Module 1

Lecture 2: Weather and hydrologic cycle (contd.)

Hydrology

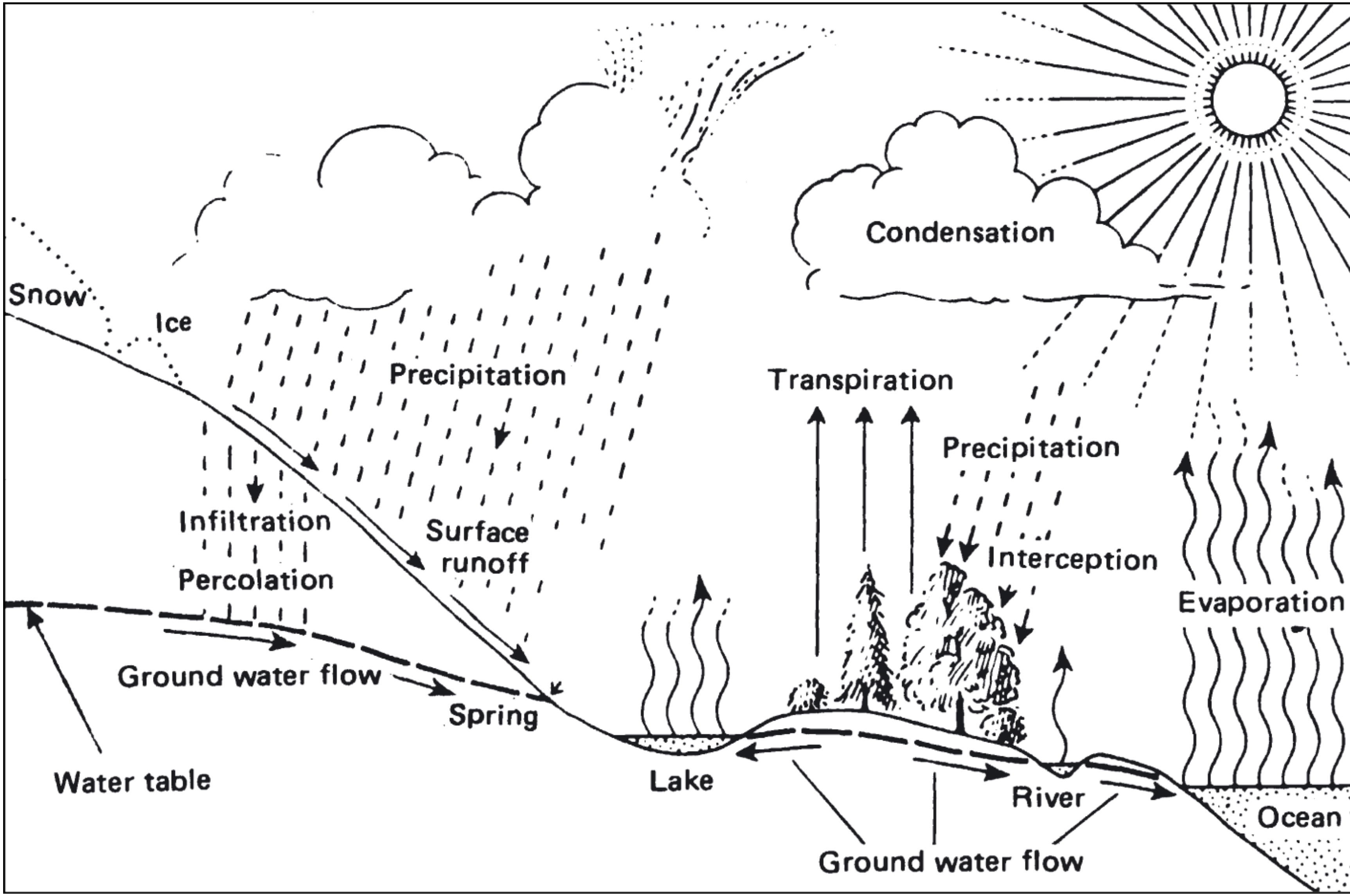
Hydor + logos (Both are Greek words)

"**Hydor**" means water and "**logos**" means study.

Hydrology is a science which deals with the occurrence, circulation and distribution of water of the earth and earth's atmosphere.

Hydrological Cycle: It is also known as water cycle. The hydrologic cycle is a continuous process in which water is evaporated from water surfaces and the oceans, moves inland as moist air masses, and produces precipitation, if the correct vertical lifting conditions exist.

