

The Gammon Ranges Project – Monitoring in a Remote Area

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Abstract

The Northern Flinders Ranges, in the semi-arid zone of South Australia, are remote and inaccessible, but despite this, a project, known as the Gammon Ranges Project, has been running for the past 20 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 km² catchment, and has taken over the running of another three 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 are publicly available.

This paper discusses the monitoring project, and shows how a successful voluntary data collection network can be run, given the right skills and resources, in an area that would otherwise be very costly to monitor. In addition, the project has provided valuable hands-on experience to university students, giving them a real feel for the value of data and the difficulties collecting it.

Rainfall monitoring has demonstrated the significant difference between summer and winter rainfall in the area. Summer rainfall events tend to be of higher intensity and shorter duration. An orographic effect is observed for both seasons.

There has been great variability in both rainfall and stream flow. In the fifteen years of stream data there have been eight years of zero flow, as well as flood flows of up to 90 m³/s. In addition, a flow occurred before the recording period estimated to be of the order of 150 m³/s to 200 m³/s. This variability has made concepts such as flood frequency difficult to apply. Modelling of two flood events has been done, showing high loss rates in the catchment, but a rapid response once flow starts.

An interesting aspect of the project has been the experience of installing and operating sensitive electronic equipment in a harsh and remote environment. Many lessons were learned which have been useful in the development of on-site operator skills; and improvements in equipment design.

1. INTRODUCTION

The Gammon Ranges in the far northern Flinders Ranges consist of a deeply dissected quartzite plateau with steep gorges and spectacular cliffs. The sites for the project are all located towards the western end of the Gammon Ranges and are reached from a camp site off the Mt Serle to Yankaninna road.

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. This area was selected (see Figure 1) because it is less popular than the eastern part of the park which means that the scientific equipment is less likely to be disturbed and the data collection trip is in an area of near wilderness which adds to the experience for participants. Four data recovery trips are made to the area each year.

