Gammon Ranges - Arcoona Creek Flood Hydrology Review

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March 2023

1 Introduction

The Arcoona Creek catchment is situated in the Northern Flinders Ranges, in the semi-arid zone of South Australia, it is remote and not accessible by vehicles. Despite these limitations, a project, known as the Vulkathunha-Gammon Ranges Scientific Project (VGRASP), has been running for the more than 30 years gathering rainfall, stream flow and environmental data. The project is managed by the Scientific Expedition Group (SEG), a volunteer organisation that aims to promote and run expeditions of a scientific, cultural and adventurous nature and to encourage knowledge and appreciation of the natural environment.

The group has installed five pluviometers and a stream gauge within a 49.1 km^2 catchment and has taken over the running of another four rainfall stations on the west side of the ranges, towards Leigh Creek. All data are stored within the State Government's water data system, and on the Bureau of Meteorology archive and are publicly available.

This report is an update of papers previously published that summarise the findings regarding flood flows in Arcoona Creek. It is prompted by a review of the rating curve of the Arcoona Creek gauging station, following heavy rainfall and a large flow in January 2017.

This report describes the rating curve review, and discusses the analysis of flood frequency and hydrological modelling of the largest events.

2 The catchment

Rainfall monitoring commenced in the Gammon Ranges in September1988, with the installation of a pluviometer on the Gammon Plateau. Spatial rainfall data collection was subsequently augmented by the installation of further pluviometers at several other sites within the western Gammon Ranges, including Sambot Waterhole, Arcoona South, Arcoona Bluff and an Exclusion Zone in the Arcoona Creek valley. To assess the importance of orographic uplift in rainfall distribution within the Gammon Ranges, a comparison has been made with data collected from monitoring stations located at Aroona Dam near Leigh Creek, and the Windy Creek (North Moolooloo, Mocatoona and Maynard's Well) and Emu Creek (Pfitzner's Well) catchments, located within 50 km in a west-south-west direction from the Gammon Ranges.

Recorded annual mean rainfall varies from 250mm at the western end of the catchment (Exclusion Zone) to 330mm at the Gammon Plateau station.

A summary of the Arcoona Creek monitoring stations is given in Table 1 and shown on Figure 1.

Table 1 Arcoona Creek Monitoring Stations

Station	Number	Parameter	Commenced	Latitude	Longitude
Arcoona Creek	A0040520	Depth	1/12/1993	-30.43	138.97
Gammon Plateau	A0040517	Rainfall	11/09/1988	-30.46	139.05
Exclusion Zone	A0040518	Rainfall	26/04/1990	-30.44	138.97
Sambot	A0040519	Rainfall	13/09/1991	-30.44	139.04
South Branch	A0040521	Rainfall	13/07/1997	-30.47	139.00
Arcoona Bluff	A0040522	Rainfall	27/04/2003	-30.43	138.98

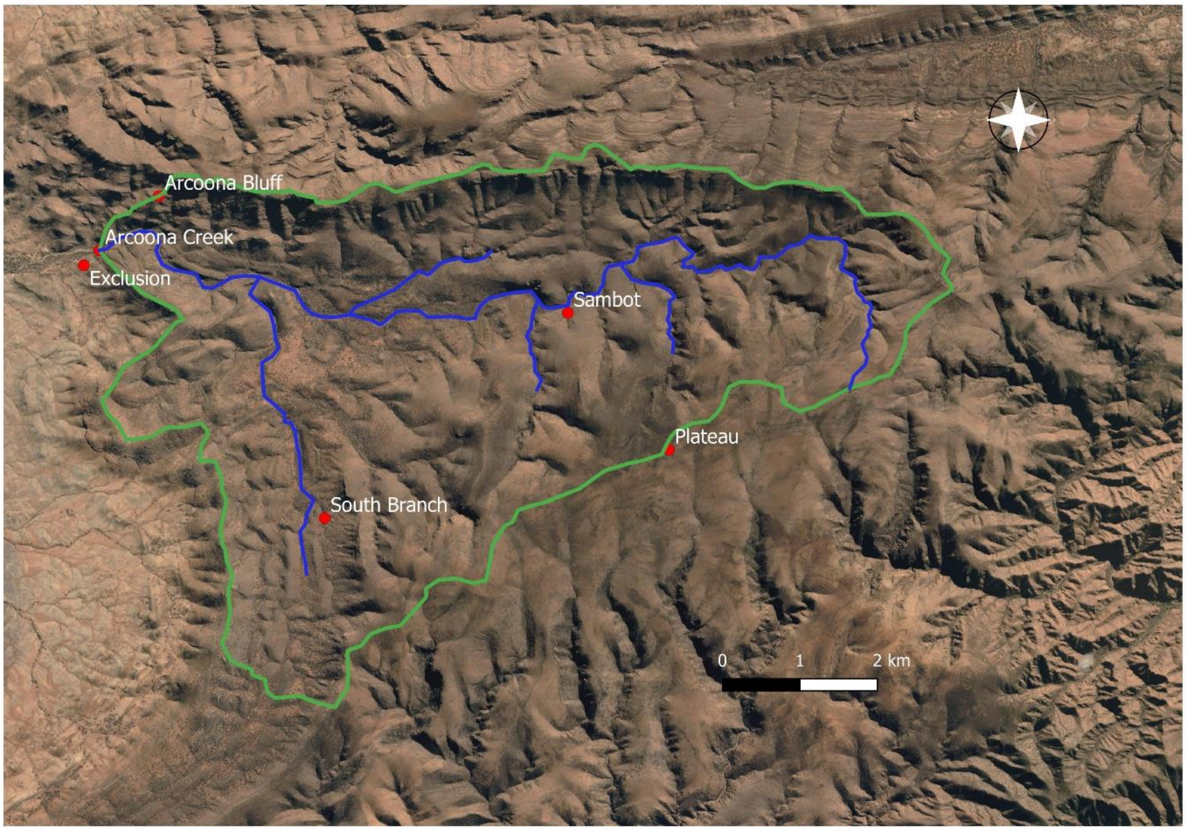


Figure 1 Arcoona Creek Catchment Showing the Monitoring Stations

3 Rating Curve Review

A flood occurred in January 2017 in Arcoona Creek that is the greatest recorded flood in the 28 years of record. The passage of the flood was recorded at the gauging station (A0040520). In April 2017 flood marks were surveyed, as well as several cross sections which were integrated with those that were surveyed in 2012 to derive the theoretical rating for the station. This gave an opportunity to review the station's rating curve and indicate whether the profile has changed.

3.1 A comparison of the 2012 and 2017 Surveys

For the 2012 survey a base line was set up along a line that was close to the centreline of the creek channel. In 2017 the survey was carried out along this base line, as well as at cross sections at four locations that had been previously surveyed. This allowed a comparison to be made between the two, that would reveal any significant change in channel shape.

3.1.1 Base Line

The result of the comparison is shown in Figure 2, and shows a difference of mainly less than 200mm. The levels in the reach that affect the rating of the gauging station at Chainage 170m are shown to be less than 100mm. This is very close, considering the time between surveys and the flood that occurred in 2017.

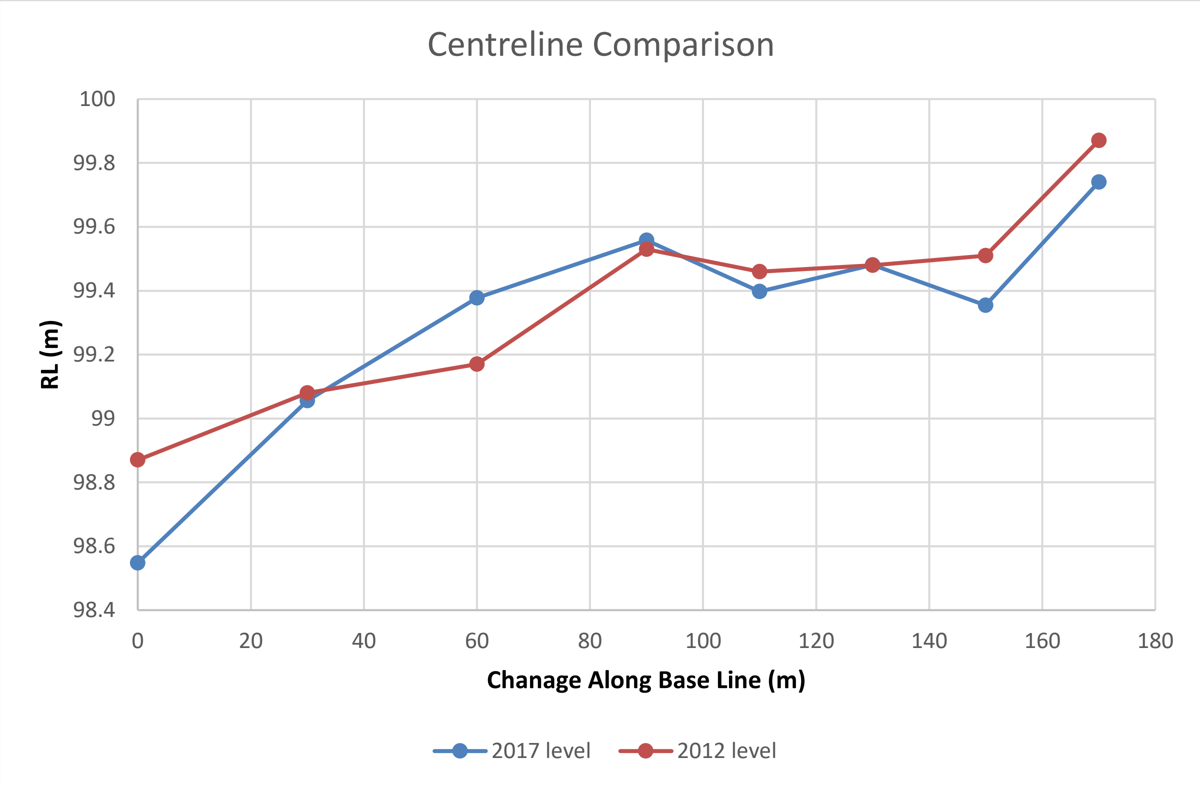
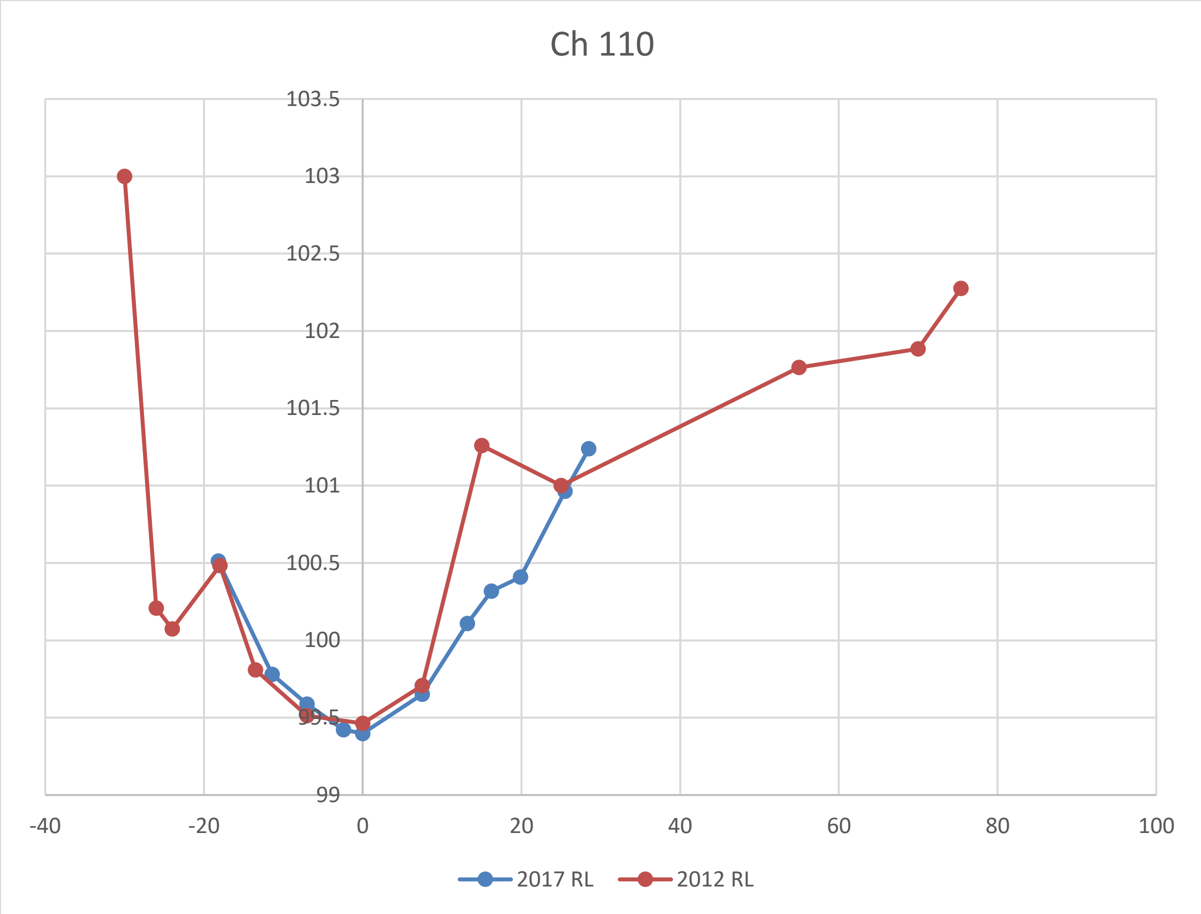
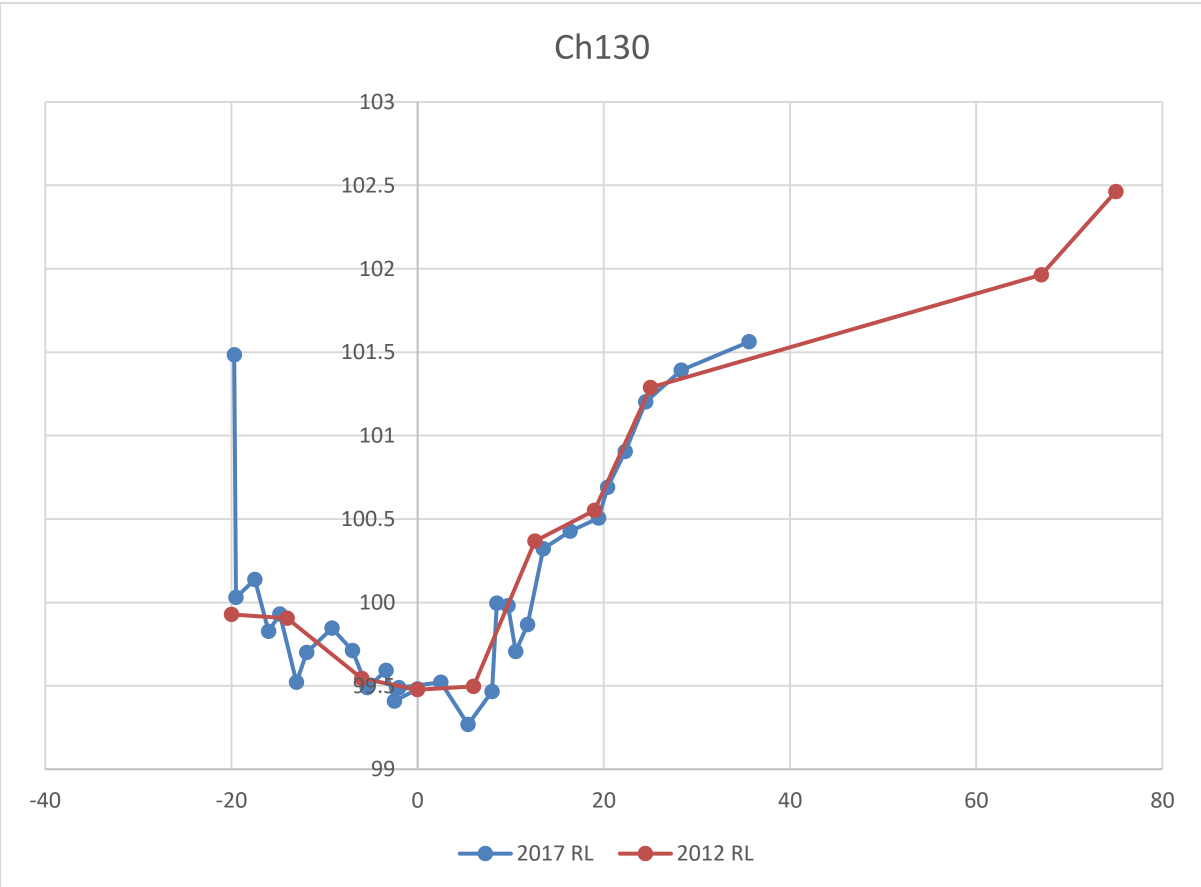


