Chapter 7

Darling Downs Regional Flood Frequency version of the Rational Method

The Darling Downs Regional Flood Frequency Version of the Rational Method is considered suitable for runoff estimation in small catchments in the Darling Downs region where contour banked land represents a small component of the catchment. However for catchments dominated by contour banks, the Empirical version of the Rational Method as described in Chapter 6 is preferred.

7.1 Description

Runoff data was used to develop the Darling Downs Flood Frequency version of the Rational Method (Titmarsh 1989, 1994) for use in the area shown in Figure 7.1. This area is described as the area bounded to the south by the QLD/NSW border, to the west by the 151°E longitude, and to the north and east by the Great Dividing Range.

For most of Queensland, sufficient runoff data from small rural catchments are not available to carry out similar analyses. For instance, all runoff data for such catchments in the Burnett and Central Highlands region were collated and examined in an effort to develop a flood frequency version of the Rational Method for that region. No reliable relationship could be derived as there were too few gauging stations, many of which had short records.

Weeks (1991) has carried out a broad scale study of this type covering most of Queensland. However, the data used were very limited and were mainly from large catchments thus restricting the application and reliability of that version for soil conservation design.

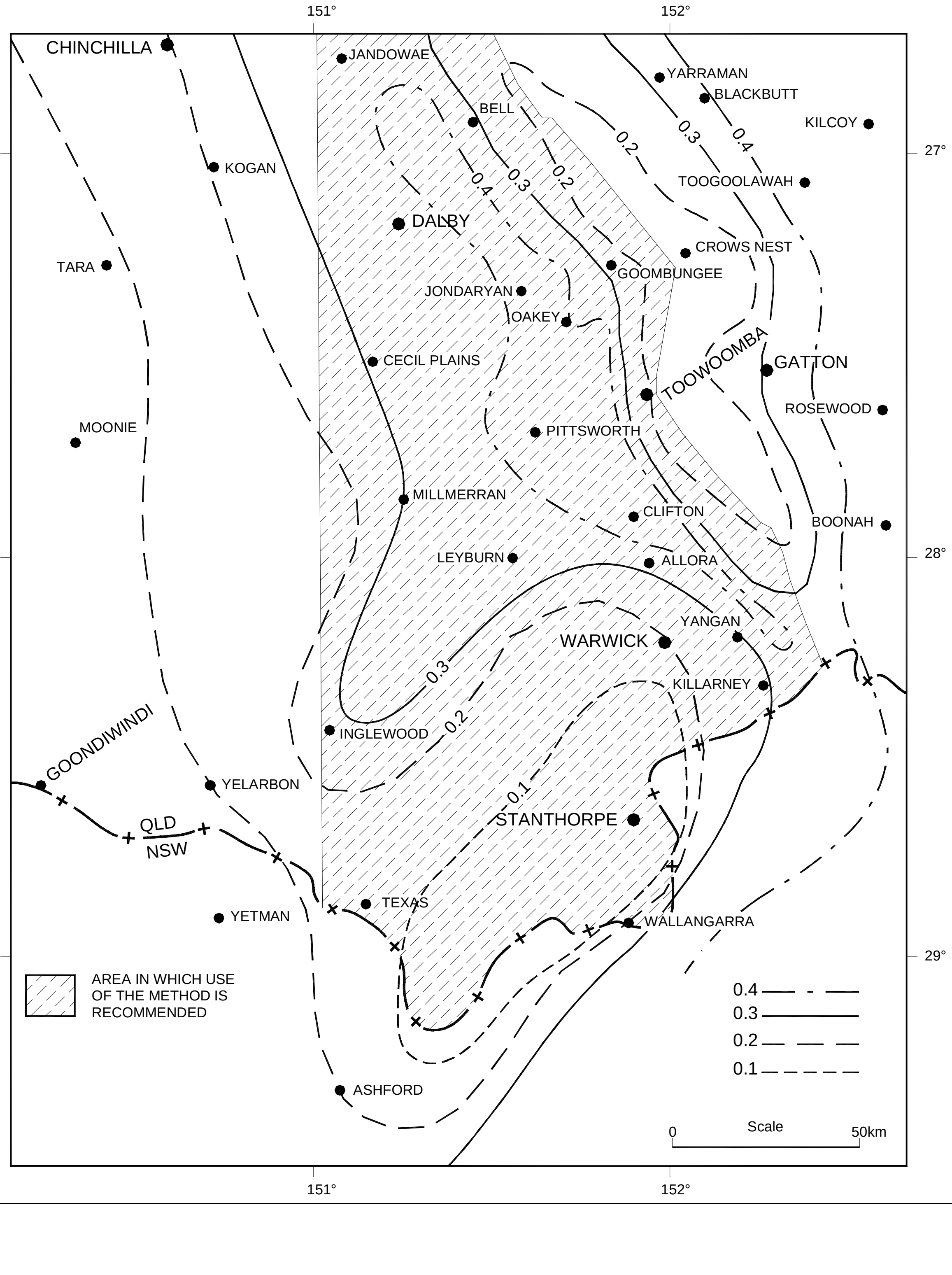
The formula for the DDFF version of the Rational Method is:

