01. PRECIPITATION

Precipitation denotes all forms of moisture that reach ground from atmosphere.

→ Forms of Precipitation:

1. Rain :-

Precipitation in the form of water droplets. of size > 0.5 mm and intensity (rate of rain) > 1 mm/hr.

$$\text{Intensity of rain } (i) = \frac{dP}{dt} = \frac{P}{t}$$

* Based on intensity, rains are classified into:

(i) Light rain :- $1 \text{ mm/hr} \leq i \leq 2.5 \text{ mm/hr}$.

(ii) Moderate rain :- $2.5 \text{ mm/hr} \leq i \leq 7.5 \text{ mm/hr}$.

(iii) Heavy rain :- $i > 7.5 \text{ mm/hr}$.

2. Drizzle :-

Precipitation in the form of water droplets of size < 0.5 mm and intensity < 1 mm/hr.

3. Snow :-

Precipitation in the form of fine ice crystals of size < 1 mm.

4. Sleet :- (Frozen rain).

Ice crystals of size 1 mm to 5 mm.

5. Hail :-

Ice crystals of size > 8 mm

6. Dew :- vapour accumulated during day condenses during night and deposited on the ground as dew.

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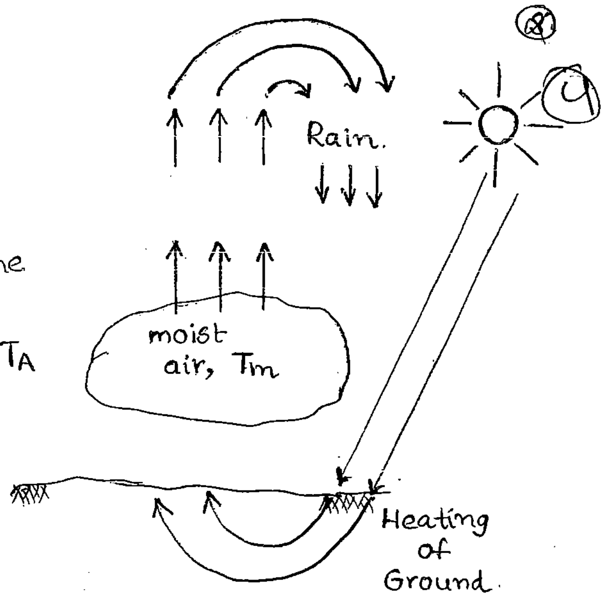
→ Types of Precipitation:

1. Convective Precipitation –

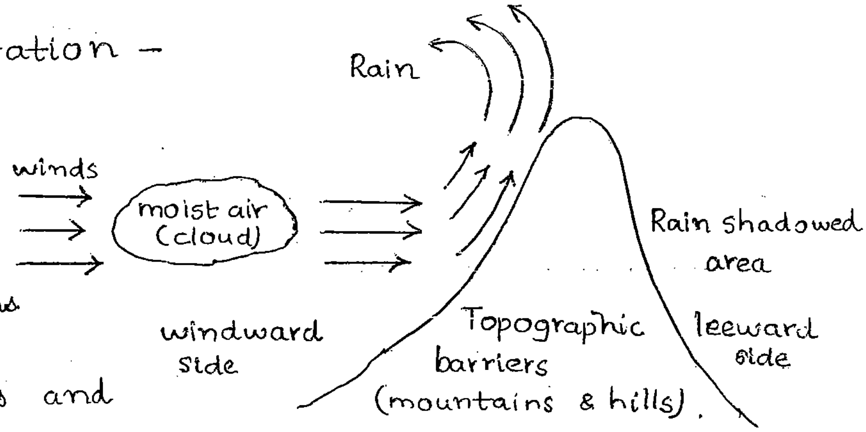


This occurs due to heating of the ground and temperature difference T_A b/w moist air and its surroundings

Eg:- Summer rains : high intensity rains occuring for short periods.

2. Orographic Precipitation –

It is caused by topographic barriers such as hills & mountains



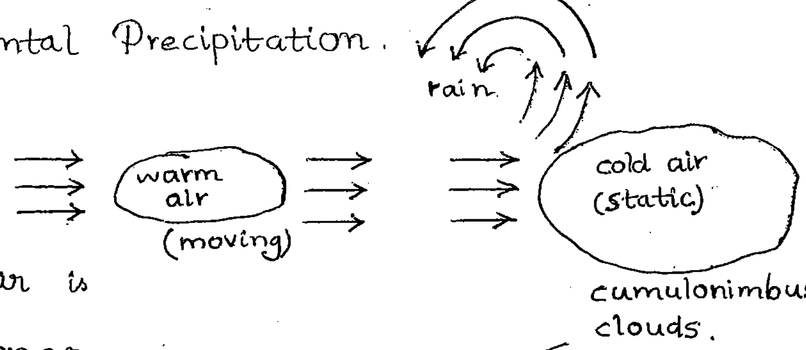
Eg: Rains at himalayas and Western ghats : moderate intensity rains for longer periods.

3. Frontal Precipitation –

Front air : It is an interface between two distinct air masses.