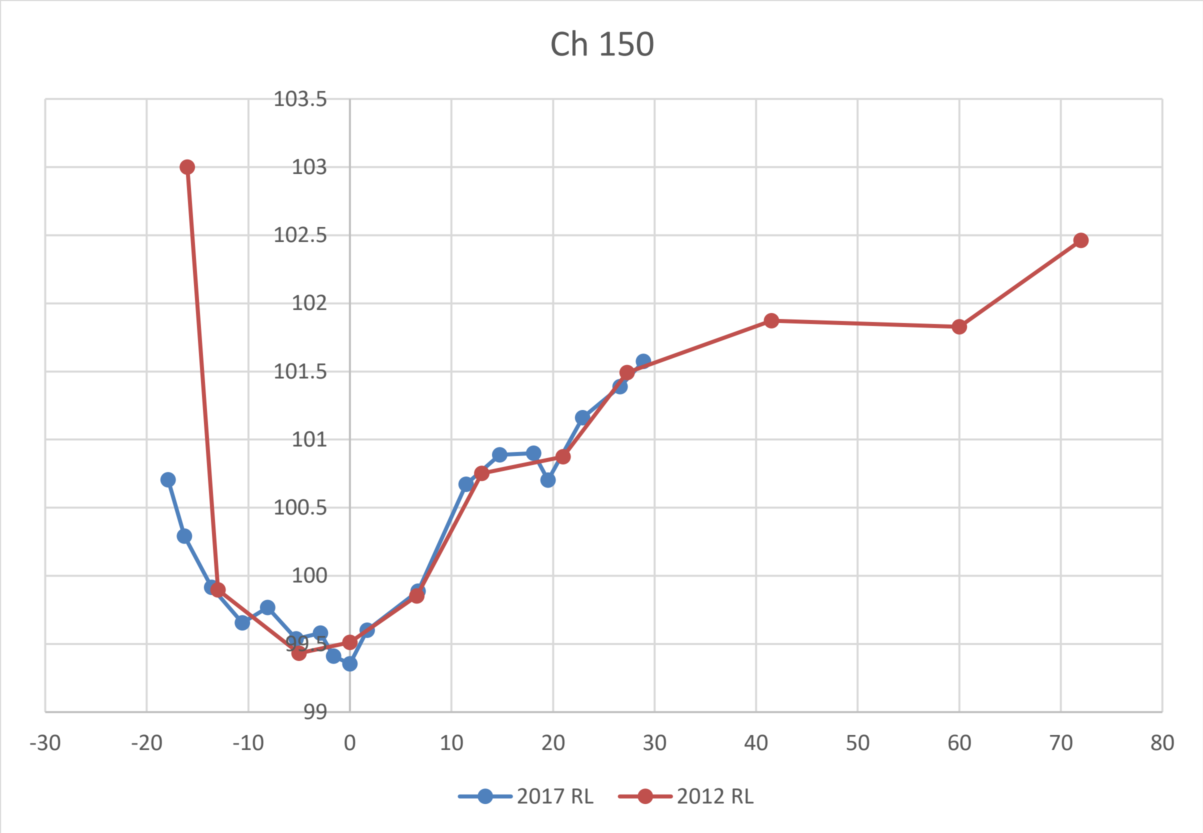
Figure 2 Channel Invert Level Comparison Along Base Line

3.1.2 Cross Section Comparison

Four cross sections can be directly compared, and show good agreement, apart from one point in the cross section at Ch:110.


Ch 110
103.5
103
102.5
102
101.5
101
100.5
100
99.5
99
-40
-20
0
20
40
60
80
100
2017 RL
2012 RL


Ch130
103
102.5
102
101.5
101
100.5
100
99.5
99
-40
-20
0
20
40
60
80
2017 RL
2012 RL



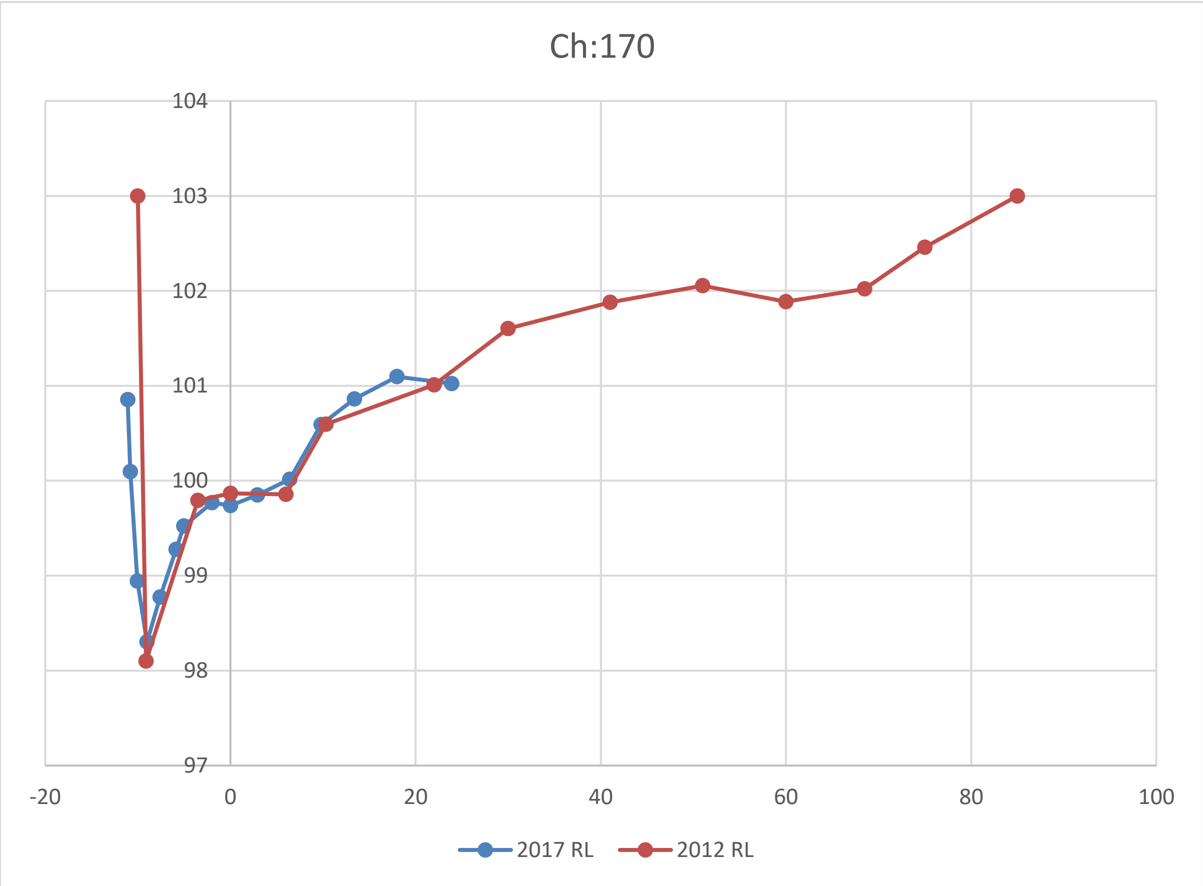


Figure 3 Comparison of Four Cross Sections

3.2 Flood Marks

Flood marks from the 2017 event were levelled, along with a base line chainage and offset. Doubtful records were removed, and the resultant flood marks compared with the predicted water surface profile derived by HECRAS for the station rating in 2012. Manning's n values for the channel (0.04) and floodplain (0.06) were selected based on Chow (1959). Ideally the station should have on-site measurements of flow during flood events (gaugings), but this is not possible for this station.

The analysis showed that the predicted flow levels were significantly below the recorded flood marks along the whole reach. A peak flow of 113m^3/sec was used, in accordance with the 2012 rating.

