Hydrograph

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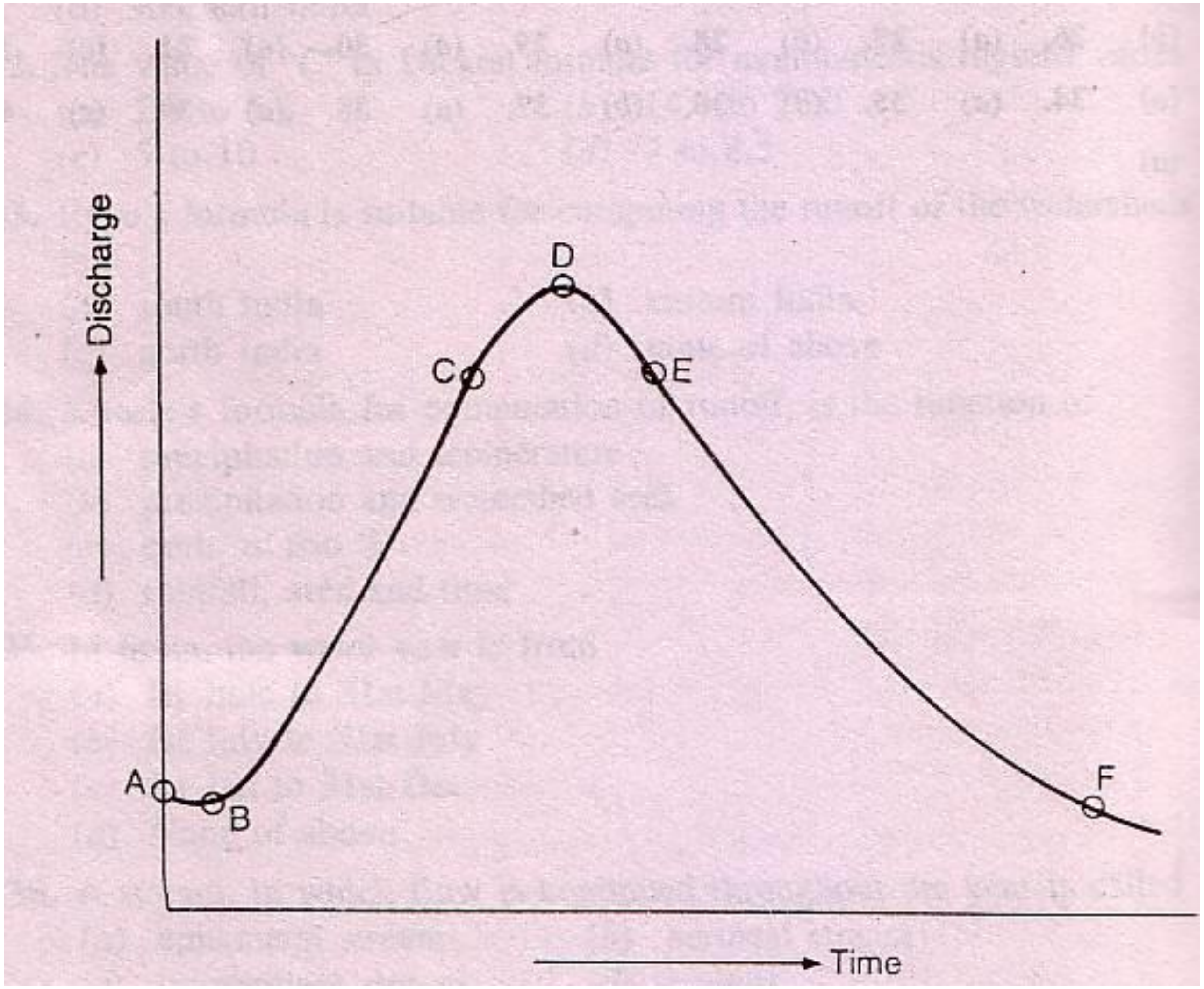
- Plot of discharge against time
- Has three regions: rising limb, crest segment and falling limb
- Nature of hydrograph depend on rainfall and watershed characters.
- Isolated storm results single peak hydrograph and complex storm yields multiple peak hydrograph.