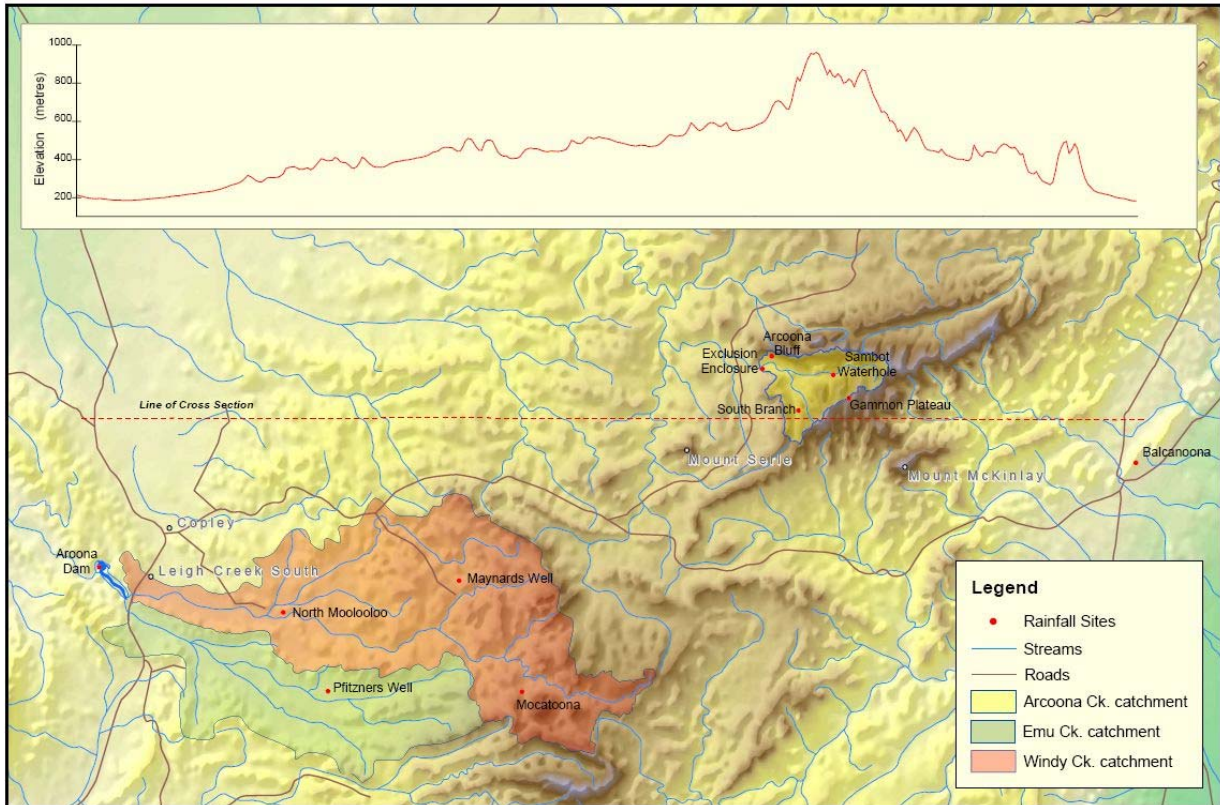


Figure 1 Cross Section of the Northern Flinders Ranges

The program has gradually expanded to now include seven activities:

- Servicing of pluviometers at eight sites,
- Botanical monitoring at six sites,
- Aquatic biology monitoring at two sites,
- Human impact monitoring at three sites,
- Stream-flow monitoring and electrical conductivity recording at one site,
- Yellow footed rock wallaby colony monitoring, and
- Feral animal counts and locations.

This paper will focus on the rainfall and stream flow monitoring.

2. MANAGING THE PROJECT

Significant challenges were encountered in developing and running this volunteer project. The costs of labour, food, accommodation and transport are borne mainly by the volunteers. Vehicle costs are relatively high due to the long distance (about 650 km each way) and poor road conditions for the last 100 km. SEG has learnt to choose privately owned vehicles that carry four or more passengers, and which have low fuel costs. Funds for purchase of the monitoring equipment were provided by State and Commonwealth Government departments.

Participants in each of the four trips per year are of all ages and experience, attracted by the chance to visit a remote and unspoilt region of South Australia, and experience bushwalking in a harsh environment, often with no surface water, and extremely hot or cold conditions, wind, dust and flies!

In the earlier years (1988-1992), the 90-day memory capacity of data loggers required that five visits per year had to be scheduled. Those loggers could be tricky to set up and to download, and as a consequence there were often periods when data were not recorded. The lesson was learned that despite careful training sessions before the start of each trip, volunteers became confused by the menu system for communicating with loggers, and it was difficult to write an instruction manual that covered all possible situations. Actions that seemed simple on the test bench became fraught with difficulty in intense heat and bright conditions, and when the volunteers were stressed out from the effort of reaching the site. Such situations are now history due to the much more user-friendly design of modern data loggers. Nevertheless some basic lessons have been learned:

- For remote sites it is better to use dual loggers at each site. This reduces the risk of loss of data. If one logger fails, hopefully the other keeps going;
- Use of laptop PCs in the field is tricky. They are heavy to carry and easily damaged, (one PC fell and broke a screen). Battery life is a problem, and PCs sometimes get switched on accidentally and run down their batteries. The screens on laptop PCs can be very difficult to read in bright sunshine;
- SEG is starting to use PDA (pocket computers) for communication with data loggers and modems with some success. These are light and easy to protect when carrying. However, there have been problems with flat batteries, and the small screen can be difficult to read;
- If volunteers are being used to service or download electronic equipment in the field, the instructions and procedures must be as simple as possible – even simple procedures can be difficult to follow when one is tired, hot or cold and working under exposed conditions;
- Logger exchange – replacing the logger in the field with one that has been serviced at home – is easy and quick. It has the disadvantage that volunteers cannot actually observe the data that has been collected;
- Standardised equipment and procedures are good, and less likely to cause confusion;

Where all of these suggestions are followed, the results have been generally good.

3. MONITORING

Rainfall monitoring commenced in the Gammon Ranges in September 1998, with the installation of a pluviometer on the Gammon Plateau. Spatial 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 and an Exclusion Zone in the Arcoona Creek valley. In order 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 Arcoona 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 west-south-west of the Gammon Ranges.

The initial rainfall monitoring site, on the Gammon Plateau, is at an elevation of approximately 930 m, which makes this the highest automatic recording rain gauge in South Australia. The others are at various elevations, down to 320 m. The eight recording sites are ideally located to investigate the orographic effect of the ranges on the rainfall. They can also be compared with recordings from Balcanoona, Arkaroola, Leigh Creek and other daily read stations on pastoral properties.

Because of the random and infrequent nature of the rainfall, it will take many years before sufficient data have been collected to enable an accurate comparison with adjacent stations; however a general understanding of the differences and similarities is already starting to develop. The five sites within the catchment of Arcoona Creek will also provide a good estimate of the total rainfall in the catchment for comparison with stream-flow measurements.

