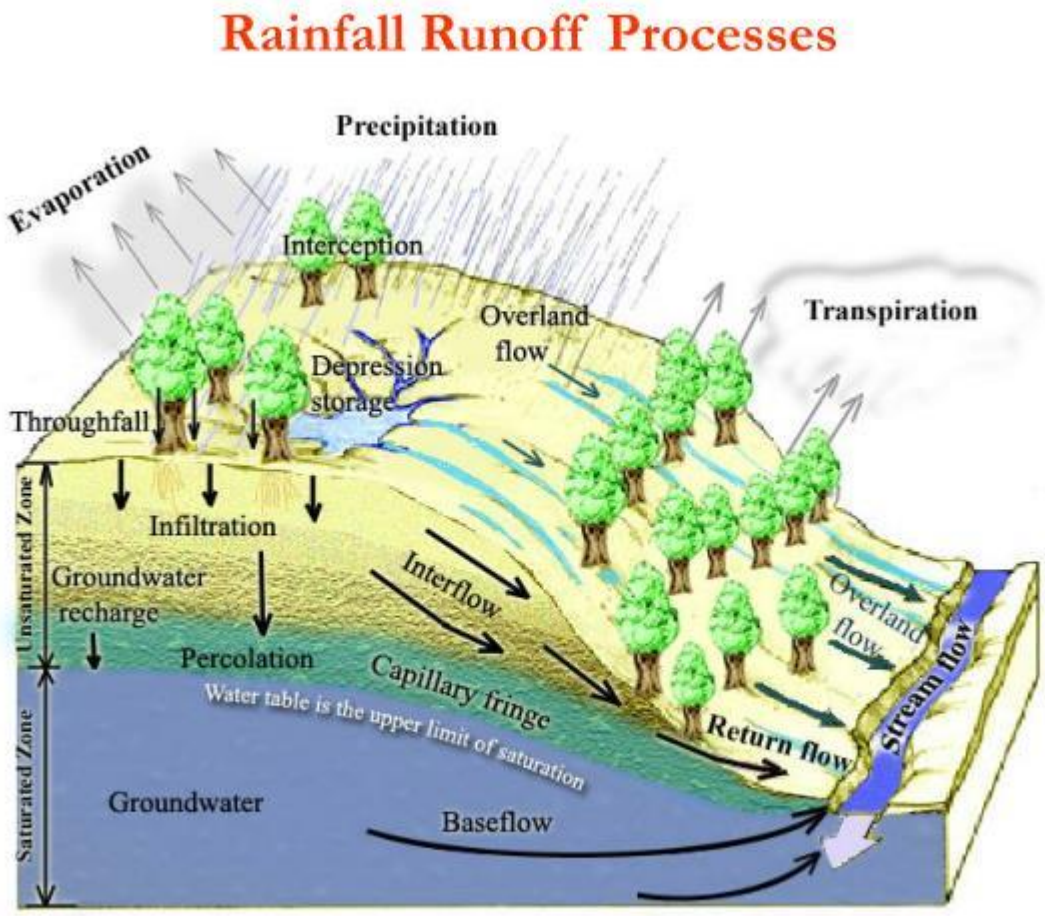
Surface Runoff

Runoff is a process of water movement under the influence of gravity in channels of variable sizes from smallest trickles to the largest rivers. It includes *stream flow, overland flow, subsurface flow,* and *ground water flow.*

Runoff Occurrence

The overland flow is the main input for generating runoff. On watershed scale, the rainwater after getting satisfied with the initial losses such as, abstractions, evapotranspiration, infiltration etc the remaining rainfall water is called excess rainfall or effective rainfall, is converted into a head of water on the ground surface, which attains motion due to land slope. In result the standing water starts moving down the slope. This phenomenon is called overland flow. As soon as the overland flow joins any flow path like channel etc, the runoff takes place. Since, this flow is through channel; therefore, runoff is also called channel flow. The length of overland flow is limited to a very short distance, normally maximum up to 150 m.

