QUEANBEYAN-PALERANG REGIONAL COUNCIL

JERRABOMBERRA CREEK AND QUEANBEYAN-PALERANG REGIONAL SPORTS COMPLEX FLOODING AND DRAINAGE INVESTIGATION

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VOLUME 1 – REPORT

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ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff (1987 Edition)
BoM	Bureau of Meteorology
Council	Queanbeyan-Palerang Regional Council
DECC	Department of Environment and Climate Change
DPIE	Department of Planning, Industry and Environment
DWR	Department of Water Resources (now OEH)
LP3	Log Pearson Type III (form of probability distribution)
LiDAR	Light Detection and Ranging
NSW SES	New South Wales State Emergency Service
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood

NOTE ON FLOOD FREQUENCY

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

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

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

1 INTRODUCTION

1.1 Study Background

This report deals with an investigation that was undertaken by Lyall & Associates on behalf of Queanbeyan-Palerang Regional Council (**Council**) to define the nature of flooding in the vicinity of a proposed regional sports complex (**proposed sports complex**) that is planned on the southern (left) overbank of Jerrabomberra Creek immediately east (upstream) of the Goulburn-Bombala Railway in Environa. The report also deals with the impact that the proposed sports complex will have on flood behaviour, as well as the hydrologic standard of the individual playing fields and car parking areas. **Figure 1.1** shows the location of the proposed sports complex relative to several key features, a brief description of which is contained in the following section of this report.

The present investigation involved the following key tasks:

- The undertaking of a review of previous flood studies in the context of the design peak flow rates that have been adopted for defining flood behaviour in Jerrabomberra Creek in the vicinity of the proposed sports complex.
- The analysis of available rainfall and stream flow data, as well as the undertaking of a flood frequency analysis of the available stream flow record.
- The development and calibration of a hydrologic model which was used to generate discharge hydrographs for both historic and design storm events.
- The development of a two-dimensional (in plan) hydraulic model of the Jerrabomberra Creek floodplain which was used to define flood behaviour in the vicinity the proposed sports complex under pre- and post-project conditions.
- The development of a stormwater drainage strategy for the proposed sports complex.
- The assessment of the impact that the proposed sports complex would have on flood behaviour.

Flood behaviour in the vicinity of the proposed sports complex was defined for design flood events with Annual Exceedance Probabilities (**AEPs**) of 20% (1 in 5), 5% (1 in 20), 1% (1 in 100), 0.5% (1 in 200) and 0.2% (1 in 500), as well as the Probable Maximum Flood (**PMF**).

1.2 Available Data

The following data were available for the present investigation:

- Aerial photography of the study area which was flown in October 2016 and July 2019.
- LiDAR survey data covering the study area which was captured in May 2015.
- Cadastre boundary data which were downloaded from NSW Government's Spatial Information Exchange in May 2018.
- Pluviographic rainfall data for a number of gauges which are operated by the Environment, Planning and Sustainable Development Directorate (**EPSDD**) and the Bureau of Meteorology (**BoM**), the locations of which are shown on **Figure 1.1**.

- Stream flow data recorded by EPSDDs *Jerrabomberra Creek at Four Mile Creek* stream gauge (Gauging Station (**GS**) 410743) (**Four Mile stream gauge**) for the period June 1969 to November 1997. **Figure 1.1** shows the location of the Four Mile stream gauge which lies about 9 km by creek upstream of the proposed sports complex, as well as two other stream gauges which are both located downstream of the site and were not relied upon for the present investigation.[1]
- Road design model for the partially constructed South Tralee Northern Entry Road (**NER2**), the alignment of which is shown on **Figure 1.1**.
- Field survey of the five transverse drainage structures that are located along the partially constructed section of NER2 (refer **Figure 1.1** for location and adopted naming convention).
- Detailed ground survey model of Jerrabomberra Creek and its overbank area in the vicinity of the proposed sports complex.
- Layout and finished surface level model of the proposed sports complex.

The following reports were reviewed as part of the present investigation:

- *Jerrabomberra Creek Flood Level Study* (Department of Housing and Construction, 1984)
- *Jerrabomberra Water Quality Pond – Jerrabomberra Creek Flood Analysis* (R.A. Young and Associates, 1991)
- *Tralee Local Environment Study - Jerrabomberra Creek Flood Study* (URS, 2003)
- *Flood Study and Riparian Corridor Assessment, Jerrabomberra Creek* (Brown Consulting, 2010)
- *ARR Revision Project 6: Loss Models for Catchment Simulation - Stage 2 Report P6/S2/016A* (Hill, P.I., Graszkiewicz, Z., Sih, K. and Rahman, A. (Hill et al.), 2013)
- *Review of North Tralee Flood Studies* (WMAwater, 2015)
- *North Tralee – Jerrabomberra Creek Flood Study – Update to 2010 Flooding* (Calibre, 2016)
- *Calibre Consulting – 2016 North Tralee Flood Study Review* (WMAwater, 2016)

1.3 Overview of Report

Chapter 2 of the report contains background information including a brief description of the study area, a review of previous flooding investigation that have been undertaken for the study area and an analysis of the available rainfall and stream gauge data.

Chapter 3 deals with the development and calibration of the computer based catchment model which was used to generate discharge hydrographs for input to the hydraulic model.

[1] The *Jerrabomberra Creek at Narrabundah* stream gauge (GS 410721) ceased to operate in October 1981, while the *Jerrabomberra Creek at Hindmarsh Drive* stream gauge (GS 410790) was only installed in January 2013, meaning both gauges did not record the flood of record that occurred in January 1995. The period of record of both gauges is also shorter than that of the Four Mile stream gauge.

Chapter 4 deals with the development of the hydraulic model that was used to define flood behaviour in the vicinity of the proposed sports complex. This chapter includes a discussion on the nature of flooding in the vicinity of the proposed sports complex under present day conditions.

Chapter 5 deals with the assessment of the impact that the construction of the proposed sports complex would have on flood behaviour, as well as an assessment of the hydrologic standard of the various playing fields and car parking areas. Included in this chapter are the findings of a sensitivity analysis of the impact of a reduction in the adopted continuing loss rate would have on flood behaviour in the vicinity of the proposed sports complex.

Chapter 6 contains a list of References.

Appendix A of this report contains a copy of the design input data which was generated by the ARR Data Hub and used design flood estimation purposes.

Figures referred to in the report are bound in a separate volume (see **Volume 2**).

2 BACKGROUND INFORMATION

2.1 Catchment Description

Jerrabomberra Creek is a major tributary of the Molonglo River and has a catchment area of about 137 km^2 where it discharges to Lake Burley Griffin in the Australian Capital Territory (**ACT**). **Figure 1.1** shows the extent of the catchment which extends to the south of the lake, noting that the upper and middle portions of the catchment are located on the New South Wales (**NSW**) side of the ACT border.

Land-use within the catchment upstream of the Goulburn-Bombala Railway is generally rural in nature. However, large-lot rural residential development is located in the upper reaches of the catchment at Googong, while more dense urban type development is located immediately to the east and upstream of the proposed sports complex in the suburb of Jerrabomberra. While slopes within the catchment generally vary between 1.5% and 3%, the land on the southern (upstream) side of NER2 is much steeper at between 4% and 10%.

The watercourses within the catchment are generally natural in condition, with the exception of the drainage lines within the suburb of Jerrabomberra which have been highly modified. While the floodplain of Jerrabomberra Creek is relatively confined upstream of the suburb of Jerrabomberra, it does commence to widen out in the vicinity of the intersection of Waterfall Drive and Woodhill Link. The bed slope of Jerrabomberra Creek also flattens at this location from about 2% to about 0.5%.

2.2 Site Description

Figure 2.1 shows that layout of the existing drainage system in the vicinity of the proposed sports complex.

The inbank area of Jerrabomberra Creek is relatively incised and is between about 3-4 m in depth, while its width remains relatively constant at about 35 m where it runs along the northern boundary of the proposed sports complex. The southern overbank of Jerrabomberra Creek in the vicinity of the proposed sports complex is relatively flat and generally falls in a westerly direction at a grade of about 0.8%. It is also noted that the elevation of the southern bank of the creek is higher than the overbank area which is located to its south.

The Goulburn-Bombala Railway crosses Jerrabomberra Creek immediately downstream of the proposed sports complex, the embankment of which has a minimum elevation of about RL 583.6 m AHD at the location of the creek crossing. The main rail crossing comprises a 32 m long four span bridge which has an approximate waterway area of 89 m^2, while a set of four 2.6 m diameter pipes that are located about 150 m to the south of the main creek crossing.