Hydrologic Cycle



(climateofindia.pbworks.com)

Stages of the Hydrologic cycle

- ❖ Precipitation
- ❖ Infiltration
- ❖ Interception
- ❖ Depression storage
- ❖ Run-off
- ❖ Evaporation
- ❖ Transpiration
- ❖ Groundwater

Forms of precipitation

- **Rain**

Water drops that have a diameter of at least 0.5 mm. It can be classified based on intensity as,

Light rain ➔ up to 2.5 mm/h

Moderate rain ➔ 2.5 mm/h to 7.5 mm/h

Heavy rain ➔ > 7.5 mm/h

- **Snow**

Precipitation in the form of ice crystals which usually combine to form flakes, with an average density of 0.1 g/cm^3.

- **Drizzle**

Rain-droplets of size less than 0.5 mm and rain intensity of less than 1mm/h is known as drizzle.

Forms of precipitation **Contd…**

➢ **Glaze**

When rain or drizzle touches ground at 0^oC, glaze or freezing rain is formed.

➢ **Sleet**

It is frozen raindrops of transparent grains which form when rain falls through air at subfreezing temperature.

➢ **Hail**

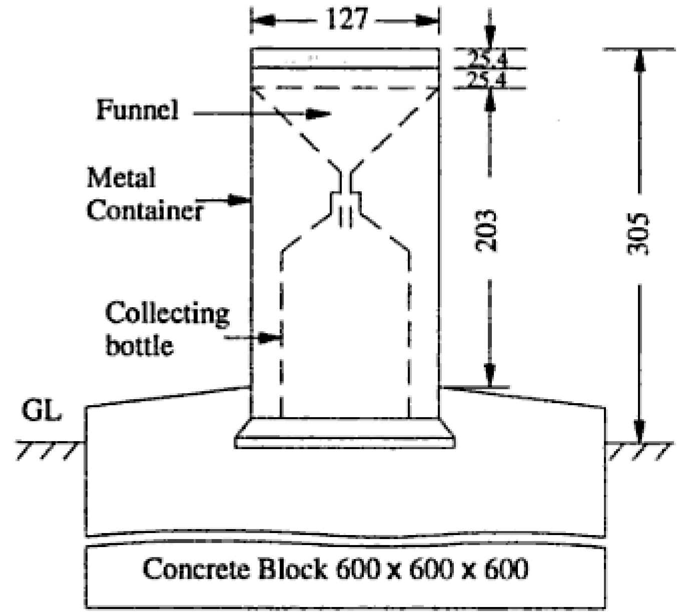
It is a showery precipitation in the form of irregular pellets or lumps of ice of size more than 8 mm.

Rainfall measurement

The instrument used to collect and measure the precipitation is called raingauge.

Types of raingauges:

1) Non-recording : Symon's gauge
2) Recording
   - Tipping-bucket type
   - Weighing-bucket type
   - Natural-syphon type



Symon's gauge

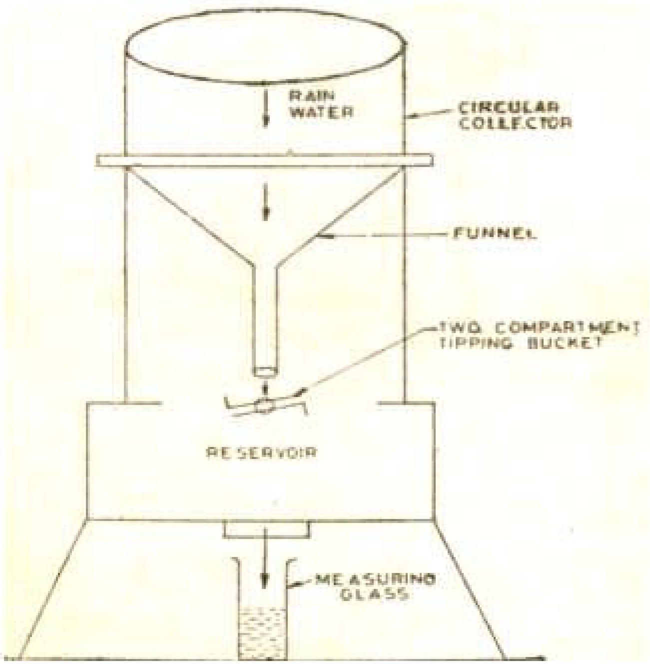
Recording raingauges

❖The instrument records the graphical variation of the rainfall, the total collected quantity in a certain time interval and the intensity of the rainfall (mm/hour).

❖It allows continuous measurement of the rainfall.

