DWLBC REPORT

Surface water assessment of the Currency Creek Catchment

2006/07

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

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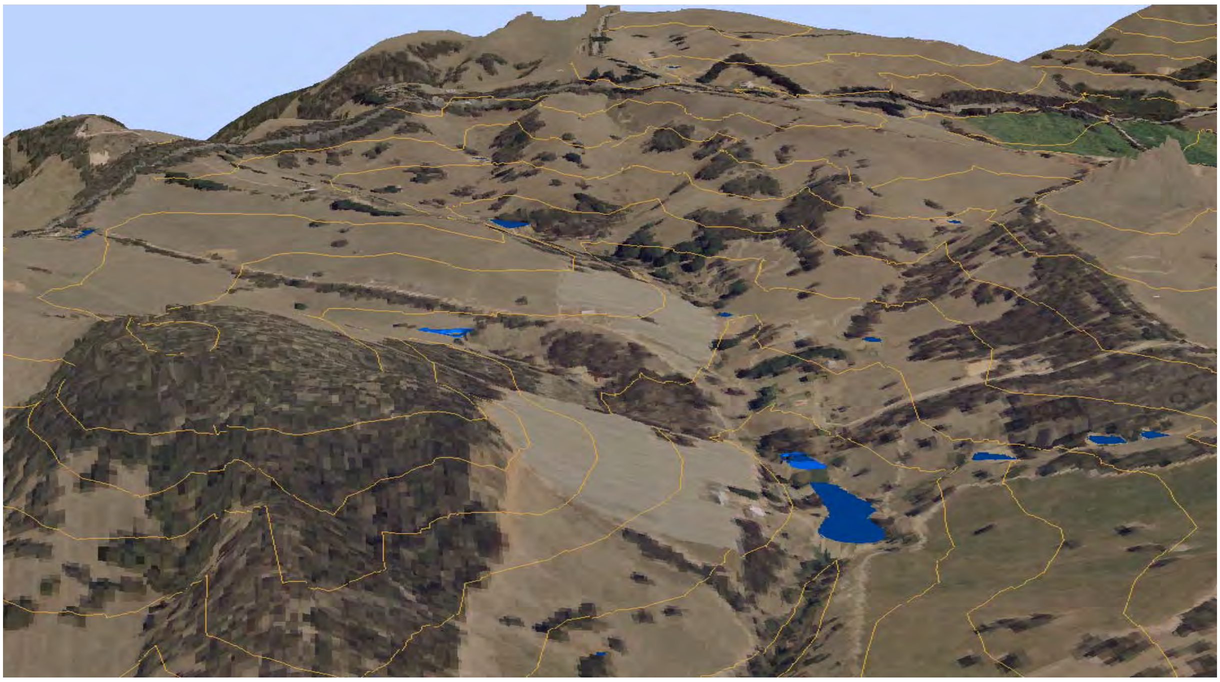

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Department of Water, Land and Biodiversity Conservation

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Government of South Australia
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Knowledge and Information Division

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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.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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EXECUTIVE SUMMARY

This technical report describes the methodology and outcomes of the detailed hydrological study of the Currency Creek catchment. It is one of the series of detailed hydrological studies undertaken for the individual catchments in the Eastern Mount Lofty Ranges Prescribed Area. The study quantifies the surface water resources within the catchment, examines the impact of farm dams on the resources using rainfall-runoff modelling, and provides guidance regarding future water resources management policies.

This report will be used as a technical foundation for the state government's consideration of water resources management measures required for this catchment. The main findings of the study are summarised below and further detailed in the conclusions section of the report.

Catchment Hydrology

The Currency Creek Catchment is about 60 km southeast of Adelaide in the most southern region of the Mount Lofty Ranges. Rainfall in the catchment varies from around 800 mm in the west to as low as 350 mm on the plains. The long-term (1936–2003) mean and median annual rainfall at rainfall station Marshall Brae (M023838) are 718 and 726 mm, respectively, making it a quite wet and high-yielding catchment.

The catchment plays host to a variety of flora and fauna including the nationally listed critically endangered Southern Fleurieu Swamps, and the endangered Mount Lofty Ranges Southern Emu-wren.

Streamflow measurements, collected in the catchment from 1972 until 1993, indicate a mean and median annual streamflow of 6070 and 6030 ML, respectively.

The relationship between rainfall and runoff suggests a runoff coefficient of around 14%, which is higher than the regional estimate used in the RMCWMP to estimate development limits, and comparable to other catchments in the southern Mount Lofty Ranges.

Farm Dam Development

Based on a combination of aerial photography and survey findings, there are around 515 dams with a combined estimated capacity of 1261 ML in the Currency Creek Catchment. The distribution of dams roughly follows the distribution of rainfall, with higher development in the upper reaches, with corresponding higher rainfall. The catchment is under-developed in relation to the River Murray Catchment Water Management Plan (RMCWMP) development limits, with dam volume accounting for 19% of mean winter runoff at the gauge.

Impacts of Farm Dams on the Hydrology of the catchment

It is estimated that farm dam development has led to a decrease in mean annual streamflow at the gauging station of 765 ML (11% of mean annual flow).

Seasonally, the effects are greatest in the autumn with flows being reduced by around 50% in that period. Summer months are also affected with a flow decrease of 45%.

On a daily time scale, farm dams have had the effect of decreasing the range of low flows below around 20 ML/d with minimal impact on high flows. It has also led to an expected decrease in the median daily flow from 5.6 ML to 2.8 ML; a reduction of 49%.

Recommendations

- Streamflow data have not been collected in the Currency Creek Catchment since 1993. In order to update the understanding of the surface water regime, it is recommended that:
    - The decommissioned gauging station be reinstated, or replaced in another suitable location.
    - Further monitoring sites be established downstream of the historical station in order to improve understanding of recharge–discharge mechanisms, and improve estimates of whole-of-catchment yields.
- In order to correctly assess the impact of farm dams, it is necessary to improve the estimation of farm dam capacities. Accurately surveying farm dams in key positions within the catchment would greatly enhance the ability of the process to predict the impact of farm dams.
- Improved catchment modelling depends on both quality streamflow data and climatological data. The use of sub-daily data would greatly improve current modelling and understanding of catchment hydrology. It is recommended that, where possible, data from relevant pluviometers be used to construct and calibrate catchment rainfall-runoff models.

Reductions in catchment yield, reduced flows during transitional seasons, and decreased low and medium flows will require various management mechanisms to ensure sustainability of the resource. It is therefore recommended that:

- Further development of farm dams in the catchment be restricted until an appropriate water allocation plan is in place, and provision for suitable measures for water trading is made. Future development should meanwhile abide by existing rules as set out in the RMCWMP.
- Following the adoption of a water allocation plan, monitoring will be necessary to gauge any impacts or improvements due to the management options.
- Best practice irrigation measures be encouraged to enhance the capability of the resource to cope with development.
- Under the current Notice of Prescription, stock and domestic dams are exempt from any management rules. This provides the catchment management board with little flexibility in terms of placing future restrictions on extraction, diversion or use. It is recommended that this decision be revisited at the review of the first water allocation plan.

1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF STUDY

This report describes the assessment of the surface water resources of the Currency Creek Catchment upstream of gauging station AW426539. It was undertaken as part of the Eastern Mount Lofty Ranges Water Resources Management Program of the Department of Water, Land and Biodiversity Conservation (DWLBC) and the South Australian Murray-Darling Basin Natural Resource Management Board (SAMDBNRMB). The report describes the methodology and outcomes of the study, and provides surface water resource management options for the future.

The study has the following scope:

- quantification of the surface water resource
- construction and calibration of a rainfall-runoff model
- assessment of the impact of farm dams on the catchment.

1.2 BACKGROUND

Surface water use in the highlands and groundwater use on the plains are vital to the economics of the Eastern Mount Lofty Ranges region (EMLR). However, the rapid development of farm dams over the last two decades in the EMLR has raised considerable concern on the sustainability of water resources and the impacts seen on the ecosystems dependent on them. Preliminary investigations indicate that farm dam development in the high rainfall areas of a number of catchments in the EMLR have either reached or exceeded allowable levels as defined in the Catchment Water Management Plan for the River Murray in South Australia (RMCWMP).

This led to the state government declaring both a Notice of Prohibition and a Notice of Intent to Prescribe the watercourse, surface and ground water resources of the EMLR. Following the declaration, the Eastern Mount Lofty Ranges Water Resources Management Program was set up between the River Murray Catchment Water Management Board (RMCWMB) and DWLBC. One of the objectives of the program was to carry out a series of detailed hydrological studies of the individual catchments in the EMLR.

The Currency Creek Catchment sustains a broad array of industries and ecosystems. From being a tourism and wine region to primary production, there is much dependence on the water resources of the catchment. The sustainability of the water resource to provide for stock and domestic demand, irrigation use, recreational amenity and the environment has come under pressure, not only in this particular catchment but also in the greater Mount Lofty Ranges. This increased pressure has come in the form of increased development of the water resource either by the construction of dams or the drilling of bores to exploit the groundwater resource (RMCWMB 2003).

1.3 STUDY APPROACH

The analysis and data generated by this study are based on the outputs from a computer rainfall-runoff model. The development of the model used available data from a variety of sources, much of which is generated by DWLBC, and includes:

- hydrological and climatological data such as rainfall and evaporation
- topographical data, useful for the delineation of watersheds and stream ordering
- aerial photography and videography for the identification of farm dams and ecological assets such as permanent pools
- farm dam surface area – volume relationships, based on previous studies to determine levels of development within the catchment.

Following the collection of all the available data, the next step was to develop a rainfall runoff model, involving:

- analysis of available hydrological data (i.e. rainfall, streamflow, evaporation)
- collection and collation of water-use data
- subdivision of the whole Currency Creek Catchment into major and minor sub-catchments based on hydrological boundaries
- input of data for each minor sub-catchment into the WaterCRESS modelling platform
- modelling of various scenarios for the purpose of identifying possible catchment management options
- analysis and discussion of results of the modelling process.

The results of the scenarios modelled are presented in this report on a sub-catchment level, and on an annual, monthly and daily basis. This provides better understanding of not only the impacts of dams on catchment yields, but also the impacts on flow regimes that are critical for environmental flow assessment. This leads to assessment of the potential risks to the sustainability of the overall surface water resources and the water-dependent ecosystems, which provides a basis for consideration for future water management options.

2. CATCHMENT DESCRIPTION

2.1 OVERVIEW

The Currency Creek Catchment is located in the southeastern Mt Lofty Ranges ~60 km from Adelaide, and occupies an area of 89.2 km^2 (Fig. 2.1).

The topography ranges from around 380 m in the west, falling to below 50 m where the main creek flows into the lower River Murray. The catchment can be split into two major sub-catchments. The western side is characterised by higher elevations and relatively steeper slopes, ranging in heights from 350 m in the west to 200 m in the centre of the catchment. The eastern major sub-catchment is far flatter by comparison, ranging from 100 to 30 m adjacent to the lower River Murray.

Rainfall in the catchment ranges from ~820 mm in the west to 500 mm in the east, with an average of ~686 mm.

Streamflow data are available for the upper half of the catchment. The period of record for gauging station A4260530 is 6 June 1972 to 23 August 1993 when the gauging station was decommissioned. Data from that period show a mean and median annual streamflow of 6070 and 6030 ML, respectively. Modelled streamflow for the 30 years from 1974–2003 shows mean and median annual flows of 5980 and 6400 ML. For the observed period of record, this gives a runoff coefficient of 14%.

Land use is predominantly made up of grazing, both broadscale (70%) and irrigated (20%), with small areas of the catchment being used to grow commercial crops such as wine grapes and other row crops, as well as flowers, olives and exotic species. Around 100 ha of the catchment is proclaimed as the Scott Creek Conservation Park.

Based on the 2003 land and water-use survey, the total number of farm dams in the Currency Creek Catchment was 515 with an estimated storage capacity of 1261 ML. The majority of this development is upstream of the gauging station, i.e.1070 ML (85% of total) is in the upper 64% of the catchment.

2.2 LAND USE

Land use data provide information on the nature of the use of land (e.g. forestry, livestock grazing, horticulture and residential). This, in addition to the land and water management information (viz., irrigated or unirrigated, usage of water from bore wells or from farm dams), provides a better understanding of resource availability and usage within the catchment.

Land use data for the catchment area was obtained from the land use dataset of the Eastern Mount Lofty Ranges compiled by DWLBC for the RMCWMB in 2003–04. The exercise involved interpreting high-resolution aerial photography (1:20 000) overlain with the latest available land parcel map as well as field verification. Results of the survey are presented in Figure 2.2 and Table 2.1, based on the eight land use categories presented below.

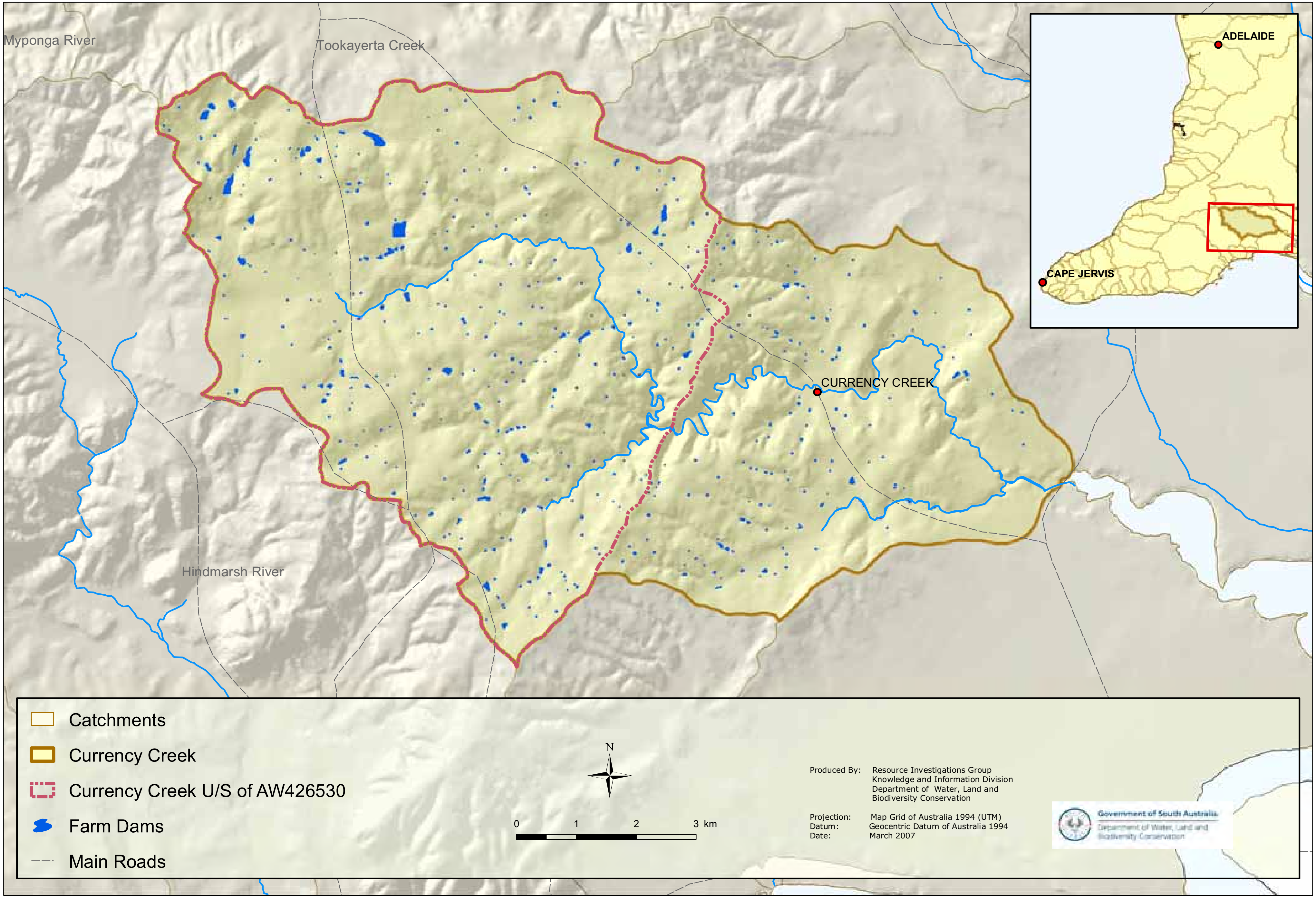

Figure 2.1 Currency Creek Catchment location map

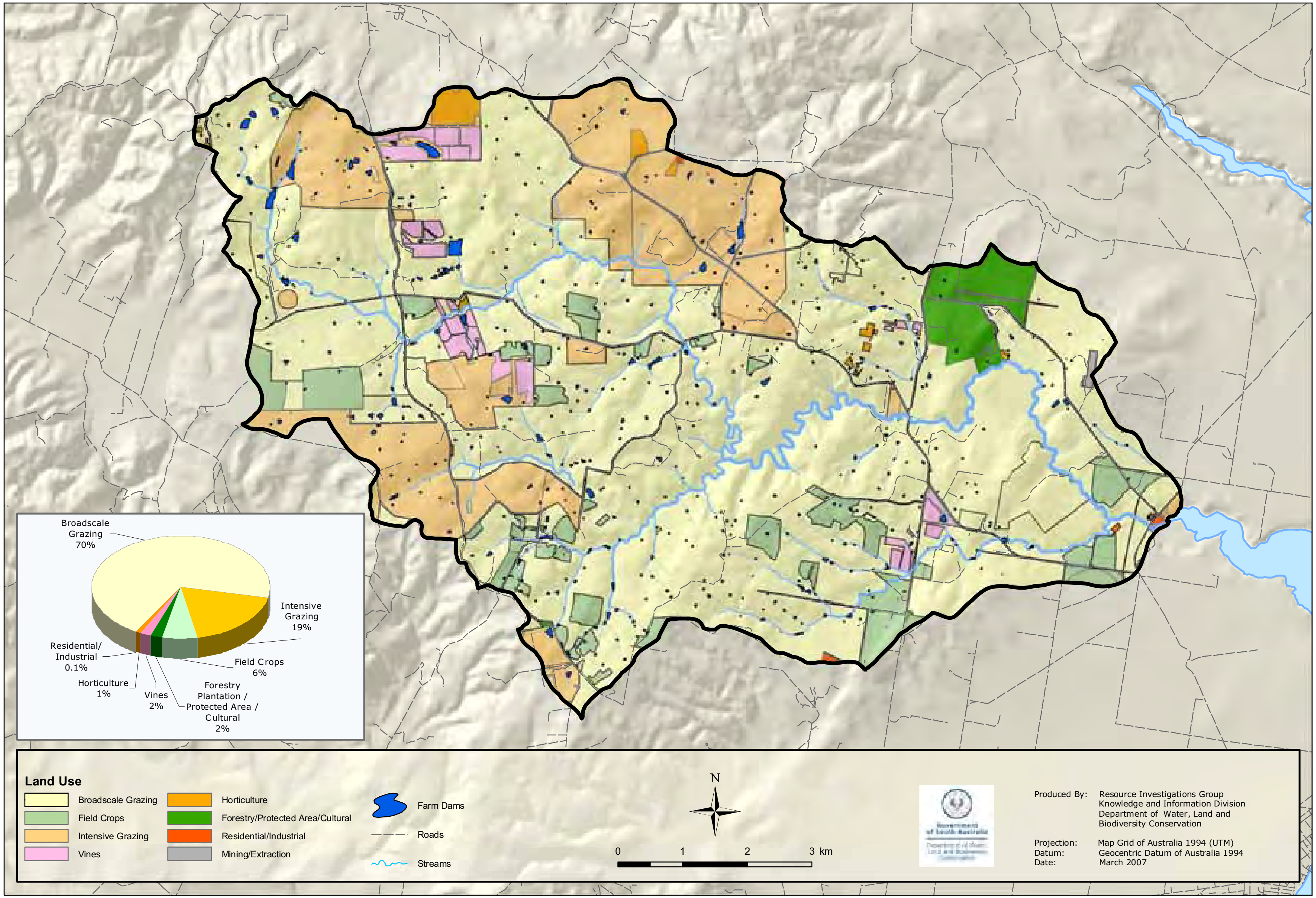

Figure 2.2 Land use in the Currency Creek Catchment

Table 2.1 Land use in Currency Creek Catchment

Land use category	Area (km^2)	% of total area
Broadscale grazing	61.2	69.8
Intensive grazing	16.3	18.6
Field crops	5.6	6.4
Forestry plantation – protected area – cultural	2.0	2.3
Vines	1.8	2.1
Horticulture	0.6	0.7
Residential–Industrial	0.1	0.1
Mining–extraction	0.1	0.1

