DWLBC REPORT

Surface Water Assessment for the Southern Fleurieu Region

2009/05

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Surface Water Assessment for the Southern Fleurieu Region

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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

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Report DWLBC 2009/05

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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SUMMARY

This report is part of a broader water resources project across the Fleurieu Peninsula, also described in four other documents. These provide an overview of:

- the water dependent ecosystems,
- hydrogeology and
- urban water use, projected future urban water demand, and stormwater/wastewater reuse potential; and
- an overarching water plan for this report and above

of the Southern Fleurieu Peninsula.

This report describes the assessment of surface water resources across the Southern Fleurieu Peninsula.

In particular, it has:

- Assessed the available hydrological information available, including land use, rainfall, streamflow and evaporation
- Determined the most appropriate method was using Tanh curves to estimate annual runoff from annual rainfall. This was used to evaluate the surface water resources of all catchments across the Fleurieu, and the impact of farm dams upon these resources
- This method was used to provide estimates of surface water resources per catchment, and the effects of farm dams upon those resources.

Overall, none of the catchments exceed the guideline limit of diversion of 25% of adjusted annual runoff.

There are identified knowledge gaps in the data for these evaluations, which are acknowledged. However, this method represents the most suitable use of the available data to assess the resources of the region.

A number of conclusions and recommendations are made to guide any future management planning of surface water resources for the region.

1. INTRODUCTION

1.1 BACKGROUND

This assessment has been undertaken as part of five components of the “Water Resource and Environmental Water Requirements Assessment for the Fleurieu Peninsula” project, as listed below:

- **Surface Water Resources Assessment**

  A surface water assessment of the impact of farm dams at current development levels is to be conducted using a hydrological models, GIS techniques, and aerial photography.

- **Groundwater Resources Assessment**

  A review of groundwater level, salinity and drilling data to review the areas of good groundwater resource, the rate and location of recent drilling.

- **Environmental Water Requirements Assessment**

  This element of the project will determine the environmental water (surface and ground) requirements of the southern Fleurieu wetlands.

- **South Coast Urban Growth Water Budget**

  This component is an examination of urban growth on the South Coast, particularly in the areas of Victor Harbor.

- **Water Plan Development and Consultation**

  The information generated by the above 4 areas of inquiry are to be drawn together into a water plan for the Southern Fleurieu Peninsula”

The overall aim of the project is to increase the level of knowledge regarding the state of water resources in the Fleurieu Peninsula, as it relates to water resources, environmental water requirements and urban water demand. The fifth component is the strategic planning and consultation element that draws the results of the first four components together.

The project has been undertaken by the Department for Water, Land & Biodiversity Conservation (DWLBC) under a partnership with the Adelaide & Mount Lofty Ranges Natural Resource Management Board (AMLR NRMB) and the National Action Plan for Water Quality and Salinity (NAP) and is part of a broader Mount Lofty Ranges Water Resource Assessment Program.

The tasks to be undertaken in the Surface Water Resources Assessment component are taken from Table C2a of the Overall Project report, as below:

1 Undertake a surface water assessment of the impact of farm dams at current development levels is to be conducted using a hydrological models, GIS techniques, and aerial photography

2 Estimate catchment yield of a natural (pre-developed) system and at current development levels, accounting for the impact of farm dams.

3 Determine the number and estimated volume of farm dams constructed in the last 5 years using aerial photography to indicate areas of recent stress on surface water resources

The assessment builds on previous work as below:

4 The South Central Regional Network (SCRN) project (Kneebone *et al*, 1999) broadly investigated the state of the water resources with a view of highlighting resources that were already stressed and those resources that may be appropriate for further development, subject to site-specific investigation.

5 In 2000 Billington and Barnett undertook an overview of the state of resources on a broad regional basis and considered only average annual quantities of resource and usage.

The above results were summarised and reported for the regional assessment of water resources undertaken in 2000 by DWLBC under the National Land & Water Resources Assessment program in 2001.

A considerable amount of the initial work on this assessment was undertaken by Steven Kotz and was delayed for several months for human resource reasons. To finalise the report a more direct approach was taken as described below.

1.2 STUDY APPROACH

In undertaking the tasks listed above, this report describes the first major surface water resource assessment for the Fleurieu Peninsula. Because of the delay in its finalisation, the Tanh method, which was originally developed for extension of the gauged catchment results to the ungauged catchments, has also been applied to the gauged catchments.

This approach has allowed a greater inclusion of data on soils, slopes and land use, as described below. This will form the technical foundations of future water resource management in this and other regions in which GIS is used more extensively.

The report addresses:

1. The identification of surface water catchments within the study area and the collation of data on factors likely to influence the level of runoff from them, ie. rainfall, slope, soils, land use and farm dams.
2. An analysis of rainfall, evaporation and observed streamflow data for the Myponga, Hindmarsh, Yankalilla and Inman Rivers and Deep Creek. The Tanh method has been used to extend the shorter runoff records and to form the basis for an investigation of the likely influence of the catchment factors on the level of runoff within these catchments.
3. An assessment of the numbers and volumes of farm dams within individual sub-catchments The development of a relationship between annual runoff, farm dam density and the reduction in runoff due to the dams, using results from all previous applications of the WaterCress model in Mt Lofty ranges gauged catchments.
4. The use of the relation found for farm dams with an estimate of the historical rate of development of farm dams and the Tanh method to produce a 100 year record of the

estimated natural flows (ie flows without the influence of farm dams) for the gauged catchments. The Tanh method results in the identification of a Tanh F factor which indicates the long-term efficiency of the gauged catchments in producing runoff from rainfall.

5. The extension of the estimated long-term average annual F values for the gauged catchments to the ungauged catchments, in which the ungauged catchments are grouped according to their assumed similarity of soils and landscapes to the gauged catchments. The F values assigned are then modified according to departures in land use and slopes of the ungauged catchments to those of the gauged catchments.

6. Finally the farm dams relation is re-applied to all estimates of the long term natural flow for all catchments to estimate the reduced present day long term average flow due to the influence of the present day level of dam development.

This method is a departure from the usual approach in which the WaterCress model has been calibrated to the gauged catchments and then applied unchanged to all similar surrounding ungauged catchments. Since the Tanh method only involves two parameters for calibration, as distinct to the 12 parameters for the WaterCress model, it offers a more direct method for investigating and incorporating the effects of differing catchment characteristics into the runoff assessments.

With experience gained using the Tanh method, it may then be possible to start to combine the power of the GIS in identifying and processing spatial data with that of the WaterCress model, which provides a detailed simulation of temporal processes, but more appropriate to any specific local area.

2. REGIONAL AND CATCHMENT DESCRIPTION

2.1 THE FLEURIEU PENINSULA REGION – AN OVERVIEW

The area covered by this assessment is that part of the Fleurieu Peninsula which is now included within the Adelaide and Mount Lofty Ranges Natural Resource Management Board's boundaries, but was not covered by previous Catchment Water Management Boards boundaries. It includes an area of approximately 1200 sq km lying to the South of the previous Onkaparinga Catchment Water Management Board area and west of the previous River Murray Onkaparinga Catchment Water Management Board area. It is referred to as the Fleurieu Local Area Group (or Area D) within the NRM Board's area.

The Fleurieu Peninsula is located in the Southern Mount Lofty Ranges, approximately 60 kilometres south of Adelaide. Figure 1 shows this area and the boundary taken for this assessment. The region has been broadly defined by the catchments that fall within the triangle extending from Myponga township down to Cape Jervis and across to Victor Harbor.

The area encompasses several larger catchments, of which the Inman River is the largest at 192 sq kms and numerous smaller coastal catchments and headland areas. A total of 55 catchments have been identified for this assessment.

The unique combinations of geology, topography and climate have supported a diverse range of agricultural industries and a unique environment. The remnant Southern Fleurieu wetlands are an important part of this and have come to support a range of flora and fauna species.

The average rainfall ranges from about 500 mm/a along the narrow areas of coast near Victor Harbor, Cape Jervis and Carrickalinga to over 900 mm/a in the two highest elevation areas centred on Mt Compass in the north and Parawa in the south.

The region generally obtains its rural water supplies from farm dams or groundwater bores. Urban supplies are predominantly via mains supply sourced from the Myponga Reservoir.

It is estimated that there are more than 5800 farm dams in the Fleurieu region with a combined storage of 9800 ML. The average farm dam density of 8.2 ML per sq.km. is much lower than for most of the other catchments of the Mount Lofty Ranges. By comparison the nearby Angas River and Currency Creek catchments both have an average farm dam density of more than 32 ML per sq.km.

Figure 1: Location of the Fleurieu Peninsula Region

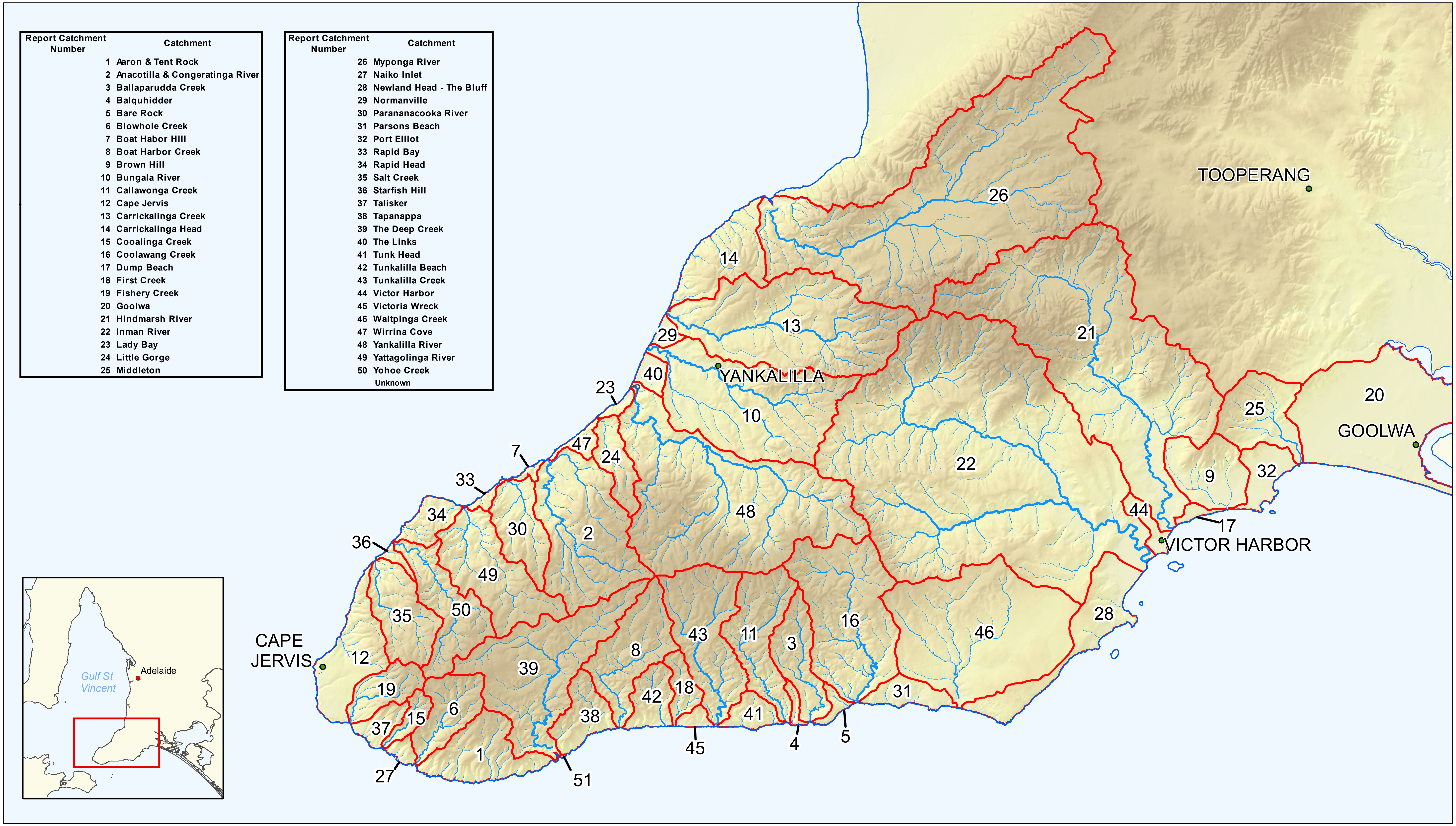

Figure 1 - Location of Southern Fleurieu subcatchmments

Town
Stream
Southern Fleurieu Catchment

N

0 5 10 15 20 km

Produced By: Water Information Group
Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

Datum: Geocentric Datum of Australia 1994 (GDA 94).

Date: 8 February 2006

Government of South Australia
Department of Water, Land and Biodiversity Conservation

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2.2 TOPOGRAPHY

The Peninsula comprises the southern extension of the main spine of the block faulted Mt. Lofty Ranges. The Peninsula is devoid of any coastal plains on either its northern or southern coastlines except for a small area between Victor harbour and Goolwa. The central spine consists of two areas of uplands over 300m elevation, which are separated by a lower area forming the upper reaches of the Inman valley. The highest elevation of 430m is located in the northern upland area in the vicinity of Spring Mount near Myponga. This area forms the headwaters of the Myponga, Hindmarsh and Inman River catchments, which are the three largest catchments on the Peninsula.

The narrower southern upland area ends at Cape Jervis and is traversed by Range Road, which runs along the central ridge at an elevation of 370m-320m and provides spectacular views over the coast to the north and south.

The average slopes of the major catchments have been calculated using a GIS. Figure 2 shows the relative flatness of the Goolwa catchment, with an average of just 1.6 degrees, in comparison to 18 degrees for the Cooalinga River catchment located near the tip of the Peninsula. Other smaller creeks draining to the south coast from Range Road have similar high slopes.

The slopes for all 55 catchments are listed in Appendix A.

Figure 2 Average slopes of major catchments in Southern Fleurieu

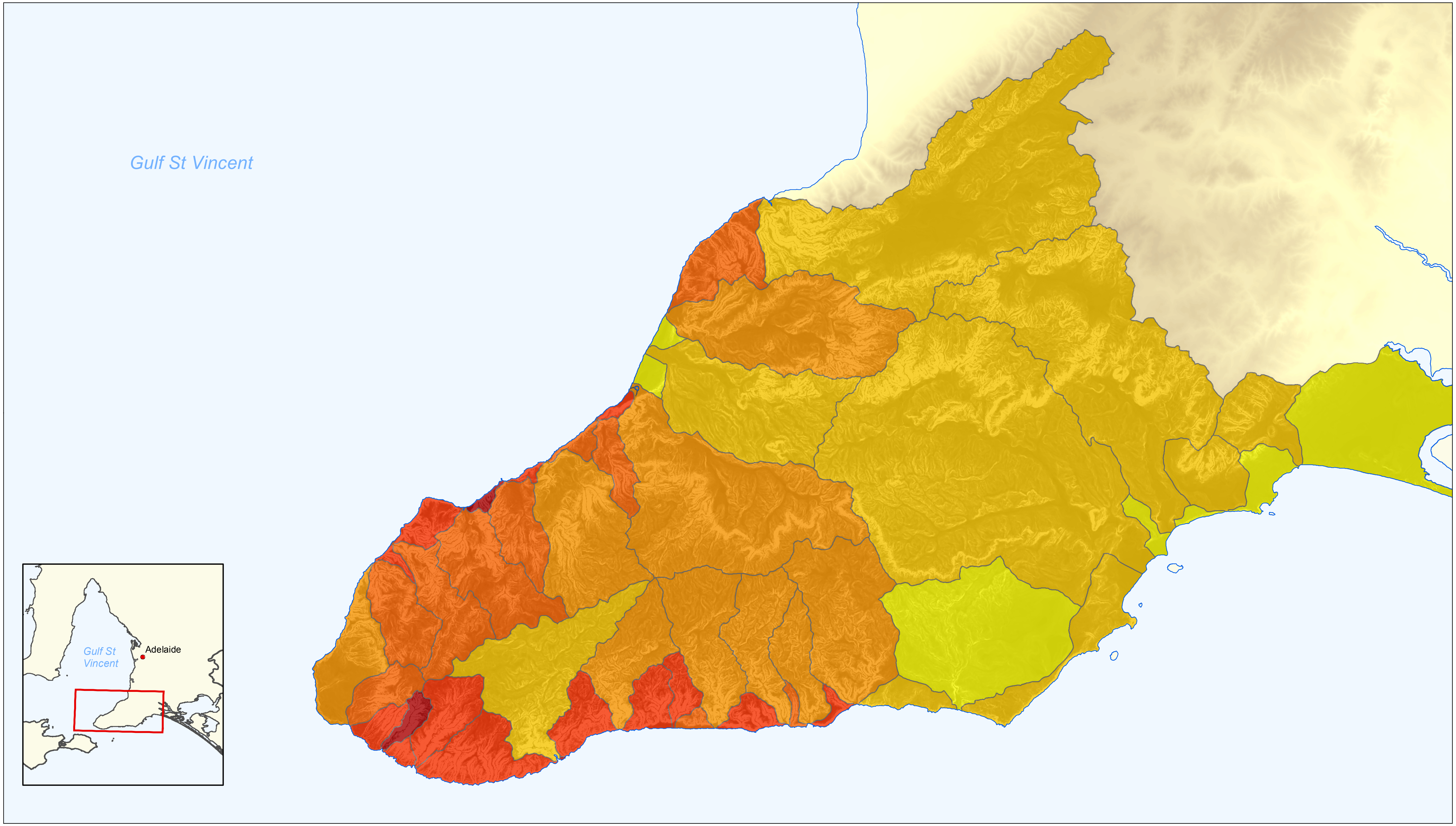

Figure 2 - Average slopes of Southern Fleurieu subcatchments

Mean Catchment Slope

- 1.4 - 4.64
- 4.65 - 7.5
- 7.51 - 9.55
- 9.56 - 12.35
- 12.36 - 17.13
- 17.14 - 24.88

N

0 5 10 15 20 km

Produced By: Water Information Group
Knowledge and Information Division
Department of Water, Land and
Biodiversity Conservation

Datum: Geocentric Datum of Australia 1994 (GDA 94).

Date: 8 February 2006

Government of South Australia
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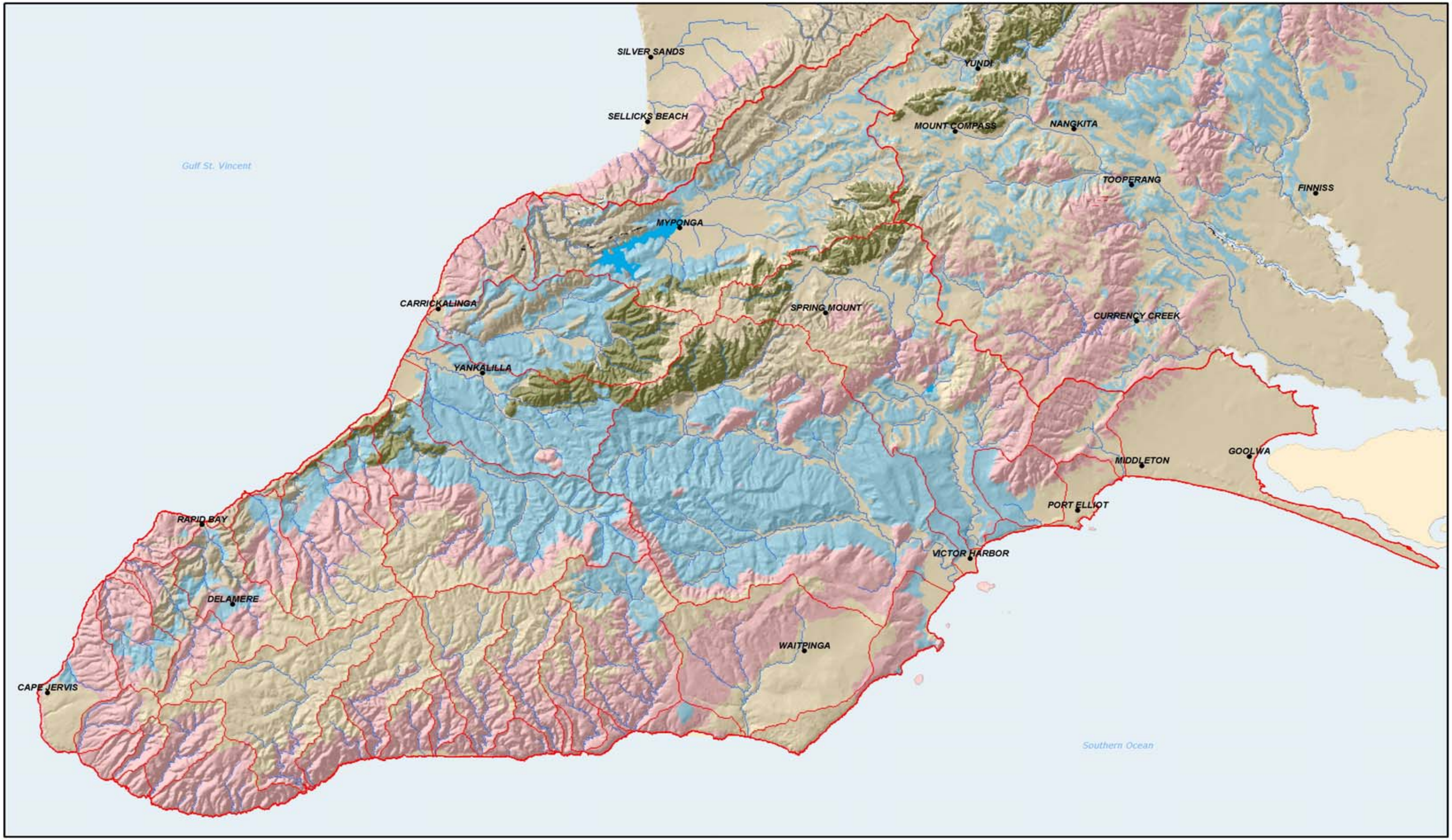
2.3 GEOLOGY AND SOILS

The geology and hydrogeology of the region are described in DWLBC report 2006/24 “Southern Fleurieu Groundwater Assessment”. A map is provided at Figure 3 that shows the central spine in the northern part of the peninsula formed by the Barossa Complex, flanked by rocks of the Kanmantoo Group which dominate along the central spine in the southern part of the peninsula.

The lower elevation, and central parts of the peninsula are formed by Permian sands. On the northern side of the Barossa Complex these outcrop through the Myonga and Carickalinga catchments and on its southern side through the central belt of the Bungala, Yankalilla, Inman, Lower Hindmarsh and south coastal catchments, extending just into the Brown Hill catchment north of Victor Harbor. These are glacial deposits consisting of sands, gravels and clays derived from the older eroded basement rocks.

The soils of the area have been mapped in association with landscape units. The database associated with this survey contains estimates of characteristics that are likely to influence the rainfall to runoff process, but analyses have not yet commenced on this. Other than in the areas influenced by the Permian sands, the higher elevation areas have shallower soils formed by weathering of the basement rocks. Lower elevations have deeper soils. The influence of soils on runoff is discussed again in greater detail when the runoff characteristics of the gauged catchments are described and compared in Figure 3.

Figure 3 Geology map of Southern Fleurieu



Geology of the Southern Fleurieu Peninsula

- Locality
- Stream
- Catchment
- Reservoir
- Permian Sands
- Kanmantoo Group
- Barossa Complex
- Adelaide Geosyncline
- Quaternary, Tertiary
- am; qz

N

0 5 10 20 km

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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Projection: MGA 54
Datum: Geocentric Datum of Australia 1994
Date: March 2005

2.4 LAND USE

Land use data for the Fleurieu Peninsula was obtained from 1999 Land use spatial dataset as Figure 4. Minor land uses, each occupying less than 0.5% of the total area, are omitted.