Since the beginning of the project in September 1988, the quality and capability of the monitoring of rainfall, using tipping bucket rain gauges (TBRGs), has improved considerably. In the early days, there were frequent occasions when the data loggers failed to record, or data was overwritten. Currently the

data is recorded using dual data loggers at each site. The instrument on Arcoona Bluff has a modem and CDMA phone facility so that it can be interrogated by the Bureau of Meteorology each day to find out whether rain has fallen. This provides vital information for the Feral Animal Research Project as there is a need to know when there has been sufficient rainfall to cause germination of mulga (*Acacia aneura*) seedlings. It is also a useful indicator of whether there is likely to be drinking water in the creeks, which will reduce the amount that must be carried in by expeditioners.

Three of the rainfall sites are accessible by vehicle. The Exclusion Zone pluviometer site and the river height gauge are some 200 m from the nearest vehicle access point. The others are remote, with the Gammon Plateau pluviometer, being the furthest, taking about eight hours to reach on foot. The tipping bucket rain gauge (TBRG) mechanisms are extremely delicate. Calibration is tricky, even in the laboratory. Great care was taken in carrying the instruments to site, but inevitably knocks occurred. The Bureau of Meteorology, which uses TBRGs extensively, tries to limit the error in rainfall measurement to $\pm 3\%$. It has been found that once an instrument is “bedded down”, the calibration tends to be reasonably stable. When drift in calibration occurs in the Gammon Ranges, the instruments must be adjusted on site. This process is time-consuming and requires a steady and careful hand. If calibration is planned on a trip, an allowance of two hours or so is required, and since only one or two people can work on the instrument, alternative tasks need to be arranged for the rest of the team.

The Field Calibration Device (FCD) (see Figure 2) has been developed by the Bureau of Meteorology for on-site testing and calibration. The instrument is light, easy to use and if carefully handled will give consistent results. Usually an electronic “counter” is used to count the bucket tips for each calibration cycle. Volunteers found that they needed to ensure that the calibrator is properly filled each time, and that the water is clean. Bureau of Meteorology procedures include recording the temperature of the water used for calibration, but to date this has not been measured during Gammon Ranges field trips.



Figure 2 Field Calibration Device in Operation

Rain gauge failures have occurred. At the Gammon Plateau, the most remote site, the magnet on the micro-switch fell off its bracket during a service run. Fortunately someone from the installation team, several years previously, had left behind a Quickset Araldite pack. The glue was still usable and the magnet was successfully glued back on.

In South Australia it is common for the water discharged through a pluviometer to be collected in an underground tank and the volume cross-checked against the recorded number of tips. However in practice in the Gammons this has proved unsatisfactory as a means of checking calibration, due to

evaporation of some of the water in store, leakage and occasional blockages in the pipes. In-situ calibration using the FCD has been found to be easier and more consistent.

Water flow has been more difficult to measure. Arcoona Creek flows infrequently, and when it does flow, it tends to be violent, carrying rocks, boulders, tree trunks and debris. A pressure transducer was installed, with a data logger stored in a cave above flood level, and a solar panel to charge the batteries. Some months after installation, all the equipment was stolen for sale as a “solar water pump”. It was recovered, but irretrievably damaged. After reinstallation, further logger problems led to loss of recording of several river flows. With the benefit of experience, the equipment has operated reasonably well in recent years, but there has been almost no flow to measure. A complete rebuild of the equipment has commenced. This work is partly to provide a more accessible spot to store the data logger and batteries, but also in preparation for installation of a telemetry link via a repeater on the ridge top to Leigh Creek. When complete, this will use the new NextG mobile phone network and will allow data to be recovered from the water level recorder each day. Regular telemetry access will allow the condition of the field equipment, particularly batteries, to be monitored. If the equipment fails or battery condition deteriorates, a maintenance visit can be planned. Prior to this arrangement, instrument failure could go undetected for many months until the next scheduled service, with a potential loss of valuable hydrological data.

Four rainfall sites have already been fitted with modems and are interrogated daily. After an early period that was plagued with modem lockups and communications failures, the problems have been resolved and it is hoped that the NextG network will perform reliably.

The design of electronic equipment suitable for operating unattended for many months at a time has progressed significantly since the project began. Generally, the Hydrological Services RRDL-3 data loggers have performed well, despite being “cooked” in the summer heat, with temperatures up in the 50°C zone, and frozen in the winter, during frosty conditions and occasional snow. The location and required exposure of the rainfall sites make it difficult to offer much in the way of protection. SEG is working on the design of shields for modem boxes so that these can be kept in the shade.

