# ESTIMATING THE IMPACT OF CURRENT FARM DAM DEVELOPMENT ON THE SURFACE WATER RESOURCES OF THE ONKAPARINGA RIVER CATCHMENT

DWLBC Report

2002/22

The Department of Water, Land and Biodiversity Conservation

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# Estimating the Impact of Current Farm Dams Development on the Surface Water Resources of the Onkaparinga River Catchment

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*In collaboration with*
*The Onkaparinga Catchment Water Management Board*
*and SA Water Corporation*

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# FOREWORD

South Australia's natural resources are fundamental to the economic and social wellbeing of the State. One of the State's most precious natural resources, water is a basic requirement of all living organisms and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters.

Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Understanding the cause and effect relationship between the various stresses imposed on the natural resources is paramount to developing effective management strategies.

Reports of investigations into the availability and quality of water supplies throughout the State aim to build upon the existing knowledge base enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

This assessment of the impact of current farm dams development on the surface water resources of the Onkaparinga Catchment is intended to contribute to the body of knowledge that will assist the effective management of water resources within the study area.

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# EXECUTIVE SUMMARY

## *Background*

The Mt Lofty Ranges Water Resources Assessment Program is an initiative of the Department of Water, Land and Biodiversity Conservation. The purpose of the Program is to quantify and assess the condition of surface and groundwater resources of the Mt Lofty Ranges Region.

The assessments undertaken within the Program include hydrological modelling, reviews of the surface water monitoring network, the construction of new streamflow gauging stations, and the determination of environmental flows. These assessments are undertaken in partnership with other relevant agencies including catchment water management boards, the Environment Protection Authority, and the South Australian Water Corporation.

This study is one of several comprehensive hydrological assessments of priority catchments in the region. Being the first, it provides an important technical foundation for collated reports assessing the resources across the region. In turn, these collated reports will inform policy decisions that will be made on future management of the natural resources in the region.

## *Key Findings*

The Department of Water, Land and Biodiversity Conservation (DWLBC), in conjunction with the Onkaparinga Catchment Water Management Board (Board) and the South Australian Water Corporation, commissioned this study to examine the impact of farm dam development on the surfacewater resources of the Onkaparinga River catchment.

- A review of the surface water balance of the Onkaparinga catchment was determined,
- The current level of impact on surface water resources by farm dams was determined, and
- Potential future impacts of farm dams were estimated.

The current level of farm dam development is summarised as follows.

- There are 2,700 farm dams in the catchment with an estimated storage capacity of 8.5 GL and a farm dam density of 15 ML/km$^2$. Among the 16 major subcatchments, six have farm dam densities greater than 25 ML/km$^2$ Mitchell Creek being the highest with 39 ML/km$^2$.
- There are only 185 farm dams greater than 10 ML which account for 60% of the aggregated dam storage volume.
- Irrigation water demand of 15-20 GL/yr from surface and groundwater sources serves 5,200ha or 9% of the catchment area.
- Water pumped from the Murray into the Mt Bold reservoir contributes 27 GL/yr on average (1975-1999).

### Surface Water Balance and Farm Dam Impacts in the Onkaparinga catchment

Figure 1 (page 20) shows the location of the Onkaparinga catchment, including the location and name of each subcatchment, and the location of SA Water infrastructure, including:

- The Murray Bridge – Onkaparinga Pipeline which transfers River Murray water to the Onkaparinga;
- The Mt Bold Reservoir, the inflow of which is measured at Houlgrave Weir; and

- The Clarendon Weir, where the offtake from the Onkaparinga for Adelaide's water supply is located.

A surface water balance was determined for:

- The Onkaparinga catchment upstream of Mt Bold Reservoir;
- The Onkaparinga catchment upstream of Clarendon Weir; and
- Each of the 16 individual subcatchments of the catchment.

A water balance was determined for the long term (99 yr) median[1] condition, as well as the wettest[2] and driest[3] recorded periods, determining the annual 'adjusted'[4] flow from the catchment. The long term median adjusted flow is the 'surface water resource' of the catchment. The wettest and driest conditions provide insight into the variability of the catchment behaviour.

## Effect of Farm Dams on the Mt Bold Reservoir Catchment

For the Mt Bold Reservoir catchment, measured at Houlgrave Weir, the surface water balance is as follows:

| Flow Condition | Annual Adjusted Flow at Houlgrave Weir | Flow diverted by farm dams | % flow diverted |
|---|---|---|---|
| Long term median (1900 – 1998) | 56.4 GL | 4.3 GL | 8% |
| Dry period (1912 – 1914) | 26.3 GL | 3.0 GL | 11% |
| Wet Period (1915 – 1917) | 121.7 GL | 3.5 GL | 3% |

In addition, an average (1975 – 1999) of 27 GL of water is pumped annually into the catchment through the Murray Bridge – Onkaparinga Pipeline, which is released into the Onkaparinga at Hahndorf, flowing down the river to Mt Bold Reservoir.

## Effect of Farm Dams on the Clarendon Weir Catchment

For the SA Water offtake at Clarendon Weir, a surface water balance with an 'adjusted' runoff has also been calculated, correcting for farm dams, pipeline transfers and Mt Bold Reservoir. The surface water balance is calculated as follows:

| Flow Condition | Annual Adjusted Flow at Clarendon Weir | Flow diverted by farm dams | % flow diverted |
|---|---|---|---|
| Long term median (1900 – 1998) | 72.1 GL | 3.9 GL | 5% |
| Dry period (1912 – 1914) | 30.0 GL | 3.6 GL | 12% |
| Wet Period (1915 – 1917) | 152.9 GL | 4.3 GL | 3% |

Overall, the total impact of farm dams on the Onkaparinga surface water resource is considered to be low (5% - 8% of median annual flow).

In comparison with the indicative sustainability indicator of the State Water Plan 2000, the total volume of farm dams is much lower than the indicative sustainable volume of farm dams for the catchment. The 8.5 GL of estimated farm dam capacity in the Onkaparinga catchment is 12% of

[1] A median year is defined as the median flow value for the period 1900-1998

[2] A wet-period is defined as the highest rainfall period of the 3-year moving average, namely occurred in 1915-1917

[3] A dry period is defined as the lowest rainfall period of the 3-year moving average, namely occurred in 1912-1914

[4] 'Adjusted' is defined as the annual catchment discharge, correcting for all diversions by farm dams and reservoirs, and importations from River Murray pipelines.

the median annual adjusted yield of the catchment flow, which is well below the 50% threshold defined in the Plan.

### Effect of Farm Dams on the 16 subcatchments

In the 16 upstream subcatchments, the effects of farm dams have been examined more closely. Six of the sixteen subcatchments were found to be highly developed, with a reduction in median annual adjusted runoff due to farm dams of 10% or more. These subcatchments are:

- Mitchell Creek (20%),
- Biggs Flat (17%),
- Echunga Creek (13%),
- Hahndorf (11%),
- Balhannah (10%), and
- Western Branch (10%).

These highly impacted subcatchments are located in the eastern part of the Onkaparinga catchment, as shown in Figure 19 (page 66).

In the dry period, *eleven* subcatchments have greater than 10% of their adjusted natural flow captured by farm dams, affecting those with dam density as low as 10 ML/km$^2$. In the wet period, only the Mitchell creek catchment is affected by a 10% reduction in adjusted natural flow.

### Effect of SA Water Infrastructure on the Surface Water Balance

On average, 60% of the water used for Adelaide's water supply from the Onkaparinga is derived from the catchment, with the remaining 40% transferred from the River Murray. In dry years, the Onkaparinga catchment contribution can reduce to only 10%.

For more than 80% of the time, there is no flow over Clarendon Weir down to the lower portions of the river. Conversely, the aqueduct portion of the river from Hahndorf to Clarendon experiences significantly higher flows when it would naturally be much drier, particularly in summer and autumn. The Onkaparinga CWMB is examining the ecological impacts of SA Water flow modifications on the catchment.

The combined storage of SA Water infrastructure and farm dams is approximately 95% of upstream catchment yield. SA Water operate the water supply network to maximise capture of catchment water and minimise spill over Clarendon Weir. Therefore, it is reasonable to assume that the combined diversions of farm dams and SA Water are well over the 50% sustainable yield indicator quoted by the State Water Plan (Volume 1 p 50).

## *Potential Future Impacts of Farm Dams*

Four scenarios of future farm dam development were also considered.

The future scenarios were based on current rates of farm dam development, and limits to development defined by current management arrangements.

The six modelling scenarios are described as follows:

| Scenario | Case | Available Farm Dam Storage | Description of case |
|---|---|---|---|
| Scenario 1 | Present Case – 1999 farm dam data | 8.5 GL | The current level of development, used to calibrate the model |
| Scenario 2 | No farm dam impact. Farm dam storage removed in the model | 0.0 GL | Used to estimate the surfacewater resources and subcatchment runoff in the absence of water diversions to derive adjusted catchment yields[5] |
| Scenario 3 | Future with business as usual to 2010 | 10.2 GL | An estimate of farm dam development in 2010 with no management intervention, based on an extrapolated rate of development from the previous 10 years of 150 ML/yr |
| Scenario 4 | Limit under present 50% Rule with runoff as 10% of rainfall | 18.7 GL | The limit of the current 50% Rule of dam development administered in the MLR Watershed, where annual runoff is calculated to be 10% of annual rainfall.<br>At current rates of development (150 ML/yr), this limit would be reached in 70 years |
| Scenario 5 | Limit under 30% Rule calculated from actual runoff | 18.7 GL | The limit to development similar to the River Murray CWMB policy of allowable volume equal to 30% of annual adjusted catchment yield. Coincidentally, the volume of dam development is identical to Scenario 4, but the spatial distribution of dam storage different. |
| Scenario 6 | Worst case situation of 50% Rule application | 29.4 GL | The limit of the 50% Rule of dam development where the **actual** annual subcatchment runoffs calculated in Scenario 2 are applied. |

In addition to the increased volume of farm dams in the future scenarios, the water demands from dams was also considered.

Currently, it is assumed that demand of water from farm dams is 30% of dam volume, a reasonable figure that has good security, with allowances for evaporation and seepage. However, under a future management regime where development is restricted, farm dam owners may extract a higher proportion of dam storage to maximise their water capture. Therefore, extraction rates of 50% and 70% of farm dam volume were also simulated.

The results of the scenario testing are shown below, illustrated as water diverted above Mt Bold Reservoir.

| **Scenarios** | **Water Diverted from Median Annual Adjusted Flow at Houlgraves Weir** | | |
|---|---|---|---|
| **Water Demand as % of farm dam volume** | *30%* | *50%* | *70%* |
| Scenario 1 (Present Case) | 4.5 GL | 5.6 GL | 6.2 GL |
| Scenario 3 (Future with business as usual to 2010) | 5.1 GL | 6.2 GL | 7.3 GL |
| Scenario 4 (Limit under present 50% Rule) | 6.8 GL | 8.5 GL | 10.7 GL |
| Scenario 5 (Limit under 30% Rule calculated from actual runoff) | 7.3 GL | 9.0 GL | 11.8 GL |
| Scenario 6 (Worst case situation of 50% Rule application) | 11.8 GL | 15.2 GL | 18.1 GL |

These figures indicate that changes in water use behaviour, in addition to total farm dam storage, are likely to affect the amount of water taken from the catchment. Some useful conclusions from this analysis are:

- Restricting farm dams at 1999 levels but allowing demand to increase to 70% of storage will reduce flows at Houlgraves Weir by an extra 3%, or 1.7 GL.

[5] The adjusted runoff is the catchment runoff modelled from a catchment with the impact of farm dams removed but with existing landuse conditions

- Impacts to flows at Houlgraves Weir from a catchment developed to the limit of the current 50% Rule (Scenario 4) would result in extra flow reductions to Mt Bold Reservoir of between 4% (2.3 GL) and 11% (6.2 GL), depending on the water demands from dams.
- There is a difference in impacts between Scenarios 4 and 5, despite both having the same total volume of dams. Each management scenario distributes dams differently among the subcatchments by using different subcatchment limits. Therefore, placement of dams in the landscape can also affect catchment impacts.
- In the worst possible case (Scenario 6, 70% water demand), water taken from the catchment could reduce flows at Houlgraves Weir by up to a further 13.6 GL.

## 50% Rule policy

The 50% Rule, as defined in the State Water Plan (Volume 1 p 50), allows total capacity of diverting storages (i.e. farm dams and reservoirs) of 50% of the median annual adjusted yield of that catchment. None of the 16 subcatchments have exceeded the 50% rule at current levels of farm dam development.

Across the catchment as a whole, with current SA Water storages and farm dams, the 50% Rule is exceeded in the Onkaparinga catchment.

According to current practice, the 50% Rule is administered in the Mt Lofty Ranges Watershed using an annual runoff estimate equal to 10% of average annual rainfall. This leads to an uneven distribution of development pressure on catchments in the region because:

- In the drier areas (<500mm annual rainfall), runoff is estimated to be *less* than 10% of rainfall, and
- In the wetter areas (>700mm annual rainfall), runoff would be *greater* than 10% of rainfall.

Consequently, retaining this practice will lead to greater impact on ecosystems and greater competition for water in the developed eastern subcatchments and result in additional losses to SA Water storages if actual runoff values are adopted.

# *Conclusions*

This study has considered the impact of farm dam development, recognising variability of rainfall and runoff across the catchment and over time. It has also considered changing impacts with increases in farm dam development and increased rates of extraction from available storage in farm dams.

### 50% Rule farm dam policy

- None of the subcatchments, at current levels of farm dam development, has exceeded the 50% sustainability indicator as defined in the State Water Plan 2000. However, the modification of flow regimes by farm dams and SA Water infrastructure may be impacting water-dependant ecosystems.
- Farm dam development approvals based on a runoff estimate of 10% of rainfall will lead to over-estimates of the resource in lower rainfall areas and under estimates of the resource in the higher rainfall catchments.

### Farm Dam Impacts on SA Water Reservoirs

- The combined storage capacity of all farm dams, Mt Bold Reservoir, Clarendon Weir and Happy Valley Reservoir is about 95% of the median adjusted annual flow estimated at

Clarendon Weir. Impacts to water-dependant ecosystems based on this impact are highly likely, and need to be examined.

- Currently, farm dams harvest approximately 4.5 GL of water entering Mt Bold Reservoir, or 8% of median annual adjusted flow. Under current management policy, this will probably increase to about 7-10 GL. An extreme upper level of development is estimated to harvest 18 GL.
- It is likely that SA Water would be required to pump a significant proportion of flow reductions from the River Murray to compensate for these losses to reservoir inflows.
- Development controls on farm dam storage alone will not be sufficient to manage risks to surface water resources associated with development. Other factors that need to be taken into account are:
  - Runoff from individual subcatchments
  - Farm dam location on the landscape, and portions of catchment that are free to flow (estimated by farm dam density)
  - Water demands from farm dams
  - Needs of nearby water-dependant ecosystems
- Managing further farm dam impacts into the future is a combination of managing:
  - new farm dam storage,
  - the siting and design of the dam, and
  - the demand of water from the dam.

## Existing background data

Hydrological modelling for the Onkaparinga River catchment can be improved further if the background data can be enhanced. Some examples of this are the timing and actual usage of irrigation water, estimation of dam storage volume, proportion of dam storage water currently being used annually and land use information.

# INTRODUCTION

## Background

The Onkaparinga River is a source of water for private development (farm dams), public water supply and for the natural environment so that the river can remain healthy and support its bio-diversity.

With farm dam developments occurring in the Onkaparinga River catchment, it has impacted on the natural surface flow of the catchment. With the pressure for more water to meet agricultural development (notably viticulture), environmental flows and the metropolitan Adelaide water supply, there is a need to quantify the impact of the farm dam developments. As a result, the Department of Water, Land and Biodiversity Conservation (DWR), in conjunction with the Onkaparinga Catchment Water Management Board (the Board) and SA Water Corporation, set out to study this impact on the natural surface flow of the Onkaparinga river.

Central to this study is the construction of a calibrated catchment-wide hydrological model using the WaterCress modelling program that can simulate runoff scenarios and assist in the evaluation of management options.

## Aims of the study

The aims of the study were to:

- Assess the current level of farm dam development in the catchment;
- Construct a calibrated hydrological model;
- Study the impact of farm dams on the adjusted[6] natural flows of the Onkaparinga River catchment based on the current and future levels of farm dams development;
- Provide the Board with access to a suitable hydrological model for studying environmental water requirements;
- Assess the impact of farm dams development on pumping from the River Murray to Mt Bold Reservoir.

## Study Approach

The hydrological and water management model *WaterCress* (Clark et al, 2002) was used to simulate catchment runoff for a range of farm dams development scenarios each with 30%, 50% and 70% dam storage use. A *current* scenario was considered as the one using the 1999 farm dams data (scenario 1) and 30% dam storage use (WFD). A without farm dams (WOFD) scenario is one that has the farm dams removed from the model. Catchment yields simulated under this scenario were considered as the *adjusted* catchment yield/runoff that becomes a reference for comparing with the runoff from other farm dams development scenarios and dam storage use.

The model was calibrated using current scenario against the gauged catchments where recorded streamflows were available. Once the model was calibrated, runoff simulations

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[6] Adjusted is defined in the State Water Plan Vol 1 page 50 as "*the annual catchment discharge with the impact of dam storage removed*".

were carried out over the short term (where records available) and long-term (1900-1998) duration for the scenarios. Short term simulations enable Tanh curve rainfall runoff relationship to be established for the gauged catchments, which could be used as a quick measure of the hydrologic characteristics of the catchment. The impact of farm dams development on the water supply from the River Murray was also modelled for the recent period only. This is because water use data, pumpage from the River Murray and the gauged streamflows from Houlgrave Weir, Echunga and Scott Creeks were used as input together with the ungauged catchments for the model simulations.

To study the impact of farm dams development on catchment runoff in a wide range of climatic conditions, such as in an average year, a drought and a wet periods, simulations were modelled over long term from1900-1998.

Results contained in the report were:

- Rainfall runoff relationships
- Impact of farm dams on individual subcatchments
- Impact of farm dams on flows at Houlgrave Weir
- Impact of farm dams on flows at Clarendon Weir
- Impact of farm dams on the water supply from Mt Bold Reservoir and Clarendon Weir reservoirs.

# CATCHMENT DESCRIPTION

The Onkaparinga River catchment is located about 25 km to the south-east of Adelaide and has a catchment area of 560 $km^2$. The catchment has been divided into 16 distinct subcatchments, each with its own creek or tributary system that discharges streamflows into the main Onkaparinga River (Figure 1). The catchment has a median annual rainfall of 770 mm, ranging from 525 mm at the coast to 1080 mm at Uraidla (near Aldgate Creek catchment in the Mount Lofty Ranges). Evaporation recorded at Mt Bold reservoir is 1560 mm per annum.

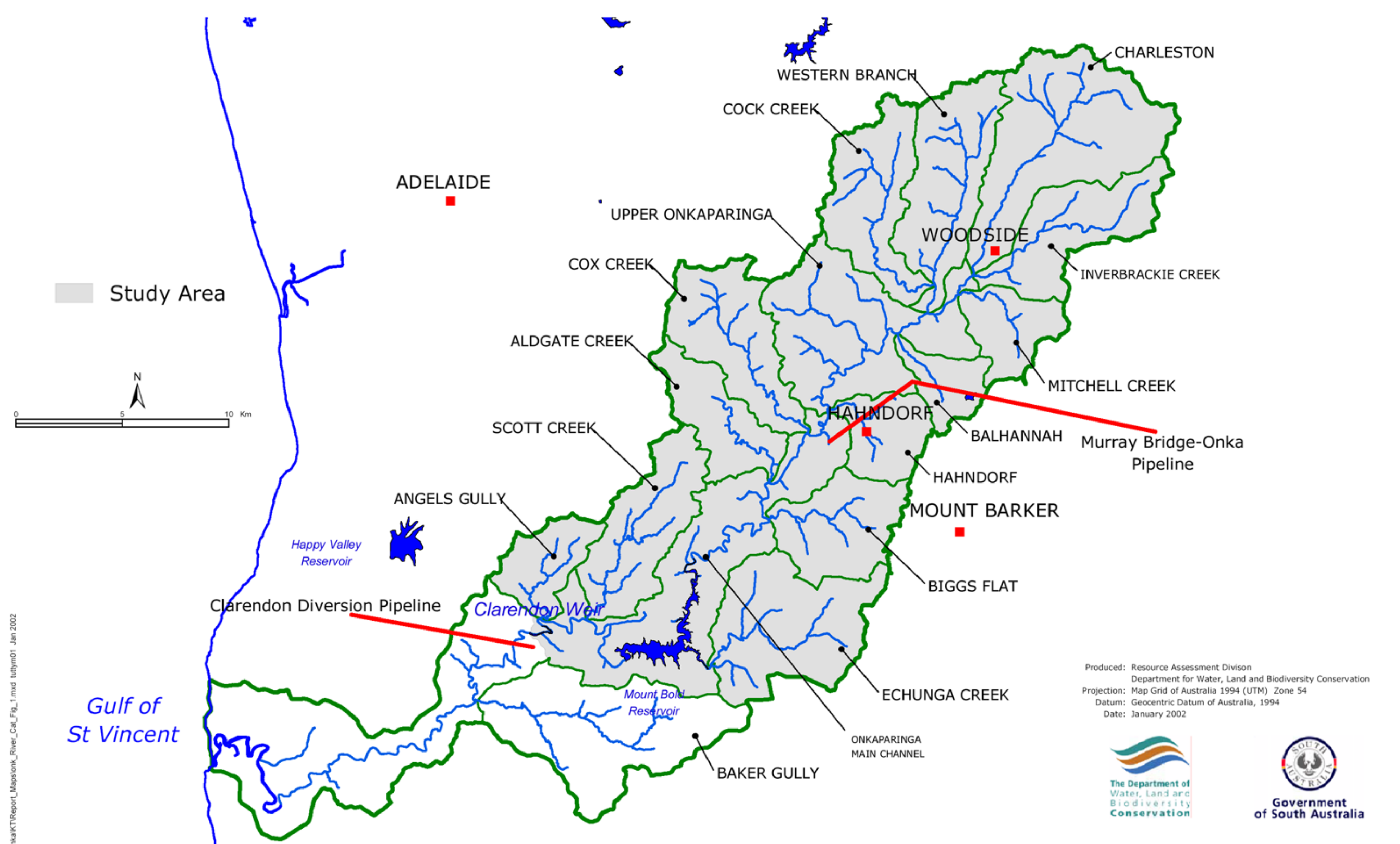



**Figure 1**

Location of Onkaparinga Subcatchments, Reservoirs and Pipeline systems

Maximum land elevations within the Onkaparinga River catchment vary from 10 m near the coast at Noarlunga to 700 m in upland regions. Topography consists of low lying plains in the lower reaches of the catchment with steep gorge country along the hills face zone of the catchment. The Onkaparinga River flows through this steep gorge country which starts near Mount Bold Reservoir. Upstream of the Reservoir the topography consists mainly of rolling / undulating hills with wide flat valley floors. The catchment is reasonably urbanised where townships such as Woodside, Hahndorf, Stirling, Balhannah, Lobethal, Summertown, Uraidla, Oakbank, Bridgewater and Aldgate can be found inland, and Old Noarlunga at the coast. Where the catchment impinges on urban areas, it contains a mixture of irrigated and temporal agriculture.

Private water abstractions are used mainly for irrigation purposes. Irrigation water is either obtained from the surface runoff stored in the farm dams or from individual groundwater bores.Extensive irrigation is predominantly for horticulture and viticulture while less intensive irrigation is associated with dairy farming and grazing. About 5,200 ha (1999) or 9.3% of the catchment is irrigated.

Water use from irrigation has been estimated from an assumed optimum irrigation rate to irrigated area and therefore assumes no restriction to water availability. It is recognised that this method may over estimate the irrigation volume as water supply may be limited by water availability. The total volume of use is estimated as 21,000 ML annually.

Streamflow systems found within the Onkaparinga River catchment are illustrated schematically in Figure 2, while the key gauging stations located within the catchment are shown in Figure 3. Streamflow is highly variable with most of the flow occurring in the winter months. The mean annual flow measured at the Houlgrave weir, including River Murray input from the Murray-Bridge Onkaparinga pipeline, is 75,000 ML and the median annual flow is 70,000 ML. Flow is severely reduced downstream of Mt Bold reservoir, with mean annual flow of 19,000 ML and a median of 4,000 ML recorded at Clarendon weir. For more than 88% of the time, no flow is recorded over the Clarendon weir.

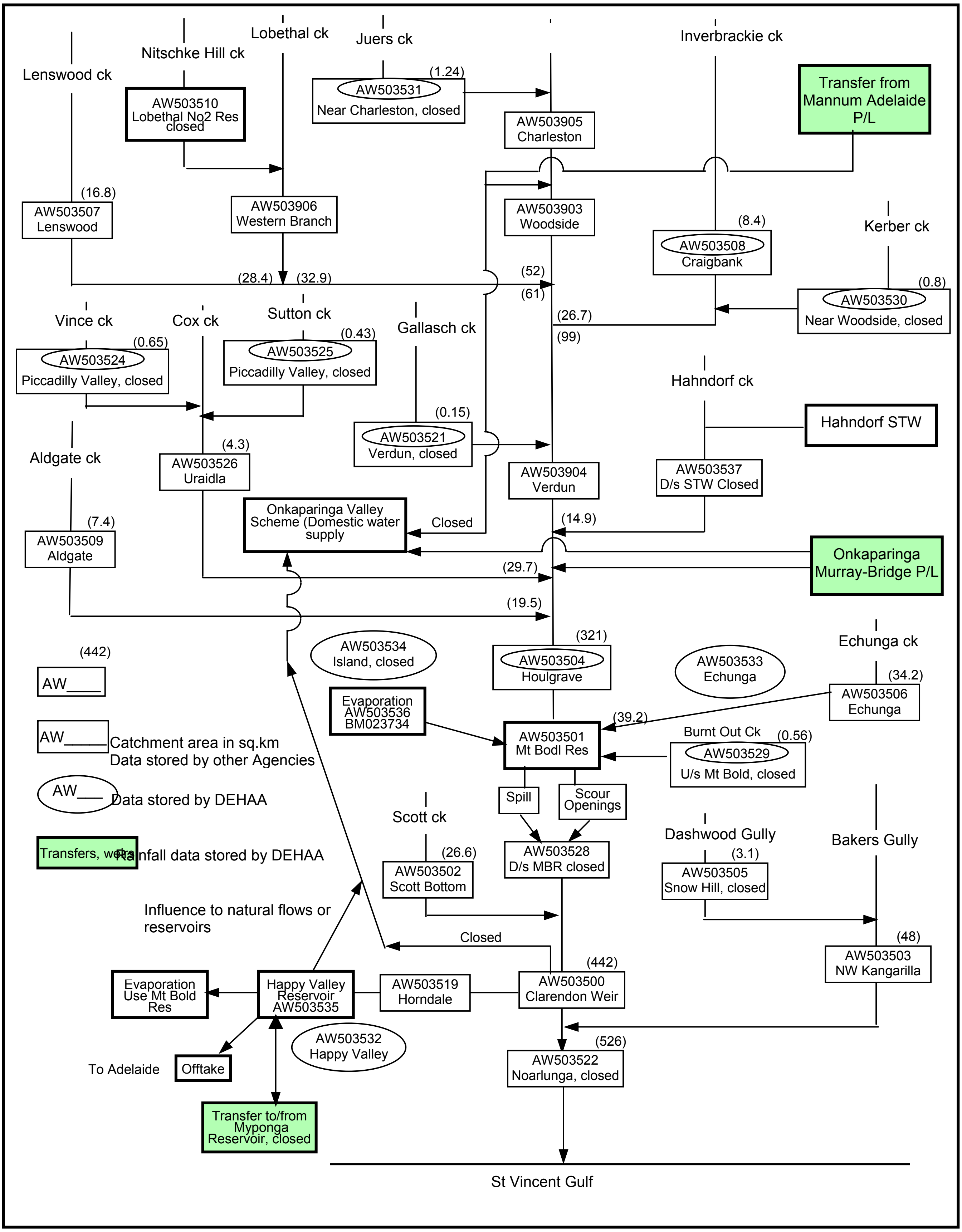
# HYDROLOGICAL DATA

## *Rainfall*

### Recording stations

A large number of rainfall stations monitored by the Bureau of Meteorology (BoM) and other agencies such as DWLBC can be found within and adjacent to the Onkaparinga catchment. At least 44 stations have been identified within the catchment and another 49 adjacent to the catchment. Among the 93 stations identified, the best 23 were selected being evenly spread out around the Onkaparinga catchment: 9 inside and 14 outside the river catchment boundary. They have long term daily rainfall records of more than 80 years. Records from these 23 stations were examined to identify any trends in catchment-wide annual rainfall. The stations are listed in Table 1.

## Figure 2. Schematic Diagram of Onkaparinga River Catchment



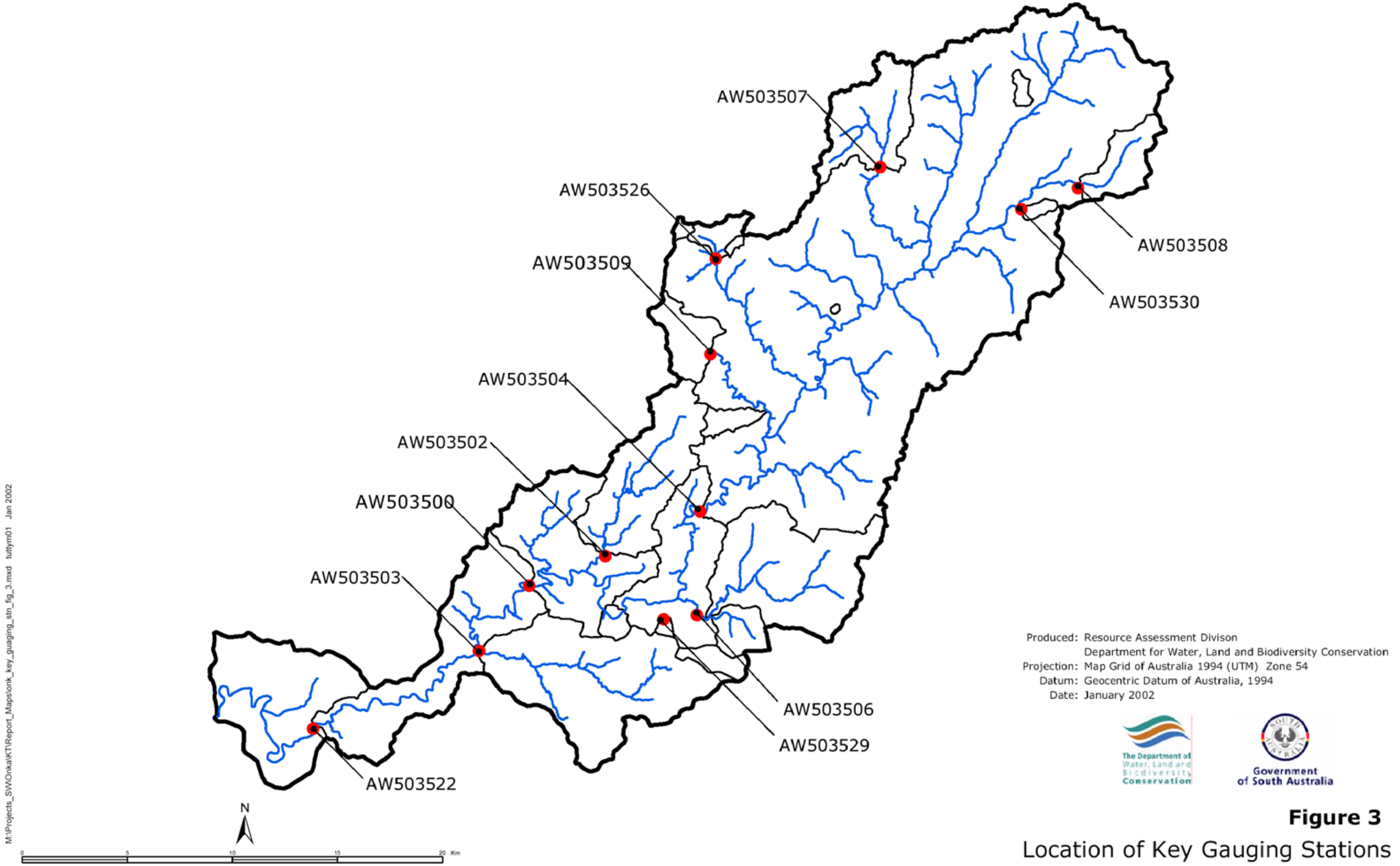



**Figure 3**

Location of Key Gauging Stations

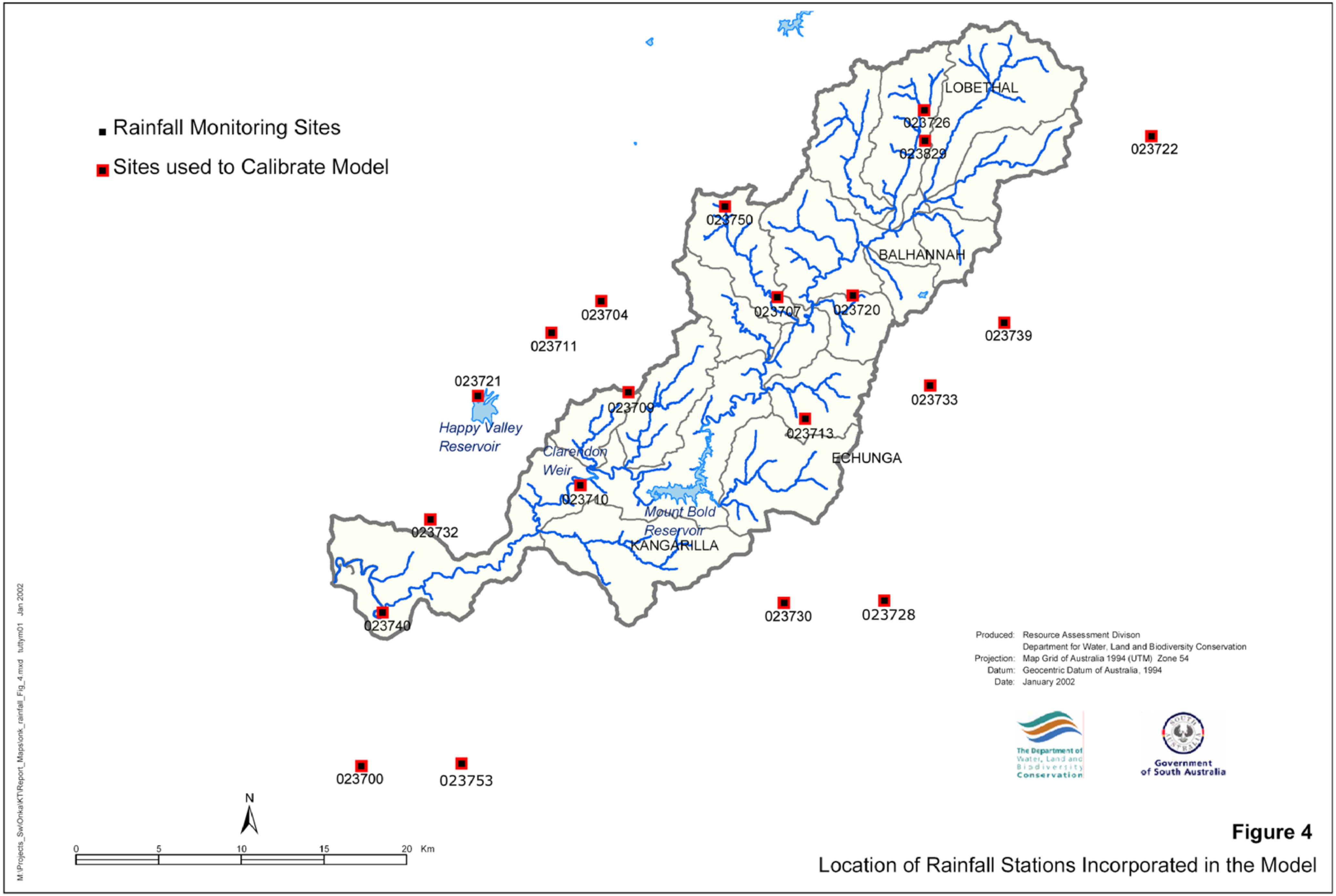



**Figure 4**

Location of Rainfall Stations Incorporated in the Model

**Rainfall Stations for the Onkaparinga River Catchment**

| Nos | Station no. | Mean (mm) | Location | Period of record |
|---|---|---|---|---|
| 1 | 023700 | 505 | Aldinga Post Office | 1893 – current |
| 2 | 023704 | 774 | Belair | 1884 – current |
| 3 | 023705 | 728 | Birdwood | 1887 – current |
| 4 | 023707 | 1045 | Bridgewater PO | 1884 – current |
| 5 | 023709 | 925 | Cherry Gardens | 1899 – current |
| 6 | 023710 | 818 | Clarendon PO | 1884 – current |
| 7 | 023711 | 710 | Coromandel Valley | 1890 – current |
| 8 | 023713 | 807 | Echunga Golf Course | 1884 – current |
| 9 | 023719 | 793 | Gumeracha DC | 1884 – current |
| 10 | 023720 | 859 | Hahndorf GC | 1884 – current |
| 11 | 023721 | 631 | Happy Valley Res | 1885 – current |
| 12 | 023722 | 554 | Harrogate | 1896 – current |
| 13 | 023726 | 885 | Lobethal | 1884 – current |
| 14 | 023728 | 736 | Macclesfield | 1885 – current |
| 15 | 023730 | 875 | Meadows | 1887 – current |
| 16 | 023731 | 859 | Cudlee Ck | 1914 - current |
| 17 | 023732 | 562 | Morphett Vale | 1886 – current |
| 18 | 023733 | 769 | Mt Barker | 1884 – current |
| 19 | 023739 | 683 | Nairne | 1884 – current |
| 20 | 023740 | 525 | Old Noarlunga PO | 1884- closed 1999 |
| 21 | 023750 | 1083 | Uraidla | 1891 – current |
| 22 | 023753 | 643 | Willunga | 1884 – current |
| 23 | 023829 | 805 | Woodside | 1884 – current |

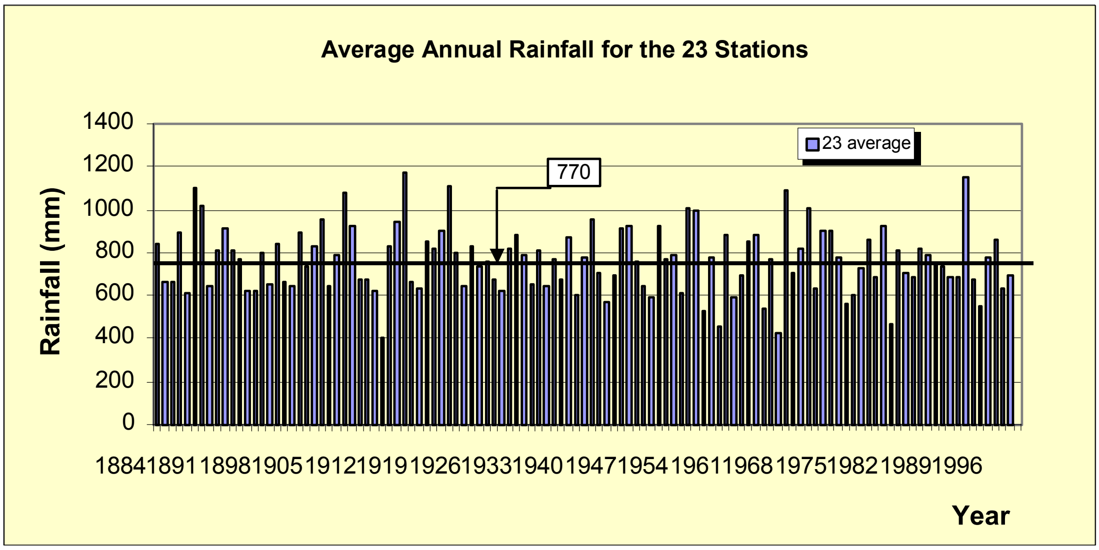
Note: rainfall records before 1884 were not taken into account due to concerns about their reliability.

Ten of these rainfall stations (nine within the catchment) were subsequently selected for rainfall input to the catchment hydrological model. The ten stations were chosen on the basis of their location within the catchment and for their long term daily records. The methodology for processing these raw rainfall data are described in Appendix A. Figure 4 shows the location of the stations.

## Annual Rainfall

The annual rainfall for the Onkaparinga River catchment as defined by the average of 23 stations varies from 400 mm to 1170 mm with a median of 770 mm. Figure 5 shows the average annual rainfall of the 23 stations used to estimate Onkaparinga River catchment rainfall.

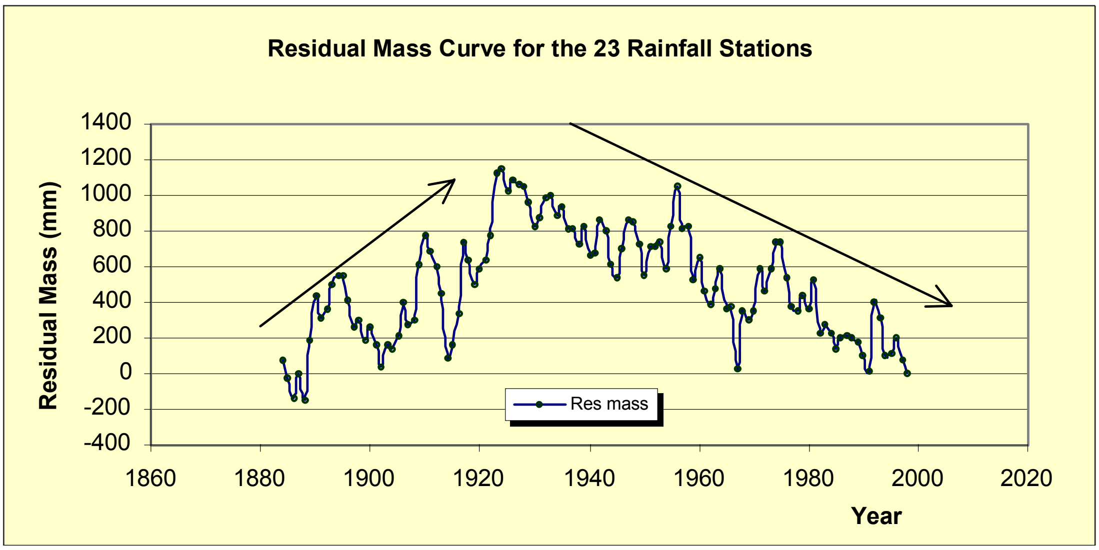
**Figure 5. The Average Annual Rainfall of the 23 Stations**




## Trend Analysis

The residual mass curve method was used to identify any trends in the period between 1884 and 1998 (Figure 6). An upward sloping curve indicates a higher than average rainfall period, while a downward sloping curve indicates a dryer than average period. From 1884 through to 1928, the long-term residual mass curve is trending upwards meaning the period was experiencing a "wet" trend with short cycles of fluctuation in between the period. From 1929 to the present, the long-term trend is towards a drier cycle.

**Figure 6. Residual Mass Curve for the 23 Rainfall Stations**




Across the whole catchment, the wettest year occurred in 1917 with 1170 mm of rainfall followed by 1992 with 1154 mm. The driest years occurred in 1914 and 1967 with 400 mm and 421 mm of rainfall respectively.

By taking a 3-year moving average, it is found that 1912-1914 recorded the lowest 3 year average rainfall of 570 mm/year and 1915-1917 the highest 3 year average rainfall of 980 mm/year. For hydrological modelling purposes, these two periods will be taken as the “dry” and “wet” years/periods for analysis.

## Check for Homogeneity

Random checks were made to test for the homogeneity of the rainfall data (Table 2) provided by Sinclair Knight Merz (SKM,2000). Adjustment for homogeneity of a rainfall station would be required if a straight line is not produced from the plot as reflected by the lower R-square value being less than one. This was done by plotting the double mass of the test station with that of the average rainfall of 23 stations listed in Table 1. From Table 2, Bridgewater station has the lowest R-square value. It is recognised that adjustment may be required for such stations to better input the rainfall data for the model calibration. Overall it was considered that the rainfall data was suitable for use.

### Table 2. $R^2$ value of test station Dmass curve

| No | Rainfall station | Mean rainfall (mm) | $R^2$ |
|---|---|---|---|
| 1 | Bridgewater (023707) | 1045 | 09986 |
| 2 | Cherry Gardens (023709) | 925 | 0.9993 |
| 3 | Clarendon (023710) | 818 | 0.9996 |
| 4 | Echunga (023713) | 807 | 0.9995 |
| 5 | Hahndorf (023720) | 859 | 0.9999 |
| 6 | Old Noarlunga (023740) | 525 | 0.9999 |
| 7 | Lobethal (023726) | 885 | 0.9997 |
| 8 | Uraidla (023750) | 1083 | 0.9999 |
| 9 | Woodside (023829) | 805 | 0.9994 |
| 10 | Morphett Vale | 562 | 0.9992 |

## Spatial Distribution of Rainfall

Rainfall varies markedly across the catchment, ranging from 525mm near Old Noarlunga to around 1080mm near Aldgate. Rainfall isohyets developed from the DWLBC GIS dataset illustrate this wide variation, refer Figure 7. The isohyets run in a north-east south west direction almost following the orientation of the Onkaparinga River catchment.

Average annual rainfall figures for the ten selected stations were compared with the isohyet map and found to match quite well with the exception of the Inverbrackie Creek catchment. The isohyet map indicates an annual average rainfall of 625mm whereas the gauge indicates a figure closer to 685mm per year is more appropriate.

This anomaly is thought to occur because of localised topography and the lower density of rainfall gauges failing to detect these changes in land elevation.

The rainfall isohyet map was used to adjust daily rainfall readings at the reading locations to subcatchment rainfall figures which must be estimated at the of the catchment for input to the WaterCress Model, refer section “Hydrological Modelling”.

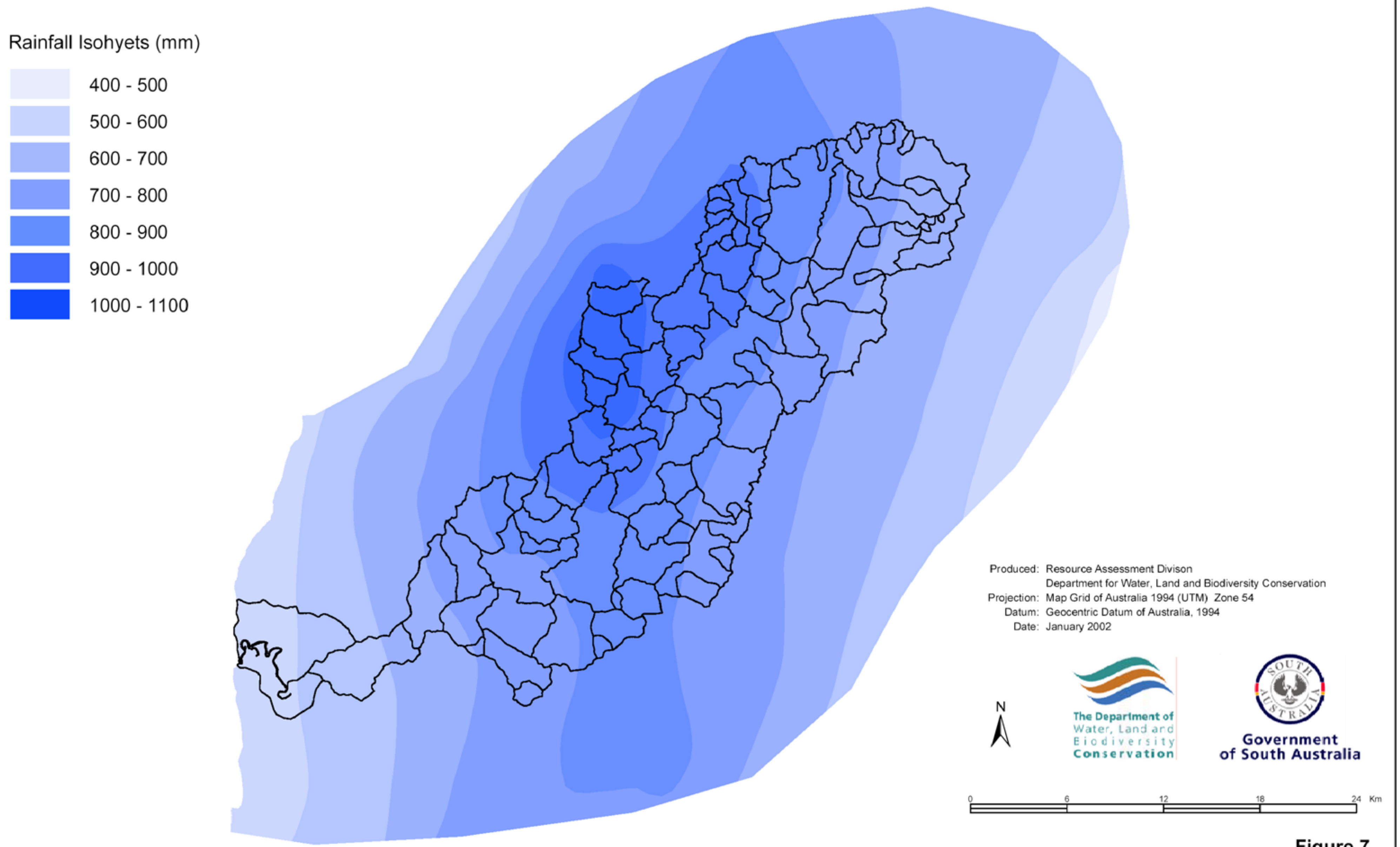



**Figure 7**

Rainfall Isohyet Map for the Catchment

# *Evaporation*

## Recording stations

There are few evaporation stations in the Onkaparinga catchment. Only four have been located within and adjacent to the catchment boundary as listed in Table 3.

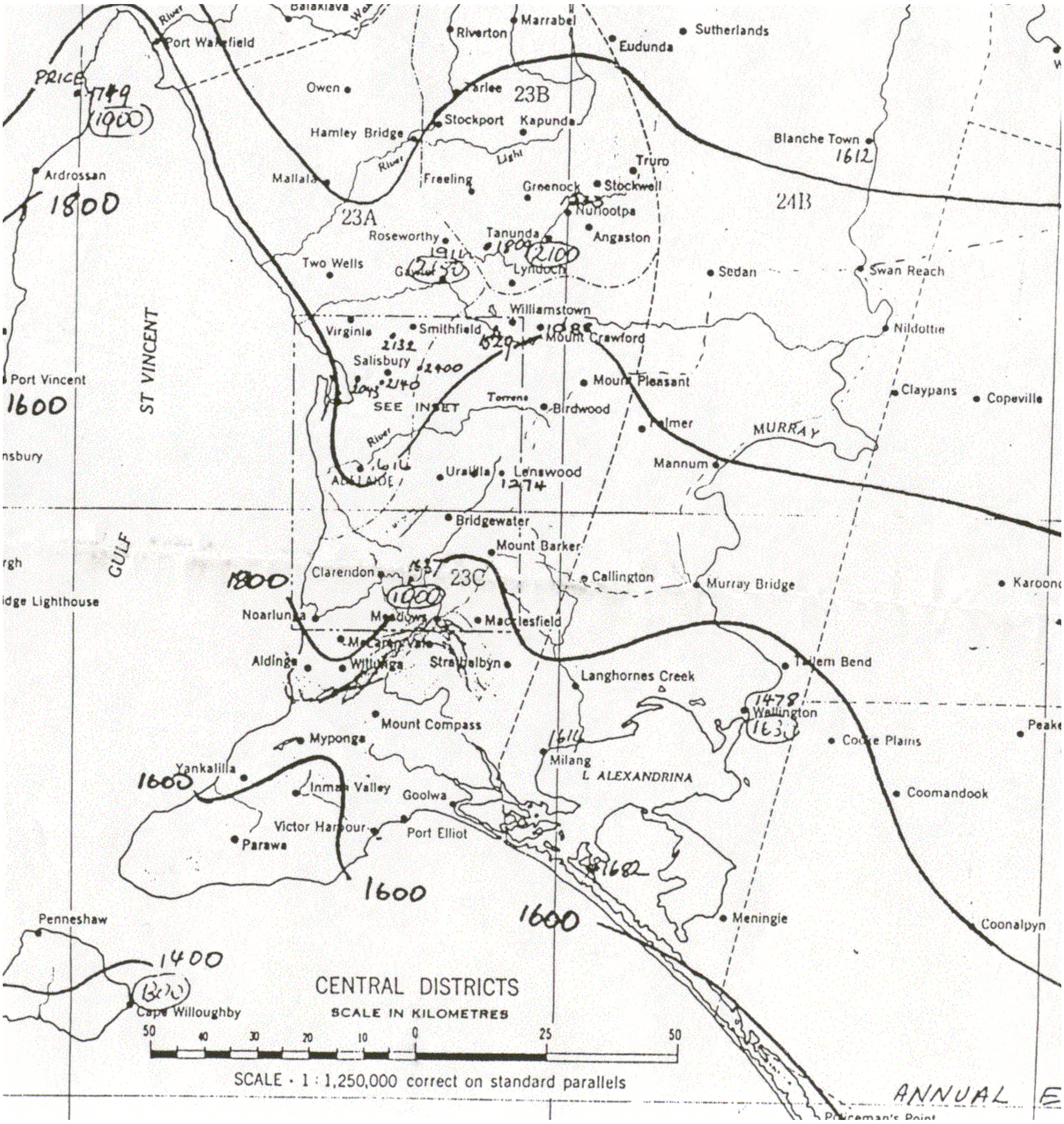
### Table 3. The location of evaporation stations

| Met | AW | Owner | Description | Evaporation (mm) | Period of record |
|---|---|---|---|---|---|
| 023734 | 503536 | SA Water | Mt Bold reservoir | 1,560 | 21/5/1968 – current |
| 023801 | | PIRSA | Lenswood Research Centre | 1,226 | 24/10/1968 – 29/10/1999 |
| 023876 | | BoM | McLaren Vale (Pirramimma) | 1,606 | 1/2/1996 – current |
| 023721 | 503532 | DWR | Happy Valley reservoir | 1,750 | 1/10/1988 – 30/11/1991 |

Of the four stations, the Mt Bold reservoir station (023734) is considered the most suitable to be used for the catchment modelling, as the station is well maintained and it has reliable long-term daily records. The annual evaporation measured with a Class A pan bird guard at this site is 1,560 mm.

Due to the proximity of the station to the reservoir water body and the pine forest around the area, which may have some impact on the reading, it is recognised that some adjustments for the records would be necessary. The monthly records were compared with those of the McLaren Vale (023876) station for the same period (1996-2000). Adjustments were then applied to the Mt Bold reservoir records, by adding the differential monthly evaporation between McLaren Vale and Mt Bold reservoir locations to the long-term monthly average records (1968-2000) of the Mt Bold reservoir. The annual evaporation thus obtained from the adjusted results was 1794 mm. This matches up quite well to the evaporation isohyets map (Figure 8) produced by the Bureau of Meteorology in 1986 (*per comm* C Wright of BoM) for the annual evaporation of the southern component of the State of South Australia (1,800 mm per annum).

**Figure 8. Evaporation Isohyet Map by BoMEvaporation Isohyet Map by BoM**




## *Streamflow*

## Recording stations

The locations of continuous streamflow gauging stations with two or more years of record in the Onkaparinga River catchment are shown in Table 4. The stations identified generally have records exceeding 25 years. Clarendon weir has the longest streamflow record, dating back to 1937; Kerber Creek station is the exception with only two years of record. While most of the gauged stations are still current, Old Noarlunga, Burnt Out Creek and Kerber Creek stations have been closed for some time. Bakers Gully station was closed in 1989 and re-opened in 2000.

### Table 4. The Location of Gauging Stations for Streamflows

| GS Station | Location | Record start | Record end | Flow gaps inclusive |
|---|---|---|---|---|
| 503500 | Clarendon weir | 20-09-1937 | 27-08-2000 | with flow gaps |
| 503502 | Scott Ck | 28-03-1969 | 01-08-2000 | No gaps |
| 503503 | Bakers Gully | 12-04-1969 | 02-08-2000 | Closed in 26-6-1989. Reopened 6-1-2000 |
| 503504 | Houlgrave | 18-04-1973 | 11-07-2000 | No gaps |
| 503506 | Echunga | 23-03-1973 | 29-08-2000 | With flow gaps |
| 503507 | Lenswood | 19-03-1972 | 29-08-2000 | With flow gaps |
| 503508 | Inverbrackie | 18-05-1972 | 14-09-2000 | With flow gaps |
| 503509 | Aldgate | 14-07-1972 | 05-09-2000 | With flow gaps |
| 503522 | Noarlunga | 28-06-1973 | 14-02-1988 | With flow gaps |
| 503526 | Cox Ck | 24-06-1976 | 01-01-2001 | With flow gaps |
| 503529 | Burnt Out | 13-01-1978 | 16-11-1988 | With flow gaps |
| 503530 | Kerber | 31-07-1987 | 07-11-1989 | With flow gaps |

## Recorded Streamflow

Table 5 shows the annual flow statistics of the gauged catchments. The coefficient of variability (Cv), taken as the ratio of standard deviation over the mean value is a measure of streamflow variability between years over the period. A high value indicates high variability. As a comparison, the mean Cv for Australian arid zone streams found by McMahon (1982) is 1.27.

The Table indicates that streamflows for the Clarendon weir, Old Noarlunga and Inverbrackie catchments are highly variable, with Cv values 1.45, 1.08 and 0.95 respectively. Obviously, the Mt Bold reservoir and farm dam storages have a large impact on the first two of these catchments.

### Table 5. Gauged Catchment Flow Records

| Gauged Station (AW) | Location | Gauged Catchment Area, km2 | Annual flow (ML) | | | | | Run-off Coefficient | Coefficient Of Variability, Cv |
|---|---|---|---|---|---|---|---|---|---|
| | | | Median | Mean | Max | Min | Std Dev | | |
| 503500 | Clarendon | 442 | 4,200 | 19,000 | 85,300 | 0 | 27,500 | 0.05 | 1.45 |
| 503502 | Scott Creek | 26.6 | 3,500 | 3,700 | 8,700 | 600 | 2,000 | 0.16 | 0.54 |
| 503503 | Bakers Gully | 48.0 | 3,600 | 4,500 | 10,500 | 700 | 3,000 | 0.12 | 0.68 |
| 503504 | Houlgrave* (Total) | 321.3 | 70,000 | 74,900 | 133,300 | 37,60 0 | 21,800 | | 0.29 |
| 503504 | Houlgrave[N] (“Natural”) | 321.3 | 52,300 | 53,700 | 123,600 | 9,300 | 29,700 | 0.17 | 0.55 |
| 503506 | Echunga | 34.2 | 2,700 | 3,300 | 8,700 | 400 | 2,200 | 0.11 | 0.68 |
| 503507 | Lenswood | 16.8 | 3,400 | 3,900 | 9,400 | 700 | 2,400 | 0.23 | 0.61 |
| 503508 | Inverbrackie | 8.4 | 900 | 900 | 3,400 | 5 | 800 | 0.14 | 0.95 |
| 503509 | Aldgate | 7.4 | 2,400 | 2,500 | 5,900 | 700 | 1,200 | 0.30 | 0.48 |
| 503522 | Noarlunga | 526.1 | 16,600 | 25,700 | 91,60 | 1,700 | 27,800 | 0.09 | 1.08 |
| 503526 | Cox Ck | 5.5 | 1,400 | 1,500 | 3,800 | 700 | 700 | 0.28 | 0.45 |
| 503529 | Burnt Out | 0.6 | 20 | 40 | 90 | 14 | 30 | 0.09 | 0.75 |
| 503530 | Kerber | 1.0 | 100 | 100 | 100 | 100 | - | 0.14 | - |

*, the flow includes the Murray water through Murray Bridge-Onkaparinga pipeline
N, estimate of the catchment runoff from upstream of Houlgrave catchment

The time series flow in Houlgrave catchment has been shown in two ways; one is the total flow recorded (shown as *) and the other the estimated “natural” flow component (shown as N). The total flow includes that water pumped from the River Murray while the “natural” component is that flow received from the upstream catchment runoff only. The mean flow component of the “natural flow” from the upstream catchment is 54,000 ML with a flow range varying from the minimum of 9,000 ML to the maximum of 124,000 ML. With additional water intake from the Murray, the mean flow recorded at Houlgrave weir is 75,000 ML. That equates to 21,000 ML of pumped volume. From the Engineering and Water Supply Department *Water Use Annual Returns* reports, the intake through the Murray Bridge-Onkaparinga pipeline is 27,000 ML. This represents 6,000 ML of unaccounted discrepancy, which could be due to the meter-reading errors, seepage and evaporation losses or usage through the 13.5 km length of conveyance, etc.

