UNIT-III

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RUNOFF

Runoff :- The term runoff is used for water that is on the 'run' (or) in a flowing state, in contrast to the water held in depression storage and water evaporated in the atmosphere.

The runoff of a catchment area in any specified period in the total quantity of water draining into a stream (or) into reservoir in that period.

This can be expressed as....

(i) Centimetres of water over a catchment.

(ii) Total water in cubic-meter (or) hectare-meters for given catchment.

Runoff is broadly classified into three types....

(i) Surface runoff
(ii) Sub-Surface runoff
} → Direct runoff.

(iii) Base flow.

Direct runoff :- Direct runoff is that water which reaches the stream shortly after it falls as rain.

Surface runoff :- The portion of water which travels across the ground surface to the nearest stream.

Sub-surface runoff :- It is only in permeable soil.

Base flow :- If the sub-soil is also permeable, water percolation deep downwards to meet the ground water.

* The total area of the basin is known as the catchment area.

Stream :- Stream is a natural flow channel towards which the water from a basin flows.

[The stream drains out the water so collected, into a large water body].

Over land flow :- It is the portion of rain water which flows over the land surface in the form of sheet of water to join the nearest stream.

Surface runoff :- It is the part of precipitation and other drainage water of a basin which moves over the natural land surface and then through a network of channels of gradually large sections.

Stream flow :- The total runoff consists of surface flow, sub-surface flow, ground water flow, and the flow due to precipitation falling on the stream.

Drainage density :- (D_d)

The ratio of the total length of all streams of the catchment divided by its area.

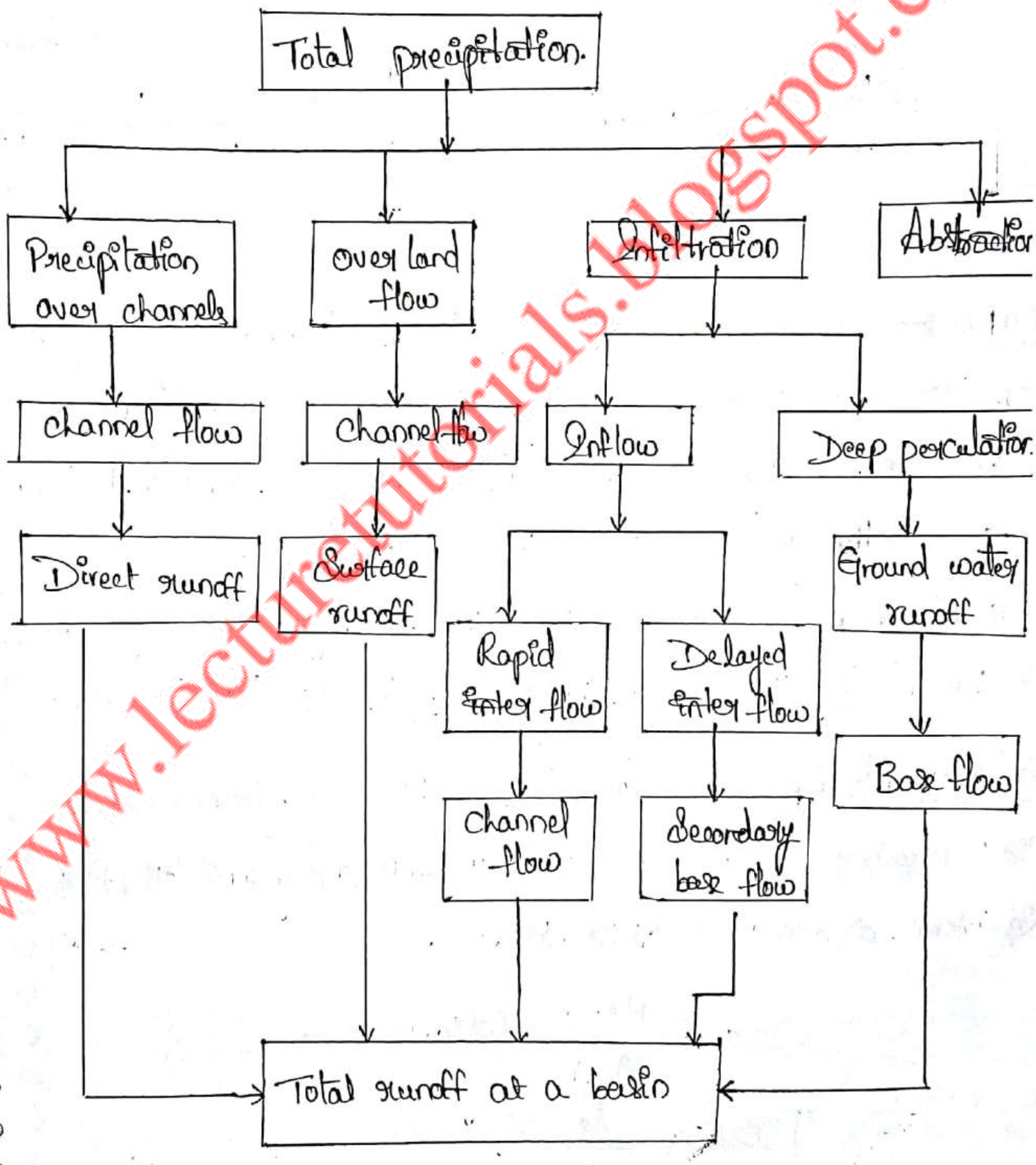
$$\boxed{\therefore D_d = \frac{L_s}{A}}$$