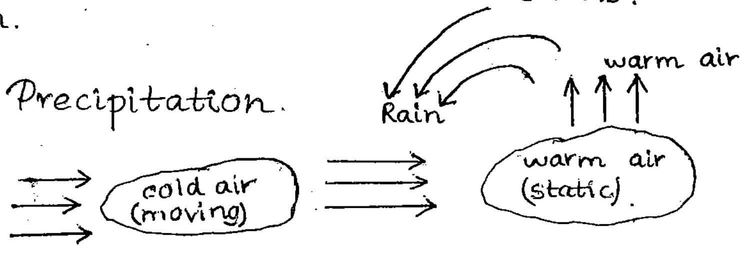
– Frontal precipitation are of two types:-

(i) Warm air frontal Precipitation.



Warm air is lighter, thinner and weaker whereas cold air is denser, thicker and stronger.

(ii) Cold air frontal Precipitation.



Cold air approaches warm air mass.

Eg : rains during rainy season.

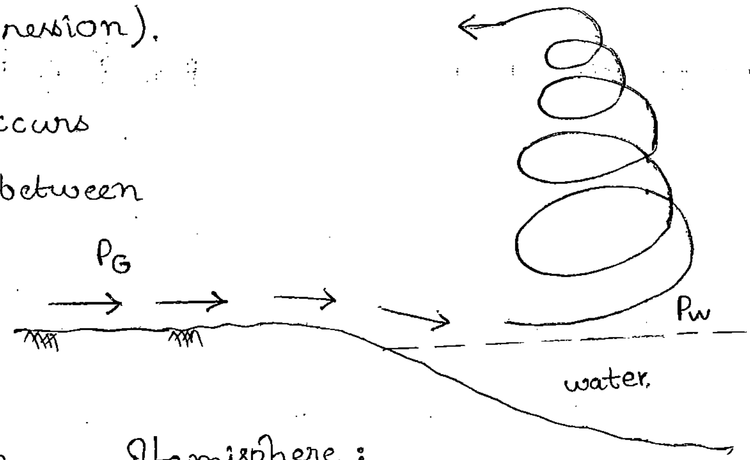
4. Cyclonic Precipitation

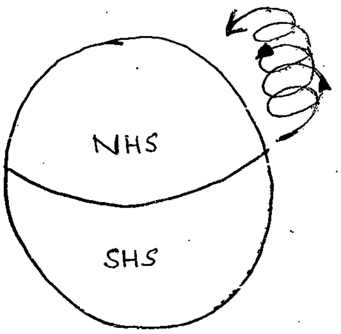
- precipitation caused by cyclones.

cyclone :- large area of low pressure region with circular wind motion. (depression).

- cyclonic precipitation occurs due to pressure difference between ground and water bodies.

($P_W <<< P_G$).





Northern Hemisphere :

Inward and anti-clockwise wind motion at northern hemisphere.

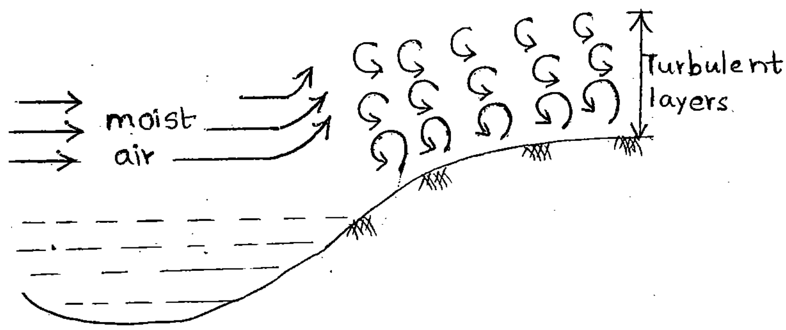
Southern Hemisphere :

Clockwise and outward.

- high intensity rains for longer period.

5. Precipitation due to Turbulent Ascent.

Eg:- winter rains along the coastal areas.



→ Rainfall Season

1. Monsoon period

- Principal rainy season.
- starts from May last week and lasts upto Oct 1st week.
- ~~North~~ South west winds cause rains during this period.

