



www.zonetech.in

ZONE TECH

Best Institute For Assistant & Junior Engineer

CIVIL ENGINEERING

E-Book
for
(Degree Students)

CE
B.Tech

Hydrology

SSC-JE

STAFF SELECTION COMMISSION-JE

RRB-JE

RAILWAY RECRUITMENT BOARD-JE

State-AE/JE

STATE LEVEL EXAMINATIONS

PSUs

PUBLIC SECTOR EXAMINATIONS

CONTACT US: **ZONE TECH**

H.O.: M-28, Madhuban Colony, Near Tonk Bridge, Tonk Phatak, Jaipur

B.O.: F-26/A, Behind Pinkcity Honda Showroom, Gatta Stand, Tonk Road, Jaipur



+91-9828747676

+91-9462447676

www.zonetech.in
www.onlinezonetech.in
info@zonetech.in

CHAPTER - 1

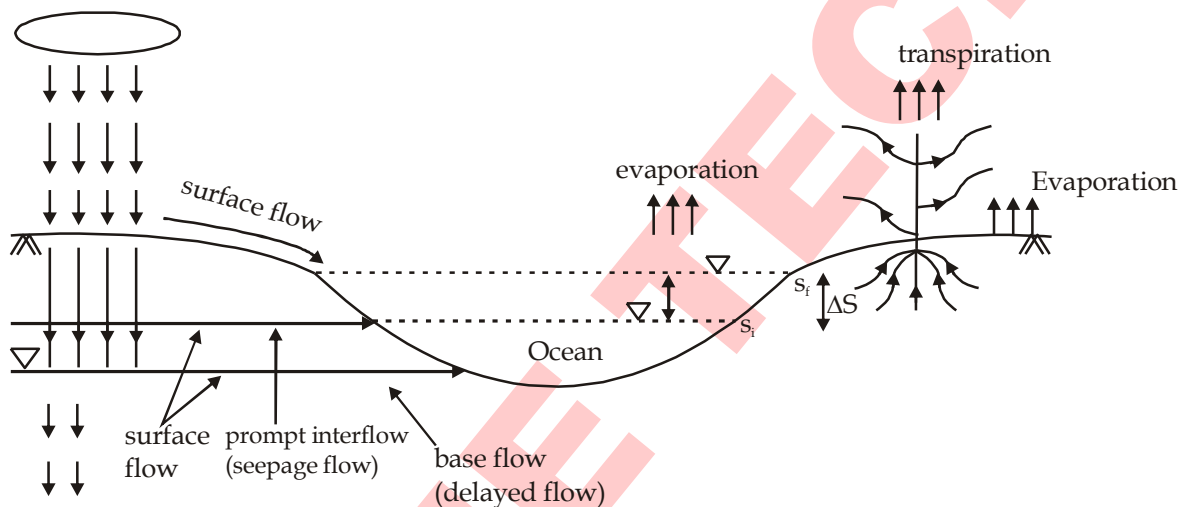
(BASIC CONCEPT)

Hydrology :

It is the science which deals with the occurrence of water, its flow on the ground and movement of moisture into the atmosphere.

Hydrological Cycle/ Water Cycle :

The precipitation and evaporation continues for each there by a balance is maintained between two. This process is known as hydrology cycle or hydrological cycle.



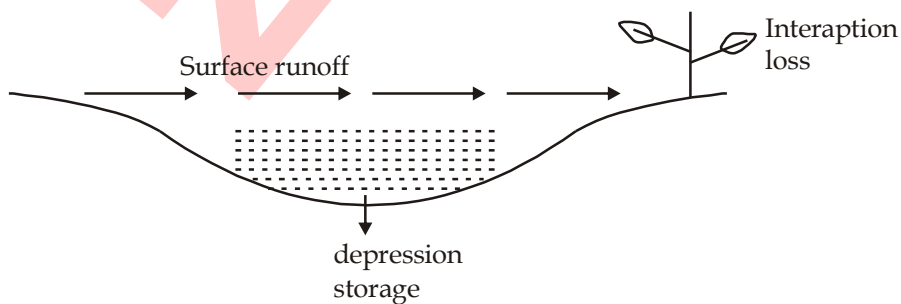
INITIAL LOSSES :

(1) Interception loss :

When it rains over a catchment then not all the precipitation falls directly on the ground surface some part of it may be received by vegetation and consequently evaporated back to the atmosphere. The water received by the vegetation in this case is called interception loss.

(2) Depression storage :

When it rains over a catchment tail, before surface runoff of water, some part of water may be received by some depressions on the surface. The water used to fill the depressions is called depression storage



(A) PRECIPITATION AND ITS MEASUREMENT :- PRECIPITATION :

The term precipitation denotes all forms of water that reaches on the earth from atmosphere.

Various Forms of Precipitation :

The term precipitation denotes all forms of water that reaches on the earth from atmosphere

Various Forms by Precipitations :

(I) Rain :

This term is used when water drops of size 0.5mm to 6.0mm of rain intensity is less than 2.5mm/hr, then it is called light rain, if rain intensity is 2.5mm/hr to 7.5mm/hr then it is called moderate rain and if rain intensity is greater than 7.5 mm/hr then it is called heavy rain.

- If total rain in a day is more than 2.5mm, then that day is called rainy day
- In India average precipitation is about 118cm - 120cm per annum which is greater than world average precipitation of 100cm/annum
- In order to find average annual precipitation of a place in minimum of 30yrs data, we can find the average annual precipitation of that catchment.

(II) SNOW :

Snow consist of ice crystals having avg density of 0.1g/cc the accumulation of snow may result into formation of glaciers. In India snow occurs only in himalayan region it has very light weight and it occur in powder form.

(III) DRIZZLE :

When water drops are of size less than 0.5mm and the intensity is less than 1mm/hr. Then it is called drizzle.

(IV) GLAZE :

When rain and drizzle comes in contact with solid body of freezing temp, then water drop weight forms ice coatings, this ice coating is called glaze.

(V) SLEET AND HAIL :

It is a frozen rain drops. If falling rain converts into ice crystals at some freezing temp. then it is called sleet.

If ice crystals converts into a lumps of size more than 8mm, then it is called hail.

Hails are formed due to violent thunder storms in which vertical currents are very high

INDEX OF WETNESS :

$$IOW : \frac{\text{rainfall in any year}}{\text{Avg. rainfall of all the yrs}} \times 100$$

$$IOW/20m = \frac{\text{rainfall in 2017}}{\text{avg. rainfall of (1988 - 2017)}} \times 100$$

If low = 60% then deficiency of rain by 40%

- If low > 100%, then it will represent flood condition
- If low < 100% then it will represent deficiency of moisture
- If rain deficiency is 30% to 45% → large deficiency
- If rain deficiency is 45% to 60% → severe deficiency
- If rain deficiency is > 60% → Disastrous deficiency

DROUGHT :

It is climatic anomaly which is characterised by insufficient supply of moisture. This may result from subnormal rainfall over large regions causing below normal natural presence of water over long period of time.

Note :-

- If probability of occurrence of drought is 20% - 40% ($0.20 \leq P \leq 0.4$) then that region is called drought

prone region.

- If probability of occurrence of drought is greater than 40% then that region is called "Chronologically drought prone region.
- A year is said to be drought prone year for a country if 20% of the area is affected by severe drought.

CLASSIFICATION OF DROUGHT : (By national commission on agriculture 1976)

(1) Meteorological Drought :

It is a situation where there is more than 25% dec in precipitation over an area from normal value.

- IMD sub-classification of drought :
- If ppt is < 75% of normal value → Drought
- or rain deficiency $\geq 25\%$ → drought
- If rain deficiency is 26% to 50% → moderate drought
- If rain deficiency is >50% → severe drought

(2) Hydrological Drought :

If the presence of water in river, lakes and various underground sources is below average then it is called hydrological drought.

- It may occur due to low precipitation, poor management of water or due to increasing demand of water

(3) Agricultural Drought :

It is characterised by deficiency of moisture required for the growth of plants or crops. It is characterised by aridity index

(AI) or palmar index (PI)

$$AI = \left(1 - \frac{AET}{PET} \right) \times 100$$

AET → Actual evapotranspiration

PET → Potential evapotranspiration

$$AET \leq PET$$

$$\left\{ \frac{AET}{PET} \leq 1 \right\}$$

PET :

It refers to the amount of water consumed by the plants for its optimum growth under sufficient moisture conditions.

AET :

It refers to the amount of water consumed by the plants under existing conditions.

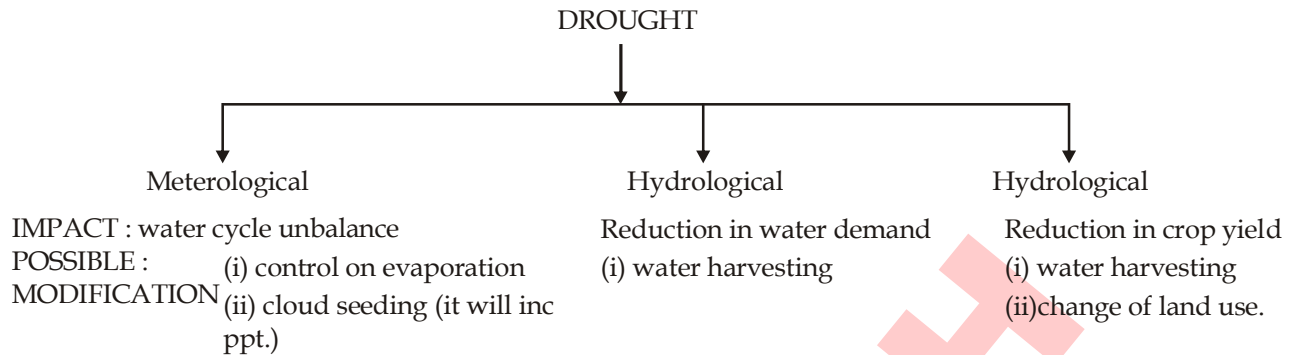
If

$AI = 0 \rightarrow$ Non Arid Region

$0 < AI \leq 25\% \rightarrow$ Mild Arid Region

$25 < AI \leq 50\% \rightarrow$ Moderate Arid Region

$AI > 50\% \rightarrow$ Severe Arid Region



Measurement of Rainfall :

Rainfall is expressed in cm or mm which is volume per unit area. The device which is used to collect and measure the rainfall is called rain guage.

