FEDERATION COUNCIL

APPENDIX E
URANA

FEDERATION VILLAGES FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

MARCH 2022

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APPENDIX G
URANA

FEDERATION VILLAGES FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

MARCH 2022

Project **Federation Villages Floodplain Risk Management Study and Plan**	**Project Number** **118048**
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1. BACKGROUND

1.1. Study Area

The Urana township is located approximately 100 km northwest of Albury and 100 km southwest of Wagga Wagga. The Urana region has a population of approximately 384 (2016 Census) and 228 private dwellings. The township consists of a small urbanised area surrounded by farming and grazing land. Urangeline Creek runs adjacent to the eastern side of the township, just before discharging into Lake Urana which is approximately four kilometres to the west of the township. The study area is shown on Figure E1.

Urangeline Creek drains into Lake Urana, with a catchment area of approximately 2,370 km^2. Tributaries of Urangeline Creek include Boree Creek and Brookong Creek from the north and Washpool Creek, Sandhill Creek and a breakout from Billabong Creek via 'the Tombstones' from the south. The Urangeline Creek catchment is predominantly cleared rural land used for grazing and agriculture. However, the banks of the creek consist of dense riparian vegetation.

1.2. Land Use

The entire town of Urana is zoned as "RU5 Village" with the surrounding areas zoned as "RU1 Primary Production" as shown on Figure E2. There is a small area on the northeast corner of the study area zoned "E1 National Parks and Nature Reserves". Urangeline Creek is zoned as "Major River".

The major facilities in Urana include Federation Council-Urana Office (previously Urana Shire Council), Water treatment facility, Urana health services, Urana Public School, St Francis Xavier Primary School, St Fiacre's Church, as well as a variety of commercial buildings such as the former Urana Hotel, Urana Caravan Park, Aquatic Centre, cafe and newsagent.

The Urana Aquatic Centre is a man-made lake developed on the original site of the towns water supply reservoir. Drinking water is now supplied from Colombo Creek, treated at a filtration plant located within the region, and piped to the township. A railway line passes through the town on its southwest side, connecting neighbouring towns and transporting goods such as wheat and rice seasonally.

1.3. Demographic Overview

Understanding the social characteristics of the Study Area can help in ensuring appropriate risk management practices are adopted and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. According to The Bureau of Meteorology Flood Preparedness Manual (Reference 5), it is also possible, using population census data and other information held by councils and state agencies, to identify the potential number and location of people in an area (or the proportion of the community's population) with special needs or requiring additional support during floods. The Flood Preparedness Manual identifies that, in general, people who belong to the following groups may be considered especially susceptible to the hazards floods pose:

- **The elderly**, especially those living alone and/or frail, who are often unable to respond quickly or without assistance;
- **Those with low incomes**, including the unemployed and others on pensions, who may lack resources which would give them independence of decision making and action;
- **Single-parent families, large families or families with very young children**: these may be characterised by low adult: child ratios making evacuation difficult;
- **Those lacking access to a motor vehicle** may need additional assistance to evacuate;
- **Newcomers** (i.e. those residents in their communities for only short periods), who are unlikely to appreciate the flood threat and may have difficulty understanding advice about flooding. They may need special attention in terms of threat education and communication of warnings and other information;
- **Members of Culturally and Linguistically Diverse (CALD) communities**, who need special consideration with respect to the development of preparedness strategies as well as warnings and communications during flood events. Special attention may also be needed if actions which become necessary during floods offend cultural sensitivities;
- **The ill** or **infirm** who need special consideration with respect to mobility, special needs, medications, support and 'management' to ensure they continue to receive appropriate care and information; and
- **Those whose homes are isolated by floods**, requiring early evacuation, or if evacuation orders are ignored, may need medical evacuation resupply of essential items, or emergency rescue.

The following information has been extracted from the 2016 Census for the town of Urana and is relevant to the above considerations. Population characteristics are compared to the NSW average.

Urana Demographic Overview

Population: 384
No. of Private Dwellings: 228
No. of lone person households: 36
Property Tenure:

- 77% owned (either outright or with a mortgage)
- 20% rented

Language

- 76.3% of people speak only English at home

No. persons over the age of 75: 41
Elderly people are often frailer and may be unable to respond as quickly to flood emergencies without requiring some assistance.
No. single-parent families: 17
Single parent families can mean a low adult-to-child ratio within the household and therefore can make evacuation more difficult.

Statistics from:
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/UCL122155?opendocument

Table E1: Characteristics of Urana (Australian Bureau of Statistics, 2016)

Characteristic	Urana	NSW
Population Age:		
0 – 14 years	13.8%	18.5%
15 - 64 years	56.9%	65.%
> 65 years	29.3%	16.2%
Average people per dwelling	2.2	2.6
Own/mortgage property	77%	64.5%
Rent property	20%	31.8%
Other tenure type/not stated	3%	3.7%
No cars at dwelling	10.2%	9.2%
Speak only English at home	76.3%	68.5%

The characteristics noted above are considered in the community engagement strategy and when evaluating response modification options, such as flood education, warning or evacuation systems. Given the high proportion of English-only households, the delivery of community consultation material and flood warnings/ information in English is deemed appropriate. With a significant proportion of residents over the age of 65 years, online engagement strategies are not as likely to be as effective as face-to-face or postal communications. This was demonstrated in the initial community consultation period, discussed further in the main FRMS&P report, to which this report forms Appendix E.

In addition to communication strategies, census data can be used as an indicator of a community's vulnerability in regard to flood risk management. In particular, aged residents are more likely to be frail and physically unable to respond as quickly to flood emergencies. Provision of assistance to such residents should be a key consideration when developing flood evacuation systems and the lead time with which warnings are provided. The family composition within a residence can also affect flood awareness and capacity to respond. In Urana there are 36 lone person households, who are at greater risk of being unaware of flood warnings or evacuation orders. There are also a number of single-parent families, which can mean a low adult-child ratio and result in difficulties preparing for and safely undertaking evacuations.

1.4. Local Environment

Urana is surrounded by natural grasslands and agricultural paddocks (mainly cattle, sheep and dryland cropping), with relatively flat topography. It is surrounded by an expansive creek system including Billabong, Coonong, Urangeline, Yanco and Colombo Creeks. The Urangeline Creek catchment is predominantly cleared rural land used for grazing and horticulture. However, the banks of the creek consist of dense riparian vegetation. A site visit was undertaken by WMAwater staff on the 8th August 2018 to inspect the Study Area, specifically the flooding hotspots identified by the Council and to gather information on hydraulic structures such as bridges and culverts.

Lake Urana and its surrounding reserve are located west of the town, 4 km downstream of the township. The lake and reserve are a significant area of remnant vegetation and native flora and fauna. Public access and recreational use is currently not permitted in order to minimise environmental impact.

The use of on-site sewage management systems (OSSMS) in the Federation Council area has brought attention to the issues on the negative impacts of these systems. OSSMS are miniature sewage treatment plants. If poorly designed and maintained, it will cause problematic effects including public health risk, water pollution of local creeks/rivers, agricultural land degradation and local amenity issues. OSSMS is commonly used on properties on the outskirts of Urana where the current reticulated sewerage network does not reach. However, many of these properties are situated on large lots, allowing enough space for effective wastewater disposal. Urana is fortunate to be supplied potable drinking water by Riverina Water, however environmental protection of its surrounding expansive creek network, as well as Lake Urana and the reserve, is a high priority. Council recently adopted an OSSMS strategy in November 2018 providing a management framework, allowing effective regulation of the system as well as the protection of the environment and public health associated with the system (Federation Council 2018).

2. PREVIOUS STUDIES

2.1. Flood Study Report for Urana, Jacobs, 2017 (Reference 4)

The Flood Study Report for Urana, completed for Council in 2017 by Jacobs, provided an estimation of mainstream and local design flooding information for the town. Urangeline Creek is the main source of flood risk in Urana, and the creek drains a catchment area of approximately 2,370 km^2 to Lake Urana.

A thorough review of the flood models established in the Flood Study is documented in Section 4, and briefly summarised as follows:

- A broadscale hydrologic model (RORB) was established for the entire Urangeline Creek catchment to Lake Urana. Design flows were estimated based on ARR 1987 methodologies;
- The Billabong Creek MIKE11 hydraulic model was adopted (from Reference 12) to route flows from the RORB model, and to model the interaction between Urangeline Creek and Billabong Creek (and its various flood-runners), where the resulting hydrographs are used as inflows into the TUFLOW model;
- An XP-RAFTS hydrologic model was established to convert rainfall to runoff within the local catchment of Urana itself (using ARR 1987 methodologies); and
- A TUFLOW hydraulic model was developed to estimate design flood behaviour using mainstream inflows for Urangeline and Billabong Creeks from the MIKE11 hydraulic model, and local inflows from the XP-RAFTS hydrologic model.

Since no stream gauges are located on Urangeline Creek, the RORB model was calibrated through a simultaneous calibration process with the TUFLOW model against recorded flood marks for the 2012 event. Verification of the model was performed based on the 2010 and 2011 flood events where the modelled flood was compared against the documented flood behaviour. A total of 37 flood levels were provided by Yeo (2013) and the Federation Council, and were used to compare the modelled and surveyed flood levels. The flood levels modelled were within 0.1 m of the recorded levels upstream of the informal Urana levee and along Urangeline Creek. The modelled flood levels within the town were generally 0.1 to 0.4 m higher than the recorded flood marks. The Flood Study notes that this is most likely due to the fact that there was an informal 'levee' constructed along Brougong Street and sand bags were placed along Vardy Street and Anna Street which would have restricted the flows into the town around the existing levee

The key findings from the report on Urana are summarised below:

- Almost the entire length of Brougong Street excluding the section between Woodhouse Street and Church Street is flooded in the 20% AEP event and properties are subjected to yard flooding. One property located at the northern end of Brougong Street is surrounded by floodwater in the 20% AEP event. Properties located on the western side of Vardy Street are also subjected to yard flooding in the 20% AEP event;
- Sections of the levee are overtopped, and extensive flooding occurs on the area located on the western side of William Street and the northern side Woodhouse Street in the 5% AEP event;

- Properties bounded by Church Street to the south, Woodhouse Street to the north, Anna Street to the East and Brougong Street to the west are surrounded by floodwaters in the 2% AEP event;
- Almost the entire levee is overtopped in the 1% AEP event and additional properties along William Street, Church Street, Anna Street, Chapman Street and Osborne Street are subject to flooding;
- Properties located on both sides of Princess Street are subjected to flooding in the 0.5% AEP event; and
- All areas of the Township located on the western side of Princess Street are subject to more than 1 m depth of flooding in the PMF event and the Township is cut off from the adjoining areas.

2.2. Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood, Final Report, June 2013 (Reference 10)

This report was completed for the NSW State Emergency Service (SES) in 2013 by Yeo to develop an understanding of flood behaviour in the Riverina. The March 2012 event affected a number of towns and villages, including Tumbarumba, Greater Hume, Urana, Tumut, Gundagai, Wagga Wagga, Lockhart, Coolamon, Narrandera and Griffith. The report provides general information about the floods in the region, including rainfall data, flood extents, depths and levels and timing. For each of the villages reported on, the document provides a description of affected buildings, properties, roads and key response actions and evacuations. The key findings from the report on the town of Urana are provided below:

- The March 2012 flood is the highest recorded flood at Urana exceeding those from the 1930s;
- The Urana Aquatic Centre Dam and the Railway embankment immediately downstream significantly control flooding in the town downstream. It is reported that the embankment of the Dam was overtopped along most of its length to a maximum depth of up to 0.6 m and an approximately 10 m long section of the embankment on the eastern side of the spillway was breached. The embankment of the disused railway appeared to serve as a detention basin;
- A section of Federation Way south of Urangeline Creek bridge, east of Urana, was overtopped;
- During the March 2012 flood, the peak travel time between Boree Creek/ Lockhart and Urana is estimated to be approximately 33 hours;
- During the March 2012 flood event, at least 29 houses and 12 businesses flooded over the floor due to 135 mm of rain recorded at a private gauge;
- Floodwaters from Billabong Creek arrived at Urana approximately 3 days after the flood peaked at Rand; and
- Flood depths in Urana are relatively shallow (up to 1.0 m) and velocities in the town are generally slow.

2.3. Lockhart Flood Study, Final Report, WMAwater, 2014 (Reference 9)

The town of Lockhart is located 60 km southwest of Wagga Wagga, 56 km south of Narrandera and 97 km north of Albury in Lockhart Shire Council Local Government Area. The township of Lockhart experiences regular flooding from the Brookong Creek and also from major overland flow. Lockhart is located within the Urangeline Creek Catchment, and Brookong Creek flows into Boree Creek, which joins Urangeline Creek further downstream. Thus the catchment characteristics (and design losses) applied in the Brookong Creek catchment can be used to inform design parameters in the broader Urangeline Creek catchment (described further below).

The Lockhart Flood Study was completed in 2014 by WMAwater for Lockhart Shire Council (Reference 10). The scope of this study included defining the flood behaviour in the township of Lockhart under existing conditions (5-year ARI, 10%, 5%, 1%, 0.5% AEP events and the Probable Maximum Flood (PMF)). Brookong Creek at Lockhart has been subjected to numerous flood events in 1934, 1931, 1974 and 1939 (presented in order to magnitude). However, the 2012 and 2010 floods surpassed all previous flood events in terms of magnitude and damage. Therefore, the study used information from March 2012 and October 2010 events to ensure the hydraulic model could reproduce observed flood behaviour in the town. Design flood of 1% AEP resulted in near identical flood to the March 2012 event where approximately 70 residential and 28 businesses suffered from over floor inundation.

Information contained in the report regarding regional flooding information, historic flooding, hydrologic and hydraulic model parameters, setup and calibration are all useful to understand the flood behaviour around Lockhart. In particular, the study undertook a calibration (March 2012 event)/ validation (October 2010 event) events to determine the losses and adopted the initial loss of 15 mm for events up to and including the 10% AEP event and an initial loss of 10 mm for events between 5% and 0.2% AEP events. An initial loss of 0 mm adopted for the PMF event. A continuing loss of 2.5 mm/hr adopted for all design events and a continuing loss of 1 mm/hr adopted for the PMF event. These losses were adopted for design flood estimation in the Urana Flood Study (Reference 4).

2.4. Billabong Creek Floodplain Management Plan (Bewsher, 2002, Reference 12)

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

The MIKE11 model was subsequently used in Phase 2 of the study to estimate flow distribution in the floodway's for a range of floodplain management options. A floodway network was adopted in the Billabong Creek Floodplain Management Plan (DNR 2006) for which the adopted design flood was the flood event of 1983 (25-year average recurrence interval) in the vicinity of Urana. The flood event of 1974 (32-year average recurrence interval) was the design flood for the lower floodplain of Billabong Creek. The Billabong Creek MIKE11 model was adopted by the Flood Study to estimate inflows for the simulation of design flooding in Rand, Urana and Oaklands (Reference 4).

2.5. Murrumbidgee Valley Floodplain Management Study (Sinclair Knight & Partners, 1987 Reference 13)

The study was one of a series of studies carried out on major inland river valleys of NSW. A principal objective of the study was the preparation of an atlas of maps showing land subject to flooding. Billabong Creek was included in the Lower Murrumbidgee Floodplain Atlas. The atlas includes five plans for the Billabong Creek floodplain between Walbundrie and Jerilderie, at a scale of 1:100,000. The extent of flood affected land was based on the extent of inundation experienced in the 1974 flood, determined through a number of interviews with landholders. The floodplain management plan included alignment of a proposed levee to protect the town from flooding.

3. AVAILABLE DATA

3.1. Site Visit

A site inspection was carried out by WMAwater staff accompanied by Council staff on 8th August 2018 to gain an overall appreciation of the study area and to identify areas of Urana that experienced the greatest flood risk. The Aquatic Centre is also perceived to be a continuing factor to flooding in Urana. A subsequent site visit was undertaken on 17th August 2018 following the community consultation session to visit locations where issues had been raised by residents, including several culverts that had been noted to be of insufficient capacity. Figure E3 illustrates the site inspection photographs.