Hydrograph



- Rising limb
  - Ascending portion representing rising discharge due to gradual increase in flow in stream
  - Slope depend on storm and basin characteristics
- Crest Segment
  - Inflection point on rising limb to falling limb
  - Indicate the peak flow
  - Controlled by storm and watershed characteristics
  - Multiple peaks – due to occurrence of two or more storms of different intensities in a closer interval

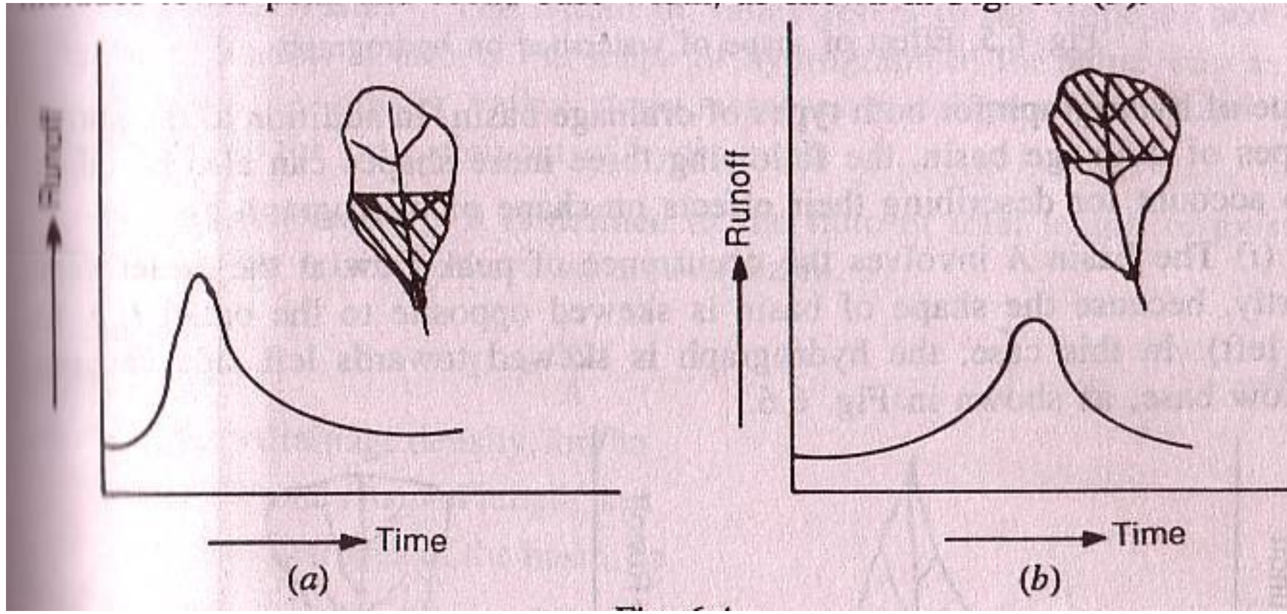
- Falling limb (recession limb)
  - From point of inflection at the end of crest segment to base flow.
  - Inflection point indicate the time at which rainfall stopped
  - Shape independent on storm characteristics but dependant on watershed characteristics