1. Tipping-bucket type

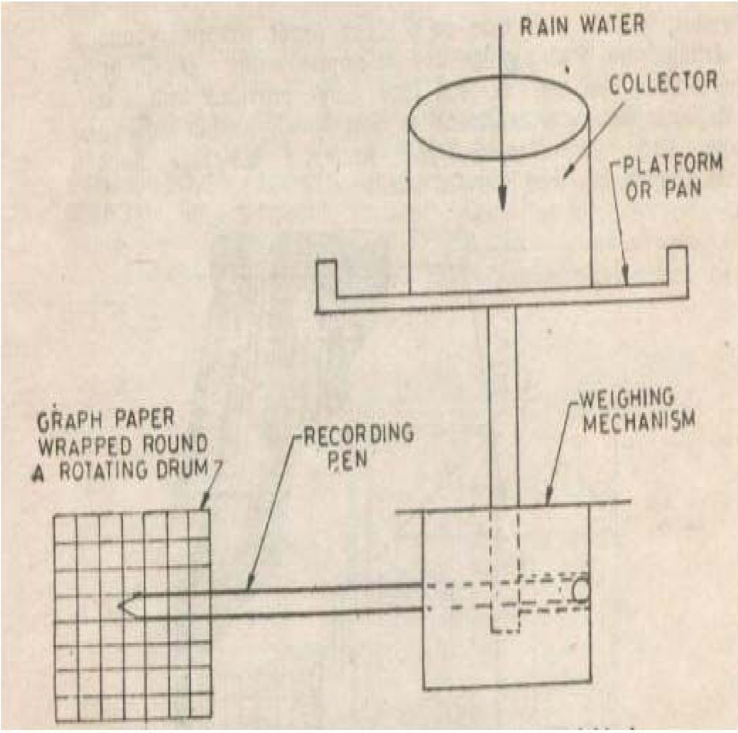
These buckets are so balanced that when 0.25mm of rain falls into one bucket, it tips bringing the other bucket in position.



Tipping-bucket type raingauge

2. Weighing-bucket type

- The catch empties into a bucket mounted on a weighing scale.
- The weight of the bucket and its contents are recorded on a clock work driven chart.
- The instrument gives a plot of cumulative rainfall against time (mass curve of rainfall).



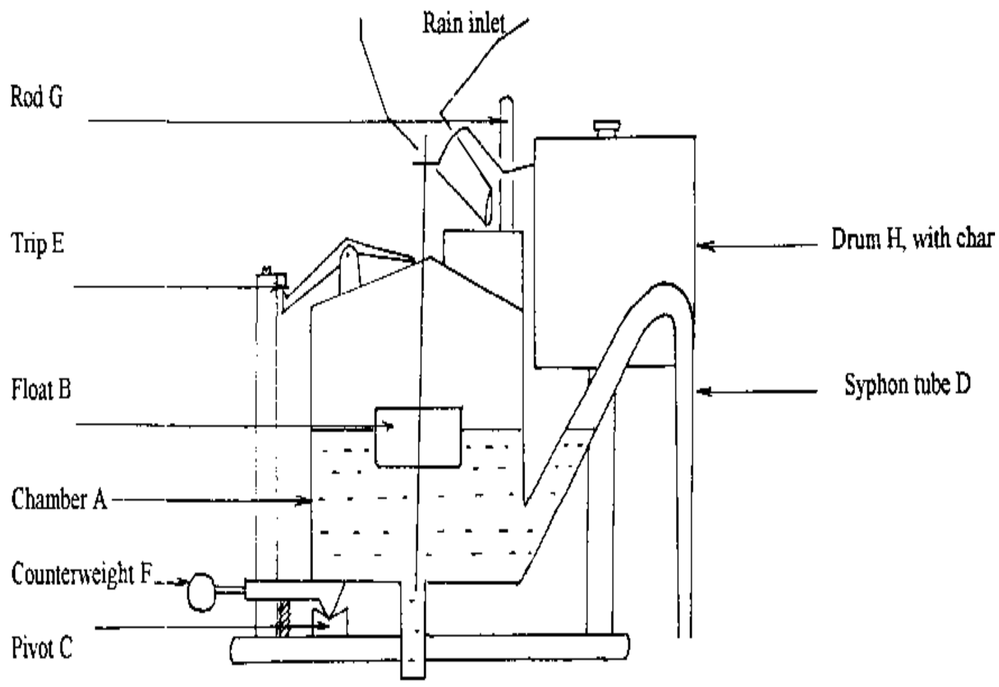
Weighing-bucket type raingauge

3. Natural Syphon Type (Float Type)

➢The rainfall collected in the funnel shaped collector is led into a float chamber, causing the float to rise.