NOTE :

Terms such as pluviometer, ombrometer, hyetometer etc are sometimes used to designate rain guage

Guidelines for setting of a rain guage :

- A rain guage must be surrounded by an open faced area of 5.5m × 5.5m No object should be near the instrument than 30m or twice the height of obstruction which even is more.
- The ground should be level such that rain guage must represent a horizontal surface.
- The rain guage must be setted as near the ground as possible to reduce the effect of wind action. But it must be sufficiently high to prevent from flooding action.

Note :

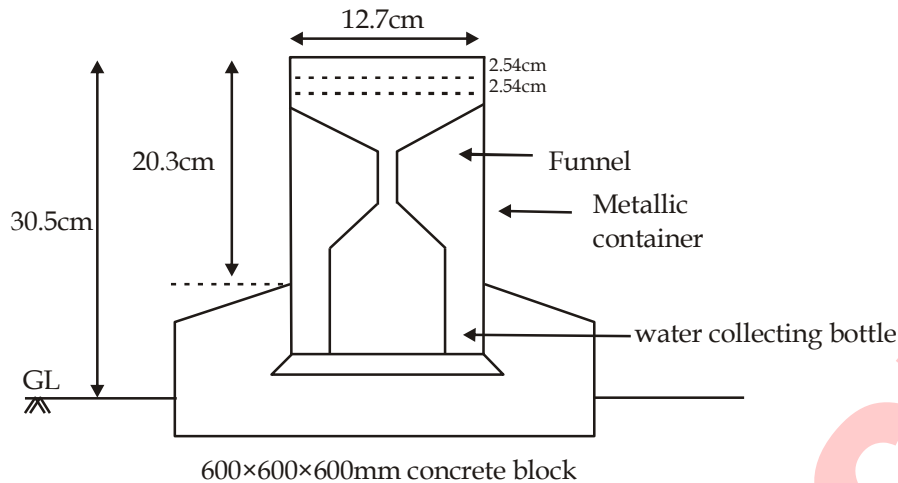
- (i) Rainfall is measured everyday at 8 : 30 am (1st) for uniformly in measurement
- (ii) The rain fall measured at a station by a rain guage is called point rainfall or station rainfall, where as the rainfall measurede by radar will give the instantaneous image of the rainfall

Types of rain guage :

- (i) Non recording rain guage
- (ii) Recording rain guage
 - (A) Tipping bucket rain guage
 - (B) Weighting bucket rain guage
 - (C) Natural syphon type rain guage or float type rain guage

Non Recording rain guage :

The most widely adopted non recording area is symons rain guage. It is also called 5inch rain guage. It is a circular vessel of 12.7cm dia and 30.5cm height above the ground level. The funnel discharges the water into a connecting bottle. The water is measured by a jar



- It can measure rainfall upto 0.1mm depth.
- Recently IMD has invented a fibre glass polyester rain gauge which is improvement over symons rain gauge.
- The details of installation of non recording rain gauge in India is specified by IS 154986 : 1968

Disadvantage :

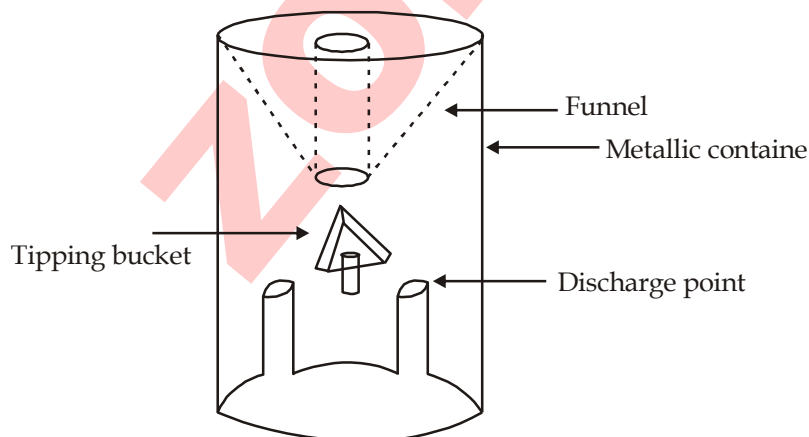
- The receiving bottle doesnot hold water more than 10cm. If the rainfall is heavy then water will overflow. Hence, frequent observations are required.
- It will give the precipitation only at the line of measurement and it is not able to give rainfall intensity.

(2) Recording Rain Gauge :

(A) Tipping Bucket Type Rain Gauge :

This is 30.5cm rain gauge having a pan of small bucket it is widely adopted in USA. The buckets are so balanced that 2.5mm rain is collected then it tips and bring another bucket in same position.

The no of tipping of the bucket is recorded by an arrangement made in the rain gauge which will produce the rainfall intensity.

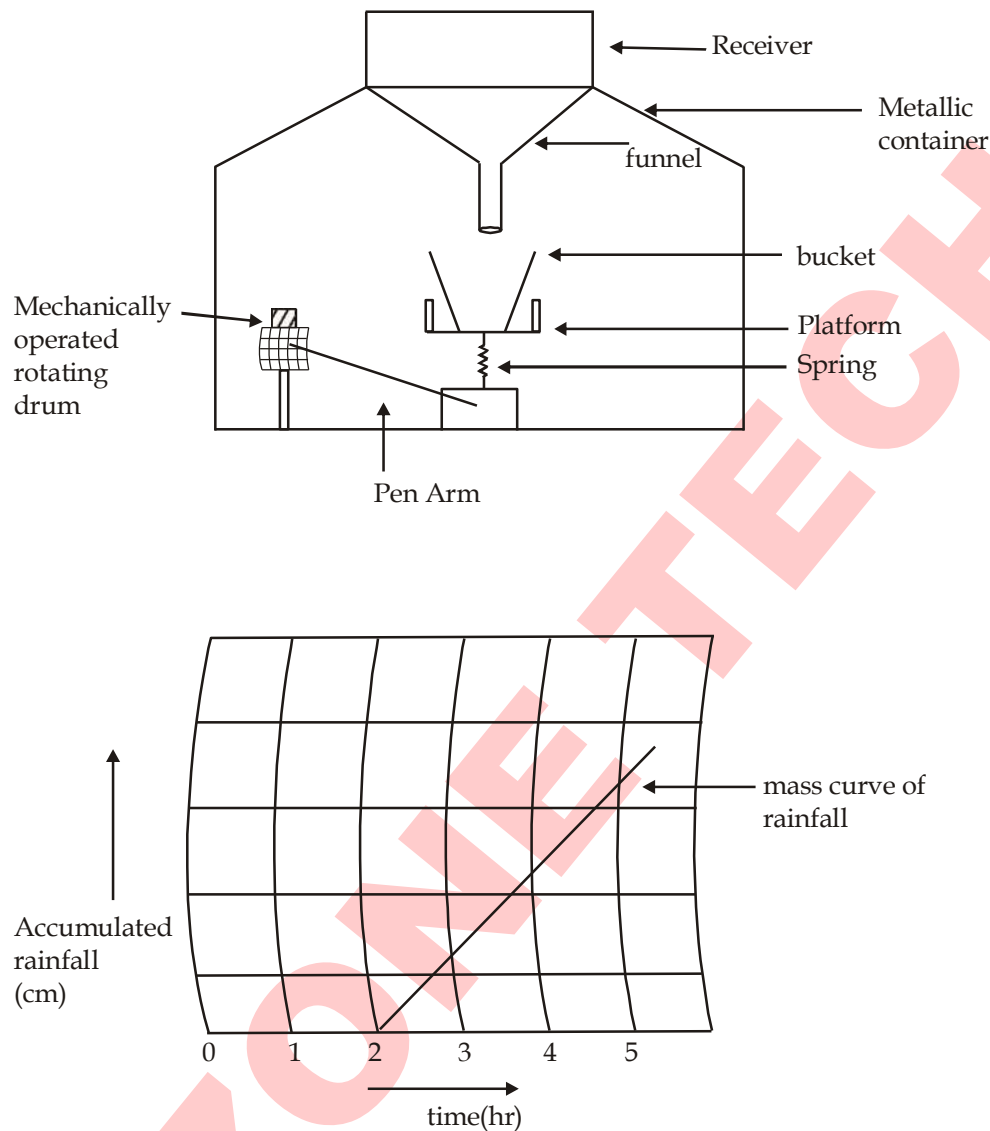


(B) Weighing Bucket Rain Gauge :

In this rain gauge water is collected from funnel into bucket which is resting on a weighing platform. The wt of the bucket and its content are recorded on a clockwork driven chart which is connected with mechanically operated drum (drum will complete one revolution in a day automatically either rainfall is

happen or not).

