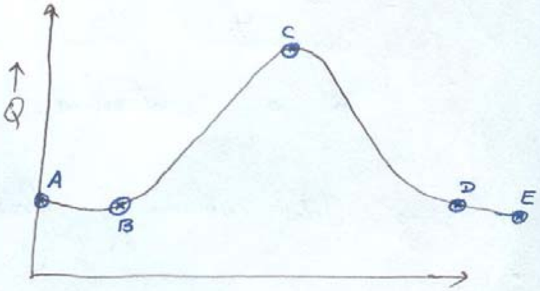
* Storm Hydrograph



→ This is a graph of discharge versus time in a basin due to an individual storm.

→ This graph has four components.
* Before the rainfall storm there is baseflow gradually decreasing (AB)
* The discharge due to this particular storm (direct runoff) begins at B and peaks at C (BC), and you can say ends at D.
* Baseflow continues at DE.

→ As a hydrologist, you may be interested to know how the streamflow is affected by a particular storm.
* That is you would like to separate the baseflow from the streamflow and find the direct runoff.

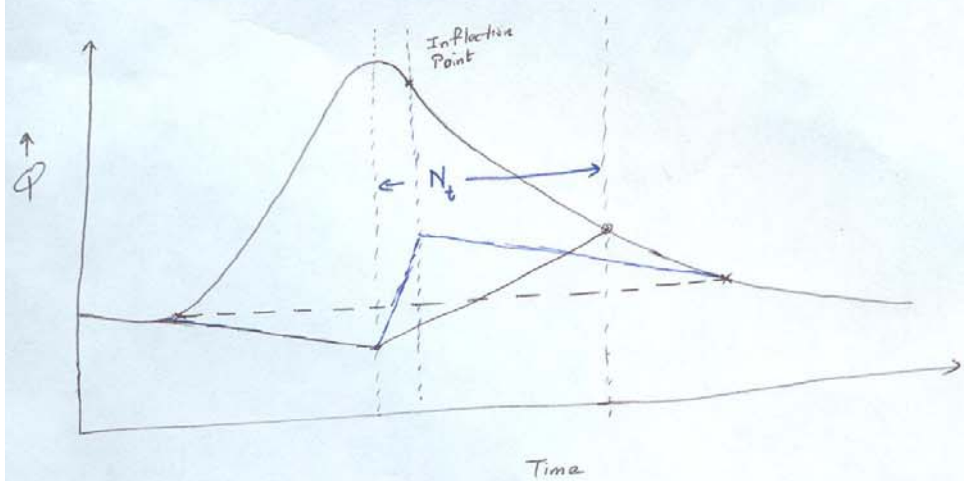
Q: So how will you separate the baseflow so you could compute direct runoff

There are various methods and still new methods are formulated (or evolved) based on extensive research.

As you have seen if you compute the area under streamflow hydrograph you will get volume of streamflow at that location.

Some crude methods to separate baseflow are:

* Straight - line method
* Fixed base length method
* Variable slope method



→ The straight - line method — draw a horizontal line from point of beginning of surface runoff to the point where it intersects the receding hydrograph curve.

→ In fixed base method, surface runoff assumed to end at a fixed time N_t after the peak. The baseflow shown as drawn in the figure. That is the same slope is maintained upto peak for baseflow and connect to time N_t from peak.

→ In variable slope method, – baseflow extrapolated to point of peak discharge. Then from the time where baseflow ceases is extrapolated backwards with same slope to the time of point of inflection.

For ~~separating baseflow~~ determining recession flow, Horton has developed

→ the normal depletion curve

→ It is also called master baseflow recession curve

→ This is obtained by super-imposing many recession curves observed on a given stream

$$Q(t) = Q_0 \, e^{-(t-t_0)/k}$$

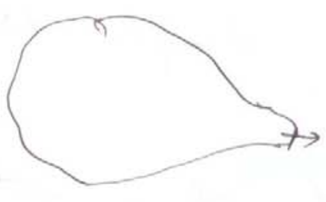
Q_0 → Flow at time t_0

k → exponential decay constant

Excess Rainfall & Direct Runoff

Excess Rainfall (Effective Rainfall) → the rainfall that is neither retained on land surface nor infiltrated into the soil.

→ That is, this effective rainfall on a watershed flows through drains and channels in the watershed to give direct runoff.