3.2. Topographic Data

Light Detection and Ranging (LiDAR) survey of the Study Area and its immediate surroundings were provided for the study by Land and Property Information (LPI). LiDAR is aerial survey data that provides a detailed topographic representation of the ground with a survey mark approximately every square metre. The data for the Urana area were collected in 2013 and was used for the 2017 Urana Flood Study (Reference 4). Grid data of 1 m, 5 m and 10 m squares were provided for the ground surface. The accuracy of the ground information obtained from LiDAR survey can be adversely affected by the nature and density of vegetation, the presence of steeply varying terrain, the vicinity of buildings and/or the presence of water. The horizontal accuracy of the data is 0.8 m at 95% confidence interval (CI), while the vertical accuracy is 0.3 m at 95% CI. A digital elevation model was sampled using the 1 m grid data. The data is projected in MGA55 with the GDA94 datum. Shuttle Radar Topography Mission (SRTM) data was also provided to produce a 30 m resolution DEM. Seven SRTM tiles covering the former Urana Shire area was provided, which was used to delineate catchment boundaries for Urangeline Creek. The ground levels are shown on Figure E4 based on model grid used in the Flood Study.

3.3. Aerial Photography

Aerial photography was provided by Council. Urana is covered by the ‘Urana’ tile, captured in 2008. It has a 0.5 m resolution and was provided as a geo-referenced raster.

3.4. Hydraulic Structures

Details of key hydraulic structures within the Study Area, including culverts and bridges, shown on Figure E5, were obtained from the Flood Study (Reference 4). A topographic survey undertaken as part of the Flood Study by TJ Hinchcliffe & Associates in 2015 provided the following:

- Details for 5 culverts (Culvert No. 2 and No 4-7) (including size, shape, invert level, top of the road, etc) (Table E2);
- Details for 4 bridges including deck and underside levels, length, width, railing height, location and width of piers and photographs.

  - o Collingullie-Jerilderie Road / Cocketgedong Road over Urangeline Creek
  - o Oaklands Railway Line bridge directly downstream of the Urana Dam spillway
  - o Oaklands Railway Line bridge just south of the Urana Dam spillway
  - o Oaklands Railway Line bridge crossing a small tributary of Urangeline Creek, south of Urana Dam
- Details of the Urana Aquatic Centre Dam (including spot heights along its embankments, details of the low-flow outlet and spillway, including photographs);
- Details of the Urana levee, extending approximately 480 m from Stephen Street to Chapman Street (including spot heights along its length and photographs); and
- Details of the two underground stormwater networks on Osborne and Chapman Streets. Details included the location, size, top level and invert levels of pits, pipe sizes and their outlet (downstream of the Urana levee).

Table E2: Culvert Details

ID	Location	Type	Width / Diameter (m)	Height (m)	Length (m)	No. barrels/ cells
2	Footbridge (Cocketgedong Road)	Circular	0.6	-	-	1
4	William Street	Box culvert	-	0.475	0.9	1
5	William Street	Box culvert	-	0.475	0.9	2
6	Federation Way	Circular	0.375	-	-	2
7	Footbridge	Circular	0.6	-	-	3
Levee	Through Levee at Anna Street	Circular	0.375	-	-	1

3.5. Pit and Pipe Network

Local stormwater drainage is conveyed towards Urangeline Creek and the Aquatic Centre via a series of roadside table drains and culverts beneath driveways, with a limited number of culverts beneath roads. The kerb and gutter system are intermittent and allows water to drain directly from roads into the adjacent table drains. Urana does not have a sub-surface stormwater drainage network, and as such, no pit and pipe details were provided.

3.6. Floor Level Database

A key outcome of the current study is a flood damages assessment. To complete this aspect of the study, floor level estimates are required to undertake a broad assessment of flood affectation. While the assessment uses floor level data for individual properties, the results are not an indicator of individual flood risk exposure but part of a regional assessment of flood risk exposure. For each property, the floor level estimation captured the following descriptors:

- Ground Level (in mAHD);
- An indication of house size (number of storeys);
- Location of the front entrance to the property; and
- Local Environmental Plans (LEP) land use (residential, commercial, industrial, primary production, or public recreation and infrastructure).

WMAwater used LiDAR data and visual inspection to estimate floor levels for all properties within the PMF extent. A summary of the total floor level estimates is provided in Table E3 below.

Table E3: Floor Level Database – Urana

Property Type	No. Included in Damages Assessment
Residential	171
Non-Residential	61
Total	232

3.7. Design Rainfall (ARR 2019) IFD

The design flood modelling inputs and methodology applied in Flood Study (Reference 4) were based on Australian Rainfall and Runoff 1987. Late in the Flood Study project in 2016, a substantial update to the ARR guidelines was released with a subsequent update released in 2019. Following discussion with NSW DPIE (then Office of Environment and Heritage) and Council, it was decided that the design flood modelling produced in the Flood Study was to be updated to implement the methodologies provided in ARR 2019, as these represent best practice and would increase the longevity of the outputs of the Study. ARR 2019 IFD information was obtained from the Bureau of Meteorology (BoM) via the ARR 2019 Data Hub, with IFDs and all other metadata provided in Attachment 1. Section 5 describes the processes used to update the hydrologic and hydraulic models to implement ARR 2019 methodologies.

4. FLOOD MODELLING REVISIONS AND UPDATES

The Flood Study for Urana (Reference 4) completed in November 2017 was completed by Jacobs for Federation Council (Council) in accordance with the NSW Government's Flood Prone Land Policy. The Flood Study aimed to determine design flood behaviour in the area based of ARR 87 methodologies and achieved this using hydrologic models (XP-RAFTS and RORB) and hydraulic models (MIKE11 and TUFLOW). The models were reviewed by WMAwater to determine the suitability for use in the Floodplain Risk Management Study and Plan (FRMS&P) and are described below. The review found that the models were largely fit for use in the FRMS&P with only minor revisions, as described below, as well as an update to ARR 2019 methodologies (See Section 5.2).

4.1. Hydrologic Modelling

4.1.1. XP-RAFTS (Local Overland Flow)

The local catchment draining to Urana village was modelled using XP-RAFTS (2018 version). The XP-RAFTS model was updated from Version 2013 to 2018 model for the efficient application of ARR 2019 methodologies (see Section 4.2.2.6).

4.1.1.1. Model Extent

The Flood Study (Reference 4) developed an XP-RAFTS hydrologic model that covered the local catchment to the Urana township, approximately 13.75 km^2, shown on Figure E6. The catchment boundary was reviewed in conjunction with the available LiDAR data confirming the boundary appropriately represented the total local Urana catchment. The local catchment boundary is located approximately 3.5 km northeast of town, running west to Lake Road and south to Butherwah Road. Urangeline Creek forms the downstream boundary of the local catchment, which is located entirely on the right bank (eastern side) of the creek.

The catchment was divided into 47 sub-catchments, delineated based on the 1 m LiDAR data, shown on Figure E5. The sub-catchment delineation was deemed appropriate and was adopted for use in the current Urana FRMS&P.

4.1.1.2. Model Parameters

The parameters used in the Flood Study for the XP-RAFTS hydrologic model simulation were investigated to assess the suitability of their application. The allocation of slope, impervious percentages and selection of hydraulic roughness values are considered suitable given the nature of development in Urana and relatively limited hardstand. XP-RAFTS model parameters have been adopted from the Flood Study (Reference 4) and are presented in Table E4.

Table E4: XP-RAFTS Parameters

Sub-catchment No.	Area (ha)	Slope (%)	Impervious fraction (%)	Hydraulic Roughness (Manning's 'n' value)
1	432.6	0.5	5	0.04
2	156.2	0.3	5	0.045
3	53.2	0.1	5	0.04
4	41.5	0.1	10	0.04
5	255.3	0.3	5	0.04
6	39.6	0.2	5	0.04
7	7.5	0.2	5	0.04
8	9.9	0.2	20	0.035
9	5.6	0.4	5	0.04
10	10.5	0.4	5	0.04
11	78.7	0.2	5	0.04
12	57.7	0.2	5	0.04
13	28.1	0.8	5	0.04
14	7.0	0.3	5	0.04
15	5.7	0.9	5	0.04
16	5.5	0.3	5	0.04
17	7.8	0.9	5	0.04
18	10.9	0.5	5	0.04
19	6.0	0.4	30	0.03
20	6.6	1.2	5	0.04
21	2.1	3.6	5	0.035
22	2.9	0.2	30	0.03
23	3.3	0.9	30	0.03
24	3.1	1.0	30	0.03
25	3.1	2.2	20	0.03
26	4.8	0.2	5	0.04
27	4.1	0.6	20	0.03
28	2.8	0.1	5	0.04
29	1.6	0.4	40	0.03
30	29.5	0.2	5	0.045
31	7.3	0.6	20	0.03
32	3.2	0.8	40	0.03
33	3.2	0.8	40	0.03
34	12.2	0.6	5	0.04
35	6.2	0.3	15	0.035
36	3.1	0.4	20	0.03
37	3.2	0.1	40	0.03
38	4.2	0.7	30	0.03
39	11.1	0.1	5	0.04
40	3.1	0.5	40	0.03
41	3.2	0.3	40	0.03
42	3.2	0.4	40	0.03
43	2.7	0.5	40	0.03

Sub-catchment No.	Area (ha)	Slope (%)	Impervious fraction (%)	Hydraulic Roughness (Manning's 'n' value)
44	5.1	1.1	10	0.035
45	2.9	0.8	40	0.03
46	12.6	1.6	5	0.04
47	5.6	0.9	5	0.04

4.1.2. RORB Model

4.1.2.1. Model Extent

The Urangeline Creek catchment to Lake Urana was modelled using RORB (version 6.42), which is commonly used in Australia with the capability to simulate both linear and non-liner catchment behaviour. The Urangeline Creek catchment covers an area of 2,370 km^2 and was delineated into 44 sub-catchments using 30 m SRTM DEM. The model was assigned a nominal impervious fraction of 5% across the catchment which is considered reasonable given the limited development within the catchment. The RORB extent and sub-catchment delineation were adopted for this FRMS&P without modification.

4.1.2.2. Model Parameters

The RORB model adopted the following parameters:

- Catchment linearity ('*m*') was retained at the recommended 0.8; and
- Catchment Lag *('kc')* value was set at 117.5 for the catchment.

The above parameters were adopted on the basis of calibration results, and were adopted for use in this FRMS&P without modification. It is noted that the RORB model established for the Billabong Creek catchment to Walbundrie (primarily for the Rand Flood Study), discussed in Appendix D, adopted the same 'm' value, and set the 'kc' value to 122.

Note: The RORB model was re-run to produce design discharge hydrographs using ARR 2019 methodologies. The IFD data, temporal patterns and loss parameters used in the design modelling are documented in Section 5. The discharge hydrographs from the RORB model are used as inflows into the MIKE11 hydraulic model, described below.

4.2. Hydraulic Model Review

4.2.1. MIKE11

The Flood Study (Reference 4) adopted the Billabong Creek MIKE11 model (produced by Bewsher, Reference 12) to a) route flows between the Urangeline Creek catchment and b) account for the interaction between Urangeline Creek and Billabong Creek upstream of Urana.

The MIKE11 model was used to simulate the discharge in Urangeline Creek (and flood runners of Billabong Creek) for the 20%, 10%, 5%, 2%, 1% AEP events and the PMF for application to the upstream boundary of the TUFLOW model. Inflow hydrographs produced by the RORB model for the design events were used as inputs in the MIKE11 model. Discharge hydrographs generated by the MIKE11 model at cross sections “URANGELINE 97507.5”, “TOMBSTONES 25100” and “U/S RAIL 1 4732.33” were used as the upstream inflows for the TUFLOW model

It is noted that the estimation of concurrent flooding assumed in the Flood Study (Reference 4), was consistent with the guideline outlined in Book VI of the Australian Rainfall and Runoff. The MIKE11 model and estimation of concurrent flooding was adopted for use in the FRMS&P without modification. The adopted relationships between concurrent flooding in Urangeline Creek and Billabong Creek (at Walbundrie), are presented in Table E5, which has been reproduced from the Flood Study (Reference 4) for ease of reference.

Table E5 Adopted Concurrent Flooding in Urangeline and Billabong Creek Catchments

Design flood event in Urangeline Creek	Concurrent design flood event in Billabong Creek @ Walbundrie
20% AEP	50% AEP
10% AEP	50% AEP
5% AEP	20% AEP
2% AEP	10% AEP
1% AEP	10% AEP
0.5% AEP	10% AEP
0.2% AEP	10% AEP
PMP	1% AEP

4.2.2. TUFLOW

A combined 1D-2D TUFLOW model was developed for Urana in the Flood Study (Reference 4). TUFLOW an industry-standard modelling platform well suited for use in FRMS&Ps as the DEM can be readily modified to efficiently assess a range of flood modification options such as levees, basins, and channel modifications.

In 2017, TUFLOW offered Heavily Parallelised Computing (HPC) an alternate 2D Shallow Water Equation (SWE) solver to TUFLOW Classic. Whereas TUFLOW Classic is limited to running a simulation on a single CPU core, HPC provides parallelisation of the TUFLOW model allowing modellers to run a single TUFLOW model across multiple CPU cores or GPU graphics cards. Simulations using GPU hardware has been shown to provide significantly quicker model run times than those modelled using CPU cores. As such, the TUFLOW model established in the Flood Study were updated and run using what is commonly referred to as ‘GPU’, using TUFLOW Version 2018-03-AB_iSP_w64. Results were compared to ensure both CPU and GPU produced consistent results, and the GPU models were adopted for use in the FRMS&P. This was particularly advantageous as updating to ARR 2019 is computationally demanding, and quicker model run times allowed for the efficient application of the ARR 2019 methodologies (described further in Section 5).

4.2.2.1. Model Extent

The TUFLOW hydraulic model extent (from the Urana Flood Study, Reference 4) includes a 2D domain of the catchment surface reflecting the catchment topography, with varying roughness as dictated by land use, and a 2D representation of the obstructions to flow, including buildings. The TUFLOW hydraulic model extent is covers an area of approximately 63 km^2, from approximately 1.4 km upstream of the Urana Aquatic Centre dam wall, to Lake Urana downstream centering on Urangeline Creek with a total width of approximately 8 km. The TUFLOW extent is presented on Figure E5 and is sufficient for providing a reliable estimate of the breadth of the PMF extent over the township.

4.2.2.2. Model Topography

The 2D model terrain used in the Flood Study (Reference 4) was derived from 1 m resolution LiDAR acquired in 2014, sampled to produce a 5 m grid (See Section 3.2). The grid size was selected to appropriately represent the flood behaviour and balance model run time. The DEM was adopted for use in the FRMS&P without modification as limited changes to the floodplain have occurred since it was collected. The DEM was used to represent small water courses across the study area

4.2.2.3. Bridges and Culverts

The model used in the Flood Study included four bridges and six culverts (shown on Figure E5). Three bridges were situated across the railway (two in the vicinity of Urana Dam and one to the south of the dam) and one bridge modelled Collingullie Jerilderie/Cocketgedong Road crossing Urangeline Creek. Three culverts were located under Federation Way, one through the levee, one culvert under the railway and one in the vicinity of the Brougong Street. The bridge and culverts were modelled as 2D and 1D elements, respectively, in the Flood Study using the data obtained from the topographic survey by TJ Hinchcliffe and Associates in 2015. The representation of hydraulic structures was considered appropriate and has been adopted for use in the current study without modification.

