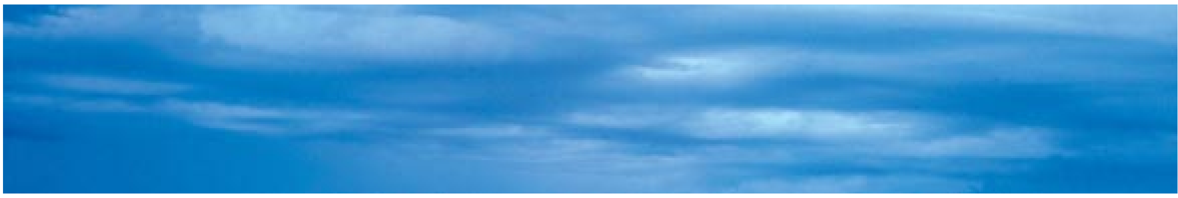
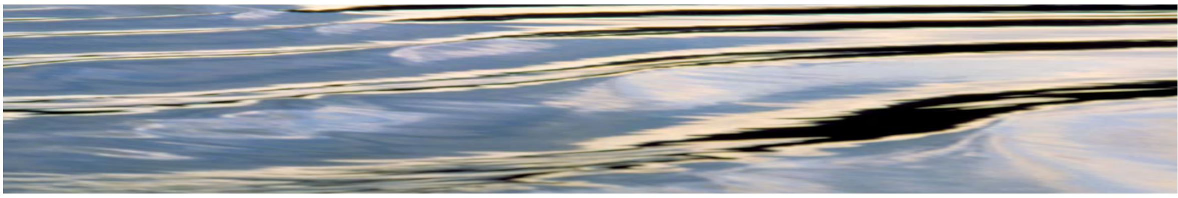
COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

CALIBRATIONS OF THE AWBM FOR USE ON UNGAUGED CATCHMENTS

TECHNICAL REPORT
Report **03/15**
December 2003

Walter Boughton / Francis Chiew





COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY

Boughton, W. C. (Walter C.)

Calibrations of the AWBM for use on ungauged catchments

Bibliography

ISBN 1 920813 05 5.

1. Runoff - Australia - Mathematical models. 2. Hydrologic models - Australia. 3. Watersheds - Australia - Mathematical models. 4. Rain and rainfall - Australia - Mathematical models. I. Chiew, Francis H. S., 1964- . II. Cooperative Research Centre for Catchment Hydrology. III. Title. (Series : Report (Cooperative Research Centre for Catchment Hydrology) ; 03/15).

551.4880994

Keywords

Modelling (Hydrological)
Rainfall-Runoff Relationship
Runoff
Catchment Areas
Calibration
Water Balance
Precipitation (Atmospheric)
Rain
Databases
Data Handling
Flow Measurement
Gauging

Calibrations of the AWBM for Use on Ungauged Catchments

Walter Boughton / Francis Chiew

Technical Report 03/15
December 2003

Preface

This report presents an approach for using the daily rainfall-runoff model, AWBM, to estimate runoff in ungauged catchments.

The report describes computer programs that can be used to optimise three key parameters in AWBM against runoff data from gauged catchments, and provides calibrated parameter values and catchment characteristics for 221 Australian catchments. The report then recommends an approach for using the calibrated parameter values in these and other catchments to guide the choice of AWBM parameter values for use in ungauged catchments.

This study relates to two current runoff estimation studies in the Cooperative Research Centre (CRC) for Catchment Hydrology. The first study, which is carried out as part of Project 5A 'Hydrological modelling for weather forecasting', involves the development of a regional model calibration approach for hydrologically similar regions and the estimation of parameter values for the daily rainfall-runoff model, SIMHYD. The second study, which is carried out as Project 2E 'Modulating daily flow duration curves to reflect the impact of land use change', involves the development of an approach for deriving daily flow duration curves for Australian catchments, particularly to model the runoff response to changes in land use.

Francis Chiew
Program Leader - Climate Variability Program
CRC for Catchment Hydrology

Summary

UGAWBM3 is a version of the AWBM daily catchment water balance model for estimating runoff from ungauged catchments. The program uses daily rainfall and monthly evaporation data to estimate daily runoff, and requires that values be specified for 3 parameters:

- runoff characteristics RC that determines the amount of runoff;
- baseflow index BFI that determines the amount of runoff that becomes baseflow; and
- baseflow recession constant Kb that determines the rate at which water is discharged from the baseflow store.

The AWBM model has been calibrated against runoff data from 221 gauged catchments across Australia. The parameter values for all 221 catchments are given in the report together with some statistical summaries that indicate some trends of the values in different regions. The data sets were initially prepared for a runoff estimation project of the National Land and Water Resources Audit. The catchments are located in the more populated and important agricultural regions of Australia.

The calibrated parameter values can be used with UGAWBM3 to estimate runoff from ungauged catchments in most areas of Australia. In addition, the different sets of calibrated parameter values in a region can be used to run UGAWBM3 to indicate the uncertainty in the estimates of runoff. Physical characteristics of the calibrated catchments are also given in the report to assist a user in selecting parameter values for use on an ungauged catchment.

The UGAWBM3 software, operating manual and test data are freely available without cost, together with the programs for calibration of parameter values on gauged catchments. All material can be obtained by contacting the senior author by email on wboughto@bigpond.net.au or by free downloading from the web site of the CRC for Catchment Hydrology at www.catchment.crc.org.au/models.

List of Tables

List of Figures

1 Introduction

There have been a number of studies in Australia directed to the estimation of runoff from ungauged catchments. The Curve Number method of the US Soil Conservation Service (Rallison 1980) has been tested on agricultural scale catchments (Boughton 1989) but the results were inaccurate enough that the method has not been used to any significant extent for engineering works on larger catchments.

In the early 1970s, the Australian Water Resources Council funded a study of runoff on small rural catchments (Snowy Mountains Engineering Corporation 1971) with the objective of calibrating a rainfall-runoff model on gauged catchments and using the results on ungauged catchments. The study by Johnston and Pilgrim (1973) showed that the modelling technology of that time was inadequate to achieve the desired objectives.

Boughton (1984) made some recommendations for use of the SFB model on ungauged catchments; however, an extensive study of the model by Nathan and McMahon (1990b,c) on 184 gauged catchments in south-eastern Australia did not produce results to justify the use of the SFB on ungauged catchments. There have been other studies such as that of the MOSAZ model by Nathan *et al* (1996) and the IHACRES model by Post and Jakeman (1999) and Post et al (1998) without producing any procedure that has attracted significant usage in engineering practice.

The AWBM model (Figure 2.1) was developed in the early 1990s (Boughton 1993) and has been used extensively throughout Australia. It has a simple structure and from its beginning offered potential for adaptation to use on ungauged catchments; however, this potential proved to be elusive.

Some recent developments have changed that situation. The first development was the auto-calibration version of the model, AWBM2002. The significant feature in this version was the use of a pattern of surface storage capacities and partial areas that allowed the runoff generating part of the AWBM to be represented by a single parameter. The second development was the establishment of a relationship between average annual runoff and average annual rainfall that could be represented by a single number - the runoff characteristic. The third development was the availability of over 200 data sets of daily rainfall and runoff that provided calibrated parameter values over much of Australia.

This report describes each of the developments and presents the calibrated sets of parameter values that can be used with the AWBM to estimate daily runoff on ungauged catchments.

2 Models and Methods

2.1 The AWBM and AWBM2002

The AWBM model is illustrated in Figure 2.1.

The parameters of the AWBM that determine the amount of runoff are the three surface storage capacities and the partial areas of the catchment represented by each capacity. The baseflow parameters determine how much runoff goes through the baseflow store and the rate at which water comes out of the store but they do not affect the amount of runoff.

When calibrations were made on many data sets that had been thoroughly checked for consistency between rainfall and runoff, it was found that the total amount of runoff was mainly affected by the average surface storage capacity and much less by how that average is spread among the three surface capacities and their partial areas. The average surface storage capacity is the sum of the three products of each surface storage capacity multiplied by its partial area. If the average capacity was determined to find the correct total amount of runoff, then a general pattern could be used to fix the three capacities and their partial areas.

Given an average surface storage capacity (Ave), the three partial areas and the three surface storage capacities are found by:

Partial area of smallest store

$$A_1 = 0.134 \tag{1}$$

Partial area of middle store

$$A_2 = 0.433 \tag{2}$$

Partial area of largest store

$$A_3 = 0.433 \tag{3}$$

Capacity of smallest store

$$C_1 = 0.01*Ave/A_1 = 0.075*Ave \tag{4}$$

Capacity of middle store

$$C_2 = 0.33*Ave/A_2 = 0.762*Ave \tag{5}$$

Capacity of largest store

$$C_3 = 0.66*Ave/A_3 = 1.524*Ave \tag{6}$$

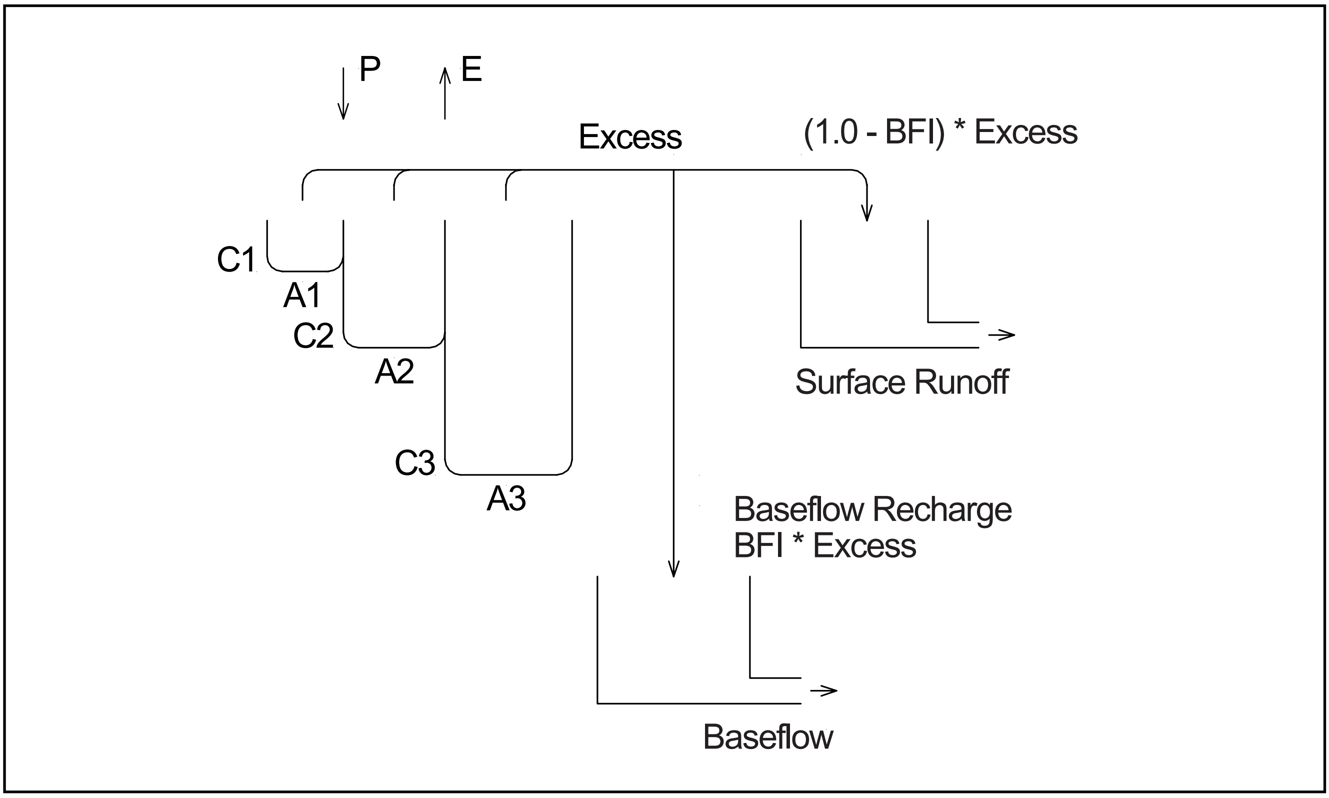


Figure 2.1 AWBM Model

These relationships are based on averages from the fully calibrated parameters on 19 catchments with very good quality rainfall and runoff data. A comparison of the results from the full calibrations and from the above relationships is given in Boughton (2003), and shows that the relationships produce good results. Further evidence in support of the relationships comes from the present study. After calibration with the relationships, the coefficient of efficiency between actual and calculated monthly totals of runoff was calculated for each of the 221 catchments. Some 80% of the coefficients were 0.75 or greater - see Section 4.5 for details. The relationships have been found to be applicable on a very wide range of catchments.

The self-calibrating program AWBM2002 uses a trial-and-error change of the average surface storage capacity until the total calculated amount of runoff equals the recorded total. At each trial, the average capacity is disaggregated into three capacities and three partial areas using the relationships shown above and the model is then used in the normal manner to calculate runoff.

2.2 Rainfall-runoff Relationship

When the rainfall-runoff data sets were carefully selected for consistency between rainfall and runoff, it was found that there was a general relationship that could be used to estimate average annual runoff from average annual rainfall. This relationship is shown in Figure 2.2.