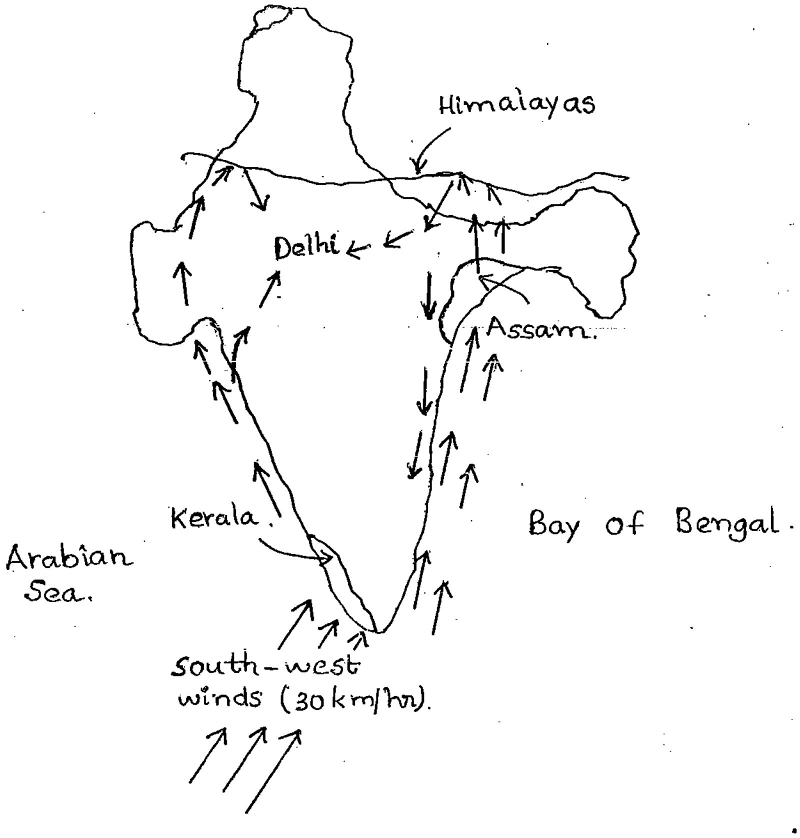
- Except Tamil Nadu & Jammu Kashmir, rest of the country receives rain during this period.

2. Post monsoon period.

- Nov 1st week to December 1st week.
- TN and its surroundings receives rains (Southern Peninsular region)
- North East winds cause rains during this period.

3. Winter Rains

- Dec last week to Feb last week
- J & K receive rainfall and snowfall.



- Kerala & Assam receive first rainfall from South-west winds.
- Assam records the highest rainfall in the country
- Arabian branch reaches upto Punjab in the North and sent back to Delhi by Himalayan Ranges.

→ Measurement of Rainfall.

- Precipitation is measured as a vertical depth of water that would accumulate over a level ground if precipitation is retained where it fell.

- It is expressed in mm or cm.

- Precipitation is measured by using devices known as 'rain gauges' (also known as Ombrometers, Pluviometers or Hyetometers)

- There are two types of rain gauges:

(i) Non Recording type Rain gauges

a) Symon's Raingauge.

b). IS (IMD) raingauge.

(ii) Recording type Raingauge.

a) Weighing Bucket type raingauge.

b) Tipping Bucket type raingauge.

c). Syphon raingauge (float type raingauge)

d). Radar measurement.

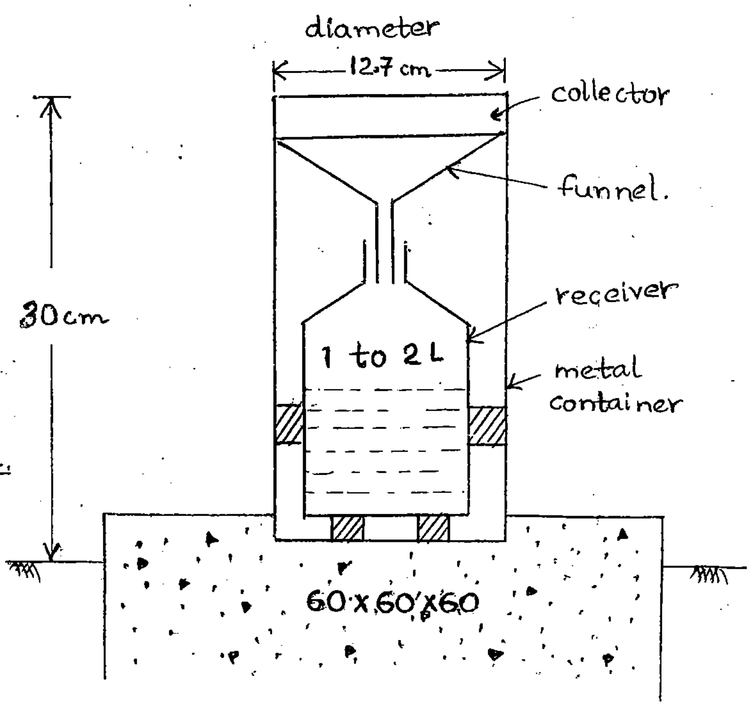
* Symon's Raingauge:

- universal gauge.

- Diameter of collector = 12.7 cm.

- Depth of rain (cm or mm) = $\frac{\text{volume of water collected by gauge}}{\text{c/s area of collector}}$

- measures 100 mm to 175 mm rain at a time.