Streamflow in the catchments occurs mostly during the winter months with little or no flow in the summer. The annual catchment runoff (“natural”) and the monthly median flow of Houlgrave weir are shown in Figures 9-10.

## Figure 9. Annual Adjusted (“natural”) Flow at Houlgrave Weir

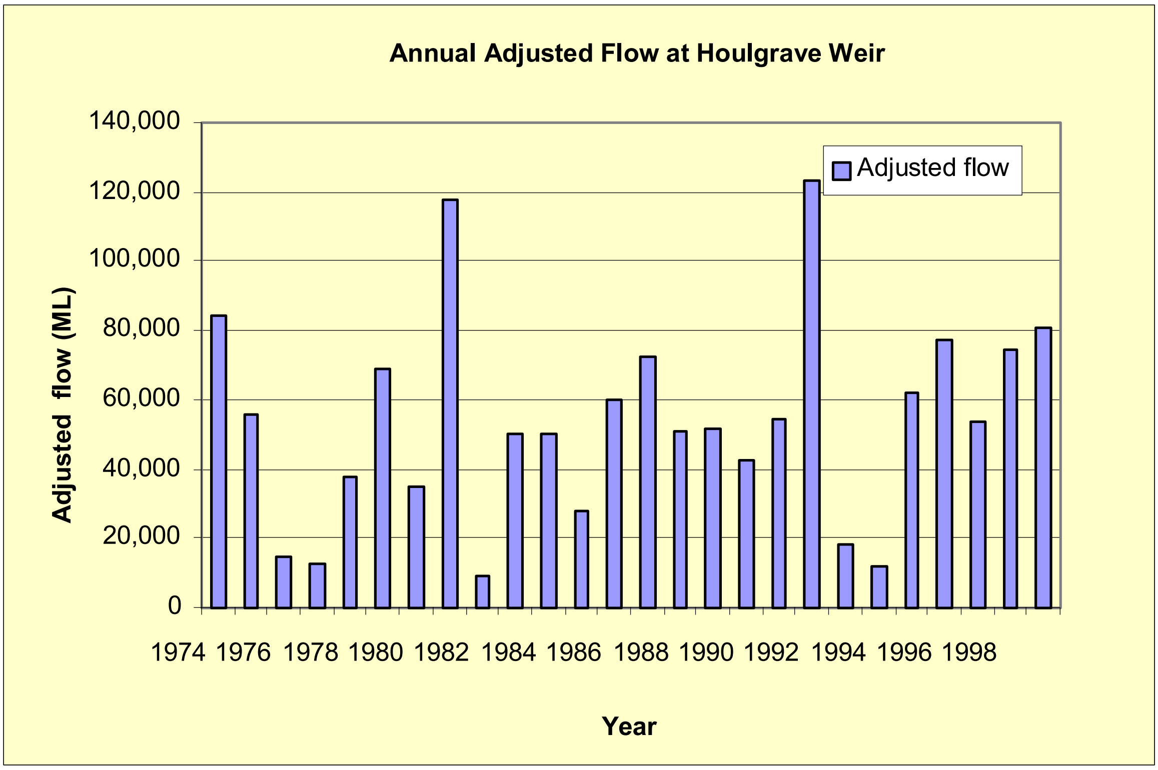
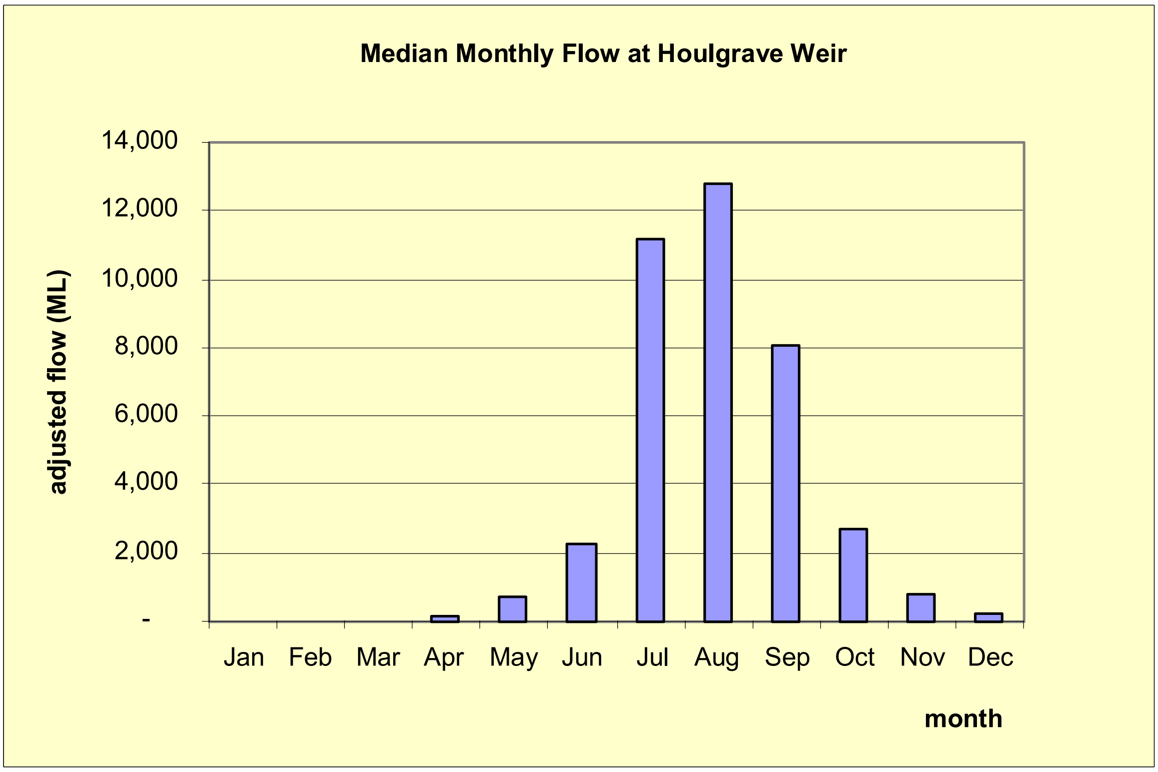


**Figure 10. Monthly Median Adjusted ("Natural") Flow at Houlgrave Weir**



# WATER HARVESTING AND USE

## *Public Water Supplies*

The main infrastructure elements associated with the Onkaparinga River catchment are related to the public water supply system operated by SA Water. They are the:

- Hahndorf Dissipator
- Murray Bridge-Onkaparinga Pipeline (which imports River Murray water from outside of catchment)
- Summit storage
- Mt Bold Reservoir
- Clarendon Diversion Weir and Pumping Station
- Onkaparinga Valley Scheme
- Horndale Flume (located outside of the catchment in Happy Valley)
- Happy Valley Reservoir (located outside of the catchment which receives water diverted from Clarendon Weir)

A schematic diagram of the water supply system and the relative positioning of this infrastructure is shown in Figure 11.

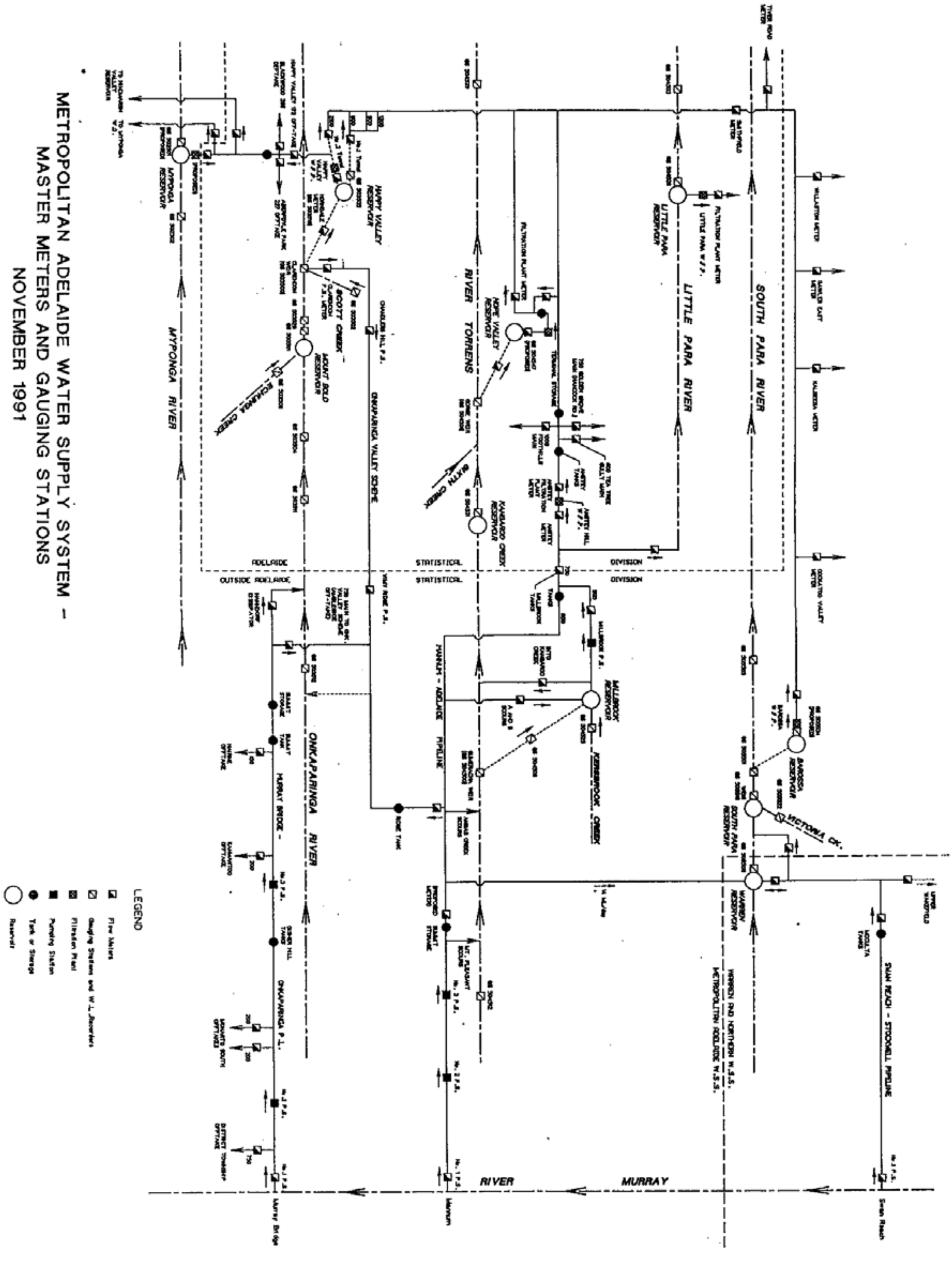
Mt Bold Reservoir is an essential water storage structure forming part of the metropolitan Adelaide water supply system. The reservoir has a storage capacity of 47,300 ML at its full supply level and derives 60% of its water supply from its local catchment. During the summer season, when the catchment runoff is minimal, water is pumped from the River Murray and conveyed to the reservoir via the Murray Bridge-Onkaparinga Pipeline. The pipeline transfers water to the Summit Storage, where it is gravity fed into the Onkaparinga River via the Hahndorf Dissipator. The intake volume into the catchment is measured at this point. It then travels through approximately 13.5 km of the river length before reaching the reservoir. Following dry winters, over 90% of water may be sourced from the River Murray. Table 6 shows the annual volume of water pumped from River Murray into Mount Bold Reservoir through MB/O P/L. The average annual intake of River Murray water to Mount Bold Reservoir is 27,000 ML.

From Mt Bold Reservoir, water is released to Clarendon Weir, where it is diverted through the Horndale Flume to the Happy Valley Reservoir. Here the water is filtered and treated before being supplied for metropolitan consumption. The Clarendon Weir is located 6 km downstream of Mt Bold Reservoir. It was constructed in 1896 and has storage capacity of 320 ML. In addition to diversion to Happy Valley Reservoir, water can also be pumped from Clarendon Weir Pumping Station to supply the Onkaparinga Valley Scheme and the surrounding suburbs for consumption. However, following the introduction of filtered water, this diversion has not occurred in recent years. Clarendon Weir also receives a significant inflow from the Scott Creek catchment. Another major subcatchment, Baker Gully, enters the Onkaparinga River downstream of the Clarendon weir and cannot be intercepted by the water supply system.

## Table 6. Water Pumped from the River Murray into the Mt Bold Reservoir

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Annual** |
| 1975 | - | - | - | - | - | - | - | - | - | - | - | 451 | 451 |
| 1976 | - | - | - | - | - | 150 | 4,392 | 11,310 | 11,708 | 11,791 | 7,975 | 8,040 | 55,366 |
| 1977 | 4,929 | 2,322 | 95 | 81 | - | - | 654 | 8,324 | 8,744 | 8,427 | 7,983 | 8,241 | 49,800 |
| 1978 | 7,784 | 7,305 | 8,046 | 4,130 | - | - | - | - | - | - | - | 4,478 | 31,743 |
| 1979 | 4,970 | 4,289 | 3,428 | - | - | - | 215 | 5,558 | 4 | - | - | - | 18,464 |
| 1980 | - | - | - | - | 1,236 | 2,978 | - | - | 4,632 | 5,225 | 3,109 | 2,804 | 19,984 |
| 1981 | 3,191 | 4,138 | 4,034 | 1,116 | 2,742 | 159 | - | - | - | - | - | - | 15,380 |
| 1982 | - | - | - | 1,501 | 2,701 | 248 | - | 8,125 | 11,048 | 12,617 | 13,276 | 12,105 | 61,621 |
| 1983 | 10,900 | 4,983 | 3,730 | - | - | - | - | - | - | - | - | - | 19,613 |
| 1984 | 2,646 | 4,450 | 3,206 | - | - | - | - | - | 5 | - | - | - | 10,307 |
| 1985 | 2,741 | 2,749 | 2,015 | - | - | - | - | - | - | 2,834 | 4,371 | 5,488 | 20,199 |
| 1986 | 5,301 | 4,501 | 3,024 | 4,285 | 191 | 533 | 347 | - | - | - | - | - | 18,181 |
| 1987 | - | - | - | - | - | - | - | - | - | - | 1,025 | 3,058 | 4,083 |
| 1988 | 2,611 | 2,421 | - | 2,214 | 1,113 | - | - | - | - | - | 709 | 3,074 | 12,142 |
| 1989 | 2,116 | 996 | 1,681 | 1,697 | 1,545 | - | - | - | - | - | 1,665 | 962 | 10,662 |
| 1990 | 1,958 | 3,438 | 2,161 | - | 1,796 | 2,187 | - | - | 1,076 | 1,305 | 4,621 | 7,402 | 25,943 |
| 1991 | 6,727 | 4,405 | 4,055 | - | 61 | 2,009 | 3,069 | 3,645 | 2,081 | 40 | 3,249 | 4,010 | 33,352 |
| 1992 | 3,682 | 2,670 | - | - | - | - | - | 1,657 | - | - | - | - | 8,009 |
| 1993 | - | - | - | - | - | - | 20 | - | 2,557 | 5,606 | 5,398 | 6,019 | 19,599 |
| 1994 | 5,962 | 5,119 | 6,784 | 7,324 | 5,115 | 2,036 | 1,954 | 4,951 | 8,850 | 9,621 | 7,240 | 6,637 | 71,593 |
| 1995 | 7,606 | 6,886 | 5,559 | 2,649 | 6 | 4 | 833 | - | 2 | - | - | - | 23,545 |
| 1996 | 228 | 2,401 | 3,869 | 2,310 | 2,919 | 2,340 | 0 | - | 0 | 0 | 984 | 2,439 | 17,490 |
| 1997 | 1,877 | 2,783 | 2,082 | 569 | 1 | 306 | 5,109 | 4,430 | 5,442 | 5,447 | 5,913 | 4,780 | 38,739 |
| 1998 | 4,738 | 6,022 | 9,096 | 6,374 | 647 | 1,444 | 389 | 2,042 | 4,762 | 5,497 | 4,881 | 3,139 | 49,031 |
| 1999 | 4,986 | 8,570 | 7,886 | 3,873 | 1,357 | 67 | 47 | 2,192 | 6,310 | 6,292 | 4,846 | 4,733 | 51,159 |
| Total | 84,951 | 80,450 | 70,749 | 38,124 | 21,429 | 14,461 | 17,029 | 52,234 | 67,220 | 74,703 | 77,245 | 87,861 | 686,456 |
| **Mean** | 3,398 | 3,218 | 2,830 | 1,525 | 857 | 578 | 681 | 2,089 | 2,689 | 2,988 | 3,090 | 3,514 | **27,458** |

## Figure 11. Schematic Diagram of SA Water Pipeline Systems



# *Farm Dams*

## Dam Statistics

Three sets of farm dams storage data were available. These data were derived from aerial photographs captured in 1987, 1995/96 and 1999

The 1987 farm dams data was obtained by manually tracing the outline of the dams from the aerial photographs and digitising the tracings into a GIS program (Cresswell and Verhoff 1990). A greater attention was paid to locating the small dams during the process. The GIS program then calculates the surface area. For this study, the volume of the dam was then calculated by employing the formula (McMurray, 1996):

$$V=0.044*S^{1.4}.$$

Where V is the estimated volume for farm dam in kilolitres based on the digitised dam “surface area” S, in square metres. This formula was also being used to estimate the farm dams volume in the report by Savadamuthu, 2002 for the Marne catchment.

For 1996 farm dams data, the dam outlines were digitised “on-screen” from scanned and registered aerial photographs captured in Dec1995/Jan1996 The volumes were also estimated using the above formula to facilitate a valid comparison with the other dataset. The 1999 farm dams data was created by digitising “on-screen” from the ortho-photography captured in 1999. The aerial photographs were flown at a scale of 1:20,000. The volumes were estimated as above.

The farm dams information for 1987, 1996 and 1999 thus obtained is briefly summarised in Tables 7 and 8 below:

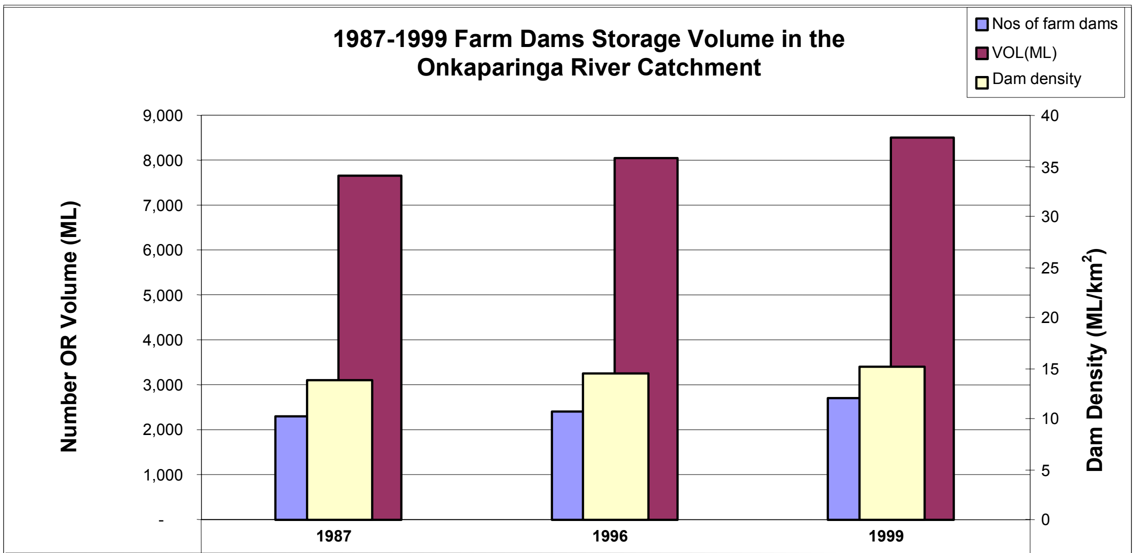
### Table 7. Farm Dam Developments in 1987, 1996 and 1999

| Onkaparinga Catchment | Catchment Area, ha | No. of Farm Dams | Storage Volume (ML) | $ML/km^2$ (mm) |
|---|---|---|---|---|
| 1987 | 55,812 | 2,300 | 7,648 | 13.70 |
| 1996 | 55,812 | 2,410 | 8,058 | 14.44 |
| 1999 | 55,812 | 2,699 | 8,495 | 15.22 |

### Table 8. The Number of Farm Dams and Storages for Various Volume Sizes

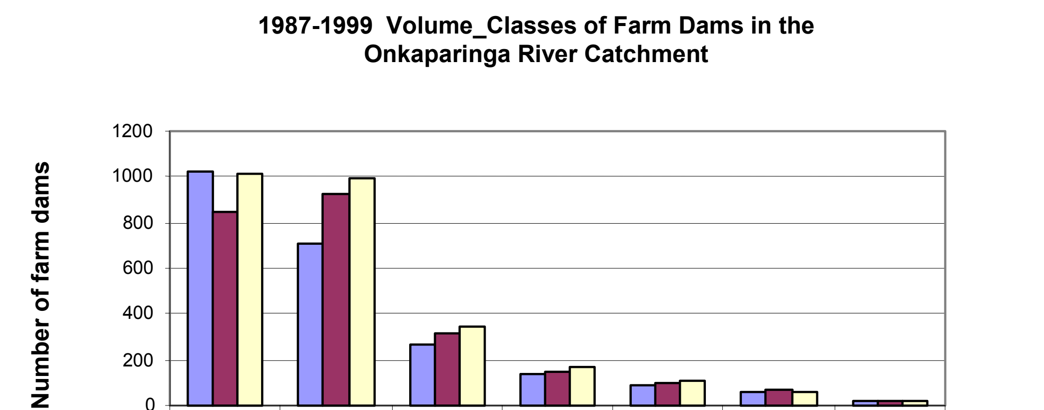
| Vol. Class ML | Number of farm dams | | | Storage Volume | | |
|---|---|---|---|---|---|---|
| | 1987 | 1996 | 1999 | 1987 | 1996 | 1999 |
| < 0.5 | 1026 | 841 | 1010 | 239 | 229 | 265 |
| 0.5 – 2 | 707 | 923 | 995 | 716 | 924 | 992 |
| 2 – 5 | 265 | 315 | 342 | 835 | 1,003 | 1,062 |
| 5 – 10 | 136 | 150 | 167 | 972 | 1,066 | 1,194 |
| 10 – 20 | 88 | 99 | 109 | 1,286 | 1,399 | 1,558 |
| 20 – 50 | 58 | 65 | 56 | 1,847 | 2,002 | 1,740 |
| > 50 | 20 | 17 | 20 | 1,754 | 1,433 | 1,684 |
| Total | 2300 | 2,410 | 2699 | 7,648 | 8,058 | 8,495 |

## Figure 12. 1987-1999 Farm Dams Storage Volume in the Onkaparinga River Catchment




| | 1987 | 1996 | 1999 |
|---|---|---|---|
| Nos of farm dams | 2,300 | 2,410 | 2,699 |
| VOL(ML) | 7,648 | 8,058 | 8,495 |
| Dam density (ML/km$^2$) | 13.70 | 14.44 | 15.22 |

## Figure 13. Volume Classes of Farm Dam in the Onkaparinga River Catchment

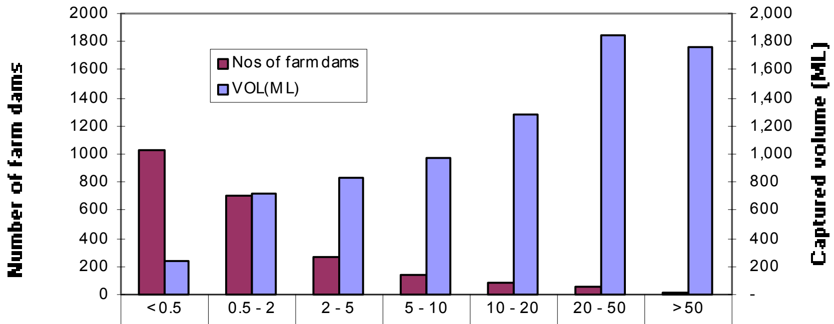



| | < 0.5 | 0.5 - 2 | 2 - 5 | 5 - 10 | 10 - 20 | 20 - 50 | > 50 |
|---|---|---|---|---|---|---|---|
| 1987 farm dams | 1026 | 707 | 265 | 136 | 88 | 58 | 20 |
| 1996 farm dams | 841 | 923 | 315 | 150 | 99 | 65 | 17 |
| 1999 farm dams | 1010 | 995 | 342 | 167 | 109 | 56 | 20 |

Volume(ML)-Class

## Figure 14. Breakdown of Storages and Volume Classes in 1987, 1996 and 1999

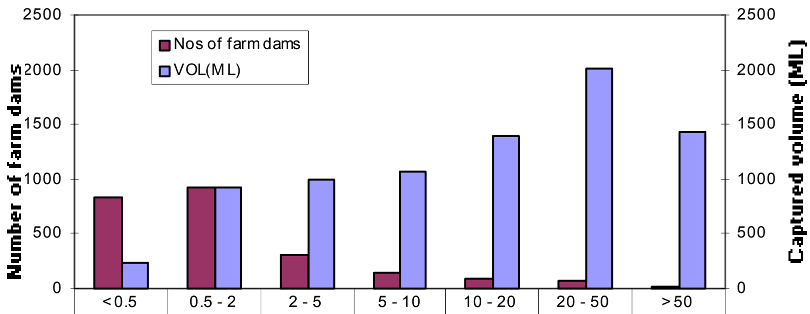
**The number of farm dams and volume_classes in 1987**




| | < 0.5 | 0.5 - 2 | 2 - 5 | 5 - 10 | 10 - 20 | 20 - 50 | > 50 |
|---|---|---|---|---|---|---|---|
| Nos of farm dams | 1026 | 707 | 265 | 136 | 88 | 58 | 20 |
| VOL(M L) | 239 | 716 | 835 | 972 | 1,286 | 1,846 | 1,754 |
| VOL(M L) | 239 | 716 | 835 | 972 | 1,286 | 1,846 | 1,754 |

class_volume (M L)

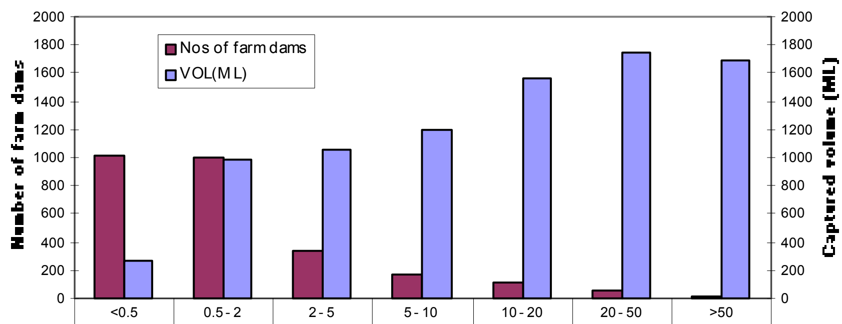
**The number of farm dams and volume_classes in 1996**




| | < 0.5 | 0.5 - 2 | 2 - 5 | 5 - 10 | 10 - 20 | 20 - 50 | > 50 |
|---|---|---|---|---|---|---|---|
| Nos of farm dams | 841 | 923 | 315 | 150 | 99 | 65 | 17 |
| VOL(M L) | 229 | 924 | 1,003 | 1,066 | 1,399 | 2,002 | 1,433 |
| VOL(M L) | 229 | 924 | 1003 | 1066 | 1399 | 2002 | 1433 |

class_volume (M L)

**The number of farm dams and volume_classes in 1999**




| | <0.5 | 0.5 - 2 | 2 - 5 | 5 - 10 | 10 - 20 | 20 - 50 | >50 |
|---|---|---|---|---|---|---|---|
| Nos of farm dams | 1010 | 995 | 342 | 167 | 109 | 56 | 20 |
| VOL(ML) | 265 | 992 | 1,062 | 1,194 | 1,558 | 1,740 | 1,684 |
| VOL(ML) | 265 | 992 | 1062 | 1194 | 1558 | 1740 | 1684 |

class_volume (M L)

Between 1987 and 1999, the number of farm dams constructed in the Onkaparinga River catchment has increased from around 2,300 to 2,700 and the storage volume from 7.6 to 8.5 GL. The current farm dam development equates to a farm dam density of 15.22 ML/km$^2$ across the catchment, or in total volume of 18% of the Mt Bold reservoir storage. It is worth noting that out of the 2,700 farm dams, 60% of the total storage volume comes from only 185 farm dams with storage size greater than 10 ML. Dam construction between 1987-1999 has been mainly in the category of 2 - 20 ML storage sizes due to development restrictions within the watershed.

For farm dam distribution on a subcatchment level, Mitchell catchment has the highest farm dam density of 39 ML/km$^2$ (1999 data) followed by Hahndorf (32 ML/km$^2$) and Western Branch (30 ML/km$^2$). Biggs Flat, Echunga, Lenswood (or Cock Creek), Inverbrackie and Upper Onkaparinga catchments lie in the middle range of 20-28 ML/km$^2$. This is illustrated in Figure 15 that shows the number of farm dams and the storage volumes found in individual subcatchments for the years 1987, 1996 and 1999.

## Trend in Farm Dams Development

It is noted that on average, farm dams development from 1987 to 1999 (Table 8) is increasing at a rate of approximately 75 ML/yr or a total of 900 ML over that period. This was lower than expected but on closer examination of the data it reveals that there was a rapid rise in the farm dams development in the recent years between 1996 to 1999 as half of the 900 ML incremental volume came from this period. The rate of farm dams development in this period was 150 ML/yr (or 0.27 mm/yr across the catchment).

Comparing with the Marne catchment (Savadamuthu, 2002), which is less than half the size in catchment, it has farm dams development at a rate of 160 ML/yr (or 0.55 mm/yr or across the catchment) from 1991 to 1999. Hence it appears that farm dam development is less rapid within the Onkaparinga River catchment. This could be due to greater control on the farm dams development in the catchment by limiting the dam size to land ownerships.

## Derivation of Farm Dams Volume

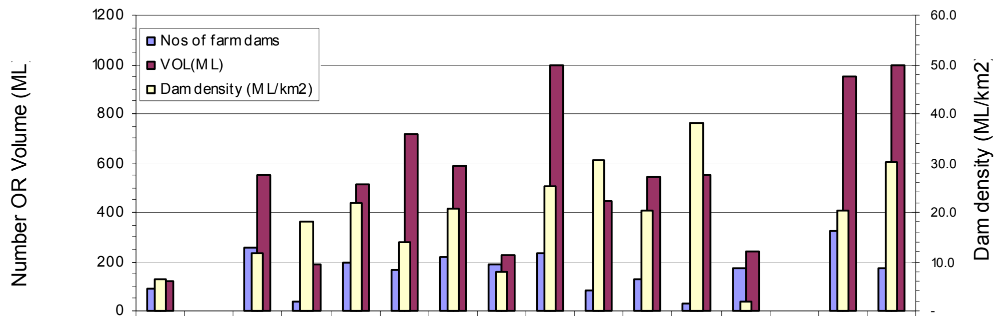
There have been a number of formulations being proposed and used for estimating the farm dams volume based on surface area of the dam's water body at full supply level. Some also have the depth incorporated into the equation. The common approach for macro-catchment analysis is using one formula fit all for estimating farm dams volume to provide a simple and quick estimation of the aggregated dam storage within the catchment. However, in reality, the constructed farm dams come in different forms and depths and such approach of one equation fits all leaves the degree of accuracy of the aggregated dam storage debatable.

For this study, the formula $V=0.044*S^{1.4}$ (McMurray 1996) was adopted as it was considered appropriate at the time "for estimating the stored water in farm dams in each of the Mt Lofty Ranges catchments" as suggested by the author. V is the dam storage in KL and S surface area of the dam in sq.m. At the time. it was also considered to be consistent with other studies such as the Marne catchment (Savadamuthu, 2002).

Further refinements to the formulae for estimating farm dam volumes are being developed as more survey information is collected. This information is to be collated by the DWLBC and a revised formula used when a sufficient body of data is available to substantiate a change.

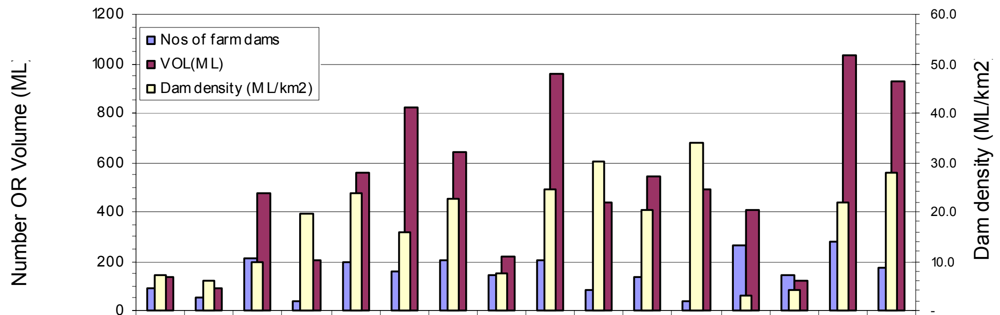
## Figure 15. Subcatchment Farm Dam Statistics in 1987, 1996 and 1999

**Sub-catchments farm dams statistics (1987)**



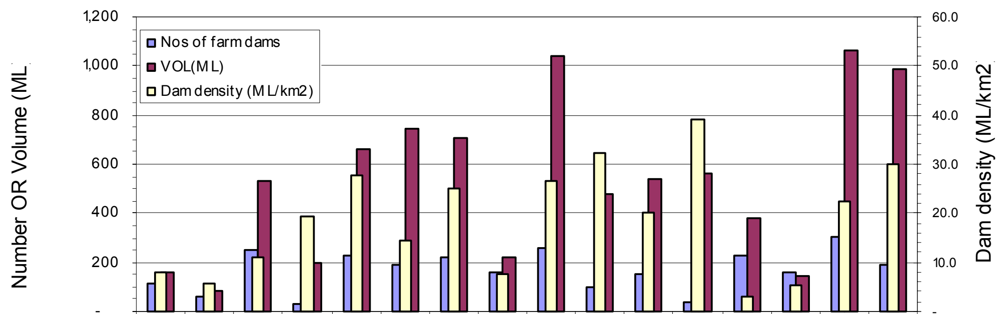

| | ALDGA TECK | ANGEL S GULLY | BAKER GULLY | BALHA NNAH | BIGGS FLAT | CHARL ESTON | COCK CK | COX CK | ECHUN GA CK | HAHN DORF | INVER BRAC KIECK | MITCH ELL CK | ONKA PARIN GA | SCOTT CK | UPPER ONKA PARIN | WESTE RN BRAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nos of farm dams | 94 | - | 256 | 34 | 199 | 165 | 220 | 191 | 231 | 83 | 130 | 33 | 171 | - | 322 | 171 |
| VOL(ML) | 124 | - | 555 | 187 | 516 | 716 | 590 | 225 | 996 | 447 | 545 | 553 | 241 | - | 954 | 999 |
| Dam density (ML/km2) | 6.4 | - | 11.6 | 18.2 | 21.8 | 13.9 | 20.8 | 7.8 | 25.4 | 30.5 | 20.4 | 38.1 | 1.9 | - | 20.3 | 30.3 |

**Sub-catchments farm dams statistics (1996)**




| | ALDGA TECK | ANGEL S GULLY | BAKER GULLY | BALHA NNAH | BIGGS FLAT | CHARL ESTON | COCK CK | COX CK | ECHUN GA CK | HAHN DORF | INVER BRAC KIECK | MITCH ELL CK | ONKA PARIN GA | SCOTT CK | UPPER ONKA PARIN | WESTE RN BRAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nos of farm dams | 87 | 56 | 210 | 34 | 199 | 156 | 201 | 145 | 205 | 85 | 139 | 37 | 266 | 140 | 276 | 174 |
| VOL(ML) | 138 | 87 | 472 | 201 | 560 | 821 | 640 | 217 | 956 | 441 | 545 | 493 | 408 | 118 | 1,034 | 927 |
| Dam density (ML/km2) | 7.1 | 6.2 | 9.8 | 19.6 | 23.7 | 15.9 | 22.5 | 7.5 | 24.4 | 30.0 | 20.4 | 34.0 | 3.1 | 4.1 | 22.0 | 28.1 |

**Sub-catchments farm dams statistics (1999)**




| | ALDGA TECK | ANGEL S GULLY | BAKER GULLY | BALHA NNAH | BIGGS FLAT | CHARL ESTON | COCK CK | COX CK | ECHUN GA CK | HAHN DORF | INVER BRAC KIECK | MITCH ELL CK | ONKA PARIN GA | SCOTT CK | UPPER ONKA PARIN | WESTE RN BRAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nos of farm dams | 113 | 64 | 252 | 30 | 226 | 193 | 222 | 158 | 262 | 98 | 152 | 41 | 229 | 161 | 305 | 193 |
| VOL(ML) | 159 | 82 | 530 | 197 | 660 | 748 | 710 | 221 | 1,038 | 476 | 538 | 566 | 377 | 148 | 1,060 | 985 |
| Dam density (ML/km2) | 8.2 | 5.9 | 11.1 | 19.2 | 27.9 | 14.5 | 25.0 | 7.7 | 26.5 | 32.4 | 20.1 | 39.0 | 2.9 | 5.2 | 22.5 | 29.9 |

Figure 13 highlights an inconsistency in the number of dams of size <0.5 ML. This is best explained by the detail of information sought and the equation used to convert area to volume. The 1987 and 1996 surveys use different methods of data capture and it is suggested that the 1987 survey placed more emphasis of seeking out the smallest dams.

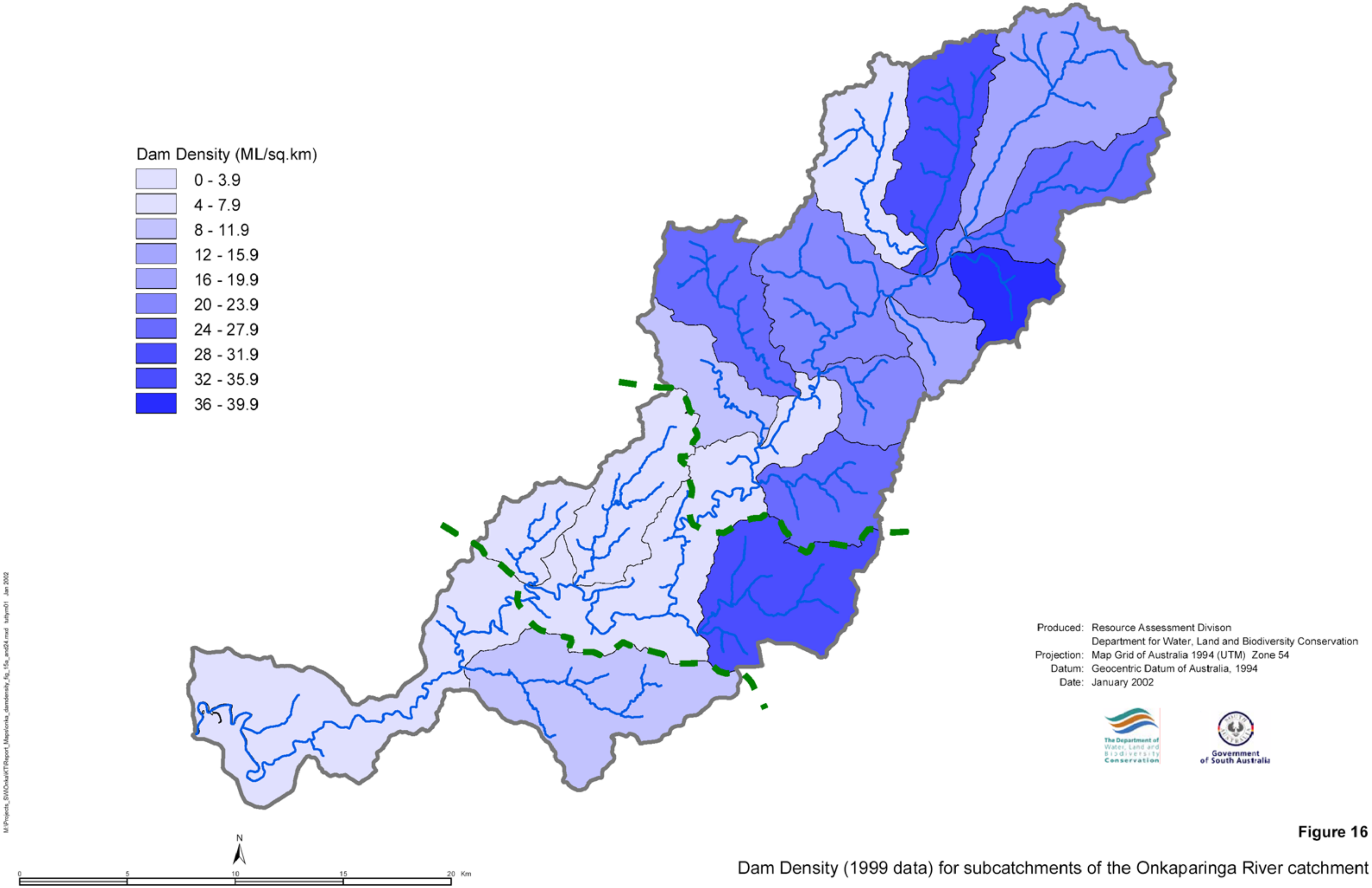



**Figure 16**

Dam Density (1999 data) for subcatchments of the Onkaparinga River catchment

## *Groundwater*

While the current study focuses on surface runoff, there is also significant groundwater use in the Onkaparinga River catchment. The interaction of groundwater and surfacewater is likely to be significant, but it has not been covered in this study. Groundwater is an important provider of baseflow, but a detailed examination of this is beyond the scope of this investigation.. For modelling purposes, with the model, groundwater recharge is assumed to be equal to 30% of the estimated runoff. Surfacewater runoff makes up the remaining 70%. (*pers comm Cresswell*). streamflow losses This proportion is consistent with other studies in the Clare Valley and Mount Lofty Ranges Watershed (*pers comm* Cresswell) but will require further refinement as more data becomes available. Groundwater is an important source of water supply for irrigation as shown in the section titled Water Use below.

## *Water use*

### Irrigated Area

The Onkaparinga River catchment is a developed semi-rural setting catchment with a number of urbanised townships scattered within the area. Among them are Woodside, Hahndorf, Stirling, Balhannah, Lobethal, Summertown, Uraidla, Oakbank, Bridgewater and Aldgate all located inland and Old Noarlunga at the coast.

Agriculture is predominantly a mixture of irrigated horticulture and viticulture and the traditional dairy farming and grazing industries. Extensive irrigated areas are found mainly in the high rainfall zones of the upper portion of the catchment. Areas of dairy and grazing are, in order of significance, Onkaparinga Main Channel, Charleston, Baker Gully, Upper Onkaparinga, Echunga Creek, Western Branch and Inverbrackie Creek. The total irrigated area for the Onkaparinga River catchment is 5,200 ha or 9.3% of the catchment (Table 11).

The information quoted above is based on the 1999 land use database obtained from Primary Industry and Resources of South Australia (PIRSA). The details are provided in Table 9. The description of land use information is based on the Standards Australia Australia and New Zealand Land Use Codes (ANZLUC).

### Table 9. Landuse Information for the Onkaparinga River Catchment (1999 data)

| Subcatchment (ha) | Dairy Cattle | Horses | Live Stock | Improved Pasture NEC | Field Crops Temporal Agriculture | Forest Plantation | Protected Area | Protected Area NEC | Field Crops Irrigated Agriculture | Horticulture Trees | Vegetables NEC | Vine Fruit | Micellaneous | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldgate Creek | 0 | 29 | 420 | 0 | 0 | 16 | 0 | 283 | 17 | 8 | 0 | 0 | 1,172 | 1,945 |
| Angels Gully | 51 | 31 | 777 | 98 | 0 | 0 | 276 | 1 | 0 | 15 | 0 | 8 | 152 | 1,408 |
| Baker Gully | 73 | 528 | 2663 | 178 | 22 | 506 | 2 | 375 | 29 | 19 | 0 | 239 | 163 | 4,796 |
| Balhannah | 29 | 182 | 547 | 42 | 22 | 0 | 0 | 3 | 0 | 17 | 19 | 40 | 122 | 1,024 |
| Biggs Flat | 285 | 269 | 1,041 | 181 | 0 | 8 | 0 | 47 | 42 | 13 | 0 | 12 | 468 | 2,365 |
| Charleston | 1,007 | 164 | 2,366 | 103 | 28 | 17 | 55 | 18 | 302 | 59 | 53 | 466 | 403 | 5,151 |
| Cock Creek | 244 | 101 | 630 | 0 | 0 | 57 | 25 | 456 | 17 | 1,100 | 2 | 167 | 42 | 2,840 |
| Cox Creek | 0 | 70 | 613 | 12 | 11 | 12 | 118 | 502 | 30 | 67 | 150 | 189 | 1,100 | 2,875 |
| Echunga Creek | 391 | 286 | 1,445 | 78 | 49 | 343 | 43 | 509 | 144 | 0 | 50 | 46 | 533 | 3,917 |
| Hahndorf | 77 | 38 | 773 | 0 | 2 | 1 | 0 | 59 | 0 | 22 | 19 | 30 | 447 | 1,468 |
| Inverbrackie Creek | 595 | 161 | 1,057 | 291 | 38 | 14 | 0 | 36 | 103 | 23 | 45 | 164 | 146 | 2,674 |
| Mitchell Creek | 200 | 225 | 621 | 92 | 0 | 4 | 0 | 0 | 51 | 19 | 74 | 0 | 164 | 1,451 |
| Onkaparinga Main Channel | 170 | 272 | 3,995 | 337 | 337 | 331 | 1,232 | 2,704 | 43 | 109 | 0 | 537 | 2,974 | 13,043 |
| Scott Creek | 140 | 72 | 1,016 | 9 | 0 | 8 | 815 | 542 | 0 | 52 | 4 | 13 | 178 | 2,850 |
| Upper Onkaparinga | 247 | 588 | 1,819 | 89 | 2 | 16 | 198 | 526 | 14 | 260 | 37 | 184 | 726 | 4,708 |
| Western Branch | 759 | 120 | 1,148 | 122 | 6 | 2 | 0 | 229 | 0 | 333 | 33 | 257 | 287 | 3,297 |
| Grand Total | 4,268 | 3,135 | 20,931 | 1,632 | 518 | 135 | 2,766 | 6,400 | 792 | 2,117 | 485 | 2,353 | 9,079 | 55,812 |

Miscelleneous includes other ANZLUC_DES classifications such as Accommodation, Cultural and Recreation services, etc not related to agricultures

## Volumetric Estimates

Irrigation volume in the Onkaparinga River catchment is estimated to be 21,000 ML (based on 1999 land use figures). The volume is estimated using the "global application" method similar to the methodology adopted by previous researchers familiar with the Mt Lofty Ranges conditions (Kneebone, et al 2000). Essentially, an irrigation application rate is applied to a proportion of the classified irrigated agricultural area to obtain the irrigated area and the volume. The application factors are shown in Table 10 below.

### Table 10. "Global Application" Factors for Irrigation"Global Application" Factors for Irrigation

| ANZLUC DES | Application mm/ha | Proportion of Irrigated Area |
|---|---|---|
| Dairy cattle | 650 | 0.15 |
| Field crops ~ irrigated agriculture | 650 | 0.5 |
| Field crops ~ temporal agriculture | 0 | |
| Forest plantation | 0 | |
| Horses | 650 | 0.1 |
| Horticulture - trees | 400 | 0.8 |
| Improved pasture nec | 650 | 0.15 |
| Livestock | 0 | |
| Vegetables nec | 400 | 0.3 |
| Vine fruit | 200 | 0.75 |

The estimated application volumes are summarised for each subcatchment in Table 11.

### Table 11. Irrigation Statistics for the Onkaparinga River Catchment (1999 data)

| Subcatchment | Area Irrigated (ha) | Total Volume (ML) | Proportion of Subcatchment Irrigated (%) |
|---|---|---|---|
| Aldgate Creek | 17.6 | 98 | 0.9% |
| Angels Gully | 43.5 | 225 | 3.1% |
| Baker Gully | 299.3 | 1,101 | 6.2% |
| Balhannah | 78.2 | 325 | 7.6% |
| Biggs Flat | 137.2 | 825 | 5.8% |
| Charleston | 746.5 | 3,122 | 14.5% |
| Cock Creek | 1,060.4 | 4,129 | 37.3% |
| Cox Creek | 264.4 | 834 | 9.2% |
| Echunga Creek | 220.5 | 1,240 | 5.6% |
| Hahndorf | 60.9 | 238 | 4.1% |
| Inverbrackie creEk | 355.8 | 1,678 | 13.3% |
| Mitchell Creek | 129.3 | 747 | 8.9% |
| Onkaparinga Main Channel | 615.6 | 1,969 | 4.7% |
| Scott Creek | 82.3 | 383 | 2.9% |
| Upper Onkaparinga | 473.8 | 1,909 | 10.1% |
| Western Branch | 613.4 | 2,428 | 18.6% |
| Grand Total | 5,198.8 | 21,251 | 9.3% |

Comparison of the 1999 data with the 1993 irrigation statistics, (which identifies 4,400 ha of irrigated area requiring 17,400 ML of irrigation water (Kneebone, et al 2000)), indicates an increase of 18% in irrigated area and 21% in the irrigation water over the six year period.

Based on a total farm dam storage of 8,500 ML (Table 8), and assuming between 30-70% of farm dam storage can be used for irrigation, it is estimated that 2,600-5,950 ML of surfacewater runoff is used for irrigation. The percentage chosen represents an educated guesstimate of the lower and upper bound water use obtained from farm dams across the catchments (*pers comm Cresswell*). This leaves the balance of irrigation water to be derived from other sources, predominantly groundwater.

The ratio of use between groundwater and surfacewater appears to be very high suggesting that 21,000 ML may be an overestimate of total water use. It should be cautioned that the irrigated area and the irrigation volume estimated by the “global application” method should be applied with care. Further verification in the estimation of water usage will be required.

# SURFACEWATER MODELLING

## *Model Construction*

A hydrological model for the Onkaparinga River catchment was constructed using a PC based computing program called *WaterCress,* which stands for *W*ater-*C*ommunity *R*esource *E*valuation and *S*imulation *S*ystem. The steps and assumptions used for constructing the model are described in Appendix B.

The Onkaparinga River catchment was sub-divided into 95 smaller catchments varying in sizes to represent the rural catchment nodes in the model. Townships within the catchment were represented in the model as urban nodes of impervious nature. Aggregated farm dams storage were represented in the model as on-stream dam nodes or off-stream dam nodes depending on the dam location relative to the stream system. Routing nodes were added in the model to facilitate better calibrations.

Daily rainfall data were used as inputs to the model to generate catchment runoff. Data from ten rainfall stations (refer Table 2) were selected for the model.

The WaterCress Model has a number of different runoff generation routines to choose from. The WC-1 runoff routine was used to simulate runoff in the rural areas and the initial loss and continuing loss routine (ILCL) was used for urban areas.

## *Calibration*

### General

Model calibration is performed by comparing the simulated runoff of a modelled catchment with the actual streamflow or reservoir volume records. The catchments that have a gauging station to calibrate against are listed in Table 12. As the length of streamflow records vary from one station to another, so does the duration of the runoff simulation for calibration. Where a data gap or doubtful record exists, an appropriate quality code is added to indicate the quality of the data. The *WaterCress* model allows these doubtful data to be taken out when comparing the simulated catchment runoff with actual streamflow records.

### Table 12. The Location of Calibrated Gauged Catchments

| GS Station | Node Number | Location | Catchment Area km$^2$ | Record Start | Record End |
|---|---|---|---|---|---|
| 503502 | 196 | Scott Ck | 26.6 | 28–03–1969 | 01–08–2000 |
| 503503 | 195 | Baker Gully | 48 | 12-04-1969 | 02-08-2000 |
| 503504 | 101 | Houlgrave | 321 | 18-04-1973 | 11-07-2000 |
| 503506 | 194 | Echunga | 34.2 | 23-03-1973 | 29-08-2000 |
| 503507 | 192 | lenswood | 16.8 | 19-03-1972 | 29-08-2000 |
| 503508 | 190 | Inverbrackie | 8.4 | 18-05-1972 | 14-09-2000 |
| 503509 | 193 | Aldgate | 7.4 | 14-07-1972 | 05-09-2000 |
| 503526 | 202 | Cox Ck | 5.5 | 24-06-1976 | 01-01-2001 |
| 503530 | 191 | Kerber | 1.0 | 31-07-1987 | 07-11-1989 |

Model calibration within *Watercress* is an iterative process that involves adjustment of input parameters for each simulation run until a good correlation can be obtained between the simulated catchment runoff and the gauged streamflows. This is carried out by comparing the plots of the modelled and the actual streamflows in daily, monthly and annual time series. In addition to the plots, the *WaterCress* program allows the statistical analysis of the modelled and the actual streamflows in these time frames. Calibration performance is indicated by attaining high values for R-squared and Coefficient of Efficiency set.

## Catchment characteristic set

In the hydrological model for rural catchment nodes, (WC-1 runoff model) there are 10 input parameters required for the model. They are:

- Median soil moisture
- Interception store
- Catchment distribution
- Groundwater discharge
- Soil moisture discharge
- Pan factor soil
- Fraction groundwater loss
- Store wetness multiplier
- Groundwater recharge fraction
- Creek loss

These 10 parameters form a "catchment characteristic set". To simplify the calibration process, among these parameters, the Pan factor, Store wetness multiplier and Groundwater recharge fraction are fixed at 0.65, 0.85 and 0.3 respectively. Soil moisture discharge is set in the range between 0.00001-0.0001. The parameters widely adjusted for calibration are the Median Soil Moisture, Interception Store and Catchment Distribution. They represent the median soil moisture holding capacity of a soil mass, the maximum initial interception from rainfall before runoff can be generated and the variation of the soil moisture capacities around the median value.

For calibration purposes, with the exception of the Houlgrave catchment, it is assumed that a gauged catchment would exhibit only one "catchment characteristic set". The catchment characteristic sets of the calibrated catchments are shown in Table 13 and relate to a particular landuse and/or geology.

As Hougrave is a large catchment (321 $km^2$), it is logical to consider that it would exhibit a number of catchment characteristic sets to be selected from the existing calibrated gauged catchments. In order to correlate these catchment characteristics, landuse and soil survey information from the respective catchments were examined. For instance, Lenswood catchment is considered to be mainly horticulture, Echunga and Baker Gully catchments are predominantly grazing, Inverbrackie catchment is general grazing with particularly rocky landscape, Aldgate catchment is mainly urban while Cox catchment is a mix of urban and horticulture. For Scott Creek catchment, it is mainly natural landscape with large reserve land. Burnt Out Creek catchment is a very small catchment (0.56 $km^2$) planted with pine trees. (It was modelled and calibrated separately as a stand alone model).

## Dam information

Dam water usage input into the model was taken as 30% (i.e. 0.3 fraction of sotrage) and the irrigation was assumed to occur during the summer months (i.e input distribution for the model is type 3). See the section on Modelling Runoff Simulations.

## Calibration Results

Calibration for the Onkaparinga model is considered to be reasonably good as reflected in the statistical values of R-squared and Coefficient of Efficiency set shown in Table 13 for the gauged catchments, particularly the Houlgrave Weir catchment. The R-squared value is in the 0.90s range and the Coefficient of Efficiency in the 0.80s range.

Model simulation produced better calibration for monthly and annual runoff than the daily flows. Extreme events such as high and low rainfall intensity are not well handled by a daily rainfall runoff model. The WaterCress model relies on the input of rainfall in daily time steps, which tells little about the rainfall intensity. In reality, rainfall can happen in a short burst of thunderstorm causing a spike in streamflow. As a result, the peak flow and the recession part of streamflow is difficult to calibrate.

The groundwater discharge, conveyance losses and baseflow characteristic of a stream can add an additional dimension of difficulties which are not easily simulated by the model. From experience, calibration in the low flow regime is particularly difficult to handle. The approach adopted was to fine-tune the routing node parameters, groundwater discharge, soil moisture discharge, fractional groundwater loss and creek losses.

Plots of modelled daily, monthly and annual catchment flows against the gauged records of Houlgrave weir catchment (diversion from the River Murray is excluded) can be found in Appendix C. Plots for other gauged catchment calibrations are also provided in the Appendix. It also contains a plot of annual catchment yield at Clarendon weir from 1900-1998, modelled with the impact of Mt Bold reservoir removed from the runoff simulation. The plot compares well with that produced by Tomlinson (1996) who derived the catchment yield from water balance method assuming Mt Bold reservoir did not exist.

It is intended that the model is to be used to determine the effects of farm dams on catchment yields, which would normally be reported in terms of monthly and annual flows. The model calibration results confirm the suitability of the model for this purpose.

