CAMDEN COUNCIL PUBLIC EXHIBITION DOCUMENT 2022

NEPEAN RIVER FLOODPLAIN RISK MANAGEMENT STUDY & PLAN INCLUDING NARELLAN CREEK:

APPENDIX C – ARR 2016 ASSESSMENT

(Final Draft Report)

NEPEAN RIVER FLOODPLAIN RISK MANAGEMENT STUDY

ARR2016 DISCUSSION PAPER

8 AUGUST 2019

In accordance with NSW Government's Floodplain Development Manual, Council is preparing a comprehensive floodplain management plan for the Nepean River and Narellan Creek catchments.

The main objective of the NSW Government's Flood Policy is to reduce both the impact of flooding and flood liability, and private and public losses arising due to flood. While technical, financial and policy assistance are provided by State Government to assist in this floodplain risk as part of this Policy, the Policy states that local government is responsible for the management of flood risk and flood prone land management.

Two sets of hydrological and hydraulic models have been previously assembled for the study area.

The first set of models was used in the Upper Nepean River Flood Study (Lyall and Macoun, 1995). Hydrological modelling was undertaken using RORB for catchment areas upstream of Menangle Weir, and XP-RAFTS for catchment areas downstream of Menangle Weir. A 1D/2D TUFLOW model was developed for the study area, utilising an 8m grid. These models covered the full study area, with the exception of Narellan Creek.

A separate set of models were developed for Narellan Creek. An XP-RAFTS model was used to define the hydrology, and a 1D/2D TUFLOW model was developed for the study area, utilising a 5m grid. These models were subsequently used to assess 10 mitigation options within Harrington Park.

Hydrological modelling undertaken as part of the preceding flood studies was based on the 1987 edition of Australian Rainfall & Runoff (ARR1987).

On 25 November 2016 Geosciences Australia announced that:

> *The ARR 2016 Guidelines have now been officially finalised, providing engineers and consultants with the guidance and datasets necessary to produce more accurate and consistent flood studies and mapping across Australia, now and into the future.*

ARR consists of different data to enable and support the guidelines.

Design rainfall can be obtained from the Bureau of Meteorology (BOM). The 2016 Intensity-Frequency-Duration (IFD) data replace both the ARR87 IFDs and the interim 2013 IFDs.

The BOM states that the 2016 IFDs are:

- *based on a more extensive data base, with more than 30 years of additional rainfall data and data from extra rainfall stations;*

- *more accurate estimates, combining contemporary statistical analysis and techniques with an expanded rainfall database; and*
- *better estimates of the 2% and 1% annual exceedance probability IFDs than the interim 2013 IFDs.*

By combining contemporary statistical analyses and techniques with an expanded database, the new 2016 IFDs provide more accurate design rainfall estimates for Australia.

Data can be also downloaded from the ARR Data Hub.

It is also noted that ARR1987 data was reported based on Average Recurrence Interval (ARI) while the ARR2016 data is reported based on Annual Exceedance Probability (AEP).

The correspondence between ARI and AEP is as follows.

ARI (yrs)	AEP		AEP	ARI (yrs)
2	39.4%		50.0%	1.44
5	18.1%		20.0%	4.48
10	10.5%		10.0%	9.5
20	5.1%		5.0%	19.5
50	2.0%		2.0%	49.5
100	1.0%		1.0%	99.5

In view of the release of ARR2016 after the commissioning of the current study, a sensitivity analysis was undertaken to determine the potential differences in flood modelling results and any implications for the study. This sensitivity analysis, which was undertaken for both the Nepean River and Narellan Creek catchments, included the update of the hydrological model only. These assessments have examined the sensitivity peak flows to the latest ARR2016 data including:

- 2016 intensity-frequency-duration (IFD) data;
- Ensemble modelling of new temporal patterns;
- New recommended initial and continuing rainfall losses; and
- Pre-burst rainfall.

1. NEPEAN RIVER HYDROLOGY

Hydrological modelling was undertaken using RORB for catchment areas upstream of Menangle Weir and XP-RAFTS for catchment areas downstream of Menangle Weir. In June 2018 a sensitivity assessment was undertaken for catchment areas upstream of Menangle Weir ie. the RORB model. It is noted that the RORB model extends up to the confluence of Nepean River with Warragamba dam and includes the Upper Nepean River catchment.

The RORB model was run with methodology specified by the new ARR2016 guidelines. The previous hydrological modelling identified the critical storm duration for the 1% AEP event to be 36 hours, consequently the same storm was run for the ARR2016 version to facilitate a “like-for-like” comparison. Furthermore the 12, 24 48 and 72 hour storms were also assessed to ensure that the critical storm duration was identified as part of this assessment.

The sensitivity assessment updated:

- IFD data (storm burst depth);
- Areal Reduction Factor;
- Temporal Patterns; and
- Storm Losses

1.1 IFD

IFD data for seven (7) locations within the catchment was downloaded from the ARR2016 Data Hub. This was undertaken to represent the variability of storm burst depths across the sub-areas. These locations can be seen in **Table 1**.

Table 1 Nepean River 12, 24, 36, 48 & 72 hour 1% AEP Storm Burst Depths (mm)

Location	Latitude	Longitude	Storm Burst Depth (mm)				
			12 Hour	24 Hour	36 Hour	48 Hour	72 Hour
1 Lake Nepean	-34.390030	150.597762	237	327	389	432	487
2 Lake Avon	-34.429706	150.682027	329	463	548	606	679
3 Lake Cordeaux	-34.376329	150.771832	257	508	606	673	756
4 Lake Cataract	-34.302924	150.836163	342	488	584	649	732
5 Mount Hunter Rivulet @ Burragorang Rd	-34.070370	150.632577	152	213	255	286	324
6 Nepean River @ Macquarie Grove Rd	-34.041601	150.695387	151	212	256	287	327
7 Nepean River @ Gulger	-33.936685	150.626055	159	223	268	302	345

The storm burst depths from **Table 1** were assigned to sub-catchments. As no spatial data was found for the RORB subareas, each subarea was assigned a storm burst depth based upon the descriptions in the report and dam locations within the RORB model.
A comparison of the ARR1987 and ARR206 IFD curves has been undertaken and the results are provided in **Figure 1** to **Figure 7**.

1.2 Areal Reduction Factor

The areal reduction factor was calculated using Equation 2.4.1 for the 12 hour event and Equation 2.4.2 from ARR2016 Book 2 Chapter 4 for catchments with storm burst durations greater than 24 hours. This was applied to the storm burst depths given in **Table 1**. **Table 2** outlines the calculated Areal Reduction Factors.

Table 2 Areal Reduction Factors

Duration	Areal Reduction Factors
12 Hour	0.792
24 Hour	0.894
36 Hour	0.904
48 Hour	0.911
72 Hour	0.919

1.3 Storm Temporal Patterns

Areal temporal patterns were also downloaded for the catchment. Areal as opposed to point temporal patterns were required because the catchment area is greater than 75 km^2. Ten (10) temporal patterns were downloaded for each duration. Consequently one (1) RORB storm file was created for each temporal pattern. **Table 3** outlines the temporal patterns

Table 3 Temporal Patterns

Pattern Number	12 Hour Event	24 Hour Event	36 Hour Event	48 Hour Event	72 Hour Event
1	TP1	TP181	TP271	TP361	TP451
2	TP2	TP182	TP272	TP362	TP452
3	TP3	TP183	TP273	TP363	TP453
4	TP4	TP184	TP274	TP364	TP454
5	TP5	TP185	TP275	TP365	TP455
6	TP6	TP186	TP276	TP366	TP456
7	TP7	TP187	TP277	TP367	TP457
8	TP8	TP188	TP278	TP368	TP458
9	TP9	TP189	TP279	TP369	TP459
10	TP10	TP190	TP280	TP370	TP460

1.4 Storm Losses

The then OEH (now DPIE) guideline (2018) recommends use of the ARR2016 data hub for estimating losses, in the absence of calibrated losses. The RORB model was calibrated to the June 1964, June 1975, March 1978, April 1988 and August 1990 historical flood events (Upper Nepean River Flood Study, 1995).

In the 1995 flood study hydrological assessment, the adopted values were an initial storm burst loss = 60 mm and a continuing rainfall loss = 0.5 mm/h. These losses have been applied for this assessment.

1.5 Results

The results were compared at the final print location in the RORB model. This location is the Nepean River at Wallacia Weir (Hyd0095) which is near the confluence of Nepean River with Warragamba dam.

Figure 8 to **Figure 12** compares the hydrographs estimated using the RORB model with previously adopted ARR1987 losses.

The peak flows at Wallacia Weir are given in **Table 4**. The median flows for all the durations are lower than the peak flow of 7,800 m^3/s estimated using the existing RORB model.

Table 4 Peak Flows (m3/s) at Wallacia Weir ARR1987 Losses

Pattern Number	12 Hour Event	24 Hour Event	36 Hour Event	48 Hour Event	72 Hour Event
1	5069	6494	3069	6955	7138
2	4532	5601	6927	6398	7089
3	4369	7729	6539	7084	6068
4	4652	5767	5992	6064	6782
5	4115	7180	6688	5111	7044
6	4745	7300	4939	7088	6065
7	4201	6320	7698	5614	4983
8	4047	6220	7041	6921	5579
9	4873	7555	7515	5103	4906
10	4849	5085	7509	6722	6893
Median	4645	6407	6807	6560	6425

1.6 Recent ARR2016 Guidance

As discussed in **Attachment A** (which was downloaded from the ARR Data Hub):

> *NSW Office of Environment and Heritage has developed a guide to assist councils and consultants undertaking studies under the NSW Floodplain Management Program to transition to Australian Rainfall and Runoff 2016.*

As part of this transition a study (Review of ARR Design Inputs for NSW report) was undertaken to review and advise on addressing under-estimation bias being experienced when using standard ARR 2016 design event methods with default data from the ARR data hub.

The outcomes of this study indicated that there is significant bias in the standard ARR 2016 design event method with default ARR data hub losses and pre-burst.

…….

Considering this new information, practitioners undertaking flood investigations in New South Wales should use a hierarchical approach to loss and pre-burst estimation. This hierarchy goes from 1 (most preferred) to 5 (least preferred) as indicated in Table 1 and described in **Attachment A**.

Under 4 it is proposed that practitioners *Use the NSW FFA-reconciled losses (See Map & Table) available through the ARR Data Hub.*

The ARR Data Hub includes FFA-reconciled losses for a gauge on the Nepean River labelled as "Nepean River at Wallacia (Station Nepean)". The location of this gauge and its relationship to the streamflow gauge located at Wallacia Weir (Station 212202) is given in **Figure 13**. The FFA-reconciled losses for the "Nepean River at Wallacia (Station Nepean)" is shown in **Figure 14**.

The FFA-reconciled losses for the gauge identified as "Nepean River at Wallacia" (Station Nepean) are in initial loss = 30 mm and a continuing loss = 4.8 mm/h. The reconciled initial loss is lower than the initial loss adopted above while the continuing loss is greater than adopted above.

The ramifications of the difference between these two sets of rainfall losses are explored in **Tables 5** and **6**.

From **Table 5** it will be noted that TP272 and TP275 gave the peak flows closest and higher and lower than the median peak flow respectively. In relation to these two storms, it is noted that the FFA-reconciled losses are estimated to change the rainfall excess by -7.0% to +0.5% and -21.9% to -1.2% respectively. Likewise, it is noted that the FFA-reconciled losses are estimated to change the rainfall excess during the highest 2 hour burst in the 36 hour storms by -6.3% to -2.4% and -7.9% to -2.8% respectively.

This suggests that the adoption of the FFA-reconciled losses would further reduce the median peak flow under a 36 hour design storm in comparison to the peak flow estimated using ARR1987 rainfall losses.