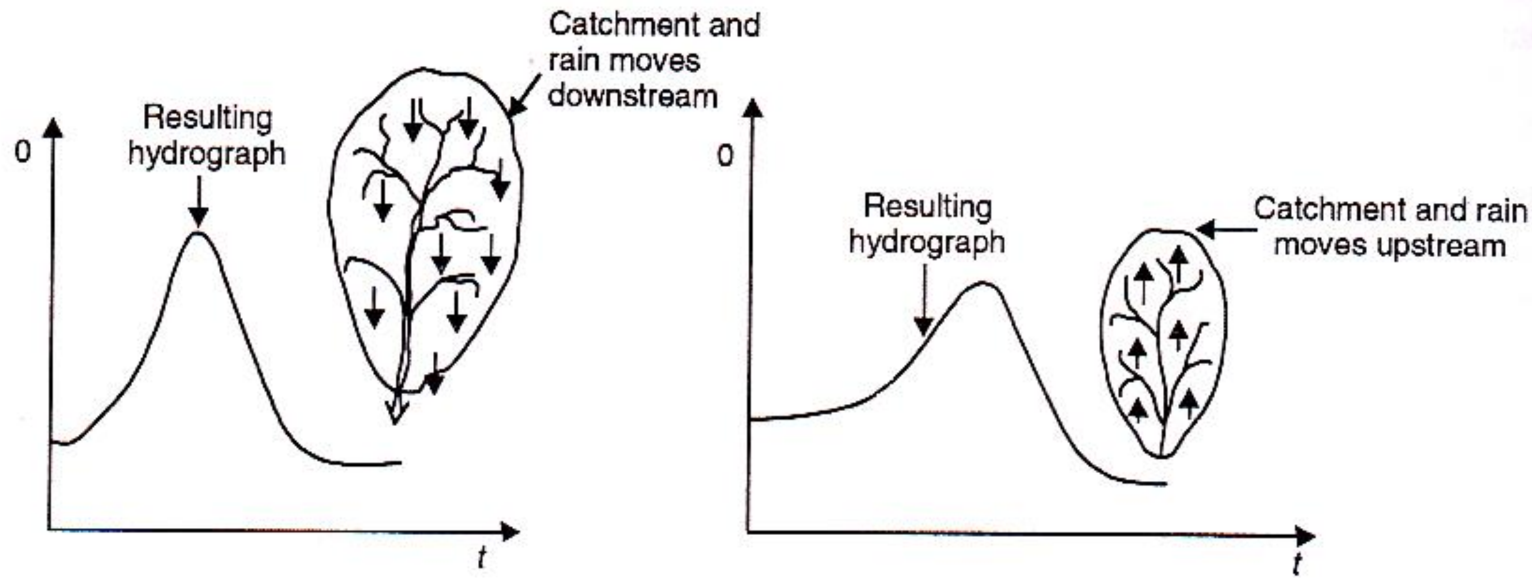
Factors affecting shape of hydrograph

- Climatic factors
  - Form of precipitation
    - Rainfall and snow fall – rainfall tends to produce runoff rapidly generating hydrograph with high peak and narrow base
  - Rainfall Intensity
    - Affect volume of runoff , occurrence of peak flow, duration of surface flow
    - Higher the intensity quicker the peak flow and conical hydrograph
  - Duration of rainfall
    - Longer the duration more the volume
    - Longer duration, peak flow occur after longer time and hydrograph is flatter with broad base

- Distribution of rainfall
  - When heavy rain occur near outlet
    - Peak flow occur quickly
  - When heavy rain occur in upper areas
    - Peak flow occur after few hours
    - Lower peak and broad base (more time taken for flow to reach outlet)
- Direction of storm movement
  - Affects amount of peak flow and surface flow duration
  - Upward direction – lower peak and broad base
  - Downward direction – sharp peak and narrow base