Table 13 contains three parts:

1) model calibrated parameter
2) dam information
3) calibration statistics

## Table 13. The Statistics of the Calibrations for the Gauged Catchments

| (1) Parameter | Cox Ck | Aldgate Ck | Scott Ck | Burnt Out Ck | Lenswood or Cock Ck | Echunga Ck | Kerber Ck | Inverbrackie | Baker Gully | Houlgrave Weir |
|---|---|---|---|---|---|---|---|---|---|---|
| Available Records (with gaps) | 24/6/76 to 1/1/00 | 14/7/72 to 5/9/00 | 28/3/63 to 1/8/00 | 13/1/78 to 16/11/88 | 19/3/73 to 29/8/00 | 23/3/73 to 29/8/00 | 31/7/87 to 7/11/89 | 18/5/72 to 14/9/00 | 12/4/69 to 2/8/00 | 18/4/73 to 11/7/00 |
| Revision No. | 10 | 16 | 35(a) | 3 | 8 | 12 | 11 | 31 | 19 | 8 |
| Start Year | 1976 | 1972 | 1982 | 1978 | 1972 | 1975 | 1987 | 1974 | 1970 | 1974 |
| Over ( Year) | 24 | 28 | 17 | 12 | 28 | 25 | 3 | 22 | 18 | 26 |
| Daily | 1995 | 1995 | 1994 | 1980 | 1995 | 1990 | 1987 | 1993 | 1980 | 1990 |
| Over (Year) | 5 | 5 | 5 | 8 | 5 | 8 | 2 | 5 | 8 | 8 |
| Node No. | 202 | 193 | 196 | N/a | 192 | 194 | 191 | 190 | 195 | 101 |
| Catchment Characteristic Set | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Mixed |
| Model Type | WC–1 | WC–1 | WC–1 | WC–1 | WC–1 | WC–1 | WC–1 | WC–1 | WC–1 | WC–1 |
| Parameters Required | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Median Soil Moisture MSM | 190 | 220 | 220 | 242 | 115 | 220 | 180 | 110 | 197 | |
| Interception Store IS | 14 | 15 | 18 | 22 | 14 | 17 | 17 | 14 | 17 | |
| Catchment Distribution CD | 41 | 60 | 60 | 60 | 41 | 50 | 50 | 45 | 40 | |
| Groundwater Discharge GWD | 0.01 | 0.3 | 0.02 | 0.01 | 0.03 | 0.01 | 0.01 | 0.03 | 0.01 | |
| Soil Moisture Discharge SMD | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00005 | 0.00004 | 0.00004 | 0.00003 | 0.00003 | |
| Pan Factor Soil PF | 0.65 | 0.65 | 0.5 | 0.65 | 0.65 | 0.5 | 0.65 | 0.65 | 0.65 | |
| Fraction Groundwater Loss FGL | 0.2 | 0.3 | 0.3 | 0.3 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | |
| Store Wetness Multiplier SWM | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | |
| Groundwater Recharge Fraction GW | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | |
| Creekloss CL | 0.002 | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 | 0.002 | |

| ( 2 ) Dam Information | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Input Annual as Fraction of Storage | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Input Distribtion | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| ( 3 ) Statistics | | No. of Samples | R Square | Coeff of Efficiency | Variation of CV | Std Error of Estimate | % Diff in Volume |
|---|---|---|---|---|---|---|---|
| Cox Ck | | | | | | | |
| | Daily | 1830 | 0.69 | –0.23 | 0.61 | 225 | –4.97 |
| | Monthly | 207 | 0.92 | 0.82 | 0.1 | 4363 | –1.77 |
| | Annual | 12 | 0.72 | 0.06 | 0.41 | 127000 | –1.23 |
| Aldgate Ck | | | | | | | |
| | Daily | 1830 | 0.7 | 0.33 | 0.07 | 289 | 4.03 |
| | Monthly | 258 | 0.92 | 0.84 | –0.1 | 7071 | –3.26 |
| | Annual | 16 | 0.79 | 0.57 | 0.014 | 161734 | –0.43 |
| Scott Ck | | | | | | | |
| | Daily | 1810 | 0.76 | 0.52 | –0.019 | 500 | –0.6 |
| | Monthly | 192 | 0.92 | 0.85 | –0.04 | 13080 | 0.31 |
| | Annual | 11 | 0.88 | 0.78 | –0.08 | 241000 | 0.035 |
| Burnt Out Ck | | | | | | | |
| | Daily | 2884 | 0.66 | –1.2 | 0.83 | 6 | 6.4 |
| | Monthly | 140 | 0.78 | 0.45 | 0.19 | 260 | –1.7 |
| | Annual | 9 | 0.79 | 0.62 | –0.14 | 5800 | –6.14 |
| Lenswood or Cock Ck | | | | | | | |
| | Daily | 1830 | 0.81 | 0.52 | 0.04 | 526 | 12.18 |
| | Monthly | 264 | 0.94 | 0.87 | –0.03 | 11900 | –8.8 |
| | Annual | 19 | 0.84 | 0.68 | 0.01 | 247787 | –4.25 |
| Echunga Ck | | | | | | | |
| | Daily | 2470 | 0.81 | 0.6 | 0.01 | 663 | 3.26 |
| | Monthly | 259 | 0.93 | 0.85 | –0.06 | 15046 | –10.3 |
| | Annual | 13 | 0.96 | 0.92 | –0.04 | 186435 | –4.9 |
| Kerber Ck | | | | | | | |
| | Daily | 628 | 0.58 | 0.26 | –0.1 | 400 | –6.04 |
| | Monthly | 27 | 0.83 | 0.67 | –0.05 | 1040 | –15.1 |
| | Annual | 3 | 0.94 | 0.82 | 0.06 | 9100 | –12.6 |
| Inverbrackie | | | | | | | |
| | Daily | 1830 | 0.74 | 0.45 | –0.32 | 150 | 57.6 |
| | Monthly | 253 | 0.89 | 0.78 | –0.14 | 5460 | –6.3 |
| | Annual | 17 | 0.88 | 0.76 | –0.19 | 91700 | –0.71 |
| Baker Gully | | | | | | | |
| | Daily | 2896 | 0.69 | 0.37 | 0.06 | 930 | –5.4 |
| | Monthly | 216 | 0.88 | 0.77 | –0.16 | 24400 | –0.17 |
| | Annual | 13 | 0.9 | 0.8 | –1.34 | 376400 | –0.37 |
| Houlgrave Weir | | | | | | | |
| | Daily | 2928 | 0.92 | 0.84 | –0.06 | 4300 | 9.4 |
| | Monthly | 311 | 0.94 | 0.88 | –0.11 | 147900 | –4.5 |
| | Annual | 25 | 0.93 | 0.86 | –0.1 | 2331100 | –2.24 |

N/a: Burnt out creek was modelled and calibrated separately

## *Modelling Runoff Simulations*

This section contains information on:

1 setting the current and future modelling scenarios with conditions applied to the scenarios

2 modelling runoff simulations for

- the short term situations to establish the rainfall-runoff relationships and the impact on water supply, and
- the long term situations to study the impact catchment yield at 16 major subcatchments, Houlgrave Weir and Clarendon Weir catchments respectively.

### Setting the current and future scenarios

Runoff simulation is applied with the following scenarios to study the impact of farm dam development on the Onkaparinga River catchment:

Scenario 1 (WFD): With farm dams. This is the scenario using 1999 farm dams data. The aggregated dam storage is 8500ML.

Scenario 2 (WOFD): Scenario 2 provides an assessment of the catchment yield as if **no farm dams** existed in the catchment (ie. with the impact of farm dams removed). This catchment yield is not the pre-European natural catchment runoff as the model uses the current land use conditions for flow calibration and runoff simulations. Hence the flow generated under this scenario is termed the "*adjusted*" flow rather than the natural flow.

Scenario 3 (S20): This scenario assumes the current storage (8500 ML) is increased by 200% of the incremental increase storage between 1987 and 1999 which gives a total storage of 10.2 GL . It would take 10 years to reach this volume if the farm dams development were to continue in a rate of 150 ML/yr as stated in the earlier "Trend in farm dams development" Section. (Note: other conditions applied in the derivation of dam storage as explained in the later paragraph)

Scenario 4 (5%RF): This scenario represents the maximum allowable farm dam developments based on the current 50% management rule (i.e. dam size can be constructed up to 50% of 10% annual rainfall or simply 5% of rainfall). To achieve this state of development, the current aggregated storage is raised to 5% of catchment annual rainfall with a total volume of 18.7 GL. Assuming farm dams development is increasing at a rate of 150 ML/yr, this would take approximately 70 years to reach this volume. (other conditions also applied as explained later).

Scenario 5 (30%RL): This scenario assumes the maximum allowable farm dam developments is 30% of the catchment median adjusted runoff. This is the proposed allowable farm dam development policy for the Eastern Mount Lofty Ranges. Hence for the scenario, the current aggregated storage is raised to 30% of median annual adjusted*[7] catchment yield with a total volume of 18.7 GL (again, other conditions applied as explained later).

[7] * the adjusted catchment yield is that yield with the impact of farm dams removed from the catchment

Scenario 6 (50%RL): The current aggregated storage is raised to 50% of median annual adjusted* catchment flow with a total volume of 29.4 GL. This is the 50% rule scenario as stated in the State Water Plan 2000, Vol 1 pp 50. At a rate of 150 ML/yr in farm dams development, this would take 140 years to reach the volume.

(* adjusted yield is that runoff generated with the impact of farm dams removed but using existing land use scenario)

The scenarios represent a range of conditions from present to the ultimate condition which are assumed to be constrained by specific policy rules, which limit the amount of storage on the catchment. These are explained in the following paragraphs. The economic capacity of the catchment to support further dam development has not been considered.

The spatial distribution of the additional storage identified in the scenarios is not considered to be uniformly distributed across the catchment, but considers the likelihood that any given area might be dammed. Areas identified as unsuitable due to presence of conservation reserves or incompatible landuse have been identified by McMurray (2002). A potential dam development factor (Dla_pc) is applied to each subcatchment node to take into account the catchment areas where farm dam development is unlikely. This factor effectively weights the proportion of potential development across each sub area of the catchment.

For scenarios 4, 5 and 6 the storage volume in each sub catchment is simply calculated by raising storage to the rules defined but limited by the potential dam development factor. Where a subcatchment is found to already exceed the scenario limit, the actual farm dam volume is retained in the model.

The derivation of allowable storage for the scenarios 3 –6 is as follows:

Scenario 3 (S20):

The existing farm dam storage were factored up using the formulae:

$$Dam\ storage = Current\ dam\ volume + \frac{Catchment\ node\ area}{Onka\ River\ catchment\ area} * Dla\_pc * 2400$$

The constant 2400 ensures the aggregated dam storage of the total catchment equals the intended volume 10.2 GL for ten years project of dam development.

Scenarios 4 (5%RF):

$$Dam\ storage = Catchment\ node\ area * Dla\_pc * 5\%\ of\ the\ catchment\ rainfall$$

Scenarios 5 (30%RL):

$$Dam\ storage = \frac{Catchment\ node\ area}{The\ major\ sub-catchment\ area} * Dla\_pc * \mathbf{30\%}\ of\ the\ median\ annual\ adjusted\ flow$$

Scenarios 6 (50%RL):

$$Dam\ storage = \frac{Catchment\ node\ area}{The\ major\ sub-catchment\ area} * Dla\_pc * \mathbf{50\%}\ of\ the\ median\ annual\ adjusted\ flow$$

In addition to total storage, three other considerations, annual usage, distribution of monthly usage, and free to flow distribution will significantly affect the impact of farm dam storage on streamflow.

The annual usage is highly significant, as can be the distribution of monthly usage across the year that this water is taken.

As little is currently known of the usage in the Mt Lofty watershed, three differing annual usage rates, namely 30%, 50% and 70% of storage were considered for each storage scenario. The usage percentages are based on what is believed to be likely range of use within the Mt Lofty Ranges. The lower bound, 30%, represents a usage rate where there will be significant carry over of stored water to the following year. The upper bound, 70%, given summer evaporation and numerous years where there would have been insufficient streamflow to fill the dam, represents the maximum volume of water achievable.

Therefore, each farm dam development scenario would generate three cases of catchment runoff simulations with varying annual water use. A total of 16 cases of runoff simulations were therefore carried out.

For runoff simulation, scenario 1 (**1999 data**) modelled with **30%** of dam storage use is considered as **the current farm dams development scenario** from which the model is calibrated. While little information is currently available regarding the usage of water from farm dams, reference to past aerial photography indicate that significant volumes of water remain in the storages following the irrigation season. For this reason 30% use, as an average throughout the entire catchment, has been considered to be the current level of use and greater percentages represent increasing irrigation development toward the ultimate conditions.

Within the model, the distribution of monthly usage drawn from dam storage was considered to be the same for all cases of runoff simulation. It was modelled with the assumption to best describe the typical usage in the Mt Lofty Ranges, when irrigation occurred mostly in summer months. The monthly usage factor, as a fraction of the annual usage, is shown below:

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Factor** | 0.21 | 0.25 | 0.20 | 0.11 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | 0.16 |

As farm dams are unlikely to be developed with a constant distribution across the catchment there will be regions where dam development is high and conversely areas of the catchment which are free to flow. Within the hydrological model, off-stream dam nodes have been incorporated to simulate this condition with varying degree of diversion. The incorporation of off-stream dams gives the user the ability to control the volume of streamflow being trapped in storage. For scenarios 3 – 6 as additional farm dam development is added, the diversion of streamflow to the off-stream dam nodes is not allowed to exceed two-thirds of the catchment runoff. If the current development scenario has already exceeded this diversion value then the current scenario is retained.

The fraction adopted of two thirds is arbitrarily estimated assuming that the proportion of the catchment that is free to flow will likely be controlled by other policy. The Water allocation plan developed for the Clare Valley limits the reduction in the free to flow area to 50%. It is suggested that the 2/3 as adopted in this study is ~~as~~ a maximum level of impact that could be accepted, and therefore in the study represents the upper bound of impacts of the future scenarios.

Table 14 shows the aggregated dam storage of individual major subcatchments under the different scenarios. The aggregated dam storage (upstream of Noarlunga gauging station) for scenario 3 is about 20% higher than the current farm dam volume, for scenarios 4 and 5, it is 2.2 times the current volume, and scenario 6 is 3.5 times. Note that the allowable 50% rule farm dam development equates to a reduction of approximately 37% of the catchment median flow due to conditions attached to the set up of the hypothetical scenario. A farm dam development of 5%

catchment rainfall has aggregated dam storage approximately equal to the 30% of catchment median flow scenario.

## Modelling runoff simulations

Modelling runoff simulations were carried out in two ways: one for the short-term runoff simulation for the duration where gauged streamflow information was available; the other for the long-term simulation from 1900 to 1998.

A. The purpose of the *short-term* simulation was two fold:

- To study the rainfall-runoff relationship of gauged catchments where this information would be useful for an assessment of runoff in a similar catchment where only rainfall records were available. Hence runoff simulations were limited to the gauged areas only. In this case, only the current scenario (with 1999 farm dam development or scenario 1 and 30% dam storage use) was modelled.
- To assess the impact of farm dams development on the water supply into the Mt Bold and Clarendon Weir reservoirs.

  To quantify the impact, the current scenario was used as the baseline. Any reduction in the inflows into Mt Bold and Clarendon weir reservoirs from the baseline as a result of increasing farm dams development was then assumed to equate to the volume of additional pumping required from the River Murray.

  Simulation for the current scenario used a combination of ungauged catchments with current scenario parameters and gauged catchments with streamflows records as input for the model. The gauged catchments applied to all of Houlgrave weir (less pumpage), and most of Echunga and Scott Creek catchments. Hence the model, with the water supply system incorporated in it, virtually used all the real flow data for the simulation of the current scenario.

  Historical water use data from the Happy Valley Reservoir, Myponga Reservoir, the Onkaparinga Valley Scheme and the pumpage of inter-basin water transfer from the River Murray into Mt Bold reservoir were inputs into the model.

  Model simulation was carried for the period from 1975-1998. Flow simulations were performed for the model such that the Mt Bold and Clarendon weir reservoirs would be allowed to fill to its full supply level whenever water was available. This is by no means reflecting the true operations of the Mt Bold Reservoir. Nevertheless, when the model was simulated with current scenario for the period 1986-1998 using the water supply system set up in this manner, it appears to replicate well with the historical Mt Bold reservoir storage level of this period, except 1994 when the reservoir was emptied for maintenance. (Refer Figure 39 in Appendix C). Refinement to the results of model simulations is possible if the operating rules to the water supply system can be established and incorporated into the model.

  The other farm dams development scenarios were also modelled, each with farm dams storage use at 30%, 50% and 70% level to study the sensitivity of dam usage impacting on the water supply. The results of simulated inflows into the Mt Bold reservoir and the Clarendon weir reservoirs were compared with that of the current scenario. Any reduction in the runoff was treated as a shortfall to be compensated from additional pumping from the River Murray. (See Tables 28-30).

B. The *long-term* runoff simulations provide a better understanding of the catchment runoff for individual catchments on a wide range of climatic conditions varying from an average year to the extreme situation such as a series of wet or dry years. This provides a reasonable assessment of the risk factor associated with the unpredictable climate for farm dams development over the long term within the studied catchment. Daily rainfall data between the period 1900 to 1998 were used for modelling each scenario listed earlier. With the exception of scenario 2, each scenario was modelled with dam storage use of 30%, 50% and 70%. Again this was to check the sensitivity of the water usage from dams on the catchment yield. Modelling and interpretation of the output results for the respective catchments were carried out for:

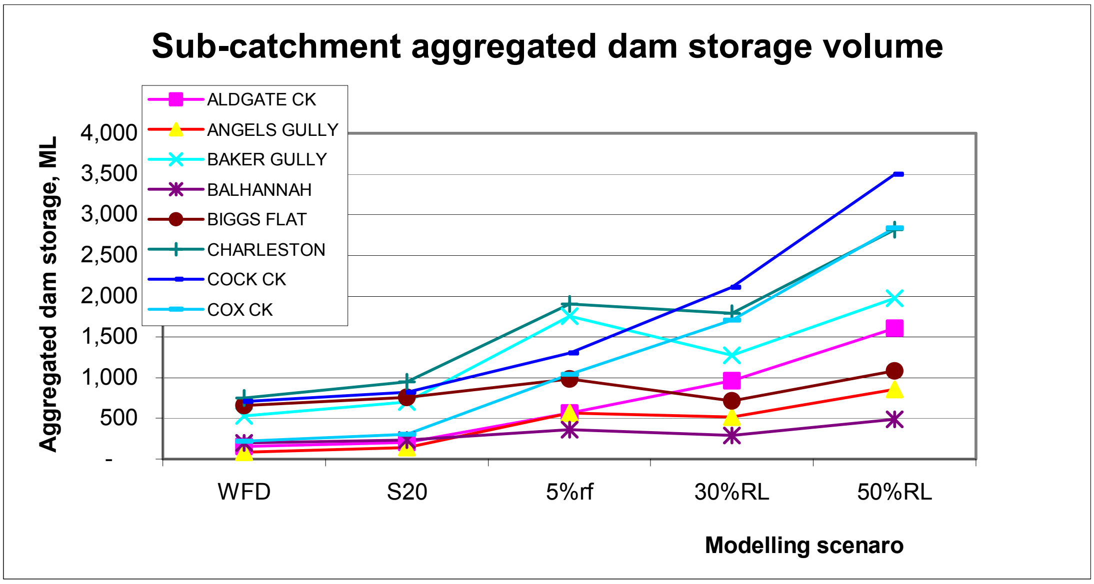
- Each of the 16 major subcatchments
- Houlgrave Weir catchment
- Clarendon Weir catchment. In this case, Mt Bold Reservoir was removed from the model runoff simulations. This was to assess the available quantity of surfacewater within the catchment if not impacted by the reservoir.

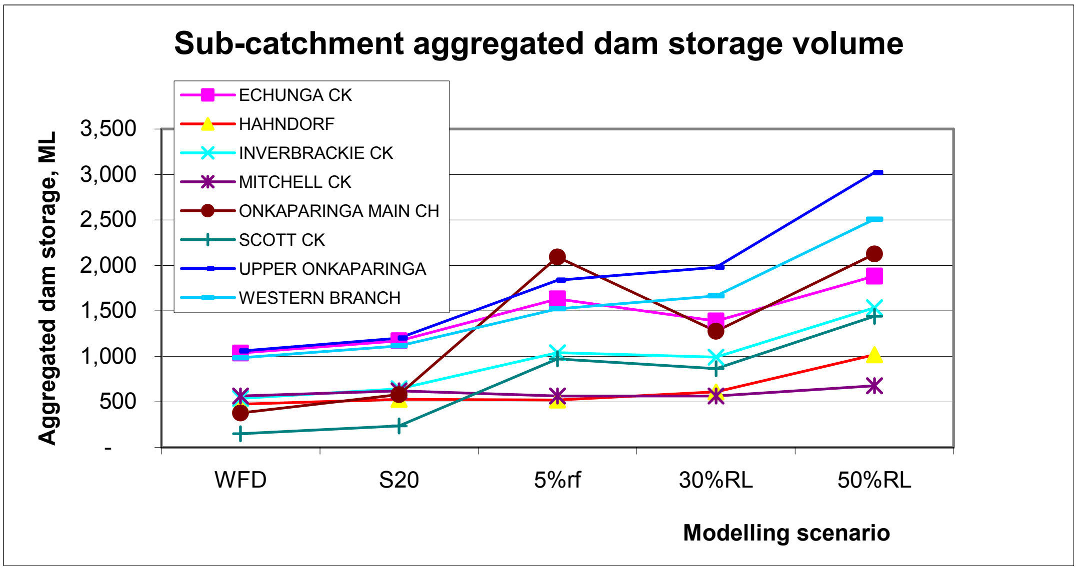
Results of each runoff simulation were presented on three climatic conditions, namely in a median year, a dry period and a wet period condition:

- Flow occurring in a median year means that it represents an average year condition. It is taken as the median flow for the period between 1990-1998.
- Flow occurring in a dry-period means that it is the average flow of a defined 3-year dry period. It represents flow in the driest condition for the last 100-year situation. The defined dry-period is derived from the lowest annual rainfall of the 3-year moving average. In this case, the dry-period occurred from 1912-1914.
- Flow occurring in a wet-period means that it is the average flow of a defined 3-year wet period. It represents the flow in the wettest condition in the last 100-year situation. The defined wet-period is derived from the highest annual rainfall of the 3-year moving average. In this case, the wet-period occurred from 1915-1917.

## Table 14. Aggregated Dam Storage for Different Scenarios

| Subcatchment | *WFD ML* | S20 ML | 5%rf ML | 30%RL ML | 50%RL ML |
|---|---|---|---|---|---|
| Aldgate Ck | 159 | 203 | 570 | 963 | 1,605 |
| Angels Gully | 82 | 139 | 567 | 514 | 857 |
| Baker Gully | 530 | 703 | 1,758 | 1,275 | 1,978 |
| Balhannah | 197 | 234 | 362 | 292 | 487 |
| Biggs Flat | 660 | 758 | 986 | 717 | 1,080 |
| Charleston | 748 | 949 | 1,902 | 1,793 | 2,819 |
| Cock Ck | 710 | 824 | 1,305 | 2,112 | 3,500 |
| Cox Ck | 221 | 304 | 1,043 | 1,704 | 2,841 |
| Echunga Ck | 1,038 | 1,173 | 1,631 | 1,389 | 1,881 |
| Hahndorf | 476 | 527 | 521 | 611 | 1,018 |
| Inverbrackie Ck | 538 | 645 | 1,040 | 992 | 1,535 |
| Mitchell Ck | 566 | 621 | 566 | 566 | 679 |
| ONKAPARINGA MAIN CH | 377 | 582 | 2,091 | 1,276 | 2,126 |
| Scott Ck | 148 | 235 | 974 | 865 | 1,441 |
| Upper Onkaparinga | 1,060 | 1,203 | 1,838 | 1,981 | 3,022 |
| Western Branch | 985 | 1,115 | 1,524 | 1,666 | 2,507 |
| **Grand Total** | **8,495** | **10,215** | **18,675** | **18,715** | **29,377** |


Sub-catchment aggregated dam storage volume
ALDGATE CK
ANGELS GULLY
BAKER GULLY
BALHANNAH
BIGGS FLAT
CHARLESTON
COCK CK
COX CK
Aggregated dam storage, ML
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
WFD
S20
5%rf
30%RL
50%RL
Modelling scenaro


Sub-catchment aggregated dam storage volume
ECHUNGA CK
HAHNDORF
INVERBRACKIE CK
MITCHELL CK
ONKAPARINGA MAIN CH
SCOTT CK
UPPER ONKAPARINGA
WESTERN BRANCH
Aggregated dam storage, ML
3,500
3,000
2,500
2,000
1,500
1,000
500
-
WFD
S20
5%rf
30%RL
50%RL
Modelling scenario

# RESULTS AND DISCUSSIONS

## *Rainfall Runoff Relationship*

### Modelling using current scenario.

Rainfall-runoff relationship of a gauged catchment can be developed by plotting the annual rainfall versus the catchment runoff. This relationship can be expressed as a Tanh curve equation. With modification to the equation expressed by Grayson R.B. et al (1996), using an addition of two constant values "a" and "b", the general form Tanh curve equation for a gauged Onkaparinga River catchment can be provided as below:

Tanh curve runoff, $Q = a \times [P - L] - b \times F \times Tanh \frac{(P - L)}{F}$

Where

a, b are constants and equal to 0.72 and 0.75 respectively

Q, discharge (mm)

P, precipitation (mm)

L, notional loss (mm)

F, notional infiltration (mm)

The values for a, b, L and F were derived by trial and error so that the best smooth curve can be plotted by eye through the points. Prior to the inclusion of parameters a and b, it was found that the derived values for L and F introduced many inconsistencies. This made useful comparison between the catchments difficult. These problems were overcome by the addition of two constants a and b into the equation. The resulting L and F values are shown in Table 15. As South Australian streams are more likely to exhibit arid or semi-arid flow characteristics, it is felt the format of Tanh curve proposed by Grayson et al (1996) may require further examination to its suitability application in this region.

Annual rainfall runoff relationships enable a quick assessment of the hydrological runoff characteristics of individual catchments. They have been commonly used in the past in Water Allocation Planning studies to identify limits to farm dam development. In 1987, Clark produced similar rainfall runoff relationship curves for a number of gauging stations in the Mt Lofty Ranges. This report, using a longer duration of gauged data currently available and with output from the hydrological model simulations, provides an update of his study.

Tanh curve rainfall-runoff relationship of a gauged catchment produced in this report was plotted with rainfall against the gauged and adjusted gauged flows. The gauged flow reflects catchment runoff with farm dams taken into account. The adjusted gauged flow assumes catchment runoff in a "natural" flow condition with the impact of farm dams removed. This is obtained by adding the volume of water trapped in farm dams to the gauged flow and hence is termed the *adjusted gauged flow* of the catchment. The trapped volume is obtained by taking the difference between the adjusted flow and the measured flow at a gauged station. The 'adjusted' or natural flow of a catchments was obtained from the model simulations with farm dams removed from the catchment.

A typical plot that compares the gauged and adjusted gauged streamflow (without the impact of farm dams) with respect to annual rainfall is shown in Figure 17 (Echunga Creek). A series of rainfall-runoff relationship curves for other gauged catchments is provided in Appendix D. The Tanh curve equations governing these curves are summarised in Table 15. It is noted that the impact of farm dams is seen as an increase in the notional loss factor L.

## Table 15. Factors for the Tanh Curve Equations

| Gauged Catchment | Gauged Flow | | Adjusted Gauged Flow | |
|---|---|---|---|---|
| | L (mm) | F (mm) | L (mm) | F (mm) |
| Aldgate | 230 | 380 | 200 | 380 |
| Bakers Gully | 260 | 450 | 235 | 450 |
| Clarendon weir | 230* | 435* | 210 | 435 |
| Cox ck | 230 | 450 | 210 | 450 |
| Echunga ck | 345 | 480 | 325 | 480 |
| Houlgrave weir | 260 | 450 | 235 | 450 |
| Inverbrackie ck | 230 | 380 | 210 | 380 |
| Lenswood ck | 230 | 460 | 200 | 460 |
| Scott ck | 280 | 470 | 265 | 470 |

* denotes modelled flow for the period 1900-1998 with current farm dam development condition.

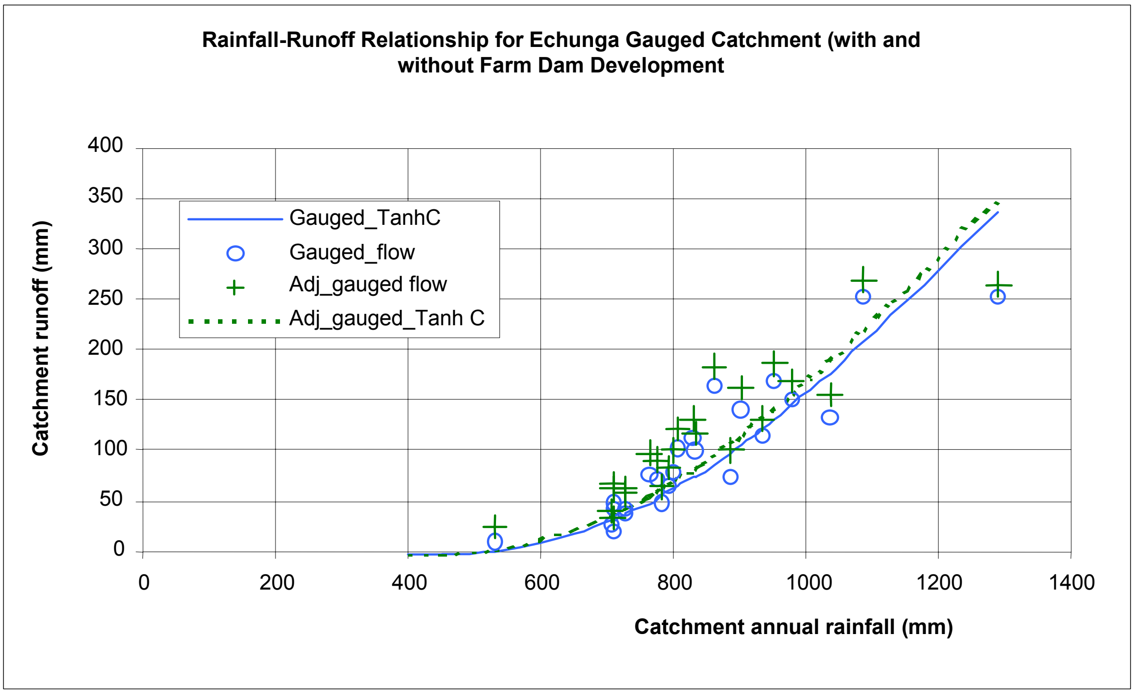
Table 16 quantifies the impact of current farm development on the gauged catchments where the adjusted gauged flow is the flow with farm dams removed from the model. It is noted that of all the available gauged stations, only Inverbrackie and Echunga gauged stations show a significant impact from farm dam development with 16% of runoff trapped in storage. However these percentages could be greater if the current usage exceeds 30% of storage volume.

## Table 16. Mean Gauged and Mean Adjusted Gauged Flow

| Gauged Catchment | Period | Mean Gauged Flow | * Mean Adjusted Gauged Flow | Percentage Trapped |
|---|---|---|---|---|
| Aldgate | 1973-1998 | 2505 | 2547 | 2 |
| Bakers Gully | 1970-1986 | 4496 | 4855 | 7 |
| Cox ck | 1976-1998 | 1486 | 1500 | 1 |
| Echunga ck | 1975-1998 | 3324 | 3971 | 16 |
| Houlgrave weir | 1974-1998 | 52645 | 56788 | 7 |
| Inverbrackie ck | 1974-1998 | 929 | 1100 | 16 |
| Lenswood ck | 1972-1998 | 3951 | 4228 | 7 |
| Scott ck | 1982-1998 | 3546 | 3592 | 1 |

* assumed usage 30% of storage

**Figure 17. Rainfall Runoff Relationship for Echunga Gauged Catchment (with and without farm dam development: 1975–1998)**




## *Impact of Farm Dams on Individual Catchments (1900-1998)*

Runoff simulations were performed on individual catchments, each “with dams” scenario, for the three levels of assumed water use (30%, 50% & 70%) from the dams. Catchment yields were then calculated for these cases.

Runoff volumes from Scenario 2 – the “without dams” case were subtracted from each case to estimate the effect of farm dams on yields. The reduction in yield was expressed as a percentage of the adjusted flow (ie scenario 2). The results are presented below and are categorised into wet, dry or average periods.

### Current scenario

Modelling was carried out using 1999 farm dam data with 30% dam storage use. The results of the runoff simulations for the 16 subcatchments are summarised in Tables 17-19. Table 17 quantifies the median catchment yield (taken as the flow of a median year) with and without farm dam development in the 99-year period. Table 18 and 19 show the catchment yields during the extreme climate of dry (1912-1914) and wet (1915-1917) period. Figures 18-19 show the plots of the percentage catchment yield captured for these periods.

More details of the individual subcatchment yield impacts from farm dams in terms of the ANNUAL mean, median, 10$^{th}$ and 90$^{th}$ percentiles are provided in Appendix D. The 10$^{th}$ and 90$^{th}$ percentile catchment yields shown in the Appendix represent the 10% and 90% in the ranking of ANNUAL data. The catchment yield based on the 10$^{th}$ and 90$^{th}$ percentiles tends to produce more extreme events than indicated in the Tables 19-20.

## Table 17. The Impact of Farm Dams on Median Catchment Yield (1900-1998)

| Catchment Location | Area | Dam Storage (a) | Farm Dam Density | Median Rainfall | Median Adjusted Catchment Yield over the Period (b) | Yield Captured by Farm Dams | | Ratio a/b (50% rule) |
|---|---|---|---|---|---|---|---|---|
| | km² | ML | ML/ km² | mm | ML | ML | % | % |
| Aldgate Creek | 19.5 | 159 | 8.16 | 1,097 | 6,058 | 104 | 2 | 3 |
| Angels Gully | 14.1 | 83 | 5.86 | 810 | 1,842 | 76 | 4 | 5 |
| Bakers Gully | 48.0 | 530 | 11.05 | 725 | 4,498 | 408 | 9 | 12 |
| Balhannah | 10.2 | 197 | 19.24 | 809 | 1,146 | 115 | 10 | 17 |
| Biggs Flat | 23.7 | 660 | 27.91 | 829 | 2,218 | 379 | 17 | 30 |
| Charleston | 51.5 | 748 | 14.52 | 807 | 6,118 | 520 | 8 | 12 |
| Cox Creek | 28.8 | 221 | 7.68 | 975 | 8,480 | 139 | 2 | 3 |
| Echunga Creek | 39.2 | 1,038 | 26.51 | 868 | 4,237 | 571 | 13 | 25 |
| Hahndorf | 14.7 | 476 | 32.40 | 851 | 2,513 | 288 | 11 | 19 |
| Inverbrackie Creek | 26.7 | 538 | 20.12 | 783 | 3,267 | 218 | 7 | 17 |
| Lenswood Creek | 28.4 | 710 | 25.00 | 972 | 7,527 | 462 | 6 | 9 |
| Mitchell Creek | 14.5 | 566 | 38.99 | 783 | 1,525 | 300 | 20 | 37 |
| Onka Main Channel | 130.4 | 377 | 2.89 | 821 | 11,663 | 301 | 3 | 3 |
| Scott Creek | 28.5 | 148 | 5.19 | 891 | 4,059 | 47 | 1 | 4 |
| Upper Onkaparinga | 47.1 | 1,060 | 22.52 | 950 | 8,623 | 621 | 7 | 12 |
| Western Branch | 33.0 | 985 | 29.87 | 876 | 5,351 | 556 | 10 | 18 |

## Table 18. The Impact of Farm Dams on Catchment Yield During the Defined Dry Period (1912-1914)

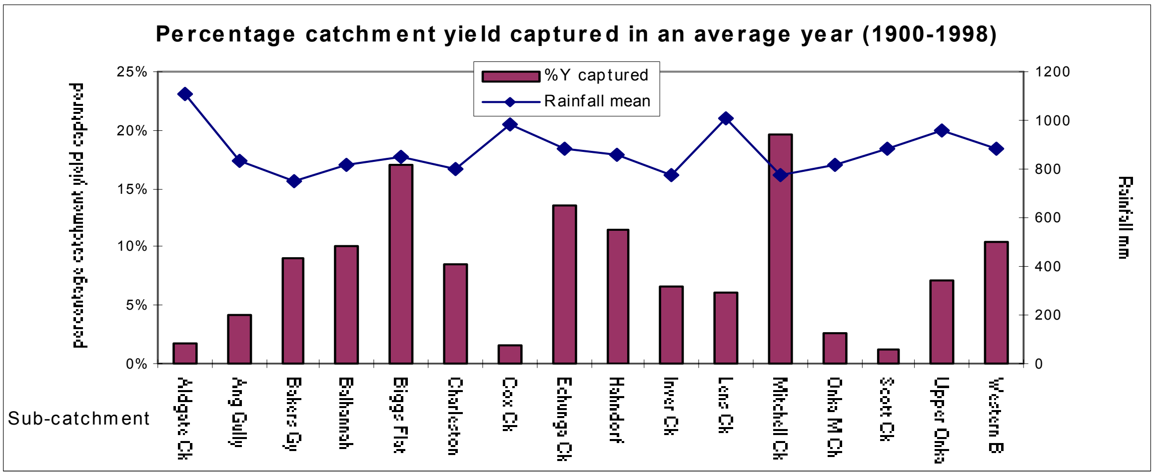
| Catchment Location | Area | Dam Storage (a) | Farm Dam Density | Rainfall (mean of 1912–1914) | Median Adjusted Catchment Yield over the Period (b) | Yield Captured by Farm Dams | | Ratio a/b (50% rule) |
|---|---|---|---|---|---|---|---|---|
| | km² | ML | ML/ km² | mm | ML | ML | % | % |
| Aldgate Creek | 19.5 | 159 | 8.16 | 853 | 2,839 | 95 | 3 | 6 |
| Angels Gully | 14.1 | 83 | 5.86 | 600 | 371 | 45 | 12 | 22 |
| Bakers Gully | 48.0 | 530 | 11.05 | 536 | 808 | 191 | 24 | 66 |
| Balhannah | 10.2 | 197 | 19.24 | 602 | 377 | 78 | 21 | 52 |
| Biggs Flat | 23.7 | 660 | 27.91 | 683 | 793 | 308 | 39 | 83 |
| Charleston | 51.5 | 748 | 14.52 | 640 | 2,923 | 339 | 12 | 26 |
| Cox Creek | 28.8 | 221 | 7.68 | 758 | 3,665 | 154 | 4 | 6 |
| Echunga Creek | 39.2 | 1,038 | 26.51 | 715 | 1,549 | 465 | 30 | 67 |
| Hahndorf | 14.7 | 476 | 32.40 | 633 | 925 | 173 | 19 | 51 |
| Inverbrackie Creek | 26.7 | 538 | 20.12 | 621 | 2,069 | 174 | 8 | 26 |
| Lenswood Creek | 28.4 | 710 | 25.00 | 720 | 3,692 | 414 | 11 | 19 |
| Mitchell Creek | 14.5 | 566 | 38.99 | 621 | 929 | 199 | 21 | 61 |
| Onka Main Channel | 130.4 | 377 | 2.89 | 589 | 3,142 | 239 | 8 | 12 |
| Scott Creek | 28.5 | 148 | 5.19 | 589 | 751 | 49 | 7 | 20 |
| Upper Onkaparinga | 47.1 | 1,060 | 22.52 | 714 | 3,197 | 421 | 13 | 33 |
| Western Branch | 33.0 | 985 | 29.87 | 651 | 2,871 | 411 | 14 | 34 |

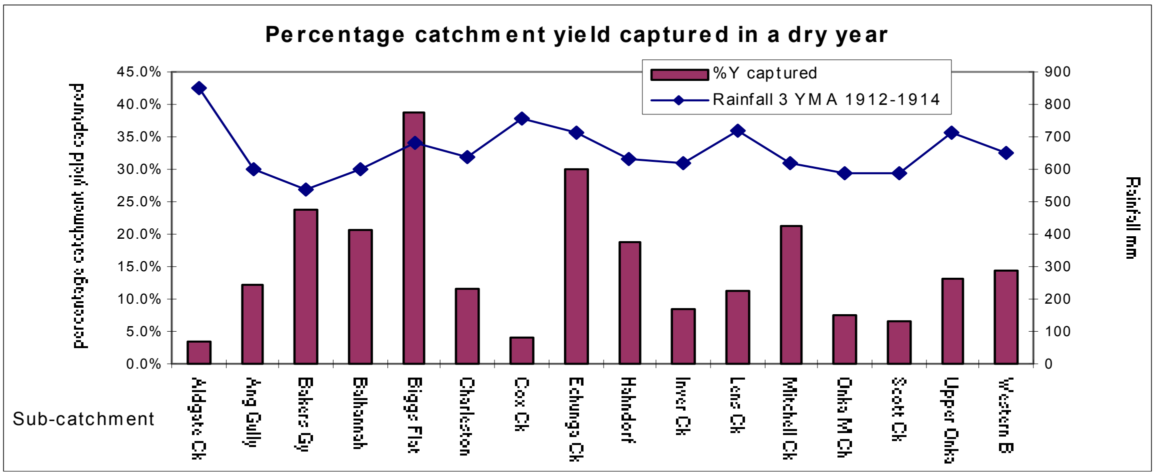
## Table 19. The Impact of Farm Dams on Catchment Yield During the Defined Wet Period (1915-1917)

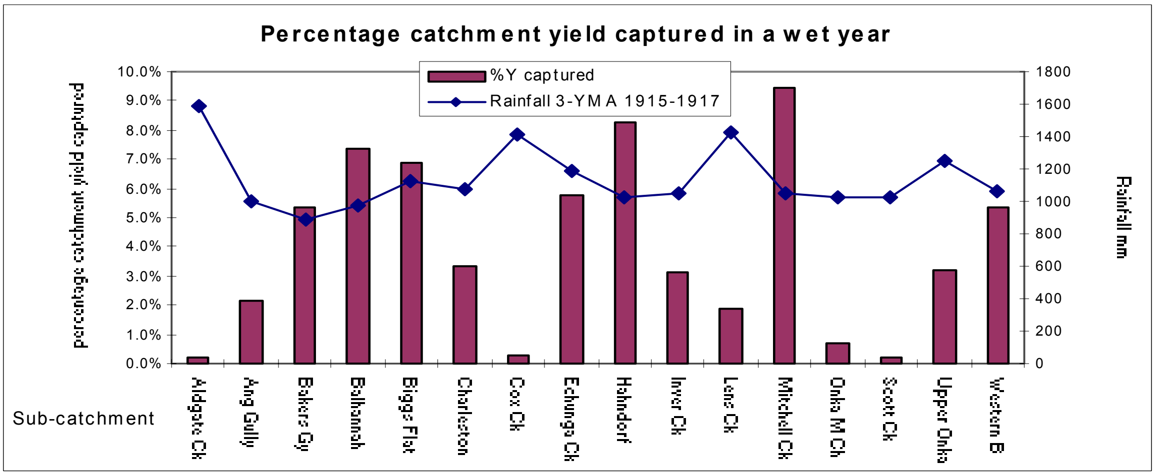
| Catchment Location | Area | Dam Storage (a) | Farm Dam Density | Rainfall (mean of 1915–1917) | Median Adjusted Catchment Yield over the Period (b) | Yield Captured by Farm Dams | | Ratio a/b (50% rule) |
|---|---|---|---|---|---|---|---|---|
| | km² | ML | ML/ km² | mm | ML | ML | % | % |
| Aldgate Creek | 19.5 | 159 | 8.16 | 1,590 | 12,415 | 26 | 0 | 1 |
| Angels Gully | 14.1 | 83 | 5.86 | 997 | 3,077 | 65 | 2 | 3 |
| Bakers Gully | 48.0 | 530 | 11.05 | 892 | 7,371 | 395 | 5 | 7 |
| Balhannah | 10.2 | 197 | 19.24 | 978 | 1,903 | 140 | 7 | 10 |
| Biggs Flat | 23.7 | 660 | 27.91 | 1,130 | 6,073 | 416 | 7 | 11 |
| Charleston | 51.5 | 748 | 14.52 | 1,078 | 14,707 | 485 | 3 | 5 |
| Cox Creek | 28.8 | 221 | 7.68 | 1,413 | 17,882 | 45 | 0 | 1 |
| Echunga Creek | 39.2 | 1,038 | 26.51 | 1,183 | 10,974 | 631 | 6 | 9 |
| Hahndorf | 14.7 | 476 | 32.40 | 1,028 | 3,841 | 318 | 8 | 12 |
| Inverbrackie Creek | 26.7 | 538 | 20.12 | 1,045 | 7,390 | 230 | 3 | 7 |
| Lenswood Creek | 28.4 | 710 | 25.00 | 1,423 | 15,020 | 281 | 2 | 5 |
| Mitchell Creek | 14.5 | 566 | 38.99 | 1,045 | 3,781 | 358 | 10 | 15 |
| Onka Main Channel | 130.4 | 377 | 2.89 | 1,022 | 23,737 | 159 | 1 | 2 |
| Scott Creek | 28.5 | 148 | 5.19 | 1,031 | 7,997 | 16 | 0 | 2 |
| Upper Onkaparinga | 47.1 | 1,060 | 22.52 | 1,251 | 16,950 | 546 | 3 | 6 |
| Western Branch | 33.0 | 985 | 29.87 | 1,059 | 10,737 | 571 | 5 | 9 |

From Table 17, in a median year, with current farm dam development, six subcatchments would have their median adjusted catchment yield reduced by 10% or more. Among them, Mitchell Creek is the most severely affected with 20% reduction in its adjusted natural flow. Not surprisingly, this catchment has the highest farm dam density of 39 $ML/km^2$ or an aggregated farm dam storage capacity of 570 ML.

## Figure 18. Percentage Catchment Yield Captured by Farm Dams in Subcatchments



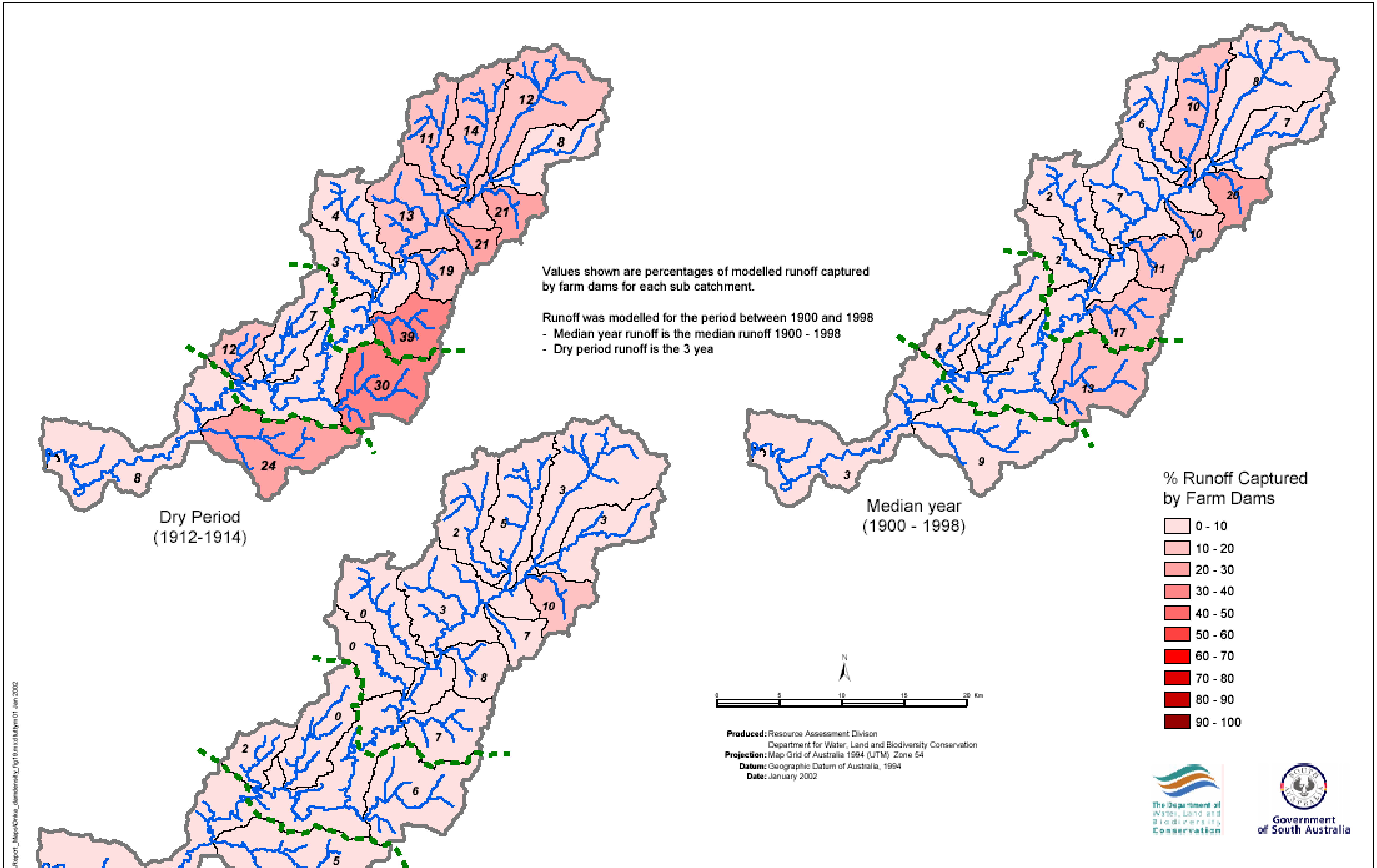



**Figure 19**

Seasonal Variation in modelled runoff captured by dams in the Onkaparinga Catchment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None of the catchments are seen to exceed the criteria of the 50% rule, which requires that the maximum allowable dam volume should not exceed 50% of the median annual adjusted runoff from a catchment. The ratio of dam storage to the adjusted catchment yield in Mitchell creek is 37%, as shown in the last column of Table 17. It is the highest found in the subcatchments of the Onkaparinga River.

Generally the runoff trapped in the subcatchment dam storage varies from around 1-2% of the annual rainfall.

The modelled runoff coefficient for the respective subcatchments can be derived easily by dividing the adjusted catchment yield by the catchment area and the median annual rainfall. As shown in Table 20, the runoff coefficient for the major subcatchments varies from 0.1 to 0.3 of the rainfall. On the high ends are Cox creek (0.3), Aldgate creek (0.28) and Lenswood (0.27). The lower ends are Biggs Flat (0.11), Onkaparinga Main Channel (0.11) Echunga (0.12) and Bakers Gully (0.13). The coefficients compare well with the streamflows of gauged catchments as shown in Table 5.

## Table 20. Runoff Coefficients

| Subcatchment | Area | Median Annual Rainfall * (mm) | Modelled Median Annual Adjusted Runoff (mm) | Modelled Runoff Coefficient |
|---|---|---|---|---|
| Aldgate Creek | 1,945 | 1,097 | 311 | 0.28 |
| Bakers Gully | 4,796 | 725 | 94 | 0.13 |
| Balhannah | 1,020 | 809 | 112 | 0.14 |
| Biggs Flat | 2,365 | 829 | 94 | 0.11 |
| Charleston | 5,151 | 807 | 119 | 0.15 |
| Cox Creek | 2,875 | 975 | 295 | 0.30 |
| Echunga Creek | 3,917 | 868 | 108 | 0.12 |
| Hahndorf | 1,468 | 851 | 171 | 0.20 |
| Inverbrakie Creek | 2,674 | 783 | 122 | 0.16 |
| Lenswood Creek (Cock Ck) | 2,833 | 972 | 265 | 0.27 |
| Mitchell Creek | 1,451 | 783 | 105 | 0.13 |
| Onkaparinga-48 (Angels Gully) | 1,408 | 810 | 131 | 0.16 |
| Onkaparinga Main Channel | 13,043 | 821 | 89 | 0.11 |
| Scott Creek | 2,850 | 891 | 142 | 0.16 |
| Upper Onkaparinga | 4,708 | 950 | 183 | 0.19 |
| Western Branch | 3,297 | 876 | 162 | 0.18 |
| Total | 55,801 | 856 | 142 | |

* Obtained from Onka WaterCress model.

Under extreme climatic condition such as the defined dry period (Table 18), the number of subcatchments with greater than 10% catchment yield captured by farm dams has increased from six to eleven. The highest percentage catchment yield captured is 39% in Biggs Flat. From Table 18, Mitchell creek is a few steps down the rank although it has the highest dam density. This may be explained in terms of the differences in the runoff coefficient between the subcatchments for different period of time. Although generally Mitchell Creek has a higher runoff coefficient than Biggs Flat, on a median year situation, the difference between these runoff coefficients is not large. Apparently Biggs Flat has a lower modelled runoff coefficient of 0.11 as compared with that of Mitchell creek 0.13. However, on a dry-period when rainfall is very low, the difference in these runoff coefficients become much more pronounce. Biggs Flat has runoff coefficient of 0.05 while Mitchell Creek 0.10. This indicates Mitchell Creek is generating more runoff and is less impacted by dams in the dry-period.

During the defined wet period, only one catchment, Mitchell Creek, has an impact exceeding 10%.

## Future Farm Dam Scenarios

Results of runoff simulation for scenario 1-6 with 50% and 70% dam storage use are presented in Tables 21-23.

Plots of farm dams development scenarios for the major subcatchments with 30%, 50% and 70% usage are presented in Appendix D. They briefly summarise the flow reduction with respect to the adjusted annual flow in the respective catchments for a median year, the defined dry-period and the wet-period situations. These flow reductions are presented in terms of percentage reduction in annual flow.

Naturally, with higher percentage of dam storage use, the dams can capture more runoff, as they are empty more quickly. In this case, for instance, using scenario 1 (WFD, ie. with 1999 farm dam data) the reduction in the adjusted flow for Mitchell Creek would increase from 20% to 35% in a median year (see Table 21) if dam storage use were from 30% to 70%. The same can be said for the defined dry period where the increased is from 21% to 37% (see Table 22). On the other hand, under the worst case scenario of "*50%RL*" situation, in a dry period the impact of farm dams would reduce the adjusted catchment flow by 43%. Interpretations of flow reduction in terms of the percentage of adjusted flow for other subcatchments are likewise shown in these Tables. The reduction in catchment runoff implies that less water will be available for Mt Bold reservoir storage hence impacting on public water supplies.

Note that the aggregated dam storage of a catchment is not the only factor that would affect the runoff simulations. Catchment runoff is also influenced by the allowable diversion of the off-stream dams set up in the model. In setting the future scenarios for this study, a degree of free flow is allowed in the catchment model nodes by limiting the diversion factor of off-stream dams to about two-thirds if they have not already exceeded this factor in the initial construction of the model (current scenario). Without putting a ceiling to the diversion factor, the dams may trap all the adjusted flow. This could be the reason why Angels Gully subcatchment traps 99% of the adjusted flow in the defined dry period (Table 22) as the subcatchment was set up in the model with on-stream dams only.

## Table 21. Subcatchments Percentage Flow Reduction in a Median Year

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Houlgrave Weir** | | | **Bakers Gully** | | | **Western Branch** | | |
| | **101_DrainFrom** | | | **195_DrainFrom** | | | **218_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 56,424 | 56,424 | 56,424 | 4498 | 4,498 | 4,498 | 5351 | 5,351 | 5,351 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 8% | 10% | 11% | 9% | 11% | 13% | 10% | 14% | 18% |
| S20_% | 9% | 11% | 13% | 11% | 14% | 16% | 12% | 16% | 19% |
| 5%RF_% | 12% | 15% | 19% | 25% | 30% | 37% | 16% | 21% | 26% |
| 30%RL_% | 13% | 16% | 21% | 17% | 21% | 26% | 17% | 22% | 28% |
| 50%RL_% | 21% | 27% | 32% | 27% | 33% | 38% | 27% | 35% | 42% |
| | **Lenswood.** | | | **Biggs_Flat** | | | **Cox ck** | | |
| | **220_DrainFrom** | | | **221_DrainFrom** | | | **222_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 7527 | 7,527 | 7,527 | 2218 | 2,218 | 2,218 | 8480 | 8,480 | 8,480 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 6% | 8% | 9% | 17% | 22% | 28% | 2% | 2% | 3% |
| S20_% | 7% | 9% | 11% | 19% | 25% | 32% | 2% | 3% | 4% |
| 5%RF_% | 10% | 13% | 16% | 24% | 33% | 41% | 6% | 9% | 11% |
| 30%RL_% | 17% | 20% | 25% | 18% | 24% | 30% | 9% | 14% | 18% |
| 50%RL_% | 25% | 33% | 40% | 27% | 36% | 45% | 17% | 22% | 28% |
| | **Aldgate** | | | **Charles.** | | | **Inverbrackie** | | |
| | **223_DrainFrom** | | | **231_DrainFrom** | | | **232_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 6058 | 6,058 | 6,058 | 6118 | 6,118 | 6,118 | 3267 | 3,267 | 3,267 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 2% | 2% | 3% | 8% | 11% | 13% | 7% | 13% | 16% |
| S20_% | 2% | 3% | 4% | 11% | 14% | 16% | 12% | 16% | 19% |
| 5%RF_% | 5% | 7% | 9% | 22% | 28% | 31% | 19% | 23% | 28% |
| 30%RL_% | 8% | 11% | 15% | 20% | 26% | 29% | 18% | 23% | 27% |
| 50%RL_% | 13% | 19% | 24% | 33% | 42% | 46% | 25% | 33% | 46% |
| | **Mitchell** | | | **Balhannah.** | | | **Hahndorf.** | | |
| | **233_DrainFrom** | | | **234_DrainFrom** | | | **235_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 1525 | 1,525 | 1,525 | 1146 | 1,146 | 1,146 | 2513 | 2,513 | 2,513 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 20% | 26% | 35% | 10% | 12% | 15% | 11% | 13% | 17% |
| S20_% | 21% | 29% | 39% | 12% | 14% | 17% | 14% | 15% | 18% |
| 5%RF_% | 20% | 26% | 35% | 20% | 24% | 28% | 13% | 15% | 18% |
| 30%RL_% | 20% | 26% | 35% | 18% | 19% | 22% | 17% | 18% | 21% |
| 50%RL_% | 23% | 32% | 43% | 25% | 30% | 39% | 28% | 34% | 39% |
| | **Echunga** | | | **Scott ck** | | | **Angels_Gully** | | |
| | **238_DrainFrom** | | | **239_DrainFrom** | | | **240_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 4237 | 4,237 | 4,237 | 4059 | 4,059 | 4,059 | 1842 | 1,842 | 1,842 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 13% | 18% | 23% | 1% | -1% | 0% | 4% | 5% | 6% |
| S20_% | 15% | 20% | 25% | 0% | 1% | 2% | 6% | 8% | 10% |
| 5%RF_% | 20% | 27% | 34% | 10% | 14% | 17% | 21% | 27% | 32% |
| 30%RL_% | 17% | 23% | 30% | 9% | 12% | 16% | 20% | 25% | 30% |
| 50%RL_% | 23% | 31% | 39% | 14% | 19% | 27% | 30% | 38% | 46% |

Note: Upper Onkaparinga and Onkaparinga Main Channel catchments are not included here as they are not a discrete catchments but comprised of several scattered subcatchments along the Onkaparinga river.