In the first instance, the relationship was considered to be singular; however, it was soon obvious that provision was needed to accommodate a range of rainfall-runoff relationships. The catchments used in the early studies were all from the east coast of Australia, and some data sets from Western Australia showed less runoff for a given average annual rainfall. In addition, there is evidence of the difference in runoff due to forest or grass cover of the catchment for the same rainfall (Vertessy 1999). Some provision for differences in land use was needed.

For these reasons, a "catchment characteristic" (RC) was introduced to allow for the effects of vegetative cover, land use and different runoff characteristics in different regions. The computer program UGTEST3

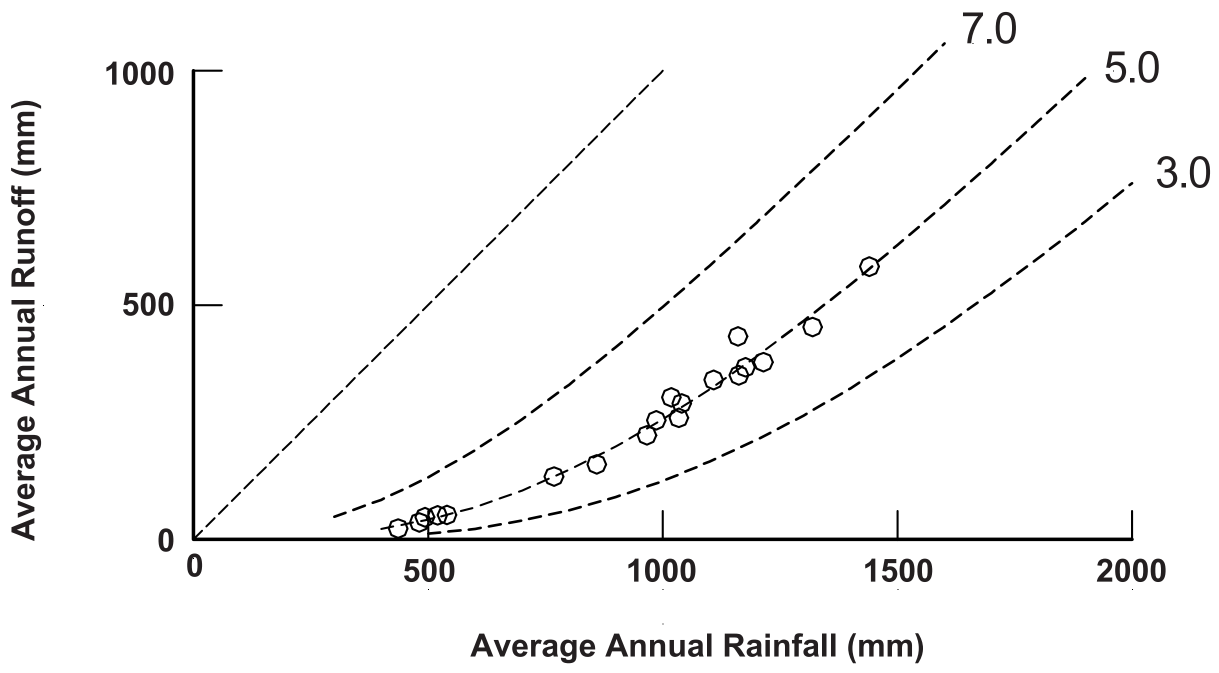


Figure 2.2 Variation in Runoff due to Runoff Characteristic (from Boughton 2003)

self-calibrates to rainfall-runoff data from a gauged catchment, in the same manner as AWBM2002, and shows the calibrated value of the runoff characteristic. It is recommended that UGTEST3 be used with data from gauged catchments in a region of interest, and the calibrated values of the runoff characteristic applied to ungauged catchments in the same region.

The rainfall-runoff relationships shown in Figure 2.2 for a given runoff characteristic are based on the hyperbolic tangent function introduced by Boughton (1966). Each relationship has a minimum annual rainfall (Min) below which no runoff occurs. In the higher rainfall range, the relationship becomes asymptotic to a 45^o line originating at a rainfall (Asy) on the x-axis. Given an average annual rainfall (Rain) and a runoff characteristic (RC), the average annual runoff (Runoff) is calculated in the following steps.

Min = 300 - 60*RC

Asy = 1950 - 200*RC

x = (Rain - Min)/(Asy - Min)

Tanh = (exp(x) - exp(-x))/(exp(x) + exp(-x))

Runoff = (Rain - Min) - (Asy - Min)*Tanh

The relationships provide a flexible procedure that can accommodate a wide range of data.

2.3 AWBM2002, UGAWBM3 and UGTEST3

UGAWBM3 is a version of the AWBM daily water balance model for estimating runoff from ungauged catchments. The program uses daily rainfall and monthly evaporation data to estimate daily runoff. To run UGAWBM3, three parameters are required: runoff characteristic (RC); baseflow index (BFI); and baseflow recession constant (K_b). UGAWBM3 can be used to simulate daily runoff in ungauged catchments, using values for the three parameters from similar catchments in the region that are gauged.

UGTEST3 and AWBM2002 are automatic calibration programs that can be used together to optimise the above three parameter values. To run either of the programs, daily rainfall and monthly evaporation data (input data), and daily runoff and monthly runoff data (calibration data) are required.

UGTEST3 determines the runoff characteristic, RC, from a daily set of rainfall and runoff. It uses the relationships in equations (1) to (6) to relate the average storage capacity to the three partial areas and partial area storage capacities, and determines an RC value such that the total modelled runoff matches the total recorded runoff.

AWBM2002 can then be used to optimise the two baseflow parameters, BFI and K_b. The program compares calculated daily flows with actual daily flows over the whole period of calibration data, and optimises the parameters to provide the best match between the daily modelled and recorded runoffs.

3 Data

3.1 Sources of Data

The dataset for this study comes from the rainfall, potential evapotranspiration and runoff data prepared for a runoff estimation project for the National Land and Water Resources Audit (see Peel *et al*., 2001; and Chiew *et al*., 2002).

Data are available for 331 unimpaired Australian catchments. "Unimpaired" is defined as data from unregulated rivers or where regulation changes the natural monthly streamflow volumes by less than five percent. The determination of whether the streamflow data is unimpaired is based on local knowledge of the respective water agencies and/or whether there is a significant dam upstream of the gauging stations (as listed in the register of dams prepared by ANCOLD – Australian National Committee on Large Dams, Boughton, 1999).

The catchment areas range from 50 km^2 to 2000 km^2 and the length of streamflow data range from 10 years to 90 years. The spatial scale of 50 km^2 to 2000 km^2 is chosen so that the lumped daily rainfall used in the modelling has similar meaning and the optimised model parameter values can be compared across catchments. Where catchments are nested, the smallest sub-catchment is used, with the subsequent bigger sub-catchment used only if it is five times bigger than the smaller sub-catchment.

The 331 catchments are located in the more populated and important agricultural regions of Australia. They do not represent all available data that fits the above criteria, but except for northeast Australia, they reflect historical streamflow data availability across Australia.

The source of the daily rainfall data is the Queensland Department of Natural Resources and Mining 0.05^o x 0.05^o (about 5 km x 5 km) interpolated gridded rainfall data based on over 6000 rainfall stations in Australia (see www.dnr.qld.gov.au/silo). The interpolation uses Ordinary Krigging of monthly rainfall data, and a variogram with zero nugget and a variable range. The monthly rainfall for each 5 km x 5 km point is then disaggregated to daily rainfall using the daily rainfall distribution from the station closest to the point. The lumped catchment-average daily rainfall is estimated from the daily rainfall in 5 km x 5 km points within the catchment.

Compared to rainfall, evapotranspiration has little influence on the water balance at a daily time scale. The inter-annual variability of areal potential evapotranspiration is also relatively small (typically less than 0.05). For these reasons, the mean monthly areal potential evapotranspiration is used. The 12 mean monthly areal potential evapotranspiration values are obtained from the evapotranspiration maps produced jointly by the Cooperative Research Centre for Catchment Hydrology and the Australian Bureau of Meteorology (Australian Bureau of Meteorology, 2001; and www.bom.gov.au/climate/averages). The areal evapotranspiration values are derived using Morton's complementary relationship model (see Morton, 1983; and Chiew and McMahon, 1991).

3.2 Selection of Data

In the first stage of this study, calibrations of UGAWBM3 were made on all 331 catchments. Several different problems became apparent that resulted in discarding some of the data sets. These problems were:

- inconsistent data in which runoff exceeded rainfall for sufficient periods of time to indicate that either the rainfall or the runoff data had errors;
- data in which the rainfall showed evidence of systematic bias, i.e. that it was either too big or too small to be consistent with the runoff, resulting in calibrated parameter values that were out of physically plausible ranges;
- data with random errors between rainfall and runoff such that the resulting correlation between calculated and actual monthly runoff was sufficiently poor that there was no confidence in the calibration; and
- catchments in which there were so many periods of missing data that the period available for calibration was too short.

Some of these problems can be overcome, e.g. by infilling missing periods of data. These improvements will be attempted in a later stage of the study. It was considered more important to make the initial results available for practical use rather than wait for all possible results to be finalised.

4 Summary of Calibrations

The three parameters needed for use of UGAWBM3 on an ungauged catchment are the runoff characteristic RC, the baseflow index BFI and the daily baseflow recession constant K_b. Two programs were used to calibrate the parameters in each of the 221 data sets.

The program UGTEST3 was used to calibrate the runoff characteristic RC. The program AWBM2002 was used to calibrate the baseflow parameters BFI and K_b. The two calibration programs are both versions of the AWBM and so the calibrated parameters are directly suited for use with UGAWBM3 on ungauged catchments. The individual calibrations of each of the 221 data sets are listed in Appendix A.

4.1 Summary by Drainage Division

The 221 data sets are spread among 8 of the 11 Drainage Divisions of Australia. Some 40% of the total are in Drainage Division 2 Southeast Coast and a similar number in Drainage Division 4 Murray-Darling Basin. Table 4.1 shows the number of data sets in each of the represented divisions and the average values of the runoff characteristic RC, the baseflow index BFI and the baseflow recession constant Kbase.

Each average value of the runoff characteristic RC is based on all data sets in the division. The average values of BFI and Kbase are based on only the non-zero values of those parameters.

4.2 Runoff Characteristic RC

For a given set of input data (rainfall and evaporation) the runoff characteristic RC is the parameter that determines the overall amount of runoff. The RC is determined from the daily rainfall and daily runoff data, and is not based on any rainfall-runoff model or calibration procedure. Figure 4.1 shows the spread of RC values from the 221 catchments, and Table 4.2 gives the median and 10th and 90th percentile values for each of the drainage divisions.

The average value over the 221 data sets is 4.2 but the spread of value is from 1.5 to 7.0 (see Figure 4.1). The Tasmanian catchments show distinctly higher RC values than those of the mainland. The median value of 5.9 in Table 4.2 is significantly higher than all of the averages of the mainland Divisions. Eleven of the twelve Tasmanian catchments have an RC value greater than 5.0. The higher end of the histogram in Figure 4.1 shows 24 values of RC greater than 5.0, and almost half of these are from the Tasmanian catchments.

Table 4.1 Summary of Calibrations by Drainage Division

Division	N	RC	BFI	Kbase
1 - NE Coast	13	3.6	0.21	0.914
2 - SE Coast	89	4.2	0.34	0.964
3 - Tasmania	12	5.9	0.37	0.961
4 - Murray-Darling	86	4.1	0.36	0.957
5 - SA Gulf	7	3.8	0.32	0.964
6 - SW Coast	10	3.7	0.53	0.946
8 - Timor Sea	3	3.7	0.26	0.958
10 - Lake Eyre	1	6.8	0	0
ALL	**221**	**4.2**	**0.34**	**0.960**