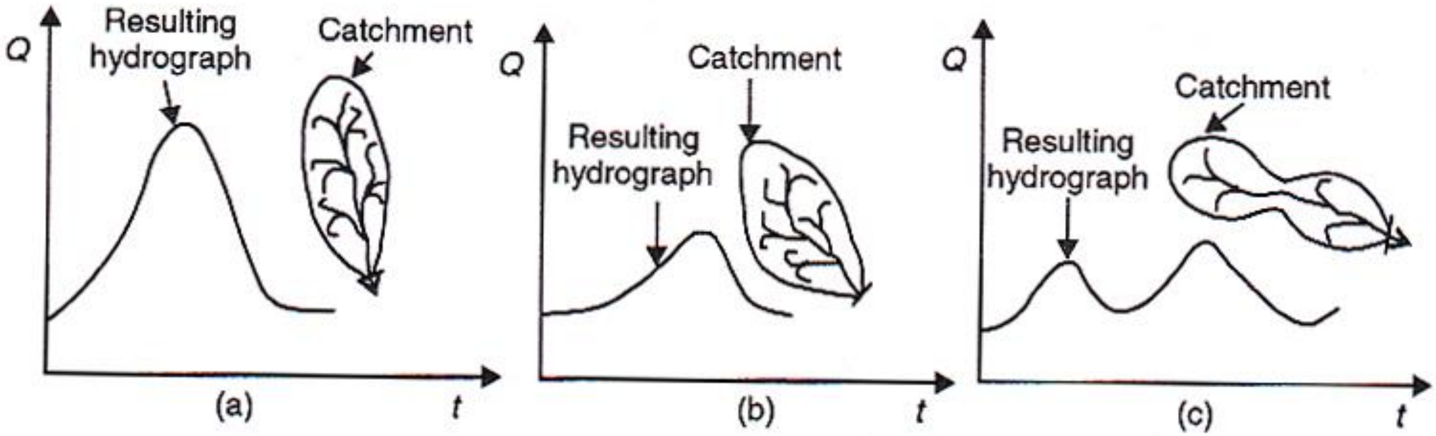
Distribution of rainfall and hydrograph

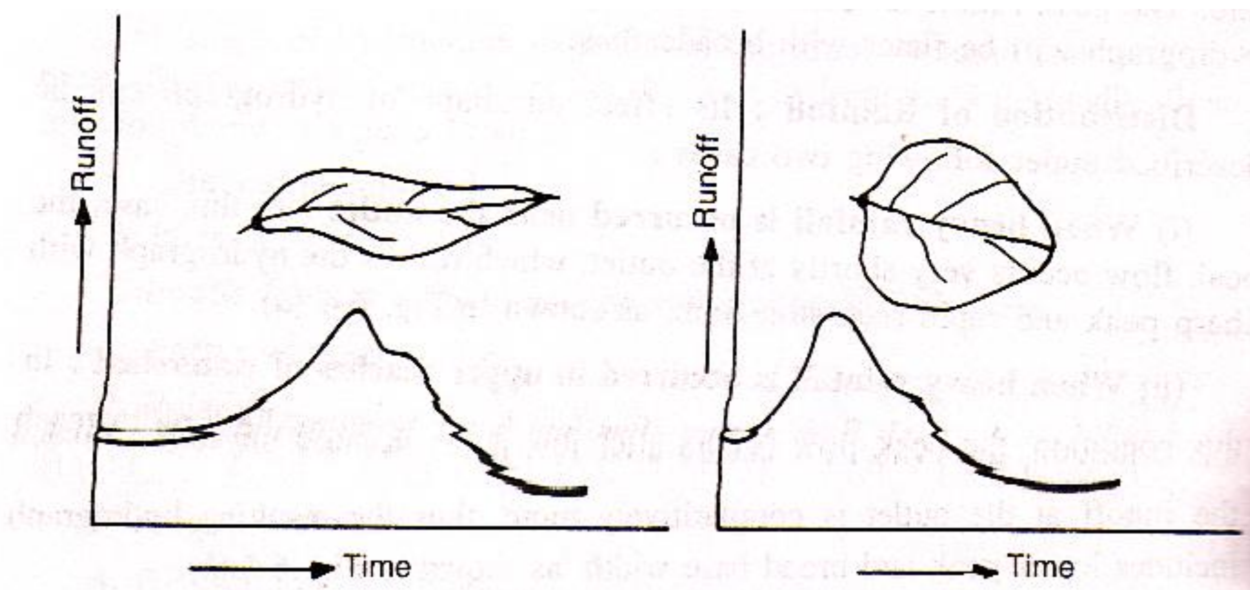




Hydrograph affected by movement of rainfall

- Physiographic factors - characteristics of watershed
  - Shape of basin
    - Affects the shape of hydrograph affecting time of concentration
    - Broad shaped – peak flow occur soon because of less time of concentration, narrow hydrograph with high peak
    - Fan shaped – peak flow occur at longer time interval because of longer time of concentration, broad base lower peak hydrograph