Table 1: Land use of the Fleurieu Penisula

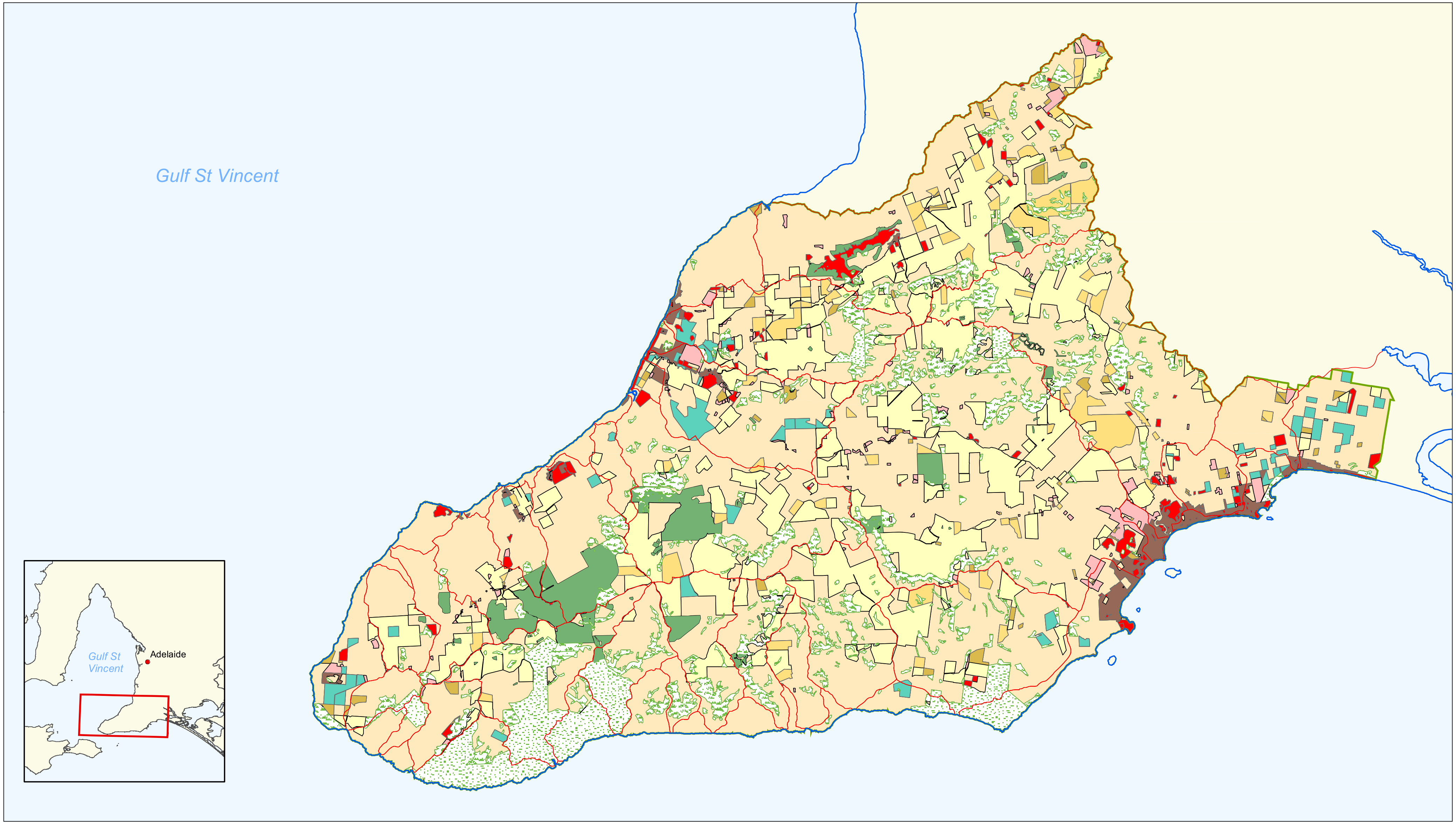
Land Use Type	Count	Total ha	
Livestock	189	67,446	56.5%
Dairy cattle	161	22,151	18.6%
Protected area nec	418	8,554	7.2%
Protected area	8	5,458	4.6%
Forest plantation	70	3,952	3.3%
Improved pasture nec	79	3,870	3.2%
Field crops	58	2,070	1.7%
Accommodation	38	1,661	1.4%
Rural accommodation	182	1,540	1.3%
Horses	85	942	0.8%
Other			1.6%

Protected Areas are comprised mainly of conservation parks and areas of natural vegetation.

The extent of each of these land uses within each of the 55 sub-catchments was identified using a GIS. The influence of land uses on surface water runoff are poorly quantified, but it is generally accepted that, other things being equal, runoff depth is inversely related to vegetation density. Land use may therefore be a large influence on runoff in small catchments where urbanisation, forestry or native vegetation may form a large part of the total catchment area.

Appendix B1 shows the full list of land use classifications, as above, but also reclassified subjectively into only 5 more generalised land uses which are known to be related to hydrological processes. The new classifications were labelled as Urban, Grassland, Crops, Natural Vegetation, and Forest Plantation. These are ordered in increasing vegetation density and thus decreasing potential runoff. The totals and percentage of these 5 land use reclassifications within each of the 55 catchments have been calculated and are given in the Appendix B2.

Figure 4 Land use information (1999 date) in Southern Fleurieu



Catchment Boundary

Land Use (1999 data)

ACCOMMODATION
OTHER
DAIRY CATTLE
FIELD CROPS
FOREST PLANTATION
HORSES
IMPROVED PASTURE NEC
LIVESTOCK
PROTECTED AREA
PROTECTED AREA NEC
RURAL ACCOMMODATION

Figure 4 - Land use information for Southern Fleurieu catchment

N

0 5 10 15 20 km

Produced By: Water Information Group
Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

Datum: Geocentric Datum of Australia 1994 (GDA 94).

Date: 8 February 2006

Government of South Australia
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2.5 SALINITY

A 2002 review of the impacts of salinity on the Fleurieu Peninsula (Liddicoat and Herrmann) found that less than 0.5% of the region (~500ha) was affected by high salinity levels. Except for approximately 1 Ha of natural saline conditions in Waitpinga catchment, all impacts are believed to be the direct result of land management practices. Liddicoat and Herrmann also suggest that riparian zones and baseflows are more impacted than are broadscale agricultural land due to the influence of the geology on the location and rates of recharge and discharge. Diversion of the fresher component of surface flows via farm dams is likely to exacerbate this situation. However, it seems that the relatively high rainfall and topography have protected the Fleurieu region from exhibiting a higher degree of salinisation.

3. SURFACE WATER RESOURCES DEVELOPMENT

Reservoirs and farm dams have played an important role in the development of the area, as below.

3.1 MYPONGA RESERVOIR

Construction of the Myponga Reservoir was completed in 1962 (E&WS Department, 1992) The reservoir was originally intended to supply areas immediately north and south of the reservoir (ie Willunga, McLaren Vale, McLaren Flat and Yankalilla, Normanville, and Myponga) with any excess transferred via a trunk main to Happy Valley Reservoir for supply to Adelaide. However, in response to urban expansion in the Victor Harbor area, the Southern Coast Water Supply Scheme was completed in 1977. This connected the Myponga reservoir supply to the Hindmarsh reservoir via a pump station and 22.5km of pipeline.

The Myponga Water Filtration plant (WFP) was opened in November 1993 (E&WS Department, 1993) with a capacity of 50ML/day. The capacity of the treatment plant is the biggest constraining factor to water use from the reservoir, consequently this reservoir spills a greater proportion of its inflow than any other South Australian reservoir.

3.2 HINDMARSH RESERVOIR METHODOLOGY

Hindmarsh Reservoir is formed by a small offstream dam, first completed in 1918 and later enlarged to 475ML. Originally it supplied a small population in Victor Harbor, but in response to demand for increased quantities and quality of supplies, the connection to the Myponga system was made.

The Hindmarsh Reservoir is now removed from the water supply system and is used to hold seasonal excess recycled water from the Victor Harbor Waste Water Treatment Plant (WWTP) for supply to local irrigation.

In 1989, the E&WS (now SA Water) commissioned a study into the prospect of a new reservoir on the Hindmarsh River at the site of the present gauging station. The supply from this site was estimated at about 4900 ML/year. The option was abandoned due to the estimated low quality of the inflows.

3.3 FARM DAMS

The development of farm dams has been driven by the intensification of agriculture and the division of land holdings into smaller blocks, including for rural living.

Farm dams are generally constructed to capture the surface water runoff from their upstream catchment. However anecdotal evidence (and occasional landholder admission) suggests that a significant number of farm dams have been constructed at the site of natural groundwater springs. These often coincide with the locations of swamps and wetlands.

3.3.1 POTENTIAL IMPACTS OF FARM DAMS

Farm dams can be vital to the successful operation of rural industries. However, large dams (generally >5ML capacity and used for irrigation) have a significant impact as, until the farm dam is full and overflowing, they reduce downstream flows over long periods and by large amounts. Onstream farm dams, typically located on the main channel of a watercourse, impact far more on the hydrology and ecology of their catchments, than offstream dams. The impact is greatest on the late Autumn and early Spring flows, thus shortening the winter flow period in the downstream reaches.

Most small farm dam are used for stock watering and are likely to be full most of the time and frequently overflowing. However, they lose significant volumes to evaporation in summer and the cumulative impact, when numbers are large, can also lead to significant impacts.

Dams reduce low flows to the greatest extent in dry years. This has a large impact on the migration of native fish and macro-invertebrates by significantly reducing their ability to escape adverse conditions and find new refuges (Greenwood, 2000).

Dams inevitably fill with accumulated sediments and contaminants. Thus old dams, or poorly constructed dams can pose a significant risk to stock, domestic users and the environment, particularly if they collapse during floods. The collapse of one upstream dam can lead to the collapse of sequential downstream dams and a severe unexpected flood situation.

3.3.2 NUMBERS, STORAGE CAPACITIES AND RATE OF GROWTH OF FARM DAMS

The flow recorded by the 5 gauging stations within the Peninsula has been during a period of significant growth in farm dams. In order to correct the flows so that they represent the natural flow that would have taken place had not the dams been established, the rate of establishment of the dams within each of the catchments upstream of the gauging stations must be identified and an allowance made for the changing number of dams.

The numbers and surface areas of farm dams presently established have been obtained from aerial surveys carried out in 2005. The volumes of the dams have been estimated from the surface areas as described in the Section below. The data on numbers, volumes and farm density (ie volume per unit area of catchment, ML/sq.km) are listed in Appendix C.

Figure 5 shows the spatial distribution of year 2005 farm dams data located across the peninsula.

Figure 5 Spatial distrubtion of farm dam data (2005)

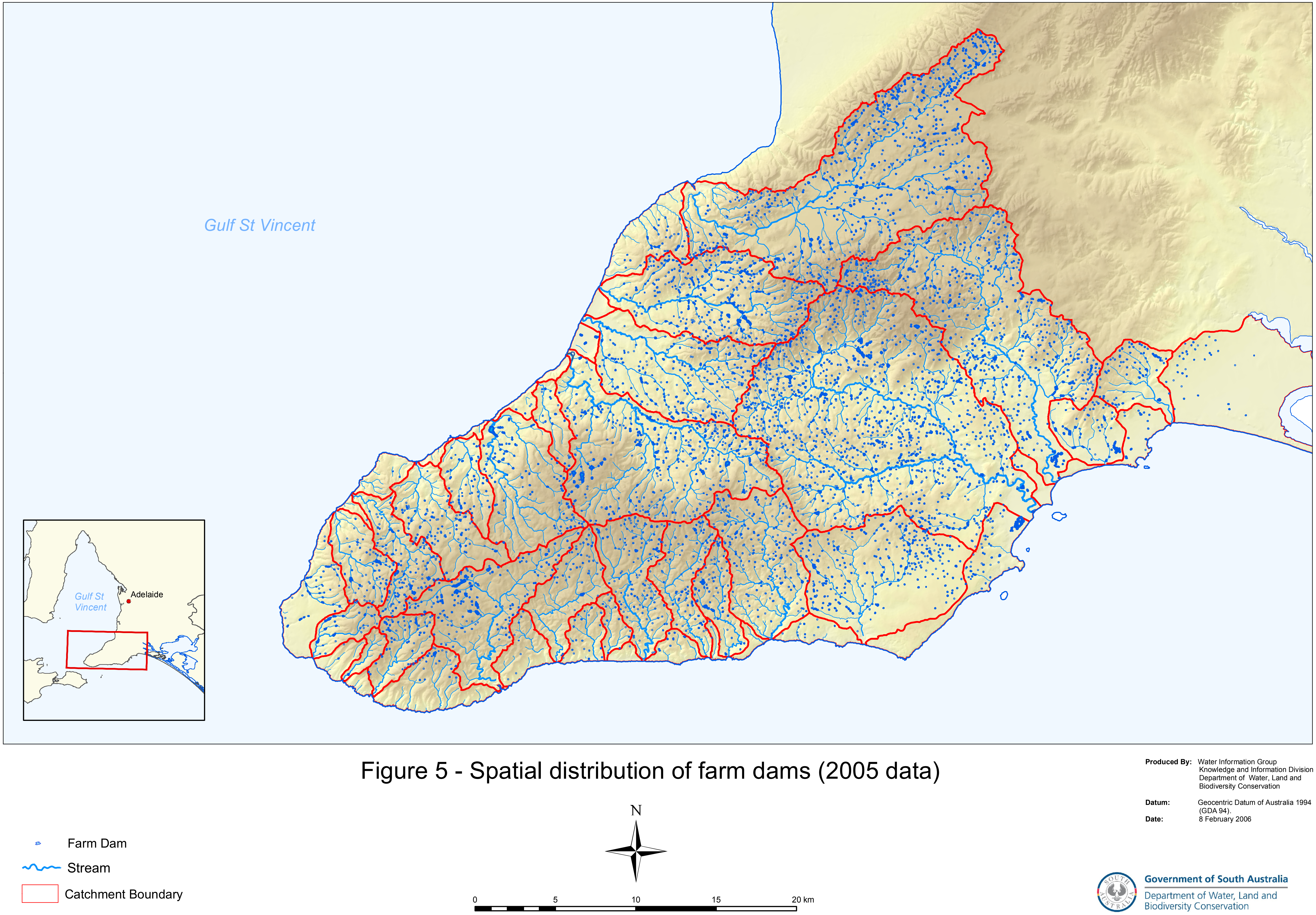

Figure 5 - Spatial distribution of farm dams (2005 data)

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Knowledge and Information Division
Department of Water, Land and
Biodiversity Conservation

Datum: Geocentric Datum of Australia 1994
(GDA 94).

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Data on the past numbers and sizes of farm dams are very sparse and are also uncertain in their collection methods and definitions. Thus estimates for the years before 2001 have to be based on indirect estimation. It is known that most of the native vegetation clearance took place early on, but most farm dam development is known to have occurred after World War 2. Most estimations of vegetation clearance and farm dam construction come from aerial photography digitised from several capture events covering the period from 1949 to 2005. The early photography was black and white and this makes it difficult to identify some smaller dams and assess their surface areas.

It is reported that the areas around Myponga, Hindmarsh, Inman and Yankalilla were seen as more productive land and were cleared earlier and to a greater extent than other areas (Lush, 1973).

Since data is sparse, the rates of establishment given in previous reports for other catchments and regions have all been collated and plotted in Figure 6. A wide scatter is apparent. Since, in this case, correction of the flow records is only required back to 1970, an approximate relation through the scatter has been assumed, as given below:

$$Dam\ volume\ in\ year\ Y = Dam\ volume\ in\ year\ 2005 \times \left(\frac{10.5 \times \{Y - 1962\}^{0.6}}{100} \right)$$

This relationship places the highest growth rate in the early 1970's. (Note this formula is based on poor data and should definitely not be applied for years before 1970).

Since the dam volumes have been estimated for year 2005, the application of the above formula allows an estimate to be made for the volumes in each year from 1970 to that date. In Section 3.3.3 the method is described whereby the gauged flows in each year are increased to account for the volume of dams estimated to be in the upstream catchment at that time.

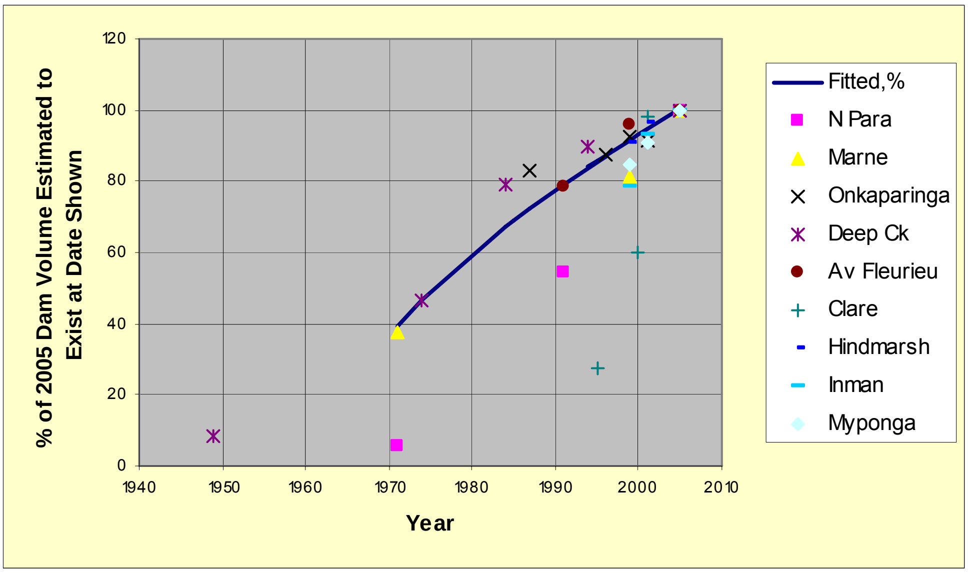


Figure 6: Rate of dam development from 1970 - 2005

3.3.3 RELATIONSHIP BETWEEN DAM SURFACE AREA AND VOLUME

Farm dam surveys based on aerial photography only reveal the top surface area of the dams. The present means for estimating the dam volumes involve a process in which a) rectified and scaled photographs are digitised and the surface areas of the dams are estimated, then b) a formula relating surface area to volume, based on averages obtained from field survey sampling of selected dams, is then applied to the surface areas. The process is highly suited to the application of a GIS (McMurray, 2006).

McMurray found that for farm dams with surface areas <15,000m^2

$$Dam\ capacity\ (ML) = 0.0002 \times (Surface\ area\ sq.m)^{1.25}$$

For those farm dams with a surface area ≥ 15,000m^2

$$Dam\ capacity\ (ML) = 0.0022 \times (Surface\ area\ sq.m)$$

Based on the 2005 photography, it is estimated that there were 5839 farm dams in the study area totalling more than 9784 ML in volume.

3.3.4 PROPORTION OF FARM DAMS ONSTREAM AND OFFSTREAM

For the purposes of this analysis an onstream farm dam has been defined as one that interrupts a defined watercourse displayed on a 1:50,000 topographic map. By default an off stream dam is one that does not intersect a watercourse. This definition still allows an offstream dam to have a significant hydrological impact. Other management areas of the state, such as the Clare Valley Prescribed Water Resources Area, have defined an offstream farm dam as one that does not receive more than 5% of its total volume of inflow from the catchment upstream of the dam.

3.3.4.1 The Table below provides statistical data on the position of the on-stream dams within the catchments.

Table 2: Proportion of farm dams located onstream

Strahler stream order	Number	Total Volume	Average Volume	% of onstream	% of total	% of onstream	% of total
	nos	ML	ML	nos	nos	ML	ML
1st Order	1397	4242	3	67.52%	24.02%	46.45%	45.13%
2nd Order	503	2926	5.8	24.31%	8.65%	32.04%	31.13%
3rd Order	142	1460	10.3	6.86%	2.44%	15.99%	15.53%
4th Order	19	242.1	12.7	0.92%	0.33%	2.65%	2.58%
5th Order	7	259.8	37.1	0.34%	0.12%	2.84%	2.76%
6th Order	1	3	3	0.05%	0.02%	0.03%	0.03%
Total Number of dams on stream	2069	9132	4.4		35.57%		97.15%
Total Number of dams off stream	3770	652	0.2		64.43%		2.85%
Total Number of Farm Dams	5839	9784	1.6				

3.3.5 FARM DAMS IN PROXIMITY TO WETLANDS

GIS analyses have been undertaken to identify the distance of farm dams from known wetlands. The esults are given in the Table below. It can be seen that 974 farm dams, having a total capacity of 1700 ML, are located within 100m of a known wetland on the Fleurieu Peninsula.

Table 3: Number, volume and proximity of farm dams to Fleurieu Peninsula wetlands

Distance from wetland	Total number	Total Volume
0	343	574
10	394	594.1
25	552	756.9
50	750	1065.4
100	974	1746.3
200	1351	2380.7
300	1659	3122.8
500	2222	3892.7

3.3.6 GENERALISED FORMULAE FOR PREDICTING FLOW REDUCTION DUE TO FARM DAMS

The WaterCress model has been previously widely used to estimate the reduction in annual and long term flow due to the presence of farm dams within many catchments in South Australia, mainly in the Onkaparinga and Torrens catchments. The reductions calculated by the model are affected by assumptions on the seasonal pattern and rates of diversion of water from the dams to supply, the assumed evaporation rates, the assumed relation between dam volume and surface area (which affects the evaporation losses), and the differences in flow characteristics, particularly the seasonal distribution of flow and the distribution between high and low flows.

Despite these many causes for differences, the results have shown that the reductions in flow are
i) relatively stable for catchments having similar farm dam densities,
ii) inversely related to the flow (ie the proportional reduction in flow is greater in low flow years than in high flow years), and
iii) approximately proportional to the farm dam density in the upstream catchment.

The results calculated from previous WaterCress modelling were collated for about 40 catchments and sub-catchments within the Onkaparinga and Torrens Rivers. In all cases two sets of flow estimates had been made, the first set was without the dams in place and the second set was with the dams in place. The flow results with the dams removed is deemed to be the ‘natural’ flow for the catchment (ie. the catchment with its present land use situation, but without the farm dams). The reduction in flow is then defined as the difference between the flows calculated for the ‘without’ and ‘with’ dams scenarios, divided by the ‘without’ flow.

Two formulae were fitted to the data. Both were of the form:

Proportional Reduction in Flow = $PRF = \left(A \times FDD^{-B}\right)^{-\left\{C \times Flow^{D}\right\}}$.

Where FDD is the farm dam density expressed as mm (or ML/km2, where ML is the total volume of the dams and km2 is the area of the catchment) and A, B, C and D are constants to be fitted to the data. This formula will give a reduction in flow of 1.0 for zero flow and a zero reduction in flow for a zero FDD. For all values of FDD the reduction decreases exponentially from 1.0 as the flow increases. Figure 7 below shows the form of the graphs relating the flow reduction, the FDD value and the catchment flow.