K. Kiran

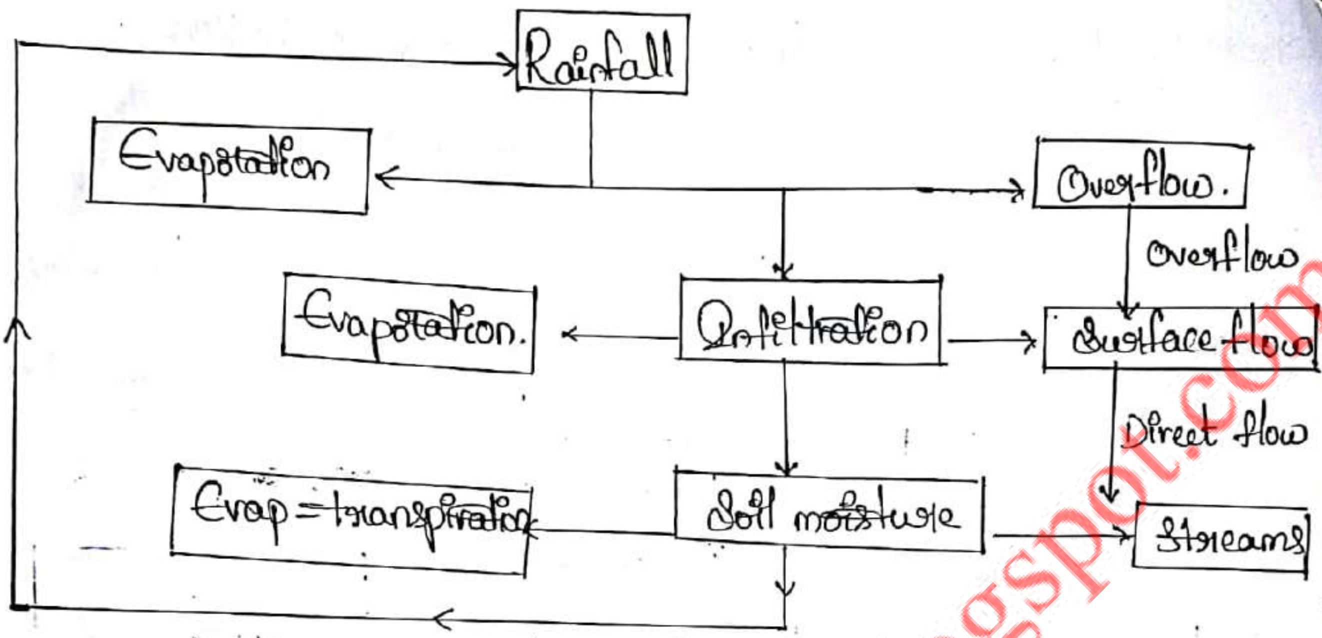
where ; L_s = Total length of all streams in a basin,

A = drainage area of the basin.

Representation of runoff process :-



Forms of runoff in Hydrology cycle :-



Basin :- A basin, also called a drainage basin, catchment (or) watershed is the area where precipitated water is collected by surface and sub-surface flows and drained out through a natural stream (or) river.

* Drainage density indicates the drainage efficiency of the basin — the higher the value, the quicker the runoff.

Stream density :- Stream density (D_s) is defined as the number (N_s) of the streams of given order per sq. km of the catchment area.

$$D_s = \frac{N_s}{A} \quad \text{(or)}$$

$$\times\left[\cancel{D_s \neq \frac{L_s}{A}}\right]\times$$

Form factor :- The ratio of the watershed area (A) to the square of its length (L^2)

K. Sridhar

$$F_f = \frac{A}{L^2} \quad (or) \quad F_f = \frac{W_b}{L_b}.$$

Compactness Coefficient :- The ratio of the perimeter of the basin to the circumference of a circle whose area is the area of the basin.

$$C_c = \frac{P}{\sqrt{4\pi A}}.$$

where ;

P = Perimeter of the basin in Km.

A = Area of the basin in Squ. Km.

Elongation ratio (E_r) :- It is defined as the dia of a circle of the same area of the basin to the max. length of the basin.

$$\therefore E_r = \frac{1}{L}\sqrt{\frac{A}{0.786}} \leq 1.$$

Circular ratio (C_r) :- It is defined as the area of the basin to the area of circle having same perimeter.

$$\therefore C_r = 12.57 \frac{A}{P^2} \leq 1$$

Factors affecting run-off :-

There are different types of factors affecting on runoff.....

1. Precipitation characteristics.
2. Shape and size of the catchment.
3. Topography of catchment.
4. Geology characteristics of basin.
5. Meteorological characteristics.
6. Character of the catchment surface.
7. Storage characteristics of the catchment.

1. Precipitation characteristics :-

Precipitation characteristics are.....

(i) Intensity. (ii) Duration. (iii) Areal distribution.
(iv) Direction of storm movement. (v) form of precipitation.
(vi) Evapo-transpiration.

* The more the rainfall, more will be the run-off.
* Runoff depends on the type of the storm causing precipitation and also upon its duration.
* Runoff also increases with the intensity of rainfall runoff also increases with the extent of the storm over the catchment. If the rainfall intensity is very less, and it rains as light showers, much of the water will be lost in infiltration and evaporation etc. and the run-off will be less great evapo-transpiration will result in lesser runoff.

3 If the precipitation is in the form of snow (or) if water freezes as it falls, it will be retained in the catchment till temperature increases. thus run-off will be less.

k.s.r.

& Shape and size of the catchment :-

The run-off from a catchment also depends upon the size, shape & location of the catchment.

* More intense rainfall are generally distributed over relatively smaller area: a stream collecting water from a small catchment area is likely to give great runoff intensity per unit area. In the case of very big catchment, uniform rain seldom falls over the entire area, with the result that only very few tributaries of the stream feed water to main stream during a particular storm. thus runoff intensity of larger stream, per unit catchment area is lesser.

* In case of shapes fan shaped catchment all the tributaries are approximately of same size, such catchment gives greater runoff since, the peak flood from the tributaries is likely to reach the main stream approximately at the same time.

* In case of fern leaf catchment, the tributaries are generally at different lengths, and meet the main stream at the regular intervals. In such a narrow catchment, the peak flood intensity is reduced since, discharges are likely to be distributed over a long period of time.

4. Geological characteristics of basin :- these include the type of surface soil and sub-soil, type of rock and their permeability characteristics. If the soil and sub-soil is pervious, seepage will be more and this in turn reduces the peak flood. If the surface is rocky, the absorption will be practically nil and runoff will be more.

5. Meteorological characteristics :- Temperature, wind and humidity also affect the runoff.

* If the temperature is low and the ground is saturated and frozen, it gives rise to greater run-off. However, if the whole of the stream freezes, the peak floods will be reduced.

On the other hand, high temperature and greater wind velocity give rise to greater evaporation loss and reduce the run-off.

6. Character of the catchment surface :- the runoff also depends upon the surface conditions - whether the surface is drained (or) un-drained, natural (or) cultivated, and whether it is bare (or) covered with vegetation etc.

* If surface has no natural drainage, absorption

..ss will be more.