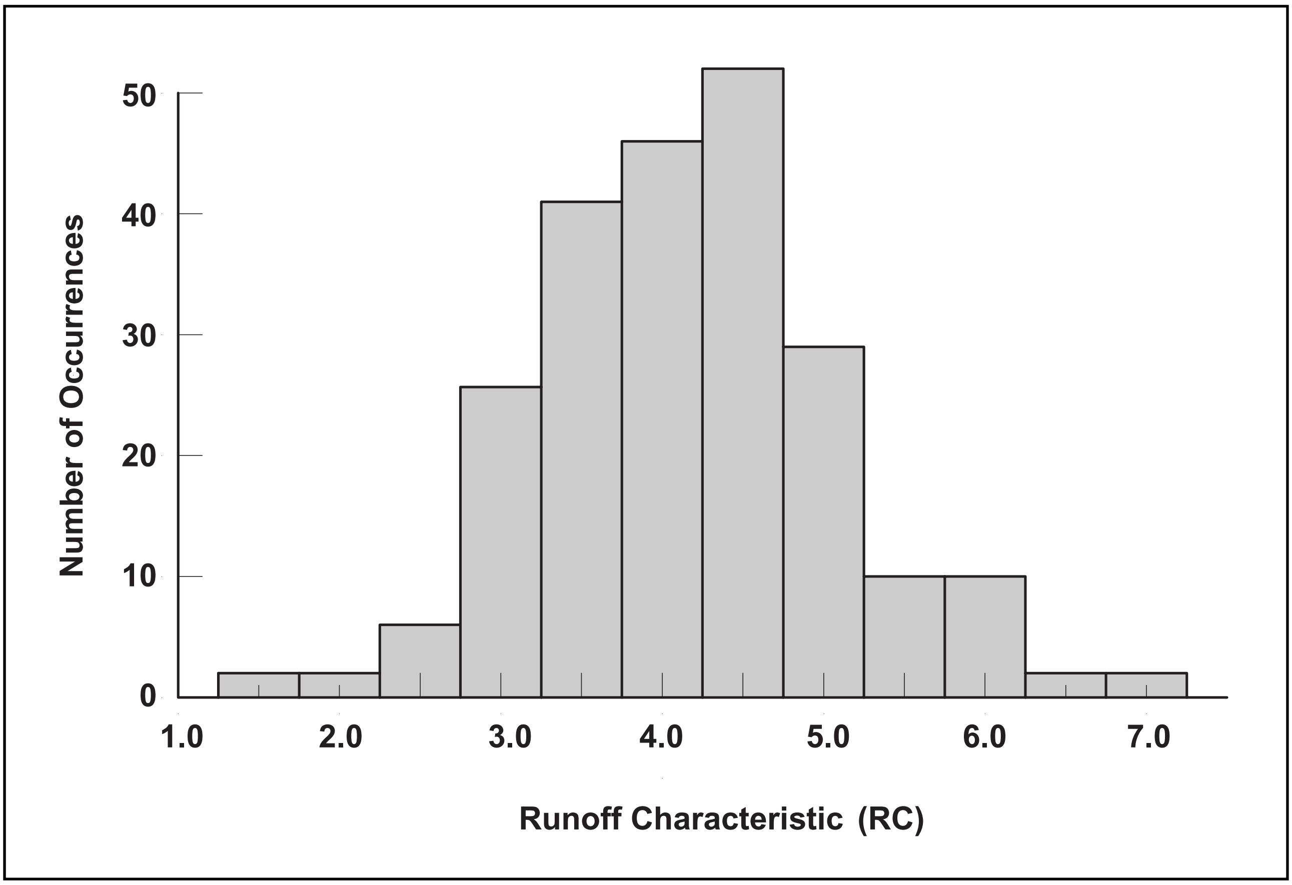


Figure 4.1 Histogram of 221 Calibrated Values of the Runoff Characteristic RC

Table 4.2 Summary Of Runoff Characteristic By Drainage Division Ranked in Order of Median Value

Division	N	90th Percentile	Median	10th Percentile
3 - Tasmania	12	4.5	5.9	6.9
4 - Murray-Darling	86	3.1	4.5	4.9
2 - SE Coast	89	3.2	4.3	5.3
5 - SA Gulf	7	3.3	3.8	4.1
8 - Timor Sea	3	2.7	3.7	4.7
6 - SW Coast	10	2.6	3.6	4.8
1 - NE Coast	13	2.1	3.5	4.9

There is no evident reason for the higher RC in the Tasmanian catchments other than the possibility that the catchment evaporation is generally less than over the mainland. The small range of median values among the mainland Divisions is noteworthy.

The lower end of the histogram in Figure 4.1 (RC below 3.0) is mainly from catchments with little rainfall and runoff. The histogram gives a succinct picture of the spread of runoff characteristics of the 221 catchments used in this study.

4.3 Baseflow Index BFI

Figure 4.2 shows a histogram of the 209 non-zero BFI values from the 221 catchments. Table 4.3 gives the median and 10th and 90th percentile BFI values for each of the drainage divisions. There is a bimodal distribution with the main group spread around a mode of BFI of 0.2 to 0.3 and a second group in the higher range of 0.55 to 0.65.

Table 4.3 suggests that the 10 catchments in the southwest of Western Australia have higher BFI values

Table 4.3 Summary of BFI Calibrations by Drainage Division Ranked in Order of Median Value

Division	N	90th Percentile	Median	10th Percentile
6 - SW Coast	10	0.30	0.56	0.63
4 - Murray-Darling	86	0.18	0.41	0.63
2 - SE Coast	89	0.21	0.33	0.60
3 - Tasmania	12	0.23	0.32	0.57
5 - SA Gulf	7	0.20	0.29	0.45
8 - Timor Sea	3	0.21	0.26	0.30
1 - NE Coast	13	0.11	0.17	0.45

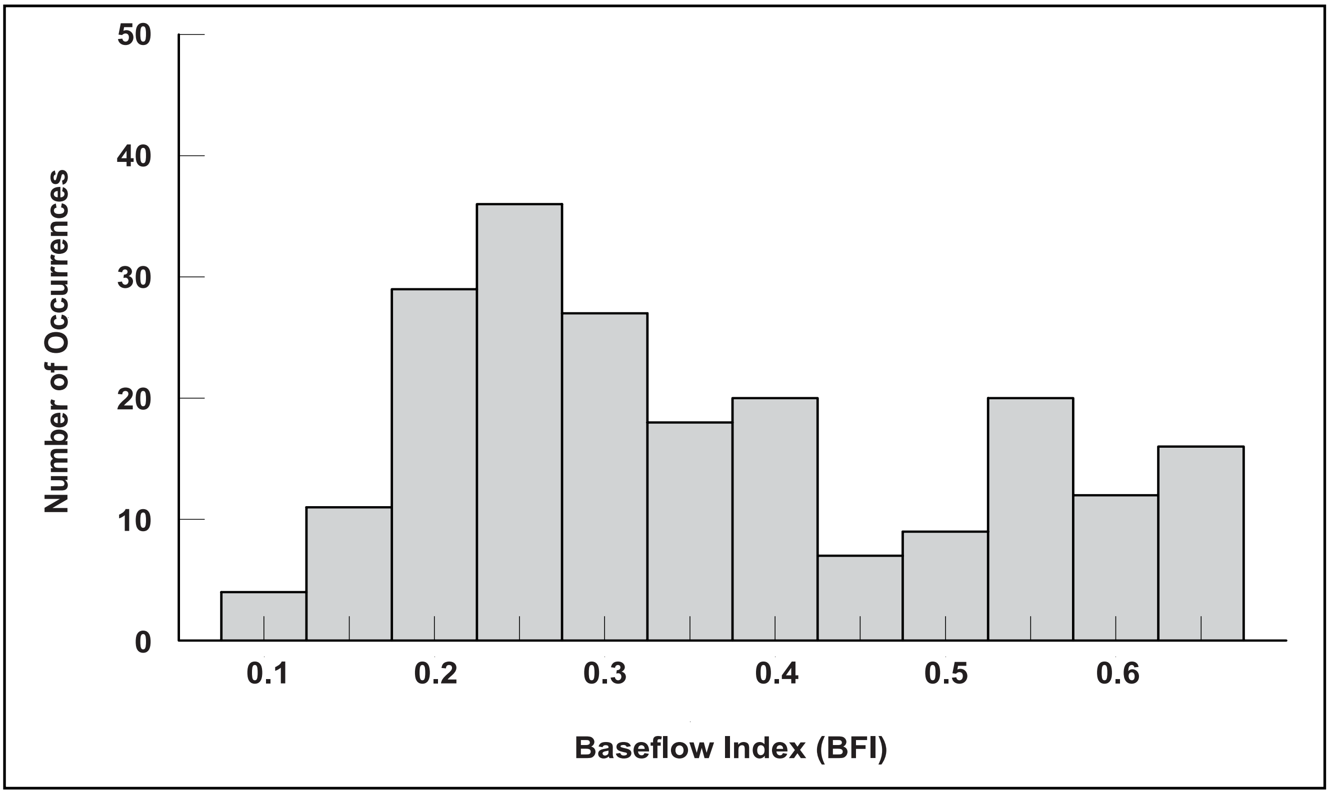


Figure 4.2 Histogram of BFI Values

then the rest of Australia, but this is misleading. The 57 catchments with BFI values of 0.50 or greater are spread among New South Wales, Victoria, Tasmania and Western Australia. No single geographical region has consistently higher BFI values than any other does.

The method of calibration of the BFI parameter makes the values below 0.15 uncertain because it is difficult to distinguish very small values of baseflow from hillslope drainage or even attenuation of surface runoff.

No relationships have been established between BFI and catchment characteristics. The establishing of such relationships will be undertaken in a later part of the study.

4.4 Baseflow Recession Constant K_b

Figure 4.3 shows a histogram of K_b values from the 221 catchments. Table 4.4 gives the median and 10th and 90th percentile K_b values for each of the drainage divisions

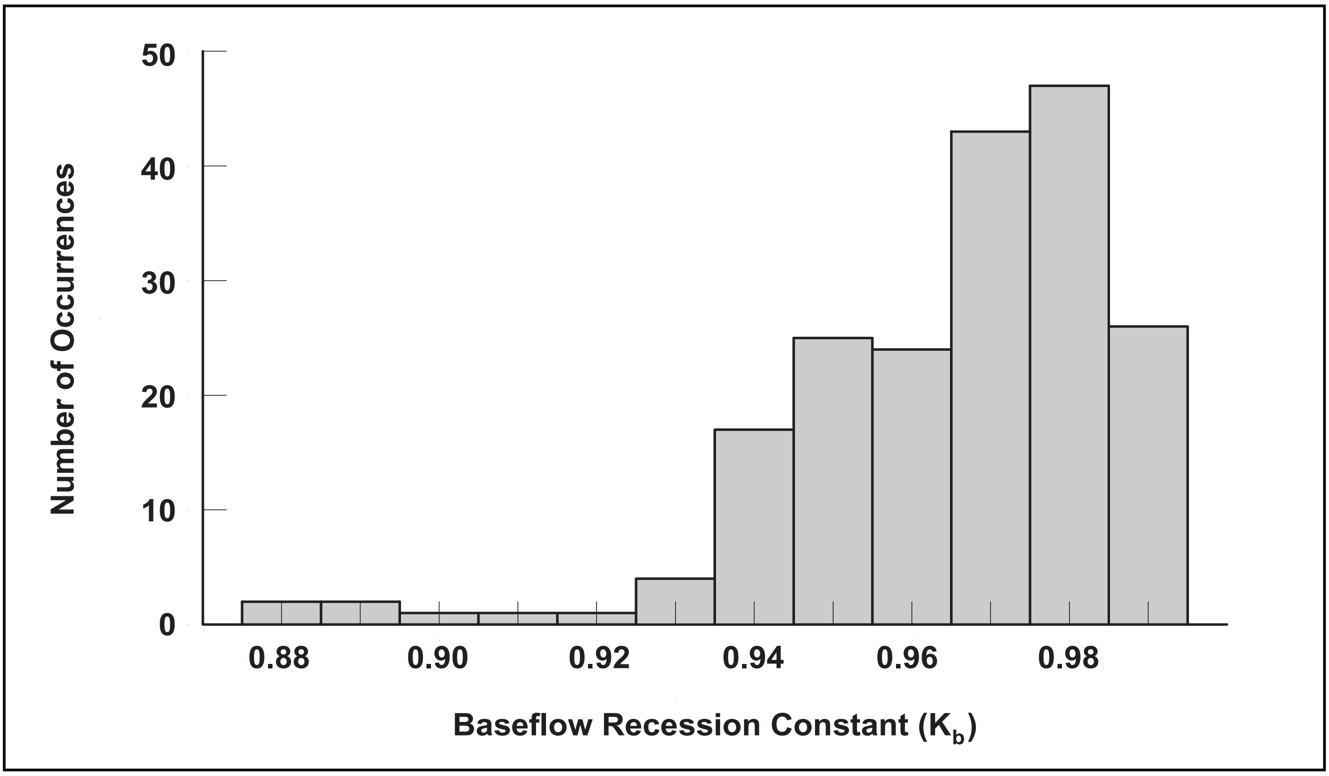


Figure 4.3 Histogram of Baseflow Recession Constant K_b

Table 4.4 Summary of K_b Calibrations by Drainage Division Ranked in Order of Median Value

Division	N	90th Percentile	Median	10th Percentile
2 - SE Coast	89	0.915	0.980	0.993
4 - Murray-Darling	86	0.910	0.976	0.989
3 - Tasmania	12	0.920	0.966	0.991
5 - SA Gulf	7	0.950	0.958	0.985
6 - SW Coast	10	0.900	0.956	0.981
1 - NE Coast	13	0.813	0.950	0.987
8 - Timor Sea	3	0.930	0.941	0.949

The range of calibrated values of the daily baseflow recession constant is generally from 0.93 to 0.99 with a few smaller values in the range 0.88 to 0.92. The higher spread of values is very similar to other results from a study of New South Wales catchments and from a group of USA catchments.

The AWBM has a baseflow component of flow but no component for interflow such as hillslope drainage. If interflow is present in the streamflow, the automatic calibration procedures of AWBM2002 will interpret it as either a baseflow or attenuation of surface runoff. It is likely that the smaller values of K_b below 0.93 are interflow components on catchments that have either no baseflow or otherwise a very small baseflow component.

4.5 Measure of Calibrations

After the AWBM was calibrated to each data set, the coefficient of efficiency of calculated versus actual monthly totals of runoff was calculated. The coefficient of efficiency E is defined as

$$E = \frac{\sum_{i=1}^{n}\left(REC_i - \overline{REC}\right)^2 - \sum_{i=1}^{n}\left(MOD_i - REC_i\right)^2}{\sum_{i=1}^{n}\left(REC_i - \overline{REC}\right)^2}$$

Where:

MOD and *REC* are the modelled and recorded monthly streamflows respectively, $\overline{REC}$ is the mean recorded streamflow and n is the number of months with streamflow data for model calibration.

Figure 4.4 shows a histogram of the values of E for the 221 data sets.