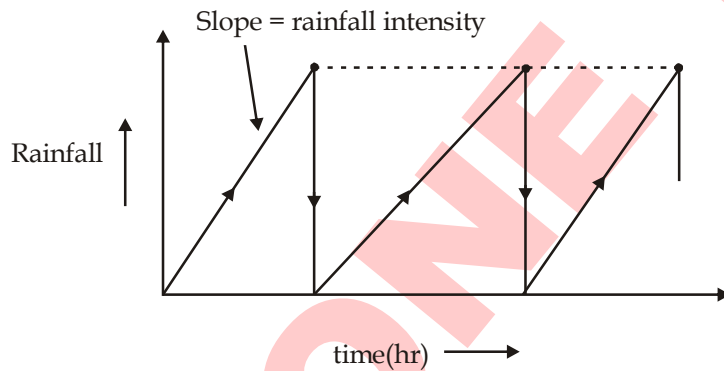
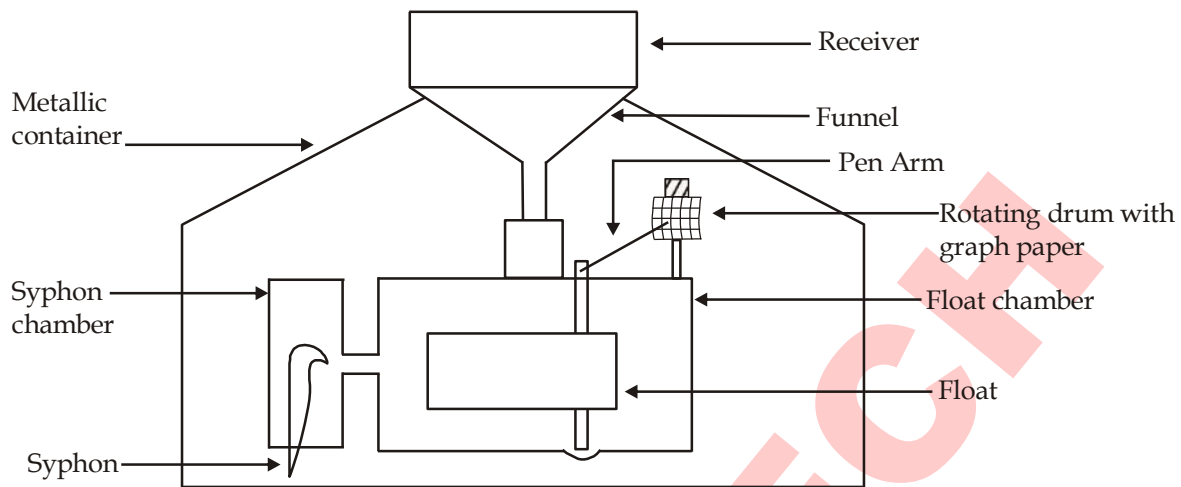
A pen arm is connected with the drum which will give a graph between accumulated rain fall v/s time (mass curve of rainfall)



(C) Natural Siphon Type Rain Gauge :

Also called float type rain gauge and most widely adopted by IMD.

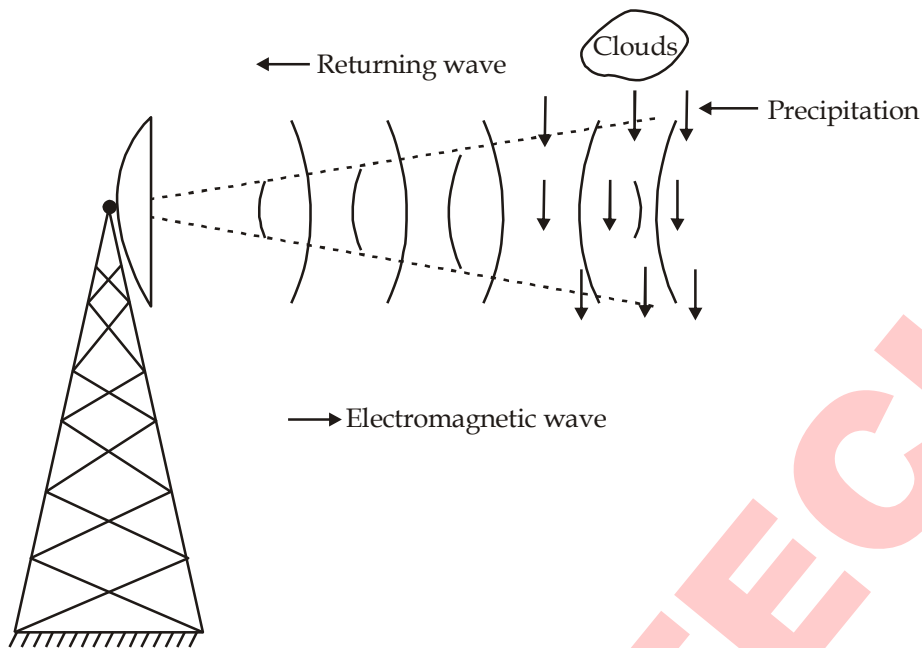
The water is collected from a funnel which is kept into a float chamber causing a float to rise. A float is attached on a chamber which is connected to the graph paper through a clockwork rotating drum. The graph is recorded automatically after self empty condition of float chamber graph automatically resets. The slope of the graph represents intensity of rainfall (Graph is between accumulated precipitation against time).



(3) Radar Measurement Of Rain Fall :

Radar emits pulses of electro magnetic wave which coincide with the rain drops and receive a back signal of returning wave. The wavelength used by the radar is 3cm to 10cm. for light rain 5cm wavelength is used where as for heavy rain, 10cm wavelength is used.

The hydrological range of radar is 350km. In India, presently 40 radars are installed. It is fully computer operated method in which we will get instantaneous picture of rain drop.



Design of Raingauge Network :

The optimum no of rain gauge will depend on allowable percentage error. If more error is permitted, then less no of stations are required.

The optimum no of rain gauge is given by

$$N = \left(\frac{C_v}{E} \right)^2$$

C_v = coeff of variation (expressed in %) for existing set of rain gauge station

$$C_v = \frac{100\sigma}{\bar{P}}$$

Standard deviation for existing set of raingauge station.

E = Allowable percentage error in the estimation of measure rain fall for existing set of raingauge station

$$\left\{ \sigma = \sqrt{\left(\frac{n}{n-1} \right) (\bar{P}^2 - \bar{P}^2)} \right\}$$

n = no of existing rain gauge

$\bar{P}$ = mean of rainfall for existing raingauge

$$\bar{P} = \left\{ \bar{P} = \frac{\sum P}{n} \right\} = \frac{P_1 + P_2 + \dots + P_n}{n}$$

$\bar{P}^2$ = mean of square of rainfall for existing set of raingauge.

$$= \frac{P_1^2 + P_2^2 + \dots + P_n^2}{n}$$

$$\left\{ \bar{P}^2 = \frac{\sum P^2}{n} \right\}$$

Method to find standard error 'E'

$$E = \frac{C_v}{\sqrt{n}}$$

it is total error for existing set of raingauge

IS Recommendations :

- (i) For plane area, one station is required for 520km² area.
- (ii) For region of average elevation about 1000m one station is required for 260-390 km² area.
- (iii) In hilly areas, one station is required for 130 km² area.

WMO Recommendations :-

- (i) for flat region of tropical zone, one station is required for 600-900 km² area.
- (ii) In mountaneous region of tropical zones, one station is reputed for 100-250 km² area.
- (iii) In polar zones, one station is required for 1500 km² 10000 area

Note :

- (i) As per WMO (World Metereological org) recommendations, atleast 10% of the total rain gauge should be of recording type.
- (ii) During 1990's India having 5472 rain gauge installed in its area. Out of these rain gauges only 572 were of recording type.

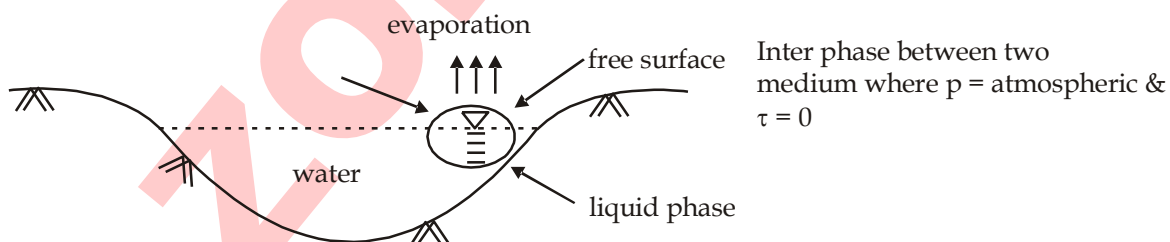
Evaporation and Its Measurement :

Evaporation :

It is a cooling process in which heat of evaporation is about 585 cal/gm provided by the water body.

In this process liquid charge into gaseous phase at free surface below the boiling point temp through the transfer of heat energy.

Evaporation can occur at 0°C also after than boiling point. Boiling will occur at boiling point



Factors affecting Evaporation :

(1) Vapour Pressure :

rate of evaporation $\propto (e_s - e_a)$

$$E = K (e_s - e_a)$$

e_s = saturation vapour pressure of air in mm of Hg

e_a = Actual vapour pressure of air in mm of Hg

K = Constant vapour pressure of air in mm of Hg

Vapour Pressure :

→ Water exist in the form of vapour in atmosphere vapour is lighter than air. The partial pressure exerted by this vapour is known as vapour pressure.

Saturation vapour pressure :

→ For a given temp. where the air holds vapour to its max capacity, the partial pressure exerted by this vapour is said to be saturation vapour pressure.

Relative Humidity (RH) :

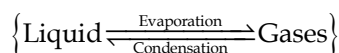
$$\left\{ R_h = \frac{e_a}{e_s} \times 100 \right\}$$

Saturation deficit :

$$\{S_s = e_s - e_a\}$$

Condensation :

The process of converting water vapour into water is called condensation
Ice Melting

**(II) Temperature :**

If other factor remain same, then rate of evaporation inc with inc in temperature.

Note :-

There is no any fixed relation of evaporation with temperature however, it is discussed only on the basis of practical experience.

(III) WIND SPEED :-

The rate of evaporation inc with the wind speed upto a critical speed beyond which any further inc in the wind speed has no significance of an evaporation rate.

Note :

- wind speed is measured by anemometer
- For evaporation there is no avg fixed relation of wind speed. However it is also discussed on the basis of practical experience

(IV) Atmospheric Pressure :

If other factor remaining same, then rate of evaporation dec. with inc in atmospheric pressure.

(V) Presence of soluble salts :

Due to presence of soluble salts, evaporation rate decreases under similar conditions, evaporation from oceans is 2-3% less than evaporation from fresh water.