Five transverse drainage structures are located along the partially constructed section of NER2, the details of which are set out in **Table 2.1** over the page. No details are available on the proposed bridge crossing of Jerrabomberra Creek.

No formed channels are located in the proposed sports complex, rather flow discharging from the transverse drainage of NER2 traverses overland in a westerly direction toward the abovementioned set of 2.6 m diameter that are located about 150 m to the south of the main rail crossing of Jerrabomberra Creek.

TABLE 2.1
DETAIILS OF NER2 TRANSVERSE DRAINAGE

Transverse Drainage Structure Identifier	No./Dimensions$^{(1)}$	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (km^2)
NER2 Culvert No. 1	3 off 1200 x 450 RCBCs	587.76	587.37	0.22
NER2 Culvert No. 2	5 off 2700 x 600 RCBCs	585.11	584.83	1.44
NER2 Culvert No. 3	3 off 1800 x 750 RCBCs	587.65	587.36	0.64
NER2 Culvert No. 4	3 x 1200 x 600 RCBCs	591.04	590.30	0.38
NER2 Culvert No. 5	1 x 1200 x 300 RCBC	591.30	591.20	0.02

1. RCBC = Reinforced Concrete Box Culvert

2.3 Previous Investigations

2.3.1 Jerrabomberra Creek Flood Level Study

The Department of Housing and Construction (**DHC**) undertook a flood study for the Jerrabomberra Creek catchment downstream of the ACT border in 1984 (**DHC, 1984**). While it was not possible to obtain a copy of DHC, 1984 as part of the present investigation, URS, 2003 (refer **Section 2.3.3** for details) contains a summary of the findings of the study.

Column B of **Table 2.2** over sets out the design peak flow estimates at the Four Mile Creek stream gauge that were derived as part of DHC, 1984 using ten years of annual peak flow data, while **Column B** of **Table 2.3** over sets out the design peak flow estimates at the NSW/ACT Border that were derived as part of DHC, 1984. The design peak flow estimates at the NSW/ACT Border were derived by multiplying the annual maximum flow data at the Four Mile Creek stream gauge by the ratio of the catchment areas, raised to the power of 0.7 and then undertaking a flood frequency analysis on the adjusted peak flows (a process which is herein referred as an *"Adjusted Flood Frequency Analysis"*).

DHC, 1984 defined the 1% AEP flow at the Four Mile Creek stream gauge and NSW/ACT Border as 180 m^3/s and 210 m^3/s, respectively.

2.3.2 Jerrabomberra Water Quality Pond – Jerrabomberra Creek Flood Analysis

R.A Young and Associates undertook a flood study for the Jerrabomberra Creek catchment in 1991 to assist in the design of Lake Jerrabomberra (**R.A. Young and Associates, 1991**). While it was not possible to obtain a copy of R.A. Young and Associates, 1991 as part of the present investigation, URS, 2003 contains a summary of the findings of the study.

Column C of **Table 2.2** sets out the design peak flow estimates at the Four Mile Creek stream gauge that were derived as part of R.A. Young and Associates, 1991 using 20 years of annual peak flow data, while **Column C** of **Table 2.3**, sets out the design peak flow estimates at the NSW/ACT Border that were derived as part of R.A. Young and Associates, 1991 by way of an Adjusted Flood Frequency Analysis.

R.A. Young and Associates, 1991 defined the peak 1% AEP flow at the Four Mile Creek stream gauge and NSW/ACT Border as 215 m^3/s and 308 m^3/s, respectively.

TABLE 2.2
COMPARISON OF ASSESSED DESIGN PEAK FLOWS AT THE FOUR MILE CREEK STREAM GAUGE
(m^3/s)

AEP (%)	Previous Investigations						Present Investigation							
	DHC, 1984[1]	R.A. Young, 1991[1]	URS, 2003		Brown, 2010	Hill et al., 2013		Flood Frequency Analysis (LP3)				Jerrabomberra Creek Hydrologic Model[2]		
	Flood Frequency Analysis (LP3)	Flood Frequency Analysis (LP3)	Flood Frequency Analysis (LP3)	RORB Hydrologic Model	RAFTS Hydrologic Model	Flood Frequency Analysis (LP3)	Regional Flood Frequency Estimation Model	EPSSD Rating Curve All Flows	EPSSD Rating Curve Censored Data	L&A Rating Curve All Flows	L&A Rating Curve Censored Data	CL = 1.6 mm/hr	CL= 3.9 mm/hr[3]	CL = 7.4 mm/hr
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]
20	-	-	-	-	88	84.3	44.7	93	77	65	59	122	94	61
10	86	-	115	113	108	134	67.5	145	121	96	85	136	112	86
5	-	-	160	174	141	187	95.1	203	175	123	113	162	139	111
2	141	-	240	239	180	258	141	273	273	155	158	206	178	147
1	180	215	320	297	217	310	184	330	380	180	200	321	224	177
0.5	-	-	-	-	-	-	-	412	545	210	262	291	266	214
0.2	-	-	-	-	-	-	-	-	920	-	393	359	329	275

1. Source: URS, 2003.
2. CL = Continuing Loss
3. Peak flows that have been adopted for defining flood behaviour in the vicinity of the proposed sports complex under pre- and post-project conditions.

TABLE 2.3
COMPARISON OF ASSESSED DESIGN PEAK FLOWS AT THE NSW/ACT BORDER
(m^3/s)

AEP (%)	Previous Investigations							Present Investigation	
	DHC, 1984(1)	R.A. Young, 1991(1)	URS Australia, 2003		Brown Consulting, 2010			Regional Flood Frequency Estimation Model	Jerrabomberra Creek TUFLOW Model
	Adjusted Flood Frequency Analysis(2)	Adjusted Flood Frequency Analysis(2)	Adjusted Flood Frequency Analysis(2)	RORB Hydrologic model	Adjusted Flood Frequency Analysis(2)	RAFTS Hydrologic Model	Probabilistic Rational Method		
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]
20	-	-	-	-	-	-	-	61.2	130
10	100	-	152	150	-	165	145	92.1	-
5	-	-	212	235	-	213	186	130	84.9
2	180	-	317	325	-	270	254	192	-
1	210	308	423	397	440	322	305	251	292
0.5	-	-	-	-	-	-	-	-	352
0.2	-	-	-	-	-	-	-	-	465

1. Source: URS, 2003.
2. Annual maximum flow data at the border was derived by multiplying annual maximum flow data at Four Mile Creek stream gauge by the ratio of the catchment areas, raised to the power of 0.7 (Procedure that was developed as part of DHC, 1984).

2.3.3 Tralee Local Environment Study - Jerrabomberra Creek Flood Study

URS were commissioned by Council in 2003 to undertake a flood study of Jerrabomberra Creek within the proposed North Tralee area for the Tralee Local Environment Study (**URS, 2003**). **Column D** of **Table 2.2** sets out the results of a flood frequency analysis that was undertaken using the 27 years of annual maximum peak flow data that were available for the Four Mile Creek stream gauge, while **Column D** of **Table 2.3** shows the results of a flood frequency analysis was also undertaken at the NSW/ACT Border using the Adjusted Flood Frequency Analysis procedure.

A hydrologic model of the Jerrabomberra Creek catchment was developed as part of URS, 2003 using the RORB software. The RORB model was calibrated to recorded discharge hydrographs at the Four Mile Creek stream gauge for storm events that occurred on 10 February 1971, 6 July 1988, 14 March 1989, 3 April 1989 and 28 January 1995.

The peak 1% AEP peak flow at the Four Mile Creek stream gauge as derived by the flood frequency analysis was 320 m^3/s (refer **Column D** of **Table 2.2**) compared to 297 m^3/s as derived by the RORB hydrologic model (refer **Column E** of **Table 2.2**). Both values were significantly higher than those derived as part of DHC, 1984 and R.A. Young and Associates, 1991.

The peak 1% AEP flow at the NSW/ACT Border as derived by the flood frequency analysis and RORB hydrologic model was 423 m^3/s and 397 m^3/s, respectively, which is about 100 m^3/s higher than the peak 1% flow that was derived as part of R.A. Young and Associates, 1991.

2.3.4 Flood Study and Riparian Corridor Assessment, Jerrabomberra Creek

Brown Consulting was commissioned in 2010 to undertake an investigation to define the nature of flooding on Jerrabomberra Creek for the proposed *Tralee North* and *The Poplars* development areas (**Brown Consulting, 2010**). The investigation formed part of the South Jerrabomberra Masterplan. Flood behaviour was defined for design storms with AEPs of 1% (1 in 100) and 0.2% (1 in 500), as well as the PMF.