## Table 22. Subcatchments Percentage Flow Reduction in a Dry Period
### *Dry Period 1912-1914 All values are mean flow*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Houlgrave weir** | | | **Bakers Gully** | | | **Western Branch** | | |
| | **101_DrainFrom** | | | **195_DrainFrom** | | | **218_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 26,282 | 26,282 | 26,282 | 808 | 808 | 808 | 2871 | 2,871 | 2,871 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 11% | 11% | 17% | 24% | 24% | 31% | 14% | 14% | 22% |
| S20_% | 13% | 17% | 20% | 29% | 35% | 39% | 16% | 21% | 25% |
| 5%RF_% | 20% | 25% | 30% | 59% | 74% | 86% | 21% | 27% | 33% |
| 30%RL_% | 22% | 27% | 33% | 46% | 57% | 67% | 22% | 30% | 35% |
| 50%RL_% | 30% | 38% | 45% | 64% | 81% | 85% | 30% | 38% | 45% |
| | **Lenswood.** | | | **Biggs_Flat** | | | **Cox ck** | | |
| | **220_DrainFrom** | | | **221_DrainFrom** | | | **222_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 3692 | 3,692 | 3,692 | 793 | 793 | 793 | 3665 | 3,665 | 3,665 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 11% | 11% | 16% | 39% | 39% | 53% | 4% | 4% | 6% |
| S20_% | 13% | 16% | 19% | 42% | 50% | 58% | 6% | 7% | 8% |
| 5%RF_% | 19% | 23% | 28% | 48% | 59% | 67% | 14% | 18% | 22% |
| 30%RL_% | 26% | 34% | 41% | 40% | 48% | 56% | 20% | 26% | 32% |
| 50%RL_% | 39% | 50% | 60% | 51% | 62% | 71% | 30% | 39% | 48% |
| | **Aldgate** | | | **Charles.** | | | **Inverbrackie** | | |
| | **223_DrainFrom** | | | **231_DrainFrom** | | | **232_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 2839 | 2,839 | 2,839 | 2923 | 2,923 | 2,923 | 2069 | 2,069 | 2,069 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 3% | 3% | 5% | 12% | 12% | 16% | 8% | 8% | 18% |
| S20_% | 4% | 5% | 6% | 15% | 17% | 20% | 14% | 18% | 22% |
| 5%RF_% | 9% | 11% | 13% | 25% | 31% | 35% | 21% | 28% | 34% |
| 30%RL_% | 12% | 16% | 21% | 24% | 29% | 33% | 21% | 26% | 32% |
| 50%RL_% | 18% | 25% | 30% | 32% | 38% | 44% | 30% | 38% | 44% |
| | **Mitchell** | | | **Balhannah.** | | | **Hahndorf.** | | |
| | **233_DrainFrom** | | | **234_DrainFrom** | | | **235_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 929 | 929 | 929 | 377 | 377 | 377 | 925 | 925 | 925 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 21% | 21% | 37% | 21% | 21% | 31% | 19% | 19% | 30% |
| S20_% | 23% | 32% | 40% | 24% | 29% | 34% | 21% | 27% | 32% |
| 5%RF_% | 21% | 29% | 37% | 31% | 38% | 46% | 20% | 27% | 32% |
| 30%RL_% | 21% | 29% | 37% | 27% | 33% | 40% | 23% | 30% | 35% |
| 50%RL_% | 25% | 35% | 43% | 37% | 47% | 55% | 33% | 41% | 49% |
| | **Echunga** | | | **Scott ck** | | | **Angels_Gully** | | |
| | **238_DrainFrom** | | | **239_DrainFrom** | | | **240_DrainFrom** | | |
| **Scenarios** | **Annual** | | | **Annual** | | | **Annual** | | |
| WOFD, ML | 1549 | 1,549 | 1,549 | 751 | 751 | 751 | 371 | 371 | 371 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 30% | 30% | 41% | 7% | 7% | 14% | 12% | 12% | 16% |
| S20_% | 33% | 40% | 45% | 15% | 18% | 21% | 18% | 22% | 26% |
| 5%RF_% | 43% | 54% | 61% | 44% | 54% | 64% | 46% | 58% | 69% |
| 30%RL_% | 38% | 46% | 54% | 41% | 49% | 58% | 43% | 53% | 63% |
| 50%RL_% | 49% | 59% | 68% | 57% | 73% | 87% | 64% | 82% | 99% |

## Table 23. Subcatchments Percentage Flow Reduction in a Wet Period
### *WET Period 1915-1917 All values as mean flow*

| | Houlgrave weir | | | Bakers Gully | | | West_Branch | | |
|---|---|---|---|---|---|---|---|---|---|
| | 101_DrainFrom | | | 195_DrainFrom | | | 218_DrainFrom | | |
| Scenarios | Annual | | | Annual | | | Annual | | |
| WOFD, ML | 121,674 | 121,674 | 121,674 | 7371 | 7,371 | 7,371 | 10737 | 10,737 | 10,737 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 3% | 3% | 5% | 5% | 5% | 7% | 5% | 5% | 8% |
| S20_% | 3% | 5% | 6% | 7% | 8% | 10% | 6% | 8% | 9% |
| 5%RF_% | 5% | 7% | 9% | 17% | 20% | 23% | 8% | 11% | 13% |
| 30%RL_% | 6% | 8% | 9% | 13% | 15% | 17% | 9% | 12% | 14% |
| 50%RL_% | 9% | 12% | 15% | 19% | 22% | 24% | 14% | 17% | 20% |

| | Lenswood. | | | Biggs_Flat | | | Cox ck | | |
|---|---|---|---|---|---|---|---|---|---|
| | 220_DrainFrom | | | 221_DrainFrom | | | 222_DrainFrom | | |
| Scenarios | Annual | | | Annual | | | Annual | | |
| WOFD, ML | 15020 | 15,020 | 15,020 | 6073 | 6,073 | 6,073 | 17882 | 17,882 | 17,882 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 2% | 2% | 4% | 7% | 7% | 10% | 0% | 0% | 1% |
| S20_% | 2% | 3% | 4% | 8% | 10% | 12% | 0% | 1% | 1% |
| 5%RF_% | 3% | 5% | 7% | 10% | 13% | 15% | 2% | 3% | 4% |
| 30%RL_% | 6% | 9% | 11% | 7% | 9% | 11% | 3% | 5% | 7% |
| 50%RL_% | 10% | 15% | 18% | 11% | 14% | 17% | 6% | 9% | 12% |

| | Aldgate | | | Charles. | | | Inverbrackie | | |
|---|---|---|---|---|---|---|---|---|---|
| | 223_DrainFrom | | | 231_DrainFrom | | | 232_DrainFrom | | |
| Scenarios | Annual | | | Annual | | | Annual | | |
| WOFD, ML | 12415 | 12,415 | 12,415 | 14707 | 14,707 | 14,707 | 7390 | 7,390 | 7,390 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 0% | 0% | 1% | 3% | 3% | 5% | 3% | 3% | 7% |
| S20_% | 0% | 1% | 1% | 4% | 5% | 6% | 6% | 7% | 8% |
| 5%RF_% | 1% | 2% | 3% | 8% | 10% | 12% | 9% | 11% | 13% |
| 30%RL_% | 2% | 4% | 5% | 8% | 10% | 11% | 9% | 11% | 12% |
| 50%RL_% | 5% | 7% | 9% | 12% | 15% | 17% | 13% | 16% | 19% |

| | Mitchell | | | Balhannah. | | | Hahndorf. | | |
|---|---|---|---|---|---|---|---|---|---|
| | 233_DrainFrom | | | 234_DrainFrom | | | 235_DrainFrom | | |
| Scenarios | Annual | | | Annual | | | Annual | | |
| WOFD, ML | 3781 | 3,781 | 3,781 | 1903 | 1,903 | 1,903 | 3841 | 3,841 | 3,841 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 9% | 9% | 14% | 7% | 7% | 11% | 8% | 8% | 12% |
| S20_% | 10% | 13% | 16% | 9% | 11% | 12% | 9% | 11% | 13% |
| 5%RF_% | 9% | 12% | 14% | 13% | 16% | 19% | 9% | 11% | 13% |
| 30%RL_% | 9% | 12% | 14% | 11% | 13% | 15% | 11% | 13% | 15% |
| 50%RL_% | 11% | 14% | 17% | 17% | 21% | 25% | 17% | 21% | 25% |

| | Echunga | | | Scott ck | | | Angels_Gully | | |
|---|---|---|---|---|---|---|---|---|---|
| | 238_DrainFrom | | | 239_DrainFrom | | | 240_DrainFrom | | |
| Scenarios | Annual | | | Annual | | | Annual | | |
| WOFD, ML | 10974 | 10,974 | 10,974 | 7997 | 7,997 | 7,997 | 3077 | 3,077 | 3,077 |
| Storage use factor | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 | 0.3 | 0.5 | 0.7 |
| WFD_% | 6% | 6% | 9% | 0% | 0% | -2% | 2% | 2% | 3% |
| S20_% | 6% | 8% | 10% | -2% | -2% | -1% | 3% | 4% | 5% |
| 5%RF_% | 9% | 11% | 14% | 3% | 5% | 6% | 13% | 15% | 18% |
| 30%RL_% | 8% | 10% | 12% | 2% | 4% | 5% | 12% | 14% | 17% |
| 50%RL_% | 10% | 13% | 16% | 6% | 8% | 11% | 19% | 23% | 26% |

# *Impact of Farm Dams on Natural Flows at Houlgrave Weir*

## Current and Without Farm Dams Scenarios

### Annual flow volume

See Tables 21-24, Figures 20-21 and Figure 24. The catchment upstream of Houlgrave Weir has an aggregated 6,600 ML of storage or 21 ML/km$^2$ (21 mm) of farm dam density. This is equivalent to 2% of the median annual rainfall (964 mm). During the period 1900-1998, runoff simulations show that:

- Over the 99 years, the median annual adjusted flow is 56,000 ML with a runoff coefficient of 0.18. This compares well with the gauged streamflow which indicates the coefficient is 0.16.
- The mean annual adjusted flow is 61,000 ML. or equivalent to 20% of the annual rainfall.

  The **mean** runoff trapped by the dams is 6% of the adjusted catchment yield (1% of 964 mm rainfall) while the **median** runoff trapped is 8%, or 4300 ML.
- In the defined dry period, the adjusted flow over the 3-year period is 26,000 ML/year with 11% of the flow trapped by dams (or 1% of 742 mm rainfall).
- In the defined wet period, the adjusted flow is 122,000 ML/year with 3% of flow trapped by dams.

Table 24 summarises the modelled catchment yield with and without farm dams under the three climatic periods. Figure 20 plots the modelled annual catchment yield with and without farm dams for the period 1900 to1998. This figure shows that during the draught years when catchment yield is low, farm dams significantly impact the flow downstream. This is shown in the graph by the peaks in the percentage yield captured by the dams which all occur in low rainfall / runoff years. For more recent years between 1960-1998, the percentage of flow captured is shown in Figure 21.

The percentage of adjusted catchment yield captured at the 10$^{th}$ and 90$^{th}$ percentiles is 17% and 4% respectively (Table 54 in Appendix D).

### Table 24. The Impact of Farm Dams on Houlgrave Catchment Yield

| Description | Area | Dam Storage (a) | Farm Dam Density | Rainfall | Adjusted Catchment Yield Without Farm Dams (b) | Yield Captured by Farm Dams | | Ratio a/b (50% Rule) |
|---|---|---|---|---|---|---|---|---|
| | km$^2$ | ML | ML/ km$^2$ | mm | ML | ML | % | % |
| Mean of 1990-1998 | 321 | 6,600 | 21 | 964 | 61,500 | 3,600 | 6 | 11 |
| Median of 1900-1998 | 321 | 6,600 | 21 | 955 | 56,400 | 4,300 | 8 | 12 |
| Wet period (1915-1917) | 321 | 6,600 | 21 | 1,384 | 121,700 | 3,500 | 3 | 5 |
| Dry period (1912-1914) | 321 | 6,600 | 21 | 742 | 26,300 | 3,000 | 11 | 25 |

### Monthly Flow Volume

Recorded and modelled flows indicate that there is a baseflow at Houlgrave Weir throughout the year. In a median year, the adjusted monthly flow can vary from as low as 600 ML in March to as high as 10,200 ML in August. The presence of farm dams has a particularly significant impact on the flow in November to May. During these drier months, farm dams trap between 20-53% of the adjusted natural flows.

Farm dams also delay the commencement of the winter flow. In the first winter month of June, flow is reduced by 21%. This is due to the replenishing of dam storages depleted during the summer.

In the defined dry period, with farm dams trapping the runoff, monthly flow can be as low as 290 ML which occurs in March. This causes a reduction in 38% of the adjusted catchment flow (470 ML)at Hougrave Weir in March. The commencement of winter flow has also been delayed to July with 23% (520 ML) reduction in the adjusted flow volume. In the defined wet period, the impact is significant only from November to April. Refer Table 25 and Figure 22.

### Daily Flow Volume

See Table 26 and Figure 23. Flow duration curve analysis from the modelled catchment runoff with and without farm dams shows that:

- Flow with magnitude less than 1 ML/day is not impacted at Houlgrave Weir by the presence of farm dams in the catchment. Baseflow from groundwater discharge would maintain the low flow regime.
- For flow range between 5 - 50 ML/day, farm dams reduce the number of days streamflow occurs by between 30 to 60 days a year. Most of the reduction occurs during the drier months of November to April.
- For flow regime above 100 ML/day, the impact due to farm dams is less significant. The reduction in the number of day streamflow occurs in the range is 10 days in a year.

### With Increased Use of Dam Storage

See Table 21- 23 under WFD_% scenario. When runoff simulations are modelled using scenario 1 with increased dam storage use from 30% to 70%, the reduction in the annual adjusted flow is increased from 8% (4.5 GL) to 11% (6.2 GL) in a median year. Similarly, in the defined dry period, the impact increases from 11% (6.2 GL) to 17% (9.6 GL); and in the defined wet period, from 3% (1.7 GL) to 5% ((2.8 GL). These results are presented in Tables 21 – 23. (WFD% scenario).

## Future farm dam development scenarios

Of all the simulation cases, the worst case is scenario-6 farm dams development with 70% of dam storage use. The model shows that in this case the reduction in the catchment runoff at Houlgrave weir in a median year is 32% (18000ML). It is assumed that this would have significant impact on the water supply and the volume and frequency of spills from Mt Bold Reservoir downstream. In a drought or dry-period situation, the impact is even more pronounced with a reduction of catchment yield by 45% (25000ML). The importance of considering the availability of water resources in a drought situation, for long term management and risk management purposes, obviously can not be overstated.

The reduction in the catchment runoff at Houlgrave Weir for all cases scenarios is presented in Figure 24.

**Figure 20. Annual Catchment Yield at Houlgrave Weir With Farm dams (1900-1998)**

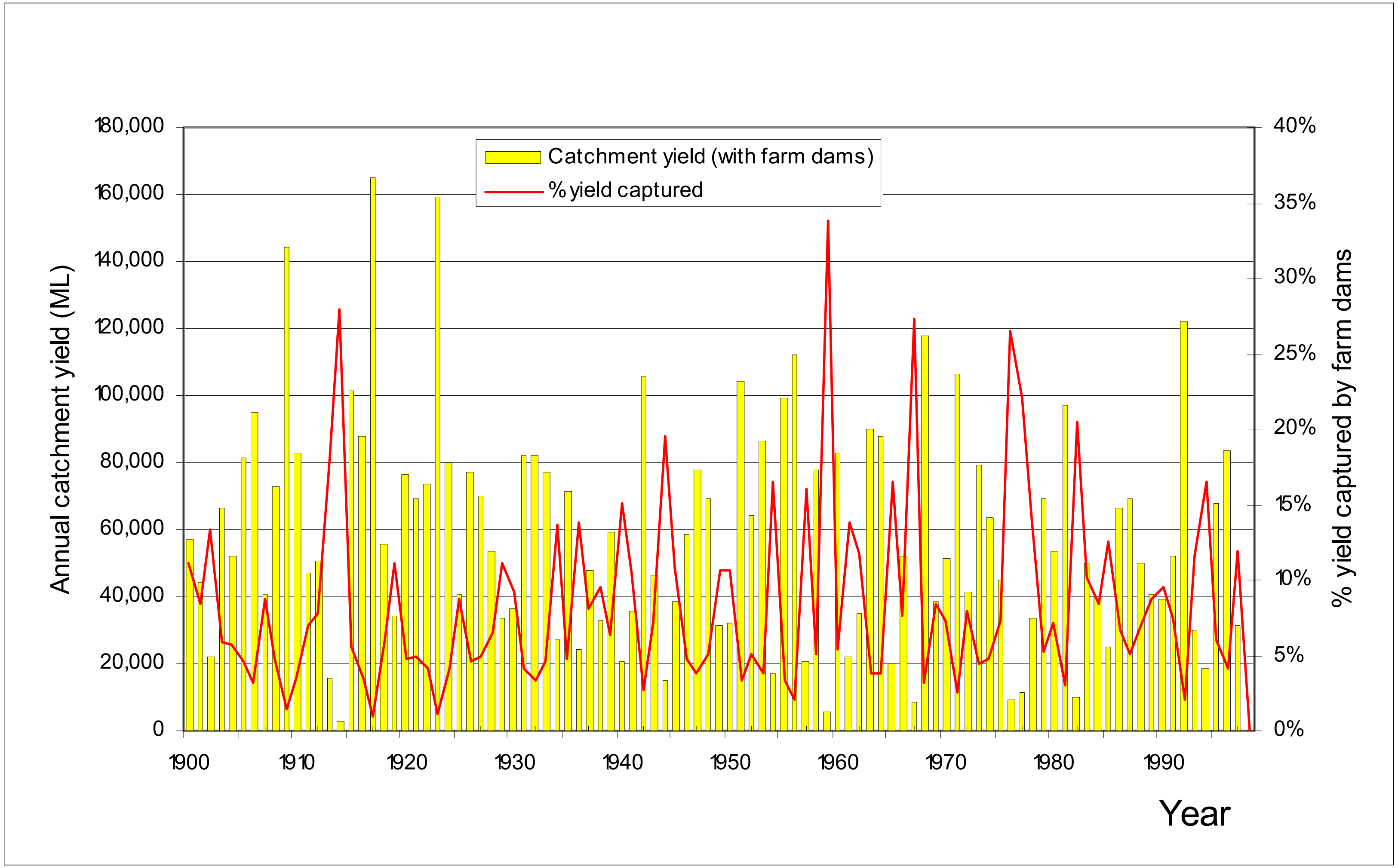
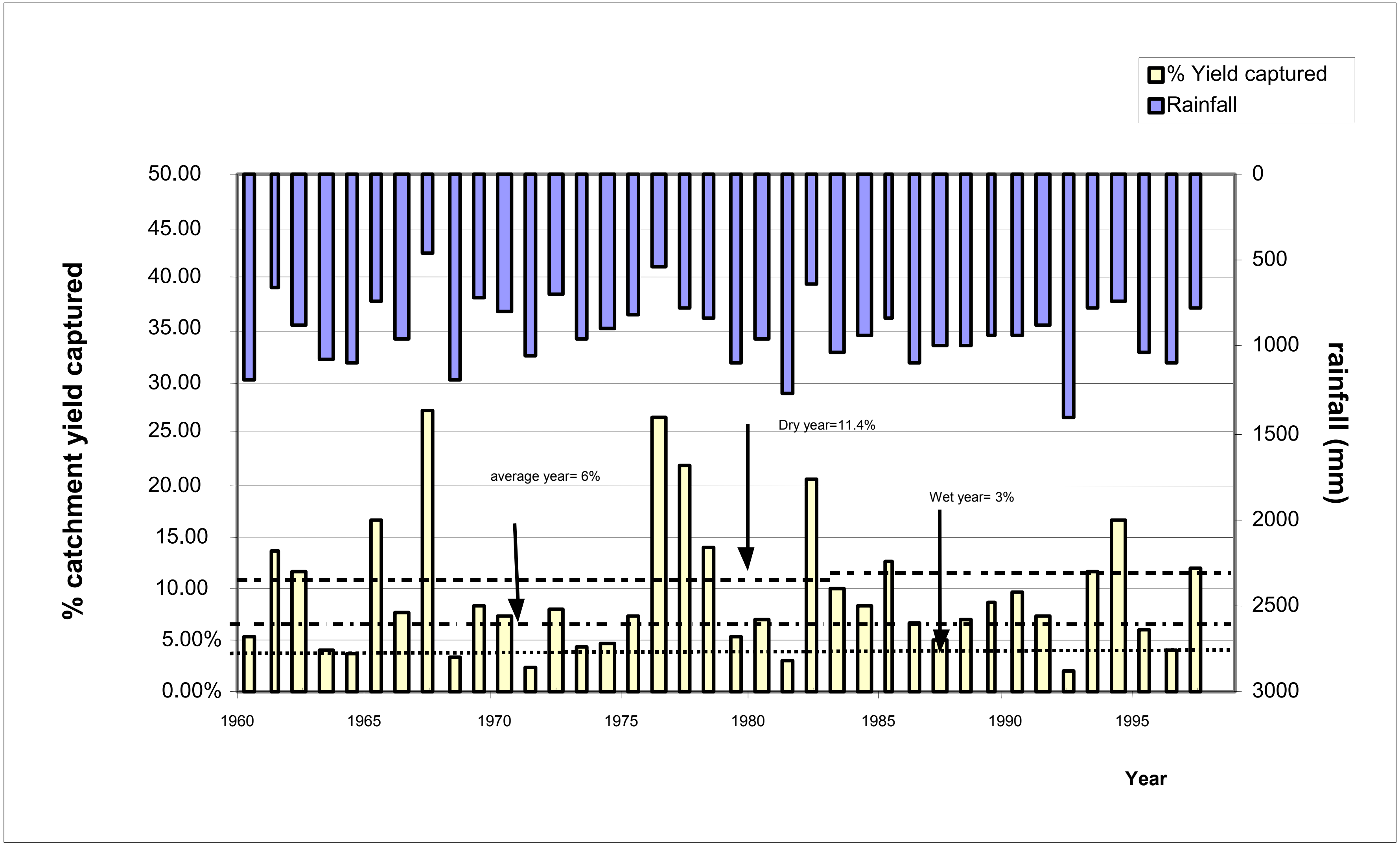


**Figure 21. Percentage Annual Catchment Yield Captured by Farm Dams Upstream of Houlgrave Weir (1960-1998)**



## Table 25. Modelled Monthly Flows (ML) with and without Farm Dams at Houlgrave Weir

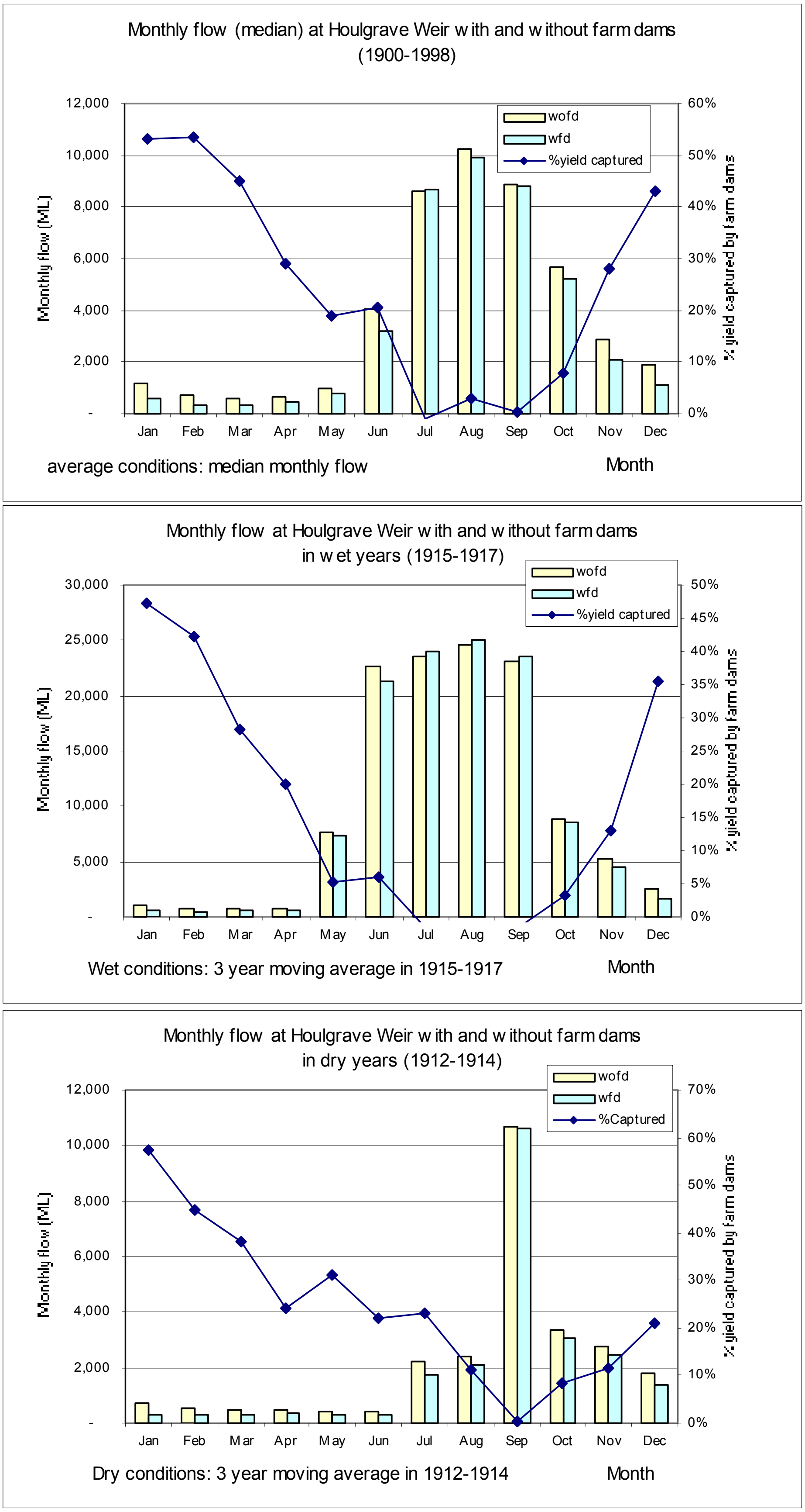
| Month | Average | Median | 90 Percentile | 10 Percentile | 3YMA (1915–1917, wet) | 3YMA (1912–1914, dry) | Std Deviation | Cooeff of Variability, CV |
|---|---|---|---|---|---|---|---|---|
| January | | | | | | | | |
| WOFD | 1,558 | 1,187 | 2,550 | 409 | 1,005 | 738 | 1,816 | 1.17 |
| WFD | 991 | 556 | 1,651 | 197 | 530 | 314 | 1,681 | 1.70 |
| February | | | | | | | | |
| WOFD | 1,010 | 715 | 1,671 | 311 | 801 | 554 | 1,436 | 1.42 |
| WFD | 638 | 333 | 939 | 121 | 463 | 305 | 1,345 | 2.11 |
| March | | | | | | | | |
| WOFD | 781 | 603 | 1,181 | 231 | 824 | 468 | 987 | 1.26 |
| WFD | 492 | 332 | 698 | 114 | 591 | 290 | 894 | 1.82 |
| April | | | | | | | | |
| WOFD | 910 | 640 | 1,402 | 281 | 777 | 453 | 1,347 | 453 |
| WFD | 722 | 454 | 1,110 | 185 | 621 | 344 | 1,214 | 1.68 |
| May | | | | | | | | |
| WOFD | 2,706 | 1,006 | 5,565 | 380 | 7,694 | 446 | 4,389 | 1.62 |
| WFD | 2,398 | 814 | 5,145 | 300 | 7,288 | 307 | 4,130 | 1.72 |
| June | | | | | | | | |
| WOFD | 6,908 | 4,023 | 17,982 | 449 | 22,659 | 404 | 8,068 | 1.17 |
| WFD | 6,534 | 3,197 | 17,436 | 401 | 21,321 | 315 | 7,976 | 1.22 |
| July | | | | | | | | |
| WOFD | 10,757 | 8,585 | 20,975 | 1,591 | 23,601 | 2,242 | 8,950 | 0.83 |
| WFD | 10,662 | 8,655 | 21,433 | 1,348 | 24,040 | 1,722 | 9,133 | 0.86 |
| August | | | | | | | | |
| WOFD | 11,957 | 10,215 | 26,107 | 2,032 | 24,549 | 2,376 | 8,681 | 0.73 |
| WFD | 11,988 | 9,902 | 26,733 | 1,898 | 25,038 | 2,108 | 8,894 | 0.74 |
| September | | | | | | | | |
| WOFD | 10,608 | 8,839 | 21,781 | 2,136 | 23,108 | 10,690 | 8,550 | 0.81 |
| WFD | 20,656 | 8,815 | 22,095 | 2,019 | 23,475 | 10,637 | 8,740 | 0.82 |
| October | | | | | | | | |
| WOFD | 7,452 | 5,656 | 16487 | 1,667 | 8,842 | 3,348 | 5,962 | 0.80 |
| WFD | 7,157 | 5,127 | 16,398 | 1,211 | 8,559 | 3,064 | 6,089 | 0.85 |
| November | | | | | | | | |
| WOFD | 4,306 | 2,892 | 10,058 | 1,074 | 5,226 | 2,789 | 4,003 | 0.93 |
| WFD | 3,710 | 2,084 | 9,459 | 689 | 4,540 | 2,467 | 4,021 | 1.08 |
| December | | | | | | | | |
| WOFD | 2,96 | 1,890 | 7,325 | 646 | 2,589 | 1,775 | 3,121 | 1.04 |
| WFD | 2,322 | 1,078 | 6,481 | 300 | 1,673 | 1,403 | 3,032 | 1.31 |

WOFD – without farm dams
WFD – with farm dams
Note: Australian arid zone streams found by McMahon (1982) has mean Cv = 1.27

**Percentage of Monthly and Annual Flows Captured Above Houlgrave Weir (1900–1998)**

| | Average | Median | 90 Percentile | 10 Percentile | 3YMA (1915–1917, wet) | 3YMA (1912–1914, dry) |
|---|---|---|---|---|---|---|
| January | 36% | 53% | 35% | 52% | 47% | 57% |
| February | 37% | 53% | 44% | 61% | 42% | 45% |
| March | 37% | 45% | 41% | 51% | 28% | 38% |
| April | 21% | 29% | 21% | 34% | 20% | 24% |
| May | 11% | 19% | 8% | 21% | 5% | 31% |
| June | 5% | 21% | 3% | 11% | 6% | 22% |
| July | 1% | 0% | 0% | 15% | 0% | 23% |
| August | 0% | 3% | 0% | 7% | 0% | 11% |
| September | 0% | 0% | 0% | 5% | 0% | 0% |
| October | 4% | 8% | 1% | 27% | 3% | 8% |
| November | 14% | 28% | 6% | 36% | 13% | 12% |
| December | 22% | 43% | 12% | 5% | 35% | 21% |
| Annual | 6% | 8% | 4% | 17% | 3% | 11% |

## Figure 22. Modelled Monthly Flows With and Without Farm Dams at Houlgrave Weir

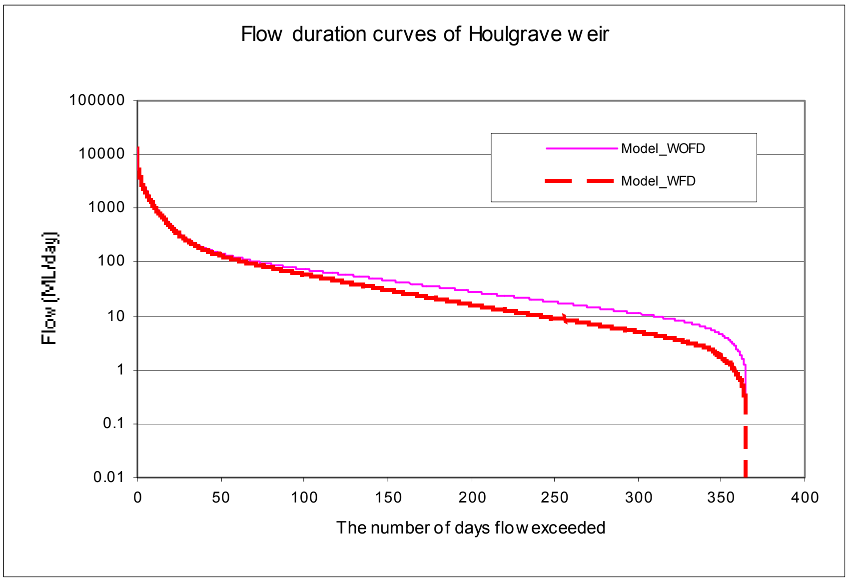


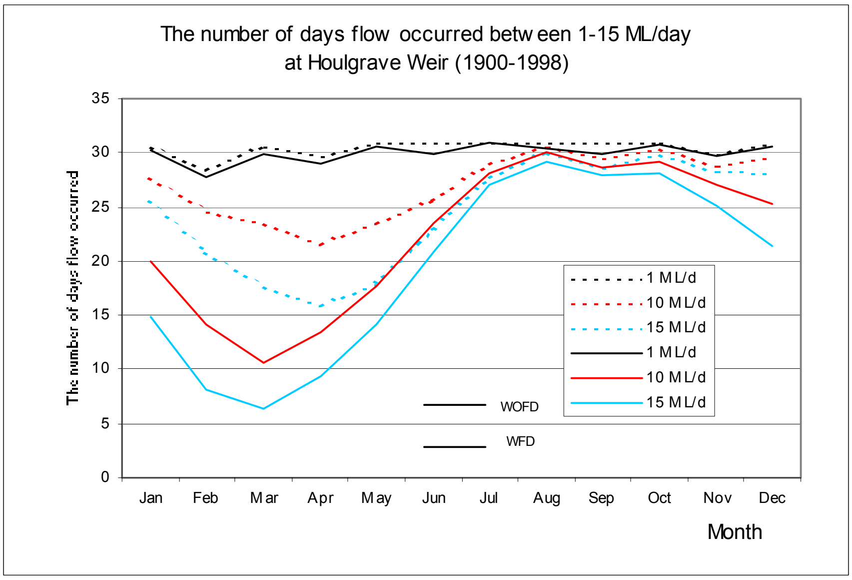
## Table 26. The Number of Days Specified Flow Impacted by Farm Dams of Houlgrave Catchment

| Month | 0.1ML/d | 1ML/d | 5ML/d | 10ML/d | 15ML/D | 20ML/d | 30ML/d | 50ML/d | 100ML/d |
|---|---|---|---|---|---|---|---|---|---|
| January | | | | | | | | | |
| WOFD | 31 | 31 | 30 | 28 | 26 | 23 | 18 | 7 | 1 |
| WFD | 31 | 30 | 26 | 20 | 15 | 10 | 6 | 2 | 1 |
| February | | | | | | | | | |
| WOFD | 29 | 28 | 27 | 24 | 21 | 17 | 10 | 3 | 1 |
| WFD | 29 | 28 | 22 | 14 | 8 | 6 | 3 | 1 | 1 |
| March | | | | | | | | | |
| WOFD | 31 | 31 | 28 | 23 | 18 | 13 | 6 | 2 | 0 |
| WFD | 31 | 30 | 20 | 11 | 6 | 4 | 3 | 1 | 0 |
| April | | | | | | | | | |
| WOFD | 30 | 30 | 27 | 22 | 16 | 11 | 6 | 3 | 1 |
| WFD | 30 | 29 | 21 | 13 | 9 | 7 | 5 | 3 | 1 |
| May | | | | | | | | | |
| WOFD | 31 | 31 | 29 | 24 | 18 | 14 | 10 | 7 | 4 |
| WFD | 31 | 31 | 24 | 18 | 14 | 12 | 9 | 6 | 4 |
| June | | | | | | | | | |
| WOFD | 30 | 30 | 29 | 26 | 23 | 20 | 17 | 13 | 9 |
| WFD | 30 | 30 | 27 | 23 | 21 | 19 | 16 | 13 | 9 |
| July | | | | | | | | | |
| WOFD | 31 | 31 | 31 | 29 | 28 | 27 | 24 | 21 | 14 |
| WFD | 31 | 31 | 30 | 28 | 27 | 26 | 23 | 20 | 14 |
| August | | | | | | | | | |
| WOFD | 31 | 31 | 31 | 31 | 30 | 29 | 27 | 25 | 17 |
| WFD | 31 | 31 | 31 | 30 | 29 | 28 | 27 | 24 | 16 |
| September | | | | | | | | | |
| WOFD | 30 | 31 | 30 | 29 | 29 | 28 | 27 | 24 | 17 |
| WFD | 30 | 30 | 30 | 29 | 28 | 27 | 26 | 23 | 16 |
| October | | | | | | | | | |
| WOFD | 31 | 31 | 31 | 30 | 30 | 29 | 28 | 24 | 14 |
| WFD | 31 | 31 | 30 | 29 | 28 | 27 | 25 | 21 | 11 |
| November | | | | | | | | | |
| WOFD | 30 | 30 | 29 | 29 | 28 | 27 | 25 | 20 | 8 |
| WFD | 30 | 30 | 29 | 27 | 25 | 23 | 19 | 13 | 5 |
| December | | | | | | | | | |
| WOFD | 31 | 31 | 30 | 30 | 28 | 26 | 23 | 16 | 4 |
| WFD | 31 | 31 | 29 | 25 | 21 | 18 | 12 | 6 | 2 |
| Annual | | | | | | | | | |
| WOFD | 365 | 365 | 352 | 324 | 294 | 265 | 221 | 165 | 90 |
| WFD | 365 | 361 | 318 | 268 | 233 | 208 | 174 | 134 | 81 |

WOFD – without farm dams
WFD – with farm dams

## Figure 23. Modelled Flow Duration Relationships



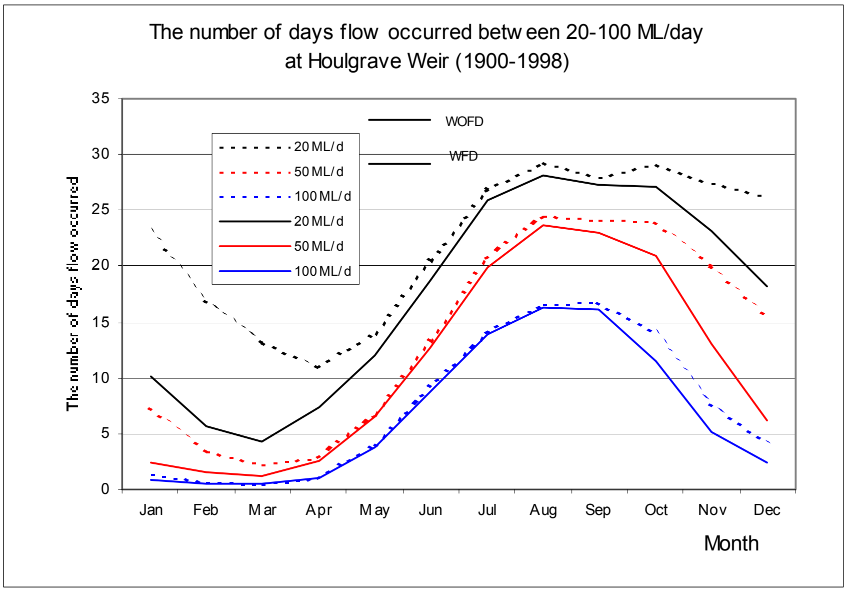
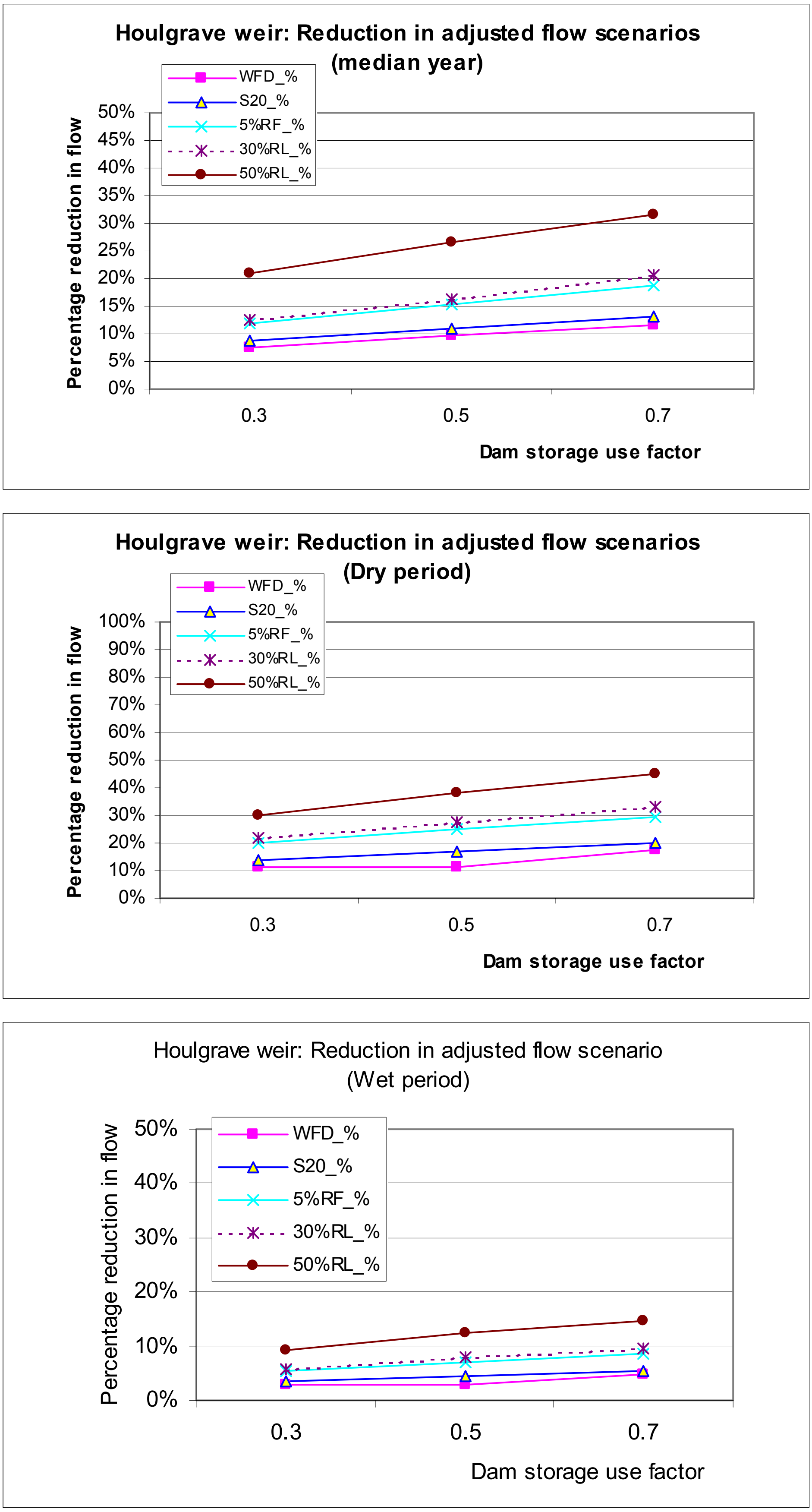



**Figure 24. Percentage flow reduction at Houlgrave Weir for all cases scenarios**



# *Impact of Farm Dams at Clarendon Weir*

## Current and without farm dams scenario

### Annual Flow volume

Runoff simulations were modelled with the Mt Bold Reservoir removed from the model. Two cases being modelled are with the current scenario and with the farm dams removed from the catchments. The difference in flow volume of the catchment between the two cases is the volume captured as farm dams storage.

The mean annual adjusted flow volume passing the Clarendon weir is 79,000 ML and the median annual adjusted flow volume is 72,000 ML. Based on the latter, it equates to a runoff coefficient of 0.2 for the catchment. From the gauged flow records (Table 5), Clarendon weir catchment is greatly impacted by the presence of Mt Bold reservoir resulting in the runoff coefficient being reduced to 0.05.

Dam storage at upstream of Clarendon Weir, excluding Mt Bold Reservoir, is 8,000 ML or 18 mm across the catchment area (2.2% of 810 mm rainfall). Assuming no Mt Bold reservoir, the presence of farm dams has reduced the mean annual adjusted catchment yield by 6% (4400 ML) and the median annual adjusted yield by 5% (3900 ML). During the three year dry period the adjusted flow is 30,000 ML / yr, or a 12% reduction, and 153,000 ML / yr for a wet period, or a 3 % reduction, from the without dams case.

From the gauged streamflow records (1937-1999), Clarendon weir has a mean annual flow of 19,000 ML and a median flow of 4,000 ML. Based on the mean figures, it implies about 60,000 ML of water has been harvested from the catchment runoff for Adelaide water supply and for the system losses.

### Table 27. The Impact of Farm Dams on Clarendon Catchment Yield

| Description | Area | Dam Storage (a) | Farm Dam Density | Rainfall | Adjusted Catchment Yield Without Farm Dams (b) | Yield Captured by Farm Dams | | Ratio a/b (50% Rule) |
|---|---|---|---|---|---|---|---|---|
| | km² | ML | ML/ km² | mm | ML | ML | % | % |
| Mean of 1900-1998 | 442 | 7940 | 18 | 835 | 78,700 | 4,400 | 6 | 10 |
| Median of 1900-1998 | 442 | 7940 | 18 | 810 | 72,100 | 3,900 | 5 | 11 |
| Wet period (1915-1917) | 442 | 7940 | 18 | 997 | 152,900 | 4,300 | 3 | 5 |
| Dry period (1912-1914) | 442 | 7940 | 18 | 600 | 30,000 | 3,600 | 12 | 26 |

### 50% Rule for Farm Dam Development

By 50% rule definition, the allowable dam storage at upstream of Clarendon weir is 50% of the median annual adjusted flow or 36,000 ML. The current aggregated dam storage in the subcatchments upstream of Clarendon weir is 8,000 ML. Mt Bold reservoir has the capacity to hold 47,000 ML of water and Clarendon weir 320 ML. In addition, Happy Valley reservoir is connected to the water supply system and it can hold a capacity of 13,000 ML of water. Without taking the Happy Valley reservoir storage into consideration, the total storage capacity at upstream of Clarendon weir is 55,300 ML or 77% of its median annual adjusted catchment yield.

This is well above the 50% rule. With Happy Valley reservoir included, the total storage would be 95% of the median annual adjusted flow of the catchments.

### Other Farm Dams Development Scenarios

Other farm dams development scenarios were not modelled for Clarendon catchment for the period 1900-1998 as it was deemed unnecessary. Flow reduction for Clarendon weir catchment can be obtained from the subcatchments (see earlier section) upstream of the weir. The provision of Clarendon weir storage as water supply impacted by the farm dams development scenarios is dealt with in the section “Impact on the water supply from Mt Bold and Clarendon weir reservoirs”.

## *Impact on the Water Supply from Mt Bold Reservoir and Clarendon weir*

For the purpose of studying the affect of catchment yield on water supply at Mt Bold reservoir, a much shorter period (1974-1998) of model simulations are performed and where available, the gauged streamflow records are used as input into the model. The analysis of the simulations is carried out using the *mean* values of flow volume rather than the *median* values

- Increasing farm dams development would naturally reduce the catchment runoff as more water is captured in the dams. Likewise for a given development scenario, with increasing dam storage use, less water would be generated from the catchments. This in turn would reduce the surface flow into Mt Bold Reservoir and Clarendon Weir and impact on the water supply to Happy Valley Reservoir. Therefore more water would need to be transferred from the River Murray to maintain the same demand for water supply to Happy Valley Reservoir (assuming the operations of the reservoirs remain the same). Hence the key issue of concern for public water supply is the reduction in catchment runoff flowing into the reservoirs as more farm dams are developed

Inflows into Mt Bold Reservoir and Clarendon Weir under a farm dam development scenario were compared with the baseline reference flows of current scenario (WFD). The reduction of inflow volume was deemed to be the quantified impact, which would be compensated from the River Murray with additional pumping. All the flow volumes thus compared use the *mean* value modelled over the period from 1975 to 1998. They are briefly summarised in Table 28-30.

The Tables show the additional water to be pumped in each month, summer and winter months or in a year under different farm dams development scenarios with 30%, 50% and 70% of aggregated dam storage use. Figure 25 provides the plots to illustrate the additional water to be pumped from the River Murray.

Under the worst case scenario (50%RL, scenario 6 with 70% dam storage use), it is anticipated that about additional 17,000 ML of water would need to be compensated from the River Murray. However this is a very unlikely situation given the fact that with 150ML/yr of farm dams development, it would take 140 years to reach this level of development!

A more likely situation is between the scenario 3 (S20) and scenario 4 (5%RF) situation when farm dams development could realistically reach this aggregated storage volume. That being the case, for 70% dam storage use case, the water to be compensated from the River Murray to meet the demand of water supply would be in the order of 4,000 to 9,000 ML in a year. Given that the current historical mean pumpage into the Mt Bold reservoir is 27,000 ML per annum, this is an increased of 30%.

This is likely to be a conservative estimate because the model simulation was carried out without any regard for the flexibility of the operating rules in Mt Bold Reservoir. The model was set up with Mt Bold and Clarendon weir reservoirs to be filled to its full capacity at all times. In reality, during the winter season when a substantial inflow to the reservoirs can be expected, storage level may be lowered to meet the demand of water supply without requiring importation of water from the River Murray. If this being the case, spills from the Mt Bold and Clarendon weir reservoirs would be less in terms of the quantity and the frequency as more water is diverted to meet the demand for water supply. This in turn would impose greater stress on the downstream environmental flow requirements.

In the future, refinements may be made to the estimates on impact of farm dams development to water supply by incorporating the actual operating rules for Mt Bold Reservoir water supply and the environmental flow water requirements to the mode.

## Table 28. Modelling Scenarios of Inflows into Mount Bold Reservoir and Clarendon Weir – Irrigation Usage = 0.3 of Dam Storage

**Water Pumped from the River Murray into Mount Bold Reservoir via Murray Bridge–Onkaparinga Pipeline**

| Desc. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Summer | Winter | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean (1975–1999) | 3,398 | 3,218 | 2,830 | 1,525 | 857 | 578 | 681 | 2,089 | 2,689 | 2,988 | 3,090 | 3,514 | 17,575 | 9,883 | 27,458 |

**Average Flow into Mount Bold Reservoir**

| Scenarios | WFD (0.3) | S20 | 5%RF | 30%RL | 50%RL |
|---|---|---|---|---|---|
| 1 | 789 | 688 | 405 | 394 | 497 |
| 2 | 509 | 445 | 273 | 273 | 327 |
| 3 | 443 | 391 | 244 | 240 | 334 |
| 4 | 513 | 475 | 337 | 328 | 410 |
| 5 | 1,053 | 1,010 | 801 | 709 | 727 |
| 6 | 3,731 | 3,662 | 3,316 | 3,116 | 2,557 |
| 7 | 11,493 | 11,405 | 11,163 | 11,085 | 9,734 |
| 8 | 12,196 | 12,164 | 12,086 | 12,147 | 11,096 |
| 9 | 10,818 | 10,816 | 10,851 | 10,869 | 10,398 |
| 10 | 7,846 | 7,780 | 7,558 | 7,527 | 7,168 |
| 11 | 3,552 | 3,435 | 3,033 | 2,972 | 2,810 |
| 12 | 2,983 | 2,861 | 2,465 | 2,410 | 2,324 |
| Summer | 8,669 | 8,182 | 6,659 | 6,520 | 6,609 |
| Winter | 47,138 | 46,837 | 45,775 | 45,454 | 41,680 |
| Annual | 55,808 | 55,018 | 52,434 | 51,974 | 48,289 |
| Additional Water to Pump | | | | | |
| Summer | – | 488 | 2,010 | 2,149 | 2,061 |
| Winter | – | 302 | 1,363 | 1,685 | 5,459 |
| Annual | – | 790 | 3,374 | 3,834 | 7,519 |
| Additional Water to Pump into Mount Bold Reservoir and Clarendon Weir Systems | | | | | |
| Summer | – | 650 | 2,469 | 2,577 | 2,595 |
| Winter | – | 313 | 1,847 | 2,053 | 6,237 |
| Annual | – | 963 | 4,316 | 4,631 | 8,823 |

| **Average Flow into Clarendon Weir** | | | | | |
|---|---|---|---|---|---|
| **Scenarios** | **WFD (0.3)** | **S20** | **5%RF** | **30%RL** | **50%RL** |
| 1 | 139 | 98 | 54 | 57 | 50 |
| 2 | 80 | 57 | 32 | 34 | 27 |
| 3 | 54 | 37 | 22 | 22 | 18 |
| 4 | 37 | 27 | 12 | 12 | 12 |
| 5 | 69 | 59 | 21 | 25 | 18 |
| 6 | 424 | 415 | 273 | 303 | 215 |
| 7 | 1,505 | 1,510 | 1,298 | 1,349 | 1,165 |
| 8 | 1,498 | 1,511 | 1,501 | 1,518 | 1,423 |
| 9 | 1,344 | 1,347 | 1,358 | 1,354 | 1,357 |
| 10 | 1,071 | 1,057 | 978 | 994 | 954 |
| 11 | 575 | 542 | 441 | 455 | 411 |
| 12 | 412 | 371 | 271 | 283 | 245 |
| Summer | 1,279 | 1,117 | 820 | 851 | 754 |
| Winter | 5,911 | 5,900 | 5,428 | 5,543 | 5,133 |
| Annual | 7,19 | 7,017 | 6,248 | 6,394 | 5,887 |
| Additional Water to Pump | | | | | |
| Summer | – | 162 | 459 | 428 | 525 |
| Winter | – | 11 | 484 | 369 | 779 |
| Annual | – | 174 | 942 | 796 | 1,303 |

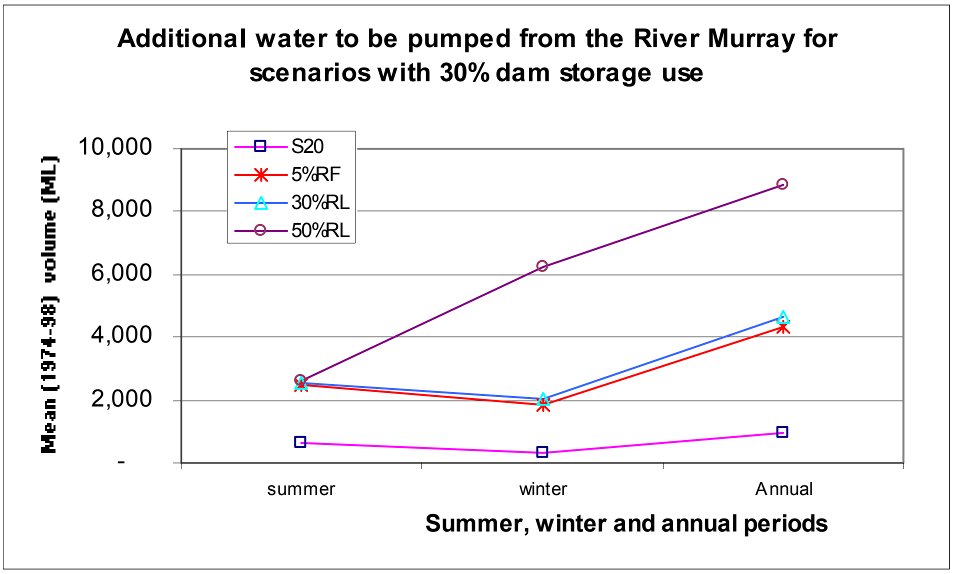
## Table 29. Modelling Scenarios of Inflows into Mount Bold Reservoir and Clarendon Weir – Irrigation Usage = 0.5 of Dam Storage, 1974–1998

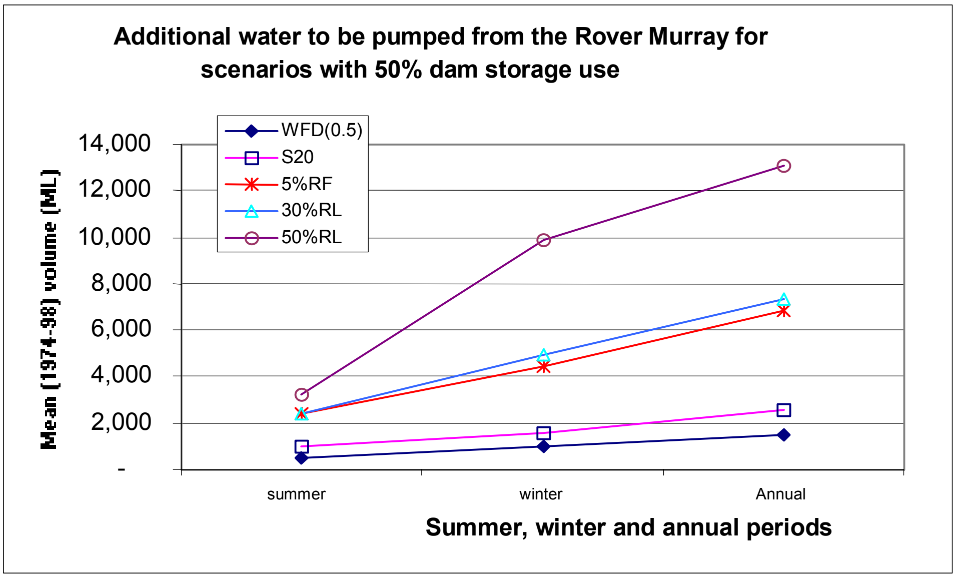
| **Average Flow into Mount Bold Reservoir** | | | | | | |
|---|---|---|---|---|---|---|
| **Scenarios** | **WFD (0.3)** | **WFD (0.5)** | **S20** | **5%RF** | **30%RL** | **50%RL** |
| 1 | 789 | 739 | 667 | 504 | 504 | 461 |
| 2 | 509 | 478 | 430 | 335 | 335 | 292 |
| 3 | 443 | 423 | 387 | 318 | 323 | 310 |
| 4 | 513 | 493 | 467 | 391 | 399 | 384 |
| 5 | 1,053 | 992 | 952 | 764 | 710 | 663 |
| 6 | 3,731 | 3,552 | 3,452 | 2,925 | 2,710 | 2,170 |
| 7 | 11,493 | 11,193 | 11,054 | 10,386 | 10,142 | 8,576 |
| 8 | 12,196 | 11,919 | 11,810 | 11,389 | 11,336 | 10,258 |
| 9 | 10,818 | 10,747 | 10,728 | 10,592 | 10,614 | 9,940 |
| 10 | 7,846 | 7,717 | 7,368 | 7,361 | 7,303 | 6,813 |
| 11 | 3,552 | 3,409 | 3,298 | 2,923 | 2,879 | 2,572 |
| 12 | 2,983 | 2,871 | 2,766 | 2,438 | 2,389 | 2,115 |
| Summer | 8,669 | 8,299 | 7,905 | 6,811 | 6,732 | 6,050 |
| Winter | 47,138 | 46,120 | 45,632 | 43,417 | 42,816 | 38,421 |
| Annual | 55,808 | 54,419 | 53,537 | 50,228 | 49,548 | 44,471 |
| Additional Water to Pump | | | | | | |
| Summer | – | 371 | 764 | 1,858 | 1,937 | 2,620 |
| Winter | – | 1,108 | 1,506 | 3,722 | 4,323 | 8,717 |
| Annual | – | 1,389 | 2,270 | 5,580 | 6,260 | 11,337 |
| Additional Water to Pump into Mount Bold Reservoir and Clarendon Weir Systems | | | | | | |
| Summer | – | 467 | 996 | 2,380 | 2,426 | 3,219 |
| Winter | – | 1,028 | 1,557 | 4,468 | 4,911 | 9,872 |
| Annual | – | 1,495 | 2,524 | 6,848 | 7,337 | 13,092 |
| **Average Flow into Clarendon Weir** | | | | | | |
| **Scenarios** | **WFD (0.3)** | **WFD (0.5)** | **S20** | **5%RF** | **30%RL** | **50%RL** |
| 1 | 139 | 114 | 90 | 49 | 542 | 46 |
| 2 | 80 | 67 | 54 | 28 | 30 | 21 |
| 3 | 54 | 44 | 34 | 19 | 20 | 13 |
| 4 | 37 | 31 | 25 | 10 | 10 | 11 |
| 5 | 69 | 63 | 54 | 16 | 17 | 16 |
| 6 | 424 | 418 | 403 | 219 | 252 | 174 |
| 7 | 1,505 | 1,508 | 1,497 | 1,180 | 1,249 | 1,020 |
| 8 | 1,498 | 1,504 | 1,509 | 1,437 | 1,481 | 1,276 |
| 9 | 1,344 | 1,346 | 1,346 | 1,357 | 1,354 | 1,345 |
| 10 | 1,071 | 1,063 | 1,052 | 955 | 696 | 926 |
| 11 | 575 | 556 | 531 | 414 | 429 | 381 |
| 12 | 412 | 387 | 358 | 248 | 260 | 217 |
| Summer | 1,279 | 1,183 | 1,077 | 758 | 790 | 680 |
| Winter | 5,911 | 5,902 | 5,860 | 5,165 | 5,323 | 4,756 |
| Annual | 7,190 | 7,085 | 6,937 | 5,923 | 6,113 | 5,436 |
| Additional Water to Pump | | | | | | |
| Summer | – | 96 | 202 | 521 | 489 | 599 |
| Winter | – | 10 | 51 | 746 | 589 | 1155 |
| Annual | – | 106 | 253 | 1268 | 1077 | 1755 |

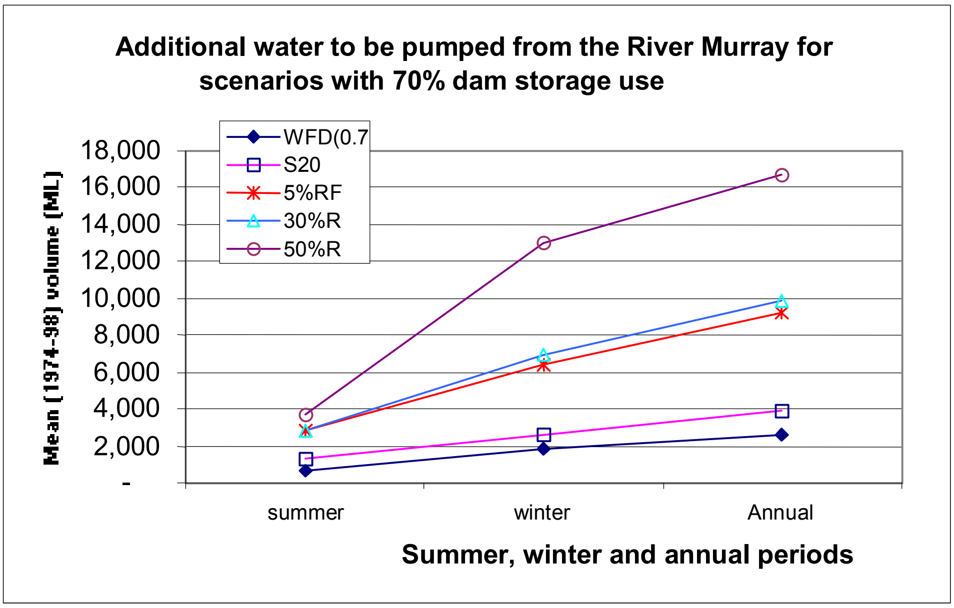
# Table 30. Modelling Scenarios of Inflows into Mount Bold Reservoir and Clarendon Weir – Irrigation Usage = 0.7 of Dam Storage

| **Average Flow into Mount Bold Reservoir** | | | | | | |
|---|---|---|---|---|---|---|
| **Scenarios** | **WFD (0.3)** | **WFD (0.7)** | **S20** | **5%RF** | **30%RL** | **50%RL** |
| 1 | 789 | 706 | 631 | 472 | 470 | 432 |
| 2 | 509 | 456 | 406 | 317 | 307 | 273 |
| 3 | 443 | 407 | 371 | 304 | 307 | 296 |
| 4 | 513 | 476 | 448 | 371 | 377 | 365 |
| 5 | 1,053 | 949 | 903 | 694 | 663 | 618 |
| 6 | 3,731 | 3,405 | 3,275 | 2,628 | 2,400 | 1,896 |
| 7 | 11,493 | 10,940 | 10,736 | 9,845 | 9,447 | 7,667 |
| 8 | 12,196 | 11,701 | 11,550 | 10,932 | 10,866 | 9,452 |
| 9 | 10,818 | 10,691 | 10,63 | 10,431 | 10,430 | 9,516 |
| 10 | 7,846 | 7,611 | 7,517 | 7,170 | 7,096 | 6,487 |
| 11 | 3,552 | 3,301 | 3,175 | 2,757 | 2,716 | 2,389 |
| 12 | 2,983 | 2,788 | 2,668 | 2,305 | 2,246 | 1,975 |
| Summer | 8,669 | 8,023 | 7,591 | 6,435 | 6,333 | 5,651 |
| Winter | 47,138 | 45,296 | 44,614 | 41,700 | 40,903 | 35,635 |
| Annual | 55,808 | 53,319 | 52,205 | 48,135 | 47,237 | 41,287 |
| Additional Water to Pump | | | | | | |
| Summer | – | 647 | 1,079 | 2,235 | 2,336 | 3,018 |
| Winter | – | 1,842 | 2,524 | 5,438 | 6,235 | 11,503 |
| Annual | – | 2,489 | 3,603 | 7,673 | 8,571 | 14,521 |
| Additional Water to Pump into Mount Bold Reservoir and Clarendon Weir Systems | | | | | | |
| Summer | – | 768 | 1,316 | 2,811 | 2,858 | 3,684 |
| Winter | – | 1,872 | 2,618 | 6,442 | 6,977 | 13,031 |
| Annual | – | 2,640 | 3,934 | 9,252 | 9,835 | 16,715 |
| **Average Flow into Clarendon Weir** | | | | | | |
| **Scenarios** | **WFD (0.3)** | **WFD (0.7)** | **S20** | **5%RF** | **30%RL** | **50%RL** |
| 1 | 139 | 109 | 84 | 46 | 50 | 42 |
| 2 | 80 | 64 | 51 | 24 | 27 | 15 |
| 3 | 54 | 42 | 32 | 15 | 18 | 12 |
| 4 | 37 | 30 | 22 | 9 | 10 | 10 |
| 5 | 69 | 60 | 50 | 13 | 17 | 14 |
| 6 | 424 | 411 | 391 | 183 | 228 | 138 |
| 7 | 1,505 | 1,503 | 1,481 | 1,078 | 1,177 | 886 |
| 8 | 1,498 | 1,503 | 1,507 | 1,346 | 1,435 | 1,111 |
| 9 | 1,344 | 1,345 | 1,344 | 1,352 | 1,353 | 1,336 |
| 10 | 1,071 | 1,060 | 1,046 | 9366 | 959 | 898 |
| 11 | 575 | 549 | 519 | 390 | 415 | 354 |
| 12 | 412 | 380 | 346 | 228 | 247 | 188 |
| Summer | 1,279 | 1,157 | 1,042 | 703 | 758 | 613 |
| Winter | 5,911 | 5,882 | 5,818 | 4,908 | 5,169 | 4,384 |
| Annual | 7,19 | 7,039 | 6,859 | 5,611 | 5,926 | 4,997 |
| Additional Water to Pump | | | | | | |
| Summer | – | 122 | 238 | 576 | 522 | 666 |
| Winter | – | 30 | 93 | 1,003 | 742 | 1,528 |
| Annual | – | 151 | 331 | 1,579 | 1,264 | 2,197 |

**Figure 25. Additional water to be pumped from the River Murray for all cases scenario**



# SUMMARY AND CONCLUSIONS

## *Rainfall-runoff relationship*

Rainfall runoff relationship can be established for a catchment using Tanh curve equation. The relationship shows that for the Onkaparinga Catchment significant annual runoff occurs when rainfall in the catchment is greater than 400~450 mm a year. The relationship indicates runoff is little with low rainfall catchment and it increases exponentially with high annual rainfall.