(VI) Size of water body :

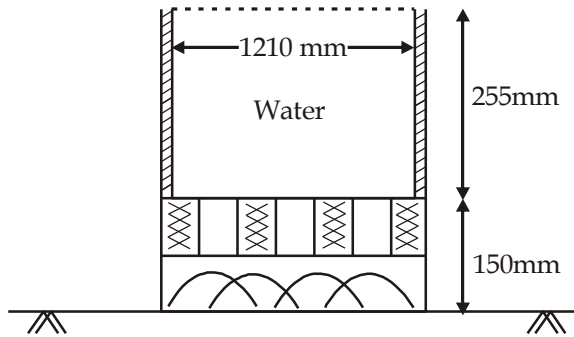
- (A) **Area :** Rate of evaporation inc with inc in area of water body.
- (B) **Depth :** If area is same then during summer, evaporation will be high in shallow water body where as in winters, evaporation will be high in deep water body

METHODS OF MEASURE EVAPORATION**(1) Evaporimeters :**

Evaporimeters are water containing pans which are exposed to atmosphere and a loss of water by evaporation is measured at regular interval.

Class A Evaporation pan :

It is a standard pan of 1210mm dia and 255mm depth and in this pan, depth of water is maintained at 18cm to 20cm . The pan is made of unpainted galvansed iron sheet. It is placed on a wooden platform of 15cm height above the ground level allow free circulation of air below the pan.



IS Pan Method :-

It is specified by IS 5973 : 1970 and it is also known as modified class A pan.

It is a pan of dia 1210mm and 255 mm depth, made of copper sheet of 0.3mm thickness. It is covered at top by hexagonal wire netting made of galvanised iron to protect the water from birds as well as any unwanted movement above the water surface and to maintain the surface of water uniform during day and night.

Evaporation from this pan is 14% less as compared to uncovered pan.

PAN COEFFICIENT : (C_p)

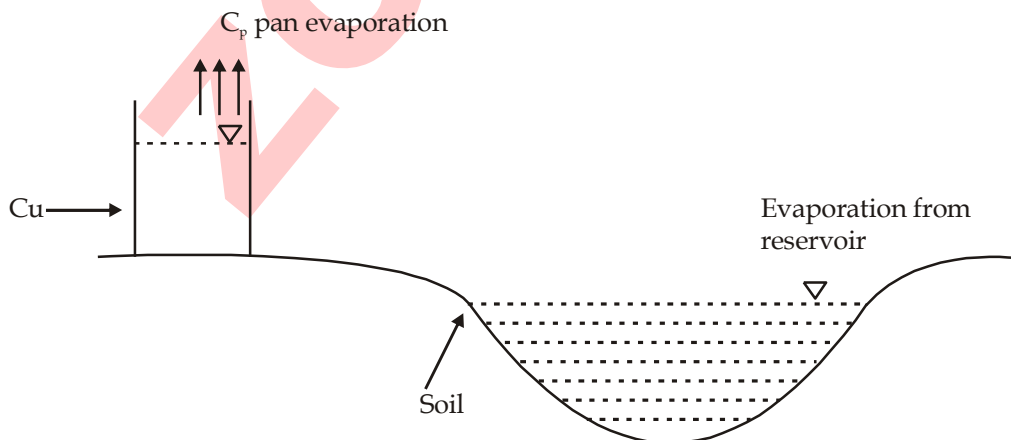
Evaporation pans are not exactly equal to large reservoir and having following principal drawbacks i.e.

- difference in heat storing capacity
- heat transfer from sides and bottom
- height of the pan effects wind action and
- heat transfer capacity of pan material is different from reservoir hence evaporation observed from pan is not exactly equal to evaporation from reservoir. That why pan coefficient is required

Therefore

Evaporation from reservoir or lake reservoir = $C_p \times$ Pan evaporation

	C_p	Avg. C_p
Class A Pan :	0.60 to 0.80	0.70
is Pan :	0.65 to 1.1	0.80



(II) EMPIRICAL FORMULA :**Mayer's formula :**

Rate of evaporation

$$E = K(e_s - e_a) \left[1 + \frac{V_9}{16} \right]$$

 V_9 = velocity of wind in km/hr at 9 m above to ground level**Note :-**If V_1 km/hr is wind velocity at height h_1 meter above CL& V_2 km/hr is wind velocity at height h_2 meter above CL

Then

$$\frac{V_1}{V_2} = \left(\frac{h_1}{h_2} \right)^{1/7}$$

This is called 1/7th power law**(III) ANALYTICAL METHOD :****(A) Water Budget Method :**

It is simplest method but it is least reliable. This is based on conservation of mass principle.

Mass Conservation : $\delta AV \rightarrow \text{Constant}$

$$\frac{\text{kg}}{\text{sec}} = \text{const.} \quad \{\text{mass flow rate is constant}\}$$

$$\frac{\text{mass}}{\text{time}} = \text{const.}$$

$$m = \text{const}$$

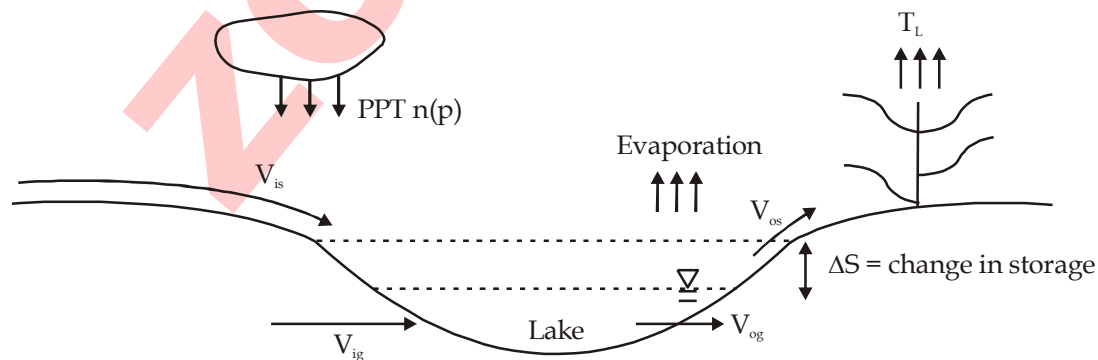
$$\left\{ \frac{dm}{dt} = 0 \right\}$$

From conservation of mass principle :

Net inflow per day = net outflow per day + change in storage per day.

$$I = Q + \Delta S$$

$$P + V_{is} + V_{ig} = V_{os} + V_{og} + E + I_L + \Delta S$$



Method To Minimise The Evaporation Losses :

- (i) Reduction in surface area and increase in depth
- (ii) Providing permanent mechanical covers such as raft, floating roof and temporary cover like light weight floating particles or floating balls
There measurement sare limited for very samll water bodies such as ponds, lakes etc.

(iii) Providing Chemical Films :

Certain chemical films such as cetyl alcohol (Hexa decanol or $C_{16}H_{33}OH$) or steryl alcohol (octadeconol or $C_{18}H_{37}OH$) forms a mono molecular layer on water surface which prevent evaporation (as the film is 1 molecule thick) hence it is called monomolecular.

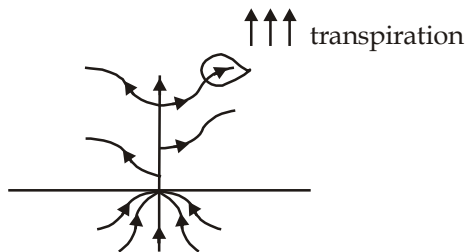
Film should have following properties :

- It should be strong as well as flexible. It means it should not break easily due to wave action or heavy raindrops like hails etc.
- It should be transparent to oxygen and CO_2 flow
- It should be colourless, odourless and non toxic

TRANSPIRATION :

It is the process by which water leaves the body of a living plant and reaches the atmosphere as water vapour. Water is taken up by the plant root system and escapes through the leaves.

- It is a discontinous process which happen only in daylight hours whereas evaporation is a continous process which happen in day and night time both.

**EVAPOTRANSPIRATION :**

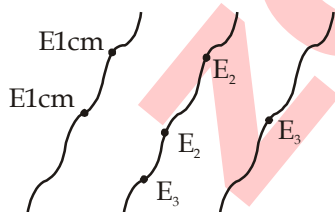
It is sum of water lost to the atmosphere by the plants through transpiration and the water evaporated from the soil or water body surrounding the plant

There are two types of evaporation

- (i) PET (potential)
- (ii) AET (Actual)

Note :-

Line joining the points in a map having equal depth of evapotranspiration is called (Isoleths)

**MEASUREMENT OF EVAPOTRANSPIRATION :**

- (i) Lysimeter
- (ii) Field plots

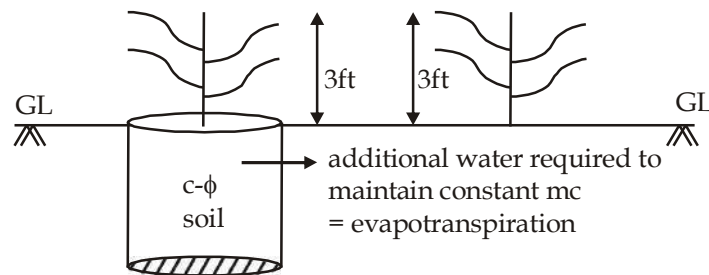
LYSIMETER :

It is a special water tight tank having black of soil and set in a field of growing plant. Plants grown in the lysimeter are same as in the surrounding field.

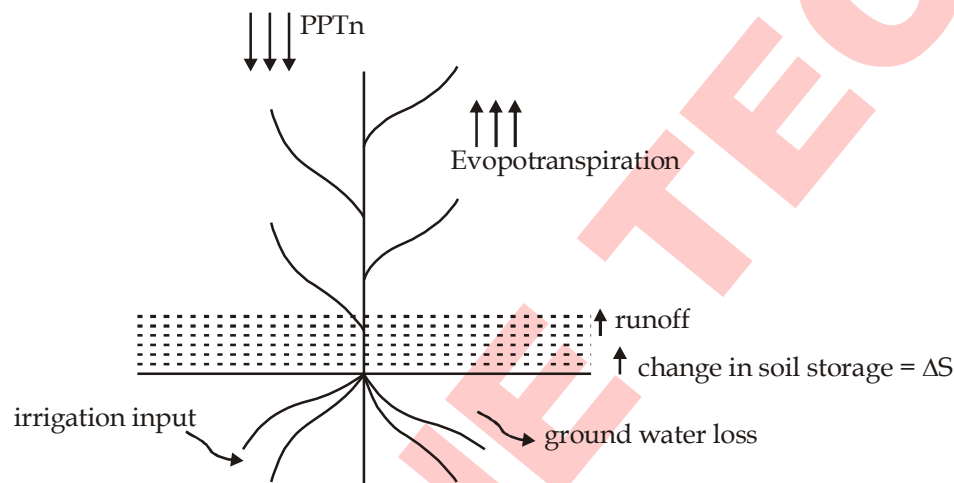
- Evapotranspiration is estimated in terms of amount of water required to maintain constant moisture conditions within the tank measured either volumetrically or gravimetrically through an arrangement

made in the lysimeter.