* If more area of a catchment is cultivated surface runoff will be less.

* The presence of vegetal cover reduce the run-off specially during smaller storms. However for a bigger storm after the vegetal cover gets saturated, water runs from the surface. for freely as if there was no vegetation.

7. Storage characteristics of the catchment :- the artificial storage. such as dams, weirs etc and natural storage. such as lakes, ponds etc. tends to reduce the peak flo

Computation of run-off :-

The run-off from a catchment can be computed daily, monthly (or) yearly. Following are some of the methods of estimation the run-off

* By linear (or) exponential regression.
* By empirical equations and tables.
* By infiltration method.
* By unit hydrograph.
* By Rational method.
* By SCS method.

* By linear (or) exponential regression :- Relation between runoff and precipitation.

Straight-line regression → for small & medium size catchment

Exponential regression → for large catchment.

→ Straight line regression between P & R:-

$$\boxed{R = ap + b}$$

where:

a & b are constants representing abstractions.

$$a = \frac{N(\Sigma P \cdot R) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P^2)}$$

$$b = \frac{\Sigma R - a\Sigma P}{N}$$

→ Exponential regression between P and R:-

For large catchment, it is advantageous to use the following exponential relationship.

$$\boxed{R = \beta P^m}$$

where: β and m are constants.

Taking logarithms on both sides, we get,

$$\log_e R = m \log_e P + \log_e \beta$$

ii) Runoff by empirical formulae and tables:-

→ Runoff Coefficient :-

$$\boxed{R = kP}$$

where: R = runoff in cm.

P = rainfall in cm.

k = run-off coefficient.

The runoff coefficient naturally depends upon all the factors which affect the runoff.

1. Runoff Coefficient:-

$$R = K \cdot P$$

for "K" values.....

Urban residential → single houses — 0.3

Garden Appartment — 0.5

Commercial & industrial — 0.9

Forest area — 0.05 to 0.2.

Concrete pavement — 0.85.

iii) Run-off by infiltration Methods:-

Infiltration is defined as the movement of water through the soil surface and into the soil.

Infiltration capacity :-

The capacity of any soil to absorb water from rainfall falling continously at an excessive rate goes on decreasing with time, until a minimum rate to infilt-ration is reached.

Infiltration index :-

It is the avg rate of loss such that the volum of Rainfall in excess of that rate will be equal to the direct runoff.

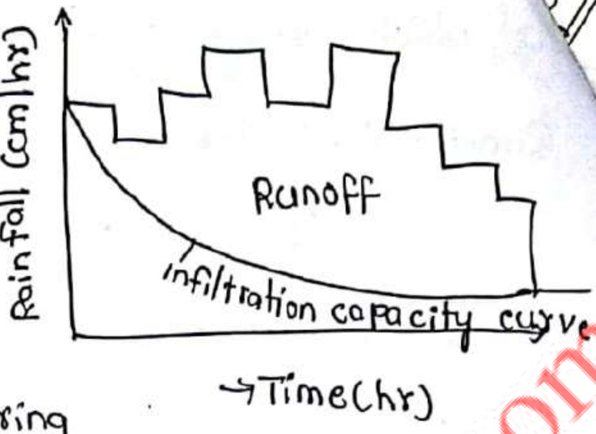
There are two types of infiltration indices

i) Avg. infiltration rate (or) W-index

ii) ϕ-index

$$W_i = \frac{P - R - I_a}{t_i}$$

$$\phi_i = \frac{P - R}{t_e}$$

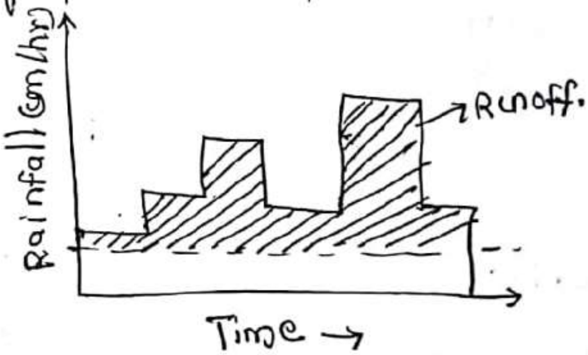


ϕ_i = Total infiltration during Period of rainfall excess.

Rainfall, $R = \Sigma (i - \phi_i) t$.

Effective rainfall hyetograph (ERH) :-

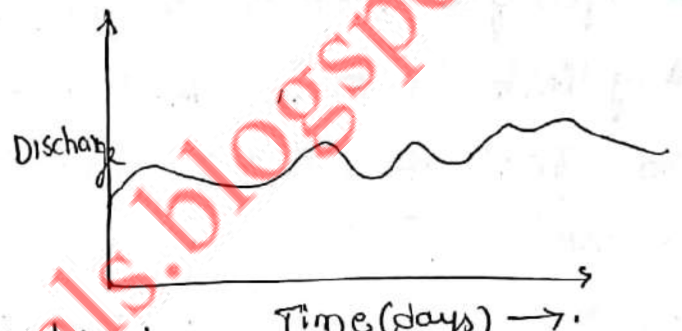
A hyetograph is a plot of the intensity of rainfall against the time interval & it is represented as a bar chart. If this hyetograph is prunned by deducting losses, the resulting hyetograph is known as "Effective rainfall hyetograph (or) hyetograph of rainfall excess.



Hydrograph Analysis

A hydrograph is a graph showing variations of discharge with time, at a particular point of stream. It shows the time distribution of total runoff at the point of measurement.

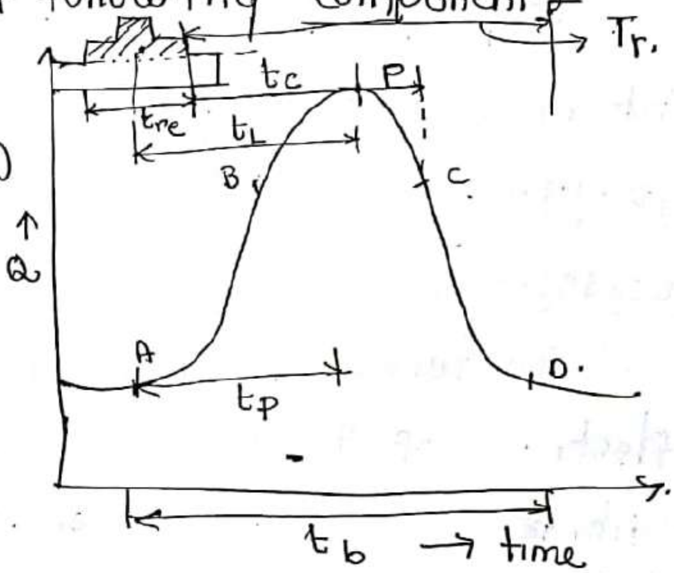
A hydrograph is generated from runoff due to precipitation resulting from either an isolated storm (or a series of consective storms. It is also known as storm hydrograph.