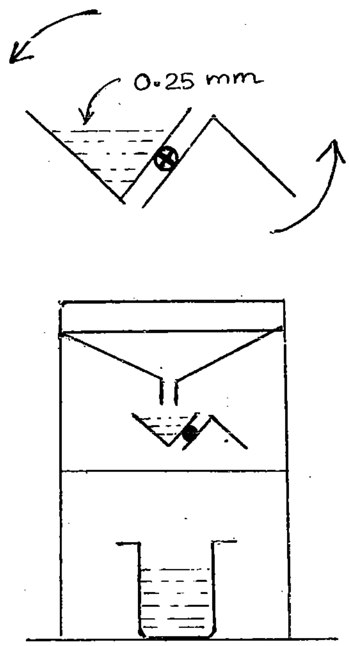


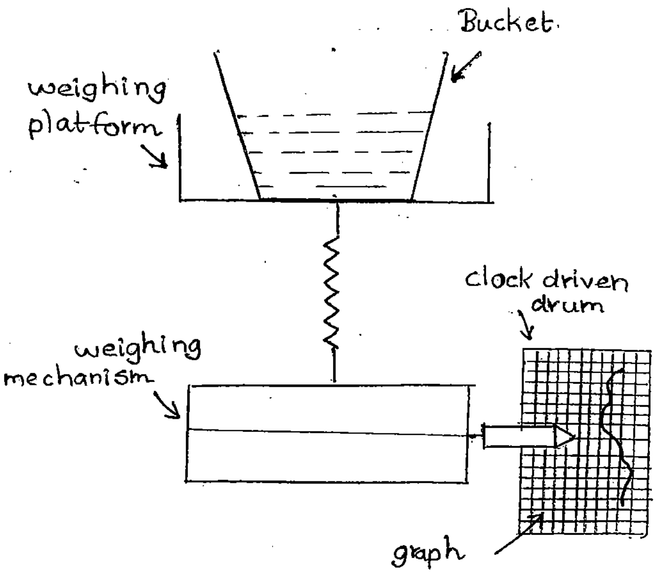
* IS raingauge

- Indian Standard raingauge to-match Indian conditions.
- Similar to Symon's gauge with following modifications.
  - (i) c/s area of collector : 100 cm^2 to 200 cm^2
  - (ii) Receiver capacity : 2 to 10 L
  - (iii) Metal container replaced with Fibre Reinforced Plastic, FRP, container.
- Measures 100 mm to 1000 mm rain at a time.
- Measurement is recorded at IST 8:30 manually.

* Weighing Bucket type Raingauge

- used to measure both rainfall and snowfall.



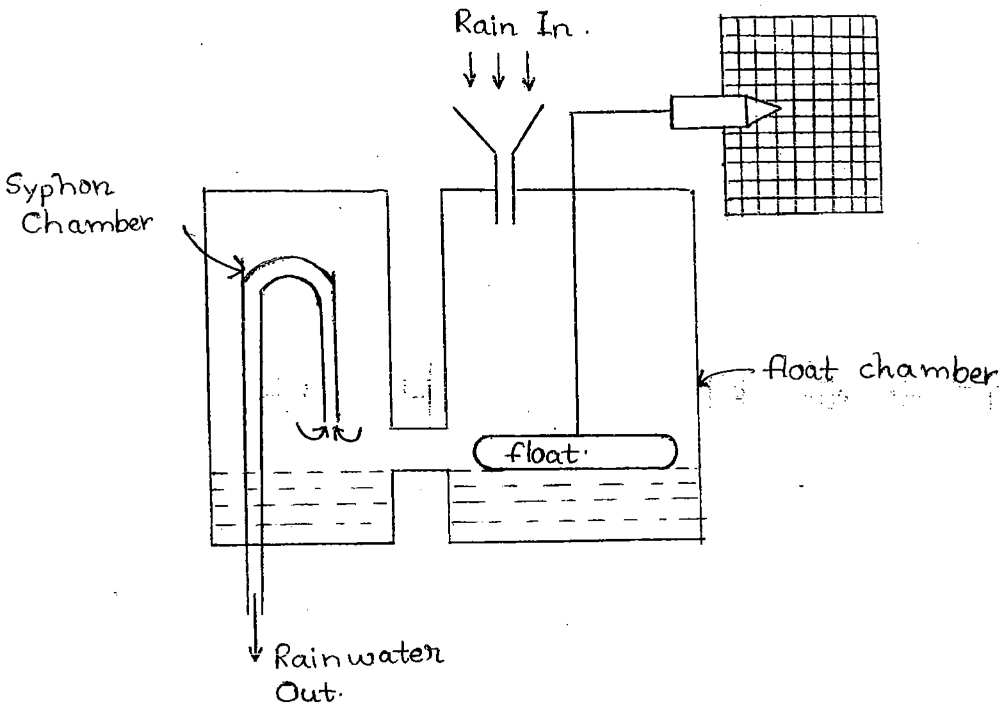


* Tipping Bucket Type Raingauge :

- to measure rainfall at remote and Inaccessible location
- tips for every 0.25 mm rainwater collection.

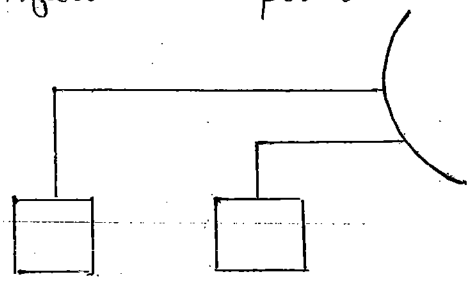
* Syphon's Rain gauge.