Lysimeter should be designe in such a way taht it will reproduce the soil conditions. moisture content, types and size of vegetation of the surrounding area. Lysimeter studies are time consuming and costly and it should be so adjusted that the soil is at the same level inside and outside the container.



FIELD PLOTS :



From conservation of mass principle :

Net inflow per unit time = Net outflow per unit time + change in soil storage

→ (Precipitation + Irrigation input) = (Evapotranspiration + Runoff + ground water loss + change in soil storage)

MEASUREMENT OF PET :

Penman's Equation :- Obtained by combination of energy balance and mass transfer

$$PET = \frac{AH_n + E_a r}{A + r}$$

r constant = 0.49 mm of Hg/°C

A slope of sat vapour pressure v/s temperature curve

H_n → Net radiation in mm of evaporable water per day

E_a = Parameter including wind velocity and saturation deficit

$$E_a = 0.35 (e_s - e_a) \left(1 + \frac{V_2}{160} \right)$$

INFILTRATION :

Infiltration is the flow of water into the ground through the soil surface

Infiltration capacity (f_p)

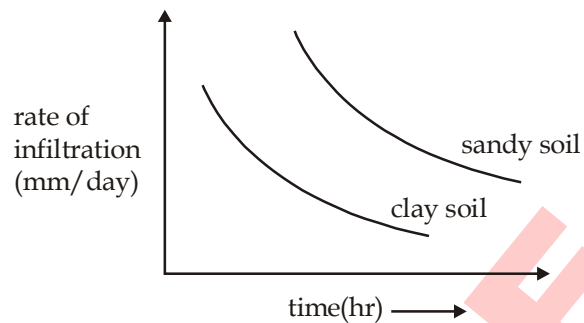
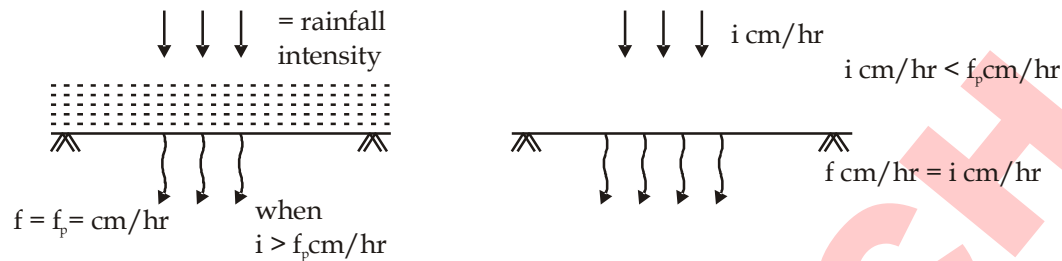
The max rate at which a given soil at a given time can absorb water is defined as infiltration capacity. IT

is denoted by ' f_p ' and unit is 'cm/hr'

Actual rate of infiltration

$$i \geq f_p \Rightarrow f = f_p$$

$$i < f_p \Rightarrow f = i$$



Cumulative Infiltration Capacity (F_p) :

It is defined as the accumulation of infiltration volume since the start of the process. It is denoted by F_p if unit is cm or mm.

$$F_{p(t)} = \int_0^t f_p \cdot dt \quad \text{or} \quad \frac{dF_p}{dt} = f_p$$

HORTON'S EQUATION :

Infiltration capacity at any time 't' is given by

$$f_p \text{ or } f = f_c + (f_0 + f_c) e^{-k_h t}$$

$$0 \leq t \leq t_c$$

INFILTRATION INDICES :

W - index and ϕ index are two infiltration indices.

W-Index :

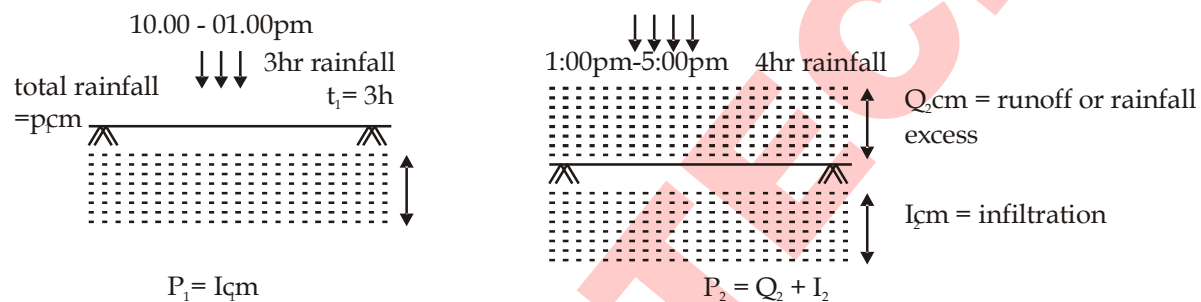
It is the ave infiltration rate or infiltration capacity over the intime period of storm

$$W\text{-index} = \frac{\text{Total infiltration}}{\text{Total time period of storm}}$$

 ϕ index :-

It is defined as the average rate of loss such that the volume of rainfall in excess of that rate will be equal to the volume of direct runoff (rainfall excess)

$$\phi \text{ index} = \frac{\text{Total infiltration in which rainfall excess occur}}{\text{Time period in which rainfall excess occur}}$$



$$W \text{ index} = \frac{I_1 + I_2}{t_1 + t_2} \text{ cm / hr}$$

$$\phi \text{ index} = \frac{I_2}{t_2} \text{ cm / hr}$$

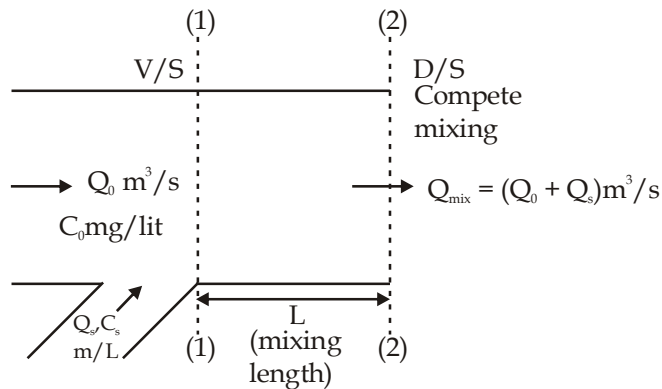
$$\begin{aligned} \rightarrow (\phi \text{ index}) t_2 &= I_2 \\ &= P_2 - Q_2 \\ \{Q_2 &= P_2 - (\phi \text{ index}) \cdot t_2\} \end{aligned}$$

(III) Dilution Method or Chemical Method :

Also called constant rate injection method.

when a solution of a chemical or tracer is injected into a flow (stream flow or pipe flow) it will get completely and uniforming mixed with the flow and the diluted concentration of downstream will decrease due to inc in discharge of the mixture.

Chemical concentrations are measured by titrations.



From conservation of mass principle :

Net incoming mass per unit time = net outgoing mass per unit time.

$$Q_0 C_0 + Q_s C_s = Q_{\text{mix}} C_{\text{mix}}$$

$$Q_0 C_0 + Q_s C_s = (Q_0 + Q_s) C_{\text{mix}}$$

$$Q_0 = \frac{Q_s (C_{\text{mix}} - C_s)}{(C_0 - C_{\text{mix}})}$$

Q_0 = Stream discharge, m^3/s

C_0 = Initial conc of stream (mg/L) which may be taken as a when there is no presence of chemicals in water initially

Q_s = Discharge of chemical or tracer (m^3/s)

CHAPTER - 2

(STREAM FLOW MEASUREMENT)

The process of discharge measurement involves the following steps

(i) Measurement of Stage :

A stage of a river is water surface elevation measured above the datum. Datum may be mean sea level or average assumed local level.

The measurement of stage is called gauging.

Stage can be measured by

(i) Manual gauge

Staff gauge

Wire gauge

(ii) Automatic gauge

Float gauge recorder

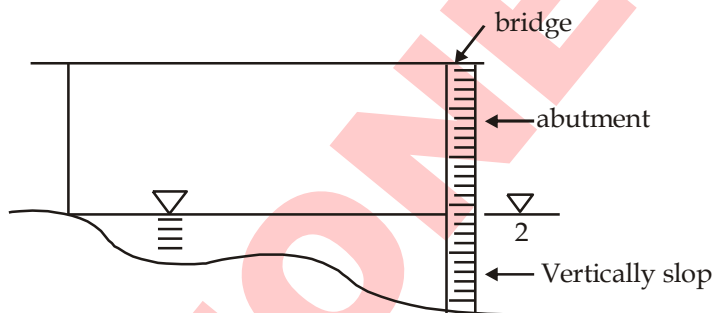
Bubble gauge recorder

Staff Gauge :

Stage can be measured by calculating the elevation of water surface in contact with a fixed staff. The staff is made of a durable material of low coefficient of thermal expansion.

It is fixed rigidly to a structure such as abutment, pier wall ect.

The staff may be vertical or inclined



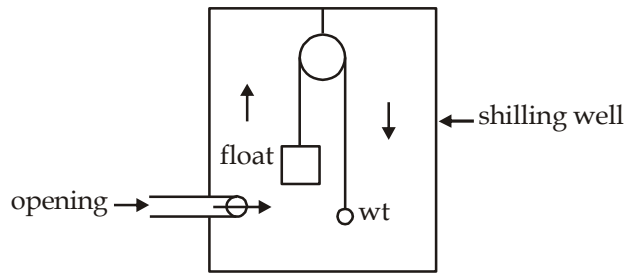
Wire Gauge :

It is a gauge used to measure the water surface elevation from above the surface such as from bridge or any similar structure.