An Adjusted Flood Frequency Analysis was undertaken using 22 years[2] of annual maximum peak flows for the NSW/ACT Border that were derived from the recorded data at the Four Mile Creek stream gauge using the Adjusted Flood Frequency Analysis procedure. **Column F** of **Table 2.3** shows that the peak 1% AEP flow estimate at the NSW/ACT Border derived as part of Brown Consulting, 2010 was 440 m^3/s, which was considered to be too high when compared to the findings of the previous studies.

Based on this finding, the authors recommended that a hydrologic (XP-RAFTS) model be developed of the catchment which incorporated accepted regional values and that this model be used for defining design peak flows on Jerrabomberra Creek at the location of the proposed development site. **Column F** in **Table 2.2** sets out the design peak flows at the Four Mile Creek stream gauge that were derived by the RAFTS hydrologic model that was developed as part of Brown Consulting, 2010, noting that they are significantly lower than those derived by the RORB hydrologic model that was developed as part of URS, 2003.

A hydraulic (SOBEK) model of the reach of Jerrabomberra Creek between Lake Jerrabomberra and Lanyon Drive which is located about 550 m downstream of the NSW/ACT Border was

[2] Brown Consulting, 2010 does not provide an explanation as to why a shorter period of record (e.g. 22 years) was adopted when compared with URS, 2003 (e.g. 27 years).

developed as part of Brown Consulting, 2010. The model was used to define flood behaviour along the abovementioned reach of creek under present day conditions for the 1% and 0.2% AEP flood events, as well as the PMF.

A hydraulic (HEC-RAS) model of the 700 m long reach of Jerrabomberra Creek immediately upstream of the NSW/ACT Border was developed in order to assess channel widening options that would offset the impact of filling the Jerrabomberra Creek floodplain. Brown Consulting, 2010 found that the existing creek would need to be widened by 50 m in order to offset the impact of filling the floodplain.

2.3.5 ARR Revision Project 6: Loss Models for Catchment Simulation - Stage 2 Report P6/S2/016A

The recent revision of *Australian Rainfall and Runoff* was underpinned by 21 projects that addressed knowledge gaps or developments since the 1987 edition of the document. Project 6 included the development of models that could be used to determine a set of loss values that were suitable for design flood estimation for rural catchments (**Hill et al., 2013**).

Phase 1 of Project 6 involved the trial of potential loss models using ten pilot catchments, one of which was Jerrabomberra Creek. A log-Pearson Type III (**LP3**) distribution was fitted to the annual series of flood peaks for the Four Mile Creek stream gauge.[3] **Column G** of **Table 2.2** shows that Hill et al., 2013 found that the peak 1% AEP flow at the Four Mile Creel stream gauge was similar to that derived as part of URS, 2003.

2.3.6 Review of North Tralee Flood Studies

Council commissioned WMAwater in 2015 to undertake an independent peer review of the following three studies (**WMAwater, 2015**):

- *Tralee LES Jerrabomberra Creek Flood Study* (URS, 2003)
- *Flood Study and Riparian Corridor Assessment, Jerrabomberra Creek* (Brown Consulting, 2010)
- *North Tralee LES 2011 (Appendix B)* (Northrop Consulting, 2010)[4]

The review found that the design peak flows derived by the RAFTS hydrologic model developed as part of Brown Consulting 2010 (refer **Column G** of **Table 2.3**) were suitable for use in design flood modelling.

The key recommendations of the review as they relate to the hydraulic model that was developed part of Brown Consulting, 2010 were:

- detailed ground survey is required in the vicinity of the Goulburn Bombala Railway;
- survey of the Lanyon Road bridge crossings of Jerrabomberra Creek should be incorporated into the model;

[3] While Hill et al., 2013 found that a Generalise Extreme Value (**GEV**) distribution gave the best fit to the recorded data, the LP3 distribution was adopted and presented as it generally gave a better fit for all of the pilot catchments analysed as part of the study.

[4] While Northrop Consulting, 2010 was not available to review was part of the present investigation, WMAwater, 2015 found that the study did not provide any additional relevant information on flooding patterns in the Jerrabomberra Creek catchment to that contained in URS, 2003 and Brown Consulting, 2010.

- the hydraulic model should be extended further downstream to remove the potential impact that Lanyon Drive has on flood behaviour upstream of the NSW/ACT Border; and
- the updated hydraulic model should be calibrated to available historic flood information.

2.3.7 North Tralee – Jerrabomberra Creek Flood Study – Update to 2010 Flooding

The letter report dated 16 July 2016 was prepared to accompany Brown Consulting, 2010 (**Calibre, 2016**). The additional flood modelling that is documented in the letter was undertaken to assist with the re-zoning application for the North Tralee site and incorporates the recommendations contained in WMAwater, 2015.

The hydraulic (SOBEK) model that was developed as part of Brown Consulting, 2010 was replaced by a TUFLOW model which incorporate the recommendations set out in WMAwater, 2015. The TUFLOW model was extended to the south in order to define the nature of major overland flow on the southern overbank of Jerrabomberra Creek.

2.3.8 Calibre Consulting – 2016 North Tralee Flood Study Review

WMAwater was engaged to undertake a peer review of Calibre, 2016, namely the two-dimensional (in plan) hydraulic model that was developed as part of the study (**WMAwater, 2016**).

WMAwater identified a number of issues with the hydraulic model which made it unsuitable for determining finished floor levels for residential properties and other outputs that are required as part of a flood study that has been undertaken under the NSW Floodplain Management Program. However, WMAwater concluded that the assumptions and modelling methods applied as part of Calibre, 2016 were generally conservative in nature and that this, coupled with the characteristics of the control formed by the railway embankment and the steep terrain on the surrounding floodplain, indicated that the model results are suitable for rezoning assessment purposes when used in conjunction with a 0.5 m freeboard.

2.4 Flood History and Analysis of Available Rainfall

2.4.1 General

Table 2.4 sets out the four largest flood events that have been recorded at the Four Mile Creek stream gauge over its period of operation between June 1969 and November 1997, while **Figure 2.2** (2 sheets) shows the cumulative rainfall and discharge hydrographs for each. **Figure 2.3** (3 sheets) shows the Intensity-Frequency-Duration (**IFD**) curves for the EPSPDD and BoM operated pluviographic rainfall stations that are located in the vicinity of the study area, while **Table 2.5** sets out the approximate AEPs of the rainfall that was recorded during the historic flood events.

2.4.2 February 1971 Storm

Figure 2.1, sheet 1 shows that the flow in Jerrabomberra Creek increased quickly from about 11:00 hours in response to rain that fell between 03:00 hours and 18:00 hours on the same day and peaked at about 13:00 hours on 10 February 1971. The information contained in **Table 2.5** and **Figure 2.3** indicates that the storm was equivalent to a design storm with an AEP of about 20%. **Figure 2.4**, which shows the two-day rainfall depth contours for the rain days of 10 and 11 February 1971 shows that the heaviest rainfall fell in the north-western corner of the catchment.

TABLE 2.4
SUMMARY OF FOUR LARGEST FLOOD EVENTS
RECORDED BY FOUR MILE CREEK STREAM GAUGE

Rank	Event	Gauge Height (m)	Elevation[1] (m AHD)	Peak Discharge		Approximate AEP[3] (%)
				EPSDD Rating Curve	L&A Derived Rating Curve[2]	
[A]	[B]	[C]	[D]	[E]	[F]	[G]
1	January 1995	2.82	698.21	261.7	145.8	2
2	February 1971	2.09	697.48	110.3	79.1	10
3	October 1976	1.85	697.23	75.5	58.4	20
4	August 1974	1.79	697.18	69.4	54.2	20

1. Gauge zero = 695.39 m.
2. Derived from HEC-RAS model developed as a part of the present investigation (refer **Section 4.1** for details).
3. Taken from flood frequency analysis that was undertaken as part of present investigation (refer **Section 4.2** for details).

2.4.3 August 1974 Storm

Figure 2.1, sheet 1 shows that the flow in Jerrabomberra Creek peaked at about 02:00 hours on 29 August 1974 in response to steady rain that generally fell between 12:00 hours on 26 August 1974 and 00:00 hours on 29 August 1974. The information contained in **Table 2.5** and **Figure 2.3** indicates that the storm was equivalent to a design storm with an AEP of about 50%. **Figure 2.5** shows the three-day rainfall depth contours for the rain days of 27, 28 and 29 August 1974.

