

COMPONENTS OF STREAM FLOW: When a storm occurs, a portion of rainfall infiltrates into the ground and some portion may evaporate. The rest flows as a thin sheet of water over the land surface which is termed as overland flow. If there is a relatively impermeable stratum in the subsoil, the infiltrating water moves laterally in the surface soil and joins the stream flow, which is termed as underflow (subsurface flow) or interflow, Fig. 1. If there is no impeding layer in the subsoil the infiltrating water percolates into the ground as deep seepage and builds up the ground water table (GWT or phreatic surface). The ground water may also contribute to the stream flow, if the GWT is higher than the water surface level of the stream, creating a hydraulic gradient towards the stream. Low soil permeability favors overland flow. While all the three types of flow contribute to the stream flow, it is the overland flow, which reaches first the stream channel, the interflow being slower reaches after a few hours and the ground water flow being the slowest reaches the stream channel after some days. The term direct runoff is used to include the overland flow and the interflow. If the snow melt contributes to the stream flow it can be included with the direct runoff (from rainfall).

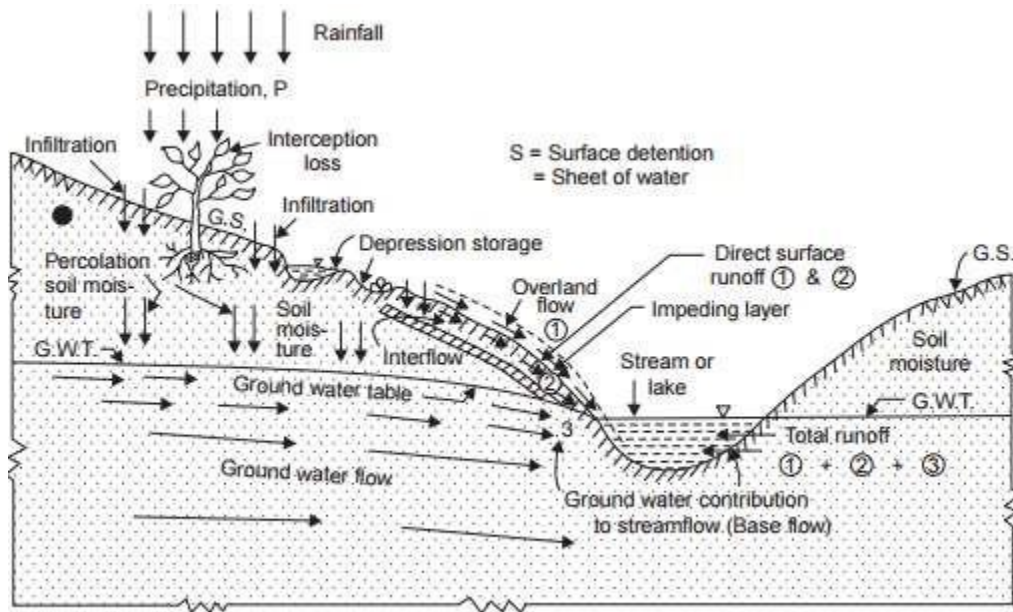


Figure 1 Disposal of rain water

Direct surface flow can be analysed for relatively large drainage areas by the unit hydrograph method and for smaller areas by overland flow analysis. The direct runoff results from the occurrence of an immediately preceding storm while the ground water contribution, which takes days or months to reach the stream, in all probability has no direct relation with the immediately preceding storm. The ground water flow into the stream would have continued even if there had been no storm immediately preceding. It is for this reason it is termed as base flow in hydrograph analysis. When the overland flow starts (due to a storm) some flowing water is held in puddles, pits and small ponds; this water stored is called depression storage. The volume of water in transit in the overland flow which has not yet reached the stream channel is called surface detention or detention storage. The portion of runoff in a rising flood in a stream, which is absorbed by the permeable boundaries of the stream above the normal phreatic surface is called bank storage, Fig. 2.

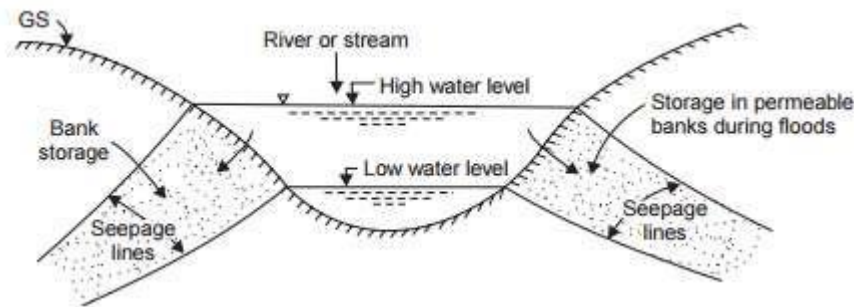


Figure 2: Bank Storage

FACTORS AFFECTING RUNOFF: The various factors, which affect the runoff from a drainage basin depend upon the following characteristics:

Low intensity storms over longer spells contribute to ground water storage and produce relatively less runoff. A high intensity storm or smaller area covered by it increases the runoff since the losses like infiltration and evaporation are less. If there is a succession of storms, the runoff will increase due to initial wetness of the soil due to antecedent rainfall. Rain during summer season will produce less runoff, while that during winter will produce more. Greater humidity decreases evaporation. The pressure distribution in the atmosphere helps the movement of storms. Snow storage and specially the frozen ground greatly increase the runoff. Peak runoff (if expressed as cumec/km^2) decreases as the catchment area increases due to higher time of concentration. A fan-shaped catchment produces greater flood intensity than a fern-shaped catchment. Steep rocky catchments with less vegetation will produce more runoff compared to flat tracts with more vegetations. If the vegetation is thick greater is the absorption of water, so less runoff. If the direction of the storm producing rain is down the stream receiving the surface flow, it will produce greater flood discharge than when it is up the stream. If the catchment is located on the orographic side (windward side) of the mountains, it receives greater precipitation

and hence gives a greater runoff. If it is on the leeward side, it gets less precipitation and so less runoff. Similarly, catchments located at higher altitude will receive more precipitation and yield greater runoff. The land use pattern—arable land, grass land, forest or cultivated area, greatly affect runoff. The storage in channels and depressions (valley storage) will reduce the flood magnitude. Upstream reservoirs, lakes and tanks will moderate the flood magnitudes due to their storage effects. For drainage basins having previous deposits, large ground water storage may be created, which may also contribute to the stream flow in the form of delayed runoff.

ESTIMATION OF RUNOFF: Runoff is that balance of rain water, which flows or runs over the natural ground surface after losses by evaporation, interception and infiltration. The yield of a catchment (usually means annual yield) is the net quantity of water available for storage, after all losses, for the purposes of water resources utilization and planning, like irrigation, water supply, etc. Maximum flood discharge. It is the discharge in times of flooding of the catchment area, i.e., when the intensity of rainfall is greatest and the condition of the catchment regarding humidity is also favorable for an appreciable runoff.

Runoff Estimation

The runoff from rainfall may be estimated by the following methods:

- (i) Empirical formulae, curves and tables
- (ii) Infiltration method
- (iii) Rational method
- (iv) Overland flow hydrograph
- (v) Unit hydrograph method

(i) Empirical formulae:

- C.C. Inglis' formula for Bombay—Deccan catchments (Ghat areas)

$$R = 0.85P + 30.5$$

and for plains $R = \frac{(P - 17.8)P}{254}$

- Lacey's formula for Indo- $R = \frac{P}{1 + \frac{304.8}{P} \left(\frac{F}{S} \right)}$ Gangetic plain

where F is a monsoon duration factor varying between 0.5 to 1.5 and S is the catchment factor depending upon the slope and varies from 0.25 for flat areas to 3.45 for hilly areas.

- A.N. Khosla's formula for north India

$$R = P - \frac{T}{3.74}$$

Formulae for some of the drainage basins in India:

- Ganga basin $R = 2.14 P^{0.64}$
- Yamuna basin (Delhi) $R = 0.14 P^{1.1}$
- Rihand basin (U.P.) $R = P - 1.17 P^{0.86}$
- Chambal basin (Rajasthan) $R = 120P - 4945$
- Tawa basin (M.P.) $R = 90.5P - 4800$
- Tapti basin (Gujarat) $R = 435P - 17200$

(ii) Infiltration Method. By deducting the infiltration loss, i.e., the area under the infiltration curves, from the total precipitation or by the use of infiltration indices, which are already discussed. These methods are largely empirical and the derived values are applicable only when the rainfall characteristics and the initial soil moisture conditions are identical to those for which these are derived.

(iii) Rational Method: A rational approach is to obtain the yield of a catchment by assuming a suitable runoff coefficient.

$$\text{Yield} = CAP$$

where A = area of catchment P = precipitation C = runoff coefficient The value of the runoff coefficient C varies depending upon the soil type, vegetation geology etc. (shown in table 1)

Table 1 Runoff coefficients for various types of catchments

| <i>Type of catchment</i> | <i>Value of C</i> |
|---------------------------------------|-------------------|
| Rocky and impermeable | 0.8–1.0 |
| Cultivated or covered with vegetation | 0.4–0.6 |
| Sandy soil | 0.2–0.3 |
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