A feature of this project has been the success with which all the data recovered, has been edited, quality controlled and entered into an industry standard data base. Data are regularly extracted for use in research and hydrological analyses.

4. RAINFALL AND CLIMATE

Early analyses of rainfall data collected in the Gammon Ranges have been undertaken by Maier and Wright (1995) and Jewell et al. (2003), and both have indicated a general correlation between average annual rainfall and altitude, indicating that orographic uplift is a significant factor in rainfall distribution in the region.

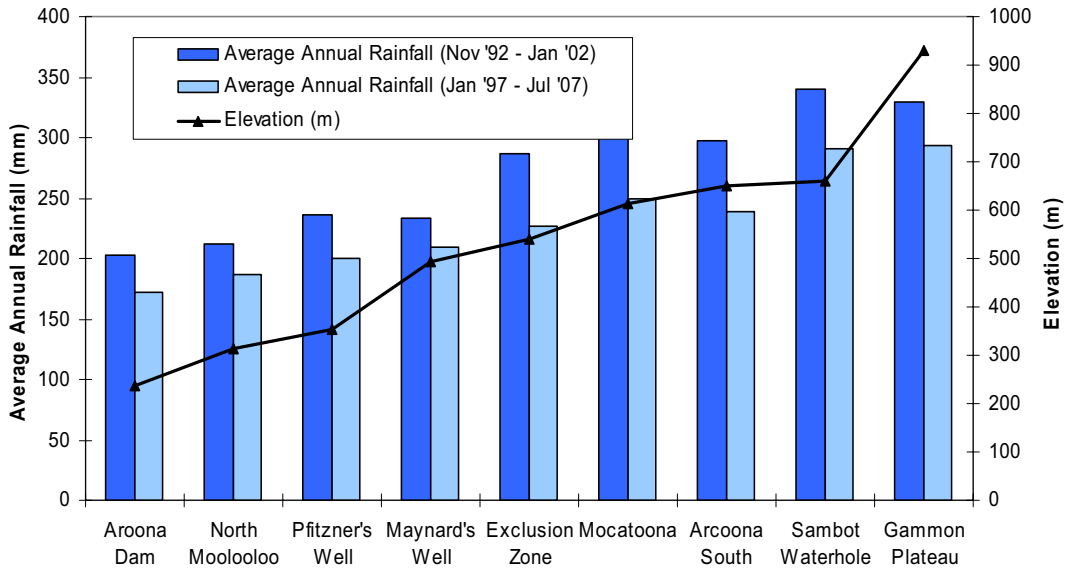


Figure 3 Average Annual Rainfall in Northern Flinders Ranges

Figure 3 shows the average annual rainfalls recorded at the stations during the periods November 1992 to January 2002, and January 1997 to July 2007, and illustrates the observed correlation between rainfall and altitude. The drought conditions experienced over the last few years have clearly resulted in a significant reduction in average annual rainfalls across each of the gauging stations. During the recent drought conditions, westerly cold fronts, which commonly bring substantial winter rainfall to southern South Australia, have been infrequent, and have rarely penetrated as far north as the Gammon Ranges.

A significant difference has been observed in the general rainfall mechanisms during the summer and winter months in the northern Flinders Ranges. Winter rainfall events are typically of low intensity, triggered by orographic or convergence uplift of cool, moist air masses from the Southern Ocean, which are often associated with the movement of cold fronts across the southern part of the Australian continent.

By contrast, summer rainfall events in the northern Flinders Ranges are commonly of much higher intensity, and are typically shorter in duration and more localized. These rainfall events are usually the result of thunderstorms produced by convective uplift of warm moist air inflows. Summer rainfall events are typically irregular and randomly distributed, and can sometimes be of extreme magnitude, causing flash flooding. Another mechanism for summer rainfall is the highly erratic and infrequent occurrence of a slow-moving tropical low-pressure system. This is commonly the result of a large monsoonal trough drifting southwards from northern Australia, and can result in periods lasting up to several weeks of well-above-average rainfall, and extensive flooding. Figure 4 shows a comparison between the average summer (November to February) and winter (May to August) rainfalls recorded in the northern Flinders Ranges and clearly illustrates the importance of irregular summer rainfall to the region.