$$\mathbf{Q_y = 0.00278\, C_y\, I_{tr.y}\, A} \qquad \text{Equation 7.1}$$

Where

- Q_y = design peak runoff rate for an ARI of y years (m^3/s)
- C_y = runoff coefficient for the same ARI (dimensionless)
- $I_{tr.y}$ = average rainfall intensity (mm/h) for a design duration equal to a catchment response time tr (minutes) and the same ARI
- A = area of catchment (ha)

Figure 7.1 Runoff coefficients for the Darling Downs Flood Frequency version of the Rational Method



7.2 Selection of a runoff coefficient

C_{10} values derived for the Darling Downs region are shown on the map in Figure 7.1. The runoff coefficients were also found to be dependent on the area of the catchment that is cultivated. If the catchment has some of its area cultivated, then C_{10} values should also be determined using Equation 7.2 or Table 7.1. The higher of the two C_{10} values (from either Table 7.1 or Equation 7.2) should then be used for the design.

$$\mathbf{C_{10} = 0.22 + 0.004\,\Phi} \quad \text{.......... Equation 7.2}$$

Where

C_{10} = runoff coefficient for the 10 year ARI
Φ = percentage of catchment area cultivated

Table 7.1 C_{10} runoff coefficients for the DDFF version of the Rational Method based on the percentage of cultivation in the catchment

Percentage cultivation	DDFF C_{10} value
10	0.3
20	0.3
30	0.3
40	0.4
50	0.4
60	0.5
70	0.5
80	0.5
90	0.6
100	0.6

Runoff coefficient values for ARI's other than 10 years can be estimated using Equation 7.3

$$\mathbf{C_y = FF_y\ C_{10}} \quad \text{.......... Equation 7.3}$$

Where

C_y = runoff coefficient for an ARI of y years
FF_y = frequency factor for an ARI of y years.
C_{10} = runoff coefficient for the 10 year ARI

The average frequency factors for ARI's of 1, 2, 5 and 20 years for use in Equation 7.3 are given in Table 7.2.

Table 7.2 Average frequency factors

ARI (years)	Average frequency factors (FF_y)
1	0.5
2	0.6
5	0.8
10	1.0
20	1.2

As an example, if the C_{10} runoff coefficient was 0.4 then the C_{20} runoff coefficient would be be determined as follows:

C_{20} = $FF_y\ C_{10}$
= 1.18 x 0.4
= 0.47

7.3 Catchment response time

The effect of catchment characteristics on the hydrologic behaviour of catchments was examined by Titmarsh (1989), in order to obtain a more objective method of determining a duration to use with IFD data. It was found that, for the catchments used, the average time from the start of the runoff to the time of peak discharge for large events was a good measure of that catchment's response time. A regression analysis between that time and many catchment characteristics determined that the catchment area alone gave a reliable estimate of that time. Use of catchment area has an advantage in that it is less affected by map scale than are measurements such as stream length.