2.4.4 October 1976 Storm

Figure 2.1, sheet 2 shows that the flow in Jerrabomberra Creek peaked at about 12:00 hours on 16 October 1976 in response to steady rain that generally fell between 15:00 hours on 15 October 1976 and 02:00 hours on 16 October 1976. The information contained in **Table 2.5** and **Figure 2.3** indicates that the storm was equivalent to a design storm with an AEP of about 20% AEP design storm. **Figure 2.6** shows the two-day rainfall depth contours for the rain days of 16 and 17 October 1976.

2.4.5 January 1995 Storm

The January 1995 flood was the largest to have been recorded by the Four Mile Creek stream gauge and was equivalent to about a 2% AEP design flood event. **Figure 2.1**, sheet 2 shows that the flow in Jerrabomberra Creek peaked at about 19:30 hours on 28 January 1995 in response to rain that fell between 11:00 hours and 21:00 hours on the same day. The information contained in **Table 2.5** and **Figure 2.3** indicates that the storm was equivalent to a design storm with an AEP of about 5%. **Figure 2.7** shows the one-day rainfall depth contours for the rain day of 29 January 1995.

TABLE 2.5
APPROXIMATE AEPs OF RECORDED RAINFALL FOR HISTORIC STORM EVENTS[(1)]
(% AEP)

Storm Event	Rain Gauge[(2)]	Storm Duration (hours)				
		1	2	3	6	9
February 1971	Googong at Queanbeyan (GS 570914	< 1EY	< 1EY	< 1EY	< 1EY	< 1EY
	Gudgenby River at Tennet (GS 570970)	20	20	20	20	20
	Jerrabomberra at Four Mile Creek (GS 570973)	< 1EY	< 1EY	< 1EY	< 1EY	< 1EY
	Long Gully Creek at Philip (GS 570977)	20	50	50	50	50
	Canberra Airport Comparison (GS 70014)	< 1EY	< 1EY	< 1EY	< 1EY	< 1EY
	Canberra Forestry (GS 70015)	20	20	20	20	20
August 1974	Googong at Queanbeyan (GS 570914	< 1EY	< 1EY	< 1EY	1EY	50
	Gudgenby River at Tennet (GS 570970)	< 1EY	< 1EY	< 1EY	1EY	1EY
	Jerrabomberra at Four Mile Creek (GS 570973)	< 1EY	< 1EY	< 1EY	< 1EY	1EY
	Long Gully Creek at Philip (GS 570977)	< 1EY	< 1EY	< 1EY	< 1EY	< 1EY
	Canberra Airport Comparison (GS 70014)	< 1EY	< 1EY	< 1EY	1EY	50
October 1976	Gudgenby River at Tennet (GS 570970)	< 1EY	< 1EY	< 1EY	50	20
	Jerrabomberra at Four Mile Creek (GS 570973)	< 1EY	< 1EY	< 1EY	50	20
	Long Gully Creek at Philip (GS 570977)	< 1EY	< 1EY	< 1EY	50	20
	Canberra Airport Comparison (GS 70014)	< 1EY	< 1EY	< 1EY	1EY	20
January 1995	Gudgenby River at Tennet (GS 570970)	5	10	10	10	20
	Jerrabomberra at Four Mile Creek (GS 570973)	20	10	5	5	10
	Long Gully Creek at Philip (GS 570977)	50	50	50	20	20
	Canberra Airport Comparison (GS 70014)	< 1EY	< 1EY	< 1EY	< 1EY	< 1EY

1. Unless otherwise noted, storm frequency is given as % AEP.
2. Refer **Figure 1.1** for location.

2.5 Analysis of Available Stream Gauge Data

2.5.1 General

As mentioned, the Four Mile Creek stream gauge was first installed in June 1969 and was decommissioned in November 1997. The highest recorded gauging was taken on 1 April 1989 when the water level at the gauge peaked at 1.45 m and the peak flow in the creek was 30.8 m^3/s. The left hand side of **Figure 2.8** shows the rating curve that was developed by EPSDD, the operator of the gauge (labelled as *"EPSDD Rating Curve"*), while the right hand side shows the cross section at the gauge.

Following the development of the hydrologic model for the study area (refer **Chapter 3** for details), it was found that it was not possible to reproduce the recorded discharge hydrographs at the Four Mile Creek stream gauge based on the EPSDD Rating Curve.

In response to this finding, a HEC-RAS model was developed of a 630 m reach of Jerrabomberra Creek in the vicinity of the gauge, the layout of which is shown on **Figure 2.9**. The HEC-RAS cross sections were derived from LiDAR survey data with the exception of the cross section at the gauge site which was taken from the survey data that were provided by EPSDD (refer right hand side of **Figure 2.8**).

The rating curve derived from the HEC-RAS model (labelled as "*L&A Derived Rating Curve"* on the left hand side of **Figure 2.8**) provides a good match with the EPSDD Rating Curve for gauge heights lower than 1.45 m (i.e. below the maximum gauged height/discharge) but provides a lower peak flow estimate for a given gauge height above this level. It was found that the hydrologic model that was developed as part of the present investigation gave a good match with the discharge hydrographs derived using the L&A Derived Rating Curve at the Four Mile Creek stream gauge (refer **Chapter 3** for further discussion). **Figure 2.10** is a long section of Jerrabomberra Creek in the vicinity of the Four Mile stream gauge showing the historic water surface profiles based on the best estimate hydraulic roughness values.

Based on the above finding, the EPSDD Rating Curve, which has been relied upon for the flood frequency analyses undertaken as part of the previous studies listed in **Section 1.2** and summarised in **Section 2.3** of this report, is considered to overestimate peak flows for gauge heights higher than 1.45 m.

2.5.2 Regional Flood Frequency Analysis

The Regional Flood Frequency Estimation (**RFFE**) model, procedures for which are set out in the 2019 edition of *Australian Rainfall and Runoff* (**ARR 2019**) was used to derive design peak flow estimates at the Four Mile Creek stream gauge. **Column H** of **Table 2.2** shows that the design peak flow estimates derived using the RFFE are lower than the design peak flow estimates derived as part of the previous studies listed in **Section 1.2** and summarised in **Section 2.3** of this report.

2.5.3 Site Specific Flood Frequency Analysis

A LP3 distribution was fitted to the EPSDD Rating Curve derived annual series of flood peaks for the 29 year period of record between 1969 and 1997 using the TUFLOW Flike software. The resulting frequency curves, along with 5% and 95% confidence limits are shown on the left-hand side of **Figure 2.10**, sheet 1. **Column I** in **Table 2.2** gives the peak flow estimates for a range of AEPs as derived by the above analysis which provide a good match with the peak flow estimates derived by the flood frequency analyses that were undertaken as part of URS, 2003 (refer **Column D**) and Hill et al., 2013 (refer **Column G**).

Values at the low end of the observed range of flood peaks can distort the fitted probability distribution and affect the estimates of large floods. Deletion of these low values may improve the fit to the remaining data. The right-hand side of **Figure 2.10**, sheet 1 shows that omitting the five annual flows less than 11.7 m^3/s[5] from the analysis provides a better fit with the historic data. **Column G** in **Table 2.2** gives the peak flow estimates based on the omission of low flows from the data set.

The LP3 distribution was also fitted to the annual series of peak flows derived using the L&A Derived Rating Curve. The left hand side of **Figure 2.10**, sheet 2 shows that the annual series of peak flows do not sit within the 5 and 95% confidence limits when the full period of record is incorporated in the analysis, while the right hand side of **Figure 2.10** shows that the omission of the five peak flows less than 11.7 m^3/s results in a better fit with the recorded data. **Column L** in **Table 2.2** shows that the design peak flow estimates are significantly lower than those derived as part of the previous studies listed in **Section 1.2** and summarised in **Section 2.3** of this report, with the exception of the flow rates derived as part of Brown Consulting, 2010.

2.5.4 Concluding Remarks

Based on the above findings, it is considered that previous studies have relied on historic annual peak flow maximums that are higher than would have been generated by the Jerrabomberra Creek catchment and hence the design peak flows that have been derived at the gauge site by way of a site specific flood frequency analysis are also an overestimate. That said, the period of record upon which the flood frequency analysis has been undertaken is relatively short (i.e. 29 years), so there is merit in adopting a slightly conservative approach to the derivation of design peak flow estimates for Jerrabomberra Creek, especially where the assessed flood risk is considered to be high, for example in the case of proposed urban development.

[5] A peak flow of 11.7 m^3/s was derived using the automated multiple Grubbs-Beck test within the TUFLOW Flike software.