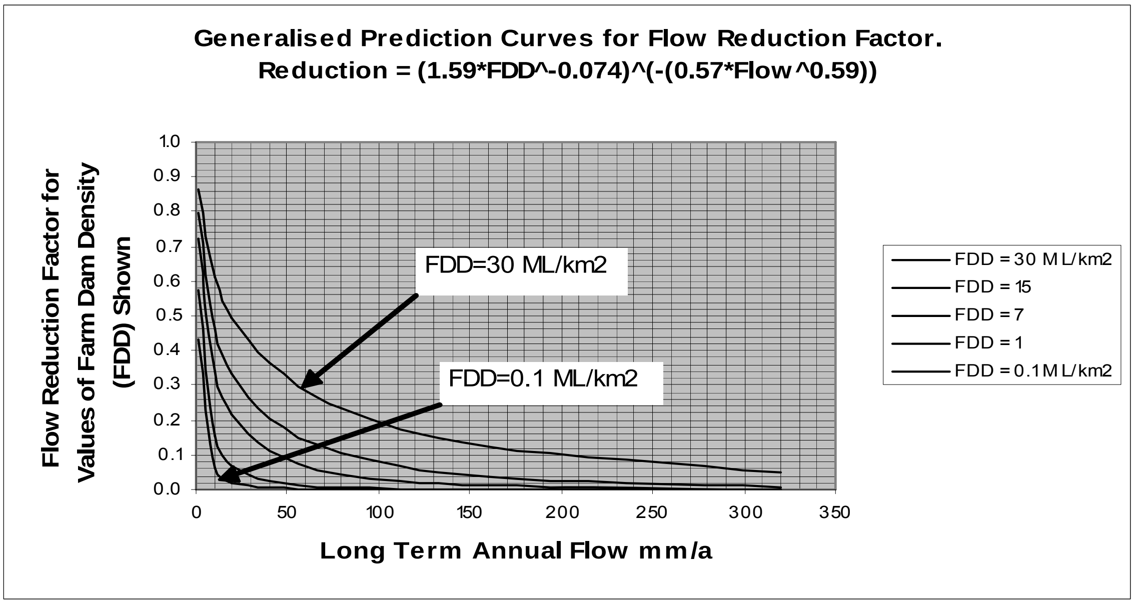


Figure 7: General form of relations between reduction in flow and farm dam density (FDD) for individual flow years or average long term flow.

This form of expression has been fitted to two data sets for each of the 40 catchments with their different values of estimated FDD. The first set included the flow and calculated flow reduction for each year of WaterCress modelling (up to 100 years for each location). The second set comprised only the 50 sets of long term average values of the catchment annual flows and flow reductions.

The first set of relations was used to increase the flows measured by the gauging stations for each separate year, taking into account the changing value of FDD for each year as calculated using the expression described in Section 3.3.2.

The second set of relations was used at the end of the calculations to decrease the long term annual flow that was calculated for each of the ungauged catchments in relation to the FDD value estimated for its catchment area.

It should be noted that the expressions are based on the assumption made in the WaterCress modelling that the rate of supply taken from the dams was equal to 30% of the maximum of the dam's capacities. This is the assumption made for smaller farm dams mainly such as exist in the Fleurieu region. While the WaterCress calculations were also made for a rate of supply of 70% of the dam capacities, reductions based on this higher figure were not used in this study.

For individual years: $PRF = \left(1.53 \times FDD^{-0.01}\right)^{-\left\{1.21 \times Flow^{0.522}\right\}}$

For long term average: $PRF = \left(1.6 \times FDD^{-0.074}\right)^{-\left\{0.57 \times Flow^{0.59}\right\}}$

These relationships have been used to derive estimates of existing (with flows) and natural flows (without farm dams) for the gauged and ungauged catchments, as described in later sections.

4. HYDROLOGICAL DATA

4.1 RAINFALL

4.1.1 SPATIAL AND TEMPORAL DISTRIBUTION

The Bureau of Meteorology lists 48 locations within the Fleurieu Peninsula region where official daily rainfall data have been collected for any period of time.

As can be seen from Figure 7 the distribution of rainfall stations is concentrated along the northern spine and town centres of the Peninsula. The distribution is particularly sparse along the southern coastal areas. As a means of improving estimates over the areas of sparse coverage, the Bureau of Meteorology has recently devised a method to estimate the rainfall in between the gauge locations based on the topography of the area.

Using correlation techniques incorporated into a GIS, the corrected data has been used to create a best estimate of the spatial distribution of rainfall over a 30 year period 1971-2000 over the whole region. This distribution has then been combined with the sub-catchment boundaries to derive an estimate of the average annual rainfall for each of the 55 sub-catchments within the whole region.

The isohyets are shown on **Figure 8 Location of hydrological stations and rainfall isohyets.**

Table 4 shows the details of the nine rain gauge records, which are current, have the longer and continuous records and have been used to define the temporal variations of the annual rainfall over the standard 30 year period but also over a 100 year period for the Yankalilla catchment.

The record closest to any catchment (or combination of two or three records) can be factored to have the same long term average as calculated for any catchment by the GIS method. Each catchment can therefore be provided with a 30 year time series of annual rainfall matched to the Bureau’s s 30 year long term average rainfall.

The long-term average annual rainfall for each catchment is listed in Appendix A.

Table 4: Rainfall stations used for the study

SITE	STATION NAME	START	END	DURATION
M023708	Second valley (Spring Grove)	1877	1983	106
M023723	Yankalilla (Inman Valley)	1932	2007	73
M023738	Myponga	1913	2006	92
M023743	Victor Harbor (Rivington Grange)	1910	2006	94
M023751	Victor harbour	1883	2006	122
M023754	Yankalilla	1892	2006	113
M023761	Parawa (sharon)	1947	2007	58
M023823	Hindmarsh valley (fernbrook)	1964	2006	41
M023824	Hindmarsh valley (springmount)	1952	2006	53

Since the rainfall is greatly influenced by topography, the lowest and highest rainfalls tend to be located at the lowest and highest parts of the catchment. The Yankalilla catchment is shown to have one of the most dramatic rainfall ranges, averaging less than 520mm in the coastal areas to more than 940mm at its headwaters.

4.1.2 RAINFALL SEASONALITY AND TREND

While there is significant variation in the rainfall depth over the region, the regional seasonality is similar, with winter rains predominating, as shown for Goolwa rain station in Figure 9.

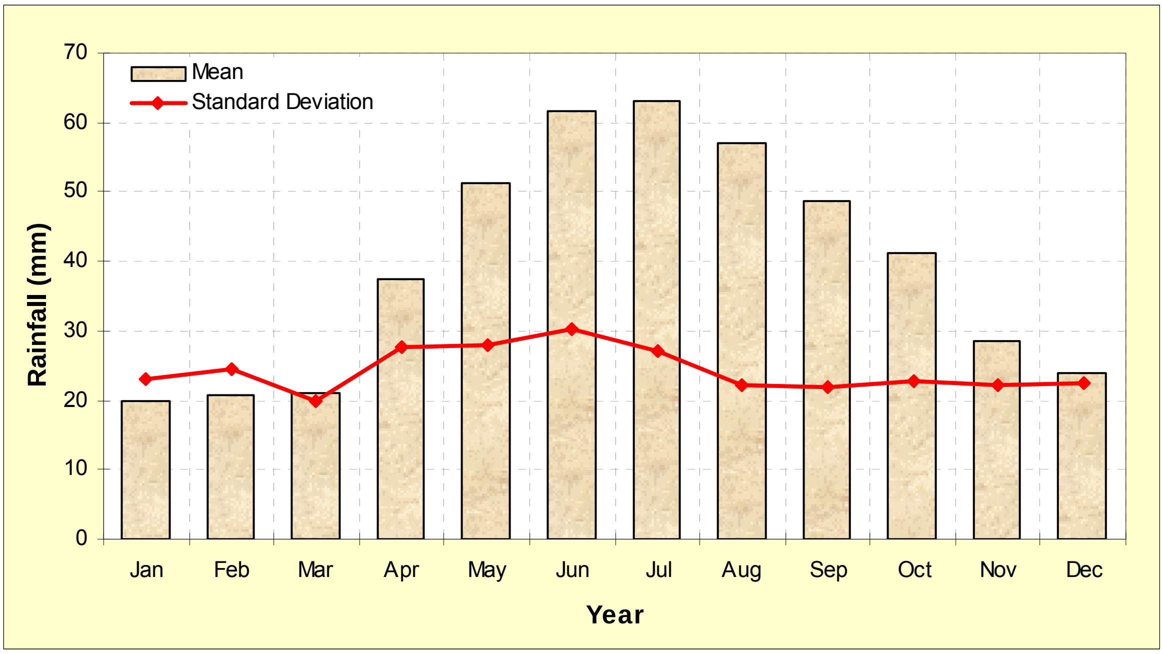


Figure 9: Average monthly rainfall (1884 – 2004) at Goolwa-Alexandrina Council Depot

Figure 10 shows the long-term variation in rainfall for Goolwa from 1884. The average over the whole period is shown as the horizontal green line at 474 mm/a. The rising and falling red line is the residual mass curve (also known as the cumulative deviation from the mean). During extended periods when the rainfall is less than average the red line falls. During periods when the rainfall is above average the line rises. Significant periods of below average rainfall have occurred from about 1888-1904, 1916-1936, 1955-1967and 1993-1999. The period 1905-1910, the long period 1937-56 and the short period 1990-92 all had above average rainfall. This record does not indicate any marked long term or recent trends towards reduced rainfall as would be expected under forecasts of climate change. However a much more rigorous analysis would be required to confirm this.

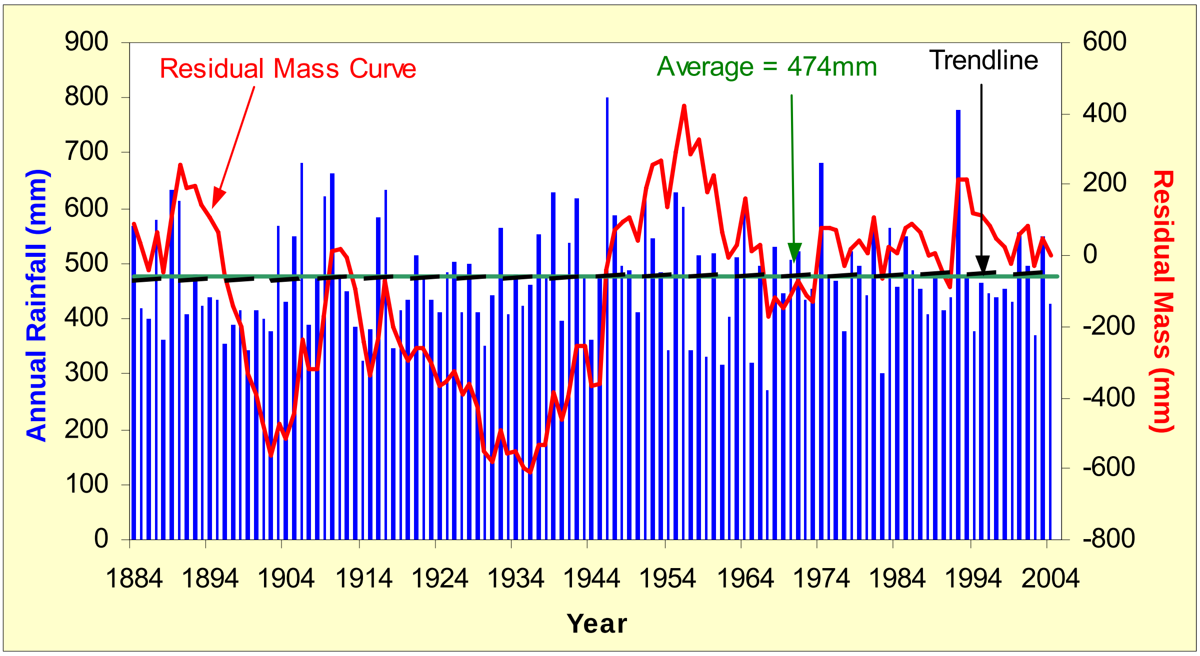


Figure 10: Annual Rainfall at M023718 – Goolwa – Alexandrina Council Depot

4.2 EVAPORATION

Table 5 below shows evaporation results for the four locations where evaporation data is collected in or close to the study area. It can be seen that evaporation generally decreases with latitude and mean temperature. Summer evaporation rates are at least four times greater than winter rates.

Table 5: Summary of available evaporation data

		Period of record	Mean mm/a	Jan av. mm.	Jun av. mm
Mount Bold Reservoir	M023734	1969 – 2004	1529	230.3	48.2
		1989 - 2001	1418	215.3	59.8
Myponga Reservoir	M023783	1989 – 2000	1400	203	49
Goolwa Mundoo Barrage	M0245575	1988 – 2003	1527	206.8	58.5
Victor Harbour West	M023804	2002 -04	1288	178.4	53.2

1. M023734 was calculated with the same period of record as M023783 for comparison. Ideally means should only be considered with same period of record due to climate variability in other years potentially biasing the mean
2. Period of record are years with whole records only
3. Victor Harbor West only has a short period of data.

The longest record is that collected at the Mount Bold Reservoir The residual mass plot and trend lines in Figure 11 below show a reduction in evaporation over the period of recording. The greatest reduction has been in the summer period from November to April with the winter period May to October remaining relatively stable.

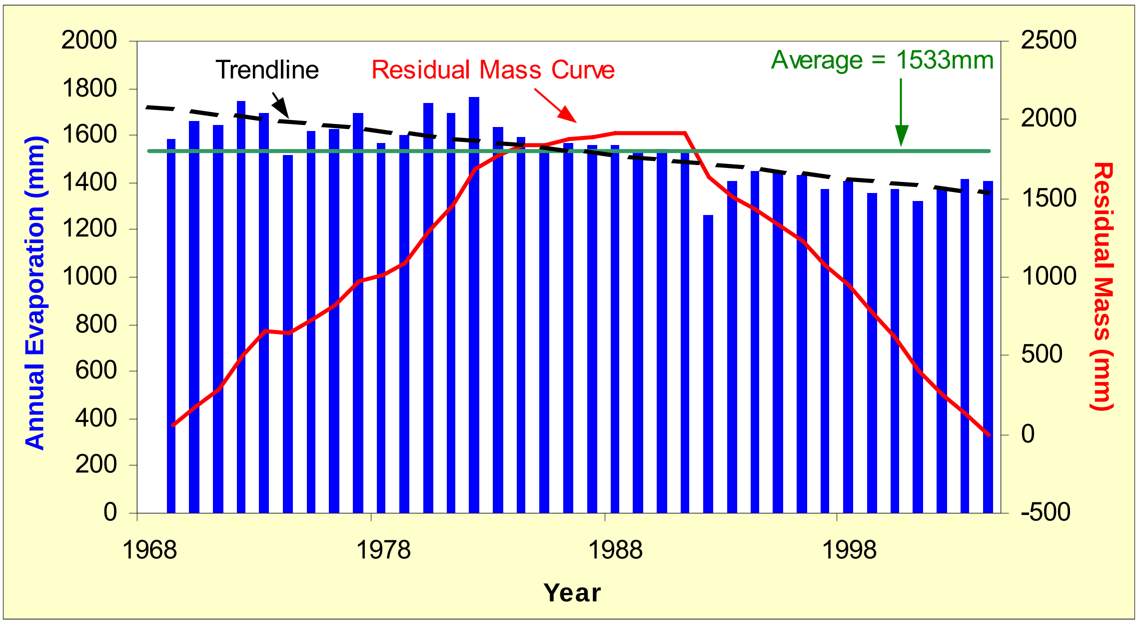


Figure 11: Annual Evaporation and trend at M023734 - Mt Bold Res Meteorological Station

Reducing pan evaporation has been reported widely in many parts of the world and is believed to be due to air pollution, with recent volcanic eruptions and global bushfires adding large irregular 'pulses' to the pollution load. For example, the downward spike in the Mt Bold record in 1991 (Figure 12 below) corresponds to the Mt Pinatubo eruption in Indonesia.

There is debate amongst climatologists on the significance or cause of this apparent trend of 'global dimming' and its interaction with the other recognised trend of global warming. Such discussion is beyond the scope of this project.

A double mass plot of Mount Bold Reservoir station versus Myponga shows that Myponga shares a strong linear relationship of 0.9797 * Mt Bold station (R^2 = 0.9997).

The Myponga station has been used for rainfall runoff modelling for this study.

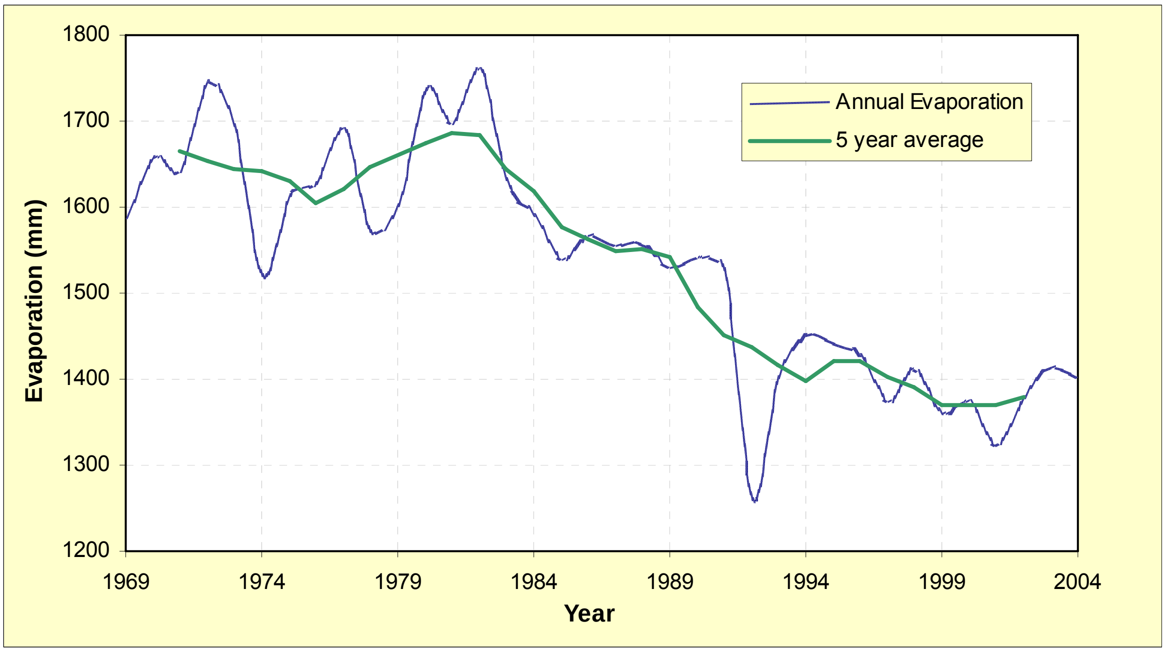


Figure 12: Five year average evaporation at M023734 - Mount Bold Reservoir Meteorological Station

4.3 STREAMFLOW

Stream flow data has been collected at 5 locations within the area, as shown in Table 6.

Table 6: Gauging stations used in the study

Catchment	GS Name	GS Number	Catchment Area km2	Start Date
Hindmarsh R	Diversion Weir	A501 0500	56.5	Mar 1969
Myponga R	U/s of Reservoir	A502 0502	77.0	Apr 1978
Inman R	Near WWTP	A501 0503	164.3	Jan 1995
Yankalilla Ck	D/s Blackfellows Ck	A501 1006	63.7	Aug 2003
Deep Ck	Tappanappa Rd	A501 1011	11.1 appx	Jun 2006

Only 26 months of data is available from the Deep Creek gauge. This is insufficient for accurate calibration of a rainfall to runoff model and thus only superficial analysis has been made of this data.

The flow records are obtained at locations where a stable relation (the station rating relation) is believed to exist between water level (as recorded by the on-site instrumentation) and flow rate. Ideally this relationship must be established over the full range of flows by field measurement. The continuously recorded measurement of water level is then combined with the rating in order to convert it into a continuous estimation of flow rate. This latter rate is accumulated to give estimations of daily flow volume at daily intervals.

Appendix D shows the water level versus flow relations used in the estimation of flows for the first 4 gauging stations (excluding Deep Creek). The Table below summarises the status of the ratings and the likely accuracy of the flow estimations based on them.

Table 7: Summary of the gauging stations rating curves

Gauge	Stability	Max Field Gauging	Notes	Summary
Hindmarsh	Weir	2.6 m3/s	Geometric weir contains all low to mid range flows. Few check gaugings in mid and higher range flows.	Likely reliable
Myponga	Low weir	13.5 m3/s	Several field check gaugings to mid-high flow rate. Rating appears unstable for mid range flows.	Likely reliable
Inman	Low weir	30 m3/s	Only one set of check gaugings, but to mid-high range.	Poss reliable
Yankalilla	Low weir	Apprx 3 m3/s	Only 2 check gaugings at low to mid-low rate.	Poss unreliable

4.3.1 FILLING GAPS IN STREAMFLOW DATA

The 5 sets of daily flow data for the flow gauging stations were listed with their data quality codes. The latter identify days for which errors are suspected and the type of error. By plotting cumulated flow for pairs of the gauges, but only for those days for which both gauges are free from suspected data errors, correlations can be derived between the different data sets. These correlations were then used to infill days with missing or suspected poor data.

5. REGIONAL AND CATCHMENT HYDROLOGY

5.1 INTRODUCTION

The main understanding of the surface hydrology of the area has been obtained via comparisons between the flow responses to rainfall shown by the 5 sets of streamflow records within the region, plus experience gained from similar analyses of records outside the region.

The purpose of the initial investigations has been to attempt to identify the size and nature of the apparent differences in flow responses and to relate these to catchment characteristics which can be gleaned from the available data sets covering rainfall, slope, soils, land use and farm dam density. If relations can be identified, these can be used to assist in estimating runoff from the ungauged catchments under the 'with' and 'without' farm dams scenarios.

The main differences in runoff response that provide insight to the processes occurring on the catchments can be seen on graphs covering:

- annual rainfall versus runoff and the estimation of the long term runoff as a % of the rainfall over the catchments, and
- recession rates and durations of flow at various flow levels

The flow records are of different durations and cover different periods. Changes that affect the runoff responses will have occurred at different times, rates and locations during the overall period of flow recording. With the exception of the effects of rainfall and farm dams on the flow rates, for which formulae have been developed (see Section 3.3.2 above), the manner in which the other catchment differences and changes have occurred are poorly quantified. Formulae have been developed and used to try to account for the effects of these on the runoff level. These are described in detail in Section 6.

The ongoing development of GIS data bases and analysis methods is likely to bring about major improvements in this area over the next decades.

5.2 PRELIMINARY FLOW COMPARISONS

5.2.1 ANNUAL RAINFALL VERSUS ANNUAL RUNOFF.

The mean annual rainfall for each of the gauged catchments was calculated as shown in Table 8 below. The coefficients were adjusted until the formulae gave approximately the same average rainfall over the catchments as determined by the Bureau of Meteorology for the period 1971-2000.

Table 8: Factors used for calculating annual rainfall in the gauged catchments

Gauged Catchment	Calculation of Annual Rainfall (mm/a)	Av 1971-2000 by Formula	BoM 1971 to 2000 Av Rain
Hindmarsh R	0.5 * (Fernbrook * 0.96) + 0.5 * (Springmount * 0.94)	878	879
Myponga R	0.5 * (Myponga * 1.18) + 0.5 * (Fernbrook * 0.96)	862	862
Inman R	0.25 * (Springmount * 0.89) + 0.37 * RivingtonG + 0.38 * InmanV	756	757
Yankalilla R	0.1 * Yankalilla + 0.1 * Inman +0.8 * (Parawa * 0.84)	775	775
Deep Ck	Parawa * 0.88	841	840

While Figure 10 indicated no marked overall trend in rainfall over the 120 years from 1884 to 2004, there were extended periods of increased or decreased rainfalls. Figure 13 shows that the average rainfall during the recent years when the shorter periods of flow records were obtained has progressively declined. This decline has influenced the analysis of the plots of annual catchment rainfall v annual catchment runoff depth for the gauged catchments.