- broadscale grazing — this includes grazing land for sheep, horses, beef cattle and goats; generally unirrigated
- intensive grazing — for example dairy cattle grazing; generally irrigated
- field crops — may also be used for grazing but included as field crops even where there is no evidence of grazing
- forestry–protected–cultural areas — this encompasses areas of plantation forests, protected native vegetation and cultural areas
- vines — includes all row crops such as grapes
- horticulture — includes floriculture, olives and other exotic species
- residential–industrial — includes residential, industrial, commercial and services
- mining — includes mining and extractive industries.

2.3 ENVIRONMENT

The Currency Creek Catchment is significant locally for its variety of habitat for flora and fauna and as a water source discharging to the lower lakes area of the River Murray, a Ramsar-listed Wetland of International Importance.

The catchment contains part of the Scott Creek Conservation Park as well as numerous areas of remnant native vegetation and Fleurieu Peninsula Swamps (Fig. 2.3). Recent surveys identified some 741 plant species. Of these, 80% were native and 30% were considered to have conservation significance either regionally or under the *National Parks and Wildlife Act 1972* or the *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* (Harding 2005).

Fleurieu Peninsula Swamps are listed as a threatened ecological community under the EPBC Act. They are located throughout Fleurieu Peninsula and the southern Mount Lofty Ranges, providing habitat for a variety of species dependent on them. Many of these species are listed as endangered, threatened or of regional conservation significance. The wetlands also provide a filtering system, trapping sediment and breaking down pollutants (Harding 2005).

Several endangered species are likely to inhabit wetland areas of Currency Creek. For example, the nationally listed Mount Lofty Ranges Southern Emu-wren (*Stipiturus malachurus intermedius*) is likely to inhabit some areas given the existence of the swamps (MLR Southern Emu-wren Recovery Team 1998; Fig. 2.3).

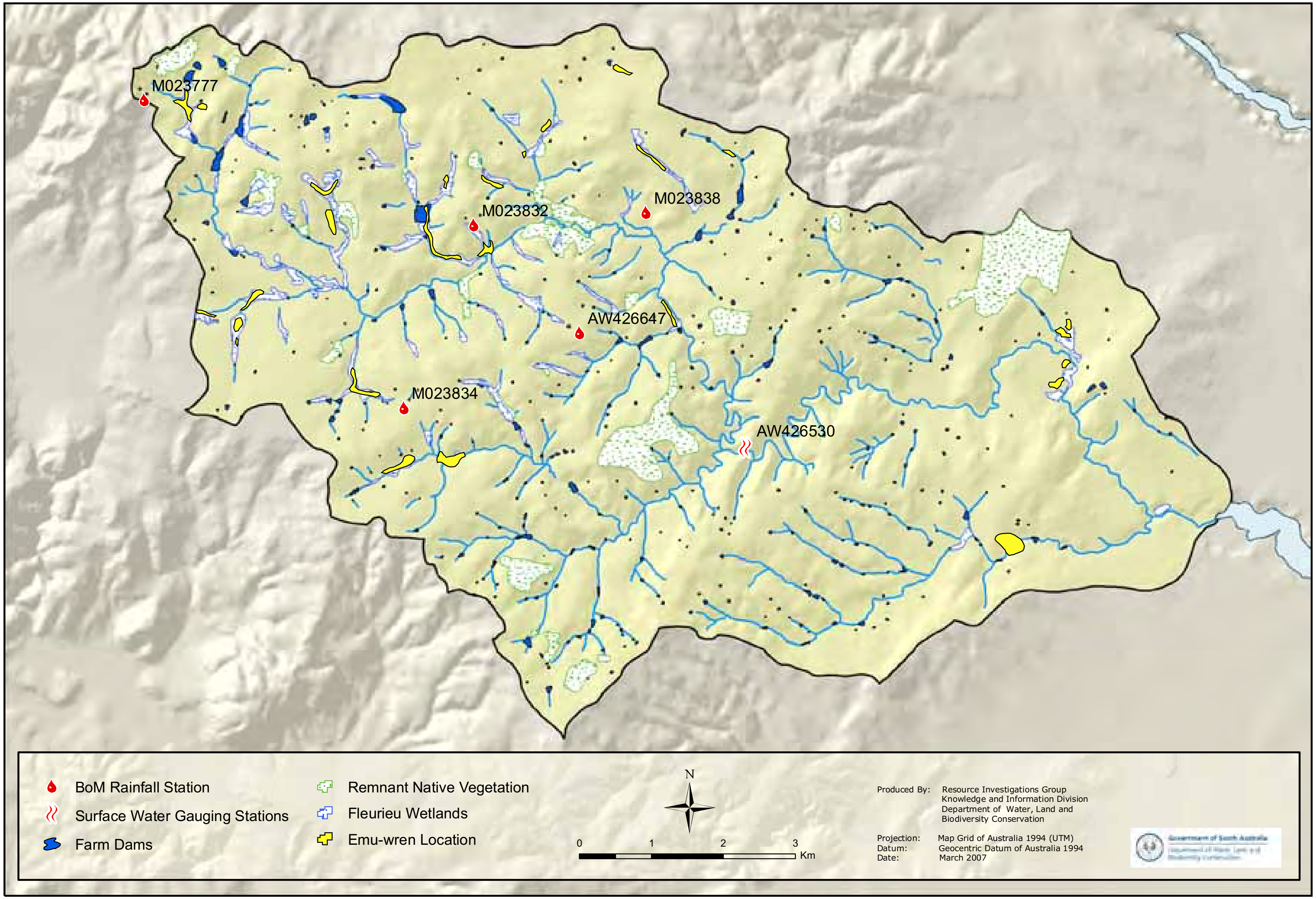

Figure 2.3 Fleurieu Peninsula Swamps, Native Vegetation and Emu-wren Habitat

This study does not directly link the current state of the water resources in the catchment with ecosystem health. However, it is hoped that an assessment of the current impact of farm dams on the surface water resource will assist in determining the factors that are critical to these systems. Along with the surface water regime, the interdependence of the groundwater resource needs to be taken into consideration when assessing ecosystem health and function.

2.4 CATCHMENT SUBDIVISION

For the purpose of modelling it is required that the entire catchment be divided into discrete components, called sub-catchments. Initially, the Currency Creek Catchment is split into two major sub-catchments, based on the area upstream and downstream of gauging station AW426530 (Fig. 2.4). The rainfall runoff model used in this report was developed only using streamflow data from above this point.

2.4.1 MAJOR SUB-CATCHMENTS

In order to group various broad areas of catchment, major sub-catchments (also called Surface Water Zones) are defined based on the following factors:

- Areas upstream of a major tributary of Currency Creek, generally of third order or above.
- Areas comprising a large area of catchment which may be defined as less than third order but otherwise draining a significant portion of the catchment.
- Areas defined as being ’free to flow‘, i.e. parts of the catchment along the main stream that have little or no obstruction from on-stream dams. Note that this may include watercourse diversions from the main stream.

Dividing the catchment in this way allows each area to be assessed separately and creates elements suitable for enacting management actions should they be required as part of the prescription process.

2.4.2 MINOR SUB-CATCHMENTS

From a modelling perspective it is necessary to define each minor sub-catchment depending on the local characteristics of each area. It is constructive to define different areas where controlling factors, such as on-stream dams, are the dominant feature of the local hydrology. The Currency Creek Catchment was divided into 100 minor sub-catchments that were defined with the following considerations in mind:

- where a dam was considered to be blocking a stream, this becomes the lower end of the sub-catchment and then envelopes the area above which contributes to that point
- in areas where more than one dam is blocking the catchment but the influence of a major dam is predominant, all other dams above are grouped into one dam node
- sub-catchments with no dams but having well-defined contributing areas are included.

Minor sub-catchment division was carried out firstly on paper using a map showing all the necessary information (elevation contours, farm dam size and location, rainfall isohyets), and then digitised onto a shapefile in ArcGIS. This enabled analysis of further data requirements

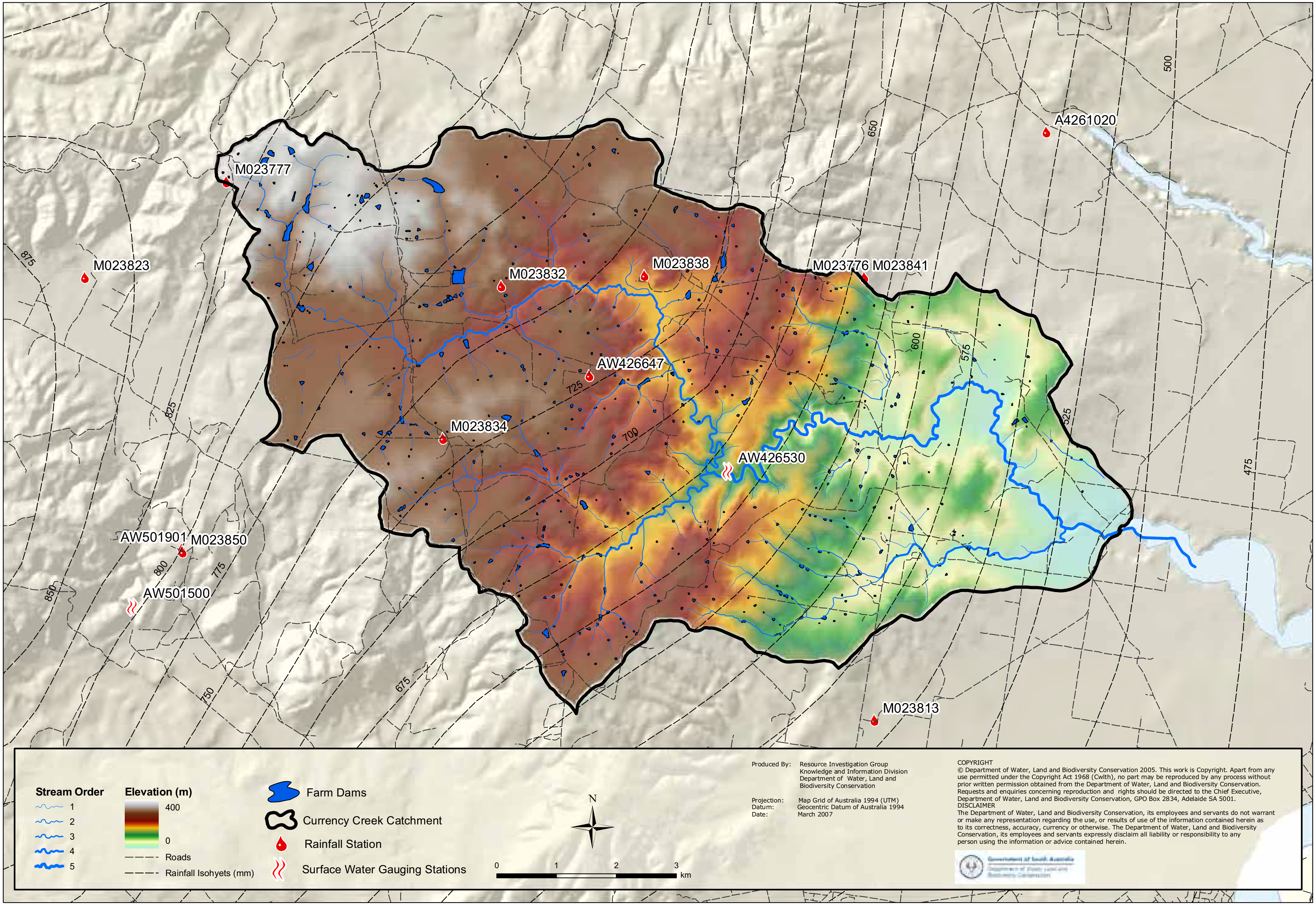

Figure 2.4 Topography and surface water features of the Currency Creek Catchment

for the model, such as average rainfall of the sub-catchment, area of the sub-catchment, and combined farm dam capacity.

As such, each sub-catchment consists of a rural catchment node that feeds into a dam node and so on, with the exception of three free-to-flow catchments, which contain only a rural catchment node. Figure 4.1 shows the set-up of the model and how it relates to the catchment.

2.5 FARM DAMS

Farm dams are water storage structures generally constructed in regional (rural) areas for capturing the runoff generated from the catchment area above them. The water stored in the dams is then used for domestic, stock and irrigation purposes. While water stored in the farm dams provide a source of water additional to rainfall and water pumped from groundwater bores for agriculture, they also act as barrier for the runoff generated from the catchment area upstream of the dam, until the dam spills. This directly affects the availability of water to users (including the environment) downstream of the dam, particularly when the dam is large. The other negative impact of this is the change in the flow regime of the stream, which directly affects the riverine and other water-dependent ecosystems. The main purpose of this study is to estimate these impacts on the flow regime in the catchment.

The constant increase of more land being brought into intensive agricultural use in the Mount Lofty Ranges has necessitated the construction of more water storage facilities, and hence the inevitable situation of construction of a large number (and higher storage capacity) of farm dams. This increase in construction of farm dams has been more predominant and rapid in the highlands of the Mount Lofty Ranges with intense vineyard development. Assessment of catchments across the region have been carried out by DWLBC, including the Barossa Valley (Cresswell 1991), Onkaparinga River Catchment (Teoh 2002), Upper River Torrens Catchment (Heneker 2003), Upper Marne Catchment (Savadamuthu 2002), Upper Finniss Catchment (Savadamuthu 2003) and Tookayerta Catchment (Savadamuthu 2004).

Farm dam development is currently measured using various methods, including:

- the overall number of dams and their storage capacity
- the estimation of Farm Dam Density, measured in volume (ML) per area of upstream catchment (km^2)
- estimated volume as a ratio of winter runoff from the catchment upstream (referred to as the RMCWMP Development Level).

Each of these factors is discussed in more detail in the following sections.

2.5.1 NUMBER AND STORAGE CAPACITY

Farm dam information for this study was obtained from a 2003 aerial photography coverage, flown for the purposes of a land and water-use survey. Detailed farm dam surveys have been carried out in the Mount Lofty Ranges in the past and dam surface area to dam capacity relationships developed. There is considerable difference in the dam capacity estimation by these different relationships, particularly for the larger dams. Physical surveys of farm dams (the larger dams, at the least) are required for better estimation of the actual depths and dam capacities and, hence, a better dam capacity to surface area relationship. Such surveys are being carried by DWLBC throughout the Mount Lofty Ranges, but at the time of writing sufficient details of the Currency Creek Catchment are not available. Comparisons between estimates and those surveyed recently reveal only small variations at this stage. As such, calculations are based on the farm dam coverage made in 2001 with some additions from a recent land use survey in the region (Daley & Dwyer 2004).

In this study, farm dam capacities were estimated using the following most recent dam surface area – volume relationship (McMurray 2004a):

For surface area <15 000 m^2

Dam Capacity (ML) = 0.0002 x Surface Area$^{1.25}$ **Equation 2.1**

For surface area ≥15 000 m^2

Dam Capacity (ML) = 0.0022 x Surface Area

Based on the 2003 farm dam survey, the total number of farm dams in the Currency Creek Catchment was 515 (Fig. 2.3). Using the formulae shown above, the total estimated storage capacity of those farm dams is 1261 ML. The number of dams and their storage capacity based on size classification are shown in Table 2.2.

Table 2.2 Farm dam size classification, Currency Creek Catchment (2003)

Classification No.	Dam size category	Number of dams (% of total dams)		Total storage capacity (ML) (% total storage capacity)	
1	<0.5ML	184	(36%)	52	(4%)
2	0.5–2 ML	229	(44%)	226	(18%)
3	2–5 ML	61	(12%)	184	(15%)
4	5–10 ML	16	(3%)	102	(8%)
5	10–20 ML	17	(3%)	241	(19%)
6	20–50 ML	5	(1%)	153	(12%)
7	>50 ML	3	(1%)	303	(24%)
Total		515	(100%)	1 261	(100%)

Data from Table 2.2 indicates that 55% of the stored water in the catchment is made up of just 5% of dams. Smaller size dams (<10 ML) make up 95% of the number of dams, but store only 45% of total capacity.