4.2.2.4. Buildings

The Flood Study (Reference 4), represented buildings by ‘nulling out’ structures from the computational grid to effectively exclude any flow from entering buildings. While this is not necessarily realistic (as the flow can enter buildings), it is an appropriate method that simulates the obstruction that buildings can impose on floodwaters. The buildings GIS layer was reviewed using aerial imagery from 2019 (GoogleEarth) to confirm no significant changes had occurred, and was adopted for use in the FRMS&P without modification.

4.2.2.5. Roughness Parameters

In the Flood Study (Reference 4), the catchment surface was assigned hydraulic roughness in accordance with the land use defined based on aerial imagery captured in 2010. Aerial photography of the area obtained from GoogleEarth in 2019 was reviewed, indicating no changes in the land use; therefore, the Manning's 'n' coefficients adopted in the Flood Study were applied in the current FRMS&P. Table E6 lists the Manning's coefficient applied to define catchment surface roughness while Figure E7 illustrates their spatial distribution.

The Manning's 'n' values assigned to densely vegetated area are considered to be at the upper limit of appropriate values, however have been adopted without modification for use in the FRMS&P. The spatial application of the Manning's 'n' coefficients was also deemed appropriate.

Table E6: TUFLOW model hydraulic roughness values

Land use type	Manning's 'n' value
Low-density residential area	0.08
Open rural area	0.045
Densely vegetated area	0.12
Road and paved areas	0.02
Creek	0.045
Medium-High density urban and commercial	0.035

4.2.2.6. Inflows - Overland Flow

The simulated hydrographs produced by the XP-RAFTS model were adopted as upstream inflow hydrographs in the TUFLOW model for overland flow in Urana. For sub-catchments within the TUFLOW model domain, local runoff hydrographs were extracted from the XP-RAFTS model. These were applied to the downstream end of the sub-catchments within the 2D domain of the hydraulic model. The location of these inflows are shown on Figure E5.

4.2.2.1. Inflows – Mainstream Flooding

Mainstream flooding in Urana is predominantly driven by flows in Urangeline Creek, however, is also subject to the influence of flood runners from Billabong Creek, which interact with Urangeline Creek upstream of Urana. To account for these inflows and floodplain interactions, TUFLOW inflow hydrographs are extracted from the Bewsher Billabong Creek MIKE11 model (rather than from the Urangeline Creek RORB model directly).

Design hydrographs were extracted from MIKE11 cross-section "URANGELINE 97507.5", "TOMBSTONES 25100" and "U/S RAIL 1 4732.33" and used as the upstream inflows for the TUFLOW model. The upstream inflow locations are shown on Figure E5.

4.2.2.2. Downstream Boundary Conditions

The TUFLOW model for Urana incorporated three downstream boundaries, including Lake Urana and two breakout locations to the north of the town. The lake boundary was a dynamic water level boundary extracted from the Billabong Creek MIKE11 model (adopted from Reference 12). The lake boundary was located approximately 4 km downstream of the town. Two normal depth conditions were applied at the breakouts north of town, which were located a sufficient distance from Urana to ensure the boundary conditions did not influence results in the Study Area. The location of the boundaries are shown on Figure E5.

5. DESIGN FLOOD MODELLING

5.1. Overview

Urana is affected by mainstream flooding from Urangeline Creek, as well as overland flow from the local catchment surrounding the town. The Urana Flood Study (Reference 4), used rainfall-runoff hydrologic models to estimate design hydrographs for both the mainstream and local runoff design flood behaviour:

- A RORB hydrologic model for the broader Urangeline Creek Catchment (with flows then routed to the TUFLOW inflow boundary via the MIKE11 model to account for complex floodplain interactions between Urangeline Creek and flood runners of Billabong Creek); and
- An XP-RAFTS hydrologic model for the local Urana catchment (with inflow hydrographs applied directly to the TUFLOW model).

The inputs and guidance for using these types of models come from Australian Rainfall and Runoff (ARR) guidelines, and as such, both are subject to revision under the updated ARR 2019 methodologies. The 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events have been simulated using the ARR 2019 guidelines. Broadly, the ARR2019 methodologies apply consistently across the two models, with some differences in terms of input data and parameters due to the different catchment locations, sizes and characteristics. The modelling approach is outlined in the subsequent sections, with specific inflow data and parameters for each model provided in Attachment 1.

The probable maximum precipitation (PMP) has also been simulated based on the Bureau of Meteorology (BoM) guidelines.

5.2. ARR 2019 Update

The Australian Rainfall and Runoff (ARR) guidelines were updated in 2016, and revised in 2019, due to the availability of numerous technological developments, a significantly larger dataset since the previous edition (1987) and development of updated methodologies. A key input to the process is information derived from rainfall gauges, and the dataset now includes a larger number of rainfall gauges which continuously recorded rainfall (pluviometers) and a longer record of storms, including additional rainfall data recorded between 1983 and 2012.

Three major changes have been made to the ARR 1987 approach (Reference 1) to develop ARR 2019 (Reference 2):

1. The recommended Intensity, Frequency and Duration (IFD) rainfall data, pre-burst, and initial and continuing loss values across Australia have been updated based on analysis of available records;
2. ARR 2019 recommends an ensemble assessment of 10 temporal patterns for each storm duration. The temporal pattern producing the mean level within each duration is selected. The *critical duration* is the duration for which the selected temporal pattern produces the maximum flood level;

3. The inclusion of Areal Reduction Factors (ARFs) based on Australian data for short (12 hours and less), long duration (larger than 24 hours) and durations between 12 and 24 hours.

Following discussion with the then NSW Office of Environment and Heritage (now DPIE) and Council, it was decided that the design flood modelling produced in the Flood Study was to be updated to implement the methodologies provided in ARR 2019, as these represent best practice and would increase the longevity of the outputs of the Study. The subsequent sections describe the application of ARR 2019 as they relate to local overland flow modelling in Urana (using the local XP-RAFTS model), and mainstream flooding in Urangeline Creek (using the RORB model). In addition, flood runners from Billabong Creek interact with and contribute to flooding in Urangeline Creek. Design flows in Billabong Creek are derived from another RORB model (covering the Billabong Creek to Walbundrie) established as part of the Rand Flood Study, and the update to ARR 2019 methodologies is documented in Appendix D to this FRMS&P.

5.3. ARR 2019 IFD Data

Design rainfalls (ARR 2019 IFDs) were obtained from the Bureau of Meteorology (BoM) for specific AEP and duration combinations across the catchment. The IFDs applicable to the local XP-RAFTS and Urangeline Creek RORB hydrologic models have been provided directly from the ARR 2019 Data Hub in Attachment 1.

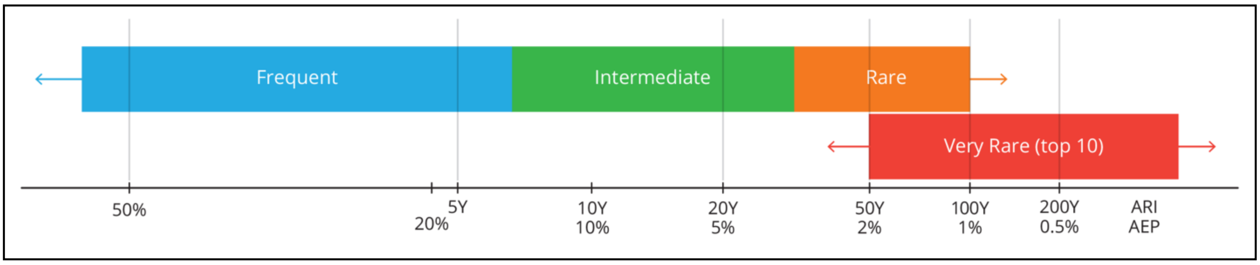
5.4. ARR 2019 Temporal Patterns

Temporal patterns describe the variation in rainfall intensity over the duration of a storm. Previously, with ARR 1987 guidelines (Reference 1), a single temporal pattern was adopted for each rainfall event duration. However, ARR 2019 (Reference 2) discusses the potential deficiencies of adopting a single temporal pattern. It is widely accepted that there is a large variety of temporal patterns possible for rainfall events of similar magnitude. This variation in temporal pattern can result in significant effects on the estimated peak flow. As such, the revised temporal patterns have adopted an ensemble of ten different temporal patterns for a particular design rainfall event. Given the rainfall-runoff response can be quite catchment specific, using an ensemble of temporal patterns attempts to produce the median catchment response.

As hydrologic modelling has advanced and more rainfall data has become available, the use of realistic temporal patterns allows a better understanding of the catchment response. The ARR 1987 temporal patterns only provided a pattern of the most intense burst within a storm, whereas the 2019 temporal patterns look at the entirety of the storm including pre-burst rainfall, the burst and post-burst rainfall. There can be significant variability in the burst loading distribution (i.e. depending on where 50% of the burst rainfall occurs an event can be defined as front, middle or back loaded). The ARR 2019 method provides patterns for 12 climatic regions across Australia, with the Urana catchment falling within the Southern Semi-arid region.

ARR 2019 provides patterns for each duration which are sub-divided into three temporal pattern bins based on the frequency of the events. Diagram E1 shows the three categories of bins (frequent, intermediate and rare) and corresponding AEP groups. At the time of the assessment, the "very rare" bin was unavailable, and temporal patterns from the Rare bin were used in this flood study update. There are ten temporal patterns for each AEP/duration in ARR 2019 that have been utilised in this study for the 20% AEP event to 0.2% AEP events.

Diagram E1: Temporal Pattern Bins



Temporal patterns for this study were obtained from the ARR 2019 data hub (Reference 2, http://data.arr-software.org/). A summary of the data hub information at the two catchment centroids (local and mainstream) is presented in Attachment 1. The method employed to estimate the PMP utilises a single temporal pattern (Reference 6).

5.5. Rainfall Losses

Both the local (XP-RAFTS) and mainstream (RORB) hydrologic models use initial and continuing loss parameters to represent the infiltration and evaporation mechanisms that reduce the amount of rainfall that is converted into runoff. The initial loss represents the wetting of the catchment prior to runoff starting to occur and the filling of localised depressions, and the continuing loss represents the ongoing infiltration of water into the saturated soils while rainfall continues.

5.5.1. Local Catchment (XP-RAFTS)

Design rainfall initial and continuing losses were obtained from the ARR 2019 data hub (http://data.arr-software.org/). Based on the recent guideline developed by NSW DPIE (Reference 11), in the absence of calibrated losses (i.e. calibrated to flows at a stream gauge) in the catchment or nearby, the continuing loss value provided by the ARR 2019 Data Hub is to be multiplied by a factor of 0.4. In the Urana local overland catchment, the continuing loss value provided by the ARR 2019 Data Hub is 0.0 mm/hr. This is used in conjunction with probability neutral burst initial loss values (presented in Attachment 1) which vary with AEP event and duration. A comparison of the design losses applied to the local catchment XP-RAFTS models are provided in Table E7.

Table E7 Urana Local Catchment – XP-RAFTS Model - Initial and Continuing Loss Parameters

Event	Flood Study (Reference 4) ARR 1987		FRMS&P (This Study) ARR 2019	
	Initial Loss (mm)	Continuing Loss (mm/hr)	Initial Loss (mm)	Continuing Loss (mm/hr)
20% AEP	15	2.5	16.15	0
10% AEP	15	2.5	11.4	0
5% AEP	10	2.5	11.8	0
2% AEP	10	2.5	11.1	0
1% AEP	10	2.5	10.2	0
0.5% AEP	10	2.5	10.2	0
0.2% AEP	10	2.5	10.2	0
PMF	0	1	0	1

5.5.2. Urangeline Creek Catchment (RORB)

Following guidance from DPIE (then OEH) (Reference 11), calibrated losses, where available, are to be used in preference to other loss estimates (such as the default ARR data hub values or FFA reconciled losses available through the ARR data hub). Given the Urangeline Creek catchment's proximity to the Billabong Creek catchment, and similar catchment characteristics (e.g. size, topography and soil types), it was deemed appropriate to adopt the continuing losses for each design event applied in the Billabong Creek to Walbundrie RORB model (documented fully in Appendix D). These were used in conjunction with probability neutral burst initial loss values (presented in Attachment 1) which vary with AEP event and duration. The adopted losses for overland and mainstream design flood estimation are provided in Table E8.

Table E8 Urangeline Creek RORB Model - Initial and Continuing Loss Parameters

Event	Flood Study (Reference 4) ARR 1987		FRMS&P (This Study) ARR 2019		Design Peak Discharges At Lake Urana (m^3/s)	
	Initial Loss (mm)	Continuing Loss (mm/hr)	Initial Loss (mm)	Continuing Loss (mm/hr)	RORB (ARR 1987)	RORB (ARR 2019)
20% AEP	15	2.5	18.9	2.1	61	60
10% AEP	15	2.5	18.4	2.1	99	116
5% AEP	10	2.5	18.5	2.1	192	176
2% AEP	10	2.5	16.8	2.5	261	226
1% AEP	10	2.5	12.4	2.5	338	306
0.5% AEP	10	2.5	12.4	2.5	424	387
0.2% AEP	10	2.5	12.4	2.5	551	508
PMF	0	1	0	1	7,797	7,797

Note: Different values for the continuing loss have been adopted for frequent events (20%, 10%, and 5% AEP) to calibrate to the flood frequency analysis at the Walbundrie Gauge.

5.6. Areal Reduction Factors

Areal Reduction Factors (ARF) are an estimate of how the intensity of a design rainfall event varies over a catchment, based on the assumption that large catchments will not have a uniform depth of rainfall over the entire catchment. The ARF were derived from the ARR 2019 Data Hub, and applied in the XP-RAFTS and RORB models for the full suite of design storm events. The ARF varies with AEP and duration and the resulting set of ARFs for the design storms are provided in Attachment 1.

5.7. Critical Duration Assessment

To determine the critical duration (the duration of rainfall over the catchment that will result in the greatest depth of flooding, or the greatest peak flow), two separate approaches were taken for each of the flood mechanisms present in Urana. These are described below:

5.7.1. Local Catchment

ARR 2019 recommends that an ensemble approach is used, where 10 temporal patterns (see Section 5.4) are analysed for each storm duration in the TUFLOW hydraulic model. Given the computational demands of so many model runs, the number of storm durations to be tested was shortlisted based on results from the hydrologic model, with the 1-hour to 6-hour durations found to result in the highest mean peak flows across the floodplain. Using the TUFLOW results for these durations, a representative temporal pattern was selected based on statistical analysis of the results of the ensemble (i.e. identification of the pattern producing peak flood levels just above the mean for the critical duration). Further description of the assessment method and box plots for each AEP duration are presented in Attachment 1. Table E9 presents a summary of the critical duration and adopted temporal pattern for each design flood event for the local catchment.

5.7.2. Urangeline Creek Catchment

The Urangeline Creek RORB model was used to determine the peak flows produced by each of the ten temporal patterns, across all storm durations, and each design flood event, using data from the ARR Data Hub (See metadata provided in Attachment 1) and continuing losses adopted from the Billabong Creek RORB model (see Appendix D). The peak flows resulting at the catchment outlet (Lake Urana) for each duration and temporal pattern were analysed to determine the duration that produced the highest mean flow, and within that duration, the ‘representative temporal pattern’ (i.e. the temporal pattern that produced the peak flow just above the mean peak flow). Further description of the assessment method and box plots for each AEP duration are presented in Attachment 1. Table E9 presents a summary of the critical duration and adopted temporal pattern for each design flood event.