Table 5 Comparison of Rainfall Excess during a 36 Hour Storm Burst (mm)

	TP271	TP272	TP273	TP274	TP275	TP276	TP277	TP278	TP279	TP280
	Excess Rainfall (mm)			IL (mm) =	45		CL (mm/h) =	3.9		
Location										
1	193.2	194.6	191.9	190.2	209.2	180.6	177.8	213.1	204.4	192.9
2	330.9	333.8	325.9	326.7	346.6	319.7	340.7	344.8	334.8	330.3
3	382.1	384.6	376.5	377.4	398.0	371.1	392.1	395.2	384.7	381.3
4	362.7	365.4	357.3	341.8	378.5	335.8	372.5	340.6	365.9	362.0
5	82.8	80.4	91.4	80.0	102.0	70.5	102.4	105.7	103.6	89.3
6	83.6	81.2	92.1	80.7	102.8	71.3	103.2	106.5	104.2	89.9
7	93.2	91.3	101.4	90.2	112.3	80.8	112.5	116.4	112.4	98.2
	Excess Rainfall (mm)			IL (mm) =	30		CL (mm/h) =	4.8		
Location										
1	174.2	180.9	170.6	168.1	197.6	162.6	187.4	200.6	185.7	179.1
2	313.1	315.1	308.6	305.4	333.4	300.0	326.0	335.0	311.0	313.8
3	364.5	365.5	359.4	356.4	385.0	351.5	377.5	384.8	360.5	364.7
4	345.0	346.1	340.1	322.6	365.4	331.9	358.0	332.3	341.4	345.3
5	72.1	81.0	73.7	58.1	89.7	55.0	87.0	94.3	87.4	77.9
6	72.7	81.7	74.4	58.9	90.4	55.7	87.7	95.0	88.1	78.5
7	82.9	89.8	82.4	68.1	99.3	64.2	95.8	104.0	96.7	86.6
	Difference in Excess Rainfall (%)									
Location										
1	-9.9%	-7.0%	-11.1%	-11.6%	-5.5%	-10.0%	5.4%	-5.9%	-9.1%	-7.1%
2	-5.4%	-5.6%	-5.3%	-6.5%	-3.8%	-6.2%	-4.3%	-2.8%	-7.1%	-5.0%
3	-4.6%	-5.0%	-4.5%	-5.6%	-3.3%	-5.3%	-3.7%	-2.6%	-6.3%	-4.4%
4	-4.9%	-5.3%	-4.8%	-5.6%	-3.5%	-1.2%	-3.9%	-2.5%	-6.7%	-4.6%
5	-12.9%	0.7%	-19.3%	-27.3%	-12.0%	-21.9%	-15.0%	-10.8%	-15.6%	-12.8%
6	-13.0%	0.5%	-19.3%	-27.1%	-12.0%	-21.9%	-15.0%	-10.8%	-15.5%	-12.7%
7	-11.0%	-1.6%	-18.8%	-24.4%	-11.6%	-20.5%	-14.8%	-10.7%	-14.0%	-11.8%

Table 6 Comparison of Highest 2 Hour Rainfall Excess in 36 Hour Design Storm Burst (mm)

Excess Rainfall (mm) IL (mm) = 45 CL (mm/h) = 3.9

TP271	TP272	TP273	TP274	TP275	TP276	TP277	TP278	TP279	TP280	Median
34.5	47.4	34.2	24.1	38.7	23.3	33.3	56.1	53.2	54.4	36.6
51.8	69.9	51.3	37.2	57.6	35.9	50.1	82.3	78.1	79.9	54.7
58.1	78.2	57.6	41.9	64.6	40.6	56.2	91.8	87.2	89.2	61.3
55.7	75.0	55.2	40.1	61.9	38.8	53.9	88.2	83.7	85.6	58.8
19.9	28.4	19.7	13.1	22.7	10.1	19.1	34.1	32.2	33.0	21.3
20.0	28.5	19.8	13.2	22.8	10.1	19.3	34.3	32.3	33.2	21.4
21.3	30.2	21.1	14.2	24.2	11.0	20.5	36.2	34.2	35.1	22.8

Excess Rainfall (mm) IL (mm) = 30 CL (mm/h) = 4.8

TP271	TP272	TP273	TP274	TP275	TP276	TP277	TP278	TP279	TP280	Median
32.7	45.6	32.4	22.3	36.9	21.5	31.5	54.3	51.4	52.6	34.8
50.0	68.1	49.5	35.4	55.8	34.1	48.3	80.5	76.3	78.1	52.9
56.3	76.4	55.8	40.1	62.8	38.8	54.4	90.0	85.4	87.4	59.5
53.9	73.2	53.4	38.3	60.1	37.0	52.1	86.4	81.9	83.8	57.0
18.1	26.6	17.9	11.3	20.9	10.8	17.3	32.3	30.4	31.2	19.5
18.2	26.7	18.0	11.4	21.0	10.8	17.5	32.5	30.5	31.4	19.6
19.5	28.4	19.3	12.4	22.4	11.8	18.7	34.4	32.4	33.3	21.0

Difference in Excess Rainfall (%)

TP271	TP272	TP273	TP274	TP275	TP276	TP277	TP278	TP279	TP280	Median
-5.2%	-3.8%	-5.3%	-7.5%	-4.7%	-7.7%	-5.4%	-3.2%	-3.4%	-3.3%	-4.9%
-3.5%	-2.6%	-3.5%	-4.8%	-3.1%	-5.0%	-3.6%	-2.2%	-2.3%	-2.3%	-3.3%
-3.1%	-2.3%	-3.1%	-4.3%	-2.8%	-4.4%	-3.2%	-2.0%	-2.1%	-2.0%	-2.9%
-3.2%	-2.4%	-3.3%	-4.5%	-2.9%	-4.6%	-3.3%	-2.0%	-2.1%	-2.1%	-3.1%
-9.0%	-6.3%	-9.1%	-13.7%	-7.9%	6.9%	-9.4%	-5.3%	-5.6%	-5.5%	-6.5%
-9.0%	-6.3%	-9.1%	-13.6%	-7.9%	6.9%	-9.3%	-5.3%	-5.6%	-5.4%	-6.4%
-8.4%	-6.0%	-8.5%	-12.7%	-7.4%	7.4%	-8.8%	-5.0%	-5.3%	-5.1%	-7.9%

2. NEPEAN RIVER FLOOD FREQUENCY ANALYSIS

Flood frequency analysis allows the magnitude of floods of a selected Annual Exceedance Probability (AEP) to be estimated by statistical analysis of recorded floods. Models have been developed to fit a probability distribution to observed data so that flood magnitudes of certain probabilities can be calculated. At least 10 to 15 years of data of streamflow data is required to undertake a flood frequency analysis.

2.1 Previous Flood Frequency Analyses

Flood frequency analyses have been reported in 1995 and 2015 as follows.

1995 Upper Nepean River Flood Study

Appendix B of the 1995 study[1] describes the flood frequency analyses (FFA), in part, as follows:

> *Following a review of gauging station data and previous investigations, flood frequency analyses were carried out at three locations along the Upper Nepean River:*
>
> - *Camden*
> - *Wallacia*
> - *Maldon Weir*
>
> *….*
>
> *Flood frequency analyses were carried out on the Wallacia record for the period 1917 to 1993, with and without the historic floods. Inclusion of three historic floods prior to 1917 increased the estimate of the 1% AEP flood from 5,100 m^3/s to 6,400 m^3/s (Table B3.6). The corresponding estimate for a partial series analysis with historic floods included was 5,400 m^3/s. Levels at this gauge are affected by backwater flooding due to high flows in the Warragamba River.*
>
> *A summary of the results is given in Table B4.1.*

TABLE B4.1
SUMMARY OF FLOOD FREQUENCY ANALYSIS

Frequency (% AEP)	*Location*		
	Maldon Weir	*Camden*	*Wallacia*
20	*2.200*	*2.100*	*1.400*
5	*4,300*	*4,900*	*3,600*
1	*6,800*	*7,900*	*6,400*

2015 Nepean River Flood Study

Likewise the 2015 study[2] describes their flood frequency analyses, in part, as follows:

> *Stream level records have been recorded at Wallacia Weir (212202) since 1908 and continuous records commenced in 1962. As with the stream records at Camden, the three highest flows assumed at this location in the study were from 1860, 1873 and 1898 (5090, 7080 and 5900 m^3/s, respectively) and are based on less reliable information from the nearby area. The fourth highest discharge was the first to be experienced after the introduction of formal recordings at Wallacia commenced in 1908 also occurred in June 1964. A number of other large events were observed, starting in 1917.*
>
> *Once again, the total number of records for inclusion in the analysis was restricted to 60 records, meaning that all flow events with a peak discharge less than 400 m^3/s were excluded.*

[1] Lyall and Macoun Consulting Engineers (*1995*), 'Upper Nepean River Flood Study*'.*

[2] Worley Parsons (20150 "Nepean River Flood Study", 2 Vols, prepared for Camden Council.

A partial series flood frequency analysis was undertaken based on this data, which is listed in Appendix A (of the 2015 Nepean River Flood Study report). *The analysis was undertaken using a log Pearson Type III distribution.*

Considering that the three highest flow events assumed to have occurred were based on estimates taken up to 150 years ago, investigations for Wallacia were also conducted with and without the pre-1917 data. The results of the analysis are presented in Table 4.3.

Table 4.3 SUMMARYOF FLOOD FREQUENCY ANALYSIS FOR WALLACIA

	***PEAK DISCHARGE** [m³/s]*						
	2yr	***5yr***	***10yr***	***20yr***	***50yr***	***100yr***	***200yr***
1860 – 2012	*881*	*1,737*	*2,643*	*3,870*	*6,177*	*8,635*	*11,931*
1917 – 2012	*833*	*1,469*	*2,053*	*2,767*	*3,960*	*5,101*	*6,494*

The results of the individual analyses again suggest that the three floods that occurred in the late 19th century had a heavy influence on the overall results of the calculations. The results of the analyses when undertaken purely on the recordings taken since 1917 (of which the first major flood was in 1964) are markedly lower. It is interesting to note that the peaks assumed at Wallacia for the 1873 and 1898 flood events were calculated as being lower at Wallacia than at Camden, suggesting that a significant degree of uncertainty is inherent in the discharge calculations undertaken for these three events. This confirms yet again that the, while it is likely that the three pre-1917 discharges do have some validity, it is likely that the "true" discharges for the various design flood events would lie somewhere between the two scenarios tested.

The values listed in Table 4.3 are also generally in agreement with the values for Wallacia reported in the Upper Nepean River Flood Study (1995), which also investigated cases with and without the earlier, higher data.

2.1 Nepean River at Wallacia

The streamflow records at Station 212202 (Nepean River @ Wallacia Weir) reported in the 2015 Nepean River Flood Study (Worley Parsons, 2015) were re-analysed using the FFA procedure released under ARR2016.

Peak-Over-Threshold (POT) Gauged Series Analysis

A POT series consists of all floods with peak discharges above a selected threshold value regardless of the number of such floods occurring each year however there should not be more than 3 or 4 floods above the threshold each year (ARR, 2016). The POT series reported by (Worley Parsons, 2015) based on a threshold of 400 m³/s was found to have no more than 3 flood events occurred above the threshold in any one year.

The POT series includes 57 events which exceeded the threshold of 400 m³/s over the period 1917 - 2012, at a ratio of 0.6 to 1. When fitting a Log Pearson III (LP III) distribution it is recommended that the ratio of floods to number of years of record be 1:1 (Jayasuriya and Mein, 1985[3]). It is noted that the selected data does not meet this criteria.

TUFLOW FLIKE analyses were undertaken of the following cases, using the LPIII probability model:

- Case 0: Period from 1860 to 2012 with a flow threshold of 400 m^3/s;
- Case 1: Period from 1917 to 2012 with a flow threshold of 400 m^3/s;
- Case 2: Case 1 plus 3 exceedances of 3,940 m^3/s in the preceding 58 years.

Results

The results of the FLIKE FFA analysis are given in **Table 7**.

Table 7 2019 FFA for Nepean River at Wallacia Weir (Stn 212202)

	AEP (1 in X)					
	2	**5**	**10**	**20**	**50**	**100**
Case 0	830	1,694	2,756	4,384	7,931	12,288
Case 1	779	1,440	2,175	3,213	5,273	7,588
Case 2	789	1,496	2,301	3,463	5,824	8,537

2.2 Conclusions

A comparison of the peak flows estimated at Wallacia Weir using RORB and the 1% AEP flows estimated by flood frequency analysis are summarized in **Table 8**.

Table 8 Comparison of 1% AEP Nepean River Peak Flows estimated at Wallacia Weir

Rainfall Losses		36 hour Temporal Pattern		Peak Flow (m3/s)		
IL (mm)	CL (mm/h)	Number	Source	Min	Median	Max
60	0.5	1	ARR1987		7,800	
60	0.5	10	ARR2016	4,939	6,807	7,698
45	3.9	10	ARR2016	3,536	5,324	6,180
FFA		**Period of Record**				
1995		1917-1993			6,400	
2015		1860 – 2012			8,635	
		1917 – 2012			5,101	
2019		1917 – 2012			7,588	
		1917 – 2012	+ 3 Exceedances		8,537	

[3] Jayasuriya, M.D.A. and Mein, R.G. (1985), Frequency analysis using the partial series. Hydrology and Water Resources Symposium 1985, Inst. Engrs Aust., Natl Conf. Publ. No. 85/2, pp: 81-85

It is concluded that:

(i) The impact of adopting the 10 ARR2016 storm burst areal temporal patterns for the various critical durations is to significantly lower the 1% AEP (median) peak flow in comparison to the 1% AEP peak flow estimated by the ARR1987 temporal pattern;
(ii) The 1% AEP peak flows estimated by FLIKE are within the range of FFA peak flows reported in the 2015 Nepean River Flood Study; and
(iii) The 1% AEP peak flows estimated by FLIKE for the period 1917-2012 is close to the 1% AEP peak flow estimated by the ARR1987 temporal pattern and rainfall losses and supports this previously adopted modelling approach.

