



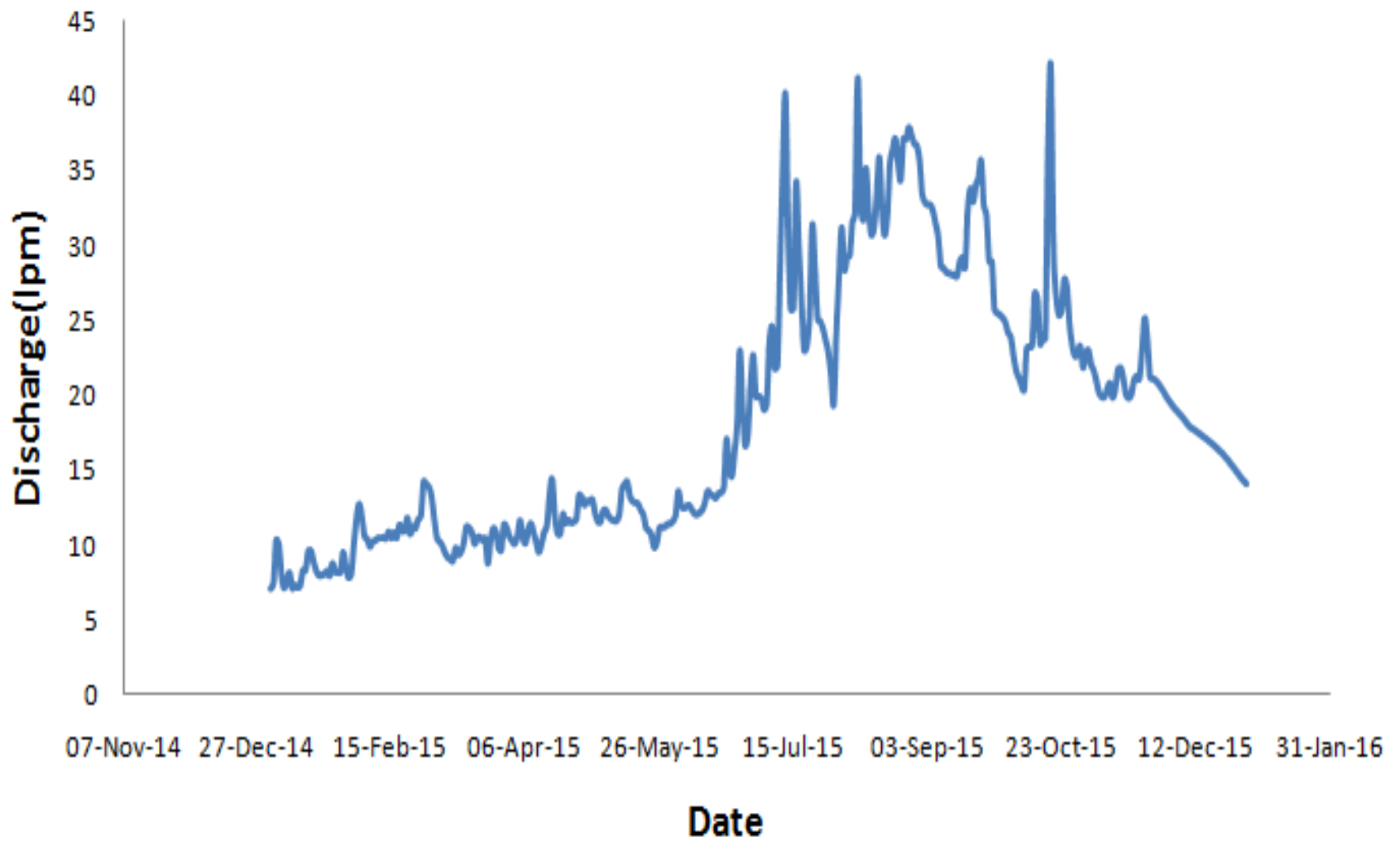


Watershed Hydrology

Hydrograph

Hydrograph

-  A hydrograph is a graphical representation of the instantaneous runoff rate against time.
-  The hydrograph is the **response** of a given catchment to a **rainfall input**. It consists of flow in all the three phases of runoff, viz. **surface runoff, interflow and base flow**.
-  The hydrograph which results due to an **isolated storm** is typically **single peaked skew distribution** of discharge and is known variously as **storm hydrograph, flood hydrograph or simply hydrograph**.
-  The **basin** and **storm characteristics** control the shape of a hydrograph.