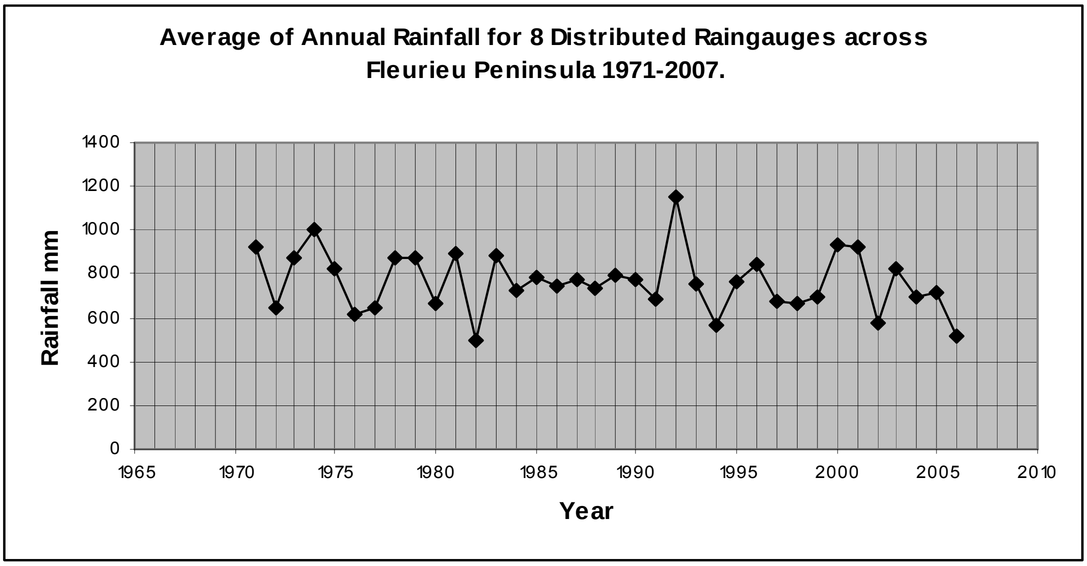


Figure 13: Trend in average rainfall over the Fleurieu Peninsula 1971-2007.

Before commencing the investigations of rainfall v runoff, each value of observed annual runoff has been corrected for the effect of the estimated volume of farm dams present in that year. This correction involved estimation of the farm dam volume as a percentage of the 2005 level for each year of record, using the formula identified in Section 3.3.2 (Numbers, Storage Capacities and Rate of Growth of Farm Dams).

This was followed by the application of the formula linking the reduction in flow for any individual year to the farm dam density (FDD) and flow for that year as per the formula for individual years given in Section 3.3.6 (Generalised Formulae for Predicting Flow Reduction due to Farm Dams). This process converts the annual series of flows at each gauged site into ‘natural’ flows under a ‘without dams’ condition.

Since farm dam densities are modest for the catchments in the Fleurieu Peninsula the corrections are generally not large. The flows were then converted to average depth of runoff by dividing the runoff volume by the catchment area.

The Tanh method was used to assess the relative efficiency in runoff generation of the gauged catchments using the modified 'natural' catchment flows. The Tanh curve is defined by the formula:

$$Annual\ runoff = (Annual\ rainfall - L) - F \times Tanh\left(\frac{Annual\ rainfall - L}{F}\right)$$

The Tanh curve is used to fit to the annual sets of catchment rainfall and runoff depth since it describes a relationship in which the annual runoff value becomes asymptotic to the annual rainfall at a point (L) along the axis and asymptotic to the 45 degree slope as annual rainfall increases. Thus:

- runoff approaches zero at a threshold level of rainfall, and
- the increase in annual runoff depth under conditions of high rainfall can approach but not exceed the increase in annual rainfall depth.

These two conditions are compatible, both in theory and in practice with the general shape of the plots of observed annual rainfall v runoff.

The value of F sets the curvature of the relation between the asymptotes and thus the slope of the relation at 'normal' values of annual rainfall. The two parameters of the model thus offer a simple and direct way of comparing the averaged broad relations between annual rainfall and runoff for different catchments and also a means for extrapolating annual runoff records for each year of historical annual rainfall.

After initial fitting of the Tanh F expression to the adjusted gauged catchment data, it was decided to constrain the value of L to be zero. The fitted unconstrained values had varied from about -100 to +150. Negative values imply some runoff for zero rain and are therefore theoretically impossible. Applying the constraint when L is small makes very little difference to the value of F. Having a single measure of the efficiency allowed for direct comparisons between different catchments and offered a simple and direct way of estimating F values on the basis of catchment characteristics, as described in Section 6.

If the Tanh method with L = 0 fitted perfectly to the data, and catchment conditions remained stable, a single F value should fit equally well to sets of data for years with higher or lower rainfall averages. It is known that changed land uses, farm dams, etc and agricultural practices have changed the runoff efficiency (and thus the values of F). Moreover, investigation of the fitted curves show that the curves do not fit equally well within the high and low rainfall v runoff data sets.

F values fitted to the different periods of the records are shown in Table 9. These show a tendancy to decline, particularly over the more recent period, when the flows were measured at the Yankallila and Deep Creek gauges. The main cause for this decline is believed to be the decreasing rainfall, but it may also be influenced by land use changes or other causes.

Table 9: Values of Tanh F values for different periods (L=0)

Period	Hndmrsh	Myponga	Inman	Yankallila	Deep Ck
71-77	1066				
78-94	1137	1321			
95-00	1171	1322	1384		
98-03	1207	1426	1418		
04-07	1353	1420	1937	1306	
06-07	1604	1672	2326	1522	2787

The values of F fitted to the short records for Yankalilla and Deep Creek are associated with low confidence levels, however, the figures given in Table 9 show strong evidence that the Tanh F values fitted to the shorter period records at Yankalilla and Deep Creek should be decreased if they are to be used to estimate runoff over the earlier period 1971-2000 for which the rainfall values have been obtained. Figure 14 shows the F values fitted to the common periods plotted against the period over which they were derived.

Since the intention is to estimate the average runoff that would have occurred during the period 1971-2000, adjustments must be made to ‘correct’ the F values estimated for the short records (Inman, Yankalilla and Deep Creek) which fall only partly within, or totally outside this period, in order to give a value that can be applied to the 1971-2000 rainfall in order to be able to calculate what their runoff would have been over the whole of this period.

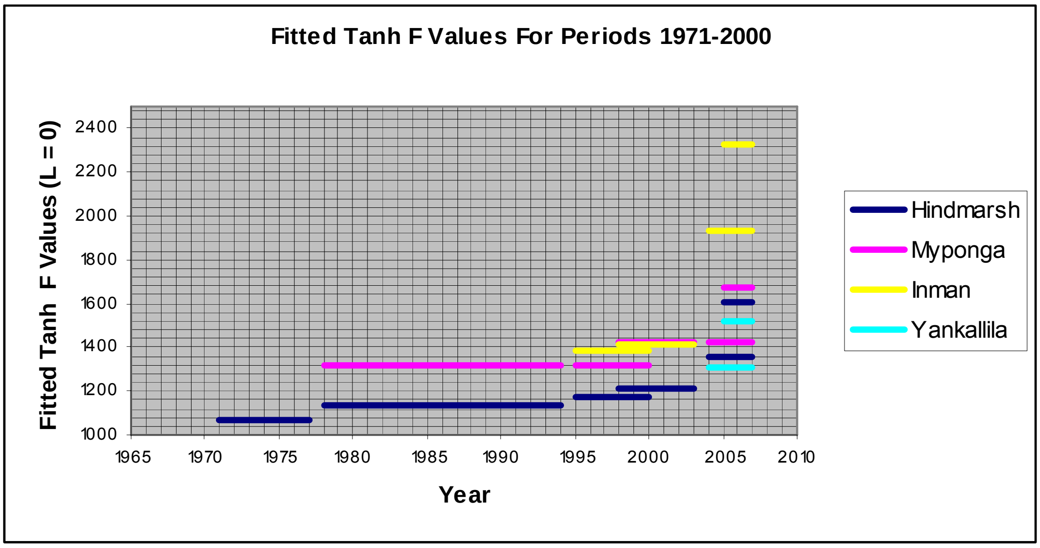


Figure 14: Fitted F values plotted for the periods over which they were calculated.

Visual inspection of the plots of cumulated annual rainfall and runoff has also been used to compare the relative efficiency of the catchments in runoff production, both between them and over time. The cumulated plots are shown in Figure 15. The plots for each gauge commence at the cumulated value for the Hindmarsh rainfall at the time of the start of the record for that gauge. However the individual plots show the cumulated rainfall and runoff for each catchment so that the slopes of the curves are a measure of the coefficient of runoff for that catchment (i.e. % (runoff depth)/rainfall).

The slopes of the Hindmarsh, Myponga, Inman and Yankalilla plots over the common periods of the Inman and Yankalilla records indicate that the order of decreasing efficiencies (and thus likely increasing F values) is Hindmarsh, Myponga, Yankalilla and Inman. The fact that Yankalilla has lower F values when fitted by least squares appears anomalous and may be caused by the fitting technique itself.

The rainfall influences the slopes of these curves; steeper sections relate to the higher rainfall years. More detailed plots using monthly rather than annual data for the period 2003 to 2007 are shown in Figure 16.

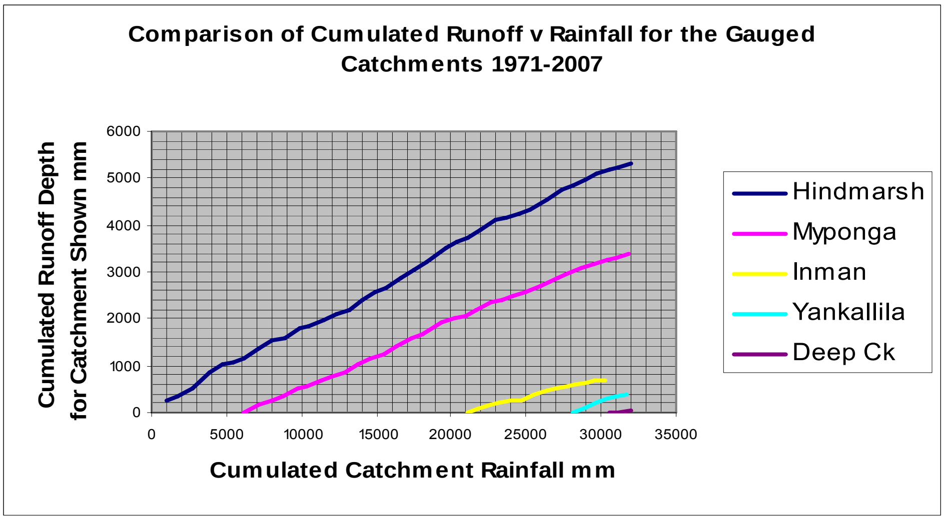


Figure 15: Plots of Cumulated 'Natural' Runoff v Rainfall for the Gauged Catchments

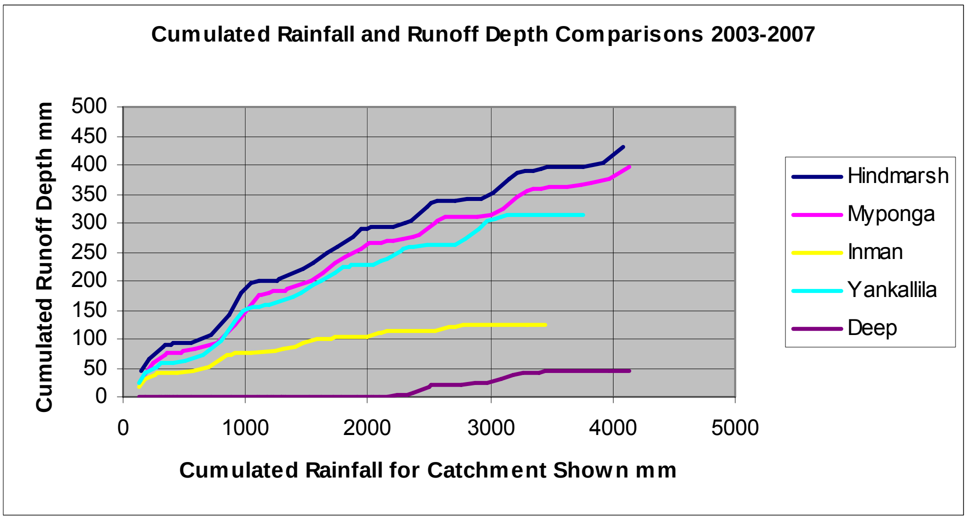


Figure 16: Cumulated Monthly Rainfall and Runoff Comparisons for 2003-07.

The average F values to be used over the whole period 1971-2000 were selected as denoted as the 'adjusted' F_0 values Table 10. Figure 17 shows the graphical plot of the Tanh curves.

Table 10: Final values of F adopted for gauged catchments for period 1971-2000

Catchment	F_0	Comment.
Hindmarsh	**1160**	Fitted F value 71-00
Myponga	**1320**	Fitted value 78-00, reduced for period 71-78.
Inman	**1420**	Increased to conform to plots
Yankallila	**1275**	Selected to be just less than Myponga
Deep Ck	**1500**	Selected high for land use (see Section 6).

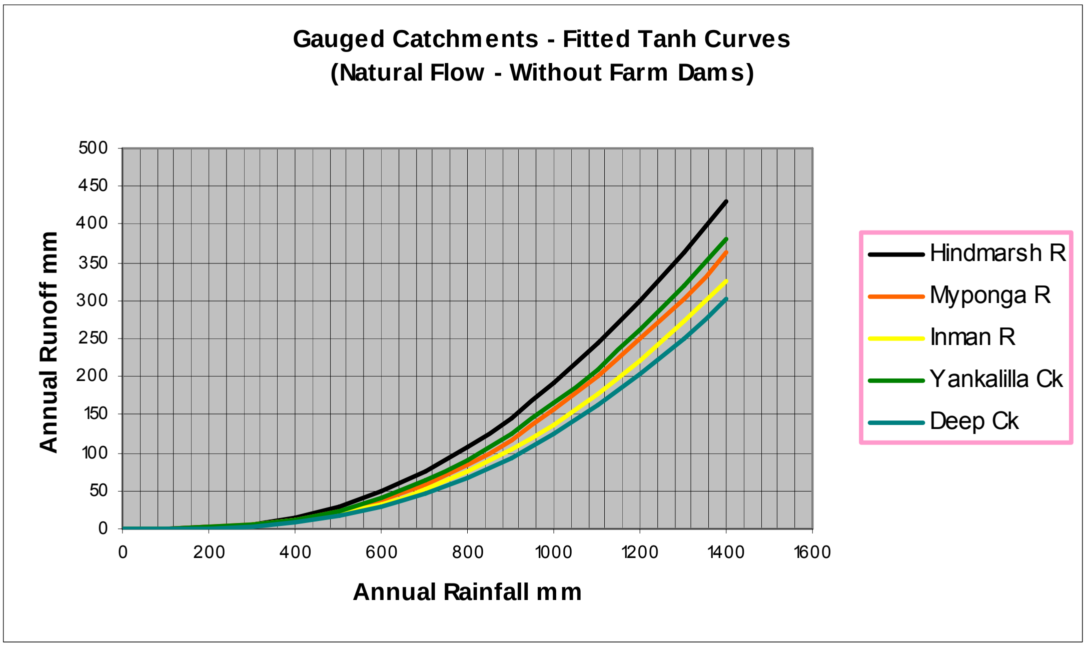


Figure 17: Tanh curve of gauged catchments' natural flows

Subsequent analysis described in Section 6 gave further information which allowed a more informed estimate to be made which was still compatible with the general location and shape of the annual and cumulated rainfall and runoff plots.

The annual runoff predicted by the Tanh formula for any value of annual rainfall increases as the value of F decreases. Thus the F values define the efficiency of runoff for any given rainfall total. The runoff efficiency for the Deep Creek catchment, which has the highest F value, is therefore the least; the Inman catchment appears to also have a low efficiency; the Yankalilla and Myponga catchments have a similar, higher efficiency, while the Hindmarsh R runoff has the greatest efficiency. Despite this, a lower efficiency, larger area catchment receiving a higher rainfall may provide a much higher total volume of runoff.

The adjusted F_0 values shown in Table 10 have been used to calibrate a method for estimating the F values based on quantified characteristics of the catchments, as described in the Section 6.

5.2.2 FLOW DURATION CURVES

The flow duration curves allow a comparison to be made between the distributions of high and low flows and the persistence of low flows in each catchment. Again the flows are plotted as mean depth across the whole catchment area (i.e. mm/day).

Figure 18 shows a comparison between the flow durations for Hindmarsh and Myponga over a common period 1978-06. The majority of the flows are contained in the ranges about 0.5 mm/d, where the higher flows for Hindmarsh can be seen. Both gauged locations show flow persisting for 95% of the year, with continuous (trickle) flow maintained throughout the whole year in years with higher rainfall and/or summer rainfall events. The cause for the deviations in flow durations at the lower flows is not known, but could be related to different groundwater interactions and/or pumping diversions.

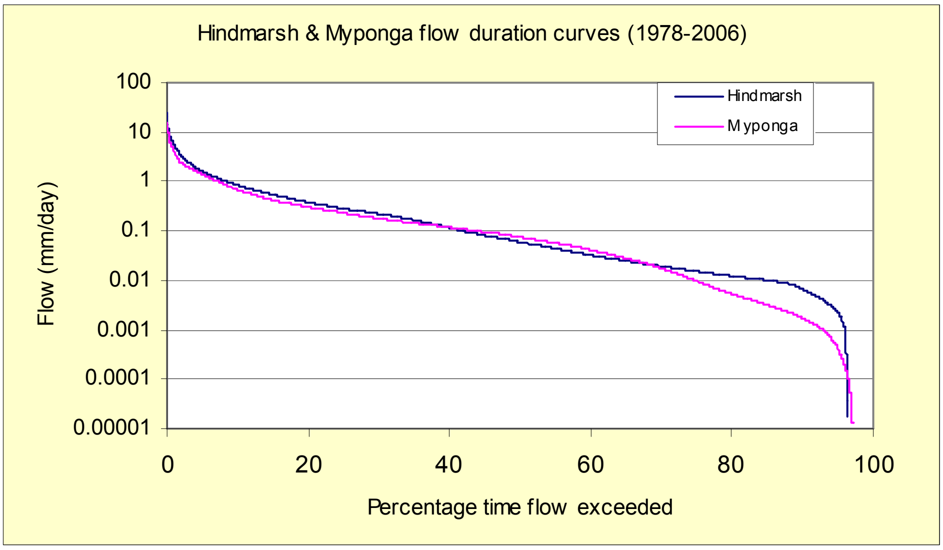


Figure 18: Hindmarsh and Myponga flow duration curves (1978-2006)

Figure 19 shows the flow duration for Inman compared to Hindmarsh. The period of flow recording for Inman is much shorter (1995-06) and therefore the flow durations for Hindmarsh are shown for both this shorter period and for the full period 1978-06. The Inman occupies a much lower rainfall area and the curves show that for the majority of time, the Inman has flows per unit area of catchment about half to a third of those for the Hindmarsh catchment. The relative stability of the Hindmarsh curves over the two periods indicates that the Inman curves can be taken to be representative of the longer term.

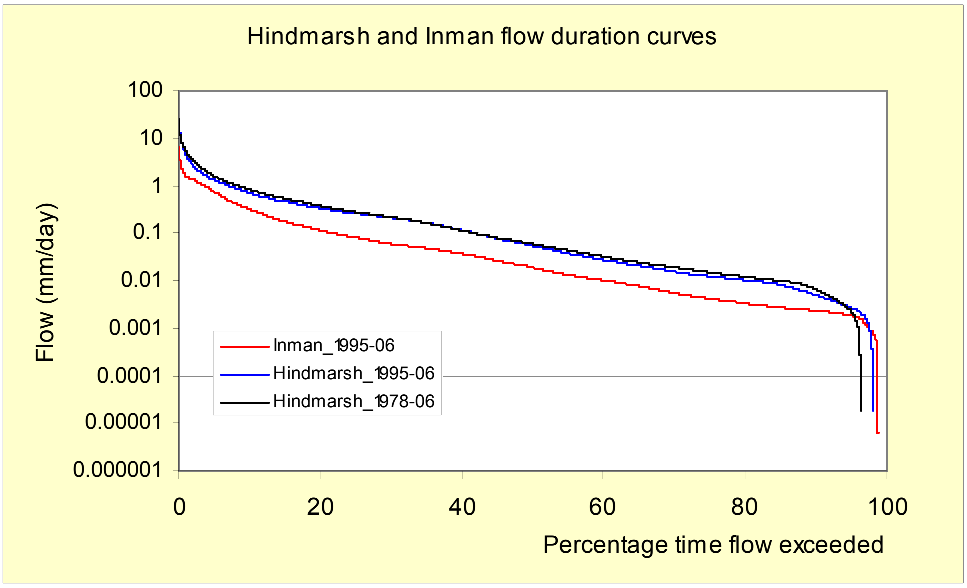


Figure 19: Hindmarsh and Inman flow duration curves

Figures 20 and Figure 21 show the curves for the Yankalilla and Deep Creek catchments in comparison to the Inman and Hindmarsh catchments. The periods of record for the former are only four years and eight months respectively, during which time rainfall has been low. Over the 4-year period 2003-06, for flows below 0.1 mm/d, the flow duration curve for Yankalilla is similar to that for Myponga and Hindmarsh over the longer term. However, above 0.1 mm/d, the frequency and duration of flows have been less than the long term averages for Myponga and Hindmarsh.

The steps and irregular shape of Figure 21 are due to having only 8 months of record for analysis. For comparison purposes, both the Hindmarsh and Yankalilla curves for the same period are shown, as well as the long term Hindmarsh curve. The difference between the Hindmarsh curves is consistent with these 8 months being a drought period. The Yankalilla curve shows a significant increase in the duration of no flow. The Hindmarsh curve shows similar but lesser increase in the duration of no flow.

The Deep Creek curve appears to indicate that the catchment behaves similarly to Yankalilla at high flows, but that base flows are more rapidly diminished to a low level where they appear to be possibly maintained by a spring flow. Unlike the records for Hindmarsh and Yankalilla, the Deep Ck records indicate no period of zero flow during this time of regional drought.

In summary, the flow duration curves show that all catchments maintain baseflows for long periods, indicating high infiltration into groundwater and the presence of springs. The low relative size and frequency of surface runoff generated by rain events in the Inman catchment does not appear to be compensated by relatively longer or higher baseflows, indicating that the infiltrated water is either taken up by additional evapotranspiration, or is lost to deeper percolation. There is evidence that the density of deep rooted vegetation in the Deep Creek catchment is responsible for drawing down superficial groundwater, but that deeper springs are present to maintain permanent low flows.