3. NARELLEN CREEK HYDROLOGY

The Narellan Creek XP-RAFTS model assembled for the Update of Narellan Creek Flood Study (Public Works Advisory, June 2017) was adopted as the base model for the ARR2016 sensitivity analysis for the Narellan Creek catchment. The sensitivity assessment updated:

- IFD data (storm burst depth);
- Areal Reduction Factor;
- Temporal Patterns; and
- Storm Losses

3.1 IFD

IFD data for one (1) representative location within the catchment was downloaded from the ARR2016 Data Hub. This location was Narellan at latitude -34.042 and longitude 150.738. The storm burst depths for selected storm burst durations and AEPs are given in **Table 9.**

Table 9 Design Storm Burst Depths at Narellan

Duration	Annual Exceedance Probability (AEP)					
	63.20%	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**
30 mins	17.0	19.2	26.6	31.8	37.1	44.4	50.2
45 mins	19.6	22.1	30.4	36.3	42.2	50.5	57.1
1 hour	21.5	24.2	33.1	39.5	45.9	54.9	62.1
1.5 hours	24.3	27.3	37.3	44.4	51.6	61.7	69.7
2 hours	26.6	29.9	40.7	48.4	56.3	67.2	76
3 hours	30.4	34.1	46.5	55.4	64.4	76.9	86.9
4.5 hours	35.1	39.5	54	64.4	75	89.6	101
6 hours	39.1	44.2	60.7	72.5	84.6	101	114
9 hours	46.1	52.3	72.6	87.1	102	122	138
12 hours	52.1	59.4	83.1	100	117	141	159
18 hours	62.1	71.2	101	122	144	173	195
24 hours	70.1	80.7	116	141	167	200	226

3.2 Areal Reduction Factor

The catchment area is 33.26 km^2. The XP-RAFTS model calculated the areal reduction factor for the catchment using Equation 2.4.4 from ARR 2016 Book 2 Chapter 4

3.3 Storm Temporal Patterns

Point temporal patterns were also downloaded for the catchment from the ARR Data Hub.

3.4 Storm Losses

Storm losses were also downloaded for the location where the IFD data was downloaded. The rural storm losses were initial loss = 38.0 mm and continuing loss = 3.7 mm/h. The ARR2016 guidance for rainfall losses in urban areas is summarised in **Table 10**.

Table 10 Urban Rainfall Losses

Surface Type	Initial Loss (mm)	Continuing Loss (mm/h)
Effective Impervious Areas	1 -2 mm	0 mm/h
Indirectly Connected Areas	60% - 80% Rural ILs 22.8 – 30.4 mm	2.5 mm/h
Urban Pervious Areas	100% Rural IL 38.0	100% Rural CL 3.7 mm/h

In the June 2017 study, the ARR1987 rainfall losses adopted for the 1% AEP storm were IL = 15 mm and CL = 2.5 mm/h. The 2017 report[4] states that these losses were validated through simulation of the 2007, 2008 and 2013 events.

3.5 Results

The results at two reference locations are compared in **Table 11**. The selected locations were Node N_34 and Node_106. The location of these reference locations are identified in **Figure 15**.

It will be noted that at Node N_34 the critical storm burst duration under ARR1987 conditions is 2 hours (just, with the 6 hour storm is very close) but the adoption of ARR2016 temporal patterns and rainfall losses increases the critical storm burst duration to 6 hours.

4 Public Works Advisory (2017) Update of Narellan Creek Flood Study, Draft Report DC17070, prepared for Camden Council, July, 50 pp + Apps

Table 11 Estimated Peak Flows (m3/s) at Nodes N_34 and N_106

	XP-RAFTS N_34					XP-RAFTS N_106			
Pervious Area Rainfall Losses									
IL (mm)	15	15	38	42.4		15	15	38	42.4
CL (mm/h)	2.5	2.5	3.7	1.04		2.5	2.5	3.7	1.04
Temporal Pattern per Storm Burst									
Number	1	10	10	10		1	10	10	10
ARR	1987	2016	2016	2016		1987	2016	2016	2016
Storm Burst Duration									
30 mins	105.4	75.6	40.8	40.1		140.8	106.1	64.0	62.3
45 mins	142.4	101.4	55.9	52.7		182.3	134.8	82.6	77.2
60 mins	167.2	117.5	66.9	62.5		210.2	152.8	95.7	89.8
90 mins	184.1	138.6	86.5	80.5		234.5	177.4	118.0	111.5
120 mins	193.8	144.1	97.6	92.2		255.4	185.0	130.6	125.0
180 mins	184.0	141.5	112.9	112.5		257.6	195.2	151.3	150.9
270 mins	181.1	137.9	124.3	131.2		257.3	190.4	170.1	179.6
360 mins	193.7	156.2	140.2	145.7		265.6	203.1	189.1	199.1
540 mins	181.7	141.8	124.8	134.7		233.1	196.0	180.3	195.2
Peak Flow (m3/s)									
	193.8	156.2	140.2	145.7		265.6	203.1	189.1	199.1
		-19%	*-28%*	*-25%*			*-24%*	*-29%*	*-25%*

Table 12 Estimated Peak Flows (m3/s) at Nodes N_34 and N_106 for 6 hour Storm Burst

	XP-RAFTS N_34					XP-RAFTS N_106			
Pervious Area Rainfall Losses									
IL (mm)	15	15	38	42.4		15	15	38	42.4
CL (mm/h)	2.5	2.5	3.7	1.04		2.5	2.5	3.7	1.04
Temporal Pattern per Storm Burst									
Number	1	10	10	10		1	10	10	10
ARR	1987	2016	2016	2016		1987	2016	2016	2016
6 hr Storm Burst Duration									
Min		129.5	111.8	121.5			177.1	147.6	160.6
Median	193.7	156.2	140.2	145.7		265.6	203.1	189.1	199.1
Max		196.3	181.7	190.6			254.1	234.1	245.6

At Node N_106 the critical storm burst is 6 hours under all scenarios.

It is noted that at Node N_34 the peak flow estimated using ARR1987 rainfall losses in combination with ARR2016 temporal patterns is equivalent to around the 30 yr ARI peak flow estimated using ARR1987 rainfall losses and temporal patterns. The combination of ARR2016 rainfall losses and temporal patterns gives a peak flow which is equivalent to around the 20 yr ARI peak flow estimated using ARR1987 rainfall losses and temporal patterns.

At Node N_106 the peak flow estimated using ARR1987 rainfall losses in combination with ARR2016 temporal patterns is equivalent to around the 25 yr ARI peak flow estimated using ARR1987 rainfall losses and temporal patterns. The combination of ARR2016 rainfall losses and temporal patterns gives a peak flow which is equivalent to around the 20 yr ARI peak flow estimated using ARR1987 rainfall losses and temporal patterns.

3.6 Recent ARR2016 Guidance

The ARR Data Hub includes FFA-reconciled losses for a gauge located at Mulgoa Road (Station 212320) north of Narellan. The location of this gauge and its relationship to Narellan is given in **Figure 16**. The FFA-reconciled losses for this gauge is shown in **Figure 17**.

The FFA-reconciled losses for the Mulgoa Road gauge are in initial loss = 42.4 mm and a continuing loss = 1.04 mm/h. The reconciled initial loss is higher than the initial loss adopted above while the continuing loss is lower than adopted above. The impact of adopting these rainfall losses for pervious urban areas is identified in **Table 11**. The range of peak flows estimated using ARR2016 6 hour duration temporal patterns are summarized in **Table 12**.

As stated in Attachment A:

> *Considering this new information, practitioners undertaking flood investigations in New South Wales should use a hierarchical approach to loss and pre-burst estimation. This hierarchy goes from 1 (most preferred) to 5 (least preferred) as indicated in Table 1 and described* in Attachment A.

It is noted that the adoption of calibrated/validated initial and continuing losses ranks higher than the adoption of FFA-reconciled losses. The 2017 Public Works Advisory report states that the losses were validated through simulation of the 2007, 2008 and 2013 events and accordingly are given greater weight than the losses obtained from the ARR Data Hub.

3.7 Conclusions

It is concluded that:

(i) The impact of adopting ARR1987 rainfall losses in combination with ARR2016 temporal patterns is to significantly lower the 1% AEP (median) peak flow to a level which is equivalent to around the 25-30 yr ARI peak flow estimated using ARR1987 rainfall losses and temporal patterns.;

(ii) The impact of adopting ARR2016 rainfall losses and temporal patterns is to further significantly lower the 1% AEP (median) peak flow to a level which is equivalent to around the 20 yr ARI peak flow estimated using ARR1987 rainfall losses and temporal patterns;

(iii) The peak flows using ARR1987 rainfall losses and temporal patterns for the 6 hour storm burst are just higher than the maximum estimated peak flow using the ARR2016 ensemble of 6 hour duration storm bursts; and

(iv) In accordance with the guidance given on the ARR Data Hub rainfall losses which were validated through simulation of the 2007, 2008 and 2013 events are to be given greater weight than the losses obtained from the ARR Data Hub.

