Run off and Hydrographs

Run off :-

Run off can be defined as the portion of the precipitation that makes its way towards rivers and oceans etc.

Run off occurs only when the rate of precipitation exceeds the rate at which water may infiltrate into the soil.

Run off can be described as the part of the water cycle that flows over land as surface water instead of being absorbed into ground water or evaporating. According to the U.S Geological Survey (USGS) runoff is that part of the precipitation, snow melt or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers.

Factors affecting Run off :-

(1) Precipitation :-

The amount of rainfall directly affects the amount of runoff. As expected if more rainfall hits the ground, more rainfall will turn into runoff. The same can be said about snowmelt. If a large amount of snow melts in a short time period, there will be a large amount of run off.

Runoff depends on the type of the storm, its duration and intensity of rainfall.

If the rainfall intensity is very less and light showers then much of the water will be lost in infiltration and evaporation resulting less runoff.

* If precipitation is in case of snow then less runoff-

(2) Size and shape of the catchment area:-

runoff depends upon size, shape and location of the catchment.

Generally more rainfall on smaller area resulting in greater runoff.

In case of elongated catchment, more will be infiltration losses and less will be the runoff-

(3) Permeability :-

The ability of the ground surface to absorb water will affect how much surface runoff occurs - If you have ever poured water onto sand, you may have noticed it sinks into the sand almost instantaneously.

on the other hand, if you pour water on the street, the water will not sink but runoff to the gutter- The less water the ground can absorb, the more runoff on the surface-

(4) Vegetation:-

Vegetation needs water to survie and plant's root system is designed to absorb water from the soil. There is less runoff in highly vegetated areas because the water is used by the plants instead of flowing off the surface of the ground.

(5) Slope:-

If the slope is steep, flow will be quick and less evaporation and absorption resulting greater runoff.

(6) Meteorological characteristics:-

Runoff may also be affected by temperature, wind and humidity.

If the temperature is low and ground is saturated then runoff will be greater.

If temperature is high and greater windvelocity give rise to greater evaporation loss and resulting in less runoff.

Estimation of Quantity of Storm water:-

1- Rational Method
2- Empirical formulae Method.

In both the above methods, the quantity of storm water is considered as function of intensity of rainfall, Coefficient of runoff and area of Catchment.

1- Rational Method:-

Storm water quantity can be estimated by rational method as below:-

Storm water quantity $Q = \frac{C.I.A}{360}$

Where Q = Quantity of storm water m^3/sec
C = Coefficient of runoff
I = intensity of rainfall (mm/hour)
A = Drainage area in hectares.

or $Q = 0.278\ CIA$

Q is $\frac{m^3}{sec}$ $I = \frac{mm}{hour}$ $A = Km^2$

2- Empirical Formulae:-

Empirical formulae are used for determination of runoff from very large area.

A - Burkli-Zeiglar Formula $Q = \frac{CIA}{141.58}\sqrt[4]{S/A}$

B - Mc Math Formula (used in USA) $Q = \frac{CIA}{148.35}\sqrt[5]{S/A}$

C - Fuller's Formula $Q = \frac{CM^{0.8}}{13.23}$

Where S - slope of the area in meter per thousand meter.

M - drainage are in sq-km

A - Area of drainage area in hectare.

Run off coefficient:-

The runoff coefficient can be defined as a fraction, which is multiplied with the quantity of total rainfall to determine the quantity of rain water, which will reach the sewers.

The runoff coefficient depends upon the porosity of soil cover, wetness and ground cover. The over all runoff coefficient for the catchment area can be worked out as follows:

Over all runoff coefficient $C = \frac{A_1C_1 + A_2C_2 + \cdots A_nC_n}{A_1 + A_2 + A_3 \cdots A_n}$

where $A_1, A_2, \cdots A_n$ are types of Area

$C_1, C_2 \cdots C_n$ as their coefficient of runoff

The typical runoff coefficient for the different ground cover is provided in table below

Type of cover	Coefficient of runoff
Business area	0.70 — 0.90
Apartment area	0.50 — 0.70
Single family area	0.30 — 0.50
Parks, play grounds, lawns	0.10 — 0.25
Paved streets	0.80 — 0.90
Water tight roofs	0.70 — 0.95.

