing flood risk at Blayney.

S.2 Study Area

While the definition of flood behaviour was limited to the township of Blayney and its immediate environs, the present study assessed the runoff potential of the whole of the Belubula River catchment. **Figures 1.1** in **Volume 2** of this report shows that the township of Blayney is located about 33 km to the west of Bathurst at the confluence of the Belubula River and Abattoir Creek. The study area, the extent of which is shown on **Figure 2.1** comprises the urbanised parts of Blayney (herein referred as the "**Urban Centre**"), as well as their immediate environs. **Figure 2.2** (3 sheets) shows the key features of the existing stormwater drainage system in the study area.

S.3 Study Method

The flood study involved the following activities:

- The collection of flood data, details of which are set out in **Appendix A** of this report. Pluviographic rainfall data recorded by Bureau of Meteorology (**BoM**) and WaterNSW operated rain gauges in the vicinity of Blayney were obtained. Drone-based footage and a single photograph were provided by Council showing historic flood behaviour that occurred at Blayney on 14 November 2022, screen shots and a copy of which are contained in **Appendix B** of this report.
- A review of the previous flooding investigations that have been undertaken at Blayney, details of which are set out in **Appendix A**. While hydrologic and hydraulic models were originally developed as part of the *Blayney Flood Study* (Jacobs, 2015) and updated as part of the *Addendum to Blayney Flood Study* (Storm Consulting, 2022a), the review of the models found that they are not consistent with the procedures that are set out in the the 2019 edition of *Australian Rainfall and Runoff* (Ball et. al., 2019) (**ARR 2019**) and the *NSW Flood Risk Management Manual* (NSWG, 2023) (**FRMM**).

- Development of a new hydrologic model of the study catchment. The RAFTS and IL-CL sub-models in the DRAINS software were used to simulate the hydrologic response of the rural and urbanised parts of the study catchment. The DRAINS-based hydrologic model was used to generate discharge hydrographs resulting from both historic and design storms.
- Development of a new hydraulic model of the study area using the TUFLOW two-dimensional modelling software. Discharge hydrographs that were generated by the DRAINS-based hydrologic model were input to the TUFLOW-based hydraulic model.
- Calibration of the new hydrologic and hydraulic models (collectively referred to herein as "the flood models") using data that were available for the November 2022 flood event.
- Definition of flood behaviour for design storms ranging between 50 and 0.2% AEP, as well as the PMF in accordance with the procedures set out in ARR 2019.
- Presentation of study results as diagrams showing indicative extents and depths of inundation, flood hazard vulnerability and the hydraulic categorisation of the floodplain into floodway, flood storage and flood fringe areas.
- Sensitivity studies to assess the effects on model results resulting from variations in model parameters such as hydraulic roughness of the floodplain and a potential partial blockage of hydraulic structures. The effects that a potential increase in rainfall intensities associated with future climate change could have on flood behaviour were also assessed.

S.4 Analysis of Historic Rainfall

Figure 2.3 shows the cumulative rainfall that was recorded at nearby Bureau of Meteorology (**BoM**) and WaterNSW operated rain gauges on the rain days of 13-14 November 2022 (refer **Figure 1.1** for the location of these gauges), while **Figure 2.4** (2 sheets) shows a comparison between the recorded rainfall and design intensity-frequency-duration curves. **Figure 2.5** shows the assessed spatial distribution of the rain that fell across the study catchment for the rain days of 13-14 November 2022, noting that the most intense rainfall was recorded along the western side of the catchment, with the rainfall depth decreasing in a south-easterly direction.

The recorded rainfall was found to be equivalent to a design storm event of about 2-5% AEP at the location of the Orange and Mandurama rain gauges, about 10% AEP at the Carcoar Dam rain gauge and about 20% AEP at the Newbridge rain gauge.

S.5 Flood Model Development and Calibration

Figures 3.1 (2 sheets) and **4.1** (3 sheets) respectively show the layout of the hydrologic (DRAINS) and hydraulic (TUFLOW) models that were developed as part of the present investigation, while **Figure 4.3** (3 sheets) shows the indicative extent and depth of inundation that resulted from the rain that fell on 13-14 November 2022.

S.6 Derivation of Design Flood Hydrographs

The procedures set out in ARR 2019, as well as intensity-frequency-duration data issued by the BoM in 2016 (**BoM 2016 IFD Data**) and the rainfall losses based on the NSW jurisdictional specific procedures set out in the *ARR Data Hub* were used as the basis for deriving design discharge hydrographs from the hydrologic (DRAINS) model for input to the hydraulic (TUFLOW) model.

S.7 Hydraulic Modelling of Design Flood Events

Figures 6.1 to **6.8** show the hydraulic (TUFLOW) model results for the 50%, 20%, 10%, 5%, 1%, 0.5% and 0.2% AEP storm events, together with the PMF. These diagrams show the indicative extent and depth of inundation in the study area for each design storm event.

Figure 6.9 (3 sheets) shows the hydrologic capacity of the existing stormwater drainage system at Blayney in AEP terms, while **Figure 6.10** (2 sheets) shows water surface profiles for the modelled design flood events along a 11 km reach of the Belubula River and 3.5 km reach of Abattoir Creek. **Figure 6.11** (2 sheets) shows stage hydrographs at selected road/rail crossings throughout the study area, while **Table E1** in **Appendix E** sets out the peak flood level and maximum depth of inundation at each crossing. **Table F1** in **Appendix F** sets out design peak flows and corresponding critical storm durations at key locations throughout the study area.

Flooding patterns derived by the hydraulic (TUFLOW) for the design storm events are described in **Chapter 6** of this report.

S.8 Comparison with Previous Studies

The peak flood levels generated by the flood models that were developed as part of the present study are generally comparable to those that were derived using the flood models that were developed as part of Jacobs, 2015 and Storm Consulting, 2022a.

S.9 Flood Hazard Classification and Hydraulic Categorisation

Diagrams showing the flood hazard vulnerability classification for the 5%, 1% and 0.5% AEP flood events, as well as the PMF are shown on **Figures 6.12** to **6.14**, while the hydraulic categorisation of the floodplain for the 1% AEP design flood event is shown on **Figure 6.15**.

The flood hazard vulnerability classification is dependent on the depth and velocity of flow on the floodplain. Flood affected areas in the study area have been divided into the following six flood hazard vulnerability categories on the basis of these two variables and the relationships presented in ARR 2019:

- H1 which is considered to be safe for people, vehicles and buildings
- H2 which is considered to be unsafe for small vehicles
- H3 which is considered to be unsafe for vehicles, children and the elderly
- H4 which is considered to be unsafe for people and vehicles
- H5 which is considered to be unsafe for people and vehicles, and where all buildings would be vulnerable to structural damage, with some less robust building types vulnerable to failure
- H6 which is considered to be unsafe for people and vehicles, and where all buildings are considered to be vulnerable to failure

The study found that in floods up to 0.5% AEP in magnitude, areas classified as H5 and H6 are confined to the inbank area of the Belubula River and Abattoir Creek, in addition to their immediate overbank areas. **T**he majority of the Urban Centre is classified as H1 or H2 in storm events up to 0.2% AEP in intensity, with H3 to H4 type flooding shown to be present in existing development that is located adjacent to the lower reaches of Abattoir Creek.

The hydraulic categorisation requires the assessment of the main flow paths. Those areas of the floodplain where a significant discharge of water occurs during floods are denoted Floodways and are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant re-distribution of flood flow or a significant increase in flood levels. The remainder of the floodplain is denoted either Flood Storage or Flood Fringe.

Floodways are generally present along the alignment of the main flow paths in the study area. While the floodways are generally contained within the drainage and road reserve boundaries in the Urban Centre, there are floodways present in rural zoned land that is presently undeveloped.

S.10 Sensitivity Analyses

Analyses were undertaken to test the sensitivity of flood behaviour to:

a. An increase in hydraulic roughness. **Figure 6.17** shows the effects a 20 per cent increase in the adopted ‘best estimate’ hydraulic roughness values would have on flood behaviour at the 1% AEP level of flooding.

b. A partial blockage of major hydraulic structures by debris. **Figure 6.18** shows the effects a partial blockage of the major culvert structures would have on flood behaviour at the 1% AEP level of flooding.

c. Increases in rainfall intensity associated with future climate change. **Figures 6.19**, **6.20** and **6.21** show the effects a 10 and 30 per cent increase in design 1% AEP rainfall intensities would have on flood behaviour in the study area.

The sensitivity analyses identified that:

- peak 1% AEP flood levels could be increased by up to 120 mm and 50 mm in areas that are subject to Main Stream Flooding and Major Overland Flow, respectively as a result of an increase in hydraulic roughness;
- a partial blockage of the hydraulic structures has a negligible impact on flood behaviour;
- an increase in the intensity of rainfall associated with future climate change has the potential to increase peak 1% AEP flood levels by a maximum of about 300 mm and 100 mm in areas that are subject to Main Stream Flooding and Major Overland Flow, respectively.

S.11 Potential Impacts of Future Development

Figures 6.22, **6.23** and **6.24** show the impact that uncontrolled development could have on flood behaviour in the study area in a 20%, 5% and 1% AEP storm event, respectively, noting that the assessment undertaken as part of the present study is of a broad-scale and strategic nature, and that more detailed site specific assessments would need to be undertaken as part of any future development.

The study found that peak flood levels could generally increase by up to 100 mm in the urbanised parts of the study area if uncontrolled development were allowed to occur in the catchment for the range of assessed storm events, while minor reductions in peak flood levels are shown to occur along the Belubula River and its eastern bank due to changes in the timing of the flood wave in its tributaries. This finding reinforces the need for Council to require detention basins to be incorporated in the design of future development to ensure that post-development peak flows are no higher than pre-development conditions.

S.12 Interim Flood Planning Area

Figure 6.25 (3 heets) shows the extent of the Interim Flood Planning Area (**IFPA**) in the immediate vicinity of the Urban Centre as it relates to both Main Stream Flooding and Major Overland Flow. The extent of the IFPA has been defined as follows:

- Main Stream Flooding IFPA – Land which is located along the three main flow paths and lies at or below the peak 1% AEP flood level plus 0.5 m freeboard.
- Major Overland Flow IFPA – Land which lies outside the Main Stream Flooding IFPA but would be subject to depths of inundation of greater than 0.1 m in a 0.2% AEP storm event.

Pending the completion of the future *Blayney FRMS&P*, it is recommended that the habitable floor levels of future development be set as a minimum at the following elevations:

a) Where a dwelling or commercial building is proposed within the extent of the Main Stream Flooding IFPA, its habitable floor level is to be set at or above the peak 1% AEP flood level plus a freeboard of 0.5 m; or

b) Where a dwelling or commercial building is proposed within the extent of the Major Overland Flow IFPA, its habitable floor level is to be set at or above the peak 1% AEP flood level plus a freeboard of 0.3 m.[1]

Consideration will need to be given during the preparation of the future *Blayney FRMS&P* to the appropriateness of the adopted IFPAs, as well as the interim freeboard requirements given the implications of recent updates to ARR 2019 in relation to the impact of climate change on design rainfall intensities and losses.

An assessment should be undertaken by Council as part of any future Development Application to confirm that the proposed development will not form an obstruction to the passage of overland flow through the subject site.

Further to the above, it is recommended that Council consider precluding critical, sensitive and vulnerable type development such as hospitals with emergency facilities, emergency services facilities, utilities, community evacuation centres, aged care homes, seniors housing, group homes, boarding houses, hostels, caravan parks, schools and childcare facilities in areas which lie in areas that are impacted by Main Stream Flooding.

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[1] Where a dwelling or commercial building is proposed within the extent of the Major Overland Flow IFPA but lies outside the extent of the 1% AEP, its habitable floor level is to be set a minimum 0.3 m above natural/finished surface levels.

1 INTRODUCTION

1.1 Study Background

This report presents the findings of an investigation of flooding at the township of Blayney which is located on the Belubula River within the Lachlan River Basin. The study has been commissioned by Blayney Shire Council (**Council**) with financial and technical support from the NSW Government, via the Department of Climate Change, Energy, the Environment and Water (**DCCEEW**). **Figure 1.1** shows the extent of the Belubula River catchment at Blayney.

The study objective was to define flood behaviour in terms of flows, water levels and velocities for floods ranging between 20 (1 in 5) and 0.2 (1 in 500) per cent Annual Exceedance Probability (**AEP**), as well as for the Probable Maximum Flood (**PMF**). The study involved rainfall-runoff hydrologic modelling to assess flows in the existing drainage system at Blayney and application of these flows to a hydraulic model to assess peak water levels and flow velocities (collectively referred to herein as 'flood modelling'). The model results were interpreted to present a detailed picture of flood behaviour at Blayney under present day conditions.

The study focuses on the following two types of flooding which are present in different parts of the study area:

- **Main Stream Flooding** which occurs when floodwater surcharges the inbank area of the Belubula River and its tributaries. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater but can include shallower and slower moving floodwater on the overbank of the aforementioned creeks.
- **Major Overland Flow**, which is experienced during periods of heavy rain and is generally characterised by relatively shallow and slow-moving floodwater that is conveyed overland in an uncontrolled manner toward the inbank area of the Belubula River and its tributaries.

While flood and flood risk management studies have previously been prepared for Blayney, the present study is aimed at more accurately defining the nature of flooding using contemporary design flood estimation processes in combination with sophisticated flood modelling software, while a future study will review and update the existing flood risk management plan for the township.

1.2 Available Data

Chapter A1 of **Appendix A** contains details of the data that were available for the present study, while **Appendix B** contains several screen shots from drone-based footage, as well as a single photograph showing the flooding that was experienced at Blayney on 14 November 2022.

The following documents (arranged in date order) were primarily used in the preparation of this report:

- *Blayney Flood Study* (Jacobs, 2015)
- *Blayney Floodplain Risk Management Study and Plan* (Jacobs, 2016)
- *Addendum to Blayney Flood Study* (Storm Consulting, 2022a)
- *Blayney Retarding Basins Study* (Storm Consulting, 2022b)

Chapter A2 of **Appendix A** contains details of the data that were available for the present study.

1.3 Layout of Report

Chapter 2 contains background information including a brief description of the study catchment and its drainage system, a brief history of flooding at Blayney and an analysis of the available rain gauge record.

Chapter 3 deals with the hydrology of the study catchment and describes the development and calibration of the DRAINS-based hydrologic model that was used to generate discharge hydrographs for input to the hydraulic model.

Chapter 4 deals with the development and calibration of the TUFLOW hydraulic model that was used to analyse flood behaviour in the study area.

Chapter 5 deals with the derivation of design discharge hydrographs, which involved the determination of design storm rainfall depths over the catchment for a range of storm durations and conversion of the rainfalls to discharge hydrographs.

Chapter 6 details the results of the hydraulic modelling of the design floods in the study area. Results are presented as plans showing indicative extents and depths of inundation for a range of design flood events up to the PMF. This chapter also includes an assessment of flood hazard and flood function. It also presents the results of various sensitivity studies undertaken using the TUFLOW model, including the effects changes in hydraulic roughness, a partial blockage of the hydraulic structures and potential increases in rainfall intensities due to future climate change would have on flood behaviour. This chapter also deals with the derivation of a preliminary set of *Flood Planning Levels* for the study area.

Chapter 7 contains a list of references, whilst **Chapter 8** contains a list of flood-related terminology that is relevant to the present study.

The following appendices are included in the report:

- **Appendix A**, which contains a list of data that were available for the present study and a review of flooding investigations that have previously been undertaken at Blayney.
- **Appendix B** which contains several screen shots from drone-based footage, as well as a single photograph showing the flooding that was experienced at Blayney on 14 November 2022.
- **Appendix C**, which contains a copy of the design input data that were extracted from the *Australian Rainfall and Runoff* (**ARR**) *Data Hub* for the study area.
- **Appendix D**, which summarises design blockage values that were assigned to the major hydraulic structures in the TUFLOW model.
- **Appendix E**, which contains a table containing flood data on individual road and rail crossings at Blayney.
- **Appendix F**, which contains a table listing the peak flow at key locations in the study area for the full range of design storm events.

Figures referred to in this report are bound separately in **Volume 2**.

2 BACKGROUND INFORMATION

2.1 Catchment Description

The township of Blayney is located on the Mid-Western Highway approximately 33 km west of Bathurst and has a population of about 7,500. **Figure 1.1** shows that Blayney lies on the banks of the Belubula River approximately 6.5 km (by river) upstream of Carcoar Dam. The Belubula River has a total catchment area of about 159 km^2 where it crosses Hobbys Yards Road which is located approximately 1 km to the south (downstream) of the urbanised parts of the town.