- under normal conditions
- Syphon raingauges are preferred to other gauges as per IS code.



* Radar Measurement (Radio Detection And Ranging).

- measures rainfall over an area, whereas other gauges measure rainfall at a point.

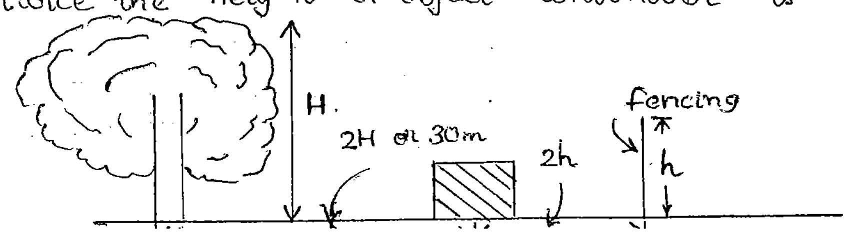


- Range = 200 km^2

nd Dec, TUESDAY → Rain Gauge Station

The place where rain gauge is installed and rainfall measurement is carried out is called Rain gauge Station.

- To install raingauge, min. plot of size 5.5m x 5.5 m required
- Level ground open to sky is required.
- Minimum distance b/w the gauge and the nearest tall object is 30m (or) twice the height of object whichever is more



→ Density of Raingauge Network :

Number of rain gauges per given area is called Raingauge Density (or) density of raingauge network.

- For plain and flat catchment : 1 raingauge for 520 km^2
- Areas elevated above 1000 m : 1 raingauge for 260-390 km^2
- Mountains and hilly regions : 1 raingauge for 130 km^2

→ Optimum number of Raingauges, 'n'

Let $P_1, P_2 \ldots P_m$ be the rainfall values recorded at the existing raingauge stations, 1, 2 ... m respectively.

By subjecting the rainfall data recorded at 'm' no. of existing raingauge stations to statistical analysis, optimum no. of raingauges 'n' can be determined for a given percentage of allowable or admissible error 'E'

Step 1: Find mean of rainfall data.

$$\bar{P} = \frac{P_1 + P_2 + \ldots P_m}{m} = \frac{\Sigma P_i}{m}$$

Step 2: Find standard deviation of rainfall data.

$$\sigma = \sqrt{\frac{\Sigma(P_i - \bar{P})^2}{m-1}}$$

Step 3: Find coeffecient of variation.

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

Step 4: For a given allowable (or) admissible % error, E

$$\left.\begin{array}{l}\text{Optimum no: of} \\ \text{raingauges}\end{array}\right\} n = \left(\frac{C_v}{E}\right)^2$$

$$\left.\begin{aligned} n &\propto \frac{1}{E} \\ E &\propto \frac{1}{\%\ \text{accuracy}} \end{aligned}\right\} \Rightarrow n \propto \%\ \text{accuracy}$$

$$\left.\begin{aligned} C_v &\propto \sigma \\ n &\propto C_v \\ \sigma &\propto \frac{1}{m} \end{aligned}\right\} \Rightarrow n \propto \frac{1}{m}$$

- If <u>$n < m$</u>, gauges installed are <u>sufficient</u> in number.
- If <u>$n > m$</u>, gauges installed are <u>deficient</u> in number

$\therefore$ additional number of raingauges $= n - m$

% accuracy $= 100 - E$

P-6

1. $\bar{P} = 92.8$ cm $\qquad C_v = \frac{100\sigma}{\bar{P}} = \underline{33.08\%}$

$\sigma = 30.7$ cm

$E = 10\%$ $\qquad n = \left(\frac{C_v}{E}\right)^2 = \left(\frac{33.08}{10}\right)^2 = 10.94 \sim \underline{11}$

2. $C_v = 33\%$, $n = 5$

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

$\therefore$ $E = \frac{33}{\sqrt{5}} = 14.76\%$

% accuracy $= \underline{85.24\%}$

3. $C_v = 29.54\%$, $E = 10\%$

$\therefore$ $n = \left(\frac{C_v}{E}\right)^2 = \left(\frac{29.54}{10}\right)^2 = 8.73 \sim \underline{9}$

Q. There are 4 rain gauges in a catchment recorded 3 cm, 5 cm, 6 cm & 8 cm rainfall values rsptly. Find optimum number for 90% accuracy. Also recommend no. of additional raingauges required.

$\sigma = 1.443^2$, $C_v = \frac{100 \times 2.08}{5.5} = 37.82\%$

$\bar{x} = 5.5$,

$$n = \left(\frac{37.82}{100-90}\right)^2 = 14.3 \sim 15\%$$

Additional rain gauges required $= 15 - 4 = 11$

→ Preparation of Rainfall Data

Before using the rainfall data in hydrological analysis, data is verified with following two conditions :

(i) Continuity - data should be continuous without any broken information.

(ii) Consistency - data should be truly representative of the region.