Hydrograph:-

When a storm occurs it contributes to the stream-flow. Various instruments are used to document storm characteristics. For example rain gauges are used to record period and depth of rainfall, current meter is used to find discharge in streams etc. The data thus collected is analyzed for its beneficial use. The stream flow characteristics are analyzed by what is called hydrograph analysis.

"The graphical relation b/w any hydrological quantity (stage, velocity, discharge etc) and the time is known as a hydrograph.

Types of Hydrographs:-

Hydrographs are of three types.

(a) **Discharge Hydrograph:-**

It is the graphical representation of discharge against time.

(b) **Stage hydrograph:-**

It is the graphical representation of stage against time. Stage hydrograph is useful only for the design of flood protection works like embankment.

(c) Velocity hydrograph :-

It is the graphical representation of velocity against time.

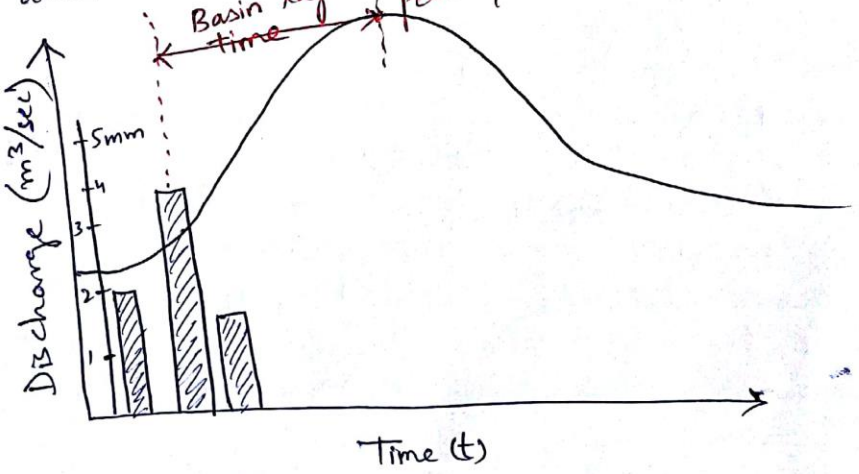
Effective Rainfall :-

As discussed under hydrologic cycle, all of the rain usually does not go into the stream but a certain part of it reaches the stream and cause rise in the stream flow while the remaining part of rain is accounted for in various forms of precipitation losses. The portion of rainfall which contributes to stream flow is called effective rainfall.

Basin lag or time lag :-

The time difference b/w the peak of the rain event and the peak discharge is known as the lag time or basin lag.

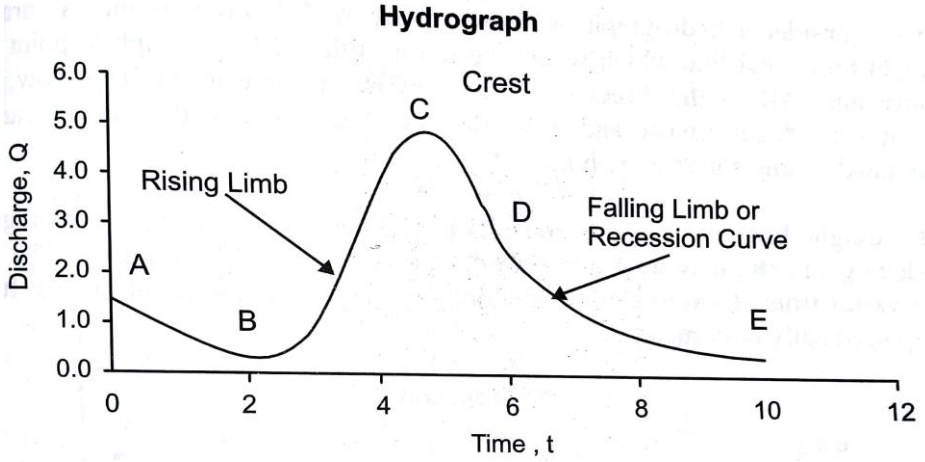
The time difference b/w the centre mass of the rain fall and the centre of the mass of the hydrograph



Parts of hydrograph:- (Characteristics of hydrograph)

A hydrograph consists of three parts

(a) the rising limb "BC"
(b) The crest or peak "C"
(c) The falling limb or Recession Curve CDE



* The shape of the rising limb depends upon the storm characteristics which are the duration of rainfall, intensity of rainfall, areal distribution of the rainfall etc.
* The crest segment is controlled by the storm characteristics and distribution of the streams in the area, which further depend upon geological structure of the area.
* The falling limb depends upon the control on storage release.