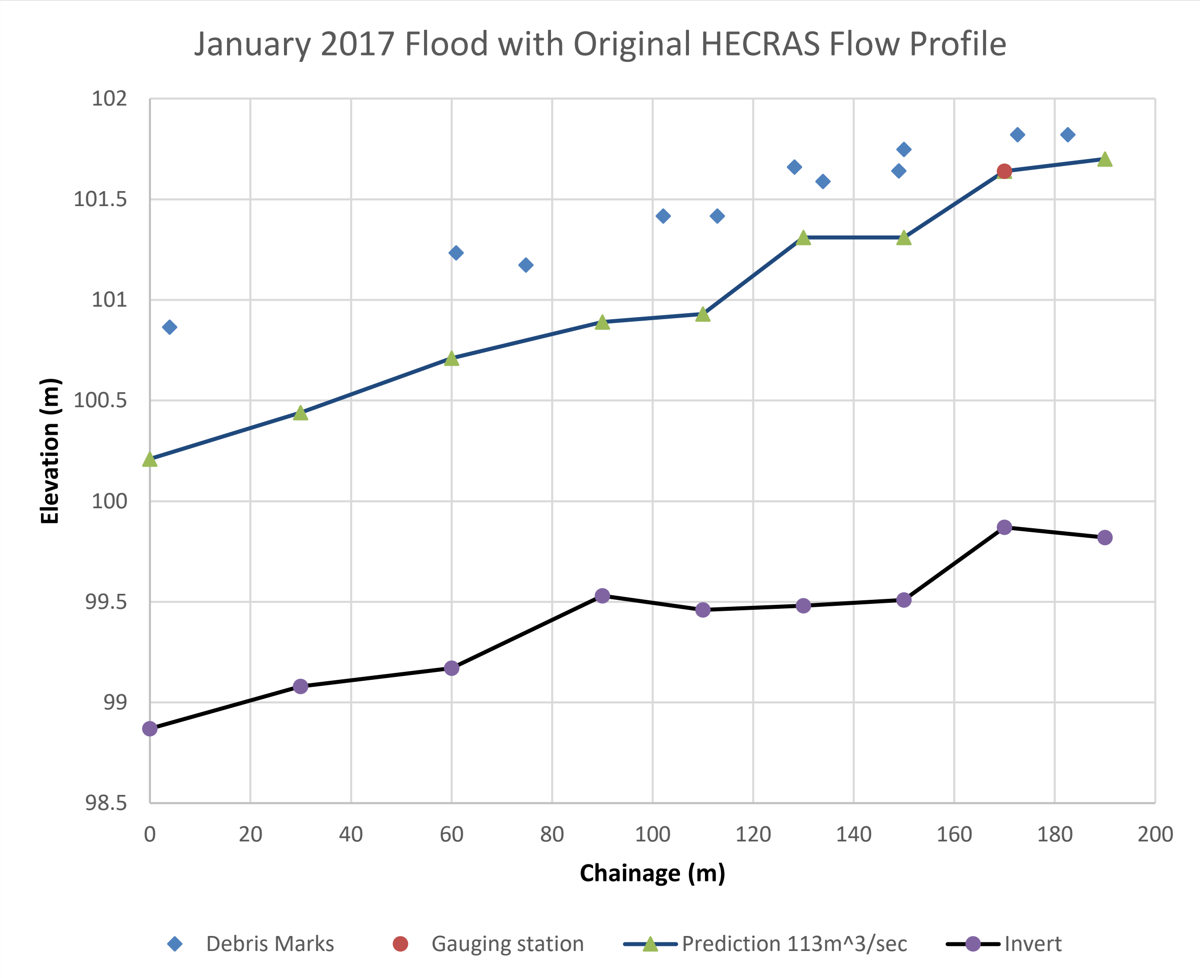
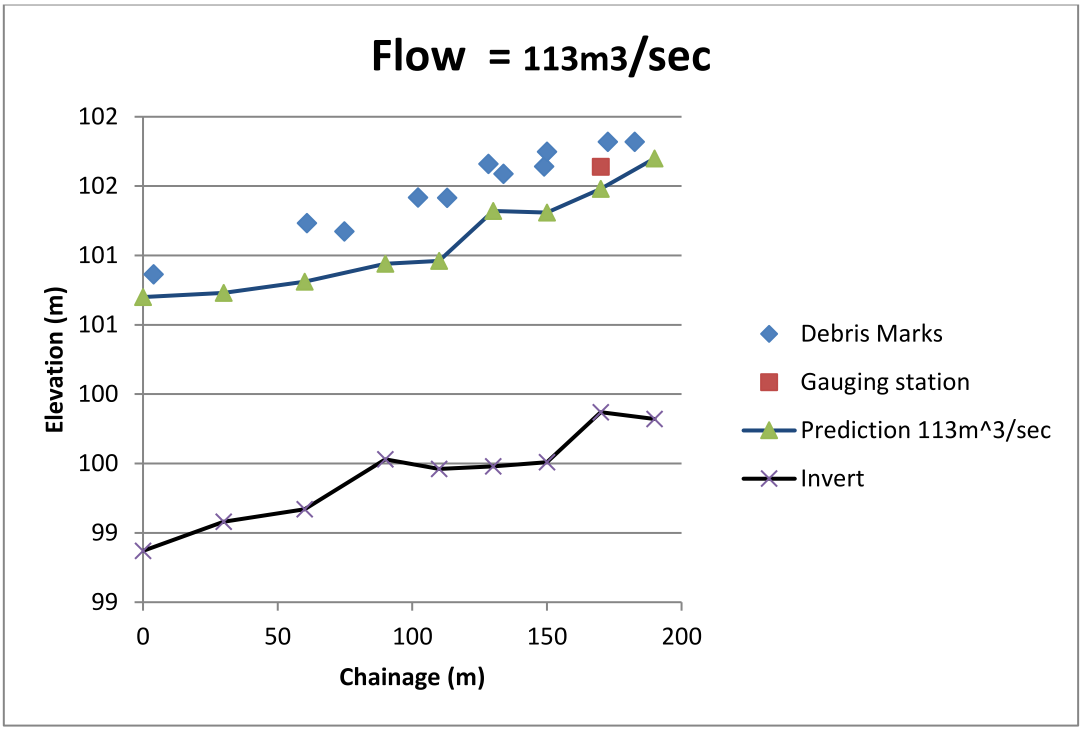
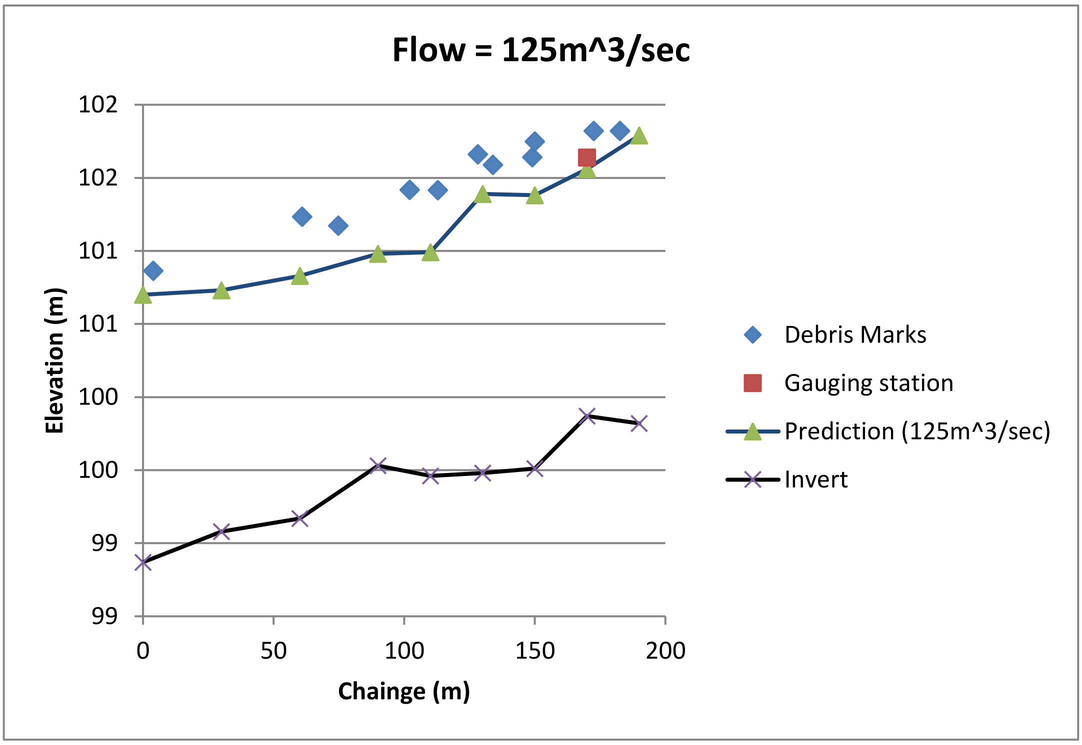


Figure 4 Comparison of Debris marks with Original Rating Curve Hydraulic Analysis

To examine the cause, a series of HECRAS runs was carried out, starting at the known level of debris of 100.7m at the downstream end (Ch:0), for flows of 113m^3/sec, 125m^3/sec and 180m^3/sec. A flow of 180m^3/sec gave the best fit to the debris marks. Also plotted is the location and level recorded at the gauging station.


Flow = 113m3/sec
102
102
101
101
100
100
99
99
0
50
100
150
200
Elevation (m)
Chainage (m)
Debris Marks
Gauging station
Prediction 113m^3/sec
Invert


Flow = 125m^3/sec
102
102
101
101
100
100
99
99
0
50
100
150
200
Elevation (m)
Chainge (m)
Debris Marks
Gauging station
Prediction (125m^3/sec)
Invert

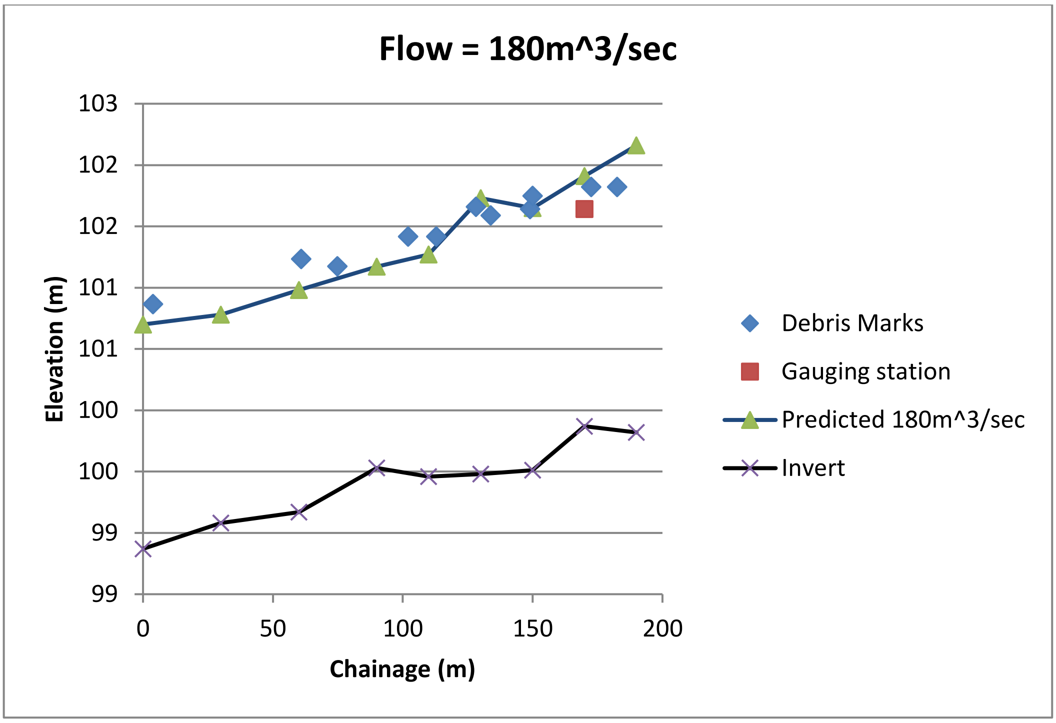


Figure 5 Flow Profiles Starting at RL 100.7

3.3 Discussion

The analysis of flood marks has indicated that the flow level in Arcoona Creek is above the measured level at the gauge for the peak flow that occurred. More HECRAS runs were done, starting at normal depth at the downstream end, and with an energy slope there of 0.005. This was done so that runs with a range of flows could be carried out to determine a rating curve. The value of 0.005 was determined from the initial run, with a known water surface elevation and a flow of 180m^3/sec. Figure 6 shows a more detailed plot of the estimated water surface from HECRAS and the debris marks and shows good agreement. The survey notes mention that the location of the most upstream mark is uncertain, at Ch172.6 or 182.6. Both points are shown on the plot. If the location was 172.6 the point plots well.

The debris marks now plot well compared with the calculated levels. The only discrepancy is the gauged peak level. However, one reasonable explanation may be that the level recorder is in an eddy, and the water surface level is more like that at Ch:150. The level transducer is protected from the flow by a rock face that could form the eddy (Figure 7). The direction of water flow in the eddy is upstream, and the water level in the eddy is that at the downstream end of the eddy. In addition, the scour hole is evidence that a significant eddy is present.

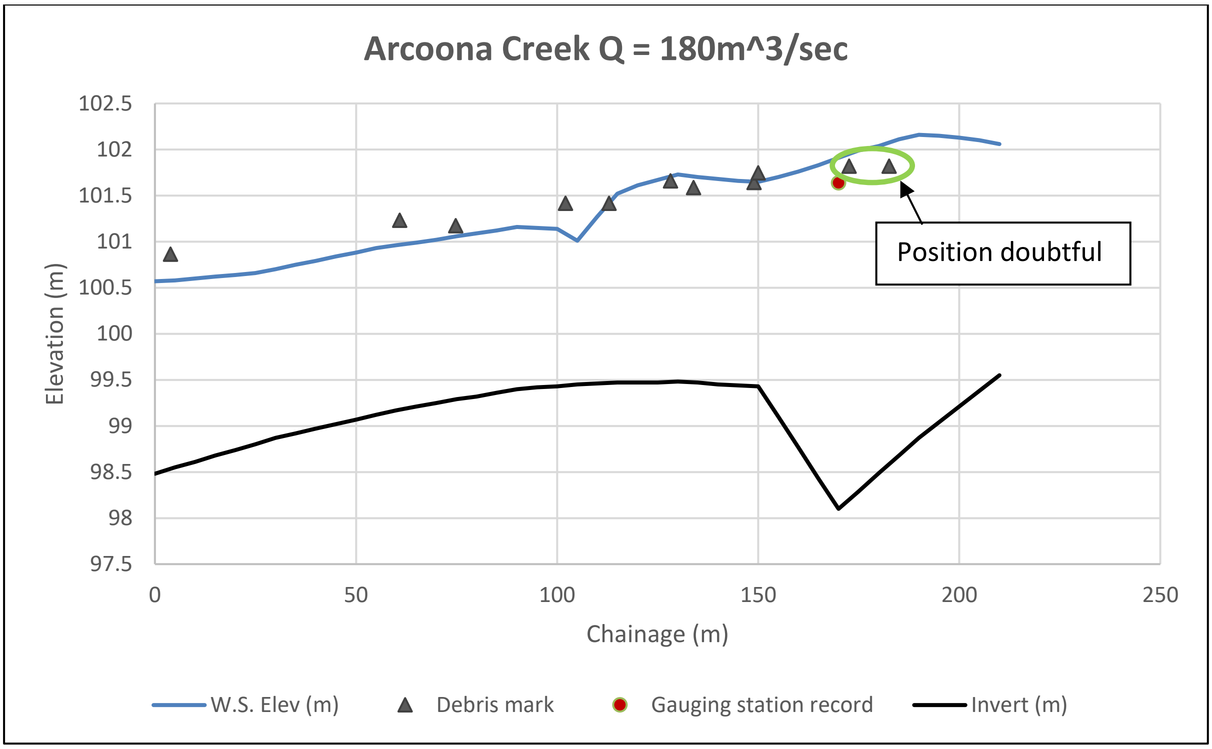


Figure 6 Detailed Water Surface Plot, starting at normal depth, energy slope = 0.005

Figure 7 View of the gauging Station Showing Scour Hole

3.4 Recommendation of an Update to Rating

The findings of this investigation into the 2017 flood indicate that the actual peak level in Arcoona Creek was above those recorded by the level transducer, due to its location in an eddy.

The HECRAS model was run with a range of flows, starting at normal depth at the downstream end. This gives a rating curve but does not contain a correction to the recorded depth that is necessary because of the placement of the transducer. It is recommended that the correction be applied based on the 2017 flood, starting with no correction at zero flow, and a correction interpolated between zero and 300mm at a flow of 200m^3/sec, and then remaining constant. A difference of 270mm is estimated for the 2017 flood. Table 2shows the calculation, and Figure 8 the comparison.

