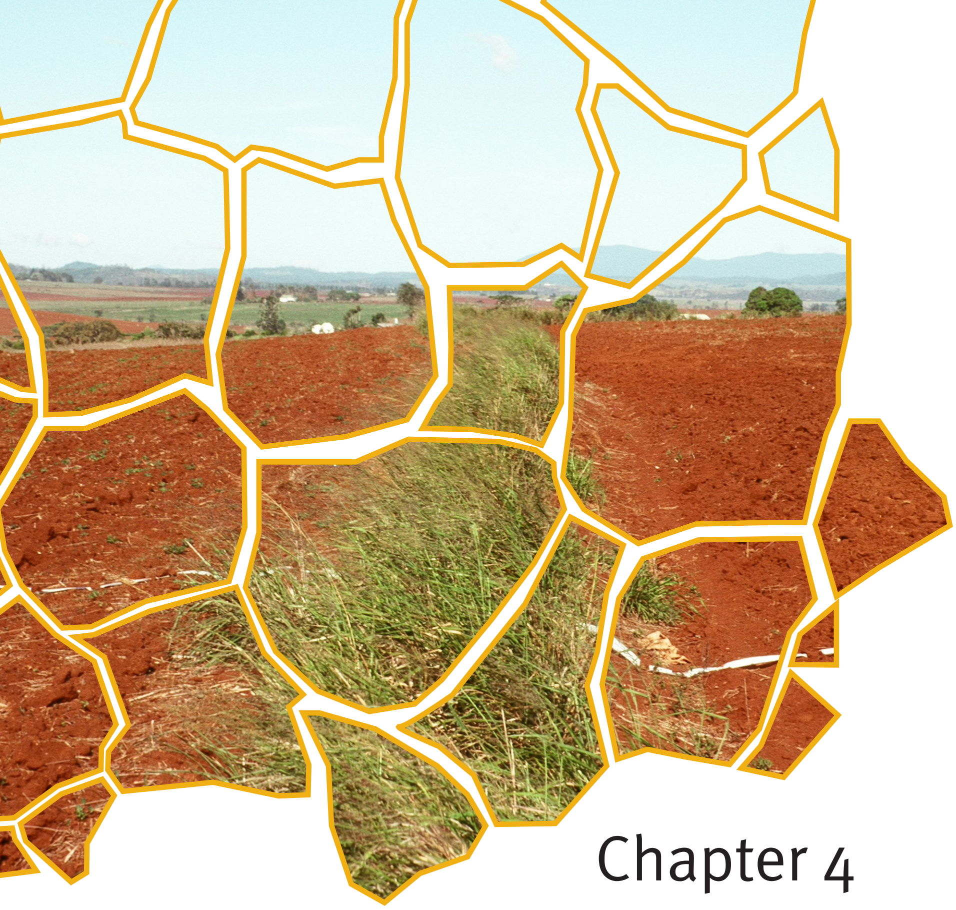


Chapter 4

The Empirical version of the Rational Method

Key points

- The Rational Method is a set of formulae used to determine the peak discharge expected from a soil conservation structure design, such as a contour bank. The Empirical version is a simplification of the full Rational Method which uses parameter values that are based on experience or observation.
- The size and timing of flows at a design point (the hydrograph) resulting from a rainfall event falling in a catchment depend on the characteristics of both the event itself (intensity, duration, and location) and the catchment (area, shape, slope, and land surface condition) above the design point.
- The peak discharge from a rainfall event can be calculated manually using charts (available in various publications, including in the appendix to these guidelines) or an excel workbook (RAMWADE) developed for use with these guidelines.
- The Darling Downs flood frequency version of the rational method has been customised for use in soil conservation design for small non-contoured bank catchments in an area of southern Queensland.

Contents

Glossary

Average Recurrence Interval (ARI): the average period in years between the occurrence of an event (usually a storm or a flood) of specified magnitude and an event of equal or greater magnitude.

design velocity: the maximum velocity of flow calculated for a given set of hydrological conditions which is used in the design of a hydrologic structure that can cope with these conditions.

Empirical version (of the rational method): a formula for estimating peak discharge of runoff from a catchment above a specific point calculated using the peak discharge, rainfall intensity for the selected period, runoff coefficient, and catchment area.

Equivalent Impervious Area (EIA): is the area of a catchment that would produce a design flood of the same size as that estimated for the catchment if that area had a runoff coefficient of 1, in other words, if all of the rainfall falling on the EIA runs off.

Horton's n: a measure of surface roughness similar but not identical to Manning's n values.

proportionality technique: is used to determine a 'weighted' runoff coefficient for the catchment. For each component of the catchment with similar runoff-producing characteristics, the assigned runoff coefficient value is multiplied by the ratio of the area of the component to the total catchment area.

rainfall intensity–frequency–duration (IFD): graphical representations of the probability that a given average rainfall intensity will occur.

roughness coefficient: a measure of the retardance to flow in a channel; the greater the retardance, the higher the roughness coefficient. Normally expressed as Manning's n.

runoff coefficient: the C factor in the rational formula which equals the ratio of the rate of runoff to the rate of rainfall. It indicates the proportion of the rainfall rate that is actually contributing to the runoff rate and as such is always < 1.0.

soil permeability: the characteristic of a soil that governs the rate at which water moves through it. This depends largely on soil texture, structure, presence of compacted or impeding layers, and the size and interconnection of pores.

time of concentration: the shortest time necessary for all points within a catchment to contribute simultaneously to flow past a specified point.