2.5.2 FARM DAM DENSITY

Farm dam density, compared to the number and capacity of farm dams, is a more important parameter in indicating the intensity or the level of farm dam development, as it includes catchment area in its calculation, as shown below.

$$FarmDamDensity(ML/km^2) = \frac{TotalFarmDamCapacity(ML)}{CatchmentArea(km^2)}$$

The farm dam density of the Currency Creek Catchment based on 2003 data is 14 ML/km^2. Dam density is represented in Figure 2.5 at a major and minor sub-catchment scale. This is in the same range as other catchments in Eastern Mount Lofty Ranges.

A better understanding of the extent and variation of farm dam development within a catchment is obtained when analysed on a sub-catchment level. A visual representation of this is provided in Figure 2.5 and 2.6 which show the highest levels of development for major and minor sub-catchments in red and orange. Full details of dam density for each minor sub-catchment are provided in Appendix B.

2.5.3 DAM DEVELOPMENT LIMITS

The RMCWMP defines the limits for the development of the surface water resource of the catchment as:

'The surface water sub-catchment zone limit of all dams (megalitres) = 0.3 (30% of) X area of the surface water sub-catchment zone (sq km) X long-term average rainfall between the months of May and November (mm) X runoff coefficient; where the runoff coefficient is 0.1 (10%), unless otherwise specified in a relevant Water Allocation Plan.' (RMCWMB 2003, p.182).

To assess whether development met this definition, dam development limits were estimated for Currency Creek on a catchment level, and major and minor sub-catchment level. These are shown in Table 2.5.

Table 2.5 RMCWMP development limits; Currency Creek sub-catchments

Sub-catchment	**Catchment area** (km^2)	**Mean May–Nov rainfall** (mm)	**Mean May–Nov runoff** (ML) — **no dams**	**Farm dam development** (ML)	**Dam density** (ML/km^2)	**Allowable farm dam volume** [1](RCWMP)	**Level of development** (Dam Vol/ Winter Q)
Wood Cone	13.3	674	1 842	304	23.0	553	17%
Kiloran Creek	14.9	651	1 870	374	24.0	561	20%
Mosquito Hill	13.6	610	1 401	203	13.7	420	14%
Mt Jagged	14.9	579	1 264	189	13.6	379	15%
Glenford Gully*	12.1	465	615	91	7.6	185	15%
Currency Creek*	20.4	454	1 072	99	4.9	322	9%
Total Currency Creek	89.2		8 065	1 261	13.9	2 420	16%

*Results extended from catchment upstream of A4260530; Q = runoff in megalitres.

Although some surface water zones exhibit relatively high dam densities, the use of the RMCWMP limits to define stressed areas does not always reflect this. This is due to the zones of high surface water development being located in the highest rainfall and runoff producing parts of the catchment. No single surface water zone exceeds the limits set out in the RMCWMP, but when analysed on a minor sub-catchment scale there are a number of areas where higher stress may be identified. Figures 2.5 and 2.6 show dam density on a major and minor sub-catchment scale. Figures 2.7 and 2.8 shows the level of dam development expressed as a percentage of winter runoff from that part of the catchment.

Glenford Gully and Currency Creek surface water zones were modelled by extending the results from the calibrated model upstream of A4260530. These two catchments lie in a lower rainfall region with lower relief, which may generate less runoff than is estimated here. As a result, the calculation of the RMCWMP development limit may be underestimated.

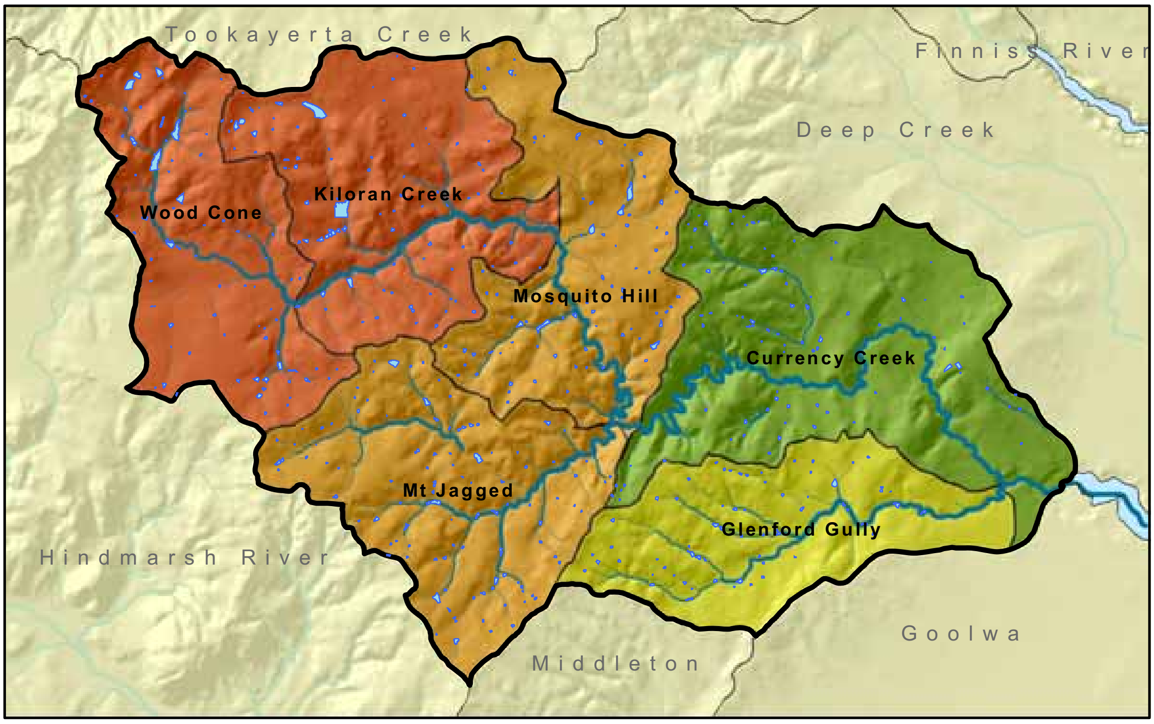

Figure 2.5 Farm dam density — major sub-catchments of the Currency Creek Catchment

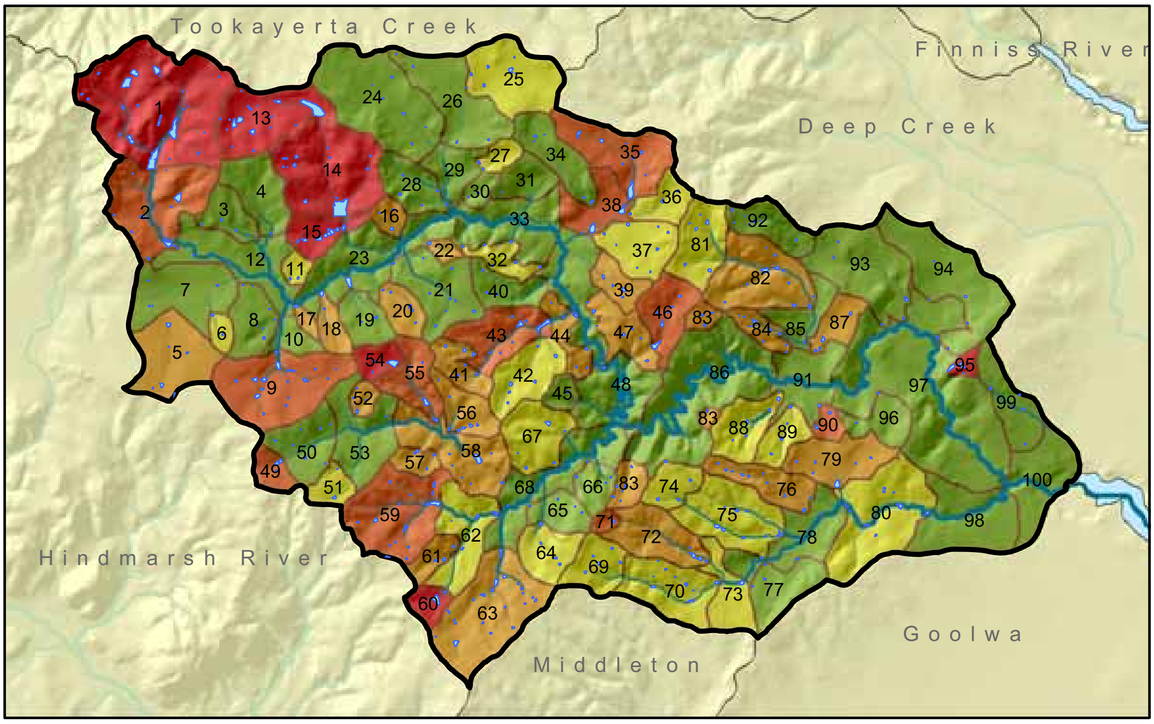

Figure 2.6 Farm dam density — minor sub-catchments of the Currency Creek Catchment

Currency Creek Dam Density (ML/km^2)

Dam Density
- 0 - 5
- 6 - 10
- 11 - 20
- 21 - 50
- >50

- EMLR Catchments
- Major Sub-catchments
- Minor Sub-catchments
- Farm Dams
- Streams

N

0 1 2 3 km

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

Projection: Map Grid of Australia 1994 (UTM)
Datum: Geocentric Datum of Australia 1994
Date: March 2007

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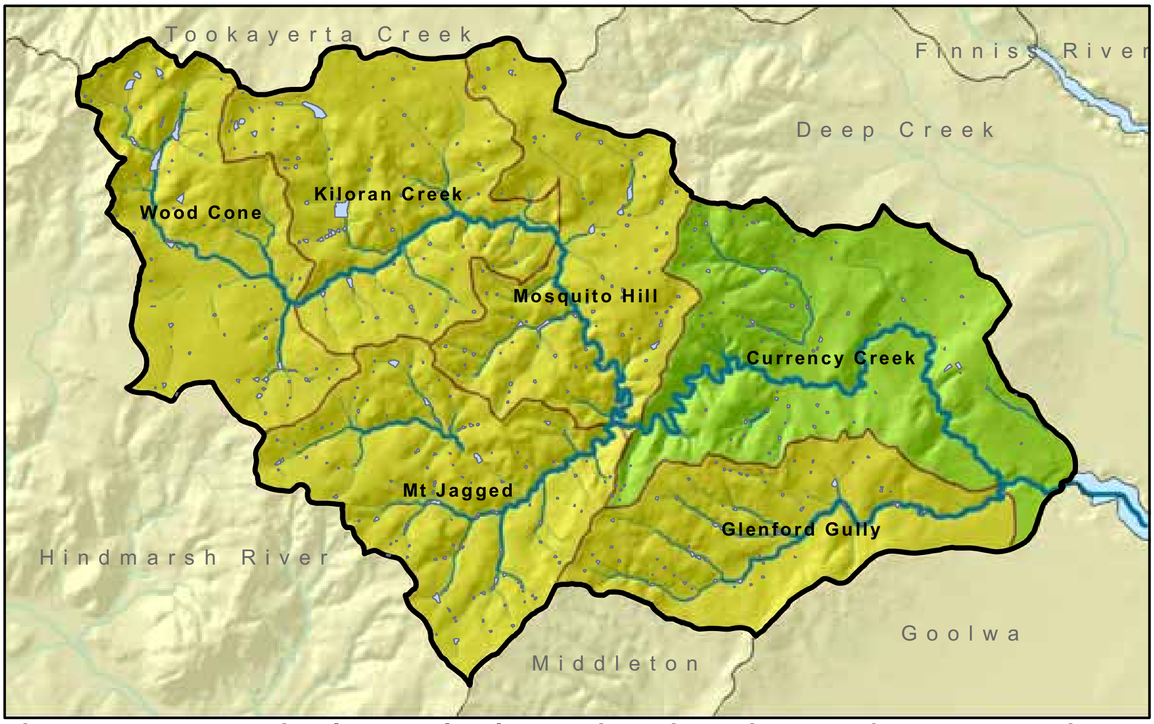


Figure 2.7 RMCWMP development levels — major sub-catchments of Currency Creek Catchment

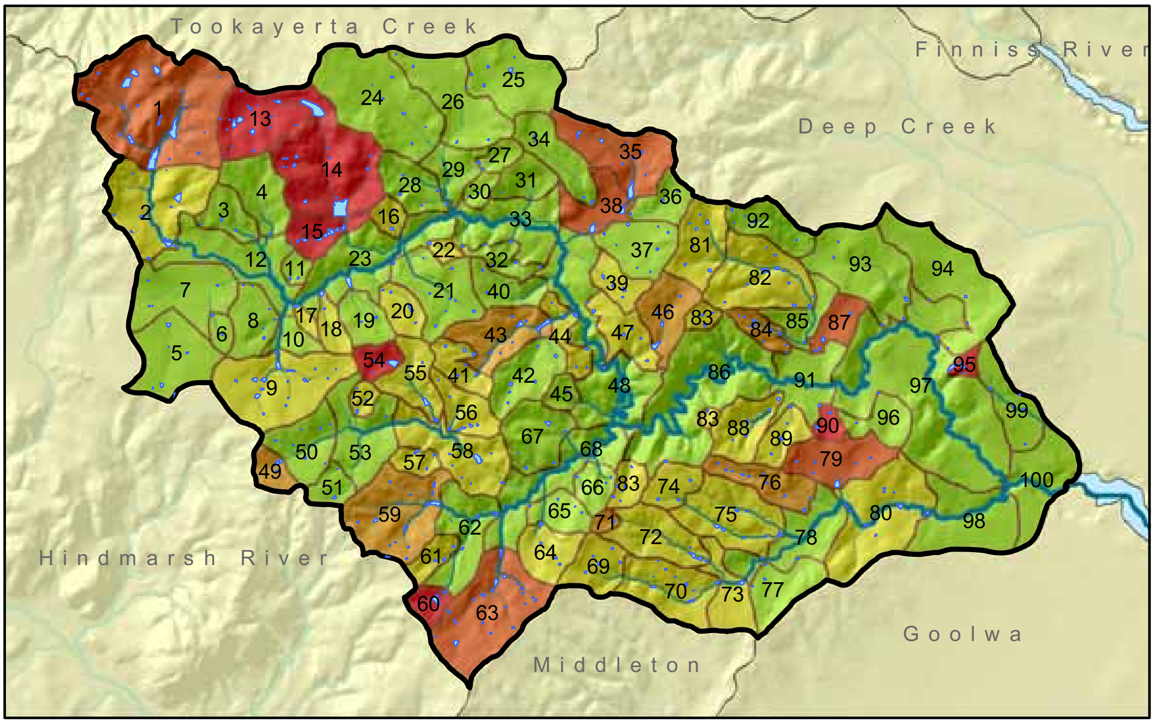
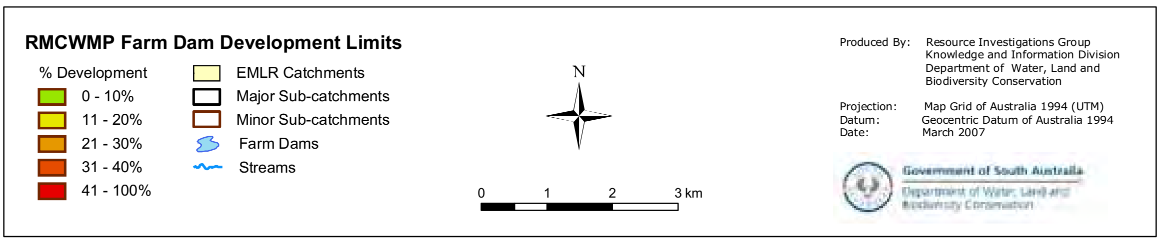


Figure 2.8 RMCWMP development levels — minor sub-catchments of Currency Creek Catchment



3. CATCHMENT HYDROLOGY

3.1 RAINFALL

Rainfall is one of the primary drivers of the hydrological cycle, with its volume and intensity directly affecting the volume of water available within a catchment and hence its productivity. Rainfall within a catchment generally varies spatially with topography, for example areas in higher elevations generally receive more rainfall than areas in lower elevations. This necessitates determination of the varying rainfall pattern within a catchment for estimation of effective runoff from the different areas or sub-catchments. This is achieved by using rainfall records from the Bureau of Meteorology (BoM) stations in the region and rainfall isohyets developed from those records.

3.1.1 DATA AVAILABILITY AND PROCESSING

Rainfall records for the Currency Creek Catchment were available with varying degrees of quality and duration. Rainfall stations within the catchment boundary are presented in Table 3.1 along with the period of data collection and the amount of missing or aggregated data. Most rainfall records have some periods of missing or aggregated data. For example, rainfall records are often not read on a weekend and so the accumulated total is recorded on the next working day. There may be various other reasons why data are missing such as equipment malfunction. Hence, disaggregation and infilling of datasets is required, and this was carried out by Sinclair Knight Merz (SKM 2000) for most available datasets up to 1998. A similar method was used where records were required after 1998.

Table 3.1 Rainfall stations in proximity to Currency Creek Catchment

Station number	Location	Period of record	% of missing and accumulated data
023832	Currency Creek (Kiloran)	1973–78	3.48%
023834	Victor Harbor (Berrima)	1973–2004	16.62%
023838	Mount Compass (Marshall Brae)	1978–97	8.96%
023841	Currency Creek	1964–74	26.74%
023823	Hindmarsh Valley (Fernbrook)*	1936–2005	0.55%

*Extended dataset (SKM 2000)

Rainfall records from within the catchment were too short for the long-term analysis needed here so an extended dataset was required for that purpose. Extension of station 23838 was carried out with a comparison station (23823) to give a longer term dataset. Details of the extension of the dataset are given in Appendix A.

3.1.2 RAINFALL DATA ANALYSIS

The extended rainfall dataset at Mount Compass (Marshall Brae) was analysed at annual, monthly and decadal time scales for this study. Trend analysis was also carried out with different methodologies.

The long-term (1936–2003) mean and median annual rainfall at Marshall Brae are 718 and 726 mm, respectively. Annual rainfall patterns in the catchment generally decrease from west to east, with a maximum of ~825 mm in the west to ~500 mm in the eastern reaches. A mean annual rainfall for the catchment of 686 mm has been calculated in GIS (ArcMap) using the distribution of rainfall isohyets and the area of catchment between them.

Trend analysis was carried out on the extended dataset to determine the existence of any long-term trend in the data and the level of significance of the trend. Results of this analysis indicate an increasing trend in the data being statistically significant at just 33.6% using the Mann's Test (Grayson et al. 1996) and at just 32.6% for both the 't' and 'F' tests (Draper 1998). This indicates the lack of significant trend in the data for that period. Generally, a significance level of 95% or greater is required to indicate a definite trend.