Float Gauge :

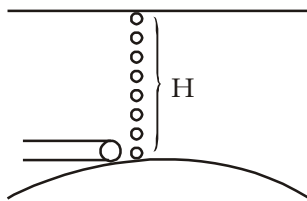
A float operated stage recorder is the most common type of automatic stage recorder induced. In this process a float operating in a stilling well is balanced by weight with the help of pulley which is installed in a recorder

- Displacement of the float due to rising or lowering of the water surface elevation causes an angular displacement of pulley
- To protect the float from debris and to reduce the wave action of water, a stilling well is used.
- Stilling well is a costly device



Bubble Gauge Recorder :

In this gauge a compressed air or gas is made to bleed out at a very small rate through an outlet placed at the bottom of the river



$$P = \gamma H$$

Pressure gauge measures the gas pressure which will be equation to the water pressure above the outlet

Measurement of Velocity :

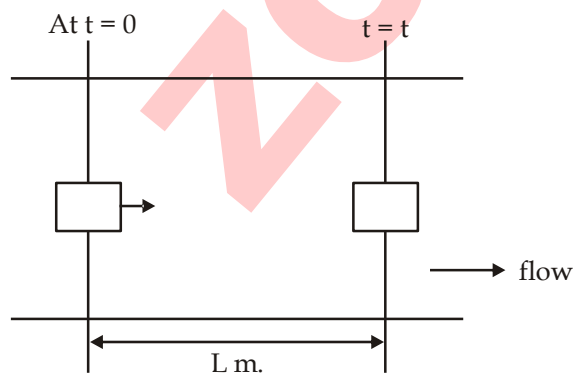
Velocity of river can be measured by

- (i) Floats methods
- (ii) By current meters

Floats Method :

In this method a float is kept on the surface of let us consider the float will travel a distance 'L' m in a time interval of 't' sec then surface velocity of the river is given by

$$V_s = \frac{L}{t} \text{ m/s}$$



By Current Meters :

It consist of rotating elements which rotate due to reactions of stream currents. The no of revolutions per sec are measured through an arrangement made in the current meter the velocity at any depth can

be found out by the help of current meter hence, current meter is used to measure point velocity at any depth.

Let V = point velocity at any depth, then, characteristic equation of current meter is given by

$$V = aN_s + b$$

There are two types of current meter :

- (i) Vertical axis current meter
- (ii) Horizontal axis current meter

(1) Vertical Axis Currentmeter :

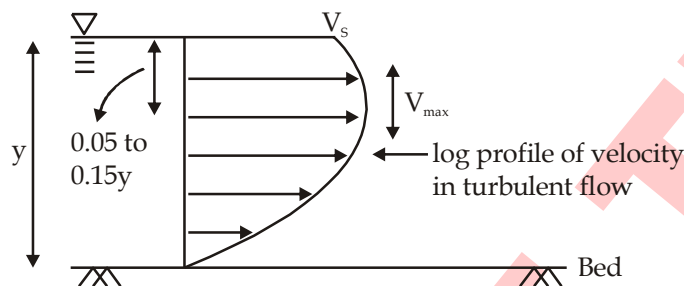
It has vertical axis and its disadvantage is that. It is not suitable when there is appreciable inclined component of velocity in a river stream.

The common example of this type of current meter is price currentmeter.

(ii) Horizontal Axis Currentmeter :

it is not effected by inclined flow of water upto 15° . It have range of velocity measurement from 0.15 m/sec. to 4.0 m/sec

Note :



→ Maximum velocity occurs at $0.05y$ to $0.15y$ from free surface and it is 10% to 15% higher than surface velocity

→ In turbulent flow, mean velocity is taken as 85% to 95% of surface velocity

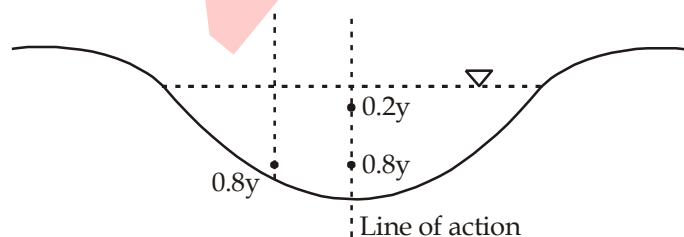
$$\bar{V} = 0.85V_s \text{ to } 0.95V_s \text{ for turbulent flow}$$

→ For shallow streams mean velocity is taken as point velocity at $0.6y$ depth from per surface.

One point method $\bar{V} = V_{0.6y}$ for shallow stream

→ For deep streams, mean velocity is taken as average of point velocity at $0.2y$ depth and $0.8y$ depth from free surface along the same line of action

$$\text{two point method} = \bar{V} = \frac{V_{0.2y} + V_{0.8y}}{2}$$



(III) Methods to determine stream discharge :**(A) (Direct Method)**

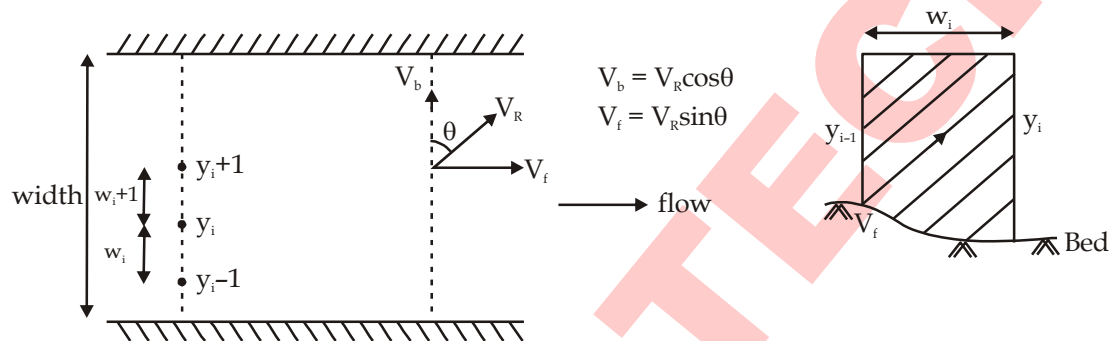
- (i) Area velocity method
- (ii) Moving boat method
- (iii) Dilution method
- (iv) Ultrasonic method
- (v) Electromagnetic method

(B) (Indirect Method)

- (i) Slope area method
- (ii) Hydraulic structures such as notch, weir, barrage, spill etc

Moving Boat Method :

For big and wide river, area velocity method becomes very tedious and complex hence moving boat method may be preferred.



Discharge through in segment, $q_i = \text{Area of C/S} \times V_f$

$$q_i = \left(\frac{y_{i-1} + y_i}{2} \right) w_i \times V_f$$

$$q_i = \left(\frac{y_{i-1} + y_i}{2} \right) V_b t \times V_f$$

$$q_i = \left(\frac{y_{i-1} + y_i}{2} \right) V_R^2 \sin\theta \cos\theta \times t$$

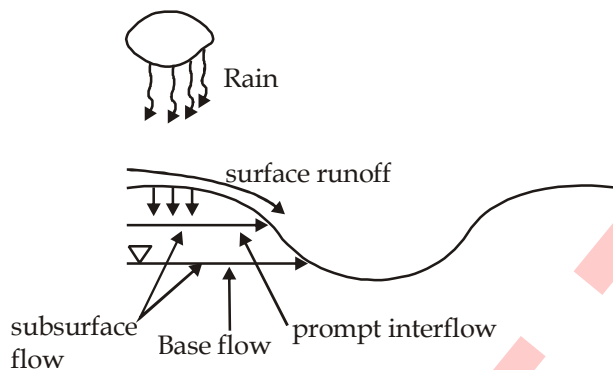
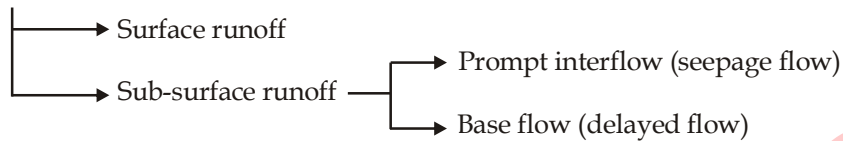
- In this method, a special propeller type of currentmeter is used which is free to move about its vertical axis and fixed in a boat. Which is moving with a velocity ' V_b ' units and right angle to the stream flow ' V_f ' units.

CHAPTER - 3

(HYDROGRAPH)

Hydrograph : Hydrograph is a graphical representation between discharge and time.

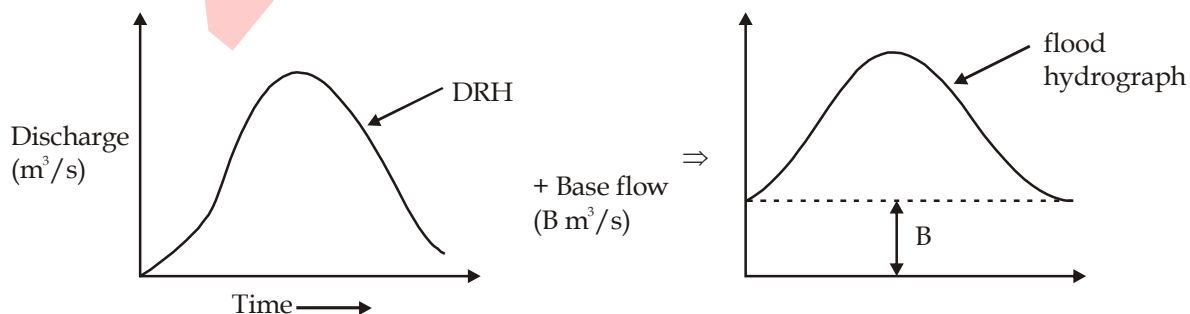
Runoff :

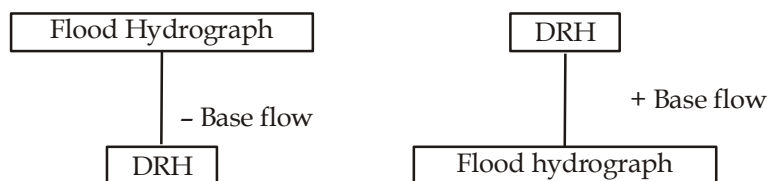


- Surface runoff and prompt interflow will join the mass stream within few hours of beginning of storm, hence it is called direct runoff.
 $\therefore \{\text{Direct runoff} = \text{Surface runoff} + \text{Prompt interflow}\}$
- Since prompt interflow is far less than surface runoff. hence direct runoff signifies to surface runoff only.
 $\therefore \{\text{Direct runoff} \approx \text{Surface runoff}\}$
- Base flow is that infiltrated water which will join the main stream after long period of time through GWT.