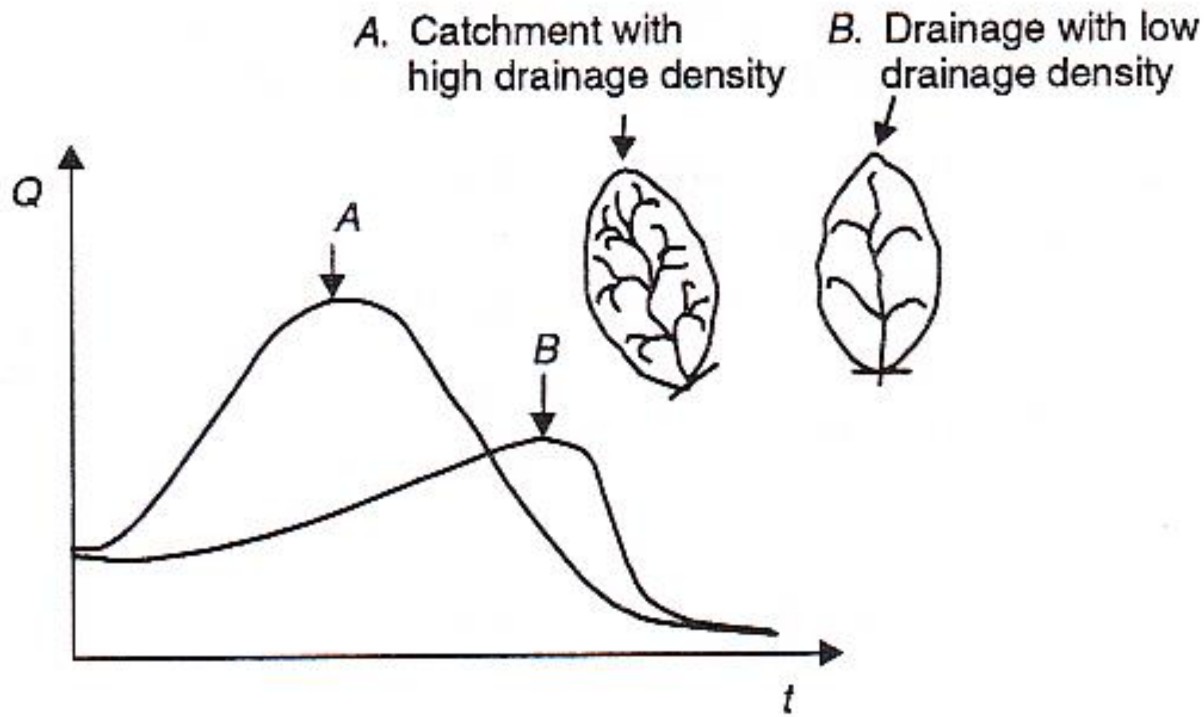




Effect on Hydrograph by Shape of catchment

- Size of basin
  - Small basin – flow dominated by overland flow that joins channel quickly, peak flow occur quickly
- Stream slope
  - More the stream slope higher the slope of recession limb, reduce base width of hydrograph
  - Small slope make recession limb flatter, base width wider
- Nature of valley
  - Greater valley slope higher the slope of recession limb

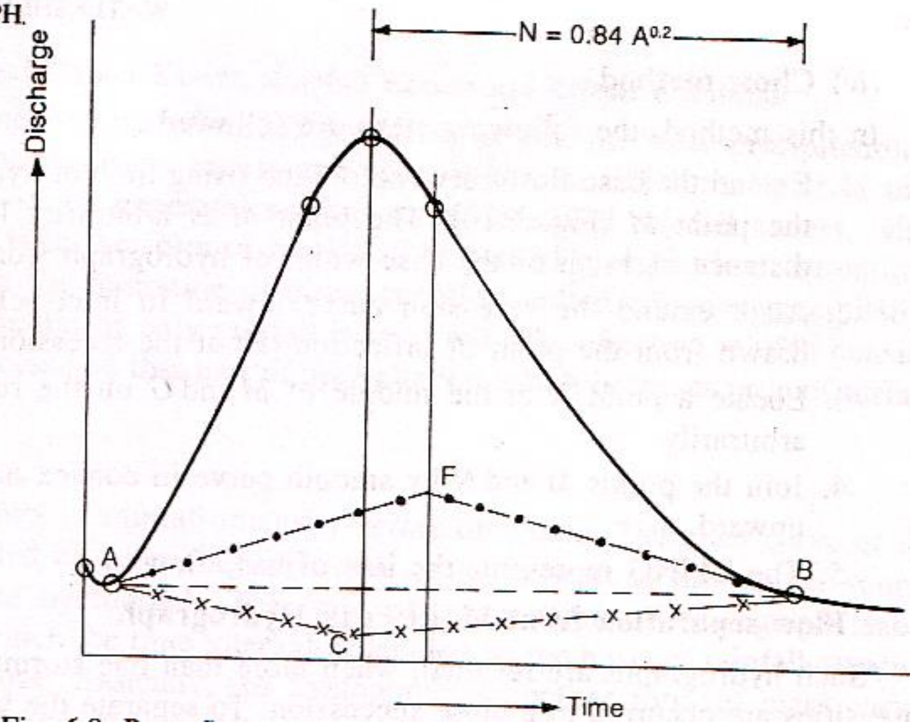
- Drainage density
  - Higher the drainage density, quicker the peak flow, recession limb is steeper with narrow hydrograph
  - Lesser the drainage density, slow moving rising limb and wide base width
- Landuse
  - Vegetation increases loss of water
  - Higher the vegetation density, lesser the peak flow
- Surface depression
  - Presence of ponds, rills etc. delay and modify flow pattern
  - Decreases peak flow and wide base width