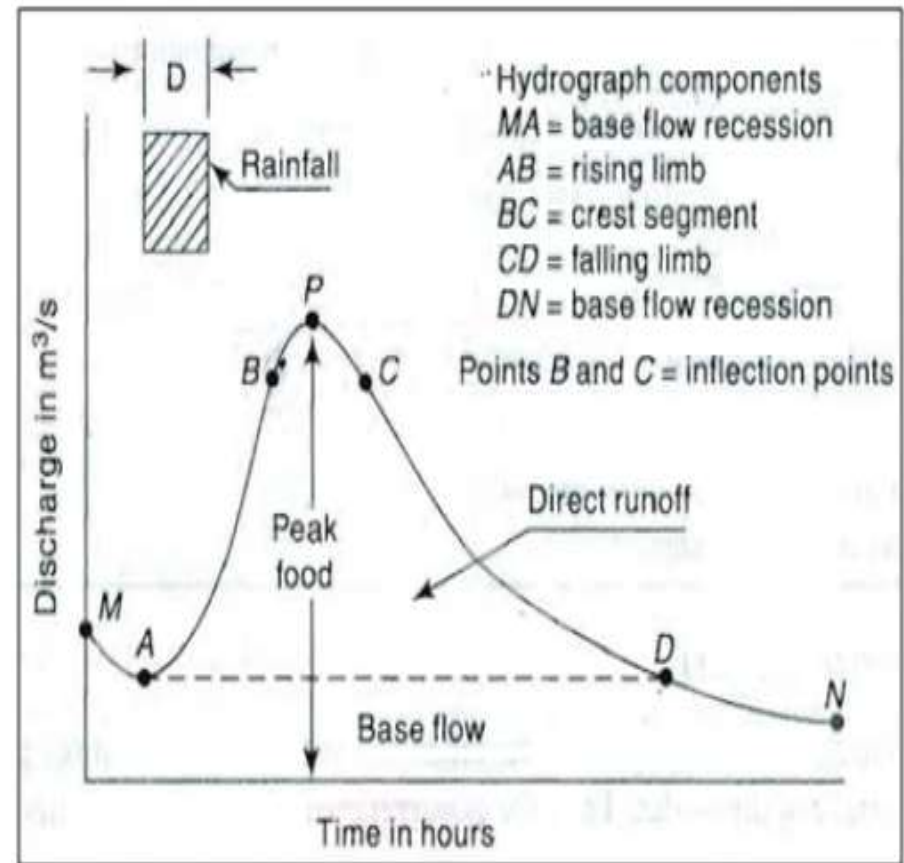


Elements of Hydrograph

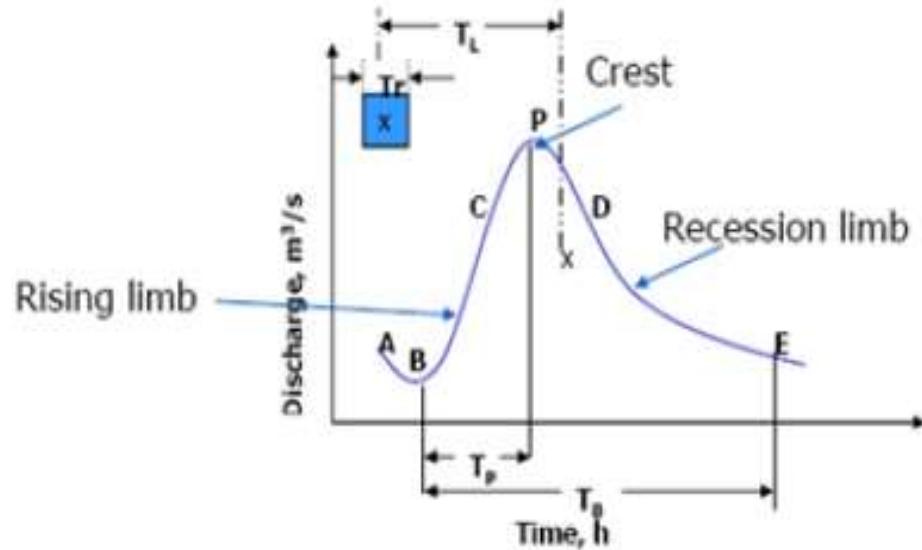


Hydrograph has three characteristic regions:

- ✓ The rising limb AB (concentration curve), joining point A, the starting point of the rising curve and point B, the point of inflection.
- ✓ The crest segment BC between the two points of inflection with a peak P in between. (various parts of the catchment simultaneously contribute water to the outlet of basin)
- ✓ The falling limb or depletion or recession curve CD starting from the second point of inflection C.