➢ As the float rises, a pen attached to the float through a lever system records the rainfall on a rotating drum driven by a clockwork mechanism.

➢A syphon arrangement empties the float chamber when the float has reached a preset maximum level.



Float-type raingauge

Presentation of rainfall data

- **Hyetograph**

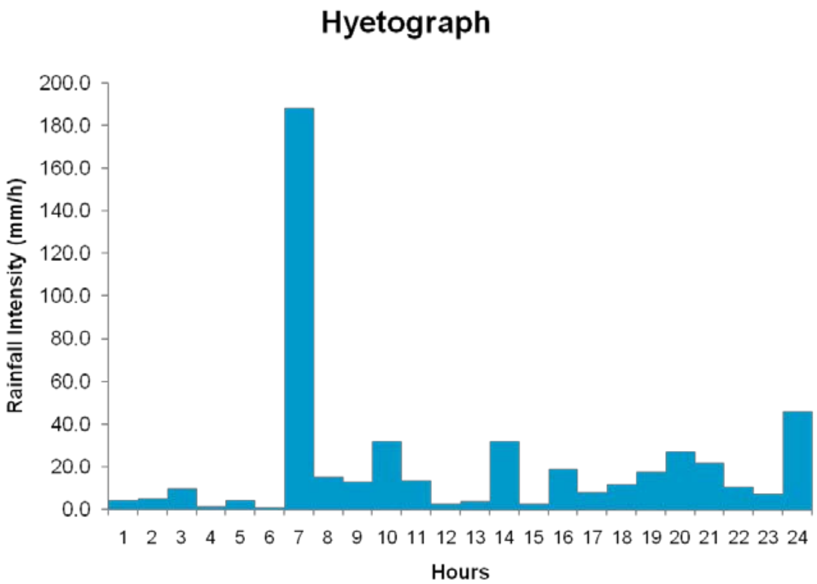
  Plot of rainfall intensity against time, where rainfall intensity is depth of rainfall per unit time

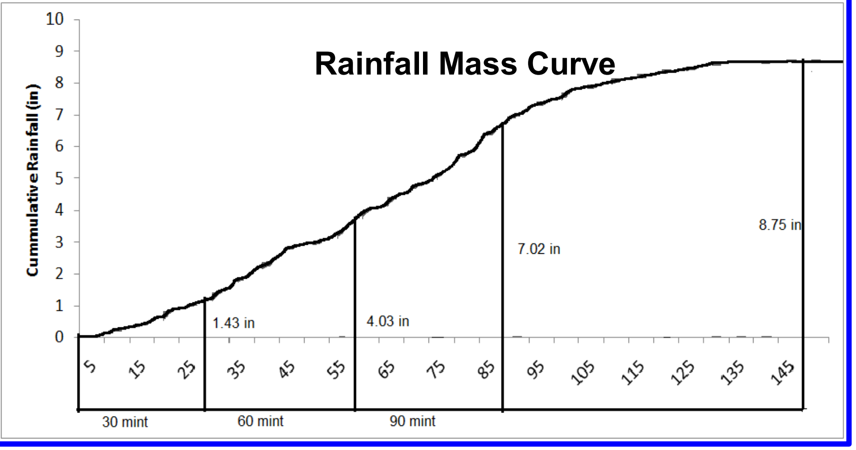
- **Mass curve of rainfall**

  Plot of accumulated precipitation against time, plotted in chronological order.

- **Point rainfall**

  It is also known as station rainfall . It refers to the rainfall data of a station





Mean precipitation over an area

The following methods are used to measure the average precipitation over an area:

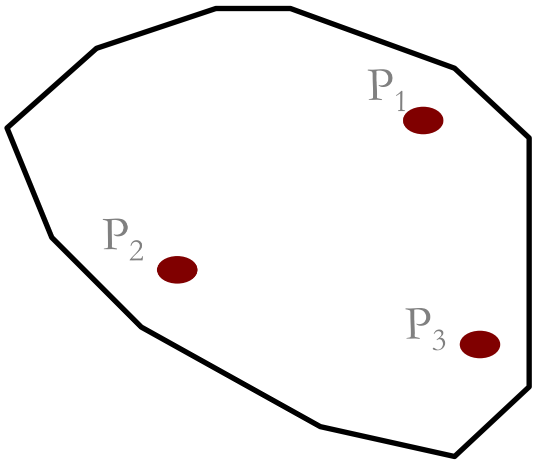
1. Arithmetic Mean Method
2. Thiessen polygon method
3. Isohyetal method
4. Inverse distance weighting