Figure 2.1 shows that the headwaters of the Belubula River lie approximately 12 km to the north of the town in the vicinity of the Mitchell Highway. The catchment generally comprises undulating pastoral land with isolated pockets of forests. The Belubula River generally comprises an incised 20 m wide by 1 m deep channel which has a grade of about 0.15% where it runs in a southerly direction along the eastern fringes of Blayney.

The Main Western Railway and Newbridge Road traverse the Belubula River floodplain in an east-west direction at Blayney. The Main Southern Railway crossing comprises a raised embankment that is up to 2 m higher than the adjacent floodplain with two waterway openings, while the Newbridge Road crossing comprises a 2 m high embankment adjacent to the two waterway openings, with a 150 m section of road on the left (eastern) overbank of the river only elevated by about 0.2 m above the adjacent floodplain.

Abattoir Creek is a major tributary of the Belubula River and generally runs in a south-easterly direction north of Blayney. In the inbank area of the creek generally comprises a 5 m wide by 1 m deep channel which has a grade of about 0.5% immediately upstream of its confluence with the Belubula River.

The Belubula River and Abattoir Creek have total catchment areas of 125 km^2 and 20 km^2, respectively at their confluence.

Figure 2.2 (3 sheets) shows the layout of the existing stormwater drainage system at Blayney. The extent of land zoned for urban type develop in the vicinity of the town (herein referred as the “Urban Centre”) is drained by a series of roadside gutters and stormwater pipes that discharge to either the Belubula River or Abattoir Creek.

The Urban Centre includes both general and large lot residential type development that is bounded by the Belubula River to the east, Abattoir Creek to the north, the Blayney Demondrille Railway to the west and rural pastural land to the south. The commercial centre of the town is located along Adelaide Street between the Main Western Railway and Charles Street. There are also isolated pockets of industrial zoned land at the following three locations:

- on the left (eastern) bank of the Belubula River between the Main Western Railway and Newbridge Road;
- on the western side of the Mid-Western Highway to the north of the Main Western Railway; and
- in the area bounded by the Main Western Railway to the north, the Blayney Demondrille Railway to the east and Orange Road to the south and west.

2.2 Flood History and Analysis of Historic Rainfall

Parts of Blayney have historically been impacted by floodwater that surcharges the banks of both the Belubula River and Abattoir Creek, as well as a result of local catchment runoff which discharges overland toward the two watercourses. Jacobs, 2015 analysed historic storm events that had occurred at Blayney on the following dates:

- 1973 [date not specified]
- 1 June 1990 (Major Overland Flow)
- 21 December 2007 (Major Overland Flow)
- 19 August 2010 (Main Stream Flooding)
- September 2010 (Main Stream Flooding) [date not specified]
- December 2010 (Main Stream Flooding) [date not specified]
- 2011 [date not specified]
- March 2012 (Main Stream Flooding) [date not specified]
- 2013 [date not specified]

The Belubula River flooded at Blayney shortly after the commencement of the present study on 14 November 2022. Screen shots of drone-based footage that was provided by Council (refer **Plates B1.1** to **B1.11** in **Appendix B**) show that flooding occurred between about 07:30 hours and 20:40 hours on 14 November 2022, with Council advising that the flood peaked at the Newbridge Road crossing of the river (known locally as the Glasson Bridges) (refer **Plate B1.2**) shortly before the time of the photograph (i.e. 07:30 hours on 14 November 2022) and was approximately three inches (76.2 mm) higher than the level shown on the photograph.

Figure 2.3 shows the cumulative rainfall that was recorded by four nearby pluviographic rain gauges during the rain days of 13-14 November 2022, while **Figure 2.4** (2 Sheets) shows design versus historic intensity-frequency-duration (**IFD**) curves for the same period. **Figure 2.5** shows the assessed spatial distribution of the rain that fell across the catchment for the rain days of 13-14 November 2022. **Table 2.1** gives the approximate AEP of the recorded rainfall for storm durations ranging between 30 minutes and 12 hours.

Figure 2.3 shows that flooding occurred after two separate rain bursts where 14-20 mm of rain fell between 7:00 and 10:00 hours on 13 November 2022 which was then followed by an additional 55-86.2 mm between 17:00 hours on 13 November 2022 and 4:00 hours on 14 November 2022. **Figure 2.5** shows that higher rainfall totals were recorded on the north-western side of the catchment, with rainfall totals decreasing in a south-easterly direction.

Table 2.1 shows that the second storm burst was equivalent to a design storm event of about 2-5% AEP at the location of the Orange and Mandurama rain gauges, about 10% AEP at the Carcoar Dam rain gauge and about 20% AEP at the Newbridge rain gauge.

TABLE 2.1
APPROXIMATE AEPs OF RECORDED RAINFALL FOR HISTORIC STORM EVENTS(1)
(% AEP)

Storm Event	Gauge Name	Storm Durations (hours)													
		0.25	**0.5**	**1**	**1.5**	**2**	**3**	**4.5**	**6**	**9**	**12**	**18**	**24**	**36**	**48**
13-14 November 2022	Mandurama Post Office (GS 63245)	<50%	<50%	<50%	<50%	20-50%	20%	20%	10%	2-5%	2-5%	5%	2-5%	10-20%	10%
	Newbridge (Stringybark Road) (GS 63264)	<50%	<50%	<50%	<50%	<50%	20-50%	20-50%	20-50%	20%	20-50%	20-50%	20%	<50%	20-50%
	Orange Airport AWS (GS 63303)	<50%	<50%	50%	20%	10-20%	5-10%	5-10%	5%	2-5%	5%	5-10%	5%	20%	10-20%
	Belubula River at Carcoar Dam (GS 412106)	<50%	<50%	<50%	<50%	<50%	50%	50%	20%	10-20%	10%	10-20%	10%	20%	20%

1. Refer **Figure 1.1** for gauge location.

3 HYDROLOGIC MODEL DEVELOPMENT AND CALIBRATION

3.1 Hydrologic Modelling Approach

The present study required the use of a hydrologic model which is capable of representing the rainfall-runoff processes that occur within both the rural and urbanised parts of the study catchment. For hydrologic modelling, the practical choice is between the models known as DRAINS, RAFTS, RORB and WBNM. Whilst there is little to choose technically between these models, Hortonian and IL-CL loss models within the DRAINS software have been developed primarily for use in modelling the passage of a flood wave through highly urbanised catchments, whilst RAFTS, RORB and WBNM have been widely used in the preparation of rural flood studies.

Both the IL-CL and RAFTS modelling approaches which are built into the DRAINS software were used to generate discharge hydrographs from urban and rural areas, respectively, as this combined approach was considered to provide a more accurate representation of the rainfall runoff process. The discharge hydrographs generated by applying the IL-CL and RAFTS modelling approach were applied to the TUFLOW hydraulic model as either point or distributed inflow sources (refer **Section 4.4** of this report for further details).

3.2 Hydrologic Model Layout

Figure 3.1 (2 sheets) shows the layout of the hydrologic model that was developed as part of the present study (**Blayney DRAINS Model**). Careful consideration was given to the definition of the sub-catchments which comprise the Blayney DRAINS Model to ensure peak flows throughout the drainage system would be properly routed through the hydraulic model. In addition to using the Light Detecting and Ranging (**LiDAR**) based contour data, the location of stormwater pits and headwalls were also taken into consideration when deriving the boundaries of the various sub-catchments. The study area was split into a total of 638 sub-catchments.

Figure 3.1 also shows that the RAFTS modelling approach has been used for sub-catchments predominately comprising the rural portion of the study catchment, while the IL-CL modelling approach has been applied in the urbanised parts of Blayney.

Sub-catchment slopes used for input to the hydrologic model were derived using the vectored average slope approach for sub-catchments characterised as rural (which are modelled using the RAFTS approach) and the average sub-catchment slope approach for sub-catchments characterised as urbanised (which are modelled using the IL-CL approach). Digital Elevation Models (**DEMs**) derived from the available LiDAR survey data were used as the basis for computing the slope.

Percentages of impervious area were based on a visual inspection of the aerial photography and experience in determining appropriate values for different land-use types. The Total Impervious Area (**TIA**) was used as input to the hydrologic model as questions have been raised in the industry about the appropriateness of adopting the Effective Impervious Area (**EIA**) approach set out in the 2019 edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) (**ARR 2019**).[2] One of the identified issues with the approach is that it is based on a volume check rather than a peak flow check, with the adjustment factor seen as taking account of additional losses that occur in the urban environment. However, Kus et al, 2018 found that the adoption of TIA in DRAINS more closely reproduced peak flows generated by an urban catchment, as well as those derived by other peak flow estimation methods.

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[2] Source: Kus et al, 2018

The adoption of the EIA approach when using a hydrologic model to generate inflow hydrographs to a two-dimensional hydraulic model is also problematic, as it is accounting for a loss of volume from each sub-catchment possibly from additional depression storage, as well as surface runoff ponding behind solid structures such as buildings and fences, a feature which is also partially accounted for in the two-dimensional model domain. If the TIA is reduced by up to 40% as recommended in ARR 2019, then the total volume and also the peak flow being input to the two-dimensional hydraulic model would be significantly reduced. This fact, coupled with the additional flood storage that is present in the two-dimensional model domain has the potential to result in an under-estimation of peak flow and volume estimates, and hence peak flood levels throughout the catchment.

The outlets of the sub-catchments in the upper reaches of the study catchment were linked and the lag times between each assumed to be equal to the distance along the main drainage path divided by an assumed flow velocity of 1 m/s based on preliminary results of the hydraulic model that was developed as part of the present study.

3.3 Hydrologic Model Testing

3.3.1. General

Historic flood data suitable for use in the model calibration process comprises drone-based footage, photographic and anecdotal evidence of flooding patterns that were observed during the flooding that occurred on 13-14 November 2022. As discussed in **Section 2.2**, the storm was equivalent to about a 2-5% AEP event.

As there are no historic data on flood flows anywhere in the study area, the procedure adopted for the calibration of the hydrologic model involved an iterative process sometimes referred to as “tuning” or “validating”. This process involved the generation of discharge hydrographs for the historic storm events using a starting set of hydrologic model parameters. The discharge hydrographs were then input to the hydraulic model, which was then run with an initial set of hydraulic roughness parameters and the resulting flooding patterns compared with the drone-based footage, photographic and anecdotal evidence.

Minimal iterations of this process were required, whereby changes were made to the hydrologic model parameters, after which the resulting adjusted discharge hydrographs were input to the hydraulic model until a good fit with observed data was achieved (refer **Chapter 4** for further details).

3.3.2. Application of Historic Rainfall to the Hydrologic Model

Figure 2.3 shows the bursts of rainfall that were incorporated in the hydrologic model for the November 2022 storm event, while **Figure 2.5** shows the extent over which the recorded rainfall was applied to the various sub-catchments comprising the hydrologic model, as well as isohyetal contours showing the cumulative depth of rainfall that was recorded over the study catchment over the rain days of 13-14 November 2022.

3.3.3. Hydrologic Model Parameters

For the sub-catchments modelled using the RAFTS hydrologic modelling approach, a Manning’s n value of 0.04 was applied to sub-catchments primarily characterised as rural pastoral land, while a value of 0.06 was applied to sub-catchments comprising a mixture of cleared pastoral land and dense vegetation. A Manning’s n value of 0.08 was applied to sub-catchments comprising mostly dense vegetation. A Bx routing parameter of 1.0 was adopted for sub-catchments that were modelled in RAFTS.

An initial loss value of 26 mm was adopted based on the Probability Neutral Burst Initial Storm Loss value extracted from the *ARR Data Hub* (a copy of which is contained in **Appendix D**). A continuing loss value of 1.92 mm/hr was also applied to the Blayney DRAINS Model which was derived by factoring the raw continuing loss value obtained from the *ARR Data Hub* of 4.8 mm/hr by a factor of 0.4 as per the recommendations for deriving design losses in *Floodplain Risk Management Guide - Incorporating 2016 Australian Rainfall and Runoff in studies* (OEH, 2019).

3.3.4. Results of Model Testing

When applied to the hydraulic model, the discharge hydrographs that were generated by the hydrologic model gave reasonable correspondence with observed flood behaviour. The hydrologic model parameters set out in this chapter were therefore adopted for design flood estimation purposes, noting that due to the limited availability of historic flood related data for use in the model calibration process, the initial and continuing loss values contained in the *ARR Data Hub* were adopted for design flood estimation purposes (refer **Chapter 5** of this report for further details).

4 HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

4.1 General

The present study required the use of a hydraulic model that is capable of analysing the time varying effects of flow in the local stormwater drainage system and the two-dimensional nature of flow on the floodplain and in the urbanised parts of the study area that are subject to overland flow. The TUFLOW modelling software was adopted as it is one of only a few commercially available hydraulic models which contain all the required features.

This chapter deals with the development and calibration of the TUFLOW model that was then used to define the nature of flooding in the study area for a range of design storm events (refer **Chapter 6** for further details).

4.2 The TUFLOW Modelling Approach

TUFLOW is a true two-dimensional hydraulic model which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave through the system.

The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. Consequently, the model is "fully dynamic" and once tuned will provide an accurate representation of the passage of the floodwave through the drainage system (both surface and piped) in terms of extent, depth, velocity and distribution of flow.

TUFLOW solves the equations of flow at each point of a rectangular grid system which represent overland flow on the floodplain and along streets. The choice of grid point spacing depends on the need to accurately represent features on the floodplain which influence hydraulic behaviour and flow patterns (e.g. buildings, streets, changes in channel and floodplain dimensions, hydraulic structures which influence flow patterns, hydraulic roughness etc.).

Piped drainage and channel systems can be modelled as one-dimensional elements embedded in the larger two-dimensional domain, which typically represents the wider floodplain. Flows are able to move between the one and two-dimensional elements of the model, depending on the capacity characteristics of the drainage system being modelled.

The TUFLOW model developed as part of the present study will allow for the future assessment of potential flood management measures, such as detention storage, increased channel and floodway dimensions, augmentation of culverts and bridge crossing dimensions, diversion banks and levee systems.

4.3 TUFLOW Model Setup

4.3.1. Model Structure

Figure 4.1 (3 sheets) shows the layout of the TUFLOW model that was developed as part of the present study (**Blayney TUFLOW Model**). The Blayney TUFLOW Model comprises a combination of one- and two-dimensional elements, details of which are set out in the following sections of the report.

The following sections provide further details of the model development process.

4.3.2. Two-dimensional Model Domain

An important consideration of two-dimensional modelling is how best to represent the roads, fences, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive, and it is not practicable to use a mesh of very fine elements without excessive times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

A grid spacing of 2 m was found to provide an appropriate balance between the need to define features on the floodplain versus model run times and was adopted for the investigation. Ground surface elevations for model grid points were initially assigned using the LiDAR derived DEMs for the study area.

Ridge and gully lines were added to the Blayney TUFLOW Model where the grid spacing was considered to be too coarse to accurately represent important topographic features which influence the passage of overland flow. The elevations for these ridge and gully lines were determined from inspection of the LiDAR survey data or site-based measurements.

Gully lines were also used to represent the major creeks and watercourses in the study area. The use of gully lines ensured that positive drainage was achieved along the full length of these watercourses, and thus avoided creation of artificial ponding areas as artefacts of the 'bumpy' nature of the underlying LiDAR survey data.

The local farm dams were assumed full at the start of the model simulation (i.e. at the onset of flood producing rain).

The existing bridge structures were incorporated in the two-dimensional domain as layered flow constriction elements based on cross sectional survey data. The bridge deck and hand rails (if present) were assumed to be 100% blocked (i.e. impervious to flow).

The footprints of individual buildings located in the two-dimensional model domain were digitised and assigned a high hydraulic roughness value relative to the more hydraulically efficient roads and flow paths through allotments. This accounted for their blocking effect on flow while maintaining a correct estimate of floodplain storage in the model.

It was not practicable to model the individual fences surrounding the many allotments in the study area. For the purpose of the present study, it was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways. Individual allotments where development is present were digitised and assigned a high hydraulic roughness value (although not as high as for individual buildings) to account for the reduction in conveyance capacity which will result from obstructive fences, such as Colorbond or brick, and other obstructions stored on these properties.

4.3.3. One-dimensional Model Elements

Details of the existing piped drainage system, a summary of which is set out in **Table 4.1** were incorporated into the Blayney TUFLOW Model (refer **Section A1.2** of **Appendix A** for sources of data).