## *Farm Dam Development*

Up to the early 90s, the rate of farm dams development in the Onkaparinga catchment was slow. Then it increased rapidly from 75 ML/yr to 150 ML/yr in the late 90s. The estimate of aggregated dam storage for Onkaparinga catchment in 1999 is 8,500ML.

A number of empirical formulae relating volume to surface area have been proposed for estimating the farm dam volume. Caution should be exercised when applying these formulae for estimating dam volumes.

## *Farm Dam Impact on Current Scenario*

### Annual Flow Volume

The median annual adjusted flow trapped by farm dam storage is:

- 8% in the catchment upstream of Houlgrave Weir;
- 5% upstream of Clarendon Weir;
- 10% or more in subcatchments where farm dam density exceeds 25 ML/km$^2$. A density of 25 ML/km$^2$ appears to be the threshold factor for the 10% impact. Farm dam density and the annual rainfall received in a catchment have counteracting effects on the amount of catchment yield trapped by the dam storage.

In the defined dry period, the annual adjusted flow trapped by farm dams is:

- 11% above Houlgrave catchment
- 12% above Clarendon catchment
- 10% or more in subcatchments where farm dam density exceeds 10 ML/km2.

In the defined wet period, the percentage of annual adjusted flow captured is:

- 3% above Houlgrave Weir;
- 5% above Clarendon Weir; and
- 10% in Mitchell subcatchment where farm dam density exceeds 39 ML/km2.

### Monthly Flow Volume

In a median year, the first month of winter flow at Houlgrave Weir is significantly impacted by farm dam storages with 21% of water retained by the dams. In a defined dry period, the impact extends to July with a 23% reduction in flow.

### Daily Flow Volume

In a median year, farm dams have reduced the frequency of natural streamflow at Houlgrave Weir in the range 5-50 ML/day by 30-60 days a year.

### Increasing dam storage use from 30% to 70%

Modelling shows that increasing the dam storage use from 30% to 70% would reduce the catchment yield further. With 70% of dam storage being used, flows at Houlgrave Weir would be reduced from the previously modelled 8% to 11% in a median year. Similarly, for Mitchell Creek, the reduction in runoff would increase from 20% to 35%. Generally, the same can be said for the other major subcatchments. This observation also occurs in the defined dry and wet periods.

## *Farm Dam Impact on Future Scenarios*

### Catchment Runoff

Increasing farm dam development naturally would reduce the catchment runoff as the dams have greater capacity to capture more surface flow. Nevertheless, the reduction in the adjusted flow of a catchment is also conditioned to the degree of free flow (or by pass) allowable within the catchment. With both the preceding factors in place, for the Houlgrave Weir catchment, under the fully developed 50% rule of scenario 6, and assuming 70% of dam storage being used, the model shows that reduction in flow is 32% in a median year and 45% in the defined dry period. For Mitchell Creek with the same scenario, flow reduction is 43% in both in a median year and the defined dry period.

Without limiting the diversion of a catchment runoff, it is possible to capture all the flow in the dams. This is illustrated in the modelling of Angels Gully subcatchment with no off-stream dams, the reduction in catchment runoff is 99% in the defined dry period.

### Water Supply System

Inflows into the Mt Bold Reservoir and Clarendon Weir are impacted to a varying degree by the farm dam developments. The greater the aggregated dam development is allowed within the catchment, the greater the impact it is on reduction of inflows into the reservoir system.

Modelling shows that for scenario 3 farm dam development with 30% storage use, assuming the water supply operations and requirement remains as status quo, the additional water to be pumped from the River Murray into the reservoir system each year to compensate for the reduction of inflows is 1000 ML. Increasing the dam storage use to 70% would require 3000 ML of pumping. Under the fully developed scenario 6 situation, with 70% of dam storage being used, the additional water to be pumped from the River Murray, with status quo supply operations and requirement, would be 17,000 ML per annum.

### 50% Rule Policy

- None of the 16 major subcatchments, at current farm dam development, has exceeded the 50% rule policy where allowable dam volume of a catchment is 50% of the median annual adjusted flow as defined in the State Water Plan Volume 1 pp 50.

In the extreme dry period, six of the 16 subcatchments are seen to have captured greater than 50% of the adjusted flow or catchment yield estimated for the dry period. This has implications for the development of water resource policies for improved management of farm dams development.

- The combined storage capacity of farm dams in the subcatchments, Mt Bold Reservoir, Happy Valley Reservoir and Clarendon Weir is 95% of the modelled adjusted median natural flow at Clarendon weir.

## *Opportunities to Enhance Modelling Outputs*

Hydrological modelling for the Onkaparinga River catchment can be improved if a number of the following background information and data can be enhanced:

- The method of estimating farm dam volumes
- Knowledge of land use information
- The amount of irrigated water derived from surface and groundwater sources
- Recharge and discharge zones of groundwater
- The proportion of water being used annually from the respective dam storage
- Infilled, correlated and disaggregated rainfall data used by the model needs further validation.
- Collating the data associated with the operation and consumption of the water supply system from the Onkaparinga River catchment to the Happy Valley Reservoir
- Inflows and outflows to the Mt Bold Reservoir and Clarendon Weir system
- Streamflow monitoring upstream of Houlgrave Weir where currently only about 12% of the catchment is gauged independently.

# SI Units Commonly Used Within Text

| Name of unit | Symbol | Definition in terms of other metric units | |
|---|---|---|---|
| Millimetre | mm | $10^{-3}$ m | length |
| Metre | m | | length |
| Kilometre | km | $10^{3}$ m | length |
| Hectare | ha | $10^{4}$ $m^{2}$ | area |
| Microlitre | µL | $10^{-9}$ $m^{3}$ | volume |
| Millilitre | mL | $10^{-6}$ $m^{3}$ | volume |
| Litre | L | $10^{-3}$ $m^{3}$ | volume |
| Kilolitre | kL | 1 $m^{3}$ | volume |
| Megalitre | ML | $10^{3}$ $m^{3}$ | volume |
| Gigalitres | GL | $10^{6}$ $m^{3}$ | volume |
| Microgram | µg | $10^{-6}$ g | mass |
| Milligram | mg | $10^{-3}$ g | mass |
| Gram | g | | mass |
| Kilogram | kg | $10^{3}$ g | Mass |

# Abbreviations Commonly Used Within Text

| Abbreviation | | Name | Units of measure |
|---|---|---|---|
| TDS | = | Total Dissolved Solids *(milligrams per litre)* | mg/L |
| EC | = | Electrical Conductivity *(micro Siemens per centimetre)* | µS/cm |
| pH | = | Acidity | |
| | | | |
| δD | = | Hydrogen isotope composition | ‰ |
| CFC | = | Chlorofluorocarbon *(parts per trillion volume)* | pptv |
| $\delta^{18}O$ | = | Oxygen isotope composition | ‰ |
| $^{14}C$ | = | Carbon-14 isotope *(percent modern Carbon)* | pmC |
| | | | |
| ppm | = | Parts per million | |
| ppb | = | Parts per billion | |
| D | = | Day | |
| M | = | Month | |
| Yr | = | Year | |
| EPA | = | Environmental Protection Agency, Department for Environment and Heritage | |
| GIS | = | geographic information systems | |
| *HYDSYS* | | a suite of hydrological and water resources management software packages employed as part of the South Australian State water data archive | |
| *WaterCress* | = | water balance computer model for designing and testing trial layouts of water systems using multiple sources of water | |
| *XP-AQUALM* | | integrated hydrological and water quality management computer package (from XP software company) | |

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# APPENDIX A - PROCESSING RAINFALL DATA PROCESSES

Before the records of rainfall stations can be used for modelling purposes, the raw data needs to be checked and processed.

Processing the raw rainfall data from these rainfall stations involved a number of steps. They are to:

- identify those stations with useful records;
- re-distribute the rainfall data of the identified stations;
- fill in the data gaps by patching the missing rainfall records;
- carry out double mass curve analysis to check for the homogeneity of the records for these stations;
- identify rainfall trends over the recording period;
- construct an isohyetal map for the catchment;
- identify the stations best representing each subcatchment area for modelling purposes.

Situations requiring the second step listed above often arise because more often than not, the raw rainfall data contain information gaps and accumulated data. Accumulated data refers to rainfall that was accumulated during weekends and public holidays and was then recorded on the next working day at 9:00 am, which is usually Monday. As a result, the accumulated data require redistribution within the period of accumulation and the missing records need patching.

This is an enormous task to perform. The Engineering Consultants Sinclair Knight Merz (SKM) provided the processing of the rainfall data for redistributing and infilling of the missing gaps. The Consultants automated the processing of the data set from Jan 1884 to December 1998. The methodology is outlined below

## Methodology for re-distribution of rainfall data

For redistribution of rainfall data, it is based on the method outlined by Porter and Ladson (1993). The method assumes that the influence of nearby stations, where records are complete, is inversely proportional to their distance from the gauged station. That is if a gauged station **S** has its rainfall accumulated over **m** days, and complete data is available from **n** rainfall stations nearby, on day **j** precipitation at **S** station is given by:

$$\mathrm{P}_{jS} = \frac{\sum_{i=1}^{m} \mathrm{P}_{iS} . \sum_{k=1}^{n} \{p_{jk} / d_k\}}{\sum_{k=1}^{n} \{1 / d_k\}}$$

where $\sum_{i=1}^{m} \mathrm{P}_{iS}$ is total rainfall accumulated over **m** days for the gauged station **S**,

$d_k$ is the distance from a rainfall station ***k*** to the gauged station **S**, and

$p_{jk}$ is that proportion of rainfall fell on day **j** at **k** station over the total rainfall accumulated over **m** days at the same **k** station. That is,

$$p_{jk} = \frac{\mathrm{P}_{jk}}{\sum_{i=1}^{m} \mathrm{P}_{\mathrm{ik}}}$$

To this effect, an automated procedure was developed to redistribute the data. The procedure limits the search to only 15 rainfall stations closest to the station of interest. If no reference can be made from these 15 stations, then it is recommended that redistribution be carried out manually from other nearby stations closest to the station of interest. If no such reference station can be found, then redistribution may be carried out evenly over the period of accumulation.

For infilling the missing rainfall records, the correlation method was used. The annual rainfall of a station **S** of interest was correlated with that of other nearby stations. The station with the highest correlation factor with S that had data concurrent with the missing period was used for infilling the records. Again, the Consultants developed an automated procedure for infilling the data and it was limited to a search of 15 closest rainfall stations only.

# APPENDIX B - HYDROLOGICAL MODELLING

## *Introduction*

The complexity of the influence of widely distributed farm dams and the importation of significant quantities of water from the River Murray within the Onkaparinga catchment require that a hydrological model be produced to serve several functions, namely:

- To check the accuracy of existing measured information by ensuring water balance is maintained throughout the system
- To assess the impact that the current farm dams have on the system
- To run a range of scenarios to assess the impact to current users and the environment given changes in volume of farm dams, landuse change and environmental flow release rules.

In view of this, a hydrological model for Onkaparinga catchment has been constructed using a PC based computing program called *WaterCress*. The program incorporates a number of runoff models for calculating water balance of a water system.

This section outlines the methodology adopted for the construction of the Onkaparinga catchment hydrological model.

### ***WATERCRESS*** **modelling program**

*WaterCress* stands for *W*ater-*C*ommunity *R*esource *E*valuation and *S*imulation *S*ystem. It is a program capable of modelling a range of water systems for computing water balance from multiple sources of water. A water system may consist of a catchment component, water demand requirements, treatment of water, diversion and/or water storages.

To construct a hydrological model, *WaterCress* uses "nodes" as the building blocks for representing each component of the water system within the model. There are five main classes of nodes noted for the program, namely:

- demand nodes for town and industry;
- catchment nodes for rural and urban type;
- storage nodes for reservoir, dam and aquifer storage;
- treatment nodes for water treatment plant and wetland, and
- diversion/transfer nodes for weir, routing and environment flows purposes.

Each node type is represented as an icon as shown in Figure 26.

Rural and urban catchments produce the necessary runoff due to precipitation. The runoff, in turn, generates streamflow in the river system which may be captured by on-stream and off-steam dams within the catchment. Hence these hydrological processes are represented in the model by the elements of rural, urban and reservoir node functions. Additional routing nodes are added to better simulate streamflow calibrations. A Routing node may be incorporated in the model to assist better calibration as it mimics the delayand attenuation characteristics of streamflows.

**Figure 26. WaterCress Model Nodes**


To calculate the runoff created from rural catchments one of a number of runoff models incorporated in the program may be chosen. These include WC-1, Hydrolog, AWBM, SFB, SDI, Aquam and Initial/Continuous loss models.

For Onkaparinga River catchment, the WC-1 model is chosen as the modelling platform since it is considered to be the most appropriate for the Mt Lofty Ranges conditions by the previous modellers. The model was developed by D. Cresswell who derived the concept from one of WC Boughton's papers that described how the runoff processes could be simulated by a number of storages of differing capacities and areas. The WC-1 model employs a three-bucket concept whereby runoff generated from precipitation would be collected by a bucket, which then passes down the excess water to another bucket when it is full. The first bucket is called an interception store (IS), the second a soil moisture store and the last one a groundwater store. The interception store represents the precipitation being intercepted by foliage of vegetation and the like. The soil moisture store represents the water holding capacity of the soil and groundwater store is that portion of water percolates to the groundwater table. Water moves from the interception store to the soil moisture store through surface runoff and interflows. From the soil moisture store, recharge to local groundwater table occurs, which in turn may discharge as baseflow to a stream at some distance down the catchment. Groundwater losses to pumping and regional aquifer may also occur. A schematic diagram of three-bucket rainfall-runoff processes is presented in Figure 27. The WC-1 model uses a daily time step to calculate the water balance of rainfall runoff processes. Figure 28 shows how the WC-1 model operates in a daily time-step.

**Figure 27. 3 Bucket Rainfall-Runoff Processes**

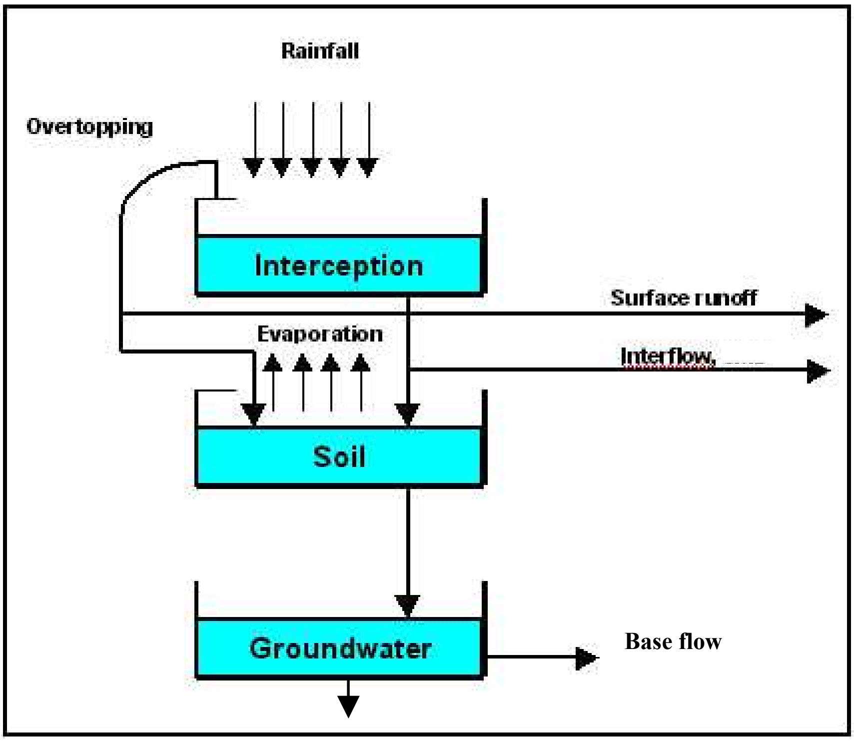
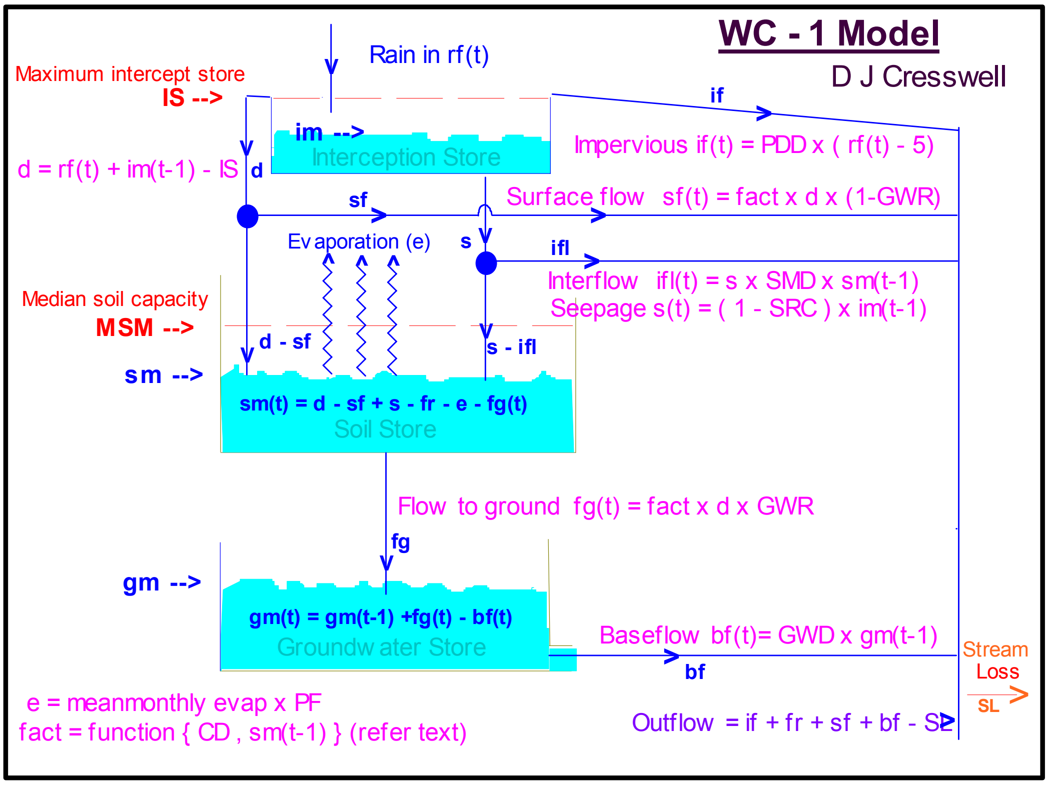



**Figure 28. WaterCress WC-1 Runoff Model**



# *Catchment data*

## Introduction

The layout of Onkaparinga catchments and a schematic diagram of the 240 node catchment hydrological model is provided as shown in Figures 29 30. It is noted that the model consists of the building blocks of nodes representing:

- rural catchments (rural nodes)
- townships (urban nodes)
- on-stream and off-stream farm dams (reservoir nodes) and
- routing components (routing nodes).

In addition to the rural catchments, there are significant urban areas within the catchment. These areas are shown in Figure 31. Table 33 provides the input data required for the construction of the model nodes. The contents of Table 33 are briefly described as:

| Column | Heading | Description |
|---|---|---|
| 2 | SUB_CATCH4 | Description of a subcatchment |
| 4 | Sub-cat Nos | shows the sub-divided catchment in sequential numbering |
| 5 | Rural Node | shows the WaterCress model node number for rural catchment |
| 6 | Dam Node | shows the WaterCress model node number for associated dams |
| 8 | Net_cat4_area,ha | area of a rural catchment in ha |
| 9 | Urban_ha | area of an urban catchment in ha |
| 10 | DamAREA_M2 | area of an aggregated farm dam's water surface, in m2 |
| 11 | VOL(ML)_Dg | volume of aggregated farm dams within catchment, in ML |
| 12 | location | location of a rainfall station used for the node in WaterCress model |
| 14 | rainfall ratio | ratio applied to the rainfall data used by the node (refer Section: DATA INPUT TO MODEL: Rainfall) |
| 16 | Off-stream Dam | indicates the node is an off-stream type dam, those not specified indicates the node is an on-stream dam |
| 17 | Diversion fraction | indicates the percentage of runoff diverted from the catchment irrespective of if the dam is full or not. |

## Rural and urban catchment nodes

The catchment is initially subdivided into 16 major subcatchments identifying the major tributaries and positions of existing gauging stations. The locations of the major subcatchments are shown in Figure 1 and the corresponding areas in Table 31. Further subdivision from the major subcatchments was carried out based on the following:

- The catchment area located upstream of a controlling dam or in areas with significant aggregated dam storage development. A controlling dam is one that has substantial storage size (say greater than 20 ML) and is found on the flow path of a creek. Runoff captured by the controlling dam can only pass the water downstream when the dam storage is full (refer Section: Reservoir nodes).

- Division of catchments into areas of similar rainfall along the rainfall isohyets where feasible.
- The catchment area immediately upstream of a gauging station where reliable streamflow records are available.

The result is a total division of the Onkaparinga River catchment into 95 smaller subcatchments (Figure 29) varying in area size considerably. These form the rural catchment nodes of the Onkaparinga hydrological model.

### Table 31. The Catchments Area and Numbering Sequence

| Subcatchment | Area (ha) | Subcatchment No. |
|---|---|---|
| Aldgate Creek | 1,945 | 54-58 |
| Bakers Gully | 4,796 | 83-90 |
| Balhannah | 1,024 | 45 |
| Biggs Flat | 2,365 | 59-61 |
| Charleston | 5,151 | 1-12 |
| Cox Creek | 2,875 | 49-53 |
| Echunga Creek | 3,917 | 64-71 |
| Hahndorf | 1,468 | 47 |
| Inverbrakie Creek | 2,674 | 13-20 |
| Lenswood Creek (Cock Ck) | 2,840 | 29-40 |
| Michell Creek | 1,451 | 22 |
| Onkaparinga-48 (Angels Gully) | 1,408 | 79-80 |
| Onkaparinga Main Channel | 13,043 | 63,72,81,82,91-95 |
| Scott Creek | 2,850 | 74-78 |
| Upper Onkaparinga | 4,708 | 23,41-44,46 |
| Western Branch | 3,297 | 24-28 |
| Grand total | 55,812 | 95 |

Urban nodes are incorporated in the model to represent townships within the Onkaparinga River catchment. An urban node may represent a combined area of several townships spread across several subcatchments. The location of the townships is shown in Figure 31 and the size adopted (refer Section: Data Input to Model: Rural and Township Catchments) in Table 32.

## Table 32. Town Nodes in the Model

| Township | Subcatchment | Urban Node | Area (ha) | Comment |
|---|---|---|---|---|
| Scott Ck | Scott Ck | 204 | 0 | Urban node u/s N203, Scott ck |
| Aldgate | Aldgate Ck | 207 | 160 | Urban node u/s N193, Aldgate |
| Uraidla, Summertown | Cox Creek | 210 | 14 | Urban node u/s N209, Cox ck |
| Woodside, Lobethal | Charleston | 224 | 56 | Urban node for township @ sub-cat nos 11&12 (33 + 23 ha), u/s of N219 |
| Lobethal | Western Branch | 225 | 43 | Urban node for township @ sub-cat nos 26 of Western Branch |
| Balhannah, Bridgewater, Oakbank | Upper Onkaparinga | 226 | 34 | Urban node for township @ sub-cat nos 41 |
| Stirling | Cox Creek | 227 | 45 | Urban node for township @ sub-cat nos 51 |
| Aldgate, Bridgewater, Stirling | Cox Creek | 228 | 97 | Urban node for township @ sub-cat nos 52 & 53 combined (91+6 ha), Cox ck |
| Aldgate, Stirling | Aldgate ck | 229 | 64 | Urban node for township @ sub-cat nos 56 (64 ha), Aldgate, u/s of N223 |
| Balhannah | Balhannah | 236 | 12 | in Balhannah catchment |
| Hahndorf | Hahndorf | 237 | 49 | in Hahndorf catchment |

Note: modelled impervious area of the urban component is taken as 1/3 of the digitised plan area of the township

## Reservoir nodes

Farm dams are represented as reservoir nodes in the model. Based on the 1999 farm dam surveys, there are 2,700 farm dams found in the Onkaparinga catchment varying in size from less than 0.5 ML to greater than 50 ML each in storage capacity with a total volume of 8,500 ML. It is not practical for every farm dam to be represented as a reservoir node in the hydrological model. So the water surface area and the storage capacity of all the farm dams within a subcatchment are "aggregated" as if only one farm dam existed within that catchment. It is then represented as a reservoir node of the catchment. With the exception of subcatchments Onkaparinga Main Channel 4&6 where no farm dams existed, all of the subcatchments have farm dams constructed in their area with a total of 93 reservoir nodes. The volume corresponding to each catchment sub-area is shown in Table 33 as DamAREA_m$^2$ and Vol (ML).

A reservoir node can be represented by either an on-stream or off-stream aggregated farm dam. The choice of which to use depends on the spatial layout of the dams within the catchment in question. An aggregated farm dam is modelled as on-stream dam if large dams are found blocking the flow path of a creek system. In this case, runoff is assumed to spill downstream only when the dam is full. An aggregated off-stream dam would allow a specified proportion of runoff to bypass the dam to downstream irrespective of the level of storage in the dam. This option is adopted where there are many dams spread spatially throughout the catchment and there are sections of stream which are free to flow. The size and type of aggregated storage are defined in Table 33.

Model calibration is carried out for streamflow in a catchment where sufficient records of a gauging station can found. For this model the location of a gauging station is represented in the model as an off-stream reservoir node, which has the storage volume set to zero. The inclusion of these additional off-stream nodes allows incremental increases in dam volumes to be made in each of the subcatchments to simulate further farm dam development as required.

## Routing nodes

The routing node is added in the model to improve the calibration of streamflows at a gauged station. It has the effect of delaying the timing of the flow. The node requires a relationship between flow passing and stored volume to be maintained thus simulating flow detention in stream channels. These nodes are necessary to enable the model to more accurately define flows on the daily time-steps.

## Table 33. Input Data for the Catchment Hydrological Model

| No. | Subcatchment | Cat Set | Subcat. Nos. | Rural Node | Dam Node | Cat4_AREA_HA | Net_cat4_area,ha | Urban_ha | DamAREA_M2 | VOL(ML)_Dg | Rainfall (mm) | | | At centroid of catchment | Rf ratio | Adjusted rainfall | Off/stream Dam | Diversion fraction |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | location | average | isohyet | | | | | |
| 1 | CHARLESTON_4c | **1** | 2 | 1 | 2 | 80.9 | 79.6 | | 12,474.2 | 22.7 | LB | 885.4 | 868 | 719 | 0.83 | 733.4 | | |
| 2 | CHARLESTON_3 | **8** | 3 | 3 | 4 | 152.5 | 148.5 | | 40,514.9 | 82.9 | LB | 885.4 | 868 | 700 | 0.81 | 714.0 | | |
| 3 | CHARLESTON_4a4 | **6** | 4 | 5 | 6 | 1,322.8 | 1,314.3 | | 85,604.5 | 84.4 | LB | 885.4 | 868 | 700 | 0.81 | 714.0 | yes | 30% |
| 4 | CHARLESTON_4d | **1** | 5 | 7 | 8 | 77.0 | 73.3 | | 36,719.2 | 65.8 | LB | 885.4 | 868 | 767 | 0.88 | 782.4 | | |
| 5 | CHARLESTON_4b | **5** | 6 | 9 | 10 | 94.5 | 92.2 | | 23,649.9 | 32.2 | LB | 885.4 | 868 | 787 | 0.91 | 802.8 | | |
| 6 | CHARLESTON_4a2 | **6** | 7 | 11 | 12 | 641.7 | 636.6 | | 51,055.6 | 57.0 | LB | 885.4 | 868 | 775 | 0.89 | 790.5 | yes | 30% |
| 7 | CHARLESTON_1 | **5** | 9 | 13 | 14 | 101.3 | 99.0 | | 23,062.1 | 46.9 | LB | 885.4 | 868 | 795 | 0.92 | 810.9 | | |
| 8 | CHARLESTON_4a3 | **8** | 8 | 15 | 16 | 541.7 | 537.6 | | 40,374.3 | 56.6 | LB | 885.4 | 868 | 707 | 0.81 | 721.2 | yes | 35% |
| 9 | CHARLESTON_4a1 | **6** | 10 | 17 | 18 | 516.4 | 508.6 | | 77,907.6 | 104.6 | WS | 805.3 | 833(706.5) | 737(685.4) | 0.97 | 781.1 | | |
| 10 | CHARLESTON_2 | **5** | 11 | 20 | 21 | 1,286.1 | 1,243.6 | 33.0 | 94,899.6 | 124.0 | WS | 805.3 | 833 | 792 | 1.00 | 805.3 | yes | 35% |
| 11 | CHARLESTON_5 | **6** | 12 | 22 | 23 | 236.4 | 212.7 | 23.0 | 6,722.4 | 6.0 | WS | 805.3 | 833 | 773 | 1.00 | 805.3 | | |
| 12 | INVERBRACKIE CK_4c | **8** | 13 | 24 | 25 | 15.4 | 14.2 | | 11,501.5 | 19.4 | WS | 805.3 | 833 | 676 | 0.97 | 781.1 | | |
| 13 | INVERBRACKIE CK_4a | **8** | 14 | 26 | 27 | 29.0 | 27.6 | | 14,467.2 | 20.1 | WS | 805.3 | 833 | 685 | 0.97 | 781.1 | | |
| 14 | INVERBRACKIE CK_4d | **8** | 15 | 28 | 29 | 26.1 | 24.9 | | 12,008.4 | 16.7 | WS | 805.3 | 833 | 688 | 0.97 | 781.1 | | |
| 15 | INVERBRACKIE CK_4b | **8** | 16 | 30 | 31 | 295.5 | 286.9 | | 86,557.0 | 128.9 | WS | 805.3 | 833 | 675 | 0.97 | 781.1 | | |
| 16 | INVERBRACKIE CK_1 | **8** | 17 | 32 | 33 | 476.7 | 470.9 | | 58,604.1 | 70.2 | WS | 805.3 | 833 | 675 | 0.97 | 781.1 | yes | 35% |
| 17 | INVERBRACKIE CK_2c | **7** | 21 | 34 | 35 | 1,489.7 | 1,475.8 | | 139,723.8 | 171.2 | WS | 805.3 | 833 | 726 | 0.97 | 781.1 | yes | 35% |
| 18 | INVERBRACKIE CK_2a | **8** | 18 | 36 | 37 | 97.3 | 94.1 | | 32,068.6 | 51.4 | WS | 805.3 | 833 | 702 | 0.97 | 781.1 | | |
| 19 | INVERBRACKIE CK_2b | **7** | 19 | 38 | 39 | 147.1 | 144.4 | | 27,357.7 | 52.3 | WS | 805.3 | 833 | 745 | 0.97 | 781.1 | | |
| 20 | INVERBRACKIE CK_3 | **7** | 20 | 40 | 41 | 97.2 | 96.5 | | 7,075.6 | 7.6 | WS | 805.3 | 833 | 726 | 0.97 | 781.1 | | |
| 21 | MITCHELL CK_1 | **1** | 22 | 42 | 43 | 1,450.7 | 1,426.6 | | 241,084.8 | 565.7 | WS | 805.3 | 833 | 726 | 0.97 | 781.1 | | |
| 22 | UPPER ONKAPARINGA_2 | **6** | 23 | 44 | 45 | 634.8 | 625.0 | | 98,053.0 | 175.0 | WS | 805.3 | 833 | 847 | 1.02 | 818.8 | | |
| 23 | UPPER ONKAPARINGA_1c1 | **6** | 41 | 46 | 47 | 1,951.7 | 1,898.2 | 34.0 | 194,550.4 | 215.8 | HD | 858.5 | 796 | 905 | 1.14 | 976.1 | yes | 40% |

| | | | | | | | | | | | Rainfall (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | WESTERN BRANCH_1a | **5** | 24 | 49 | 50 | 191.0 | 184.1 | | 68,674.1 | 114.7 | LB | 885.4 | 868 | 906 | 1.04 | 924.2 | | |
| 25 | WESTERN BRANCH_2 | **5** | 25 | 51 | 52 | 87.6 | 83.6 | | 40,589.0 | 85.2 | LB | 885.4 | 868 | 858 | 0.99 | 875.2 | | |
| 26 | WESTERN BRANCH_1b | **1** | 26 | 53 | 54 | 2,129.2 | 2,060.2 | 43.0 | 260,651.5 | 344.1 | WS | 805.3 | 833 | 878 | 1.05 | 848.8 | yes | 65% |
| 27 | WESTERN BRANCH_4 | **5** | 27 | 55 | 56 | 293.3 | 281.5 | | 117,934.1 | 245.0 | WS | 805.3 | 833 | 908 | 1.09 | 877.8 | | |
| 28 | WESTERN BRANCH_3 | **6** | 28 | 57 | 58 | 595.6 | 583.2 | | 123,496.8 | 195.9 | HD | 858.5 | 796 | 838 | 1.05 | 903.8 | yes | 60% |
| 29 | COCK CK_6 | **5** | 29 | 59 | 60 | 95.0 | 91.5 | | 35,109.5 | 51.8 | UR | 1082.8 | 1037 | 931 | 0.90 | 972.1 | | |
| 30 | COCK CK_8 | **5** | 30 | 61 | 62 | 115.2 | 111.4 | | 38,533.0 | 46.7 | UR | 1082.8 | 1037 | 938 | 0.90 | 979.4 | | |
| 31 | COCK CK_1 | **5** | 31 | 63 | 64 | 105.5 | 102.9 | | 25,999.0 | 35.8 | UR | 1082.8 | 1037 | 950 | 0.92 | 992.0 | | |
| 32 | COCK CK_5c | **5** | 32 | 65 | 66 | 264.2 | 260.6 | | 35,304.9 | 32.3 | UR | 1082.8 | 1037 | 963 | 0.93 | 1005.5 | | |
| 33 | COCK CK_5a | **5** | 33 | 67 | 68 | 229.1 | 227.7 | | 13,098.8 | 14.3 | WS | 805.3 | 833 | 943 | 1.13 | 911.6 | yes | 50% |
| 34 | COCK CK_3 | **5** | 34 | 69 | 70 | 405.4 | 394.6 | | 107,318.2 | 115.7 | WS | 805.3 | 833 | 924 | 1.11 | 893.3 | | |
| 35 | COCK CK_2 | **5** | 35 | 71 | 72 | 47.3 | 44.3 | | 30,445.4 | 46.9 | WS | 805.3 | 833 | 925 | 1.11 | 894.2 | | |
| 36 | COCK CK_5b | **5** | 36 | 73 | 74 | 301.4 | 295.8 | | 55,652.0 | 75.4 | WS | 805.3 | 833 | 933 | 1.12 | 902.0 | yes | 50% |
| 37 | COCK CK_5d | **5** | 37 | 75 | 76 | 120.7 | 120.0 | | 6,887.9 | 4.8 | UR | 1082.8 | 1037 | 957 | 0.92 | 999.3 | | |
| 38 | COCK CK_4 | **5** | 38 | 77 | 78 | 68.7 | 66.1 | | 26,178.0 | 38.9 | UR | 1082.8 | 1037 | 975 | 0.94 | 1018.1 | | |
| 39 | COCK CK_7a | **5** | 39 | 79 | 80 | 695.5 | 683.3 | | 121,825.3 | 160.7 | UR | 1082.8 | 1037 | 995 | 0.96 | 1038.9 | yes | 80% |
| 40 | COCK CK_7b | **5** | 40 | 81 | 82 | 391.7 | 385.8 | | 59,615.2 | 86.7 | WS | 805.3 | 833 | 900 | 1.08 | 870.1 | yes | 50% |
| 41 | UPPER ONKAPARINGA_1a | **6** | 42 | 83 | 84 | 470.8 | 453.9 | | 168,940.2 | 312.7 | BW | 1044.7 | 962 | 962 | 1.00 | 1044.7 | | |
| 42 | UPPER ONKAPARINGA_1c3 | **6** | 43 | 85 | 86 | 894.1 | 882.3 | | 117,789.8 | 124.5 | UR | 1082.8 | 1037 | 961 | 0.93 | 1003.4 | yes | 60% |
| 43 | UPPER ONKAPARINGA_1c2 | **6** | 44 | 87 | 88 | 482.0 | 478.1 | | 39,008.3 | 32.0 | BW | 1044.7 | 962 | 950 | 0.99 | 1031.7 | | |
| 44 | BALHANNAH_1 | **6** | 45 | 89 | 90 | 1,024.3 | 1,000.7 | 12.0 | 116,214.8 | 197.0 | HD | 858.5 | 796 | 772 | 0.97 | 832.6 | yes | 80% |
| 45 | UPPER ONKAPARINGA_1b | **6** | 46 | 91 | 92 | 274.8 | 265.3 | | 95,084.7 | 200.5 | HD | 858.5 | 796 | 844 | 1.06 | 910.3 | | |
| 46 | HAHNDORF_1 | **1** | 47 | 93 | 94 | 1,468.4 | 1,394.0 | 49.0 | 253,520.9 | 475.7 | HD | 858.5 | 796 | 812 | 1.02 | 875.8 | yes | 75% |
| 47 | ONKAPARINGA MAIN CH_1 | **6** | 48 | 95 | 96 | 107.0 | 106.0 | | 9,686.9 | 7.9 | HD | 858.5 | 796 | 863 | 1.08 | 930.8 | | |
| 48 | CHARLESTON_4e | **6** | 1 | 97 | 98 | 99.5 | 96.5 | | 30,238.5 | 64.8 | LB | 885.4 | 868 | 738 | 0.85 | 752.8 | | |
| 49 | ONKAPARINGA MAIN CH_3b | **6** | 63 | 99 | 100 | 1,952.1 | 1,925.7 | | 263,545.5 | 297.1 | BW | 1044.7 | 962 | 900 | 0.94 | 977.4 | | |
| 50 | COX CK_1a | **1** | 49 | 102 | 103 | 552.3 | 536.0 | 14.0 | 22,771.1 | 18.5 | UR | 1082.8 | 1037 | 1041 | 1.00 | 1087.0 | | |
| 51 | COX CK_1b | **1** | 50 | 104 | 105 | 595.9 | 586.2 | | 97,018.8 | 100.0 | UR | 1082.8 | 1037 | 1030 | 0.99 | 1075.5 | | |

| | | | | | | | | | | | Rainfall (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 52 | COX CK_1c | **1** | 51 | 106 | 107 | 713.7 | 663.1 | 45.0 | 56,041.6 | 69.1 | UR | 1082.8 | 1037 | 1066 | 1.03 | 1113.1 | yes | 50% |
| 53 | COX CK_1e | **1** | 52 | 108 | 109 | 741.9 | 647.3 | 91.0 | 35,588.8 | 30.6 | BW | 1044.7 | 962 | 1000 | 1.04 | 1086.0 | yes | 40% |
| 54 | COX CK_1d | **1** | 53 | 110 | 111 | 271.2 | 264.8 | 6.0 | 3,983.1 | 2.8 | BW | 1044.7 | 962 | 925 | 0.96 | 1004.5 | yes | 20% |
| 55 | ALDGATE CK_1b | **2** | 54 | 112 | 113 | 455.8 | 375.0 | 80.0 | 7,987.6 | 9.2 | UR | 1082.8 | 1037 | 1075 | 1.04 | 1122.5 | yes | 15% |
| 56 | ALDGATE CK_1a | **2** | 55 | 114 | 115 | 286.9 | 205.1 | 80.0 | 18,794.1 | 28.4 | UR | 1082.8 | 1037 | 1075 | 1.04 | 1122.5 | | |
| 57 | ALDGATE CK_1d | **2** | 56 | 116 | 117 | 616.0 | 545.2 | 64.0 | 68,093.6 | 69.7 | BW | 1044.7 | 962 | 1038 | 1.08 | 1127.2 | yes | 60% |
| 58 | ALDGATE CK_1c | **2** | 57 | 118 | 119 | 271.0 | 266.2 | | 48,351.4 | 43.9 | BW | 1044.7 | 962 | 1004 | 1.04 | 1090.3 | | |
| 59 | ALDGATE CK_1e | **2** | 58 | 120 | 121 | 315.5 | 314.4 | | 10,951.4 | 7.6 | BW | 1044.7 | 962 | 950 | 0.99 | 1031.7 | yes | 20% |
| 60 | ONKAPARINGA MAIN CH_3a | **2** | 95 | 122 | 123 | 275.4 | 274.1 | | 13,430.6 | 9.3 | BW | 1044.7 | 962 | 977 | 1.02 | 1061.0 | yes | 60% |
| 61 | BIGGS FLAT_1a | **6** | 59 | 124 | 125 | 58.9 | 56.6 | | 23,255.3 | 42.3 | EC | 806.8 | 775 | 775 | 1.00 | 806.8 | | |
| 62 | BIGGS FLAT_1b1 | **6** | 60 | 126 | 127 | 1,442.1 | 1,414.5 | | 276,310.8 | 332.1 | EC | 806.8 | 775 | 800 | 1.03 | 832.8 | yes | 80% |
| 63 | BIGGS FLAT_1b3 | **6** | 62 | 128 | 129 | 425.8 | 414.8 | | 109,970.1 | 166.4 | EC | 806.8 | 775 | 875 | 1.13 | 910.9 | | |
| 64 | BIGGS FLAT_1b2 | **6** | 61 | 130 | 131 | 438.1 | 428.8 | | 93,689.6 | 119.2 | EC | 806.8 | 775 | 825 | 1.06 | 858.9 | | |
| 65 | ONKAPARINGA MAIN CH_5a | | 73 | 132 | 214 | 2,325.7 | 2,324.7 | | 10,298.1 | 7.6 | CG | 925.2 | 905 | 875 | 0.97 | 894.5 | | |
| 66 | ECHUNGA CK_4b | **6** | 64 | 134 | 135 | 268.4 | 259.0 | | 94,065.1 | 168.8 | EC | 806.8 | 775 | 771 | 0.99 | 802.6 | | |
| 67 | ECHUNGA CK_4c | **6** | 65 | 136 | 137 | 129.1 | 126.4 | | 27,373.7 | 36.0 | EC | 806.8 | 775 | 775 | 1.00 | 806.8 | | |
| 68 | ECHUNGA CK_4a | **6** | 66 | 138 | 139 | 356.6 | 348.6 | | 80,123.1 | 93.5 | EC | 806.8 | 775 | 805 | 1.04 | 838.0 | | |
| 69 | ECHUNGA CK_4d1 | **6** | 67 | 140 | 141 | 929.8 | 918.0 | | 118,021.3 | 151.8 | EC | 806.8 | 775 | 800 | 1.03 | 832.8 | yes | 85% |
| 70 | ECHUNGA CK_4d2 | **6** | 70 | 142 | 143 | 955.8 | 947.0 | | 88,012.8 | 90.7 | EC | 806.8 | 775 | 864 | 1.11 | 899.5 | | |
| 71 | ECHUNGA CK_2 | **6** | 69 | 144 | 145 | 595.2 | 578.0 | | 172,469.8 | 267.7 | EC | 806.8 | 775 | 875 | 1.13 | 910.9 | | |
| 72 | ECHUNGA CK_3 | **6** | 68 | 146 | 147 | 187.9 | 178.0 | | 98,625.2 | 204.8 | EC | 806.8 | 775 | 838 | 1.08 | 872.4 | | |
| 73 | ECHUNGA CK_1 | **6** | 71 | 148 | 149 | 494.2 | 491.8 | | 23,669.7 | 25.1 | EC | 806.8 | 775 | 848 | 1.09 | 882.8 | yes | 70% |
| 74 | ONKAPARINGA MAIN CH_7 | | 72 | 150 | 151 | 59.1 | 58.5 | | 5,422.8 | 6.7 | EC | 806.8 | 775 | 850 | 1.10 | 884.9 | | |
| 75 | ONKAPARINGA MAIN CH_5b | | 81 | 152 | 153 | 1,512.3 | 1,509.4 | | 28,819.0 | 23.2 | CL | 818.4 | 785 | 813 | 1.04 | 847.6 | yes | 15% |
| 76 | SCOTT CK_2b | **3** | 74 | 154 | 155 | 735.9 | 728.6 | | 72,765.6 | 68.0 | UR | 1082.8 | 1037 | 1019 | 0.98 | 1064.0 | yes | 90% |
| 77 | SCOTT CK_2a | **3** | 75 | 156 | 157 | 923.8 | 917.9 | | 59,495.1 | 46.0 | CG | 925.2 | 905 | 945 | 1.04 | 966.1 | yes | 80% |
| 78 | SCOTT CK_2c | **3** | 76 | 158 | 159 | 433.4 | 431.1 | | 23,099.6 | 21.5 | CG | 925.2 | 905 | 900 | 0.99 | 920.1 | yes | 70% |
| 79 | SCOTT CK_2d | **3** | 77 | 160 | 161 | 570.1 | 561.8 | 7.0 | 13,135.9 | 10.8 | CG | 925.2 | 905 | 869 | 0.96 | 888.4 | yes | 15% |

| | | | | | | | | | | | Rainfall (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | SCOTT CK_1 | **3** | 78 | 162 | 163 | 186.5 | 186.3 | | 2,165.3 | 1.6 | CL | 818.4 | 785 | 838 | 1.07 | 873.7 | | |
| 81 | ANGELS GULLY_1b | | 79 | 164 | 165 | 281.1 | 279.0 | | 20,686.0 | 20.2 | CG | 925.2 | 905 | 892 | 0.99 | 911.9 | | |
| 82 | ANGELS GULLY_1a | | 80 | 166 | 167 | 1,126.8 | 1,120.1 | | 66,371.0 | 62.3 | CL | 818.4 | 785 | 820 | 1.04 | 854.9 | | |
| 83 | ONKAPARINGA MAIN CH_2b | | 82 | 168 | 169 | 783.8 | 782.0 | | 17,681.6 | 25.3 | CL | 818.4 | 785 | 780 | 0.99 | 813.2 | yes | 10% |
| 84 | ONKAPARINGA MAIN CH_2c | | 91 | 170 | 171 | 1,325.6 | 1,325.6 | | 0.0 | 0.0 | CL | 818.4 | 785 | 713 | 0.91 | 743.3 | yes | 10% |
| 85 | BAKER GULLY_1a | **9** | 83 | 172 | 173 | 523.1 | 519.7 | | 34,099.2 | 55.9 | CL | 818.4 | 785 | 840 | 1.07 | 875.7 | | |
| 86 | BAKER GULLY_1b | **9** | 84 | 174 | 175 | 114.6 | 110.6 | | 39,987.1 | 86.1 | CL | 818.4 | 785 | 832 | 1.06 | 867.4 | | |
| 87 | BAKER GULLY_1d3 | **9** | 85 | 176 | 177 | 1,248.6 | 1,235.4 | | 131,862.9 | 136.4 | CL | 818.4 | 785 | 818 | 1.04 | 852.8 | | |
| 88 | BAKER GULLY_1c | **9** | 86 | 178 | 179 | 182.6 | 178.6 | | 39,707.6 | 65.1 | CL | 818.4 | 785 | 782 | 1.00 | 815.3 | | |
| 89 | BAKER GULLY_1e | **9** | 87 | 180 | 181 | 81.8 | 78.3 | | 34,990.0 | 80.1 | CL | 818.4 | 785 | 730 | 0.93 | 761.1 | | |
| 90 | BAKER GULLY_1d2 | **9** | 88 | 182 | 183 | 750.6 | 745.3 | | 52,455.9 | 50.8 | CL | 818.4 | 785 | 775 | 0.99 | 808.0 | yes | 70% |
| 91 | BAKER GULLY_1d4 | **9** | 89 | 184 | 185 | 1,158.6 | 1,153.3 | | 53,484.8 | 37.3 | CL | 818.4 | 785 | 782 | 1.00 | 815.3 | yes | 60% |
| 92 | BAKER GULLY_1d1 | **9** | 90 | 186 | 187 | 736.4 | 734.4 | | 19,760.7 | 18.4 | CL | 818.4 | 785 | 730 | 0.93 | 761.1 | yes | 10% |
| 93 | ONKAPARINGA MAIN CH_2a | | 92 | 188 | 189 | 1,504.3 | 1,504.3 | | 0.0 | 0.0 | MV | 562.2 | 569 | 595 | 1.05 | 587.9 | yes | 10% |
| 94 | ONKAPARINGA MAIN CH_4 | | 93 | | | 1,032.7 | 991.7 | 41.0 | 0.0 | 0.0 | ON | 524.7 | 515 | 515 | 1.00 | 524.7 | | |
| 95 | ONKAPARINGA MAIN CH_6 | | 94 | | | 2,164.9 | 1,758.9 | 406.0 | 0.0 | 0.0 | ON | 524.7 | 515 | 520 | 1.01 | 529.8 | | |
| 96 | **GRAND TOTAL** | | | | | **55,811.9** | **54,184.6** | **1,028.0** | **5,992,262.5** | **8,495.3** | | | | | | | | |

Note: Mt Bold Reservoir

a) from EWS report Ref 82/30:
MBR volume at FSL = 47,300 ML
MBR surface area at FSL = 308 ha

Rainfall data (1900 -- 1998)
BW, BridgeWater, 023707inf.rai
CG, Cherry Garden, 023709inf.rai
CL, Clarendon, 023710omf.rai
EC, Echunga, 023713inf.rai
HD, Hahndorf, 023720inf.rai
LB, Lobethal, 023726inf.rai
MV, Morphett Vale, 023732inf.rai
ON, Old Norlunga, 023740inf.rai
UR, Uraidla, 023750inf.rai
WS, Woodside, 023829inf1.rai

## Table 34. Input Data for the Catchment Hydrological Model (cont)

| Nos | Gauging station location | Sub-cat No. | Rural Node | Dam Node | Cat4_Area_ha | Net_cat4_area,ha | Urban ha | Dam AREA M2 | VOL(ML)_Dg | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AW503504, Houlgraves weir | O-3b | 101 | 101 | 32,133 | 31,102 | 574 | 4,563,617 | 6,634 | OSD @ d/s of N100 |
| 2 | AW503508, Inverbrackie ck | O3 | 190 | 190 | 843 | 824 | 0 | 183,138 | 255 | OSD @ d/s of N33 |
| 3 | AW503530, Kerber ck of Inverbrackie catchment | O4 | 191 | 191 | 97 | 96 | 0 | 7,076 | 8 | OSD @ d/s of N41 |
| 4 | AW503507, Lenswood ck | O5 | 192 | 192 | 1,684 | 1,649 | 0 | 348,349 | 424 | OSD @ u/s of N79 |
| 5 | AW503509, Aldgate ck @ railway stn | O6 | 193 | 193 | 743 | 580 | 160 | 26,782 | 38 | OSD @ u/s of N116 |
| 6 | AW503506, Echunga ck | O7 | 194 | 194 | 3,423 | 3,355 | 0 | 678,691 | 1,013 | OSD @ d/s of N143 |
| 7 | AW503503, Bakers Gully | O8 | 195 | 195 | 4,796 | 4,756 | 0 | 406,348 | 530 | OSD @ d/s of N187 |
| 8 | AW503502, Scott ck | O9 | 196 | 196 | 2,663 | 2,639 | 7 | 168,496 | 146 | OSD @ d/s of N161 |
| 9 | AW503500, Clarendon weir | O10 | 197 | 197 | 44,204 | 42,796 | 581 | 8,272,736 | 55,240 | OSD @ d/s of N153 |
| 10 | AW503522, Norlunga ck | O11 | 198 | 198 | 52,614 | 51,164 | 581 | 8,696,766 | 55,795 | OSD @ d/s of N189 |
| 11 | AW503528, Onka river d/s of MBR | O12 | 199 | 199 | | | | | | OSD @ d/s of N133 |
| 12 | AW503526, Cox Ck | O13 | 202 | 202 | 552 | 536 | 14 | 22,771 | 18 | OSD @ d/s of N103 |
| | **Subcatchment node** | | | | | | | | | |
| 1 | Houlgraves Weir catchment | O-3b | 101 | 101 | 32,133 | 31,102 | 574 | 4,563,617 | 6,634 | OSD @ d/s of N100 |
| 2 | MtBold Reservoir catchment | O_5a | 133 | 133 | 38,434 | 37,062 | 574 | 7,986,198 | 54,986 | inclusive Mt Bold Reservoir volume |
| 3 | Bakers Gully | O8 | 195 | 195 | 4,796 | 4,756 | 0 | 406,348 | 530 | OSD @ d/s of N187 |
| 4 | Clarendon Weir catchment | O10 | 197 | 197 | 44,204 | 42,796 | 581 | 8,272,736 | 55,240 | OSD @ d/s of N153 |
| 5 | Old Norlunga ck catchment | O11 | 198 | 198 | 52,614 | 51,164 | 581 | 8,696,766 | 55,795 | OSD @ d/s of N189 |
| 6 | Western Branch catchment | O14 | 218 | 218 | 3,297 | 3,193 | 43 | 611,345 | 985 | OSD @ d/s of N58, forming part of the "main" river |
| 7 | Cock catchment | O16 | 220 | 220 | 2,840 | 2,784 | 0 | 555,967 | 710 | OSD @ d/s of Cock catchment, forming part of the "main" river |
| 8 | Biggs Flat catchment | O17 | 221 | 221 | 2,365 | 2,315 | 0 | 503,226 | 660 | OSD @ d/s Biggs Flat catchment, forming part of the "main" river |
| 9 | Cox catchment | O18 | 222 | 222 | 2,875 | 2,697 | 156 | 215,403 | 221 | OSD @ d/s Cox catchment, forming part of the "main" river |
| 10 | Aldgate catchment | O19 | 223 | 223 | 1,945 | 1,706 | 224 | 154,178 | 159 | OSD @ d/s of Aldgate catchment, forming part of the "main" river |
| 11 | Charleston catchment | Char | 231 | 231 | 5,151 | 5,043 | 56 | 523,223 | 748 | OSD @ d/s of Charleston catchment |
| 12 | Inverbrackie catchment | Inve | 232 | 232 | 2,674 | 2,635 | 0 | 389,364 | 538 | OSD @ d/s of Inverbrackie catchment |
| 13 | Mitchell Ck catchment | Mitc | 233 | 233 | 1,451 | 1,427 | 0 | 241,085 | 566 | OSD @ d/s of Mitchell catchment |
| 14 | Balhannah catchment | Balh | 234 | 234 | 1,024 | 1,001 | 12 | 116,215 | 197 | OSD @ d/s of Balhannah catchment |
| 15 | Hahndorf catchment | Hahn | 235 | 235 | 1,468 | 1,394 | 49 | 253,521 | 476 | OSD @ d/s of Hahndorf |

| Nos | Gauging station location | Sub-cat No. | Rural Node | Dam Node | Cat4_Area_ha | Net_cat4_area,ha | Urban ha | Dam AREA M2 | VOL(ML)_Dg | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | catchment |
| 16 | Echunga catchment | Euch | 238 | 238 | 3,917 | 3,847 | 0 | 702,361 | 1,038 | OSD @ d/s of Echunga catchment |
| 17 | Scott Creek catchment | Scot | 239 | 239 | 2,850 | 2,826 | 7 | 170,662 | 148 | OSD @ d/s of Scott ck catchment |
| 18 | Angels Gully catchment | Ange | 240 | 240 | 1,408 | 1,399 | 0 | 87,057 | 82 | OSD @ d/s of Angels Gully catchment |
| 19 | Upper Onka catchment | | varies | varies | 4,708 | 4,603 | | 713,426 | 1,060 | Dam node numbers are: 45,47,84,86,88 and 92. |
| 20 | Onka Main CH catchment | | varies | varies | 13,043 | 12,290 | | 348,884 | 377 | Dam node numbers are: 96, 100, 123, 133, 151, 153,169, 171 and 189. Vol for N133=7.6 ML only |
| | **Township** | | | | | | | | | |
| 1 | Scott ck | U1 | 204 | 204 | | | 0 | | | Urban node u/s N203, Scott ck, 0 ha |
| 2 | Aldgate | U2 | 207 | 207 | | | 160 | | | Urban node u/s N193, Aldgate, 160 ha |
| 3 | Uraidla+Summertown | U3 | 210 | 210 | | | 14 | | | Urban node u/s N209, Cox ck, 14 ha |
| 4 | Woodside+Lobethal | U4 | 224 | 224 | | | 56 | | | Urban node for Charleston @ sub-cat nos 11&12 (33 + 23 ha), u/s of N219 |
| 5 | Lobethal | U5 | 225 | 225 | | | 43 | | | Urban node for township @ sub-cat nos 26 of Western Branch |
| 6 | Balhannah+Bridgewater+Oakbank | U6 | 226 | 226 | | | 34 | | | Urban node for Upper Onkaparinga @ sub-cat nos 41 |
| 7 | Stirling | U7 | 227 | 227 | | | 45 | | | Urban node for Cox ck @ sub-cat nos 51 |
| 8 | Aldgate+Bridgewater+Stirling | U8 | 228 | 228 | | | 97 | | | Urban node for Cox ck @ sub-cat nos 52 & 53 combined (91+6 ha), Cox ck |
| 9 | Aldgate+Stirling | U9 | 229 | 229 | | | 64 | | | Urban node for township @ sub-cat nos 56 (64 ha), Aldgate, u/s of N223 |
| 10 | Balhannah | Balh | 236 | 236 | | | 12 | | | Township (location #45) within Balhannah catchment |
| 11 | Hahndorf | Hahn | 237 | 237 | | | 49 | | | Township (location #47) within Hahndorf catchment |
| Note: modelled urban area is taken as 1/3 of the digitised plan area | | | | | | | | | | |
| | **Other off-stream dam and routing nodes** | | | | | | | | | |
| 1 | Onka river @ Charleston_4a1 | O1 | 19 | 19 | | | | | | OSD @ d/s of N18 |
| 2 | Onka river @ Upper Onka_1c1 | O2 | 48 | 48 | | | | | | OSD @ d/s of N47 |
| 3 | Routing | R1 | 200 | 200 | | | | | | routing @ d/s of N33, Cox ck |
| 4 | Routing | R2 | 201 | 201 | | | | | | routing @ u/s of N192, Lenswood (Cock) ck |
| 5 | Routing | Null | 203 | 203 | | | | | | routing @ u/s of N196, Scott ck |
| 6 | Routing | R4 | 205 | 205 | | | | | | routing @ u/s of N196, Scott ck |
| 7 | Routing | R5 | 206 | 206 | | | | | | routing @ u/s of N158, Scott ck |
| 8 | Routing | R6 | 208 | 208 | | | | | | routing @ u/s of N193, Aldgate ck |
| 9 | Routing | R7 | 209 | 209 | | | | | | routing @ u/s of N202, Cox ck |

| Nos | Gauging station location | Sub-cat No. | Rural Node | Dam Node | Cat4_Area_ha | Net_cat4_area,ha | Urban ha | Dam AREA M2 | VOL(ML)_Dg | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Routing | R8 | 211 | 211 | | | | | | routing @ u/s of N194, Echunga ck |
| 11 | Routing | R9 | 212 | 212 | | | | | | routing @ u/s of N195, Baker Gully ck |
| 12 | Routing | R10 | 213 | 213 | | | | | | routing @ d/s of N177, Baker Gully ck |
| 13 | Baseflow separation catchment | BFC1 | 214 | 214 | | | | | | Baseflow separation catchment #1 in Baker Gully (cat area=4755.6 ha, 023710inf.rai, rf factor = 0.93) |
| 14 | Routing | R11 | 215 | 215 | | | | | | routing @ u/s of N19 of Onka river |
| 15 | Routing | R12 | 216 | 216 | | | | | | routing @ u/s of N48 of Onka river |
| 16 | Routing | R13 | 217 | 217 | | | | | | routing @ u/s of N101 of Onka river |
| 17 | Off-stream dam | O15 | 219 | 219 | | | | | | OSD @ d/s of N218, forming part of the "main" river |
| 18 | Routing | R14 | 230 | 230 | | | | | | routing @ u/s of N219 |