A. Catchment with high drainage density
B. Drainage with low drainage density
Q
A
B
t

Base flow separation

- Surface runoff hydrograph derived by separating base flow from hydrograph
- Straight line method
  - Join the starting and end points of surface runoff by straight line
  - Area under the straight line is base flow

HYDROGRAPH



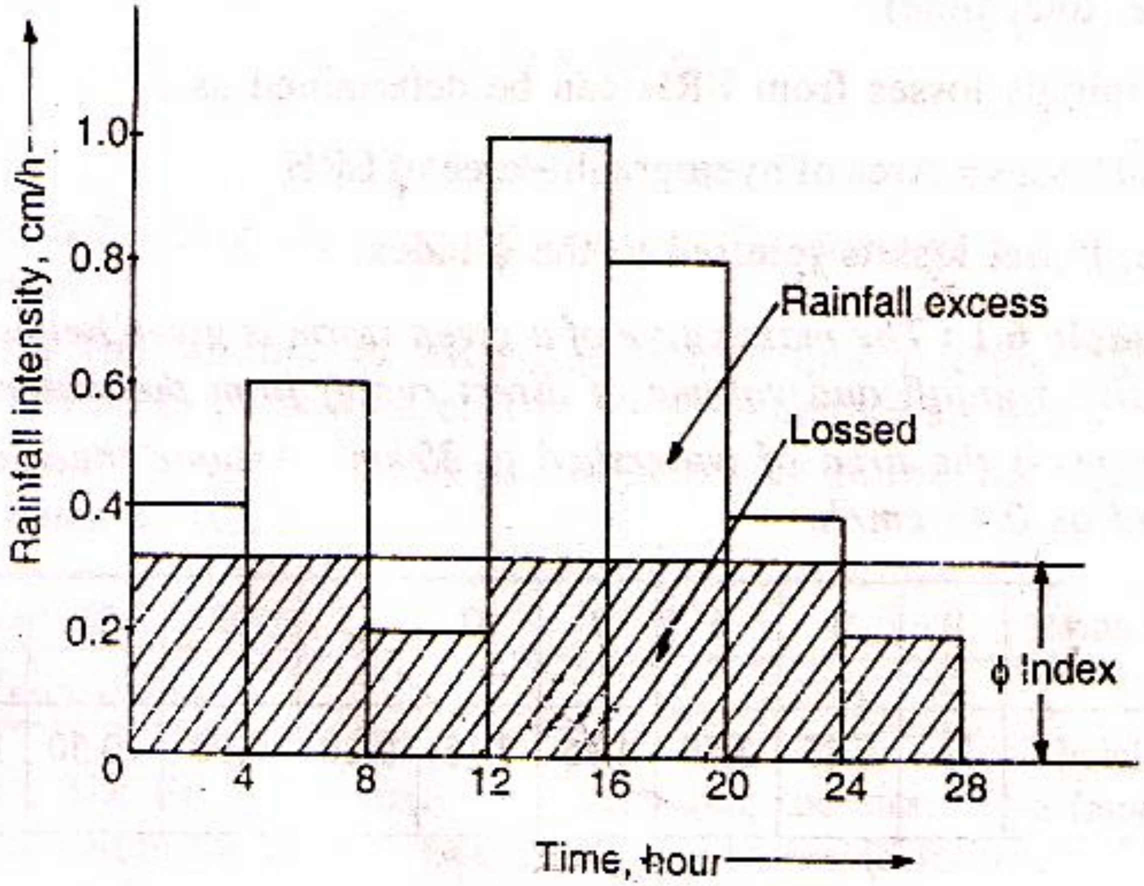
- Fixed base method
  - Draw straight line from end point of surface runoff on rising limb to a point obtained by $N = 0.83\ A^{0.2}$ where A is area of watershed in km^2 and N is days
  - Fig 7.8 madan

- Variable slope method
  - Base flow before concentration with surface runoff is extended till it reaches the perpendicular line drawn from peak
  - Intersection point is extended to a point given by $N = 0.83\ A^{0.2}$ on recession limb
  - (Fig 7.9 Madan)

- Base flow recession curve method
  - Extend base flow recession curve backward till it intersects perpendicular line drawn from inflection point on recession limb
  - Join surface runoff concentration point on rising limb to intersection point
  - (Fig 6.9 Suresh)