TABLE 4.1
SUMMARY OF MODELLED DRAINAGE STRUCTURES

Pipes		Box Culverts		Inlet Pits	Junction Pits	Headwalls
No.	**Length (m)**	**No.**	**Length (m)**	**No.**	**No.**	**No.**
689	22,428	63	2,160	487	126	296

4.3.4. Model Parameters

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces comprising the overland flow paths, as well as inbank areas of the creeks. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as "Manning's n". Flow in the piped system also requires an estimate of hydraulic roughness.

Manning's n values along the channel and immediate overbank areas along the modelled length of creeks were varied, with the values in **Table 4.2** providing reasonable correspondence between recorded and modelled flood levels.

The adoption of a value of 0.02 for the surfaces of roads, along with an adequate description of their widths and centreline/kerb elevations, allowed an accurate assessment of their conveyance capacity to be made. A relatively high roughness value of 0.1 has been applied to the grassed and paved inter-allotment area to account for the blocking effect that various features in private properties such as fences, landscaping, vegetation etc. will have on flood behaviour.

TABLE 4.2
BEST ESTIMATE HYDRAULIC ROUGHNESS VALUES

Surface Treatment	Manning's n Value
Concrete piped elements	0.015(1)
Asphalt or concrete road surface	0.02
Overbank area, including grass and lawns	0.045
Railway land	0.05
Inbank area of Belubula River and Abattoir Creek	0.05
Lightly vegetated areas	0.06
Heavily vegetated areas	0.08
Allotments (between buildings)	0.10
Buildings	10

1. It has been assumed that the piped elements are old and have a slightly higher Manning's n value than a new concrete pipe.

Figure 4.2 is a typical example of flow patterns derived from the above roughness values. This example applies to the 1% AEP flood event and shows flooding patterns along the overland flow path that runs in a north-easterly direction between the intersection of Osman Street and Charles Street, and the intersection of Adelaide Street and Martin Street. The left hand side of the figure shows the roads and inter-allotment areas, as well as the outlines of buildings, which have all been assigned different hydraulic roughness values in the model, while the right hand side shows the resulting flow paths in the form of scaled velocity vectors and the depths of inundation. Similar information to that shown on **Figure 4.2** may be presented at any location within the model domain and will be of assistance to Council in assessing individual flooding problems in the study area.

4.4 Model Boundary Conditions

The locations where sub-catchment inflow hydrographs were applied to the Blayney TUFLOW Model are shown on **Figure 4.1**. These comprise both inflow boundaries at selected locations around the perimeter of the two-dimensional model domain, as well as internal to the model (for example, at the location of surface inlet pits) and as distributed inflows via "Inflow Regions".

The Inflow Regions act to "inject" flow into the Blayney TUFLOW Model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Inflow Regions as the grid in the two-dimensional model domain becomes wet as a result of overland flow. The Inflow Regions have been digitised at the outlet of the catchment in order to reduce the "double-routing" of runoff from each sub-catchment, as well as internal to the model (for example, at the location of surface inlet pits).

Figure 4.1 shows the downstream boundary of the model comprises a TUFLOW-derived normal depth relationship which is located approximately 1.5 km to the south of the Hobbys Yards Road crossing of the Belubula River. The downstream boundary has been located a sufficient distance downstream of the urbanised parts of Blayney so as to not impact flood behaviour in the area of interest.

4.5 Results of Model Calibration Process

As previously mentioned, the hydrologic and hydraulic models were calibrated using data that were available for the flooding that was experienced in parts of Blayney on 13-14 November 2022.

Figures 4.3 (3 sheets) shows the Blayney TUFLOW Model results for the 13-14 November 2022 storm event, while **Table 4.3** at the end of this chapter briefly describes the flood behaviour that was observed during the storm event and how it compares to the results of the Blayney TUFLOW Model.

In general, the Blayney TUFLOW Model was able to reproduce flood behaviour that was captured by the drone-based footage and the single photograph, as well as anecdotal descriptions of flooding for the 13-14 November 2022 storm event.

Based on the findings of the model calibration process, the flood models were considered to give satisfactory correspondence with the available historic flood data, noting that the accuracy of the model calibration is limited by the accuracy of the underlying flood data. In the absence of more detailed flood data, the hydraulic model parameters set out in **Sections 4.3** and **4.4**, and in particular the hydraulic roughness values set out in **Table 4.2,** were considered appropriate for use in defining flood behaviour in the study area over the full range of design flood events. Further discussion and presentation of hydrologic model parameters that were adopted for design flood estimation purposes is provided in **Section 5.3**.

TABLE 4.3
COMPARISON OF OBSERVED AND MODELLED FLOOD BEHAVIOUR
NOVEMBER 2022 STORM EVENT

Response Identifier[1]	Observed Flood Behaviour/ Other Comment	Model Verification Comments
2022.1	**Plate B1.3** shows Dakers Oval completely inundated by floodwater.	Blayney TUFLOW Model shows that Dakers Oval was inundated to a minimum depth of 0.4 m.
2022.2	**Plate B1.5** shows a 150 m section of Henry Street to the north of its intersection with Burns Street was inundated.	The modelled flood extents achieve a good match with the observed flood extent.
2022.3	**Plates B1.1** and **B1.2** show floodwater overtopping Newbridge Road at 07:30 hrs on 14 November 2022, noting that peak of the flood was observed to occur approximately 3 hours earlier.	Blayney TUFLOW Model results show that the flood peaked at approximately 04:00 hrs on 14 November 2022.
	Peak flood level during the storm event calculated to be RL 862.69 m AHD.	Modelled peak flood levels computed to be approximately 0.05 m higher than peak level (i.e. RL 862.74 m AHD).
2022.4	**Plate B1.7** shows that the Henry Street entrance to the Christ Church Retirement Village was completely inundated.	Blayney TUFLOW Model shows that the entrance was inundated to a depth of about 1 m.
2022.5	The high water mark on **Plate B1.7** shows evidence of the floodwater extending approximately 30 m west along Burns Road from its intersection with Henry Street.	The modelled flood extents achieve a good match with the observed flood extent.
2022.6	**Plate B1.4** shows Lower Farm Street completely inundated to the north of its intersection with Charles Street.	Blayney TUFLOW Model shows that Lower Farm Street was inundated to a maximum depth of 0.4 m.
2022.7	**Plate B1.8** shows that the Blayney Sewage Treatment Plant pond embankments were not overtopped during the flood event.	Blayney TUFLOW Model results show that the pond embankments were not overtopped.
2022.8	**Plate B1.8** shows floodwater had completely inundated two sheds that are located in the Blayney Sewage Treatment Plant.	Blayney TUFLOW Model shows that floodwater ponded to a maximum depth of about 0.6 m adjacent to the sheds.
2022.9	**Plate B1.9** show that floodwater overtopped the low point in Hobbys Yards Road approximately 200 m to the north of the bridge crossing of the Belubula River.	The modelled flood extents achieve a good match with the observed flood extent.

1. Refer **Figure 4.3** (3 sheets) for location of observed flood behaviour.

5 DERIVATION OF DESIGN FLOOD HYDROGRAPHS

5.1 Design Storms

5.1.1. Rainfall Intensity

The procedures used to obtain temporally and spatially accurate and consistent Intensity-Frequency-Duration (**IFD**) design rainfall curves for the assessment of flood behaviour in the study area are presented in the 2019 edition of *Australian Rainfall and Runoff* (Ball et. Al., 2019) (**ARR 2019**). Design storms for frequencies of 50%, 20%, 10%, 5%, 1%, 0.5% and 0.2% AEP were derived for storm durations ranging between 15 minutes and seven days. The IFD dataset was downloaded from the BoM's *2016 Rainfall IFD Data System* (**BoM 2016 IFD Data**).

The left hand side of **Figure 5.1** shows a comparison of the IFD deign rainfall curves that were adopted as part of the present study with those that were relied upon as part of Jacobs, 2015 which were based on the procedures set out in the 1987 edition of *Australian Rainfall and Runoff* (**ARR 1987**) (**ARR 1987 IFD Data**). The rainfall intensities associated with the BoM 2016 IFD Data are between 8% and 11% lower than the corresponding ARR 1987 IFD Data for the 6 hour storm event which was found to be critical for maximising peak flows on the Belubula River.

5.1.2. Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR 2019 are applicable strictly to a point. In the case of a catchment of over tens of square kilometres area, it is not realistic to assume that the same rainfall intensity can be maintained. An Areal Reduction Factor (**ARF**) is typically applied to obtain an intensity that is applicable over the entire catchment.

An ARF of 0.92 was found to achieve a good match between the peak flows that were generated by the Blayney DRAINS Model and those derived as part of previous investigations at the Mid-Western Highway Crossing of the Belubula River (refer **Section 5.3** for further discussion).

It is noted that it is not appropriate to apply the above ARF to all sub-catchments in the Blayney DRAINS Model as the purpose of the present study was to define flood behaviour in areas that are subject to Major Overland Flow where the contributing catchments are relatively small. As such, an ARF value of 1.0 was applied to all the sub-catchments which lie to the south of the Mid-Western Highway crossing of the Belubula River.

5.1.3. Temporal Patterns

ARR 2019 prescribes the analysis of an ensemble of 10 temporal patterns per storm duration for various zones in Australia. These patterns are used in the conversion of a design rainfall depth with a specific AEP into a design flood of the same frequency. The patterns may be used for AEPs down to 0.2 per cent where the design rainfall data is extrapolated for storm events with an AEP less than 1 per cent.

The temporal pattern ensembles that are applicable to Frequent (more frequent than 14.4% AEP), Intermediate (between 14.4% and 3.2% AEP) and Rare (rarer than 3.2% AEP) storm events were obtained from the ARR Data Hub[3], while those for the very rare events were taken from BoMs update of *Bulletin 53* (BoM, 2003) and Jordan et. al., 2005.

A copy of the data extracted from the ARR Data Hub is contained in **Appendix C**.

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[3] It is noted that the temporal pattern data set for the *Murray-Darling Basin* region is suitable for use in the study area.

5.1.4. Probable Maximum Precipitation

Estimates of Probable Maximum Precipitation (**PMP**) were made using the Generalised Short Duration Method (**GSDM**) as described in the BoM, 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 3 hours.

The steps involved in assessing PMP for the study catchment are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.
- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data but modified in the light of Australian experience.
- Derive storm hyetographs using the eleven temporal distributions contained in BoM, 2003 (one) and Jordan et. al., 2005 (ten), all of which are based on pluviographic traces recorded in major Australian storms.

Figure 3.1 shows the location and orientation of the PMP ellipses which were used to derive the rainfall estimates for the present study. Note that in order to accurately derive the upper limit of flooding in the study area, the following two orientations of the PMP ellipses were adopted:

- **PMP Ellipse Alignment 1**, which is aimed at maximising flow in the Belubula River at Blayney; and
- **PMP Ellipse Alignment 2**, which is aimed at maximising flow in the various drainage lines and Major Overland Flow paths at Blayney.

5.2 Design Rainfall Losses

The initial and continuing loss values to be applied in flood hydrograph estimation were derived using the NSW jurisdictional specific procedures set out in the *ARR Data Hub*. The raw Probability Neutral Burst Initial Loss (**PNBIL**) values obtained from the *ARR Data Hub* were reviewed and adjusted to remove inconsistencies in values with varying storm probability and duration. **Figure 5.1** shows the original PNBIL curves derived from the tables obtained from the *ARR Data Hub*, together with the adopted PNBIL curves following the adjustments that were made as part of the present study.

The NSW jurisdictional advice recommends multiplying the raw (or unadjusted) continuing loss value that is contained on the *ARR Data Hub* of 4.8 mm/hr by a factor of 0.4 for design flood estimation. As such, a continuing loss value of 1.92 mm/hr has been adopted for design flood estimation purposes.

While it is not possible to determine the exact initial and continuing loss values that were adopted upon for the Flood Study (refer **Section A2.1** of **Appendix A** for further discussion), the initial and continuing loss values that were adopted for the present study are significantly lower than those recommended in *Initial Losses for Design Flood Estimation in New South Wales* (Walsh et al, 1991), which was the basis of deriving loss values as part of Jacobs, 2015.

An Initial loss value of 0 mm and continuing loss value of 1.92 mm/h were adopted for deriving design discharge hydrographs for the PMF event.

5.3 Derivation of Design Discharges

The Blayney DRAINS Model was run with the design rainfall data set out in **Sections 5.1** and **5.2**, as well as the hydrologic model parameters that are set out in **Section 3.3.3** in order to obtain design discharge hydrographs for input to the Blayney TUFLOW Model.

Table 5.1 over the page shows a comparison of design peak flow estimates derived from the Blayney DRAINS Model for the loss values that are set out in **Section 5.2** compared to those derived by Jacobs, 2015, Storm Consulting, 2022a, the Probabilistic Rational Method (**PRM**), the procedures for which are set out in the 1987 edition of *Australian Rainfall & Runoff* (The Institution of Engineers Australia, 1987) (**ARR 1987**) and the RFFE Model, the procedures for which are set out in ARR 2019, noting that **Figure 3.1** shows the locations at which the comparisons were made.

TABLE 5.1
COMPARISON OF DESIGN PEAK FLOW ESTIMATES
(m^3/s)

Identifier(1) [A]	AEP (%) [B]	ARR 1987		ARR 2019		
		Jacobs, 2015 [C]	PRM [D]	Storm Consulting, 2022a [E]	RFFE [F]	Blayney DRAINS Model(2) [G]
BR Belubula River at Mid-Western Highway [Area = 112 km^2]	1	246	200	246(4)	513	244
	5	123	102	123(4)	257	146
	20	48	53	48(4)	116	81
AC Abattoir Creek at Marshalls Lane [Area = 15 km^2]	1	-(3)	63	76	102	70
	5	-(3)	32	44	47	43
	20	-(3)	17	25	19	27

1. Refer **Figure 3.1** for location of peak flow comparisons
2. Based on design rainfall losses set out in **Section 5.2**.
3. Peak flow in Abattoir Creek at this location not reported in Jacobs, 2015.
4. Note that the flow in the Belubula River at the Mid-Western Highway in the RAFTS Model that was developed as part of Storm Consulting, 2022a was derived from the Jacobs RORB Model which was based on the procedures that are set out in ARR 1987 (refer **Section A2.3** of **Appendix A** for further discussion).

The key findings of the comparison are as follows:

- The Jacobs, 2015 derived flows are higher than the PRM derived flows, noting that this is consistent with the findings of the previous investigation.
- The Storm Consulting, 2022a derived flows on the Belubula River are identical to those that were derived as part of Jacobs, 2015 as the hydrologic model that was relied upon to derive flows at this location was not updated as part of the more recent study (refer **Section A2.3** of **Appendix A** for further discussion).
- The Storm Consulting, 2022a derived flows are slightly higher than the PRM derived flows on Abattoir Creek.
- The RFFE derived peak flows are more than double those derived as part of Jacobs, 2015 and up to 2.6 times those derived using the PRM.

- While the Blayney DRAINS Model derived 1% AEP peak flow on the Belubula River compare closely with those derived as part of Jacobs, 2015 and Storm Consulting, 2022a, it generates higher peak flows for the more frequent flood events. The higher peak flows in the more frequent events are attributable to the adoption of the adjusted PNBIL and continuing loss values that were derived using the NSW jurisdictional specific procedures set out in the *ARR Data Hub* which are substantially lower than those that were adopted as part of Jacobs, 2015.

Based on the above, the design rainfall data set out in **Sections 5.1** and **5.2**, as well as the hydrologic model parameters set out in **Section 3.3.3** are considered to be suitable for deriving design discharge hydrographs for input to the Blayney TUFLOW Model.

6 HYDRAULIC MODELLING OF DESIGN FLOOD EVENTS

6.1 Hydraulic Model Structure

As per the requirements of ARR 2019, the potential for the existing drainage system to experience a partial blockage during a flood event was taken into account when deriving the design flood envelopes. **Table D1** in **Appendix D** provides a summary of the blockage factors that were derived for each individual headwall and bridge structure in the study area based on the procedures set out in ARR 2019. As per the recommendations in ARR 2019, an L_{10}[4] of 1.5 m was adopted for the blockage assessment, which is the recommended minimum value that should be adopted for urban areas in the absence of a record of past debris accumulated at the structure. **B**lockage factors of 20% and 50% were applied to on-grade and sag stormwater inlet pits, respectively.