The relationship used to calculate response time (tr) is:

tr = 7.8 $A^{0.36}$ minutes.. Equation 7.4

Where

tr = response time (minutes)
A = catchment area (ha).

This version of the Rational Method was developed using IFD information from Pilgrim (1987) and Equation 7.4. No other method of deriving a catchment response time or IFD data should be used with the C_{10} values shown in Figure 7.1.

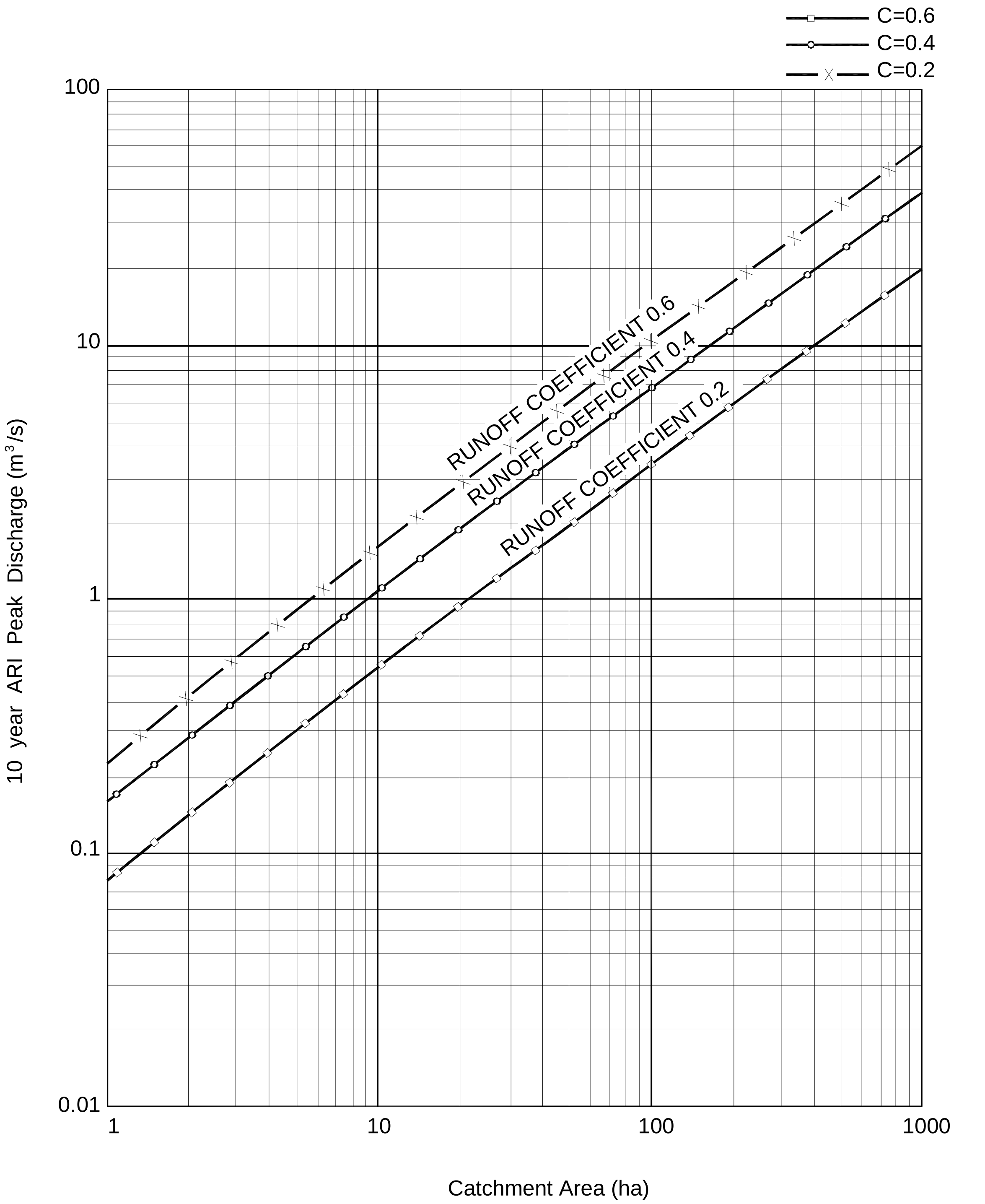
7.4 Applying the Darling Downs Flood Frequency version

The following procedure is used to determine the design peak discharge at a design point.