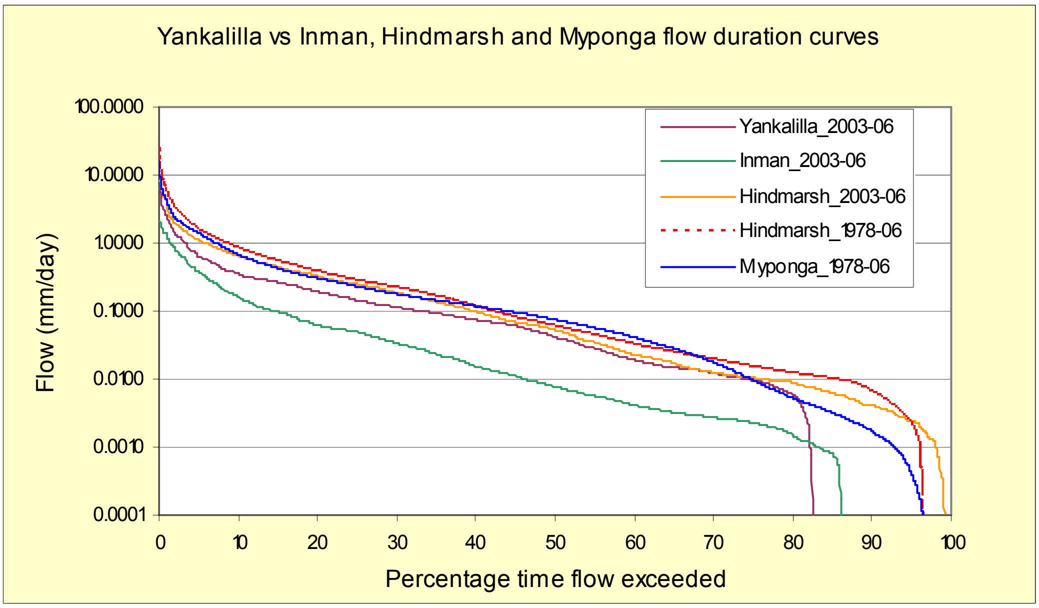


Figure 20: Yankalilla vs Inman, Hindmarsh and Myponga flow duration curves

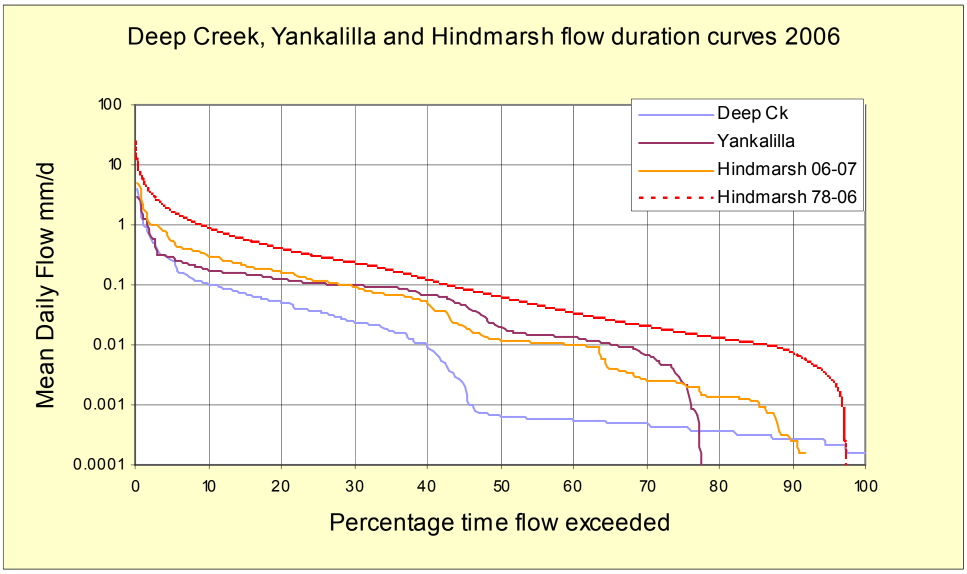


Figure 21: Deep Creek, Yankalilla and Hindmarsh flow duration curves

5.2.3 RECESSION RATES

Periods of likely zero rain were identified by listing the daily flow records alongside an ‘index’ record of daily rainfall from a gauge situated within the catchment. Dry periods, when flow recession rates should be established and undisturbed were then defined as those occurring after at least three days of zero rain and with at least two clear days of zero rain before the next rainfall event. This ‘windowing’ of the record allows for errors due to the relatively common misplacement of rainfall records by one or two days from the true date. The resulting ‘dry period’ flow records were then smoothed by taking their 3-day average, including the day before and after. This reduces the inevitable ‘wobbles’ that occur in the processed flow records due to minor errors in field recording and office processing. The recession rate for each day of record falling within these dry periods was then calculated as the ratio of the smoothed flow value q for the day in question to that of the previous day (ie q_t/q_{t-1}).

Recession rates should be less than 1.0 and, for small catchments similar to those on the Fleurieu Peninsula, are generally found to fall from values of about 0.5 immediately after a high flow event to about 0.95 for well established low flow periods. However, errors and wobbles in the records cause the calculated ratios to vary well above and below the 'true' values. Since a wobble will generally create a similar sized correction error to balance out the initial error, an averaging process can be undertaken by plotting all the ratios against the flow rates at which they are calculated and fitting a curve through the points.

Figure 22 shows the curves fitted by eye through the plotted points for each of the gauged flow records.

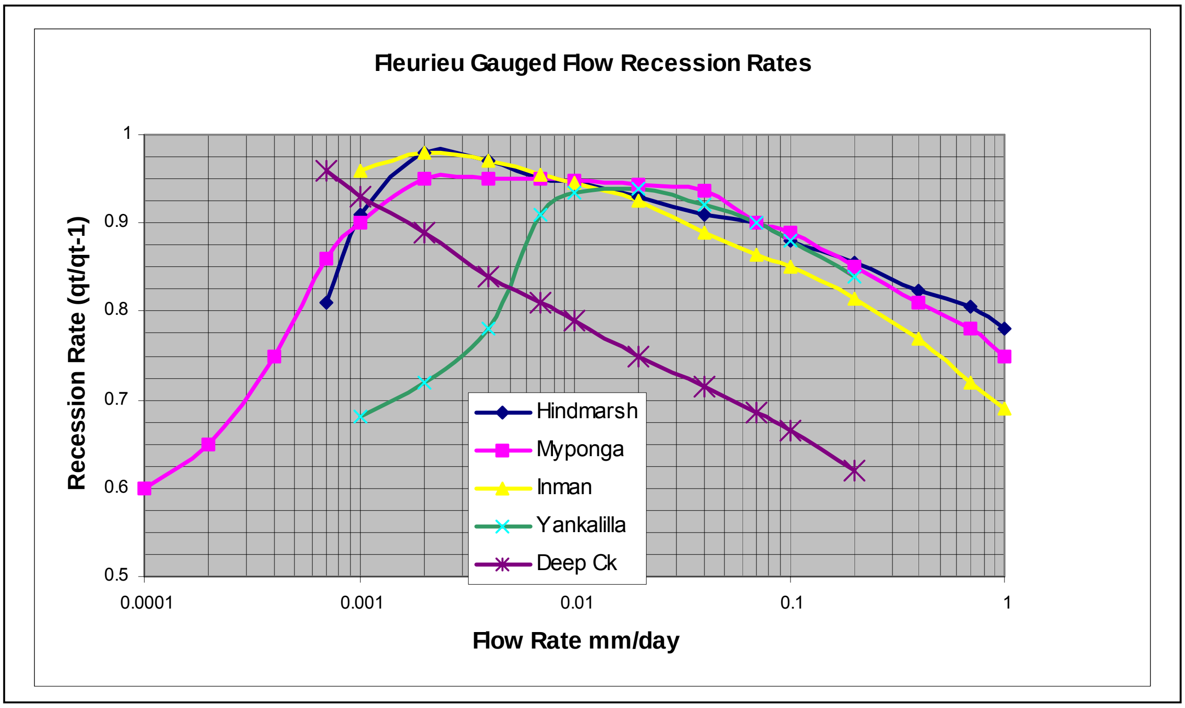


Figure 22: Fleurieu gauged flow recession rates

The recession rates are related to the slope of the flow duration curves. The steep tail on several of the flow duration curves at low flow rates (probably due to the rapid diminishing of baseflows by evapotranspiration during hot summer periods) are reflected by the increased recession rates occurring at the lowest flows. The fact that the Yankalilla curve exhibits this reversal at a higher flow rate than the others may be caused by the Yankalilla gauge being sited at a 'losing' reach of the river. The Deep Ck recession rates are high at all flow rates except the very lowest. This appears to tie in with the suggested losses to recession flows via higher evapotranspiration rates, but the maintenance of lowest flows by deeper springs.

The Section below examines possible causes for variation in the values of F in relation to average rainfall, land use, slopes and soils.

6. RESOURCE CALCULATION FOR UNGAUGED CATCHMENTS

6.1 PROCESS

The estimation of runoff from the ungauged catchments has proceeded via a two step operation. In the first step, it is assumed that the differences in the Tanh F values fitted to the observed annual rainfall and runoff data for the gauged catchments (modified to remove the effect of farm dams) can be shown to stem from the influences of their different land uses, slopes and soil types. This will be shown by first establishing a set of generic mathematical relations between quantifiable measures of the influencing factors and the F value in the Tanh expression and then fitting these to the measures for the gauged catchments and showing that the observed Tanh F values for the gauged catchments identified in Section 5.2.1 can be reproduced with reasonable accuracy by the application of these relations.

The second step then follows by using these same relations between the Tanh F values and the quantified measures for the land uses, slopes and soils for the gauged catchments to derive similar 'best estimates' of Tanh F for the ungauged catchments. By applying this derived Tanh F value for each ungauged catchment to their annual rainfall records, their annual flows and their average long term runoff under the 'no dams' (natural flow) condition can be calculated. By knowing their farm dam densities (FDD), the annual runoff under the 'with dams' condition can then also be calculated.

6.1.1 FIRST STEP

The first of the above steps is itself composed of four sub-steps. The first (sub-step 1.1) has commenced with the derivation of a set of generic Tanh F curves for different land uses within the Mt Lofty Ranges. These have been derived by inspection of previous annual rainfall and runoff data collated for many gauging stations in this area, primarily reported in EWS 87/19. The derivation is described in more detail in Section 6.2 below.

Sub-step 1.2 interpolates separate values of F from the set of generic curves for each of the classifications of land use adopted for the Fleurieu peninsula in this study and combines these with the proportions of the land use present within each gauged catchment. This provides a 'land use' weighted first estimate (F1) of the likely final (theoretical) F value for each gauged catchment. This should have some resemblance to the F values fitted to the data for the gauged catchments (F_0, See Table 10 of Section 5), but may not be a 'perfect fit' since other influencing factors have yet to be applied.

Sub-step 1.3 modifies the F1 values for the gauged catchment on the basis of their slopes. The Fleurieu peninsula catchments have a very wide range of slopes and it is almost certain that all other things being equal, the steeper catchments will have a higher runoff than the flatter ones. The F1 values are therefore increased or decreased according to a formula which has its coefficient fitted to reduce the root mean squared (RMS) differences between the 'theoretically' derived F2 values and the actual F values fitted to the observed gauged catchment data. The result is to provide a second set of modified F values (F2).

Sub-step 1.4 performs a similar modification to the F2 values, but this time on the basis of the estimated % of the total area of each gauged catchment shown as Permian sand on the geological map of the area. Once again it is almost certain that, other things being equal, those having a high proportion of area with Permian sand cover will have a lower runoff than those with no sand cover. The F2 values are therefore increased or decreased according to a formula which has its coefficients similarly fitted to reduce the root mean squared (RMS) differences between the 'theoretically' derived F3 values and the actual F values fitted to the observed gauged catchment data. The result is to provide a third set of modified F values (F3). These are the final F values derived for the gauged catchments and if the expressions and coefficients adopted to reflect these catchment influences are adequate, the F3 values should resemble the values of the F0 values derived by fitting to the data.

The process is in effect a calibration of the set of generic mathematical expressions and the set of data on quantified catchment characteristics to match the observed F0 values for the gauged catchments. If these assumptions and expressions are valid, it would be expected that the calibration could result in a relatively close match between the finally derived 'theoretical' F3 values and the 'observed' values using well established (but previously unquantified) knowledge about the influences of land uses, slopes and soils on runoff.

6.1.2 SECOND STEP

The second step consists of three sub-steps. In the first sub-step (2.1) the same set of formulae and coefficients used to derive the F3 values for the gauged catchments is used to derive the F3 values for the ungauged catchments.

In Sub-step 2.2 the F3 values for each of the ungauged catchments are combined with their 30 year set of 1971-2000 annual rainfalls to calculate their 30 year average runoff. This will be the 'no dams' condition runoff.

In Sub-step 2.3 the 30 year average 'no dams' runoff is converted to the 'with dams' runoff by applying the formula given in Section 3.3.6.

The actual calculations related to each of these steps and sub-steps can be followed by reference to Appendices A-G with the more detailed description given below.

6.2 CALIBRATION OF LAND USE, SLOPE AND SOIL DATA FOR DERIVATION OF TANH F VALUES FOR GAUGED CATCHMENTS

Annual rainfall versus annual runoff curves have been previously plotted and compared for 34 gauged catchments in the Mt Lofty Ranges (EWS 87/19). Subsequently many other curves have been produced for other catchments, including urban catchments. Preliminary analysis of these show that, in general, urban catchments have the highest runoff efficiencies (lowest Tanh F values), while rural catchments have a wide spread of runoff, but at lower values of efficiency (higher Tanh F values). In general, within the rural catchments, forested and uncleared catchments have the lowest runoff while steep, elevated, cleared catchments have the highest runoff.

The Tanh curves plotted on Figure 23 below are generalised curves with selected F values so as to fit through the range and scatter of points plotted on EWS 87/19 (Figure 2.11, p 22). Selected F value curves have been labelled with the land uses and/or catchment conditions known to be present for the curves which occupy a similar location within the spread of annual rainfall to runoff points shown in EWS 87/19, with the two urban F values added from later experience.

In Appendix B1 the land use classifications given for the Fleurieu Peninsula have all been grouped under one of the headings of Forest plantation, Natural vegetation, Grass, Crops and Urban, as deemed appropriate. For initial investigatory purposes, Tanh F values have been assigned to each of these classifications to fit with those shown on Figure 23.

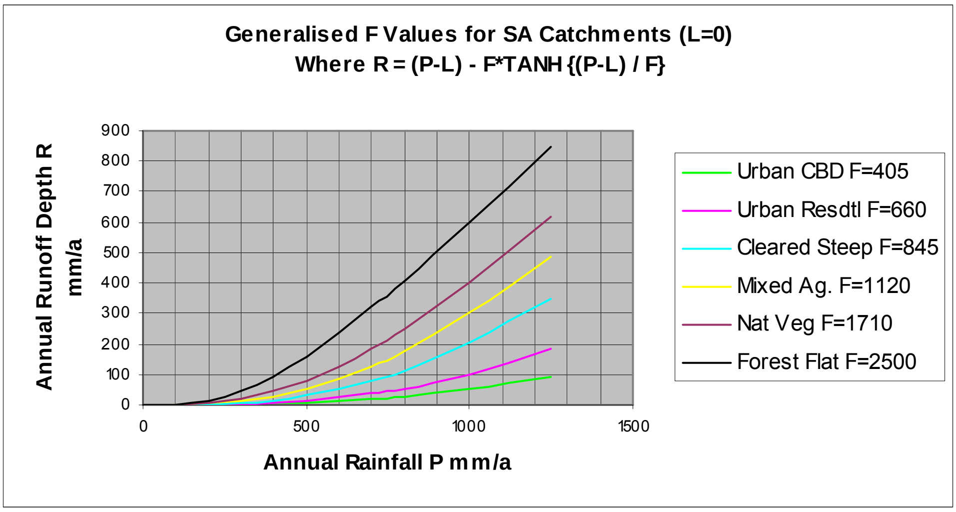


Figure 23: Tanh curves derived from data contained in EWS 87/19.

Since 80% of the land use within the Fleurieu peninsula falls within the Crops and Grass classification, the selected F values must align close to the F=1120 value shown for Mixed Agriculture in Figure 23. Since little information is known about the relative amounts of runoff from the various components of the Mixed Agriculture land uses, its two major components used in this study, ie. Grass and Crops, have been given similar F values at 1100 and 1200, respectively. The F values selected for Natural Vegetation and Forestry classifications, which have classifications the same as shown in Figure 23, are based on the same experience with runoff from catchments with these land uses.

Table 11: F values for general land uses as selected for initial testing

Urban	Grass	Crops	Nat. Veg.	Forest
605	1100	1200	1700	2200

In Appendix E, Columns 5 to 9 show the percentages of the different land uses within each of the 55 catchments. At the top of the columns are the Tanh F values for each of the land uses, as given in Table 11. The results in Column 10 are the first estimate of the value of Tanh F (F1) for each of the catchments, based on the formula:

F1 = K1 * {% Urban area*605 + % Grass area*1100 + …% Forest area *2200}/100.

The factor K1 adjusts the mean of the calculated F1 values for the gauged catchments to be equal to the average of their values of F, as fitted to their observed data, as shown in Column 4. The value of K1 is 1.030 and appears near the top of Column 10. The average of the 'observed' F_0 values is shown as 1335 near the top of Column 4. Column 11 shows the squares of the differences (SqDiff) between the values of F_0 and F1 for each of the gauged catchments. Near the top is the average for all the 5 gauged catchments (ie 10402). It can be seen that the worst fits between F_0 and F1, based on the application of the theoretical formula above to the land use data (only), are for the Inman and Hindmarsh Rivers. The highest value of the F1 values (ie lowest runoff) is 1647 for the Tapanappa catchment which has an 83% natural vegetation cover. The lowest value of F1 (ie the highest runoff) is 805 for Dump Beach which has 77% of its catchment urbanised.

Column 12 shows the average slopes calculated by GIS for each of the 55 catchments. Near the top is the average slope for the gauged catchments (ie. 6.9%). Column 13 shows the modification to the value of F1, to give a revised value F2 reflecting the influence of the differences in slope. The values are calculated by the simple formula:

F2 = F1 * (1 + (average slope - catch.slope) / K2)

The value of K2 has been fitted at 177 to give the least squares differences between the values of F2 and F_0. The value of K2 is shown near the top of Column 13. The squared differences are shown in Column 14. The values of F2 are raised for those with a flat slopes (eg Goolwa with a slope 1.4 has F2 raised from 1134 to F3 equal to 1169 (giving a lower runoff). Tunk Head with a slope 14.5 has its F2 lowered from 1133 to F3 equal to 1084 (giving a higher runoff).

A similar process is shown in Columns 15 to 17 to account for the percentage that mapped Permian sands occupy within the total area of each of the catchments. Column 15 shows the % for each of the 55 catchments. The average for the gauged catchment is 30% and is shown near the top of Column 15. A similar formula is used to adjust the F2 value for each of the gauged catchments to account for the differences in Permian sand coverage:

F3 = F2 * (1+ (catch.sand% - av.sand%) / K3)

The value of K3 has been fitted at 506 to give the least squares differences between the values of F3 and F. The value of K3 is shown near the top of Column 16. The squared differences are shown in Column 17. The values of F3 are raised for those with a larger proportion of Permian sand than the average for the gauged catchments and reduced for those with a lesser proportion. Thus the Inman with a proportion of 75% has its F2 raised from 1258 to F3 equal to 1269 (giving a lower runoff). Hindmarsh with a zero proportion has its F2 lowered from 1249 to F3 equal to 1188 (giving a higher runoff). The application of the adjustments for slope and % Permian Sand has reduced the average sum of the squared differences from 10402 to 4397. The squared differences fell to 10122 after the modification for slope. The method of fitting in which each set of influences are dealt with separately could be replaced with a more powerful method that fits all the coefficients together.

The % differences between the Tanh F values fitted directly to the data (F_0) and the values derived 'theoretically' from the catchment data sets on land use, slopes and soils are shown in Column 18. The Yankalilla F3 estimate (1379) is 8% above the 'observed' fitted F value (1275). The remaining errors are less, and all errors are small in comparison to the range of 25% between the highest and lowest of the observed F_0 values.

The relatively good calibration achieved from the series of adjustments, based on slopes and soils, to the original set of F1 values derived by reference to the generic set of F values for different land uses shows the potential of this technique. The great advantage of the method is that it gives an objective method for distinguishing runoff from different land parcels on the basis of well known (but generally unquantified) influences on surface runoff.

The degree to which these 'errors' would affect the estimation of runoff is considered below.

6.3 ESTIMATION OF RUNOFF FOR UNGAUGED CATCHMENTS USING CATCHMENT DATA SETS.

The same formulae developed and used to calibrate the Tanh F values for the gauged catchments are also shown applied to all the ungauged catchments in Appendix E. The F3 values have been taken to be the best estimate of the F values for the ungauged catchments.

Figure 24 below shows the areal statistical distribution of the calculated F3 values.

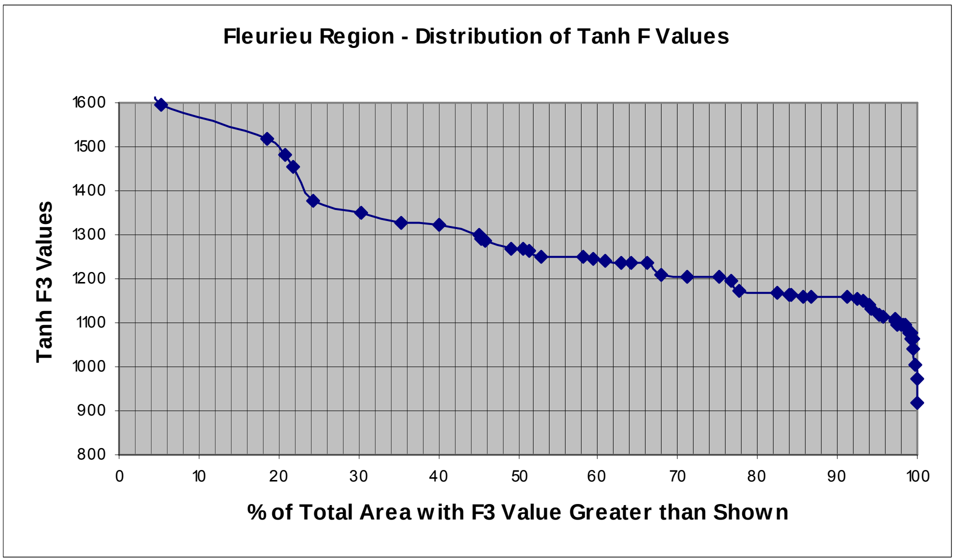


Figure 24: Percentage of total region with F3 values greater than shown

The estimation of long term flow, with and without dams, has followed the process below. The process can best be understood by reference to Appendix F:

The 30 years of annual natural runoff (1971-2000) was first calculated for each catchment by applying the Tanh relationship with its respective catchment F3 value, to each year of the nearest 'index' rainfall record, as listed in Column 5. This record was generally that of the nearest gauge but in the calculation process, each of its annual rainfall values were proportioned so that its 30-year average equalled the spatially averaged rainfall calculated by GIS for the catchment. The average runoff over this period is then the estimated long-term natural flow for this catchment (column 7 and 8).

The 'with dams' flow was then calculated from the natural flow by application of the long term formula linking the farm dam density and long term average flow to the reduction in flow, as given in Section 3.3.6.

The final results are given in Appendix F which lists all the basic data for each of the 55 catchments along with their long term average runoff expressed as mm depth and ML volume per annum for the two conditions of 'natural flow' and 'with dams' at the present level of dam development.

6.4 LIMITATIONS AND ASSUMPTIONS

The Tanh method gives a simple and useful indicator of the relative efficiency of catchments in producing runoff from rainfall (Grayson, R.B. et al 1996). The method uses average annual rainfall as input data and therefore cannot give an indication of the shorter (eg daily or monthly) period variation in runoff generation.

There is some evidence that the fitting of the Tanh curve with L=0, which was done to make comparisons and adjustments between the F values more direct, overestimates the runoff in low rainfall years. If L was made a fixed proportion of F a better fit might have been possible while still retaining a simple method for adjusting both L and F together.

The method described assumes that the land use classifications and quantifications, as finally amalgamated and reclassified, are accurate and relevant to hydrological processes. The apparent success of the method described above shows some promise in this respect, but improvements could undoubtedly be made in land use classifications for water management purposes.