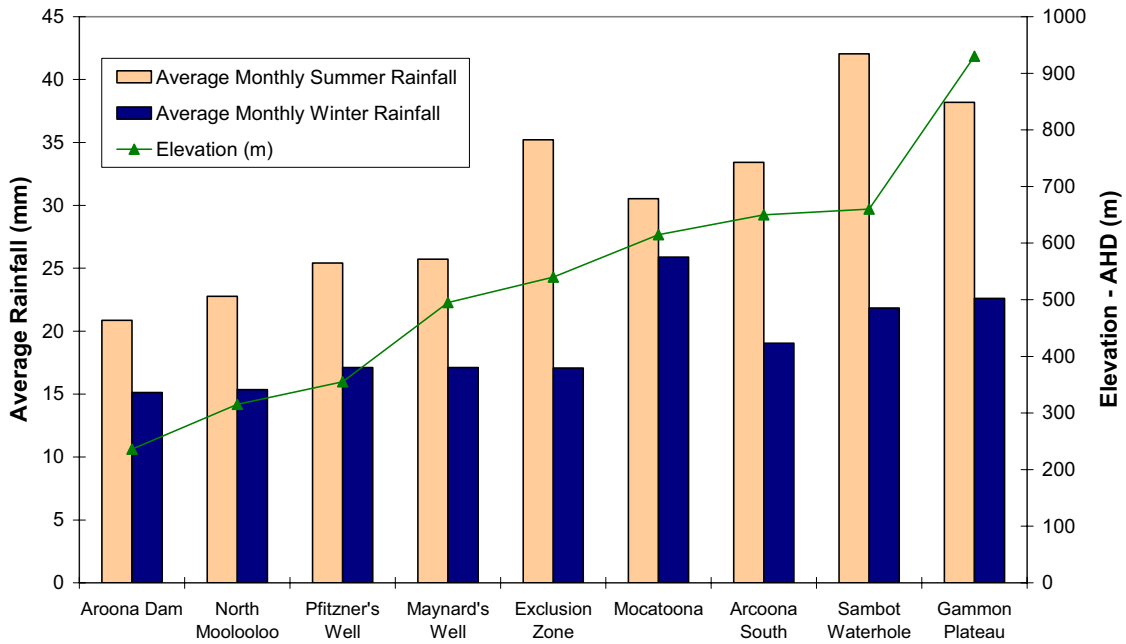


Figure 4 Average Seasonal Rainfall (Nov '92 to Jan '02)

Despite the irregularity of summer rainfall, its significance can clearly be observed in Figure 5, which compares the average monthly rainfalls for seven of the stations, including the Gammon Plateau, Sambot Waterhole and Exclusion Zone in the Gammon Ranges. The rainfall monitoring stations have been ordered from left to right according to altitude. It can be seen that:

- In terms of its contribution to average annual rainfalls, summer rainfall appears to be appreciably more important in the Gammon Ranges than in the regions further south-west.
- March, April, May and August seem to be characterized by low rainfalls across all stations, but in the other months, there is generally a tendency for higher rainfalls at higher elevations.
- It was noted that the effects of orographic uplift appear to be more pronounced at Mocatoona than in the Gammon Ranges during the winter months. This is may be attributable to the fact that it is the most southerly of all the gauging stations and hence more likely to be influenced by the westerly frontal systems that commonly affect southern Australia during the winter months.
- The higher average monthly summer rainfall at Sambot Waterhole than the Gammon Plateau may be a reflection of the random nature and variability of summer rainfall events. There is also the possibility of inaccuracy in the pluviometers. These are calibrated to +/- 3%, but recent field checks found that several instruments were down to +/- 7%.