Components of a single peaked hydrograph :-

The hydrograph consists of following components

1. Rising limb (AB)
2. Crest / Peak element (BC)
3. Recession limb (CD)



Rising limb :-

A rising limb (AB) is the ascending portion of the hydrograph corresponding the increasing of discharge due to gradual formation of channels existing in the area. This is also known as concentration curve.

As the time increases, the initial losses stop & the infiltration rate also decreases. Point 'A' is the starting point while 'B' is the point of inflection. The rising limb shape is controlled by the characteristics of basin & duration, intensity & uniformity of rain.

recession be

Peak (or) crest segment :-

The peak or crest segement includes the part of the hydrograph from the inflection point (B) on the rising limb to an inflection point (C) on the recession limb. The peak represents the arrival of flow at the outlet from all parts of the basin. The peak may be sharp (or) flat depending upon the rainfall catchment characterstics.

The point of inflection represent the change point of contribution of the catchment to the channel system.

Recession limb :-

The recession limb extends from the point of inflection of the crest segment to the point 'D', the point of commencement of the natural ground water flow. The recession limb indicates the storage contribution from surface storage, inter flow & ground water flow. The Recession curve can be considered as a rate of discharge resulting form be draining off process. The equation of the recession curve may be expressed as

$$Q_{rt} = Q_{ro}\, k_r^{\,t}.$$

where Q_{rt} = Discharge at any time interval 't'

Q_{ro} = Discharge at the point of inflection

k_r^t = recession constant.

* The recession constant k_r^t is composed of all the three components & is given by

$$K_r^t = K_{rs} \cdot K_{ri} \cdot K_{rg}$$

K_{rs} = recession constant for surface storage
= 0.08 to 0.4

K_{ri} = recession constant for interflow
= 0.5 to 0.9

K_{rg} = recession constant for ground water flow
= 0.9 to 1.

Time parameters used in hydrograph analysis:

Effective time duration (t_{re}) :-

It is the net duration of precipitation during which rainfall rates are more than infiltration rate.

Lag time (or) Basin lag (t_L) :-

It is the time interval between the centre of mass of net rainfall & centre of mass of runoff hydrograph.

Time to peak (t_p) :-

It is the time interval between the starting of the rising limb to the peak of the hydrograph.

Time of concentration (t_c) :-

It is taken as the time from the end of the net rainfall to the point of inflection of the falling limb of the hydrograph. According to kirpich

$$t_c = \frac{0.000323\, L^{0.77}}{S^{0.385}}.$$

L = maximum length of travel of water

S = slope of the channel $= \frac{H}{L}$

Recession time (T_r) :-

It is the difference in time between the end of effective rainfall & lowest point (D) of the recession limb.

Time base of hydrograph (T_b) :-

The time from the begining point to the end point of the direct run off.

Separation of Base flow :-

separation of Base flow & direct run off in a single peaked storm hydrograph are done by using following.

i. straight line method.
ii. Two lines method.
iii. curves extension method.

An empirical equation for the time interval N from the peak (P) to the point D is given by

$$N = 0.827 A^{0.2}$$

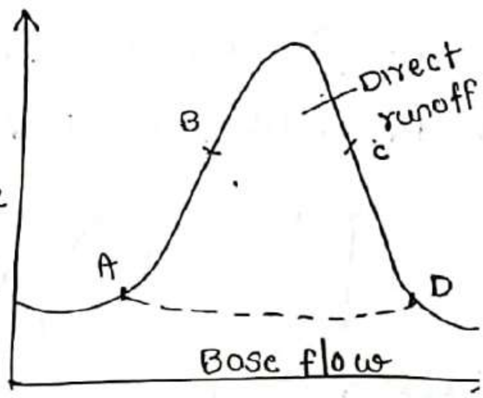
A = area of drainage Basin. in km^2

$$N = a t_p.$$

t_p = time to peak
a = constant whose value may be taken b/n
2 to 4 — small basins
4 — large basins.

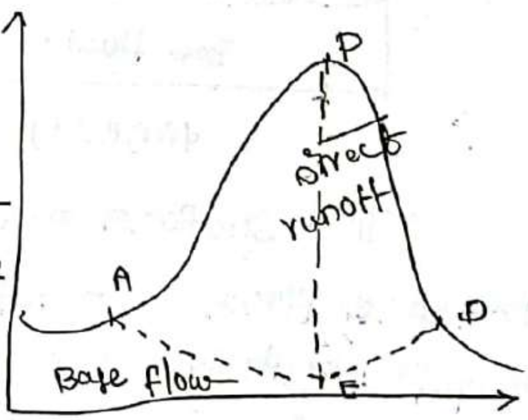
straight line method :-

The two points A & D which marks the beginning & end of direct runoff. In the straight line method, points A & D are joined by a straight line AD. This is the simplest method of separation.



Two lines method :-

This is most widely used method in which the base flow is separated from direct runoff by two lines.