Some 80% of the calibrations have a value of E of 0.75 or greater. The very lowest values < 0.55 are mainly associated with the drier catchments with the lower range of rainfall and runoff. These catchments typically have partial area storms and runoff. It is already established in the hydrological literature that such catchments commonly have poorer results of rainfall-runoff modelling. A number of such catchments were deliberately included in the selected data sets to make the range of catchments types as broad as possible.

Figures 4.5a to 4.5c show X-Y plots comparing calculated and actual monthly totals of runoff for 3 values of E - 0.973, 0.854 and 0.750. These figures illustrate the relative quality of the results from the main group of data sets with E => 0.750.

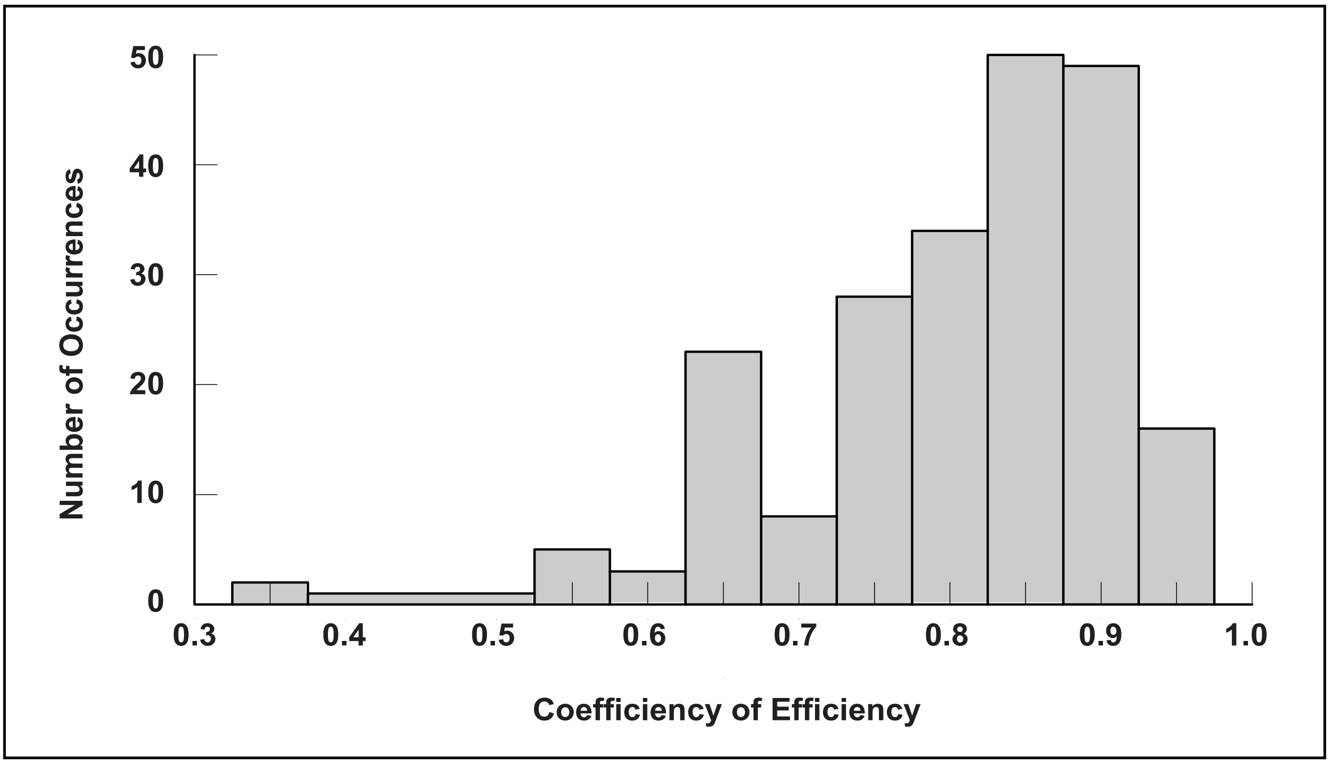


Figure 4.4 Histogram of the Coefficient of Efficiency for the Calibrated Data Sets

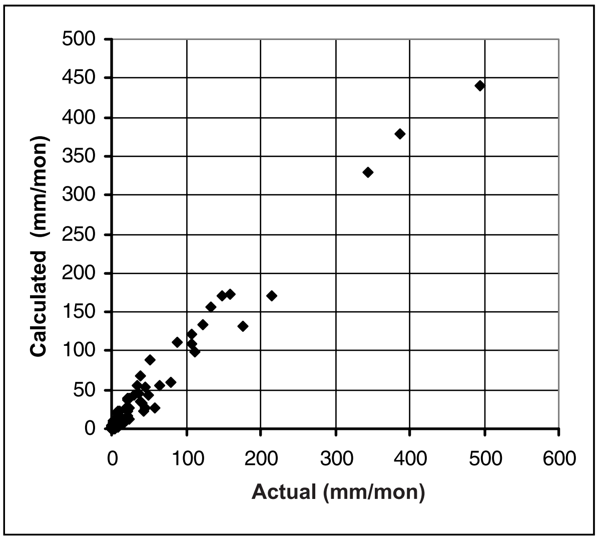


Figure 4.5a 220004 E = 0.973

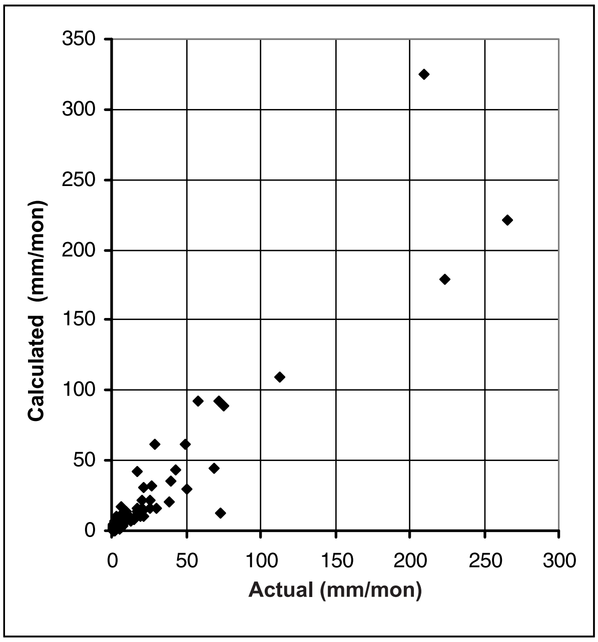


Figure 4.5b 8140159 E = 0.854

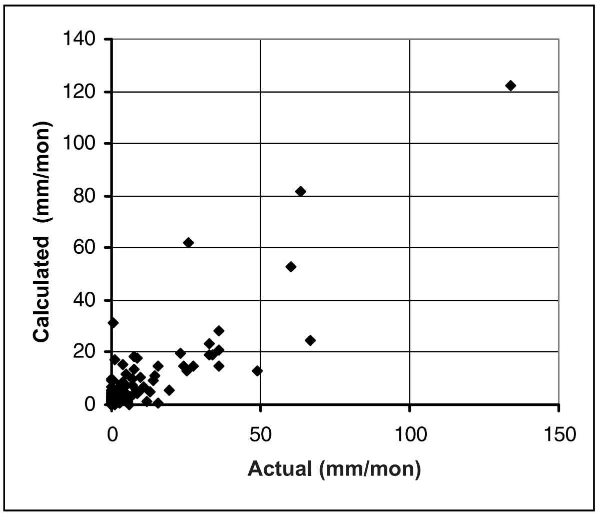


Figure 4.5c 412076 E = 0.750

Figure 4.5 X-Y Plots Comparing Calculated and Actual Monthly Totals of Runoff for 3 values of E

4.6 Runoff v. Rainfall

The shape of the rainfall-runoff relationships shown in Figure 2.2 was based on a small number of catchments. The larger number of data sets in the present study provides an opportunity to see if that shape is consistent with a much larger set of data. Figure 4.6 shows the average annual rainfall and runoff data from Appendix B for the 208 mainland catchments.

The data points show a surprisingly consistent pattern for such a large number of catchments from diverse locations from coastal Victoria to the Indian Ocean Drainage Division and from the southwest of Western Australia to the northeast coast of Queensland. The overall shape of the plotted points in Figure 4.6 gives credibility to the form of rainfall-runoff relationship on which the UGAWBM3 model for ungauged catchments is based.

One aspect of Figure 4.6 warrants mention. 70% of the catchments have average annual rainfall between 700 and 1100 mm (i.e., an average of about 900 mm with a standard deviation of about 180 mm or 20%). Rainfall must therefore be determined to better than +/- 20% to reliably describe the rainfall-runoff relationship for modelling. The difficulty of measuring areal rainfall to such accuracy has been well documented, e.g. see Hall and Barclay (1975).

The uncertainties and errors in rainfall (and runoff) data also have other implications. For example, if the spread of the 208 data point in Figure 4.6 is within the range of uncertainty in the estimation of the rainfall data, then it would be difficult to identify residuals that can be attributed to differences in catchment characteristics such as soil type or vegetative cover. It seems that considerable effort will be needed to ensure accuracy of the areal rainfall estimates before the effects of catchment characteristics on runoff can be evaluated with confidence.

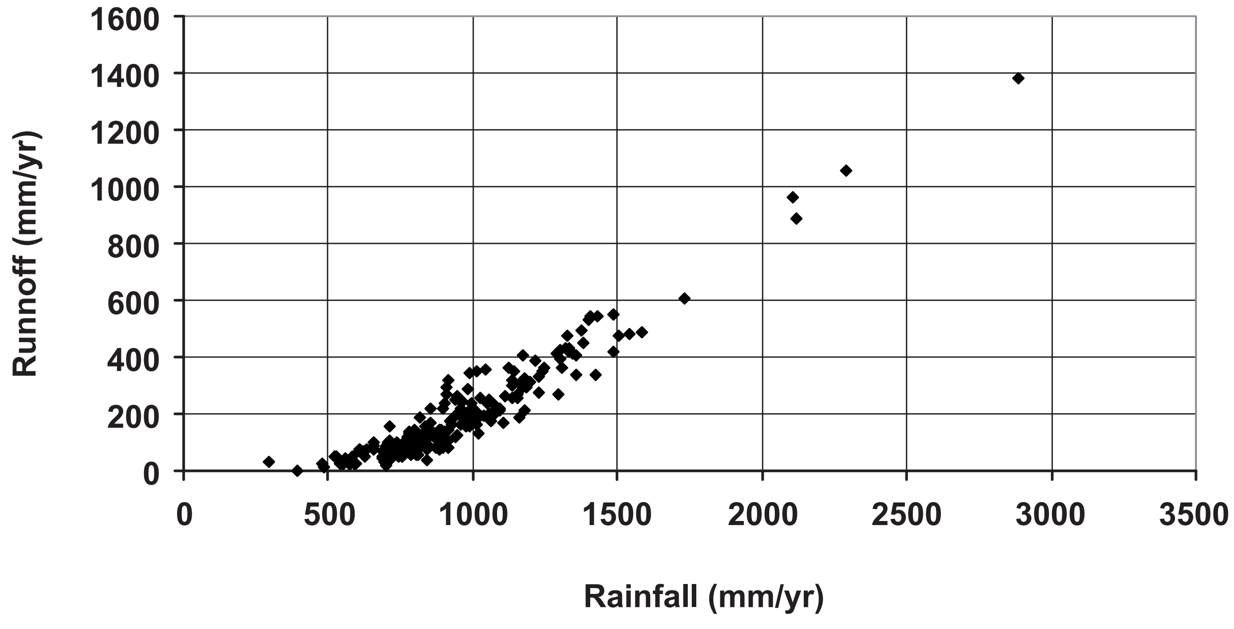


Figure 4.6 Rainfall and Runoff for 209 Mainland Catchments

5 Use of the Results on Ungauged Catchments

5.1 General

The calibrated parameter values for all of the 221 catchments are listed in Appendix A. Appendix B contains the details of physical characteristics of the catchments. The information in Appendix A and B can be used to guide selection of appropriate parameter values for use in ungauged catchments.

Where the calibrated parameter values of several nearby catchments are similar and the physical characteristics match those of the target catchment, then the parameter values of the nearby catchments can be used on the ungauged catchment with reasonable confidence. Where there is a spread of calibrated parameter values among nearby catchments, the different values can be used to give an indication of the likely range of error in the estimated runoff. The consequences of error in the estimates of runoff differ from one application to another, and it is better for design engineers to have some indication of the uncertainty rather than have the variations in the calibrated parameters smoothed through statistical relationships with catchment characteristics.

5.2 Method

Step 1:

Prepare rainfall and evaporation files in AWBM formats.

Step 2:

If there are gauged catchments in the location of interest that can be used as a guide (known to have similar rainfall-runoff characteristics as the ungauged catchment), then use the programs UGTEST3 to determine a value of the runoff characteristic RC and the program AWBM2002 to determine calibrated values of the baseflow parameters BFI and Kb. Use those parameter values with UGAWBM3 to calculate runoff from the ungauged catchment. If no gauged catchments are available for calibration, then proceed as in Step 3.

Step 3:

(a) From Appendix A, find the nearest calibrated catchments to the ungauged catchment. If the nearest catchments all have similar calibrated parameter values, then averages of the values are the best guide for values to use with UGAWBM3.