The application of the generalised relation between farm dam density, annual flow and flow reduction implies that the evaporation and withdrawal of supply from the dams is similar to the average conditions and assumptions made for previous investigations for catchments in the Mt Lofty Ranges. Leakage losses from the farm dams are not considered. There is no evidence to show that this is not a reasonable assumption.

The adjustments made to the Tanh F values on the basis of land use, slope and %sand do not constitute standard practice in South Australia, as yet. However the alternative of assigning F values to ungauged catchments based merely on the F value of a nearest gauged catchment, ignores the likelihood of differences in runoff which are known to occur due to different land characteristics. The range of F values and runoff estimates do not appear to be far different to those that would be estimated by any other method, except for those smaller catchments that have a distinctive/unusual land use which makes up a significant part of their total area (eg, urbanisation or forestry) and which do not appear dominant within the gauged catchments.

It is therefore believed that the method used could be regarded as resulting in a more accurate prediction of runoff than a blanket average prediction across all catchments without regard to the influences known to influence hydrological processes and outcomes.

7. SUMMARY OF RESULTS

Appendix F (columns 7,8,15 and16) shows the final results of the estimated runoff with and without farm dams for the 55 identified catchments.

The estimated 30-year average flows for the gauged catchments are shown in the Table below.

Table 12: Estimated 30 year average flows for the gauged catchments using the Tanh F3 values.

Catchment	Area km2	Natural Flow ML/a	Present Flow ML/a	Present Flow mm/a
Hindmarsh to gauge	55.7	7765	7455	133.8
Hindmarsh to sea	112.1	11542	10759	96.0
Myponga to gauge	75.5	9604	9076	120.2
Myponga to sea	138.9	15647	14649	106.4
Inman to gauge	68.2	12125	10640	64.8
Inman to sea	191.8	13995	12256	63.9
Yankalilla to gauge	63.7	5007	4429	69.5
Yankalilla to sea	83.1	6241	5471	65.9
Deep Ck to gauge	11.1	922	810	73.0
Deep Ck to sea	41.3	3510	3096	75.0

The total natural flow to the sea from all catchments in the region is estimated at 98.2 GL/a while the present day flow is estimated at 89.8 GL/a. Thus the present level of farm dams are estimated to be reducing the long term average annual natural flow by 8.4 GL/a or 8.5%.

The estimated efficiency of runoff of the catchments is indicated by the F3 values in Appendix F. Figure 24 shows the distribution of the F values plotted against the % of the total area which has F values greater than shown.

It can be seen that only about 16 of the catchments have higher F values than that for 50% of the area (about F = 1240). These have the lowest runoff efficiencies. They include the larger catchments which tend to have lower slopes and higher proportions of Permian sands. The majority of the catchments are short and steep and many are situated along the south coast. Where these are cleared they have lower values of F (higher runoff) since they also have little or no Permian sands and are steep. The lowest F values are those of the catchments with a high proportion of urban land use. These low F values give a higher runoff efficiency. Only six catchments are estimated to have higher F values (lower runoff efficiency) than the gauged Inman catchment, which is also the largest within the Region.

Runoff has not been predicted specifically from urban areas. An accurate prediction would require a significantly more detailed study of the impervious areas and their drainage network. However the weighting given to the urban land use should result in the predictions correctly reflecting the urban presence.

Figure 24 shows that the majority of the total area is estimated to have runoff efficiencies between F = 1150 and 1350. Of the gauged catchments, only the Myponga catchment falls just within this range (at F = 1239).

To test the longer term variations of flow the Yankallila runoff estimates were extended to the full 100 years of rainfall data available. The distribution of annual runoff values over the 100 years shows that the driest year had a runoff of only 23% of the average, while the wettest year had a runoff 2.67 times that of the average year.

The 3-year driest period was in 1912-14 while the wettest 3 year period followed almost immediately in 1915-1917. The driest 3-year period had a runoff of only 27% of that of the wettest 3-year period. Due to the skew in the distribution of annual runoff, 56 years out of 100 have runoff less than the average runoff.

Figure 25 shows the predicted reduction in annual flow plotted against the total volume of dams in the upstream catchment. The reduction in flow is about 8.5% of the total catchment flow.

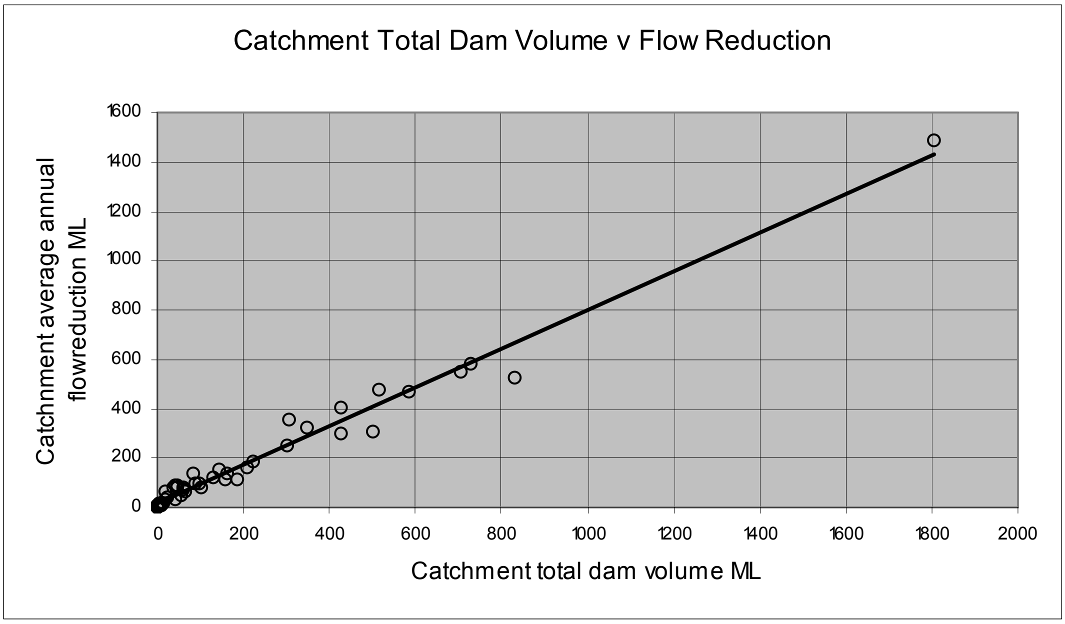


Figure 24: Predicted reduction in annual flow vs total dam volume of upstream catchments

8. CONCLUSIONS & WATER RESOURCE MANAGEMENT MECHANISMS

8.1 CONCLUSIONS

Prescription of the Mount Lofty Ranges catchments aims to provide a balance of water sharing arrangements amongst all users, including the environment. To protect ecological assets them there will need to be a concerted partnership between community and organisational stakeholders as part of the prescription process.

This does not have to mean a halt to any of the traditional or new innovative industries that have and will occur in Fleurieu Peninsula, it does however mean greater consideration will need to be given to where and how these ventures are established and operated.

8.2 MECHANISMS FOR IMPROVING WATER RESOURCE MANAGEMENT

Many of the management options are based on trying to harmonise the impact on business with the impact on the environment. There is no one single quick fix that will result in the appropriate management

8.2.1 FARM DAMS

Unless evidence is provided to support alternatives management regimes the future placement of farm dams on the Fleurieu Peninsula would benefit from:

- improved location
  - maintaining free to flow areas
  - maintaining a 100m buffer between dams and ecological assets.
  - Avoiding locations of dams on-stream, particularly on third order or greater tributaries. (NB dams can be located alongside major streams but should only be filled when flows are high. This will provide flows for support of water dependant ecosystems Avoiding locating dams on springs (ie not directly accessing ground water).
- Upstream farm dam density should be not greater than *x* ML/km^2; where *x* is yet to be determined.
- Consider voluntary retrospective removal of farm dams directly above high value ecological assets or on springs
- Licensing required for all farm dams (including those less than 5 ML), however metering only required on that used for irrigation or intensive industrial use

8.2.2 EXTRACTION DIRECT FROM A WATERCOURSE

- To be strongly discouraged at low flows as this will have the same impact as an onstream farm dam
  - if allowed conditions should require no/minimal damming of water course, and pre-determined maximum pipe/pump capacities

8.2.3 LAND MANAGEMENT

- Placement of high water affecting activities such as forestry, dairying, or irrigation should have a minimum buffer of 50m plus an additional free to flow area that is large enough to ensure a sustainable water balance for any environmental needs of the catchment.
  - Investigate the possibility of determining a standard relationship between the required buffer distances for wetland areas or other ecological needs.

No future development should further impact on the water quality of the region.

  - Certain regions may require integrated salinity management to ensure salinisation does not further impact on the catchment. Particular catchments highlighted by Liddicoat, et al (2004) include the Inman River and Waitpinga and Coolawang Creeks.
  - Agricultural land productivity could be maintained or improved with a balanced soil health program that ensures either an integrated organic program or appropriate levels and type of fertiliser are applied to the paddock and not within 50m of a watercourse or Fleurieu Peninsula Swamp.

8.3 MONITORING AND INVESTIGATIONS

Many of the mechanisms for management are likely to require fine tuning as further information becomes available, this is only possible if appropriate monitoring is in place:

- Improved distribution of rainfall data collection, particularly coastal and mid-slope area
- Enhance program of streamflow monitoring
  - Appropriate maintenance of existing gauging stations
  - Gaugings of existing gauging stations, particularly high flow regimes
  - Maintain expanded network of gauging station, established by this project for a minimum period of twelve years.
- Improved land management information
  - Irrigation rates = meters on irrigation and dairy production bores
- Improved understanding of interaction rates between surface and groundwater systems
- Water dependant ecosystems actual water requirements

    - Investigate what level of surface water development is likely to be acceptable before detrimental impact on ecological assets
    - Investigate cumulative impacts of different stress factors, eg forestry + farm dams + grazing
- Different land use impacts of hydrological cycle
    - Forestry – particularly water use at:
        - different age classes of
        - different forestry species and
        - covering different Hydrogeological units
- Localised Evapotranspiration rates
- Further refine the models constructed to cater for scenarios likely to be required for Water Allocation Processes.
- Finalise historic adjustment of Hindmarsh River gauging station to fully account for the diversion to the Hindmarsh Reservoir. This will extend the calibration period available.
- Model calibration and consequently our knowledge of the impact of farm dams on the Fleurieu Peninsula can be further improved once the land use survey (associated with the Notice of Prescription) is complete. This survey will identify those farm dams that have an irrigation demand and the average annual demand from them.
    - Yankalilla River catchment can also be calibrated properly once there is sufficient observed flow data. A short calibration period can skew the calibration..

Investigate rainfall to runoff relationships for all past data in conjunction with GIS analyses of land use characteristics to enable continued improvement in means for estimating runoff in ungauged catchments. It is well established that in the South Australian climate both losses and gains occur as flows move downstream. Current models do not take the losses into account and thus tend to underestimate the inter-actions between surface and groundwater.

APPENDIX A: AVERAGE SLOPES OF SOUTHERN FLUERIEU CATCHMENTS

No	Catchment	Catchment area sq.km	Average annual rainfall (mm)	Maximum elevation, m	Average slope of catchment	Rainfall station
1	Aaron & Tent Rock	16.5	677	326	14.5	Para
2	Anacotilla & Congeratinga Rivers	38.2	744	375	9.0	Para
3	Ballaparudda Creek	12.6	796	344	8.8	Para
4	Balquhidder	1.4	677	245	12.4	Para
5	Bare Rock	1.9	653	172	13.2	Para
6	Blowhole Creek	12.1	761	354	12.8	Para
7	Boat Habor Hill	0.9	544	134	15.3	Yank
8	Boat Harbor Creek	19.8	818	375	8.9	Para
9	Brown Hill	15.2	619	262	6.3	VicH
10	Bungala River	49.3	661	360	7.2	yank
11	Callawonga Creek	19.5	839	356	9.6	Para
12	Cape Jervis	17.3	574	290	8.7	Para
13	Carrickalinga Creek	55.9	712	421	9.2	yank
14	Carrickalinga Head	16.6	603	263	11.6	yank
15	Cooalinga Creek	3.5	725	346	18.6	Para
16	Coolawang Creek	40.8	796	363	8.1	Para
17	Dump Beach	1.4	542	52	4.6	VicH
18	First Creek	4.8	761	321	12.7	para
19	Fishery Creek	8.5	673	345	10.5	Para
20	Goolwa*	26.7	530	164	1.4	VicH
21	Hindmarsh River	55.7	879	441	9.5	Fern
	Hindmarsh River d/s	56.4	693		7.5	VicH
23	Inman River	164.3	757	441	7.5	InmV
	Inman River d/s	27.5	671		7.2	VicH
25	Lady Bay	1.3	560	182	14.7	Yank
26	Little Gorge	7.8	697	351	10.1	Yank
27	Middleton	16.2	665	284	6.5	VicH
28	Myponga River	75.5	862	443	5.0	Myp
	Myponga River d/s	63.4	774		6.6	Myp
30	Naiko Inlet	1.8	607	300	17.1	Para
31	Newland Head - The Bluff	19.0	647	173	6.5	VicH
32	Normanville	1.9	538	111	3.5	Yank
33	Parananacooka River	12.9	655	325	10.1	Para
34	Parsons Beach	6.1	638	133	6.4	Para

No	Catchment	Catchment area sq.km	Average annual rainfall (mm)	Maximum elevation, m	Average slope of catchment	Rainfall station
35	Port Elliot	7.5	554	152	3.4	VicH
36	Rapid Bay	1.2	564	223	19.5	Para
37	Rapid Head	5.9	576	274	14.3	Para
38	Salt Creek	15.8	675	343	10.4	Para
39	Starfish Hill	1.3	578	270	14.7	Para
40	Talisker	4.2	618	320	14.5	Para
41	Tapanappa	9.3	702	324	13.1	para
42	The Deep Creek	11.1	840	371	4.0	Para
	The Deep Creek d/s	30.2	795		6.8	Para
44	The Links	2.9	539	100	2.9	Yank
45	Tunk Head	4.6	682	241	14.5	Para
46	Tunkalilla Beach	7.5	727	313	12.6	Para
47	Tunkalilla Creek	26.5	834	375	8.4	Para
48	Victor Harbor	3.4	581	110	2.7	VicH
49	Victoria Wreck	1.7	655	217	11.4	Para
50	Waitpinga Creek	61.1	726	293	4.1	VicH
51	Wirrina Cove	2.4	578	152	11.9	Yank
52	Yankalilla River	63.7	775	375	8.7	Yank
	Yankalilla River d/s	19.4	702		8.7	Yank
54	Yattagolinga River	24.7	708	335	10.1	Para
55	Yohoe Creek	18.3	737	345	10.3	Para
	Grand Total, sq.km	**1,195.2**				

Rainfall gauging stations

M023708	2nd, Second valley (Spring Grove)
M023723	InmV, Yankalilla (Inman Valley)
M023738	Myp, Myponga
M023751	VicH, Victor harbour
M023754	Yank, Yankalilla
M023761	Para, Parawa (sharon)
M023823	Fern, Hindmarsh valley (fernbrook)
M023824	Hindmarsh valley (springmount)
M023743	Victor Harbor (Rivington Grange)

APPENDIX B: LAND USE CLASSIFICATION

APPENDIX B1: ANZLUC_DESCRIPTORS (1999 DATA) RECLASSIFIED INTO LAND USES RELATED TO HYDROLOGICAL PROCESSES

ANZLUC Descriptors	Grouping	NEW LAND USE	Total, ha	% Area
ACCOMMODATION	ACCOMMODATION	Urban	1,664	1.39%
AIRPORT / AIRSTRIP	OTHER	grass	28	0.02%
AQUACULTURE	OTHER	grass	3	0.00%
CULTURAL AND RECREATIONAL SERVICES	OTHER	grass	314	0.26%
DAIRY CATTLE	DAIRY CATTLE	crops	22,189	18.6%
EDUCATION	OTHER	grass	45	0.04%
FIELD CROPS ~ IRRIGATED AGRICULTURE	FIELD CROPS ~ IRRIGATED AGRICULTURE	crops	6	0.00%
FIELD CROPS ~ TEMPORAL AGRICULTURE	FIELD CROPS ~ TEMPORAL AGRICULTURE	grass	2,074	1.73%
FOREST PLANTATION	FOREST PLANTATION	Forest	3,959	3.31%
HORSES	HORSES	grass	943	0.79%
HORTICULTURE - TREES	HORTICULTURE - TREES	crops	127	0.11%
IMPROVED PASTURE NEC	IMPROVED PASTURE NEC	crops	3,876	3.24%
LANDSCAPE / SEASCAPE / CONSERVATION RECREATION AREA	OTHER	Natural vegetation	91	0.08%
LIVESTOCK	LIVESTOCK	grass	67,559	56.5%
MANUFACTURING	OTHER	Urban	25	0.02%
MINING OR EXTRACTIVE INDUSTRIES	OTHER	Forest	75	0.06%
OUTDOOR RECREATION AREA	OTHER	grass	411	0.34%
PROTECTED AREA	PROTECTED AREA	Natural vegetation	5,467	4.57%
PROTECTED AREA NEC	PROTECTED AREA NEC	Natural vegetation	8,568	7.17%
RURAL RESIDENTIAL ACCOMMODATION	RURAL RESIDENTIAL ACCOMMODATION	Natural vegetation	1,543	1.29%
SEWAGE NEC	SEWAGE NEC	Urban	35	0.03%
VEGETABLES NEC	OTHER	crops	42	0.04%
VINE FRUIT	OTHER	crops	246	0.21%
WATER STORAGE (RESERVOIR / DAM / TOWER / TANK)	OTHER	Urban	277	0.23%
Grand Total			**119,566**	**100.0%**

APPENDIX B2: NEW LAND USE CLASSIFICATION - 1999 LAND USE DATA FOR FLEURIEU CATCHMENTS

No	CATNAME	Forest	grass	crops	Natural veg	Urban	Grand Total, ha	Forest	grass	crops	Natural veg	Urban
1	Aaron & Tent Rock		345	1	1306		1652	0%	21%	0%	79%	0%
2	Anacotilla & Congeratinga Rivers	951	2128	415	302	24	3820	25%	56%	11%	8%	1%
3	Ballaparudda Creek	1	892	317	49		1259	0%	71%	25%	4%	0%
4	Balquhidder	0	136				136	0%	100%	0%	0%	0%
5	Bare Rock		177		8		185	0%	96%	0%	4%	0%
6	Blowhole Creek	0	980	75	155		1209	0%	81%	6%	13%	0%
7	Boat Habor Hill		73	15			87	0%	83%	17%	0%	0%
8	Boat Harbor Creek	38	1047	32	864		1981	2%	53%	2%	44%	0%
9	Brown Hill		1249	79	50	146	1525	0%	82%	5%	3%	10%
10	Bungala River	8	3660	824	296	144	4932	0%	74%	17%	6%	3%
11	Callawonga Creek	43	1118	404	385		1951	2%	57%	21%	20%	0%
12	Cape Jervis		1409	98	178	42	1727	0%	82%	6%	10%	2%
13	Carrickalinga Creek	10	2818	2072	635	54	5589	0%	50%	37%	11%	1%
14	Carrickalinga Head		1550	17	51	42	1659	0%	93%	1%	3%	3%
15	Cooalinga Creek		199		154		353	0%	56%	0%	44%	0%
16	Coolawang Creek		2428	1282	367		4077	0%	60%	31%	9%	0%
17	Dump Beach		17		14	104	135	0%	13%	0%	10%	77%
18	First Creek		299	1	182		481	0%	62%	0%	38%	0%
19	Fishery Creek		649	66	135		850	0%	76%	8%	16%	0%
20	Goolwa*	0	2407	96	60	86	2649	0%	91%	4%	2%	3%
21	Hindmarsh River	78	6124	3472	1399	135	11209	1%	55%	31%	12%	1%
22	Inman River	332	11039	5364	2307	142	19183	2%	58%	28%	12%	1%
23	Lady Bay		118		0	8	127	0%	93%	0%	0%	7%
24	Little Gorge	1	654	112	14		781	0%	84%	14%	2%	0%
25	Middleton		1453	101	29	34	1617	0%	90%	6%	2%	2%
26	Myponga River	375	7170	4897	1133	310	13885	3%	52%	35%	8%	2%
27	Naiko Inlet		175		6		181	0%	97%	0%	3%	0%
28	Newland Head - The Bluff		1007	3	593	302	1905	0%	53%	0%	31%	16%
29	Normanville		116		20	51	187	0%	62%	0%	11%	27%
30	Parananacooka River	110	953	154	42	34	1293	8%	74%	12%	3%	3%
31	Parsons Beach		443		163		606	0%	73%	0%	27%	0%
32	Port Elliot		473	17	127	130	748	0%	63%	2%	17%	17%
33	Rapid Bay		115			3	117	0%	98%	0%	0%	2%
34	Rapid Head	41	544			1	586	7%	93%	0%	0%	0%
35	Salt Creek	12	1035	497	40		1583	1%	65%	31%	3%	0%

No	CATNAME	Forest	grass	crops	Natural veg	Urban	Grand Total, ha	Forest	grass	crops	Natural veg	Urban
36	Starfish Hill		127				127	0%	100%	0%	0%	0%
37	Talisker		373	18	33		424	0%	88%	4%	8%	0%
38	Tapanappa		157		772		929	0%	17%	0%	83%	0%
39	The Deep Creek	335	1501	767	1526		4129	8%	36%	19%	37%	0%
40	The Links		199	43	4	47	293	0%	68%	15%	1%	16%
41	Tunk Head		461				461	0%	100%	0%	0%	0%
42	Tunkalilla Beach		650		98		748	0%	87%	0%	13%	0%
43	Tunkalilla Creek	183	1316	839	309		2648	7%	50%	32%	12%	0%
44	Victor Harbor		38	0	147	157	342	0%	11%	0%	43%	46%
45	Victoria Wreck		170				170	0%	100%	0%	0%	0%
46	Waitpinga Creek	2	4087	1291	734		6115	0%	67%	21%	12%	0%
47	Wirrina Cove		243	1			244	0%	100%	0%	0%	0%
48	Yankalilla River	826	4277	2394	811	0	8308	10%	51%	29%	10%	0%
49	Yattagolinga River	614	1533	245	77	4	2474	25%	62%	10%	3%	0%
50	Yohoe Creek	76	1212	456	82		1826	4%	66%	25%	4%	0%
51	(blank)				6		6	0%	0%	0%	100%	0%
	Grand Total*	4034	71377	26486	15668	2000	119566	3%	60%	22%	13%	2%
	*Note: Part of the Goolwa catchment outside the prescription boundary has been excluded in the grand total catchment area.											
	Currency Creek		35	20	2		57	0%	62%	34%	4%	0%

Gauged catchments	area, ha	Forest	grass	crops	Natural vegetation	urban
Hindmarsh	5575	46	2,564	2,197	767	0
Inman	16425	306	9,103	4,988	2,025	3
Myponga	7546	101	4,010	2,731	705	0
Yankalilla	6368	671	3,068	2,066	563	0
The Deep Creek	1105	322	584	3	195	0
	(percentage of catchment area)					
Hindmarsh		0.8	46.0	39.4	13.8	0.0
Inman		1.9	55.4	30.4	12.3	0.0
Myponga		1.3	53.1	36.2	9.3	0.0
Yankalilla		10.5	48.2	32.4	8.8	0.0
The Deep Creek		29.1	52.9	0.3	17.6	0.0