6.2 Critical Duration and Temporal Pattern Assessment

The critical storm durations and associated median temporal patterns for the design storm events were derived based on the results of running both the DRAINS and TUFLOW models in tandem. For example, design discharge hydrographs for the ensemble of temporal patterns for storm durations ranging between 30 minutes and 24 hours were exported from the DRAINS model and input to the TUFLOW model. The assessment was undertaken for the 20%, 5% and 1% AEP storm events which represent the three temporal pattern bins (i.e. frequent, intermediate and rare, respectively) that were downloaded from the *ARR Data Hub.*

A similar process was adopted for determining the critical durations for the PMF using the procedures set out in BoM, 2003 and Jordan et al, 2005, whereby design discharge hydrographs for storm durations ranging between 15 minutes and 6 hours were exported from the DRAINS model and input to the TUFLOW model.

Table 6.1 over the page sets out the storm durations and temporal patterns that were adopted as being critical for AEPs ranging from 50% and 0.2%, as well as the PMF.

6.3 Presentation and Discussion of Results

6.3.1. Accuracy of Hydraulic Modelling

The accuracy of results depends on the precision of the numerical finite difference procedure used to solve the partial differential equations of flow, which is also influenced by the time step used for routing the floodwave through the system and the grid spacing adopted for describing the natural surface levels in the floodplain. Channels are described by cross-sections normal to the direction of flow, so their spacing also has a bearing on the accuracy of the results. The results are also heavily dependent on the size of the two-dimensional grid, as well as the accuracy of the LiDAR survey data which has a design accuracy based on 95% of points within +/- 150 mm. Given the uncertainties in the LiDAR survey data and the definition of features affecting the passage of flow, maintenance of a depth of flow of at least 200 mm is required for the definition of a “continuous” flow path in the areas subject to shallow overland flow. Lesser modelled depths of inundation may be influenced by the above factors and therefore may be spurious, especially where that inundation occurs at isolated locations and is not part of a continuous flow path. In areas where the depth of inundation is greater than the 200 mm threshold and the flow path is continuous, the likely accuracy of the hydraulic modelling in deriving peak flood levels is considered to be between 100 and 150 mm.

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[4] L_{10} is defined as the average length of the longest 10% of the debris reaching the site.

TABLE 6.1
CRITICAL DURATIONS AND TEMPORAL PATTERNS

Design Storm Event	Temporal Pattern Bin	Critical Storm Duration and Temporal Pattern(1)
50%	Frequent	30 minute, temporal pattern 1 [3807] 3 hour, temporal pattern 3 [3982] 4.5 hour, temporal pattern 6 [4016] 9 hour, temporal pattern 3 [4069] 12 hour, temporal pattern 10 [4102]
20%		
10%	Intermediate	30 minute, temporal pattern 7 [3828] 2 hour, temporal pattern 3 [3913] 3 hour, temporal pattern 2 [3969] 6 hour, temporal pattern 6 [4038] 9 hour, temporal pattern 6 [4063]
5%		
2%	Rare	30 minute, temporal pattern 6 [3815] 1 hour, temporal pattern 2 [3819] 1.5 hour, temporal pattern 8 [3907] 3 hour, temporal pattern 6 [3963] 6 hour, temporal pattern 7 [4025]
1%		
0.5%		
0.2%		
PMF	Very Rare	15 minute, Melbourne 1972 temporal pattern 45 minute, Melbourne 1972 temporal pattern 1 hour, Melbourne 1972 temporal pattern 1.5 hour, Melbourne 1972 temporal pattern 3 hour, Melbourne 1972 temporal pattern 4 hour, Seventeen Mile Creek, 1998 temporal pattern

1. Value in [ ] represent the Event ID for the critical storm duration and temporal pattern.

Use of the flood study results when applying flood related controls to development proposals should be undertaken with the above limitations in mind. Proposals should be assessed with the benefit of a site survey to be supplied by applicants in order to allow any inconsistencies in results to be identified and given consideration. This comment is especially appropriate in the areas subject to shallow overland flow, where the inaccuracies in the LiDAR survey data or obstructions to flow would have a proportionally greater influence on the computed water surface levels than in the deeper flooded areas.

6.3.2. Design Flood Extents, Depths and Elevations

Figures 6.1 to **6.8** (3 sheets each) show the TUFLOW model results for the 50%, 20%, 10%, 5%, 1%, 0.5% and 0.2% AEP floods, together with the PMF. These diagrams show the indicative extent and depth of inundation within the extent of the two-dimensional model domain.

In order to create realistic results which remove most of the anomalies caused by inaccuracies in the LiDAR survey data, a filter was applied to remove depths of inundation over the natural surface less than 100 mm. This has the effect of removing the very shallow depths which are more prone to be artefacts of the model, but at the same time giving a reasonable representation of the various overland flow paths. The depth grids shown on the figures have also been trimmed to the building polygons, as experience has shown that property owners incorrectly associate depths of above-ground inundation at the location of buildings with depths of above-floor inundation.

Figure 6.9 (3 sheets) shows the hydrologic capacity of the existing stormwater drainage system at Blayney in AEP terms, while **Figure 6.10** (2 sheets) shows water surface profiles for the modelled design flood events along a 11 km reach of the Belubula River and 3.5 km reach of Abattoir Creek. **Figure 6.11** (2 sheets) shows stage hydrographs at selected road/rail crossings throughout the study area, while **Table E1** in **Appendix E** sets out the peak flood level and maximum depth of inundation at each crossing. **Table F1** in **Appendix F** sets out design peak flows and corresponding critical storm durations at key locations throughout the study area.

The sensitivity studies and discussion presented in **Section 6.5** provide guidance on suitable freeboard provisions under present day catchment and climatic conditions.

In accordance with DCCEEWs flood risk management guideline FB01 entitled "*Understanding and Managing Flood Risk*", sensitivity studies have also been carried out to assess the potential impacts of future climate change on flood behaviour (refer **Section 6.6**). While increases in flood levels due to future increases in rainfall intensities may influence the selection of Flood Planning Levels (**FPLs**), final selection of FPLs is a matter for more detailed consideration during the preparation of the future *Blayney FRMS&P*.

6.3.3. Description of Flood Behaviour

The key features of Main Stream Flooding along the Belubula River are as follows:

i. **Figure 6.1** shows that floodwater surcharges the inbank area of the Belubula River and is conveyed on its adjacent overbank area during floods as frequent as 50% AEP.

ii. **Figure 6.11** and **Table E1** in **Appendix E** shows that the road and rail crossings of the river commence to become inundated by floodwater as follows:
    - While the Newbridge Road crossing of the river (refer Peak Flood Level Location (**PFLL**) H03a) will remain flood free up to the 0.2% AEP, the low point that is located approximately 240 m to the east (refer PFLL H03b) will be inundated during floods as frequent as 50% AEP.
    - While the Hobby Yards Road crossing of the river (refer PFLL H04) will remain flood free in a PMF, the low point that is located approximately 220 m to the north will be inundated during floods as frequent as 20% AEP.
    - While the Mid-Western Highway crossing of the river (refer PFLL H01) will remain flood free up to the PMF, floodwater surcharges the right (western) bank of the river on the upstream side of the bridge in a 1% AEP flood where it flows in a southerly direction along the western side of the highway, before inundating the road approximately 530 m to the north of its intersection with Marshalls Lane.
    - The Main Western Railway crossing of the river (refer PFLL H02) will commence to be overtopped in a 1% AEP flood.

iii. **Figure 6.1**, sheet 3 shows that floodwater surcharges the right (western) bank of the river upstream of Newbridge Road in flood events as frequent as 50% AEP where it inundates the low point in Henry Street that is located approximately 70 m to the north of its intersection with Newbridge Road, flooding the entrance to the Christ Church Retirement Village.

iv. **Figure 6.3**, sheet 3 shows that floodwater that surcharges the right (western) bank of the river inundates Newbridge Road to the east of its intersection with Henry Street in a 10% AEP flood.

v. **Figure 6.4**, sheet 3 shows that floodwater surcharges the right (western) bank of the river downstream of Newbridge Road in a 5% AEP flood where it inundates Lower Farm Road to the south of its intersection with Charles Street.

vi. The Blayney Sewage Treatment Plant remain flood free up until the PMF.

vii. **Table F1** in **Appendix E** shows that the peak flow in a PMF event is about 10-12 times the corresponding peak 1% AEP flow.

viii. **Figure 6.10** shows that peak flood levels along the Belubula River in a PMF event are generally about 2 to 3 m higher than the corresponding peak 1% AEP flood levels, but are up to 4 m higher between Newbridge Road and the Blayney Sewage Treatment Plant.

The key features of Main Stream Flooding along Abattoir Creek are as follows:

i. **Figure 6.1** shows that floodwater surcharges the banks of Abattoir Creek where it runs through the study area during floods as frequent as 50% AEP.

ii. **Figure 6.1** shows that floodwater surcharges the culvert that runs under the disused abattoir (refer PFLL H05) in flood events as frequent as 50% AEP. The depth of overland flow through the disused abattoir exceeds 1 m during a 50% AEP flood.

iii. **Figure 6.11** and **Table E1** in **Appendix E** shows that the road and rail crossings of the creek commence to become inundated by floodwater as follows:

  - Gerty Street (refer PFLL H06) and the Dakers Oval Access Road (refer PFLL H10) during floods as frequent as 50% AEP.
  - The William Street crossing (refer PFLL H07) will commence to be overtopped in a 20% AEP flood.
  - While the Mid-Western Highway crossing (refer PFLL H08) will commence to be overtopped in a 1% AEP flood, the low point in the road approximately 100 m to the east will be inundated in a 10% AEP flood.
  - The Main Western Railway crossing of the river (refer PFLL H09) will remain flood free up until the PMF.

iv. **Figure 6.1**, sheet 2 shows that floodwater surcharges the left (northern) bank of Abattoir Creek upstream of William Street during floods as frequent as 50% AEP where it inundates low lying land in the St Joseph's Catholic Primary School.

v. **Figure 6.1**, sheet 2 shows that floodwater surcharges Abattoir Creek downstream of the Mid-Western Highway during floods as frequent as 50% AEP where it inundates existing development that is located adjacent to the creek to a maximum depth of about 0.3 m.

vi. **Table F1** in **Appendix E** shows that the peak flow in a PMF event is about 12 times the corresponding peak 1% AEP flow.

vii. **Figure 6.10** shows that peak flood levels along Abattoir Creek in a PMF event are generally about 2 to 3 m higher than the corresponding peak 1% AEP flood levels.

The key features of Major Overland in the urbanised parts of the study area are as follows:

i. **Figure 6.9** (3 sheets) shows that the piped drainage system generally has a capacity of 20% AEP or less.

ii. Floodwater will inundate existing development to depths greater than 0.3 m in a 1% AEP storm event at the following locations:

  - along the flow path that runs in an easterly direction between Raphael Street and Doust Street (refer Peak Flow Locations (**PFLs**) Q14a and Q15);

- along the flow path that runs in an easterly direction between Burton Street and Carcoar Street to the south of Binstead Street (refer upstream of PFL Q19a);
- in low lying land that is located south-east of the intersection of Orange Road and Carcoar Street;
- along the flow path that runs in an easterly direction between Streatfeild Close and Carcoar Street to the south of Plumb Street;
- along the flow path that runs in an easterly direction between Queen Street and Osman Street to the south of Water Street;
- along the flow path that runs in a north-easterly direction between Oldham Place and Queen Street to the south of King George VI Oval (refer PFL Q35b);
- along the flow path that runs in a north-easterly direction between the intersection of Stillngfleet Street and Queen Street and the intersection of Water Street and Adelaide Street (refer PFLs Q36b and Q36c);

6.3.4. Comparison with Previous Studies

Table 6.2 over the page shows a comparison of the design peak 5% and 1% AEP flood levels at the major road and railway crossings of the Belubula River and Abattoir Creek that were derived as part of the present study with those derived as part of Jacobs, 2015 and Storm Consulting, 2022a.

The Jacobs, 2015 derived design peak flood levels that are set out in **Table 6.2** were taken from Table 6-1 of the report which are much lower than the ponding levels shown on the Figure 6-1 of the report. While **Table 6.2** shows that the design peak flood levels that were derived as part of the present study are up to 0.7 m higher than those derived as part of Jacobs, 2015, they are comparable to the ponding levels shown on Figure 6-1 of the previous report.

It was found that the peak flood levels derived as part of the present study generally match those that were derived as part of Storm Consulting, 2022a except in the vicinity of the Hobbys Yards Road crossing of the Belubula River where they are higher due to the incorporation of blockage in the present study as per ARR 2019 requirements.

TABLE 6.2
COMPARISON OF DESIGN PEAK FLOOD LEVELS DERIVED AS PART OF PREVIOUS INVESTIGATIONS

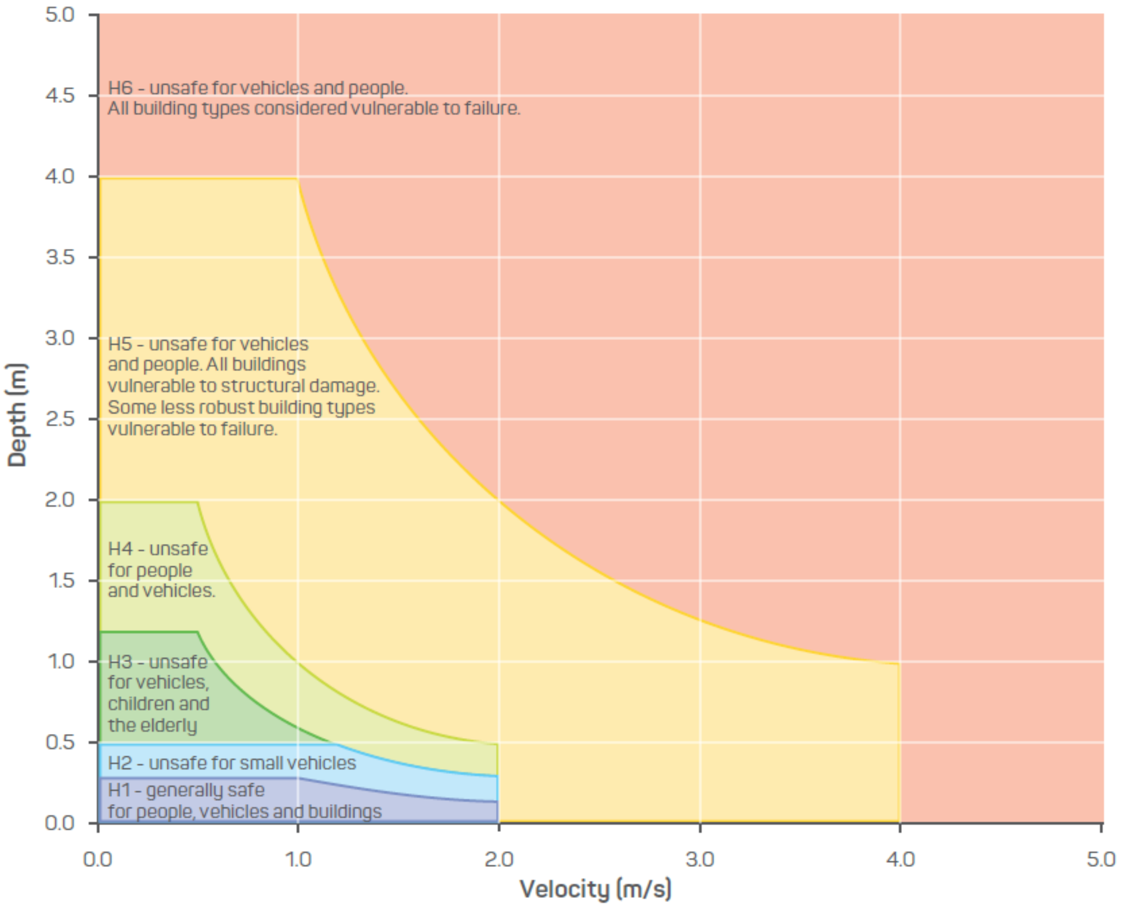
Watercourse	Location	5% AEP					1% AEP				
		Peak Flood Level			Difference		Peak Flood Level			Difference	
		Jacobs, 2015(1)	Storm Consulting, 2022a	Present Study	Jacobs, 2015(2)	Storm Consulting, 2022a(3)	Jacobs, 2015(1)	Storm Consulting, 2022a	Present Study	Jacobs, 2015(2)	Storm Consulting, 2022a(3)
Belubula River	Main Western Railway	863.55	864.26	864.26	+0.71	0	863.98	864.73	864.71	+0.73	-0.02
	Newbridge Road	862.47	862.6	862.54	+0.07	-0.06	862.86	862.82	862.81	-0.05	-0.01
	Hobby Yards Road	858.58	858.74	858.91	+0.33	+0.17	859.05	858.92	859.23	+0.18	+0.31
Abattoir Creek	Mid-Western Highway	865.16	865.15	865.27	+0.11	+0.12	865.46	865.44	865.48	+0.02	+0.04
	Main Western Railway	863.73	864.29	864.2	+0.47	-0.09	864.19	864.75	864.64	+0.45	-0.11

1. Flood levels taken from Table 6-1 of Jacobs, 2015, noting that the elevations don't match those shown on Figure 6-1 of the previous report.
2. A positive value indicates that the design peak flood levels derived as part of the present study are higher, and conversely a negative value indicates they are lower than those derived as part of Jacobs, 2015.
3. A positive value indicates that the design peak flood levels derived as part of the present study are higher, and conversely a negative value indicates they are lower than those derived as part of Storm Consulting, 2022a.