Hydrograph Analysis:-

Seperation of hydrograph Components:-

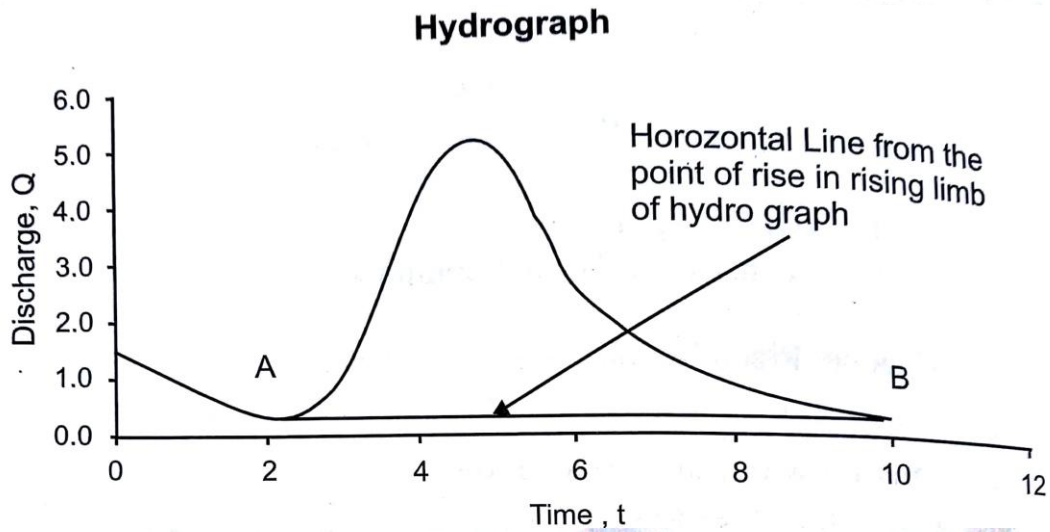
Hydrograph Analysis means dividing total runoff indicated by the hydrograph into its components of which direct runoff (DRO) and Base flow are more important.

The seperation of hydrograph components is done by one of the following three methods:-

(a) Straight Line Method:-

Let us consider a hydrograph as shown in figure from point "A" draw a straight horizontal line which meets the falling limb of hydrograph at point "B". Above line "AB" is the direct runoff (DRO) and below the line is the base flow.

* The volumes of direct runoff and base flow can be calculated by any suitable method.



(b) fixed Base length Method :-

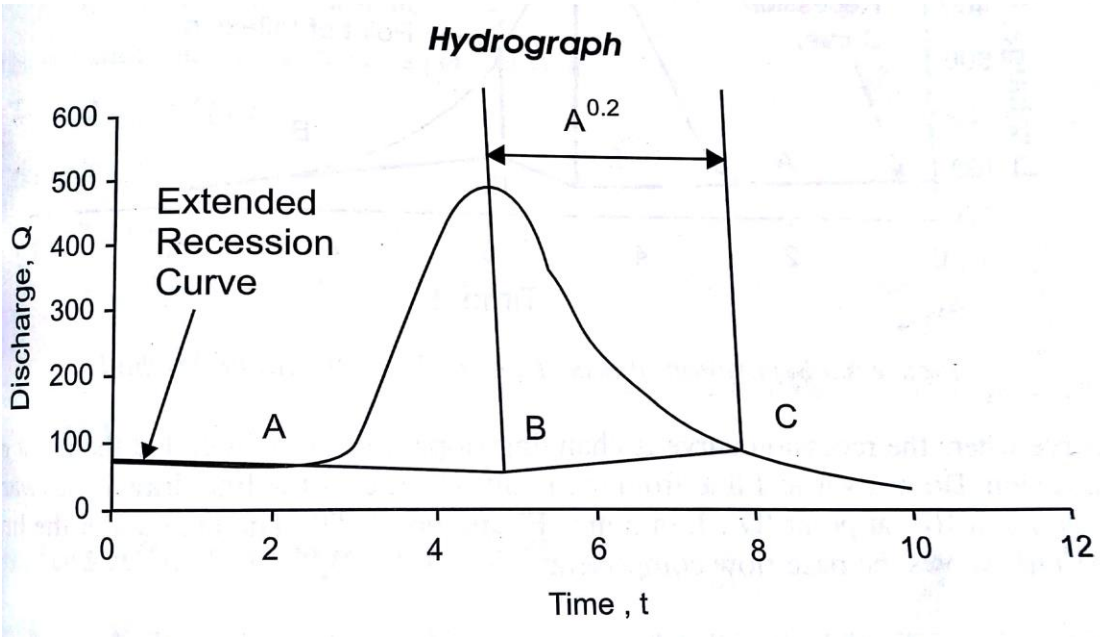
let us we have the hydrograph shown in figure, from point "A" extend the line to point "B" which is vertically below the peak - Now draw a line from point B to C on the hydrograph equal to a distance on X axis given by equation below :-