(b) From Appendix B, check the catchment characteristic of the nearby catchments - elevation characteristics, leaf area index, percent of area that is woody vegetation, plant water holding capacity, and transmissivity of the soil. If the ungauged catchment has similar characteristics to one or more of the nearby catchments, then the calibrated parameter values from those catchments can be given more weight in selecting values for use.

(c) Use each of the sets of calibrated parameter values with UGAWBM3. The different results will indicate the likely range of uncertainty in the estimates of runoff. The final selection of which set of parameter values and which set of results to use will depend on the circumstance of each particular application, including the consequences of error in the estimates of runoff. The user must make that selection.

6 Conclusions

The calibrated parameter values in Appendix A from 221 catchments in Australia, in conjunction with the catchment characteristics in Appendix B, form a substantial data base to assist those who want to use the AWBM to estimate runoff from an ungauged catchment. The catchments were selected to avoid those with evident problems in the input data that could make the calibrations questionable. The calibrations in Appendix A are presented as the best that can be provided from the data available at the time of the study.

There will always be some uncertainty in the results from such an extensive collection of rainfall-runoff data sets, and users are advised to make use of all of the calibrations in the region of interest to see the range of results. This practice will give some indication of the uncertainty in the results from which users can judge the consequences in their own particular circumstances.

The catchments used in this study range in area from a few tens of square kilometres to a few thousand square kilometres. Most of the catchments have a significant baseflow component in the runoff. The hydrological characteristics of these catchments are very different to those of small agricultural scale catchments. The calibrations in this report are not recommended for use on small agricultural scale catchments.

References

Australian Bureau of Meteorology, Climate Atlas of Australia – Evapotranspiration, Bureau of Meteorology, Australia, 2001.

Boughton, W. C., A mathematical model for relating runoff to rainfall with daily data, *Civil Engineering Transactions, I.E.Aust.,* CE8(1): 83-97, 1966.

Boughton, W. C., A simple model for estimating the water yield of ungauged catchments. *Civil Engineering Transactions, I.E.Aust.,* CE26(2): 83-88, 1984.

Boughton, W. C., A review of the USDA SCS Curve Number method, *Australian Journal of Soil Research,* 27: 511-523, 1989.

Boughton, W. C., A hydrograph based model for estimating the water yield of ungauged catchments, Inst. Engs. Aust., Nat. Conf. Publ. 93/14, pp.317-324, 1993.

Boughton, W. C., Detecting data errors in rainfall-runoff data sets, Rept. 96/2, CRC for Catchment Hydrology, Monash University, 23pp, 1996.

Boughton, W.C., A Century of Water Resources Development in Australia 1900-1999, Institution of Engineers, Australia, 256 pp, 1999.

Boughton, W. C., The Australian Water Balance Model, accepted for publication in *Environmental Modelling and Software,* Elsevier, in press October 2003.

Chiew, F.H.S., Peel, M.C. and Western, A.W., Application and testing of the simple rainfall-runoff model SIMHYD, In: Mathematical Models of Small Watershed Hydrology and Applications (Editors: V.P. Singh and D.K Frevert), Water Resources Publication, Littleton, Colorado, (ISBN 1-887201-35-1), pp. 335-367, 2002.

Chiew, F.H.S. and McMahon, T.A., The applicability of Morton's and Penman's evapotranspiration estimates in rainfall-runoff modelling, *Water Resources Bulletin,* 27: 611-620, 1991.

Hall, A. J. and Barclay, P. A., Methods of determining areal rainfall from observational data. In *Prediction in Catchment Hydrology,* edited by T. G. Chapman and F. X. Dunin, Australian Academy of Science, Canberra, pp.47-57.

Hawkins, R. H., The importance of accurate curve numbers in the estimation of storm runoff. *Water Resources Bulletin,* 11: 887-891, 1975.

Hill, P., R. Mein and L. Siriwardena, How much rainfall becomes runoff? Loss modelling for flood estimation, Industry Report 98/5, CRC for Catchment Hydrology, Monash University, 30 pp., 1998.

Johnson, P. R. and D. H. Pilgrim, A study of parameter optimization for a rainfall-runoff model, Report 131, Water Research Laboratory, University of New South Wales, 1973.

Klaassen, B. and D. H. Pilgrim, Hydrograph recession constants for New South Wales streams, *Civil Engineering Transactions, I.E.Aust.,* CE17(1): 43-49, 1975.

Lacey, G. C., The scaling of baseflow, Working Document 96/1, CRC for Catchment Hydrology, Monash University, 35 pp., 1996a.

Lacey, G. C., Relating baseflow to catchments properties. A scaling approach, Report 96/8, CRC for Catchment Hydrology, Monash University, 51 pp., 1996b.

Mwakalila, S., J. Feyen and G. Wyseure, The influence of physical catchments properties on baseflow in semi-arid environments, *Journal of Arid Environments,* 52: 245-258, 2002.

Morton, F.I., Operational estimates of actual evapotranspiration and their significance to the science and practice of hydrology, *Journal of Hydrology,* 66: 1-76, 1983.

Nathan, R. J. and T. A. McMahon, The estimation of low flow characteristics and yield from small ungauged rural catchments, AWRAC Research Project Report 85/105, Dept. of Primary Industries & Energy, 213 pp., 1990a.

Nathan, R. J. and T. A. McMahon, The SFB model part I - validation of fixed model parameters, *Civil Engineering Transactions I.E.Aust.,* CE32(3): 157-161, 1990b.

Nathan, R. J. and T. A. McMahon, The SFB model part II - operational considerations, *Civil Engineering Transactions, I.E.Aust.,* CE32(3): 162-166, 1990c.

Nathan, R. J. and T. A. McMahon, Estimating low flow characteristics in ungauged catchments. A practical guide, Dept. of Civil and Agricultural Engineering, University of Melbourne, 60pp + accompanying software, 1991.

Nathan, R. J., K. Austin, D. Crawford and N. Jayasuriya, The estimation of monthly yield in ungauged catchments using a lumped conceptual model, *Australian Journal of Water Resources,* 1(2): 65-75, 1996.

Peel, M.C., Chiew, F.H.S., Western, A.W. and McMahon, T.A., Extension of Unimpaired Monthly Streamflow Data and Regionalisation of Parameter Values to Estimate Streamflow in Ungauged Catchments, Report prepared for the National Land and Water Resources Audit, In http://audit.ea.gov.au/anra/water/docs/national/streamflow/streamflow.pdf, 2000.

Post, D. A. and A. J. Jakeman, Predicting the daily streamflow of ungauged catchments in S.E. Australia by regionalising the parameters of a lumped conceptual rainfall-runoff model, *Ecological Modelling,* 123: 91-104, 1999.

Post, D. A., J. A. Jones and G. E. Grant, An improved methodology for predicting the daily hydrologic response of ungauged catchments, *Environmental Modelling and Software,* 13: 395-403, 1998.

Rallison, R. E., Origin and evolution of the SCS runoff equation, In "Symposium on Watershed Management 1980 Volume II", pp.912-924, American Society of Civil Engineers, 1980.

Snowy Mountains Engineering Corporation, Hydrology of small rural catchments, Aust. Water Resources Council, Research Project 68/1, SMEC, Cooma, New South Wales, 1971.

Vertessy, R. A., The impacts of forestry on streamflows: a review, in Forest Management for Water Quality and Quantity, CRC for Catchment Hydrology, Report 99/6, pp.93-109, 1999.

Appendix A - Rainfall-runoff Data Sets in Order of Drainage Division and Station Number

Division 1 North-east Coast

State	Stn. No.	Stream	RC	BFI	Kbase
QLD	111007	Mulgrave	2.0	0.59	0.990
QLD	117002	Black	4.6	0.00	0.000
QLD	119003	Haughton	5.3	0.17	0.943
QLD	120216	Broken	3.5	0.30	0.983
QLD	125002	Pioneer	4.1	0.17	0.973
QLD	122003	Proserpine	4.6	0.13	0.813
QLD	130319	Bell	3.2	0.00	0.000
QLD	132001	Calliope	4.1	0.15	0.953
QLD	135002	Kolan	3.5	0.18	0.883
QLD	136202	Barambah	2.8	0.21	0.823
QLD	136315	Boyne	2.1	0.00	0.000
QLD	142001	Caboolture	3.4	0.13	0.970
QLD	143110	Bremer	3.5	0.10	0.813

Division 2 South-east Coast

State	Stn. No.	Stream	RC	BFI	Kbase
NSW	201005	Rous	4.2	0.36	0.977
NSW	201011	Doon Doon	3.4	0.20	0.953
NSW	203002	Coopers	3.7	0.34	0.968
NSW	203005	Richmond	4.2	0.25	0.990
NSW	203030	Myrtle	3.1	0.27	0.958
NSW	204033	Timbara	3.6	0.42	0.987
NSW	204034	Henry	3.5	0.35	0.983
NSW	204036	Cataract	4.8	0.37	0.986
NSW	204037	Clouds	2.5	0.36	0.981
NSW	204055	Sportsman	3.9	0.25	0.920
NSW	204067	Gordon	4.0	0.20	0.833
NSW	205002	Bellinger	4.4	0.32	0.981
NSW	205008	Taylors Arm	3.6	0.25	0.963
NSW	205012	Corindi	2.7	0.21	0.913
NSW	206034	Mihi	3.2	0.00	0.000
NSW	207012	Doyles	3.4	0.39	0.993
NSW	207013	Ellenborough	3.4	0.32	0.993
NSW	207014	Wilson	4.6	0.29	0.953
NSW	208005	Nowendoc	3.9	0.34	0.987
NSW	208012	Manning	4.0	0.46	0.991
NSW	208015	Landsdowne	3.9	0.21	0.893
NSW	208019	Dingo	4.3	0.21	0.973
NSW	208022	Barnard	3.9	0.51	0.977
NSW	208026	Myall	3.0	0.62	0.992
NSW	209002	Mammy J.	4.7	0.23	0.823
NSW	209006	Wang Wauk	4.4	0.13	0.813
NSW	210014	Rouchel	4.1	0.38	0.976
NSW	210042	Foy	4.0	0.25	0.978
NSW	210048	Wollombi	3.2	0.21	0.953
NSW	210088	Dart	3.0	0.22	0.861
NSW	210091	Merriwa	3.6	0.36	0.991
NSW	210092	Krui	3.2	0.25	0.983
NSW	211008	Jigadee	4.8	0.11	0.813
NSW	211013	Ourimbah	3.9	0.25	0.981
NSW	211014	Wyong	3.3	0.33	0.993
NSW	212018	Capertee	3.5	0.19	0.973
NSW	212040	Kialla	4.7	0.40	0.966
NSW	212045	Coxs	4.6	0.41	0.981
NSW	215008	Shoalhaven	4.9	0.56	0.953
NSW	216009	Buckenbowra	5.3	0.28	0.981
NSW	218002	Tuross	6.2	0.37	0.986
NSW	218006	Wandella	6.1	0.21	0.943
NSW	218007	Wadbilliga	6.0	0.27	0.962
NSW	219013	Brogo	6.1	0.26	0.983
NSW	219016	Narira	4.7	0.20	0.933

State	Stn. No.	Stream	RC	BFI	Kbase
NSW	219017	Double	5.4	0.23	0.963
NSW	220002	Stockyard	3.9	0.33	0.992
NSW	220003	Pambula	4.4	0.21	0.933
NSW	220004	Towamba	5.4	0.21	0.983
NSW	221003	Genoa	4.8	0.29	0.993
VIC	221201	Cann	4.1	0.42	0.993
VIC	221204	Thurra	4.8	0.31	0.991
VIC	221210	Genoa	4.2	0.23	0.981
NSW	222004	Little Plains	4.6	0.56	0.989
NSW	222010	Bobundara	4.4	0.40	0.991
NSW	222011	Cambalong	5.2	0.22	0.983
NSW	222014	Delegate	4.6	0.60	0.986
NSW	222017	Maclaughlin	5.2	0.30	0.980
VIC	222206	Buchan	4.1	0.56	0.976
VIC	223202	Tambo	3.7	0.63	0.976
VIC	223207	Timbarra	5.3	0.63	0.992
VIC	225217	Barkly	4.6	0.60	0.976
VIC	225218	Freestone	4.9	0.22	0.933
VIC	224219	Macalister	4.0	0.56	0.976
VIC	226007	Tyers	4.3	0.62	0.993
VIC	226218	Narracan	5.7	0.63	0.993
VIC	226405	Middle	3.7	0.32	0.978
VIC	227200	Tarra	3.8	0.37	0.983
VIC	227202	Tarwin	4.5	0.36	0.976
VIC	227211	Agnes	4.1	0.37	0.986
VIC	227219	Bass	4.9	0.29	0.908
VIC	228203	Eumemmering	4.5	0.27	0.983
VIC	229215	Woori Yallock	4.4	0.56	0.989
VIC	230205	Maribyrnong	4.3	0.36	0.950
VIC	231213	Lerderderg	3.7	0.41	0.966
VIC	233215	Leigh	4.5	0.30	0.978
VIC	233223	Warrambine	3.2	0.00	0.000
VIC	234200	Woady Yallock	3.5	0.21	0.953
VIC	234203	Pirron Yallock	3.8	0.61	0.946
VIC	235203	Curdies	4.0	0.26	0.963
VIC	235211	Kennedys	3.7	0.36	0.958
VIC	236203	Mount Emu	3.4	0.33	0.958
VIC	236205	Merri	4.0	0.27	0.980
VIC	236212	Brucknell	4.2	0.27	0.993
VIC	237200	Moyne	4.3	0.27	0.961
VIC	237205	Darlot	4.5	0.63	0.989
VIC	237206	Eumeralla	3.5	0.46	0.976
VIC	238223	Wando	4.8	0.45	0.966