Table E9: Adopted durations and temporal patterns for design flood events

	Local Catchment (XP-RAFTS)			Urangeline Creek Catchment (RORB)		
Event	**Critical Duration (min)**	**Adopted Temporal Pattern**	**Peak flood discharge (m^3/s) at the catchment outlet**	**Critical Duration (min)**	**Adopted Temporal Pattern**	**Peak flood discharge (m^3/s) at the catchment outlet**
20% AEP	540	TP7: 4075	16	1440	TP8: 4157	60
10% AEP	180	TP2: 3969	20	1440	TP10: 4148	116
5% AEP	180	TP2: 3969	25	1440	TP10: 4148	176
2% AEP	180	TP10: 3967	39	1440	TP4: 4105	220
1% AEP	180	TP10: 3967	47	1440	TP4: 4105	306
0.5% AEP	180	TP10: 3967	55	1440	TP4: 4105	392
0.2% AEP	180	TP10: 3967	66	1440	TP4: 4105	508
PMF	180	NA	518	2160	NA	7797

6. DESIGN FLOOD MODELLING RESULTS

6.1. Design Flood Behaviour

The hydrologic and hydraulic models described in Section 4 and the design flood inputs discussed in Section 5 have been used to estimate design flood behaviour for the 20%, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP events and the PMF. Results have been mapped for all investigated events, presented as an envelope of mainstream and overland flow flood mechanisms. The flood behaviour across the full range of design events is described below, and shown on Figure E8 to Figure E15 respectively.

6.2. Local Overland Flow

Runoff generated north of Urana (between Lake Road and Federation Way) generally ponds in low lying parts of the terrain outside Urana, before draining northwards and west, re-joining Urangeline Creek downstream (north) of Urana. This runoff does not pose a threat to properties within town itself, though may restrict access to the north and northeast, and standing water on fields may cause damage to crops and agricultural infrastructure. In the depression west of Federation Way (heading towards Oaklands) there is approximately 200 mm difference between peak flood levels in the 1% AEP event and the 20% AEP event. The scale between events is less pronounced in gently sloping areas, where overland flow remains shallow across a range of event magnitude.

Runoff generated in Urana itself typically drains in a south westerly direction towards Urangeline Creek, ponding in the vacant lots west of William Street. The existing informal levee south of Cocketgedong Road locally obstructs overland flow. Generally, overland flow generated on the eastern side of the railway embankment (parallel to Stephen Street) is retained on the south-eastern side of town, draining to Urangeline Creek via a swale running from Federation Way just downstream of the Aquatic Centre.

6.3. Mainstream Flooding

Running along the south-western edge of the town, Urangeline Creek is the main sources of mainstream flood risk in Urana. Out-of-bank flow occurs in events as frequent as the 20% AEP event, and 4 buildings are estimated to be flooded above floor level in events as frequent the 10% AEP event, as out-of-bank flow comes around the inside of the informal levee. Further breakouts occur downstream of Cocketgedong Road, indicating that, to be effective, a levee would need to extend beyond the developed part of town to the northwest. Table E10 provides peak flood levels at key road and railway crossings in the Urana Study Area as well as at Urana Public School and a property located on the north-west of the township, shown on Figure E5.

Table E10: Modelled peak flood levels at major waterway crossings

ID	Waterway Crossing	Soffit Level (m AHD)	Deck Level (m AHD)	Peak Flood Level (m AHD)				
				20% AEP	5%AEP	1%AEP	0.5%AEP	PMF
Bridge 8	Railway 1	116.98	117.48	115.86	116.47	116.84	117.02	119.17
E004	Lot 84//DP756447	115.21 (ground level)	NA	Not Flooded	115.39	115.84	116.04	118.61
E085	Urana Public School	116.39 (ground level)	NA	Not Flooded	Not Flooded	116.42	116.60	118.82
Bridge 1	Cocketgedong Rd	116.45	117.10	115.48	116.09	116.48	116.66	118.88

6.3.1. Comparison to Flood Study

A comparison of the peak design inflows at the upstream boundaries of the TUFLOW hydraulic model is provided in Table E11.

Table E11 Comparison of Design Mainstream Inflows

Design Event	FRMS&P (ARR 2019)		Flood Study (Reference 4) (ARR 1987)	
	Urangeline Creek (m^3/s)	Billabong Ck (m^3/s)	Urangeline Creek (m^3/s)	Billabong Ck (m^3/s)
20% AEP	-	-	74	26*
0.2EY	66	13	-	-
10% AEP	116	13	74	26*
5% AEP	171	29	226	3
2% AEP	216	34	308	3
1% AEP	283	34	381	4
0.5% AEP	348	34	437	3
0.2% AEP	423	34	502	19
PMF	844	2,840	844	2,840

A comparison between the 1% AEP peak flood levels is provided on Figure E16. In general, with the implementation of ARR 2019 methodologies (Section 5), the peak flood levels in Urangeline Creek are on average 0.25 m lower than the results from the Flood Study (Reference 4), which used ARR 1987. This corresponds with the reduction in inflows (from 381 m^3/s to 283 m^3/s in the 1% AEP). The areas subject to local overland flow, northeast of town, are much less sensitive to the change in methodologies, with the revised results falling within 0.1 m of the Flood Study Results. Values marked with an asterisk* have been reproduced directly from the Flood Study.

6.4. Hydraulic Hazard Classification

Hazard classification plays an important role in informing floodplain risk management in an area as it reflects the likely impact of flooding on development and people. In the Floodplain Development Manual (Reference 3) hazard classifications are essentially binary – either Low or High Hazard as described on Figure L2 of that document. However, in recent years there has been a number of developments in the classification of hazard especially in *Managing the floodplain: a guide to best practice in flood risk management in Australia (Third Edition)* (Reference 7).

The Flood Study (Reference 4) presents hazard categorisation mapping based on the Floodplain Development Manual, while this study presents revised mapping based on the methodology outlined in Reference 7. The classification is divided into 6 categories (H1-H6), listed in Table E12, which indicate constraints of hazard on people, buildings and vehicles appropriate to apply in each zone. The criteria and threshold values for each of the hazard categories are presented in Diagram E2.

Table E12: Hazard Categories

Category	Constraint to people/vehicles	Building Constraints
H1	Generally safe for people, vehicles and buildings	*No constraints*
H2	Unsafe for small vehicles	*No constraints*
H3	Unsafe for vehicles, children and the elderly	*No constraints*
H4	Unsafe for vehicles and people	*No constraints*
H5	Unsafe for vehicles and people	All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	Unsafe for vehicles and people	All building types considered vulnerable to failure

Diagram E2: Hazard Classifications

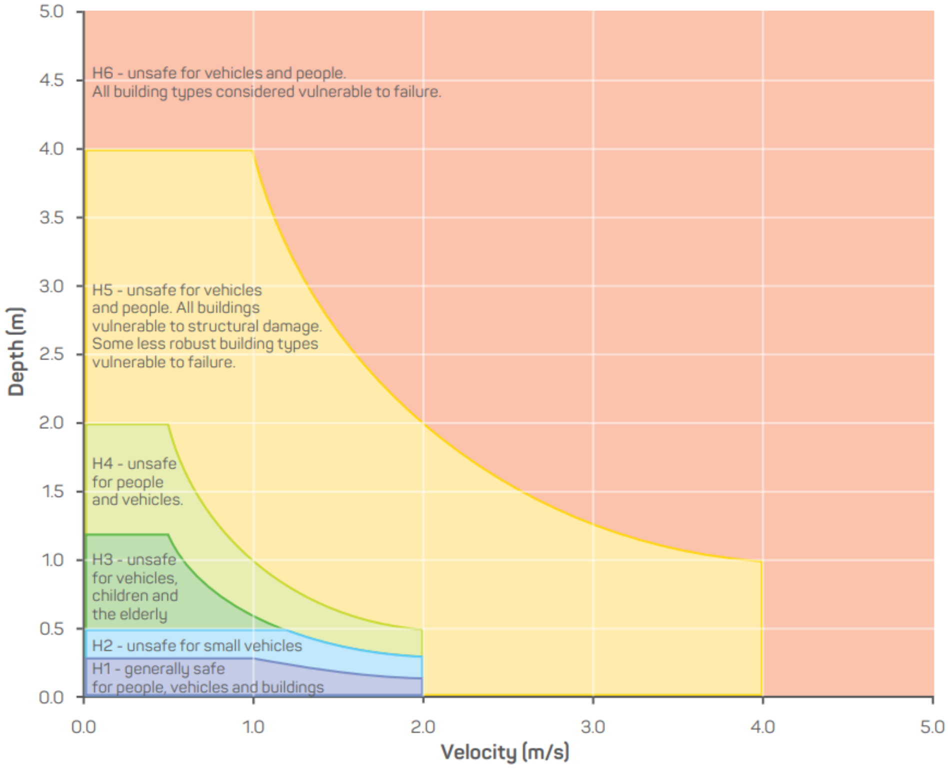


Figure E17 to Figure E19 present the hazard classifications based on the H1-H6 delineations for the 5% and 1% AEP events, as well as the PMF event, respectively. In the 5% and 1% AEP events, the majority of Urana township areas are classified as H1 "generally safe for people, vehicles and buildings". However, areas located in the western side of William Street are categorised as H3 "unsafe for vehicles, children and elderly" and cross-sections along the Talbot Street are classified as H5 "Unsafe for vehicles and people". In the PMF event, most parts of the developed area in Urana are categorised as H5, due to the Urangeline Creek breakout flows.

6.5. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the Floodplain Risk Management process to assist in the assessment of the suitability of future types of land use and development, and the formulation of floodplain risk management plans. The Floodplain Development Manual (Reference 3) defines land inundated in a particular event as falling into one of the three hydraulic categories listed in Table E13.

Table E13: Hydraulic Categorisation Definitions (*Floodplain Development Manual* (Reference 3))

Category	Definition
Floodway	• Those areas where a significant volume of water flows during floods; • Often aligned with obvious natural channels; • Areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which my adversely affect other areas; and • Often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
Flood Storage	• 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, for example by the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased; and • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
Flood Fringe	• 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.

To define the floodway, the Howells et al. (Reference 8) methodology was applied, which differentiates the floodway from other hydraulic categories by selecting a velocity-depth product criteria that exceeds a specific threshold. These parameters were confirmed iteratively through encroachment analysis, in which all areas not defined as 'floodway' were totally excluded from the modelling domain, and the subsequent impact on flood levels examined. If the reduction in conveyance area resulted in an increase of greater than 0.1 m to existing flood levels, the floodway area was increased. This approach is informed by Section L4 of the Floodplain Development Manual (Reference 3), which defines Flood Storage areas as *"those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%."* The resulting parameters are provided in Table E14.

Following application of these criteria, the resulting floodway areas were examined to ensure continuity of flowpaths, and to remove any isolated grid cells inappropriately classified as floodway (for example as an artefact of the modelling).

Table E14: Hydraulic Category Definition Parameters

Category	Floodway Definition Parameters
Floodway	$V \times D$ > 0.25 m²/s and V > 0.25 m/s, or V > 1.0 m/s and D > 0.0 m
Flood Storage	Areas outside floodway where D > 0.5 m
Flood Fringe	Areas outside floodway where D < 0.5 m

Hydraulic Categorisation for the 5% AEP, 1% AEP and PMF events are shown on Figure E20 to Figure E22, respectively. The analysis indicates that in the 5% AEP event, Urangeline Creek and its tributaries are classified as floodways. The majority of areas located within the developed areas of Urana's township are categorised as flood fringe. However, some properties behind the Urana levee were classified as floodway. In the 1% AEP event, most of the floodway remains within Urangeline Creek and its tributaries. Some areas located between Brougong Street and William Street were classified as floodways. In the PMF event, most of the Urana township becomes a floodway.

7. FLOOD RISK MANAGEMENT MEASURES

The FRMS process aims to identify and assess risk management measures which could be put in place to mitigate areas of unacceptable flood risk. The following section discusses the options considered specific to Urana, whilst the main report considers options relevant to all the Federation Villages.

The 2005 NSW Government's Floodplain Development Manual (Reference 3) separates risk management measures into three broad categories, outlined below:

Property modification measures modify existing properties, and land use and development controls for future new development or redevelopment. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase/voluntary house raising.

Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning, emergency services, and improved awareness and education of the community.

Flood Modification Measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered where practical.

The Federation Villages Floodplain Risk Management Study assessed a range of potential options for the management of flooding. A range of options are considered separately and discussed in the following sections.

7.1. Flood Modification Measures

Flood modification measures aim to change the behaviour of a flood (e.g. reducing flood levels or velocities or excluding water from particular areas). These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale, and in general, to be effective in the 1% AEP event.

Flood modification measures were identified by Council, Emergency Services or by members of the community (as part of the community consultation process) and through the examination of available flood modelling and identified hotspots; as having the potential to reduce flood risk at Urana. An initial hydraulic impact assessment has been undertaken for each identified option to determine its effectiveness in reducing flood risk, and to facilitate a general assessment of the option. Those which were identified as being potentially viable then underwent a more detailed assessment, from which the Floodplain Risk Management Plan recommendations are then derived.

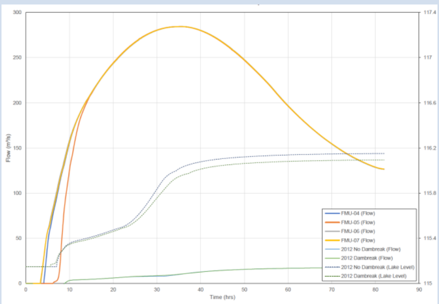
Types of flood modification measures can include,

- Retarding basins,
- Bypass floodways,
- Major channel or structure modifications,
- Levees and diversion embankments,
- Road raising and
- Local drainage upgrades.

Table E15 provides a summary of the flood modifications options considered for Urana.

Table E15: Flood modification options considered for Urana

ID	Configuration	Summary of Assessment	Recommended for FRMS&P
FMU-01: Urana Levee Upgrade alignment 1	This option looks to formalise and extend the informal levee in Urana to provide a 1% AEP level of protection. This requires raising the existing levels by 0.5 m – 3 m, and creating a levee with a total length of 2.6 km.	Refer to Figure E23. The results indicate that in a 1% AEP event (and more frequent events), Urana would be no longer flooded by Urangeline Creek. Outside of the levee, peak flood levels are increased by approximately 0.2 m, and the flood extent broadened to the west by approximately 300 m. The impacts extend to the upstream boundary of the hydraulic model, and just downstream of the proposed levee. It is noted also that the levee would form a major obstruction to overland flow draining towards Urangeline Creek, and that levee pipes would have to be included to allow for internal drainage. Option FMU-03 investigates opportunities for improving the local stormwater network through Urana, part of which involves levee pipes.	No, significant challenges, high costs, unlikely to be economically viable. Alternative preferred alignment (FMU-02)
FMU-02: Urana Levee Upgrade alignment 2	Similar to FMU-01 although a shorter levee alignment (2.2 km) that excludes two dwellings adjacent to Urangeline Creek.	Refer to Figure E24. The results indicate that in a 1% AEP event (and more frequent events), Urana would be no longer flooded by mainstream flooding from Urangeline Creek. Outside of the levee, peak flood levels are increased by approximately 0.2 m, and the flood extent broadened to the west by approximately 300 m (similar to FMU-01). It is noted also that the levee would form a major obstruction to overland flow draining towards Urangeline Creek, and that levee pipes would have to be included to allow for internal drainage. Option FMU-03 investigates opportunities for improving the local stormwater network through Urana, part of which involves levee pipes.	**Yes** (discussed in Section 7.1.1)
FMU-03: Stormwater drainage upgrade	This option involves a range of works to improve drainage in Urana. It assumes the levee is also raised. Works include duplication of Champan Street trunk drain, installation of additional pits and culverts, and regarding the levee.	Refer to Figure E25 (1% AEP overland flow event). Results in broad scale peak flood level reductions ranging from 0.01 m to 0.15 m through the urbanised area, across both roads and properties. The levee tail at the northern end of town however restricts the overland flow draining to the north (causing flow to back up inside of the levee), indicating that an additional levee pipe is needed at this location. Option should be coupled with regular maintenance.	**Yes** (discussed in Section 7.1.2)

ID	Configuration	Summary of Assessment	Recommended for FRMS&P
FMU-04: Aquatic Centre dam draw-down	This option considers drawing down the water level in the Aquatic Centre prior to the arrival of flood flows from Urangeline Creek or the breakout from Billabong Creek. The option models the initial dam level set to the current outlet invert (i.e. lowering the top water level by approximately 2.7 m, to RL 112.41 mAHD), creating an estimated capacity of 179,000 m^3.	Refer to Figure E26 (5% AEP) and Figure E27 (1% AEP). The additional storage reduces peak flood levels upstream of the railway embankment by up to 0.05 m. As the total available storage capacity of the option represents only 0.3% of the total inflow in a 1% AEP (and no more than 1.5% in the 20% AEP) it does not materially reduce the peak flow exiting the dam, and subsequently the peak flood levels observed downstream through town are not reduced.	No, provides no material change to flood risk.
FMU-05: Aquatic centre capacity upgrades	This option considers major expansion and excavation of the existing Aquatic Centre Dam upstream along Urangeline Creek to provide a significant amount of additional storage capacity with the aim of reducing the peak flow arriving downstream at Urana. An estimated 1.4 million cubic metres of earth would be excavated to create approximately 1.6 million cubic metres (1600 ML) of storage capacity, assuming the dam would be emptied prior to a flood event to mimic the maximum benefit that could be achieved from the increased capacity.	Refer to Figure E28 (5% AEP) and Figure E29 (1% AEP). The additional storage significantly reduces peak flood levels upstream of the railway, however peak flood levels downstream of the railway are unaffected as a result of flow filling the storage relatively quickly and backing up behind the railway embankment. In the context of the 1% AEP volume (59,300 ML) – the newly excavated storage can take only the first 3% of this volume. Peak flood levels downstream of the railway embankment (i.e. in Urana) are not reduced by this option, as the flow through the railway embankment is already constrained as is not materially reduced by the increased capacity. The graph below shows the peak flow during the 1% AEP event at Chapman Street under the various scenarios for utilising the Aquatic Centre for flood mitigation. It can be seen that the various scenarios change flood behaviour in smaller events but have no impact on the peak of the event. 	No, provides no material change to flood risk.