$$N = A_d^{0.2}$$

where N = length of time in days

A_d = Drainage area in Square miles.

This line will meet the falling limb at point "C". Joint point B to C by line BC - Area below ABC is the base flow and that above it is the direct runoff.



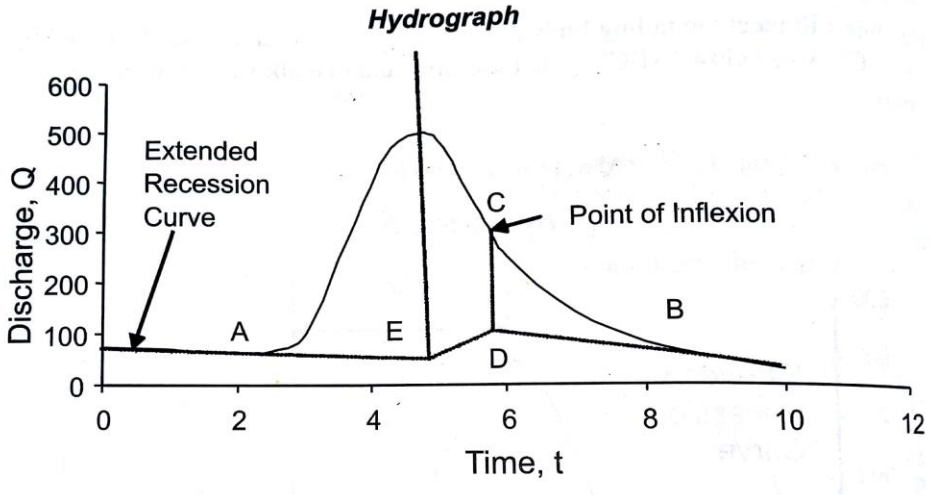
(C) Variable Slope Method :-

Take a point A on the previous recession curve and the line in AE as previously alone. Point E is under the peak - Now take a point "B" on the recession curve and extend it backward Take a point "C" on curve where curve is changing slope, this point is called "point of Inflexion"

" The inflection point on the falling limb is also can be assumed to be the point where (DRO) direct runoff ends".

Draw a vertical line from the point "C" - It cut the line drawn back ward from point B at point "D" - Joint point "E" and point "D" - The area under the line "AEDB" shows the base flow component.

* This Method is not a well defined one - It depends upon experience, so it may vary from one expert to another -



* In general straight line Method is the simplest and easiest but also the least accurate.
* Fixed Base Method is widely used and gives practically good results.
* Whereas variable slope Method is not commonly used and is difficult but can give better depending upon the expertise of the person using it.

Important terms:-

Rising limb is the part of the hydrograph b/w where it begin to rise and then reaches to peak.

Recession Curve:- The recession limb or recession Curve is the part of the hydrograph b/w the peak flow and where the flow returns to relatively steady-state.

Inflection Point or inflexion point:-

It is the point on the recession curve of the hydrograph where the slope of graph begins to decline or changes.