* Missing Rainfall Data :

Let $P_1, P_2, \ldots P_m$ be the rainfall values recorded by the adjacent raingauge stations during the period, station 'X' was missed in recording rainfall. & $N_1, N_2 \ldots N_x \ldots N_m$ be the normal annual rainfall values (min 30 years, latest average rainfall data) of raingauge stations $1, 2, \ldots x \ldots m$, then missing rainfall data at station X is worked out by :

(i) Simple Mean Method.

- used when $N_1 = N_2 = \ldots N_m = N_x \pm 10\%$

$$\boxed{P_x = \frac{P_1 + P_2 + \ldots + P_m}{m}}$$; $P_x \rightarrow$ missing rainfall data at station X

(ii) Normal Ratio Method.

- used when $N_1 = N_2 = \ldots N_m \neq N_x \pm 10\% N_x$.

$$P_x = \frac{N_x}{m}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \dots \frac{P_m}{N_m}\right]$$

While working missing rainfall data at any station, rainfall data of all adjacent stations lying in same climatic zone is considered.

04.

A	B	C
$N_A = 170.6$ cm	$N_B = 180.3$ cm	$N_C = 165.3$
$P_A = 153$ cm	$P_B = ?$	$P_C = 145.1.$

$N_B \pm 10\% \; N_B$ → 198.33 / 162.27.

$N_A = N_C = N_B \pm 10\% \; N_B.$

∴ Simple mean method is used.

$$P_B = \frac{P_A + P_C}{2} = \frac{153 + 145.1}{2} = \underline{\underline{149.1 \text{ cm}}}$$

05.

I	II	III	IV
$N_I = 60$ cm	$N_{II} = 75$ cm	$N_{III} = 80$ cm	$N_{IV} = 100$ cm
$P_I = 90$ cm	$P_{II} = 60$ cm.	$P_{III} = ?$	$P_{IV} = 70$ cm.

$80 \pm 10\%(80)$ → 88 / 72

$N_I = N_{IV} \neq N_{III} \pm 10\% \; N_{III}$

∴ Normal ratio method used

$$P_{III} = \frac{N_{III}}{m}\left(\frac{P_1}{N_1} + \frac{P_2}{N_{II}} + \frac{P_{IV}}{N_{IV}}\right) = \frac{80}{3}\left(\frac{90}{60} + \frac{60}{75} + \frac{70}{100}\right) = \underline{\underline{80 \text{ cm}}}$$

06.

A	$N_A = 75$ cm	$P_A = 8.5$ cm.
B	$N_B = 84$ cm	$P_B = 6.7$ cm
C	$N_C = 70$ cm	$P_C = 9$ cm
D	$N_D = 90$ cm.	$P_D = ?$

$90 \pm 10\%(90)$ → 99 / 81

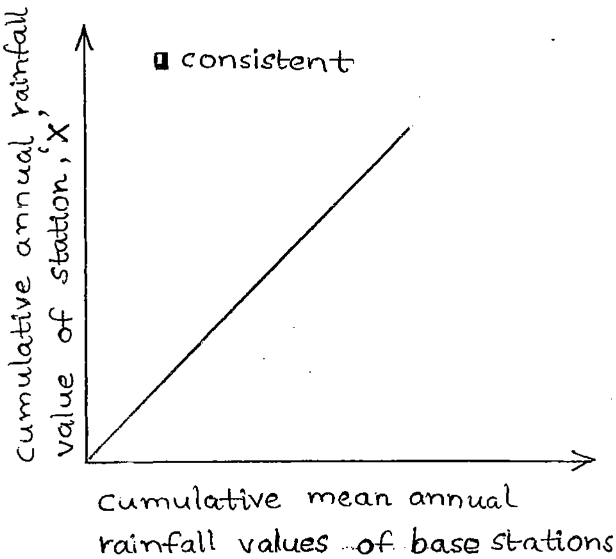
Normal ratio method is used.

$$P_D = \frac{N_D}{m}\left(\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C}\right)$$

$$= \frac{90}{3}\left(\frac{8.5}{75} + \frac{6.7}{84} + \frac{9}{70}\right) = \underline{9.65 \text{ cm}}$$

* Consistency of Rainfall Data : (true representation)

Consistency of rainfall data is verified by plotting "Double Mass Curve."

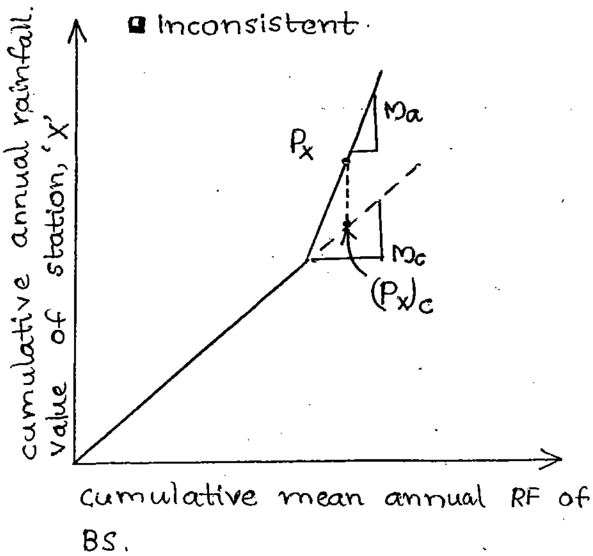


Base Stations :-

Adjacent rain gauge station's whose data is consistent.