T_r = Storm duration
 T_p = Time to peak
 T_B = Time base
 T_L = Time lag or Basin lag



- ✓ **Time Base of Hydrograph (T_B)**- It is the time from the beginning to the end of the direct runoff
- ✓ **Lag Time (T_L)**- It is the difference in time between the center of mass of net rainfall and center of mass runoff.
- ✓ **Time to Peak (T_p)**- It is the time difference between the beginnings of direct runoff to peak.
- ✓ **Rainfall Duration (T_r)**- It is the effective rainfall duration, which causes direct runoff.

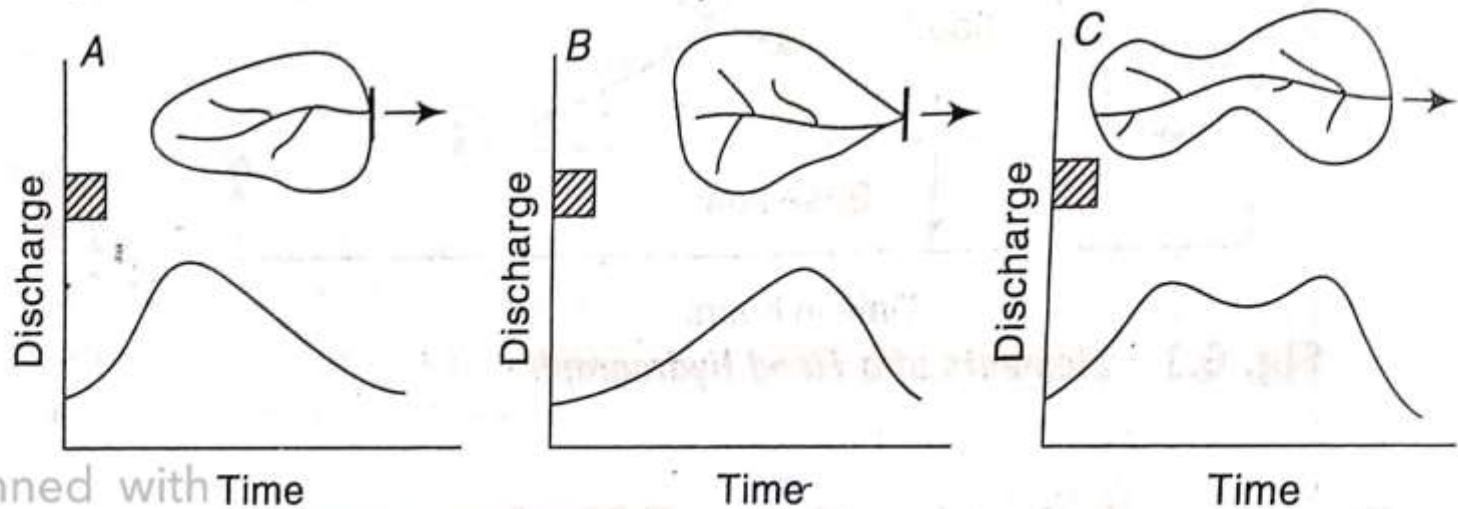
Factors Affecting Hydrograph

Physiographic factors

1. Basin characteristics
 - (a) Shape
 - (b) Size
 - (c) Slope
 - (d) Nature of the valley
 - (e) Elevation
 - (f) Drainage density
 2. Infiltration characteristics
 - (a) Land use and cover
 - (b) Soil type and geological conditions
 - (c) Lakes, swamps and other storage
 3. Channel characteristics: cross-section, roughness and storage capacity
-

Climatic factors

1. Storm characteristics: precipitation, intensity, duration, magnitude and movement of storm
2. Initial loss
3. Evapotranspiration