Removing Baseflow from the Hydrograph

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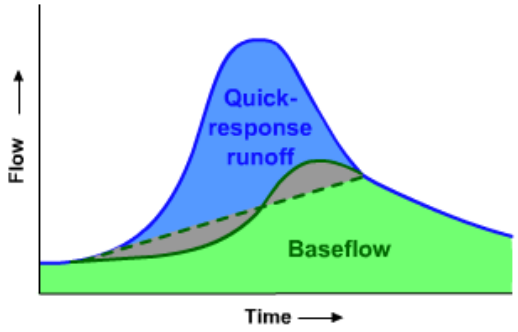
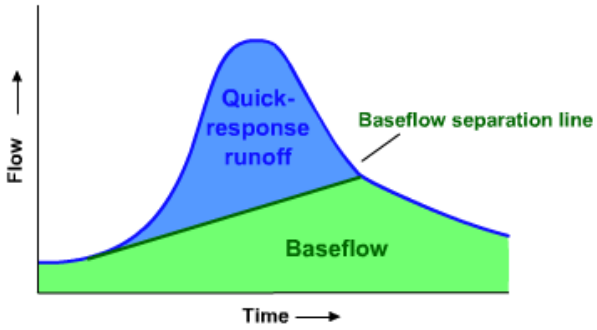
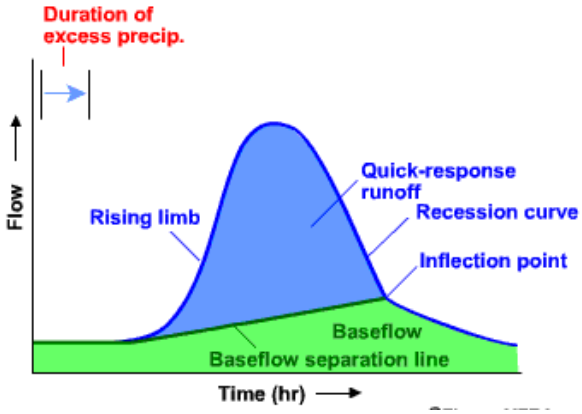
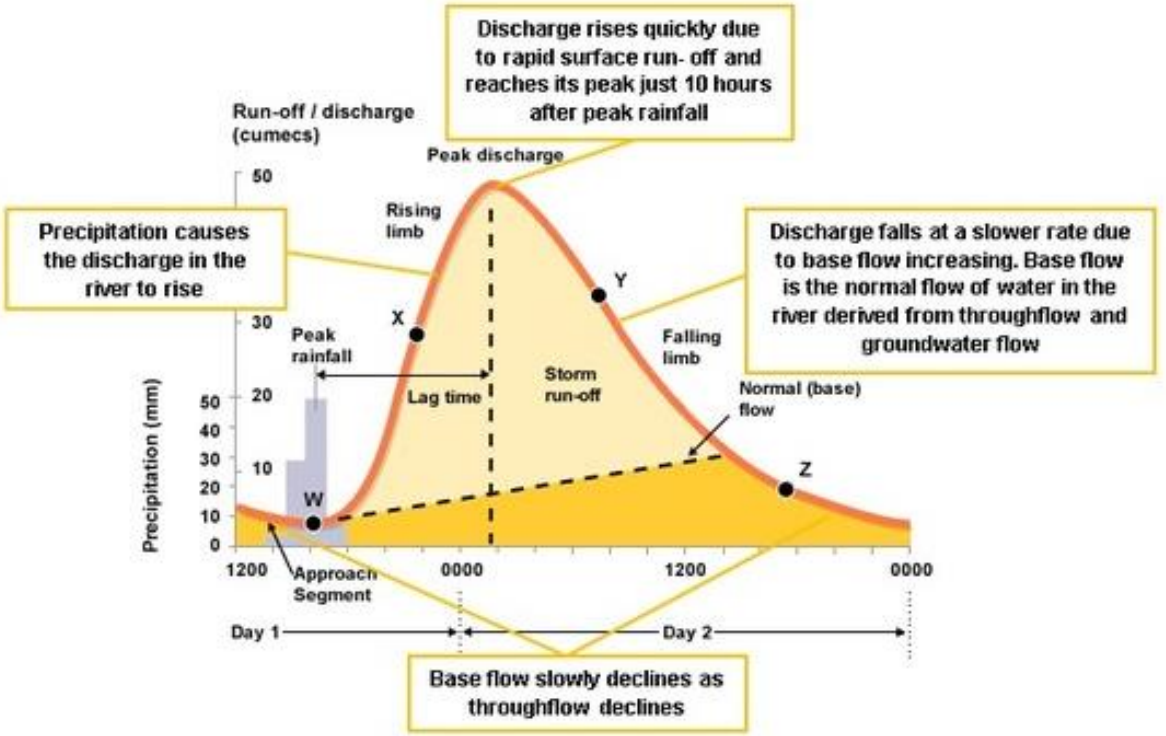


Removing Baseflow from the Hydrograph







Components of hydrograph:-

A hydrograph normally consist of the four components.

i — Channel precipitation.
ii — Direct runoff (DRO)
iii — Inter Flow or Sub-Surface flow
iv — Ground or Base flow.