Long-terms trends can also be observed using the residual mass curve, which is a plot of the cumulative deviation of a dataset from the mean (Grayson et al. 1996). Peaks or troughs in the curve of the residual mass indicate trends in the rainfall. A positive slope above the mean indicates an increasing trend, and vice versa. Figure 3.1 shows the residual mass curve plotted against annual rainfall for the Fernbrook station. The residual mass curve indicates a wetter than average period from 1946–54, and a sharply increasing residual mass due to the high rainfall in 1992. A drier than average period is seen from 1960–67.

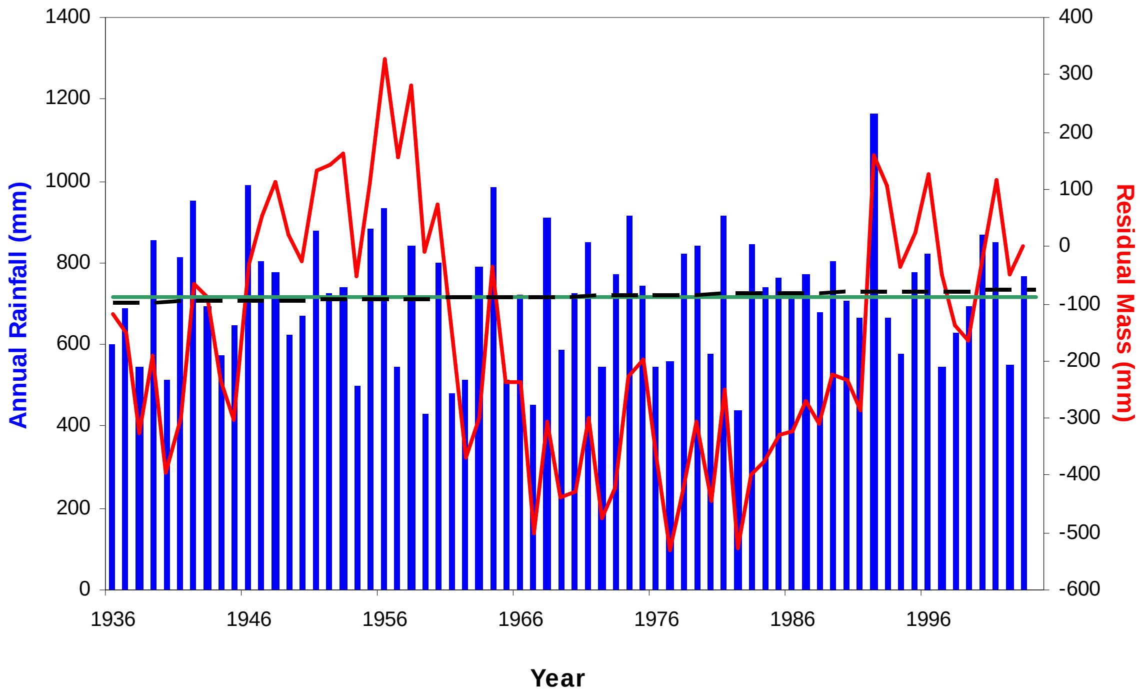


Figure 3.1 Annual rainfall at BoM Station 23838

Decadal analysis (Fig. 3.2) of the extended rainfall data at Marshall Brae reveals little change over the last three decades. The 1960s are revealed as the lowest period of rainfall in the last 60 years.

Monthly rainfall analysis (Fig. 3.3) indicates that the catchment receives ~76% of its rainfall in the six-month period of May to November.

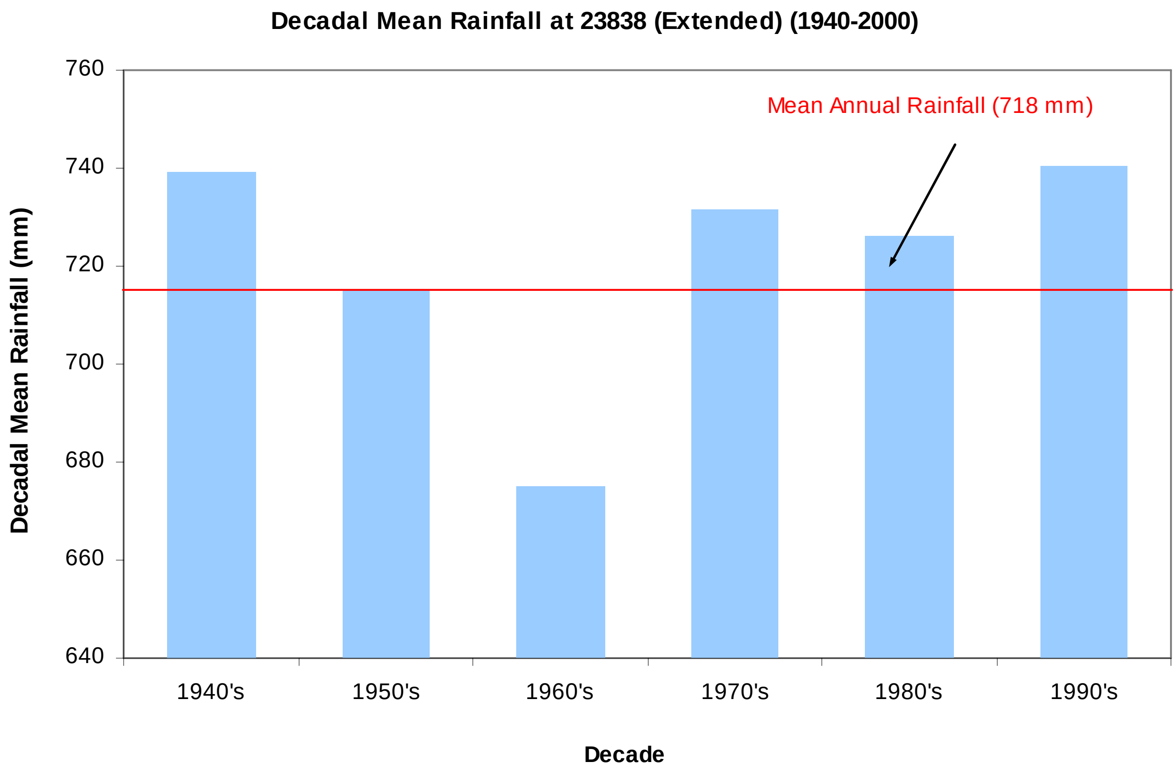


Figure 3.2 Decadal rainfall at BoM Station 23838

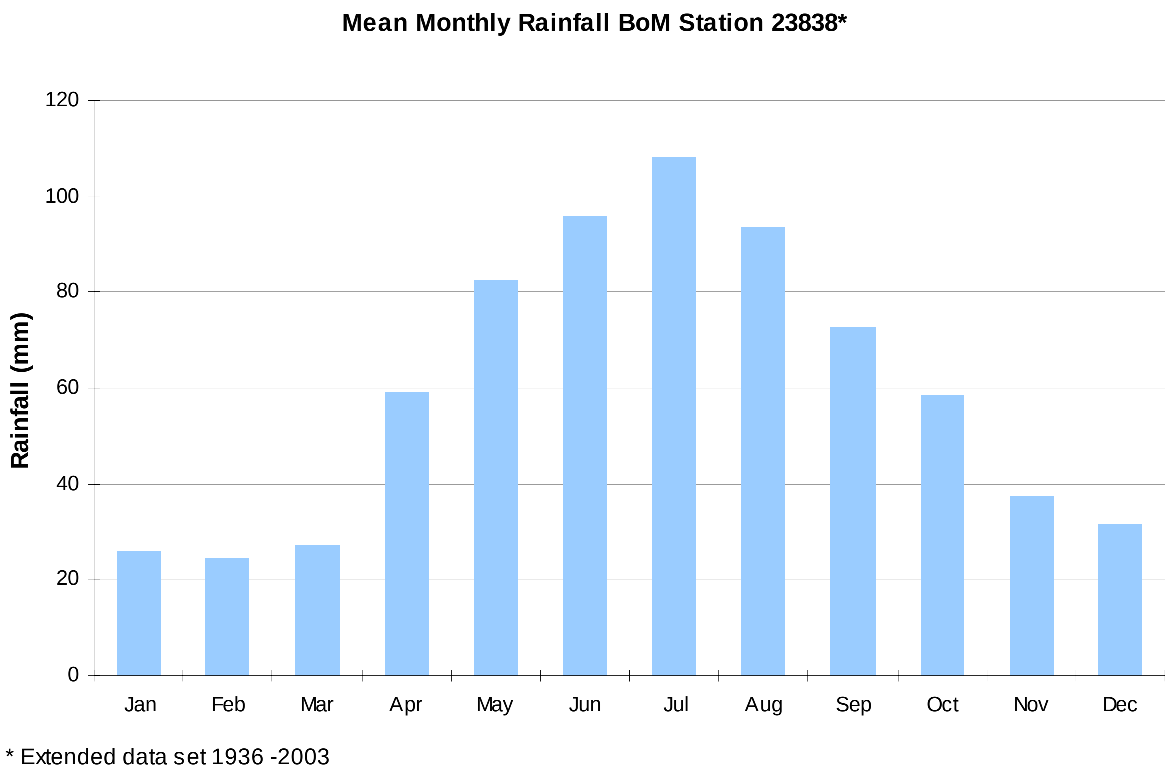


Figure 3.3 Mean monthly rainfall at BoM Station 23838

3.2 STREAMFLOW

Streamflow monitoring of the Currency Creek @ Higgins (A4260530) gauging station (Fig. 2.4) was carried out from 8 June 1972 until the station closed on 23 August 1993. The station gauged flows from ~57 km^2, which makes up some 64% of the total catchment area.

Approximately 2% of data from A4260530 are missing, with a further 4% measured outside the reasonable bounds of the rating table. During periods of high streamflow, such as after prolonged or intense rainfall, the estimation of streamflow through a fixed ‘V‘ gauge, by a measurement of height, becomes unreliable and should be treated with caution.

3.3 RAINFALL RUNOFF RELATIONSHIP

The relationship between rainfall on a catchment and the resultant runoff can be described in a number of ways, the simplest of which is to use a linear runoff coefficient where:

Runoff Coefficient = Mean Annual Runoff (mm) / Mean Annual Rainfall (mm).

Using this method requires the mean annual runoff, which cannot be determined in years with significant periods of missing data. The gauging station at A4260530 contains 17 out of 21 complete years of data. For those 17 years, the mean annual runoff was 6097 ML (107 mm), and the mean annual rainfall over the same complete years was 752 mm. The runoff coefficient for Currency Creek upstream of the gauging station is therefore:

Runoff Coefficient = 107 mm / 752 mm = 0.14 (14%)

This estimation is higher than the regional estimate for the EMLR which is given as 0.1 (10%) in the RMCWMP, but there is much regional variation in this factor based on differing rainfall and catchment characteristics. For example, runoff coefficients vary from as much as 25% in the Tookayerta Catchment to as little as 6% in the Marne River Catchment in the northern Mount Lofty Ranges.

Another method used to estimate runoff is to plot runoff and rainfall against each other and fit a modified Tanh hyperbolic function. This method, described by Grayson et al. (1996), more appropriately defines runoff based on different rainfall. The non-linear nature of this relationship means that for higher rainfall events the runoff is more likely to be much higher than if a standard runoff coefficient was used. In most cases this can be three to four times higher. The Tanh relationship for Currency Creek Catchment is shown in Figure 3.4, and shows both modelled and observed data. The Tanh parameters were fitted initially by visual trial and error, and then by the use of the Solver optimisation tool to minimise the RMS error. The visual method is applied firstly in order to find the suitable level for the Notional Infiltration parameter, which was then fixed for both the ’Current‘ and ’No Dams‘, modelled data. This method makes the assumption that parameter L (Notional Infiltration or Initial Loss) is most applicable to the component of water taken up by dams and hence should be the dominant variant between the two modelled cases.

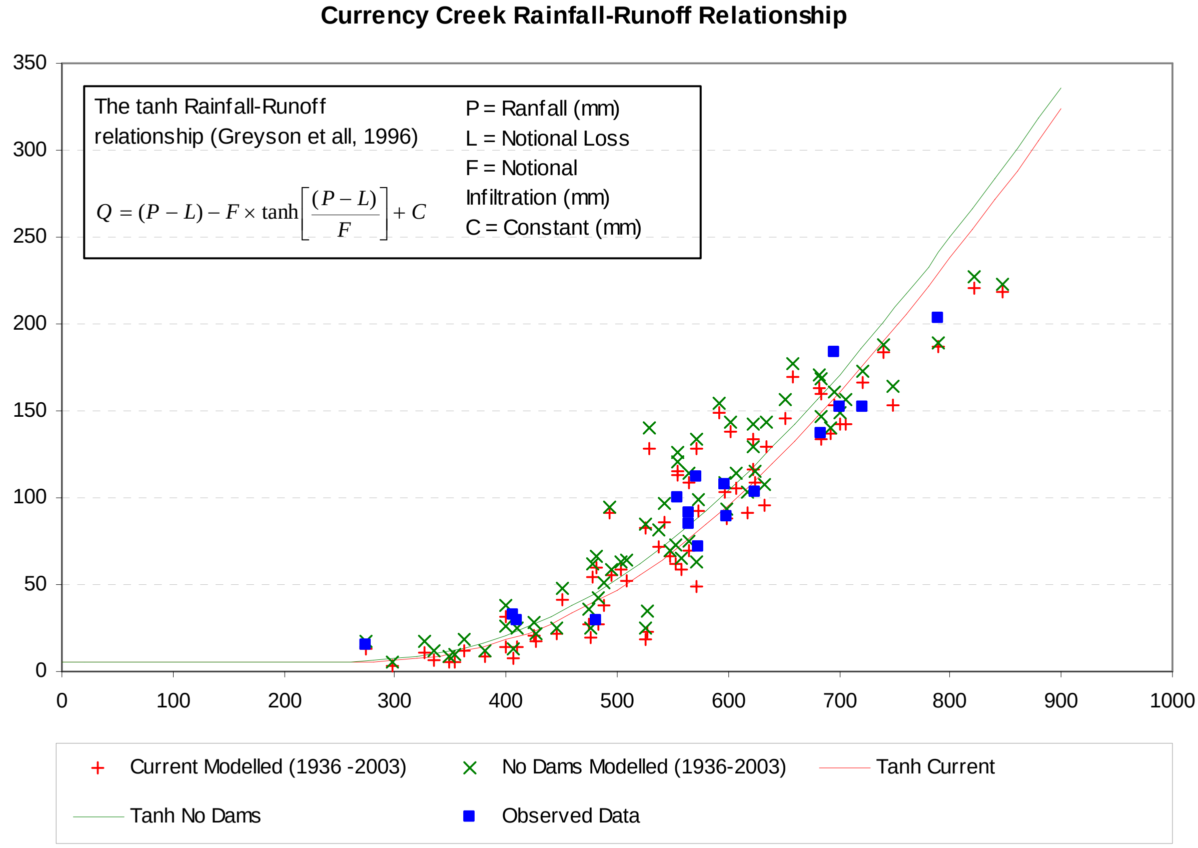


Figure 3.4 Tanh Relationship for the Currency Creek Catchment

4. SURFACE WATER MODELLING

4.1 OVERVIEW

Hydrologic models are conceptual models that represent the various components of the hydrologic cycle (viz. rainfall, interception, evaporation, infiltration, surface runoff, groundwater recharge and baseflow) and the links between them. The components and the links of the hydrological cycle are represented by mathematical functions that are built into a model by using computer-programming languages. The models are built to simulate catchment conditions, to generate long-term data and to enhance further understanding of the hydrological behaviour of catchments. They are further used for assessment of the impacts of various changes and activities within the catchment.

In this study, a rainfall-runoff water balance hydrological model was used.

4.2 METHODOLOGY

WaterCRESS (Cresswell 2002), a PC-based water-balance modelling platform, was used for construction of the model in this study. This modelling platform incorporates some of the most widely used models in Australia, viz. AWBM, SFB, HYDROLOG and WC1. WaterCRESS allows the incorporation of different components in its water balance models. Some of the components that can be incorporated are:

- Demand Components — which include town and rural demands.
- Catchment Components — which include rural and urban catchments.
- Storage Components — which include reservoir, aquifer, tank, and off-stream dam.
- Treatment components — which include sewage treatment works and wetlands.
- Transfer Components — which include weir and routing component.

A model is then constructed as a series of 'nodes', each being one of the components mentioned above. The nodes are then linked, based on the drainage direction, to form one major catchment (Fig. 4.1).

4.3 MODEL CONSTRUCTION

4.3.1 MODEL NODES

Using the criteria described in section 2.4, the Currency Creek Catchment was divided into 100 rural catchment nodes with a total of 87 dam nodes. This leaves 13 rural catchment nodes as free-to-flow zones with no controlling dam to impede flows. These catchments are located primarily on the main channel of Currency Creek. As such, each sub-catchment consists of a rural catchment node that then feeds into a dam node and so on, with the exception of those 13 free-to-flow catchments that contain only a rural catchment node. Figure 4.1 shows the set-up of the model and how it relates to the catchment.