Table 2 Rating Correction table

Flow	water surface	Depth	Adjustment	Adjusted Depth	
(m^3/sec)	RL (m)	(m)	(m)	(m)	
0	99.480	0.000	0.000	99.480	0.000
0.2	99.638	0.158	0.000	99.638	0.158
0.5	99.715	0.235	0.001	99.714	0.234
0.75	99.761	0.281	0.001	99.759	0.279
1	99.796	0.316	0.002	99.795	0.315
2	99.899	0.419	0.003	99.896	0.416
5	100.079	0.599	0.008	100.072	0.592
7.5	100.176	0.696	0.011	100.165	0.685
10	100.257	0.777	0.015	100.242	0.762
20	100.497	1.017	0.030	100.467	0.987
50	100.943	1.463	0.075	100.868	1.388
75	101.186	1.706	0.113	101.073	1.593
100	101.389	1.909	0.150	101.239	1.759
150	101.712	2.232	0.225	101.487	2.007
180	101.911	2.431	0.270	101.641	2.161
200	102.037	2.557	0.300	101.737	2.257
250	102.481	3.001	0.300	102.181	2.701
300	102.565	3.085	0.300	102.265	2.785
		Maintain constant			
		Interpolate			

Table 3 Comparison of 2012 and 2017 rating tables

Flow (m^3/sec)	2012 depth (m)	2017 Depth with adjustment (m)
0	0.000	0.000
0.2	0.163	0.158
0.5	0.243	0.234
0.75	0.291	0.279
1	0.330	0.315
2	0.439	0.416
5	0.631	0.592
7.5	0.737	0.685
10	0.825	0.762
20	1.089	0.987
50	1.579	1.388
75	1.843	1.593
100	2.059	1.759
150	2.423	2.007
200	2.757	2.257
250	3.122	2.701
300	3.278	2.785

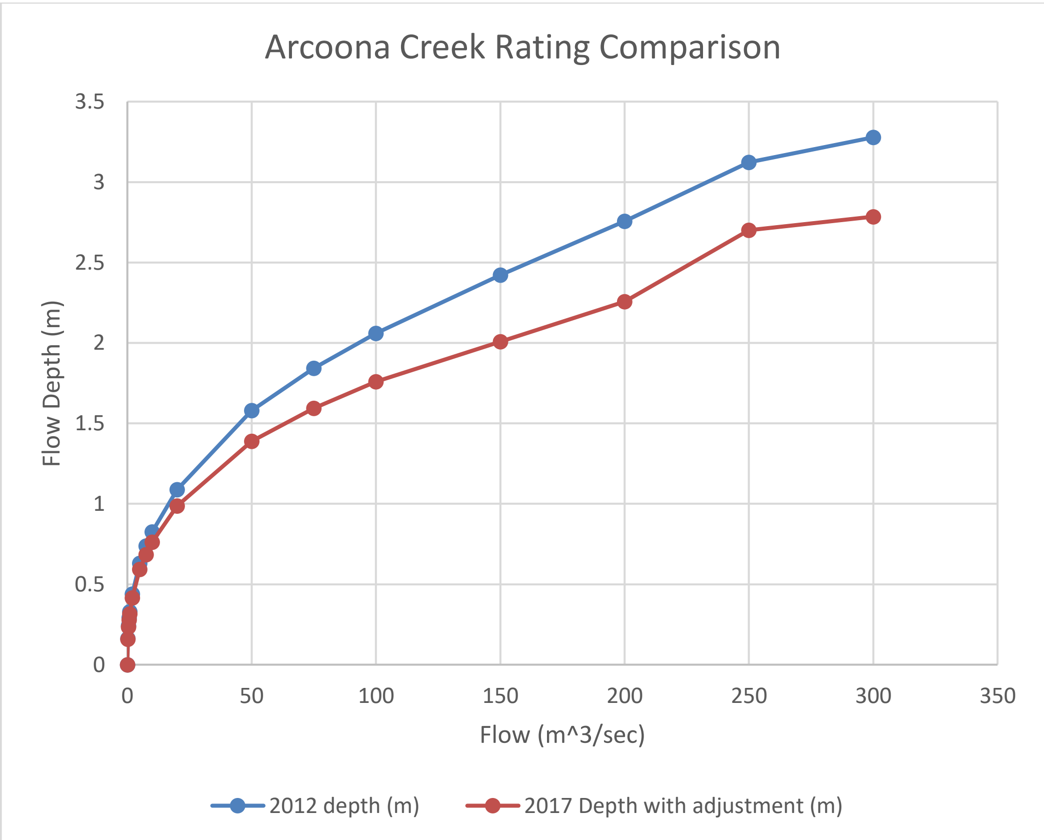


Figure 8 Rating Comparison

4 Derivation of Flow Record

Water level data were retrieved from the South Australia Department for Environment and Water (DEW)for the whole period of record for the gauging station, and these were converted to flow using an equation derived to match the rating table given as Table 3. Figure 9 shows the recommended rating, limited to 200 m^3/sec maximum, which is greater that any recorded flood. It does not include the unreliable extrapolation that maintains a constant water surface elevation adjustment beyond 180m^3/sec.

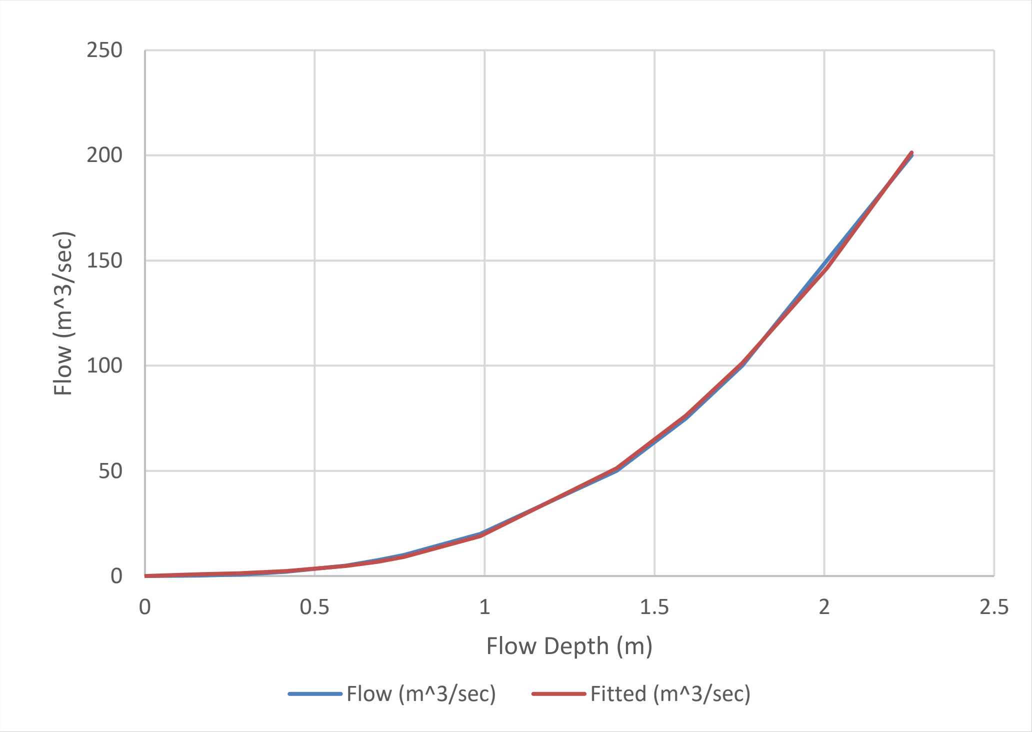


Figure 9 Fitted Rating Curve

A 4th order polynomial equation was fitted to the data points as follows, where x is the flow depth and y is the flow.

$$y = -4.53x^4 + 33.58x^3 - 16.15x^2 + 6.73x \; (r^2 = 0.999)$$

5 Flow Analysis

The record examined ran from 1st December 1993 until 26th October 2022, but had periods of missing record as follows:

- 30/12/1993 until 15/01/1995
- 27/09/1996 until 4/10/1996
- 9/11/1996 until 15/07/1997

From this record annual maximum flows could be derived. These ran from 1995 until 2022. 1996 was included as the rainfall record indicated that the highest annual flow had occurred in the record. However, 1997 was excluded as there was an instrument failure and there was doubt that the record included the highest annual flow.

Table 4 Annual Maximum Flows in Arcoona Creek

Year	Annual Maximum Flow(m^3/sec)
1995	31.92
1996	83.22
1998	0.00
1999	1.04
2000	3.78
2001	1.24
2002	0.00
2003	0.00
2004	0.00
2005	0.00
2006	0.00
2007	0.00
2008	0.00
2009	1.16
2010	12.72
2011	10.39
2012	19.34
2013	0.00
2014	0.00
2015	18.02
2016	15.18
2017	180.9
2018	0.00
2019	0.00
2020	0.00
2021	0.00
2022	6.55

Flood Frequency analysis was carried out for these annual maxima using the FLIKE software, for both the LPIII and GEV distributions. As there were many years of low or zero flow, flows less than $1m^3$/sec were censored.

This resulted in the estimated flood frequency distribution in Table 5, and shown in Figure 10 and Figure 11.

Table 5 Flood Probability Estimates for Arcoona Creek

Annual Exceedance Probability (AEP %)	GEV Flow (m^3/sec)	LPIII Flow (m^3/sec)
20	14.9	14.9
10	51	52.3
5	150	120
2	584	252
1	1598	373

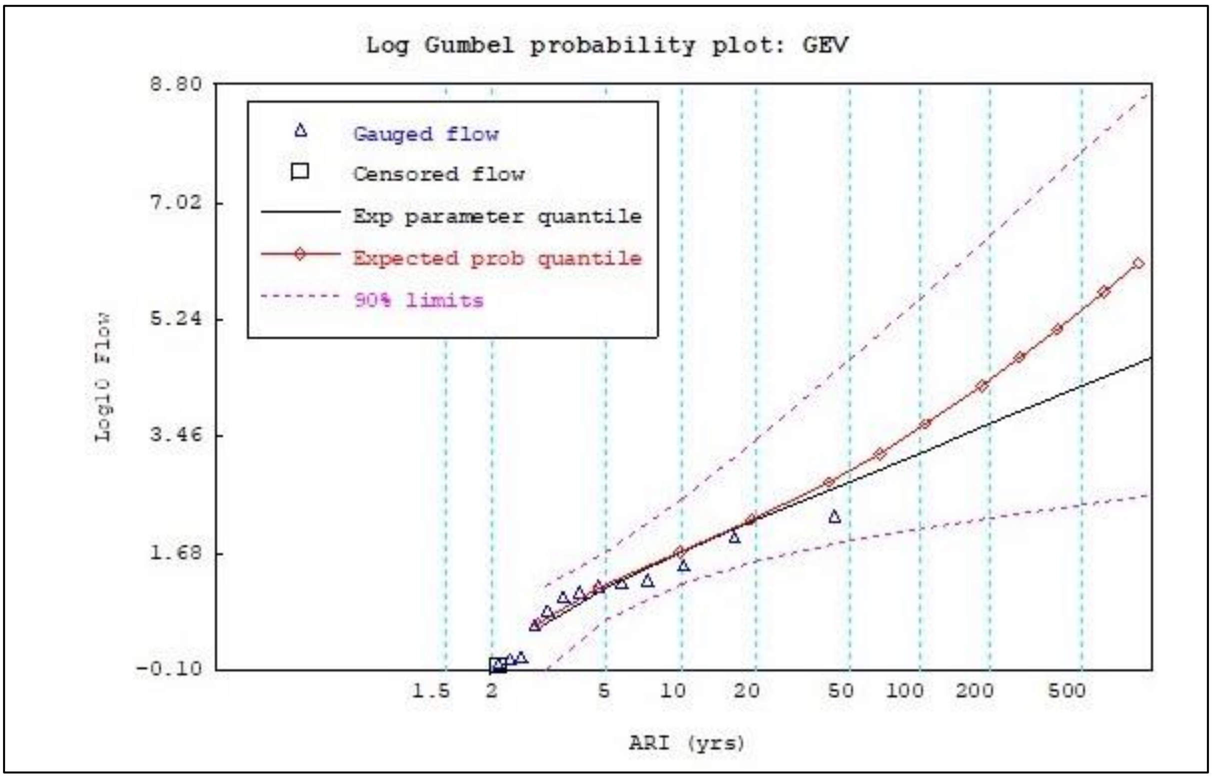


Figure 10 GEV Distribution for Arcoona Creek 1995-2022

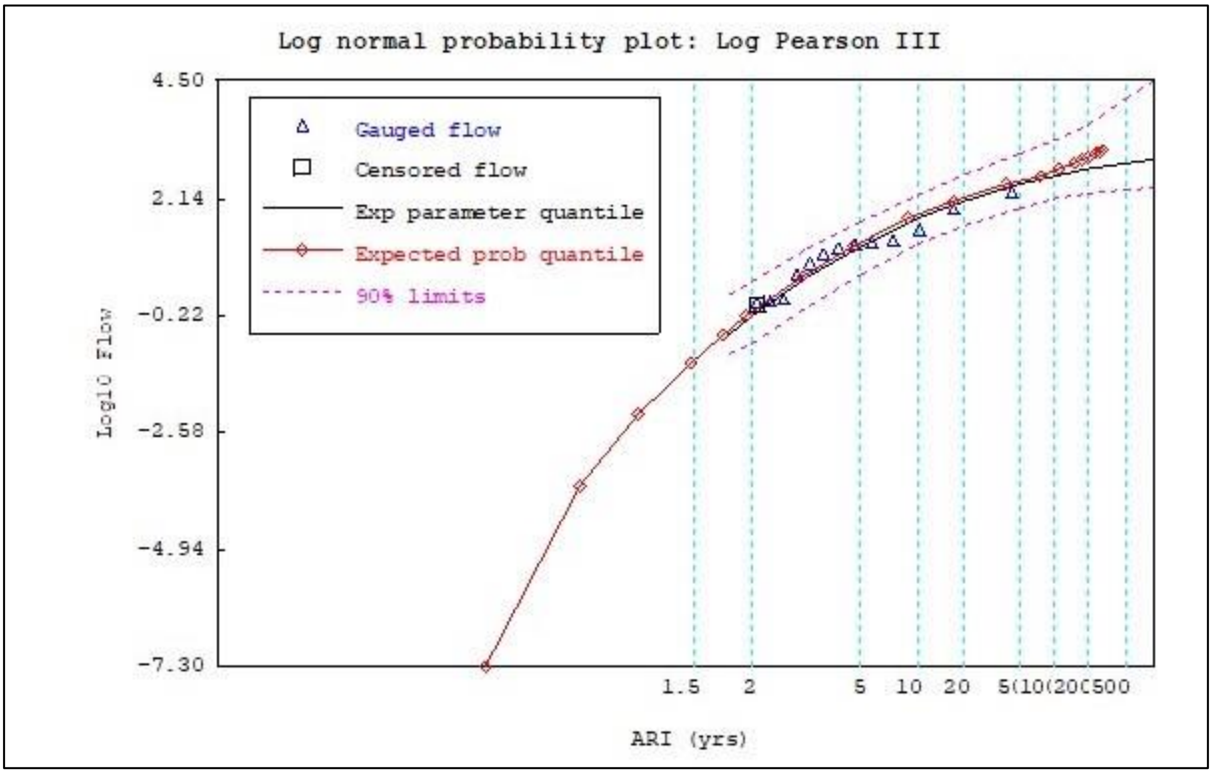


Figure 11 LPIII Distribution for Arcoona Creek 1995-2022

Partial series analysis was also carried out using the power law procedure (Malamud and Turcotte, 2006), and the total number of days of record from 15/01/1995 until 26/10/2022, which is equivalent to 27 years.