Effective rainfall hyetograph

- Effective rainfall – Part of precipitation that entirely contribute to the formation of direct runoff
- ERH shows effective rainfall and initial loss
- ERH provide information on
  - Effective rainfall depth and duration
  - Direct runoff volume
  - Amount of initial loss
- ERH can be used to determine effective rainfall



Rainfall intensity, cm/h
1.0
0.8
0.6
0.4
0.2
0
4
8
12
16
20
24
28
Rainfall excess
Lossed
ϕ Index
Time, hour

$$ER = \sum_{i=1}^{n} I_i \, \Delta t$$

ER – effective rainfall depth (cm or mm)

I_i = Rainfall intensity at time i (cm/h or mm/h)

Δt = time interval

Volume of runoff = ER x A (Unit conversion needs to be done)

Initial Loss = Area of hyetograph – Area of ERH

Direct Runoff Hydrograph

- Plot of direct runoff and time
- Area of hydrograph gives the volume of direct runoff which is response to effective rainfall
- No base flow included to direct runoff hydrograph

- Relationship between DRH and ERH
  - Both shows the same total quantity of direct runoff but in different units

$$A_{ERH} \; x \; A_W = A_{DRH}$$

$$A_{ERH} = \frac{A_{DRH}}{A_W}$$

$$ER = \frac{A_{DRH}}{A_W}$$

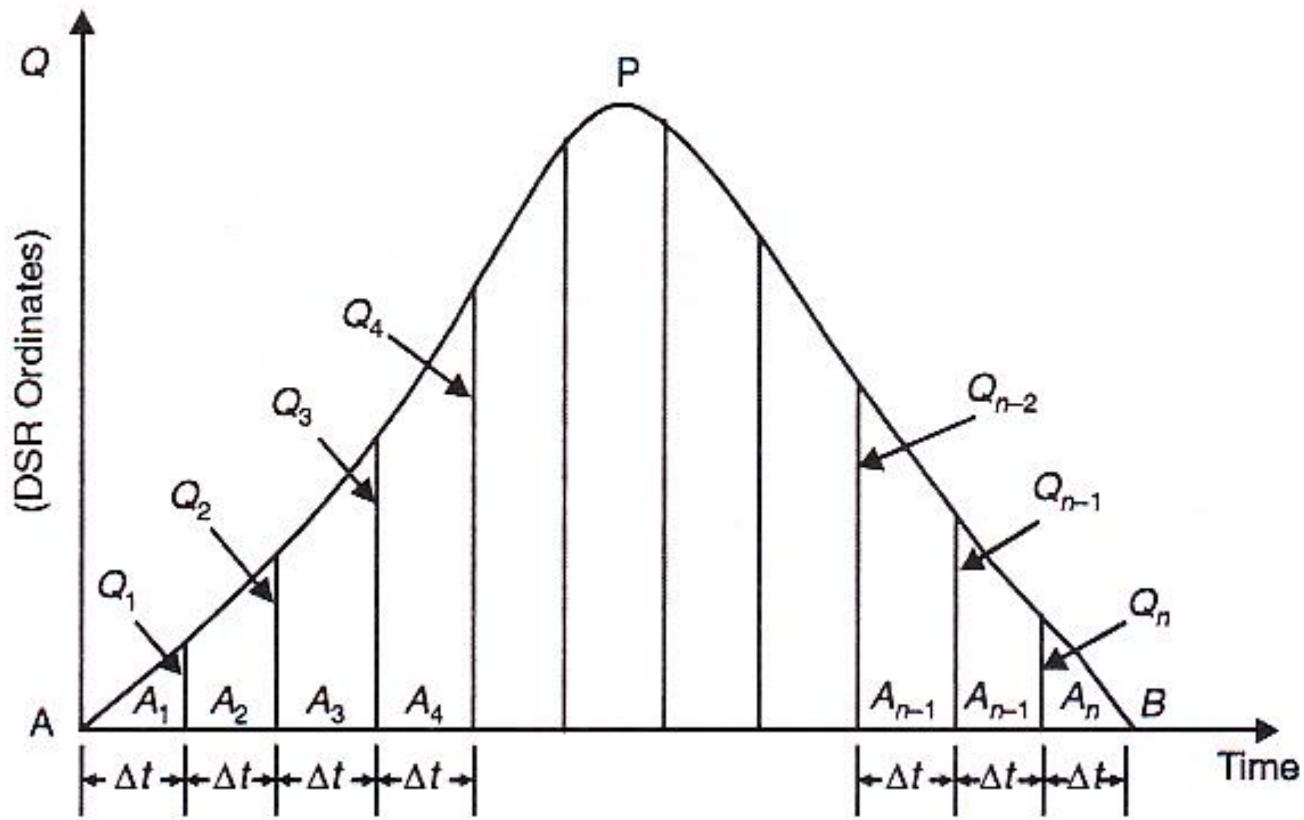
A_{ERH} – Area of ERH
A_w – Area of watershed
A_{DRH} – Area of DRH