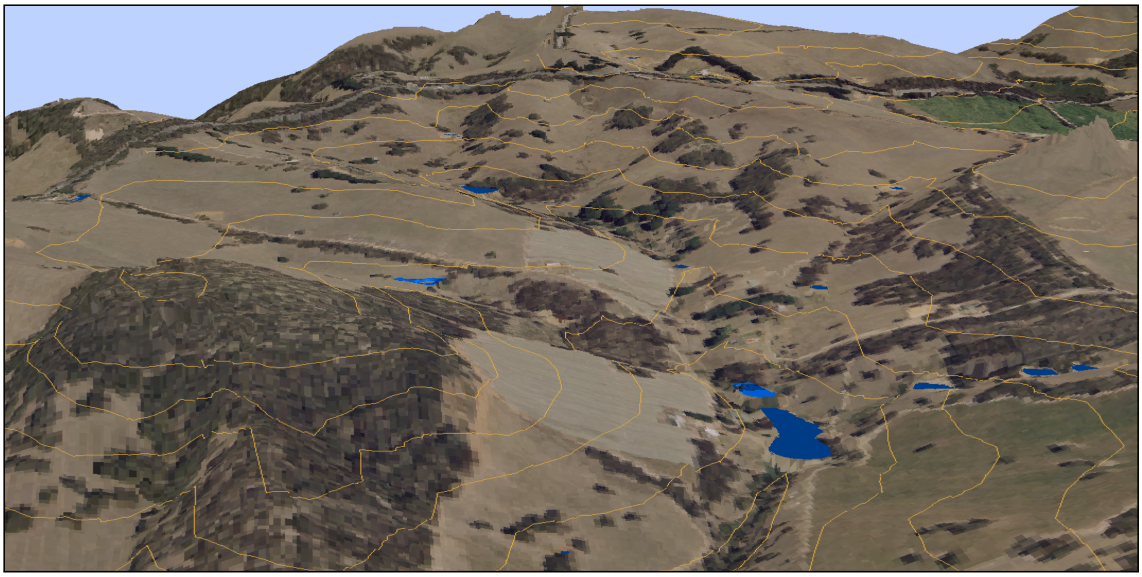


Figure 4.1 (a) Adding contours and farm dams to catchment map

Figure 4.1 (b) Delineating subcatchments based on the layout of the catchment

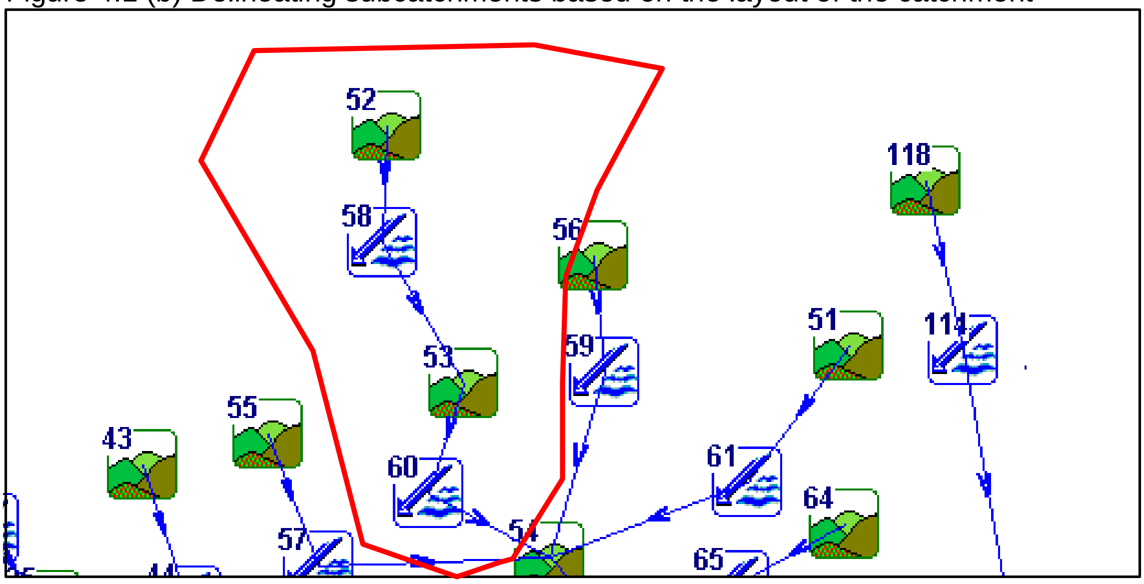


Figure 4.1 (c) Converting the digitised subcatchment map into WaterCRESS model

Figure 4.1 (a-c) WaterCRESS Model Construction showing representation of Subcatchments and Dam Nodes

The model chosen for this analysis was WC1 because it is thought to be well suited to modelling the ephemeral streams of the Mount Lofty Ranges.

4.3.2 CATCHMENT NODE INPUTS

The input data for each rural catchment node were:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall dataset, rainfall factor and monthly evaporation dataset
- model to be used, which was WC1, and the catchment parameters.

4.3.3 DAM NODE INPUTS

Each catchment node with farm dams was then linked to an off-stream dam node (Fig. 4.1 Representation of sub-catchment and dam nodes in the WaterCRESS Model). The input data for each off-stream dam node were:

- dam storage volume, which in this case was the cumulative storage capacity of all the dams in the minor sub-catchment
- corresponding measured daily rainfall dataset (Marshall Brae M023838), and monthly evaporation dataset
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam.

The fraction of catchment runoff diverted to the dam was dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). For example, this fraction was 1.0 if there was a large on-stream dam located on the downstream end of the catchment. It would be considered a controlling dam that is deemed to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream.

Water usage from all dams was assumed to be 30% of the total dam capacity, on an annual basis. This rate of water usage was found to allow for some carry over of storage to following years in previously calibrated models for other catchments in the Mount Lofty Ranges. A recent study of over 700 dams across the ranges supports this figure of 30% as an average water-use from farm dams (McMurray 2004b).

4.3.4 RAINFALL SPATIAL VARIABILITY

The spatial variability of rainfall within the catchment is accounted for by the use of a rainfall factor for each rural catchment node. The rainfall for each node is calculated using a spatial rainfall dataset provided by BoM (Fawcett et al. 2006). The dataset used describes mean annual rainfall at 1 km x 1 km intervals. Details of that process are described in Appendix H.

4.4 MODEL CALIBRATION

Following completion of the fully constructed WaterCRESS model, calibration between the observed daily record from A4260530 (Currency @ Higgins) and modelled daily data was carried out. The period of record for calibration was 19 years between 1973–92. The data between these periods was of suitable quality to enable calibration.

4.4.1 CALIBRATION METHOD

Calibration of the model was carried out with a combination of methods.

1. Initially, regional parameter estimates were gathered from catchment models developed in the same area. Using these parameters gave an initial starting point for the calibration process.
2. Using a Genetic Algorithm calibration tool built into the WaterCRESS platform, various parameters were coupled and optimised until suitable calibration statistics were found.
3. Finally, fine adjustment of parameters was applied in order to achieve the best calibration possible.

Using the Genetic Algorithm tool to optimise the parameters was initially helpful but did not fully account for some of the requirements of the modelling process. For example, while it is possible within the Genetic Algorithm to optimise to different objective functions, and use several error models, it was necessary to visually fit some aspects of the calibration output such as the difference in flow duration curves. Optimisation of low flows is an imperative part of model requirement and as such may require more weight than, say, monthly flow totals. Overall, the model parameters were fitted using both automated and visual fitting methods to ensure best optimisation for the expected use of the model and model output.

4.4.2 CALIBRATION RESULTS

The model was calibrated to daily recorded runoff data for the period 1973–92. The following calibration statistics were used to determine the fit of the model: R squared, Coefficient of Efficiency, %Volume Difference, and are provided in Table 4.1. See Appendix I for a description of relevant statistics.

Table 4.1 Calibration statistics for A4260530

Time scale	R^2	CE	Mean flow (ML)	% Volume difference
Daily	0.89	0.76	16.14/15.57	3.65
Monthly	0.95	0.90	491/473	3.64
Annual	0.91	0.81	5895/5687	3.64

Calibration at a daily time step was generally good, but the model may not adequately model low flows (<1 ML/d). Figure 4.2 shows the modelled and observed output on a flow duration curve, which depicts the amount of time we can expect to see a flow greater than that indicated on the y-axis. For example we could expect to see a flow of ~2.8 ML/d or greater for at least 50% of the time from 1973–92.

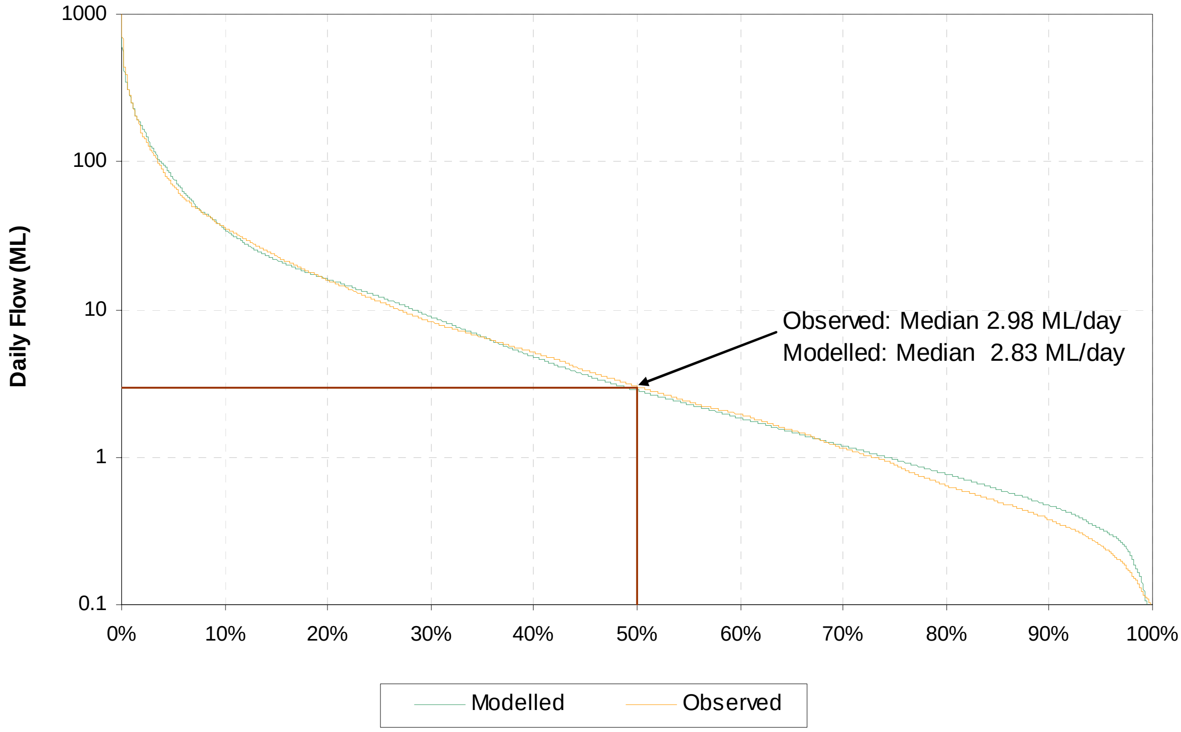


Figure 4.2 Daily flows exceedance — modelled and observed flows

Likewise, model results showed weaker performance in well below average rainfall years such as 1976 and 1982. Whilst the majority of average years correlated well, low rainfall years yielded lower correlation statistics, generally around 0.7 for the R2 statistics. Figure 4.3 shows the modelled and predicted yearly totals along with the daily correlation for that year.

For average years however, the daily calibration performs well as seen in Figure 4.4, which shows the daily hydrograph for the year 1986.

Figure 4.5 again shows the difficulty in accurately modelling late autumn and early spring flows, with correlation being generally lower.

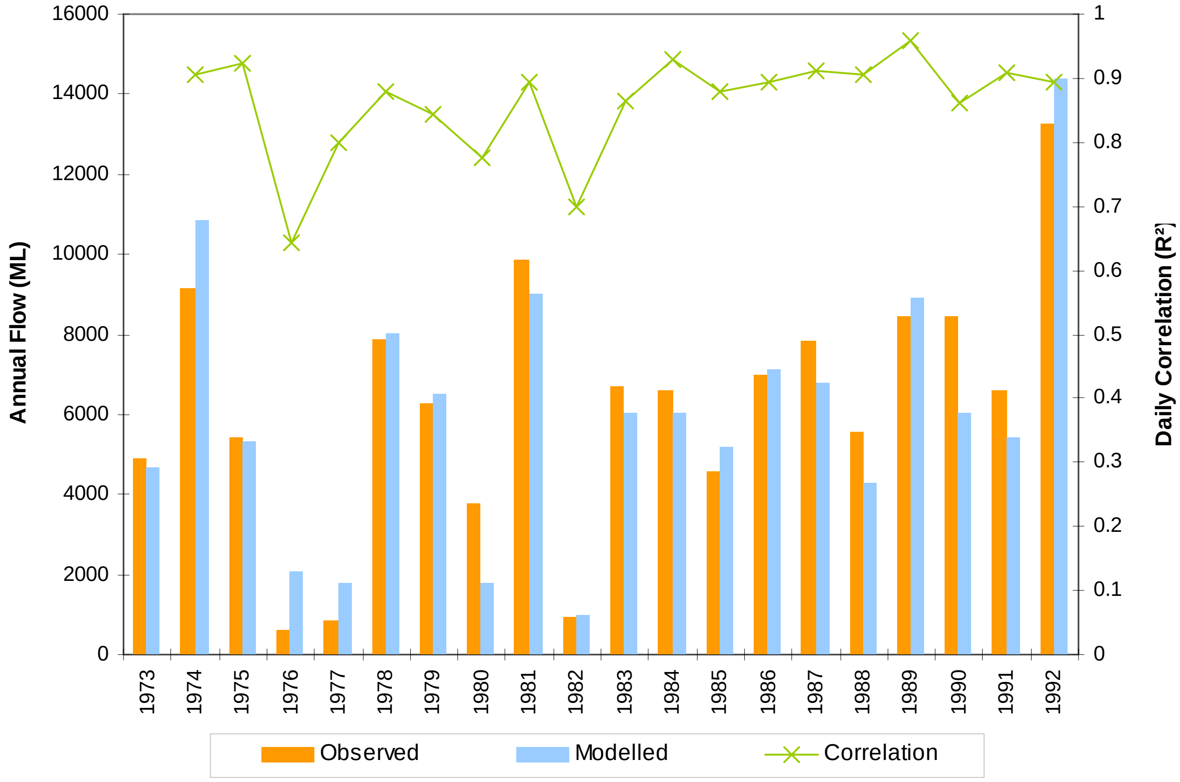


Figure 4.3 Annual calibration chart showing daily correlation for each year

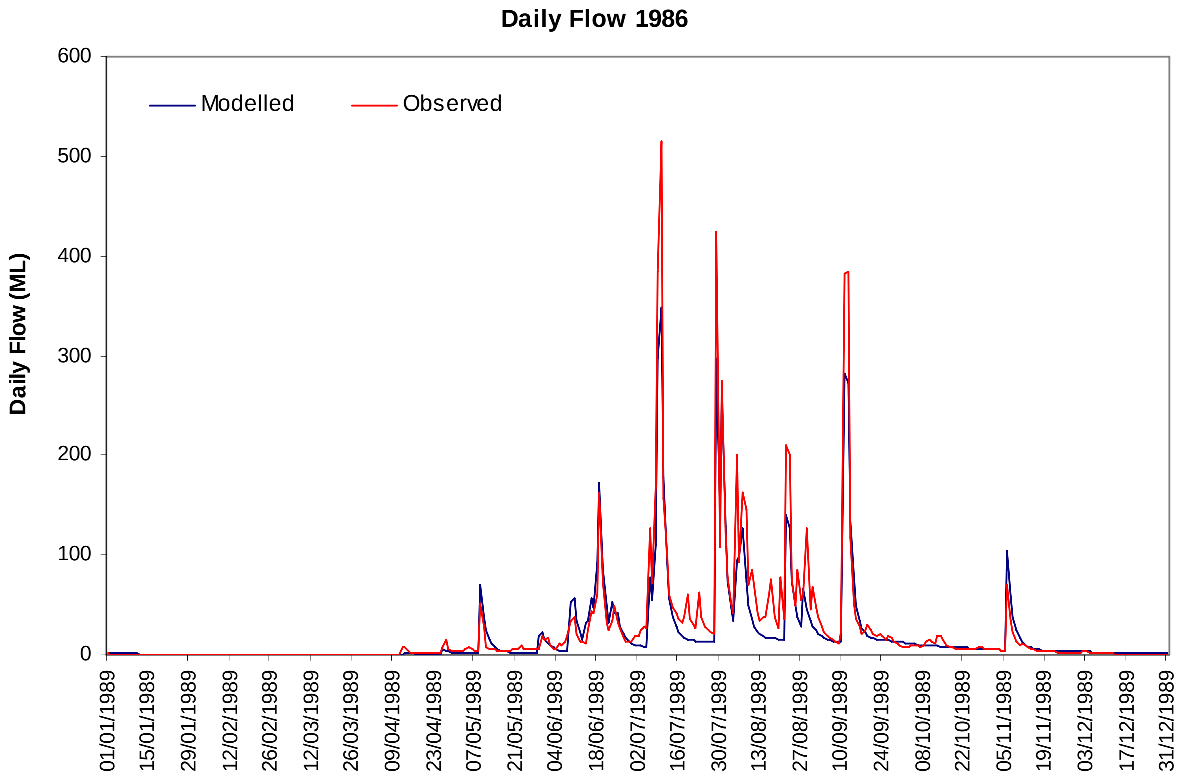


Figure 4.4 Daily calibration chart showing daily correlation for each year

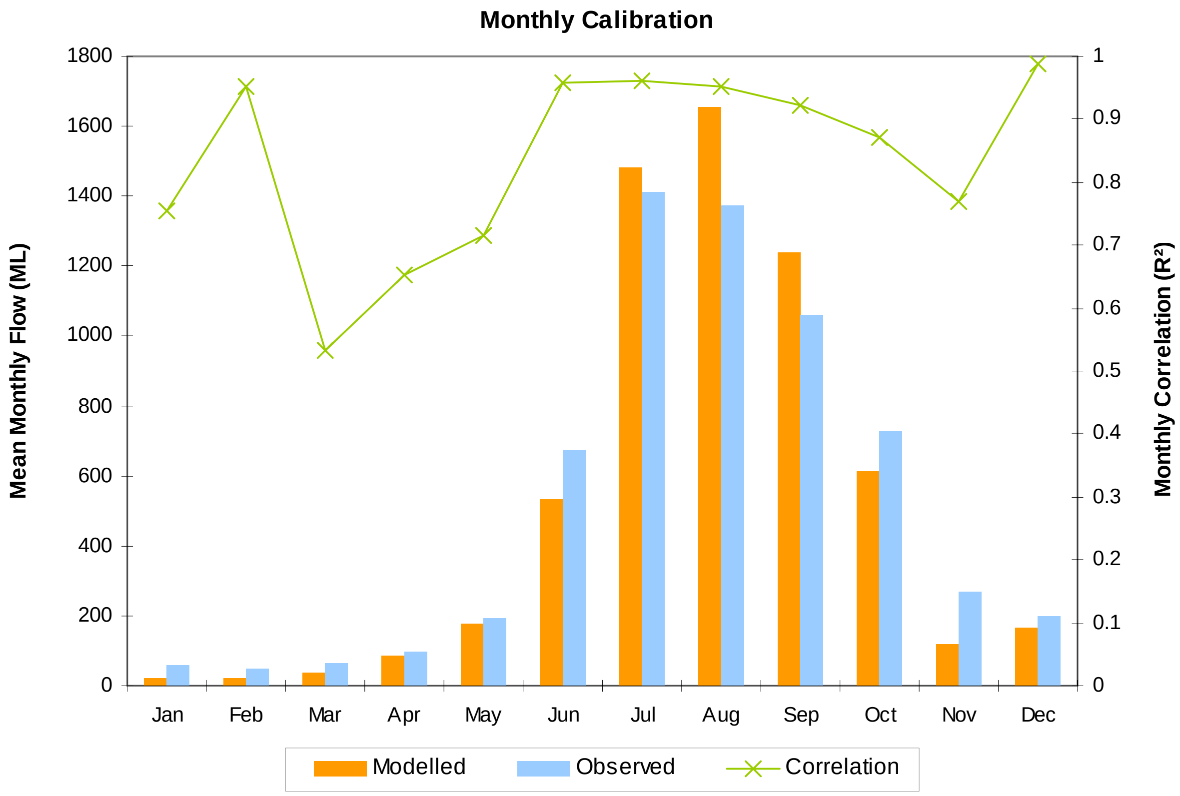


Figure 4.5 Monthly Calibration (monthly averages shown against correlation)

5. SCENARIO MODELLING

5.1 CURRENT — NO DAMS SCENARIO

The purpose of this scenario is to assess the impact that the development of farm dams has had on the catchment. By firstly modelling the current situation and then removing the dams from the model, the impact of those farm dams is determined. This step is also essential in determining the allowable level of farm dam development as defined in the catchment plan, as the rule requires an estimate of surface water flows before the development of the catchment.