APPENDIX B3: ANZLUC CLASSIFICATIONS FOR FLEURIEU CATCHMENTS

No	CATNAME	ACCOMMODATION	AIRPORT / AIRSTRIP	AQUACULTURE	CULTURAL AND RECREATIONAL SERVICES	DAIRY CATTLE	EDUCATION	FIELD CROPS ~ IRRIGATED AGRICULTURE	FIELD CROPS ~ TEMPORAL AGRICULTURE	FOREST PLANTATION	HORSES	HORTICULTURE - TREES	IMPROVED PASTURE NEC	LANDSCAPE / SEASCAPE / CONSERVATION RECREATION ARFA	LIVESTOCK	MANUFACTURING	MINING OR EXTRACTIVE INDUSTRIES	OUTDOOR RECREATION AREA	PROTECTED AREA	PROTECTED AREA NEC	RURAL RESIDENTIAL ACCOMMODATION	SEWAGE NEC	VEGETABLES NEC	VINE FRUIT	WATER STORAGE (RESERVOIR / DAM / TOWER / TANK)	Grand Total
1	Aaron & Tent Rock					1			35		0				310			0	1,216	89	1					1,652
2	Anacotilla & Congeratinga Rivers	24			34	349	1		36	951			66		1,989			69		302						3,820
3	Ballaparudda Creek					205				1			112		892					48	2					1,259
4	Balquhidder									0					136											136
5	Bare Rock														177					8						185
6	Blowhole Creek					73				0	49		2		907			23	3	130	22					1,209
7	Boat Habor Hill					15									73											87
8	Boat Harbor Creek					32				38					1,047				653	211						1,981
9	Brown Hill	120			29	61		6	39		32	13		2	1,147	12		2			49	14				1,525
10	Bungala River	142			16	774	31		500	8	78		49		2,982	2		53		124	172					4,932
11	Callawonga Creek					404				43	31		0		1,087					385						1,951
12	Cape Jervis	42				70			238		63	28			1,108					115	62					1,727
13	Carrickalinga Creek	45			14	1,632			204	3	60	11	391		2,534	8	6	5	170	399	66			38		5,589
14	Carrickalinga Head	42			4	3					13	5	9		1,532					11	40					1,659
15	Cooalinga Creek														199				150	4						353

No	CATNAME	ACCOMMODATION	AIRPORT / AIRSTRIP	AQUACULTURE	CULTURAL AND RECREATIONAL SERVICES	DAIRY CATTLE	EDUCATION	FIELD CROPS ~ IRRIGATED AGRICULTURE	FIELD CROPS ~ TEMPORAL AGRICULTURE	FOREST PLANTATION	HORSES	HORTICULTURE - TREES	IMPROVED PASTURE NEC	LANDSCAPE / SEASCAPE / CONSERVATION RECREATION ARFA	LIVESTOCK	MANUFACTURING	MINING OR EXTRACTIVE INDUSTRIES	OUTDOOR RECREATION AREA	PROTECTED AREA	PROTECTED AREA NEC	RURAL RESIDENTIAL ACCOMMODATION	SEWAGE NEC	VEGETABLES NEC	VINE FRUIT	WATER STORAGE (RESERVOIR / DAM / TOWER / TANK)	Grand Total
16	Coolawang Creek					1,282									2,428					365	2					4,077
17	Dump Beach	104			7		2							14	8											135
18	First Creek					1									299					182						481
19	Fishery Creek					66					40				609				48	87	1					850
20	Goolwa	86	28		5	96			424	0	59			26	1,851			40		25	8			0		2,649
21	Hindmarsh River	126			29	2,444	7			78	62	2	1,003	1	5,949			77	5	1,276	116			23	9	11,209
22	Inman River	139		3	19	5,145	3			306	74	13	206	8	10,813		25	126	194	1,753	351	2				19,183
23	Lady Bay	8													118					0						127
24	Little Gorge					112			17	1					637					14						781
25	Middleton	34			5	27			65		36		40		1,345			1			29			34		1,617
26	Myponga River	22				3,520				375	204	32	1,261		6,961	2		6	41	841	251	18	42	42	267	13,885
27	Naiko Inlet														175				6							181
28	Newland Head - The Bluff	302			39	3			27		2			36	932			6	431	62	65					1,905
29	Normanville	51			22				0						94					20						187
30	Parananacooka River	34			1	99			30	110		6	23		923					26	17			26		1,293
31	Parsons Beach								58						386				138	24						606
32	Port Elliot	130			41	11	1		115					2	315			2	52		73			6		748
33	Rapid Bay	3													115											117
34	Rapid Head	1													544		41									586
35	SaltCreek					475			33	12					1,002					38	2			22		1,583

No	CATNAME	ACCOMMODATION	AIRPORT / AIRSTRIP	AQUACULTURE	CULTURAL AND RECREATIONAL SERVICES	DAIRY CATTLE	EDUCATION	FIELD CROPS ~ IRRIGATED AGRICULTURE	FIELD CROPS ~ TEMPORAL AGRICULTURE	FOREST PLANTATION	HORSES	HORTICULTURE - TREES	IMPROVED PASTURE NEC	LANDSCAPE / SEASCAPE / CONSERVATION RECREATION ARFA	LIVESTOCK	MANUFACTURING	MINING OR EXTRACTIVE INDUSTRIES	OUTDOOR RECREATION AREA	PROTECTED AREA	PROTECTED AREA NEC	RURAL RESIDENTIAL ACCOMMODATION	SEWAGE NEC	VEGETABLES NEC	VINE FRUIT	WATER STORAGE (RESERVOIR / DAM / TOWER / TANK)	Grand Total
36	StarfishHill														127											127
37	Talisker					18									373				18	15						424
38	Tapanappa														157				702	70						929
39	TheDeepCreek					736			0	335			31		1,501				1,212	312	2					4,129
40	TheLinks	47			26	17			9		16		14		148						4			11		293
41	TunkHead														461											461
42	TunkalillaBeach														650				2	96						748
43	TunkalillaCreek					838			75	183			2		1,241					309	1					2,648
44	VictorHarbor	157			20	0					2			2	16						145					342
45	VictoriaWreck														170											170
46	WaitpingaCreek					967			102		111	12	302		3,874		2		418	307	9			9		6,115
47	WirrinaCove					1									243											244
48	YankalillaRiver	0			2	2,056			68	826	3	4	299		4,205					806	4			35		8,308
49	YattagolingaRiver	4				235	1			614	5		10		1,527					55	21			0		2,474
50	YohoeCreek					400				76	3		56		1,209					57	25					1,826
51	(blank)																		6							6
	GrandTotal	1,664	28	3	314	22,189	45	6	2,074	3,959	943	127	3,876	91	67,559	25	75	411	5,467	8,568	1,543	35	42	246	277	119,566
52	CurrencyCreek					19					0		0		35						2					57

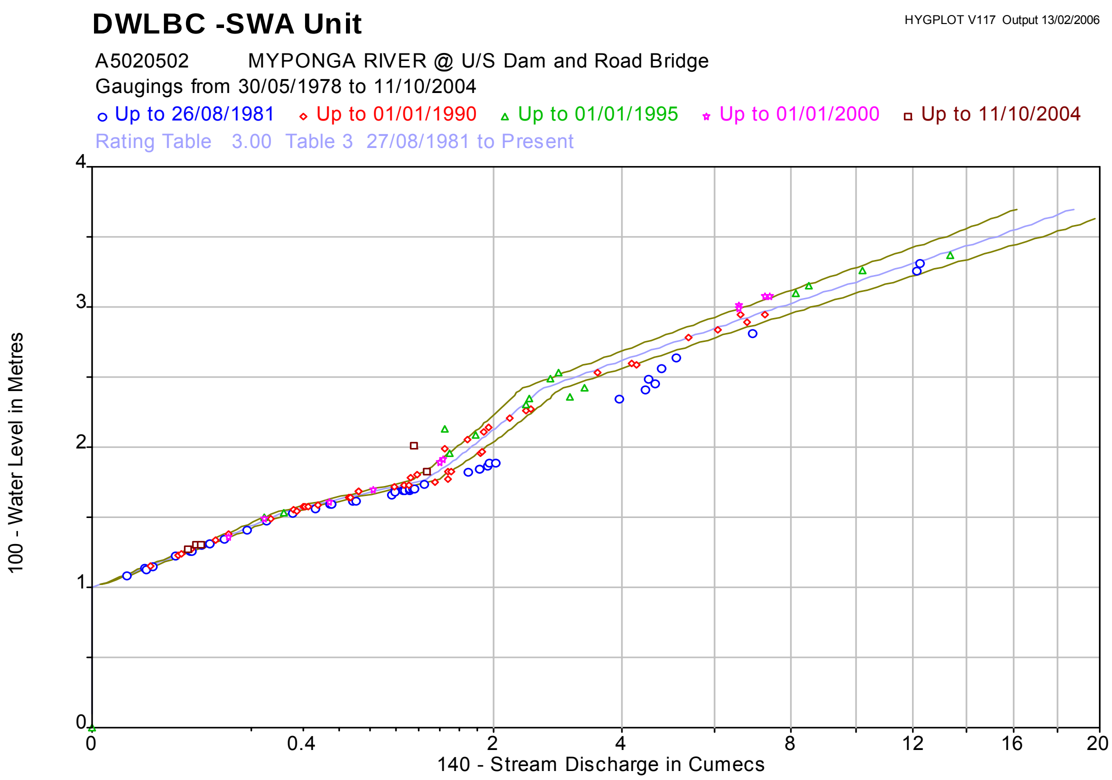
APPENDIX C: 2005 FARM DAM DATA

CATNAME	Catchment area sq.km	Farm dams < 5 ML Nos	Farm dams < 5 ML Volume ML	Farm dams > 5ML Nos	Farm dams > 5ML Volume ML	Total Nos	Total Volume ML	Total Farm dam density ML/sq.km
Aaron & Tent Rock	16.5	25	11	2	27	27	39	2.34
Anacotilla & Congeratinga Rivers	38.2	99	99	4	249	103	348	9.12
Ballaparudda Creek	12.6	54	34	6	151	60	185	14.70
Balquhidder	1.4	3	1			3	1	1.08
Blowhole Creek	12.1	67	46	1	8	68	54	4.47
Boat Harbor Creek	19.8	42	22	1	37	43	59	2.97
Brown Hill	15.2	66	50	16	159	82	209	13.73
Bungala River	49.3	260	223	9	84	269	307	6.22
Callawonga Creek	19.5	86	56	1	10	87	66	3.39
Cape Jervis	17.3	45	38	1	5	46	44	2.54
Carrickalinga Creek	55.9	369	298	20	407	389	705	12.61
Carrickalinga Head	16.6	42	32	2	15	44	47	2.84
Cooalinga Creek	3.5	2	1	1	8	3	9	2.43
Coolawang Creek	40.8	182	114	4	31	186	144	3.54
First Creek	4.8	15	10			15	10	2.05
Fishery Creek	8.5	21	15	7	88	28	103	12.13
Goolwa	26.7	35	18			35	18	0.68
Hindmarsh River	112.1	651	543	34	487	685	1,030	9.19
Inman River	191.8	1292	989	51	1,124	1343	2,113	11.01
Little Gorge	7.8	24	20			24	20	2.60
Middleton	16.2	81	63	1	25	82	88	5.47
Myponga River	138.9	709	651	45	636	754	1,287	9.27
Newland Head - The Bluff	19.0	48	26	3	272	51	299	15.68
Parananacooka River	12.9	51	40	2	19	53	59	4.55
Parsons Beach	6.1	12	5			12	5	0.77
Port Elliot	7.5	16	15	1	7	17	22	2.93
Rapid Head	5.9	2	1			2	1	0.14
Salt Creek	15.8	71	31	3	98	74	129	8.15
Starfish Hill	1.3	1	0			1	0	0.29
Talisker	4.2	2	1			2	1	0.34
Tapanappa	9.3	8	2			8	2	0.27
The Deep Creek	41.3	144	128	13	455	157	583	14.13
The Links	2.9	2	4	2	37	4	41	14.09

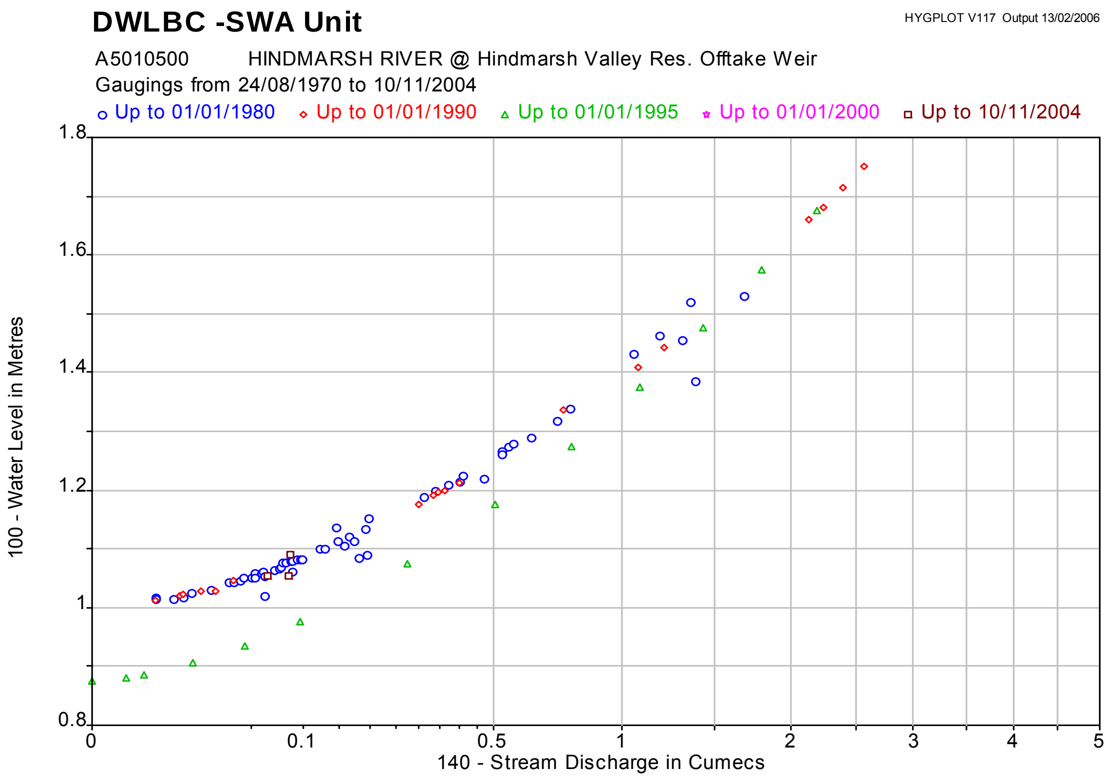
CATNAME	Catchment area sq.km	Farm dams < 5 ML Nos	Farm dams < 5 ML Volume ML	Farm dams > 5ML Nos	Farm dams > 5ML Volume ML	Total Nos	Total Volume ML	Total Farm dam density ML/sq.km
Tunk Head	4.6	10	8			10	8	1.74
Tunkalilla Beach	7.5	20	13			20	13	1.77
Tunkalilla Creek	26.5	125	63	3	37	128	100	3.76
Victor Harbor	3.4	6	3			6	3	0.79
Victoria Wreck	1.7	1	0			1	0	0.08
Waitpinga Creek	61.1	264	229	15	201	279	430	7.03
Wirrina Cove	2.4	4	2			4	2	0.67
Yankalilla River	83.1	385	282	24	667	409	948	11.41
Yattagolinga River	24.7	95	80	1	5	96	86	3.47
Yohoe Creek	18.3	124	72	5	92	129	165	9.03
Grand Total	1,185.0	5561	4,341	278	5,443	5839	9,784	8.26
Grand total inclusive of no dams catchments	**1,195.2**							**8.19**

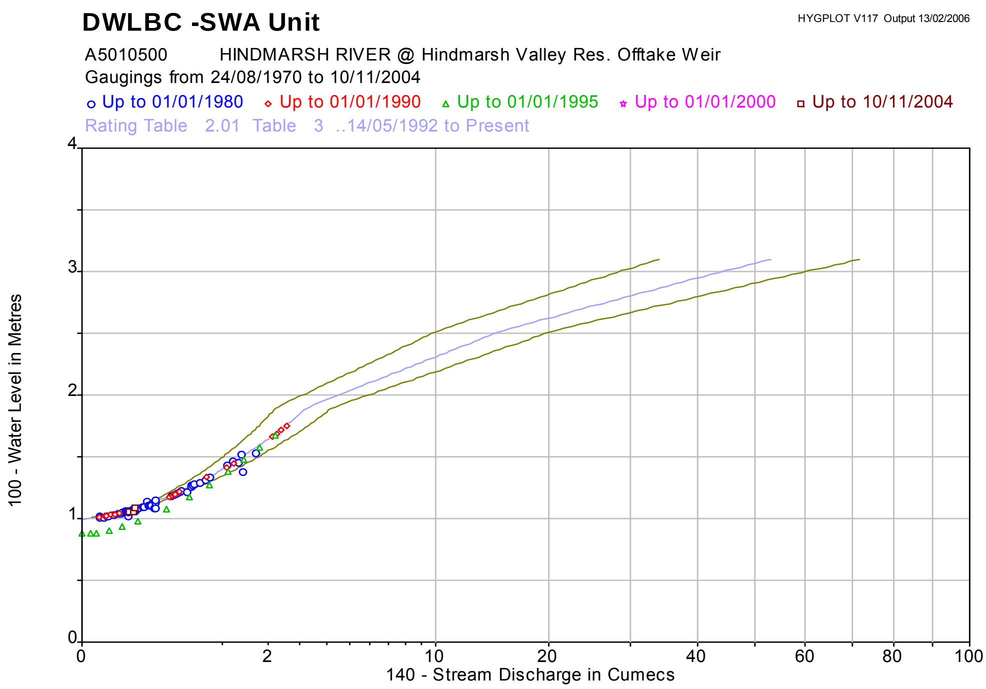
APPENDIX D: HYDROLOGICAL GAUGING STATION RATING CHARTS

Rating chart for Myponga River

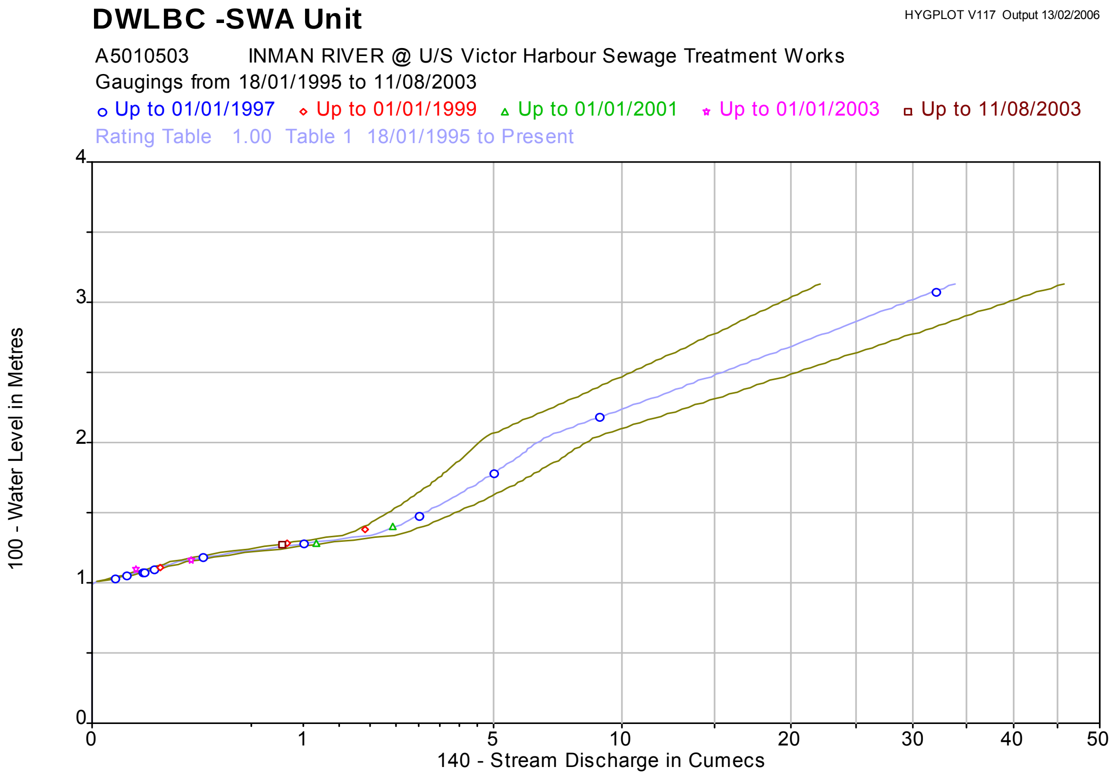


Rating charts for Hindmarsh River (A5010500)

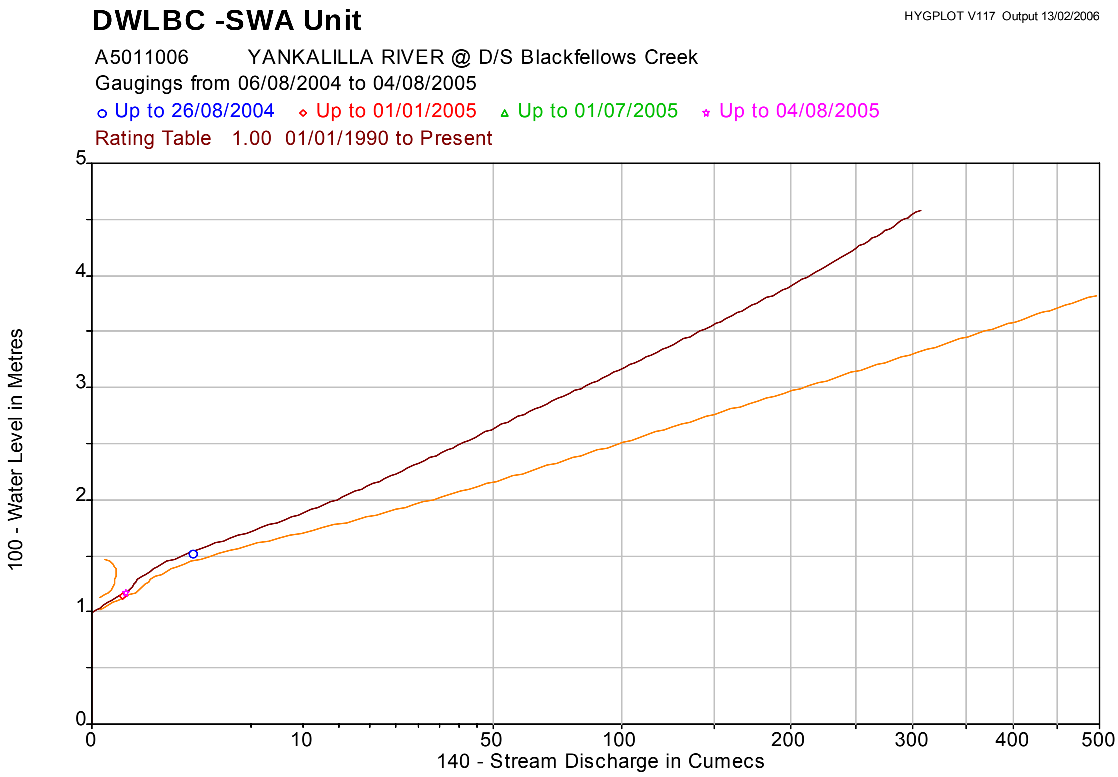




Rating chart for Inman River



Rating chart for Yankalilla River



APPENDIX E: TANH CALCULATIONS FOR UNGAUGED CATCHMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
			AvGs	605	1100	1200	1700	2200	AvGs		AvGs	AvGs		AvGs	AvGs		
		km^2	1335		Land use %				1337		6.9	1338		30	1334		
Catchment	Nos	Area	Fo	Urb.	Grass	Crops	Nt.Vg	Forest	F1	SqDiff	Slope	F2	SqDiff	%Sand	F3	SqDiff	%Dep
									1.030	10402		177	10122		506	4397	
Aaron & Tent Rock	1	16.5		0.0	20.9	0.0	79.1	0.0	1622		14.5	1552		0	1460		
Anacotilla & Congeratinga Rivers	2	38.2		0.6	55.7	10.9	7.9	24.9	1472		9.0	1454		10	1397		
Ballaparudda Creek	3	12.6		0.0	70.8	25.2	3.9	0.1	1184		8.8	1172		0	1102		
Balquhidder	4	1.4		0.0	99.8	0.0	0.0	0.2	1135		12.4	1100		0	1035		
Bare Rock	5	1.9		0.0	95.7	0.0	4.3	0.0	1159		13.2	1118		0	1052		
Blowhole Creek	6	12.1		0.0	81.0	6.2	12.8	0.0	1219		12.8	1178		0	1108		
Boat Habor Hill	7	0.9		0.0	83.2	16.8	0.0	0.0	1150		15.3	1096		0	1031		
Boat Harbor Creek	8	19.8		0.0	52.8	1.6	43.6	1.9	1426		8.9	1410		0	1326		
Brown Hill	9	15.2		9.6	81.9	5.2	3.3	0.0	1110		6.3	1114		25	1103		
Bungala River	10	49.3		2.9	74.2	16.7	6.0	0.2	1174		7.2	1172		75	1277		
Callawonga Creek	11	19.5		0.0	57.3	20.7	19.7	2.2	1301		9.6	1282		0	1206		
Cape Jervis	12	17.3		2.5	81.6	5.7	10.3	0.0	1190		8.7	1178		5	1120		
Carrickalinga Creek	13	55.9		1.0	50.4	37.1	11.4	0.2	1238		9.2	1223		50	1271		
Carrickalinga Head	14	16.6		2.5	93.4	1.0	3.0	0.0	1140		11.6	1110		5	1055		
Cooalinga Creek	15	3.5		0.0	56.4	0.0	43.6	0.0	1402		18.6	1310		0	1233		
Coolawang Creek	16	40.8		0.0	59.6	31.5	9.0	0.0	1221		8.1	1213		25	1201		
Dump Beach	17	1.4		77.0	12.5	0.0	10.5	0.0	805		4.6	816		85	904		
First Creek	18	4.8		0.0	62.0	0.1	37.9	0.0	1367		12.7	1323		0	1244		
Fishery Creek	19	8.5		0.0	76.3	7.8	15.9	0.0	1239		10.5	1214		0	1142		