ID	Configuration	Summary of Assessment	Recommended for FRMS&P
FMU-06: Aquatic centre secondary spillway	This option considers extending the auxiliary spillway to 200m in length and lowering by 1m. This option aims to allow additional flow to move through the Aquatic Centre while directing flow away from the original outlet.	Refer to Figure E30 (1% AEP). The option results in peak flood level reductions of up to 0.1 m through the existing dam and upstream to the model boundary. The increased flow over the lowered spillway is again obstructed by the railway embankment, and peak flood levels are increased between the spillway and embankment by up to 0.1 m in a localised area. The results indicate that downstream of the railway embankment (i.e. in the urbanised part of Urana), peak flood levels are not materially altered, and there is no reduction in flood risk to properties or roads.	No, provides no material change to flood risk.
FMU-07: Aquatic centre dam outlet upgrade	The Aquatic Centre has been flagged by Council as potentially requiring condition assessment and replacement, which provides a potential future opportunity to optimise the outlet capacity and install an alternative gate operation arrangement. This would allow some control over the outflow from the Aquatic Centre (noting the assessment above has shown in large flood events there is insufficient capacity within the Aquatic Centre even with a substantial upgrade to materially alter peak flood levels). This option was modelled by duplicating the existing 1.2 m diameter circular culvert through the weir, and assumed the dam was full prior to arrival of a flood event.	Refer to Figure E31 (5% AEP) and Figure E32 (1% AEP). The effect on peak flood levels is limited, lowering levels in the dam and the southern fringe of the floodplain by less than 0.02 m and no change in flood levels downstream of the railway embankment. The capacity of the doubled pipe (13.5 m^3/s) represents only 5% of the peak 1% AEP flow (283 m^3/s) entering this area from upstream. Improvements to the outlet arrangement are unlikely to provide material improvements to flood levels during flood events. The assessment also considered a “sunny day” dam failure of the outlet embankment and structure. Upgrade of degraded embankment and outlet will provide some protection to the town due to this type of failure mechanism.	Not as a flood mitigation strategy, provides no material change to flood risk. Improvements to the existing spillway and outlet could prevent “sunny day” events and minor flooding. Council could seek funding via alternative opportunities.
FMU-08: Aquatic centre combined options	This option was modelled to investigate the impact of combining Option FMU-04 (dam drawdown), FMU-06 (secondary spillway) and FMU-07 (Dam Outlet Upgrade).	Refer to Figure E33 (1% AEP). Peak flood levels are reduced upstream of the railway embankment, however downstream (i.e. in the village itself), peak flood levels are unchanged. The effect of the railway (Rock-Oaklands Railway line) is such that any works in the Aquatic Centre are rendered ineffective, as the embankment forms a significant hydraulic control already limiting flow. In addition, there are substantial challenges associated with modifying the railway embankment as it currently presents a significant constraint to flow reaching town.	No, as with the individual options, this option showed no material change to flood risk.

ID	Configuration	Summary of Assessment	Recommended for FRMS&P
FMU-09: Vegetation management	Manning's 'n' values modified by +/- 20% to represent changing vegetation cover.	Refer to Figure E36 (5% AEP) and Figure E37 (1% AEP). Limited consistent impacts on flood behaviour, up to 0.1m in both the 5% and 1% AEP event, therefore not recommended as a specific flood management measure. However, ongoing Council works for environmental / weed management should be maintained.	No, does not materially reduce flood risk. There are opportunities through other Council programs (such as environmental/weed management) to maintain vegetation levels.
FMU-10: Coonong Street Bund	An overland flow path moves from the east of Coonong Street and through town between Chapman and Osborne Streets towards the existing levee. A small bund is proposed along the unnamed street to the east of Coonong Street by raising a section adjacent to the road by 0.3m.	Refer to Figure E34 (1% AEP). Limited consistent impacts on flood behaviour, up to 0.1m in both the 5% and 1% AEP event, therefore not recommended as a specific flood management measure. However, ongoing Council works for environmental / weed management should be maintained.	Not as a flood mitigation strategy, provides negligible impacts on property inundation. Can provide benefits to nuisance flooding.
FMU-11: Cocketgedong Road Causeway	During observed flood events portions of Cocketgedong Road between Urangeline Creek and the existing town levee have been damaged and washed away. This option considers the installation of a causeway at this location to minimise damage to the road.	Refer to Figure E35 (1% AEP). The installation of a causeway results in broadscale minor (up to 0.05m) reductions in flood level upstream of the proposed causeway in the 1% AEP event. This option is not recommended as a specific flood management measure but should be considered to reduce damage and improve access following flood events.	Not as a flood mitigation strategy, provides no material change to flood risk. Improvements to the road will prevent damage and reduced access following flood events.
FMU-12: Tombstones Causeway	During observed flood events the crossing of Federation Way at the Tombstones flowpath has been observed as undersized, directing flood flows towards town. This option considers what would be an appropriately sized causeway or structure at this location to reduce the flow diversion.	This structure is not included in the hydraulic model extent and can not be assessed using the hydraulic model. Flow estimates through the Tombstones flowpath are available from the Flood Study and can be used to determine the structure capacity required. During the 5% AEP the peak flow at this location is 28.7m^3/s and 34.3m^3/s for the 1% AEP event.	Not as a flood mitigation strategy. Improvements to the structure should be investigated and undertaken as part of regular road maintenance.

7.1.1. Option FMU-02: Urana Levee Upgrade Alignment 2

7.1.1.1. Option Description

This option considers formalising and raising the Urana Levee to provide a 1% AEP level of protection (with a freeboard allowance of 0.5 m). The proposed alignment covers 2.2km in length and involves raising levels by 0.5 m – 3m.

7.1.1.2. Option Assessment

Modelled Flood Behaviour
The levee has been assessed to determine its impact on mainstream flooding from Urangeline Creek, with modelled changes in peak flood levels shown on Figure E24. The elevation of the levee was based on the peak flood levels in a 1% AEP event + 0.5 m freeboard. The results indicate that in a 1% AEP event (and more frequent events), Urana would be no longer flooded by mainstream flooding from Urangeline Creek.

Outside of the levee, peak flood levels are increased by approximately 0.2 m, and the flood extent broadened to the west by approximately 300 m. The increased flood levels do not appear to affect any dwellings or other buildings, however would exacerbate the flood risk on Cocketgedong Road and potentially Federation Way (which is outside of the hydraulic model extent). Further investigation into the effect of flood level increases on agricultural land and key access routes would be required. Flood levels are unchanged upstream of the Aquatic Centre.

The levee would form a major obstruction to overland flow draining towards Urangeline Creek, and that levee pipes would have to be included to allow for internal drainage. Option FMU-03 investigates opportunities for improving the local stormwater network through Urana, part of which involves levee pipes.

Costs and economic viability
Costs for upgrading and extending the existing Urana levee stem from design, earthworks and ongoing maintenance. Additionally, compensatory works to offset potential third party impacts. These are likely to be substantial and will depend on the site-specific challenges, including potential acquisition of land. Costs of the works are estimated to be approximately $2,860,000 (plus annual maintenance of $10,000).

Average annual damages were calculated assuming the option is in place, which provided a reduction to the AAD of $109,400 (48%). This equates to a Net Present Value of $1,615,488 assuming an effective asset life of 50 years and a 7% discount rate, and results in a BCR of 0.54. Option FMU-03 assesses the combined levee and drainage upgrade option.

Social and environmental impacts
The option provides benefit to property and building inundation, as well as likely to reduce nuisance ponding from heavy rainfalls, and is therefore likely to be generally well received. There are a small number of properties which would not be included within the protected area and other offsetting measures will need to be considered through detailed design.

There is unlikely to be negative environmental impacts, however standard sediment and erosion control measures would be required during construction. In parts the levee will need to be raised by a number of metres and the visual amenity considerations may need to be considered.

Financial viability
The option provides benefit to residential properties in all design events modelled (noting that there is one newly flooded above floor property in the 20% AEP event although under the current conditions it is flooded above the floor level in a 10% AEP event however, this requires further investigation), and is therefore eligible for grant funding. This option has a higher cost benefit than Option FMU-01 which is a longer levee.

7.1.1.3. Recommendation

FMU-02: Urana Levee Upgrade Alignment 2
☑ Further investigation/design of the Urana Levee upgrade is recommended.

7.1.2. Option FMU-03: Combined Levee Plus Culvert/Stormwater Improvements

7.1.2.1. Option Description

During the community consultation period, residents raised concerns regarding poor stormwater drainage within Urana following periods of rainfall. Without a complete sub-surface stormwater drainage network, local runoff is conveyed towards Urangeline Creek and the Aquatic Centre via a series of roadside table drains and culverts beneath driveways, with a limited number of culverts beneath roads. The kerb and gutter system is intermittent and allows water to drain directly from roads into the adjacent table drains.

This option involves a range of works to improve drainage in Urana, and reduce nuisance flooding and ponding over roads, intersections and driveways. The works involved:

- Assumption that levee is raised (as either Option FMU-01 or FMU-02);
- Duplication of the Chapman Street trunk drain;
- Installation of additional pits and culverts through Urana; and
- Regrading inside the levee to facilitate improved drainage to low points (and into levee pipes) out to Urangeline Creek.

Locations of proposed pits, culverts, trunk drains and earthworks are indicated on Figure E25.

7.1.2.2. Option Assessment

Modelled Flood Behaviour

The effect of the above works on peak flood levels in the 1% AEP overland flow event is shown on Figure E25. The works result in broad scale peak flood level reductions ranging from 0.01 m to 0.15 m through the urbanised area, across both roads and properties. This provides a benefit compared to existing conditions, which, as shown on Figure E12 generally consist of shallow inundation and areas of ponding less than 0.3 m deep.

The levee tail at the northern end of town however restricts the overland flow draining to the north (causing flow to back up inside of the levee), indicating that an additional levee pipe is needed at this location.

The impacts on property affectation (both residential and commercial) are shown in Table E16 below (where negative values show the number of properties no longer impacted compared to the base case, and positive show newly flooded properties).

Table E16: Option impacts on property affected (relative to base case)

Event	Change in number of Properties Affected	Change in number of properties flooded Above Floor Level
20% AEP	-3	1
10% AEP	-7	-2
5% AEP	-12	-4
2% AEP	-20	-12
1% AEP	-48	-29
0.5% AEP	-47	-53
0.2% AEP	-71	-74
PMF	-113	-158

This shows that one property is newly flooded above floor in the 20% AEP, this should be further investigated to confirm validity and may require modification to the option to avoid.

Costs and economic viability

The capital costs of the work would derive from design, earthworks and pipe / culvert installation, pumps, as well as works to the levee, including ongoing maintenance. These are likely to be substantial and will depend on the site specific challenges (such as presence of existing sub-surface services and potential acquisition of land). Costs of the works are estimated to be approximately $3,370,000 (plus annual maintenance of $10,000). Average annual damages were calculated assuming the option is in place, which provided a reduction to the AAD of $116,800 (52%) assuming an envelope of overland and mainstream flooding. This equates to a Net Present Value of $1,724,762 assuming an effective asset life of 50 years and a 7% discount rate, and results in a BCR of 0.49.

Social and environmental impacts

The option provides benefit to property and building inundation, as well as likely to reduce nuisance ponding from heavy rainfalls, and is therefore likely to be generally well received. There are a small number of properties which would not be included within the protected area and other offsetting measures will need to be considered through detailed design. There is unlikely to be negative environmental impacts, however standard sediment and erosion control measures would be required during construction. In parts the levee will need to be raised by a number of metres and the visual amenity considerations may need to be considered. Flap values should be considered for any structure passing through the levee to prevent backflow. Any upgrade works should be coupled with a regular maintenance to ensure drains and structures remain clear of debris.

Financial viability

The option provides benefit to residential properties in all design events modelled (noting that there is one newly flooded above floor property in the 20% AEP event, however this requires further investigation), and is therefore eligible for grant funding.

7.1.2.3. Recommendation

FMU-03: Stormwater Drainage Upgrades	
☑	Further investigation/design stormwater drainage upgrades in Urana.

7.1.3. FMU-11: Coonong Street Bund

7.1.3.1. Option Description

This option has been identified by members of the Floodplain Management Committee. An overland flow path moves from the east of Coonong Street and through Urana between Chapman and Osborne Streets. The flow path then moves through existing table drains towards the town levee. The spread of the flowpath is exacerbated by the intermittent kerb and gutter system. While the flow path does not cause over floor inundation to properties, it results in inconvenience to motorists.

This option involves the construction of a small bund adjacent to the unnamed street to the east of Coonong Street to deflect the overland flow path. The bund is 0.3m high.

Location of the proposed bund is shown on Figure E38.

7.1.3.2. Option Assessment

Modelled Flood Behaviour

The effect of the above works on peak flood levels in the 1% AEP overland flow event is shown on Figure E39. The works result in a deflection of the overland flow path towards Osborne Street, newly flooding some areas. There is also a reduction in flood levels through the existing flow path including areas that are no longer flooded. Peak flood level reductions of up to 0.05m occur. This provides a benefit compared to existing conditions, which, as shown on Figure E12 generally consist of shallow inundation and areas of ponding less than 0.15 m deep.

The impacts on property affectation (both residential and commercial) are shown in Table E17 below (where negative values show the number of properties no longer impacted compared to the base case, and positive show newly flooded properties).

Table E17: Option impacts on property affected (relative to base case)

Event	Change in number of Properties Affected	Change in number of properties flooded Above Floor Level
20% AEP	-2	0
10% AEP	0	0
5% AEP	0	0
2% AEP	0	0
1% AEP	-1	0
0.5% AEP	0	0
0.2% AEP	-1	0
PMF	-3	-1

This shows that one property is no longer flooded overfloor in the PMF event. The other property benefits are related to the property lot and not the building.