Computation of Direct Runoff from DRH

- Separate base flow and get the DRH
- For different time intervals calculate the area under the curve

$$Volume\ of\ Direct\ Runoff = A_1 + A_2 + A_3 + \ldots + A_n$$

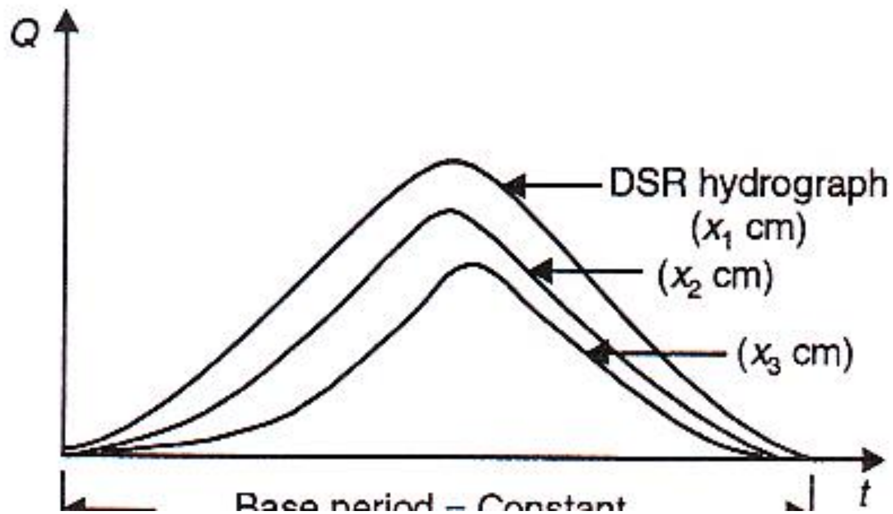
$$= \left(\frac{1}{2} Q_1 \Delta t\right) + \left[\left(\frac{Q_1 + Q_2}{2}\right)\Delta t\right] + \ldots\ldots$$


Q
(DSR Ordinates)
P
Q1
Q2
Q3
Q4
Qn–2
Qn–1
Qn
A1
A2
A3
A4
An–1
An–1
An
A
B
Δt
Time

Unit Hydrograph

- Hydrograph of surface runoff of a catchment resulting from unit depth (usually 1 cm) of rainfall excess (effective rainfall) occurring uniformly over the watershed and at uniform rate for a specified duration.
- A constant for the watershed
- Can be used to determine volume of direct runoff of any storm occurring in the catchment

- Assumptions in deriving Unit Hydrograph
  - Uniform intensity of rainfall within a specified duration
  - Effective rainfall is uniformly distributed in the watershed
  - Base of time duration of the direct runoff hydrograph is constant



- Direct runoff due to effective rainfall over the watershed is always same, not vary with time
- Relationship between direct runoff and effective rainfall is linear (Example: if ER of x cm generate y m^3 of direct runoff, 3x will generate 3y m^3)

Derivation of unit hydrograph

- Step 1: Separate base flow from any method
- Step 2: Determination of the volume of direct runoff (discussed earlier)
- Step 3: Determine the effective rainfall

$$= \frac{Volume\ of\ Direct\ Runoff}{Area\ of\ Watershed}$$

- Step 4: Determination of ordinates of unit hydrograph

$$OUHG = \frac{Ordinate\ of\ DRH}{ER}$$

- Step 5: Plot the unit hydrograph

- Unit hydrograph can be used to get the hydrographs for other rainfall events.
  - Example : If 1 hour unit hydrograph is known, it can be used to compute hydrograph of a three hour event. (Example calculations 6.11 Suresh and 7.3 Madan)

- Uses of unit hydrograph
  - Development of flood hydrographs for extreme rainfall events that can be used to design hydraulic structures such as bridges, culverts etc.
  - Flood forecasting and warning
  - To extend flood flow records based on rainfall