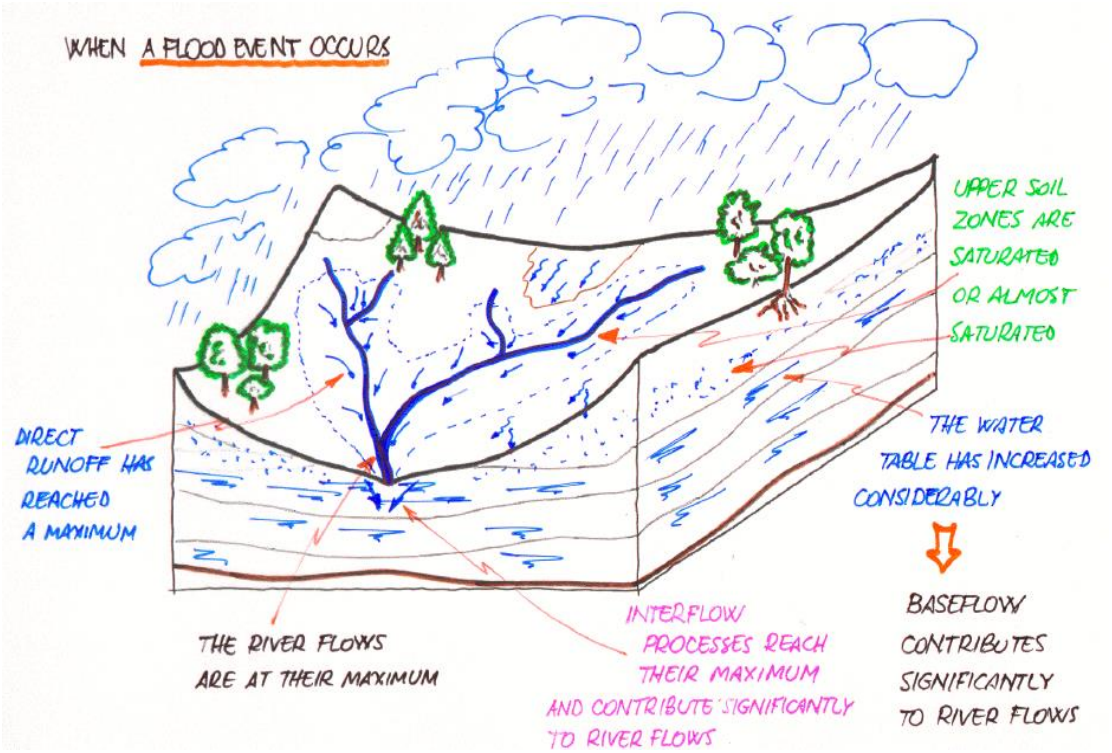


Physical Processes involved in Runoff Generation

Torrent: a stream of water flowing with great speed and violence..

Flooding: is the rise in the water level in the river to a level higher than the river's edge, causing this water to flow over the flood plains, causing heavy losses of lives and property.

When a flood event occurs?



Surface water sources

1: Precipitation is the main source of fresh water, by falling rain, snow, or melting snow and refrigerators.

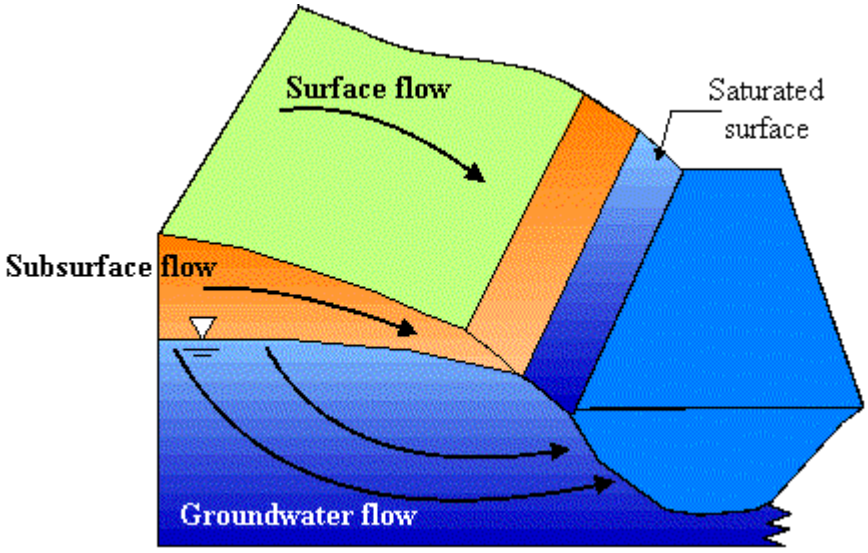
2: Ground water in the subsurface flow: After the water infiltrates the soil on the upper part of the slope, this water may flow horizontally through the soil, and infiltrate (flow out of the soil) into the nearby river channel.

