2.16 INFILTRATION-INDEX APPROACH FOR DIRECT RUNOFF

The index approach is the simplest procedure to estimate the total volume of storm runoff. The object of this method is to obtain a coefficient that may be applied to an entire rain period, or to an entire storm if it is made up of several rain periods, to arrive at an estimate of the direct runoff (Cook, 1946). Three types of indices are common: (1) the ϕ index, which represents a level (horizontal line) of intensity that divides the rainfall intensity diagram in such a manner that the depth of rain above the index line is equivalent to surface runoff depth over the basin, as illustrated in Figure 2.21; (2) the f_{av} index, which indicates the average rate of infiltration during a period in which the rainfall intensity is equal to or more than the infiltration capacity, f_p; and (3) the W index, which is a mean of f_{av} when it varies across a watershed. The value of W for a rain occurring after the watershed is wetted and the infiltration capacity is reduced to the minimum is known as the W_{min} index.

The ϕ index is the simplest of these indices. For its determination, the storm rainfall is measured and the amount of runoff is obtained from the corresponding direct hydrograph. The difference is the ϕ index. The value of ϕ increases with the increase of rain intensity up to a certain level and then approaches a constant number. It also is affected by the rainfall pattern (Cook, 1946). Whenever possible, the ϕ index should be applied to a similar storm from which it is derived. However, it must be appreciated that the use of indices does not constitute a rational application of the infiltration theory. Rainfall intensities less than the ϕ index are not considered in determining ϕ. Trial and error is involved.

EXAMPLE 2.19

The rainfall intensities during each 30 min of a 150-min storm over a 500-acre basin are 4.5, 3, 1, 3.5, and 2 in./hr, respectively. The direct runoff from the basin is 105 acre-ft. Determine the ϕ index for the basin.

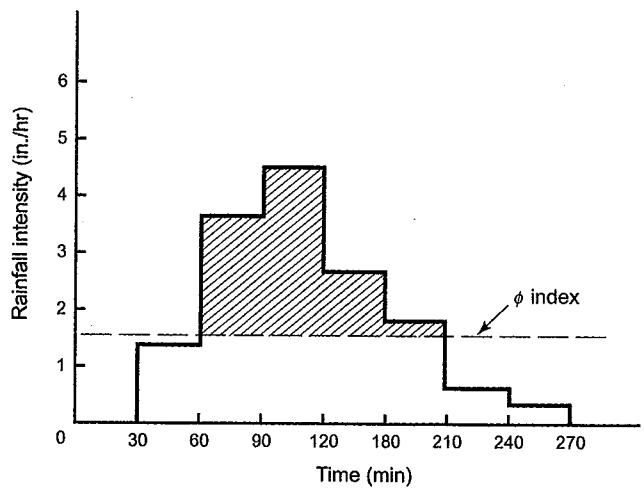

Figure 2.21 Representation of the ϕ index.

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SOLUTION (see hyetograph below)

1. Total rainfall $= \left(4.5\frac{\text{in.}}{\text{hr}}\right)(30\text{ min})\left(\frac{1\text{ hr}}{60\text{ min}}\right)$

$$+3\left(\frac{30}{60}\right)+1\left(\frac{30}{60}\right)+3.5\left(\frac{30}{60}\right)+2\left(\frac{30}{60}\right)$$

$$= 7.0 \text{ in. or } 0.583 \text{ ft.}$$

2. Rainfall volume = (500) (0.583) = 291.5 acre-ft.

3. Runoff volume = 105 acre-ft (given).

4. Volume under ϕ index = 291.5 – 105 = 186.5 acre-ft.

5. Infiltration depth $= \frac{186.5}{500} = 0.373$ ft or 4.48 in.

6. ϕ index $= (4.48\text{ in.})\left(\frac{1}{150\text{ min}}\right)\left(\frac{60\text{ min}}{1\text{ hr}}\right)$

$= 1.79$ in./hr.

7. The revised ϕ index should be computed excluding the rainfall of 1 in./hr intensity since it is less than the computed ϕ index.

8. Total rainfall (excluding 1 in./hr)

$$= 4.5\left(\frac{30}{60}\right)+3\left(\frac{30}{60}\right)+3.5\left(\frac{30}{60}\right)+2\left(\frac{30}{60}\right)$$

$= 6.5$ in. or 0.542 ft

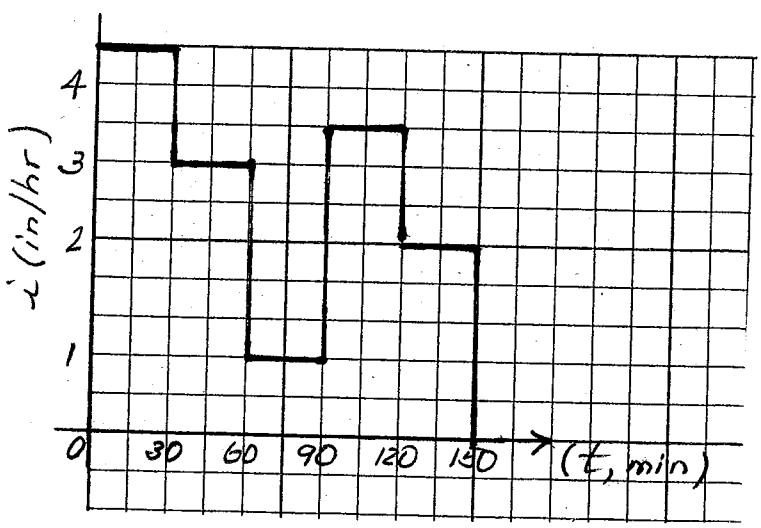
9. Rainfall volume = (500)(0.542) = 271 acre-ft

10. Volume under ϕ index = 271 – 105 = 166 acre-ft

11. Infiltration depth $= \frac{166}{500} = 0.332$ ft or 4 in.

12. ϕ index $= (3.98)\left(\frac{1}{120\text{ min}}\right)\left(\frac{60\text{ min}}{1\text{ hr}}\right)$

$= 2$ in./hr



EXAMPLE 2.16

A storm pattern for a watershed is as follows:

t (min)	Intensity (in./hr)
0–10	0.5
10–20	2.0
20–30	6.5
30–40	5.0
40–50	0.9
50–60	2.0
60–70	3.0

The soil texture is sandy with a saturated moisture content (porosity) of 0.50, an effective hydraulic conductivity of 1.0 in./hr, and an average capillary suction of 6 in. The initial moisture content is 0.3. Determine the rainfall excess for successive 10-min periods. Assume a depression storage of 0.5 in.

Using the ϕ index of 2 in. /hr, determine the rainfall excess from the storm.

SOLUTION

1. Runoff intensities = rainfall intensities – ϕ index, but not less than zero.
2. Hence the runoff intensities for successive 10-min periods are 0, 0, 4.5, 3.0, 0, 0, and 1.0, respectively.
3. Total runoff $= 4.5\left(\frac{10}{60}\right) = 3.0\left(\frac{10}{60}\right) + 1.0\left(\frac{10}{60}\right)$
   $= 1.42$ in.

SOURCE:
Gupta, R. S.
Hydrology and Hydraulic Systems
Waveland Press, Inc., 3rd Edition
2008