Scanned with Time

Time

Time

Fig. 6.2(a) Effect of Catchment Shape on the Hydrograph

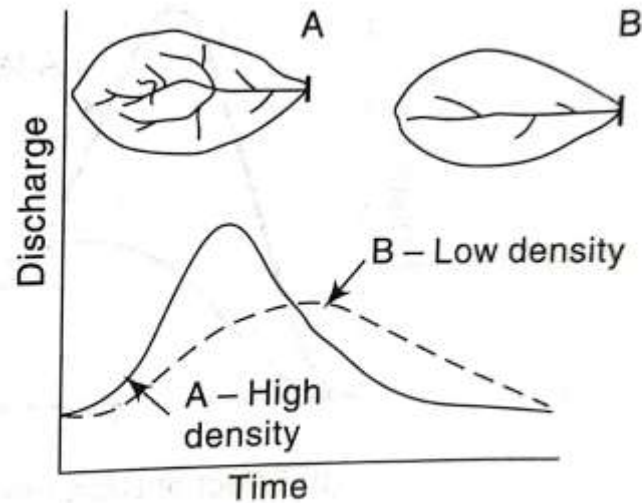
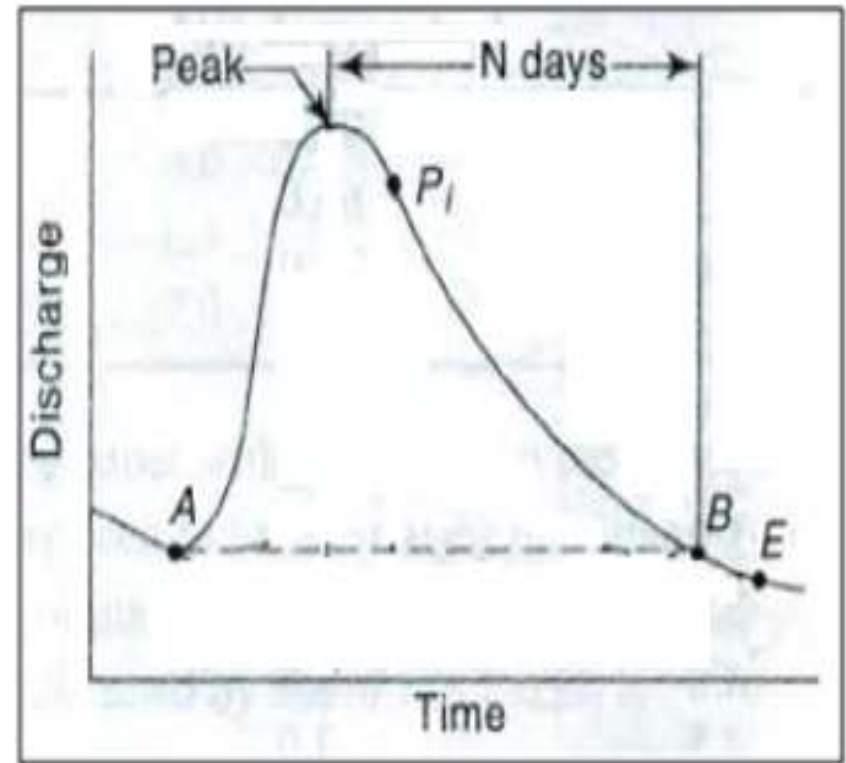


Fig. 6.2(b) Role of Drainage Density on the Hydrograph

Base Flow Separation Method



M1: Straight line Method

Locates a point 'B' on the recession limb that marks the beginning of the baseflow as:

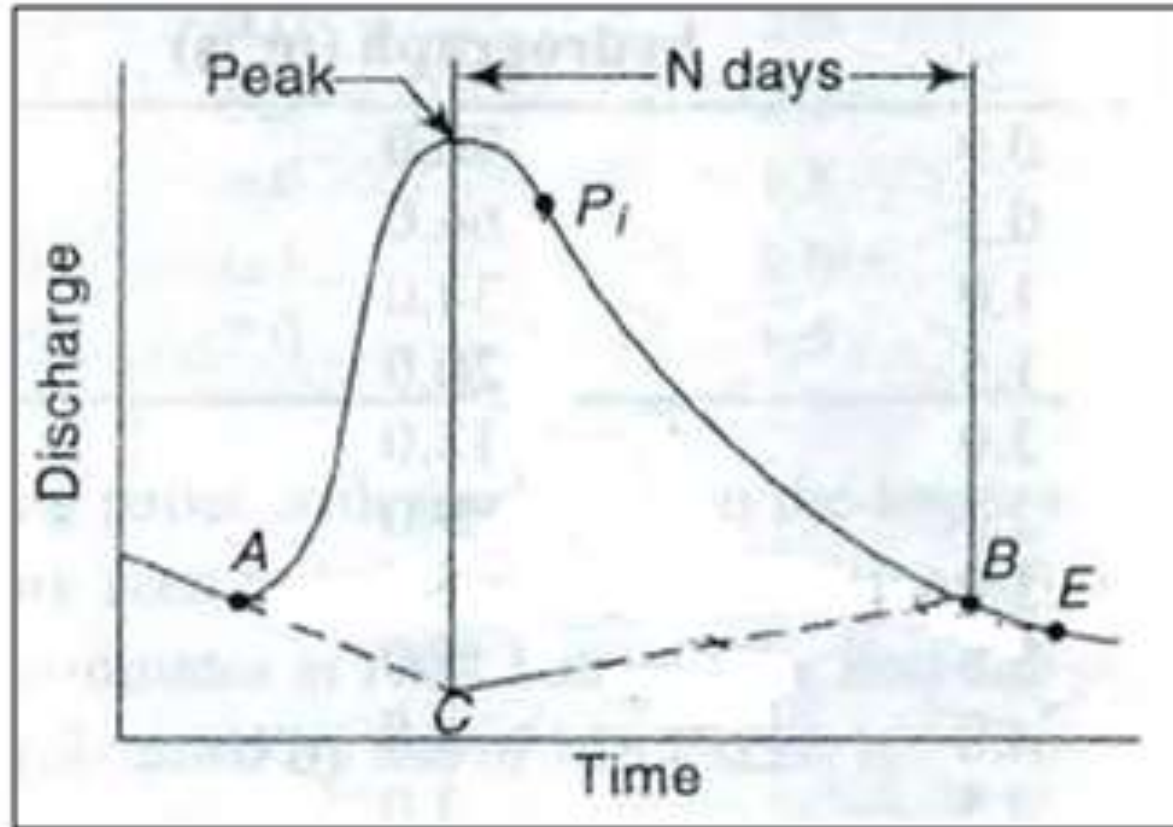
$$N = 0.83 A^{0.2}$$

N = Time in days measured from the hydrograph peak

A = catchment area (km²)

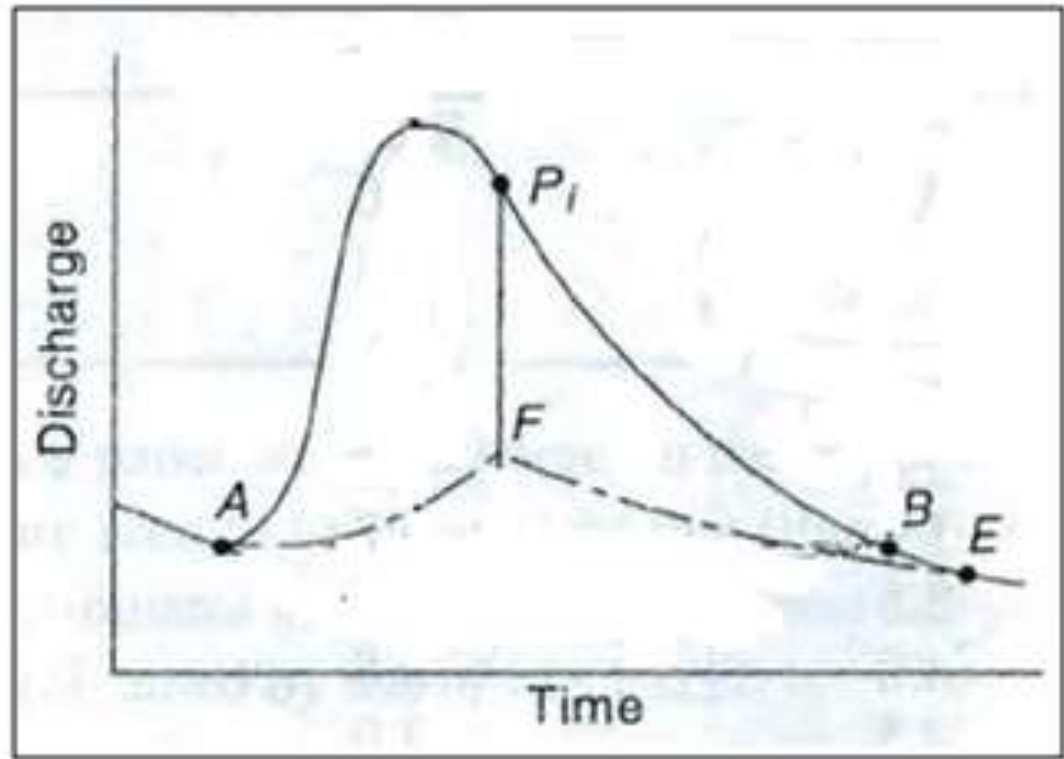
Limitation: Not suitable for small watersheds