1. Decide on the design ARI.
2. Measure the area of cultivation and total catchment area to the design point.
3. Calculate the catchment response time using Equation 7.4.
4. From the IFD diagram for the district, determine the design rainfall intensity.
5. Determine a C_{10} value from Figure 7.1
6. Calculate the percentage of the catchment that is cultivated.
7. Calculate C_{10} value using Equation 7.2.
8. Select the higher of the C_{10} values from steps 5 and 7.
9. For ARI's other than 10 years, calculate a C_y value using Equation 7.3 and Table 7.2.
10. Calculate the design peak discharge using Equation 7.1.

A refinement of this procedure involves the use of a district specific chart as shown in Figure 7.2. With these charts, catchment area and runoff coefficient are the only variables to consider in determining the peak rate of runoff for a catchment in a specific district. It is not necessary to determine a rainfall intensity value when using this chart as rainfall intensity is directly related to response time, which is directly related to catchment area.

Figure 7.2 Catchment area - peak discharge relationship for the Oakey district



7.5 Example

Estimate the 10 year ARI peak discharge for a 120 hectare catchment at Oakey. Assume that 20 ha of the catchment is cultivated.

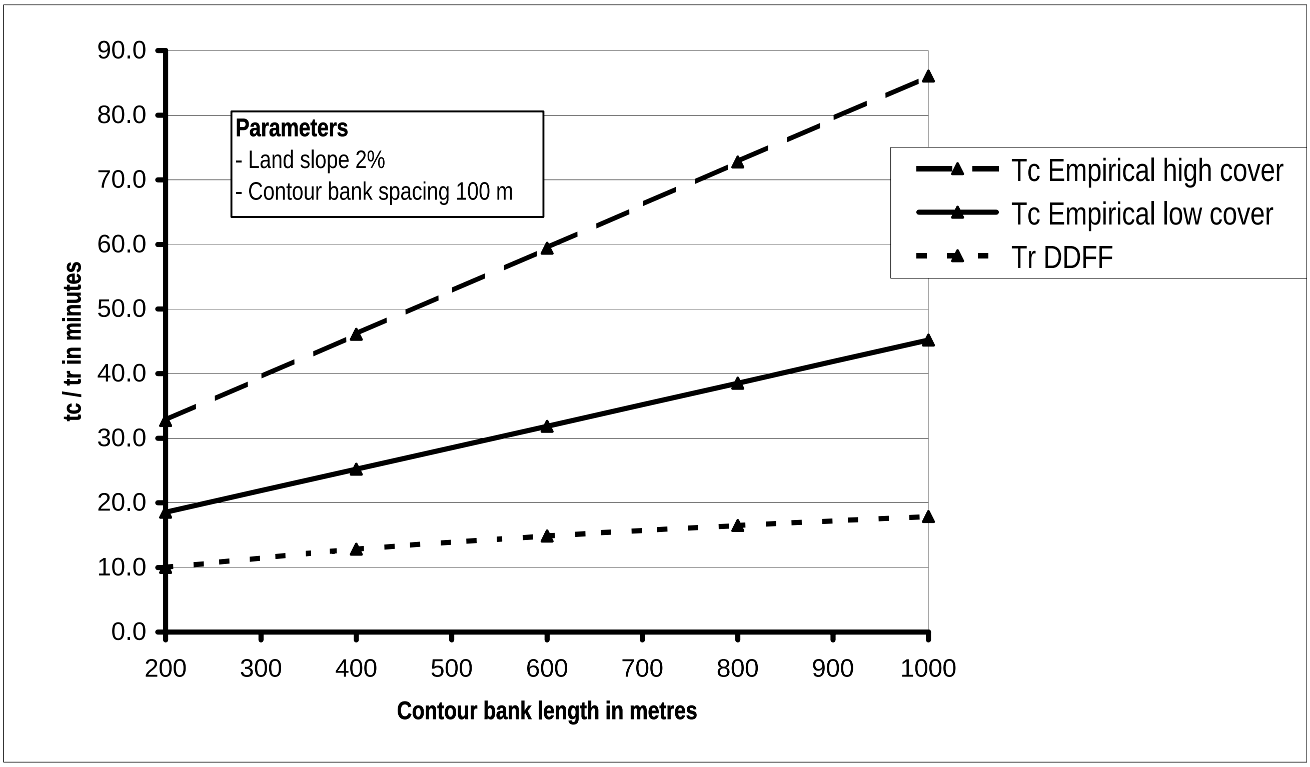
1. ***Calculate a design rainfall duration (tr) for the catchment***
   Tr = $7.8\ A^{0.36}$
   = $7.8 * 120^{0.36}$
   = 44 minutes
2. ***Determine the rainfall intensity from an IFD chart for Oakey for a 10 year ARI event of 44 minutes duration***
   55 mm/h
3. ***Determine a C_{10} value for Oakey from Figure 7.1***
   C_{10} = 0.4
4. ***Calculate the percentage of the catchment that is cultivated using Equation 7.2***
   Φ = (20/120) * 100
   = 17%
5. ***Calculate the C_{10} value using equation 7.2***
   C_{10} = 0.22 + 0.004 * 17
   = 0.3
6. ***Select the higher of the C_{10} values from steps 2 and 3 (0.4)***
7. ***Calculate the design peak discharge using Equation 7.1***
   Q_{10} = .00278 * 0.4 * 55 * 120
   = 7.3 m^3/s