4.1 Introduction

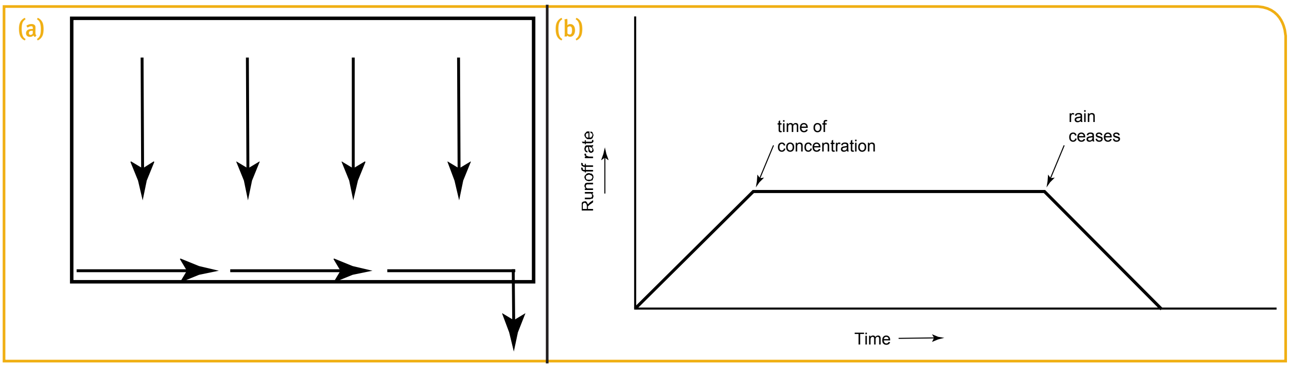
The Empirical version is so named because the parameters it uses (apart from rainfall data) are generally based on experience or observation rather than field measurements obtained over a long period of time. The Empirical version of the Rational Method for waterway design has been used in Queensland for many years and remains the accepted method for small catchments of up to 2500 ha with a high proportion of contour banked paddocks.

4.2 Description

While there are few long-term measurements of runoff from small agricultural catchments, reliable long-term rainfall records exist for most parts of Queensland. The Rational Method uses this rainfall data to predict peak discharge for design purposes. The Rational Method assumes that a rainfall event of a particular Average Recurrence Interval (ARI) and duration will produce a runoff event of the same ARI. In practice, runoff produced by a specific rainfall event will vary depending on the conditions of the catchment at the time that the event occurs. If the design rainfall falls on a dry catchment the resulting peak runoff will be lower than that for the design. Conversely, if the catchment is wet, the resulting peak runoff will be higher than that for which the works have been designed. A design method must therefore be based on 'average' catchment conditions.

To understand the basis of the Empirical method, consider the runoff that would occur from the tin roof of a building as a result of a storm in which the rate of rainfall was constant (Figure 4.1a). The resultant hydrograph from such a storm is shown in Figure 4.1b.

Figure 4.1: Runoff from a tin roof: (a) flows (b) resultant hydrograph



After it starts to rain, the rate of runoff will progressively increase until it reaches a peak. At this point the whole of the tin roof would be contributing to the outlet where the runoff is being measured. The period of time taken for the whole catchment to contribute is referred to as the time of concentration (tc). After this point has been reached, because rain continues to fall at a constant rate, runoff remains constant at the peak rate until the rain stops falling, after which time the rate of runoff will decline steadily until it ceases.

To determine the peak rate of runoff for the tin roof, there are only two factors to consider:

- area of the roof
- rainfall intensity.

The formula used to determine the peak rate of runoff is expressed in Equation 4.1.

Equation 4.1

$Q = I * A * 0.00278$

Where

Q = peak discharge (m^3/s)

I = rainfall intensity (mm/hr)

A = area (ha).

The value 0.00278 is a constant required to balance the units. A uniform rainfall rate of 1 mm/hr on 1 ha would produce a peak discharge of 0.00278 m^3/s if all of the rain resulted in runoff. If the area is in square kilometres (km^2) instead of hectares, the conversion factor is 0.278.

To use this formula in a design problem to predict rates of runoff from tin roofs, the appropriate rainfall intensity would need to be determined. In doing this, it would be necessary to consider the ARI of the event for which a design is required. Rainfall intensity–frequency–duration (IFD) charts (refer to Chapter 3) could then be used to determine a rainfall intensity for the appropriate time of concentration and ARI. Equation 4.1 can be applied to any ‘catchment’ if it is assumed that all of the rainfall resulted in runoff. While this is almost true for a tin roof it does not apply to a natural catchment.

To account for all of the variables that reduce the rate of runoff from a catchment, the Rational Method uses a single factor known as the runoff coefficient (C). The C factor is an estimate of the proportion of rainfall that becomes runoff. The C factor for a tin roof would be very close to 1. The C factor for a soil similar to a beach sand would be as low as 0.1 or 0.2 because of the very high infiltration rates.