3: Groundwater flow: Water that infiltrates into the soil surface and infiltrates into the groundwater will transport horizontally to the main channels through the saturated zone.

Runoff components

- Direct rainfall over the stream:-
  It is a very small portion of the precipitation because open water channels do not occupy much of catchment area.
- Surface runoff or overland flow: –
  When the intensity of rainfall is higher than the infiltration rate, then after infiltration the excess water will flow over the land surface to the channel and is called surface runoff. The quantity of water moving towards the stream is called overland flow. The surface runoff becomes streamflow for the nearest channels.
- Subsurface flow or interflow:–
  Some of the water which infiltrates the soil surface may move laterally through the upper soil layers until it enters a stream and is called subsurface or interflow. It reaches the stream later and its basin (watershed).
- Base flow, groundwater flow or Dry weather flow:-
  Some of the rainwater percolates downward under gravity through the soil and merges into the water table and if the water table intersects the stream channels

and water appears in streams, it is called base flow, groundwater flow or dry water flow.



TYPES OF RUNOFF

Surface Runoff:

It is the amount of water which is drained over the surface of the soil of watershed after saturation of micro- and macropores of soil, and under gravitational pull from a higher altitude to lower altitude having a much-defined rate of flow.

Sub-surface Runoff:

This type of runoff takes place below the ground surface. In the course of occurrence of rainfall a part of rain water which is infiltrated into the soil media moves downward and joins to the water –table.

Factors affecting runoff

1. Rainfall: Higher rainfall; higher runoff
2. Area of w-shed: Greater area; greater runoff
3. The shape of w-shed: More circular/ square (as compared to other shapes); more runoff
4. The aspect of w-shed: On Northern Aspect more runoff.
5. Vegetation: More vegetation; less runoff
6. Land moisture: More moisture; more runoff
7. Slope: More slopes; more runoff.

Measurement of streamflow

Measuring stream stage: obtaining a continuous record of stage—the height of the water surface at a location along a stream or river.

The discharge measurement: obtaining periodic measurements of discharge (the quantity of water passing a location along a stream)

The stage-discharge relation: defining the natural but often changing relation between the stage and discharge; using the stage-discharge relation to convert the continuously measured stage into estimates of streamflow or discharge

Stream Gauging: Measuring Discharge Rate

1: Volumetric gauging: collect the stream water into a container with known volume and record the time. Suitable for small streams only.

2: Velocity-area method: measure the flow velocity and area of a cross-section in a stream to derive the discharge rate. Needs a proper cross-section to work well.

3:Dilution gauging: inject a tracer (e.g., salt) into the stream and measure its concentration at a downstream location. Best method for turbulent streams with irregular channels.

4: Gauging with portable weirs and flumes: install man-made V-shaped plate (weir) or a constricted short channel (flume), both with known height (stage)-flow rate relationship.

5: Stage measurement: measure the steam surface water level (stage) height and convert it into a flow rate. Relatively easy and thus widely used.

Velocity-area method

Velocity-area method: measure the flow velocity and area of a cross-section in a stream to derive the discharge rate.