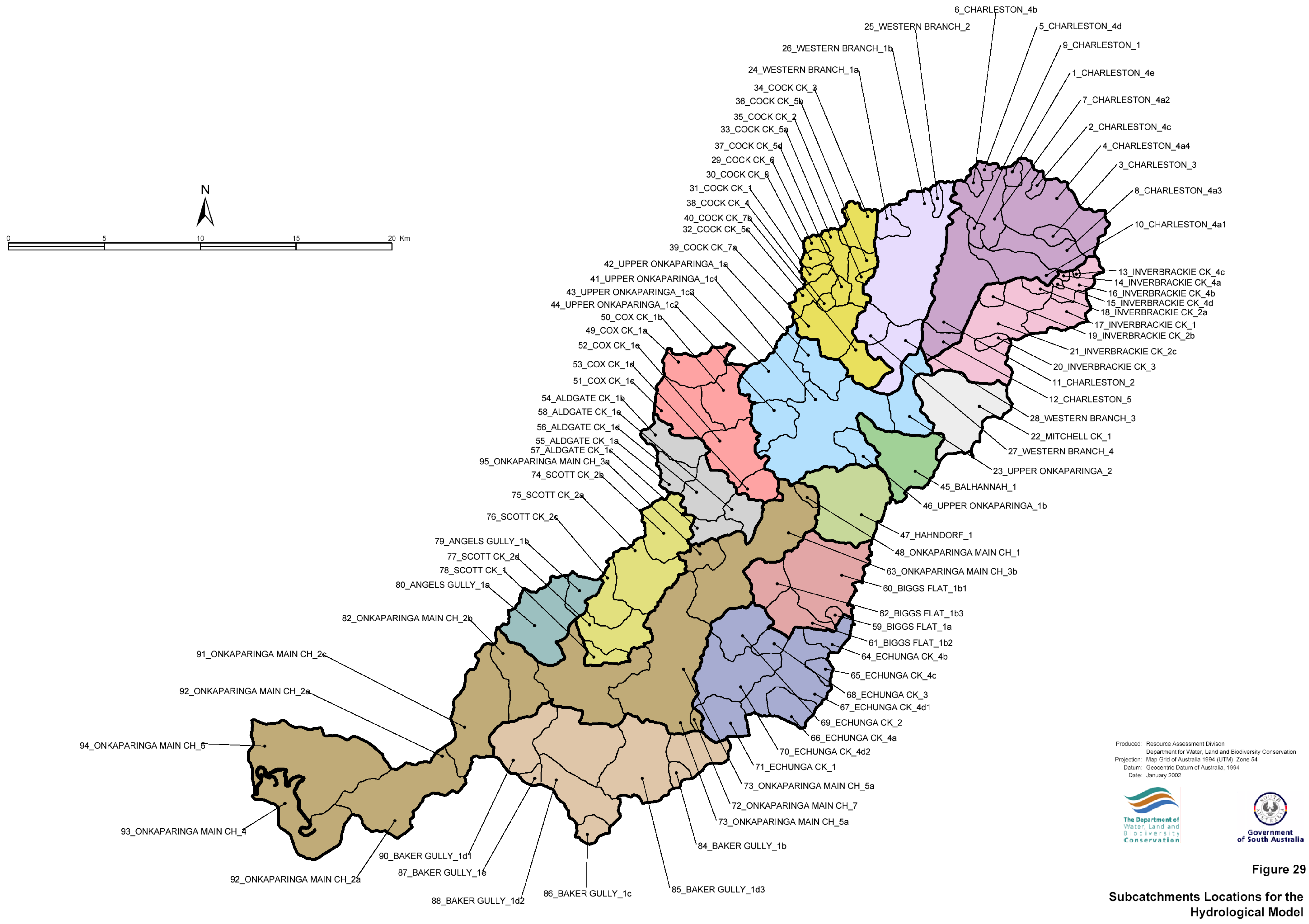
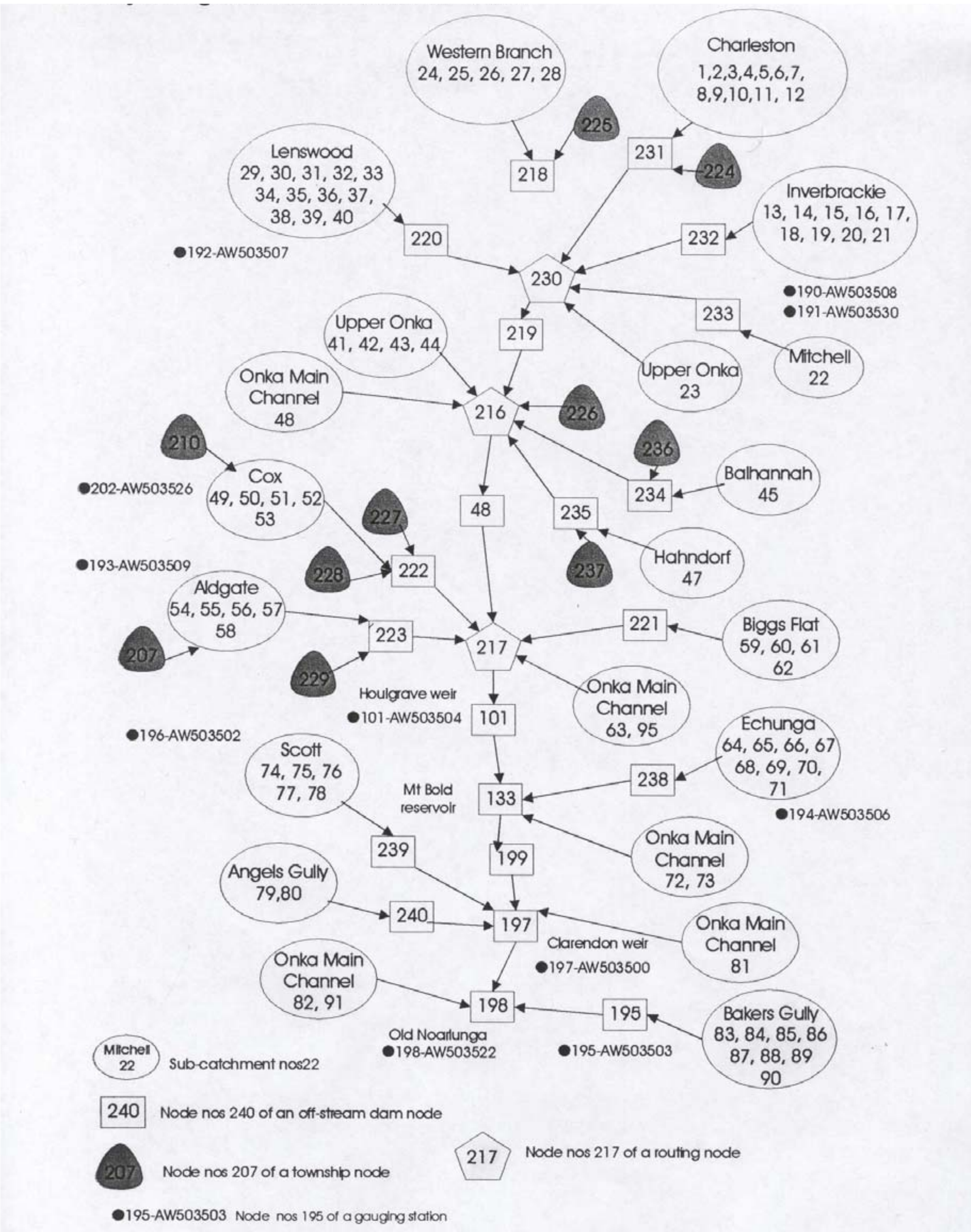



**Figure 29**

**Subcatchments Locations for the Hydrological Model**

## Figure 31. A Schematic Diagram of the Hydrological Model Catchment Nodes



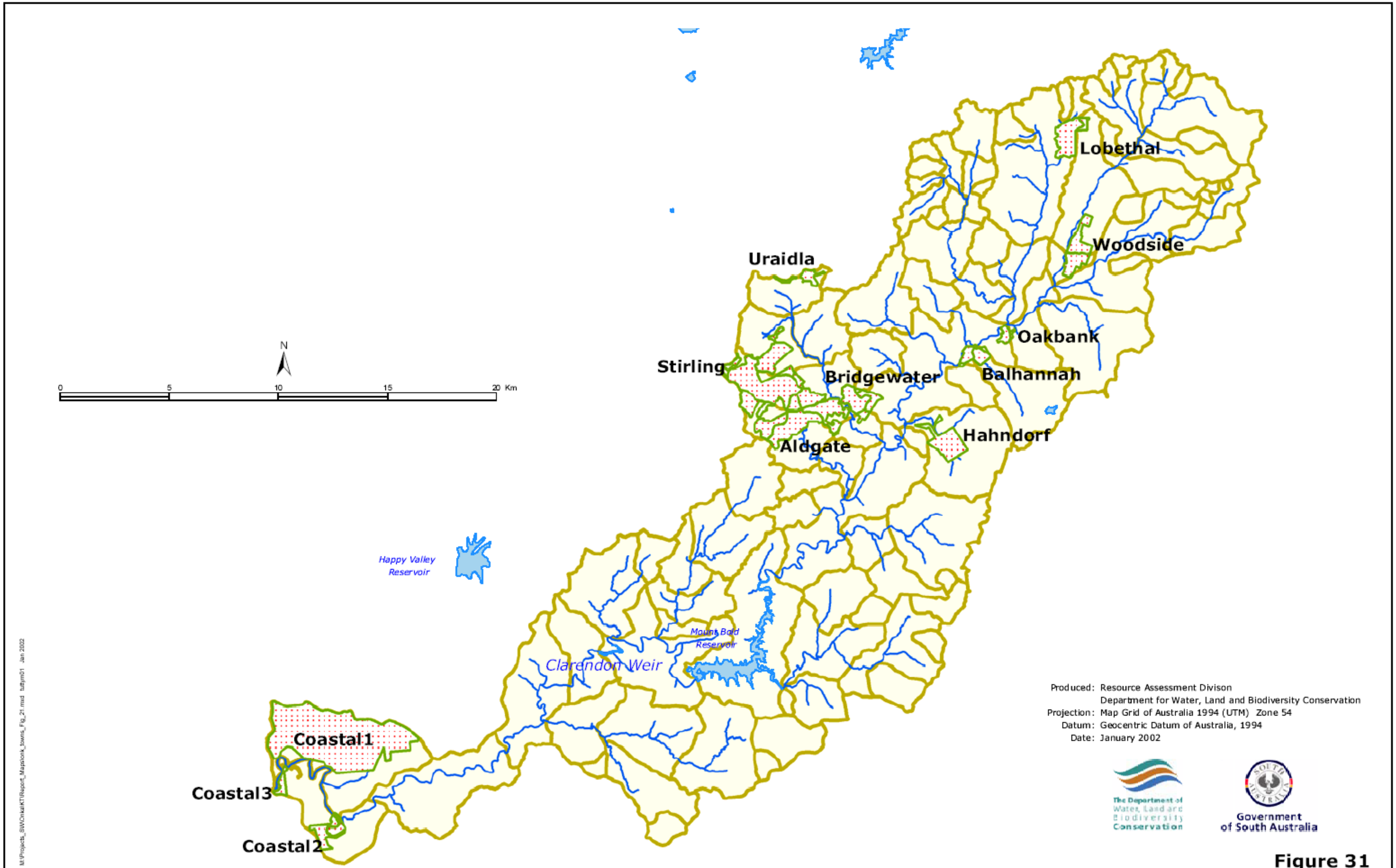



**Figure 31**

Townships in the Onkaparinga River Catchment isohyet of the subcatchment, and Y is the isohyet of the chosen rainfall station, then the adjustment for the rainfall factor is calculated as (X/Y) and is applied uniformly to the entire period of record.

The rainfall adjustment factor applied to each model node can be found in Table 33 as “rf ratio”.

The above method was used for all the catchments except Inverbrackie and Mitchell catchments. The factor for these two subcatchments was derived using AW503508 station, which is a pluviometer located within the gauged catchment. This exception was made as the isohyet information is thought to be inaccurate in this area (refer to earlier Section: Catchment Rainfall Distribution). This is borne out in the data recorded at AW503508, which indicates significantly higher rainfall than that estimated by the isohyet map.

## Evaporation

Input to the model nodes requires only a set of monthly evaporation data, which does not vary from year to year.

Mt Bold reservoir station (023734), with minor modification, has been used for catchment modelling purposes, as the station is well maintained, has reliable long-term daily records and is likely to be reasonably representative of the catchment.

The station commenced recording evaporation in 1968. Some modification was required due to the proximity of the station to the reservoir water body and the existence of pine forest surrounding the area. McLaren Vale (023876) evaporation station was used to adjust the monthly records of Mt Bold reservoir station. (refer Section: Evaporation Recording Stations). The annual evaporation thus obtained from the adjusted results is 1794 mm which is found to be satisfactory.

A pan coefficient factor of 0.75 based on Table 5 pp81 of Allen (1998), FAO Irrigation and Drainage Paper No.56 was used to estimate the reference crop evapotranspiration, ETo. The value is input to the model.

Assumptions:

- Evaporation is constant for each month for all years for the period of model simulation.

## Rural and township catchments

Inputs to rural nodes include:

- Rainfall and evaporation data
- Catchment area in hectares
- Specify a runoff model, in this case WC-1 model.
- Specify a set of catchment characteristics

Inputs to township nodes include:

- Rainfall and evaporation data
- Catchment area in sq.m.
- Specify a runoff model, in this case the initial and continuing loss model (ILCL)

Assumptions:

- The impervious area that input into the model node is taken as 30% of the digitised GIS map area. This figure of 30% was found appropriate as it was obtained by calibration from the gauged catchment of Aldgate Creek. The remaining 70% is assumed to have similar runoff characteristics as the local rural nodes and because of this the area is included into the closest rural node.

## Farm dams and Reservoirs

Input to storage nodes include:

- Rainfall and evaporation data
- Aggregated farm dam volume-area relationship
- Usage of storage water
- Schedule for water usage

When calibrating a catchment runoff against the actual streamflow records over time, farm dam data based on the 1999 surveys is used. This means that farm dam development is assumed to be "frozen" in time for the period of streamflow calibration which may date back to 1980s.

Using 1999 farm dam data for calibrating the gauged streamflows appears not significant in affecting the calibration. An exception was Scott Creek and it was calibrated using a shorter period of records starting from 1982 rather than the entire period beginning from 1969 (prior to 1987, there were no farm dams in Scott Creek). The insignificant effect may be partially explained by:

- The reduction in catchment runoff due to increasing farm dams development over time (11% increment since 1987) has been offset to a degree by the change in land use and increasing urban development for the same period. These changes tend to increase the catchment runoff and compensate for the losses captured by farm dams.
- The small reduction in runoff due to farm dam development over time has not been picked up particularly well by the model simulations which uses daily time step rainfall. DWLBC is in the process of incorporating rainfall intensity into the modelling process to improve the model accuracy.
- Only 30% of the aggregated farm dam storage water was used for irrigation and consumption purposes. This is consistent with other model studies of the Mt Lofty Ranges (MLR) Watershed (*pers comm* Cresswell).

To study the sensitivity of dam usage impacting on catchment runoff, usage in the range of 50% and 70% are also modelled for various scenarios

- Usage of farm dam water was assumed to only occur in summer months.

For Mt Bold reservoir, instead of streamflow data, the node is calibrated with the storage volumes with the attached text file Mtbold_volume.flo.

## Streamflow

Table 35 shows the nodes incorporated in the model to allow for input of daily streamflow data used for model calibration. They can represent the location of a gauging station where daily streamflow data is available. A quality code can be attached to the daily record to indicate the quality of the data. The data is stored in the format of a text file with filename extension as "flo".

For Houlgrave weir (AW503504), the flow records obtained directly from Hydsys which include the water pumped from the Murray via Murray Bridge-Onkaparinga pipeline is stored in the text file named WC2_Houlgrave.flo. For calibrating the "catchment runoff" condition, the component of water pumped from the Murray is deducted from the records. This data is stored in text file as trueHoulgrave.flo.

### Table 36. The Location of Gauging Stations Incorporated in the Model

| GS Station | Node Number | Location | Record Start | Record End | Filename |
|---|---|---|---|---|---|
| 503500 | 197 | Clarendon | 20-09-1937 | 27-08-2000 | WC2_Clarendon.flo |
| 503502 | 196 | Scott Ck | 28-03-1969 | 01-08-2000 | WC2_Scott.flo |
| 503503 | 195 | Bakers Gully | 12-04-1969 | 02-08-2000 | WC2_Baker.flo |
| 503504 | 101 | Houlgrave | 18-04-1973 | 11-07-2000 | WC2_Houlgrave.flo & trueHoulgrave.flo |
| 503506 | 194 | Echunga | 23-03-1973 | 29-08-2000 | WC2_Echunga.flo |
| 503507 | 192 | lenswood | 19-03-1972 | 29-08-2000 | WC2_Lenswood.flo |
| 503508 | 190 | Inverbrackie | 18-05-1972 | 14-09-2000 | WC2_Inverbrackie.flo |
| 503509 | 193 | Aldgate | 14-07-1972 | 05-09-2000 | WC2_Aldgate.flo |
| 503522 | 198 | Noarlunga | 28-06-1973 | 14-02-1988 | WC2_Norlunga.flo |
| 503526 | 202 | Cox Ck | 24-06-1976 | 01-01-2001 | WC2_Cox.flo |
| 503529 | nil | Burnt Out | 13-01-1978 | 16-11-1988 | WC2_Burntout.flo |
| 503530 | 191 | Kerber | 31-07-1987 | 07-11-1989 | WC2_Kerber |

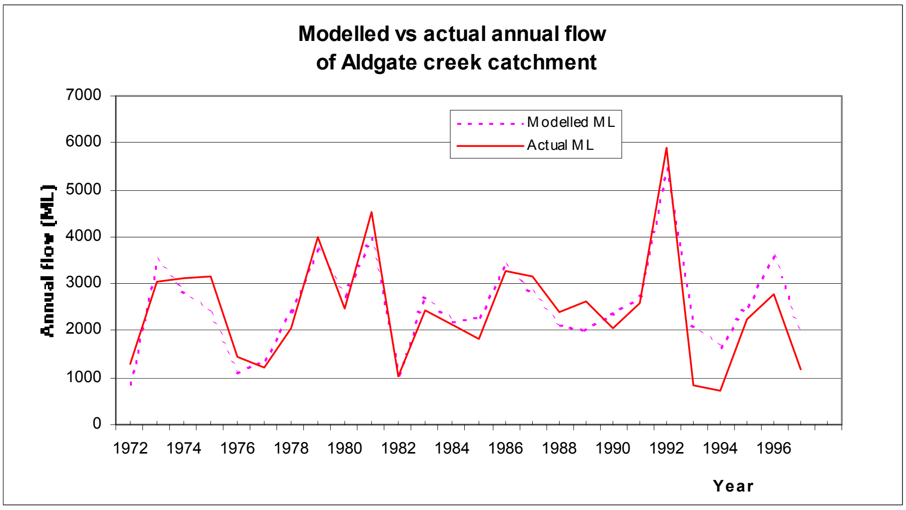
Except for Noarlunga and Clarendon weir, streamflows at all the locations have been calibrated. Burnt Out creek catchment is not separately incorporated in the hydrological model due to its small catchment size. Nevertheless, it was calibrated as a stand-alone model for estimating runoff coefficients in forest areas. Figure 3 shows the locations of the gauging stations within the Onkaparinga catchment.

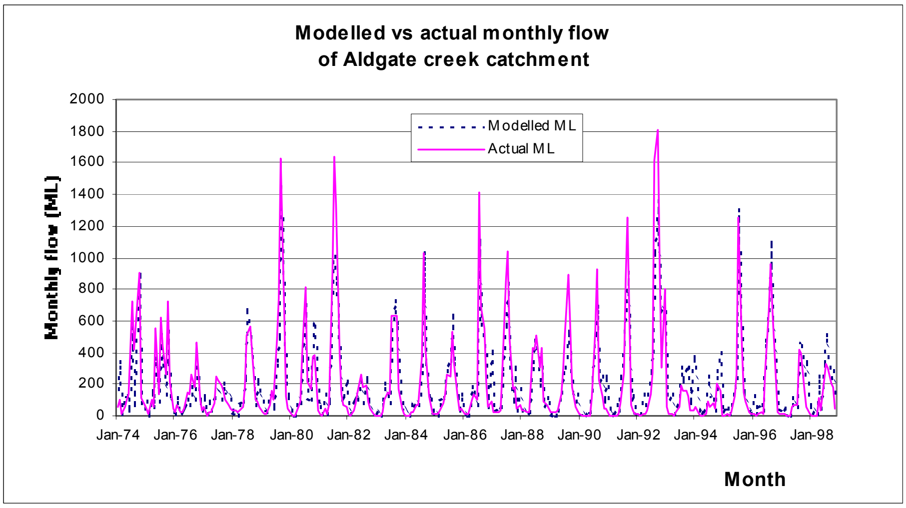
## Groundwater

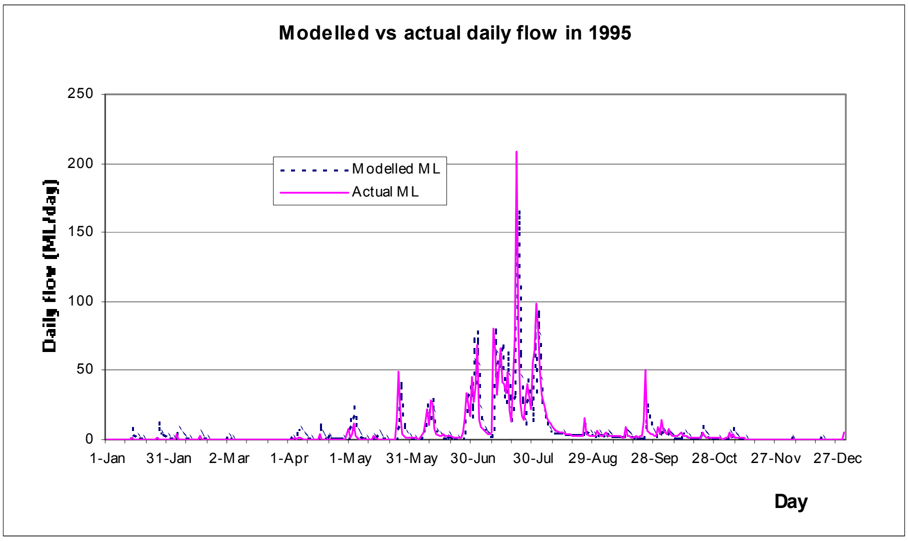
Groundwater recharge rate is assumed to be 30% of surface runoff for the entire Onkaparinga catchment which is consistent with assumptions for similar models of the MLR Watershed (*pers comm* Cresswell). The sensitivity of this assumption has not been assessed. Further refinement in the assumption may be made when more information is available.

# APPENDIX C - MODELLED AND ACTUAL FLOW CALIBRATIONS OF THE SUBCATCHMENTS

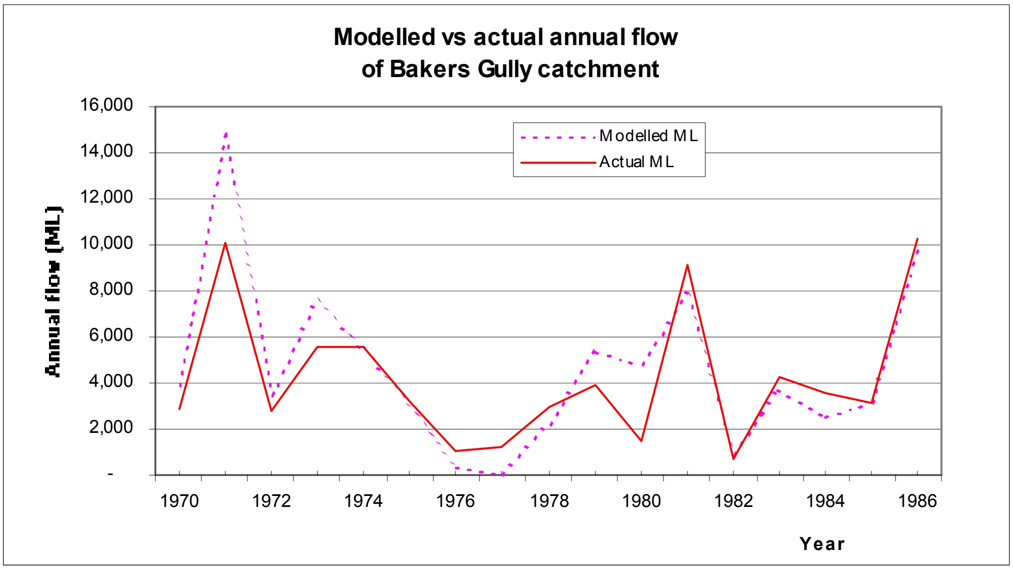
## Figure 33. Modelled and actual flow calibrations of Aldgate creek catchment

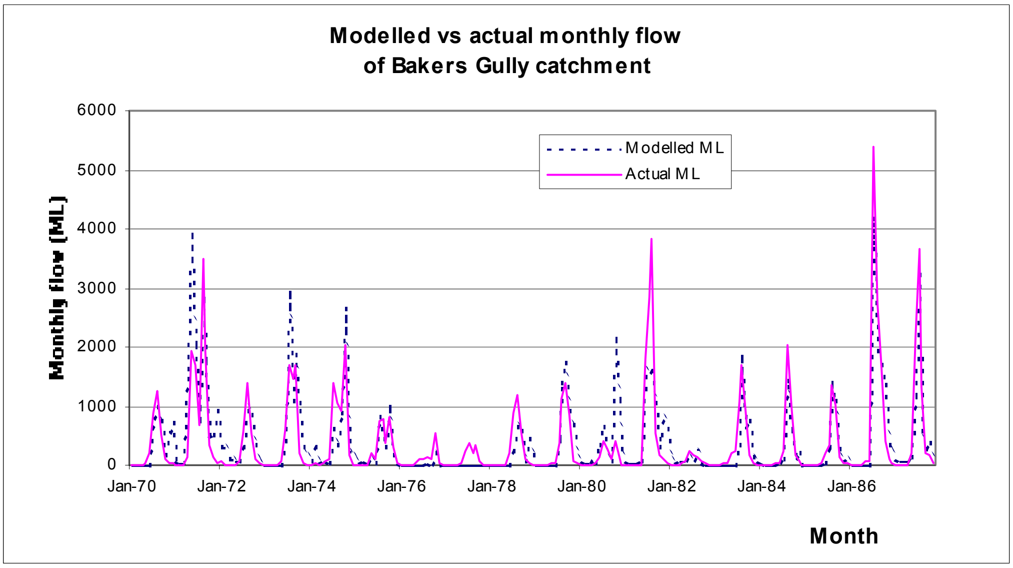


## Figure 34. Modelled and actual flow calibrations of Bakers Gully catchment



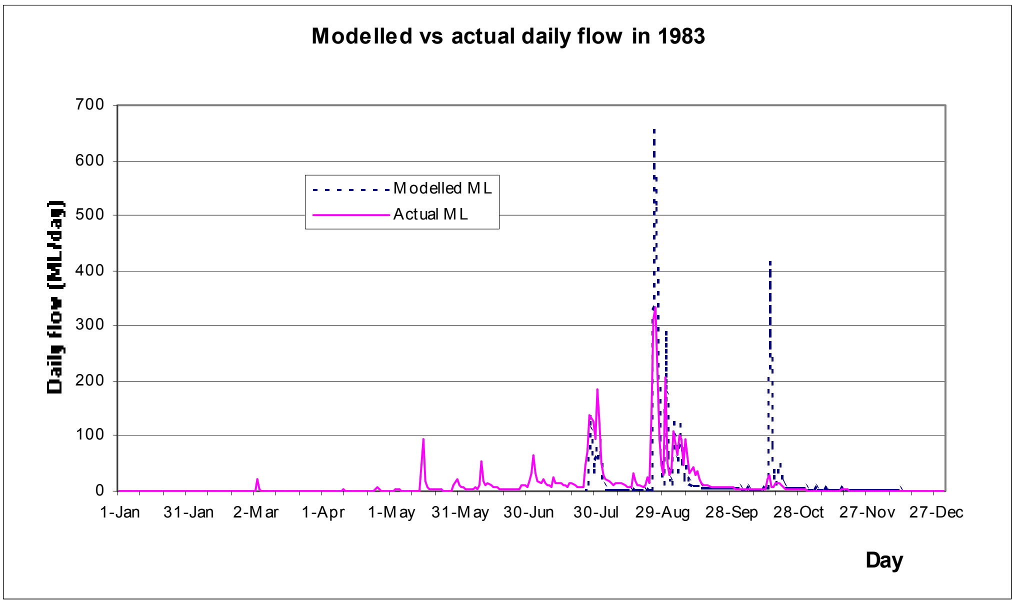
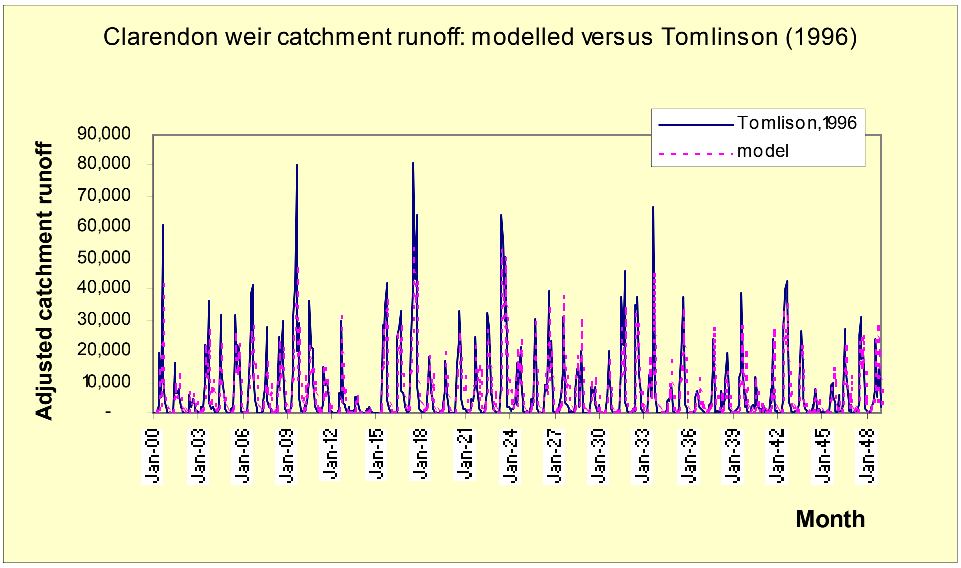
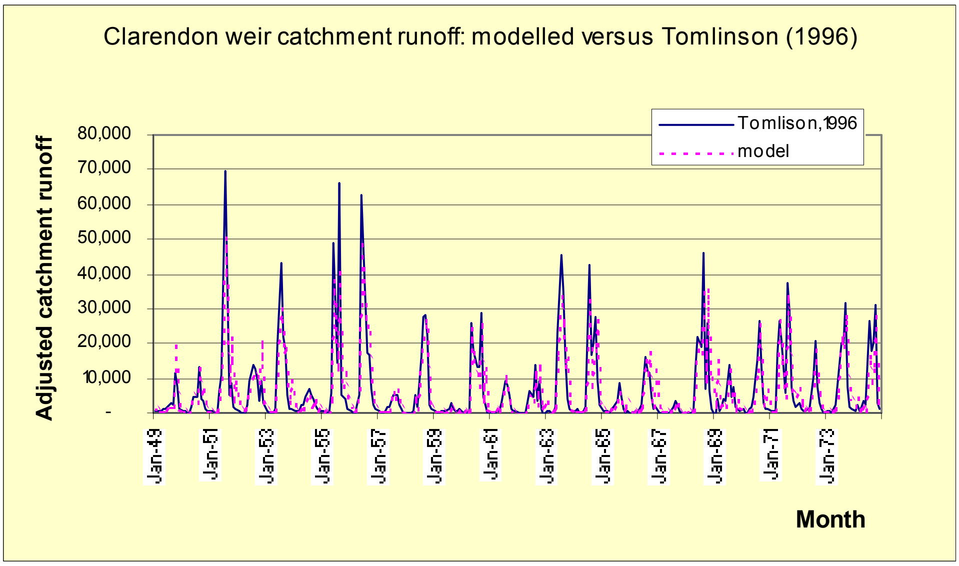



**Figure 35. Modelled and Tomlinson's flow estimates at Clarendon Weir Catchment**



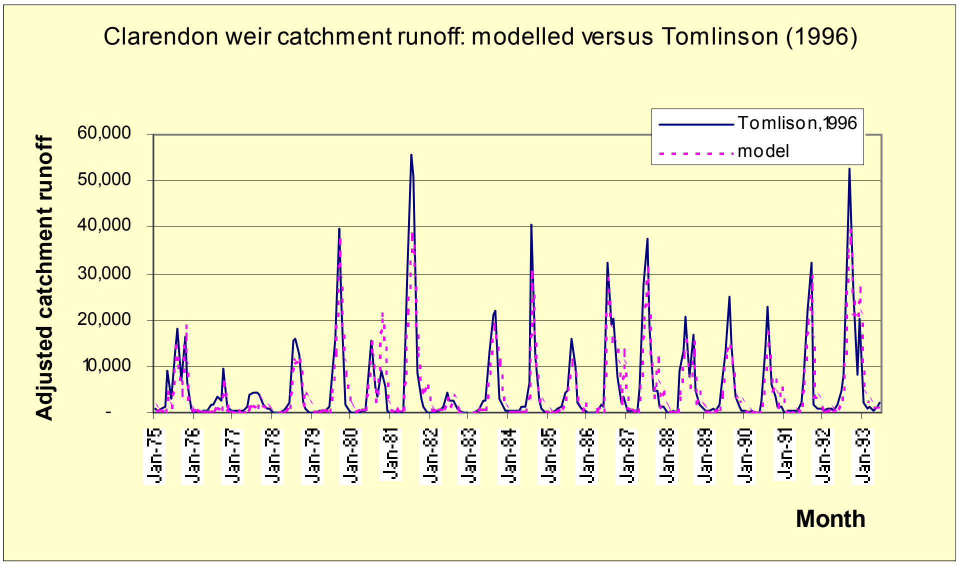
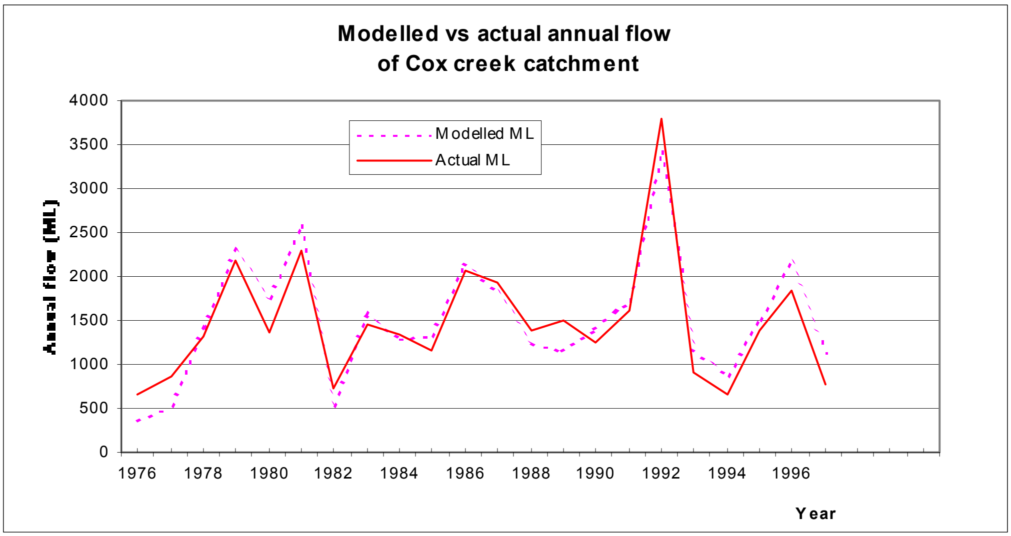
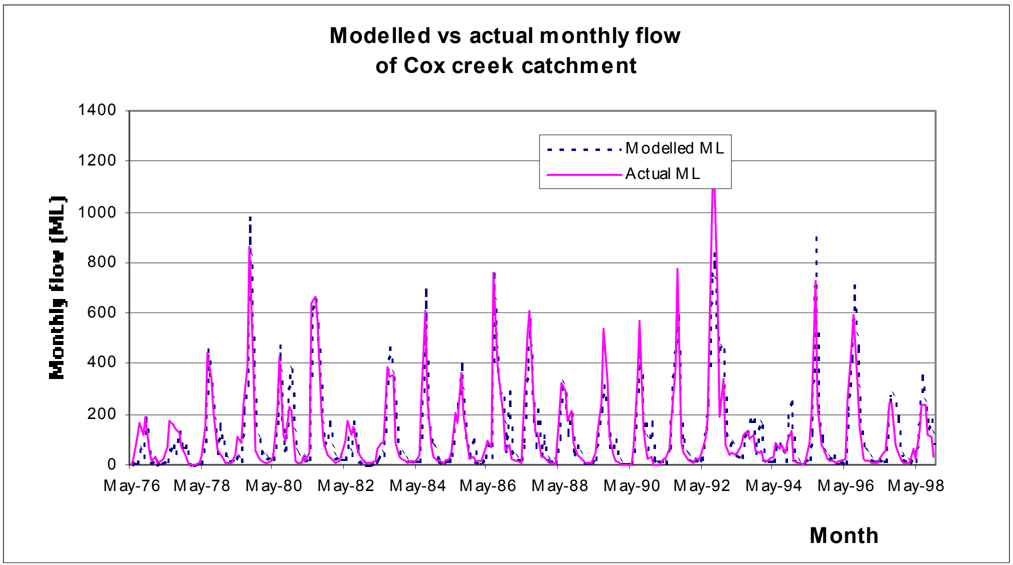
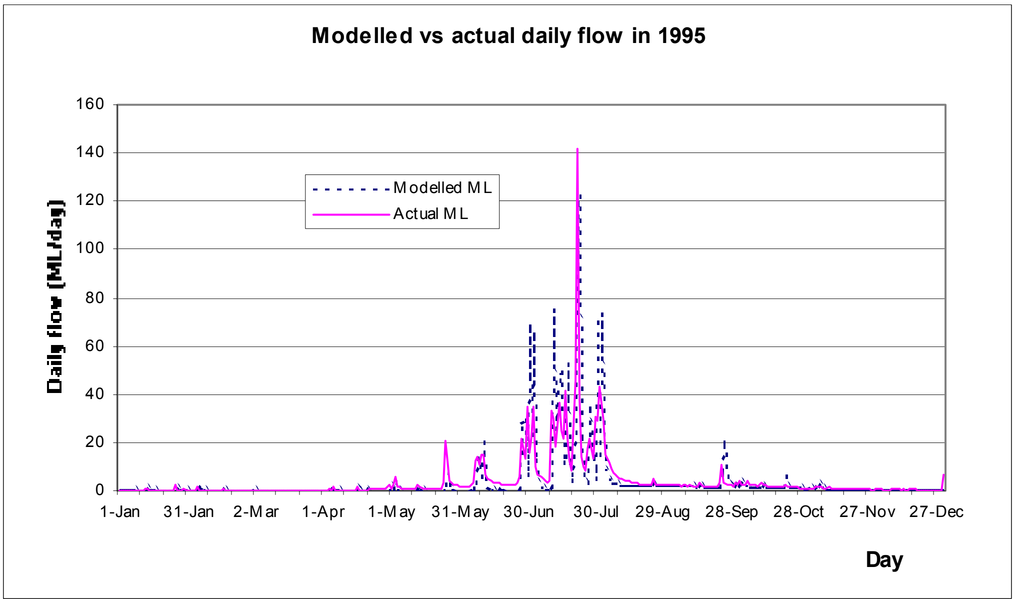



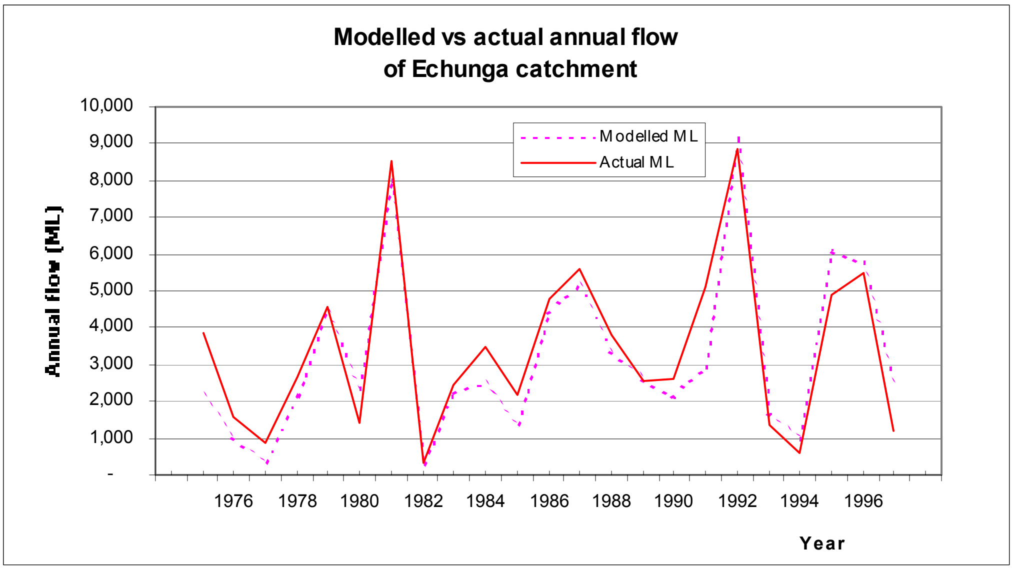
**Figure 36. Modelled and actual flow calibrations of Cox creek catchment**

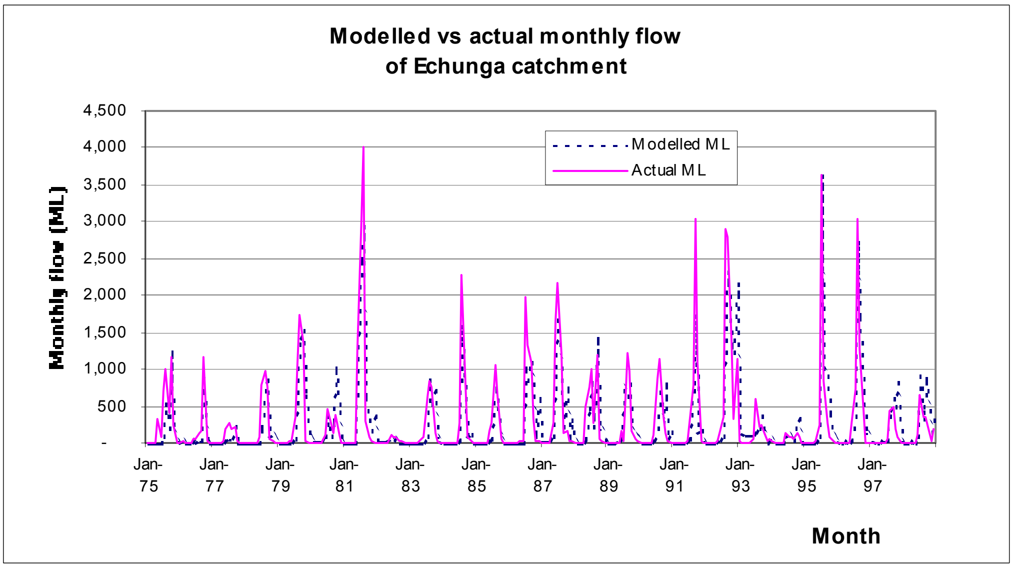


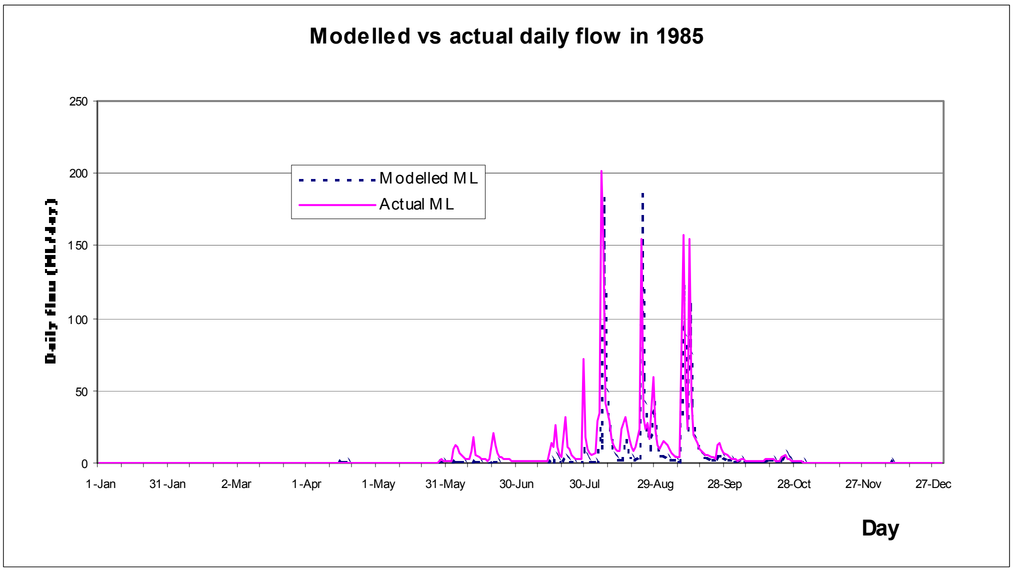



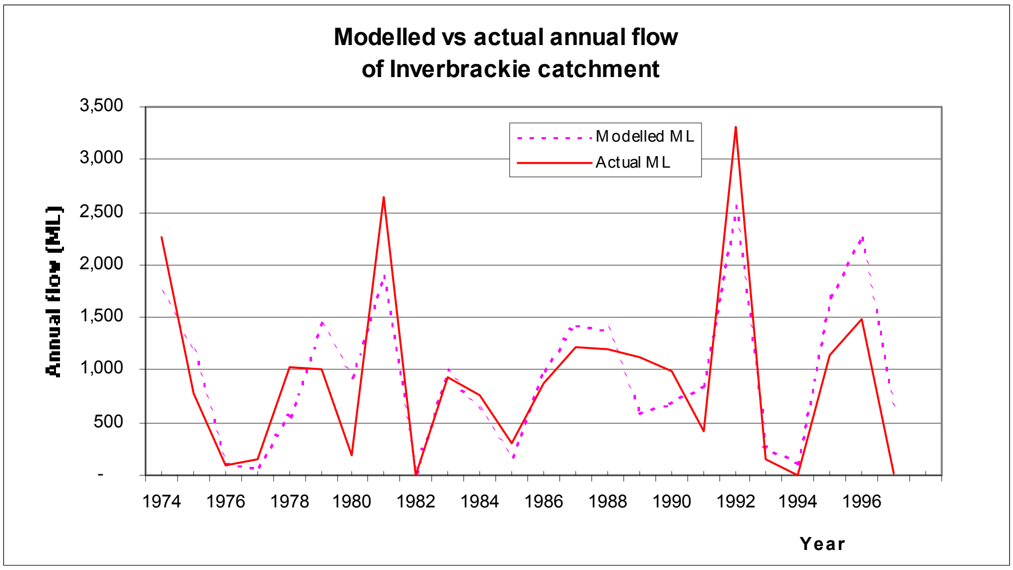
## Figure 37. Modelled and actual calibrations of Echunga catchment

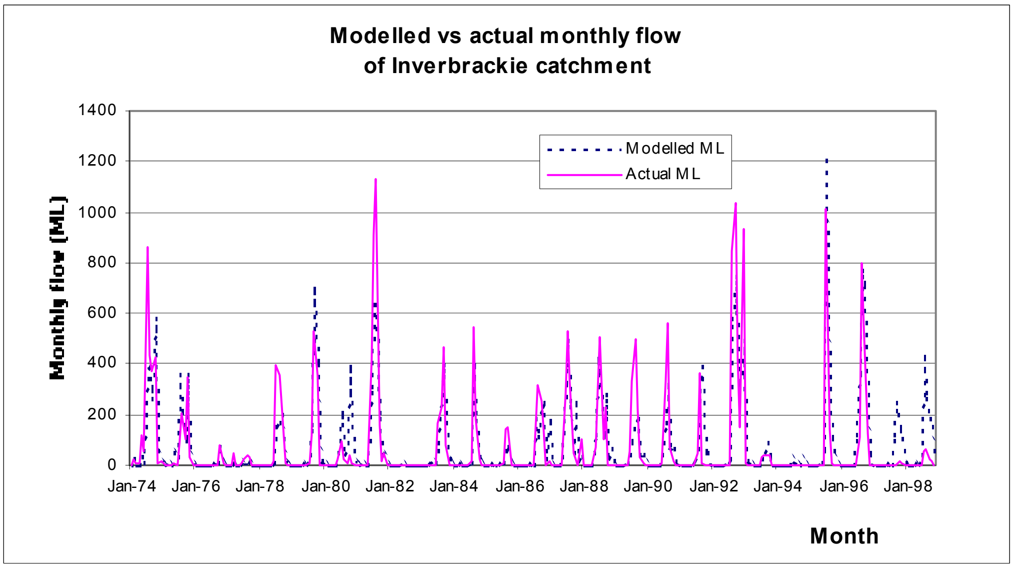


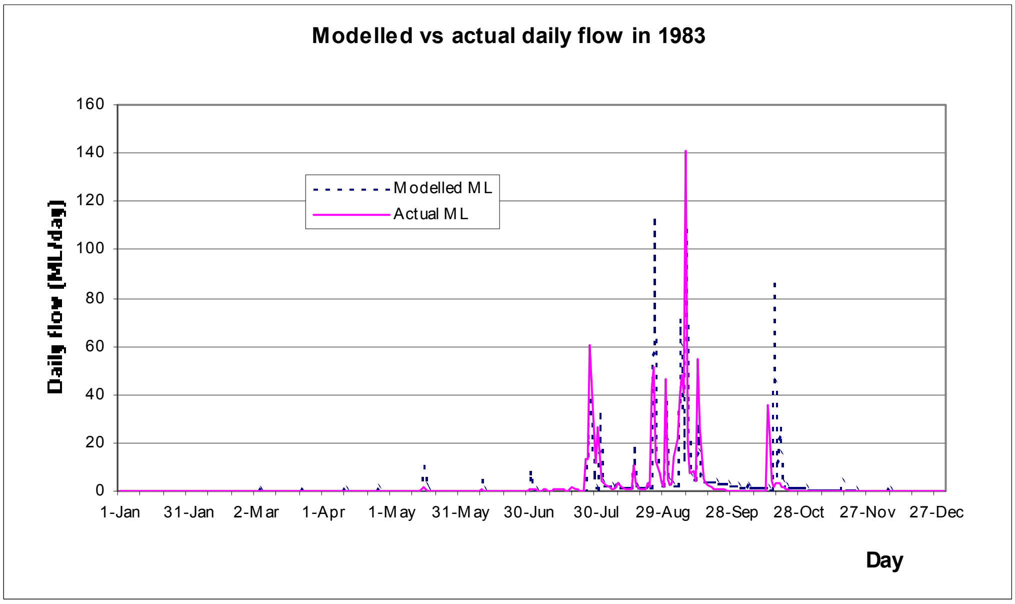



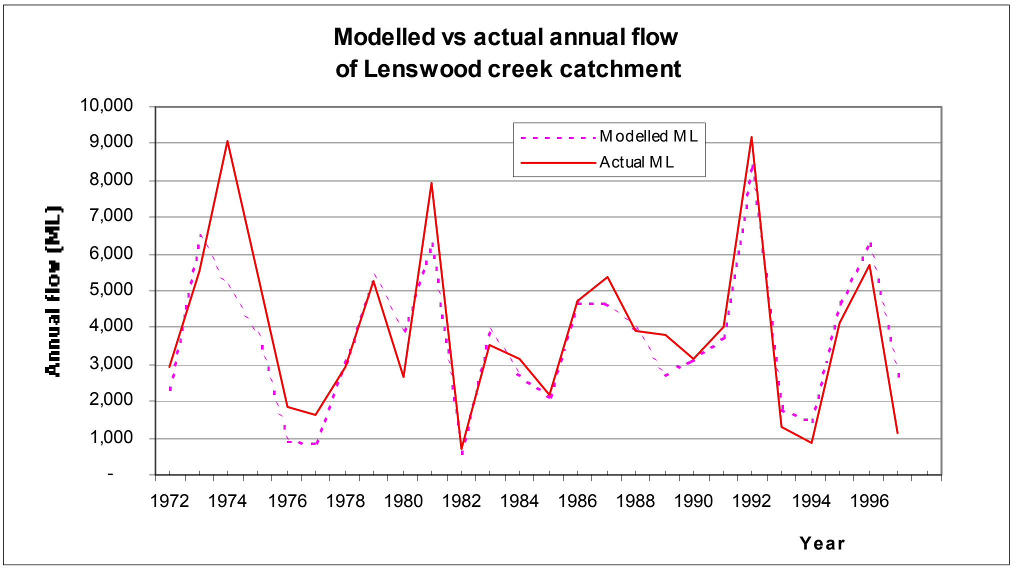
## Figure 38. Modelled and actual calibrations of Inverbrackie catchment