1. Arithmetic Mean Method

Simplest method for determining areal average

$$\overline{P} = \frac{1}{N}\sum_{i=1}^{N} P_i$$

where, P_i : rainfall at the i^{th} raingauge station
N : total no: of raingauge stations



Mean precipitation over an area Contd…

2. Thiessen polygon method

This method assumes that any point in the watershed receives the same amount of rainfall as that measured at the nearest raingauge station. Here, rainfall recorded at a gage can be applied to any point at a distance halfway to the next station in any direction.

Steps:

a) Draw lines joining adjacent gages

b) Draw perpendicular bisectors to the lines created in step a)

c) Extend the lines created in step b) in both directions to form representative areas for gages

d) Compute representative area for each gage

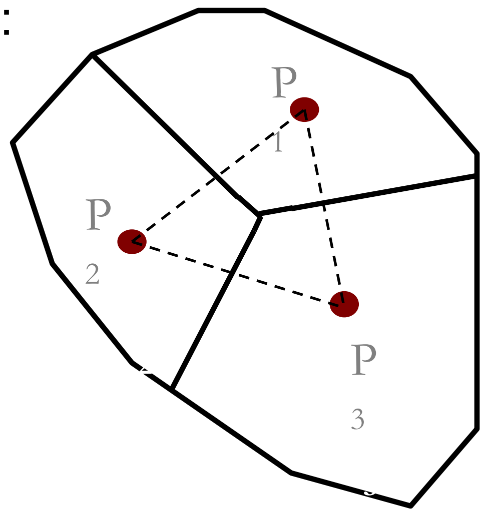
e) Compute the areal average using the following:

$$\overline{P} = \frac{1}{A}\sum_{i=1}^{N} A_i P_i$$

$P_1 = 10$ mm, $A_1 = 12$ Km^2

$P_2 = 20$ mm, $A_2 = 15$ Km^2

$P_3 = 30$ mm, $A_3 = 20$ km^2



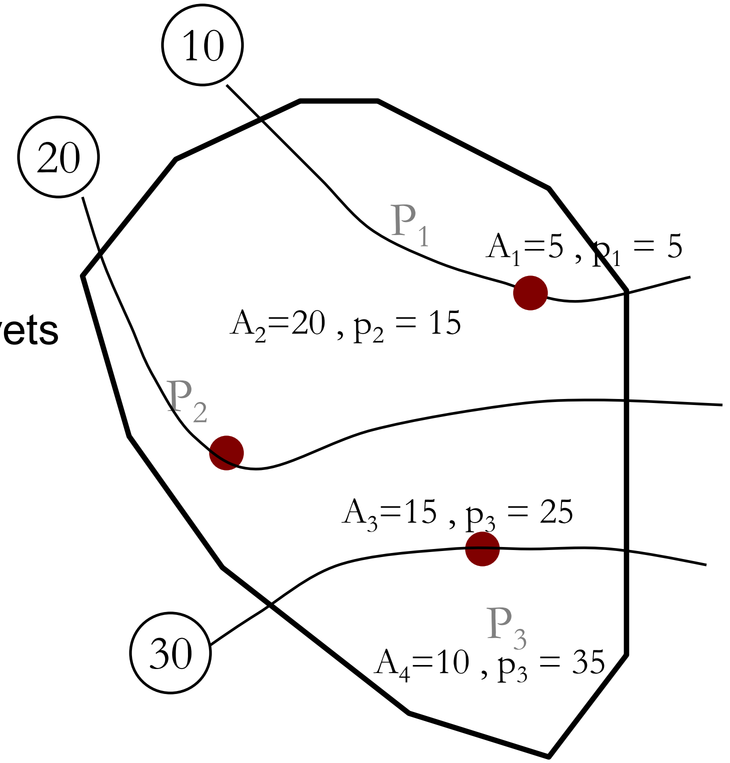
$$\overline{P} = \frac{12\times10+15\times20+20\times30}{47} = 20.7\ mm$$

3. Isohyetal method

$$\overline{P} = \frac{1}{A}\sum_{i=1}^{N} A_i P_i$$

where, A_i : Area between each pair of adjacent isohyets

P_i : Average precipitation for each pair of adjacent isohyets



$$\overline{P} = \frac{5\times5+20\times15+15\times25+10\times35}{50} = 21mm$$

4. Inverse distance weighting (IDW) method

Prediction at a point is more influenced by nearby measurements than that by distant measurements. The prediction at an ungauged point is inversely proportional to the distance to the measurement points.