Q=A*V=$\sum_i^N V_i A_i$

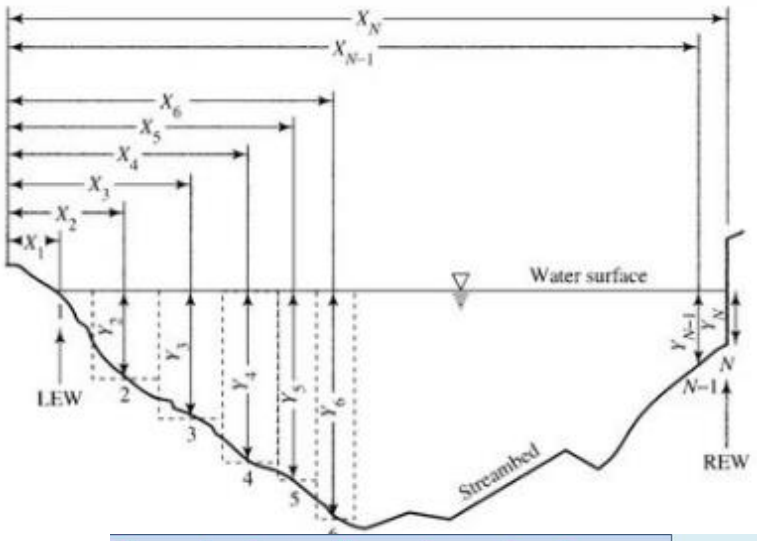
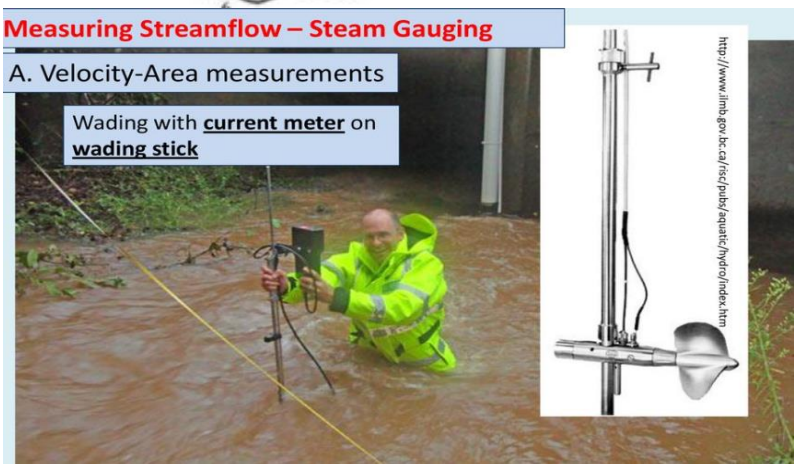
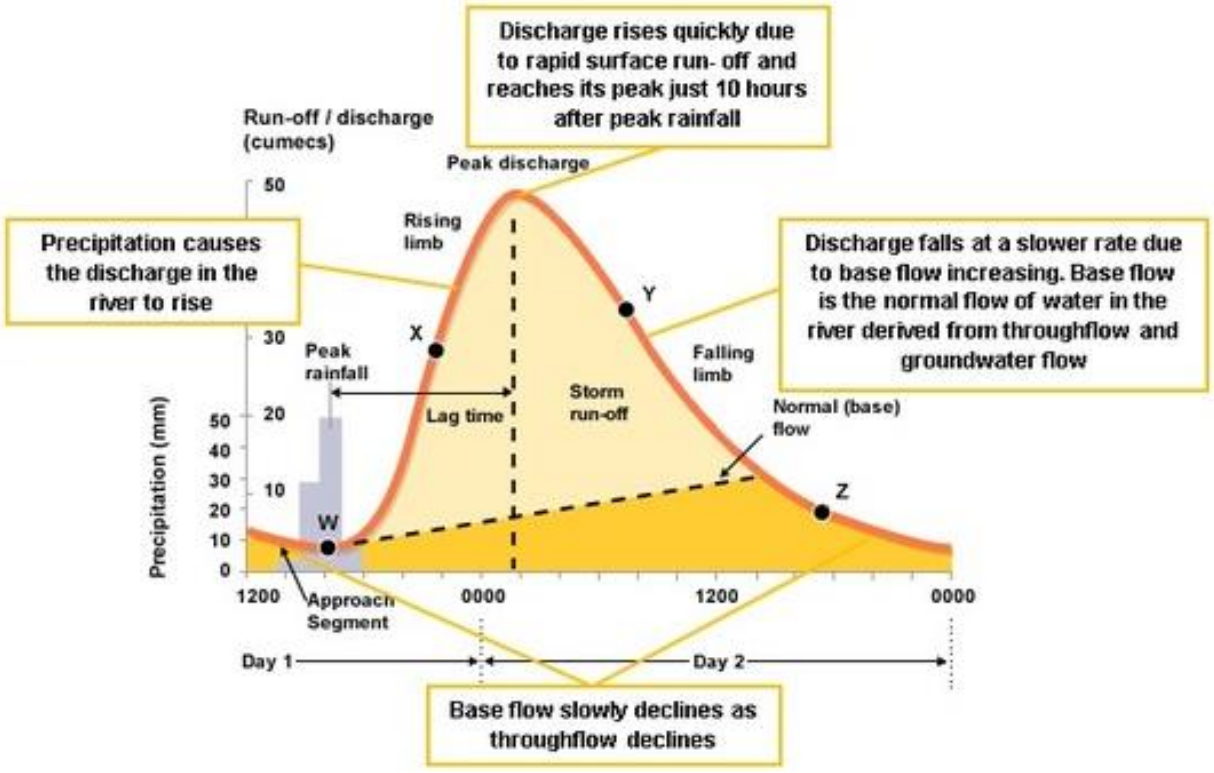