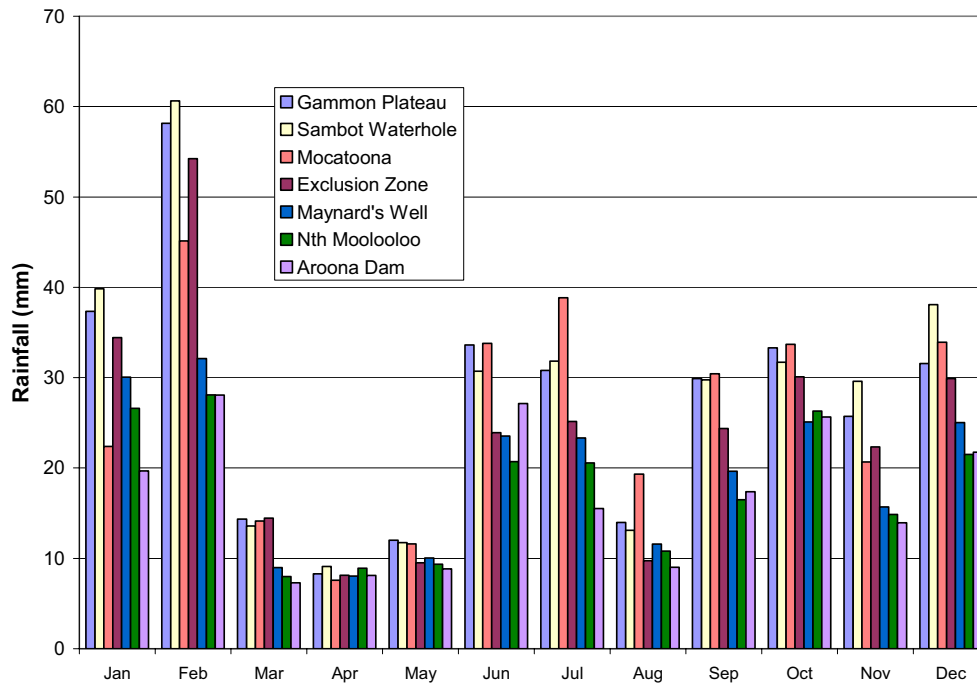


Figure 5 Average Monthly Rainfall (Nov '92 to Jan '02)

5. STREAM FLOWS

Since 1991 SEG has operated a stream flow monitoring program on Arcoona Creek. Because of the nature of the site, the rating (the relationship between the water level and the flow) could only be determined theoretically, from surveyed channel cross sections and using a mathematical model. There is little opportunity to confirm the flow velocities for various depths, as would normally be carried out at a gauging station to confirm the relationship. In addition, the cease-to-flow level varies with time as the shape of the bed changes.

However, given these limitations valuable information is being gained as to the way the catchment behaves in response to rainfall. Of particular note in the record is that flow in the creek is rare, and it may not flow for several years at a time. However, it has been noticed that there are several times when the local pool at the gauging station has filled from local runoff, without the main creek flowing.

In addition to the above there was a large flood in the creek in April 1989, with an estimated flow of 150 m³/s to 200 m³/s.

It can be seen from Table 1 that although the creek flows infrequently large flows do occur. For the same catchment area of 49.1 km² in the more humid Mount Lofty Ranges, the 100 year ARI flow would be expected to be of the order of 60 m³/s to 100 m³/s.

The flood pattern in Arcoona Creek makes it difficult to do analysis to predict flood frequency. This is generally undertaken by fitting a probability distribution to maximum annual flows, and using this distribution to assess flows for a range of probabilities. However in the case of Arcoona Creek the number of years with no flow means that the application of such an approach would require many more years of record, to make up for the lack of flow in most years.

Table 1 Summary of Peak Annual Flows

Year	Peak Flow Date	Peak Flow (m ³ /s)	Comment
1993	12 December	6.0	
1994	-	-	No flow recorded
1995	16 January	47.5	
1996	15 March	92.7	
1997	7 February	10	Gauge not operating – estimated flow from flood level
1998	-	-	
1999	-	-	
2000	20 February	2.7	
2001	-	-	
2002	-	-	
2003	-	-	
2004	-	-	
2005	-	-	

Figure 6 shows a plot of the peak annual flow, with a probability for that flow based on the total of 13 years of record. The indication from this plot is that the 100 year ARI flow would be of the order of 400 m³/s. However there is a high degree of uncertainty in this estimate. It also indicates that the 20-year ARI flow is about 110 m³/s. By comparison, the regional regression derived by Kemp(1989) for catchments in the Flinders Ranges near Leigh Creek and McQueen (1979) for the Alice Springs area gives a flow of 150 m³/s to 175 m³/s for the same frequency.