Corrected consistent rainfall at station 'X',

$$(P_x)_c = P_x * \frac{M_c}{M_a}$$



→ Presentation of Rainfall Data :

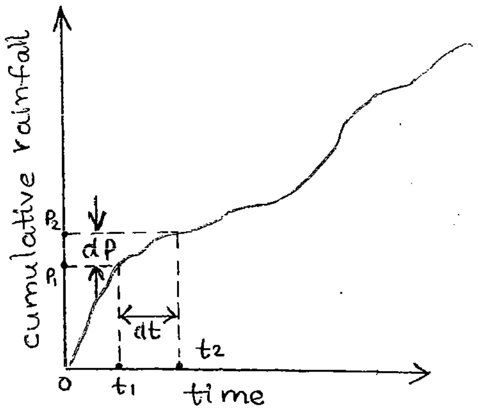
(i) Rainfall Mass curve
(ii) Rainfall Hyetograph
(iii) Depth – area – duration curves.
(iv) Intensity – duration – Frequency curves.
(v) Depth – duration – Frequency curves.

* Rainfall mass curve :

Recording type raingauges record rainfall data in the form of mass curve. Mass curve is a plot b/w accumulated rainfall and time.

* Rainfall Hyetograph:

It is a plot between rainfall intensity and time.



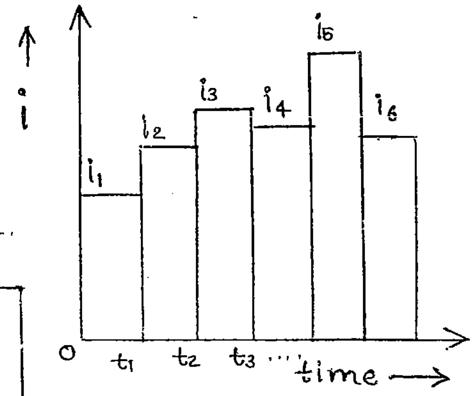
▫ Rainfall Mass Curve

$$\boxed{i = \frac{dP}{dt} = \frac{P}{t}}$$

– It is a histogram (or) bar diagram, easy to read rainfall information from this.

$$i = \frac{dP}{dt}.$$

$$\Rightarrow \int dP = \int_0^t i_i\, dt = \text{area of hyetograph.}$$



∴ Total rainfall in time, 't'

$$= \text{total area of hyetograph} = \sum_0^t i_i t_i$$

Eg: Total rainfall b/w time intervals t_i & t_{i+n} = area of hyetograph b/w t_i & t_{i+n}

$$= \sum_{t_i}^{t_{i+n}} i_i t_i$$

09 Total rainfall = total area of hyetograph

$$= (66+75+54)\frac{20}{60} + (48+69+51)\frac{40}{60} + (38+47+25)\frac{60}{60}$$

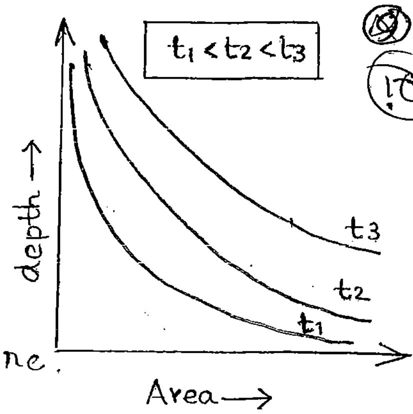
$$= \underline{\underline{287 \text{ mm}}}$$

07.

time (min)	i	i (20 min duration)
0 – 10	0.7	$\frac{0.7\times10 + 1.1\times10}{20} = 0.9$
10 – 20	1.1	
20 – 30	2.2	$\frac{2.2\times10 + 1.5\times10}{20} = 1.85$
30 – 40	1.5	
40 – 60	1.2	$\frac{1.2\times10 + 1.3\times10}{20} = 1.25$
50 – 60	1.3	
60 – 70	0.9	$\frac{0.9\times10 + 0.4\times10}{20} = 0.65$
	0.4	

⇒ Max intensity of rainfall for 20 min duration of storm = $\underline{\underline{1.85}}$ mm/min

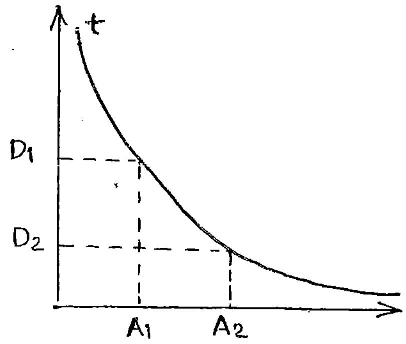
* Depth - Area - Duration curve



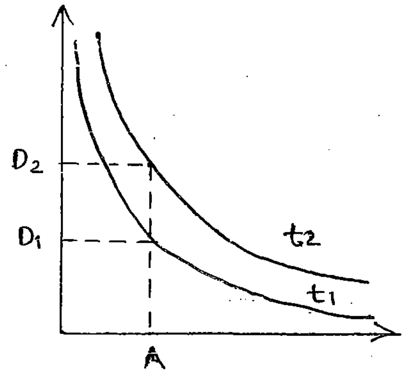
$$P = P_0 e^{-KA^n}$$

where,
P_0 → depth of rainfall at storm centre.
P → depth of rainfall.
A → areal distribution of storm.
K & n are constants.