FIGURES

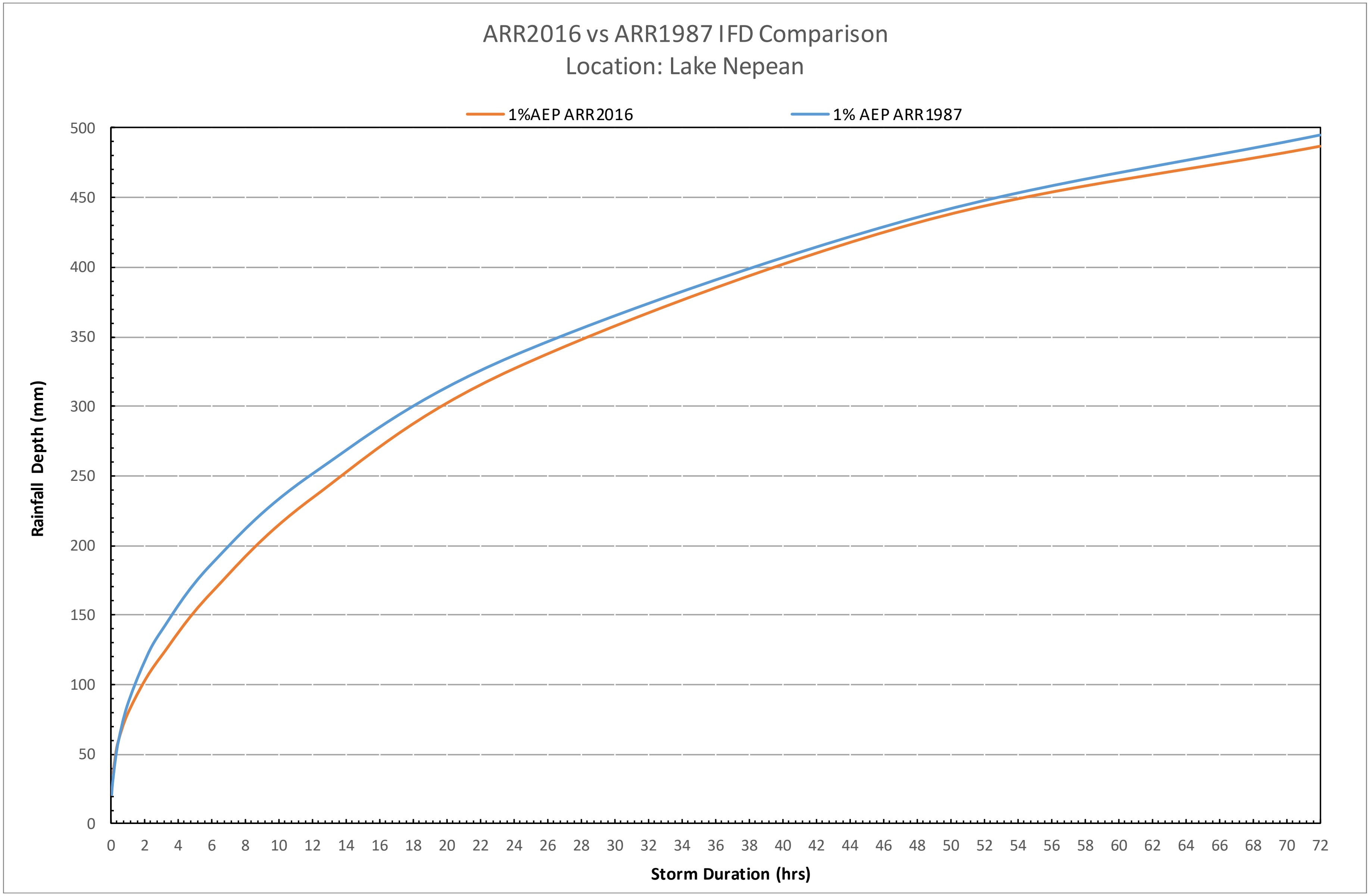

Figure 1 1% AEP IFD Comparison at Lake Nepean

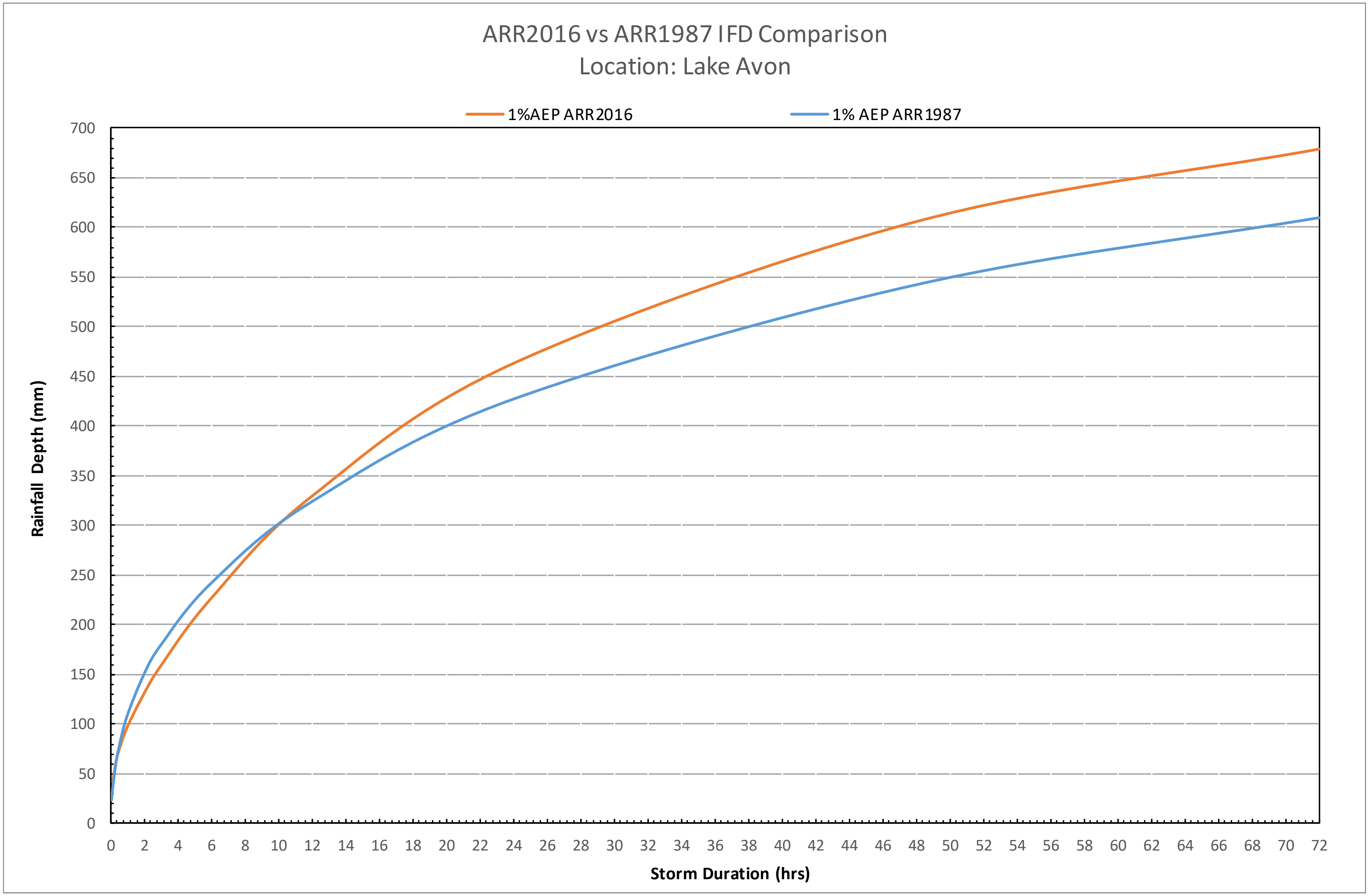

Figure 2 1% AEP IFD Comparison at Lake Avon

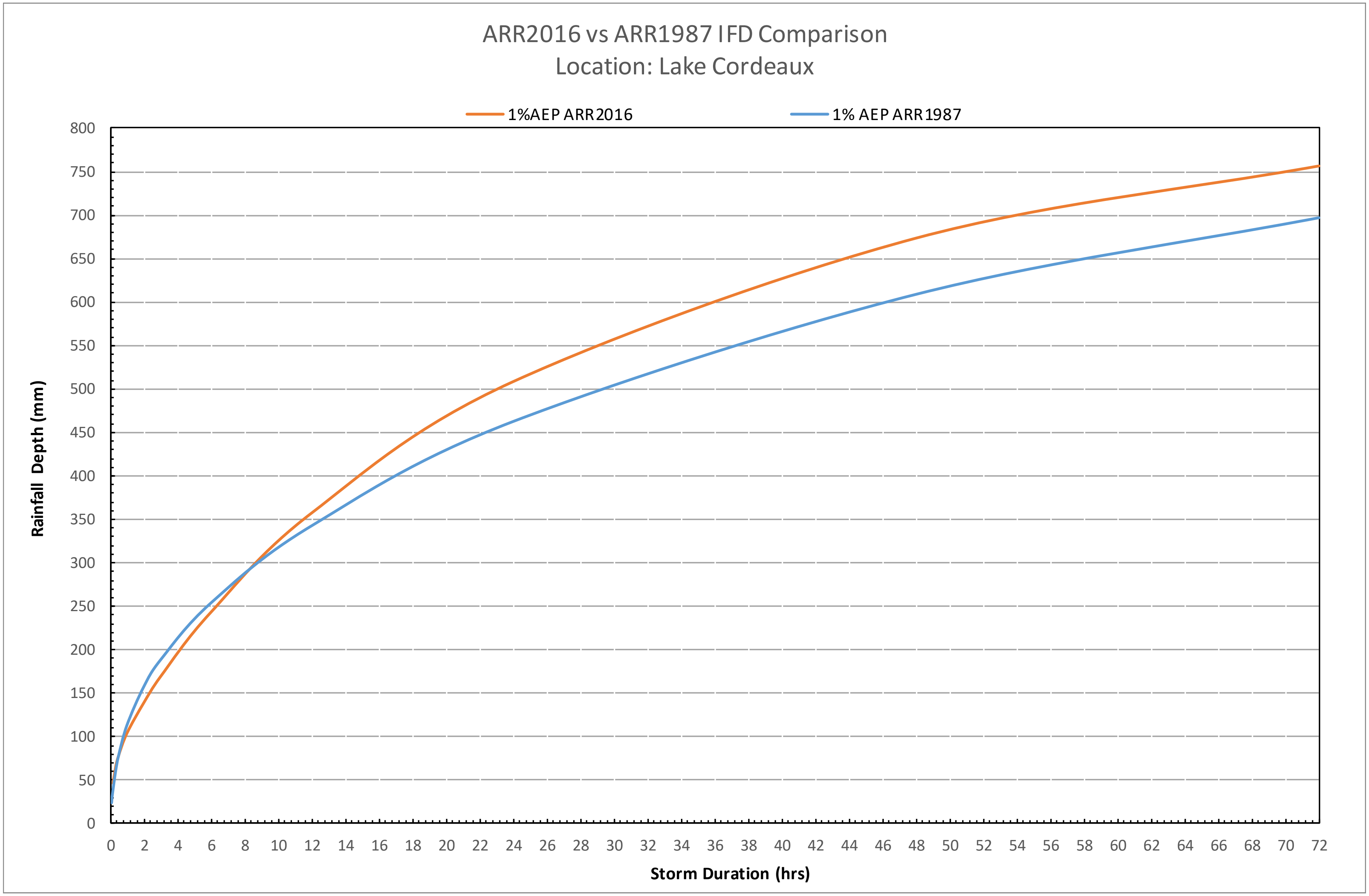

Figure 3 1% AEP IFD Comparison at Lake Cordeaux

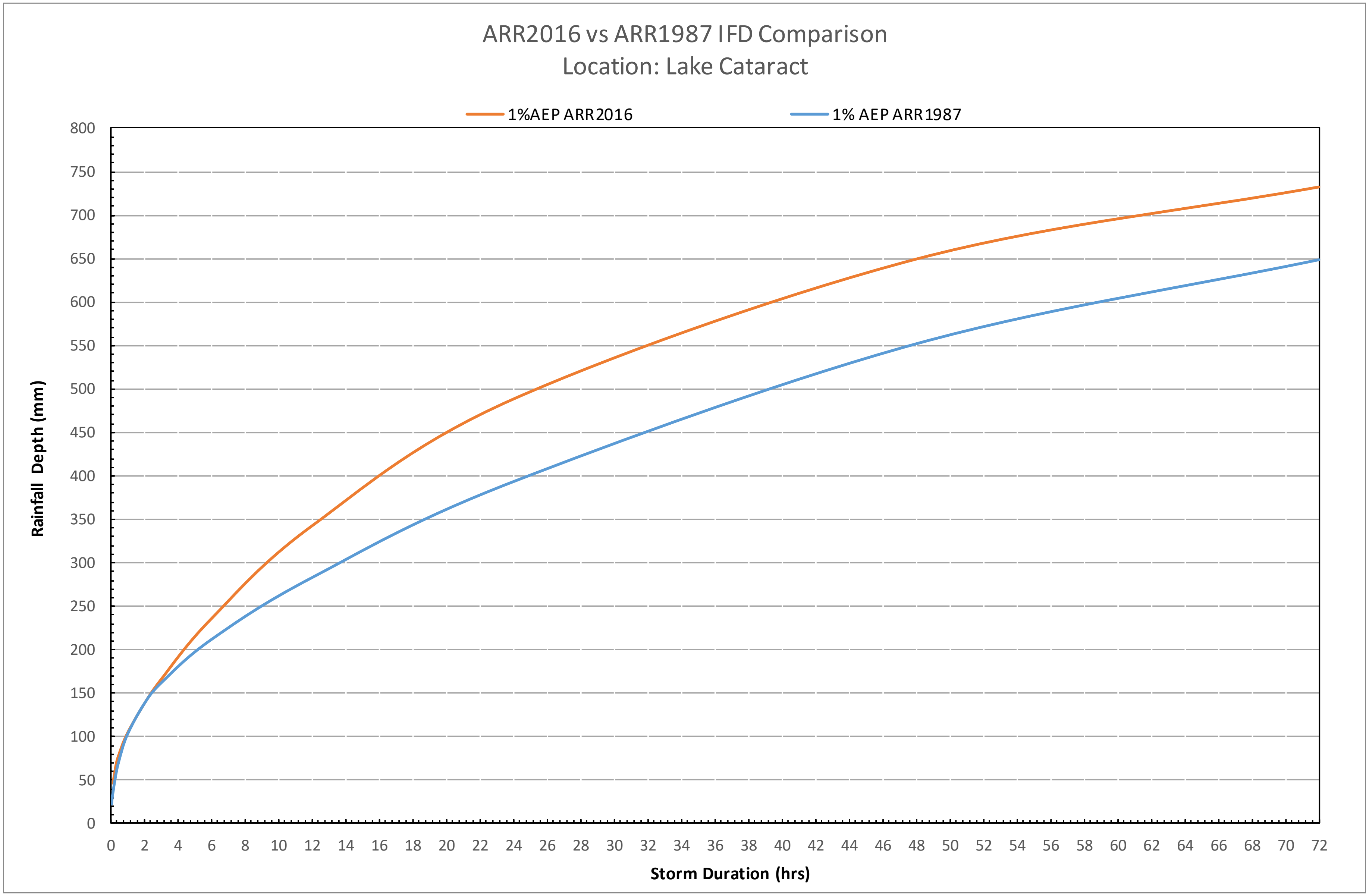

Figure 4 1% AEP IFD Comparison at Lake Cataract