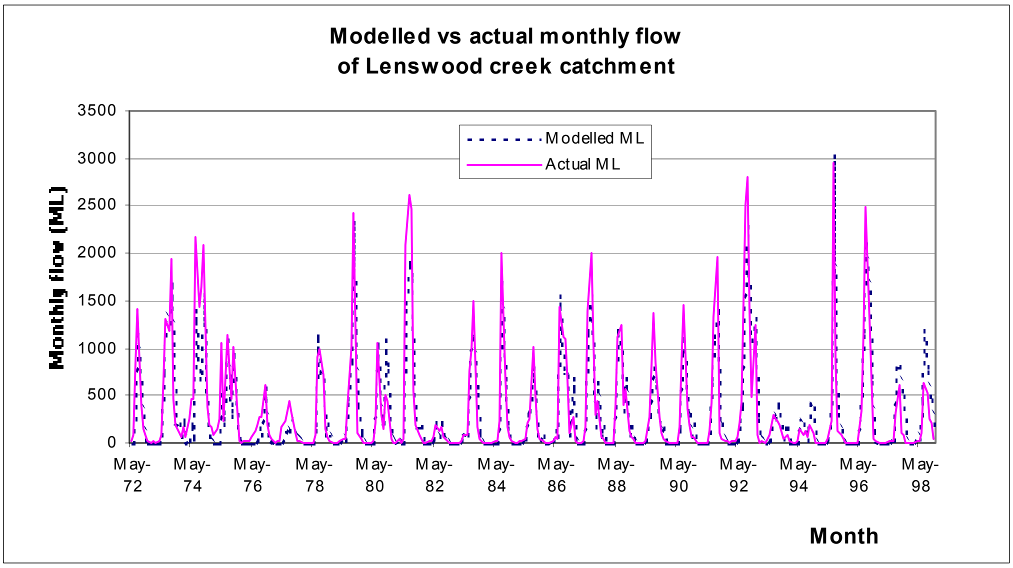


## Figure 39. Modelled and actual flow calibrations of Lenswood creek catchment



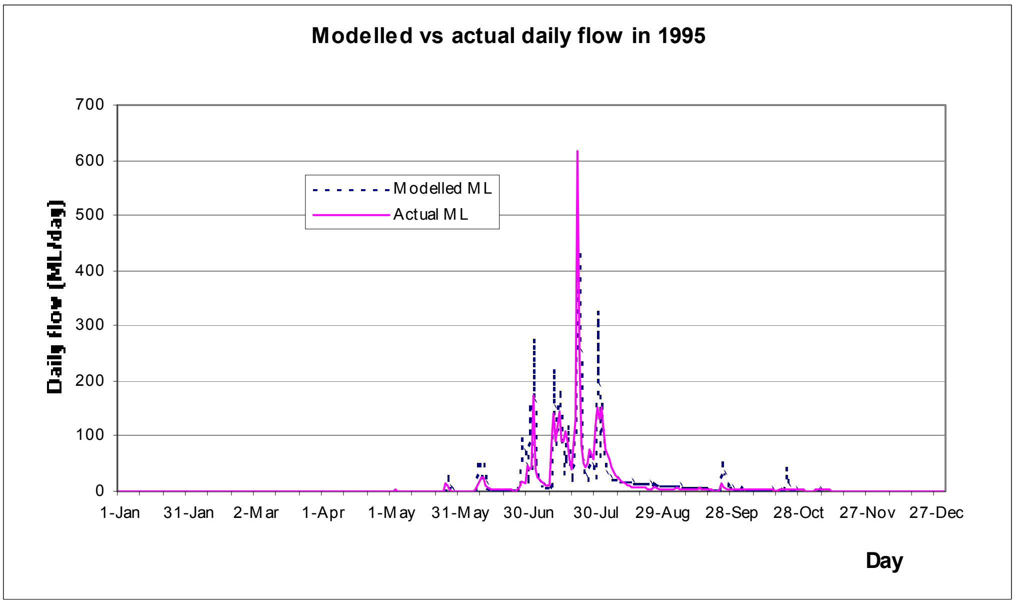
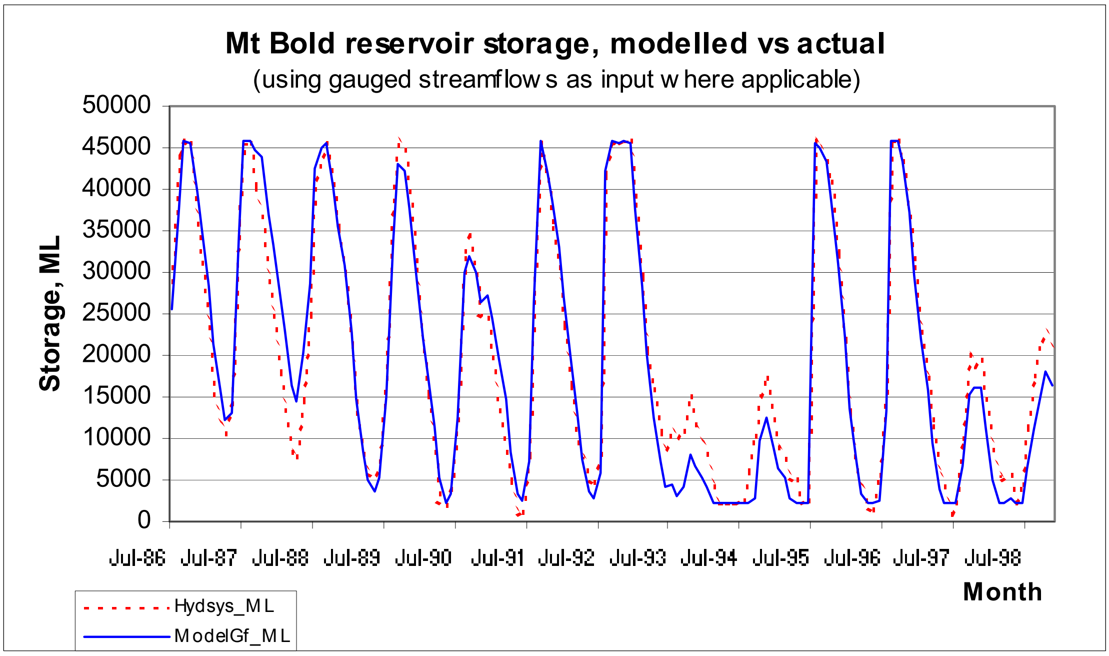
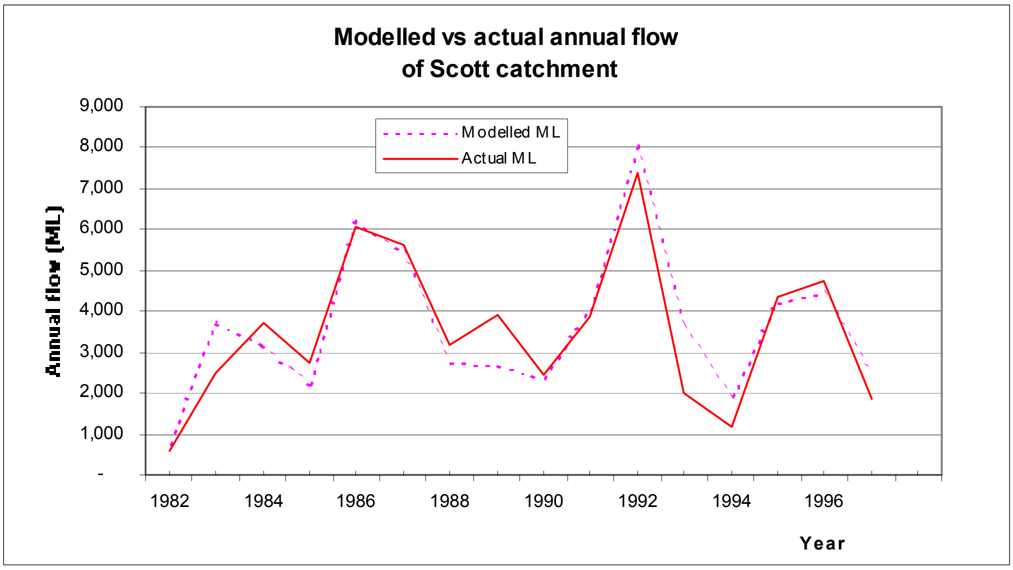
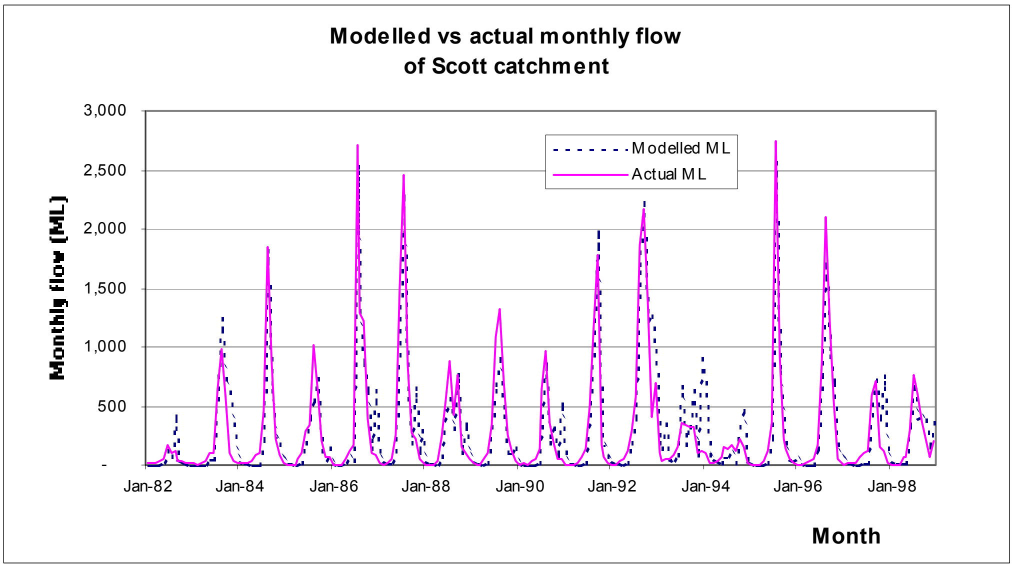



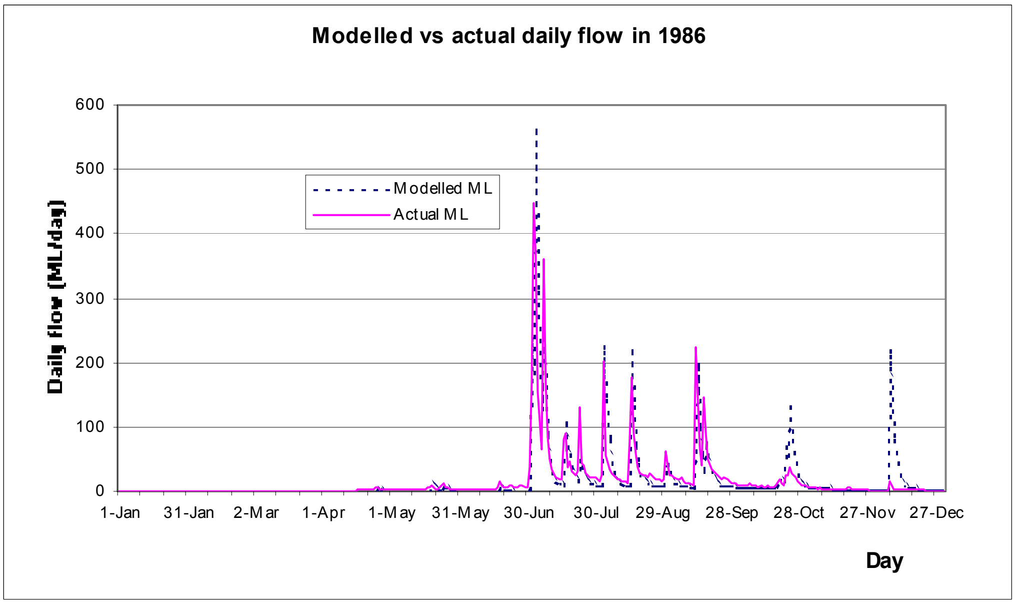
**Figure 40. Modelled and actual flow calibrations of Mt Bold Reservoir catchment (1986-1998)**



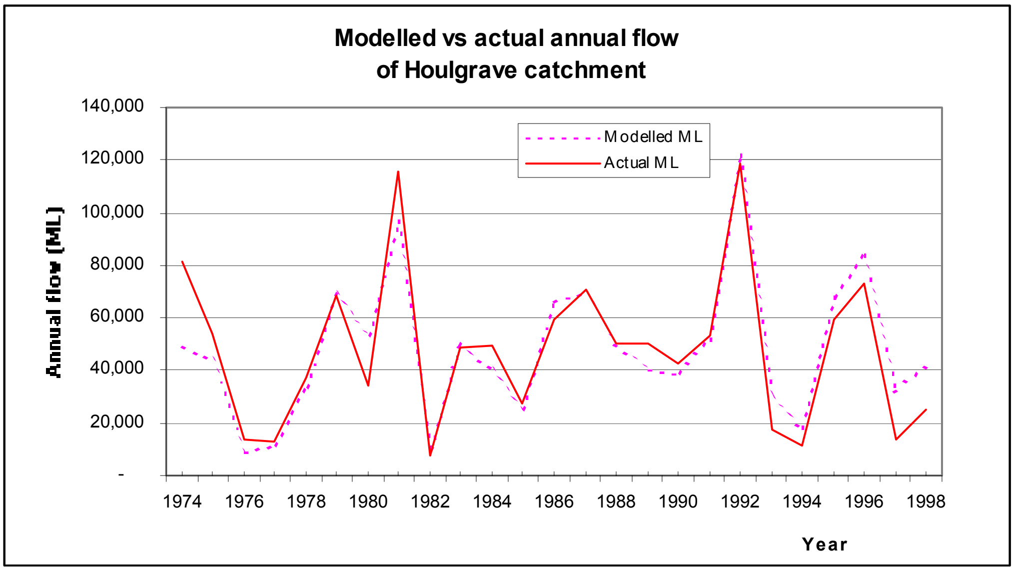
## Figure 41. Modelled and actual flow calibrations of Scott creek catchment

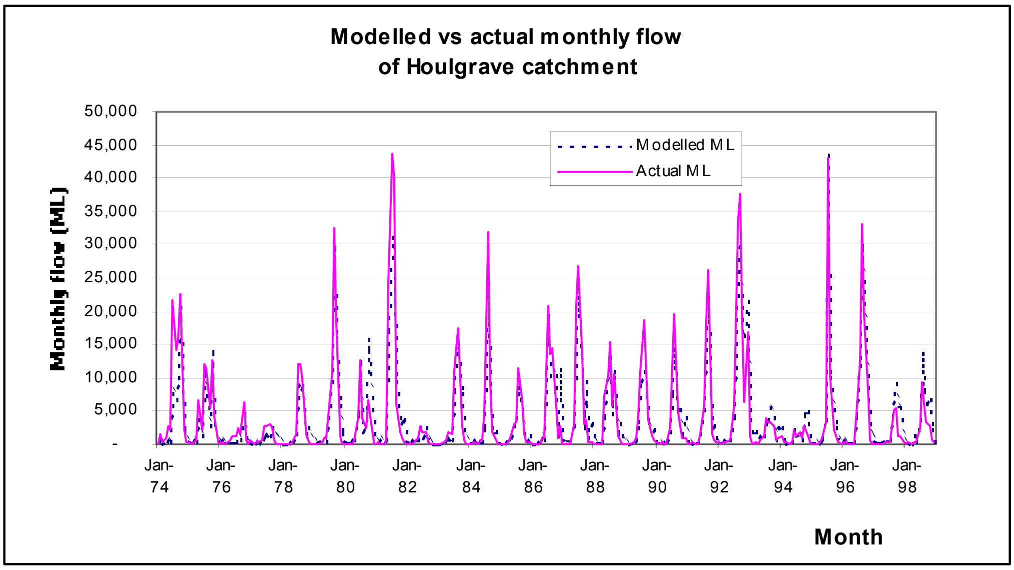


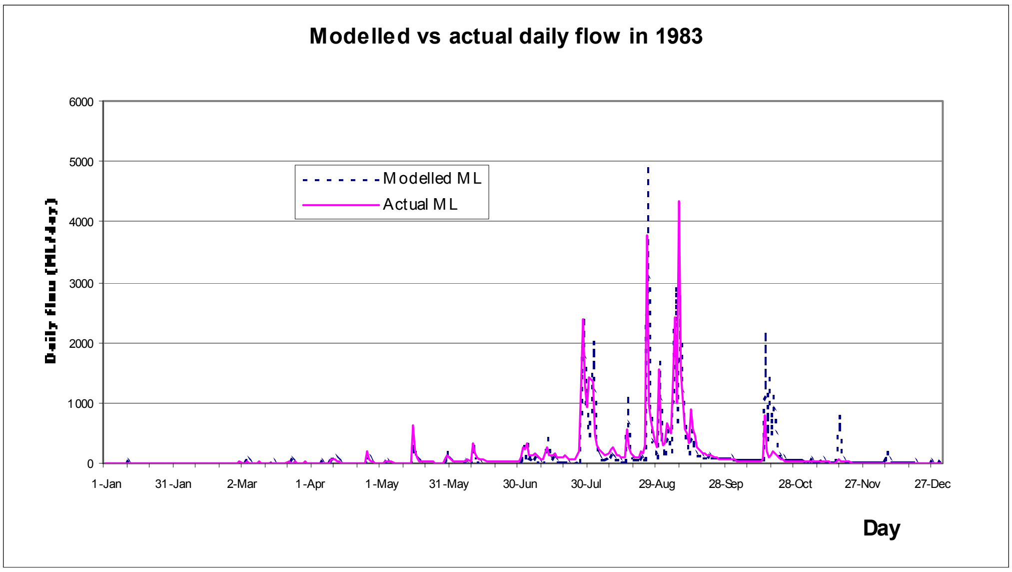



## Figure 42. Modelled and actual flow calibrations of Houlgrave catchment

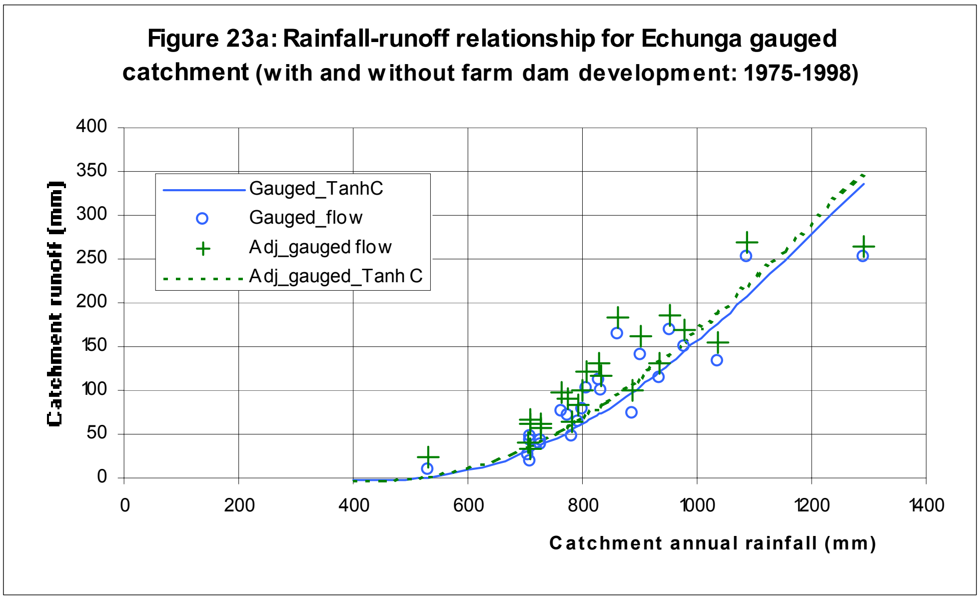


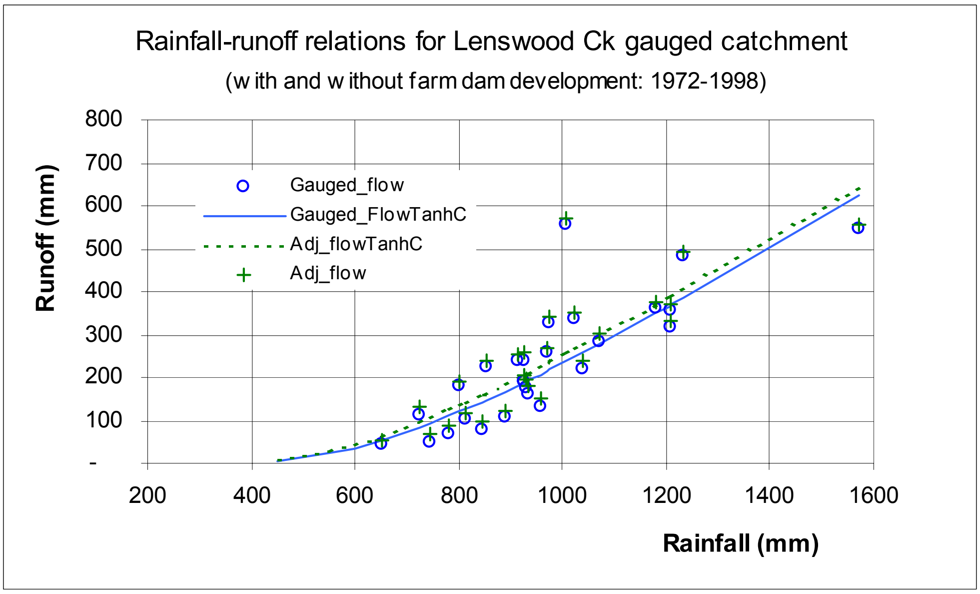



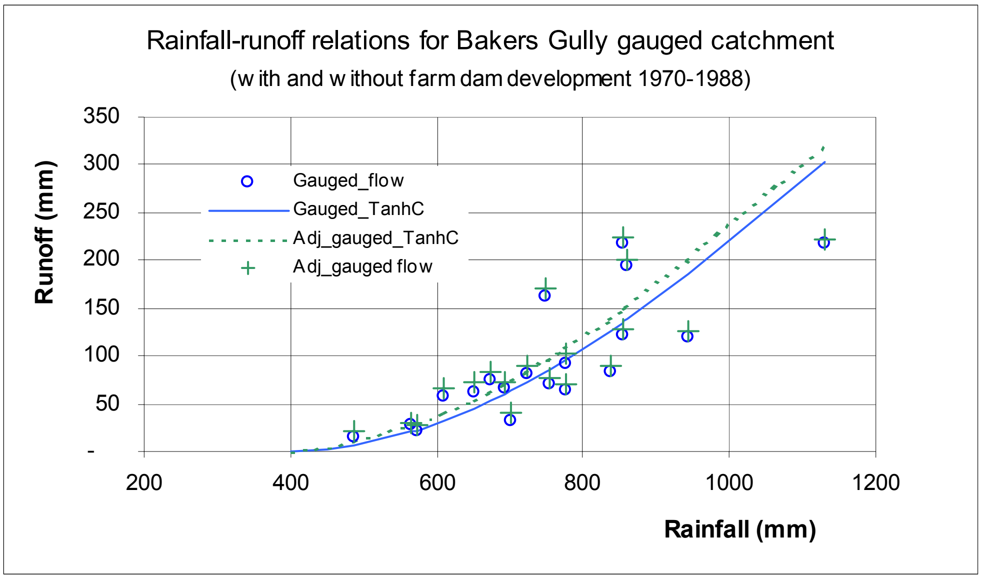



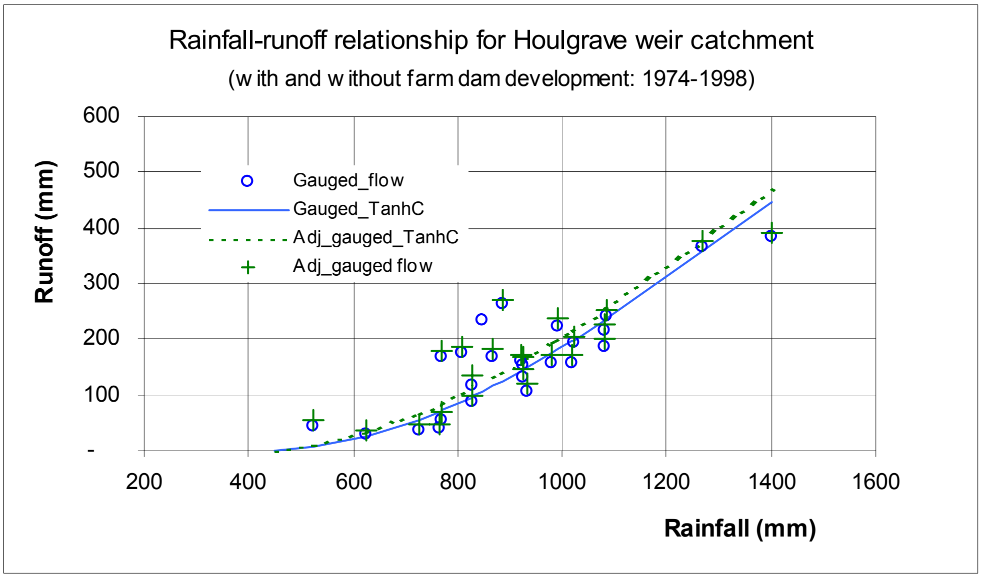
# APPENDIX D - TANH CURVES OF GUAGED CATCHMENTS, MODELLED SUBCATCHMENT YIELDS WITH AND WITHOUT FARM DAMS, REDUCTION IN ADJUSTED FLOWS OF SUBCATCHMENTS MODELLED WITH FUTURE SCENARIOS

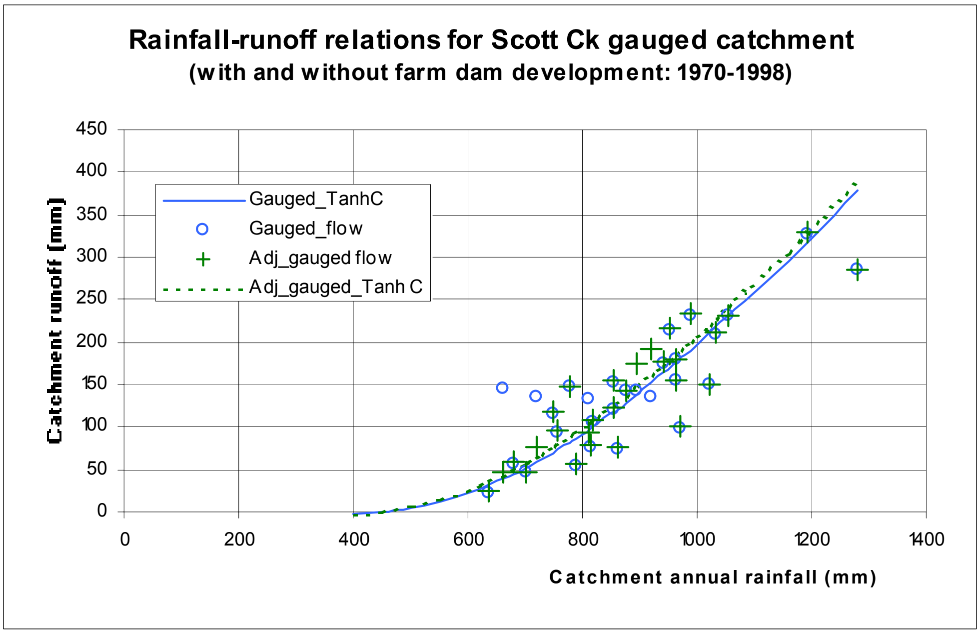
**Figure 43. Tanh curves of rainfall runoff relationship for the gauged catchments**

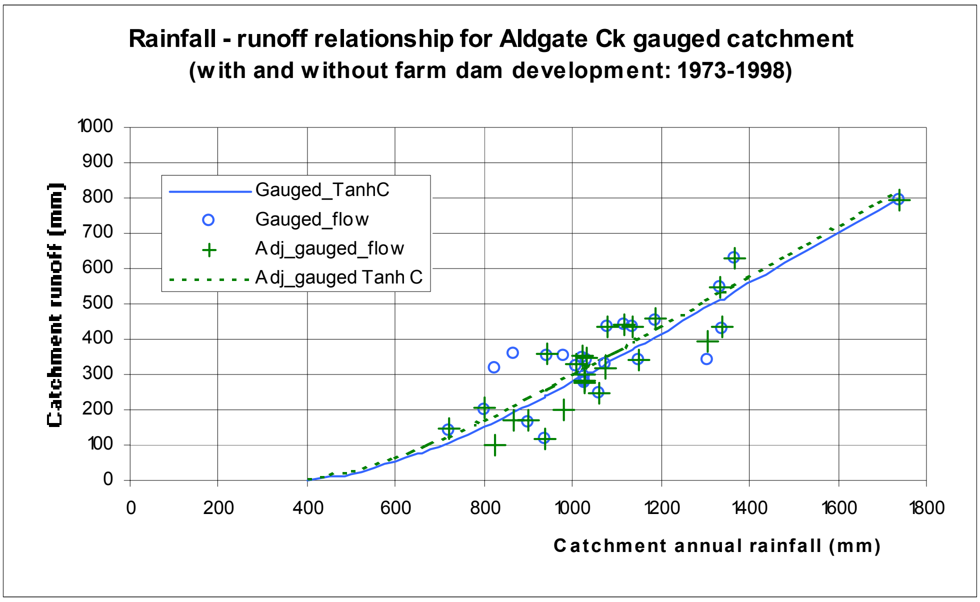


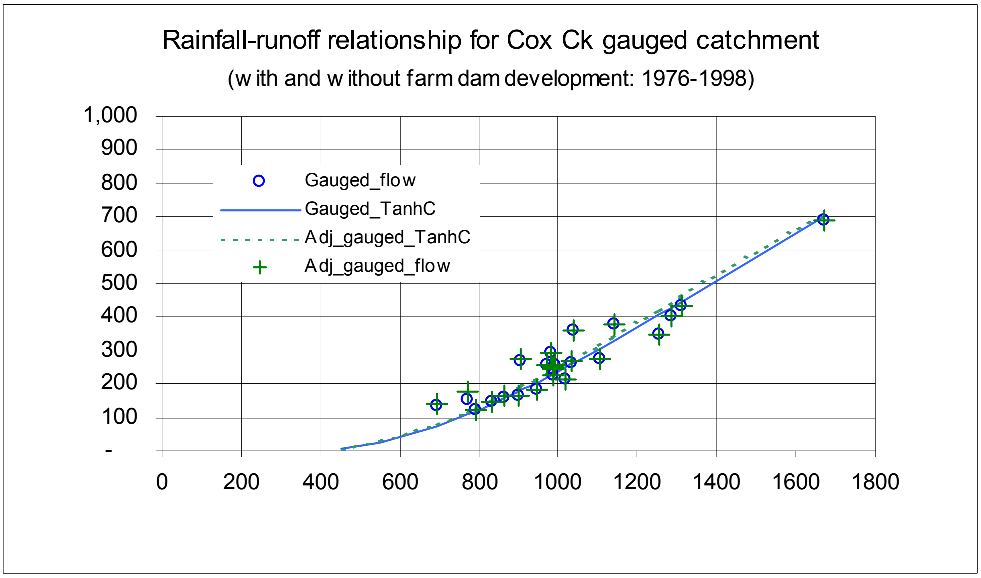



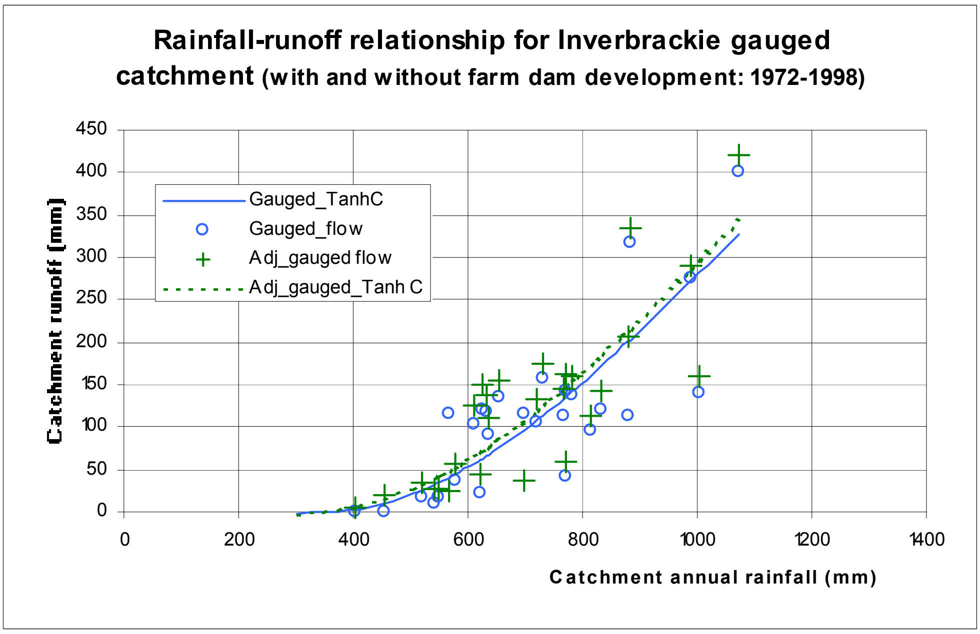

Rainfall-runoff relations for Bakers Gully gauged catchment
(with and without farm dam development 1970-1988)
Runoff (mm)
350
300
250
200
150
100
50
-
Gauged_flow
Gauged_TanhC
Adj_gauged_TanhC
Adj_gauged flow
200
400
600
800
1000
1200
Rainfall (mm)


Rainfall-runoff relationship for Houlgrave weir catchment
(with and without farm dam development: 1974-1998)
Runoff (mm)
600
500
400
300
200
100
-
Gauged_flow
Gauged_TanhC
Adj_gauged_TanhC
Adj_gauged flow
200
400
600
800
1000
1200
1400
1600
Rainfall (mm)


Rainfall-runoff relations for Scott Ck gauged catchment
(with and without farm dam development: 1970-1998)
Catchment runoff (mm)
450
400
350
300
250
200
150
100
50
0
Gauged_TanhC
Gauged_flow
Adj_gauged flow
Adj_gauged_Tanh C
0
200
400
600
800
1000
1200
1400
Catchment annual rainfall (mm)


Rainfall - runoff relationship for Aldgate Ck gauged catchment
(with and without farm dam development: 1973-1998)
Gauged_TanhC
Gauged_flow
Adj_gauged_flow
Adj_gauged Tanh C
Catchment runoff (mm)
Catchment annual rainfall (mm)
0
100
200
300
400
500
600
700
800
900
1000
1200
1400
1600
1800


Rainfall-runoff relationship for Cox Ck gauged catchment
(with and without farm dam development: 1976-1998)
Gauged_flow
Gauged_TanhC
Adj_gauged_TanhC
Adj_gauged_flow
1,000
900
800
700
600
500
400
300
200
100
-
0
200
400
600
800
1000
1200
1400
1600
1800


Rainfall-runoff relationship for Inverbrackie gauged catchment (with and without farm dam development: 1972-1998)
Gauged_TanhC
Gauged_flow
Adj_gauged flow
Adj_gauged_Tanh C
Catchment runoff (mm)
Catchment annual rainfall (mm)
450
400
350
300
250
200
150
100
50
0
200
400
600
800
1000
1200
1400

## Table 37. Annual flow at Aldgate Creek with and without farm dams (1900 - 1998)

| **Catchment area** | **19.450 km2** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **8.165 ML/km2** | | **Dam storages** | **158.8 ML, a** | | | | | |
| **Aldgate Creek** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 1,107 | 6,224 | 6,146 | 78 | 1.25% | 320.00 | 4.01 | 3% | 49% |
| median | 1,097 | 6,058 | 5,953 | 104 | 1.72% | 311.44 | 5.37 | 3% | 66% |
| 90%tile | 1,429 | 9,897 | 9,863 | 34 | 0.34% | 508.85 | 1.74 | 2% | 21% |
| 10%tile | 809 | 2,686 | 2,526 | 159 | 5.93% | 138.08 | 8.18 | 6% | 100% |
| 3YMA(1915-1917,wet) | 1,590 | 12,415 | 12,389 | 26 | 0.21% | 638.30 | 1.34 | 1% | 16% |
| 3YMA(1912-1914,dry) | 853 | 2,839 | 2,744 | 95 | 3.36% | 145.96 | 4.90 | 6% | 60% |
| Std deviation | | 2,967 | 2,990 | | | | | | |
| Coeff of variability, Cv | | 0.48 | 0.49 | | | | | | |

## Table 38. Annual flow at Angels Gully with and without farm dams (1900 - 1998)

| **Catchment area** | **14.080 km2** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **5.86 ML/km2** | | **Dam storages** | **82.5 ML, a** | | | | | |
| **Angels Gully** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 835 | 2,060 | 1,995 | 64 | 3.13% | 146.30 | 4.58 | 4% | 78% |
| median | 810 | 1,842 | 1,766 | 76 | 4.15% | 130.82 | 5.43 | 4% | 93% |
| 90%tile | 1,107 | 3,853 | 3,815 | 38 | 0.98% | 273.68 | 2.69 | 2% | 46% |
| 10%tile | 640 | 627 | 554 | 73 | 11.67% | 44.52 | 5.20 | 13% | 89% |
| 3YMA(1915-1917,wet) | 997 | 3,077 | 3,011 | 65 | 2.12% | 218.50 | 4.64 | 3% | 79% |
| 3YMA(1912-1914,dry) | 600 | 371 | 326 | 45 | 12.11% | 26.36 | 3.19 | 22% | 54% |
| Std deviation | | 1,257 | 1,264 | | | | | | |
| Coeff of variability, Cv | | 0.61 | 0.63 | | | | | | |

## Table 39. Annual flow at Bakers Gully with and without farm dams (1900 - 1998)

| Catchment area | 47.960 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **11.1 ML/km2** | | **Dam storages** | **530 ML, a** | | | | | |
| **Bakers Gully** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 747 | 5,042 | 4,699 | 343 | 6.81% | 105.14 | 7.16 | 11% | 65% |
| median | 725 | 4,498 | 4,090 | 408 | 9.07% | 93.79 | 8.51 | 12% | 77% |
| 90%tile | 989 | 10,166 | 9,813 | 352 | 3.47% | 211.96 | 7.35 | 5% | 66% |
| 10%tile | 572 | 1,252 | 948 | 304 | 24.25% | 26.10 | 6.33 | 42% | 57% |
| 3YMA(1915-1917,wet) | 892 | 7,371 | 6,977 | 395 | 5.35% | 153.70 | 8.23 | 7% | 74% |
| 3YMA(1912-1914,dry) | 536 | 808 | 617 | 191 | 23.69% | 16.85 | 3.99 | 66% | 36% |
| Std deviation | | 3,541 | 3,538 | | | | | | |
| Coeff of variability, Cv | | 0.70 | 0.75 | | | | | | |

## Table 40. Annual flow at Balhannah catchment with and without farm dams (1900 - 1998)

| Catchment area | 10.2 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **19.24 ML/km2** | | **Dam storages** | **197 ML, a** | | | | | |
| **Balhannah** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 818 | 1,195 | 1,081 | 114 | 9.54% | 116.69 | 11.13 | 16% | 58% |
| median | 809 | 1,146 | 1,031 | 115 | 10.04% | 111.96 | 11.24 | 17% | 58% |
| 90%tile | 1,041 | 2,147 | 2,043 | 104 | 4.83% | 209.66 | 10.12 | 9% | 53% |
| 10%tile | 633 | 307 | 202 | 104 | 34.05% | 29.95 | 10.20 | 64% | 53% |
| 3YMA(1915-1917,wet) | 978 | 1,903 | 1,763 | 140 | 7.37% | 185.86 | 13.70 | 10% | 71% |
| 3YMA(1912-1914,dry) | 602 | 377 | 299 | 78 | 20.60% | 36.79 | 7.58 | 52% | 39% |
| Std deviation | | 767 | 768 | | | | | | |
| Coeff of variability, Cv | | 0.64 | 0.71 | | | | | | |

## Annual flow at Biggs Flat catchment with and without farm dams (1900 - 1998)

| Catchment area | 23.650 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **27.91 ML/km2** | | **Dam storages** | **660 ML, a** | | | | | |
| **Biggs Flat** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 846 | 2,668 | 2,257 | 411 | 15.39% | 112.81 | 17.36 | 25% | 62% |
| median | 829 | 2,218 | 1,839 | 379 | 17.09% | 93.77 | 16.02 | 30% | 57% |
| 90%tile | 1,078 | 4,706 | 4,172 | 533 | 11.34% | 198.97 | 22.56 | 14% | 81% |
| 10%tile | 667 | 571 | 171 | 399 | 69.96% | 24.14 | 16.89 | 116% | 61% |
| 3YMA(1915-1917,wet) | 1,130 | 6,073 | 5,657 | 416 | 6.86% | 256.80 | 17.61 | 11% | 63% |
| 3YMA(1912-1914,dry) | 683 | 793 | 485 | 308 | 38.85% | 33.55 | 13.03 | 83% | 47% |
| Std deviation | | 1,836 | 1,843 | | | | | | |
| Coeff of variability, Cv | | 0.69 | 0.82 | | | | | | |

## Table 41. Annual flow at Charleston catchment with and without farm dams (1900 - 1998

| Catchment area | 51.510 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **14.52 ML/km2** | | **Dam storages:** | **748 ML, a** | | | | | |
| **Charleston** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 802 | 6,652 | 6,189 | 464 | 6.97% | 129.15 | 9.00 | 11% | 62% |
| median | 807 | 6,118 | 5,598 | 520 | 8.50% | 118.78 | 10.09 | 12% | 70% |
| 90%tile | 1,071 | 11,886 | 11,374 | 512 | 4.31% | 230.75 | 9.94 | 6% | 68% |
| 10%tile | 567 | 1,698 | 1,298 | 400 | 23.55% | 32.96 | 7.76 | 44% | 53% |
| 3YMA(1915-1917,wet) | 1,078 | 14,707 | 14,222 | 485 | 3.30% | 285.52 | 9.42 | 5% | 65% |
| 3YMA(1912-1914,dry) | 640 | 2,923 | 2,584 | 339 | 11.61% | 56.75 | 6.59 | 26% | 45% |
| Std deviation | | 4,332 | 4,304 | | | | | | |
| Coeff of variability, Cv | | 0.65 | 0.70 | | | | | | |

## Annual flow at Cox Creek with and without farm dams (1900 - 1998

| Catchment area | 28.750 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm dam density | 7.68 ML/km2 | | Dam storages | 221 ML, a | | | | | |
| Cox Creek | Rainfall mm | Without farm dam ML, b | With farm dam ML | Yield captured by FD | | Natural runoff (mm) | Runoff captured (mm) | 50% RL a/b | c/a |
| | | | | ML, c | % captured | | | | |
| mean | 984 | 9,024 | 8,904 | 121 | 1.34% | 313.89 | 4.20 | 2% | 55% |
| median | 975 | 8,480 | 8,341 | 139 | 1.64% | 294.95 | 4.82 | 3% | 63% |
| 90%tile | 1,270 | 14,496 | 14,441 | 55 | 0.38% | 504.20 | 1.90 | 2% | 25% |
| 10%tile | 719 | 4,055 | 3,870 | 185 | 4.57% | 141.06 | 6.44 | 5% | 84% |
| 3YMA(1915-1917,wet) | 1,413 | 17,882 | 17,836 | 45 | 0.25% | 621.98 | 1.58 | 1% | 21% |
| 3YMA(1912-1914,dry) | 758 | 3,665 | 3,512 | 154 | 4.19% | 127.49 | 5.35 | 6% | 70% |
| Std deviation | | 4,313 | 4,353 | | | | | | |
| Coeff of variability, Cv | | 0.48 | 0.49 | | | | | | |

## Table 42. Annual flow at Echunga Creek catchment with and without farm dams (1900 - 1998

| Catchment area | 39.170 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm dam density | 26.510 ML/km2 | | Dam storages | 1,038 ML, a | | | | | |
| Echunga Creek | Rainfall mm | Without farm dam ML, b | With farm dam ML | Yield captured by FD | | Natural runoff (mm) | Runoff captured (mm) | 50% RL a/b | c/a |
| | | | | ML, c | % captured | | | | |
| mean | 886 | 4,970 | 4,363 | 608 | 12.23% | 126.89 | 15.52 | 21% | 59% |
| median | 868 | 4,237 | 3,666 | 571 | 13.47% | 108.16 | 14.57 | 25% | 55% |
| 90%tile | 1,129 | 8,601 | 7,739 | 863 | 10.03% | 219.59 | 22.02 | 12% | 83% |
| 10%tile | 699 | 1,160 | 612 | 548 | 47.25% | 29.62 | 14.00 | 90% | 53% |
| 3YMA(1915-1917,wet) | 1,183 | 10,974 | 10,343 | 631 | 5.75% | 280.16 | 16.10 | 9% | 61% |
| 3YMA(1912-1914,dry) | 715 | 1,549 | 1,084 | 465 | 30.03% | 39.55 | 11.88 | 67% | 45% |
| Std deviation | | 3,272 | 3,273 | | | | | | |
| Coeff of variability, Cv | | 0.66 | 0.75 | | | | | | |

## Annual flow at Hahndorf catchment with and without farm dams (1900 - 1998)

| Catchment area | 14.680 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm dam density | 32.40 ML/km2 | | Dam storages | 476 ML, a | | | | | |
| Hahndorf | Rainfall mm | Without farm dam ML, b | With farm dam ML | Yield captured by FD | | Natural runoff (mm) | Runoff captured (mm) | 50% RL a/b | c/a |
| | | | | ML, c | % captured | | | | |
| mean | 860 | 2,521 | 2,270 | 251 | 9.97% | 171.73 | 17.12 | 19% | 53% |
| median | 851 | 2,513 | 2,225 | 288 | 11.48% | 171.20 | 19.65 | 19% | 61% |
| 90%tile | 1,094 | 4,308 | 4,056 | 253 | 5.87% | 293.48 | 17.22 | 11% | 53% |
| 10%tile | 665 | 929 | 673 | 256 | 27.58% | 63.29 | 17.45 | 51% | 54% |
| 3YMA(1915-1917,wet) | 1,028 | 3,841 | 3,523 | 318 | 8.29% | 261.67 | 21.69 | 12% | 67% |
| 3YMA(1912-1914,dry) | 633 | 925 | 752 | 173 | 18.69% | 63.00 | 11.78 | 51% | 36% |
| Std deviation | | 1,402 | 1,397 | | | | | | |
| Coeff of variability, Cv | | 0.56 | 0.62 | | | | | | |

## Table 43. Annual flow at Inverbrackie Creek catchment with and without farm dams (1900 - 1998)

| Catchment area | 26.740 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm dam density | 20.120 ML/km2 | | Dam storages: | 538 ML, a | | | | | |
| Inverbrackie Creek | Rainfall mm | Without farm dam ML, b | With farm dam ML | Yield captured by FD | | Natural runoff (mm) | Runoff captured (mm) | 50% RL a/b | c/a |
| | | | | ML, c | % captured | | | | |
| mean | 778 | 3,721 | 3,496 | 225 | 6.06% | 139.17 | 8.43 | 14% | 42% |
| median | 783 | 3,267 | 3,049 | 218 | 6.67% | 122.17 | 8.15 | 16% | 41% |
| 90%tile | 1,039 | 7,619 | 7,384 | 235 | 3.08% | 284.93 | 8.78 | 7% | 44% |
| 10%tile | 550 | 751 | 531 | 220 | 29.30% | 28.08 | 8.23 | 72% | 41% |
| 3YMA(1915-1917,wet) | 1,045 | 7,390 | 7,160 | 230 | 3.11% | 276.36 | 8.60 | 7% | 43% |
| 3YMA(1912-1914,dry) | 621 | 2,069 | 1,895 | 174 | 8.42% | 77.37 | 6.51 | 26% | 32% |
| Std deviation | | 2,458 | 2,461 | | | | | | |
| Coeff of variability, Cv | | 0.66 | 0.70 | | | | | | |

## Annual flow at Lenswood catchment with and without farm dams (1900 - 1998

| Catchment area | 28.40 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **25.000 ML/km2** | | **Dam storages:** | **710 ML, a** | | | | | |
| **Lenswood Creek** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 1,009 | 8,056 | 7,664 | 391 | 4.86% | 283.65 | 13.78 | 9% | 55% |
| median | 972 | 7,527 | 7,066 | 462 | 6.13% | 265.05 | 16.25 | 9% | 65% |
| 90%tile | 1,325 | 13,572 | 13,320 | 252 | 1.86% | 477.88 | 8.87 | 5% | 35% |
| 10%tile | 758 | 3,588 | 3,035 | 553 | 15.42% | 126.36 | 19.49 | 20% | 78% |
| 3YMA(1915-1917,wet) | 1,423 | 15,020 | 14,738 | 281 | 1.87% | 528.87 | 9.91 | 5% | 40% |
| 3YMA(1912-1914,dry) | 720 | 3,692 | 3,278 | 414 | 11.21% | 129.98 | 14.57 | 19% | 58% |
| Std deviation | | 4,068 | 4,132 | | | | | | |
| Coeff of variability, Cv | | 0.51 | 0.54 | | | | | | |

## Table 44. Annual flow at Mitchell Creek catchment with and without farm dams (1900 - 1998)

| Catchment area | 14.510 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dams density** | **39.0 ML/km2** | | **Dam storages** | **565.7 ML, a** | | | | | |
| **Mitchell Creek** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 778 | 1,782 | 1,491 | 291 | 16.32% | 122.79 | 20.05 | 32% | 51% |
| median | 783 | 1,525 | 1,225 | 300 | 19.69% | 105.09 | 20.69 | 37% | 53% |
| 90%tile | 1,039 | 3,848 | 3,485 | 363 | 9.43% | 265.22 | 25.01 | 15% | 64% |
| 10%tile | 550 | 228 | 1 | 227 | 99.41% | 15.72 | 15.63 | 248% | 40% |
| 3YMA(1915-1917,wet) | 1,045 | 3,781 | 3,423 | 358 | 9.46% | 260.57 | 24.66 | 15% | 63% |
| 3YMA(1912-1914,dry) | 621 | 929 | 730 | 199 | 21.40% | 64.00 | 13.70 | 61% | 35% |
| Std deviation | | 1,324 | 1,304 | | | | | | |
| Coeff of variability, Cv | | 0.74 | 0.87 | | | | | | |

## Table 45. Annual flow at Onkaparinga Main Channel catchment with and without farm dams (1900 - 1998)

| Catchment area | 130.428 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm dam density | 2.89 ML/km2 | | Dam storages | 377 ML, a | | | | | |
| Onka Main Channel | Rainfall mm | Without farm dam ML, b | With farm dam ML | Yield captured by FD | | Natural runoff (mm) | Runoff captured (mm) | 50% RL a/b | c/a |
| | | | | ML, c | % captured | | | | |
| mean | 819 | 12,897 | 12,657 | 240 | 1.86% | 98.88 | 1.84 | 3% | 64% |
| median | 821 | 11,663 | 11,362 | 301 | 2.58% | 89.42 | 2.31 | 3% | 80% |
| 90%tile | 1,032 | 22,412 | 22,171 | 241 | 1.08% | 171.83 | 1.85 | 2% | 64% |
| 10%tile | 629 | 3,687 | 3,370 | 317 | 8.59% | 28.27 | 2.43 | 10% | 84% |
| 3YMA(1915-1917,wet) | 1,022 | 23,737 | 23,578 | 159 | 0.67% | 181.99 | 1.22 | 2% | 42% |
| 3YMA(1912-1914,dry) | 589 | 3,142 | 2,903 | 239 | 7.61% | 24.09 | 1.83 | 12% | 63% |
| Std deviation | | 7,744 | 7,784 | | | | | | |
| Coeff of variability, Cv | | 0.60 | 0.61 | | | | | | |

## Table 46. Annual flow at Scott Creek catchment with and without farm dams (1900 - 1998)

| Catchment area | 28.500 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Farm dam density | 5.19 ML/km2 | | Dam storages | 147.9 ML, a | | | | | |
| Scott Creek | Rainfall mm | Without farm dam ML, b | With farm dam ML | Yield captured by FD | | Natural runoff (mm) | Runoff captured (mm) | 50% RL a/b | c/a |
| | | | | ML, c | % captured | | | | |
| mean | 882 | 4,217 | 4,177 | 39 | 0.94% | 147.96 | 1.38 | 4% | 27% |
| median | 891 | 4,059 | 4,012 | 47 | 1.16% | 142.43 | 1.65 | 4% | 32% |
| 90%tile | 1,120 | 7,277 | 7,245 | 32 | 0.44% | 255.33 | 1.13 | 2% | 22% |
| 10%tile | 638 | 1,024 | 967 | 57 | 5.59% | 35.93 | 2.01 | 14% | 39% |
| 3YMA(1915-1917,wet) | 1,031 | 7,997 | 7,981 | 16 | 0.20% | 280.59 | 0.56 | 2% | 11% |
| 3YMA(1912-1914,dry) | 589 | 751 | 702 | 49 | 6.53% | 26.35 | 1.72 | 20% | 33% |
| Std deviation | | 2,539 | 2,551 | | | | | | |
| Coeff of variability, Cv | | 0.60 | 0.61 | | | | | | |

## Annual flow at Upper Onkaparinga catchment with and without farm dams (1900 - 1998)

| **Catchment area** | **47.080 km2** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **22.52 ML/km2** | | **Dam storages** | **1,060 ML, a** | | | | | |
| **Upper Onkaparinga** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 957 | 9,005 | 8,466 | 539 | 5.99% | 191.27 | 11.46 | 12% | 51% |
| median | 950 | 8,623 | 8,002 | 621 | 7.20% | 183.15 | 13.19 | 12% | 59% |
| 90%tile | 1,207 | 14,743 | 14,312 | 431 | 2.93% | 313.15 | 9.16 | 7% | 41% |
| 10%tile | 716 | 3,238 | 2,697 | 541 | 16.71% | 68.77 | 11.49 | 33% | 51% |
| 3YMA(1915-1917,wet) | 1,251 | 16,950 | 16,404 | 546 | 3.22% | 360.02 | 11.60 | 6% | 52% |
| 3YMA(1912-1914,dry) | 714 | 3,197 | 2,776 | 421 | 13.16% | 67.91 | 8.94 | 33% | 40% |
| Std deviation | | 4,958 | 4,996 | | | | | | |
| Coeff of variability, Cv | | 0.55 | 0.59 | | | | | | |

## Table 47. Annual flow at Western Branch catchment with and without farm dams (1900 - 1998)

| **Catchment area** | **32.970 km2** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **29.873 ML/km2** | | **Dam storages** | **985 ML, a** | | | | | |
| **Western Branch** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 885 | 5,760 | 5,216 | 544 | 9.44% | 174.71 | 16.50 | 17% | 55% |
| median | 876 | 5,351 | 4,796 | 556 | 10.38% | 162.31 | 16.85 | 18% | 56% |
| 90%tile | 1,127 | 10,923 | 10,443 | 480 | 4.39% | 331.31 | 14.56 | 9% | 49% |
| 10%tile | 685 | 1,513 | 941 | 572 | 37.81% | 45.90 | 17.36 | 65% | 58% |
| 3YMA(1915-1917,wet) | 1,059 | 10,737 | 10,165 | 571 | 5.32% | 325.65 | 17.33 | 9% | 58% |
| 3YMA(1912-1914,dry) | 651 | 2,871 | 2,460 | 411 | 14.32% | 87.09 | 12.47 | 34% | 42% |
| Std deviation | | 3,471 | 3,490 | | | | | | |
| Coeff of variability, Cv | | 0.60 | 0.67 | | | | | | |

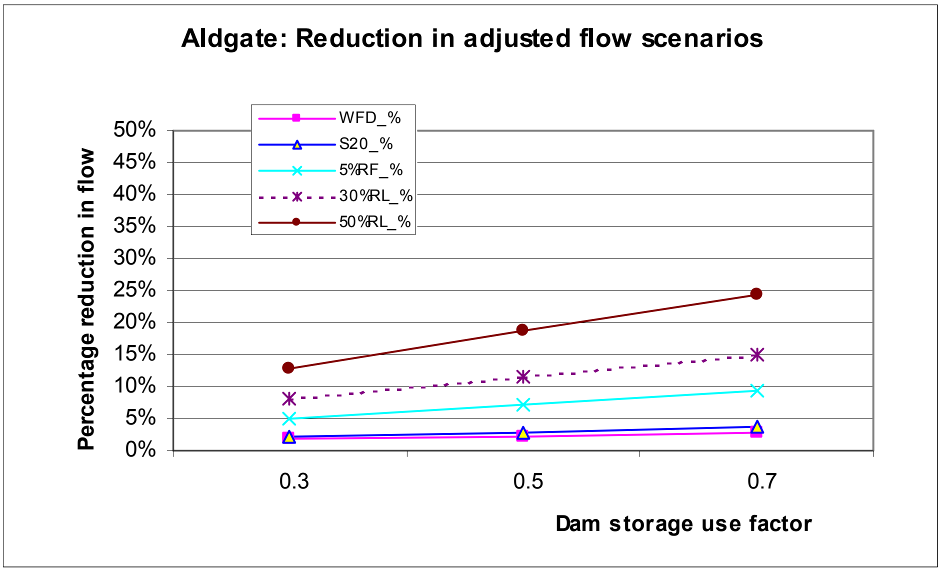
## Annual flow at Clarendon Weir (assuming no Mt Bold Reservoir) with and without farm dams (1900 - 1998

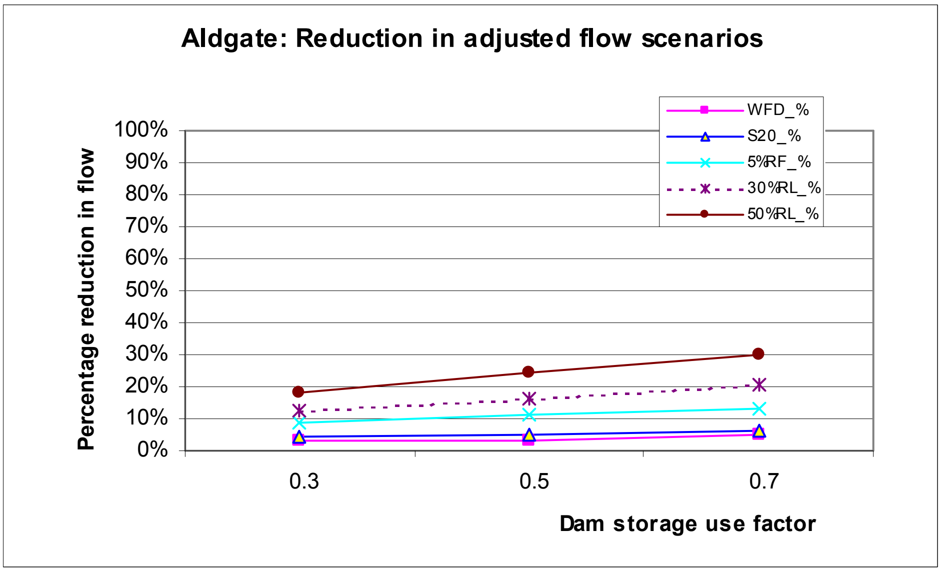
| Catchment area | 442.040 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **17.962 ML/km2** | | **Dam storages** | **7,940 ML, a** | | | | | |
| **Clarendon Weir** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 835 | 78,664 | 74,279 | 4,385 | 5.57% | 177.96 | 9.92 | 10% | 55% |
| median | 810 | 72,138 | 68,197 | 3,942 | 5.46% | 163.19 | 8.92 | 11% | 50% |
| 90%tile | 1,107 | 133,201 | 129,503 | 3,697 | 2.78% | 301.33 | 8.36 | 6% | 47% |
| 10%tile | 640 | 27,642 | 23,319 | 4,323 | 15.64% | 62.53 | 9.78 | 29% | 54% |
| 3YMA(1915-1917,wet) | 997 | 152,872 | 148,599 | 4,273 | 2.80% | 345.83 | 9.67 | 5% | 54% |
| 3YMA(1912-1914,dry) | 600 | 29,960 | 26,372 | 3,588 | 11.98% | 67.78 | 8.12 | 27% | 45% |
| Std deviation | | 43,184 | 43,328 | | | | | | |
| Coeff of variability, Cv | | 0.55 | 0.58 | | | | | | |

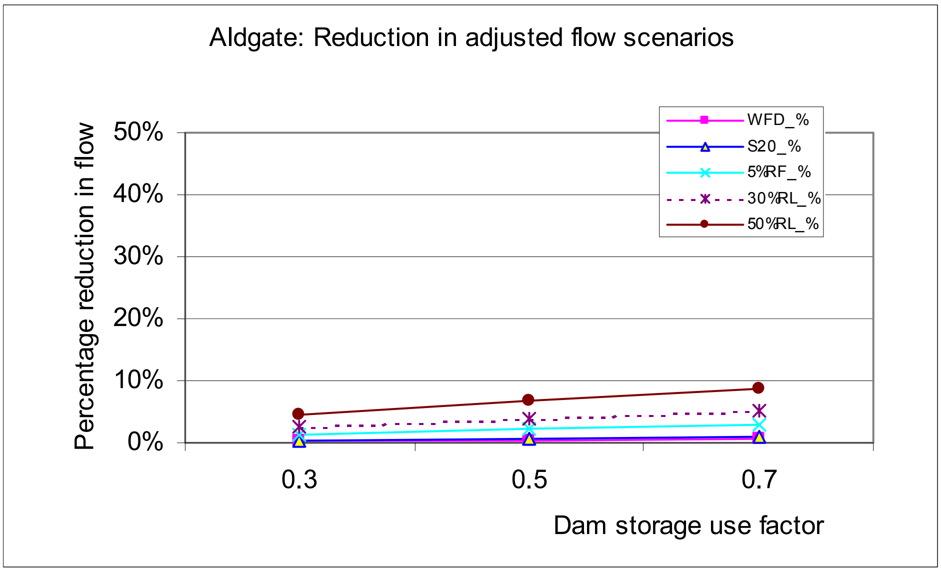
## Table 48. Annual flow at Houlgrave with and without farm dams (1900 - 1998)

| Catchment area | 321.327 km2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Farm dam density** | **20.644 ML/km2** | | **Dam storages** | **6,634 ML, a** | | | | | |
| **Houlgrave Weir** | **Rainfall mm** | **Without farm dam ML, b** | **With farm dam ML** | **Yield captured by FD** | | **Natural runoff (mm)** | **Runoff captured (mm)** | **50% RL a/b** | **c/a** |
| | | | | **ML, c** | **% captured** | | | | |
| mean | 964 | 61,494 | 57,849 | 3,645 | 5.93% | 191.38 | 11.34 | 11% | 55% |
| median | 955 | 56,424 | 52,126 | 4,298 | 7.62% | 175.60 | 13.38 | 12% | 65% |
| 90%tile | 1,243 | 103,736 | 99,804 | 3,932 | 3.79% | 322.84 | 12.24 | 6% | 59% |
| 10%tile | 704 | 21,763 | 18,160 | 3,603 | 16.56% | 67.73 | 11.21 | 30% | 54% |
| 3YMA(1915-1917,wet) | 1,384 | 121,674 | 118,140 | 3,534 | 2.90% | 378.66 | 11.00 | 5% | 53% |
| 3YMA(1912-1914,dry) | 742 | 26,282 | 23,275 | 3,007 | 11.44% | 81.79 | 9.36 | 25% | 45% |
| Std deviation | | 33,410 | 33,551 | | | | | | |
| Coeff of variability, Cv | | 0.54 | 0.58 | | | | | | |

**Figure 44. Reduction in adjusted flows of Aldgate subcatchment modelled with future scenarios and varying dam storage use[8]**