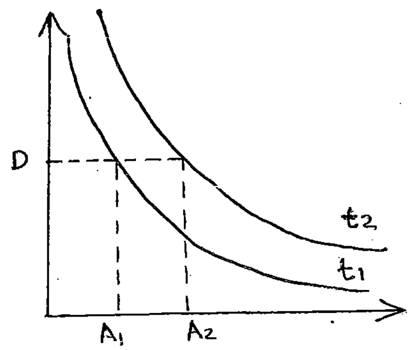
- For a given t hour storm, if $A_2 > A_1$, then $D_2 < D_1$



- For a given catchment basin of area A, if $t_2 > t_1$, then $D_2 > D_1$



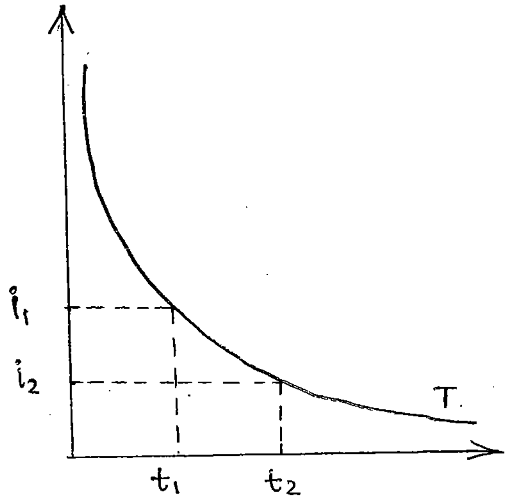
- For given depth 'D', if $t_2 > t_1$ then $A_2 > A_1$



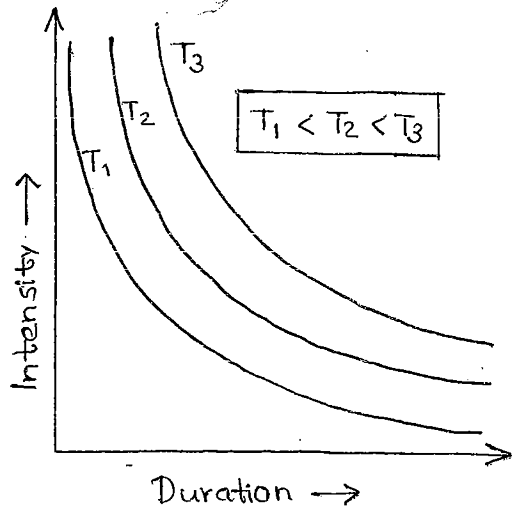
* Intensity - Duration - Frequency Curves

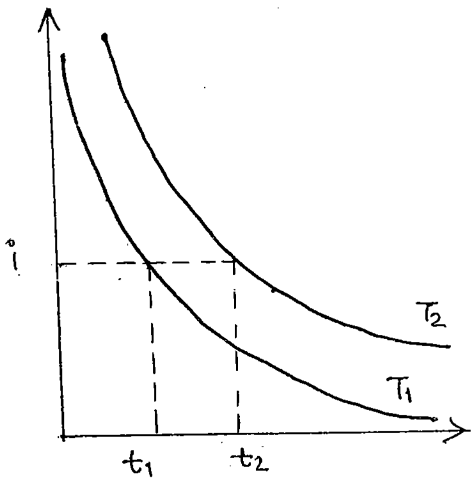
$$i = \frac{KT^x}{(D+a)^n}$$

where i → intensity of rainfall.
T → frequency (year) of rainfall.
D → duration of rainfall.
K, x, a, n are constants.

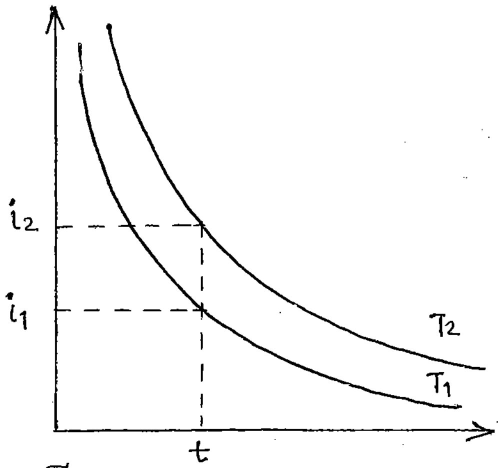


⊙ For given T, if $t_2 > t_1$, then $i_2 < i_1$





⊙ For given i, if $T_2 > T_1$, then $t_2 > t_1$



⊙ For given duration 't', if $T_2 > T_1$, then $i_2 > i_1$

* Depth - duration - frequency curves :