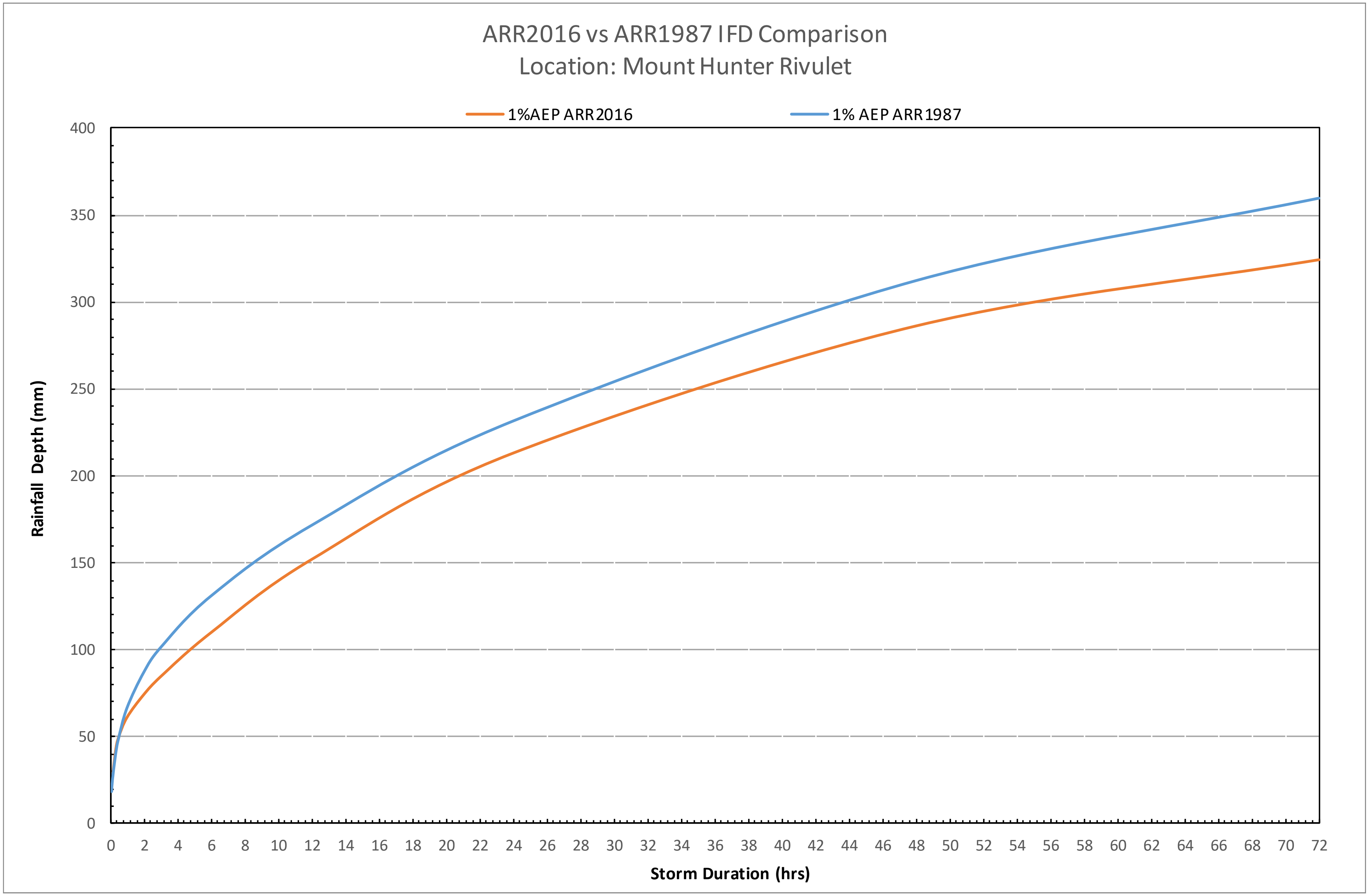

Figure 5 1% AEP IFD Comparison at Mount Hunter Rivulet

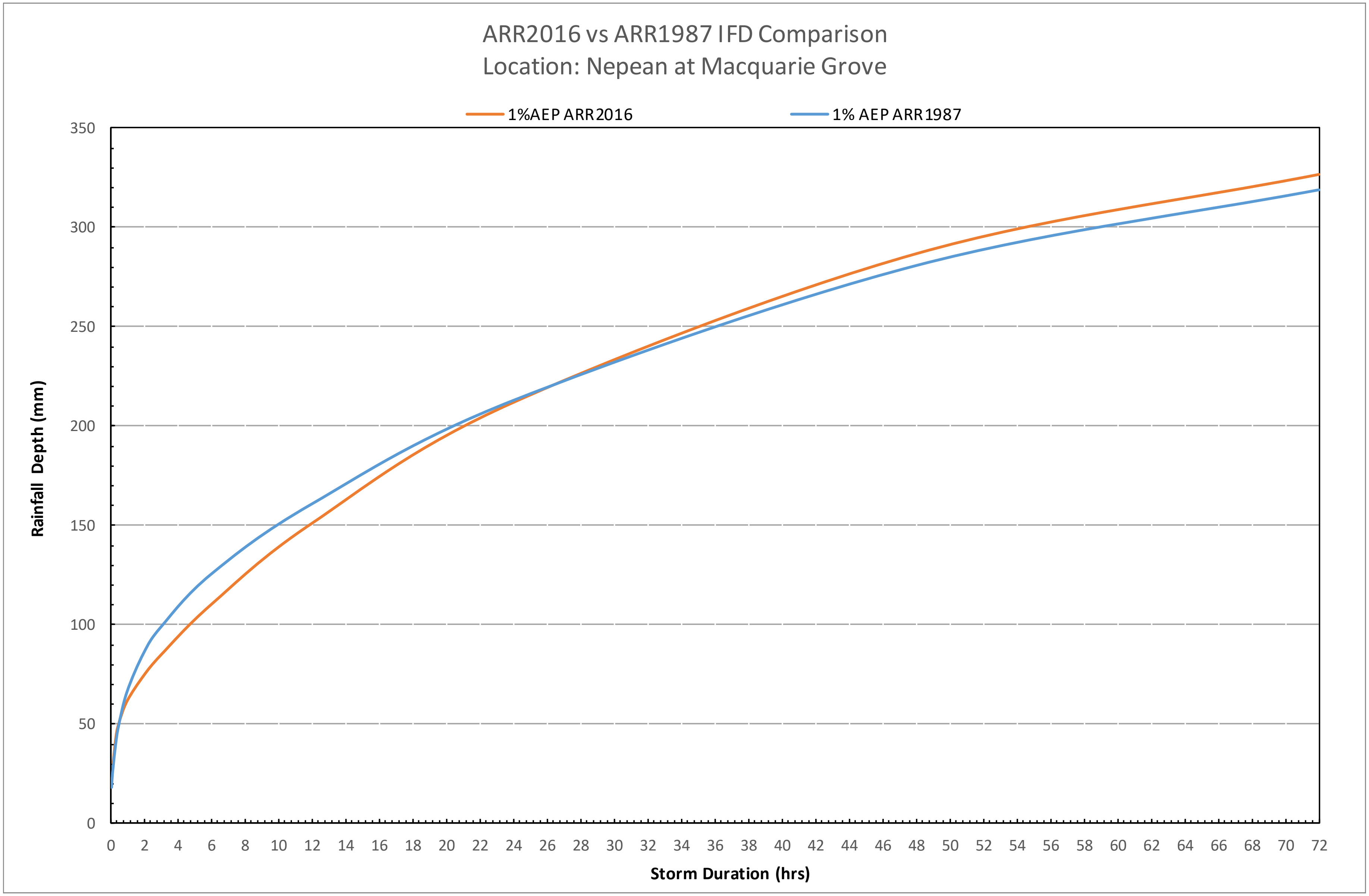

Figure 6 1% AEP IFD Comparison at Macquarie Grove

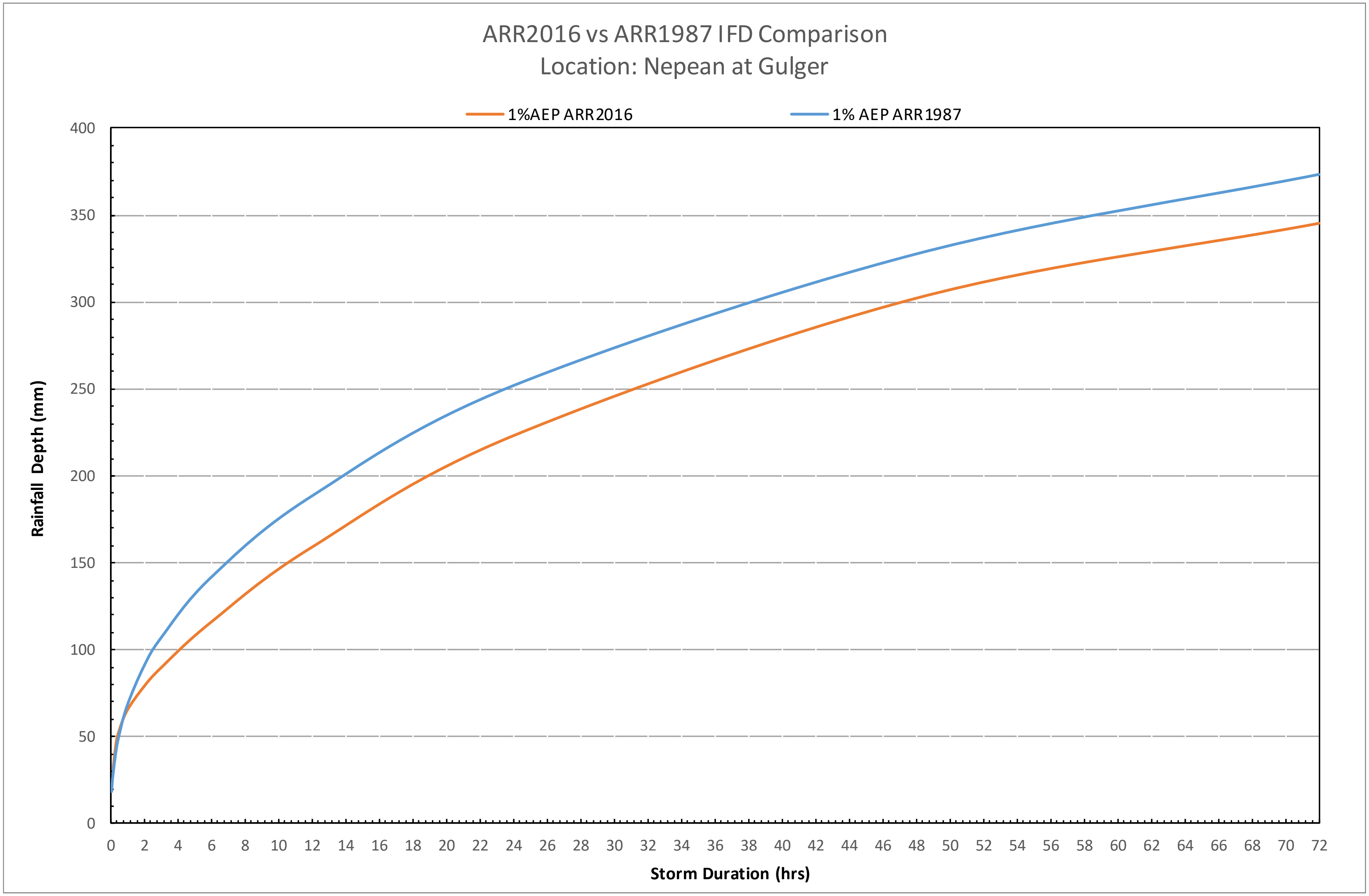

Figure 7 1% AEP IFD Comparison at Nepean at Gulger

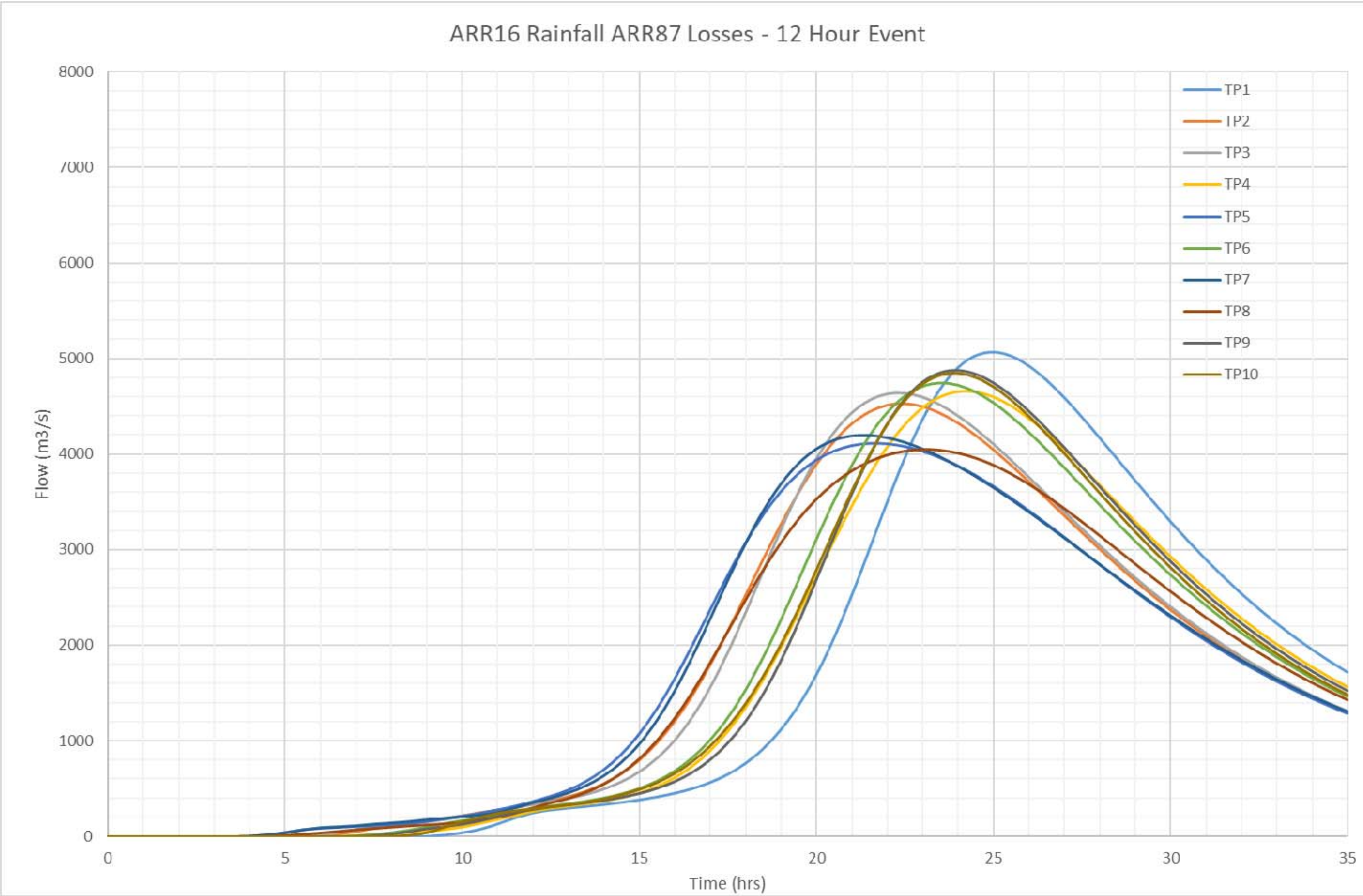

Figure 8   1% AEP 12 Hour Duration Flood Hydrographs at Wallacia Weir