3 HYDROLOGIC MODELLING

3.1 Model Development and Calibration

A hydrologic (DRAINS) model of the Jerrabomberra Creek catchment (**Jerrabomberra Creek Hydrologic Model**) was developed as part of the present investigation, the sub-catchment layout of which is shown on **Figure 3.1**. The hydrologic response of the rural parts of the Jerrabomberra Creek catchment were simulated using the RAFTS sub-model, while the hydrologic response of the urbanised parts of catchment was simulated using the IL-CL sub-model within the DRAINS software which has been developed primarily for this purpose.

The outlets of each sub-catchment were linked, with the lag time between each assumed to be equal to the distance along the main drainage line divided by an assumed flow velocity of 2.5 m/s.[6] The following PERN values were adopted for the two principal rural land uses in the catchment:[7]

- heavily wooded slopes = 0.10
- cleared pastoral land = 0.045

Rainfall recorded at the pluviographic rain gauges were input to the hydrologic model for the historic flood events set out in **Table 2.3**. Figures 4 to 8 show the extent over which the recorded rainfall data were applied to the Jerrabomberra Creek Hydrologic Model, with the rainfall factored up or down based on the spatial distribution of total rainfall show on the figures.

Table 3.1 sets out the RAFTS hydrologic parameters which were required to obtain a good match with the historic flood data.

TABLE 3.1
RAFTS HYDROLOGICAL MODEL PARAMETERS

Hydrologic Model Parameter	February 1971 Storm	August 1974 Storm	October 1976 Storm	January 1995 Storm
Initial Loss (mm)	15	50	20	4
Continuing Loss (mm/hr)	4.4	1.2	2.5	1.1
BX	0.8	0.8	0.8	0.8

Figure 2.1 (2 sheets) shows a comparison of the discharge hydrographs that were recorded by the Four Mile Creek stream gauge based on both the EPSDD Rating Curve and the L&A Derived Rating Curve with the modelled hydrographs derived from the Jerrabomberra Creek Hydrologic Model. It was not possible to obtain a good match between the recorded discharge hydrographs derived using the EPSDD Rating Curve and the Jerrabomberra Creek Hydrologic Model using reasonable hydrologic model parameters which further highlights the finding that the EPSDD Rating Curve overestimates flow in the creek above the maximum gauged height of 1.45 m (refer **Section 2.5.1** for further details).

[6] A flow velocity of 2.5 m/s was adopted based on preliminary results of the hydraulic (TUFLOW) model that was developed as part of the present investigation.

[7] A PERN value of 0.06 was applied to those sub-catchments which comprised a mixture of both wooded and cleared pastoral land.

3.2 Derivation of Design Discharges

3.2.1 General

As previously mentioned, the L&A Derived Curve is considered to more accurately define the flow in Jerrabomberra Creek for a given gauge height and has hence been relied upon when deriving design peak flow estimates as part of the present investigation. The design peak flow estimates given in **Column L** of **Table 2.1**, as well as those derived from the right hand side of **Figure 2.9**, sheet 2 have therefore been adopted when deriving design discharge hydrographs.

3.2.2 Rainfall Intensity

The procedures used to obtain temporally and spatially accurate and consistent Intensity-Frequency-Duration (**IFD**) design rainfall curves for the assessment of local catchment flooding at Yass are presented in ARR 2019. Design storms for frequencies of 20, 5, 1, 0.5 and 0.2% AEP were derived for storm durations ranging between 30 minutes and 36 hours.

As recommended in the *Floodplain Risk Management Guide – Incorporating 2016 Australian Rainfall and Runoff in Studies* (NSW Office of Environment and Heritage (**OEH**), 2019), IFD data were downloaded from BoMs *2016 Rainfall IFD Data System* and applied to each individual sub-catchment in the Jerrabomberra Creek Hydrologic Model as the spatial variability in design rainfall across the study area was greater than 10 per cent.

3.2.3 Temporal Patterns

The design rainfalls were converted into rainfall hyetographs using the temporal patterns presented in ARR 2019 for the range of design storm events. ARR 2019 requires the analysis of ten temporal patterns for each storm duration and the selection of the pattern that produces a peak flow estimate that is closest to the mean.

3.2.4 Areal Reduction Factors

Areal reduction factors (**ARFs**) of between 0.71 and 0.96 were derived using the procedures set out in ARR 2019 in order to achieve a match between the design peak flow estimates derived from the flood frequency analysis at the Four Mile Creek stream gauge where the total catchment area is 54 km^2. ARFs of between 0.74 and 0.95 were also used to derive design peak flow estimates at the location of the future NER2 crossing of Jerrabomberra Creek where the total catchment area is 75 km^2.

3.2.5 Design Rainfall Losses

The rainfall loss parameters for ARR 2019 design storms were obtained from the ARR Data Hub and applied using the procedures set out in OEH, 2019. A copy of the data extracted from the ARR Data Hub for the Jerrabomberra Creek Hydrologic Model is contained in **Appendix A** of this report.

The raw probability neutral burst initial loss values obtained from the ARR Data Hub were reviewed and adjusted to remove inconsistencies in values with varying storm probability and durations. **Figure 3.2** shows the original probability neutral burst initial curves derived from the tables obtained from the ARR Data Hub, together with the adopted probability neutral burst initial loss curves following the adjustments that were made for the purpose of the present investigation.

Based on the NSW jurisdictional advice contained on the ARR Data Hub, the raw Continuing Loss (**CL**) value of 3.9 mm/hr was multiplied by a factor of 0.4, resulting in a CL of 1.6 mm/hr which was applied to the Jerrabomberra Creek Hydrologic Model. **Column M** of **Table 2.1** and the right hand side of **Figure 2.9**, sheet 2 show that adopting a CL of 1.6 mm/hr results in design peak flows at the Four Mile Creek stream gauge which are higher than the flows derived from the flood frequency analysis for flood events up to 0.2% AEP.

Column N of **Table 2.1** shows the application of the raw CL value from the ARR Data Hub (i.e. 3.9 mm/hr) to the Jerrabomberra Creek Hydrologic Model results in a peak 1% AEP flow of 224 m^3/s at the Four Mile Creek stream gauge, which is slightly higher than the 200 m^3/s that was derived by the flood frequency analysis undertaken as part of the present investigation, but gives a good match with the RAFTS Hydrologic Model that was developed as part of Brown Consulting, 2010. The right hand side of **Figure 2.9** shows that the adoption of a CL of 3.9 mm/hr also doesn't match the shape of the flood frequency curve.

Column O of **Table 2.1** shows that a CL value of 7.4 mm/hr was required in order to obtain a good match between the flood frequency analysis that was undertaken as part of the present investigation and the Jerrabomberra Creek Hydrologic Model.

While a CL of 7.4 mm/hr provides a good match with the flood frequency curve that was derived using the L&A Derived Raining Curve, as remarked in Section 2.5.4, the peak design flow estimates are based on a relatively short period of stream flow data. Given the proposal to develop part of the floodplain, albeit for recreational purposes as opposed to say residential or commercial development, there is merit in adopting a slightly conservative approach to the derivation of design peak flows for Jerrabomberra Creek at the location of the proposed Sports Complex. As such the raw CL value from the ARR Data Hub of 3.9 mm/hr has been adopted for deriving design discharge hydrographs for input to the Jerrabomberra Creek TUFLOW Model, with a sensitivity analysis undertaken on the impact that the adoption of a CL value of 1.6 mm/hr which is based on the NSW jurisdictional advice contained on the ARR Data Hub.

3.2.6 Probable Maximum Flood

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

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

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

The left hand side of **Figure 3.1** show the location and orientation of the PMP ellipses which were used to derive the rainfall estimates for each individual sub-catchment in the Jerrabomberra Creek catchment.

4 DEFINITION OF FLOOD BEHAVIOUR UNDER PRESENT DAY CONDITIONS

4.1 Background to TUFLOW Model Development

4.1.1 General

In order to accurately define flood behaviour in the vicinity of the proposed sports complex a two-dimensional (in plan) hydraulic model was developed using the TUFLOW software. **Figure 4.1** shows the layout of the TUFLOW model that was developed as part of the present investigation (**Jerrabomberra Creek TUFLOW Model**).

TUFLOW is a true two-dimensional hydraulic model which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave through the system. The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. Consequently, the model is "fully dynamic" and once tuned will provide an accurate representation of the passage of the floodwave through the drainage system (both surface and piped) in terms of depth, velocity and distribution of flow

4.1.2 Two-dimensional Model Domain

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

A grid spacing of 2 m was found to provide an appropriate balance between the need to define features on the floodplain versus model run times, and was adopted for the present investigation. This grid spacing also allowed for the waterway area of Jerrabomberra Creek (which is about 20 m wide where it flows adjacent to the proposed sports complex) to be modelled within the two-dimensional (in plan) model domain.