Costs and economic viability

The capital costs of the work would derive from design and earthworks, including ongoing maintenance. There may be some site specific challenges (such as presence of existing sub-surface services and potential acquisition of land). Average annual damages were calculated assuming the option is in place, which provided a reduction to the AAD of $1,700 assuming an envelope of overland and mainstream flooding. This equates to a Net Present Value of $25,104 assuming an effective asset life of 50 years and a 7% discount rate. The approximate capital cost of the bund would be around $300,000, assuming an annual maintenance cost of $5,000 would result in a BCR of 0.07. It should be noted that this BCR considers only the direct impacts on properties and does not consider benefits to road user inconvenience.

Social and environmental impacts

The option provides limited benefit to property and building inundation, but does reduce nuisance ponding from heavy rainfalls, and is therefore likely to be generally well received. There is unlikely to be negative environmental impacts due to the removal of flow from the already developed flow paths. During construction standard sediment and erosion control measures would be required.

The proposed bund is relatively small and therefore visual amenity is not of concern.

Financial viability

This option is unlikely to be eligible for grant funding due to the negligible impacts on property inundation and low BCR. However, there may be benefits in constructing the proposed bund to minimise nuisance flooding.

7.1.3.1. Recommendation

FMU-11: Coonong Street Bund	
☒	Option FMU-11 is not recommended as a flood risk management measure due to the negligible impacts on property inundation.
☑	It is recommended for Council to undertake the minor works to minimise nuisance overland flow flooding.

7.2. Property Modification Measures

7.2.1. PMU-01: Voluntary House Raising

7.2.1.1. Option Assessment

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL). This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain, such as the need to evacuate prior to properties being isolated by floodwaters.

VHR schemes are eligible for state government funding based on criteria set out in the *Guidelines for Voluntary House Raising Schemes* (Reference 14). In accordance with these guidelines, VHR is generally excluded for properties located within floodways; is limited to low hazard areas; and applies only to houses constructed before 1986. House raising is most suitable for non-brick single storey buildings on piers, and is typically not feasible for slab-on-ground constructions. However, advances in construction techniques and other alternatives may make house raising a viable option for slab-on-ground properties, and therefore individual assessments are required. Repurposing the ground floor for non-habitable use and constructing a second story (above the FPL) for habitable uses may also be a possibility. The VHR guideline states that "*VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomical"*.

Outputs from the flood damages assessment and classification of the floodplain into hydraulic categories and hazard classifications have been used to identify residential dwellings that are located outside of the floodway and within low to moderate hazard areas only (H1 to H3) and are inundated over floor in events up to and including the 1% AEP event under current conditions. Two properties in Urana met this criteria.

Costs of house raising is typically in the order of $60,000 although is highly variable and dependant on the specific property and building characteristics. An economic assessment of the option was undertaken and presented below, using a 70-year effective life of the house raising assuming the properties are raised to the 1% plus 300mm level, and allowing for a 20% contingency factor. The option was tested for both 4%, 7% and 10% discount rates, and for raising one or both properties, with the results shown below (note, the results are the same when AAD is rounded, for raising properties individually due to a very similar level of flood impacts at the two properties).

Table E18: VHR economic assessment for Urana

Option	NPV Costs	Change in AAD	NPV Benefits	Discount rate	BCR
Raising both properties	**$114,000**	**$5,787**	**$87,682**	**7%**	**0.61**
			$140,799	4%	0.98
			$63,576	10%	0.44
Raising individual properties					
Prop E039	$72,000	$2,925	$44,318	7%	0.62
Prop E220	$72,000	$2,861	$43,349	7%	0.60

This shows that a voluntary house raising scheme is unlikely to be economically viable, unless the costs of VHR are found to be substantially lower than currently estimated.

7.2.1.1. Recommendation

PMU-01: Voluntary House Raising

A VHR scheme is not recommended for Urana.

7.2.1. PMU-02: Voluntary Purchase

Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard. VP is recognised as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;
- A property is located within a floodway and tis removal may contribute to a floodway clearance program that aims to reduce significant impacts of flood behaviour elsewhere in the floodplain by improving the conveyance of the floodway; or
- Purchase of a property enables other flood mitigation works to be implemented (e.g. channel improvements of levee construction).

In the NSW Government *Guidelines for Voluntary Purchase Schemes* (Reference 15), the eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property, and that subsidised funding is generally only available for residential properties. Once a dwelling is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development. The Guideline further sets out the way in which a VP scheme should be undertaken and how properties should be valued.

To understand the suitability of Voluntary Purchase in the Federation Villages, a first-pass assessment was undertaken to identify the locations of dwellings in relation to the floodway. Dwellings situated inside the 1% AEP floodway extent may be eligible for voluntary purchase, as their removal would reduce the number of occupants in highly hazardous areas, as well as reduce obstruction to flow caused by the dwelling itself. This process identified two potential properties for a voluntary purchase scheme.

The median house price for residential properties in Urana is $114,000 (realestate.com.au as of 24 February 2021). An economic assessment of the option was undertaken and presented below, using a 100-year effective life of the house raising. The option was tested for both 4%, 7% and 10% discount rates, and for purchasing one or both properties. The damages were derived based on existing flood behaviour (that is, no change in flow behaviour as a result of the buildings removal is accounted for in the damages).

Table E19: VP economic assessment for Urana

Option	NPV Costs	Change in AAD	NPV Benefits	Discount rate	BCR
Purchasing both properties	**$228,000**	**$17,434**	**$266,184**	**7%**	**1.17**
			$444,309	4%	1.95
			$191,760	10%	0.84
Purchasing individual properties					
Prop E001	$114,000	$3,149	$48,079	7%	0.42
Prop E207	$114,000	$14,285	$218,105	7%	1.91

7.2.1.1. Recommendation

PMU-02: Voluntary Purchase

☑ Undertake a VP feasibility study to determine viability of a scheme, including consultation with the identified properties, and if appropriate, prepare the documentation for funding applications.

7.3. Summary of Recommended Options

The following management options specific for the Boree Creek catchment are recommended.

Reference	Name	Type
FMU-02	Urana Levee Upgrade (Alignment 2)	Flood modification
FMU-03	Stormwater Drainage Upgrades	Flood modification
FMU-10	Coonong Street Bund	Flood modification
FMU-11	Cocketgedong Road Causeway	Flood modification
FMU-12	Tombstones Causeway	Flood modification
PMU-02	Voluntary Purchase	Property modification

These will be further assessed in the overarching FRMS and in turn prioritise for implementation as part of the FRMP.

8. REFERENCES

1. Pilgrim DH (Editor in Chief)
Australian Rainfall and Runoff – A Guide to Flood Estimation
Institution of Engineers, Australia, 1987.

2. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)
Australian Rainfall and Runoff – A Guide to Flood Estimation
Commonwealth of Australia (Geoscience Australia), 2019

3. NSW Government
Floodplain Development Manual
April 2005

4. Jacobs
Flood Study Report for Urana
Federation Council, November 2017

5. Australian Government (Attorney – General's Department)
Flood Preparedness (Manual 20)
Australian Emergency Manuals Series
2009

6. Bureau of Meteorology
The Estimate of Probable Maximum Precipitation in Australia: Generalised Short Duration Method
June 2003

7. Australian Institue for Disaster Resilience
Technical Flood Risk Management Guideline: Flood Hazard
Second edition, 2017

8. Howells, L., McLuckie, D., Collings, G. and Lawson, N.
Defining the Floodway – Can One Size Fit All?
Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes
February 2003

9. WMAwater
Lockhart Flood Study Report
Lockhart Shire Council, 2014

10. Yeo, S
Flood Intelligence Collection and Review for 24 Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood
Volume 1 and 2 Final Report, prepared for State Emergency Service (SES), January 2013

11. Office of Environment and Heritage
Floodplain Risk Management Guide
Incorporating 2016 Australian Rainfall and Runoff in Studies
January 2019

12. Bewsher Consulting PTY LTD,
Billabong Creek Floodplain Management Plan, Phase A: Data Review and Flood Behaviour
Main Report, prepared for NSW Department of Land and Water Conservation, June 2002

13. Sinclair Knight & Partners
Murrumbidgee Valley Floodplain Management Study
1987

14. NSW Government
Floodplain Management Program
Guidelines for voluntary house raising scheme
February 2013

15. NSW Government
Floodplain Management Program
Guidelines for voluntary purchase scheme
February 2020

Attachment 1

1. ARR 2019 Data Hub Metadata

The metadata provided in this section has been downloaded directly (or calculated as required) from http://data.arr-software.org/, originally accessed in April 2019.

1.1. Local Catchment Model (XP-RAFTS)

1.1.1. IFD Data

Design rainfall depths (mm) at the Urana local catchment centroid (35.3375 , 146.2875)

Duration	AEP							
(min)	20%	0.2EY	10%	5%	2%	1%	0.5%	0.2%
15	14.8	15.1	17.7	20.6	24.4	27.4	31.0	35.5
30	19.7	20.1	23.6	27.5	32.7	36.8	41.6	47.7
45	22.6	23.1	27.1	31.7	37.7	42.5	48.0	55.1
60	24.7	25.2	29.7	34.6	41.3	46.5	52.5	60.3
90	27.8	28.4	33.3	38.9	46.3	52.1	58.9	67.6
120	30.1	30.7	36.0	42.0	49.9	56.1	63.5	72.9
180	33.6	34.2	40.0	46.5	55.2	62.0	70.0	80.3
270	37.4	38.1	44.4	51.3	60.8	68.1	77.0	88.2
360	40.4	41.2	47.8	55.1	65.1	72.9	82.4	94.3
540	45.0	45.9	53.0	60.9	71.8	80.4	90.9	104
720	48.6	49.6	57.2	65.5	77.3	86.4	97.8	112
1080	54.2	55.3	63.6	72.7	85.9	96.2	109	124
1440	58.3	59.5	68.5	78.4	92.8	104	118	135
1800	61.7	62.9	72.4	83.1	98.6	111	125	143
2160	64.4	65.7	75.7	87.0	104	117	131	151
2880	68.6	70.0	80.9	93.2	112	126	142	164
4320	74.1	75.6	87.8	102	123	139	158	183
5760	77.5	79.0	91.9	107	129	148	167	195
7200	79.7	81.3	94.5	109	133	152	172	202
8640	81.1	82.8	95.9	111	135	154	175	205
10080	82.1	83.8	96.7	111	135	155	175	205

1.1.2. Areal Reduction Factors

Areal Reduction Factors for the Design Storm Events (Local Catchment)

Duration	AEP						
(min)	20%	10%	5%	2%	1%	0.5%	0.2%
60	0.9109	0.9043	0.8976	0.8889	0.8822	0.8756	0.8669
90	0.9246	0.9168	0.9090	0.8987	0.8909	0.8830	0.8727
120	0.9325	0.9237	0.9149	0.9032	0.8944	0.8856	0.8739
180	0.9422	0.9324	0.9227	0.9098	0.9000	0.8902	0.8773
360	0.9629	0.9578	0.9528	0.9461	0.9410	0.9360	0.9293
720	0.9762	0.9734	0.9706	0.9669	0.9641	0.9613	0.9576
1080	0.9809	0.9788	0.9768	0.9741	0.9720	0.9700	0.9672
1440	0.9856	0.9843	0.9830	0.9813	0.9799	0.9786	0.9769
2160	0.9885	0.9871	0.9858	0.9840	0.9827	0.9813	0.9795
2880	0.9902	0.9888	0.9874	0.9856	0.9842	0.9829	0.9811
4320	0.9921	0.9907	0.9893	0.9875	0.9861	0.9847	0.9828

1.1.3. Initial Losses

Probability Neutral Burst Initial Loss at the Events Local Catchment Centroid (mm)

Duration	AEP				
(min)	20%	10%	5%	2%	1%
60	11.4	10.1	10.2	10.3	9.2
90	11.5	10.6	10.6	10.9	10.1
120	12.6	11.2	11.0	10.2	9.2
180	12.5	11.4	11.8	11.1	10.2
360	14.8	13.1	13.2	11.2	7.9
720	17.5	16.8	17.0	14.5	9.3
1080	18.9	18.0	18.3	16.1	10.8
1440	20.8	20.4	19.8	17.9	13.3
2160	22.1	22.0	22.0	20.0	13.6
2880	22.7	23.2	23.3	22.4	17.6
4320	23.3	24.1	24.4	22.8	16.7

1.2. Urangeline Creek Mainstream Model (RORB)

1.2.1. IFD Data

Design rainfall depths (mm) at the Urangeline Creek catchment centroid (-35.299214, 146.595349)

Duration	AEP							
(min)	20%	0.2EY	10%	5%	2%	1%	0.5%	0.2%
15	15.4	15.7	18.4	21.4	25.5	28.7	32.2	36.8
30	20.6	21.0	24.6	28.6	34.0	38.3	42.9	49.1
45	23.6	24.1	28.3	32.9	39.1	43.9	49.2	56.3
60	25.9	26.4	30.9	35.9	42.6	47.8	53.6	61.4
90	29.0	29.6	34.5	40.1	47.5	53.3	59.7	68.4
120	31.3	31.9	37.2	43.1	51.0	57.1	64.0	73.3
180	34.6	35.3	41.0	47.4	56.0	62.7	70.3	80.5
270	38.1	38.8	45.0	52.0	61.3	68.6	77.0	88.0
360	40.7	41.6	48.1	55.4	65.4	73.2	82.1	93.9
540	44.8	45.7	52.8	60.8	71.7	80.3	90.1	103
720	47.9	48.8	56.5	65.1	76.8	86.1	96.6	110
1080	52.6	53.6	62.1	71.7	84.8	95.2	107	122
1440	56.1	57.3	66.4	76.8	91.1	102	115	131
1800	59.0	60.2	69.9	81.0	96.3	108	120	138
2160	61.4	62.6	72.8	84.6	101	113	126	144
2880	65.1	66.4	77.4	90.2	108	122	135	155
4320	70.2	71.6	83.7	97.8	117	132	148	171
5760	73.4	74.9	87.6	102	123	139	156	181
7200	75.6	77.1	90.1	105	126	142	161	187
8640	77.0	78.6	91.6	107	127	144	163	189
10080	78.0	79.6	92.4	107	127	144	163	190

1.2.2. Areal Reduction Factors

Areal Reduction Factors for the Design Storm Events at the Urangeline Creek catchment centroid

Duration	AEP						
(min)	0.2EY	10%	5%	2%	1%	0.5%	0.2%
60	0.5314	0.5147	0.4952	0.4694	0.4499	0.4304	0.4046
90	0.5905	0.5708	0.5479	0.5176	0.4947	0.4717	0.4414
120	0.6260	0.6039	0.5780	0.5439	0.5181	0.4922	0.4581
180	0.6710	0.6464	0.6178	0.5800	0.5514	0.5227	0.4849
360	0.7588	0.7458	0.7307	0.7108	0.6957	0.6806	0.6606
720	0.8202	0.8128	0.8042	0.7928	0.7842	0.7756	0.7642
1080	0.8539	0.8477	0.8404	0.8308	0.8235	0.8163	0.8067
1440	0.8875	0.8825	0.8766	0.8687	0.8628	0.8569	0.8491
2160	0.9023	0.8971	0.8911	0.8831	0.8770	0.8710	0.8630
2880	0.9115	0.9062	0.9000	0.8919	0.8858	0.8796	0.8715
4320	0.9228	0.9174	0.9111	0.9027	0.8964	0.8902	0.8818

1.2.3. Initial Losses

Probability Neutral Burst Initial Loss at the Urangeline Creek catchment centroid (mm)

Duration	AEP				
(min)	20%	10%	5%	2%	1%
60	9.8	9.3	9.7	9.7	8.1
90	10.3	9.4	9.8	9.7	8.8
120	11.1	10.0	10.1	9.5	8.4
180	11.6	10.3	10.7	10.1	8.6
360	13.7	12.4	12.8	10.9	7.0
720	16.0	15.3	15.5	13.3	8.9
1080	17.5	16.9	17.4	14.9	9.9
1440	18.9	18.4	18.5	16.8	12.4
2160	20.4	20.5	21.3	19.7	15.2
2880	20.7	21.0	22.1	20.3	15.3
4320	21.6	22.9	24.0	21.9	16.1

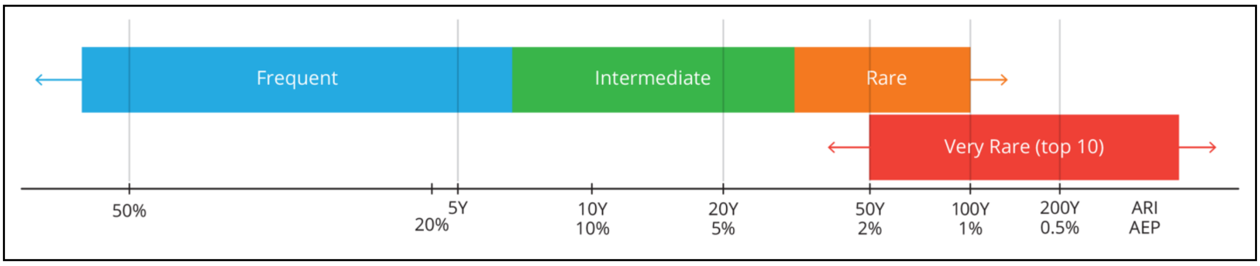
2. Critical Duration Assessment

This section provides supporting material relating to the critical duration assessment undertaken for the local runoff through Urana, as well as the mainstream Urangeline Creek model. The mechanisms are assessed separately, as described in Section 5.7 of Appendix G to the main Federation Villages FRMS&P.