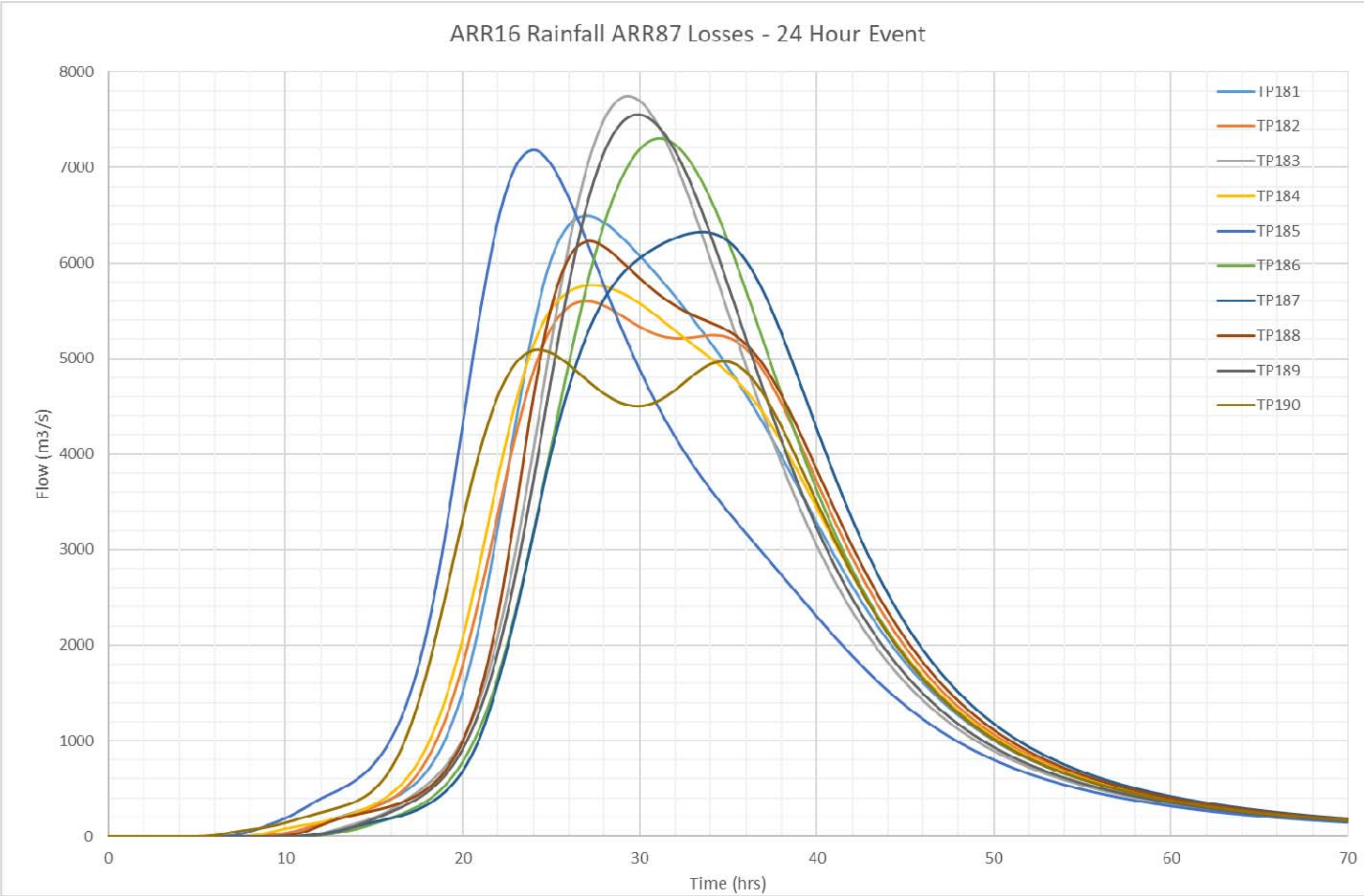

Figure 9 1% AEP 24 Hour Duration Flood Hydrographs at Wallacia Weir

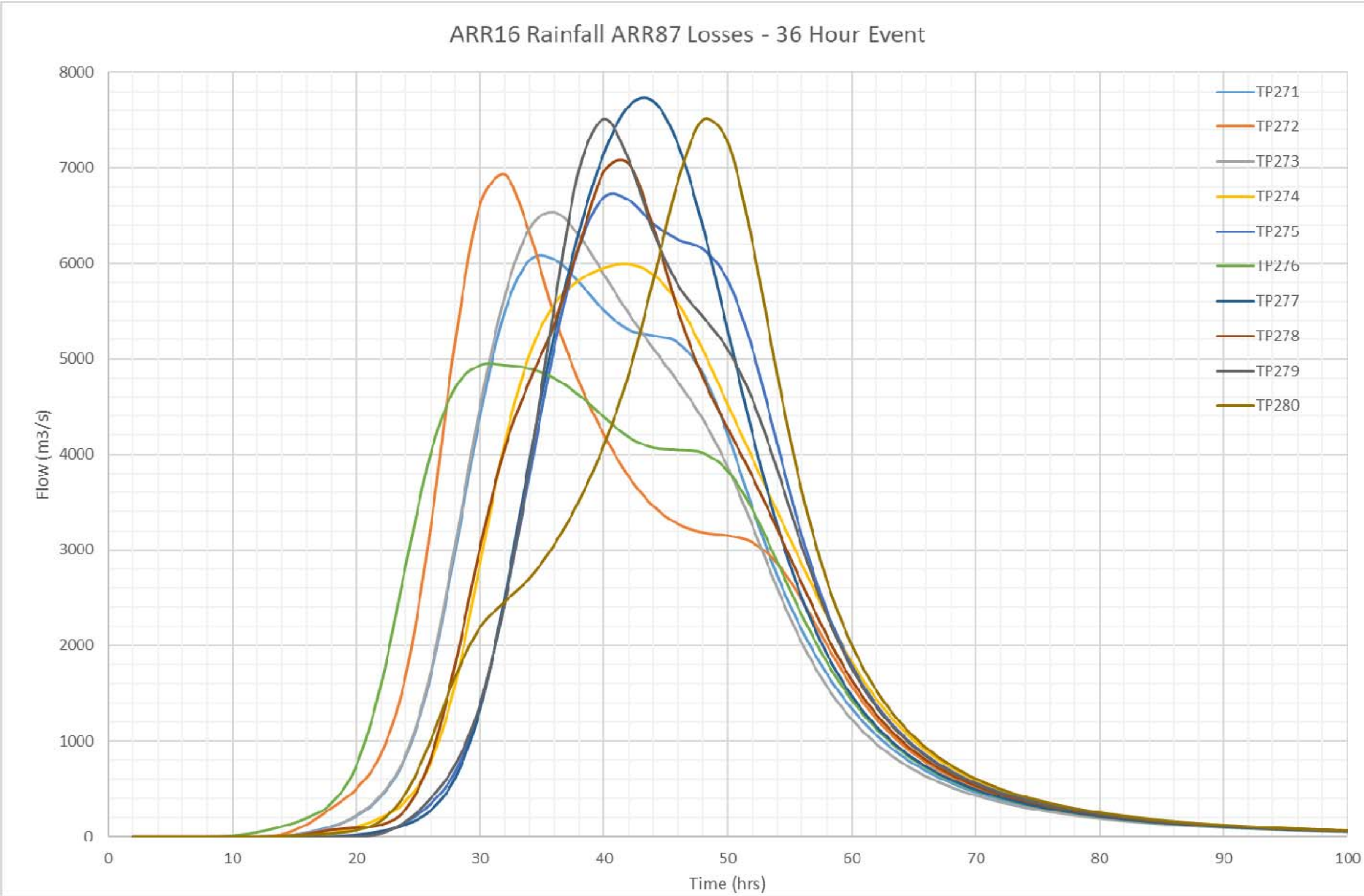

Figure 10 1% AEP 36 Hour Duration Flood Hydrographs at Wallacia Weir

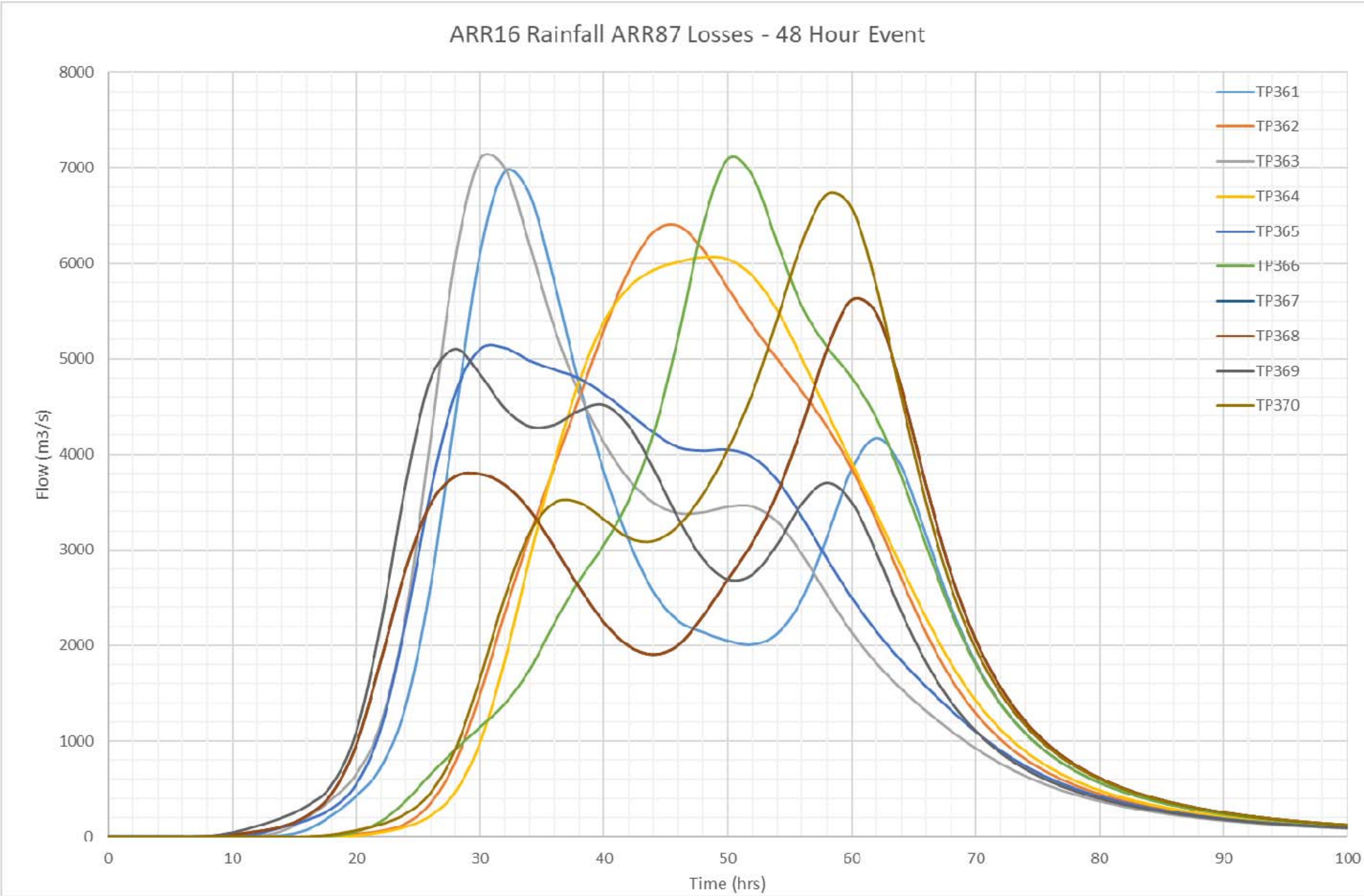

Figure 11 1% AEP 48 Hour Duration Flood Hydrographs at Wallacia Weir