Ground surface elevations for model grid points were initially assigned using a detailed ground survey (refer **Figure1.1** for extent) and supplemented by a digital terrain model derived from the available LiDAR survey data. Details of the partially constructed section of NER2 were also incorporated in the TUFLOW model based on the road design model that was provided by Council, along with details of the five transverse drainage structures that are located along its length. Note that details of the Proposed NER2 Bridge Crossing of Jerrabomberra Creek and the section of road to its north were not available for the present investigation.

A default Manning's n roughness of 0.045 was applied to the Jerrabomberra Creek TUFLOW Model, while the following Manning's n roughness values were applied to the remaining principal land use types.

- riparian corridor = 0.06
- natural creek bed = 0.05
- asphalt or concrete road surface = 0.02

Based on the findings of a blockage analysis that was undertaken using the procedures set out in ARR 2019, no blockage factors were applied to the openings in the railway embankment.

4.1.3 Boundary Conditions

The locations where discharge hydrographs derived by the Jerrabomberra Creek Hydrologic Model were applied to the Jerrabomberra Creek TUFLOW Model are shown on **Figure 4.1**. These comprise both point-source inflows at selected locations around the perimeter of the two-dimensional model domain, as well as internal to the model (for example, at the location of surface inlet pits) and as distributed inflows via “Rain Boundaries”.

The Rain Boundaries act to “inject” flow into the two-dimensional domain of the Jerrabomberra Creek TUFLOW Model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Rain Boundary as the grid in the two-dimensional model domain becomes wet as a result of overland flow.

The downstream boundary of the Jerrabomberra TUFLOW Model comprised a “free discharge” outlet, where a TUFLOW derived normal depth calculation was used to define hydraulic conditions.

4.2 Present Day Flooding Patterns

Figure 4.2 (2 sheets) shows the indicative extent and depth of inundation, while **Figure 4.3** (2 sheets) shows maximum flow velocities in the vicinity of the proposed sports complex for a 20% AEP design flood event. Also shown on sheet 2 of the series are scalar and directional flow velocity vectors. **Figures 4.4** to **4.13** show similar information for design flood events with AEPs of 5%, 1%, 0.5%, 0.2%, as well as the PMF.[8] **Figure 4.14** shows design water surface profiles along Jerrabomberra Creek in the vicinity of the proposed sports complex for the full range of design flood events.

Table 4.1 over the page sets out the peak flows sourced from the Jerrabomberra Creek TUFLOW Model at key locations along NER2, while **Column J** of **Table 2.2** sets out the peak design flows that were sourced from the hydraulic model at the NSW/ACT Border.

The key findings of the investigation as they relate to the flooding patterns in the vicinity of the proposed sports complex under present day conditions are:

i. Floodwater commences to break the southern bank of Jerrabomberra Creek at a location about 275 m upstream of the existing rail bridge for floods that are more frequent than 20% AEP. Floodwater which breaks out of the creek at this location discharges toward the set of four 2.6 m diameter pipes which are located about 150 m to the south of the main creek crossing.

ii. Floodwater which breaks out of Jerrabomberra Creek at the aforementioned location joins overland flow which discharges across NER2 via the five transverse drainage structures, where it ponds on the upstream side of the rail corridor to depths exceeding 1 m in a 20% AEP flood event.

iii. Floodwater commences to break the southern bank of Jerrabomberra Creek in the north-east corner of the proposed Sports Complex site at the 5% AEP level of flooding, albeit at a relatively shallow depth. Floodwater which break out of the creek at this location also discharges toward the set of four 2.6 m diameter pipes which are located about 150 m to the south of the main creek crossing.

[8] Note that a different depth legend has been adopted on **Figure 4.12** (2 sheets) given the larger depth range for the PMF.

iv. Flow velocities in the inbank area of Jerrabomberra Creek adjacent to the proposed sports complex site generally exceed 2 m/s during floods as frequent as 20% AEP, increasing to close to 3 m/s at the 1% AEP level of flooding.

v. While flow velocities on the southern overbank of Jerrabomberra Creek within the extent of the proposed sports complex site are generally less than 1 m/s for floods up to 1% AEP in in magnitude, there are a number of areas where the velocity of overland flow approaches 2 m/s. Flow velocities exceeding 3 m/s are experienced immediately downstream of NER2 Culvert No. 3, where flow discharges down a relatively steep cut.

vi. Major surcharge of the southern bank of Jerrabomberra Creek occurs immediately adjacent to and upstream of the proposed sports complex site for floods that are larger than 1% AEP in magnitude.

vii. The whole of the proposed sports complex site would be inundated during a PMF, with depths of flow generally exceeding 2 m.

TABLE 4.1
PEAK FLOWS ALONG NER2
PRESENT DAY CONDITIONS[1]
(m^3/s)

AEP (%)	Jerrabomberra Creek at Proposed NER2 Bridge	NER2 Culvert No. 1	NER2 Culvert No. 2	NER2 Culvert No. 3	NER2 Culvert No. 4	NER2 Culvert No. 5
20	118	1.3	6.2 [-]	2.6	2.1	0.2
5	187	2.5	17.1 [-]	6.8	4.2	0.2
1	294	3.7	27.4 [1.9]	11.4	5.4	0.3
0.5	354	4.3	31.7 [4.6]	13.0	5.8	0.3
0.2	447	4.6	33.9 [18.5]	14.2	6.2	0.5
PMF	2,724	5.5	37.5 [241][2]	16.8 [124][3]	9.5	1.4

1. Values in [ ] indicate peak flow across NER2 in vicinity of bridge/culvert.
2. Peak flow across NER2 between NER2 Culverts Nos. 1 and 3.
3. Peak flow across NER2 between NER2 Culverts Nos. 3 and 4.

5 DEFINITION OF FLOOD BEHAVIOUR UNDER POST-PROJECT CONDITIONS

5.1 Description of Proposed Sports Complex

Figure 5.1 shows the plan layout of the proposed sports complex which will comprise a total of six outdoor playing fields which will be utilised for soccer and hockey, as well as indoor aquatic and basketball facilities. A warm-up area will also be provided in the north-west corner of the site. Two open car parking areas will also be built as part of the proposed development. Access to the proposed sports complex will be via a new road which will have its intersection with NER2 immediately to the east of NER Culvert No. 2

Table 5.1 over the page sets out the finished levels of the six outdoor playing fields and the two open car parking areas, as well as their minimum hydrologic standard. Also given is the maximum depth of inundation, flow velocity and flood vulnerability classification which effects each playing field and car parking area over the full range of flood events.

5.2 Description of Proposed Stormwater Drainage Strategy

The proposed stormwater drainage strategy that has been developed for the proposed sports complex principally comprises the construction of three trapezoidal shaped channels with 1 vertical:2 horizontal side slopes which will convey flow which discharges from the transverse drainage of NER2 through the site (denoted herein as the “Western Channel”, “Central Channel” and “Eastern Channel”). **Figure 5.1** shows the key features of the proposed channel system, including adopted invert levels, base widths and grades.

The Western Channel would run along the western boundary of the proposed sports complex and tie into existing ground levels on the eastern (upstream) side of the set of four 2.6 m diameter pipes that are located about 150 m to the south of the main rail crossing of Jerrabomberra Creek. It will be necessary to regrade the area which lies between the Western Channel and Fields 3 and 4 in order to prevent flow from surcharging the channel along its northern bank.[9]

The Central Channel would run in a northerly direction through the proposed sports complex where it would join Jerrabomberra Creek on its southern bank. A 35 m length of the Central Channel would need to be enclosed where it runs beneath the internal road network and car parking area, with 5 off 2700 x 600 RCBCs found to provide sufficient waterway area to convey the peak 1% AEP flow without surcharge. It will be necessary to incorporate scour protection in the form of dumped rock riprap within the inbank area of the Central Channel at the location of the culvert outlets and where it ties into Jerrabomberra Creek.

The Eastern Channel would run along the eastern boundary of the proposed sports complex where it would join the Central Channel to the north of Carpark 1. It is noted that a new industrial subdivision is planned immediately to the east of the proposed sports complex, with preliminary plans showing that runoff from this area will be controlled by a new piped stormwater drainage system, the outlets of which will discharge directly to Jerrabomberra Creek (i.e. no runoff from the land to the east of the proposed sports complex will discharge to the Eastern Channel).

[9] A ridge line was incorporated in the TUFLOW model to prevent flow from surcharging the Western Channel at this location.