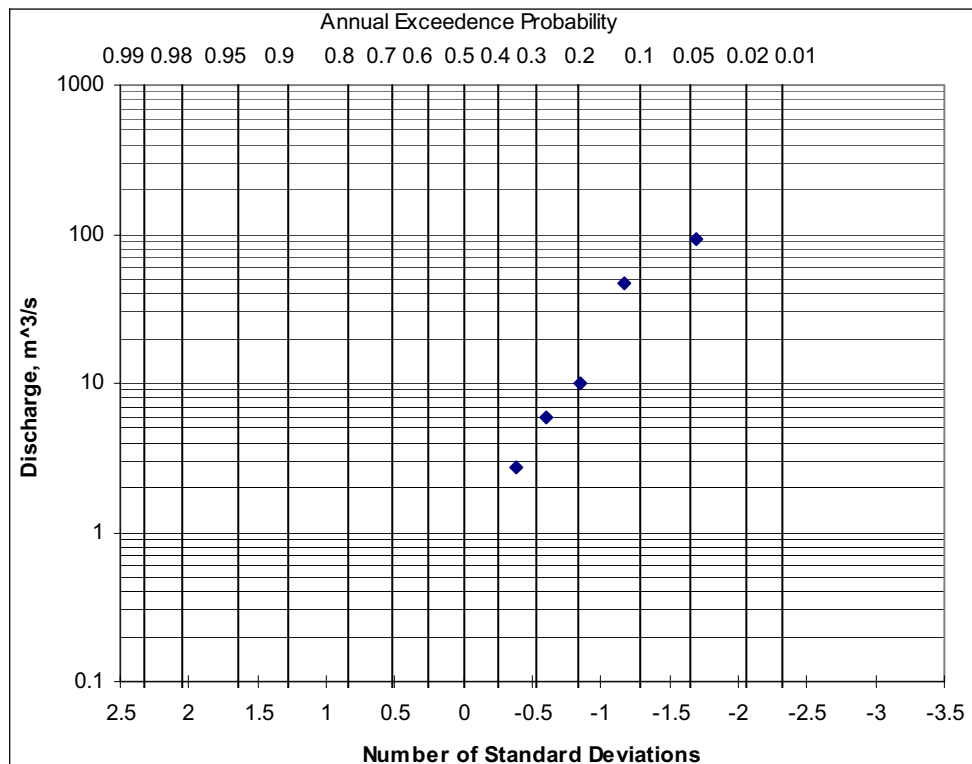


Figure 6 Arcoona Creek Flood Frequency Plot

6. FLOOD MODELLING

Two flood events, in January 1995 and March 1996, have been used in a hydrological model to gain knowledge on how the catchment responds during flood events.

The model represents the catchment in a mathematical sense by a series of storages that represent the movement of water both from the hillsides and along the stream channels. Up to three runoff processes have been found to exist in the Mount Lofty Ranges, and these same processes were assumed to exist in the Arcoona Creek catchment. These processes are base flow, where water moves down to the water table, and then into streams; slow flow where water moves through soil layers to the stream and fast flow, which is flow along the surface.

For each process losses occur, where the rainfall is lost to the system, or to another process. It was found in the Mount Lofty Ranges that an initial loss – proportional loss model was most appropriate, where a percentage of rainfall after an initial loss was lost.

The model was applied with rainfall measured at the Exclusion Zone site (near the gauging station) and the Gammon Plateau (in the upper part of the catchment), and the outflow compared with the measured hydrograph at the gauging station.

The rainfall that caused both runoff events was characterised by short duration, intense rainfall. In the first burst of the January 1995 event, and the runoff causing burst in the March 1996 event the rainfall was of about 1 hour duration, and 17.6mm to 36.8mm, having an ARI of about 10 years in accordance with Australian Rainfall & Runoff 1987. The March 1996 runoff occurred after an initial rainfall of approximately 33mm, of 10 hours duration, but containing several bursts.

An automatic and objective method was used to find the best fit parameters for the model for both storm events. It was found that a loss model with a continuing loss in mm/hr provided a better fit for the Arcoona Creek catchment than the proportional loss model. Figure 7 shows the recorded and fitted hydrograph for the two runoff events examined. A significant fact is that for both flood events the flow went from zero to the peak within 10 minutes, which is extremely fast given the size of the catchment. However, this is a characteristic of Flinders Ranges creeks which often surprise travellers and campers by the sudden arrival of a flood.