7.6 Comparison with the Empirical version of the Rational Method

In comparing the Empirical and DDFF versions of the Rational Method, the DDFF version will provide higher estimates of peak discharge for contour bays. A contour bay represents an unnatural catchment with a long but relatively narrow rectangular shape. A contour bank has considerable storage capacity and has an attenuating affect on discharge from the contour bay. This is especially so when a contour channel has a crop or standing stubble which is likely to reduce flow velocity by a factor of 5 when compared to a bare channel. The longer the contour bank, the greater this effect will be. Because the time of return estimate for the DDFF is based only on the area of the catchment, this method assumes that all catchments have a similar shape and it cannot take into account the effect that contour banks have in retarding flows.

Figure 7.3 provides a comparison of time of response for the DDFF method compared to time of concentration for the Empirical version. It is considered that the method of calculating time of concentration gives a better reflection of the ability of contour banks to attenuate discharge rates than does the time of response value for the DDFF method.

Figure 7.3 Comparison of times of concentration and time of response for a contour bay



Values of the runoff coefficient derived from observed flood data in the DDFF version show no dependence on paddock characteristics such as soil type, slope or vegetation type and condition. One reason for this is that most runoff data used in the analysis of runoff estimation methods comes from catchments that are much larger than paddock size. Hence variation in runoff resulting from different attributes of the components of a catchment tends to average out. As discussed in Chapter 3, *Runoff Processes*, land management practices can have a significant effect on peak discharge at the paddock level. Even if the soil profile is full, stubble will retard overland flows and especially flow in contour bank channels.

The Empirical Version attempts to consider the impact of various paddock characteristics by using assumed values of the runoff coefficient as shown in Table 6.2 of Chapter 6. If the whole of a paddock is cultivated, as is the case in most soil conservation designs, the runoff coefficient for the DDFF method will be 0.6 irrespective of soil type or land management. With the estimated values of the runoff coefficient for the Empirical Method, it is common to use coefficient values ranging from 0.3 to 0.6 depending on the runoff potential of the landscape and the cropping system. Such values, while only estimates, are considered to reflect the situation occurring at the paddock level.

For the above reasons, use of the DDFF version of the Rational Method should be restricted to small non-contoured catchments in the area indicated in Figure 7.1. However it could be expected to give reasonable results for non-contoured catchments in other areas of Queensland that had comparable soils, topography and rainfall intensities to the area indicated in Figure 7.1. ■