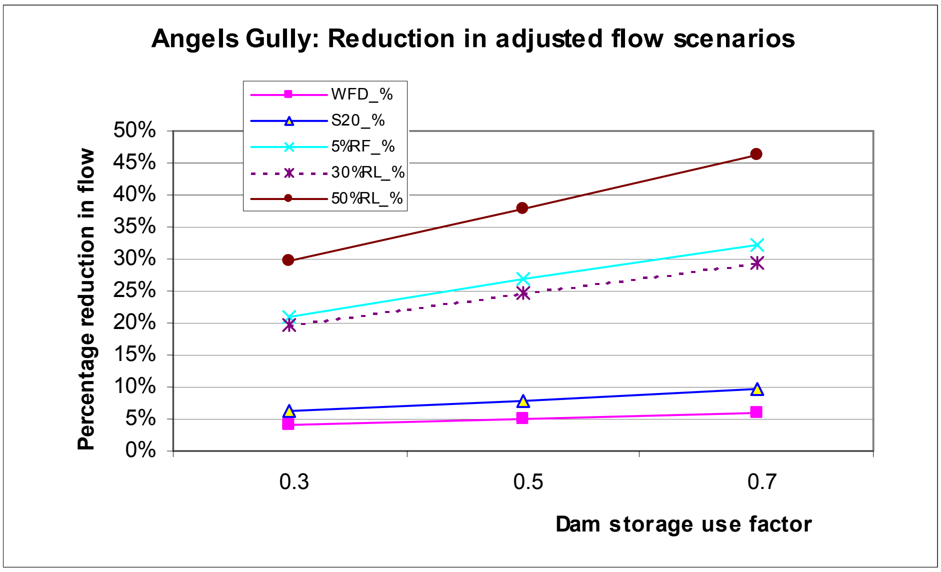


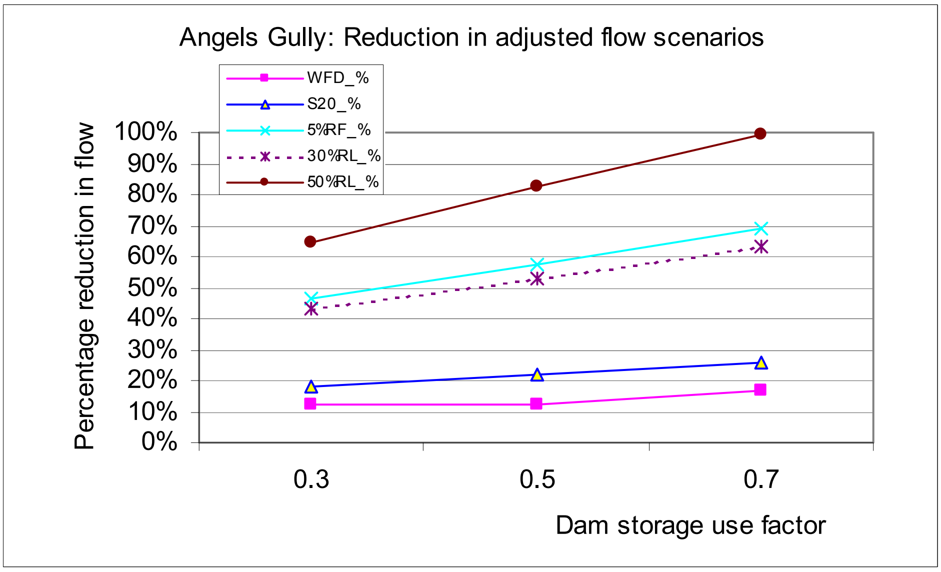




[8] **Note: All the figures are arranged in order of median, dry and wet years.**

**Figure 45. Reduction in adjusted flows of Angels Gully subcatchment modelled with future scenarios and varying dam storage use**



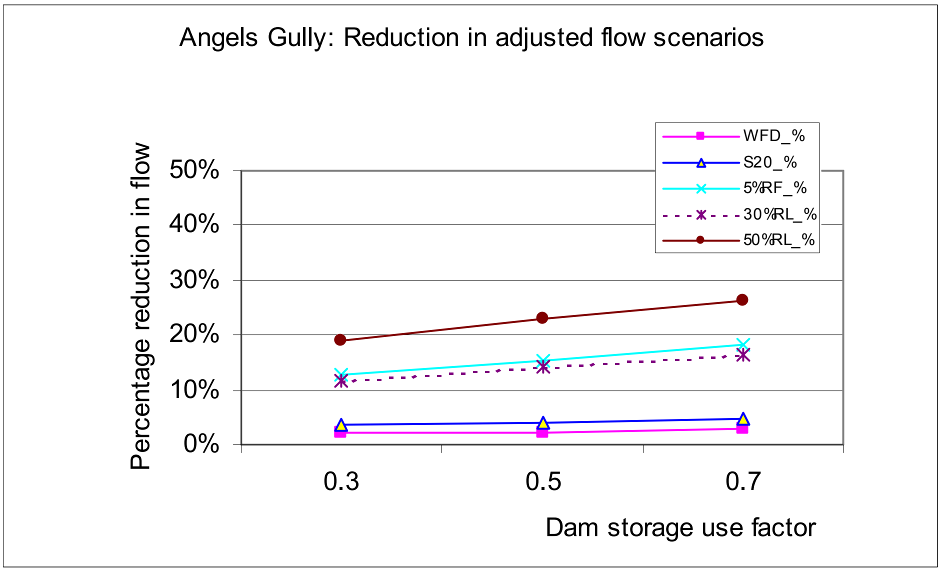
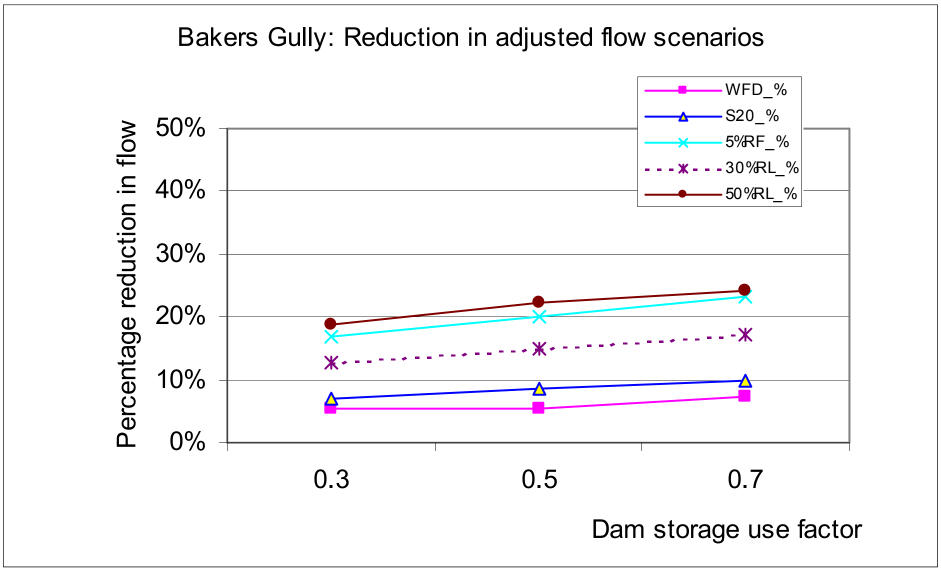



**Figure 46. Reduction in adjusted flows of Bakers Gully subcatchment modelled with future scenarios and varying dam storage use**



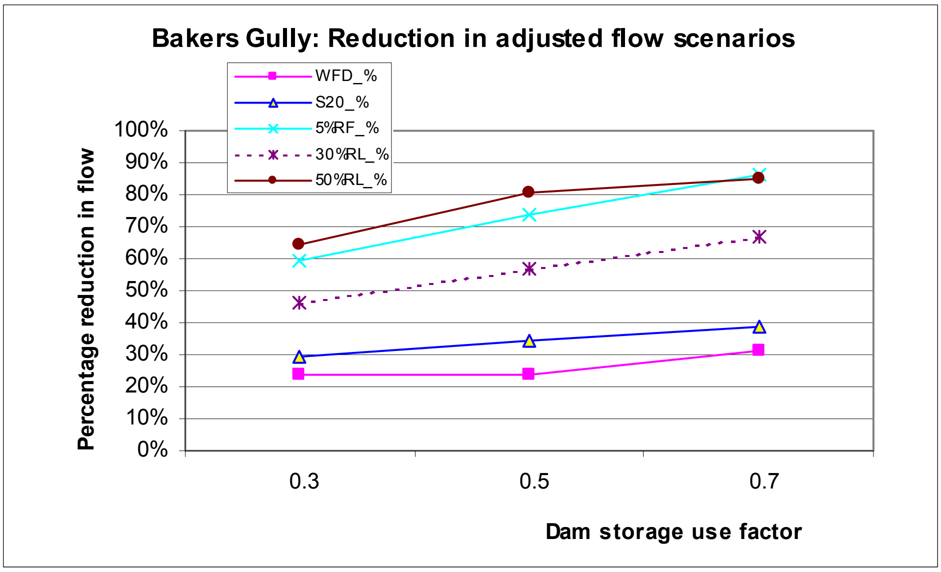
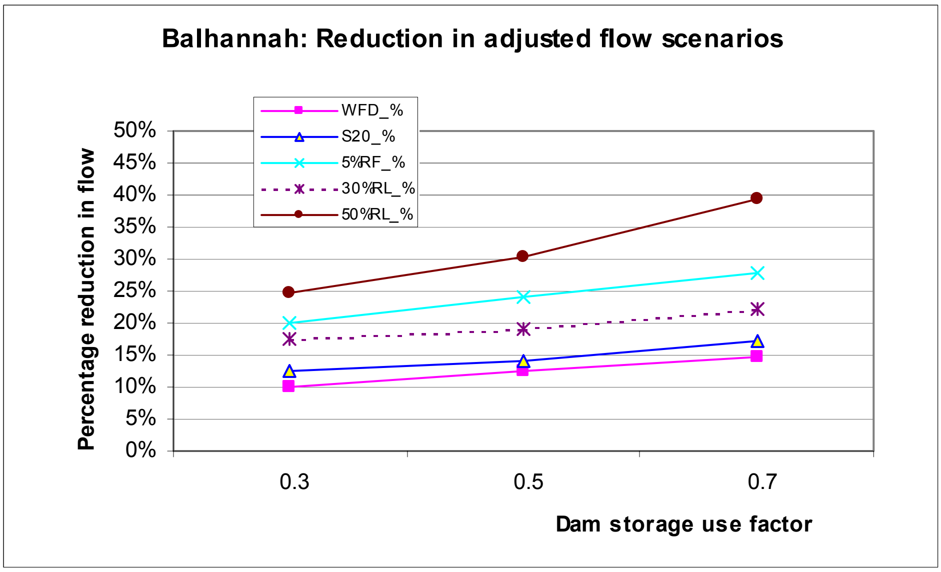
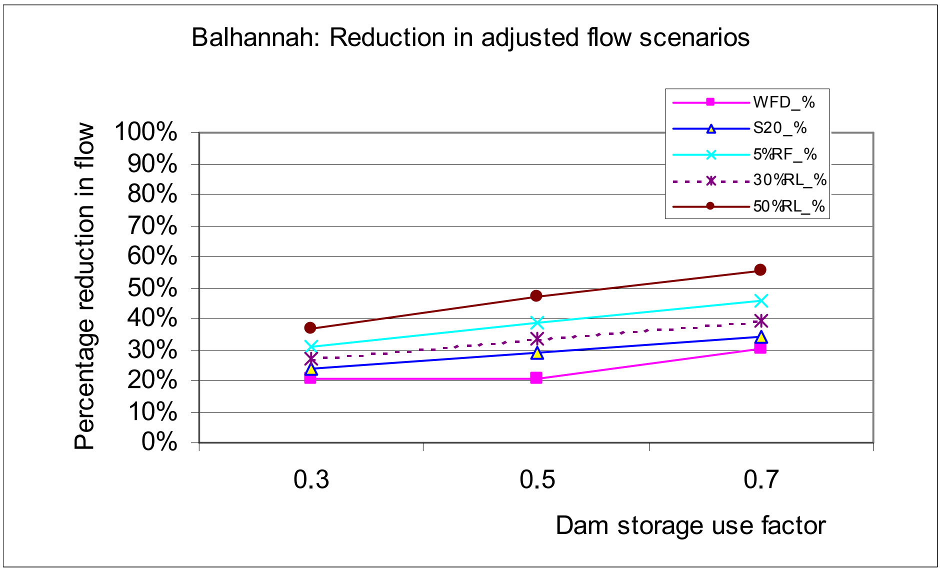



**Figure 47. Reduction in adjusted flows of Balhannah subcatchment modelled with future scenarios and varying dam storage use**



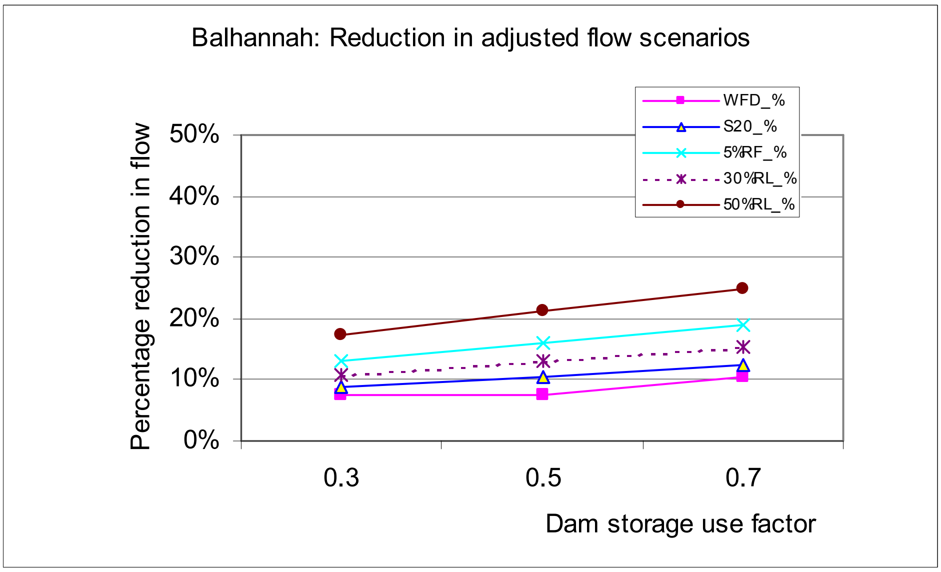
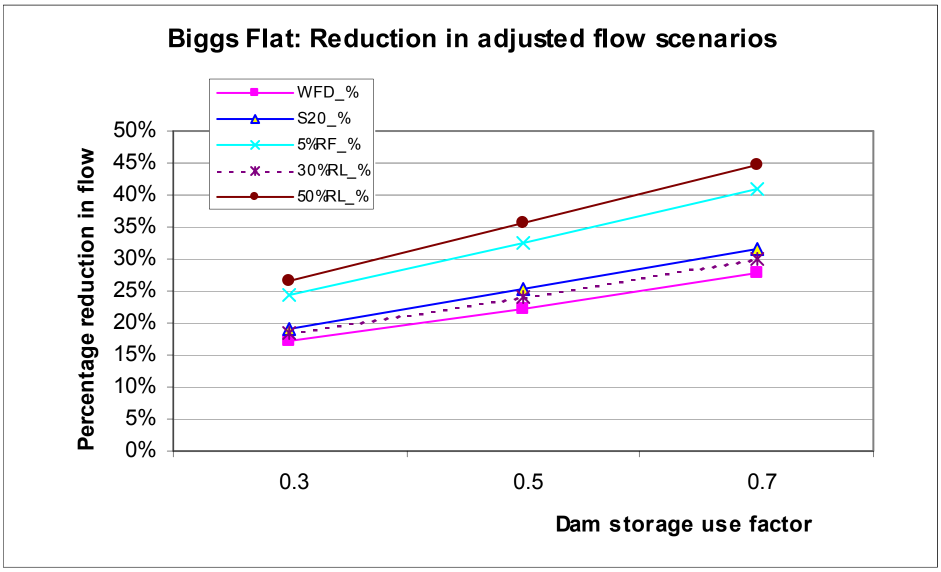
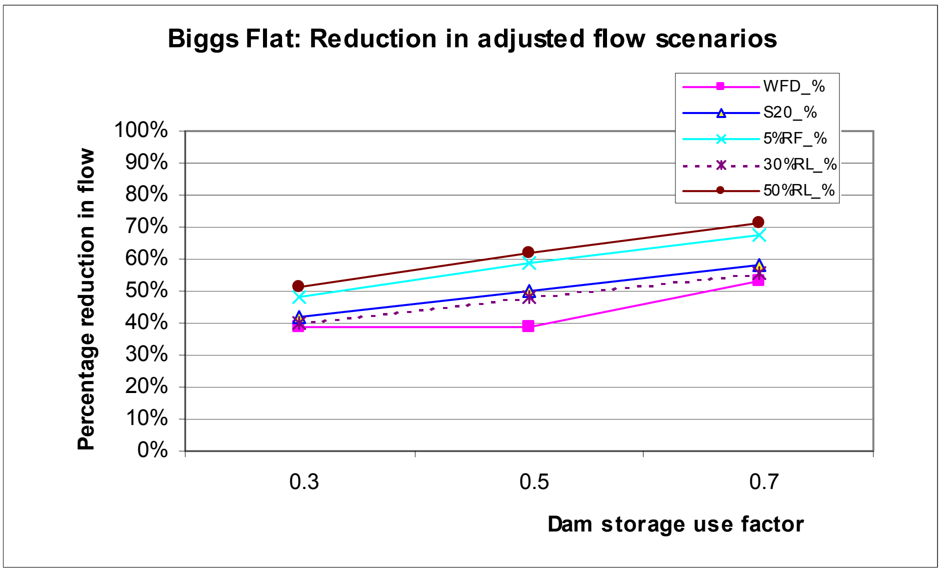



**Figure 48. Reduction in adjusted flows of Biggs Flat subcatchment modelled with future scenarios and varying dam storage**



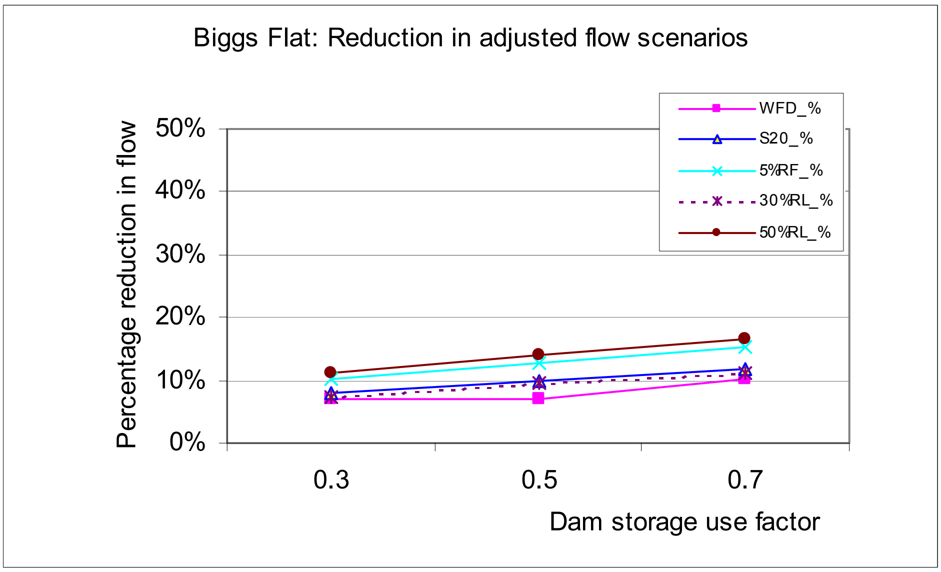
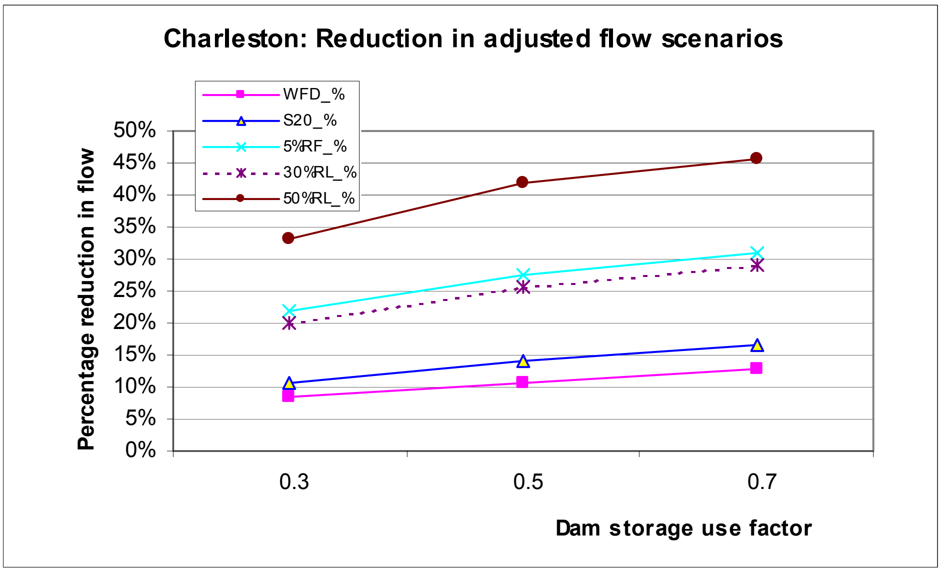
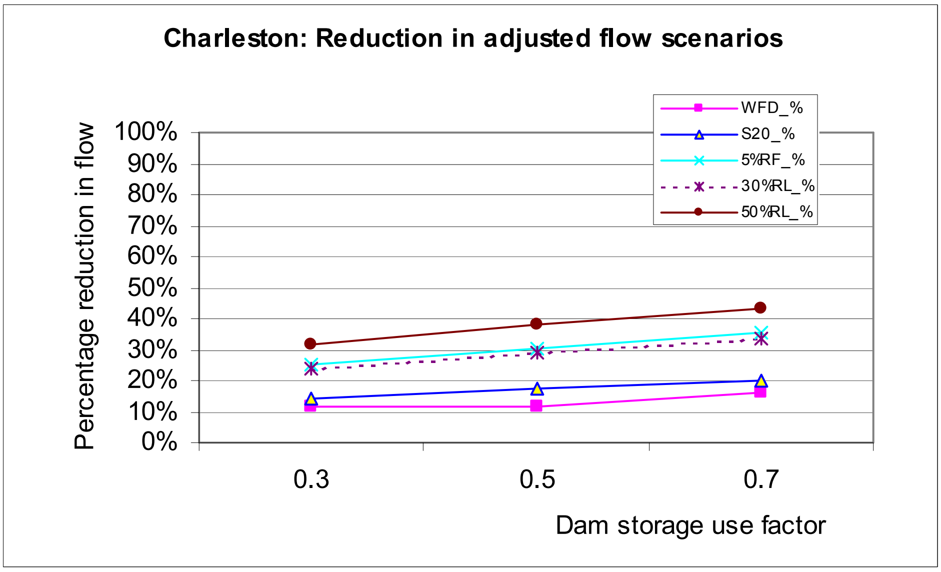



**Figure 49. Reduction in adjusted flows of Charleston subcatchment modelled with future scenarios and varying dam storage**



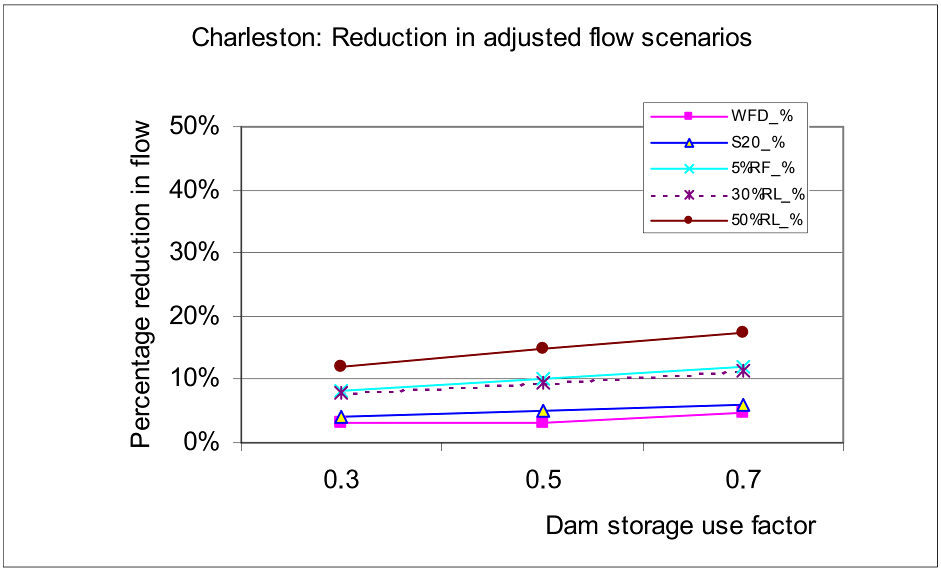
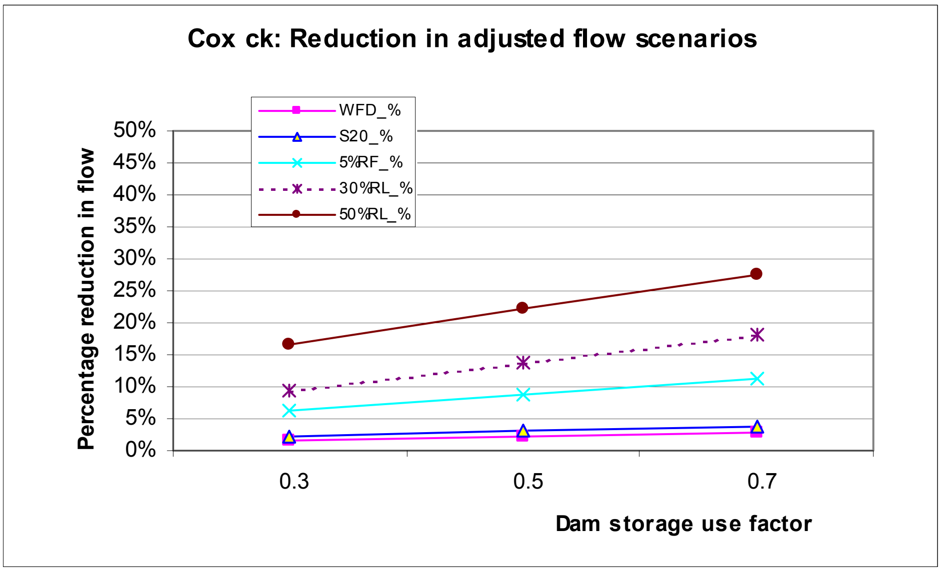
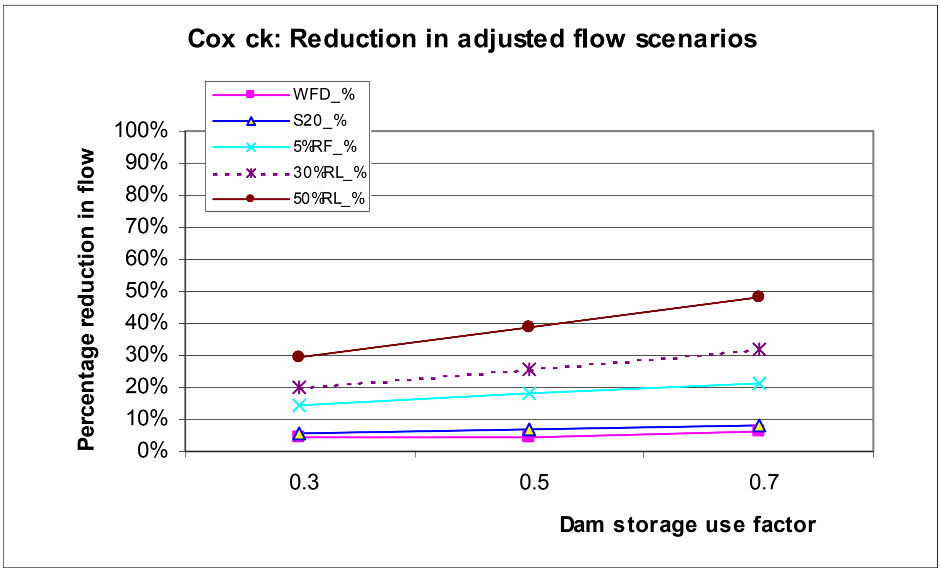



**Figure 50. Reduction in adjusted flows of Cox Creek subcatchment modelled with future scenarios and varying dam storage**



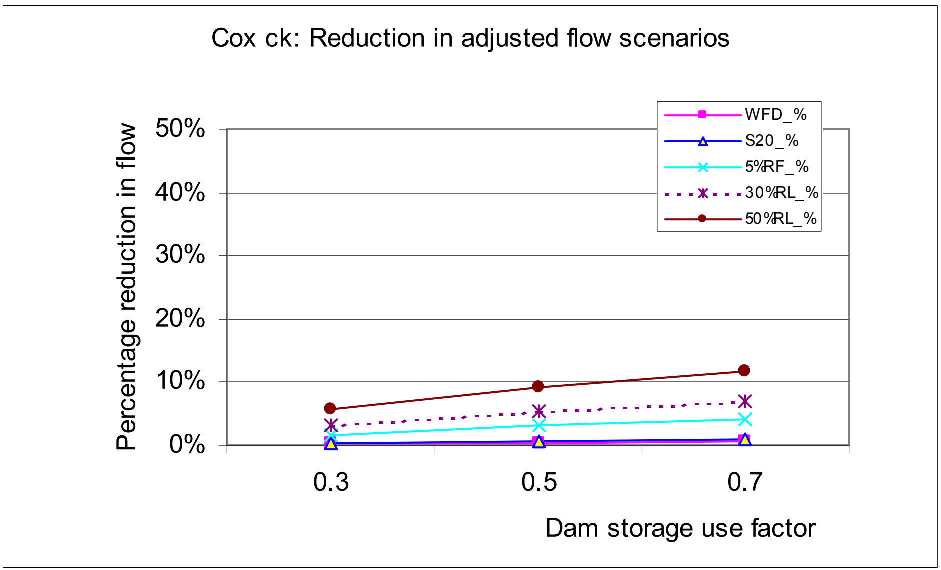
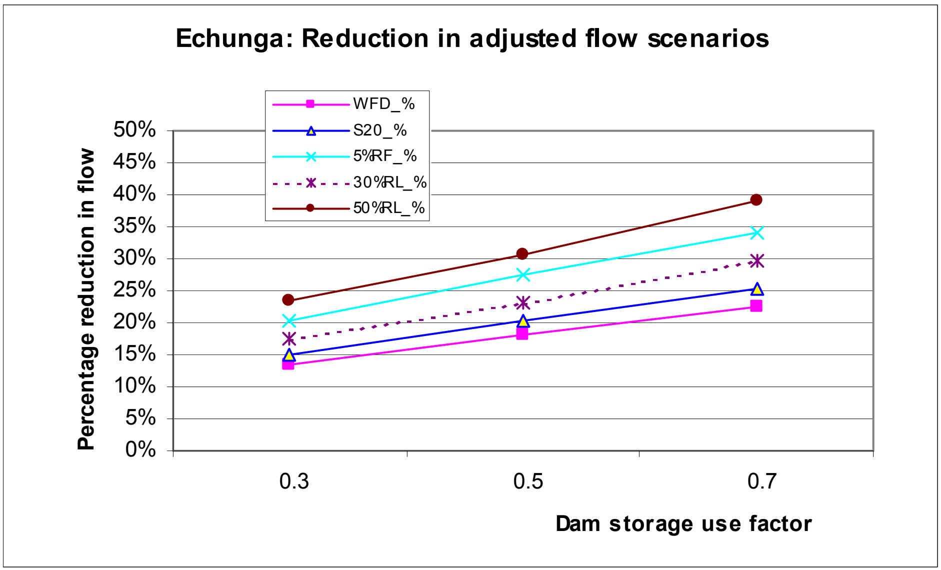
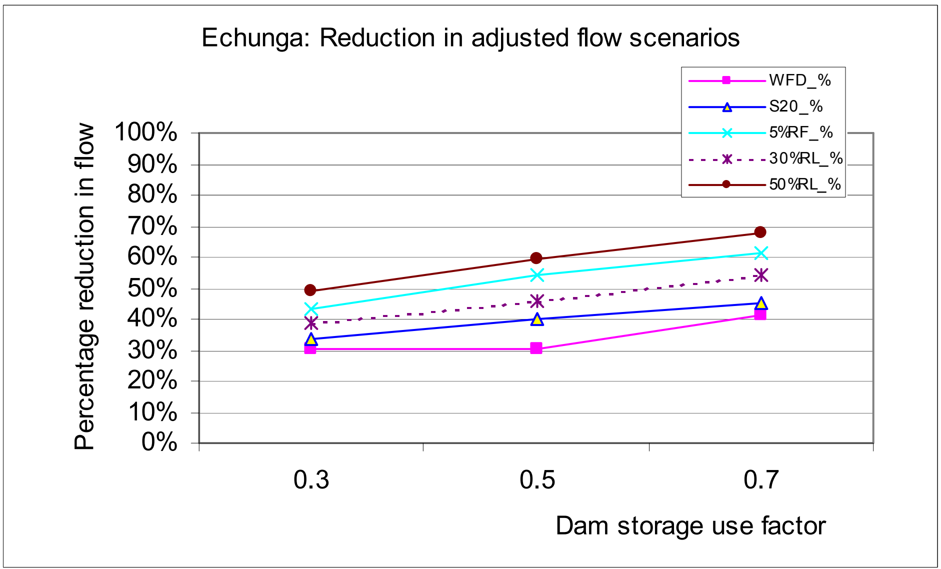



**Figure 51. Reduction in adjusted flows of Echunga subcatchment modelled with future scenarios and varying dam storage**



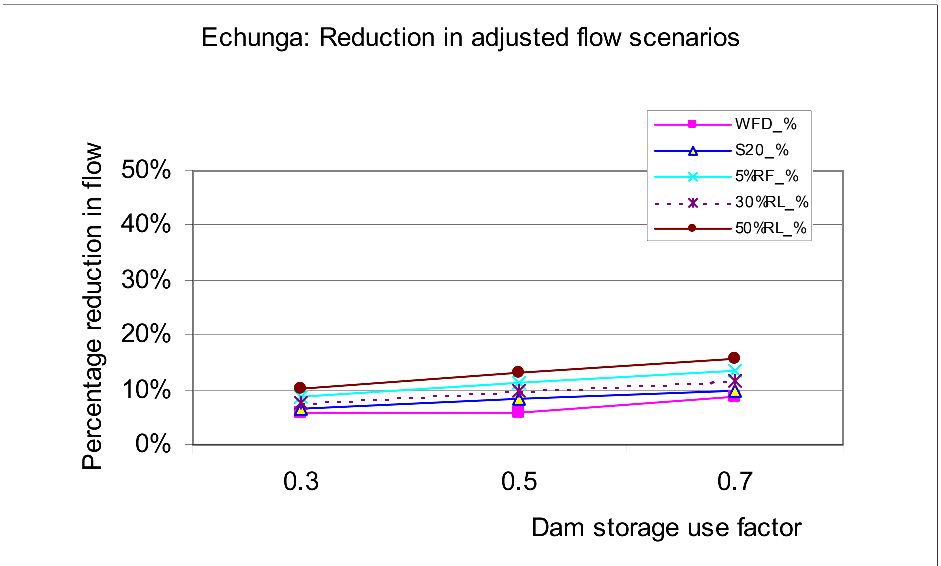



**Figure 52. Reduction in adjusted flows of Hahndorf subcatchment modelled with future scenarios and varying dam storage**

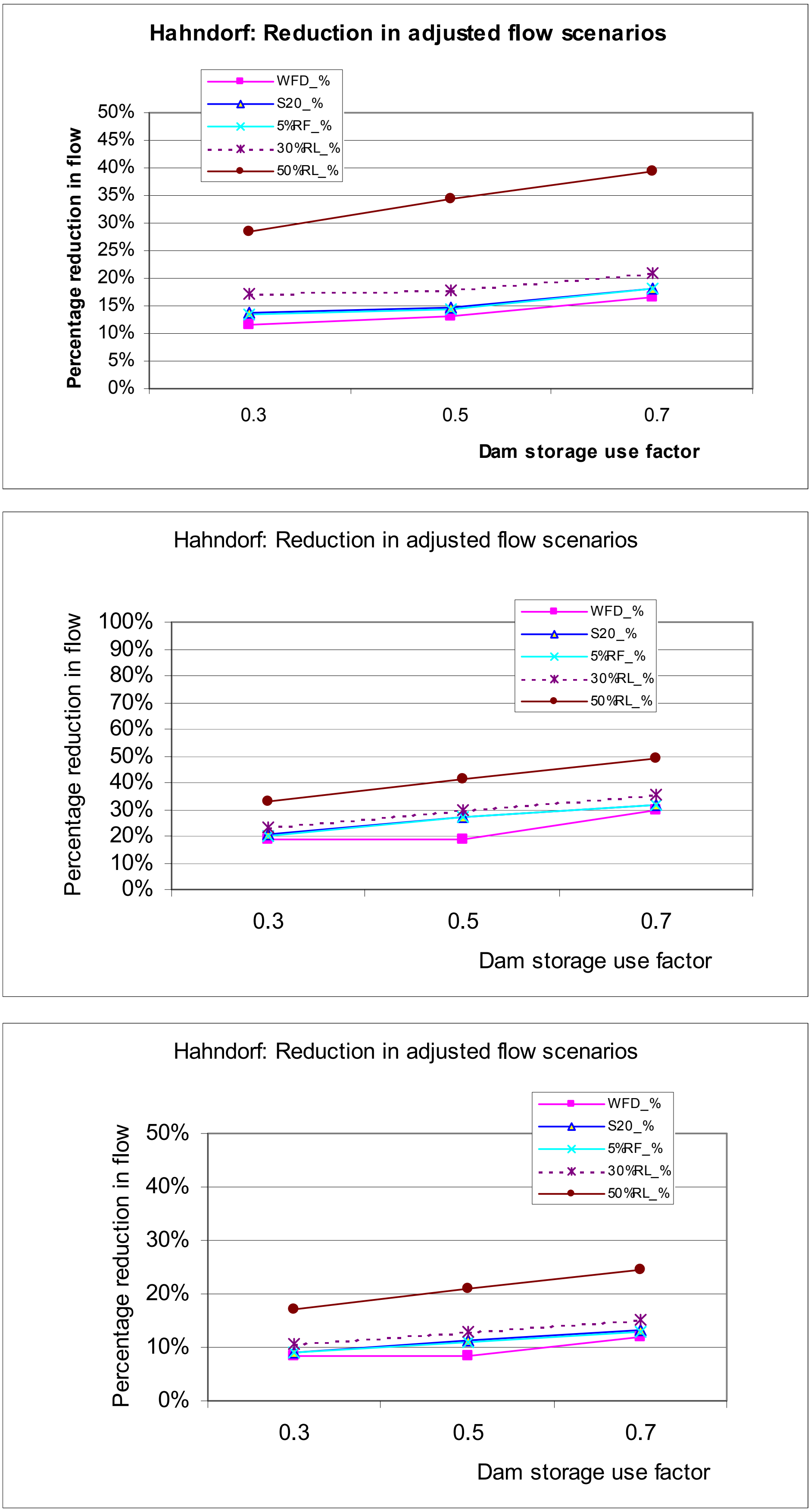
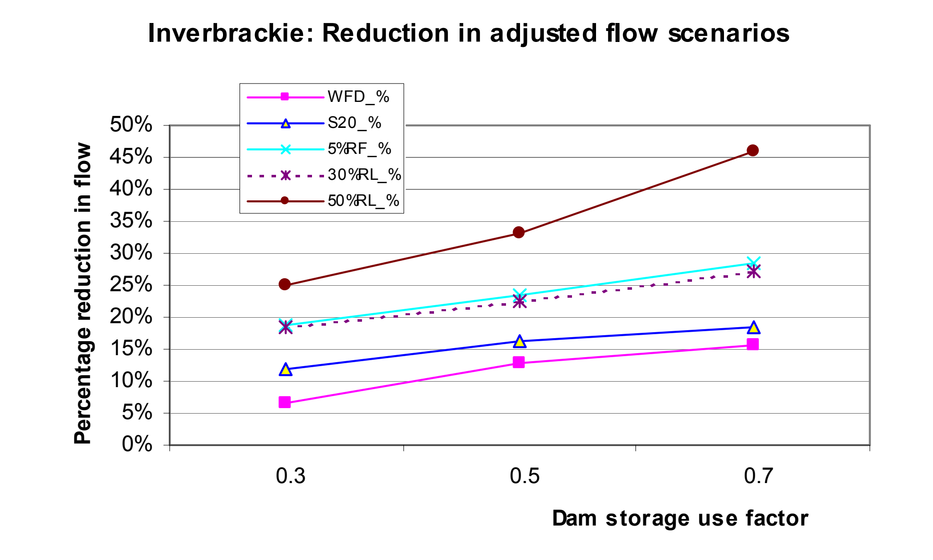
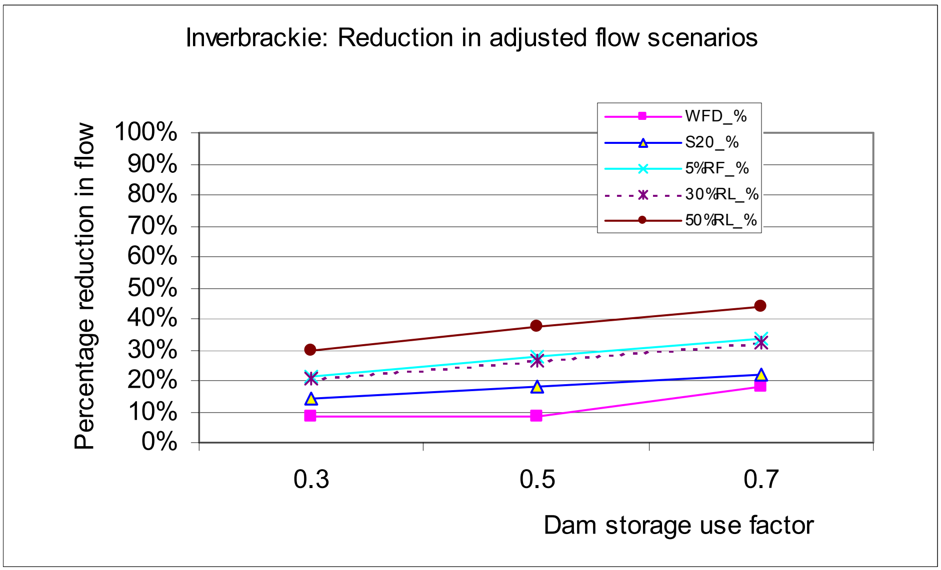


**Figure 53. Reduction in adjusted flows of Inverbrackie subcatchment modelled with future scenarios and varying dam storage**



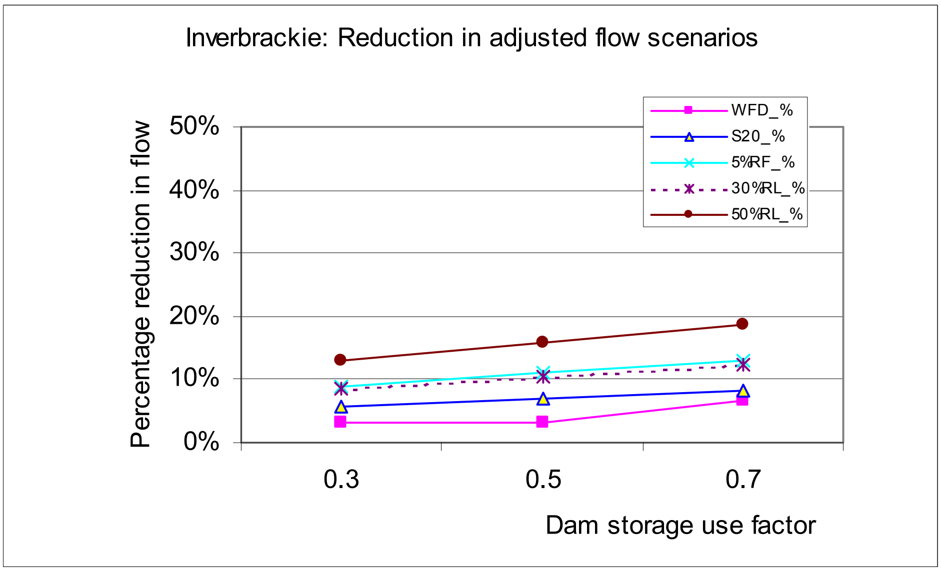
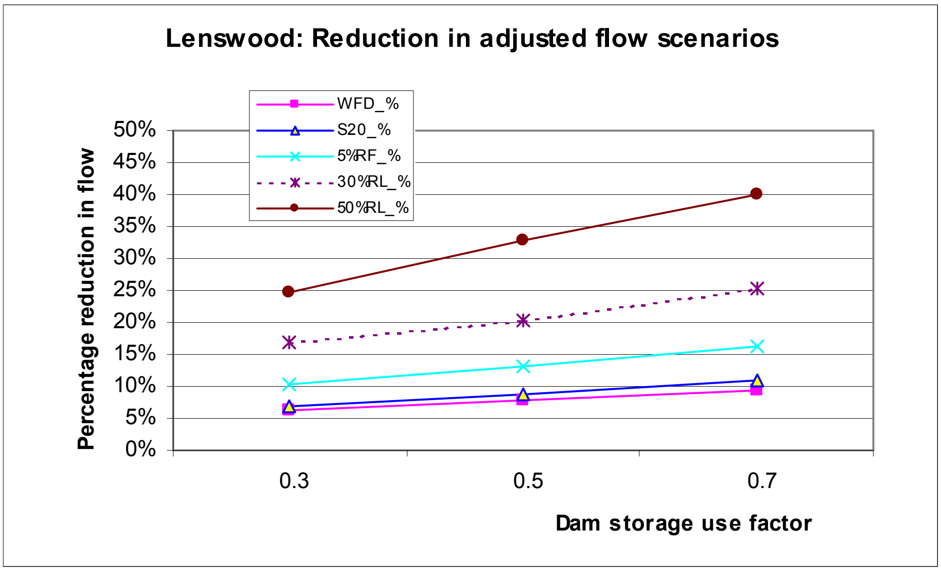
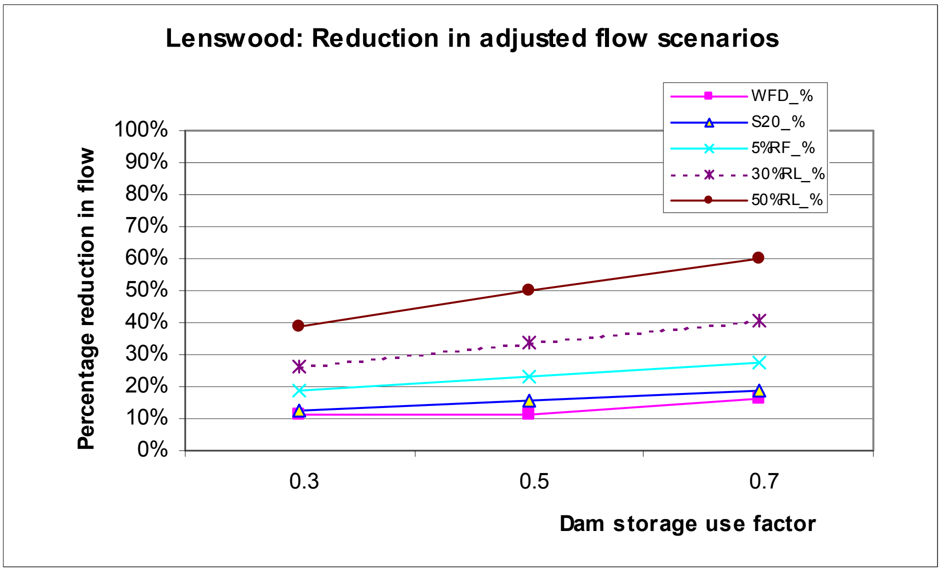



**Figure 54. Reduction in adjusted flows of Lenswood subcatchment modelled with future scenarios and varying dam storage**



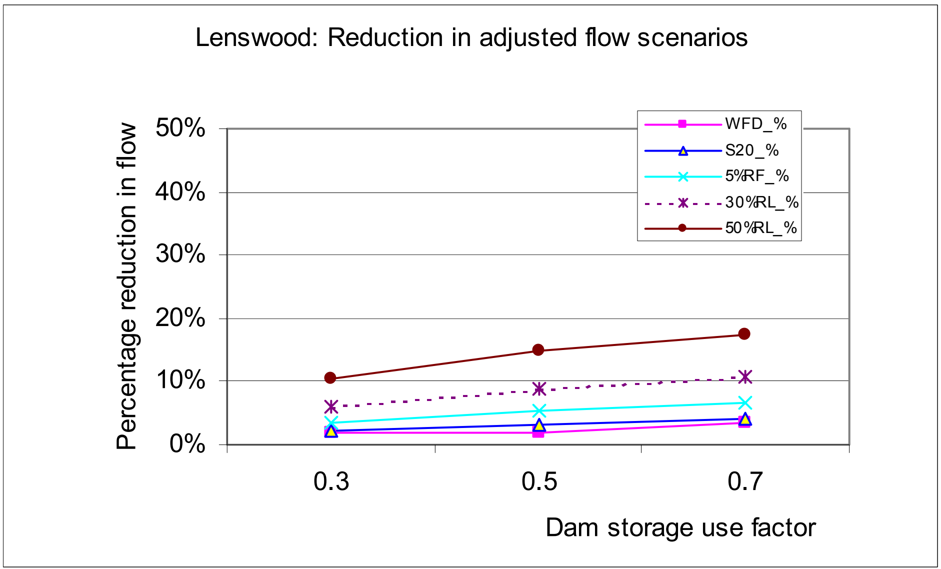
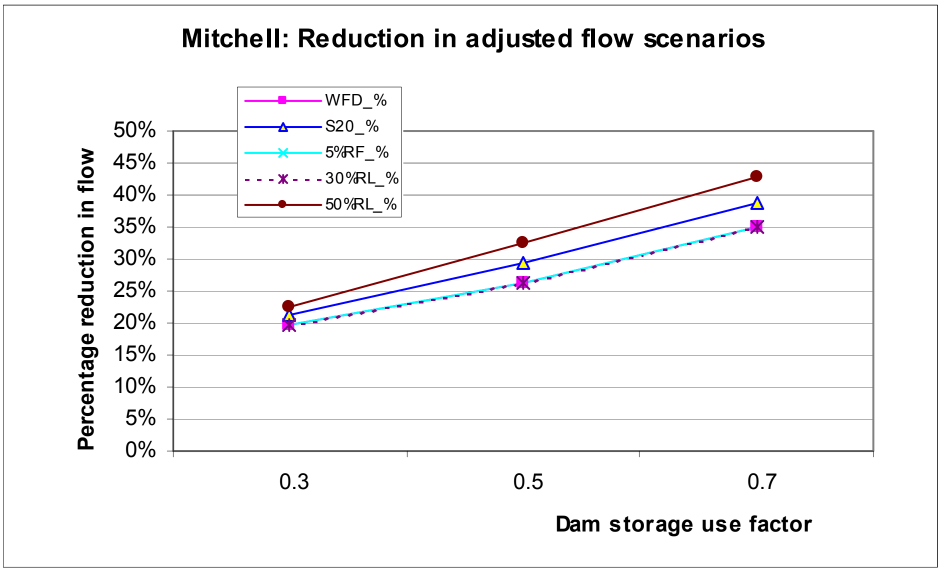
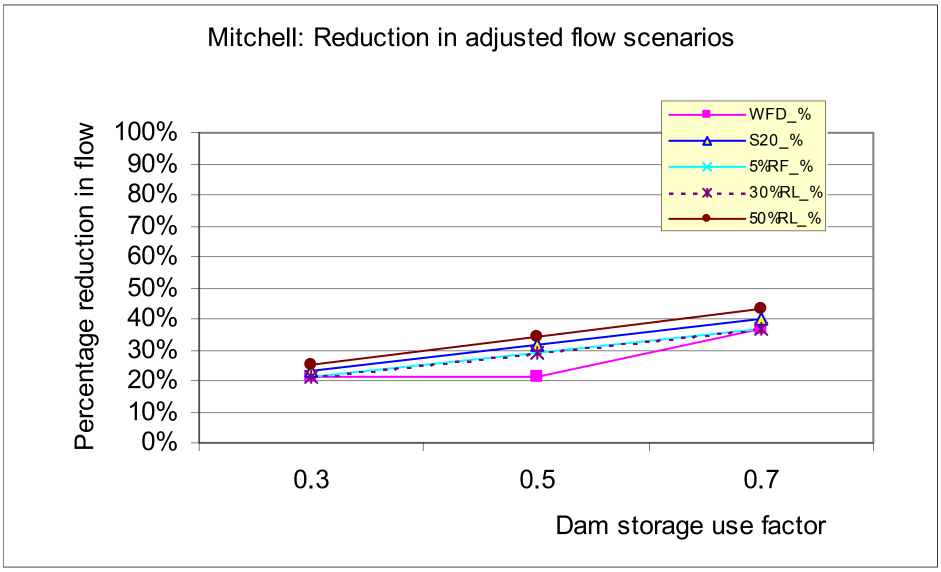



**Figure 55. Reduction in adjusted flows of Mitchell subcatchment modelled with future scenarios and varying dam storage**



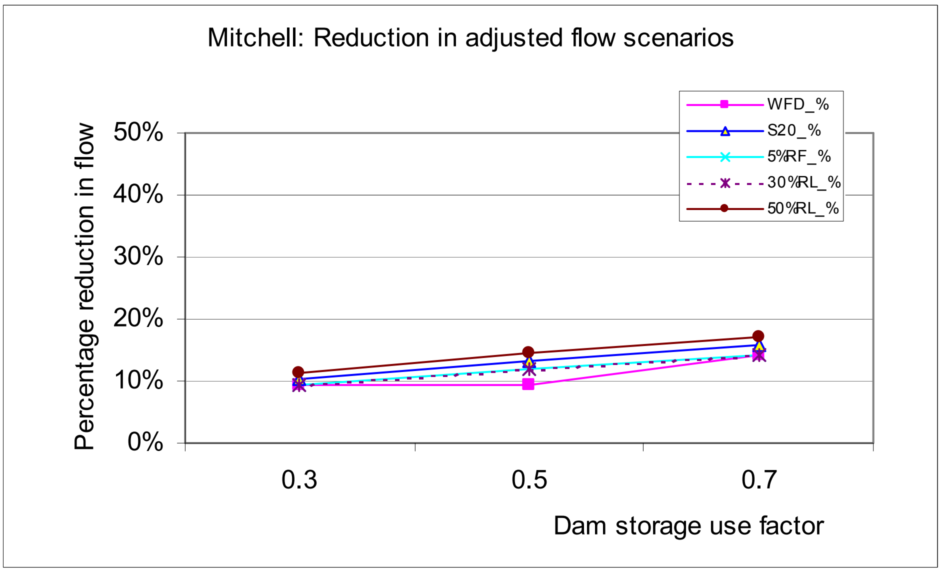
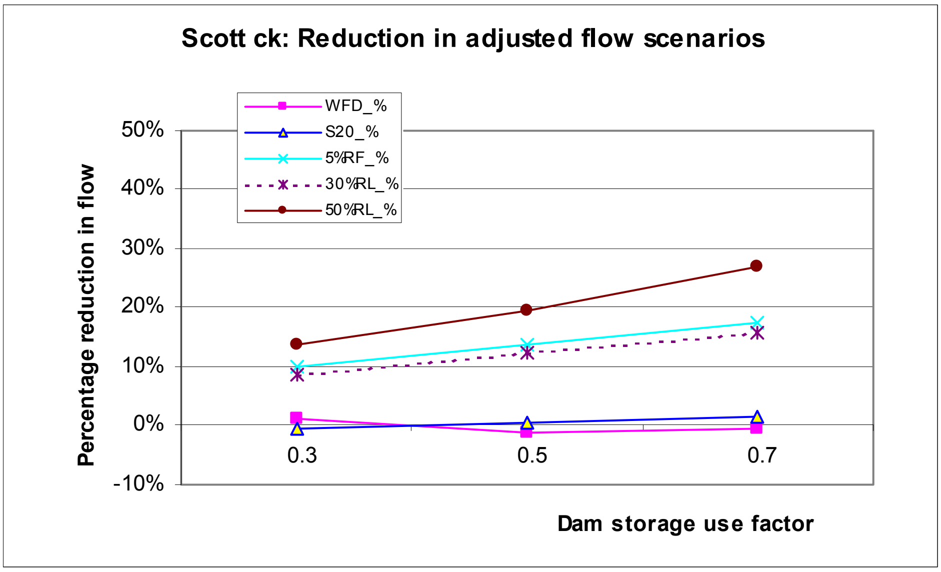
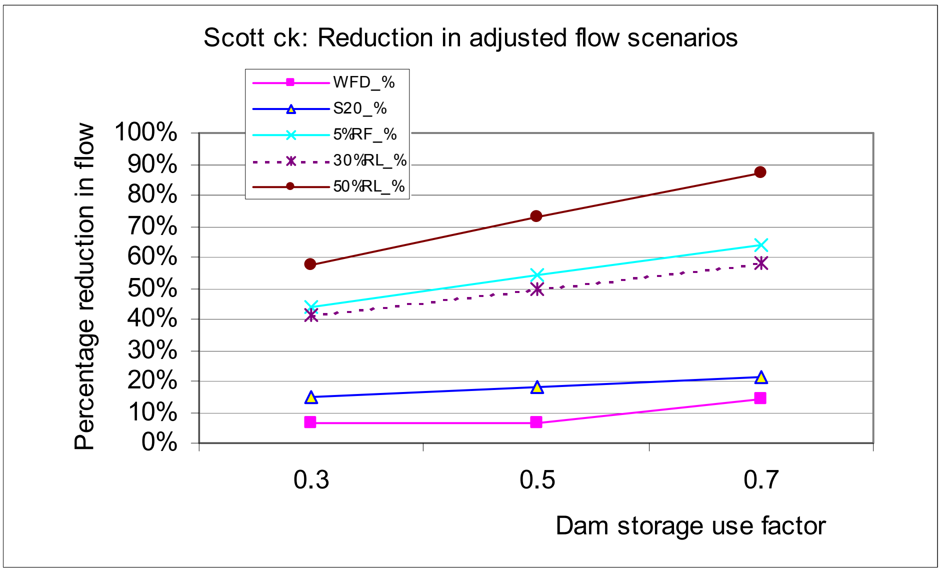



**Figure 56. Reduction in adjusted flows of Scott Creek subcatchment modelled with future scenarios and varying dam storage**



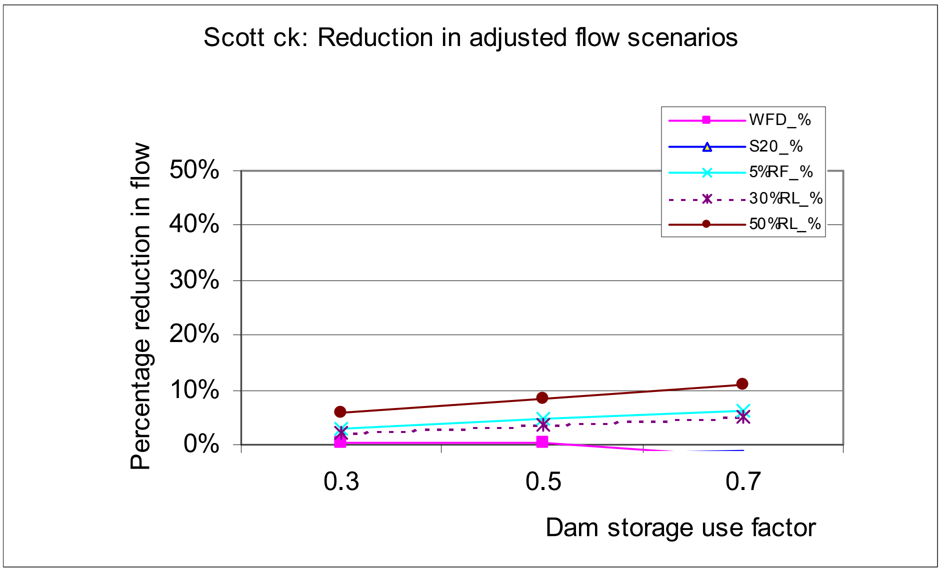



**Figure 57. Reduction in adjusted flows of Western Branch subcatchment modelled with future scenarios and varying dam storage**