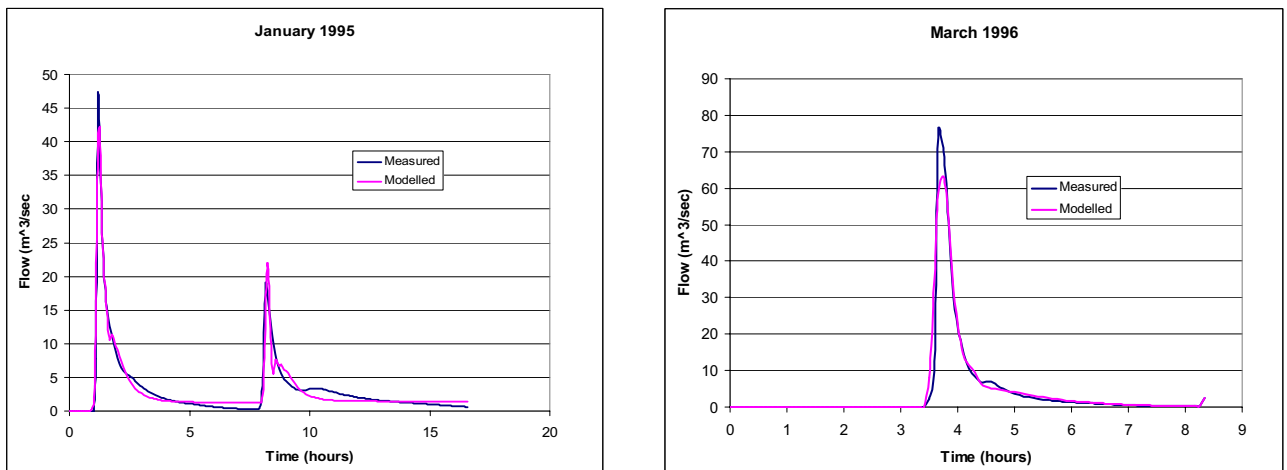


Figure 7 Arcoona Creek Fitted Hydrograph, January 1995 and March 1996

Table 2 Arcoona Creek Fitted Losses

Event	IL1 (mm)	IL2 (mm)	IL3 (mm)	CL1 (mm/hr)	CL2 (mm/hr)	CL3 (mm/hr)
January 1995	11.0	32.2	36.8	8.9	11.3	8.3
March 1996	49.9	58.1	-	27.2	33.4	-

Table 3 Arcoona Creek Fitted Storage Parameters

Event	cp ₁	cp ₂	V _c (m/s)
January 1995	6.63	0.172	7.26
March 1996	0.056	0.310	4.30

The parameters from the model fit are given in Table 2 and Table 3. The continuing loss is much higher than would be expected in the Mount Lofty Ranges, where a loss of the order of 3 mm/hr is expected.

The cp₁ and cp₂ are storage parameters related to the response time of hillsides in the catchment. The mean values found in the Mount Lofty Ranges would be of the order of 1.22 for cp₁ and 0.22 for cp₂. The cp₂ for the Arcoona Creek catchment is of the same order, but the cp₁ is not consistent.

The characteristic velocity for streams in the Mount Lofty Ranges is 1.0 m/s. This indicates that the flood wave velocity in Arcoona Creek is substantially faster than the in the Mount Lofty Ranges and is reflected in the very rapid time of rise of the hydrograph.

Although there is similarity in the rainfall in January 1995 and March 1996, there is a significant variation in the fitted parameters. This may be as much as anything caused by the rainfall from the two pluviometers not being representative of the rainfall over the whole catchment. The rainfall pattern across the catchment will influence both the calibrated losses and the storage parameters (due to the timing of the runoff). The addition of more pluviometers since 1996 may help to better define parameters, once significant runoff events occur.

7. FLOOD FLOW CONJECTURE

The results of the flows monitored so far indicate that the Arcoona Creek behaves much differently to catchments in the humid areas of the state, for instance the Mount Lofty Ranges.

The creek flows a lot less often, but when it does the flood is larger than would be expected in humid areas, and the response time is a lot more rapid. The rarity of flows can be attributed to both the infrequency of rainfall, and the high loss rates in the catchment. It was noted that when looking through the records some high daily rainfalls did not produce significant floods. For instance, the February 1997 flood was caused by a daily rainfall of 106mm, but the peak flow was only of the order of 10m³/s.

Personal observation and that of others familiar with the catchment is that the hillsides, being quite rocky, have relatively frequent flow, but the creek channels have significant gravel deposits that soak up the flow. It takes a rainfall event large enough to overcome the channel loss to produce a flood at the gauging station. More often a rainfall event will fill local waterholes, particularly at rock bars across the channel. The pool that is formed at the gauging station has filled several times without flows occurring. Once there is enough flow to overcome the channel loss the response is very rapid due to the efficiency of the channels.

8. CONCLUSIONS

The Gammon Ranges project commenced in 1988, and has grown to the extent that eight pluviometers and a gauging station are now managed by the Scientific Expedition Group. The project

is run on a voluntary basis, and all data recovered have been edited, quality controlled and entered into an industry standard data base, owned by the SA State Government.

The project has given many expeditioners the chance to be involved in a hands-on data collection activity, which has a real purpose and has produced a substantial amount of information in an area that would be difficult to service in a commercial or public service environment. Many lessons have been learned in the provision of a monitoring network that is reliable and easy to manage in a very remote environment.

The project has provided information on how climate and rainfall vary seasonally and with altitude in this arid area. Summer rainfall has higher intensities and totals than winter rainfall, but of significance is the high level of variability.

The same variability is evident in the stream flow record that has been collected, with years of zero flow, and some events that are of a much greater magnitude than would be expected in a humid catchment of the same size.

9. ACKNOWLEDGEMENTS

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