TABLE 5.1
HYDROLOGIC CHARACTERISTICS OF PROPOSED PLAYING FIELDS AND CAR PARKING AREAS

Component	Minimum Hydrologic Standard	Maximum Depth of Inundation (m)						Maximum Flow Velocity (m/s)						Maximum Flood Hazard Vulnerability Classification					
		20%	5%	1%	0.5%	0.2%	PMF	20%	5%	1%	0.5%	0.2%	PMF	20%	5%	1%	0.5%	0.2%	PMF
Field 1	<0.20% AEP	-	-	-	-	0.21	1.93	-	-	-	-	0.4	3.5	-	-	-	-	H1	H6
Field 2	<0.20% AEP	-	-	-	-	0.42	2.13	-	-	-	-	0.7	3.1	-	-	-	-	H2	H6
Field 3	<PMF	-	-	-	-	-	2.34	-	-	-	-	-	3.3	-	-	-	-	-	H6
Field 4	<PMF	-	-	-	-	-	2.09	-	-	-	-	-	2.0	-	-	-	-	-	H5
Field 5	<1% AEP	-	-	0.39	0.54	0.68	2.94	-	-	1.1	1.4	1.7	2.7	-	-	H2	H3	H4	H6
Field 6	<1% AEP	-	-	0.41	0.61	0.81	3.06	-	-	1.1	1.5	1.9	3.9	-	-	H3	H4	H5	H6
Warm-up Area	<20% AEP	0.40	1.08	1.86	2.30	2.74	5.20	0.8	1.4	1.7	1.8	1.9	2.6	H2	H4	H5	H5	H5	H6
Aquatic Centre(1)	<0.50% AEP	-	-	-	0.21	0.34	2.62	-	-	-	1.2	1.6	2.6	-	-	-	H1	H2	H6
Basketball Centre(1)	<0.50% AEP	-	-	-	0.16	0.27	2.49	-	-	-	0.4	0.7	2.8	-	-	-	H1	H1	H6
Carpark 1	<5% AEP	-	0.20	0.76	0.95	1.13	3.41	-	0.1	1.2	1.5	1.7	3.3	-	H1	H3	H4	H5	H6
Carpark 2	<1% AEP	-	-	0.09	0.37	0.79	3.23	-	-	0.4	1.2	2.0	5.8	-	-	H1	H2	H5	H6

1. The information presented in the table relates to finished surface levels, not finished floor levels within individual buildings.

It is recommended that a low flow channel arrangement be incorporated into the base of the three channels in order to control runoff that is generated by the upstream catchment, noting that future development to the south of NER2 will increase the runoff potential of the area, thereby increasing the frequency and volume of runoff discharging to the channel system potentially creating ongoing maintenance issues.

5.3 Post-Project Flooding Patterns

Figure 5.2 (2 sheets) shows the indicative extent and depth of inundation under post-project conditions, while **Figure 5.3** (2 sheets) shows the impact that the construction of the proposed sports complex would have on flood behaviour for a 20% AEP design flood event. **Figure 5.4** (2 sheets) shows the maximum flow velocities under post-project conditions, while **Figure 5.5** (2 sheets) shows the impact that the construction of the proposed sports complex would have on maximum flow velocities for a 20% AEP design flood event. **Figure 5.6** shows the flood hazard vulnerability classification of the flood affected areas for a 20% AEP flood event based on the definitions contained in the publication entitled "*Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*" (Australian Institute for Disaster Resilience (**AIDR**), 2017), the velocity x depth relationships for which are shown in the illustration over the page. **Figures 5.7** to **5.31** show similar information for design flood events with AEPs of 5%, 1%, 0.5%, 0.2%, as well as the PMF.[10]

Note that based on the findings of a blockage analysis that was undertaken using the procedures set out in ARR 2019, no blockage factors were applied to the culverts that are located within the proposed sports complex.

The key findings of the investigation as they relate to the flooding patterns in the vicinity of the proposed sports complex under post-project conditions are:

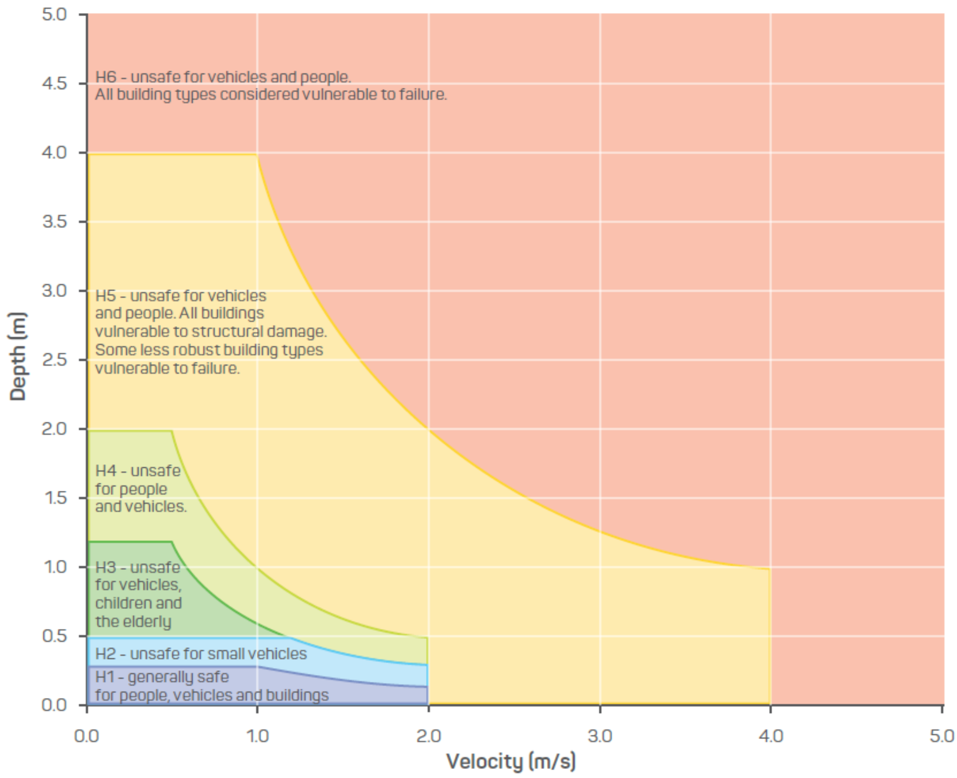
i. Increases in peak flood levels attributable to the construction of the proposed sports complex are generally limited to the immediate reach of Jerrabomberra Creek where it runs along its northern boundary and do not extend downstream of the NSW/ACT border over the full range of flood events.

ii. While increases in peak flood levels occur to the east and south of the proposed sports complex during flood larger than 1% AEP, they are relatively minor in nature and occur in areas that are presently undeveloped and where finished ground levels will likely be altered as part of future development.[11]

iii. While the proposed sports complex will only have a minor impact on flow velocities in Jerrabomberra Creek, it will be important to incorporate appropriate scour countermeasures at the confluence between it and the Central Channel in order to prevent scour due to turbulence in the flow.

[10] Note that a different depth legend has been adopted on **Figure 5.22** (2 sheets) given the larger depth range for the PMF.

[11] Note that the impacts that are shown to occur to the east (upstream) of the proposed sports complex are largely attributable to changes in natural surface levels that are associated with the future industrial subdivision, details of which were also incorporated in the TUFLOW model.



Source: AIDR, 2017

iv. Consideration will need to be given during detailed design stage to incorporating additional scour countermeasures along sections of the Western, Central and Eastern Channels given the relatively high flow velocities which would be experienced during storms up to 1% AEP in intensity.

v. While Fields 1 to 6 are impacted by floodwater which breaks out of Jerrabomberra Creek during floods that are more frequent than 20% AEP, flow velocities are relatively mild for floods up to 0.5% AEP in magnitude due to the backwater effects caused by the railway culverts and embankment.

vi. Conditions would generally become unsafe for children and the elderly in the parts of the warm up area during floods that are larger than about 20% AEP in magnitude and along the eastern edge line of Field 6 during a 1% AEP flood.

vii. Sections of Carpark 1 would start to become unsafe for small vehicles during floods larger than 5% AEP in magnitude, while Carpark 1 would become unsafe for small vehicles at the 1% AEP level of flooding.

viii. The access road leading into the proposed sports complex, as well as NER2 would remain flood free for all floods up to 1% AEP in magnitude.

ix. Potential increases in rainfall intensity associated with future climate change will increase the depth of inundation across parts of the proposed sports complex, with the Aquatic Centre, Basketball Centre and the eastern end of Carpark 2 impacted by a 10% increase, and Fields 1 and 2 impacted by a 30% increases in 1% AEP design rainfall intensities.[12]

[12] The characteristics of flooding associated with floods with AEP's of 0.5% and 0.2% can be considered analogous to conditions that would arise if 1% AEP rainfall intensities were to increase by about 10% and 30%, respectively.