2.1.1. Local Catchment Critical Duration Assessment

To determine the critical duration (the duration of rainfall over the catchment that would result in the greatest depth of flooding) in Urana, ARR 2019 recommends than an ensemble approach is used, where 10 temporal patterns are analysed for each storm duration in the TUFLOW hydraulic model. Given the computational demands of this number of model runs, the number of storm durations to be tested was shortlisted based on results from the hydrologic model. This attachment provides further details of this process (which was undertaken for an event in each bin (see Diagram G1), using the 1% AEP event as an example.

Diagram G1 Temporal Pattern Bins



Three key sub-catchment outlet locations were chosen to assess the peak flows generated by rainfall over the Urana local catchment using the XP-RAFTS hydrologic model. The chosen sub-catchments are listed below and are shown on Figure G05:

- No. 1 – area north of Brookong Creek Road;
- No. 2 – area between Brookong Creek Road and Butherwah Road;
- No. 37– Urban area south of Osborne Street; and
- No. 43 – Urban area north of Osborne Street.

The peak flows were assessed across the Urana catchment. A range of storm durations from 15 minutes to 4320 minutes (72 hours) and the ensemble of temporal patterns were run in XP-RAFTS and the results were analysed at each sub-catchment. Box plots of 1% AEP flows for the above listed sub-catchments represented in Diagram G2 to Diagram G5.

The box and whiskers for each duration indicate the spread of results obtained from the ensemble of temporal patterns. The box defines the first quartile to the third quartile of the results and the bottom and top line (also called ‘whiskers’) represent the maximum and minimum values. The hollow circles beyond these lines are statistical outliers. The red horizontal line within the box represents the median value. The red circle is the mean (average) value.

Diagram G2: Box plot of peak local flows at sub-catchment No.1: 1% AEP event

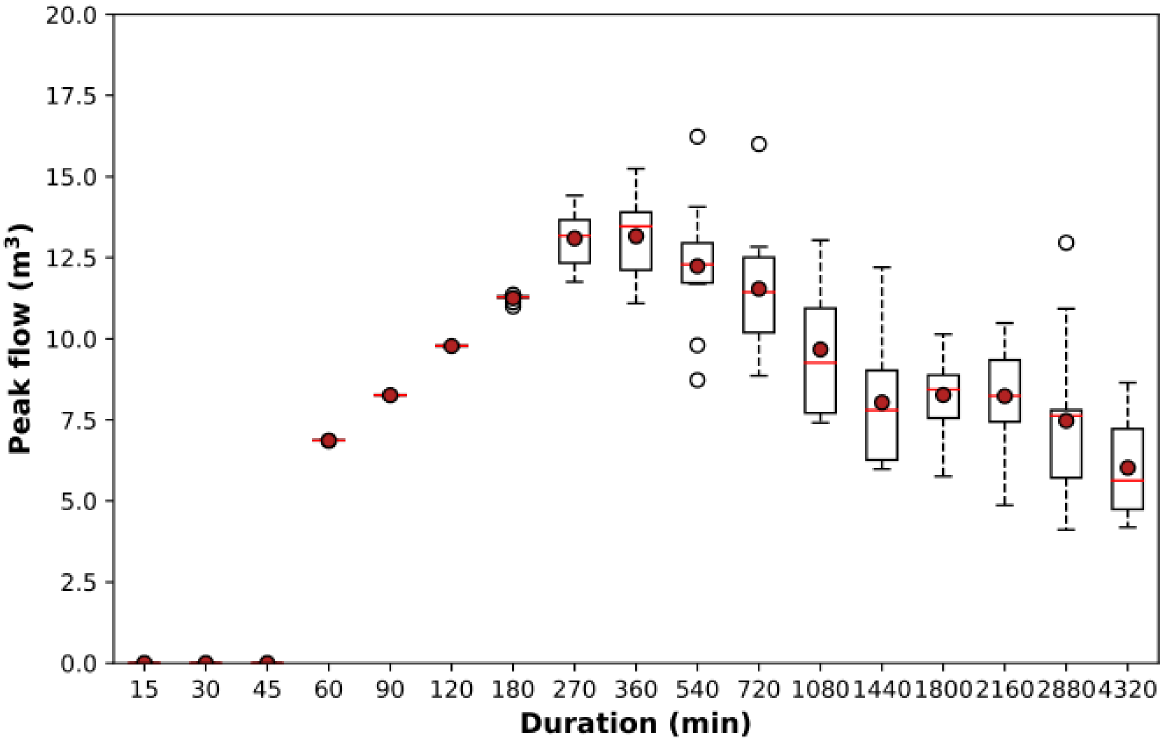


Diagram G3: Box plot of peak local flows at sub-catchment No.2: 1% AEP event

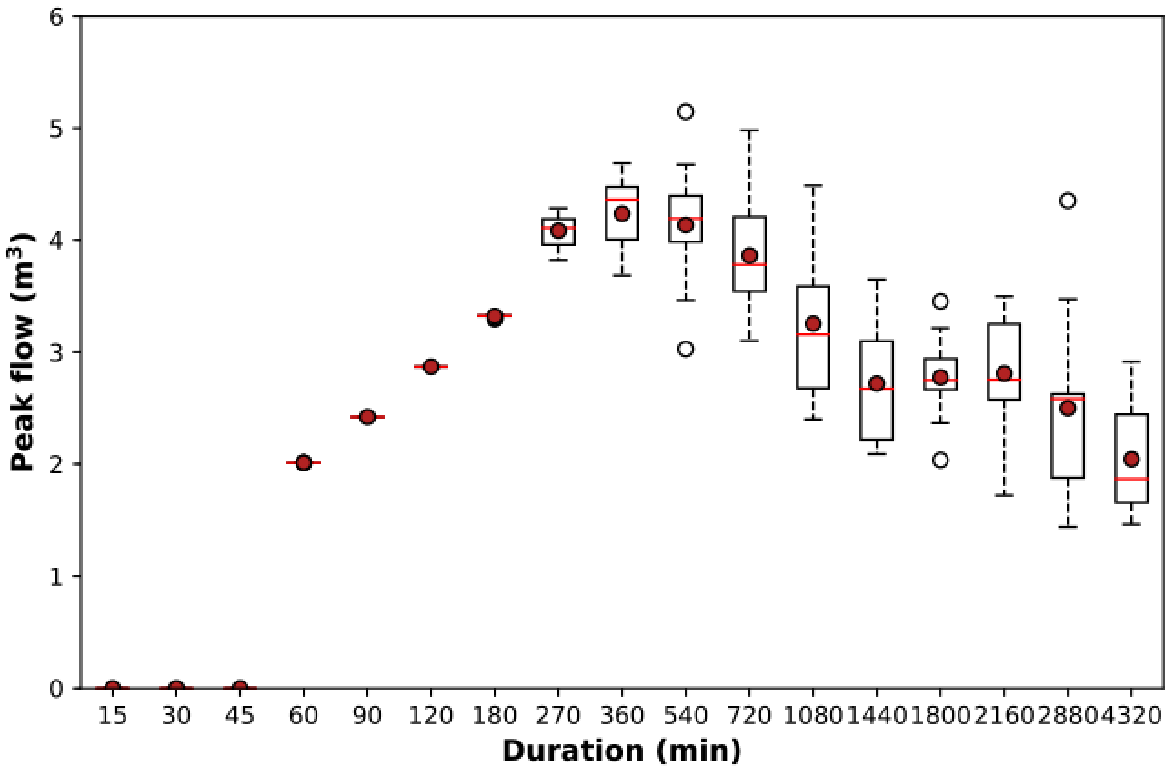


Diagram G4: Box plot of peak total flows at sub-catchment No.37: 1% AEP event

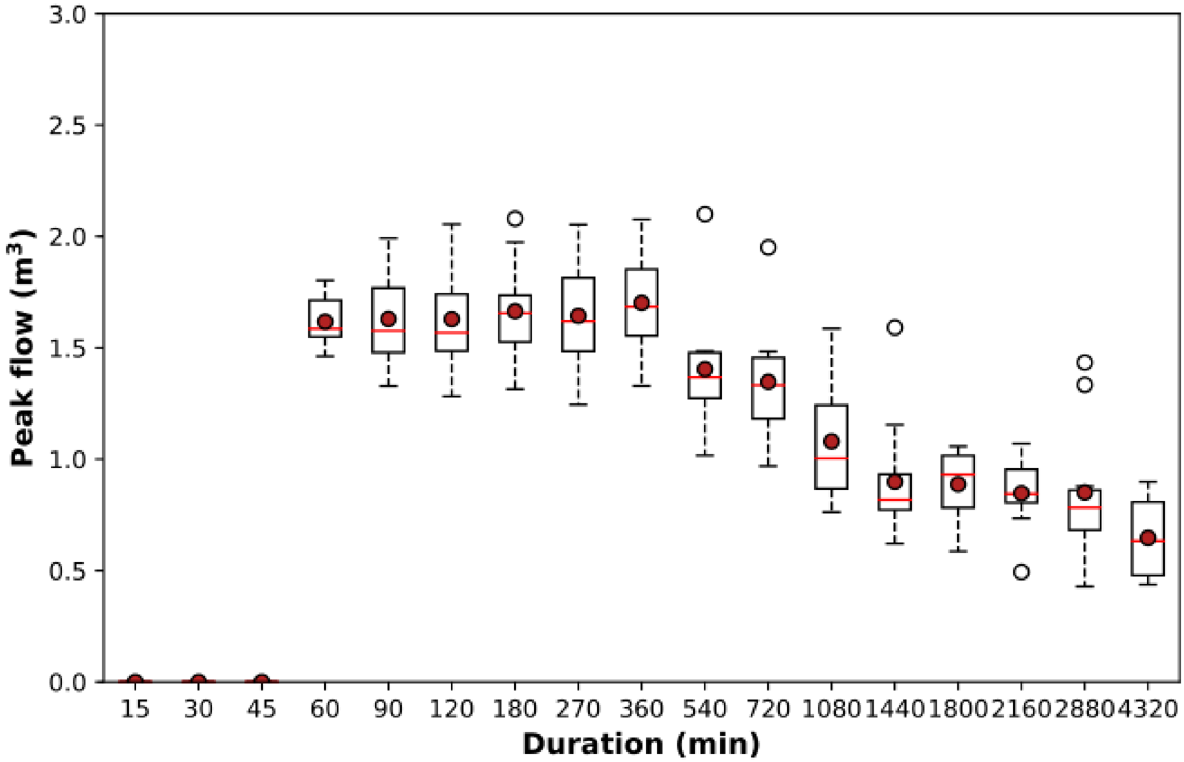
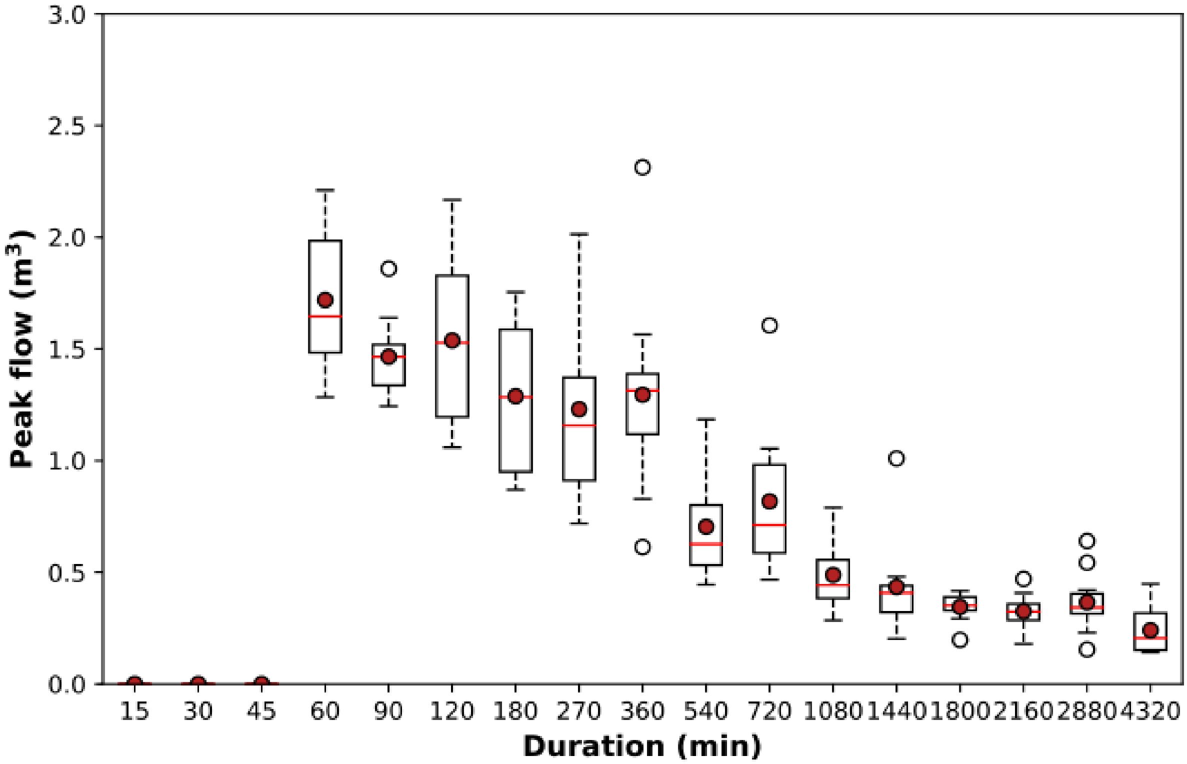


Diagram G5: Box plot of peak total flows at sub-catchment No.43: 1% AEP event

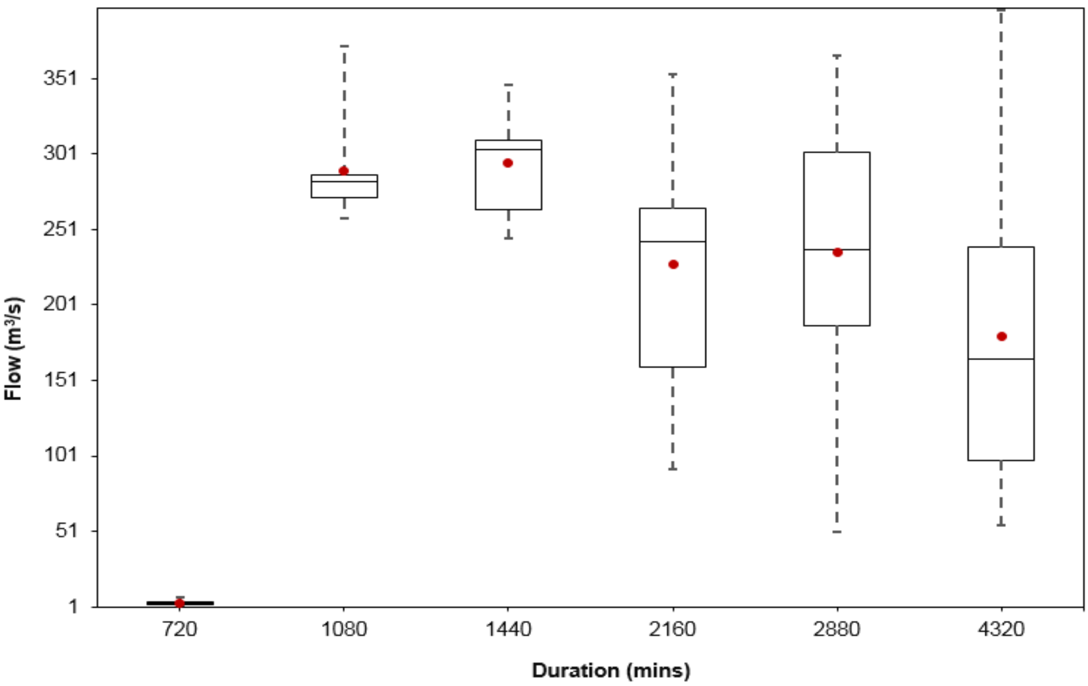


For the 1% AEP event, similar mean peak flows occur for a range of durations from 60 minutes to 540 minutes. Diagram 2 to Diagram 5 showed that the 360 minutes (6 hours) storm is critical at sub-catchments No.1, 2 and 37 (highest mean flows from the ensemble of temporal patterns). However, for sub-catchment No.43 the highest average total flow corresponds to the 1-hour duration event, and the second highest average total flow occurred in the 2 hour duration event.