Division 3 Tasmania

State	Stn. No.	Stream	RC	BFI	Kbase
TAS	3080003	Franklin	6.9	0.25	0.960
TAS	3120001	Hellyer	6.5	0.56	0.976
TAS	3190200	Brid	5.1	0.56	0.989
TAS	318900	Break O'Day	5.6	0.23	0.963
TAS	303203	Coal	6.1	0.26	0.893
TAS	319201	Great Forester	5.6	0.58	0.992
TAS	304201	Jordan	4.0	0.32	0.941
TAS	314207	Leven	5.8	0.37	0.986
TAS	318852	Meander	6.2	0.46	0.969
TAS	319204	Pipers	5.8	0.31	0.971
TAS	318311	St Pauls	6.1	0.28	0.937
TAS	302200	Swan	6.6	0.23	0.953

Division 4 Murray-Darling

State	Stn. No.	Stream	RC	BFI	Kbase
NSW	401008	Mannus	3.9	0.48	0.966
NSW	401009	Maragle	3.5	0.63	0.979
NSW	401012	Murray	4.7	0.63	0.986
NSW	401013	Jingellic	4.3	0.57	0.976
NSW	401016	Welumba	3.9	0.63	0.989
VIC	401210	Snowy	4.7	0.63	0.988
VIC	401212	Nariel	4.5	0.63	0.986
VIC	402200	Kiewa	4.7	0.63	0.986
VIC	402204	Yackandandah	4.2	0.51	0.986
VIC	403213	Fifteen Mile	4.0	0.56	0.976
VIC	403217	Rose	4.9	0.56	0.966
VIC	403224	Hurdle	3.7	0.41	0.976
VIC	403226	Boggy	4.4	0.60	0.976
VIC	404208	Moonee	4.3	0.57	0.993
VIC	405214	Delatite	4.1	0.53	0.979
VIC	405219	Goulburn	4.8	0.55	0.976
VIC	405226	Pranjip	4.8	0.46	0.946
VIC	405228	Hughes	5.3	0.51	0.976
VIC	405229	Wanalta	4.4	0.00	0.000
VIC	405237	Sevens	5.1	0.42	0.976
VIC	406213	Campaspe	4.9	0.30	0.948
VIC	406214	Axe	4.9	0.30	0.943
VIC	407220	Bet Bet	4.8	0.17	0.953
VIC	407221	Jim Crow	4.9	0.41	0.967
VIC	407236	Mount Hope	4.0	0.38	0.946
VIC	407253	Piccaninny	5.0	0.26	0.963
VIC	408202	Avoca	4.8	0.32	0.963

State	Stn. No.	Stream	RC	BFI	Kbase
NSW	410038	Adjungbilly	3.3	0.41	0.986
NSW	410044	Muttama	4.0	0.25	0.972
NSW	410047	Tarcutta	4.4	0.51	0.986
NSW	410048	Kyeamba	4.4	0.21	0.806
NSW	410057	Goobarragandra	4.7	0.63	0.989
NSW	410059	Gilmore	4.8	0.63	0.989
NSW	410061	Adelong	4.2	0.57	0.993
NSW	410071	Brungle	3.9	0.49	0.976
NSW	410077	Bredbo	4.6	0.41	0.986
NSW	410105	Numeralla	5.7	0.27	0.987
NSW	410111	Yaven Yaven	6.2	0.45	0.987
NSW	410141	Micaligo	2.9	0.30	0.970
ACT	410705	Molonglo	5.2	0.21	0.983
ACT	410730	Cotter	4.7	0.63	0.986
ACT	410731	Gudgenby	3.4	0.54	0.981
ACT	410733	Coree	4.5	0.58	0.977
ACT	410734	Queanbyan	4.3	0.42	0.990
ACT	410736	Orroral	3.3	0.62	0.992
NSW	411003	Butmaroo	4.8	0.13	0.813
NSW	412063	Lachlan	4.3	0.25	0.973
NSW	412066	Abercrombie	4.5	0.30	0.973
NSW	412076	Bourimbla	3.7	0.21	0.956
NSW	412080	Flyers	3.0	0.61	0.976
NSW	412082	Phils	4.4	0.52	0.990
NSW	412089	Cooks Vale	3.8	0.41	0.940
NSW	412092	Coombing	3.7	0.39	0.940
NSW	412096	Pudmans	4.6	0.28	0.963
NSW	412110	Bolong	4.3	0.25	0.953
VIC	415207	Wimmera	4.8	0.36	0.967
NSW	416021	Frazers	4.0	0.22	0.813
NSW	416022	Severn	3.3	0.26	0.953
NSW	416023	Deepwater	3.1	0.40	0.967
NSW	416035	Macintyre	3.4	0.17	0.988
NSW	418005	Copes	3.1	0.22	0.943
NSW	418015	Horton	3.0	0.27	0.973
NSW	418017	Myall	3.5	0.18	0.853
NSW	418027	Horton	4.6	0.18	0.883
NSW	418032	Tycannah	2.9	0.18	0.813
NSW	418033	Bakers	3.4	0.25	0.960
NSW	419035	Goonoo Goonoo	2.8	0.20	0.981
NSW	419044	Maules	1.6	0.05	0.806
NSW	419053	Manilla	3.3	0.32	0.991
NSW	419055	Mulla	4.1	0.23	0.973
NSW	419076	Warrah	3.2	0.17	0.973
NSW	420003	Belar	4.6	0.26	0.953

State	Stn. No.	Stream	RC	BFI	Kbase
NSW	420010	Wallumburrawang	1.7	0.00	0.000
NSW	421018	Bell	4.5	0.23	0.973
NSW	421026	Turon	4.2	0.31	0.972
NSW	421036	Duckmaloi	4.9	0.63	0.976
NSW	421048	Little	4.2	0.18	0.963
NSW	421050	Bell	3.8	0.29	0.948
NSW	421055	Coolbaggie	4.7	0.00	0.000
NSW	421066	Green Valley	5.1	0.00	0.000
NSW	421076	Bogan	3.7	0.00	0.000
NSW	421084	Burrill	3.1	0.00	0.000
NSW	421100	Pyramul	4.9	0.06	0.810
NSW	421101	Campbells	2.7	0.40	0.966
NSW	421106	Cheshire	4.6	0.17	0.953
SA	426504	Finniss	4.6	0.24	0.953

Division 5 South Australian Gulf

State	Stn. No.	Stream	RC	BFI	Kbase
SA	502502	Myponga	4.2	0.38	0.958
SA	505504	N. Para	3.8	0.29	0.949
SA	505532	Light	3.3	0.29	0.979
SA	506500	Wakefield	3.3	0.28	0.990
SA	507500	Hill	3.7	0.25	0.953
SA	507501	Hutt	3.8	0.19	0.953
SA	513501	Rocky	4.0	0.57	0.969

Division 6 South-west Coast

State	Stn. No.	Stream	RC	BFI	Kbase
WA	601001	Young	2.7	0.25	0.813
WA	603004	Hay	3.5	0.51	0.956
WA	603136	Denmark	2.8	0.56	0.956
WA	604001	Kent	3.5	0.46	0.946
WA	606001	Deep	2.6	0.56	0.956
WA	608151	Donnelly	3.6	0.56	0.976
WA	610001	Margaret	4.6	0.63	0.966
WA	611111	Thomson	4.0	0.59	0.946
WA	613002	Harvey	4.4	0.63	0.986
WA	614196	Williams	4.9	0.56	0.957

Division 8 Timor Sea

State	Stn. No.	Stream	RC	BFI	Kbase
NT	8140159	Seventeen Mile	2.7	0.21	0.983
NT	8200045	S. Aligator	3.7	0.26	0.949
NT	8210007	Magela	4.7	0.30	0.941

Division 10 Lake Eyre

State	Stn. No.	Stream	RC	BFI	Kbase
NT	60046	Todd	6.8	0.00	0.000

Appendix B

Median elevation is the median elevation in the catchment (in metres).

90% - 10% is the 90th percentile elevation minus the 10th percentile elevation in the catchment (in metres).

LAI is leaf area index.

%woody is the percentage of woody vegetation in the catchment.

PAWHC is the plant water holding capacity (in mm).

Transmissivity is the lateral soil transmissivity (in m^2/day).

The derivation and sources of this data are given in Chiew *et al.,* (2002). The catchment characteristic information will be updated shortly with more recent work by the CRC for Catchment Hydrology.

Catchment Characteristics

STATE	Station Code	Station Name	Area (km^2)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics: Elevation Median	Elevation 90%-10%	LAI	%woody	PAWHC	Transmissivity
ACT	410705	Molonglo R. At Burbong Bridge	505	721	91	1099	0.52	827	292	2.4	39	100	575346
ACT	410730	Cotter At Gingera	148	1139	318	1099	0.20	1296	486	3.0	97	169	1386432
ACT	410731	Gudgenby At Tennent	670	905	106	1101	0.33	1139	499	2.3	79	107	603040
ACT	410733	Coree At Threeways	70	1006	213	1120	0.27	910	426	2.7	93	162	768513
ACT	410734	Queanbyan At Tinderry	490	884	141	1093	0.36	1072	320	2.4	62	89	437872
ACT	410736	Orroral At Crossing	90	1017	132	1108	0.30	1136	380	2.9	89	110	190938
NSW	201005	Rous River @Boat Harbour No.2	111	2119	887	1234	0.50	117	331	3.8	60	150	1540220
NSW	201011	Doon Doon Creek @Lower Doon Doon	54	2289	1056	1359	0.57	119	238	4.7	68	158	882400
NSW	203002	Coopers Creek @Repentance	62	2104	964	1355	0.45	187	315	4.2	86	187	1352930
NSW	203005	Richmond River @Wiangaree	702	1249	364	1359	0.46	325	484	4.6	80	147	2318608
NSW	203030	Myrtle Creek @Rappville	332	1159	190	1410	0.47	107	208	2.6	70	77	275885
NSW	204033	Timbarra River @Billyrimba	985	990	158	1320	0.39	912	551	3.5	74	190	4026960
NSW	204034	Henry River @Newton Boyd	389	939	118	1262	0.45	943	606	3.2	65	160	1880655
NSW	204036	Cataract Creek @Sandy Hill(Below Snake Ck)	236	993	237	1330	0.41	881	203	2.7	35	74	93560
NSW	204037	Clouds Creek @Clouds Creek	62	1298	267	1320	0.40	709	205	4.3	91	161	274652
NSW	204055	Sportsmans Creek @ Gurranang Siding	202	1157	259	1422	0.56	49	82	2.6	90	74	141488
NSW	204067	Gordon Brook @Fine Flower	315	1154	267	1381	0.60	122	158	2.5	51	87	312176
NSW	205002	Bellinger River @Thora	433	1485	550	1289	0.39	390	702	4.4	95	134	1156296
NSW	205008	Taylors Arm @Grays Crossing	319	1506	478	1255	0.52	178	453	4.3	78	140	526648
NSW	205012	Corindi Creek @ Upper Corindi	55	1583	489	1462	0.61	82	143	3.8	91	97	211047
NSW	206034	Mihi Creek @Abermala	117	787	54	1162	0.66	1090	134	1.7	14	72	142310
NSW	207012	Doyles River @Doyles River Road	65	1354	337	1286	0.39	611	283	4.2	99	157	652212
NSW	207013	Ellenborough River D/S Bunnoo River Junction	515	1423	337	1294	0.42	442	490	3.8	74	164	1054705