It should be noted here that the calibrated model and its outputs make no assumptions about land or water-use change over the period of assessment. Whilst it may be the case that, for example, the number of farm dams has increased considerably over the past 30 years, a constant level has been assumed.

5.1.1 ANNUAL FLOWS

Determining the water balance is essential in making decisions about the estimated impacts and assists in making decisions about the allocation of the resource. Runoff generated during the wet periods is not only important to the catchment as surface water flows, but may contribute to recharge and late season baseflow.

For the gauged section of the catchment, it is estimated that the reduction in mean annual flow due to farm dams is 846 ML, or 12%. Results for each surface water zone are given in Table 5.1. Annual reductions in flows above gauging station A4260530 are shown in Figure 5.1. Note that while results are presented for the Currency Creek and Glenford Gully surface water zones, these are extrapolated downstream from the gauge. It is expected that the hydrologic characteristics of the catchment change somewhat from the gauging station down. For example, the catchment becomes flatter with lower development of the resource observed.

Table 5.1 Reduction in flow due to farm dams in the Currency Creek Catchment

Sub-catchment	Mean annual rain (mm)	Dam density (ML/km^2)	Modelled mean annual catchment runoff (ML) 1974–2003		Reduction in mean annual runoff due to the impact of farm dams
			With Dams	*Without Dams*	
Wood Cone	877	23.0	1 710	1 939	12%
Kiloran Creek	835	24.0	1 968	2 195	10%
Mosquito Hill	807	13.7	1 166	1 330	12%
Mt Jagged	766	13.6	1 104	1 244	11%
Glenford Gully*	628	7.6	562	648	13%
Currency Creek*	620	4.9	1 052	1 132	7%
Total Currency Creek		13.9	7 562	8 488	11%

* Model extended from calibration upstream of A4260530 to lower catchments

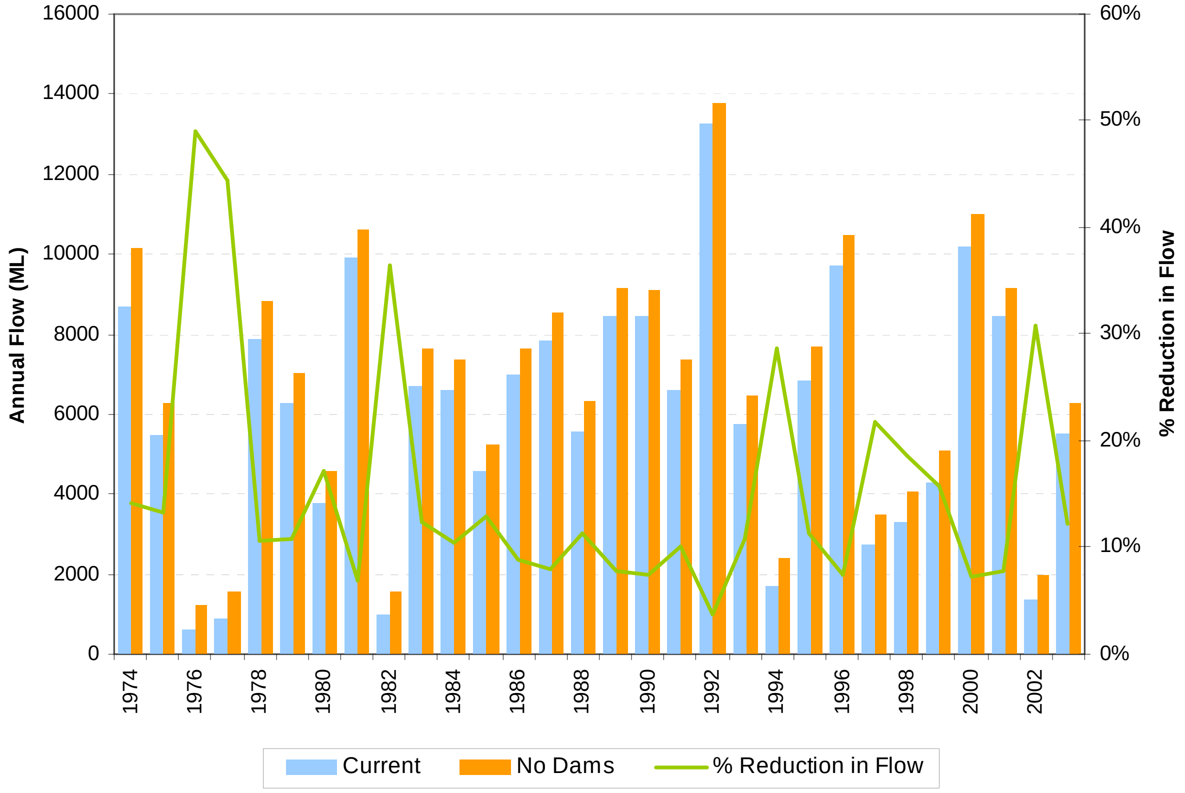


Figure 5.1 Annual reduction in flow due to farm dams of the Currency Creek Catchment.

5.1.2 MONTHLY FLOWS

For the purpose of providing information useful in determining the effect of farm dams on the seasonal flow regime of the catchment, it is necessary to further investigate the monthly flow patterns. As expected, the greatest reduction in flows due to the influence of farm dams is in the drier months.

In summary, farm dams have had the impact of reducing winter flows by 7% and summer flows by 48% (Fig. 5.2). This reduction in summer flows is significant due to the level of baseflow. The reduction in winter flow is still to be regarded as significant, as it reduces the total runoff for the catchment by ~400 ML.

5.1.3 DAILY FLOWS

The impact of dams on the daily flow regime is important in assessing the impact on the regime concerning environmental water requirements. Figure 5.3 shows that impact in a daily flow frequency curve. The figure also shows the range of flows that are affected. It shows a reduction in the 10th percentile flow of 27% from 7. 5 ML to 4.5 ML. The impact of farm dams is apparent across nearly the full range of flows below the 10th percentile in the Currency Creek Catchment.

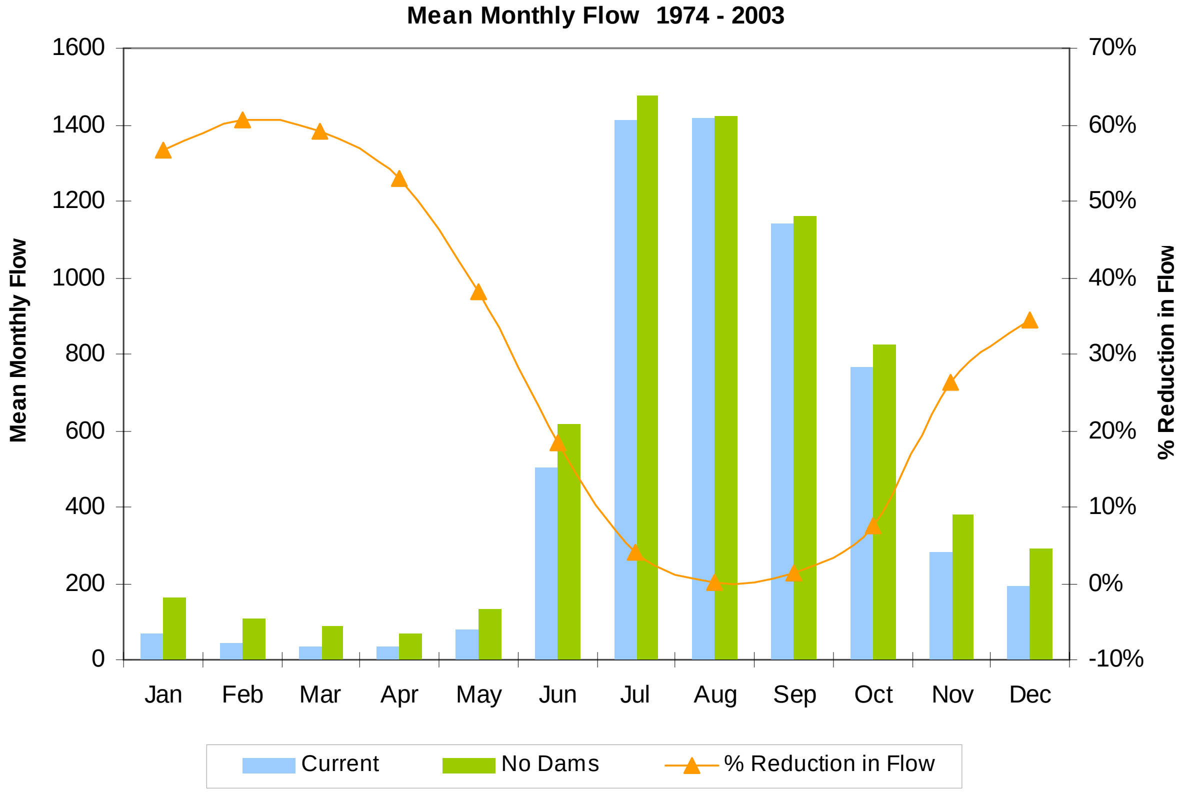


Figure 5.2 Mean monthly flow comparison; current — no dams scenario

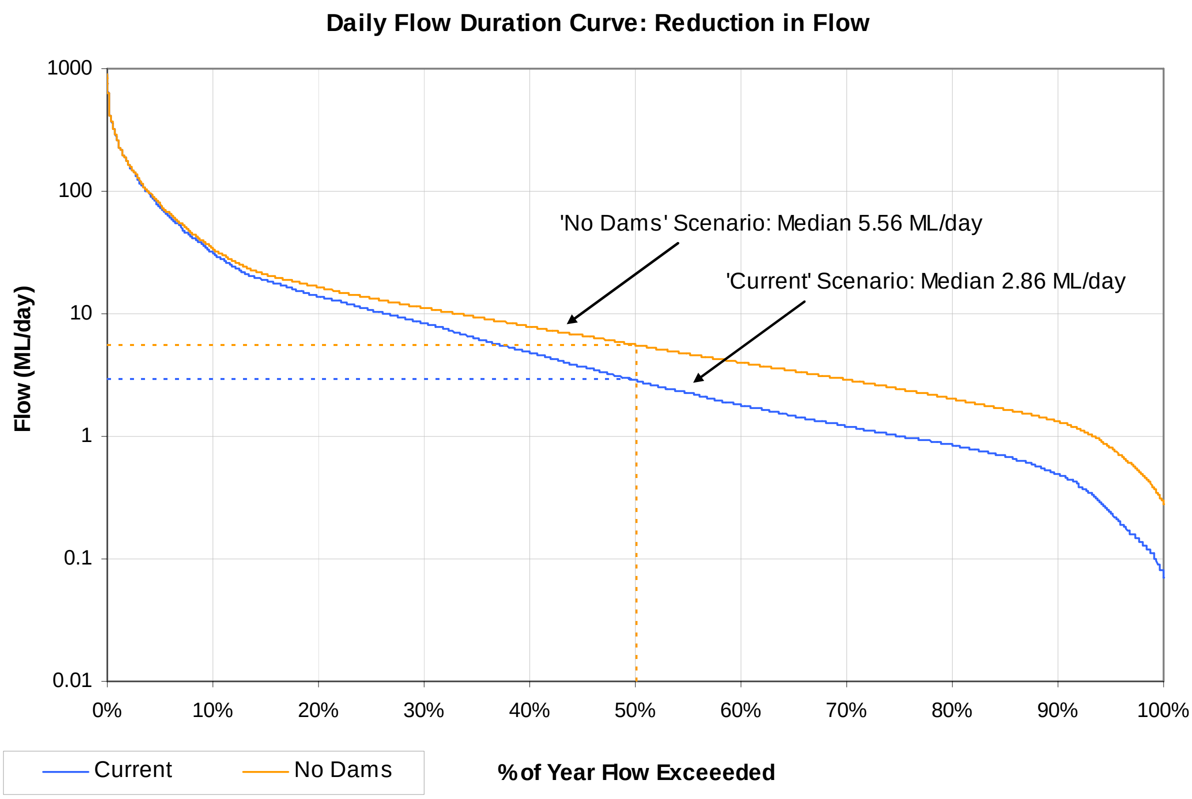


Figure 5.3 Daily flow frequency curves showing the effect of farm dams on daily flow regime

Table 5.2 describes the daily flow exceedance — the number of days we can expect to see a flow greater than that indicated. The greatest impact is seen in the number of days the catchment ceases to flow, with an extra 20 days being observed under the current scenario. Overall, the impact is greatest in the range of low flows, typically below 20 ML.

Table 5.2 Difference in flow exceedance days between the current and no dams scenarios

Flow criteria	Number of days in a year of flow being exceeded		Difference in flow exceedance days
	'With dams' scenario	*'Without dams' scenario*	
Cease to flow	0	0	0
>0.01 ML/d	365	365	0
>1 ML/d	341	274	67
>10 ML/d	121	96	25
>20 ML/d	58	51	7
>50 ML/d	27	26	2
>100 ML/d	14	14	1
>200 ML/d	5	5	0
>500 ML/d	1	1	0

Climate can also influence the permanence of flow in a river system, particularly where a system has a close connection to local aquifers. Like runoff, aquifer recharge (whether alluvial or fractured rock) significantly increases in years of greater than average rainfall. Streams fed by these aquifers would flow over a greater period of the year.

6. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This report describes the methodology and outcomes of a hydrological study of the Currency Creek Catchment. It examines the surface water flow regime of the catchment and the likely impacts of farm dams on its hydrology. The following section summarises the main findings and lists recommendations for the management of surface water resources in the catchment.

6.1 SUMMARY OF DATA INPUTS

6.1.1 RAINFALL DATA

The daily rainfall data used for this study was from BoM station M023838 at Mount Compass (Marshall Brae). The station was located in the middle of the study area and performed well in the double-mass analysis, making it the most suitable record to use for calibration. The use of a rainfall isohyet set generated by DWLBC, from data supplied by BoM, was employed to give spatial distribution over the Currency Creek Catchment.

6.1.2 STREAMFLOW DATA

There is currently no streamflow gauging station operational in the Currency Creek Catchment. Historical data for from Station A4260530 was used in this study. With a period of record spanning 21 years with 98.3% reliable data, this is considered a valuable record for the region. This allowed calibration over a long period with a good representation of wet, dry and average years. The gauge received flows from 64% of the entire catchment.

6.1.3 EVAPORATION DATA

Mount Bold Reservoir daily evaporation was used in this study. Its proximity to the Currency Creek Catchment was considered to be suitable for use. The record is considered reliable and has been used in numerous hydrologic models in the region.

6.1.4 FARM DAM DATA

The collection of farm dam data for this study comprised three main components:

1. The digitising of farm dams from aerial photography onto a GIS coverage to obtain numbers and spatial distribution of farm dam development.
2. The estimation of farm dam volumes from the GIS coverage using a relationship developed by McMurray (2004a).
3. Collection of specific information about usage, and better estimates of farm dam sizes through the land and water-use survey conducted by DWLBC, such as measuring dam wall height and applying a formula based on dam shape.

It is hoped that through the extensive DWLBC land and water-use survey, more accurate information about farm dam capacity will be available to enhance the water allocation planning process.

6.2 CATCHMENT MODELLING

6.2.1 MODEL CALIBRATION

Having a good length and high quality record, the streamflow data used to calibrate this model yielded good calibration of the rainfall-runoff model on daily, monthly and annual time steps.

The daily flow exceedance curve indicates that the most significant deviation from the observed record occurs at between the 80th and 90th percentiles (i.e. the very low flows). The model response was to over estimate the rate in these flow bands. As such, the interpretation of results must keep in mind that effects on the low flow regime may be underestimated.

The model could be improved by incorporating sub-daily rainfall intensity data, and by using more rainfall stations from within the catchment.

6.3 MODELLING RESULTS

Both the current scenario and a pre-farm dam scenario were run to estimate the impacts of farm dams on the hydrology of the catchment. Results indicate that:

- Farm dams in the catchment currently reduce the mean annual flow out of the Upper Currency Creek sub-catchment by around 11% or 765 ML.
- Seasonally, the impact of farm dams significantly affects the transitional months (May, June, July), which are important seasons for various processes such as wetting up of the stream bed. However, the greatest impact is noted in the summer months.
- All daily flows below ~20 ML/d (low flows) are reduced significantly.

The Currency Creek Catchment is currently under-developed in relation to the RMCWMP limit of 30% of adjusted runoff. However, given the nature of some of the unique ecological assets in the upper reaches of Currency Creek, close controls should be kept on further development where there is likely to be environmental impact.

6.4 TECHNICAL RECOMMENDATIONS

- Streamflow data are not currently collected in the Currency Creek Catchment. In order to update the understanding of the surface water regime it is recommended that:
  - The decommissioned gauging station be reinstated, or replaced in another suitable location.
  - Further monitoring sites be established downstream of the historical station in order to provide estimates of recharge and discharge through the stream bed, and improved estimates of whole-of-catchment yields.