Steps:

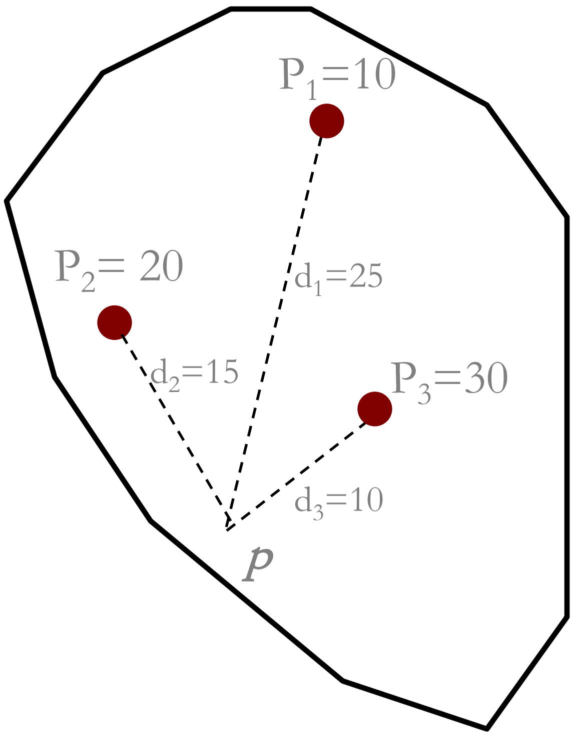
a) Compute distance (di) from ungauged point to all measurement points.

$$d_{12} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

b) Compute the precipitation at the ungauged point using the following formula:

$$\hat{P} = \frac{\sum_{i=1}^{N}\left(\frac{P_i}{d_i^{\,2}}\right)}{\sum_{i=1}^{N}\left[\frac{1}{d_i^{\,2}}\right]} \qquad \hat{P} = \frac{\frac{10}{25^2} + \frac{20}{15^2} + \frac{30}{10^2}}{\frac{1}{25^2} + \frac{1}{15^2} + \frac{1}{10^2}} = 25.24 \ mm$$

N = No: of gauged points



Adjustments of precipitation data

- Check for continuity and consistency of rainfall records

- Normal rainfall as standard of comparison

  - Normal rainfall: *Average value of rainfall at a particular date, month or year over a specified 30-year period.*

Check for Continuity: (Estimation of missing data)

$P_1, P_2, P_3, \ldots, P_m$ ➔ annual precipitation at neighboring M stations 1, 2, 3,…, M respectively

Px ➔ Missing annual precipitation at station X

$N_1, N_2, N_3, \ldots, N_m$ & Nx➔ normal annual precipitation at all M stations and at X respectively

Adjustments of precipitation data Contd…

Check for continuity

1. ***Arithmetic Average Method:***

   This method is used when normal annual precipitations at various stations show variation within 10% w.r.t station X

2. ***Normal Ratio Method***

   Used when normal annual precipitations at various stations show variation >10% w.r.t station X

Adjustments of precipitation data Contd…

Test for consistency of record

Causes of inconsistency in records:

- Shifting of raingauge to a new location
- Change in the ecosystem due to calamities
- Occurrence of observational error from a certain date
- Relevant when change in trend is >5years

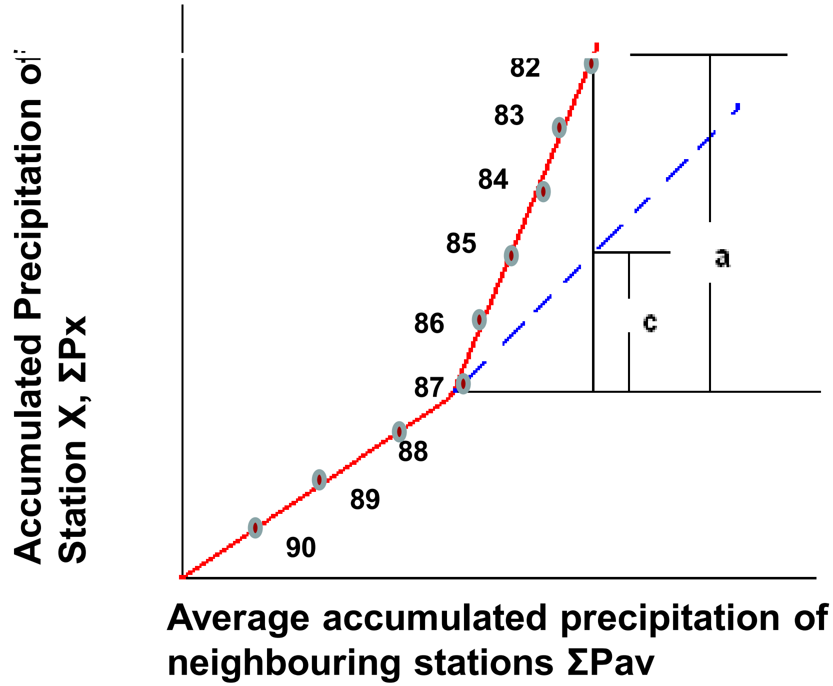
Adjustments of precipitation data Contd…