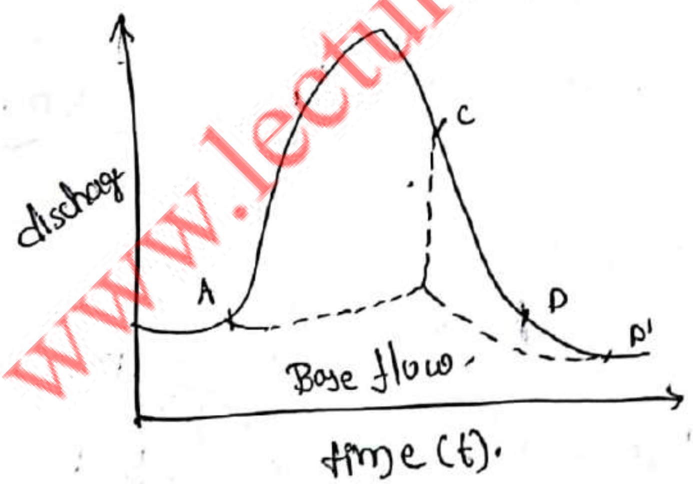


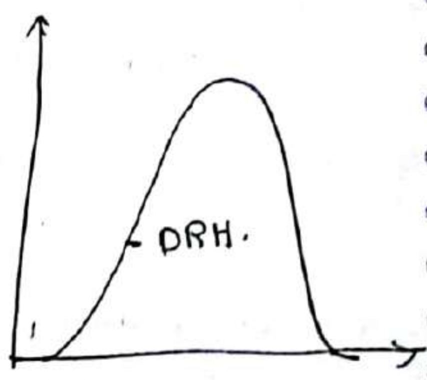
The first line AE is obtained by extending the base flow curve, till it intersects a vertical line drawn from the peak in a point E.

Point E & point D are joined by a st. line the segements marked by two line AE & ED demarcate the base flow & direct runoff.

<u>curves extension method</u> :-

This method consisting of extending the base flow curve on recession side backward till it intersects a vertical line through the point of inflection (C), in point F. Thus D'F is the curve extended backwards. Points A & F are then joined by an arbitary smooth curve. This method is preferred where the stream & ground water table hydraulically connected & flow from G.W.





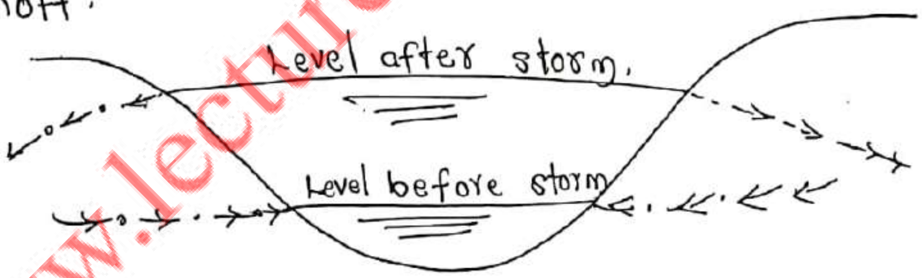
The surface run off hydrograph obtained after the base flow separation is known as direct runoff hydrograph (DRH).

Actual Base flow (or) depletion curve :-

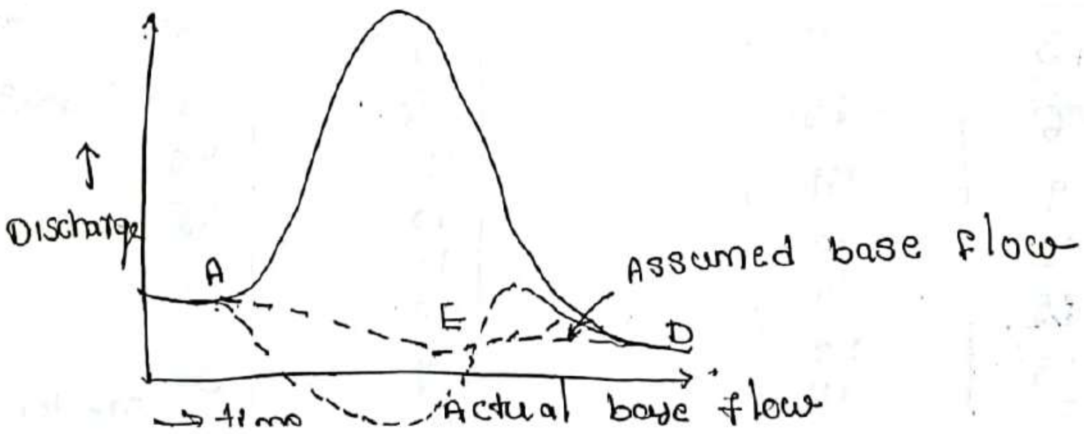
The base flow or Depletion curve 'AED' are, theoretical & may not represent actual conditions at the site. Actual contribution of ground water is shown by dotted line.

when the water level before the storm is low there is a flow from ground water to the stream But as the water level in the stream raised due to storm, there is a flow from the stream to the ground water.

As the flood level in the stream recedes, the ground water again starts contributing to the stream. 'AED' denotes the ground water line only if there were no flood. since the ground water contribution is very small & Above AED denotes the direct runoff.



stages in stream before & after storm.



Computation of Direct runoff or Rainfall Excess from storm Hydrograph :-

1. Find ordinates of storm hydrograph, representing total discharge 'Q' at a time interval, say 't' hrs.
2. Seperate the ground water flow, Find the ordinates of the base flow at the same time interval.
3. Find the ordinates of direct runoff by subtracting the ordinates of base flow from total discharge ordinates.
4. Direct run off = $\frac{\text{Total volume of direct runoff}}{\text{Area of basin}}$

$$= \left[\frac{(\Sigma O)\, t \times 60 \times 60}{A \times 10^6}\right] 100$$

$$= 0.36 \frac{(\Sigma O)\, t}{A} \text{ cm.}$$

where, A = Area of basin in km²

t = Time interval b/n two ordinates in hrs

ΣO = Sum of discharge ordinates.

Eg:-

Date & time		ordinates of hydrograph	Base flow	Direct runoff (O).
21/07	3	14	14	0
	6	25	12	13
	9	51	11	40
	12	65	10	55
	15	54	11	43
	18	28	13	15
	21	14	14	0
				ΣO = 166

Direct runoff $= \frac{0.36\,(80)\,t}{A}$ $[A = 30\,km^2]$.

$= \frac{0.36\,(166)\,3}{30} = 5.98\,cm$.

unit hydrograph :-

A unit hydrograph is a hydrograph representing "1cm" of run off from a rainfall of some unit duration and specific areal distribution

unit duration refers to the duration of a runoff producing rainfall excess, that results in a unit hydrograph

If a unit hydrograph results from a 3 hours unit rainfall duration, it is known as a 3-hrs unit hydrograph, meaning there by a hydrograph produced by surface run off from a storm lasting for 3hrs & yielding rainfall excess of '1cm'.

sherman suggested the following values of unit time duration are.

Area of Basin	unit time duration (hrs)
> 2500 km^2	12 to 24
250 – 2500 km^2	6, 8 (or) 12
50 – 250 km^2	2
Small areas	1/3 (or) 1/4 of time of concentration.