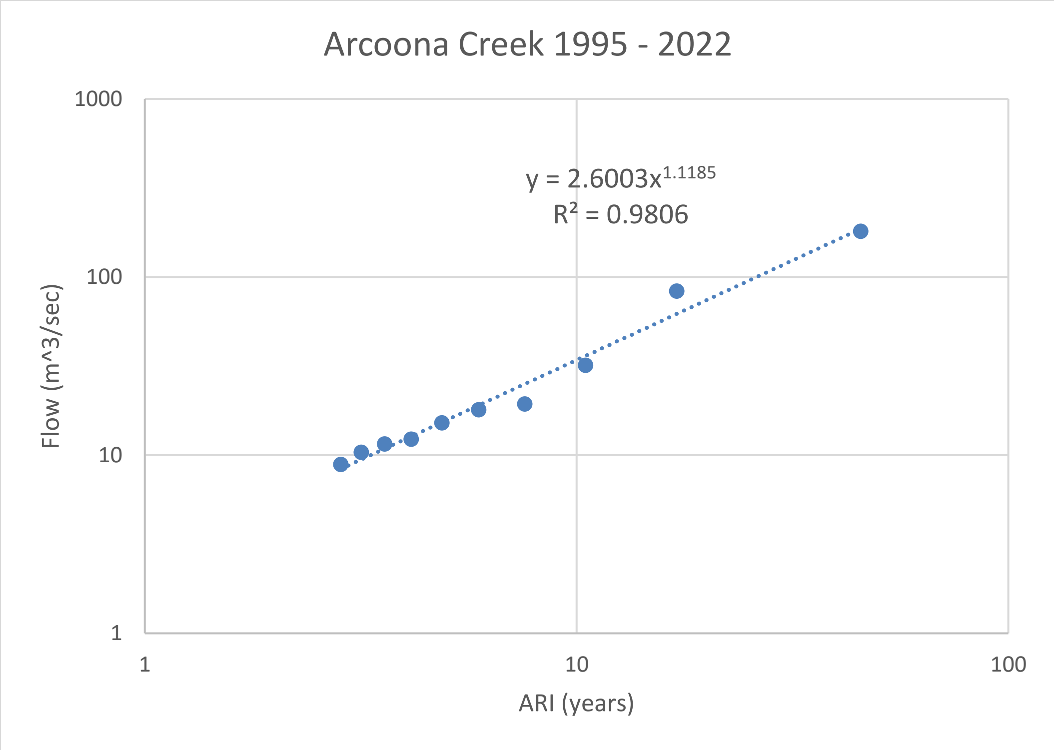


Figure 12 Partial Series Power Trendline Fit

A good fit to the data was obtained. Figure 12 shows the fitted trendline and Table 2 shows the resultant estimated flows.

Table 6 Partial Series Flood Frequency Analysis for Arcoona Creek

Average Recurrence Interval (years)	Flow (m^3/sec)
5	15.7
10	34.2
20	74.2
50	207
100	449

The LPIII annual series and partial series give results, which are similar and have a better fit to the data.

6 Flood Modelling Using RORB

6.1 Introduction

The five highest flows have been modelled using the RORB runoff routing model as described in Laurenson et al, 2010.

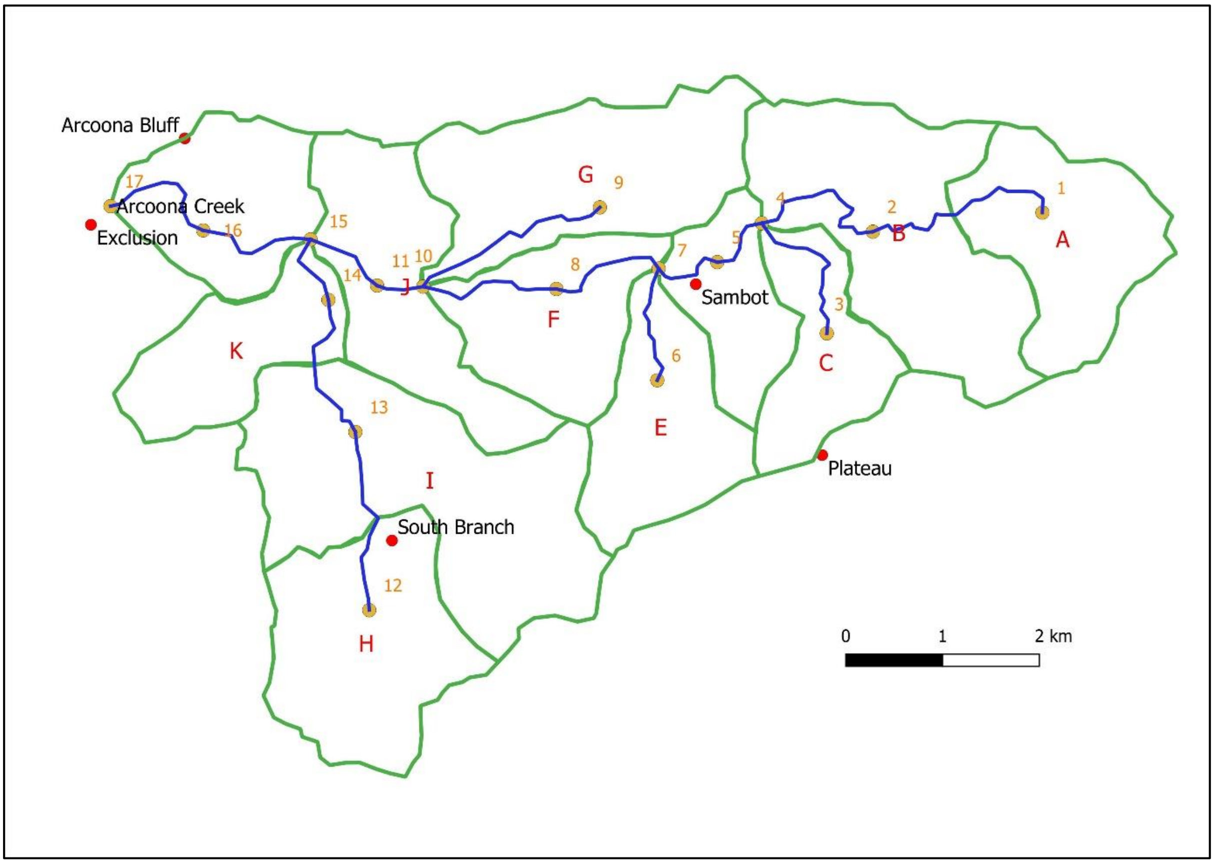


Figure 13 Arcoona Creek RORB Catchment

The catchment was sub-divided into sub-areas as per the RORB procedure, with the resultant model shown in Figure 13. A 5-minute time step was used due to the very short response time of the catchment. Rainfall data from Arcoona South was only available for the 2010 and 2017 events.

Table 7 Arcoona Creek Events Modelled in RORB

Start Date	Start Time	Duration (mins)	Plateau Rainfall (mm)	Exclusion Rainfall (mm)	Arcoona South Rainfall (mm)	Runoff (mm)	Peak Flow (m^3/sec)
16/01/1995	12:40	1000	50.4	58.4	n/a	5.39	31.9
15/03/1996	20:05	750	33.3	34.8	n/a	5.31	83.2
11/02/2010	19:00	1585	53.6	59.8	55.2	3.17	12.7
28/02/2012	08:30	3810	133.2	125.6	n/a	14.6	19.3
23/01/2017	12:00	1480	106.4	77.8	76.2	19.9	181

The hydrograph for the 1995 event indicates a very rapid rise, as shown in Figure 14. The flow level changed from 0.5m (below cease to flow) to 2.12m within 5 minutes, a rise from cease to flow of 1.61m.

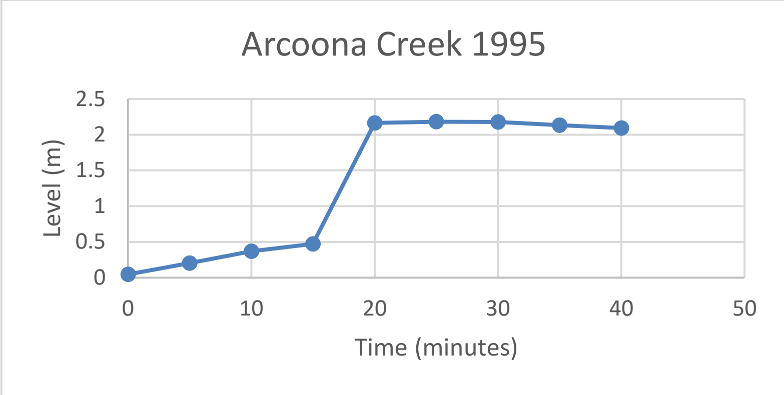


Figure 14 Arcoona Creek 1995 Recorded Flow Level

6.2 Modelling – Full Hydrograph

It was initially assumed that there was no baseflow, and the RORB model was calibrated to the full recorded hydrograph. The objective function used for the RORB model calibrations was the overall fit of the hydrographs thus the average absolute ordinate error was minimized, as this is given as an output for model runs.

Table 8 gives the modelling results, together with the weighted mean parameter values. The error in the hydrograph fit must be normalized if the fit of different events is to be compared. The weighting factor chosen for each event and parameter was thus observed peak flow divided by the root mean square error of the estimated hydrograph. Weighted mean parameter values are then determined using these weighting factors applied to the parameters of each event.

The weighting factor used is:

$$WF = \frac{Observed\ peak\ flow}{Root\ mean\ square\ error} = \frac{Q_{op}}{\sqrt{\frac{\sum_1^n (q_0 - q_c)^2}{n}}} \qquad \text{Equation 1}$$

where q_o is the observed flow at each time step
q_c is the calculated flow at the time step
n is the number of time steps or observations
Q_{op} is the observed peak flow

Table 8 Arcoona Creek RORB Modelling Results - Continuing Loss

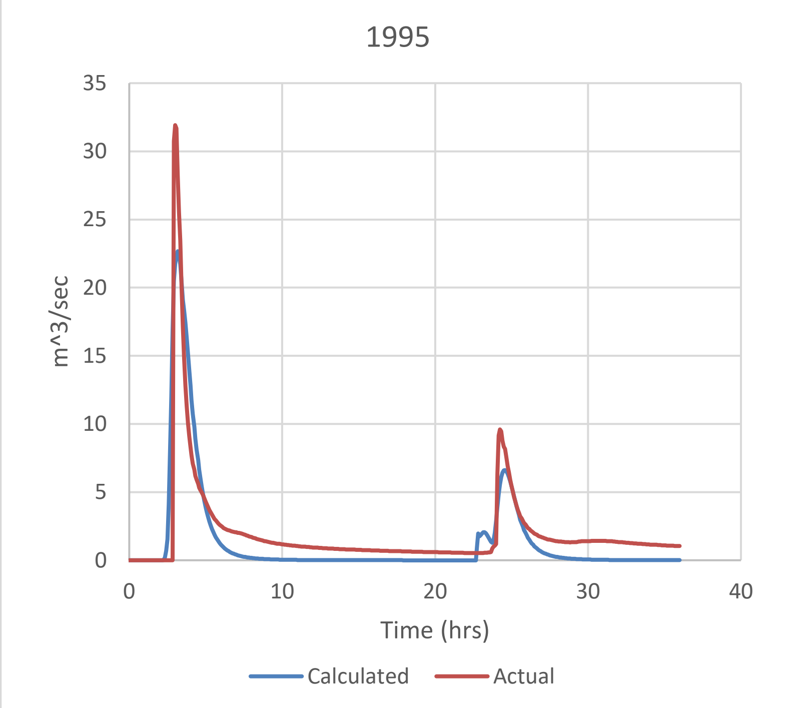
Event	kc	IL (mm)	CL (mm/hr)	Mean Ordinate error (ME)	Weighting (peak flow/ME)
16/01/1995	1.5	30.0	10.3	58.1	0.68
15/03/1996	1.15	21	35.0	15.7	5.30
11/02/2010	1.2	28	33.0	108.6	0.12
28/02/2012	7.1	68	9.7	39.8	0.49
23/01/2017	2.5	62	9.4	35.6	5.08