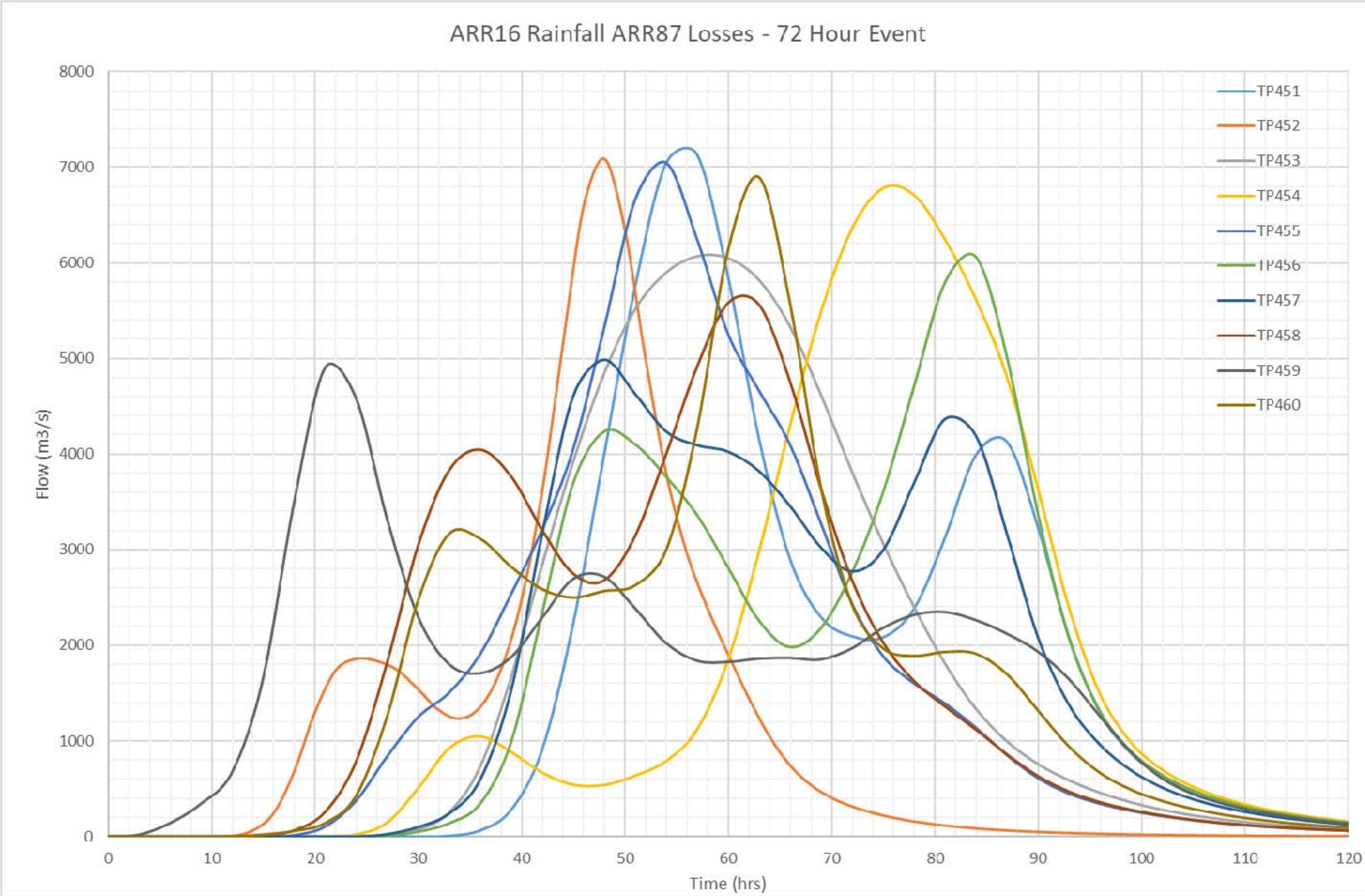

Figure 12 1% AEP 72 Hour Duration Flood Hydrographs at Wallacia Weir

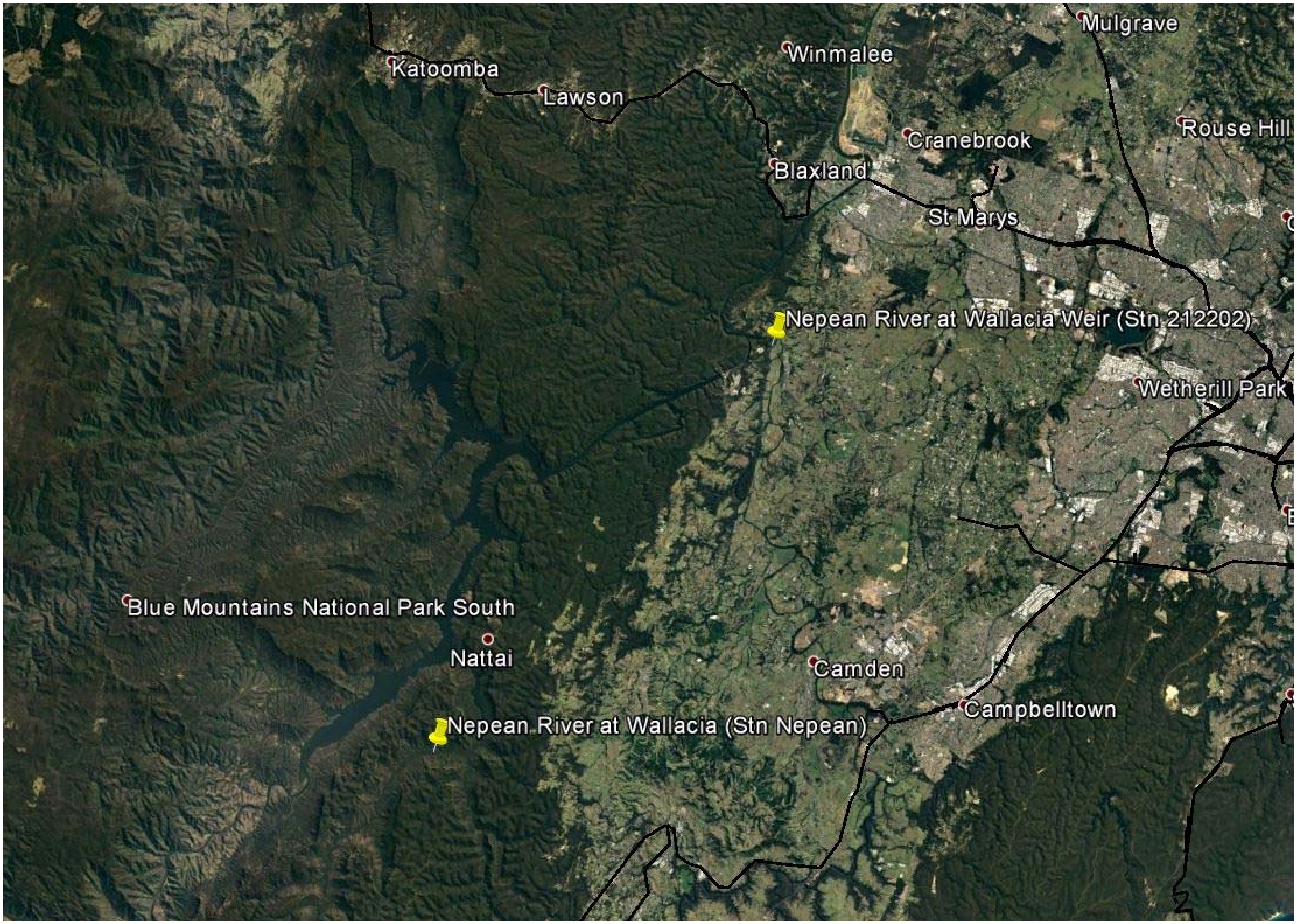

Figure 13 Location of Streamflow Gauges (Source: Google Earth access 11 February 2019)

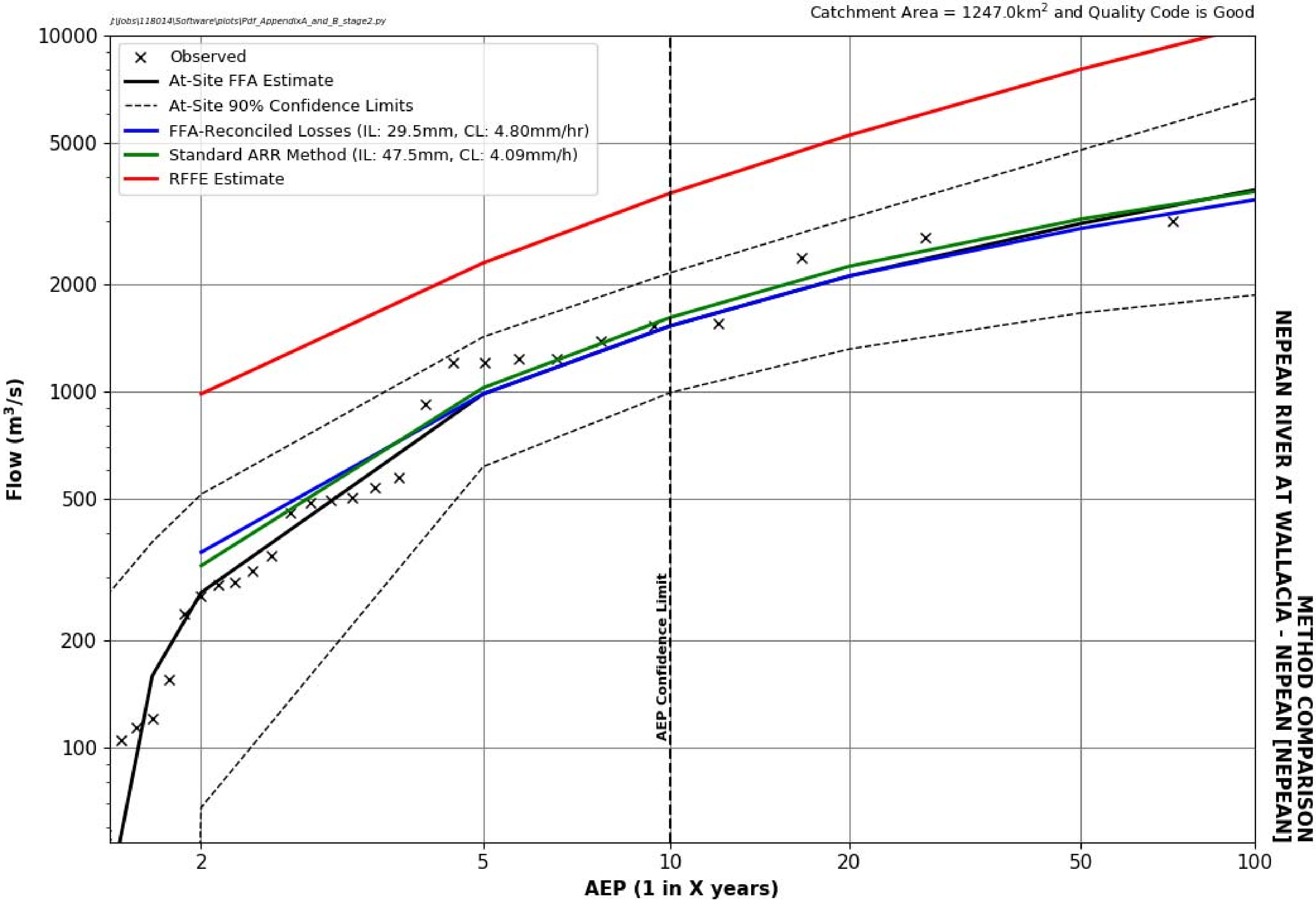

Figure 14 FFA-Reconciled Losses at Station Nepean (Source: ARR2016 Data Hub accessed 11 February 2019)