Assumptions of U.H :-

1. The effective rainfall is uniformly distributed with its duration of specified period of time.
2. The effective rainfall is uniformly distributed throughout the whole area of drainage basin.
3. The base / time duration of the hydrograph of direct runoff due to an effective rainfall of unit duration is constant.
4. The ordinates of direct runoff of common base time are directly proportional to the amount of direct runoff represented by each hydrograph.
5. For a given drainage basin the hydrograph of runoff due to a given period of rainfall reflects all the combined physical characterstics of the basin.

Construction of unit hydrograph :-

The following are the steps for constructing a unit hydrograph of some unit duration from a storm hydrograph of the same unit duration.

1. From the past records, select some unit period of intense rainfall duration corresponding to an isolated storm uniformly distributed over the area.
2. From the past records of the river discharge for that storm, plot the storm hydrograph for some days before & after the period of rainfall of that duration.

3. By using the method, separate the ground water flow from the direct runoff.

4. Subtracting the ordinates of base flow from the total ordinates, find the ordinates of direct runoff

5. calculate direct runoff by using.

$$n = 0.36 \frac{(\Sigma o)\, t}{A} \text{ cm}.$$

6. calculate the ordinates of unit hydrograph by the relation.

$$\text{ordinate of unit hydrograph} = \frac{\text{ordinate of direct runoff}}{\text{Direct runoff in cm}}$$

S-Hydrograph (Summation Hydrograph) :-

S-hydrograph (or) S-curve is a hydrograph that is produced by a continous effective rainfall at a constant rate for indenfinite period. It is a continous rising curve, in the form of letter 's', till equilibrium is reached.

At the time of equilibrium, the S-curve will represen have constant rate of eff. rainfall (R_0) cm/hr.

At the time of equilibrium, discharge is given by

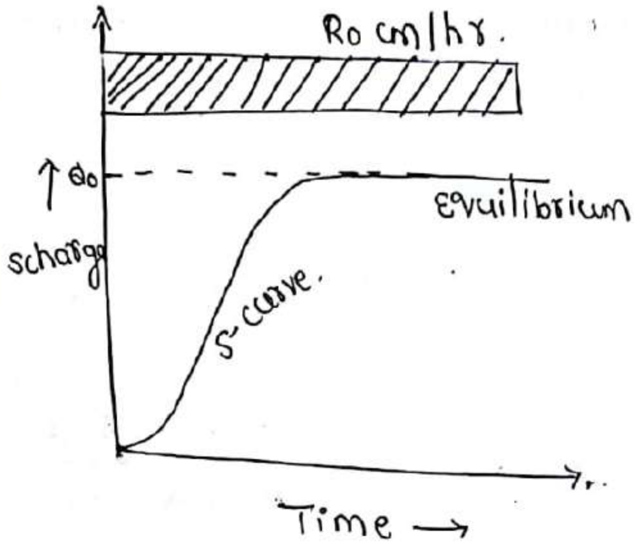
$$Q_0 = \frac{(A \times 100 \times 100)\, R_0}{100 \times 3600} = \frac{A R_0}{36} \text{ cumecs}$$

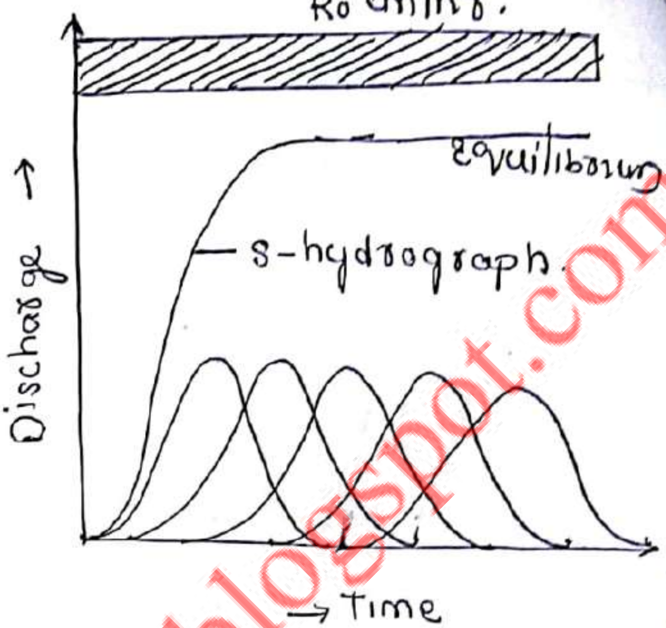
A = Area of catchment in hectares.

If Area is in Km^2, then $Q_0 = 2.778\, A\, R_0$ cumecs

R_0 = constant rate of Eff. rainfall $= \frac{1}{T_0}$ cm/hr.

The s-hydrograph (or) s-curve is constructed by adding together a number of unit hydrographs of unit time duration.



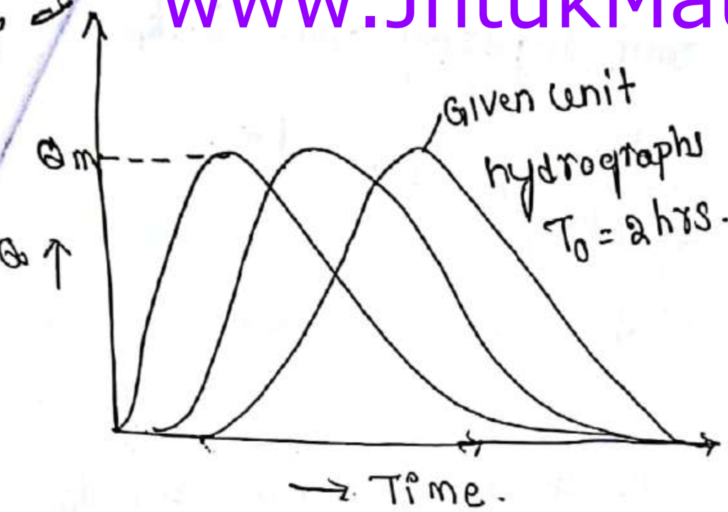


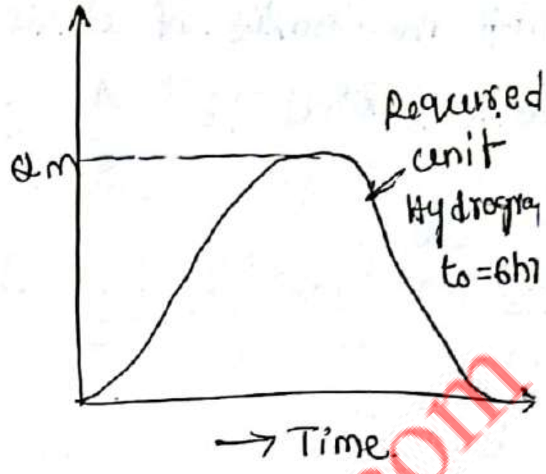
Construction of unit hydrograph of different unit duration from a unit hydrograph of some given unit duration:-

) construction of longer period U.H from a given U.H of shorter unit period:-

Let it be required to derive a U.H of unit duration 'to' hrs from a unit hydrograph of unit duration T_0 where $t_0 > T_0$. If t_0 is an integral multiple of T_0.