6.4 Flood Hazard Zones and Floodways

6.4.1. Flood Hazard Vulnerability Classification

Flood hazard categories may be assigned to flood affected areas in accordance with the definitions that are set out in ARR 2019. Flood prone areas may be classified into six hazard categories based on the depth of inundation and flow velocity that relate to the vulnerability of the community when interacting with floodwater as shown in the illustration over which has been taken from ARR 2019.



Flood Hazard Vulnerability Classification diagrams for the 5%, 1% and 0.5% AEP flood events, as well as the PMF based on the procedures set out in ARR 2019 are presented on **Figures 6.12** to **6.15**.

It was found that generally in flood events up to 0.5% AEP in magnitude, areas classified as H5 and H6 are confined to the inbank areas of the Belubula River and Abattoir Creek and their immediate overbank areas. Existing development is subject to H3 or greater type Main Stream Flooding conditions at the following locations:

- H5 type flooding in the disused abattoir;
- H4 type flooding on the left (northern) overbank of Abattoir Creek upstream of William Street; and
- H3 type flooding in existing development that is located adjacent to Abattoir Creek between downstream of the Mid-Western Highway.

The majority of the Urban Centre is classified as H1 and H2 during storms up to 0.5% AEP in intensity.

6.4.2. Flood Function

According to the FRMM, the floodplain may be subdivided into the following three hydraulic categories:

- Floodways;
- Flood storage; and
- Flood fringe.

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant re-distribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow 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. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

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.

Flood Risk Management Guideline FB02 Flood Function offers guidance in relation to two alternative procedures for identifying the portion of the floodplain that functions as floodways, flood storage and flood fringe areas.

The indicator technique set out in *Howells et al, 2003* was used to identify the preliminary extent of the floodway based on flow velocity and depth. Based on the findings of a trial and error process, the following criteria were adopted for identifying those areas which operate as a "floodway" in a 1% AEP event:

- Velocity x Depth greater than 0.25 m^2/s **and** Velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Manual assessment and cleaning of the raw model output data was then undertaken as recommended in *Flood Risk Management Guideline FB02 Flood Function*.

Flood storage areas are identified as those areas which do not operate as floodways in a 1% AEP flood event but where the depth of inundation exceeds 300 mm. The remainder of the flood affected area was classified as flood fringe.

Figures 6.16 (3 sheets) shows the division of the floodplain into floodway, flood storage and flood fringe areas for the 1% AEP storm event.

Floodways are present along the alignment of the Belubula River and Abattoir Creek and their immediate overbank areas. In areas subject to Major Overland Flow, floodways are generally contained within the drainage and road reserve boundaries in the Urban Centre, there are floodways present in presently undeveloped land.

Flood storage areas are confined to the major ponding areas which are located on the upstream side of the roads and railway embankments, as well as in the local farm dams that have been constructed to capture surface runoff in different parts of the study area.

6.5 Sensitivity Studies

6.5.1. General

The sensitivity of the hydraulic model to variations in model parameters such as hydraulic roughness and the partial blockage of the major hydraulic structures by woody debris was tested as part of the present study. The main purpose of these studies was to give some guidance on:

a) the freeboard to be adopted when setting minimum floor levels of development in flood prone areas, pending the completion of the future *Blayney FRMS&P*; and

b) areas where additional flood related planning controls should be implemented due to the development of new hazardous flow paths.

6.5.2. Sensitivity of Flood Behaviour to an Increase in Hydraulic Roughness

Figure 6.17 shows the difference in peak flood levels (referred to as “afflux”) for the 1% AEP flood event resulting from an assumed 20% increase in hydraulic roughness (compared to the values given in **Table 4.2**).

The typical increases in peak 1% AEP flood levels in the areas that are subject to Main Stream Flooding are generally in the range 20 to 100 mm, with a maximum increases of up to 120 mm shown to occur in the vicinity of natural constrictions of the floodplain. Increases in peak flood levels in areas that are subject to Major Overland Flow are generally in the range 10 to 50 mm.

6.5.3. Sensitivity of Flood Behaviour to a Partial Blockage of Hydraulic Structures

As mentioned in **Section 6.1**, the design flood envelopes presented in this report incorporate the probability neutral blockage factors that are set out in **Table D1** in **Appendix D** of this report. As the degree to which each individual hydraulic structure experiences a blockage will varying during a real flood, the sensitivity of flood behaviour assuming no blockage of each structure was assessed as part of the present study.

Figure 6.18 shows that while the removal of the probability neutral blockage factors generally has a negligible effect on flood behaviour at the 1% AEP level of flooding, minor reductions in peak flood levels are shown to occur on the upstream side of the road and rail crossings of the Belubula River and Abattoir Creek, with minor increases in peak flood levels shown to occur along the drainage lines that are located immediately downstream of the aforementioned road and rail corridors.

6.6 Climate Change Sensitivity Analysis

6.6.1. General

At the present flood study stage, the principal issue regarding climate change is the potential increase in flood levels and extents of inundation throughout the study area. In addition, it is necessary to assess whether the patterns of flow will be altered by new floodways being developed for key design events, or whether the provisional flood hazard will be increased.

DCCEEW currently recommends that the advice set out in its flood risk management guideline FB01 entitled "*Understanding and managing flood risk*" be used as the basis for examining climate change in projects undertaken under the State Floodplain Management Program and the FRMM. The guideline recommends that flood behaviour resulting from 0.5% and 0.2% AEP events be used as a proxy for the scale of change that could occur to flood behaviour in a 1% AEP event as a result of future climate change.[5]

During the preparation of the *Blayney FRMS&P* it will be necessary to consider the impact of climate change on flood damages to existing development. Consideration will also be given both to setting floor levels for future development and in the formulation of works and measures aimed at mitigating adverse effects expected within the service life of development. Mitigating measures which could be considered in the *Blayney FRMS&P* include the implementation of structural works such as levees and channel improvements, improved flood warning and emergency management procedures and education of the population as to the nature of the flood risk.

6.6.2. Sensitivity to Increased Rainfall Intensities

As mentioned, the investigations undertaken at the flood study stage are mainly seen as sensitivity studies pending more detailed consideration in the *Blayney FRMS&P*. For the purposes of the present study, the design rainfalls for 0.5% and 0.2% AEP events were adopted as being analogous to flooding which could be expected should present day 1% AEP rainfall intensities increase by 10% and 30%, respectively.

Figure 6.19 shows the increase in peak flood levels resulting from a 10 per cent increase in 1% AEP rainfall intensities. The increase in peak flood levels in areas that are subject to Main Stream Flooding varies between 50 and 200 mm, while increases in peak flood levels of generally between 10 to 50 mm are shown to occur in areas that are subject to Major Overland Flow.

Figure 6.20 shows the afflux for a 30 per cent increase in 1% AEP rainfall intensities. The increase in peak flood levels in areas that are subject to Main Stream Flooding varies between 10 and 300 mm, while increases in peak flood levels of generally up to 100 mm are shown to occur in areas that are subject to Major Overland Flow.

Figure 6.21 shows the increase in the extent of land that would be affected by floodwater should 1% AEP rainfall intensities increase by 10 or 30 per cent. The extent of land that would be inundated by floodwater should 1% AEP rainfall intensities increase by up to 30% is generally negligible, with the following exceptions:

- on both banks of the Belubula River in the vicinity of the Mid-Western Highway;
- on both banks of the Belubula River to the east of the intersection of the Mid-Western Highway and Marshalls Lane;
- on the right (western) bank of the Belubula River between Church Street and Martin Street;

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[5] While ARR 2019 updated the advice in relation to the impact that climate change will have on the BoM, 2016 design rainfall intensities, as well as initial and continuing losses for design flood estimation in late 2024, due to the timing of its release, the advice set out in flood risk management guideline *FB01* has been adopted for undertaking the present study. Consideration will need to be given to the implications of the updated advice in ARR 2019 when preparing the review and update of the *Blayney FRMS&P*.

- on the right (western) bank of the Belubula River between Charles Street and Martha Street;
- on the left (eastern) bank of the Belubula River between the Main Western Railway and Newbridge Road;
- on the right (western) bank of the Belubula River immediately downstream of Hobbys Yards Road;
- in the vacant land that is located south-west of the intersection of Orange Road and Palmer Street;
- along the overland flow path that runs in an easterly direction between Hawkes Street and Burton Street to the north of Binstead Street; and
- along the overland flow path that runs in an easterly direction between Carcoar Street and Queen Street to the south of King George VI Oval.

Consideration will need to be given to the identified changes that occur in flood behaviour during the preparation of the future *Blayney FRMS&P*.

6.7 Potential Impacts of Future Development

Future infill development has the potential to increase the rate and volume of runoff conveyed by the various watercourses, as well as increase the frequency of surcharge of the local stormwater drainage system. It is also likely to result in changes to the existing drainage system. For example, while existing minor watercourses are likely to be retained and formalised in drainage reserves, piped drainage systems associated with urban subdivisions will result in significant amendments to existing overland flow paths leading to the watercourses.

Figures 6.22, **6.23** and **6.24** show the impact that uncontrolled development could have on flood behaviour in the study area in a 20%, 5% and 1% AEP storm event, respectively. Note that the assessment undertaken as part of the present study is of a broad-scale and strategic nature, and that more detailed site specific assessments would need to be undertaken as part of any future development.

Peak flood levels are shown to generally increase by up to a maximum of about 100 mm in the urbanised parts of Blayney if uncontrolled development were allowed to occur in the study catchment for the range of assessed storm event, with increases of up to 300 mm shown to occur on the western side of the Mid-Western Highway to the north of Abattoir Creek. Minor reductions in peak flood levels are shown to occur along the main arm of the Belubula River and on its eastern bank due to changes in the timing of the flood wave in its tributaries. It is noted that the increases are greatest for the more frequent events when future uncontrolled development would result in the more frequent surcharge of the existing stormwater drainage system.

This finding reinforces the need for Council to require detention basins to be incorporated in the design of future development to ensure that post-development peak flows are no higher than pre-development conditions.

6.8 Selection of Interim Flood Planning Levels

After consideration of the findings of the present study and in advance of the future review and update of the *Blayney FRMS&P*, the following criteria were adopted for defining the Interim FPA (**IFPA**) for the study area:

- in areas subject to Main Stream Flooding, the extent of the IFPA was defined as land lying at or below the peak 1% AEP flood level plus a freeboard allowance of 0.5 m (**Main Stream Flooding IFPA**); and
- in areas subject to Major Overland Flow and that also lie outside the extent of the Main Stream Flooding IFPA, the extent of the IFPA was defined as land inundated to a depth greater than 100 mm or within the extent of the floodway (**Major Overland Flow IFPA**).[6]

Figure 6.25 (3 sheets) shows the extent of the Main Stream Flooding and Major Overland Flow IFPAs. Pending the completion of the future *Blayney FRMS&P*, it is recommended that the habitable floor levels of future development be set as a minimum at the following elevations:

a) Where a dwelling or commercial building is proposed within the extent of the Main Stream Flooding IFPA, its habitable floor level is to be set at or above the peak 1% AEP flood level plus a freeboard of 0.5 m.

b) Where a dwelling or commercial building is proposed within the extent of the Major Overland Flow IFPA, its habitable floor level is to be set at or above the peak 1% AEP flood level plus a freeboard of 0.3 m.

Figure 6.25 also shows the extent of the *Outer Floodplain*, which is the area which lies between the FPA and the extent of the PMF. Consideration will need to be given during the preparation of the future *Blayney FRMS&P* as to whether Council should adopt clause 5.22 in the *Blayney Local Environmental Plan 2012*, noting that this clause relates to the need for Council to assess sensitive and hazardous type development that is proposed on land that lies between the FPA and the PMF.

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[6] The extent of Major Overland Flow FPA was filtered to remove pockets of flooding where the area was less than 100 m^2.

7 REFERENCES

Ball et. al. (Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I), 2019. ***"Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia"***

BOM (Bureau of Meteorology), 2003. **"*The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"***

The Institution of Engineers Australia, 1987. ***"Australian Rainfall and Runoff – A Guide to Flood Estimation"***, Volumes 1 and 2.

Jacobs, 2015. ***"Blayney Flood Study***"

Jacobs, 2016. ***"Blayney Floodplain Risk Management Study and Plan"***

Jordan et. al. (Jordan, P., Nathan, R., Mittiga, L. and Taylor, B.), 2005. ***"Growth Curves and Temporal Patterns for Application to Short Duration Extreme Events"***. Aust J Water Resource, 9(1), 69-80.

Kus et al (Kus B, O'Loughlin G, Stack B), 2018. ***"Applying ARR 2016 to Stormwater Drainage Design"***

NSWG (New South Wales Government), 2023. ***"Flood risk management manual – The policy and manual for the management of flood liable land".***

OEH (Office of Environment and Heritage), 2019. ***"Floodplain Risk Management Guide - Incorporating 2016 Australian Rainfall and Runoff in studies"***
Storm Consulting, 2022a. ***"Addendum to Blayney Flood Study"***

Storm Consulting, 2022b. ***"Blayney Retarding Basins Study"***

Walsh et al, 1991. **"*Initial Losses for Design Flood Estimation in New South Wales"***

8 FLOOD-RELATED TERMINOLOGY

TERM	DEFINITION
Afflux	Increase in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
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. For example, if a peak flood discharge of 50 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 50 m^3/s or larger events occurring in any one year (see average recurrence interval).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average period in years between the occurrence of a flood of a particular magnitude or greater. In a long period of say 1,000 years, a flood equivalent to or greater than a 100 year ARI event would occur 10 times. The 100 year ARI flood has a 1% chance (i.e. a one-in-100 chance) of occurrence in any one year (see annual exceedance probability).
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.
Critical Duration	The storm duration which produces the highest peak flood level for a given design flood event.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second [m/s]).
Flood fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood Planning Area (FPA)	The area of land inundated at the Flood Planning Level.
Flood Planning Level (FPL)	A combination of flood level and freeboard selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the 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.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (i.e. flood prone land).

TERM	DEFINITION
Floodplain Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the *Floodplain Development Manual, 2005*. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Floodway area	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	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such and wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as “greenhouse” and climate change. Freeboard is included in the flood planning level.
High hazard	Where land in the event of a 1% AEP flood is subject to a combination of flood water velocities and depths greater than the following combinations: 2 metres per second with shallow depth of flood water depths greater than 0.8 metres in depth with low velocity. Damage to structures is possible and wading would be unsafe for able bodied adults.
Low hazard	Where land may be affected by floodway or flood storage subject to a combination of floodwater velocities less than 2 metres per second with shallow depth or flood water depths less than 0.8 metres with low velocity. Nuisance damage to structures is possible and able bodied adults would have little difficulty wading.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State’s rivers and floodplains.
Major Overland Flow	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.

TERM	DEFINITION
Peak flood level	The maximum water level occurring during a flood event.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled 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 (i.e. the floodplain). The extent, nature and potential consequences of flooding associated with events up to and including the PMF should be addressed in a floodplain risk management study.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
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.
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum).

APPENDIX A

DETAILS OF AVAILABLE DATA

TABLE OF CONTENTS

ANNEXURES

LIST OF FIGURES (BOUND IN VOLUME 2)

A1 BACKGROUND INFORMATION

A1.1 LiDAR Survey Data

Figure A1.1 (3 sheets) shows the extent of LiDAR survey data that are available in the vicinity of Blayney, while **Table A1.1** sets out the details of the available LiDAR survey data. The data set were captured in accordance with the International Committee on Surveying and Mapping guidelines for digital elevation data with a 95% confidence interval on horizontal accuracy of ±800 mm and a vertical accuracy of ±150 mm.