- In order to correctly assess the impact of farm dams, it is necessary to improve the estimation of farm dam capacities. Accurately surveying farm dams in key positions within the catchment would greatly enhance the ability of the process to predict their impact. Better estimates of water-use from farm dams would also greatly enhance this effort.
- Improved catchment modelling depends on both quality streamflow data and climatological data. The use of sub-daily data would greatly improve current modelling and understanding of catchment hydrology. It is recommended that, where possible, data from relevant pluviometers be used to construct and calibrate catchment rainfall-runoff models.

6.5 ENVIRONMENTAL CONSIDERATIONS

The hydrological analysis in this study has highlighted a number of key concerns relating to the environmental flow regimes of the catchment. Although this study was not an attempt to define the environmental water requirements, it provided some insight into the level of change within the catchment due to the impact of farm dams. Reductions in catchment yield, reduced flows during transitional seasons, and decreased low and medium flows will require various management mechanisms to ensure sustainability of the resource. It is therefore recommended that:

- Further development of farm dams in the catchment be restricted until an appropriate water allocation plan is in place, and provides suitable measures for water trading. Future development should then abide by existing rules as set out in the RMCWMP.
- Following the adoption of a water allocation plan, monitoring will be necessary to gauge any impacts or improvements due to the management options.
- Best practice irrigation measures be encouraged to enhance the capability of the resource to cope with development.
- Under the current Notice of Prescription, stock and domestic dams are exempt from any management rules. This provides the catchment management board with little flexibility in terms of placing future restrictions on extraction, diversion or use. It is recommended that this decision be revisited at the review of the first water allocation plan.

APPENDICES

A. RAINFALL ANALYSIS

Rainfall data for all stations in and around the Currency Creek Catchment were gathered from two sources.

1. SKM (2000) data, which cover up to 1998 and are infilled and disaggregated.
2. Extracted from the Hydstra database for all data from 1/1/1999.

Table A.1 Correlation of daily rainfall between stations

	23701	23714	23735	23808	23823	23824	23832	23834	23838	23841
23701	1									
23714	0.772	1								
23735	0.747	0.750	1							
23808	0.741	0.770	0.834	1						
23823	0.717	0.749	0.815	0.858	1					
23824	0.675	0.704	0.789	0.795	0.905	1				
23832	0.687	0.835	0.838	0.820	0.886	0.813	1			
23834	0.739	0.825	0.707	0.707	0.800	0.741	0.893	1		
23838	0.849	0.863	0.804	0.811	0.926	0.842	0.930	0.771	1	
23841	0.578	0.743	0.751	0.943	0.752	0.969	0.915	0.834	N/A	1

Data extracted from Hydstra was infilled and disaggregated using the method described by SKM so that a complete dataset was obtained.

All local stations were then checked for correlation between each other. Stations with high daily correlation were flagged for use as possible comparison stations within the catchment. Table A.1 provides correlation statistics.

As most of the stations within the catchment had relatively short datasets, a station with comparable rainfall was needed to extend the datasets. For this purpose, the station had to have similar characteristics (e.g. similar rainfall and topography). This means that stations on the plains were unsuitable for use.

Results from the correlation showed that of the three stations inside the catchment, only one appeared to be suitable. Although 23834 had a longer record (30 years) than 23838 (20 years), it showed far lower correlation with any of the stations used for analysis. The correlations for 23834 were much lower than any of the others and for this reason it was left out of the analysis, instead relying on the data available for 23838.

Of the rest of the stations with longer term records, 23823 provided the highest correlation and had a reasonably long rainfall record (68 years).

Further analysis was required of 23823 to ensure that the record was homogenous, and for this purpose the Double-Mass technique was used. The station was checked against six other stations, all chosen for their concurrent data record. They were also taken from further a field than the original station search in order to find a sufficient number.

Results from the Double-Mass analysis showed one area of inconsistency where the change in slope from the most homogenous section was greater than 5% (7.2%), which was the required level of homogeneity chosen for this exercise (Table A.2). Double Mass charts are provided in Figure A.1. The data for that period were then adjusted to produce a relatively homogenous dataset.

Table A.2 Double-Mass analysis results for station M023838

Section	slope	Change in slope	Adjustment factor	Start	End
s1b	1.499	-3.76%	1.038	Jan-40	Oct-52
s2b	1.414	-9.98%	1.100	Nov-52	Mar-64
s3b	1.581	1.64%	0.984	Apr-64	Oct-72
s4b	1.598	2.63%	0.974	Nov-72	Dec-98
Slope (average)	**1.556**				

The Double-Mass curve was plotted against monthly averages from six nearby long-term rainfall stations (M023751, M023718, M023742, M023747, M023753, M023735) for the period January 1940–December 1998 (Fig. A.1). The period of analysis reflects the availability of concurrent long-term data for all stations.

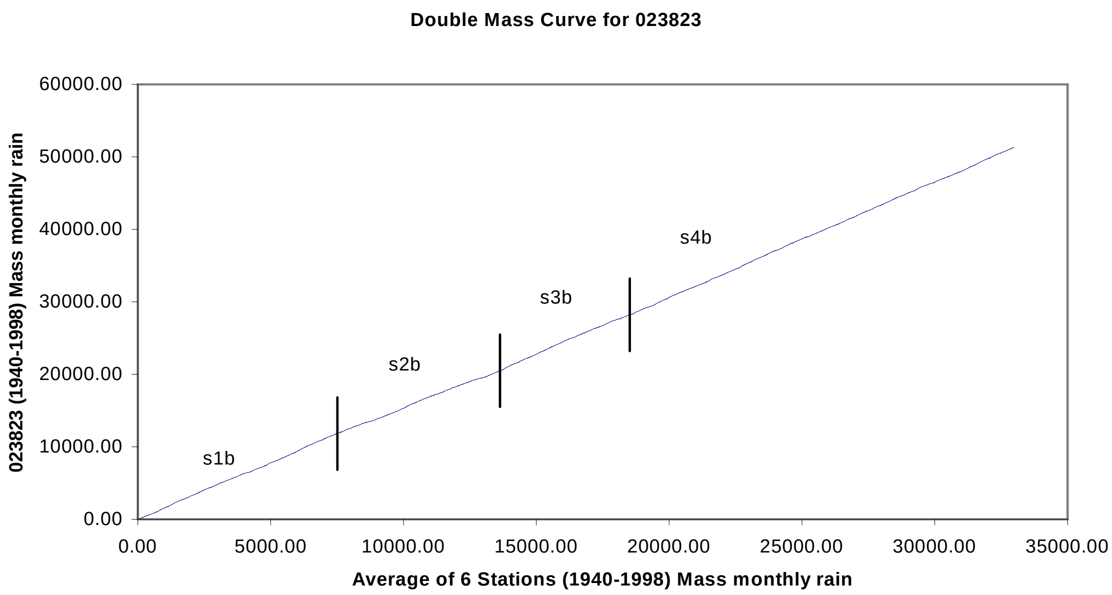


Figure A.1 Double-Mass curve for Hindmarsh Valley (Fernbrook 023823) against an average of stations 023751, 023757, 023747, 023718, 023735 and 023742.

From Table 2.1, the difference in slope of section 2 from the average slope is 9.98%. Where the difference in section slope from overall homogeneous slope is greater than about 5%, it is regarded as showing some inconsistency. The inconsistency may occur for various reasons such as a change in instrument exposure. The period from November 1952 through to March 1964 was therefore adjusted by a factor of 1.1. Inspection of the Double Mass curve post-adjustment reveals a more homogeneous dataset.

In order to extend the 23838 dataset, both 23838 and 23823 were plotted and a relationship was derived between the two (the slope). This slope was then used to extend the data from 1972 back to 1936.

B. SUB-CATCHMENT DETAILS

Minor sub-catchment number	**Rain** (mm)	**Area** (km^2)	**Total dam volume** (ML)	**Dam density** (ML/km^2)	**Mean winter runoff** (ML)	**Mean annual adjusted flow**	**30% of winter**	**RMCWMP limit** (%)	**% reduction in flow — farm dams**
1	837	3.4	200	58.9	523.3	550.8	157.0	38	26
2	821	1.7	43	25.2	248.5	261.6	74.6	17	22
3	806	0.5	2	4.0	69.2	72.8	20.8	3	3
4	806	0.8	1	0.6	110.7	116.5	33.2	0	0
5	806	1.2	13	10.8	166.1	174.8	49.8	8	6
6	784	0.2	2	10.0	25.4	26.7	7.6	8	7
7	806	1.3	2	1.5	179.9	189.4	54.0	1	4
8	776	0.6	3	4.8	74.0	77.9	22.2	4	4
9	761	1.8	39	21.4	208.7	219.7	62.6	18	14
10	769	0.3	0	0.0	35.9	37.8	10.8	0	12
11	784	0.2	1	6.5	25.4	26.7	7.6	5	5
12	799	1.3	0	0.0	174.9	184.1	52.5	0	12
13	814	1.4	139	99.6	199.1	209.6	59.7	70	36
14	791	2	145	72.5	261.6	275.4	78.5	55	33
15	784	0.5	30	59.2	63.5	66.8	19.0	47	33
16	776	0.2	3	14.5	24.7	26.0	7.4	12	10
17	769	0.1	2	20.0	12.0	12.6	3.6	17	14
18	761	0.3	6	20.3	34.8	36.6	10.4	18	13
19	754	0.5	2	3.0	56.2	59.2	16.9	3	3
20	754	0.4	6	14.5	45.0	47.3	13.5	13	11
21	754	1.2	7	5.4	134.9	142.0	40.5	5	4
22	761	0.1	2	19.0	11.6	12.2	3.5	16	13
23	769	1.6	0	0.0	191.4	201.5	57.4	0	14
24	799	2.1	5	2.1	282.6	297.4	84.8	2	2
25	776	1.3	7	5.5	160.2	168.7	48.1	4	4
26	791	1.3	2	1.7	170.0	179.0	51.0	1	3
27	769	0.2	2	10.5	23.9	25.2	7.2	9	8
28	784	0.7	3	3.7	88.9	93.6	26.7	3	3
29	776	0.5	0	0.0	61.6	64.9	18.5	0	2
30	769	0.2	1	5.0	23.9	25.2	7.2	4	4
31	761	0.5	0	0.2	58.0	61.0	17.4	0	0
32	754	0.4	4	10.3	45.0	47.3	13.5	9	9
33	761	1.2	0	0.0	139.1	146.4	41.7	0	11
34	761	0.8	4	4.8	92.7	97.6	27.8	4	4
35	746	1.3	45	34.9	141.4	148.8	42.4	32	21
36	716	0.5	4	8.2	47.4	49.9	14.2	9	8
37	724	0.8	6	7.6	78.6	82.7	23.6	8	7
38	746	0.7	30	43.4	76.1	80.1	22.8	40	14
39	724	0.4	7	17.0	39.3	41.4	11.8	17	14
40	746	0.6	3	4.3	65.3	68.7	19.6	4	4

Minor sub-catchment number	**Rain** (mm)	**Area** (km^2)	**Total dam volume** (ML)	**Dam density** (ML/km^2)	**Mean winter runoff** (ML)	**Mean annual adjusted flow**	**30% of winter**	**RMCWMP limit** (%)	**% reduction in flow — farm dams**
41	731	0.5	8	15.4	50.8	53.5	15.2	15	13
42	724	0.9	7	8.2	88.4	93.0	26.5	8	8
43	739	1	29	29.3	105.2	110.7	31.5	28	14
44	724	0.4	7	17.5	39.3	41.4	11.8	18	14
45	708	0.2	1	4.5	18.3	19.3	5.5	5	5
46	693	0.8	21	25.8	67.8	71.4	20.4	30	22
47	708	0.7	8	10.9	64.0	67.4	19.2	12	10
48	716	2.2	0	0.0	208.6	219.6	62.6	0	11
49	746	0.3	7	24.3	32.6	34.3	9.8	22	17
50	739	0.8	4	5.0	84.1	88.6	25.2	5	8
51	724	0.3	2	8.0	29.5	31.0	8.8	8	7
52	739	0.2	3	15.5	21.0	22.1	6.3	15	14
53	731	1.1	0	0.0	111.8	117.7	33.5	0	5
54	746	0.3	22	72.3	32.6	34.3	9.8	67	41
55	739	0.7	15	20.9	73.6	77.5	22.1	20	23
56	724	0.6	8	13.3	58.9	62.0	17.7	14	12
57	716	0.3	4	12.3	28.4	29.9	8.5	13	12
58	708	1.3	22	17.2	118.9	125.2	35.7	19	11
59	701	1.6	36	22.6	141.0	148.4	42.3	26	19
60	671	0.3	19	63.7	22.6	23.7	6.8	85	52
61	686	0.3	4	12.3	24.5	25.8	7.3	15	14
62	686	1	7	7.3	81.6	85.9	24.5	9	18
63	603	2	34	17.0	98.2	103.4	29.5	35	28
64	663	0.6	5	8.3	43.3	45.5	13.0	12	11
65	671	0.5	2	3.2	37.6	39.6	11.3	4	8
66	671	0.4	2	5.3	30.1	31.7	9.0	7	7
67	701	0.9	7	8.0	79.3	83.5	23.8	9	8
68	686	1.4	0	0.0	114.2	120.2	34.3	0	12
69	648	0.6	6	10.2	39.6	41.6	11.9	15	13
70	626	1.1	9	8.5	63.0	66.3	18.9	15	14
71	663	0.1	2	21.0	7.2	7.6	2.2	29	24
72	641	0.9	10	10.7	56.8	59.8	17.0	17	15
73	610	0.7	5	7.3	36.2	38.1	10.9	14	14
74	648	0.5	5	9.8	33.0	34.7	9.9	15	14
75	626	1.3	13	10.3	74.4	78.4	22.3	18	15
76	618	0.7	8	12.0	38.1	40.1	11.4	22	21
77	595	0.8	3	3.6	37.0	39.0	11.1	8	8
78	603	1.1	0	0.0	54.0	56.8	16.2	0	13
79	595	1	15	15.4	46.3	48.7	13.9	33	26
80	595	1.9	14	7.5	88.0	92.6	26.4	16	14
81	693	0.9	9	9.8	76.3	80.3	22.9	12	10
82	663	1.4	19	13.6	100.9	106.2	30.3	19	14
83	663	0.6	7	11.3	43.3	45.5	13.0	16	15
84	648	0.3	6	19.7	19.8	20.8	5.9	30	27

Minor sub-catchment number	**Rain** (mm)	**Area** (km^2)	**Total dam volume** (ML)	**Dam density** (ML/km^2)	**Mean winter runoff** (ML)	**Mean annual adjusted flow**	**30% of winter**	**RMCWMP limit** (%)	**% reduction in flow — farm dams**
85	633	0.5	1	1.4	30.1	31.7	9.0	2	13
86	663	2.8	0	0.0	201.9	212.5	60.6	0	11
87	618	0.4	8	19.5	21.8	22.9	6.5	36	29
88	641	0.7	7	9.6	44.2	46.5	13.3	15	14
89	626	0.5	5	10.0	28.6	30.1	8.6	17	16
90	610	0.2	6	32.0	10.3	10.9	3.1	62	46
91	626	0.9	0	0.0	51.5	54.2	15.5	0	11
92	663	0.7	3	4.7	50.5	53.1	15.1	7	7
93	610	1.6	6	3.4	82.8	87.1	24.8	7	7
94	565	1.8	3	1.8	65.7	69.2	19.7	5	6
95	558	0.1	17	166.0	3.4	3.6	1.0	486	100
96	588	0.5	1	2.0	21.9	23.1	6.6	5	5
97	573	4.5	0	0.0	174.9	184.1	52.5	0	11
98	543	1.4	0	0.0	41.6	43.8	12.5	0	13
99	535	0.8	2	2.9	22.2	23.4	6.7	10	9
100	520	1.2	0	0.0	22.2	30.0	6.7	0	11

C. THE TANH FUNCTION

The Tanh function (Grayson et al. 1996) is a standard hyperbolic function and was used by Boughton (1996) as simple rainfall-runoff relationship.

Calculation

$$Q = (P - L) - F \times \tanh[(P - L)/F]$$

where

Q is runoff (mm)

P is rainfall (mm)

L is notional loss (mm)

F is notional infiltration (mm).

The equation can be applied to any data but should be used for data where average storage of soil water is approximately constant (i.e. where the notional loss and infiltration might be expected to be similar). Annual data satisfies this requirement but monthly data will need to be separated into data for each month or at least for season and a different L and F derived for each month's (or season's) set.

Determination of F and L

The values of the notional loss (L) and infiltration (F) are determined by plotting monthly flow sets, seasonal flow sets or annual flow sets against the associated rainfall. A preliminary value of L is chosen from the data and F fitted either by trial and error or with a curve fitting technique. Similarly, the preliminary estimate of L can be changed to improve the fit. It is often simplest to just plot the data in a spreadsheet and visually fit the parameters.

D. DESCRIPTION OF WC-1 MODEL

WC-1 is a water balance model developed by David Cresswell based on experience with South Australian rainfall run-off calibration in the Mount Lofty Ranges, Barossa Valley and Mid North. The program was developed in 1988 to estimate the impact of farm dams in the Barossa Valley when it was found that most of the existing models tried were not able to reproduce the recorded runoff of South Australia's drier catchments. When annual rainfall lies in the range 450–650 mm, the estimation of run-off becomes a tricky exercise.

Model Concept

The model is a 10-parameter model using three storages as shown in Figure A.2 to track interception, soil moisture and groundwater. The soil store is generally the main runoff-producing component requiring four parameters for calibration.