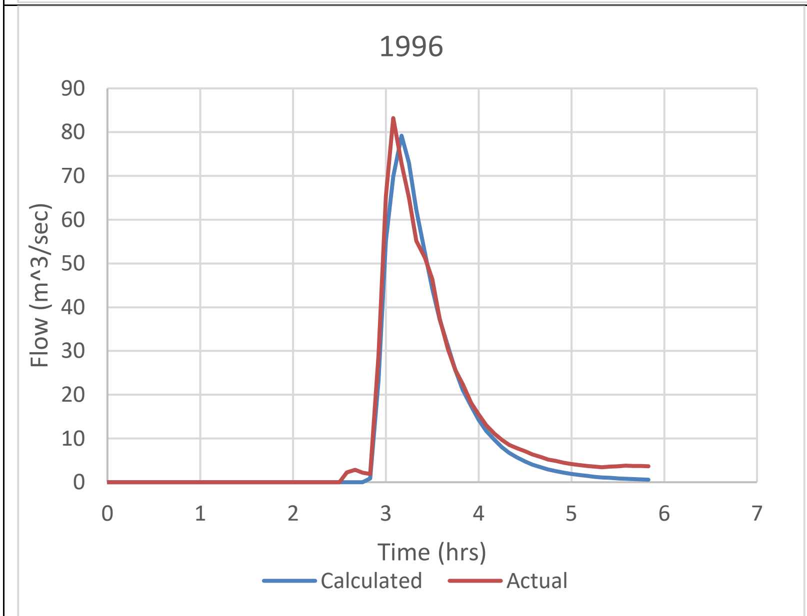
Weighted mean	2.01	41.4	21.3		

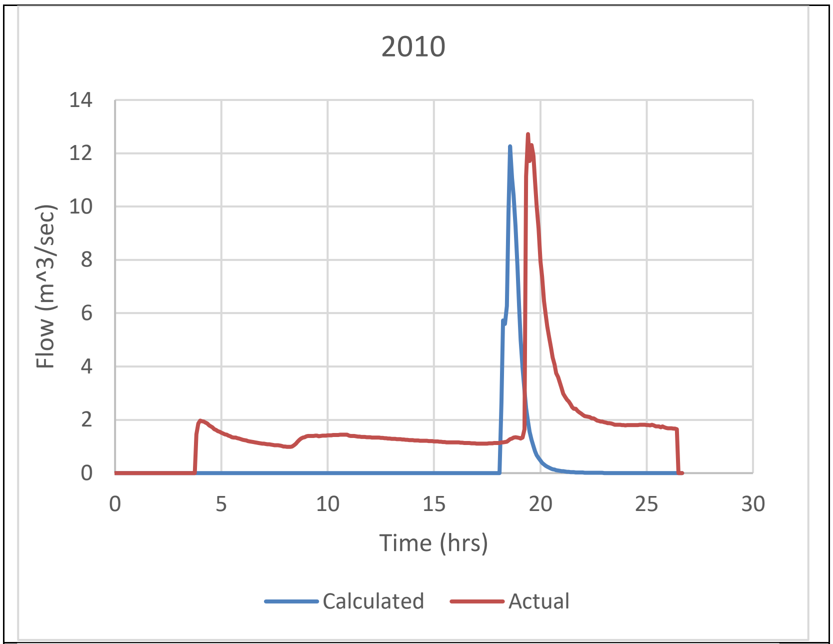
Notes:

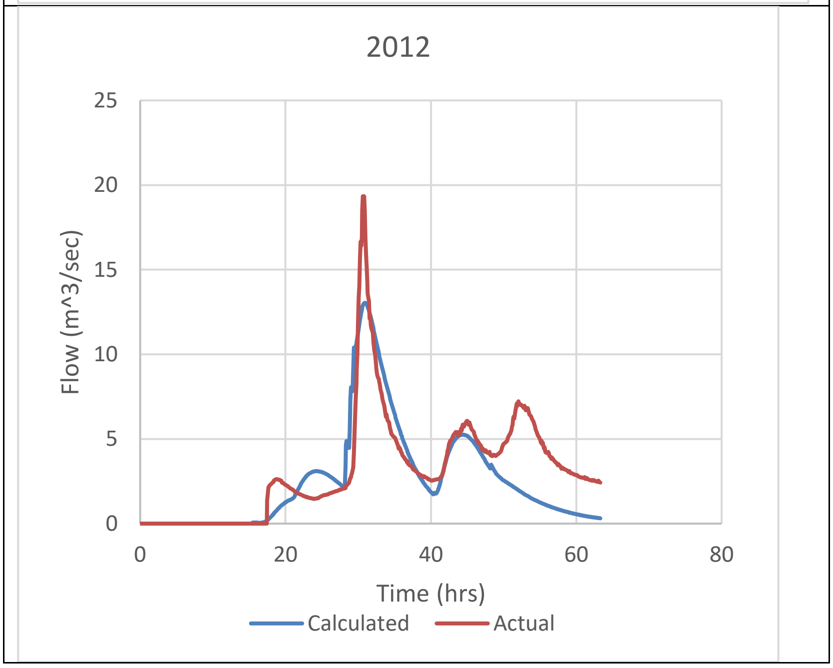
- 15 minute translation of hydrograph has been applied to the 1996 event
- 2010 event has very poor fit. Values given match shape of the main peak.

The weighted mean kc = 2.0, compared with the expected value of the Mount Lofty Ranges of 7.58 . This is based on the relationship in Australian Rainfall and Runoff of $k_c = 0.89A^{0.55}$ (Ball et al, 2019).






2010
Flow (m^3/sec)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
Time (hrs)
Calculated
Actual


2012
Flow (m^3/sec)
0
5
10
15
20
25
0
20
40
60
80
Time (hrs)
Calculated
Actual

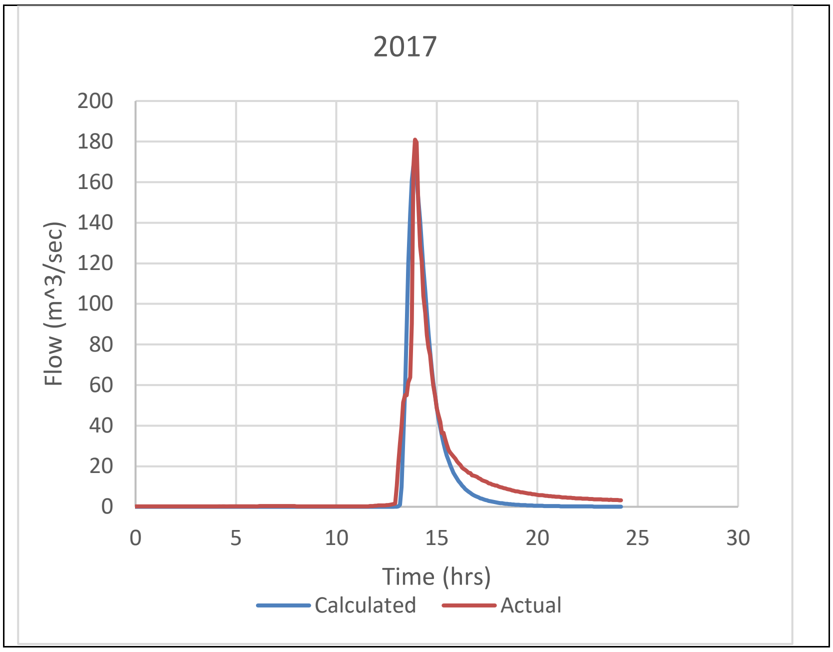


Figure 15 RORB model fits to full hydrograph, continuing loss

Because of the very poor fit for the 2010 event, two modifications were made to the model run to provide a more realistic result.

- A flow of $1m^3$/sec was subtracted for all ordinates, where the flow exceeded this amount, and
- The calculated hydrograph was delayed by one hour. There was possibly a timing error on the monitored data, due to an error in the daylight saving adjustment. The data is now being reviewed.

The resultant predicted hydrograph is shown in Figure 16.

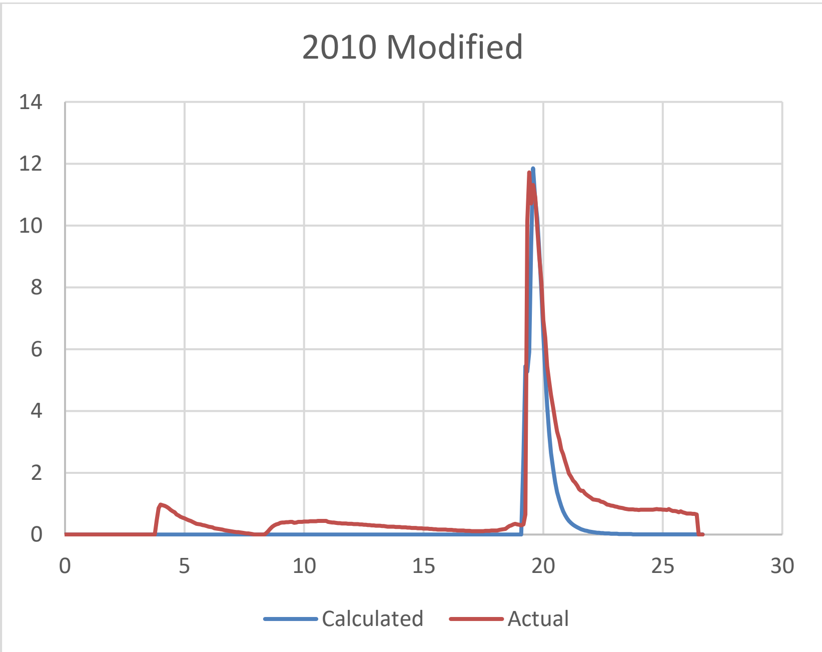


Figure 16 RORB model fit to 2010 event, adjusted flow and timing

6.3 Modelling – Fast Flow Hydrograph

RORB is a single process model and only models surface runoff. Therefore, the treatment of baseflow is an issue of significance with the RORB model calibration and verification. Baseflow extraction was undertaken using a 3 pass Lyne and Hollick filter (Lyne and Hollick, 1979). A 9 pass filter is recommended by Australian Rainfall & Runoff, 2019 (Ball et al, 2019), but these 9 passes for the Arcoona Creek hydrographs produced an unrealistically low baseflow. As the time step is 5 minutes, a Lyne and Hollick filter parameter value of 0.994, equivalent to a filter parameter of 0.925 for the hourly time step as recommended by ARR 2019. Figure 17 shows the result of the baseflow extraction.

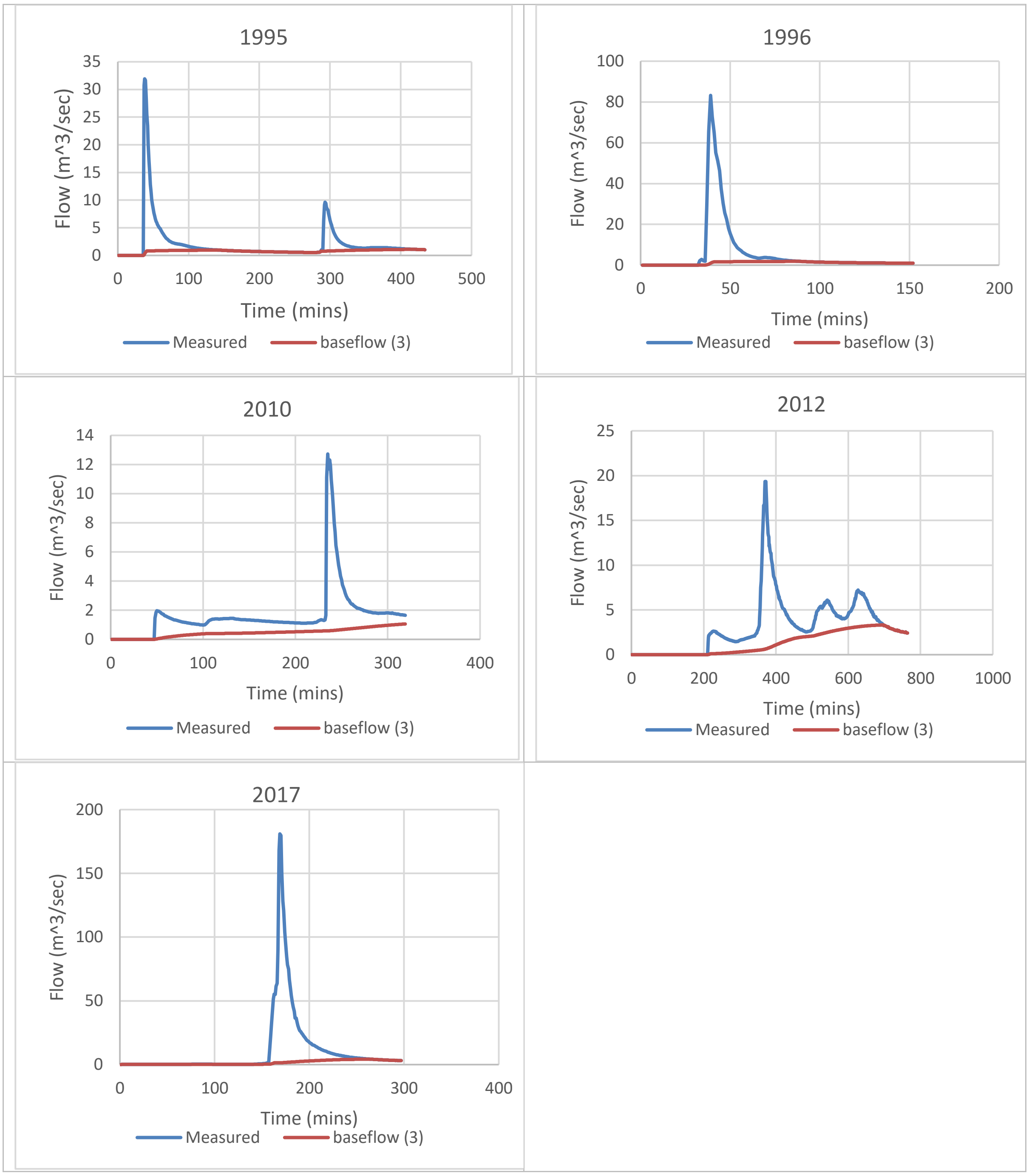


Figure 17 Baseflow extraction results

Figure 18 Arcoona Creek RORB Modelling Results - Continuing Loss and fast flow only

Event	kc	IL (mm)	CL (mm/hr)	Mean Ordinate error (ME)	Weighting (peak flow/ME)
16/01/1995	1.45	30	10.6	43.8	0.72
15/03/1996	1.1	23	13.6	13.6	6.05
28/02/2012	4.9	68	11.8	44.3	0.42
23/01/2017	2.65	64	9.4	24.1	7.45
Weighted Mean	2.02	45.5	18.9		

As expected, when compared with the full hydrograph, the kc value, as a measure of catchment response does not change much, but the initial and continuing loss values change. The 2010 event was not included in the analysis, due to the uncertainty about the recorded flow and timing of the peak.