TABLE A1.1
LiDAR SURVEY DATA SPECIFICATIONS

Data Set	Date of Capture	Data Provider
Blayney201704	11 April 2017	Geoscience Australia

Figure A1.1, sheet 2 shows the extent of drone-based LiDAR survey data that were captured in the vicinity of several residential subdivisions that are located on Hoynes Circuit, Starr Place and at the southern end of Athol Street and post-date the capture of the 2017 LiDAR survey data.

A1.2 Existing Stormwater Network

Council provided a GIS database of the piped stormwater drainage system at Blayney, the alignment of which is shown on **Figure A1.1**. The stormwater pipe/culvert component of the database contained details of the dimensions, material and alignment, as well as limited information on invert levels, while the stormwater pit component contained information on the pit type (i.e. inlet, junction, etc.), as well as limited information on pit inverts and dimensions (i.e. lintel length, grate size, etc.).

A review of Council's GIS-based stormwater drainage database identified a number of missing pits and pipes. **Figure A1.1** shows where Council subsequently undertook field inspections to confirm the alignment and dimensions of the stormwater drainage system in the identified areas.

The alignment and dimensions of stormwater drainage infrastructure that were subsequently identified during the model development phase of the present study were estimated based on a desktop analysis of aerial photography, LiDAR survey data and Google Street View.

A1.3 Historic Rainfall Data

Figure 1.1 shows the plan location of the two Bureau of Meteorology (**BoM**) operated Flood Warning Network (**FWN**), one All Weather Station (**AWS**) and six daily rain gauges that are located in the vicinity of Blayney, while **Table A1.2** over the page sets out the details of each.

Table A1.2 shows that daily rainfall totals are available between June 1885 and September 2020 after which the Blayney (Orange Road) (GS 63,294) daily read rain gauge was closed. The closest rain gauge that is currently in operation is the Newbridge (Stringybark Road) (GS 63,264) that is located 13 km to the east of Blayney.

TABLE A1.2
SUMMARY OF AVAILABLE RAIN GAUGE DATA[(1)]

Gauge Number	Gauge Name	Gauge Type	Site Commence	Site Cease	Distance from Blayney
63,303	Orange Airport AWS	BoM AWS[(2)]	October 2010	Ongoing	21 km
63,245	Mandurama Post Office	BoM FWN[(3)]	March 1969	Ongoing	21 km
63,264	Newbridge (Stringybark Rd)		May 2011	Ongoing	13 km
63,010	Blayney Post Office	BoM Daily	June 1885	July 1990	-
63,294	Blayney (Orange Road)		April 1990	September 2020	-
63,114	Lucknow (Newman St)		January 2002	Ongoing	23 km
63,214	Rock Forest (Bimbil)		May 1963	July 2010	24 km
63,005	Bathurst Agricultural Station		July 2008	Ongoing	30km
63,287	Bathurst Stanley St (Macquarie River)		December 2000	Ongoing	33 km
412106	Belubula River at Carcoar Dam	WaterNSW	January 1990	Ongoing	12 km

1. Refer **Figure 1.1** for location
2. AWS = All Weather Station
3. FWN = Flood Warning Network

A1.4 Photographic Record

A number of photographs were provided by Council showing flood behaviour that was observed in the study area during the storm that occurred on 13-14 November 2022.

A1.5 Cross Sectional Survey

Council undertook inbank cross sectional survey at regular intervals along the Belubula River and Abattoir Creek in the vicinity of the Urban Centre (refer **Figure A1.1** for location). Council also undertook cross sectional survey of the road bridges on the Belubula River (two off) and Abattoir Creek (two off). Inbank cross section data were provided as 3d polylines in AutoCAD, while the bridge details were pdf cross sectional plans.

A1.6 Surveyed Flood Mark

Figure A1.1 shows the plan location of flood marks from the 13-14 November 2022 flood that were surveyed by Council.

A2 REVIEW OF PREVIOUS INVESTIGATIONS

A2.1 Blayney Flood Study (Jacobs, 2015)

The aim of the *Blayney Flood Study* which was undertaken by Jacobs in 2015 was to define flood behaviour in the township under then present day conditions. Jacobs, 2015 states that Blayney is impacted by the following mechanisms of flooding:

- riverine type flooding from the Belubula River and Abattoir Creek; and
- local urban stormwater flooding.

A hydrologic model was developed of the Belubula River catchment at Blayney as part of Jacobs, 2015 based on the procedures set out in ARR 1987. A RORB model that was originally developed as part of the "*Portfolio Risk Assessment for 24 Dams*" (SKM, 2001) was relied upon to calculate the runoff from the upper reaches of the Belubula River catchment (**SKM RORB Model**), while a new RAFTS model which comprised a total of 124 sub-catchments was developed as part of Jacobs, 2015 to calculate the runoff from the catchments in the immediate vicinity of the town (**Jacobs RAFTS Model**).

The SKM RORB Model derived hydrographs were input at the upstream end of the Jacobs RAFTS Model as a "direct hydrograph" and then routed to the upstream extent of a hydraulic (TUFLOW) model that was also developed as part of Jacobs, 2015 (**Jacobs TUFLOW Model**).

While the Jacobs TUFLOW Model was developed to assess the two aforementioned mechanisms of flooding at Blayney, it is noted that the piped stormwater drainage system that was incorporated in the model was limited to the trunk piped drainage elements that run in a easterly direction through the urbanised part of the town and did not include the piped drainage system in areas subject to local urban stormwater flooding.

Jacobs, 2015 states that the SKM RORB Model was calibrated to stream flow data at the *Belubula River at Upstream Blayney* stream gauge (GS 412104) which is located on the upstream side of the old Mid-Western Highway crossing of the river approximately 2.5 km upstream of town for floods that occurred in November 1973, August 1974 and September 1974. As no additional stream flow data are available because the stream gauge was decommissioned in September 1997, the Jacobs RAFTS Model was not formally calibrated.

The Jacobs RAFTS Model was used to derive design discharge hydrographs for 20%, 5%, 1%, 0.5% and 0.2% AEP storm events, as well as the PMF. While design rainfall losses are said to have been derived based on the recommendations set out in *Initial Losses for Design Flood Estimation in New South Wales* (Walsh et al, 1991), the values are not presented in Jacobs, 2015, with the exception of the initial loss value that was applied to pervious areas in the urbanised parts of the town (i.e. 10 mm).

The Jacobs RAFTS Model derived peak flows were validated against flows derived as part of previous investigations, noting that they were generally found to be higher than the previous studies. **Table A2.1** over the page sets out the Jacobs RAFTS Model derived design peak flows at the location of the Mid-Western Highway crossing of the Belubula River.

TABLE A2.1
DESIGN PEAK FLOWS AT MID-WESTERN HIGHWAY CROSSING OF BELUBULA RIVER DERIVED AS PART OF PREVIOUS INVESTIGATIONS

Design Flood Event	Jacobs, 2015
PMF	4,420
0.5% AEP	286
1% AEP	246
5% AEP	123
20% AEP	48

A2.2 Blayney Floodplain Risk Management Study and Plan (Jacobs, 2016)

The *Blayney Floodplain Risk Management Study and Plan* (***Blayney FRMS&P***) was prepared in 2016 by Jacobs and relied on the results of the Jacobs RAFTS and TUFLOW Models to assess a range of measures which were aimed at reducing the existing, future and continuing flood risk in the township.

Table A2.2 sets out the results of a flood damages assessment that was undertaken as part of Jacobs, 2016 using the modelled peak flood levels derived from the Jacobs TUFLOW Model. The floor levels of 185 properties were surveyed as part of Jacobs, 2016, while the remaining floor levels were assumed to be 0.15 m above natural surface level as defined by the available LiDAR survey data.

TABLE A2.2
ECONOMIC IMPACTS OF FLOODING AT BLAYNEY DERIVED AS PART OF JACOBS, 2016 NOMINAL FLOOD LEVELS

Flooding Mechanism	Design Flood Event	Number of Properties Flooded Above-Flood Level		Estimated Flood Damages ($ Million)		
		Residential	Non-Residential	Residential	Non-Residential	Total
Main Stream Flooding	20% AEP	2	2	0.17	0	0.17
	5% AEP	2	3	0.18	0.07	0.25
	1% AEP	3	6	0.41	0.14	0.55
	0.5% AEP	9	6	0.7	0.16	0.86
	PMF	61	23	6.76	4.59	11.35
Major Overland Flow	20% AEP	43	8	5.81	0.25	6.06
	5% AEP	58	10	7.58	0.35	7.93
	1% AEP	84	13	11.09	0.60	11.69
	0.5% AEP	115	13	12.33	0.68	13.01
	PMF	494	43	36.49	4.59	41.08

Jacobs, 2016 found that Major Overland Flow was the dominant mechanism of flooding in terms of flood damages and resulted in a total of 84 residential and 13 non-residential buildings being inundated above-floor level in a 1% AEP storm event, equating to total flood damages of about $11.7 Million. By comparison, Jacobs, 2016 found that a total of three residential and six non-residential buildings were subject to above-floor inundation as a result of Main Stream Flooding in a 1% AEP flood event, equating to total flood damages of about $0.6 Million.

Table A2.3 sets out the results of a flood damages assessment that was also undertaken as part of Jacobs, 2016 using the modelled peak flood levels derived from the Jacobs TUFLOW Model plus freeboard, noting that freeboards of 0.3 m and 0.5 m were adopted in areas that are subject to Major Overland Flow and Main Stream Flooding, respectively. Freeboard allowance was incorporated in the damages assessment based on the recommendation in DECC, 2007 as flood damages are assumed to start accumulating once the freeboard is encroached.

TABLE A2.3
ECONOMIC IMPACTS OF FLOODING AT BLAYNEY DERIVED AS PART OF JACOBS, 2016
NOMINAL FLOOD LEVELS PLUS FREEBOARD

Flooding Mechanism	Design Flood Event	Number of Properties Flooded Above-Flood Level		Estimated Flood Damages ($ Million)		
		Residential	Non-Residential	Residential	Non-Residential	Total
Main Stream Flooding	20% AEP	4	3	0.34	0.07	0.41
	5% AEP	4	5	0.34	0.25	0.59
	1% AEP	12	6	1.00	0.33	1.33
	0.5% AEP	12	6	1.03	0.36	1.39
	PMF	64	24	7.66	8.76	16.42
Major Overland Flow	20% AEP	248	11	18.47	1.08	19.55
	5% AEP	305	14	22.81	1.38	24.19
	1% AEP	416	21	31.02	2.21	33.23
	0.5% AEP	436	22	32.64	2.41	35.05
	PMF	666	45	51.80	6.52	58.32

The number of properties impacted by flooding and total flood damages increase significantly when freeboard is taken into account, with total flood damages in a 1% AEP flood increasing to $1.33 Million and $33.23 Million in areas that are subject to Main Stream Flooding and Major Overland Flow, respectively.

The *Blayney FRMS&P* concluded that the following measures should be included in the Floodplain Management Plan for Blayney:

i. update Local Flood Plan for Blayney using data contained in the *Blayney Flood Study* and *Blayney FRMS&P*;
ii. application of appropriate controls over development in flood prone areas of Blayney;
iii. provide flood signage and depth indicators at major road crossings and public areas;
iv. undertake feasibility study and concept design of a network of nine flood retarding basins to reduce the impact of overland flow on existing development; and
v. undertake feasibility study for voluntary purchase and/or voluntary house raising for three dwellings that are impact by Main Stream Flooding.

A2.3 Addendum to Blayney Flood Study (Storm Consulting, 2022a)

Council engaged Storm Consulting to update the *Blayney Flood Study* in accordance with the procedures that are set out in ARR 2019. The Jacobs RAFTS Model was subsequently updated as part of Storm Consulting, 2022a (**Storm RAFTS Model**), noting that the SKM RORB Model which was integrated into the Jacobs RAFTS Model as direct inflow hydrographs was not updated as part of the more recent study (i.e. the Storm RAFTS Model comprises a mixture of ARR 1987 and ARR 2019 procedures).

The Jacobs TUFLOW Model was updated as part of Storm Consulting, 2022a (**Storm TUFLOW Model**) to incorporate the following:

- discharge hydrographs that were derived from the Storm RAFTS Model; and
- additional details of the stormwater infrastructure in the urbanised parts of Blayney to improve the definition of major overland flow.

The Storm RAFTS and TUFLOW Models were used to redefine flood behaviour at Blayney under present day conditions.

The Storm RAFTS and TUFLOW Models were then used to define flood behaviour under future catchment conditions (denoted “proposed scenario” in Storm Consulting, 2022a), noting that fully developed catchments were assumed to be 25% impervious. Storm Consulting, 2022a found that future development would have a minor impact of flood behaviour in Blayney.

A2.4 Blayney Retarding Basins Study (Storm Consulting, 2022b)

Storm Consulting undertook the *Blayney Retarding Basins Study* in 2022 based on recommendation iv of the *Blayney FRMS&P* (i.e. undertake feasibility study and concept design of a network of nine flood retarding basins to reduce the impact of overland flow on existing development).

The Storm TUFLOW Model that was developed as part of Storm Consulting, 2022a was used to assess the impact that the nine detention basins that were recommended as part of Jacobs, 2016 (denoted Scenario 1) and a refined strategy that comprised a total of five detention basins, three upstream on the western side of the railway to the south of Orange Road, one to the south-west of the intersection of Orange Road and Palmer Street and one in King George VI Oval (denoted Scenario 2).

Table A2.4 over the page show the results of an economic analysis of the two assessed retarding basin scenarios, noting that the benefits were calculated using the flood damages assessment based on the nominal flood levels plus freeboard. The study found that both scenarios had a benefit cost ratio greater than one.

TABLE A2.4
ECONOMIC ANALYSIS OF DETENTION BASIN SCENARIOS
STORM CONSULTING, 2022b

Scenario	Cost ($ Million)	Benefits ($ Million)	Benefit Cost Rato
1	10.61	13.17	1.24
2	5.26	7.99	1.51

A3 REFERENCES

DECC (Department of Environment and Climate Change, NSW), 2007. ***"Floodplain Risk Management Guideline No 4. Residential Flood Damage Calculation"***.

Jacobs, 2015. ***"Blayney Flood Study***"

Jacobs, 2016. ***"Blayney Floodplain Risk Management Study and Plan"***

Storm Consulting, 2022a. ***"Addendum to Blayney Flood Study"***

Storm Consulting, 2022b. ***"Blayney Retarding Basins Study"***

APPENDIX B

SCREEN SHOTS OF DRONE-BASED FOOTAGE AND PHOTOGRAPH SHOWING OBSERVED FLOOD AT BLAYNEY – 14 NOVEMBER 2022

Plate B1.1 – Looking north-west at the intersection of Newbridge Road and Henry Street from the bridge crossing of the Belubula River (Taken on 14 November 2022 at 07:30 hours).

Plate B1.2 – Zoom in of **Plate B1.1** showing flood level at the Glasson Bridges. The flood was observed to peak approximately 3 inches (76.2 mm) higher than the flood level in the photograph, three hours prior to it being taken.

Plate B1.3 – Looking north across Dakers Oval and the Belubula River floodplain from its confluence with Abattoir Creek. (Taken on 14 November 2022 at 19:27 hours).

Plate B1.4 – Looking south along the western (right) overbank of the Belubula River from Newbridge Road (Taken on 14 November 2022 at 19:27 hours).

Plate B1.5 – Looking south along the western (right) overbank of the Belubula River from its confluence with Abattoir Creek (Taken on 14 November 2022 at 19:27 hours).

Plate B1.6 – Looking east across the Belubula River floodplain from its confluence with Abattoir Creek. (Taken on 14 November 2022 at 19:27 hours).

Plate B1.7 – Looking west along Newbridge Road from its intersection with Henry Street (Taken on 14 November 2022 at 19:27 hours).

Plate B1.8 – Looking north along the Belubula River from the intersection of Hobbys Yards Road and Hills Lane (Taken on 14 November 2022 at 20:40 hours).

Plate B1.9 – Looking south along the Belubula River from the intersection of Hobbys Yards Road and Hills Lane (Taken on 14 November 2022 at 20:40 hours).

Plate B1.10 – Looking east across the Belubula River from the intersection of Hobbys Yards Road and Hills Lane (Taken on 14 November 2022 at 20:40 hours).

