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
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
• 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 $\text{km}^2$ 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
\[ ER = \sum_{i=1}^{n} I_i \Delta t \]

ER – effective rainfall depth (cm or mm)

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

\( \Delta t \) = time interval

Volume of runoff = \( ER \times A \) (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
\[ A_{ERH} \times A_W = A_{DRH} \]

\[ A_{ERH} = \frac{A_{DRH}}{A_W} \]

\[ ER = \frac{A_{DRH}}{A_W} \]

\( A_{ERH} \) – 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 = \( A_1 + A_2 + A_3 + \ldots + A_n \)

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

\[
Volume\ of\ Direct\ Runoff = \frac{\text{Watershed of Area} \times \text{Runoff Direct of Volume}}{\text{Area of Watershed}}
\]

- Step 4: Determination of ordinates of unit hydrograph

\[
OUHG = \frac{\text{Ordinate of DRH}}{ER}
\]

- 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