The final selection of critical duration was conducted based on peak flood levels produced by the TUFLOW hydraulic model. The TUFLOW model was run for 1% AEP events for the 60 minute, 120 minute, 180 minute and 360 minute durations for the ensemble of 10 temporal patterns. The peak flood levels produced by running TUFLOW for these durations revealed that 180 minutes (3 hours) is critical duration. Overall, the results of Urana's sub-catchments revealed that for events of 1% AEP, 180 minutes duration and temporal pattern 10 resulted in the slightly higher peak flood levels just above the mean across the area. This analysis was undertaken for all the design storm events, considering the key flow locations described above. A single duration and temporal pattern were adopted for each bin (see Diagram 1), being representative across the range of events and locations.

The probable maximum precipitation (PMP) uses a single temporal pattern (Reference 1). In this case, the peak flows at each of the key sub-catchments were analysed to determine the critical duration (duration which produces the peak flows). At all the locations of interest, the 180 minutes (3 hours) storm was the critical duration and was adopted for the PMF design flood event. Table 9 illustrated the adopted representative temporal pattern and duration for all design events and PMP included in the present study.

Diagram G6 Box plot of peak flow at Urangeline catchment of different durations for the 1% AEP event



2.1.2. Critical Duration Assessment Results

Table G1 presents a summary of the critical duration and adopted temporal pattern for each design flood event.

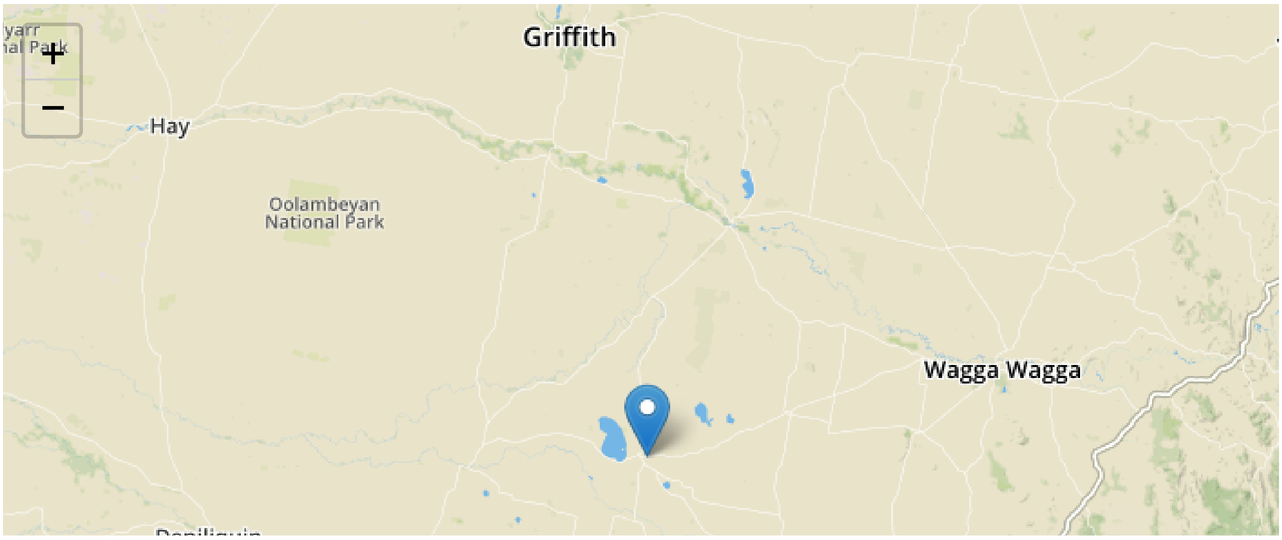
Table G1: Adopted durations and temporal patterns for design flood events (local catchment)

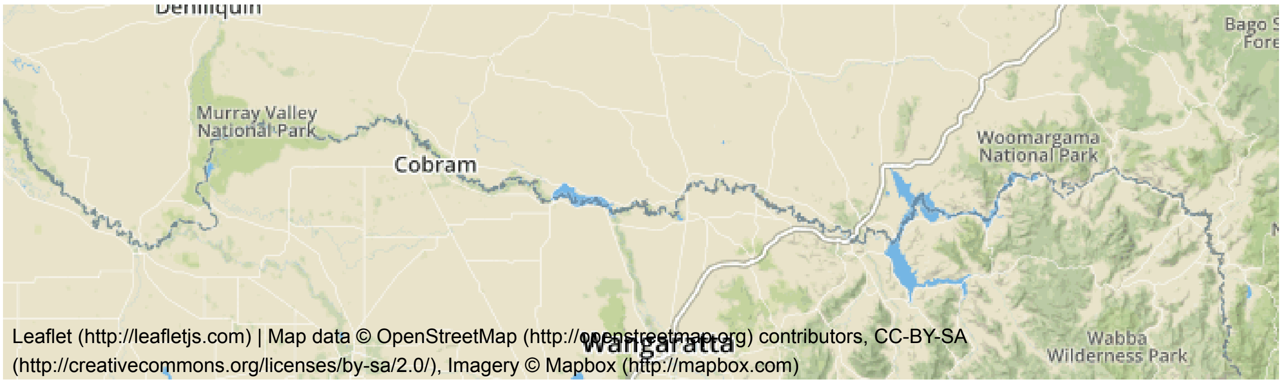
	Local Catchment (XP-RAFTS)			Urangeline Creek Catchment (RORB)		
Event	Critical Duration (min)	Adopted Temporal Pattern	Peak flood discharge (m^3/s) at the catchment outlet	Critical Duration (min)	Adopted Temporal Pattern	Peak flood discharge (m^3/s) at the catchment outlet
0.2EY	540	TP7: 4075	16	1440	TP8: 4157	60
10% AEP	180	TP2: 3969	20	1440	TP10: 4148	116
5% AEP	180	TP2: 3969	25	1440	TP10: 4148	176
2% AEP	180	TP10: 3967	39	1440	TP4: 4105	220
1% AEP	180	TP10: 3967	47	1440	TP4: 4105	306
0.5% AEP	180	TP10: 3967	55	1440	TP4: 4105	392
0.2% AEP	180	TP10: 3967	66	1440	TP4: 4105	508
PMF	180	NA	518	2160	NA	7797

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	146.287
Latitude	-35.337
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
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show





Data

River Region

Division	Murray-Darling Basin
River Number	11
River Name	Billabong-Yanco Creeks

Layer Info

Time Accessed	14 February 2019 03:57PM
Version	2016_v1

ARF Parameters

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

Zone	a	b	c	d	e	f	g	h	i
Southern Semi-arid	0.254	0.247	0.403	0.351	0.0013	0.302	0.058	0.0	0.0

Short Duration ARF

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

Layer Info

Time Accessed	14 February 2019 03:57PM
Version	2016_v1

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.

ID	12906.0
Storm Initial Losses (mm)	27.0
Storm Continuing Losses (mm/h)	0.0

Layer Info

Time Accessed	14 February 2019 03:57PM
Version	2016_v1

Temporal Patterns | Download (.zip) (http://192.168.70.224/static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	14 February 2019 03:57PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (http://192.168.70.224/./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	14 February 2019 03:57PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-35.3375&longitude=146.2875&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	14 February 2019 03:57PM

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)	2.5 (0.143)	1.9 (0.076)	1.5 (0.050)	1.1 (0.031)	1.1 (0.028)	1.2 (0.026)
90 (1.5)	1.7 (0.087)	1.3 (0.048)	1.1 (0.033)	0.8 (0.022)	0.7 (0.015)	0.6 (0.012)
120 (2.0)	1.6 (0.072)	1.2 (0.041)	1.0 (0.028)	0.8 (0.018)	0.4 (0.009)	0.2 (0.003)
180 (3.0)	2.9 (0.121)	2.8 (0.084)	2.7 (0.068)	2.6 (0.057)	1.2 (0.022)	0.2 (0.003)
360 (6.0)	0.9 (0.029)	1.7 (0.041)	2.2 (0.046)	2.7 (0.049)	2.1 (0.032)	1.6 (0.022)
720 (12.0)	0.0 (0.000)	0.2 (0.005)	0.4 (0.007)	0.6 (0.009)	2.0 (0.025)	3.0 (0.035)
1080 (18.0)	0.0 (0.000)	0.1 (0.002)	0.2 (0.002)	0.2 (0.003)	0.9 (0.011)	1.4 (0.015)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.2 (0.003)	0.4 (0.004)
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	14 February 2019 03:57PM

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

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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)	0.1 (0.003)	0.0 (0.001)	0.0 (0.001)	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	14 February 2019 03:57PM
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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)	11.8 (0.666)	13.4 (0.542)	14.5 (0.487)	15.5 (0.447)	14.9 (0.362)	14.5 (0.312)
90 (1.5)	12.2 (0.612)	14.1 (0.508)	15.4 (0.462)	16.6 (0.428)	14.2 (0.306)	12.3 (0.237)
120 (2.0)	9.2 (0.423)	13.0 (0.430)	15.5 (0.429)	17.9 (0.426)	15.3 (0.307)	13.4 (0.239)
180 (3.0)	11.7 (0.480)	12.9 (0.384)	13.7 (0.341)	14.4 (0.310)	13.1 (0.237)	12.1 (0.194)
360 (6.0)	6.0 (0.203)	10.4 (0.258)	13.3 (0.279)	16.1 (0.293)	17.2 (0.265)	18.1 (0.248)
720 (12.0)	2.6 (0.073)	4.5 (0.092)	5.7 (0.099)	6.8 (0.104)	11.8 (0.153)	15.6 (0.181)
1080 (18.0)	1.2 (0.029)	2.9 (0.053)	4.0 (0.063)	5.1 (0.070)	11.0 (0.128)	15.4 (0.161)
1440 (24.0)	0.0 (0.000)	1.4 (0.024)	2.4 (0.034)	3.3 (0.042)	5.4 (0.058)	7.0 (0.067)
2160 (36.0)	0.0 (0.000)	0.2 (0.003)	0.3 (0.004)	0.4 (0.005)	3.0 (0.029)	5.0 (0.043)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.6 (0.006)	1.1 (0.009)
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

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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)	22.2 (1.254)	24.9 (1.005)	26.6 (0.897)	28.3 (0.818)	27.0 (0.654)	26.0 (0.559)
90 (1.5)	24.8 (1.241)	28.0 (1.006)	30.1 (0.903)	32.2 (0.827)	27.5 (0.593)	23.9 (0.459)
120 (2.0)	20.1 (0.925)	26.1 (0.868)	30.2 (0.837)	34.0 (0.811)	35.8 (0.718)	37.2 (0.663)
180 (3.0)	23.4 (0.962)	26.9 (0.801)	29.2 (0.729)	31.4 (0.675)	28.6 (0.519)	26.6 (0.429)
360 (6.0)	18.3 (0.618)	21.5 (0.534)	23.7 (0.495)	25.7 (0.466)	32.6 (0.500)	37.7 (0.517)
720 (12.0)	13.8 (0.382)	15.5 (0.319)	16.6 (0.291)	17.7 (0.270)	23.9 (0.310)	28.6 (0.331)
1080 (18.0)	9.7 (0.240)	13.1 (0.241)	15.3 (0.241)	17.5 (0.240)	22.9 (0.267)	27.0 (0.281)
1440 (24.0)	2.9 (0.068)	8.2 (0.140)	11.6 (0.170)	14.9 (0.190)	19.6 (0.211)	23.1 (0.222)
2160 (36.0)	0.5 (0.010)	4.5 (0.071)	7.2 (0.095)	9.8 (0.113)	18.3 (0.177)	24.7 (0.212)
2880 (48.0)	0.0 (0.000)	2.1 (0.031)	3.5 (0.044)	4.9 (0.052)	10.3 (0.093)	14.4 (0.114)
4320 (72.0)	0.0 (0.000)	1.2 (0.016)	2.0 (0.023)	2.8 (0.027)	13.6 (0.111)	21.8 (0.156)

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Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.816 (4.1%)**	0.726 (3.6%)	**0.934 (4.7%)**
2040	**1.046 (5.2%)**	1.015 (5.1%)	**1.305 (6.6%)**
2050	**1.260 (6.3%)**	1.277 (6.4%)	**1.737 (8.8%)**
2060	**1.450 (7.3%)**	1.520 (7.7%)	**2.214 (11.4%)**
2070	**1.609 (8.2%)**	1.753 (8.9%)	**2.722 (14.2%)**
2080	**1.728 (8.8%)**	1.985 (10.2%)	**3.246 (17.2%)**
2090	**1.798 (9.2%)**	2.226 (11.5%)	**3.772 (20.2%)**

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Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	17.5	11.4	10.1	10.2	10.3	9.2
90 (1.5)	19.5	11.5	10.6	10.6	10.9	10.1
120 (2.0)	20.4	12.6	11.2	11.0	10.2	9.2
180 (3.0)	19.4	12.5	11.4	11.8	11.1	10.2
360 (6.0)	21.4	14.8	13.1	13.2	11.2	7.9
720 (12.0)	23.2	17.5	16.8	17.0	14.5	9.3
1080 (18.0)	24.3	18.9	18.0	18.3	16.1	10.8
1440 (24.0)	25.9	20.8	20.4	19.8	17.9	13.3
2160 (36.0)	26.8	22.1	22.0	22.0	20.0	13.6
2880 (48.0)	27.1	22.7	23.2	23.3	22.4	17.6
4320 (72.0)	27.3	23.3	24.1	24.4	22.8	16.7

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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.

Baseflow Factors

Downstream	0
Area (km2)	1820.83392
Catchment Number	10811
Volume Factor	0.07387
Peak Factor	0.031334

Layer Info

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