Figure E.2 Definitions of terms for stream gauging by the velocity-area method [equation (E.3) and (E.4)]. Left and right edges of water (LEW and REW, respectively) are defined for an observer facing downstream. Dashed lines delineate individual subsections numbered consecutively $i = 1, 2, \ldots, N$, in this case from the left bank. X_i are distances from the horizontal datum, which can be on either bank; Y_i are depths.

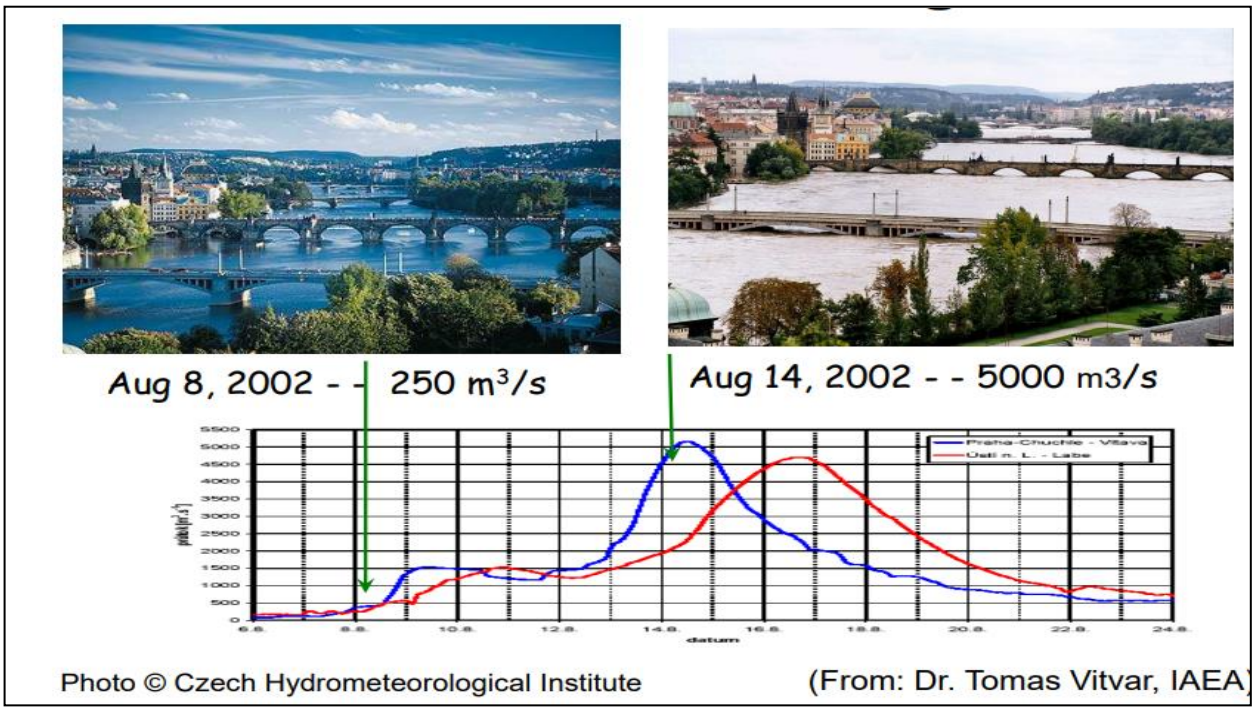


Hydrograph

A hydrograph is a graph showing the rate of flow versus time past a specific point in a river, channel, or conduit carrying flow. It can also refer to a graph showing the volume of water reaching a particular outfall.