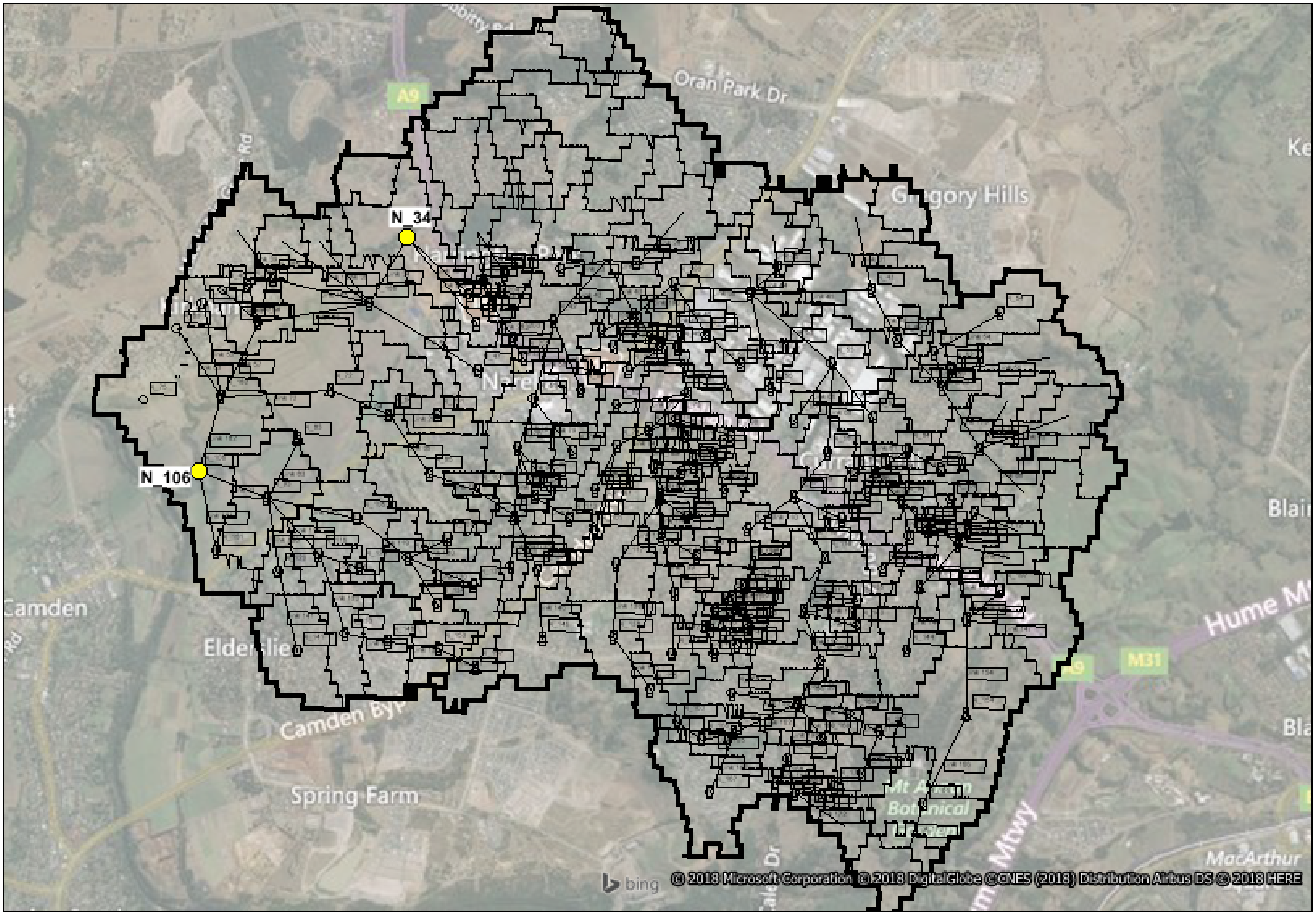

Figure 15 XP-RAFTS Model Layout and Locations of Nodes N_34 and N_106

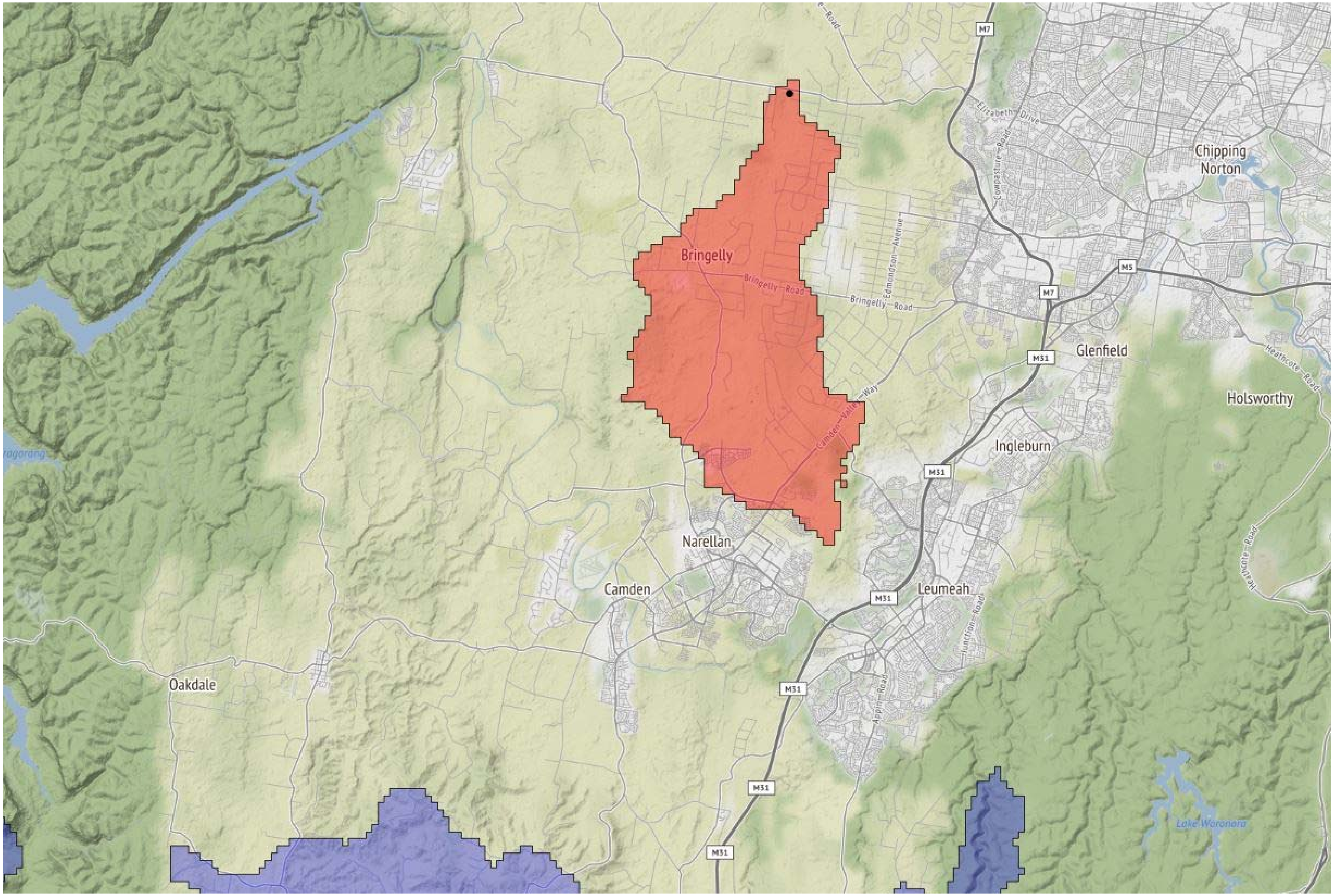

Figure 16 Location of Mulgoa Road Gauge (Source: ARR Data Hub accessed 12 February 2019)

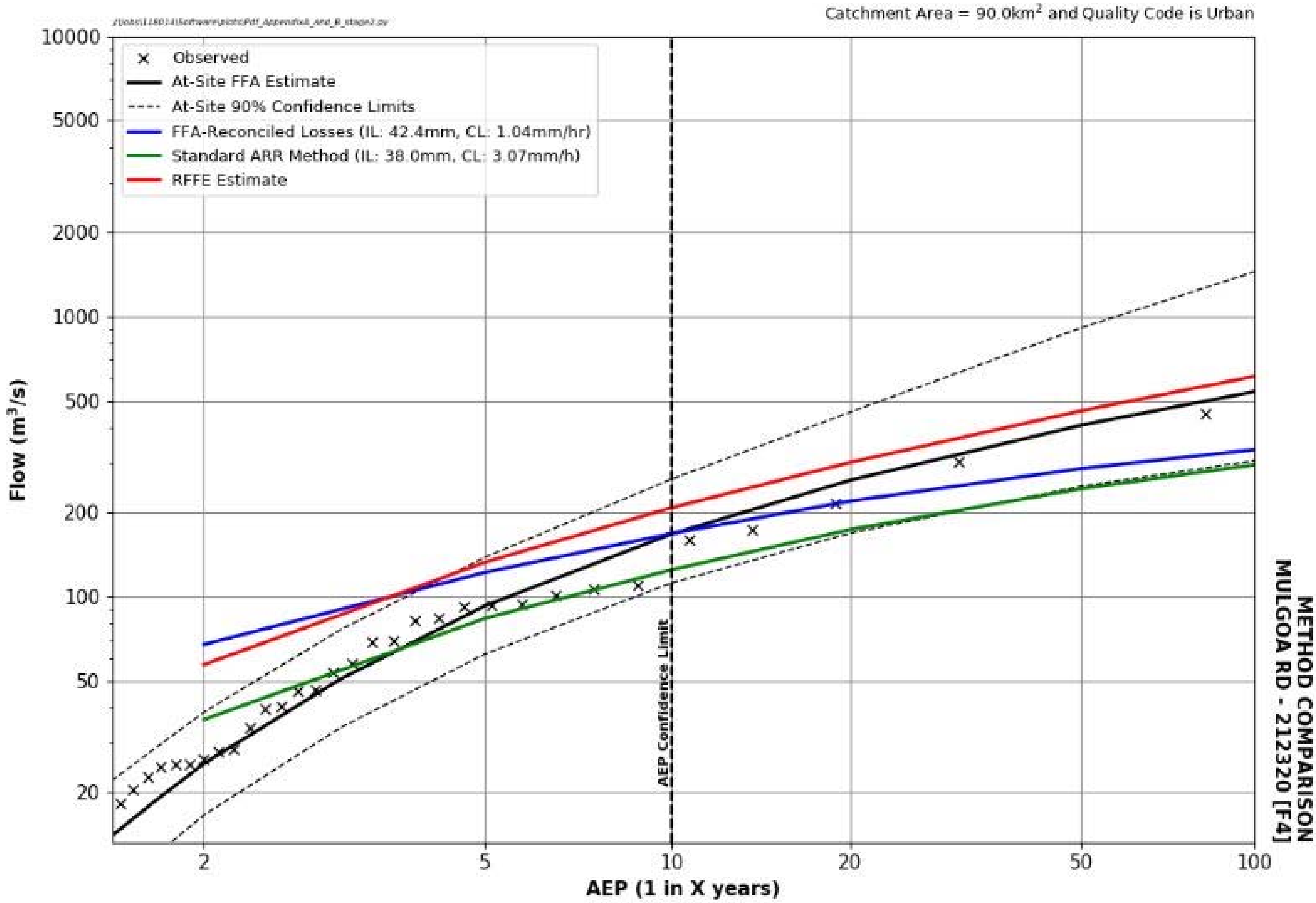

Figure 17 FFA-Reconciled Losses at Mulgoa Road (Station 212320) (Source: ARR2016 Data Hub accessed 12 February 2019)

ATTACHMENT A

NSW Specific Data Info

NSW Office of Environment and Heritage has developed a guide (https://www.environment.nsw.gov.au/research-and-publications/publications-search/floodplain-risk-management-guide) to assist councils and consultants undertaking studies under the NSW Floodplain Management Program to transition to Australian Rainfall and Runoff 2016.

As part of this transition a study (/static/pdf/nsw_losses_report.pdf) (Review of ARR Design Inputs for NSW report) was undertaken to review and advise on addressing under-estimation bias being experienced when using standard ARR 2016 design event methods with default data from the ARR data hub.

The outcomes of this study indicated that there is significant bias in the standard ARR 2016 design event method with default ARR data hub losses and pre-burst.

It identified that default continuing losses from the ARR data hub over-estimated losses and therefore were not fit for purpose and should only be used where better information was not available (see hierarchy below). If default continuing losses from the ARR datahub are to be used these should only be used with a multiplier of 0.4 applied.

It also found that in cases 4 and 5 in the hierachy below the probability neutral burst initial loss values provided from the ARR data Hub for catchments in NSW should be used in all instances unless a detailed Monte Carlo assessment of pre-burst and losses has been carried out.

Considering this new information, practitioners undertaking flood investigations in New South Wales should use a hierarchical approach to loss and pre-burst estimation. This hierarchy goes from 1 (most preferred) to 5 (least preferred) as indicated in Table 1 and described below.

1. Use the average of calibration losses from the actual study on the catchment if available.
2. Use the average calibration losses from other studies in the catchment, if available and appropriate for the study.
3. Use the average calibration losses from other studies in the similar adjacent catchments, if available and appropriate for the study.
4. Use the NSW FFA-reconciled losses (See Map (/catchmentlosses/map) & Table (/static/pdf/appendix.pdf)) available through the ARR Data Hub. These losses may be used within the catchment in which they were derived (available through the ARR Data Hub) or similar adjacent catchments with appropriate scrutiny. This is used with the unmodified ARR Data Hub initial losses which requires the application of additional scrutiny to the balance between initial loss and pre-burst to ensure it is reflective of flood history and observations for the catchment being investigated in the lead-up to events. This is particularly important in catchments of 100 km^2 or less.
5. Use default ARR data hub continuing losses with a multiplication factor of 0.4. This is used with the unmodified ARR Data Hub initial losses which requires the application of additional scrutiny to the balance between initial loss and pre-burst to ensure it is reflective of flood history and observations for the catchment being investigated in the lead-up to events. This is particularly important in catchments of 100 km^2 or less.

Where good local initial loss data is not available (Cases 4 and 5) the probability neutral burst initial loss values determined in the WMAWater 2019 study and available through the ARR datahub should be used in all instances unless a detailed Monte Carlo assessment of pre-burst and losses has been carried out.

The study resulted in the development of the following information that may inform studies in

NSW:

- To use the FFA-reconciled Losses Map (/catchmentlosses/map) click on the black points representing test gauges to see a plot containing the FFA-reconciled and standard method estimates in comparison to at-site FFA. NSW-reconciled loss values are detailed on these plots and in the Tables C1, C2, and C3.
- For storm initial losses obtained by methods other than the ARR data hub, burst initial losses should be adjusted using the below equation

$$IL_{Burst\text{-}chosen} = IL_{Storm\text{-}chosen} \times IL_{Burst\text{-}ARR} \ / \ IL_{Storm\text{-}ARR}$$

Table 1: Hierarchy of Approaches from most (1) to least (5) preferred

Approach	Storm Initial Loss	Pre-burst (transformational)	IL Burst	Continuing Loss
1	Average Calibration	Not required or back calculated using IL_{Storm} - IL_{Burst}	Calculated from Equation 1 above	Average Calibration
2	Average Calibration	Not required or back calculated using IL_{Storm} - IL_{Burst}	Calculated from Equation 1 above	Average Calibration
3	Average Calibration	Not required or back calculated using IL_{Storm} - IL_{Burst}	Calculated from Equation 1 above	Average Calibration
4	NSW FFA reconciled initial loss (see ARR Data Hub)	Not required or back calculated using IL_{Storm} - IL_{Burst}	Probability Neutral Burst Loss available through ARR Data Hub	NSW FFA reconciled continuting losses where available (see ARR Data Hub)
5	ARR Data Hub initial loss	Not required or back calculated using IL_{Storm} - IL_{Burst}	Probability Neutral Burst Loss available through ARR Data Hub	NSW FFA reconciled continuting losses where available (see ARR Data Hub)