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Goolwa	20	26.7		3.3	90.9	3.6	2.3	0.0	1134		1.4	1169		0	1100		
Hindmarsh River	21	**55.7**	**1160**	**0.0**	**46.0**	**39.4**	**13.8**	**0.8**	**1268**	11612	**9.5**	**1249**	7999	**5**	**1188**	770	**-2**
Hindmarsh River d/s	22	56.4		2.4	63.2	22.7	11.2	0.6	1220		7.5	1216		45	1252		
Inman River	23	**164.3**	**1420**	**0.0**	**55.4**	**30.4**	**12.3**	**1.9**	**1261**	25127	**7.5**	**1258**	26403	**75**	**1369**	2573	4
Inman River d/s	24	27.5		5.0	70.2	13.6	10.2	0.9	1195		7.2	1193		25	1181		
Lady Bay	25	1.3		6.6	93.3	0.0	0.1	0.0	1100		14.7	1051		20	1031		
Little Gorge	26	7.8		0.0	83.7	14.3	1.8	0.2	1161		10.1	1140		15	1107		
Middleton	27	16.2		2.1	89.8	6.3	1.8	0.0	1140		6.5	1143		5	1086		
Myponga River	28	**75.5**	**1320**	**0.0**	**53.1**	**36.2**	**9.3**	**1.3**	**1243**	5878	**5.0**	**1257**	3973	**20**	**1232**	7718.6	7
Myponga River d/s	29	63.4		4.9	49.9	34.2	6.7	4.3	1234		6.6	1236		30	1236		
Naiko Inlet	30	1.8		0.0	96.5	0.0	3.5	0.0	1154		17.1	1088		0	1024		
Newland Head - The Bluff	31	19.0		15.8	52.8	0.2	31.1	0.0	1245		6.5	1248		15	1211		
Normanville	32	1.9		27.3	61.9	0.0	10.9	0.0	1061		3.5	1081		60	1145		
Parananacooka River	33	12.9		2.6	73.7	11.9	3.3	8.5	1248		10.1	1226		15	1190		
Parsons Beach	34	6.1		0.0	73.2	0.0	26.8	0.0	1299		6.4	1302		15	1264		
Port Elliot	35	7.5		17.4	63.3	2.3	17.0	0.0	1152		3.4	1175		5	1117		
Rapid Bay	36	1.2		2.1	97.9	0.0	0.0	0.0	1122		19.5	1043		0	981		
Rapid Head	37	5.9		0.1	92.9	0.0	0.0	6.9	1211		14.3	1160		5	1103		
Salt Creek	38	15.8		0.0	65.3	31.4	2.5	0.7	1189		10.4	1166		30	1166		
Starfish Hill	39	1.3		0.0	100.0	0.0	0.0	0.0	1133		14.7	1084		0	1019		
Talisker	40	4.2		0.0	87.8	4.3	7.8	0.0	1186		14.5	1136		0	1068		
Tapanappa	41	9.3		0.0	16.9	0.0	83.1	0.0	1647		13.1	1590		0	1495		
The Deep Creek	42	**11.1**	**1500**	**0.0**	**52.9**	**0.3**	**17.6**	**29.1**	**1571**	5108	**4.0**	**1598**	9524	**0**	**1503**	9	0
The Deep Creek d/s	43	30.2		0.0	30.3	25.3	44.1	0.4	1436		6.8	1437		0	1352		
The Links	44	2.9		16.1	68.0	14.6	1.4	0.0	1074		2.9	1099		20	1077		
Tunk Head	45	4.6		0.0	100.0	0.0	0.0	0.0	1133		14.5	1084		0	1020		
Tunkalilla Beach	46	7.5		0.0	86.9	0.0	13.1	0.0	1214		12.6	1175		0	1106		

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Tunkalilla Creek	47	26.5		0.0	49.7	31.7	11.7	6.9	1316		8.4	1306		0	1228		
Victor Harbor	48	3.4		45.8	11.2	0.1	42.9	0.0	1165		2.7	1192		60	1263		
Victoria Wreck	49	1.7		0.0	100.0	0.0	0.0	0.0	1133		11.4	1104		0	1039		
Waitpinga Creek	50	61.1		0.0	66.8	21.1	12.0	0.0	1229		4.1	1249		0	1175		
Wirrina Cove	51	2.4		0.0	99.5	0.5	0.0	0.0	1133		11.9	1102		75	1200		
Yankalilla River	52	**63.7**	**1275**	**0.0**	**48.2**	**32.4**	**8.8**	**10.5**	**1340**	4282	**8.7**	**1327**	2709	**50**	**1379**	10915	-8
Yankalilla River d/s	53	19.4		0.0	62.3	16.9	12.8	8.0	1320		8.7	1307		40	1333		
Yattagolinga River	54	24.7		0.2	62.0	9.9	3.1	24.8	1443		10.1	1417		25	1403		
Yohoe Creek	55	18.3		0.0	66.4	25.0	4.5	4.1	1233		10.3	1210		10	1162		

APPENDIX F: FLOW REDUCTION CALCULATIONS FOR UNGAUGED CATCHMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
				Index	Bom ave	Nat flow	Nat flow	Runoff	2005	Dam	Flow	Flow	Flow	Present	Present
		Area	F3	rainfall	Rain	Runoff	Runoff	Coef	FDD	Vol	Redctn	Redctn	Redctn	flow	flow
Catchment	Nos	km2			mm/a	mm/a	ML/a		mm	ML	%	mm	ML	mm/a	ML/a
Aaron & Tent Rock	1	16.5	1460	Para	677	48.0	793	7.1	2.3	38.6	10.3	5.0	82	43.0	711
Anacotilla & Congeratinga Rivers	2	38.2	1397	Para	744	67.7	2586	9.1	9.1	347.9	12.4	8.4	320	59.3	2267
Ballaparudda Creek	3	12.6	1102	Para	796	121.2	1526	15.2	14.7	185.1	7.4	8.9	112	112.3	1413
Balquhidder	4	1.4	1035	Para	677	87.5	119	12.9	0.9	1.2	2.2	1.9	3	85.6	116
Bare Rock	5	1.9	1052	Para	653	77.3	143	11.8	5.0	9.3	7.5	5.8	11	71.5	132
Blowhole Creek	6	12.1	1108	Para	761	106.6	1289	14.0	4.5	54.0	4.0	4.3	52	102.3	1238
Boat Habor Hill	7	0.9	1031	Yank	544	49.4	43	9.1	6.0	5.2	14.8	7.3	6	42.1	37
Boat Harbor Creek	8	19.8	1326	Para	818	95.9	1899	11.7	3.0	58.8	3.8	3.6	72	92.3	1828
Brown Hill	9	15.2	1103	VicH	619	61.3	935	9.9	13.7	209.4	17.0	10.4	159	50.9	776
Bungala River	10	49.3	1277	yank	661	58.0	2861	8.8	6.2	305.0	12.4	7.2	355	50.8	2506
Callawonga Creek	11	19.5	1206	Para	839	120.0	2341	14.3	3.4	66.1	2.6	3.1	61	116.9	2280
Cape Jervis	12	17.3	1120	Para	574	48.6	839	8.5	2.5	43.8	10.5	5.1	88	43.5	751
Carrickalinga Creek	13	55.9	1271	yank	712	71.8	4013	10.1	12.6	704.9	13.6	9.8	547	62.0	3466
Carrickalinga Head	14	16.6	1055	yank	603	63.0	1045	10.4	2.8	47.0	7.6	4.8	80	58.2	965
Cooalinga Creek	15	3.5	1233	Para	725	78.3	276	10.8	2.4	8.6	4.9	3.8	14	74.5	263
Coolawang Creek	16	40.8	1201	Para	796	105.0	4281	13.2	3.5	144.4	3.5	3.7	151	101.3	4129

Dump Beach	17	1.4	904	VicH	542	60.1	81	11.1	2.5	3.4	7.7	4.6	6	55.5	75
First Creek	18	4.8	1244	para	761	87.9	423	11.6	2.0	9.8	3.6	3.1	15	84.8	408
Fishery Creek	19	8.5	1142	Para	673	73.0	621	10.8	12.1	103.2	13.1	9.6	81	63.4	540
Goolwa	20	26.7	1100	VicH	530	40.1	1069	7.6	0.3	18.2	6.2	2.5	66	37.6	1002
Hindmarsh River	21	**55.7**	1188	Fern	**879**	**139.4**	**7765**	**15.9**	**9.0**	**501.3**	**4.0**	**5.6**	**309**	**133.8**	**7455**
Hindmarsh River d/s	22	56.4	1252	VicH	693	67.0	3778	9.7	9.1	515.8	12.5	8.4	474	58.6	3304
Inman River	23	**164.3**	1369	InmV	**757**	**73.8**	**12125**	**9.8**	**11.0**	**1807.3**	**12.3**	**9.0**	**1485**	**64.8**	**10640**
Inman River d/s	24	27.5	1181	VicH	671	67.9	1869	10.1	11.0	303.2	13.6	9.2	254	58.7	1616
Lady Bay	25	1.3	1031	Yank	560	53.5	68	9.6	2.0	2.5	8.3	4.4	6	49.1	62
Little Gorge	26	7.8	1107	Yank	697	85.9	671	12.3	2.6	20.3	4.3	3.7	29	82.2	642
Middleton	27	16.2	1086	VicH	665	76.5	1237	11.5	5.5	88.4	8.0	6.1	99	70.4	1138
Myponga River	28	**75.5**	1232	Myp	**862**	**127.2**	**9604**	**14.8**	**11.0**	**830.5**	**5.5**	**7.0**	**527**	**120.2**	**9076**
Myponga River d/s	29	63.4	1236	Myp	774	95.4	6043	12.3	9.3	586.9	7.8	7.4	470	88.0	5573
Naiko Inlet	30	1.8	1024	Para	607	66.4	120	10.9	1.0	1.8	4.1	2.8	5	63.6	115
Newland Head - The Bluff	31	19.0	1211	VicH	647	58.9	1122	9.1	2.5	46.8	7.9	4.6	88	54.3	1034
Normanville	32	1.9	1145	Yank	538	39.8	75	7.4	1.5	2.8	11.1	4.4	8	35.4	66
Parananacooka River	33	12.9	1190	Para	655	63.2	817	9.6	4.5	58.5	9.5	6.0	78	57.2	739
Parsons Beach	34	6.1	1264	Para	638	52.6	319	8.2	0.8	4.6	5.6	2.9	18	49.7	301
Port Elliot	35	7.5	1117	VicH	554	44.1	330	8.0	2.9	21.9	12.6	5.6	42	38.5	288
Rapid Bay	36	1.2	981	Para	564	58.6	69	10.4	0.7	0.8	4.4	2.6	3	56.0	66
Rapid Head	37	5.9	1103	Para	576	50.6	296	8.8	0.0	0.0	0.0	0.0	0	50.6	296
Salt Creek	38	15.8	1166	Para	675	70.9	1123	10.5	8.2	129.1	11.0	7.8	123	63.1	999
Starfish Hill	39	1.3	1019	Para	578	58.6	75	10.1	0.3	0.4	2.9	1.7	2	56.9	72
Talisker	40	4.2	1068	Para	618	64.8	275	10.5	0.3	1.4	2.5	1.6	7	63.2	268
Tapanappa	41	9.3	1495	para	702	50.9	473	7.3	0.3	2.5	3.7	1.9	18	49.0	455
The Deep Creek	42	**11.1**	1503	Para	**840**	**83.1**	**922**	**9.9**	**14.1**	**156.8**	**12.1**	**10.1**	**112**	**73.0**	**810**

The Deep Creek d/s	43	30.2	1352	Para	795	85.7	2587	10.8	14.1	426.5	11.7	10.0	302	75.7	2285
The Links	44	2.9	1077	Yank	539	44.7	131	8.3	14.1	41.3	23.2	10.4	30	34.3	101
Tunk Head	45	4.6	1020	Para	682	91.3	421	13.4	1.7	8.0	3.0	2.7	13	88.6	409
Tunkalilla Beach	46	7.5	1106	Para	727	95.0	711	13.1	1.8	13.2	2.8	2.6	20	92.4	691
Tunkalilla Creek	47	26.5	1228	Para	834	114.8	3040	13.8	3.8	99.6	3.1	3.5	94	111.3	2946
Victor Harbor	48	3.4	1263	VicH	581	40.4	138	7.0	0.8	2.7	8.6	3.5	12	36.9	126
Victoria Wreck	49	1.7	1039	Para	655	79.7	135	12.2	0.1	0.1	0.7	0.5	1	79.2	135
Waitpinga Creek	50	61.1	1175	VicH	726	85.0	5198	11.7	7.0	428.9	7.8	6.7	407	78.3	4791
Wirrina Cove	51	2.4	1200	Yank	578	44.7	109	7.7	0.7	1.6	6.9	3.1	8	41.6	102
Yankalilla River	52	**63.7**	1379	Yank	**775**	**78.6**	**5007**	**10.1**	**11.4**	**726.8**	**11.5**	**9.1**	**578**	**69.5**	**4429**
Yankalilla River d/s	53	19.4	1333	Yank	702	63.6	1234	9.1	11.4	221.3	14.9	9.5	184	54.1	1050
Yattagolinga River	54	24.7	1403	Para	708	58.4	1445	8.3	3.5	85.7	9.4	5.5	135	52.9	1309
Yohoe Creek	55	18.3	1162	Para	737	90.4	1651	12.3	8.9	163.2	8.2	7.5	136	82.9	1514
Grand total		1195.2					**98164**								**89809**

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

GLOSSARY

Ambient — The background level of an environmental parameter (eg. a measure of water quality such as salinity)

Ambient water monitoring — All forms of monitoring conducted beyond the immediate influence of a discharge pipe or injection well, and may include sampling of sediments and living resources

Ambient water quality — The overall quality of water when all the effects that may impact upon the water quality are taken into consideration

Annual adjusted catchment yield — Annual catchment yield with the impact of dams removed

Aquatic community — An association of interacting populations of aquatic organisms in a given water body or habitat

Aquatic ecosystem — The stream channel, lake or estuary bed, water, and/or biotic communities, and the habitat features that occur therein

Aquatic habitat — Environments characterised by the presence of standing or flowing water

Aquatic macrophytes — Any non-microscopic plant that requires the presence of water to grow and reproduce

AusRivAS — Australian River Assessment System; a national river and stream health assessment program run by the Australian Government

Baseflow — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Biodiversity — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

Biological diversity — See 'biodiversity'

Biological integrity — Functionally defined as the condition of the aquatic community that inhabits unimpaired water bodies of a specified habitat as measured by community structure and function

Biomonitoring — The measurement of biological parameters in repetition to assess the current status and changes in time of the parameters measured

Biota — All of the organisms at a particular locality

BoM — Bureau of Meteorology, Australia

Buffer zone — A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (eg. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses)

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

Catchment Water Management Board — A statutory body established under the Act whose prime

Codes of practice — Standards of management developed by industry and government, promoting techniques or methods of environmental management by which environmental objectives may be achieved

COAG — Council of Australian Governments; a council of the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association which exists to set national policy directions for Australia

CSIRO — Commonwealth Scientific and Industrial Research Organisation

Dams, off-stream dam — A dam, wall or other structure that is not constructed across a watercourse or drainage path and is designed to hold water diverted or pumped from a watercourse, a drainage path, an aquifer or from another source; may capture a limited volume of surface water from the catchment above the dam

Dams, on-stream dam — A dam, wall or other structure placed or constructed on, in or across a watercourse or drainage path for the purpose of holding and storing the natural flow of that watercourse or the surface water

Dams, turkey nest dam — An off-stream dam that does not capture any surface water from the catchment above the dam

Diversity — The distribution and abundance of different kinds of plant and animal species and communities in a specified area

d/s — Downstream

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia)

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

ESD — Ecologically sustainable development; using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased

Ecological processes — All biological, physical or chemical processes that maintain an ecosystem

Ecological values — The habitats, natural ecological processes and biodiversity of ecosystems

Ecology — The study of the relationships between living organisms and their environment

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

EMLR — Eastern Mount Lofty Ranges

Environmental water provisions — That part of environmental water requirements that can be met; what can be provided at a particular time after consideration of existing users' rights, and social and economic impacts

Environmental water requirements — The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk

Ephemeral streams or wetlands — Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

Estuaries — Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences, and experience periodic fluctuations and gradients in salinity

Estuarine habitat — Tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater run-off from the land

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

EWS — Engineering and Water Supply Department (Government of South Australia); now 'SA Water'

Fixed-station monitoring — The repeated long-term sampling or measurement of parameters at representative points for the purpose of determining environmental quality characteristics and trends

Floodout — An area where channelised flow ceases and floodwaters spill across adjacent alluvial plains

Floodplain — Of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development (SA) Act 1993*; or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

Flow bands — Flows of different frequency, volume and duration

Flow regime — The character of the timing and amount of flow in a stream

Geological features — Include geological monuments, landscape amenity and the substrate of land systems and ecosystems

Geomorphic — Related to the physical properties of the rock, soil and water in and around a stream

Geomorphology — The scientific study of the landforms on the Earth's surface and of the processes that have fashioned them

GIS — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis

Greenhouse effect — The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere, such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers; see also 'hydrology'

Hydrography — The discipline related to the measurement and recording of parameters associated with the hydrological cycle, both historic and real time

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

Hydrometric — Literally relating to water measurement, from the Greek words 'hydro' (water) and metrikos (measurement); see also DWLBC fact sheet FS1 <http://www.dwlbc.sa.gov.au/assets/files/fs0001_hydrometric_surface_water_monitoring.pdf>

Hydstra — A time series data management system that stores continuously recorded water-related data such as water level, salinity and temperature; it provides a powerful data analysis, modelling and simulation system; contains details of site locations, setup and other supporting information

Impact — A change in the chemical, physical, or biological quality or condition of a water body caused by external sources

Impairment — A detrimental effect on the biological integrity of a water body caused by impact that prevents attainment of the designated use

Implementation monitoring — Documents whether or not management practices were applied as designed; project and contract administration is a part of implementation monitoring

Infrastructure — Artificial lakes; dams or reservoirs; embankments, walls, channels or other works; buildings or structures; or pipes, machinery or other equipment

Integrated catchment management — Natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints

Irrigation — Watering land by any means for the purpose of growing plants

Irrigation season — The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May

Lake — A natural lake, pond, lagoon, wetland or spring (whether modified or not) that includes part of a lake and a body of water declared by regulation to be a lake. A reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

Land — Whether under water or not, and includes an interest in land and any building or structure fixed to the land

MLR — Mount Lofty Ranges

Model — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change

Monitoring — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things

Native species — Any animal and plant species originally in Australia; see also 'indigenous species'

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

NRM — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively

NLWRA — National Land and Water Resource Audit; 'The Audit'

Pasture — Grassland used for the production of grazing animals such as sheep and cattle

Percentile — A way of describing sets of data by ranking the dataset and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

Pluviometer — An automated rain gauge consisting of an instrument to measure the quantity of precipitation over a set period of time

Precautionary principle — Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation

Prescribed area, surface water — Part of the state declared to be a surface water prescribed area under the Act

Prescribed lake — A lake declared to be a prescribed lake under the Act

Prescribed watercourse — A watercourse declared to be a prescribed watercourse under the Act

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Ramsar Convention — This is an international treaty on wetlands titled *The Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

SA Water — South Australian Water Corporation (Government of South Australia)

State Water Plan — Policy document prepared by the Minister that sets the strategic direction for water resource management in the State and policies for achieving the objects of the *Natural Resources Management (SA) Act 2004*

Sub-catchment — The area of land determined by topographical features within which rainfall will contribute to run-off at a particular point

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

Surface Water Archive — An internet-based database linked to Hydstra and operated by DWLBC. It contains rainfall, water level, streamflow and salinity data collected from a network of surface water monitoring sites located throughout South Australia

TDS — Total dissolved solids, measured in milligrams per litre (mg/L); a measure of water salinity

Tributary — A river or creek that flows into a larger river

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

u/s — Upstream

WAP — Water Allocation Plan; a plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with the Act

Water body — Includes watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

Water-dependent ecosystems — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems

Water hardness — A measure of the amount of metallic salts (normally Ca and Mg) found in water; hard water can inhibit the action of some surfactants and reduce the effectiveness of the cleaning process

Water resource monitoring — An integrated activity for evaluating the physical, chemical, and biological character of water resources, including (1) surface waters, groundwaters, estuaries, and near-coastal waters; and (2) associated aquatic communities and physical habitats, which include wetlands

Watershed — The land area that drains into a stream, river, lake, estuary, or coastal zone

WDE — Water dependent ecosystem

Well — (1) An opening in the ground excavated for the purpose of obtaining access to underground water. (2) An opening in the ground excavated for some other purpose but that gives access to underground water. (3) A natural opening in the ground that gives access to underground water

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres.

WMLR — Western Mount Lofty Ranges

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