Hydrograph



Components of hydrograph

- **Rising limb:** The rising limb of hydro graph, also known as concentration curve, reflects a prolonged increase in discharge from a catchment area, typically in response to a rainfall event
- **Recession (or falling) limb:** The recession limb extends from the peak flow rate onward. The end of stormflow (aka quickflow or direct runoff) and the return to groundwater-derived flow (base flow) is often taken as the point of inflection of the recession limb. The recession limb represents the withdrawal of water from the storage built up in the basin during the earlier phases of the hydrograph.
  - **Peak discharge:** the highest point on the hydro graph when the rate of discharge is greatest

Factors affecting Hydrograph

8. •The climatic factor such as

   A: The form of precipitation. Rainfall or snowfall usually the rainfall tends to produce fast surface runoff with a high peak and a narrow base

   B: The intensity of the rainstorm.

   C: The length of the period of precipitation

   D: Rainfall distribution

   E: Direction of the rainstorm movement.

9. Characteristics of the drain basin, such as

   A: The shape of the pelvis usually affects the focus period

   B: The size of the basin

   C: The slope of the river or stream

   D: The nature of the valley

   E: River density

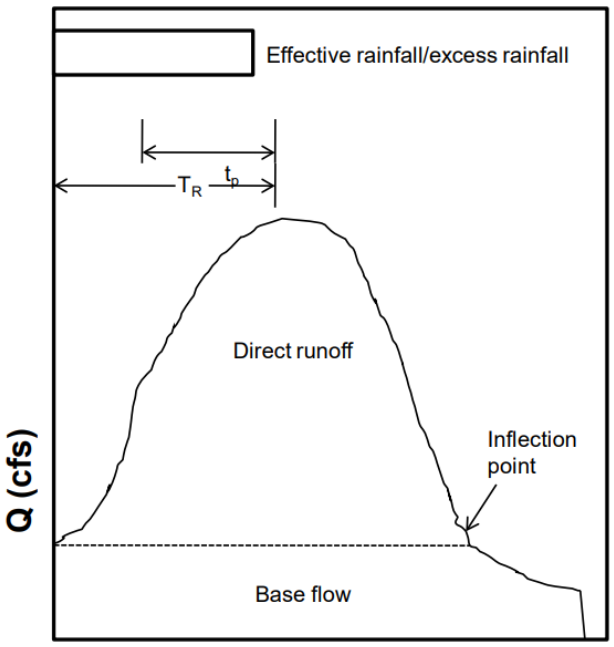
   F: Land use

   G: Surface depressions

10. Slope: More slopes; more runoff.

Terminologies

1. **Duration** of effective rainfall : the time from start to finish of effective rainfall
2. **Lag time** (L or t_p): the time from the center of mass of rainfall excess to the peak of the hydrograph
3. **Time of rise** (T_R): the time from the start of rainfall excess to the peak of the hydrograph
4. **Time base** (T_b): the total duration of the DRO hydrograph



Hydrograph separation

The term hydrograph separation refers to various analyses that are commonly performed to decompose hydrographs into sub-hydrographs. Within the simplest storage based water balance models the hydrograph is expected to have three main contributors - fast overland flow, inter-flow/sub-surface flow and baseflow (groundwater contribution).

In many hydrograph analyses a relationship between the surface flow hydrograph and effective rainfall (that is rainfall minus losses) is sought to be established. The surface flow hydrograph is obtained from the total storm hydrograph by separating the quick response flow from the slow response runoff. It is usual to consider the interflow as a part of surface flow in view of its quick response. Thus only the base flow is to be deducted from the total storm hydrograph to obtain surface flow hydrograph. There are four methods of base flow separation that are commonly used. Different methods of base flow separation are illustrated in following Fig.

(1) Simply by drawing a line AC tangential to both the limbs at their lower portion. This method is very simple

but is approximate and can be used only for preliminary estimates.