→ From your basic principle on conservation of mass

Q: What is the relation between effective rainfall and direct runoff.

→ They are same.

Excess Rainfall Hyetograph

→ Graph of excess rainfall versus time

One can obtain actual rainfall versus time graph. From that you need to find effective rainfall.

* Difference between observed total rainfall hyetograph and excess rainfall hyetograph → Abstractions.
* Mainly these abstractions (or loses) are due to infiltration, some interception and surface storage.
* You can determine effective rainfall hyetograph
  - → If streamflow data available
  - → Not available

φ - index method

→ This method is used when streamflow data is available to you for a storm.

→ φ - index is that constant rate of abstraction that will yield an excess rainfall depth = depth of direct runoff r_d over the watershed.

Say if you have the following data

Time	Rainfall (cm)	Streamflow (m^3/s)
t_0	–	Q_0
t_1	R_1	Q_1
t_2	R_2	Q_2
t_3	R_3	Q_3
⋮	⋮	⋮
t_m	R_m	Q_m
t_{m+1}	0	Q_{m+1}
⋮		⋮
t_n		Q_n

From the streamflow data,

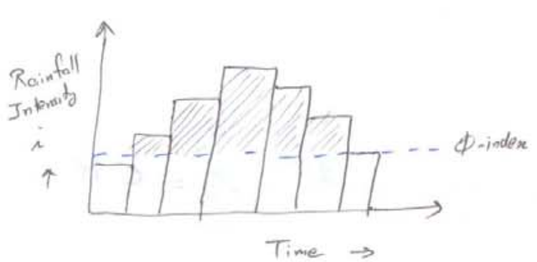
$$\text{Direct Runoff} = \text{Observed Streamflow} - \text{Baseflow}$$

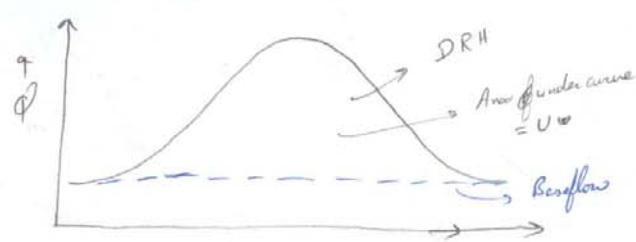
$$DRH = Q - B$$

∴ Total volume of water as direct runoff $= U = \sum_i (DRH_i \cdot \Delta t_i)$

∴ Depth of direct runoff, $r_d = \dfrac{U}{A}$

$A \rightarrow$ Watershed area





As depth of ~~diract~~ direct runoff $= r_d \rightarrow [L]$

Intensity ~~Depth~~ of rainfall $= R_i \rightarrow [L T^{-1}]$

$\therefore$ Depth of excess rainfall = depth of direct runoff

$$= r_d = \sum_{i=1}^{M} (R_i - \phi \Delta t)$$

where M is the number of intervals of rainfall that actually contribute to direct runoff.

Runoff Coefficients

→ You can also account abstractions to the actual rainfall by using runoff coefficients.

Runoff coefficient → Ratio of the peak rate of direct runoff to the average intensity of rainfall in a storm.

→ It is also defined as ratio of runoff to rainfall over a given time period.

e.g. If $R_1, R_2, R_3, \ldots, R_M$ are the total rainfall recorded and if r_d is the corresponding depth of runoff, then

$$C = \frac{r_d}{\sum_{m=1}^{M} R_m}$$

Then ~~$r_d = C$~~ you can model $\underline{r_d = C R}$

SCS Method for Abstractions

→ The Soil Conservation Service has developed methods for computing abstractions from storm rainfall.

For a storm as a whole:

(i) Depth of excess precipitation P_e ≤ the depth of actual precipitation P (i.e. $P_e \leq P$)

(ii) As the runoff begins, the additional depth of water retained in the watershed F_a is ≤ to some potential maximum retention, S. (i.e. $F_a \leq S$)

(iii) Potential excess precipitation $= P - I_a$

$I_a \rightarrow$ initial abstraction before ponding.

∴ SCS method suggest that

$$\frac{F_a}{S} = \frac{P_e}{P - I_a}$$

→ If you have total precipitation depth P

then. $P = P_e + I_a + F_a$