Let it be required to derive a U.H of 6hr unit duration from a given U.H of 2hr duration (t_0 = 6hrs & T_0 = 2hrs). This can be obtained of the three unit hydrographs of 2hrs duration, each lagging from the other by 2-hrs & diving the sum by '3'.





$t_0 > T_0$.

Construction of shorter / longer period unit hydrograph from a given unit hydrograph :-

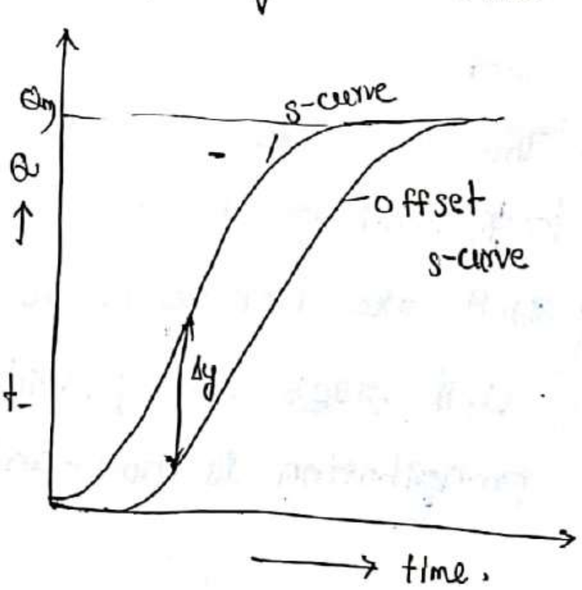
Let it is required to obtain a u.H of unit period t_c from a given unit hydrograph of unit period T_0.

S-curve can be derived by using

S-curve will represent a constant effective rainfall of R_0 cm/hr. An offset curve is then drawn by advancing (or) offsetting the position of original S-curve for a period equal to the desired unit period "t_0" hrs

The difference b/n the ordinates of original S-curve & off-set S-curve, divided by $R_0 t_0$ will give the ordinate of desired unit hydrograph.

At any time period, t, If the ordinate difference between them are 'Δy'



Then ordinates of desired unit hydrograph of to unit period $= \frac{\Delta y}{R_0 t_0} = \frac{\Delta y}{\frac{1}{T_0}(t_0)} = \Delta y \cdot \frac{T_0}{t_0}$.

~~Assumptions~~ Uses & limitations of U.H :-

Uses :-

1. Based on the rainfall records, the flood flow records can be extended.
2. They are used in the developement of flood hydrograph releating to design storms which are required for the design of hydraulic structures.
3. Hydrographs are used in watershed simulation model.

Limitations :-

1. The unit hydrograph can be applied only to drainage basin with small area, as the uniform areial distribution of rainfall over large area is less.
2. when large portion of storm precipitation is in the form of snow, the U.H is not applicable,
3. The base period of the direct runoff hydrograph depends on the intensity of rainfall.
4. The U.H are not well adopted in basins which are long, narrow & unequal rainfall.
5. U.H are not suitable for areas less than 200 hectares
6. U.H does not provide better results when the precipitation is non-uniform.

Synthetic unit hydrograph :-

The resulting hydrograph, derived from basin characteristic relationships is known as a synthetic unit hydrograph. It is used for ungauged rivers, data are not available for draw the hydrograph.

There are several methods to derive synthetic unit hydrograph, but one given by synder is widely used.

Synder's Method :-

Synder studied the data of catchments of Appalachian highlands of eastern united states & then developed empirical equations for synthetic hydrograph.

Synder selected three parameters of unit hydrograph (i) Base width (T_b)

ii) Peak discharge (Q_p)

(iii) Basin lag (t_L)

⇒ The equations given by him take in to account catchment area, shape of basin, topography, channel slopes, stream density & channel storage. He eliminated all these parameters except first two & give a single coefficient 'C_t'.

Base lag $t_L = C_t (L_{ca} \cdot L)^{0.3}$

t_L = basin lag in hours

C_t = a coefficient depending upon units & basin characterstics

= 1.35 & 1.65.

L = Distance from station to catchment boundary

L_{ca} = Distance along the main stream

The peak discharge of Q_p unit hydrograph of standard duration 'T' is given by

$$Q_p = \frac{2.778\, C_p . A}{t_L}.$$

Q_p = Peak discharge. (m^3/sec)

A = Area of catchment (km^2)

C_p = A regional constant

= 0.56 – 0.69.

Synder adopted the standard duration (T) hrs of effective rainfall is given by

$$T = \frac{2}{11} t_L.$$

→ The duration of surface runoff (or) base length T_b of unit hydrograph is given by

$$T_b = 3 + 3\left[\frac{t_L}{24}\right] \text{ in days}$$

$$T_b = 72 + 3t_L \text{ (in hrs)}.$$

→ Some investigators recommend that a base period equal to five times the time to peak should be taken.

$$T_b = 5\left[\frac{T}{2} + t_L\right] = 5\left[\frac{t_L}{11} + t_L\right]$$

$$T_b = 5.455\, t_L$$

for triangular shape of unit hydrograph

$$T_b = \frac{5.556}{q_p}$$

For widths of unit hydrographs at 50 & 75 % of the peak discharge.