Method 2



In this method the base flow curve existing prior to the commencement of the surface runoff is extended till it intersects the ordinate drawn at the peak (point C in Fig. 23.2). This point is joined to point B by a straight line. Segment AC and CB demarcate the base flow and surface runoff. This is probably the most widely used base-flow separation procedure.

Method 3



- ✓ In this method the base flow curve existing prior to the commencement of the surface runoff is extended till it intersects the ordinate drawn at the peak. This point is joined to point F by a straight line. Segment AF and EF demarcate the base flow and surface runoff.
- ✓ Most widely used baseflow separation procedure.

Problem

The following are the ordinates of the hydrograph of flow from a catchment due to a 6h rainfall. Derive the ordinates of DRH. Make suitable assumptions regarding the base flow.

Time from beginning of storm (h)	Discharge (m ³ /s)	Base flow (m ³ /s)	DRH (m ³ /s)
0	42	42	0
6	65	42	23
12	215	42	173
18	360	42	318
24	400	42	358
30	350	42	308
36	270	42	228
42	205	42	163
48	145	42	103
54	100	42	58
60	70	42	28
66	50	42	8
72	42	42	0

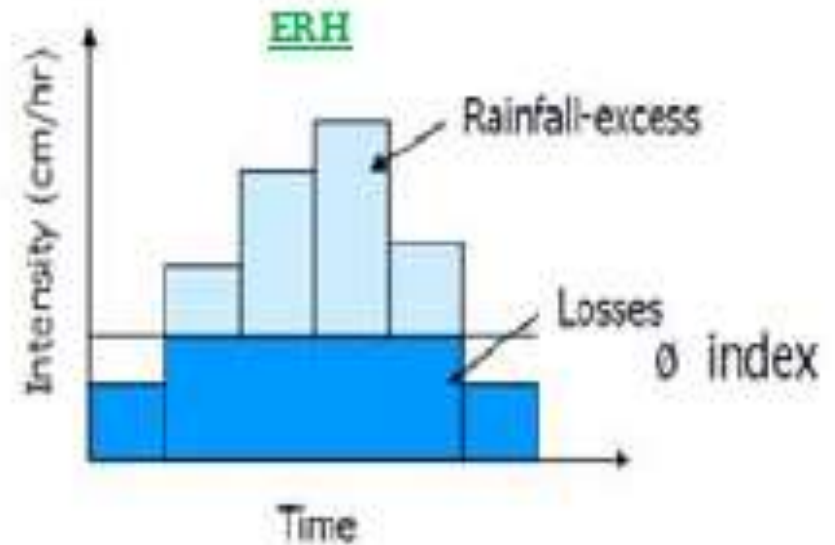


Effective Rainfall Hyetograph (ERH)

Volume of direct runoff hydrograph (DRH) = Depth of ERH \times Catchment area

Effective rainfall (also known as Excess rainfall) is that part of the rainfall that becomes direct runoff at the outlet of the watershed.

Effective rainfall hyetograph (ERH) is also known as excess rainfall hyetograph.