STATE	Station Code	Station Name	Area (km^2)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics					
								Elevation		LAI	%woody	PAWHC	Transmissivity
								Median	90%-10%				
NSW	207014	Wilson River @Avenel	505	1303	424	1214	0.50	140	414	3.8	81	147	992467
NSW	208005	Nowendoc River @Rocks Crossing	1870	1057	203	1266	0.39	590	717	3.6	79	161	2671053
NSW	208012	Manning River @Woko	480	1114	263	1281	0.31	703	896	3.4	70	144	1733627
NSW	208015	Landsdowne River @Landsdowne	96	1540	481	1311	0.59	86	332	4.2	59	149	907965
NSW	208019	Dingo Creek @Munyaree Flat	492	1408	541	1319	0.48	220	489	4.0	72	147	1179024
NSW	208022	Barnard River @The Pimple	745	905	132	1255	0.34	789	626	3.0	58	149	1769908
NSW	208026	Myall River @Jacky Barkers	560	1065	203	1248	0.30	963	777	3.4	79	160	1601754
NSW	209002	Mammy Johnsons River @ Crossing	156	1133	302	1363	0.61	258	254	4.0	85	151	129353
NSW	209006	Wang Wauk River @Willina	150	1007	208	1363	0.66	118	166	2.9	46	137	561275
NSW	210014	Rouchel Brook At Rouchel Brook (The Vale)	395	864	120	1308	0.46	497	529	2.4	42	140	848127
NSW	210022	Allyn River @Halton	205	1171	409	1342	0.49	362	584	3.9	64	163	1262886
NSW	210042	Foy Brook At Ravensworth	170	771	95	1337	0.54	270	282	1.9	18	127	305892
NSW	210048	Wollombi Brook @Paynes Crossing	1064	899	102	1326	0.49	199	221	3.1	84	131	455840
NSW	210088	Dart Brook @Aberdeen No.2	799	698	44	1327	0.54	351	391	2.0	19	107	889174
NSW	210091	Merriwa River At Merriwa	465	707	37	1328	0.50	423	314	1.8	9	144	50604
NSW	210092	Krui River At Collaroy	498	689	49	1328	0.50	505	395	2.2	16	135	69585
NSW	211008	Jigadee Creek @Avondale	55	1125	365	1402	0.67	36	100	3.3	72	80	101602
NSW	211013	Ourimbah Creek @U/S Weir	83	1230	331	1343	0.48	198	247	3.5	77	140	125883
NSW	211014	Wyong River @Yarramalong	181	1078	223	1346	0.52	224	263	4.5	88	140	125883
NSW	212018	Capertee River At Glen Davis	1010	712	38	1223	0.52	559	446	2.3	59	137	2008488
NSW	212040	Kialla Creek At Pomeroy	96	757	86	1108	0.49	855	150	1.5	5	118	513936
NSW	212045	Coxs River At Island Hill	970	876	116	1136	0.40	896	431	2.5	51	119	810040
NSW	215002	Shoalhaven River At Warri	1450	856	219	1086	0.44	777	368	2.8	52	92	1041586
NSW	216009	Buckenbowra River At Buckenbowra No.3	168	943	261	1109	0.47	278	473	3.7	98	136	563265
NSW	218002	Tuross River At Belowra	556	909	271	1080	0.35	858	759	3.4	81	110	257552
NSW	218006	Wandella Creek At Wandella	57	1013	349	1089	0.57	316	380	3.5	75	125	227601
NSW	218007	Wadbilliga River At Wadbilliga	122	915	317	1081	0.46	535	728	3.4	94	123	242685
NSW	219013	Brogo River At North Brogo	460	906	291	1076	0.45	494	746	3.6	93	120	376390
NSW	219016	Narira River At Cobargo	92	983	206	1096	0.61	132	147	3.3	25	133	198240
NSW	219017	Double Creek Near Brogo	152	938	253	1075	0.53	207	431	3.4	63	133	196128
NSW	220002	Stockyard Creek At Rocky Hall (Whitbys)	75	1094	216	1067	0.45	664	451	3.2	87	109	134640
NSW	220003	Pambula River At Lochiel	105	903	237	1093	0.60	189	290	2.7	78	114	147794
NSW	220004	Towamba River At Towamba	745	949	204	1077	0.51	418	524	3.2	81	114	225522
NSW	221003	Genoa River At Bondi	235	958	219	1059	0.41	651	341	3.3	88	107	128814

STATE	Station Code	Station Name	Area (km^2)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics: Elevation Median	Elevation 90%-10%	LAI	%woody	PAWHC	Transmissivity
NSW	222004	Little Plains River At Wellesley (Rowes)	604	893	144	1030	0.26	824	194	2.3	58	101	227768
NSW	222010	Bobundara Creek At Dalgety Road	360	583	47	1044	0.48	934	246	1.2	3	121	247086
NSW	222011	Cambalong Creek At Gunning Grach	188	654	98	1049	0.56	891	208	1.9	8	118	644814
NSW	222017	Maclaughlin River At The Hut	313	618	69	1050	0.43	957	270	1.6	14	122	476456
NSW	401008	Mannus Creek @ Tooma	504	1002	187	1128	0.41	585	172	2.5	36	117	679775
NSW	401009	Maragle Creek @ Maragle	220	1062	177	1083	0.29	769	549	3.0	65	179	970572
NSW	401012	Murray River @ Biggara	1165	1331	421	1005	0.18	1050	806	3.1	98	190	1960630
NSW	401013	Jingellic Creek @ Jingellic	378	929	164	1144	0.32	445	270	2.4	63	90	268205
NSW	401016	Welumba Creek @ The Square	52	1038	191	1067	0.21	649	378	3.1	95	196	307915
NSW	410038	Adjungbilly Creek @ Darbalara	411	1180	211	1144	0.34	695	445	2.9	58	110	548760
NSW	410044	Muttama Creek @ Coolac	1025	628	53	1199	0.45	382	199	1.3	6	85	492768
NSW	410047	Tarcutta Creek @ Old Borambola	1660	818	110	1169	0.34	353	393	1.9	38	88	854184
NSW	410048	Kyeamba Creek @ Ladysmith	530	610	74	1195	0.53	291	161	1.4	8	66	511500
NSW	410057	Goobarragandra River @ Lacmalac	673	1319	429	1117	0.20	905	716	3.6	94	157	1583964
NSW	410059	Gilmore Creek @ Gilmore	233	1216	386	1126	0.26	669	661	2.9	52	140	1606248
NSW	410061	Adelong Creek @ Batlow Road	155	1138	256	1138	0.30	606	390	3.1	39	117	879150
NSW	410071	Brungle Creek @ Red Hill	114	975	168	1152	0.38	469	309	1.8	27	73	188991
NSW	410077	Bredbo River @ Laguna	75	925	179	1087	0.42	1135	246	2.3	49	78	141255
NSW	410105	Numeralla River @ Numeralla Dam Site	321	712	154	1065	0.46	1005	237	2.1	41	111	316128
NSW	410111	Yaven Yaven Creek @ Spyglass	77	988	344	1148	0.39	544	322	2.4	34	100	279639
NSW	410141	Micaligo Creek @ Michelago	190	763	54	1101	0.44	856	410	2.0	52	106	138158
NSW	411003	Butmaroo Creek At Butmaroo	65	713	108	1093	0.61	855	231	1.9	37	66	41378
NSW	412063	Lachlan River @ Gunning	570	737	76	1114	0.52	722	208	1.5	10	85	715403
NSW	412066	Abercrombie River @ Hadley No.2	1630	814	123	1078	0.42	866	338	2.4	43	135	1841565
NSW	412076	Bourimbla Creek @Cudal	124	779	134	1197	0.44	577	354	1.7	14	131	671352
NSW	412080	Flyers Creek @Beneree	98	915	106	1160	0.31	882	169	2.2	10	149	918476
NSW	412082	Phils Creek @Fullerton	106	821	124	1098	0.35	819	156	1.6	4	147	163312
NSW	412089	Cooks Vale Creek @ Peelwood	142	780	86	1098	0.42	780	160	1.9	27	133	268376
NSW	412092	Coombing Creek @Near Neville	132	918	172	1131	0.46	959	85	1.6	4	156	485286
NSW	412096	Pudmans Creek @ Kennys Creek Road	332	697	85	1167	0.53	589	146	1.3	6	85	90386
NSW	412110	Bolong River @ U/S Giddigang Creek	171	794	102	1078	0.55	886	157	1.8	9	121	522120
NSW	416021	Frazers Creek @Ashford	804	805	86	1221	0.63	713	434	1.7	25	104	764124
NSW	416022	Severn River @Fladbury	1100	843	76	1258	0.54	1056	218	2.0	17	96	910746
NSW	416023	Deepwater River @Bolivia	505	874	82	1300	0.43	997	287	2.5	34	114	1206423

STATE	Station Code	Station Name	Area (km^2)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics					
								Elevation Median	Elevation 90%-10%	LAI	%woody	PAWHC	Transmissivity
NSW	416035	Macintyre River @Elsmore	521	886	106	1203	0.59	889	433	1.9	23	127	764532
NSW	418005	Copes Creek @Kimberley	259	850	89	1192	0.56	825	174	1.8	30	114	602910
NSW	418015	Horton River @Rider (Killara)	1970	819	108	1345	0.51	541	393	1.8	25	89	862972
NSW	418017	Myall Creek @Molroy	842	742	48	1267	0.60	499	301	1.3	15	118	1206416
NSW	418027	Horton River @Horton Dam Site	220	946	199	1344	0.61	788	550	2.1	46	109	448024
NSW	418032	Tycannah Creek @Horseshoe Lagoon	866	693	31	1379	0.61	399	269	1.6	40	98	544005
NSW	418033	Bakers Creek @Bundarra	173	758	51	1218	0.45	787	217	1.7	43	146	848725
NSW	419035	Goonoo Goonoo Creek @Timbumburi	503	811	55	1280	0.54	563	278	1.4	5	72	283176
NSW	419044	Maules Creek At Damsite	171	842	40	1353	0.59	637	366	1.8	64	91	176432
NSW	419053	Manilla River At Black Springs	791	755	53	1338	0.55	639	223	1.5	8	78	447916
NSW	419055	Mulla Creek @Goldcliff	254	905	140	1220	0.50	813	504	2.2	41	94	226947
NSW	419076	Warrah Creek @Old Warrah	150	845	80	1305	0.58	508	391	1.9	11	155	197420
NSW	420003	Belar Creek @Warkton (Blackburns)	133	887	78	1273	0.47	604	280	1.9	32	144	152456
NSW	420010	Wallumburrawang Creek @Bearbung	452	701	20	1271	0.57	492	356	1.5	21	140	973525
NSW	421018	Bell River @Newrea	1620	729	73	1174	0.47	575	377	1.5	11	98	1553058
NSW	421026	Turon River At Sofala	883	840	133	1169	0.47	879	308	2.1	52	141	1636792
NSW	421036	Duckmaloi River @Below Dam Site	112	967	244	1098	0.26	1172	131	2.9	35	166	825447
NSW	421048	Little River @Obley No.2	612	687	71	1233	0.50	501	212	1.5	29	82	234490
NSW	421050	Bell River @Molong	365	826	94	1160	0.54	723	260	1.8	20	119	796845
NSW	421055	Coolbaggie Creek @Rawsonville	626	591	28	1259	0.70	303	73	1.2	28	122	472676
NSW	421066	Green Valley Creek At Hill End	119	772	119	1210	0.67	825	186	1.3	30	80	44165
NSW	421076	Bogan River @Peak Hill No.2	1036	543	23	1327	0.61	293	120	1.1	9	76	248577
NSW	421084	Burrill Creek @Mickibri	163	597	25	1283	0.53	400	230	1.7	36	91	157659
NSW	421100	Pyramul Creek @U/S Hill End Road	193	778	136	1229	0.68	830	174	1.6	18	82	99178
NSW	421101	Campbells River At U/S Ben Chifley Dam	950	802	70	1105	0.43	981	278	2.1	22	168	840300
NSW	421106	Cheshire Creek At Wiagdon	102	769	106	1156	0.56	863	279	1.8	35	87	198306
NT	60046	Todd R At Wigley Gorge	360	297	32	1392	0.76	732	90	0.3	0	63	502360
NT	8E+06	Seventeen Mile Ck At Waterfall View	619	1106	171	2030	0.39	296	156	0.9	91	139	2282544
NT	8E+06	South Aligator R At El Sharana	1300	1305	364	2070	0.46	247	202	0.9	NA	89	935473
NT	8E+06	Magela Ck At Upstream Bowerbird Waterhole	260	1357	409	2118	0.47	282	144	0.9	#N/A	87	105974
QLD	111007	Mulgrave R At Peets Bridge	545	2886	1383	1831	0.34	358	634	3.8	91	197	3671459
QLD	117002	Black R At Bruce Highway	260	1195	311	1767	0.57	90	364	1.8	84	89	1079410
QLD	119003	Haughton R At Powerline	1735	898	220	1770	0.56	129	361	1.2	65	86	3910200
QLD	120216	Broken R At Old Racecourse	78	1729	605	1713	0.44	757	204	3.6	97	169	1505145