Factors affecting hydrograph shape:-

Hydrograph shape depends on climatic and catchment characteristics. Among the climatic characteristics the most important are the rainfall intensity, duration and weather.

Among the catchment characteristises the topography and geological conditions are more important. These are given below:-

A. Storm Characteristics.
   (a) intensity of rainfall
   (b) Duration of rainfall.
   (c) weather

B. Catchment Characteristics.
   (a) Size of Catchment
   (b) Shape of the catchment area.
   (c) Elevation of the catchment.
   (d) Slope of catchment.

S curve or S Hydrograph :-

* "S" hydrograph is nothing but a hydrograph generated by a continous effective rainfall occuring at an uniform rate for an indefinite period.
* It is called "S" hydrograph because the shape of the hydrograph comes out like alphabet "S".
  Figure shows a typical "S" hydrograph.
* It can be derived by summation of the ordinates of an infinite series of unit hydrographs of same unit duration spaced at the same unit duration apart and hence the name summation hydrograph.
* It is a curve which rises continously in the form or shape of the letter S, till a constant discharge value i.e. equilibrium is reached.

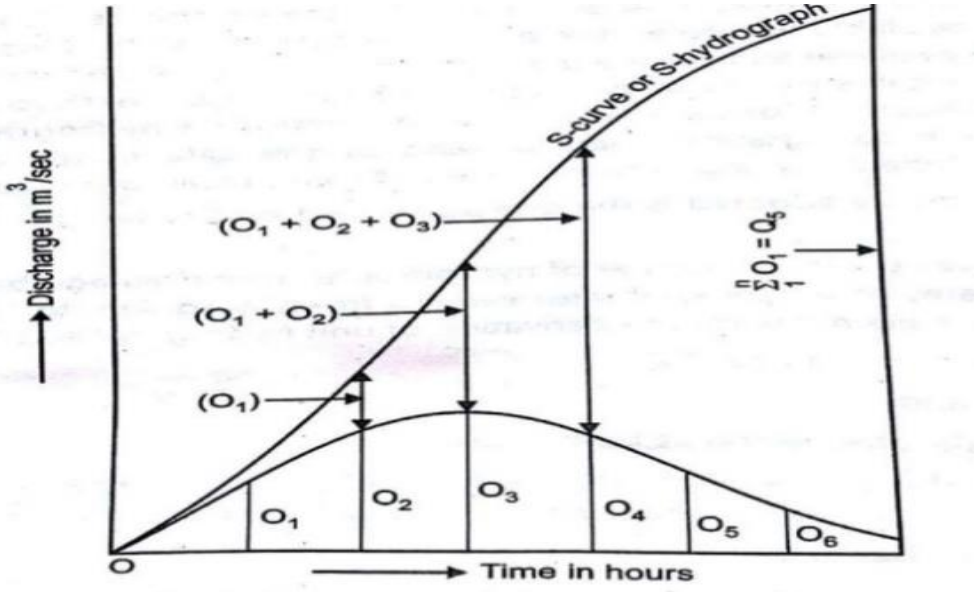


Fig. 9.13 : S-curve or S-hydrograph

Unit hydrograph:-

A unit hydrograph is defined as the hydrograph of direct run off resulting from one unit depth (1cm or 1 inch or 1mm) of rainfall occurring uniformly over the basin and at a uniform rate for a Specified duration (D) hours.

For example if one inch of excess rainfall produces a direct run off peak of 100 cfs then two inch of excess rainfall will produce a direct run off of $2 \times 100 = 200$ cfs.

"The unit hydrograph may be defined as the direct runoff (out flow) hydrograph resulting from one unit of effective rainfall, which is uniformly distributed over the basin at a uniform rate during a Specified Period of time Know as unit time or unit duration."

* Effective rainfall should be uniformly distributed over the basin i.e. if there are five rain gauges in the basin, which represents the areal distribution of rainfall over the basin, all the five rain guages Should record for almost Same amount of rainfall during specified time.
* In addition, effective rainfall should be at a uniform rate during the unit duration. If the average rainfall over a particular basing during 6hour

is 126 mm, a unit hydrograph of 6 hours duration can be derived only if the intensity of rain fall is more or less 21 mm/hour $\left(\frac{126\text{ mm}}{6\text{ hour}}\right)$ over 6 hour.