7 Discussion

7.1 Introduction

The Arcoona Creek catchment now has a significant period of rainfall and flow data available, and this review uses that data to examine flood frequency and flood hydrograph modelling using RORB.

Firstly, a review was carried out of the station rating, based on measured peak water levels for the 2017 flood event. This showed that the level recorded at the station was lower than expected given the water surface levels along the stream. The most probable explanation for this is that the instrument is situated in an eddy, and thus not recording the true flow depth at the station.

Using the HECRAS model a new rating curve was derived and applied to the full period of record to obtain flows. The annual maximum series was derived. Of the 27 years of record a total of 14 years, or more than 50% of all years there was no flow recorded in the creek. It is useful now to compare the Arcoona Creek flow record with that of humid catchments and discuss the reasons for the differences.

7.2 Channel Manning's n Value

This analysis has used a Manning's n value of 0.04 for the channel, based on Chow (1959). However, without on-site velocity measurement during flow (gauging) this value cannot be directly confirmed. The rating directly affects event volumetric runoff coefficients, so an assessment was made as to the Arcoona Creek mean event volumetric runoff coefficient and how this compared with other Australian catchments. An inconsistent value may indicate that the selected Manning's n needs review.

Table 9 summarises the volumetric runoff coefficients for the Arcoona Creek events modelled by RORB.

Event	Peak Q (m^3/sec)	Rainfall (mm)	Runoff (mm)	Volumetric ROC

1995	31.9	68.2	5.4	0.079
1996	83.2	33.7	5.3	0.157
2010	12.7	56.2	1.5	0.027
2012	19.3	131.1	14.6	0.111
2017	181	93.7	19.9	0.212
			Average	0.117

Table 9 Event Volumetric Runoff Coefficients for Arcoona Creek Events

To assess whether these are reasonable other catchments across Australia, including in more humid areas were compared, again by looking at the larger events. In each catchment the 5 or 6 large events were chosen, and volumetric runoff coefficients were determined, either using the RORB model or by daily rainfall and flow volume records. Baseflow was not extracted. Table 10 provides the summary of the volumetric runoff coefficients.

	Station no.	Catchment Area (km^2)	Annual Rainfall (mm)	Mean volumetric ROC
Arcoona	A0040520	49.3	332	0.117
Inverbrackie	A5030508	8.44	624	0.545
Echunga	A5030506	34.2	769	0.403
Sixth	A5040523	44	899	0.486
Finch Hatton	GS125006A	35.7	2180	0.736
Burra	410774	68.7	600	0.263
Marrinup	614003	45.6	1230	0.226
Torrens	A5040512	26.1	559	0.710
Scott	A5030502	26.6	790	0.304
Aroona Dam	A5100500	704	225	0.265
Kanyaka	A5090503	186.7	293	0.106
Celia	G8150151	52.2	1340	0.425

Table 10 Event Volumetric Runoff Coefficients for Selected Australian Catchments

The location of the selected catchments is shown in Figure 19 and Figure 20.

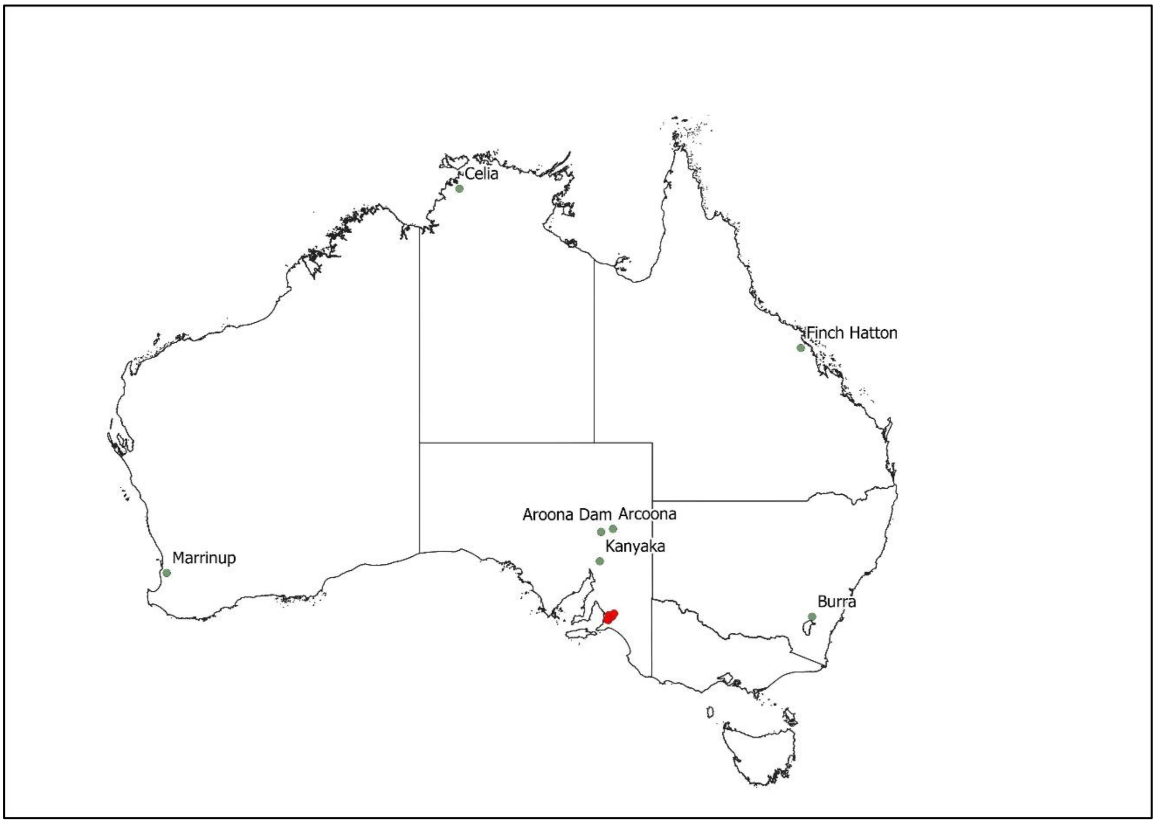


Figure 19 Australian Catchments for Volumetric Runoff Coefficients

Figure 20 Australian Catchments for Volumetric Runoff Coefficients (Mount Lofty Ranges Detail)

Plotting the event volumetric runoff coefficients against annual rainfall indicates that there is a relationship between the event volumetric runoff coefficient and mean annual rainfall, as shown in Figure 21. Many more catchments would have to be examined to determine if a relationship did exist. However, there is no indication that the volumetric runoff coefficient for Arcoona Creek is unreasonably high.

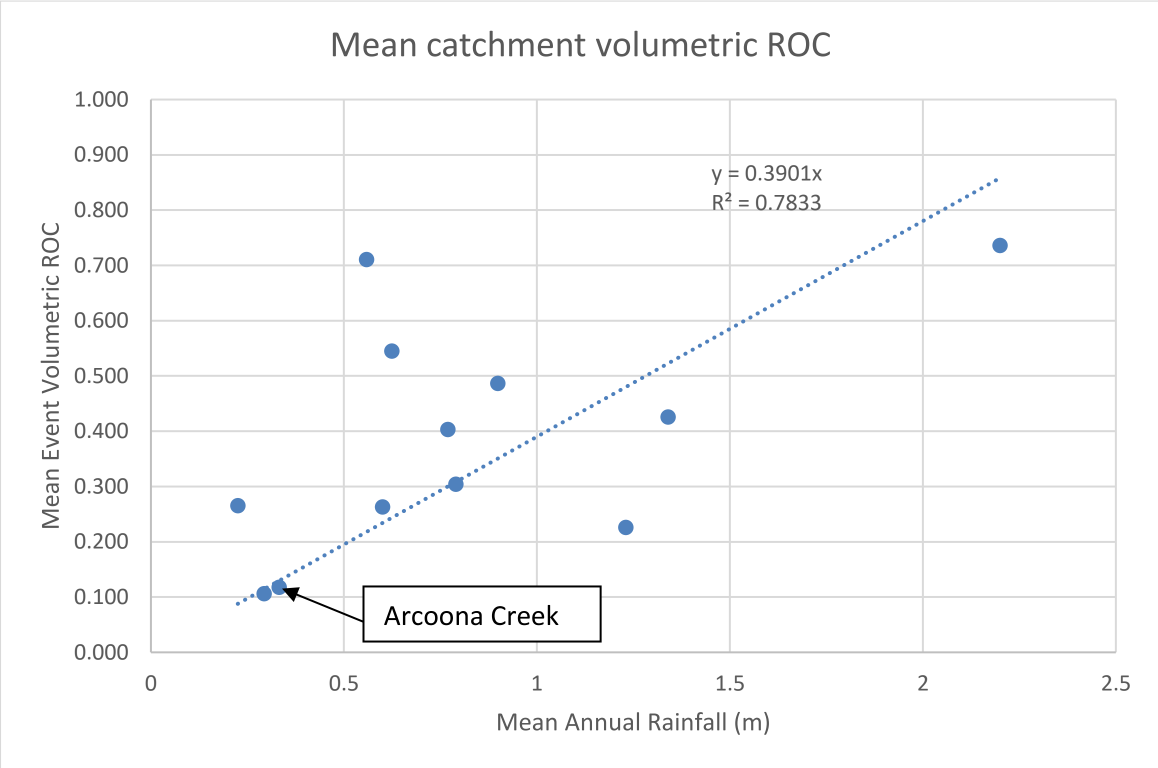


Figure 21 Relationship Between Mean Annual Rainfall and Event Volumetric Runoff Coefficient

Ho et al (2022) examined flood event volumetric runoff coefficients in 467 Australian catchments to examine possible changes with climate change and confirmed the trend for higher event volumetric runoff coefficients with higher annual rainfall. They selected events by annual maximum 3-day rainfalls, and in addition excluded baseflow for their analysis. Because of the selection method and the baseflow extraction the resultant volumetric runoff coefficients were generally lower than those determined here.

The sensitivity of the selection of the Manning's n value was undertaken by increasing the channel Manning's n by 10% to 0.044. This resulted in an estimated maximum flow for the 2017 flood event of 130m^3/sec, compared with 180m^3/sec with an n value of 0.04. It is known that the Manning's n of the channel can vary during the food event, due to debris and rock movement. But until further baseline level information is obtained after another major event to further characterise the amount of rock material moving downstream then the adjusted rating using a Manning's n of 0.04 can be used.

7.3 Expected Arid Catchment Flood Response

Arid and semi-arid catchments are quite different and behave differently to catchments in more humid areas of Australia. Pilgrim et al (1988) provide a very good summary of the differences, and the difficulties of modelling in arid and semi-arid areas.

Regarding arid and semi-arid flood flows:

- There is a different mix of hydrological processes, with some humid zone processes (e.g. baseflow) essentially absent, while channel transmission losses are of critical importance.
- Rainfall tends to be more variable in both space and time than in humid regions.
- Plant cover is sparse, and consists mainly of xerophytes, ephemeral grasses and small leafy plants.
- For desert areas and a large percentage of most arid basins, the surface soil largely is the first point of contact by rainfall. Thus soil type and the soil's surficial properties probably play a primary role in runoff production, especially as saturation of the surface soil occurs relatively rarely. Hydrophobic soils, armouring, dispersive soils, cracks, scald or claypan areas, sand dunes and bare surface rock are some of the features which are influential in arid zone runoff production.
- While the water table is typically below stream beds and disconnected from the surface drainage system, a temporary saturated hydraulic connection may occur in flood events.

Pilgrim et al (1988) also stated that

"hydrographs in arid and semiarid regions tend to be flashy, with short time bases and steep rising and falling limbs. In particular, times of rise are often very short. On the Walnut Gulch watershed in south eastern Arizona, Renard & Keppel (1966) found that time of rise decreased with increasing size of drainage basin. They attributed this to transmission losses during rising stages and the presence of overriding translatory waves as the flow moves through the channel. Abrupt translatory waves, or the "wall of water" of folklore, also occasionally occurred, but were not typical."

The transmission loss occurs in the gravel beds that are typical of arid area streams such as Arcoona Creek.

Rainfall and flows in arid areas tend to be much less frequent but also have a greater variability than those in humid areas.

7.4 Flow Variability

The variability of flow can be compared with a humid catchment, by looking at both the range of annual maximum flows, and the flood frequency.