Taking into account the C factor, the rational formula then becomes Qy = 0.00278*Cy*Itcy*A (Equation 4.2).

It is accepted that the Rational Method is an oversimplification of a complex process. However it is considered to be suitable for runoff estimation for the relatively small catchments for which soil conservation measures are generally designed. As discussed in Chapter 3 the ability of a soil conservation structure to convey the runoff for which it was designed can vary by a factor of 5 (or greater) depending on the season and the stage of the cropping cycle when the event occurs. For this reason there is limited benefit in using a more complex model in an attempt to further refine the method of runoff prediction.

Equation 4.2

Qy = 0.00278*Cy*Itcy*A

Where:

Qy = design peak runoff rate (m^3/s), for an ARI of y years

Cy = the runoff coefficient (dimensionless) for an ARI of y years

Itcy =average rainfall intensity (mm/h), for the design ARI and for a duration equal to the ‘time of concentration’ tc, (minutes) of the catchment

A = catchment area (ha).

4.3 Runoff coefficient

The runoff coefficient (Cy) is defined as the ratio of the peak runoff rate of a given ARI to the mean rate of rainfall for a duration equal to the catchment 'time of concentration' and of the same ARI. The runoff coefficient attempts to take into account all catchment characteristics that affect runoff. Runoff coefficient values for use in soil conservation designs in Queensland are based on a number of factors including the potential of the land management system to produce runoff. It should be noted that these values are arbitrary and are not based on hydrological data. Three 'runoff potential' categories are listed in Table 4.1.

Table 4.1: Runoff potential categories for use in designs for soil conservation purposes

Runoff potential	Forest	Pasture	Cultivation
1	Dense forest in undisturbed condition	Not applicable	Not applicable
2	Medium density forest with moderate levels of surface cover in most seasons	Pasture with high levels of pasture density in most seasons	Zero tillage/opportunity cropping. Rotations with crops or pastures with high cover levels
3	Forested area subject to high pressure with compacted soils and no surface cover	Pasture with low levels of pasture density in most seasons	Predominantly bare fallows with a rotation giving moderate to low levels of cover

Table 4.2 provides 10 year ARI values for runoff coefficients based on the runoff potential categories from Table 4.1 as well as soil permeability values and topography. Soil permeability ratings can be obtained from district land management field manuals.

Table 4.2: Runoff coefficients for use with the empirical version of the Rational Method

Runoff potential based on topography and land slope	10-year ARI runoff coefficients		
	Soil permeability		
	High	Medium	Low
Runoff potential 1			
Flat (0–2%)	0.1	0.2	0.3
Rolling (2–10%)	0.1	0.3	0.4
Hilly (10–30%)	0.2	0.4	0.5
Runoff potential 2			
Flat (0–2%)	0.15	0.3	0.4
Rolling (2–10%)	0.2	0.4	0.5
Hilly (10–30%)	0.3	0.5	0.6
Runoff potential 3			
Flat (0–2%)	0.2	0.4	0.5
Rolling (2–10%)	0.3	0.5	0.6
Hilly (10–30%)	0.4	0.6	0.7

To estimate runoff coefficient values for ARIs other than 10 years, the 10 Year ARI should be multiplied by the conversion factors in Table 4.3. For example, the ARI 50 runoff coefficient can be obtained by multiplying the ARI 10 coefficient by 1.5. The values in Table 4.3 are based on values obtained for the Darling Downs Flood Frequency Version of the Rational Method (see Chapter 5).

Table 4.3: Conversion factors to determine peak discharge for different ARIs

ARI (years)	Conversion factor
1	0.5
2	0.6
5	0.8
10	1.0
20	1.2
50	1.5
100	1.8

There are two methods of accounting for situations where runoff coefficients vary within a catchment:

- equivalent impervious area
- proportionality.

4.3.1 Equivalent Impervious Area

The Equivalent Impervious Area (EIA) of a catchment is the area that would produce a design flood of the same size as that estimated for the catchment if that area had a runoff coefficient of 1, in other words if all of the rainfall falling on the EIA runs off.

The catchment EIA is calculated by firstly dividing the catchment into component areas across each of which the runoff-producing characteristics are relatively consistent. The EIA for each component is then determined by multiplying its area by its runoff coefficient. The EIAs for each component are then added to determine the EIA for the total catchment. EIAs within the one ARI are additive. If the ARI is changed it is necessary to calculate a new EIA based on the runoff coefficient applicable to the new ARI.

As EIA incorporates both the runoff coefficient and the catchment area, the Rational Method formula then becomes Equation 4.3.

Table 4.4 gives an example of determining the Equivalent Impervious Area for a 90 ha catchment that consists of 20 ha of cultivation (Cy = 0.6), 30 ha of forest (Cy = 0.3) and 40 ha of pasture (Cy = 0.4). The EIA is 37 ha.

Equation 4.3

Qy = 0.00278 *Itc *Eiay

Where:

Qy = design peak runoff rate (m^3/s), for an ARI of y years

Itc,y = average rainfall intensity (mm/h), for the design ARI and for a duration equal to the tc (minutes) of the catchment

Aei,y = Equivalent Impervious Area (ha) for the design ARI of y years.

Table 4.4: Example of calculations to determine Equivalent Impervious Area for a catchment in three parts

Land use	Area (ha)	Runoff co-efficient	EIA (ha)
Cultivation	20	0.6	12
Forest	30	0.3	9
Pasture	40	0.4	16
Total	90		37

4.3.2 Proportionality

The proportionality technique is used to determine a ‘weighted’ runoff coefficient for the catchment. For each component of the catchment with similar runoff-producing characteristics, the assigned runoff coefficient value is multiplied by the ratio of the area of the component to the total catchment area (Equation 4.4). The products of this calculation for each component are then summed to give a catchment proportional runoff coefficient.

Equation 4.4

$$\text{Component proportional } C_y = \frac{\text{Component area x component } C_y}{\text{Total catchment area}}$$

Example: Table 4.5 gives an example of calculating weighted runoff coefficient for the same catchment as in the previous example.

Table 4.5: Example calculations to determine weighted runoff coefficient

Land use	Area (ha)	Runoff co-efficient	Proportional runoff coefficient
Cultivation	20	0.6	0.13
Forest	30	0.3	0.10
Pasture	40	0.4	0.18
Total	90		0.41

Note: The catchment proportional runoff coefficient multiplied by the total catchment area is the same as the catchment EIA i.e. 90 x 0.41 = 36.9.

4.4 Rainfall intensity

Estimates of the average rainfall intensity for a design storm of duration equal to the calculated ‘time of concentration’ (tc) of a catchment are determined from the IFD (intensity, frequency, duration) information for the catchment. The catchment ‘time of concentration’ is the estimated time taken by water to flow from the most hydraulically remote point of the catchment to the outlet. The Rational Method assumes that the highest peak rate of runoff from the catchment will be caused by a storm of duration just long enough for runoff from all parts of the catchment to contribute simultaneously to the design point.

The ‘time of concentration’ is calculated by summing the travel times of flow in the different hydraulic components. Those components may include overland flow, stream flow and/or flow in structures. Several flow paths may need to be assessed to determine the longest estimated travel time, which is then used to determine rainfall intensity.

The following guidelines should be used when estimating the time of concentration.

4.4.1 For contoured catchments

Overland flow

Equation 4.5

$t = 107*n*L^{0.333}/S^{0.2}$

Where

t = time of travel over the surface (minutes)

n = Horton’s n values for the surface (from Table 4.6)

L = length of flow (metres)

s = slope of surface (%).

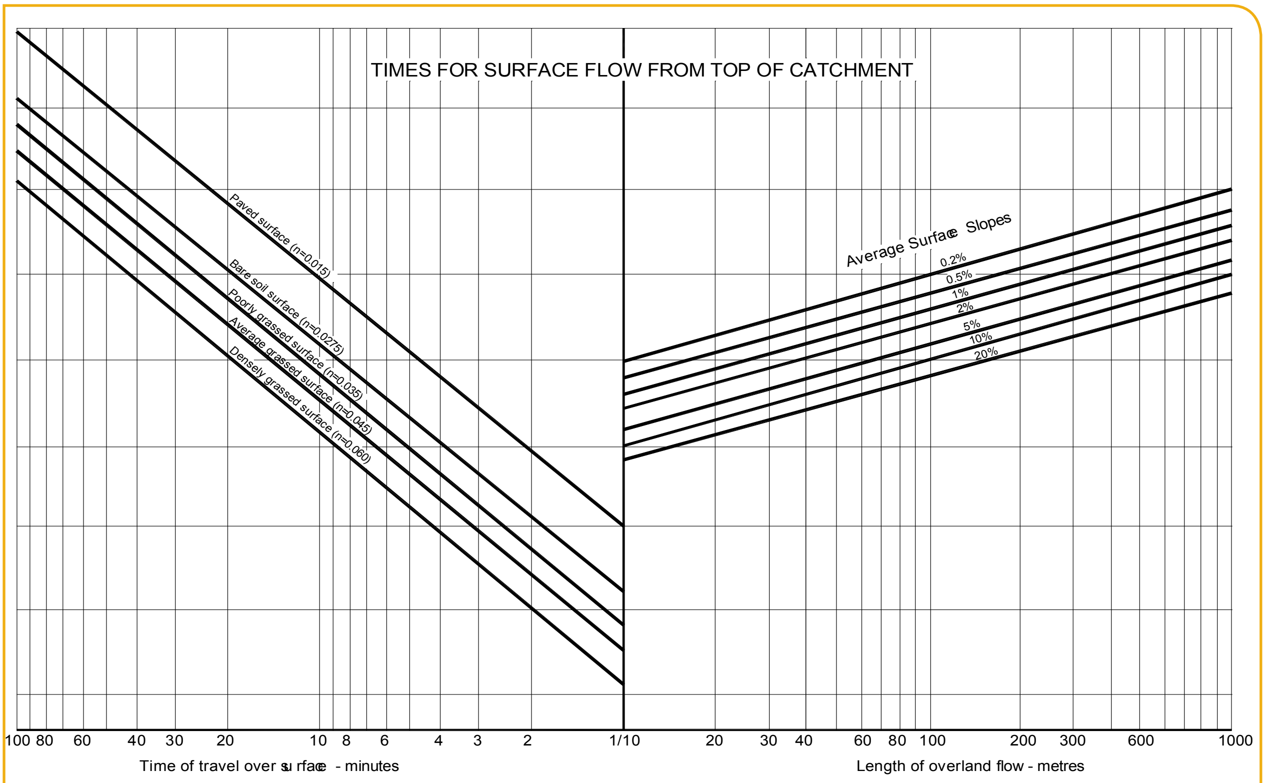
Overland flow travel times can be determined for the most remote part of the contour bay. The formula used for calculating overland flow is expressed in Equation 4.5.

Table 4.6: Horton’s n values for different surface conditions

Surface condition	Horton’s n value
Paved surface	0.015
Bare soil surface	0.0275
Poorly grassed surface	0.035
Average grassed surface	0.045
Densely grassed surface	0.060

The chart in Figure 4.2 is based on Equation 4.5. An average condition for the paddock surface should be chosen. Where stubble is normally retained on the soil surface, this would mean selecting for an average or poorly grassed surface. While Horton’s n values (Table 4.6) are related to surface roughness, they should not be confused with the n values for roughness coefficients in the Manning equation (refer to Chapter 6).

Figure 4.2: Travel time for overland flow



Formula $t = \frac{107\, n \sqrt[3]{L}}{5 \sqrt{s}}$

where t = time of travel over surface in minutes
n = Horton's values for the surface
L = Lenght of flow in metres
s = slope of surface in %

Example

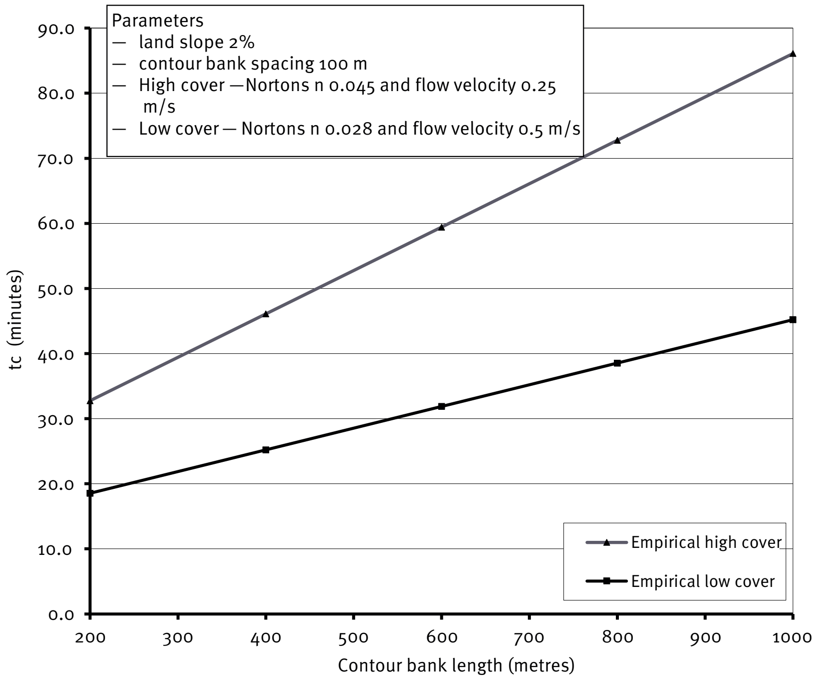
Length of overland flow 200m
Average slope of surface 5%
Densely grassed surface (n= 0.060)
Time of travel = 27.2 minutes

Interception structure flow

Travel times along interception structures (contour and diversion banks) are calculated by dividing the length of flow by the design velocity of the structure. Since it is recommended that designs should be based on average conditions, it is appropriate to select a velocity appropriate to the average condition of the channel. In a paddock where there would normally be either a crop or standing stubble, then a velocity representative of that situation should be chosen. Where contour bank channels have either a crop or standing stubble, it is most unlikely that the average velocity in the contour bank channel will exceed 0.25 m/sec even though the maximum acceptable velocity may be 0.5 or 0.6 m/sec. Chapter 7 has more information on this topic.

Figure 4.3 shows a comparison of times of concentration in a contour bay in a high-cover farming system with those in a low-cover system.

Figure 4.3: Comparison of times of concentration in a contour bay for a high- and low-cover farming system



Waterway flow

For waterways, as with contour banks, a velocity based on the average condition should be chosen rather than designing for the maximum potential velocity.

4.4.2 For non-contoured banked catchments

Overland flow

The overland flow chart in Figure 4.2 above provides distances for flows of up to 1000 metres.

A guide to estimating the length of overland flow is to assume that flow would begin to concentrate at a distance appropriate to the recommended contour bank spacing for that slope (refer to Chapter 7). This means that lengths of overland flow would rarely exceed 100 metres despite the fact that the chart provides values for up to 1000 metres.

Concentrated flow

A velocity of 1 m/s is considered to be an acceptable value to use until a well-defined drainage line is reached.

Stream flow

Travel time for stream flow would not normally be required in order to estimate runoff from cropping lands. However it may need to be considered when preparing a design for the construction of diversion banks and gully control structures.

Travel time for stream flow can be calculated by dividing the length of the stream by an estimated average velocity of the flow. Chow (1959) describes a method of determining a Manning roughness coefficient for a stream reach. This requires a summation of values given to factors affecting the roughness coefficient. A guide to velocities that can be expected for a range of situations developed using Chow’s method is provided in the Appendices.

4.5 Calculating peak discharge

The following procedure is used when determining the design peak discharge at a design point. It is recommended that the waterway design pro forma shown in Figure 4.4 is used with the procedure to guide the user through the steps and to provide a record of the calculations. The computer program RAMWADE (Rational Method Waterway Design) takes users through the same steps as those in the pro forma:

1. Decide on the design ARI.
2. Locate design points on the plan (refer to Chapter 2).
3. Estimate the ‘time of concentration’ for each design point.
4. From the IFD diagram for the district, determine the design rainfall intensity relevant to the ‘time of concentration’ and the required ARI.
5. Identify and measure component areas within the catchment and assign a runoff coefficient to each.
6. Either (a) calculate the Equivalent Impervious Area for the catchment or (b) calculate the catchment proportional runoff coefficient.
7. Calculate the design peak discharge by substitution into Equation 4.4 or Equation 4.5 as appropriate.

The procedure can be simplified by preparing a graph relating the catchment Equivalent Impervious Area and ‘time of concentration’ for a particular ARI and locality. This chart is often referred to as a constant discharge diagram. An example is given in Figure 4.5. Similar charts can be made for any district by using the relevant IFD data to solve Equation 4.5 and plotting the results.

Figure 4.4: Waterway design pro forma

Landholder:

Date: Farm code: Plan no.:

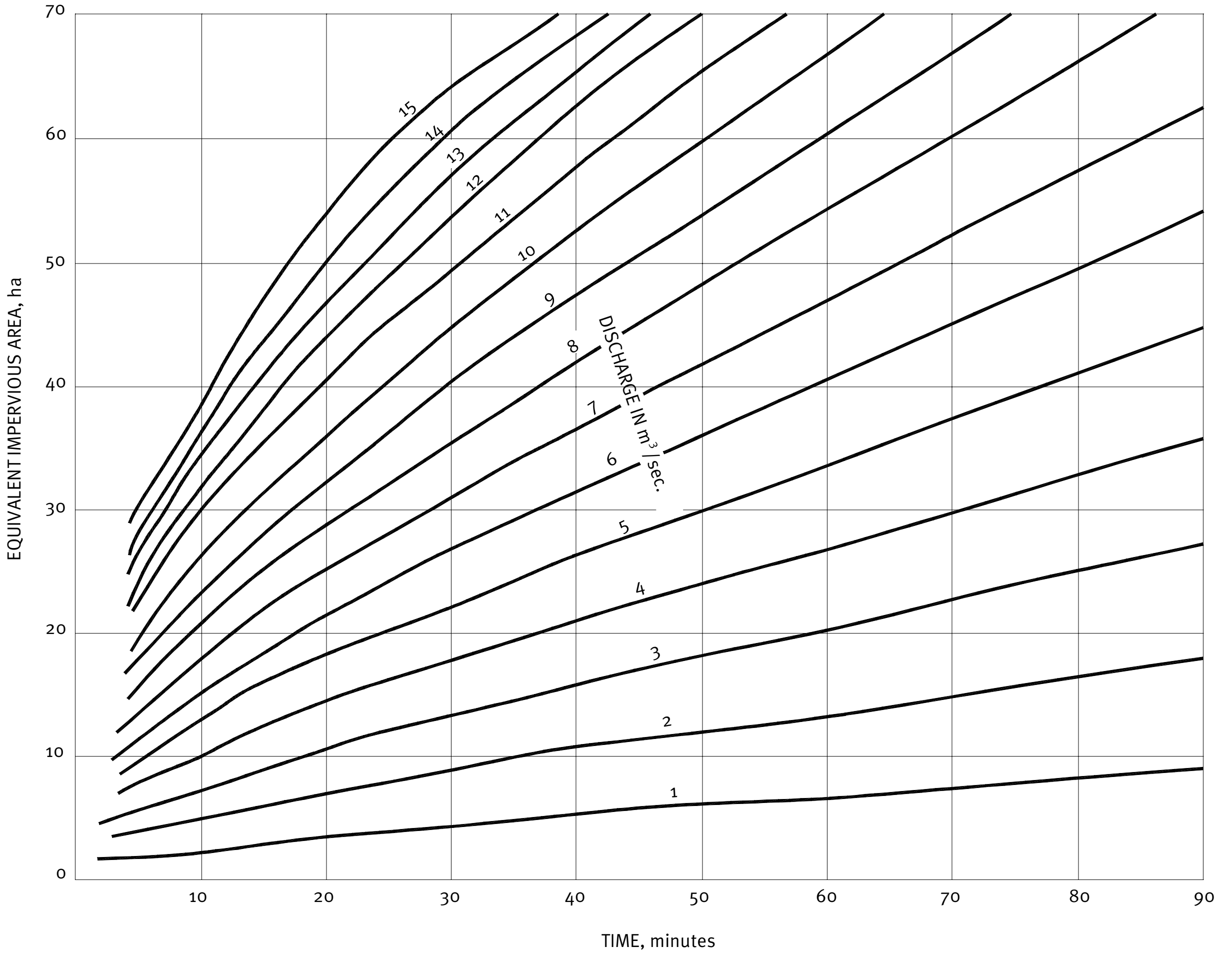
Contact details:

Property description:

1	Design point							
2	Design ARI in years							
3	Length of overland flow (m)							
4	Average slope (%)	From survey or farm plan						
5	Time of travel for overland flow (min)							
6	Length of stream flow (m)							
7	Average slope of stream (%)							
8	Stream velocity (m/s)							
9	Time of travel in stream (minutes)	Row 6 / (Row 8 *60)						
10	Length of interception bank flow (m)							
11	Interception bank velocity (m/s)							
12	Time of travel in interception bank (min)	Row 10 / (Row 11 * 60)						
13	Tc previous design point (minutes)	Previous design point						
		Time						
14	Length of waterway flow (m)	Additional length if row 13 is used						
15	Waterway velocity (m/s)	Estimated or previous design point						
16	Time of travel in waterway (minutes)	Row 14 / (row 15 * 60)						
17	Time of concentration, tc, (minutes)	Total rows 5,9,12, 13, 16 as applicable						
18	Rainfall Intensity, Itc,y (mm/h)	From IFD data for this location						
19	Area at previous design point	Previous point						
		Total area						
		Equivalent Impervious Area (EIA)						
20	Area of pasture and average slope (ha)	Additional area if row 19 is used						
21	Runoff coefficient							
22	EIA, pasture (ha)	Row 20 x Row 21						
23	Area of cultivation and average slope (ha)	Additional area if row 19 is used						
24	Runoff coefficient							
25	EIA, cultivation (ha)	Row 23 x row 24						
26	Other area and average slope (ha)	Additional area if row 19 is used						
27	Runoff coefficient							
28	EIA, other (ha)	Row 26 x row 27						
29	Total area (ha)	Rows: 19+20+23+26						
30	Total EIA, Aei,y (ha)	Rows: 19+22+25+28						
31	Peak discharge, Qy (m3/s)	Qy = 0.00278 x I x Aei,y						
32	Design point slope (%)							
33	Retaining bank batters (1:Z (V:H))							
34	Minimum retardance value							
35	Design velocity, V (m/s)							
36	Bottom width, W (m)							
37	Maximum retardance value							
38	Flow depth, d (m)							
39	Settled bank height (m)	d + 0.15 m freeboard						

Comments:

Figure 4.5: Constant discharge diagram showing the relationship between Equivalent Impervious Area and 'time of concentration' for the Kingaroy District



4.5.1 Worked example

The task

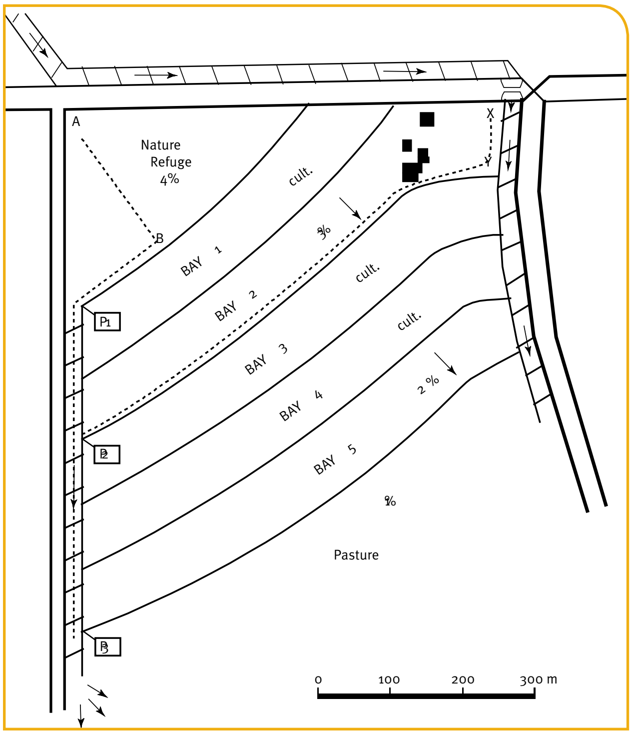
Using the RAMWADE Excel workbook and Kincon\Capella peak discharge calculator and waterway design pro forma (Figure 4.4) estimate the peak discharge for an ARI of ten years for the waterway at design points, P1, P2 and P3 for the property shown on Figure 4.6. For the sake of this exercise it is assumed that the property is located in the Capella district, the soil is rated as being of low permeability and that a farming system providing moderately low levels of cover is practised.

Physical parameters for the property required to populate the waterway design pro forma (Figure 4.4) are provided in Table 4.7.

Table 4.7: Specifications for calculation of peak discharge for example catchments

Length	Area	Design velocity	Runoff coefficient (10 yr ARI)
A to B is 290 m	Nature refuge is 8 ha	Diversion bank is: 0.4 m/s	Nature refuge is 0.5
B to P1 is 180 m	Contour bays 1+2 is 15 ha	Contour bank is 0.3 m/s	Cultivation is 0.6
X to Y is 130 m	Contour bays 3+4+5 is 25 ha	Waterway is 1.2 m/s	
P1 to P2 is 220 m			
P2 to P3 is 320 m			
Y to P2 is 820 m			

Figure 4.6: Catchment for design example



Step 1: Determine peak discharge for P1

Table 4.8: Waterway design pro forma for Point 1 in the example catchment

Pro-forma row number	Parameter	Value
3	Length of overland flow, A–B	290 m
4	Average slope, A–B	4%
5	Time of travel, overland flow, A–B (Figure 4.2; assume average grassed surface)	24 minutes
10	Length of diversion bank flow, B–P1	180 m
11	Design velocity, diversion bank	0.4 m/s
12	Time of travel, diversion bank [row 10/(row 11 x 60)]	8 minutes
17	‘Time of concentration’ (row 5 + row 12)	32 minutes
18	Rainfall intensity, Capella (Chapter 3, Figure 3.3 of these guidelines)	88 mm/h
26	Area of nature refuge	8 ha
27	Runoff coefficient, nature reserve (Tables 4.1 and 4.2; for forest land use)	5
28	Equivalent Impervious Area (row 26 x row 27)	3.2
30	Total Equivalent Impervious Area	3.2
31	Peak discharge (0.00278 x Row 18 x Row 30)	0.8 m3/s

Step 2: Determine peak discharge for P2

To determine the ‘tc’ for P2, it is necessary to compare the time of travel for flows along two different routes. Route A-B-P1-P2 should be compared with route X–Y P2.

For route A–B–P1–P2, the travel time to P1 was calculated as 32 minutes (row 17, previous chart). There is additional travel time along waterway P1–P2, 220 m at 1.2 m/s. This adds 3 minutes, giving a total time of travel of 35 minutes.

For route X–Y–P2, the time of travel is calculated in Table 4.9 in the same order as previously for A–B–P1.

Table 4.9: Determining travel time to design point P2 in the example catchment

Pro-forma row number	Design point P2	Value
3	Length of overland flow, X–Y	130 m
4	Average slope, X–Y	3%
5	Time of travel, overland flow, X–Y. (Assume average grassed surface beside house and buildings, Figure 4.2)	20 minutes
10	Length of contour bank, Y–P2	820 m
11	Design velocity, contour bank	0.3 m/s
12	Time of travel, Y–P2 [row 10/(row 11 x 60)]	46 minutes
17	Time of travel X–Y–P2 (row 5 + row 12)	66 minutes

Select the longest travel time to P2 (here it is route X-Y-P2, being 66 minutes) and proceed to calculate peak discharge.

Table 4.10: Waterway design pro forma for design point P2 in the example catchment

Pro-forma row number	Design point P2	Value
17	'Time of concentration'	66 minutes
18	Rainfall intensity, Capella (Chapter 3, Figure 3.3)	58 mm/h
19	Total area, previous design point, P1	8 ha
	Total Equivalent Impervious Area, previous design point, P1	3.2 ha
23	Area of cultivation (contour bays 1 + 2)	15 ha
24	Runoff coefficient, cultivation (Tables 4.1 & 4.2)	0.6
25	Equivalent Impervious Area, cultivation (Row 23 x Row 24)	9 ha
29	Total area contributing to P2 (row 19 + row 23)	23 ha
30	Total Equivalent Impervious Area for P2 (row 19 + row 25)	12.2 ha
31	Peak discharge (0.00278 x row 18 x row 30)	2.0 m^3/s

Step 3: Determine peak discharge for P3

The longest route for determining 'tc' is X-Y-P2-P3.

Table 4.11: Waterway design pro forma for design point P3 in the example catchment

Pro-forma row number	Design point P3	Value
13	'Time of concentration' for previous design point, P2	66 minutes
14	Length of waterway, P2–P3	320 m
15	Design velocity, waterway	1.2 m/s
16	Time of travel, P2–P3 [row 14/(row 15 x 60)]	4 minutes
17	'Time of concentration', P3 (row 13 + row 16)	70 minutes
18	Rainfall intensity, Capella (Chapter 3, Figure 3.3)	55 mm/h
19	Total area, previous design point, P2	23 ha
	Total Equivalent Impervious Area, previous design point, P2	12.2 ha
23	Area of cultivation (contour bays 3, 4, 5)	25 ha
24	Runoff coefficient, cultivation (Tables 4.1 and 4.2)	0.6
25	Equivalent Impervious Area, cultivation (row 23 x row 24)	15 ha
29	Total area contributing to P3 (row 19 + row 23)	48 ha
30	Total Equivalent Impervious Area for P3 (row 19 + row 25)	27.2 ha
31	Peak discharge (0.00278 x row 18 x row 30)	4.2 m^3/s

4.6 Further information

References

Chow, V. T. (1959) *Open channel hydraulics*, McGraw-Hill, New York.

Other information

RAMWADE (Rational Method Waterway Design) (workbook available for download from qld.gov.au/soilguide)