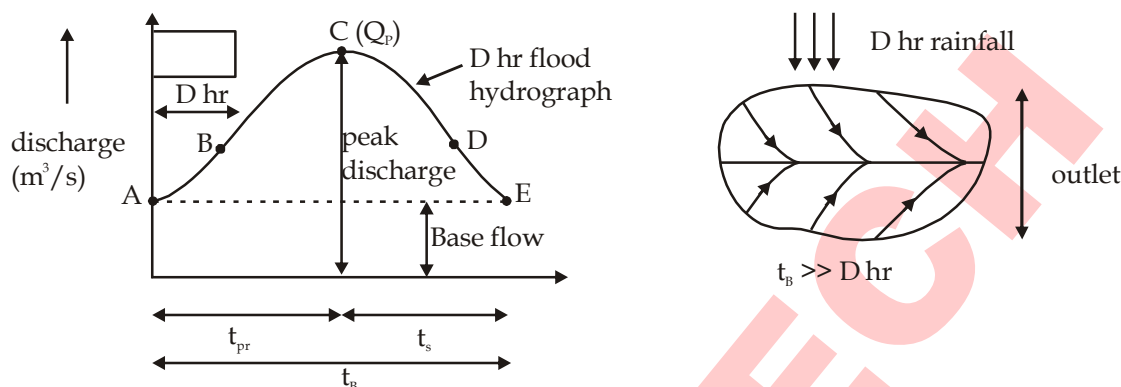
Note :-

- The hydrograph corresponding to direct runoff depth is called direct runoff hydrograph and the hydrograph corresponding to total runoff depth is called flood hydrograph.
- In order to find flood hydrograph, add base flow in a given DRH (Direct runoff hydrograph).





Elements of flood hydrograph:



- Rising limit of hydrograph is a function of catchment slope. If slope of catchment is high then t_p will be less and vice versa.
- CDE is called falling limb of hydrograph where point D is called point of contraflexure.
- It is a function of storage characteristic of a catchment.

If storage is more, t_s will be more and vice versa.

Q_p = Peak discharge of hydrograph.

t_B = Base period of hydrograph.

It depends on characteristic of catchment and duration of storm

D = Duration of storm (hr)

$$t_B \gg D$$

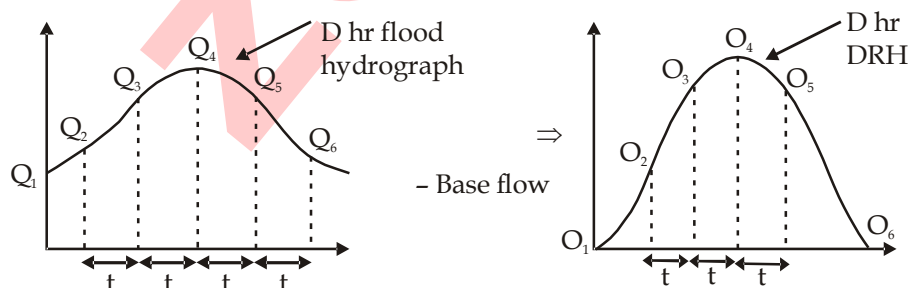
t_{pk} = time of occurrence of peak of hydrograph

t_s = time of recession of hydrograph

$$t_s = t_B - t_{pk}$$

Generally base flow is assumed to be uniform but in actual practise it may be variable.

Determination of direct runoff depth by using flood hydrograph:



- First and last ordinate of a DRH is always 0
In order to find ordinate of DRH, subtract base flow in a flood hydrograph.

Ordinate of DRH

$$O_1 = Q_1 - B = 0 \rightarrow 1^{\text{st}} \text{ ordinate}$$

$$O_2 = Q_2 - B$$

$$O_n = Q_n - B = 0 \rightarrow \text{last ordinate}$$

Area of DRH = Total direct runoff volume

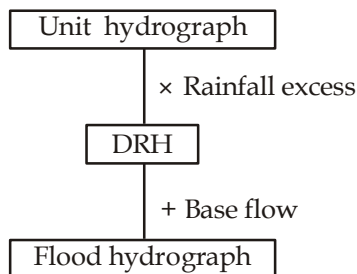
Area of DRH = Catchment area $\times$ Runoff

$$\text{Runoff} = \frac{\text{Area of DRH}}{\text{Area of catchment}} = \frac{A_h}{A_c}$$

$\therefore$ Since equation of curve is not available hence approximate method of strips may be used to find area of DRH.

$$A_h = O_1 t + O_2 t + O_3 t + \dots + O_n t$$

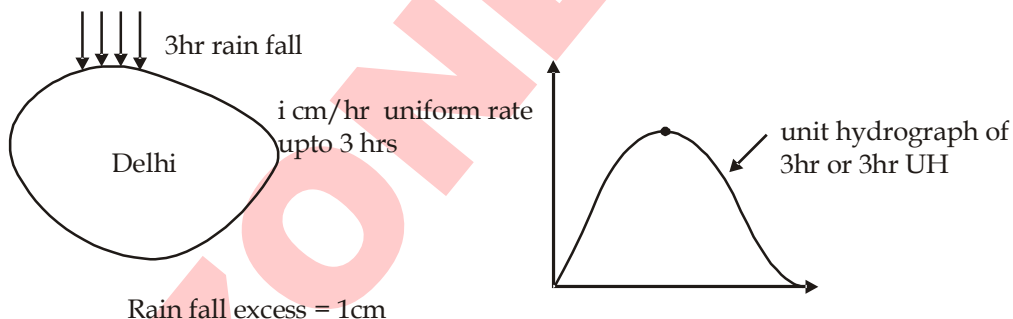
Method to find flood hydrograph from a UH:



Unit hydrograph:-

It is a direct runoff hydrograph which results into unit depth of rainfall excess occurring during a storm of uniform rate of specified duration 'D' hrs.

Eg:-



In a given catchment due to a storm of 3 hrs of uniform intensity one unit depth of rainfall excess is obtained then corresponding DRH will be called unit hydrograph of 3 hrs.

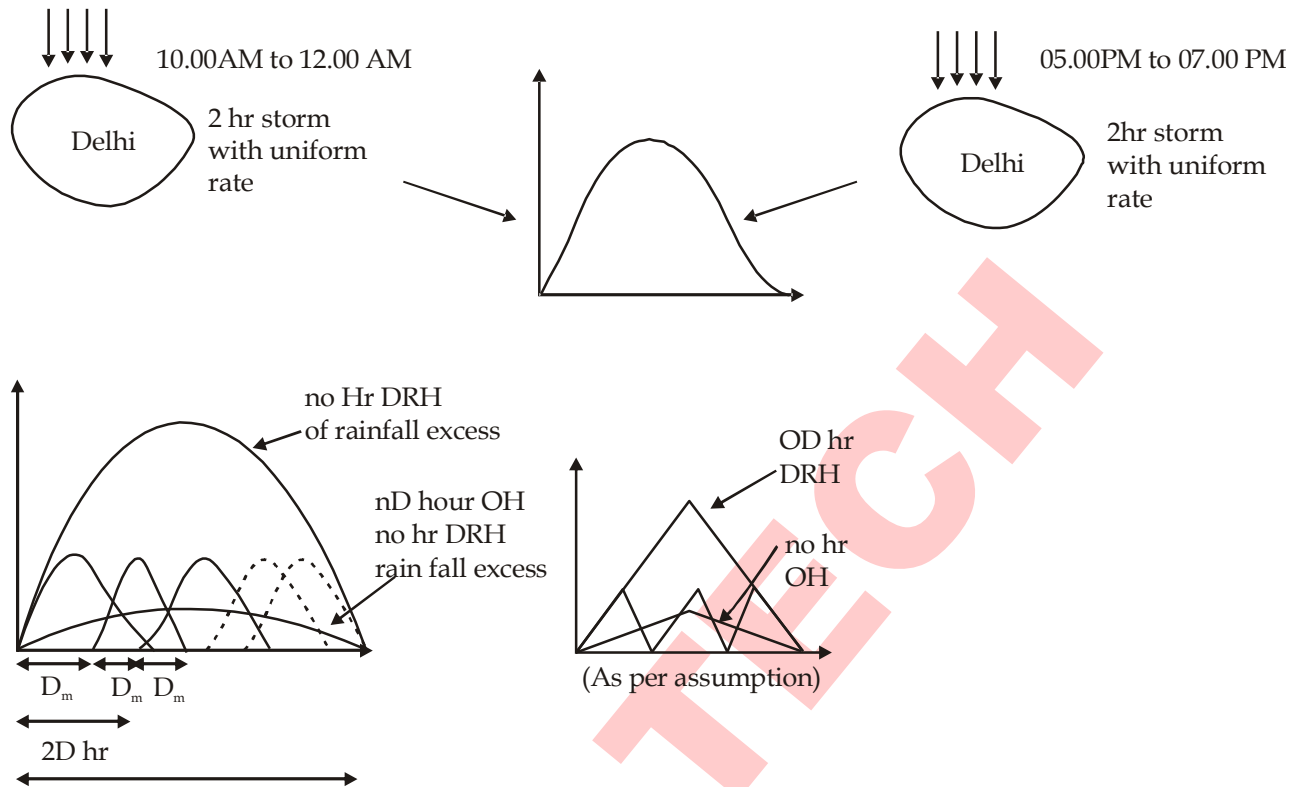
Assumptions involved in L.K. sharma's theory of unit hydrograph:

(I) **Linear Response :-**

It means that super position theorem may be applied. If it is required to obtain n cm depth by using unit hydrograph of same catchment then n units of unit hydrograph may be added directly with a time lag of D hr each.