$$W_{50} = \frac{5.87}{q_p^{1.08}}$$

$$W_{75} = \frac{W_{50}}{1.75}$$

W_{50} = width of unit hydrograph in hrs, at 50 % peak discharge

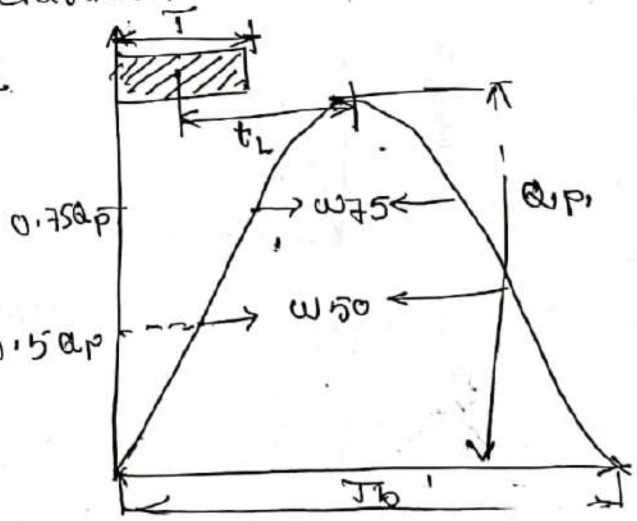
W_{75} = width of unit hydrograph in hrs, at 75 % peak discharge.

usually one third of the width is kept before the U.H. peak & 2/3 after the peak.

* The S.U.H of any other duration T' is required, then the modified basin log is

$$T_L' = T_L + \frac{T' - T}{4}$$

$$Q_p' = \frac{2.778 A C_p}{t_L'}$$



Flow-mass curve :-

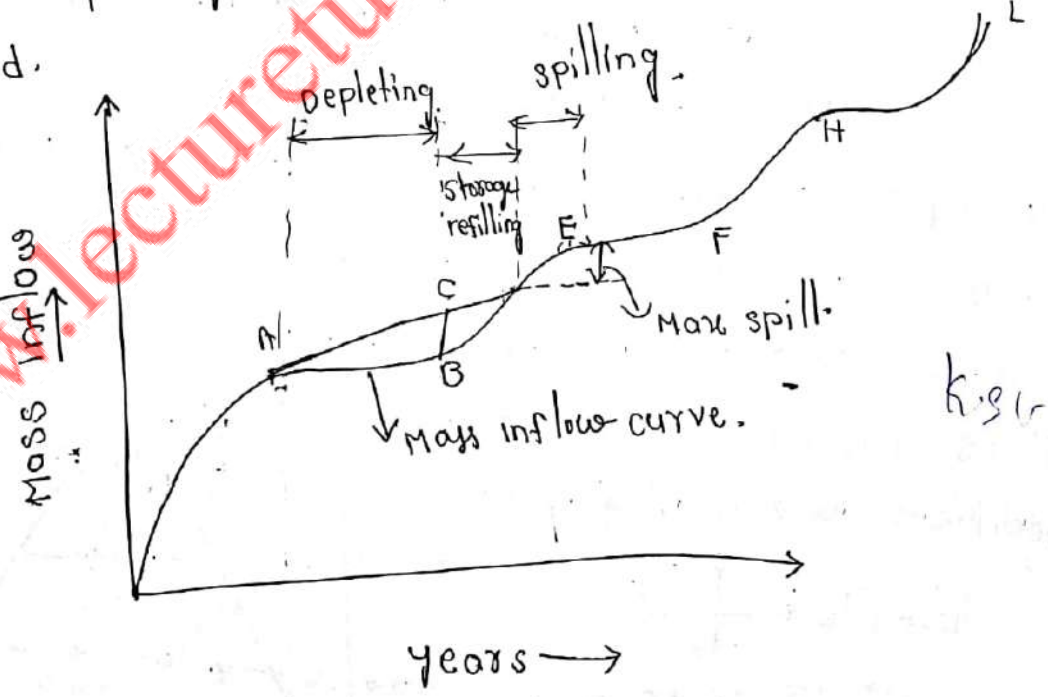
Flow mass curve / runoff mass curve (or) inflow mass curve / simply mass curve is cumulative flow volume V versus time curve. The mass curve ordinate 'V' at any time t is given by.

$$V = \int_{t_0}^{T} Q \, dt.$$

t_0 = Time at the beginning of the curve.

⇒ It is an integral curve of a given hydrograph. The slope of mass curve at any point on the plot i.e. $\frac{dV}{dt}$ equals the rate of stream flow at that time.

Mass curve is always a rising curve or horizontal & it is useful by which one can calculate storage capacity of a reservoir to meet specified demand.



slope of the cumulative demand curve is the demand rate. The reservoir is assumed to be full at the begining of a dry period. Draw a line AD, such that it is tangential to the mass curve at 'A' & has a slope of demand rate.

The maximum difference in the ordinates of the demand line & mass curve b/n A & D represents the volume of water required as storage in the reservoir to meet the demand from the time of reservoir was full.

In pratice, demand rates for irrigation, power generation of water supply vary with time. For that situations, mass curve of demand is superposed over the flow mass curve with proper matching of time.

Flow - duration curve :-

Flow duration curve / discharge frequency curve of a stream is graphical plot of stream discharge against the corresponding %. of time the stream discharge equalled (or) exceeded. It is useful for

i) Determining dependable flow which information is required for planning of water resources & hydropower projects.

ii) Designing drainage system.

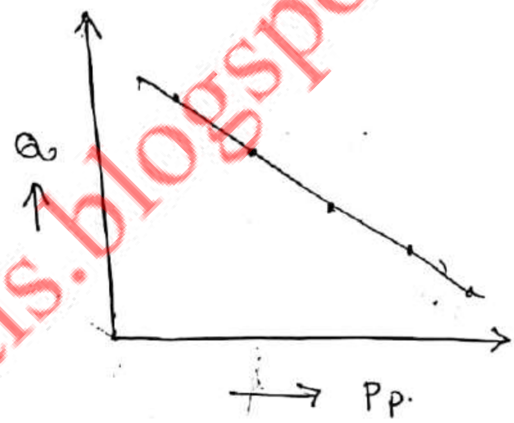
iii) Flood control studies.

For preparing a flow duration curve, the stream flow data are arranged in a descending order of stream discharges. Percentage probability P_p of any flow magnitude Q being equalled or exceeded is given by

$$P_p = \frac{m}{N+1} \times 100 \, (\%)$$

m = order number of the discharge.

N = number of data points in the list.



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