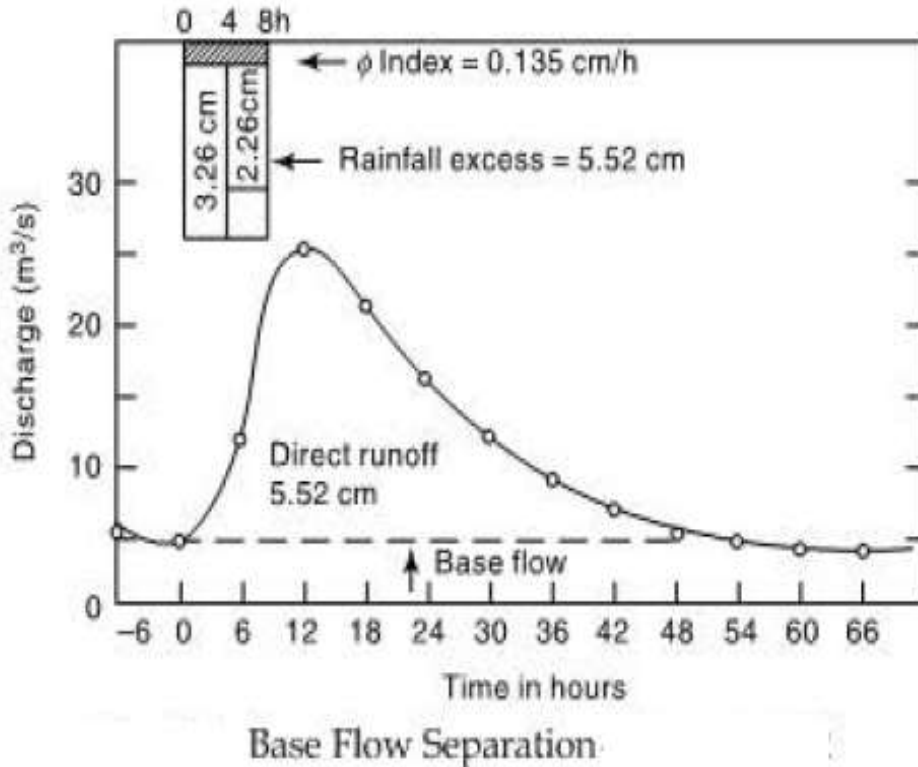


Both DRH and ERH represent the same total quantity but in different units. Since ERH is usually in cm/h plotted against time, the area of ERH multiplied by the catchment area gives the total volume of direct runoff which is the same as the area of DRH

Problem

Rainfall of magnitude 3.8 cm and 2.8 cm occurring on two consecutive 4h durations on a catchment of area 27 km² produced the following hydrograph of flow at the outlet of the catchment. Estimate the rainfall excess and ϕ index.

Time start of rainfall (h)	-6	0	6	12	18	24	30	36	42	48	54	60	66
Observed flow (m ³ /s)	6	5	13	26	21	16	12	9	7	5	5	4.5	4.5
Base flow (m ³ /s)	-	5	5	5	5	5	5	5	5	5	5	5	5
DRH (m ³ /s)	-	0	6	21	16	9	7	4	2	0	0	-	-



Given:

catchment area (A) = 27 km²

$$\begin{aligned}
 N &= 0.83 A^{0.2} \\
 &= 0.8 \times (27)^{0.2} \\
 &= 1.6 \text{ day} \\
 &= 38.5 \text{ h}
 \end{aligned}$$

Area of DRH

$$= (6 \times 60 \times 60) \left[\frac{1}{2} (8 + \frac{1}{2} (8 + 21)) + \frac{1}{2} (21 + 16) + \frac{1}{2} (16 + 11) + \frac{1}{2} (11 + 7) + \frac{1}{2} (11 + 7) + \frac{1}{2} (7 + 4) + \frac{1}{2} (4 + 2) + \frac{1}{2} (2) \right]$$

$$= 3600 \times 6 \times (8 + 21 + 16 + 11 + 7 + 4 + 2)$$

$$= 1.4904 \times 10^6 \text{ m}^3$$

$$\text{runoff depth} = \frac{\text{runoff volume}}{\text{catchment area}} = \frac{1.4904 \times 10^6}{27 \times 10^6} = 0.0552 \text{ m} = 5.52 \text{ cm}$$

$$\text{Total rainfall} = 3.8 + 2.8 = 6.6 \text{ cm}$$

$$\text{Rainfall duration} = 8 \text{ h}$$

$$\phi = \frac{6.6 - 5.52}{8} = 0.135 \text{ cm/h}$$