Test for consistency of record

Double Mass Curve Technique

When each recorded data comes from the same parent population, they are consistent.

- Break in the year : 1987
- Correction Ratio : Mc/Ma = c/a
- Pcx = Px*Mc/Ma



P_{cx} – corrected precipitation at any time period t_1 at station X

P_x – Original recorded precipitation at time period t_1 at station X

M_c – corrected slope of the double mass curve

M_a – original slope of the mass curve

Depth-Area-Duration relationships

It indicates the areal distribution characteristic of a storm of given duration.

Depth-Area relationship

For a rainfall of given duration, the average depth decreases with the area in an exponential fashion given by:

$$\overline{P} = P_0 \exp(-KA^n)$$

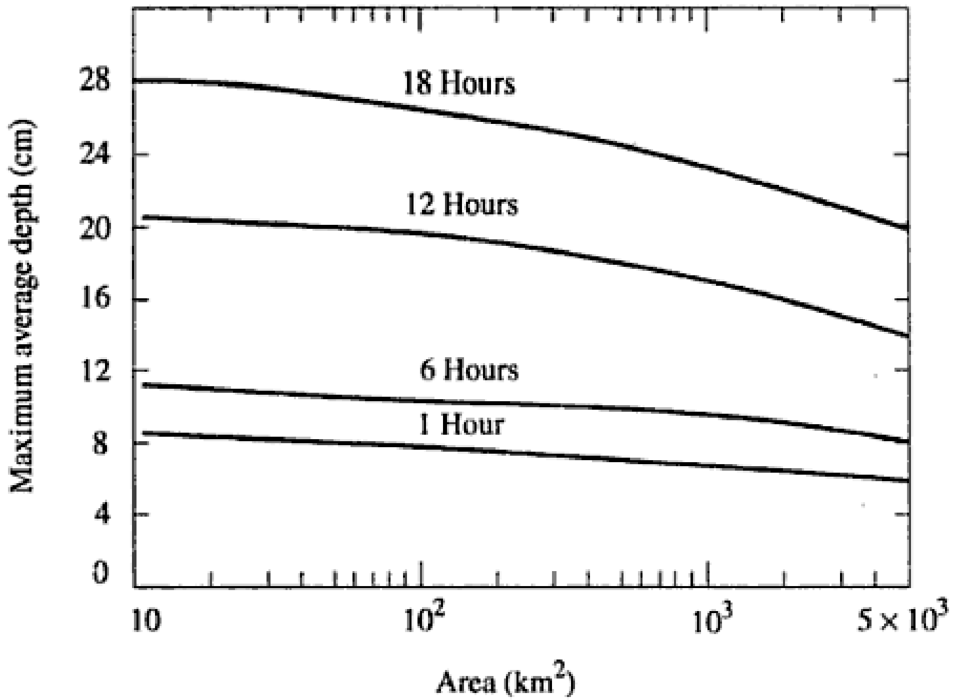
where $\overline{P}$: average depth in cms over an area A km^2,

P_o : highest amount of rainfall in cm at the storm centre

K, n : constants for a given region

Depth-Area-Duration relationships Contd…

- The development of maximum depth-area-duration relationship is known as DAD analysis.
- It is an important aspect of hydro-meteorological study.