(II) **Time Invariance:-**

It means that DRH/unit hydrograph for a given rainfall excess in a catchment is always same irrespective when it occurs.

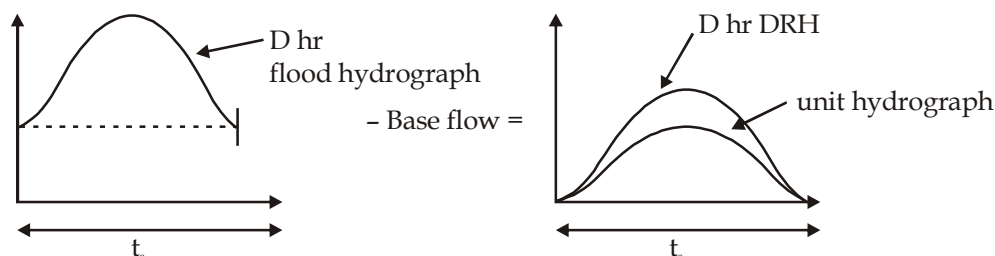
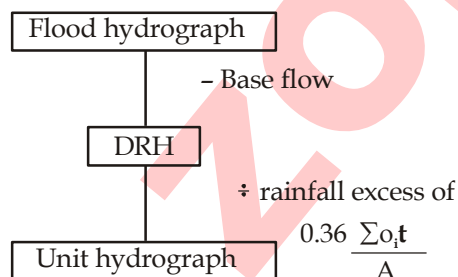


If $T = nD$ and base period of D hr. UH is t_b hr, then base period of T hr UH is given by
 $t_b' = t_b + (n - 1) D$

Now, Runoff = $\frac{A_h}{A_c}$ cm

Note:- Direct runoff depth is also called rainfall excess depth. If rainfall excess depth is 1 unit then such a DRH is called unit hydrograph.

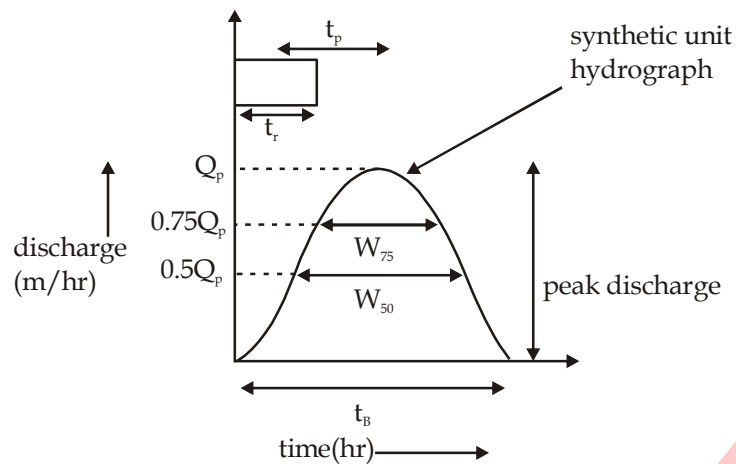
Procedure to derive unit hydrograph from a given flood hydrograph



SYNTHETIC UNIT HYDROGRAPH:

It represents relationship between discharge and time for a catchment for which detailed information of rainfall data are not available.

Snyder developed a sets of empirical equation for synthetic unit hydrograph.



He define basin lag ' t_p ' which is similar to lag time of unit hydrograph which will be equal to time of concentration for a small catchment.

Step 1:- Basin lag,

$$t_p = C_t (L \cdot L_{co})^{0.3}$$

C_t = Region constant

(It depends on type of catchment, slope and storage)

L = Distance from most remote points of the catchment to arrive at the outlet in km.

L_{co} = Distance from centroid of the basin to outlet in km.

Step 2:

Now, standard duration of rainfall of t_r hour is calculated by

$$t_r = \frac{t_p}{55} \text{ hours}$$

Peak distance

$$Q_p = \frac{2.78 C_p A}{t_p}$$

C_p = Regional constant

= 0.3 to 0.92

Step 3:-

Width of the unit hydrograph of 50% peak discharge.

$$W_{50} = \frac{5.87}{(q)^{1.08}} \text{ hr}$$

$$\left\{ q = \frac{Q_p}{A} \right\}, \text{ where } A \text{ is in km}^2$$

width of the UH at 75% peak discharge :

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

Base period of UH is

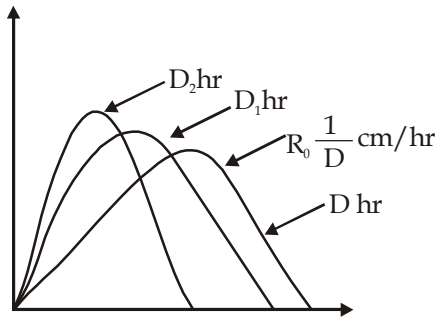
$$t_B = 72 + 3t_p \text{ (for large basin)}$$

$$t_b = 5 \left(t_p + \frac{t_R}{2} \right) \text{ (for small basin)}$$

Instantaneous Unit Hydrograph (IUH):-

The limiting case of a unit hydrograph of 0 duration is known as IUH.

An IUH is a fictitious conceptual unit hydrograph having duration just tends to 0 ($D \rightarrow 0$) consists finite base width and single peak. (Single peak discharge)



$$D \text{ hr} \downarrow \rightarrow R_0 \uparrow \rightarrow Q \uparrow (Q = AR_0)$$

$$D_2 \text{ hr} < D_1 \text{ hr} < D \text{ hr}$$

A finite UH is possible as the duration, $D \rightarrow 0$

It is a hydrograph which represent rainfall excess of 1 cm due to an instantaneous precipitation

CHAPTER - 4

(FLOOD ROUTING)

Floods are unusual high stages in a river which cause disturbance to near by area.

Estimation of flood peak discharge :-

(i) Rational Formula

$$Q_p = \frac{1}{36} KIA$$

I = intensity of rainfall (cm/hr)

A = area of catchment (km²)

t_c = time of concentration

K = Runoff Coefficient

The runoff coefficient used in determination of peak discharge is applicable for homogeneous catchment.

If catchment is non homogeneous then equivalent runoff coefficient may be used.

Equivalent runoff coefficient

$$K_{eq} = \left\{ \frac{K_1 A_1 + K_2 A_2 + \dots + K_n A_n}{A_1 + A_2 + \dots + A_n} \right\}$$

(ii) Empirical Formula :-

(A) DICKEN'S FORMULA :- (1865)

Peak discharge, $Q_p = C_D \times (A)^{3/4}$

C_D = Dickens constant

= 6 to 30

A = catchment area in km²

Q_p = peak discharge in m³/s

→ Valid for north and central India.

(B) RYVE'S Formula : (1884)

$Q_p = C_R (A)^{2/3}$

C_R = Ryve's constant

→ Suitable for south India, specially in western ghats

(C) INGLIS Formula :

$$Q_p = \frac{124A}{\sqrt{A + 10.4}}$$

Some important definitions :-

(i) Recurrence Interval :- (T)

It is an average time period in which the specified flood peak have probability to occur again. It is also known as return period.

(ii) Probability of occurrence of flood :- (p)

$$p = \frac{1}{T}$$

(iii) Probability of non-occurrence :

$$q = 1 - p$$

→ The probability of an event occurring r times in 'n' successive years is given by

$$P_{r,n} = n_c \cdot p^r \cdot q^{n-r}$$

$$= \frac{n!}{(n-r)!r!} p^r \cdot q^{(n-r)}$$

Flood Routing:

Flood routing is the process of calculating water level in the reservoir, storage quantity and overflow rate to a prelicular inflow hydrograph at various instant of time.

Flood routing is an important technique necessary to determine solution of floods. By moving a reservoir floods can be controlled because when flood passes through the reservoir, its peak is reduced and its outflow hydrograph requires greater time for occurrence of peak.

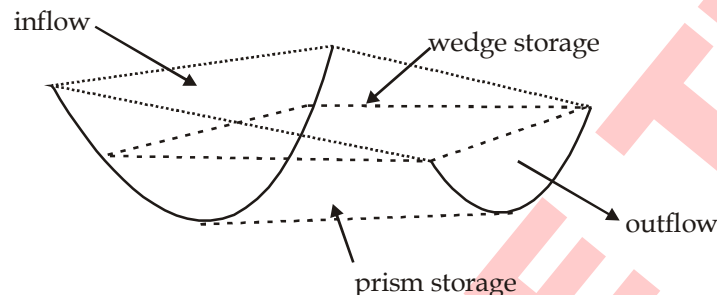
Types of Storage :

(i) Prism Storage :-

It is the volume which is formed if uniform flow occurs at the downstream depth. It means it is the volume found by an imaginary plane parallel to the channel bottom drawn as the outflow section of water surface.

(ii) Wedge Storage :

It is the volume which is formed between actual water surface profile and the top of prism storage.



Prism storage is a function of outflow discharge.

Wedge storage is a function of inflow discharge

Total storage $(S) = f_n(I) + f_n(Q)$

Reservoir storage equation :-

$$S = k[xI^m + (1-x)Q^m]$$

x = weighing factor

$$0 < x < 0.5$$

for natural channel, $0.1 < x < 0.3$

k = storage time constant which has dimension of time.

m = constant

$m=1 \Rightarrow$ for natural channel

$= 0.6 \Rightarrow$ for rectangular channel

If outflow governs the channel storage only then

$$xI^m = 0$$

$$S = KQ^m$$

If channel is natural $m = 1$

$$S = kQ$$

It is linear reservoir i.e. storage is function of outflow discharge only