(2) Extending the recession curve existing prior to the occurrence of the storm up to the point D directly under the peak of the hydrograph and then drawing a straight line DE, where E is the point on the hydrograph N days after the peak, and N (in days) is given by

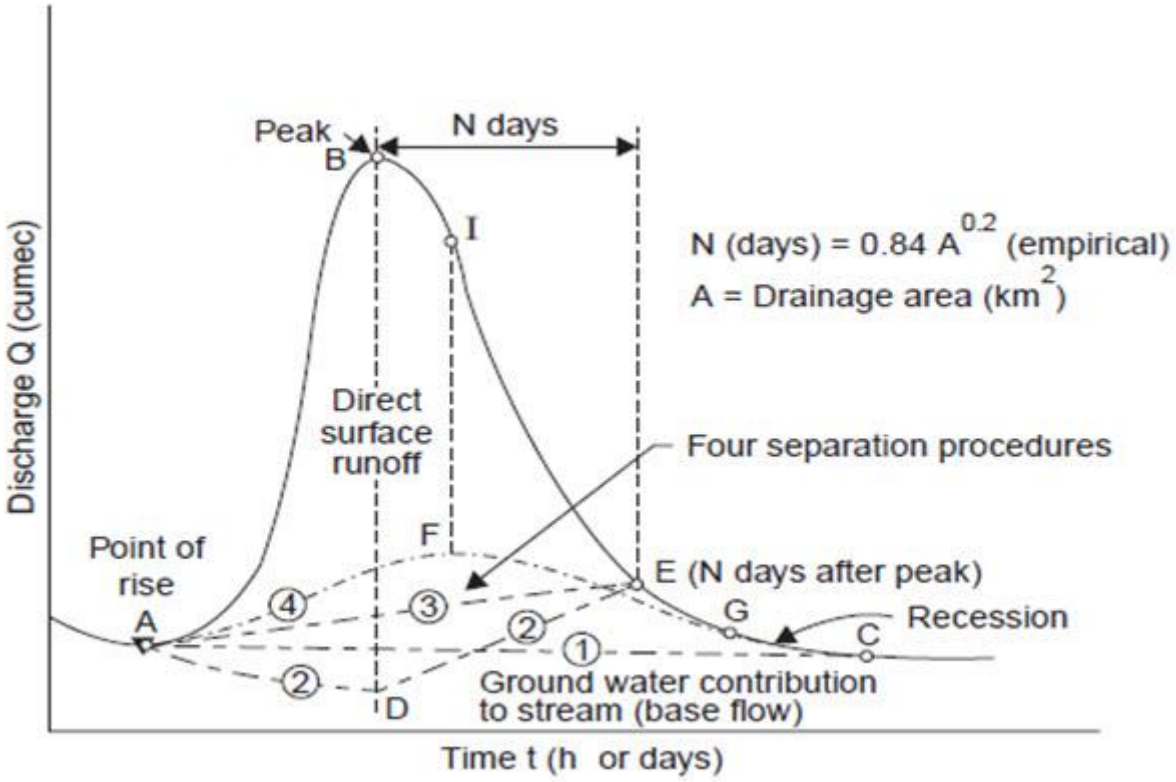
$$N=0.83\ A^{0.2}$$

Where, A= area of the drainage basins (km^2)

(3) Simply by drawing a straight line AE, from the point of rise to the point E, on the hydrograph, N days after the peak.

(4) A line AFG is drawn, by projecting the groundwater recession curve after the storm backwards, to a point F directly under the second inflection point of the falling limb and sketch an arbitrary rising line from the point of the rise of the hydrograph to connect with the projected base flow recession. This method of separation is preferred where the ground water storage is relatively large and reaches the stream fairly rapidly, as in lime stone terrains.

In all the above flow separation procedures, the area below the line constructed represents the base flow, which is the ground water contribution to the stream flow.


Peak
B
N days
I
N (days) = 0.84 A^0.2 (empirical)
A = Drainage area (km^2)
Discharge Q (cumec)
Direct surface runoff
Four separation procedures
F
Point of rise
A
E (N days after peak)
G
Recession
C
④
③
②
①
②
D
Ground water contribution to stream (base flow)
Time t (h or days)