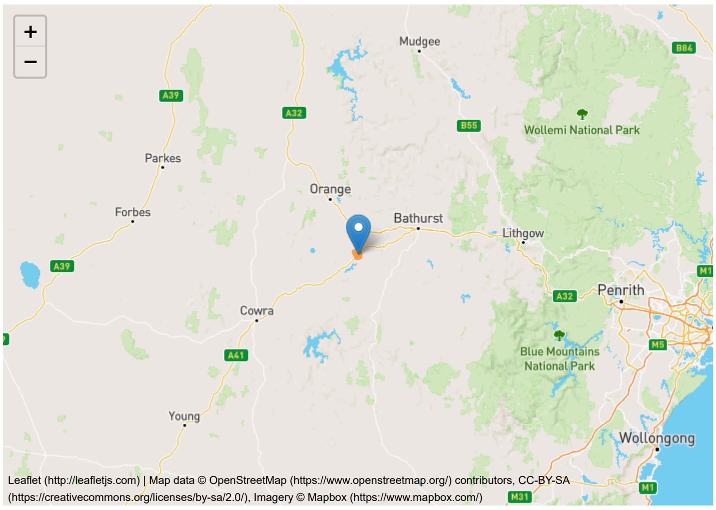
APPENDIX C

DESIGN INPUT DATA FROM ARR DATA HUB

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	149.247
Latitude	-33.537
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Leaflet (http://leafletjs.com) | Map data © OpenStreetMap (https://www.openstreetmap.org/) contributors, CC-BY-SA (https://creativecommons.org/licenses/by-sa/2.0/), Imagery © Mapbox (https://www.mapbox.com/)

Data

River Region

Division	Murray-Darling Basin
River Number	13
River Name	Lachlan River
Shape Intersection (%)	100.0

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d}\right.\right.$$
$$+ eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right)$$
$$\left.\left. + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i	Shape Intersection (%)
Central NSW	0.265	0.241	0.505	0.321	0.00056	0.414	-0.021	0.015	-0.00033	100.0

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2016_v1

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36}\right.$$
$$+ 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right)$$
$$\left. + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

Storm Initial Losses (mm)	25.0
Storm Continuing Losses (mm/h)	4.8

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin
Shape Intersection (%)	100.0

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin
Shape Intersection (%)	100.0

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-33.536611421&longitude=149.24674476&sdmin=true&sdhr=true to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	23 January 2026 05:00PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.9 (0.047)	1.1 (0.041)	1.2 (0.038)	1.3 (0.036)	1.4 (0.032)	1.4 (0.030)
90 (1.5)	1.5 (0.066)	1.1 (0.039)	0.9 (0.027)	0.7 (0.018)	0.6 (0.013)	0.5 (0.010)
120 (2.0)	0.9 (0.038)	0.7 (0.023)	0.6 (0.016)	0.5 (0.011)	0.8 (0.015)	1.0 (0.017)
180 (3.0)	1.2 (0.043)	1.0 (0.027)	0.9 (0.020)	0.8 (0.015)	0.5 (0.009)	0.3 (0.005)
360 (6.0)	1.6 (0.044)	1.2 (0.026)	1.0 (0.018)	0.7 (0.012)	2.7 (0.038)	4.2 (0.052)
720 (12.0)	0.0 (0.000)	0.8 (0.014)	1.4 (0.020)	1.9 (0.024)	7.3 (0.079)	11.3 (0.110)
1080 (18.0)	0.0 (0.000)	0.8 (0.012)	1.3 (0.017)	1.8 (0.020)	4.1 (0.038)	5.8 (0.049)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.004)	0.5 (0.005)	2.5 (0.021)	4.0 (0.031)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.003)	0.8 (0.005)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.1 (0.621)	11.2 (0.428)	10.6 (0.344)	10.1 (0.282)	11.1 (0.265)	11.9 (0.254)
90 (1.5)	19.2 (0.867)	14.6 (0.494)	11.6 (0.332)	8.7 (0.216)	8.9 (0.188)	9.0 (0.170)
120 (2.0)	13.5 (0.557)	10.3 (0.317)	8.1 (0.213)	6.0 (0.138)	10.4 (0.203)	13.7 (0.240)
180 (3.0)	9.1 (0.329)	11.4 (0.309)	12.8 (0.298)	14.2 (0.289)	13.1 (0.227)	12.3 (0.191)
360 (6.0)	10.8 (0.305)	14.5 (0.310)	16.9 (0.311)	19.2 (0.310)	26.8 (0.371)	32.5 (0.404)
720 (12.0)	4.5 (0.098)	9.5 (0.158)	12.8 (0.184)	16.0 (0.203)	28.9 (0.314)	38.6 (0.378)
1080 (18.0)	4.6 (0.087)	9.7 (0.140)	13.0 (0.162)	16.2 (0.178)	20.6 (0.194)	23.9 (0.203)
1440 (24.0)	0.8 (0.014)	4.5 (0.058)	6.9 (0.078)	9.2 (0.092)	14.5 (0.124)	18.5 (0.142)
2160 (36.0)	0.0 (0.000)	2.3 (0.027)	3.8 (0.038)	5.3 (0.046)	7.7 (0.058)	9.5 (0.064)
2880 (48.0)	0.0 (0.000)	1.1 (0.011)	1.8 (0.016)	2.5 (0.020)	4.0 (0.028)	5.2 (0.032)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.9 (0.005)

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	29.4 (1.510)	29.4 (1.124)	29.4 (0.952)	29.3 (0.824)	30.0 (0.714)	30.5 (0.647)
90 (1.5)	47.6 (2.147)	40.7 (1.375)	36.2 (1.038)	31.8 (0.793)	33.9 (0.719)	35.5 (0.672)
120 (2.0)	35.3 (1.454)	31.4 (0.971)	28.8 (0.758)	26.3 (0.603)	47.5 (0.926)	63.3 (1.106)
180 (3.0)	26.4 (0.948)	29.3 (0.797)	31.3 (0.727)	33.2 (0.673)	55.8 (0.966)	72.7 (1.129)
360 (6.0)	25.0 (0.706)	34.9 (0.748)	41.4 (0.763)	47.6 (0.771)	55.5 (0.768)	61.3 (0.763)
720 (12.0)	18.3 (0.399)	35.0 (0.585)	46.1 (0.664)	56.8 (0.719)	72.7 (0.790)	84.6 (0.828)
1080 (18.0)	17.4 (0.329)	27.5 (0.396)	34.1 (0.424)	40.5 (0.444)	54.3 (0.511)	64.7 (0.549)
1440 (24.0)	8.9 (0.153)	19.0 (0.248)	25.6 (0.288)	32.0 (0.317)	44.1 (0.376)	53.2 (0.410)
2160 (36.0)	8.0 (0.121)	12.3 (0.141)	15.1 (0.149)	17.8 (0.155)	28.9 (0.217)	37.2 (0.253)
2880 (48.0)	2.6 (0.036)	7.6 (0.080)	10.8 (0.099)	14.0 (0.112)	17.0 (0.118)	19.3 (0.121)
4320 (72.0)	7.6 (0.096)	7.3 (0.070)	7.1 (0.058)	6.9 (0.050)	13.8 (0.087)	18.9 (0.109)

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	18.9	10.1	9.7	10.2	10.0	8.5
90 (1.5)	16.8	9.4	9.4	10.3	10.8	9.3
120 (2.0)	18.3	11.0	10.8	12.0	9.9	8.3
180 (3.0)	19.3	12.4	11.2	11.6	9.6	8.5
360 (6.0)	18.8	12.9	11.1	11.2	9.5	5.8
720 (12.0)	21.3	15.0	13.1	12.4	9.7	4.9
1080 (18.0)	21.7	16.0	15.1	14.5	12.5	7.8
1440 (24.0)	24.0	18.9	17.5	17.3	14.5	9.2
2160 (36.0)	25.2	20.4	20.4	21.4	17.9	11.2
2880 (48.0)	26.3	21.6	22.2	23.0	21.1	14.9
4320 (72.0)	25.6	22.0	23.8	25.4	22.9	16.9

Layer Info

Time Accessed	23 January 2026 05:00PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

APPENDIX D

ARR 2019 DESIGN BLOCKAGE ASSESSMENT AT DRAINAGE STRUCTURES

TABLE E1
ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES

ID(1)	Structure Details			Floating Debris													Non-Floating Debris										Adopted Design Blockage B_{DES}%		
	Structure Type(2)	Width (m)	No. of Barrels	L_{10}(3)	L&A Debris Type Identifier	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Mean Sediment Size Present	Approx. Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP					> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
pBFS_348	C Culvert	0.525	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_366	C Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_625	C Culvert	0.6	2	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_630	C Culvert	1.2	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_761	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_704	C Culvert	1.2	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_735	C Culvert	0.6	2	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_702	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_703	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_760	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_734	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_733	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_732	R Culvert	1.5	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_731	R Culvert	1.5	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_730	R Culvert	1.5	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_729	R Culvert	1.5	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_728	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_727	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_689	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_701	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_736	C Culvert	0.375	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_633	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_632	R Culvert	1.8	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	1.2	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_636	C Culvert	0.9	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_599	C Culvert	0.3	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_067	C Culvert	0.3	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_738	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_737	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_726	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_725	C Culvert	1.2	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_740	C Culvert	0.6	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_041	C Culvert	0.375	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_753	R Culvert	1.8	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.9	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_651	C Culvert	0.22	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_352	C Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_635	C Culvert	1.5	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_643	C Culvert	1.2	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_644	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_477	C Culvert	0.75	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_595	R Culvert	1.2	3	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_596	R Culvert	1.2	3	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_669	R Culvert	1.2	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.7	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_670	C Culvert	1.4	2	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.8	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_378	R Culvert	0.3	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_593	R Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_516	R Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_515	R Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_682	R Culvert	1.5	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.8	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_258	R Culvert	1.2	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_259	C Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_468	C Culvert	0.3	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_174	R Culvert	1.5	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_217	C Culvert	0.45	3	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_716	R Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_715	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_714	C Culvert	0.45	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_713	C Culvert	0.9	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_748	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_749	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_747	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_746	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%

TABLE E1
ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES

ID(1)	Structure Details			Floating Debris													Non-Floating Debris										Adopted Design Blockage B_{DES}%		
	Structure Type(2)	Width (m)	No. of Barrels	L_{10}(3)	L&A Debris Type Identifier	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Mean Sediment Size Present	Approx. Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP					> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
pBFS_711	C Culvert	0.45	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_710	R Culvert	1.2	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_712	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_709	R Culvert	1.2	5	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_708	R Culvert	1.2	2	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_658	C Culvert	0.375	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_660	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_661	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_662	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_665	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_707	C Culvert	0.45	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_671	R Culvert	1.8	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_676	C Culvert	0.45	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_672	R Culvert	2.75	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_677	R Culvert	1.8	5	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_678	C Culvert	0.45	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.8	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_679	C Culvert	0.9	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.9	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_680	C Culvert	0.76	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_681	C Culvert	0.92	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_674	C Culvert	0.92	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_675	R Culvert	2.4	7	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_673	C Culvert	3.1	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pBFS_744	C Culvert	0.45	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_721	C Culvert	1	3	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_688	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_724	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	2.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_720	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.9	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_668	C Culvert	0.9	2	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_719	C Culvert	0.9	3	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.8	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_718	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_717	C Culvert	0.9	3	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_666	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_667	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_687	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_410	C Culvert	0.9	1	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.6	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_598	C Culvert	0.6	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_411	C Culvert	0.6	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.5	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_221	C Culvert	0.6	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_222	C Culvert	0.6	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.7	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_321	C Culvert	0.375	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_233	R Culvert	1.2	2	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.9	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_416	C Culvert	0.45	2	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.9	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_527	R Culvert	1.2	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_526	R Culvert	1.2	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_757	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_758	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_683	R Culvert	1.2	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_764	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_256	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_257	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.8	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_763	C Culvert	0.9	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_637	C Culvert	2.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_650	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_762	C Culvert	0.45	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_755	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_756	C Culvert	0.6	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_634	R Culvert	2.15	2	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	0%	0%	10%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_591	C Culvert	0.45	2	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.8	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_161	C Culvert	0.925	2	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_517	C Culvert	0.45	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_218	C Culvert	0.525	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	1.8	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%

TABLE E1
ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES

ID[1]	Structure Details			Floating Debris													Non-Floating Debris										Adopted Design Blockage B_{DES}%		
	Structure Type[2]	Width (m)	No. of Barrels	L_{10}[3]	L&A Debris Type Identifier	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Mean Sediment Size Present	Approx. Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP					> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
pBFS_684	C Culvert	0.63	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pBFS_685	C Culvert	0.525	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
pBFS_686	C Culvert	0.525	1	1.5	B	L	M	M	LMM	Low	Low	Low	Medium	25%	25%	50%	Cobbles 63 to 200 mm	-1E+37	High	Low	Low	Low	Medium	25%	25%	60%	25%	25%	60%
BFS_Bridge_01	Bridge	5	1	1.5	C	L	M	L	LML	Low	Low	Low	Medium	0%	0%	0%	Cobbles 63 to 200 mm	2.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
BFS_Bridge_02	Bridge	14.5	2	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	0%	Cobbles 63 to 200 mm	3.1	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
BFS_Bridge_03	Bridge	14.39	4	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	0%	Cobbles 63 to 200 mm	1.9	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
BFS_Bridge_04	Bridge	9.36	4	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	0%	Cobbles 63 to 200 mm	1.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
BFS_Bridge_05	Bridge	7.65	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	0%	Cobbles 63 to 200 mm	1.5	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
BFS_Bridge_06	Bridge	5.43	3	1.5	A	L	L	M	LLM	Low	Low	Low	Medium	0%	0%	0%	Cobbles 63 to 200 mm	1.9	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%

1. Note that the plan location of each structure can be identified in the GIS layers contained in the data handover for the present study.
2. C Culvert = Circular Pipe Culvert, R Culvert = Rectangular Box Culvert
3. L_{10} is the average length of the longest 10% of the debris that could arrive at the culvert.

APPENDIX E

FLOOD DATA FOR INDIVIDUAL ROAD AND RAIL CROSSINGS AT BLAYNEY

TABLE E1
PEAK FLOOD LEVEL AND MAXIMUM DEPTH OF INUNDATION AT INDIVIDUAL ROAD AND RAIL CROSSINGS AT BLAYNEY(1,2)

ID(3)	Watercourse	Road Name	Road/ Rail/ Spillway Level (m AHD)	November 2022		50% AEP		20% AEP		10% AEP		5% AEP		1% AEP		0.5% AEP		0.2% AEP		PMF	
				Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]
H01	Belubula River	Mid Western Highway	870.90	869.55	NF	868.81	NF	869.10	NF	869.29	NF	869.44	NF	869.77	NF	869.89	NF	870.11	NF	872.11	1.21
H02	Belubula River	Main Western Railway	864.40	863.83	NF	863.13	NF	863.48	NF	863.76	NF	864.01	NF	864.50	0.10	864.61	0.21	864.75	0.35	866.92	2.52
H03a	Belubula River	Newbridge Road	862.90	862.42	NF	861.96	NF	862.21	NF	862.37	NF	862.47	NF	862.74	NF	862.84	NF	862.99	0.09	866.3	3.40
H03b	Belubula River	Newbridge Road	861.90	862.44	0.54	862.13	0.23	862.26	0.36	862.37	0.47	862.44	0.54	862.62	0.72	862.69	0.79	862.78	0.88	866.29	4.39
H04	Belubula River	Hobbys Yards Road	859.90	858.96	NF	858.36	NF	858.58	NF	858.76	NF	858.89	NF	859.21	NF	859.35	NF	859.53	NF	862.87	2.97
H05	Abattoir Creek	Disused Abbatoir	868.85	869.8	0.95	869.41	0.56	869.70	0.85	869.85	1.00	870.01	1.16	870.40	1.55	870.54	1.69	870.73	1.88	874.46	5.61
H06	Abattoir Creek	Gerty Street	866.40	866.53	0.13	866.43	0.03	866.53	0.13	866.58	0.18	866.63	0.23	866.76	0.36	866.82	0.42	866.89	0.49	868.27	1.87
H07	Abattoir Creek	William Street	865.45	865.55	0.10	865.35	NF	865.59	0.14	865.69	0.24	865.76	0.31	865.93	0.48	865.98	0.53	866.07	0.62	867.25	1.80
H08	Abattoir Creek	Mid Western Highway	865.30	864.12	NF	864.65	NF	864.97	NF	865.13	NF	865.24	NF	865.43	0.13	865.49	0.19	865.60	0.30	867.28	1.98
H09	Abattoir Creek	Main Western Railway	865.00	864.49	NF	863.42	NF	863.69	NF	863.94	NF	864.17	NF	864.60	NF	864.70	NF	864.88	NF	866.77	1.77
H10	Abattoir Creek	Dakers Oval Access Road	862.70	863.2	0.50	863.42	0.72	863.69	0.99	863.94	1.24	864.17	1.47	864.60	1.90	864.70	2.00	864.88	2.18	866.69	3.99

1. While elevations have generally been rounded to nearest 0.1 m, the depth of overtopping shows where the depth of overtopping is less than 0.1 m.
2. NF = Not Flooded.
3. Refer relevant figures in Volume 2 for location of Peak Flood Level Location.