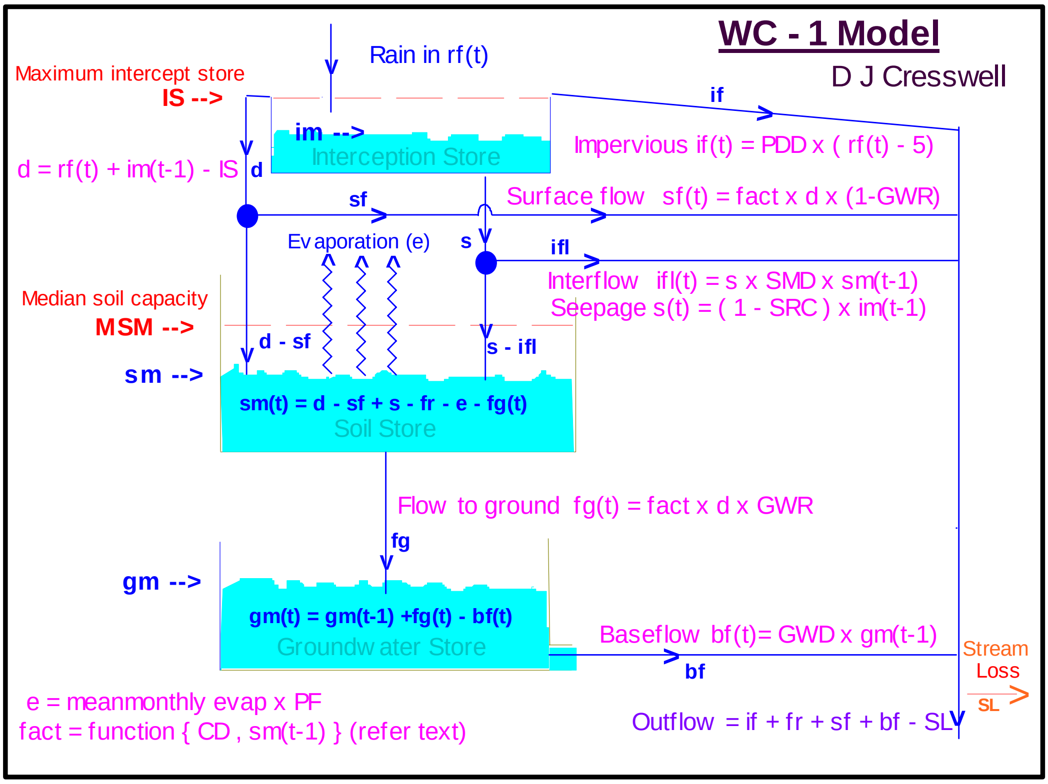


Figure A.2 Concept of the WC-1 Model

Surface runoff (not including the groundwater contribution) is calculated with both a hortonian and saturated surface area component. The hortonian component is generally small and is calculated as the runoff from an impervious area that has a daily loss rate of 5 mm. The parameter PDD is used to input the fraction of the catchment contributing.

By far the greatest proportion of surface flow is generated by calculating the saturated surface area of the catchment. To do this, the model tracks the soil storage and calculates the area saturated, based on the assumption that the soil moisture holding capacity is normally distributed across the catchment (Fig. A.3).

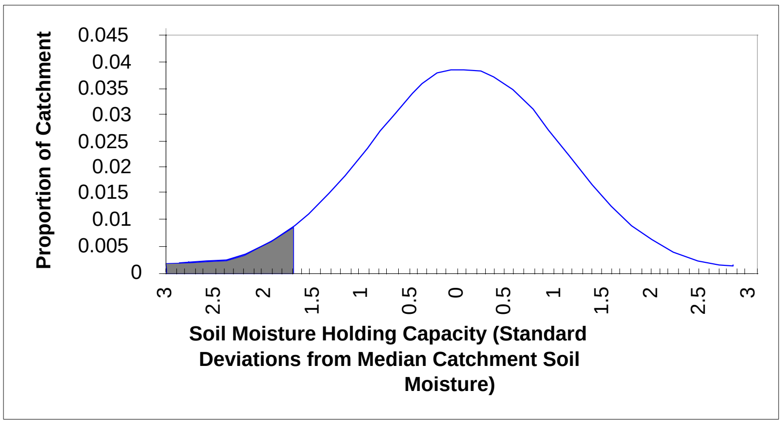


Figure A.3 Contributing catchment calculated from soil moisture — catchment contribution = 5.5%

To calibrate such a model, two parameters are required — the median soil moisture of the catchment (MSM) and the catchment standard distribution (CD). Typically these values lie between 150–250 mm (MSM) and 20–80 mm (CD).

When dry, the soil moisture lies >3 standard deviations to the left of the median centre and as the catchment wets up moves towards the fully saturated catchment which occurs at median soil moisture plus 3 standard deviations. At any point on the axis, the proportion of catchment assumed to be saturated is calculated as the area under the normal distribution curve.

For example, Figure A.3 indicates that when the soil moisture of the soil store reaches MSM – 1.6 x CD, the area shaded is the proportion of the catchment contributing to the runoff. From normal distribution tables this is 5.5% of the catchment.

When the median soil moisture is reached, the catchment contributing is 50% as shown in Figure A.4.

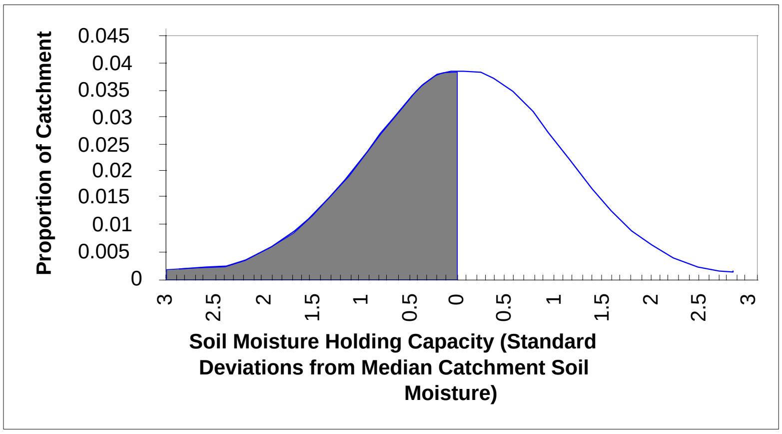


Figure A.4 Contributing catchment calculated from soil moisture — catchment contribution = 50%

The shape of this relationship is similar to a power curve but asymptotic to Y = 0 and Y = 1. Intuitively this is what is expected and overcomes the problem of the power curve that is required to be silled at 1.0.

The volume of water running off the catchment is then the product of the contributing area and the effective rainfall. Catchments in semi-arid areas show a capacity to retain quite significant rainfall events requiring the use of an interception store for accurate simulation.

The effective rainfall is defined as the volume of water spilling the interception store.

The maximum interception store (IS) may typically range from zero to 30 mm and is tracked continuously within the model. Water may leave the interception storage either by overtopping the storage, thus becoming effective rainfall, or it may percolate slowly into the soil store where it contributes to an interflow component of flow. This percolation occurs at a rate calculated in a similar way to the Annual Precipitation Index (API).

The transfer rate is independent of season and is set by the soil wetness multiplier (SWM) typically to a value of 0.9. The value set is the proportion of the water held in the store (im(t)) which is retained to the next day. Seepage is calculated equal to S = (1 – SWM) x im (t)

During the wet season, the baseflow of the streams are seen to rise but the duration of such flow remains dependent on relatively continuous rainfall on the catchment. It is proposed that this baseflow return occurs due to the over-saturated areas of the catchment returning a fraction of this moisture back to the streams. As the catchment dries or during long spells of no rain it is expected that this return will drop to zero.

This interflow is assumed in the model to equal Ifl = s x SMD x sm(t)

SMD is the parameter defining the proportion returned to the stream.

The catchment response is therefore defined by the six parameters mentioned above but evaporation can potentially override all of these. In semi-arid catchments, choosing the correct evaporation rate is critical.

Models use various formulas ranging from linear to power functions to estimate the moisture loss from soils. Experimentation with the linear model was not found to improve the estimate of runoff and was discarded for the simpler constant model. Here evapotranspiration is assumed to equal the pan factor times recorded daily evaporation. Typically a value of 0.6 to 0.7 is used for class A pan recordings.

Groundwater is simulated within the model using two parameters — GWR (recharge) and GWD (discharge). Both operate in a simple linear fashion.

Groundwater recharge is seen to have a greater relationship with streamflow than total rainfall. This suggests that groundwater recharge requires similar conditions to streamflow, hence the wetting up of the catchment, to occur. Tying recharge to streamflow simulates this, which assumes the greater the saturated catchment-generated streamflow occurring the more recharge occurs from the soil to groundwater store.

The parameter GWR is used to define the proportion passing to ground and often this may be up to 20–30%.

Baseflow discharging from the groundwater store is simply a linear relationship defined by parameter GWD. No loss is assumed to occur from the groundwater store to external basins.

Summary of WC-1 Parameters

Medium soil moisture (MSM) — represents the field capacity of the soil; usually in the range 150–300 mm. Increasing this value delays the early season initiation of runoff, decreases runoff by providing greater opportunity for evapotranspiration and assists in keeping late season groundwater flows up.

Interception store (IS) — represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10–25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) — sets the range of soil moisture values about MSM. Usual values are 25–60 mm. A larger value will initiate runoff earlier and more often.

Groundwater discharge (GWD) — is the proportion of the groundwater store that discharges as baseflow to the stream.

This is a simple linear function: Baseflow = groundwater store x GWD

Usual values are small (0.001–0.0001).

Soil moisture discharge (SMD) — as soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small (0.0001).

Pan factor for soil (PF) — this factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6–1.0. The higher the value, the less the runoff. The higher the value, the earlier runoff ceases after winter.

Store wetness multiplier (SWM) — this value determines the rate that water from the interception store moves to the soil store. The transfer rate is independent of season and ensures that the amount of water retained in the interception store follows a similar power recession curve of the API. Usual values are around 0.9.

Groundwater recharge (GWR) — is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05–0.3 indicating that 5–30% of the flow running off the catchment is entering the groundwater system.

Creek loss (CL) — is a reduction factor used to decrease runoff. It is generally set to zero.

Values for the parameters used for calibrating the Currency Creek Catchment Model:

MSM	125
IS	14.8
CD	45.783
GWD	0.011
SWD	0.000
PF	0.69
FGL	0.18
SWM	0.9
GWR	0.38
Routing coefficients	2.0, 0.7

E. STREAMFLOW QUALITY REPORT

HYQUAL report for gauging station A4260530

SITE DATA QUALITY REPORT **HYQUAL V42 Output 08/06/2006**

Site: A4260530.Z

Variable: 100.00 Water Level Recording

Report Period: 15:45_06/06/1972 to 11:50_23/08/1993 Duration 21.21 years

SUMMARY

Quality	Subtotal	%	Reliable data	Unreliable data
1	20.78 y	97.98	20.85 y (98.31%)	130.93 d (1.69%)
76	25.39 d	0.33	Cut-off @ 150	
151	68.20 d	0.88		
201	62.73 d	0.81		
Totals	21.21 y	100.00		

F. METHODOLOGY FOR DISAGGREGATION OF ACUMMULATED RAINFALL RECORD

Rainfall data are collected at 0900 on a daily basis in the BoM stations. Rainfall collected during weekends and public holidays is recorded at 0900 on the next working day. This necessitated disaggregation of the accumulated rainfall for those days when rainfall was not recorded. The methodology used by SKM for disaggregation is based on the method outlined by Porter and Ladson (1993).

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

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

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

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

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

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

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

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

G. TREND TEST (GREYSON 1996)

Mann's Test (Kendall 1970)

Given a time series (X_1, X_2, X_3, …..X_n), Mann's test statistic evaluates the null hypothesis H_0 that the observations are randomly ordered versus the alternative of a monotonic trend over time. Let R_1, R_2, R_3, …R_n be the ranks of the corresponding X values and define the function sgn(x) as follows:

sgn(x) = 1 for x >0, sgn(x) = 0, for x = 0 and sgn(x) = -1 for x <0

If the null hypothesis is true, the statistic:

$$S = \sum_{i<j} \mathrm{sgn}(R_j - R_i)$$

has a mean of zero and a variance of:

Var(S) = (n (n-1) (2n+5)) / 18

and is asymptotically normal. The normal Z-test statistic is:

u(n) = S / $[\mathrm{Var(S)}]^{0.5}$

The statistic u(n) can be computed for any values of i to detect whether there is a trend in the data up to i at the chosen level of significance using the z-test. A positive value of u(n) indicates that there is an increasing trend and vice versa.

H. RAINFALL SPATIAL VARIABILITY

BoM developed rainfall data, in the form of a gridded rainfall map, for DWLBC (BoM 2006). This was used in analysing the spatial variability of rainfall throughout the Mount Lofty Ranges. The dataset used in this report was developed in 2006 and uses rainfall data for the period 1971–2000 (30 years) from all rainfall stations in the vicinity of the Mount Lofty Ranges that had data available for that period. As such, rainfall averages derived from the gridded map are only appropriate for the period defined above. In order to relate the averages taken from the GIS datasets to the rainfall data used in this report, namely that from the BoM station at Keyneton, the following approach was used.

The Spatial Analyst function in ArcMap was used to derive an area weighted mean based on the above gridded 1 km x 1 km rainfall map for each major and minor sub-catchment. For full details of rainfall for all the minor sub-catchments, refer to Appendix B.

Where the rainfall factor is required for use in the WaterCRESS 2000 model, the comparison has been made with the mean at Marshall Brae for the same period (1971–2000).

Rainfall Factor = Mean Rain at sub-catchment/ Mean Rainfall @ Marshall Brae (1971–2000)

e.g. For rainfall factor in sub-catchment 50:

Mean Rainfall Marshall Brae (1971–2000)	= 732 mm
Mean rainfall sub-cat Upper One Tree Hill Creek	= 739 mm
Rainfall Factor	= 732/739
	= 0.99

Where long-term rainfall for each minor sub-catchment is required, for the application of Tanh curves, the rainfall obtained from the GIS coverage is multiplied by the ratio of the long-term mean to the mean for the period 1961–90. In this case that is:

Long term mean (1936–2003)	= 718 mm
Short term Mean (1971–2000)	= 732 mm
Conversion Factor	= 0.98

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

Act (the). In this document, refers to The *Natural Resources Management Act* (South Australia) 2004.

Adaptive management. A management approach, often used in natural resource management, where there is little information and/or a lot of complexity and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.

Ambient. The background level of an environmental parameter (e.g. a background water quality like salinity).

Anabranch. A branch of a river that leaves the main stream.

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

Aquifer. An underground layer of rock or sediment which holds water and allows water to percolate through.

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

Basin. The area drained by a major river and its tributaries.

Benchmark condition. Points of reference from which change can be measured.

Biological diversity (biodiversity). The variety of life forms: the different life forms including plants, animals and micro-organisms, the genes they contain and the *ecosystems (see below)* they form. It is usually considered at three levels — genetic diversity, species diversity and ecosystem diversity.

Biota. All of the organisms at a particular locality.

Bore. *See well.*

Catchment. A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Catchment Water Management Board. A statutory body established under Part 6, Division 3, s. 53 of the Act whose prime function under Division 2, s. 61 is to implement a catchment water management plan for its area.

Catchment Water Management Plan. The plan prepared by a CWMB and adopted by the Minister in accordance with Part 7, Division 2 of the Water Resources Act 1997.

CWMB. Catchment Water Management Board.

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. Off-stream dams 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.

Domestic purpose. The taking of water for ordinary household purposes and includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares.

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

EMLR. Eastern Mount Lofty Ranges.

Environmental values. The uses of the environment that are recognised as of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water-use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

Environmental water requirements. The water regimes needed to sustain the ecological values of

Ephemeral streams/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 waterbodies 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.

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

Floodplain. Of a watercourse means: (a) the floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under Part 7 of the Water Resources Act 1997; or (b) where paragraph (a) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the Development Act 1993, or (c) where neither paragraph (a) nor paragraph (b) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse.

Flow bands. Flows of different frequency, volume and duration.

Gigalitre (GL). One thousand million litres (1 000 000 000).

GIS (geographic information system). Computer software allows for the linking of 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.

GL. *See gigalitre.*

Groundwater. *See underground water.*

Habitat. The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

Heavy metal. Any metal with a high atomic weight (usually, although not exclusively, greater than 100), for example mercury, lead and chromium. Heavy metals have a widespread industrial use, and many are released into the biosphere via air, water and solids pollution. Usually these metals are toxic at low concentrations to most plant and animal life.

Hydrogeology. The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See 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 hydrogeology.)*

Intensive farming. A method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or by mechanical means.

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.

Licence. A licence to take water in accordance with the Water Resources Act 1997. *(See water licence.)*

Licensee. A person who holds a water licence.

Local water management plan. A plan prepared by a council and adopted by the Minister in accordance with Part 7, Division 4 of the Act.

Megalitre (ML). One million litres (1 000 000).

ML. *See megalitre.*

MLR. Mount Lofty Ranges.

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

Mount Lofty Ranges watershed. The area prescribed by Schedule 1 of the regulations.

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

Natural Resources Management (NRM). 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.

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 data set 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.

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 Water Resources Act 1997.

Prescribed water resource. A water resource declared by the Minister 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.

Prescribed watercourse. A watercourse declared to be a prescribed watercourse under the Water Resources Act 1997.

Prescribed well. A well declared to be a prescribed well under the Water Resources Act 1997.

PWRA. Prescribed Water Resources Area.

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.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

Rehabilitation (of waterbodies). Actions that improve the ecological health of a waterbody by reinstating important elements of the environment that existed prior to European settlement.

Restoration (of waterbodies). Actions that reinstate the pre-European condition of a waterbody.

Seasonal watercourses or wetlands. Those watercourses and wetlands that contain water on a seasonal basis, usually over the winter/spring period, although there may be some flow or standing water at other times.

State water plan. The plan prepared by the Minister under Part 7, Division 1, s. 90 of the Act.

Stock Use. The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act).

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.

To take water. From a water resource includes (a) to take water by pumping or syphoning the water; (b) to stop, impede or divert the flow of water over land (whether in a watercourse or not) for the purpose of collecting the water; (c) to divert the flow of water in a watercourse from the watercourse; (d) to release water from a lake; (e) to permit water to flow under natural pressure from a well; (f) to permit stock to drink from a watercourse, a natural or artificial lake, a dam or reservoir.

Transfer. A transfer of a licence (including its water allocation) to another person, or the whole or part of the water allocation of a licence to another licensee or the Minister under Part 5, Division 3, s. 38 of the Act. The transfer may be absolute or for a limited period.

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

Water allocation. (a) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence; (b) in respect of water taken pursuant to an authorisation under s. 11 means the maximum quantity of water that can be taken and used pursuant to the authorisation.

Water allocation, area based. An allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water-use year.

Water allocation plan (WAP). A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

Water licence. A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area. This grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water. A water licence confers a property right on the holder of the licence and this right is separate from land title.

Water plans. The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act.

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; and a lake through which water flows; and 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, which 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.

Well. (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) 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/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.

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