Typical DAD curves

(Subramanya, 1994)

Intensity-Duration-Frequency (IDF) curves

- It is necessary to know the rainfall intensities of different durations and different return periods, in case of many design problems such as runoff disposal, erosion control, highway construction, culvert design etc.
- The curve that shows the inter-dependency between i (cm/hr), D (hour) and T (year) is called IDF curve.
- The relation can be expressed in general form as:

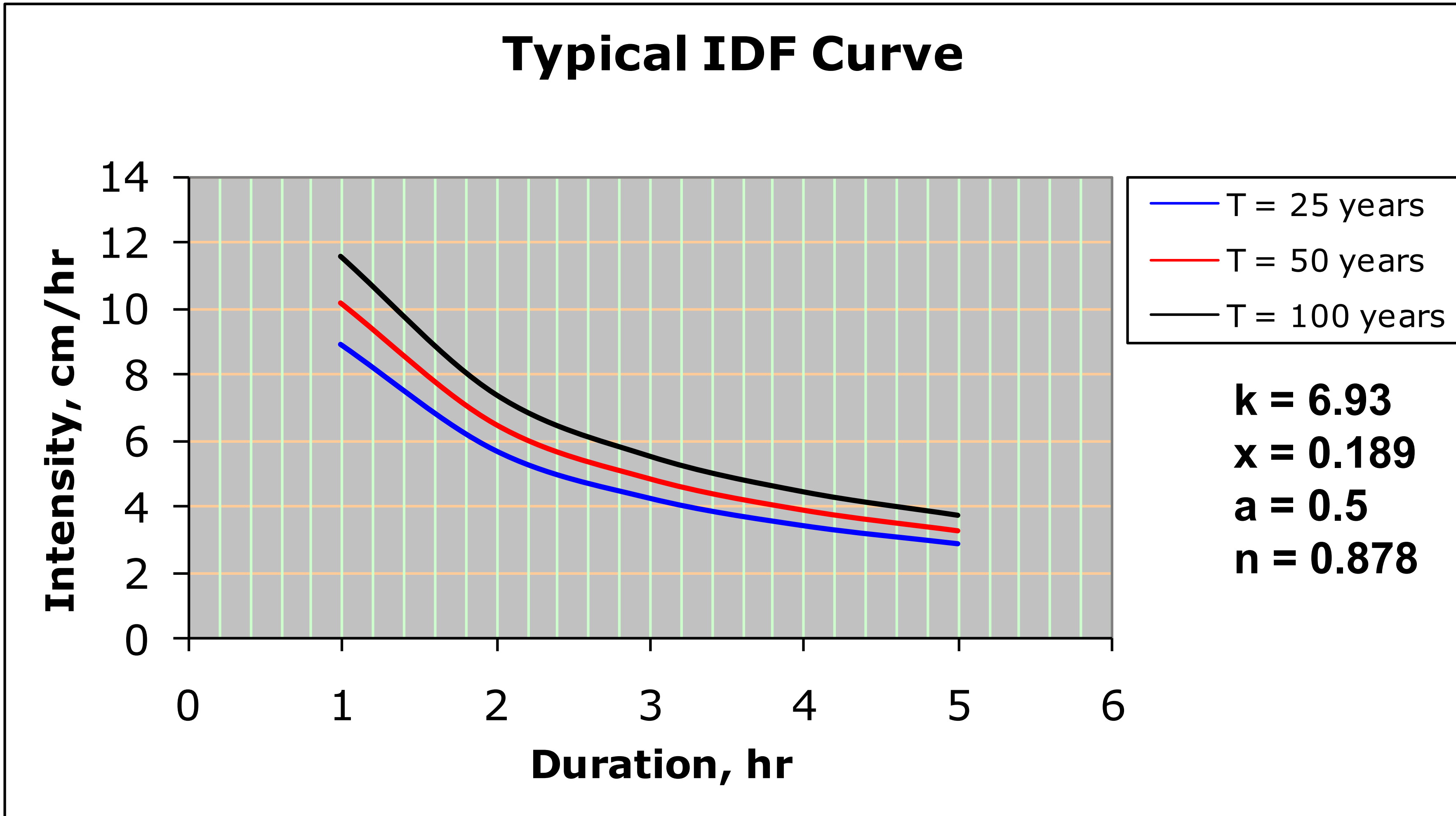
$$i = \frac{k\,T^{x}}{(D+a)^{n}}$$

i – Intensity (cm/hr)

D – Duration (hours)

K, x, a, n – are constant for a given catchment

Intensity-Duration-Frequency (IDF) curves Contd…



Exercise Problem

- The annual normal rainfall at stations A,B,C and D in a basin are 80.97, 67.59, 76.28 and 92.01cm respectively. In the year 1975, the station D was inoperative and the stations A,B and C recorded annual precipitations of 91.11, 72.23 and 79.89cm respectively. Estimate the rainfall at station D in that year.