5.4 Sensitivity Analysis

An analysis was undertaken to assess the sensitivity of flood behaviour to the adoption of a reduced continuing loss rate of 1.6 mm/hr which is consistent with the recommendations set out in OEH, 2019 for studies where there are no available stream flow data (which is not the case in this situation).

As shown in **Table 2.2**, the adoption of a reduced continuing loss rate of 1.6 mm/hr results in an increase in the peak 1% AEP flow estimate at the NSW/Act border from 224 m^3/s to 321 m^3/s. The higher peak flow rate is generally consistent with the values that were derived as part of URS, 2003 and Hill et al., 2013, noting that both these investigations relied on the EPSDD Rating Curve for deriving peak flows at the Four Mile Creek stream gauge.

Figure 5.32 (2 sheets) shows that there would only be a minor increase in the extent of land which would be inundated during a 1% AEP flood event. Peak flood levels be increased in the range 0.2-0.3 m over the warm-up area, and by a maximum of about 0.1 m over Fields 5 and 6. Fields 1 to 4 would still remain flood free at the 1% AEP level of flooding. Peak 1% flood levels across Carpark 1 would be increased by a maximum of about 0.1 m.

Figure 5.33 (2 sheets) shows that the increase in the peak 1% AEP flow would not translate into a significant increase in flow velocities within the proposed sports complex.

6 REFERENCES

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APPENDIX A

DESIGN INPUT DATA FROM ARR DATA HUB FOR JERRABOMBERRA CREEK HYDROLOGIC MODEL

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	149.18
Latitude	-35.389
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

Data

River Region

Division	Murray-Darling Basin
River Number	12
River Name	Murrumbidgee River

Layer Info

Time Accessed	28 November 2019 09:47AM
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
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	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	28 November 2019 09:47AM
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	20887.0
Storm Initial Losses (mm)	18.0
Storm Continuing Losses (mm/h)	3.9

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2016_v1

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

code	MB
Label	Murray Basin

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2016_v2

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

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-35.389356&longitude=149.179747&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	28 November 2019 09:47AM

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)	1.9 (0.097)	1.5 (0.055)	1.3 (0.038)	1.0 (0.026)	0.6 (0.013)	0.3 (0.006)
90 (1.5)	3.0 (0.132)	2.0 (0.063)	1.3 (0.034)	0.6 (0.015)	0.6 (0.012)	0.6 (0.010)
120 (2.0)	2.3 (0.091)	2.0 (0.059)	1.8 (0.045)	1.7 (0.035)	0.7 (0.013)	0.0 (0.000)
180 (3.0)	3.1 (0.110)	2.3 (0.060)	1.7 (0.038)	1.2 (0.023)	0.7 (0.010)	0.2 (0.003)
360 (6.0)	1.5 (0.043)	1.0 (0.021)	0.7 (0.012)	0.3 (0.005)	1.1 (0.014)	1.7 (0.018)
720 (12.0)	0.0 (0.000)	1.6 (0.026)	2.6 (0.037)	3.6 (0.044)	8.0 (0.080)	11.3 (0.099)
1080 (18.0)	0.0 (0.000)	1.3 (0.019)	2.1 (0.027)	3.0 (0.032)	7.2 (0.063)	10.4 (0.079)
1440 (24.0)	0.0 (0.000)	0.3 (0.004)	0.5 (0.005)	0.6 (0.006)	4.3 (0.034)	7.0 (0.048)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.5 (0.003)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)
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	28 November 2019 09:47AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

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

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

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	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)	0.1 (0.001)	0.2 (0.001)
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	28 November 2019 09:47AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	14.3 (0.714)	13.3 (0.481)	12.7 (0.382)	12.1 (0.311)	12.4 (0.264)	12.5 (0.237)
90 (1.5)	11.8 (0.519)	10.2 (0.326)	9.2 (0.244)	8.1 (0.185)	11.1 (0.211)	13.3 (0.224)
120 (2.0)	14.7 (0.589)	16.3 (0.477)	17.3 (0.425)	18.3 (0.386)	11.6 (0.204)	6.5 (0.101)
180 (3.0)	14.0 (0.492)	16.8 (0.436)	18.7 (0.408)	20.5 (0.384)	17.6 (0.276)	15.5 (0.214)
360 (6.0)	10.3 (0.289)	13.0 (0.274)	14.8 (0.263)	16.5 (0.252)	24.6 (0.311)	30.6 (0.339)
720 (12.0)	3.4 (0.075)	10.9 (0.185)	15.9 (0.228)	20.7 (0.253)	32.6 (0.327)	41.5 (0.362)
1080 (18.0)	2.3 (0.045)	7.1 (0.106)	10.3 (0.129)	13.3 (0.143)	27.3 (0.240)	37.8 (0.287)
1440 (24.0)	0.2 (0.004)	3.1 (0.043)	5.1 (0.058)	6.9 (0.068)	15.7 (0.126)	22.2 (0.154)
2160 (36.0)	0.0 (0.000)	1.0 (0.012)	1.6 (0.017)	2.3 (0.020)	7.9 (0.056)	12.1 (0.075)
2880 (48.0)	0.0 (0.000)	1.6 (0.018)	2.7 (0.025)	3.7 (0.030)	5.3 (0.035)	6.6 (0.038)
4320 (72.0)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)	0.2 (0.001)	0.4 (0.003)	0.6 (0.003)

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	25.6 (1.280)	24.5 (0.885)	23.9 (0.716)	23.2 (0.595)	33.7 (0.721)	41.6 (0.784)
90 (1.5)	25.1 (1.099)	25.0 (0.797)	25.0 (0.666)	25.0 (0.571)	31.9 (0.608)	37.0 (0.624)
120 (2.0)	31.2 (1.247)	31.9 (0.934)	32.4 (0.796)	32.9 (0.693)	36.5 (0.642)	39.1 (0.609)
180 (3.0)	33.5 (1.176)	37.0 (0.960)	39.3 (0.859)	41.6 (0.780)	42.6 (0.667)	43.3 (0.598)
360 (6.0)	24.6 (0.690)	30.9 (0.651)	35.1 (0.623)	39.1 (0.596)	60.2 (0.760)	76.0 (0.840)
720 (12.0)	17.2 (0.387)	31.2 (0.530)	40.5 (0.579)	49.3 (0.603)	64.3 (0.646)	75.6 (0.659)
1080 (18.0)	17.8 (0.353)	21.7 (0.325)	24.3 (0.306)	26.8 (0.288)	55.4 (0.486)	76.7 (0.584)
1440 (24.0)	6.1 (0.111)	10.4 (0.142)	13.2 (0.152)	15.9 (0.156)	30.9 (0.248)	42.2 (0.293)
2160 (36.0)	6.5 (0.106)	10.0 (0.122)	12.3 (0.126)	14.5 (0.126)	21.0 (0.150)	25.8 (0.160)
2880 (48.0)	1.0 (0.016)	10.6 (0.120)	17.0 (0.160)	23.0 (0.185)	23.5 (0.156)	23.8 (0.138)
4320 (72.0)	3.2 (0.045)	6.6 (0.069)	8.9 (0.076)	11.0 (0.081)	9.8 (0.060)	8.9 (0.048)

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2018_v1
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%)**

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2019_v1
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)	11.3	8.0	7.6	8.6	7.6	5.4
90 (1.5)	11.6	8.4	8.4	9.4	8.9	5.4
120 (2.0)	10.7	7.9	7.8	8.4	8.5	7.0
180 (3.0)	10.6	7.8	7.8	7.8	8.2	6.0
360 (6.0)	12.2	9.1	9.2	9.4	8.3	5.0
720 (12.0)	14.4	9.7	9.5	8.5	7.8	2.5
1080 (18.0)	14.9	11.1	11.5	10.7	10.0	3.0
1440 (24.0)	17.2	13.7	13.7	14.7	9.7	4.1
2160 (36.0)	17.5	14.4	14.9	17.2	13.0	8.4
2880 (48.0)	18.6	14.7	14.8	16.0	13.5	8.8
4320 (72.0)	18.4	16.0	16.4	19.2	17.0	12.3

Layer Info

Time Accessed	28 November 2019 09:47AM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/7d2d0fc1-d851-4687-a59d-950036a71b05.txt)

Download JSON (downloads/33235c92-41b3-4230-948f-125c3bda12d4.json)

Generating PDF... (downloads/39458ab1-8e60-4d0f-9869-310beeeb87dc.pdf)