STATE	Station Code	Station Name	Area (km²)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics					
								Elevation		LAI	%woody	PAWHC	Transmissivity
								Median	90%-10%				
QLD	122003	Proserpine R At Peter Faust Dam	270	1185	295	1791	0.58	121	234	1.7	71	86	370275
QLD	125002	Pioneer R At Sarich'S	740	1346	410	1736	0.54	254	501	2.7	96	146	2631984
QLD	130319	Bell Ck At Craiglands	300	697	42	1597	0.62	335	221	1.8	68	64	368154
QLD	132001	Calliope R At Castlehope	1310	849	123	1640	0.60	90	189	1.6	36	76	816088
QLD	135002	Kolan R At Springfield	545	946	126	1575	0.57	251	266	2.5	86	72	279564
QLD	136202	Barambah Ck At Litzows	640	898	84	1551	0.58	430	181	2.3	47	69	398180
QLD	136315	Boyne R At Carters	1715	700	20	1527	0.63	412	200	1.5	40	68	495132
QLD	142001	Caboolture R At Upper Caboolture	98	1483	418	1563	0.63	200	362	2.7	52	143	1288371
QLD	143110	Bremer R At Adams Bridge	130	960	163	1379	0.68	159	198	2.4	35	86	290507
SA	426504	Finniss River @ 4Km East Of Yundi	191	849	147	1115	0.53	317	86	1.6	43	75	165429
SA	502502	Myponga River @ U/S Dam And Road Bridge	76.5	820	115	1095	0.44	293	87	1.5	28	78	166116
SA	505504	North Para River @ Turretfield	708	546	28	1124	0.48	279	290	1.1	20	65	465579
SA	505532	Light River @ Mingays Waterhole	828	487	14	1117	0.50	397	192	1.0	6	61	101994
SA	506500	Wakefield River @ Near Rhynie	417	551	25	1125	0.47	380	168	1.1	14	57	106362
SA	507500	Hill River @ Andrews	235	553	24	1125	0.57	409	125	1.0	5	58	68494
SA	507501	Hutt River @ Near Spalding	280	569	28	1131	0.59	383	145	1.0	12	60	60990
SA	513501	Rocky River @ Flinders Chase(Ki)	190	757	83	1213	0.33	162	177	2.4	98	66	351755
TAS	3E+06	Franklin R At Mt Fincham	757	2445	2095	765	0.43	614	574	2.5	90	166	1101770
TAS	3E+06	Hellyer R At Guilford	102	2062	1337	784	0.26	635	79	2.3	69	229	353499
TAS	3E+06	Brid R U/S Of Tidal Limit	139	1052	318	925	0.25	149	399	2.6	58	114	347832
TAS	302200	Swan R. @ The Grange	448	763	281	910	0.51	302	594	2.4	88	77	219756
TAS	303203	Coal R. @ Baden	53.2	625	139	825	0.52	483	143	1.7	44	75	220630
TAS	304201	Jordan R. @ Mauriceton	742	546	30	828	0.45	418	326	1.8	36	71	1041930
TAS	314207	Leven R. D/S Bannons Bridge	500	1775	1014	802	0.31	585	569	2.8	78	173	1774157
TAS	318311	St Pauls R. U/S South Esk R.	495	687	161	900	0.47	429	468	2.4	81	97	373648
TAS	318852	Meander R. @ Strathbridge	1012	1085	469	856	0.39	297	723	2.5	53	124	3677250
TAS	318900	Break O'Day R. @ Killymoon Br.	187	942	271	920	0.52	328	397	2.7	68	111	369492
TAS	319201	Great Forester R. 2Km	193	1141	425	909	0.25	210	538	3.0	75	129	433242
TAS	319204	Pipers R. D/S Yarrow Ck.	298	956	317	923	0.44	195	427	2.9	60	78	401620
VIC	221201	Cann R (West Branch) At Weeragua	311	1016	196	1045	0.31	537	517	3.4	96	128	372417
VIC	221204	Thurra R At Point Hicks	345	1027	257	1072	0.40	210	345	3.9	97	138	575913
VIC	221210	Genoa R At The Gorge	837	966	189	1072	0.49	434	553	3.4	90	113	588168
VIC	222206	Buchan R At Buchan	850	1025	191	988	0.30	888	952	3.3	99	160	2000160

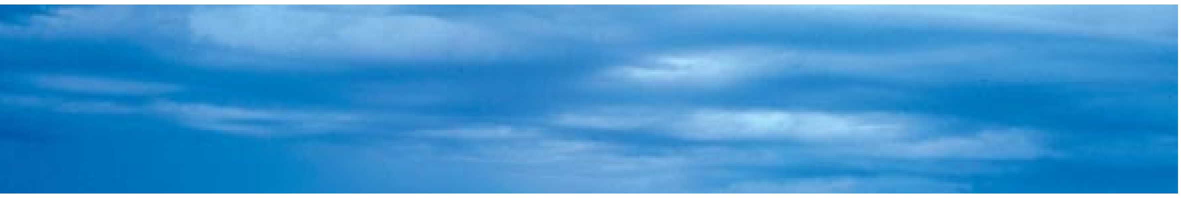
STATE	Station Code	Station Name	Area (km^2)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics					
								Elevation		LAI	%woody	PAWHC	Transmissivity
								Median	90%-10%				
VIC	223202	Tambo R At Swifts Ck	943	819	87	969	0.28	767	745	2.9	78	133	757335
VIC	223207	Timbarra R At Timbarra	205	985	287	980	0.22	995	650	3.5	98	119	358128
VIC	225217	Barkly R At Glencairn	248	1288	412	1057	0.27	738	541	3.6	99	188	530854
VIC	225218	Freestone Ck At Briagolong	311	797	129	1051	0.51	326	458	3.6	100	129	449061
VIC	225219	Macalister R At Glancairn	570	1330	432	1042	0.27	984	838	3.1	97	180	742665
VIC	226007	Tyers R At Browns	207	1380	449	1009	0.27	351	833	4.1	96	138	835585
VIC	226218	Narracan Ck At Thorpdale	66	1042	356	1027	0.14	301	105	2.9	15	192	530728
VIC	226405	Middle Ck At Yinnar South	69.2	1225	275	1009	0.41	321	269	4.0	88	243	649076
VIC	227200	Tarra R At Yarram	218	1060	190	987	0.39	165	404	3.9	64	143	1295912
VIC	227202	Tarwin R At Meeniyan	1067	1054	252	1047	0.35	143	249	2.8	19	203	3825976
VIC	227211	Agnes R At Toora	67	1301	391	1003	0.37	267	257	4.4	63	194	485302
VIC	227219	Bass R At Loch	52	1140	347	1067	0.50	175	114	2.7	7	127	225732
VIC	228203	Eumemmering Ck At Lyndhurst	149	834	159	988	0.53	42	104	2.4	10	94	380610
VIC	229215	Woori Yallock Ck At Woori Yallock	311	1169	313	988	0.25	203	211	2.8	44	126	1512288
VIC	230205	Maribyrnong R At Bulla (Ds Of Emu Ck Junction)	865	730	82	1046	0.46	403	349	1.6	13	84	303612
VIC	231213	Lerderderg R At Sardine Ck (O'Briens X-Ing)	153	1083	207	1016	0.39	667	209	3.0	88	114	513452
VIC	233215	Leigh At Mount Mercer	593	738	98	1024	0.47	406	142	2.1	31	63	98930
VIC	233223	Warrambine Ck At Warrambine	57.2	688	41	1023	0.72	250	134	1.7	0	59	19270
VIC	234200	Woady Yallock At Pitfield	324	709	55	1042	0.53	374	140	2.0	44	63	76548
VIC	234203	Pirron Yallock Ck At Pirron Yallock (Above Hw Br)	166	841	111	1008	0.32	145	35	2.4	19	101	443312
VIC	235203	Curdies R At Curdie	790	912	143	1012	0.47	115	106	2.4	13	106	564360
VIC	235211	Kennedys Ck At Kennedys Creek	268	978	155	1015	0.40	135	116	3.0	34	94	425712
VIC	236203	Mount Emu Ck At Skipton	1251	693	47	1050	0.37	371	95	1.6	13	66	238080
VIC	236205	Merri R At Woodford	899	746	78	1019	0.45	118	126	1.6	1	74	87140
VIC	236212	Brucknell Ck At Cudgee	223	886	143	1009	0.39	79	82	1.9	8	90	271810
VIC	237200	Moyne R At Toolong	570	761	96	1043	0.43	89	135	1.6	1	77	70515
VIC	237205	Darlot Ck At Homerton Bridge	760	707	88	1072	0.16	102	121	1.9	13	78	86160
VIC	237206	Eumeralla R At Codrington	502	753	69	1066	0.29	109	158	2.0	7	77	112105
VIC	238223	Wando R At Wando Vale	174	705	101	995	0.40	240	131	1.5	5	108	139048
VIC	401210	Snowy Ck At Below Granite Flat	407	1374	493	1031	0.17	824	645	3.8	97	172	739350
VIC	401212	Nariel Ck At Upper Nariel	252	1483	551	1020	0.17	1047	605	3.9	99	192	1141624

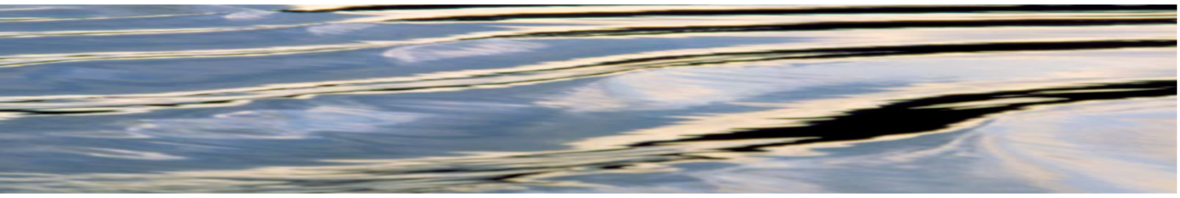
STATE	Station Code	Station Name	Area (km^2)	Annual Rainfall (mm)	Annual Runoff (mm)	Annual APET (mm)	Surface Runoff Ratio	Catchment Characteristics					
								Elevation		LAI	%woody	PAWHC	Transmissivity
								Median	90%-10%				
VIC	402200	Kiewa R At Kiewa (Combined Flow)	1145	1428	542	1060	0.20	596	1282	3.1	67	110	376552
VIC	402204	Yackandandah Ck At Osbornes Flat	255	1066	237	1126	0.30	480	478	2.5	55	92	121734
VIC	403213	Fifteen Mile Ck At Greta South	229	1171	291	1043	0.26	530	541	2.8	74	158	1661178
VIC	403217	Rose R At Matong North	154	1326	473	1039	0.29	607	451	3.2	86	179	776133
VIC	403224	Hurdle Ck At Bobinawarrah	155	1091	211	1076	0.33	340	325	2.7	57	78	110097
VIC	403226	Boggy Ck At Angleside	108	1182	324	1054	0.26	409	476	2.2	53	141	916264
VIC	404208	Moonee Ck At Lima	90.9	1076	234	994	0.22	521	479	2.9	76	92	143828
VIC	405214	Delatite R At Tonga Bridge	368	1239	348	1017	0.28	602	615	3.0	54	137	626176
VIC	405219	Goulburn R At Dohertys	694	1399	530	1052	0.23	720	550	3.4	99	184	490630
VIC	405226	Pranjip Ck At Moorilim	787	655	85	1027	0.40	168	235	1.3	5	74	203712
VIC	405228	Hughes Ck At Tarcombe Road	471	815	189	981	0.35	448	260	1.6	15	94	159060
VIC	405229	Wanalta Ck At Wanalta	108	557	42	1074	0.69	163	68	1.7	52	71	40740
VIC	405237	Seven Creeks At Euroa, Township	332	959	241	1000	0.35	493	378	2.3	18	94	157212
VIC	406213	Campaspe R At Redesdale	629	800	144	1045	0.45	513	268	1.7	19	81	403660
VIC	406214	Axe Ck At Longlea	234	608	72	1077	0.54	273	177	1.4	44	60	40266
VIC	407220	Bet Bet Ck At Norwood	347	607	66	1029	0.61	275	154	1.5	19	64	131150
VIC	407221	Jim Crow Ck At Yandoit	166	854	169	1009	0.43	526	337	2.5	60	108	765060
VIC	407236	Mount Hope Ck At Mitiamo	1629	479	22	1078	0.35	151	100	1.2	24	83	200475
VIC	407253	Piccaninny Ck At Minto	668	520	48	1061	0.55	176	97	1.3	39	73	104540
VIC	408202	Avoca R At Amphitheatre	78	658	78	1029	0.49	343	197	1.9	30	68	74008
VIC	415207	Wimmera R At Eversley	298	634	73	1018	0.43	400	351	2.3	53	74	143856
WA	601001	Young R At Neds Corner	1610	390	3	1250	0.56	199	151	1.0	41	91	493268
WA	603004	Hay R At Sunny Glen	1161	713	54	1192	0.38	157	178	1.7	50	122	1604940
WA	603136	Denmark R At Mt Lindesay	525	807	59	1171	0.35	176	108	2.2	83	140	1251408
WA	604001	Kent R At Rocky Glen	1108	577	27	1172	0.37	237	50	1.3	39	107	1339632
WA	606001	Deep R At Teds Pool	457	916	82	1159	0.31	180	72	2.9	93	146	524554
WA	608151	Donnelly R At Strickland	807	1013	164	1176	0.23	241	112	3.1	75	98	217314
WA	610001	Margaret R At Willmots Farm	442	1000	216	1175	0.24	109	78	1.9	76	123	346400
WA	611111	Thomson Brook At Woodperry Homestead	102	862	125	1163	0.32	228	109	2.8	76	99	122120
WA	613002	Harvey R At Dingo Rd	148	1052	240	1234	0.19	284	105	2.7	100	139	583536
WA	614196	Williams R At Saddleback Rd Br	1437	531	48	1230	0.34	305	101	1.3	24	77	507144

CENTRE OFFICE

CRC for Catchment Hydrology
Department of Civil Engineering
Building 60
Monash University
Victoria 3800
Australia

Tel +61 3 9905 2704
Fax +61 3 9905 5033
email crcch@eng.monash.edu.au
www.catchment.crc.org.au





The Cooperative Research Centre for Catchment Hydrology is a cooperative venture formed under the Australian Government's CRC Programme between:

- Brisbane City Council
- Bureau of Meteorology
- CSIRO Land and Water
- Department of Infrastructure, Planning and Natural Resources, NSW
- Department of Sustainability and Environment, Vic
- Goulburn-Murray Water
- Griffith University
- Melbourne Water
- Monash University
- Murray-Darling Basin Commission
- Natural Resources and Mines, Qld
- Southern Rural Water
- The University of Melbourne
- Wimmera Mallee Water

ASSOCIATE:

- Water Corporation of Western Australia

RESEARCH AFFILIATES:

- Australian National University
- National Institute of Water and Atmospheric Research, New Zealand
- University of New South Wales
- Sustainable Water Resources Research Center, Republic of Korea

INDUSTRY AFFILIATES:

- WBM
- Earth Tech
- Sinclair Knight Merz
- Ecological Engineering

CRC AUSTRALIA

Established and supported under the Australian Government's Cooperative Research Centre Program

COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY