FACT SHEET

Evaluation of Peak Flows for Small Agricultural Drainage Basins in Quebec

Warning :

This sheet makes it possible to calculate the parameters that are essential to sizing small soil and water conservation structures. However, their use is limited to simple situations where the risk of erosion and the potential damage to property and crops are moderate. The choice of working methods and the results obtained from the information presented in this sheet must be subject to an in-depth analysis by the user and are his or her complete responsibility. It is strongly recommended that you consult a drainage specialist when the water volume or flow is significant.

Source : Richard Laroche (MAPAQ)

1) Calculation of concentration time

The concentration time is the elapsed time between the start of precipitation and the achievement of maximum flow at the drainage basin outflow. The concentration time corresponds to time S: the time required to allow the water to drain from the furthest point of the drainage basin to the outflow.
Two simplified methods can be used to estimate concentration time for small agricultural drainage basins: the Kirpich method and Mockus method. Each method is good for distinct conditions in terms of soil type, slope and drainage basin surface area. The methods can be compared to one another in intermediate situations.

1. Kirpich method

This method is suited to drainage basins that have areas between 0.4 ha and 81 ha, clayey soil, and an average slope between 3% and 10%. The concentration time is therefore calculated using the following equation:

$$T_c = \frac{(0{,}000325 \times L^{0{,}77})}{S^{0{,}385}}$$

T_c: Concentration time (h)

L: Maximum length of the water's path in the drainage basin (m). In Figure 2, this length corresponds to the distance between points 1 and 4.

S: Average longitudinal slope of the drainage basin, following the water flow. This slope is calculated between the points found at 10% and 85% of the total distance between the furthest point of the drainage basin outflow (in terms of the water's travel time) and the drainage basin outflow. In the following drawing, this distance corresponds to points 2 and 3. The slope must be expressed in metres per metre (a 1% slope is equivalent to 0.01 m/m).

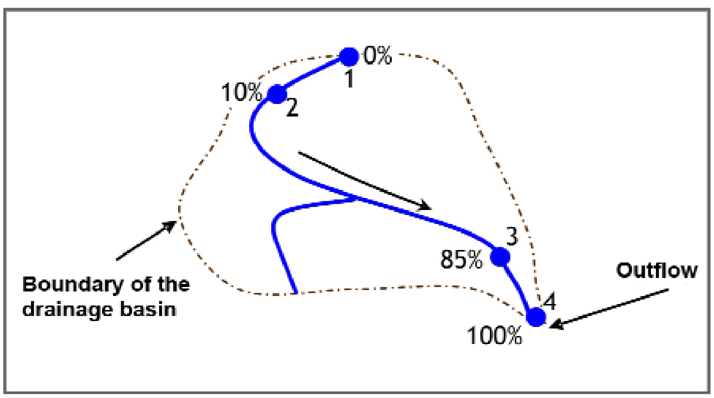


Figure 1 : Determination of the average longitudinal slope of a drainage basin

2. Mockus method

This method is suited to drainage basins that have an area between 4 and 1,000 ha and are characterized by an average longitudinal slope under 1% and by loamy or clayey soils.

$$T_c = \frac{L^{0,8} \times \left[\frac{1000}{CN} - 9 \right]^{1,67}}{2083 \times (100 \times S)^{0,5}}$$

Where

T_c: Concentration time

L: Maximum length of the water's path in the drainage basin (m). This parameter is defined in the previous section.

CN: Curve number (no units). This factor represents the effect of the drainage basin surface conditions on the run-off.

It takes into account all the physical characteristics and the use of the soil in the drainage basin as a whole (Table 1). Since a drainage basin is rarely uniform, the CN factor to be used is the average of the curve numbers of the various subsections of the drainage basin, weighted by the area of these subsections.

For example, in a drainage basin that is relatively flat with Class C soil, if 70% of the surface area is under intensive farming (CN = 80) and 30% is woodland (CN = 70), the weighted CN will be equal to: 70% × 80 + 30% × 70 = 77.

S: Average longitudinal slope of the drainage basin, following the water's path. This parameter is defined in the previous section.

In order to ensure sufficient sizing, it is preferable to choose a CN factor value that represents the worst surface runoff conditions in the drainage basin.

Tableau 1 : Values of the surface runoff curve number (CN)

Soil Usage	Transverse Slope of the Drainage Basin (Perpendicular to the Watercourse)	Hydrological Conditions	Soil Class			
			A	B	C	D
Intensive farming	<3%	Poor Good	63 60	74 70	80 78	82 81
	3-8%	Poor Good	65 63	76 75	84 83	88 87
	>8%	Poor Good	72 67	81 78	88 85	91 89
Extensive farming	<3%	Poor Good	39 25	61 40	74 70	80 78
	3-8%	Poor Good	49 39	69 61	79 74	84 80
	>8%	Poor Good	68 49	79 69	86 79	89 84
Woodland	<3%	Poor Good	25 22	55 53	70 65	77 74
	3-8%	Poor Good	41 25	63 55	75 70	81 77
	>8%	Poor Good	47 41	68 63	80 75	84 81
Residential		Dense Low-density	73 59	83 74	88 82	90 86

Hydrological Conditions
Poor : Low vegetation cover and conditions limiting infiltration
Good : Good vegetation cover and conditions favouring infiltration

Soil Classes
A: Gravel and coarse sands (high infiltration); **B:** Average and fine sands (average infiltration); **C:** Poorly drained fine sands, permeable loamy and clayey soils (fair infiltration); **D:** Heavy clay and thin soils (low infiltration)

Source : Laroche et Champagne (1989)

Nomogram for the Mockus method

The concentration time according to the Mockus method can also be estimated based on Figure 2.

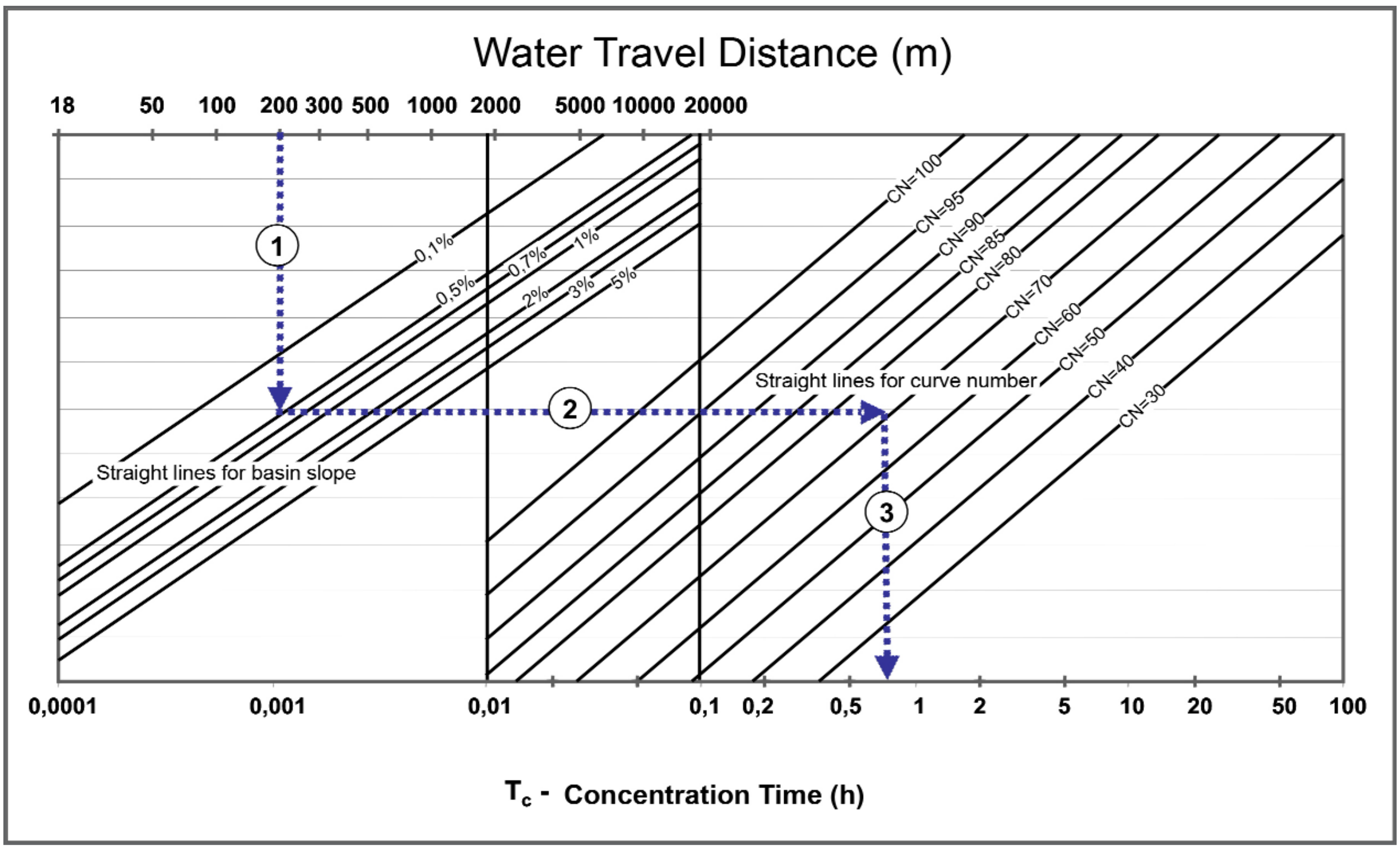
The nomogram is used as follows:

1) On the upper x-axis, look for the maximum length of the water's path measured in the drainage basin **(note: the scale is logarithmic).** Go down vertically to the intersection with the straight line indicating the average slope of the drainage basin under study.

2) Move horizontally to the intersection with the straight line of the weighted curve number of the drainage basin under study.

3) Go down vertically to the lower x-axis and read the concentration time for the basin under study **(note: the scale is logarithmic).**

For example, for a water travel distance of 200 m in a drainage basin with an average slope of 0.5% and a weighted CN factor equal to 70, the concentration time is 0.76 hours (45 minutes).



Adapted of Schwab *et al.* (1966)

Figure 2 : Estimation of the concentration time according to the Mockus method

Table 2 : Determination of the C factor

Soil Usage	Transverse Slope of the Drainage Basin (Perpendicular to the Watercourse)	Soil Texture		
		Loamy Sand	Loam	Loamy Clay
Intensive farming	0 à 0.5%	0.16	0.25	0.40
	0.5 à 5%	0.22	0.35	0.55
	5 à 10%	0.30	0.45	0.60
	10 à 30%	0.40	0.65	0.70
Forage crops	0 à 0.5%	0.07	0.20	0.35
	0.5 à 5%	0.10	0.28	0.40
	5 à 10%	0.15	0.35	0.45
	10 à 30%	0.22	0.40	0.55
Woodland	0 à 0.5%	0.05	0.18	0.30
	0.5 à 5%	0.08	0.25	0.35
	5 à 10%	0.12	0.30	0.42
	10 à 30%	0.18	0.35	0.52
Lake, marsh		0.05	0.05	0.05
		Impermeability		
		30%	50%	70%
Rock, asphalt	0 à 5%	0.40	0.55	0.75
	5 à 10%	0.50	0.65	0.80
	10 à 30%	0.55	0.70	0.85

Sources : Montas *et al*. (1990) and McNeely (1982)

2) Calculating the peak flow

The peak flow is the maximum flow of a drainage basin for a given precipitation. It can be evaluated using the rational method. This method is well suited to drainage basins that measure less than 250 ha and have an average longitudinal slope greater than 0.5%.

The rational method is based on the hypothesis that constant and uniform rain over an entire drainage basin produces a peak flow when all sections of the drainage basin contribute to the flow, after a time that is equal to the concentration time. Through simplification, the rational method also assumes that the duration of the rain is equal to the concentration time. The rational method does not take into account the heterogeneity of the pluviometry and has a tendency to overestimate the peak flow.

$$Qp = \frac{C \times Ip \times A}{360}$$

Where

Qp: Peak flow of the drainage basin (m^3/s)

C: Surface runoff coefficient (no units). This factor represents the proportion of the total precipitated water flowing (Table 2, previous page). **In order to ensure sufficient sizing of structures, it is preferable to choose a value for the C coefficient that represents the worst conditions for surface runoff from the drainage basin.**

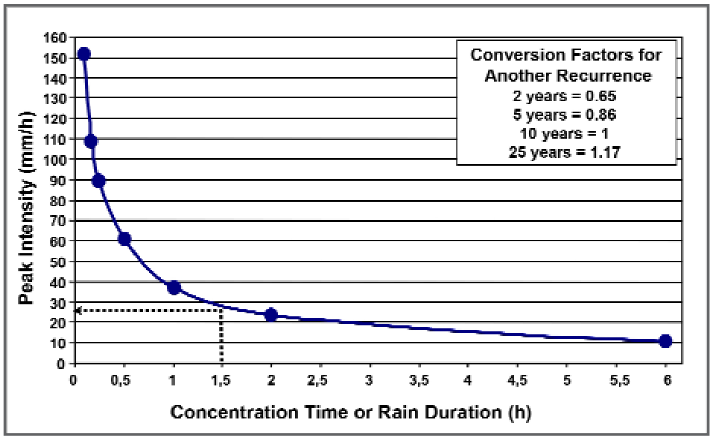
Ip: Intensity of precipitation for a duration of precipitation equal to the concentration time (mm/h). This value can be evaluated using Figure 3.

A : Surface area of the drainage basin (ha)

Determining the peak intensity (Ip)

As mentioned previously, the rational method assumes that the concentration time and the duration of the rain are the same. Therefore, the peak intensity for a given concentration time can be estimated based on the peak intensity corresponding to a rain that is equal in duration to this concentration time.

Figure 3 presents the relationship between the peak intensity of precipitation and its duration. Data from 20 meteorological stations representative of most regions in Quebec were compiled to develop this chart. The text box provides the conversion factor by which the peak intensity must be multiplied when using a rain recurrence other than 10 years.



Source : Environment Canada; 20 meteorological stations; 1964-1990

Figure 3 : Relationship between the intensity and duration of rain (recurrence of 10 years)

Choice of rain recurrence to be used for sizing the structures

The recurrence of rain corresponds to the probability that a given rain will occur and to the associated risk. For example, an event with a recurrence of 25 years will only be exceeded in significance every 25 years, which corresponds to a 4% risk of occurrence. Such an event is therefore a major event that can cause serious damage. In contrast, an event with a recurrence of 5 years (20% risk of occurrence) will generate flows and runoff volumes that are much less significant.

Table 3 presents the recurrences to be used for designing small soil and water conservation structures in various situations. The choice must reflect the risks of erosion and damage to crops and infrastructures.

Table 3 : Recurrences to be used for sizing small soil and water conservation structures

Application	Recurrence to be used
Sites under extensive farming or inlet wells combined with an emergency overflow	2 to 5 years
Sites under intensive farming, grassed watercourses or inlet wells without emergency overflow	5 to 10 years
Significant diking or sites near inhabited areas or public infrastructure	To be determined by the designer

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This fact sheet was prepared as a result of a partnership between Agriculture and Agri-Food Canada (AAFC) and the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ). This sheet is part of a series aimed at promoting hydro-agricultural installations for improving surface drainage and combating erosion in agricultural areas. The other sheets in the series are as follows: Diagnosis and Solutions for Field Erosion and Surface Drainage Problems; Inlet and Drainage Wells; Infiltration Wells; Permeable Trenches; Calculations for Sizing Inlet Wells.

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Last updated: April 2007

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