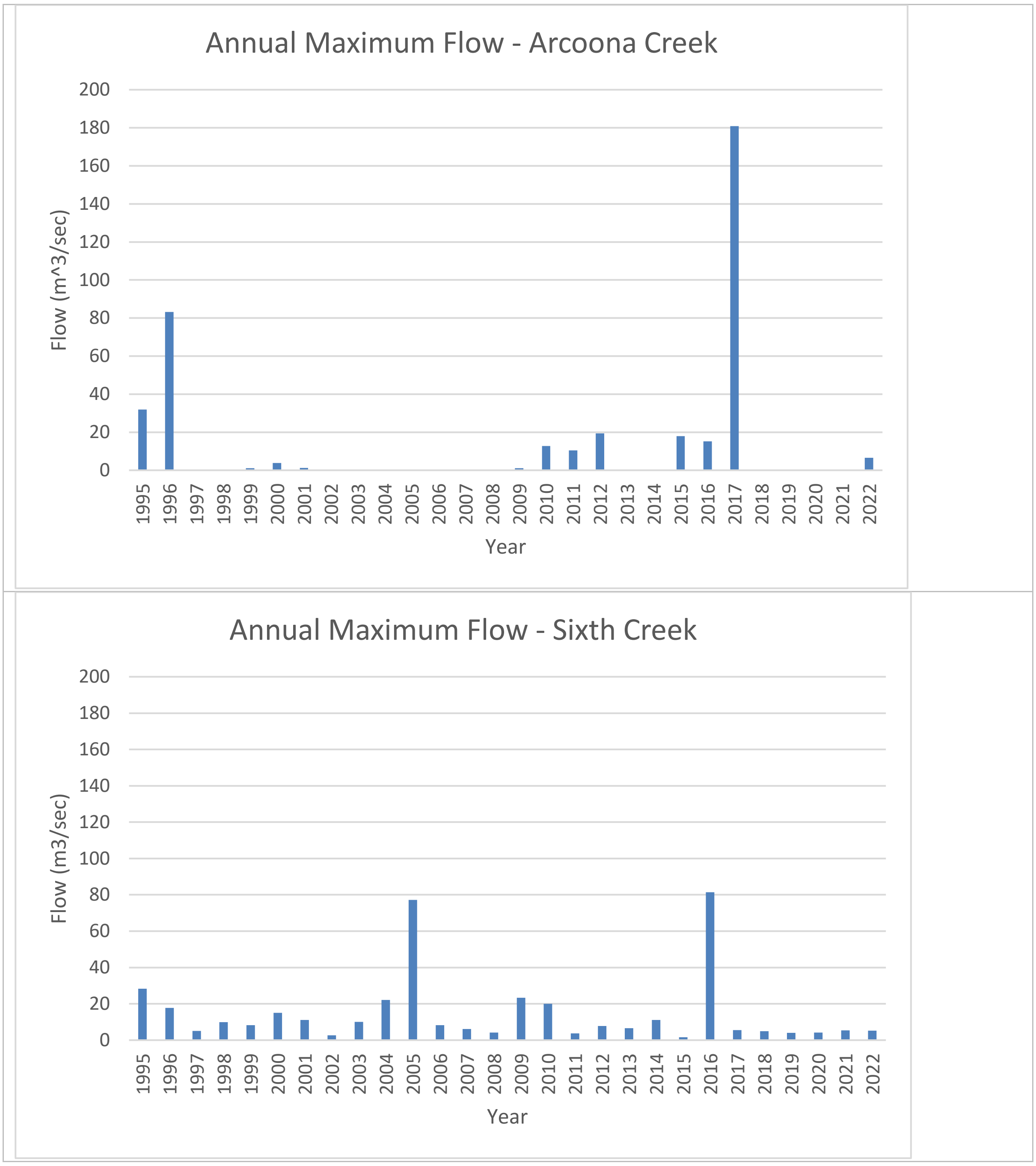


Figure 22 Annual Maximum Flows in Arcoona Creek and Sixth Creek

Figure 22 Shows the annual maximum flows for Arcoona Creek and Sixth Creek (AW504523) for the period 1995 until 2022. The Sixth Creek catchment is in the Mount Lofty Ranges and has a very similar catchment area to Arcoona Creek. However, the Sixth Creek annual rainfall is approximately 950mm, compared with 260mm to 330mm for Arcoona Creek. The two plots have the same vertical scale.

The Arcoona Creek catchment has many years with no flow, whereas the Sixth Creek catchment has none. In addition, the peak recorded flow in the Arcoona Creek catchment is much greater than the Sixth Creek catchment.

The difference is also evident in a flood frequency plot. Figure 23 shows a comparison of flood frequency between the Arcoona Creek catchment and a typical Mount Lofty Ranges catchment, derived from an unpublished University of South Australia regional regression derived during the update of Australian Rainfall and Runoff (2019).

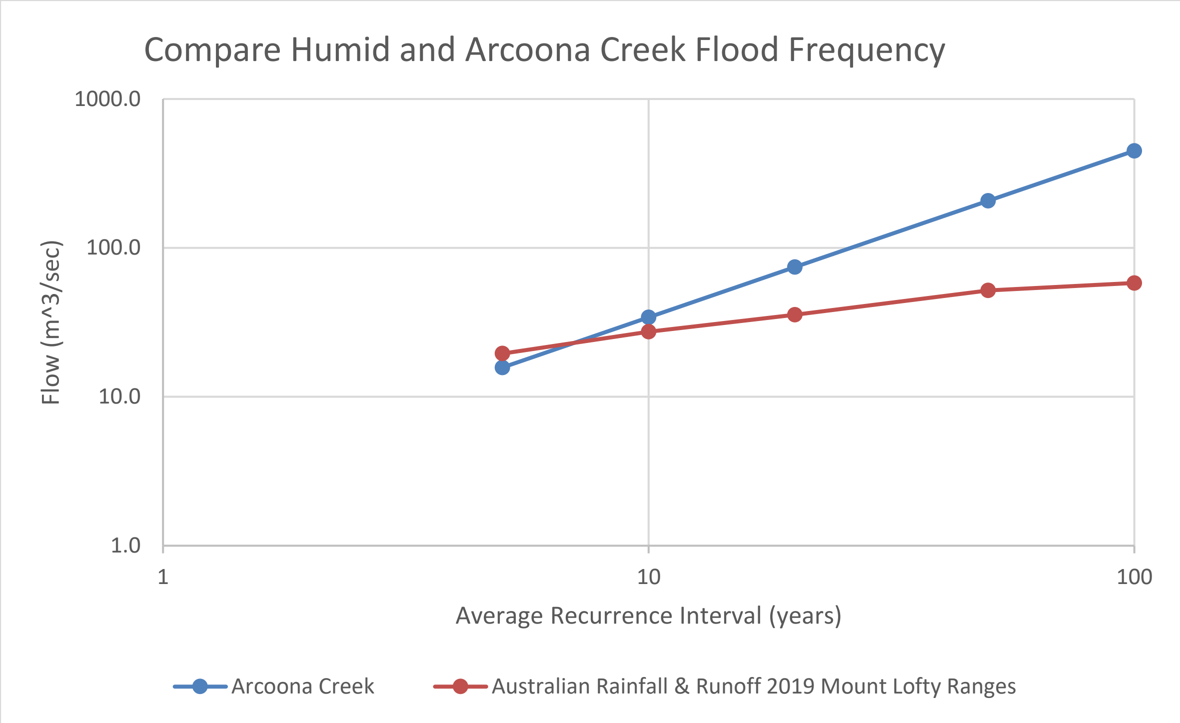


Figure 23 Comparison of Flood Frequency Between the Arcoona Creek Catchment in Blue and a Typical Humid (Mount Lofty Ranges) Catchment in Red

It is evident that the Arcoona Creek catchment plot has a greater slope indicating greater variability, with more extreme high flows. The 100 year Average Recurrence Interval (ARI) flow for Arcoona Creek is 449m^3/sec, and for the Mount Lofty Ranges catchments 58m^3/sec, using the ARR regression. In addition, the Mount Lofty Ranges catchments have greater flows for more frequent events, reflecting the percentage of time that flow actually occurs in the catchment.

7.5 Catchment Response Time

As shown in Section 6.2 the RORB kc value, a measure of the catchment response time is 2.0, compared with the expected kc value of the humid Mount Lofty Ranges of 7.6 (Kemp, 1993), in other words the response is almost 4 times as fast.

Published evidence (Jayatalika and Connell, 1996, Dunne and Black, 1970, Gillham, 1984, Hewlett and Hibbert, 1967) indicates that generally three distinct runoff processes can occur in a catchment, depending on climate and physical characteristics. O'Loughlin et al (1996) summarised the modelling of rainfall-runoff processes and concluded that a physical process model would have to model three components of flow to enable flow to be modelled at a range of time scales.

These are:

- Groundwater or baseflow. This is the traditional concept of baseflow and is what is generally referred to as the steady state regional groundwater runoff and is the slowest flow process contributing to the hydrograph. It is known that the lag between rainfall and groundwater runoff to the stream discharge can be substantial, due to the long flow path length in the groundwater system,

- Interflow. This mechanism occurs within the unsaturated zone and acts with a lag from rainfall to stream flow that is less than that of the baseflow above, due to the quicker response time from rainfall to runoff into the stream, and.
- Direct runoff, on the surface either from a part of the catchment area, or the full catchment area. The response time of this mechanism is short compared with the two above, as no infiltration and flow through soil and rock flow is involved.

Kemp & Daniell (2020) discusses the modelling of flood flows by runoff routing models such as RORB in Australia and concluded that in general there is lag due to runoff processes on the hillside, so implying that baseflow and interflow are the dominant process in humid areas. However, in arid areas, with skeletal soils and little vegetation it is probable that direct surface runoff is occurring, with the resultant more rapid catchment response time.

7.6 Baseflow and Transmission Loss

With the skeletal soils and the dominance of surface runoff it is unlikely that baseflow is occurring in the Arcoona Creek catchment. However, the creek channels themselves contain large amounts of gravel that can store and then release water (Bob Read, Regional Groundwater Hydrologist, personal communication – "a depth of unconsolidated riverbed gravels of 1 to 2 metres is likely, with a possible maximum depth up to 3 metres"). There is evidence from the 1995 event with a rapid increase in hydrograph depth that an abrupt translatory wave has occurred, as predicted by Pilgrim et al (1988).

The relatively large RORB weighted mean initial loss of 41.4mm may in fact be due to loss in the gravels of the creek channels.

The author was present in the catchment for an event in April 2009 that had a mean rainfall of around 40mm in 9 hours, an annual exceedance probability between 20% and 50%, for durations between 3 hours and 9 hours. No flow was observed in the mainstream channel, but the hillsides and small steep streams had reasonable flows. This observation suggests that high losses occur in mainstream channel gravels.

8 Summary

The January 2017 flood in Arcoona Creek has given the opportunity to investigate the flood profile and compare this with the recorded peak depth at the gauging station. It has indicated that the water surface profile in Arcoona Creek lies above the recorded depth, probably due to the location of the level transducer in an eddy. A recommendation has been made to adjust the rating curve based on the findings.

Using the updated rating, flood frequency analysis and modelling using the RORB model, has been carried out. The results of this work indicate that the Arcoona Creek responds in a way that is expected of streams in arid areas in that:

- There is greater variability in flows than a catchment in a more humid area, with a significant number of years having no flow.
- The response time of the catchment is significantly shorter than that of a humid catchment, most probably due to different runoff processes occurring in the arid catchment.
- There is evidence that runoff is stored in the gravels of the mainstreams, which can lead to flash flooding, with very rapid water level rises in the creek.

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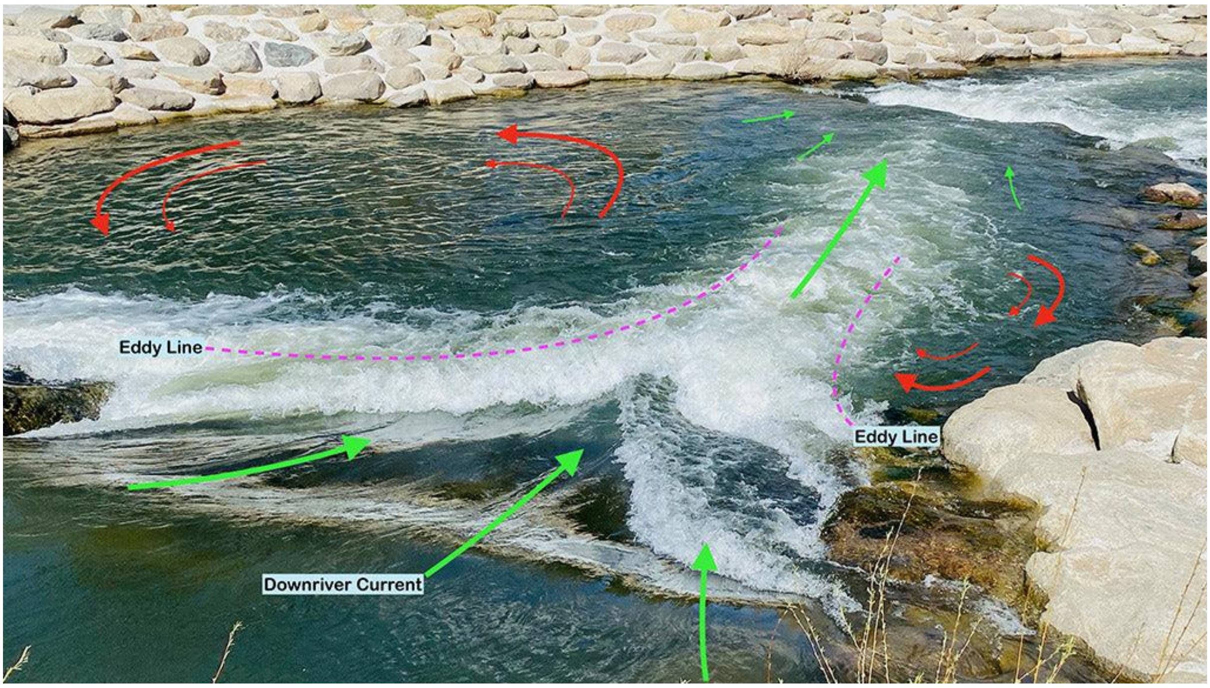
Eddy Line
Eddy Line
Downriver Current