APPENDIX F

DESIGN PEAK FLOWS

TABLE F1
DESIGN PEAK FLOWS[1]

Peak Flow Location Identifier[2] [A]	Watercourse [B]	Location [C]	20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s) [D]	Critical Storm Duration[3] (minutes) [E]	Critical Temporal Pattern[4] [F]	Peak Flow (m^3/s) [G]	Critical Storm Duration[3] (minutes) [H]	Critical Temporal Pattern[4] [I]	Peak Flow (m^3/s) [J]	Critical Storm Duration[3] (minutes) [K]	Critical Temporal Pattern[4] [L]	Peak Flow (m^3/s) [M]	Critical Storm Duration[3] (minutes) [N]	Critical Temporal Pattern[4] [O]	Peak Flow (m^3/s) [P]	Critical Storm Duration[3] (minutes) [Q]	Critical Temporal Pattern[4] [R]	Peak Flow (m^3/s) [S]	Critical Storm Duration[3] (minutes) [T]	Critical Temporal Pattern[4] [U]	Peak Flow (m^3/s) [V]	Critical Storm Duration[3] (minutes) [W]	Critical Temporal Pattern[4] [X]	Peak Flow (m^3/s) [Y]	Critical Storm Duration[3] (minutes) [Z]
Q01	Belubula River	0.8km upstream of Mid Western Highway	42.6	720	S10	79.6	720	S10	113	540	S6	144	540	S6	242	360	S7	291	360	S7	346	360	S7		
Q02a		0.5km downstream of Mid Western Highway	45.1	720	S10	82.7	720	S10	117	540	S6	148	540	S6	230	360	S7	266	360	S7	304	360	S7		
Q02b		0.5km downstream of Mid Western Highway	1.8	540	S3	3.8	270	S6	5.4	120	S3	6.9	120	S3	21.6	360	S7	34.1	360	S7	53.4	360	S7		
Q03		1.7km upstream of Main Western Railway	47.9	720	S10	89.8	720	S10	126	540	S6	160	540	S6	258	360	S7	308	360	S7	366	360	S7		
Q04		0.55km downstream of Main Western Railway	58.8	720	S10	107	720	S10	151	540	S6	190	540	S6	312	360	S7	371	360	S7	438	360	S7		
Q05		0.45km downstream of Newbridge Road	59.7	720	S10	109	720	S10	154	540	S6	194	540	S6	317	360	S7	378	360	S7	445	360	S7		
Q06		0.7km upstream of Hobbys Yards Road	60.5	720	S10	110	720	S10	157	540	S6	198	540	S6	323	360	S7	385	360	S7	455	360	S7		
Q07		0.8km downstream of Hobbys Yards Road	60.0	720	S10	110	540	S3	157	540	S6	198	540	S6	323	360	S7	386	360	S7	456	360	S7		
Q08	Abattoir Creek	0.6km downstream of Greghamstown Road	14.1	720	S10	27.0	270	S6	35.0	180	S2	44.0	180	S2	71.5	180	S6	83.5	180	S6	97.6	180	S6		
Q09		1.8km downstream of Greghamstown Road	16.1	720	S10	29.7	270	S6	38.0	180	S2	48.6	180	S2	79.2	180	S6	92.0	180	S6	108	180	S6		
Q10		0.15km upstream of Gerty Street	16.6	720	S10	30.5	270	S6	39.3	360	S6	49.6	180	S2	80.6	180	S6	94.0	180	S6	109	180	S6		
Q11		0.4km downstream of Gerty Street	16.7	720	S10	30.7	270	S6	39.8	360	S6	49.9	180	S2	81.7	180	S6	95.6	180	S6	112	180	S6		
Q12	Major Overland Flow	Palmer Street	0.3	720	S10	1.1	180	S3	1.6	120	S3	2.1	120	S3	3.8	60	S2	4.7	60	S2	6.9	30	S2		
Q13		Upstream Hawke Street	0.0	180	S3	0.8	30	S1	1.3	30	S7	2.1	120	S3	3.9	60	S2	5.1	60	S2	7.3	60	S2		
Q14a		Raphael Street	0.0	30	S1	0.1	30	S1	0.4	30	S7	0.9	120	S3	1.9	60	S2	2.5	60	S2	3.6	60	S2		
Q14b			0.0	30	S1	0.2	180	S3	0.4	120	S3	0.6	120	S3	1.1	90	S8	1.4	60	S2	2.1	60	S2		
Q15		Doust Street	2.1	180	S3	3.8	30	S1	4.5	30	S7	4.9	30	S7	6.2	30	S6	7.2	90	S8	8.3	90	S8		
Q16		Palmer Street	0.2	180	S3	0.6	180	S3	0.7	180	S2	0.9	120	S3	1.7	30	S6	1.8	30	S6	1.9	30	S6		
Q17		Oliver Street	0.0	180	S3	0.1	180	S3	0.2	180	S2	0.2	120	S3	1.2	60	S2	1.5	60	S2	1.8	30	S2		
Q18a		Cooper Street	0.0	30	S1	0.0	30	S1	0.1	30	S7	0.2	30	S7	0.5	30	S6	0.7	30	S6	0.9	30	S6		
Q18b			0.0	30	S1	0.3	30	S1	0.5	30	S7	0.7	30	S7	1.1	30	S6	1.3	30	S6	1.5	30	S6		
Q19a		Carcoar Street	0.0	30	S1	0.0	30	S1	0.1	30	S7	0.3	30	S7	1.3	30	S6	1.7	30	S6	2.2	30	S6		
Q19b			0.0	180	S3	0.7	30	S1	1.2	30	S7	1.6	30	S7	2.3	30	S6	2.5	30	S6	2.8	30	S6		

Refer over for footnote to table

TABLE F1 (Cont'd)
DESIGN PEAK FLOWS(1)

Peak Flow Location Identifier(2) [A]	Watercourse [B]	Location [C]	20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s) [D]	Critical Storm Duration(3) (minutes) [E]	Critical Temporal Pattern(4) [F]	Peak Flow (m^3/s) [G]	Critical Storm Duration(3) (minutes) [H]	Critical Temporal Pattern(4) [I]	Peak Flow (m^3/s) [J]	Critical Storm Duration(3) (minutes) [K]	Critical Temporal Pattern(4) [L]	Peak Flow (m^3/s) [M]	Critical Storm Duration(3) (minutes) [N]	Critical Temporal Pattern(4) [O]	Peak Flow (m^3/s) [P]	Critical Storm Duration(3) (minutes) [Q]	Critical Temporal Pattern(4) [R]	Peak Flow (m^3/s) [S]	Critical Storm Duration(3) (minutes) [T]	Critical Temporal Pattern(4) [U]	Peak Flow (m^3/s) [V]	Critical Storm Duration(3) (minutes) [W]	Critical Temporal Pattern(4) [X]	Peak Flow (m^3/s) [Y]	Critical Storm Duration(3) (minutes) [Z]
Q20	Major Overland Flow	Adelaide Street	0.0	30	S1	0.4	30	S1	0.9	30	S7	1.4	30	S7	2.3	30	S6	2.8	30	S6	3.3	30	S6		
Q21		Downstream Blayney Demondrille Railway	0.2	180	S3	0.5	30	S1	0.8	30	S7	1.0	30	S7	1.2	30	S6	1.3	30	S6	1.5	30	S6		
Q22			0.7	180	S3	1.2	270	S6	1.6	120	S3	1.9	120	S3	3.5	30	S6	3.9	30	S6	3.3	60	S6		
Q23		Gilchrist Street	0.7	180	S3	1.2	270	S6	1.6	120	S3	1.9	120	S3	3.4	60	S2	3.7	60	S2	3.3	60	S2		
Q24			0.7	180	S3	1.2	270	S6	1.6	120	S3	1.9	120	S3	3.4	60	S2	3.7	60	S2	3.3	60	S2		
Q25		Carcoar Street	0.1	180	S3	0.3	270	S6	0.7	120	S3	1.1	120	S3	2.3	60	S2	2.9	60	S2	3.3	60	S2		
Q26		Downstream Blayney Demondrille Railway	0.3	180	S3	0.4	270	S6	0.5	120	S3	0.6	30	S7	1.3	30	S6	1.5	30	S6	1.8	30	S6		
Q27		Carcoar Street	0.3	30	S1	0.5	30	S1	0.7	30	S7	0.9	120	S3	1.5	60	S2	1.8	60	S2	2.4	30	S2		
Q28		Downstream Blayney Demondrille Railway	0.5	180	S3	0.7	180	S3	1.0	30	S7	1.5	30	S7	2.3	30	S6	2.4	30	S6	1.7	30	S6	2.9	45
Q29a		Haddon Place	1.0	720	S10	2.4	180	S3	2.3	30	S7	3.6	30	S7	7.5	30	S6	8.9	30	S6	10.5	30	S6	-	
Q29b			0.3	180	S3	0.8	30	S1	1.2	30	S7	1.4	30	S7	1.9	30	S6	2.2	30	S6	2.6	30	S6	17.5	15
Q30a		Upstream Athol Street	0.0	180	S3	0.2	180	S3	0.4	30	S7	0.7	30	S7	1.7	30	S6	2.0	30	S6	3.5	30	S6	35.6	45
Q30b			1.7	180	S3	2.9	180	S3	3.6	120	S3	4.7	120	S3	8.0	30	S6	9.6	30	S6	10.4	30	S6	-	
Q31		Downstream Quamby Place	0.1	180	S3	0.3	180	S3	0.8	120	S3	1.3	120	S3	3.4	30	S6	3.8	30	S6	4.3	30	S6		
Q32		Upstream Medway Street	1.7	180	S3	2.9	180	S3	3.6	120	S3	4.8	120	S3	8.2	30	S6	9.8	30	S6	10.8	30	S6		
Q33		Oldham Place	1.8	180	S3	3.0	180	S3	3.5	120	S3	5.0	120	S3	8.5	30	S6	9.9	30	S6	10.4	30	S6		
Q34		Downstream Medway Street	0.0	30	S1	0.0	30	S1	0.1	30	S7	0.1	30	S7	0.1	30	S6	0.2	30	S6	0.9	30	S6		
Q35a		King George VI Oval	0.0	180	S3	0.9	180	S3	1.1	120	S3	1.4	120	S3	2.9	60	S2	3.4	60	S2	4.0	60	S2		
Q35b			0.0	180	S3	1.1	180	S3	2.0	120	S3	3.2	120	S3	7.4	60	S2	9.2	60	S2	10.5	30	S2		
Q36a		Osman Street	0.4	30	S1	1.1	30	S1	1.9	120	S3	3.1	120	S3	5.6	90	S8	7.0	60	S2	8.2	60	S2		
Q36b			0.3	180	S3	1.9	180	S3	3.2	120	S3	4.6	120	S3	8.8	60	S2	10.8	60	S2	12.4	60	S2		
Q36c			0.0	30	S1	0.1	30	S1	0.2	30	S7	0.3	30	S7	1.5	60	S2	2.1	60	S2	2.5	60	S2		

Refer over for footnote to table

TABLE F1 (Cont'd)
DESIGN PEAK FLOWS[1]

Peak Flow Location Identifier[2] [A]	Watercourse [B]	Location [C]	20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s) [D]	Critical Storm Duration[3] (minutes) [E]	Critical Temporal Pattern[4] [F]	Peak Flow (m^3/s) [G]	Critical Storm Duration[3] (minutes) [H]	Critical Temporal Pattern[4] [I]	Peak Flow (m^3/s) [J]	Critical Storm Duration[3] (minutes) [K]	Critical Temporal Pattern[4] [L]	Peak Flow (m^3/s) [M]	Critical Storm Duration[3] (minutes) [N]	Critical Temporal Pattern[4] [O]	Peak Flow (m^3/s) [P]	Critical Storm Duration[3] (minutes) [Q]	Critical Temporal Pattern[4] [R]	Peak Flow (m^3/s) [S]	Critical Storm Duration[3] (minutes) [T]	Critical Temporal Pattern[4] [U]	Peak Flow (m^3/s) [V]	Critical Storm Duration[3] (minutes) [W]	Critical Temporal Pattern[4] [X]	Peak Flow (m^3/s) [Y]	Critical Storm Duration[3] (minutes) [Z]
Q37	Major Overland Flow	Adelaide Street	0.3	180	S3	2.0	270	S6	4.2	120	S3	6.7	120	S3	12.1	60	S2	15.2	60	S2	18.0	60	S2		
Q38		Downstream Lovejoy Avenue	0.0	30	S1	0.3	30	S1	0.9	30	S7	1.3	30	S7	2.1	30	S6	2.5	30	S6	3.0	30	S6		
Q39		Downstream Polona Street	1.2	30	S1	2.0	30	S1	2.8	30	S7	3.5	30	S7	4.5	30	S6	5.2	30	S6	5.9	30	S6	35.1	15
Q40		Upstream Mitchell Street	1.5	30	S1	2.9	30	S1	4.0	30	S7	5.0	30	S7	6.7	30	S6	7.6	30	S6	8.8	30	S6	-	
Q41		Upstream Prices Lane	0.4	180	S3	0.5	180	S3	0.7	30	S7	1.1	30	S7	2.0	30	S6	2.3	30	S6	2.7	30	S6		
Q42			1.0	180	S3	1.4	180	S3	2.1	30	S7	3.0	30	S7	5.4	30	S6	6.2	30	S6	7.2	30	S6	41.4	45
Q43			1.0	180	S3	1.7	180	S3	2.3	120	S3	2.9	30	S7	6.5	30	S6	7.7	30	S6	9.1	30	S6	54.1	45
Q44a		Napier Street	0.3	180	S3	0.6	270	S6	0.8	120	S3	0.9	120	S3	1.7	30	S6	2.1	30	S6	2.6	30	S6	28.0	45
Q44b			0.9	180	S3	1.5	270	S6	2.0	120	S3	2.4	30	S7	5.6	30	S6	6.6	30	S6	7.9	30	S6	-	
Q45		Upstream Hobbys Yards Road	0.2	180	S3	0.5	30	S1	0.7	30	S7	0.9	30	S7	1.1	30	S6	1.3	30	S6	1.5	30	S6		
Q46			0.9	180	S3	1.4	30	S1	2.4	30	S7	3.4	30	S7	5.6	30	S6	6.4	30	S6	7.4	30	S6		
Q47a			0.8	180	S3	1.5	180	S3	1.9	120	S3	2.4	120	S3	5.0	30	S6	6.1	30	S6	7.3	30	S6		
Q47b			0.9	180	S3	1.3	270	S6	2.2	30	S7	3.1	30	S7	5.5	30	S6	6.3	30	S6	7.3	30	S6		
Q48		Upstream Newbridge Road	2.5	540	S3	4.8	180	S3	6.6	120	S3	8.7	120	S3	13.6	90	S8	15.9	90	S8	18.6	90	S8		
Q49a			2.6	540	S3	5.1	270	S6	7.2	120	S3	9.4	120	S3	14.7	90	S8	17.1	90	S8	20.2	90	S8		
Q49b			2.1	180	S3	3.2	270	S6	4.1	120	S3	4.9	120	S3	8.2	30	S6	9.8	30	S6	11.4	30	S6		
Q50a			2.5	540	S3	3.6	270	S6	4.1	120	S3	4.6	120	S3	7.7	90	S8	9.2	90	S8	11.3	60	S8		
Q50b			0.5	540	S3	2.2	270	S6	3.8	120	S3	5.4	120	S3	7.1	90	S8	7.6	60	S2	8.3	60	S2		
Q50c			3.3	180	S3	5.6	270	S6	7.6	120	S3	9.3	120	S3	16.4	30	S6	17.2	30	S6	17.6	30	S6		

1. Peak flows less than 100 m^3/s have been quoted to one decimal place in order to show minor differences.
2. Refer **Figures 6.1** to **6.8** for location of Flow Location Identifiers.
3. Relates to storm duration that is critical for maximising the peak flood level at each location, not necessarily the peak flow.
4. Relates to temporal pattern that is critical for maximising the peak flood level at each location, not necessarily the peak flow.