Precipitation

Precipitation denotes all forms of water that reach the earth from the atmosphere. The usual forms are rainfall, snowfall, hail, frost and dew.

To form precipitation

There are four conditions that must be present for the production of precipitation

(i) Atmosphere must have moisture

(ii) Must be sufficient nuclei present to aid condensation

(iii) Weather conditions must be good for condensation of water vapor to take place

(iv) product of condensation must reach the earth

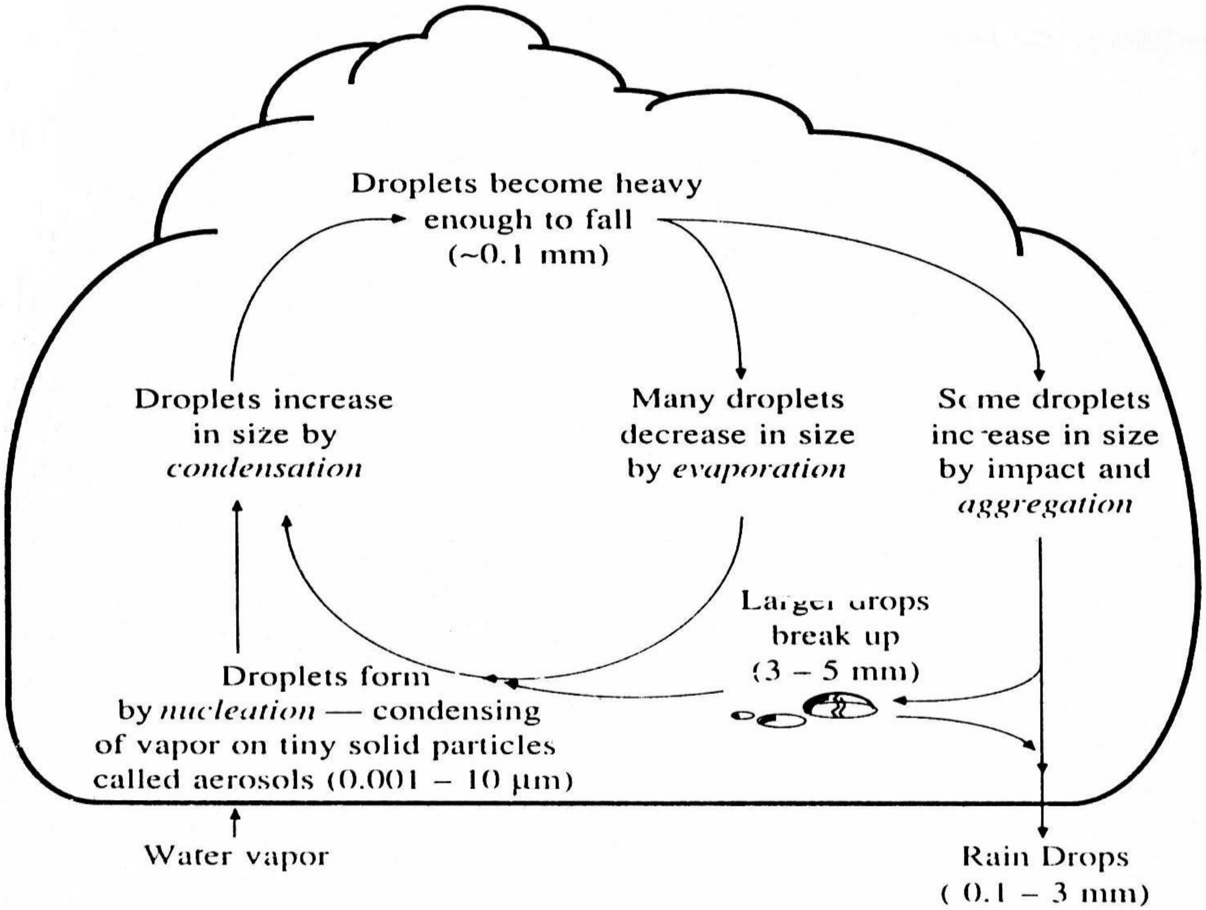


FIGURE 3.3.1
Water droplets in clouds are formed by nucleation of vapor on aerosols, then go through many condensation-evaporation cycles as they circulate in the cloud, until they aggregate into large enough drops to fall through the cloud base.

Different forms of precipitation

Rainfall

Sizes of raindrop 0.5 mm to 6 mm

Type	Intensity
Light rain	trace to 2.5 mm/h
Moderate rain	2.5 mm/h to 7.5 mm/h
Heavy rain	>7.5 mm/h

Snow

Density varies from 0.06 to 0.15 gm/ cm^3 (average density 0.1 gm/ cm^3).

Drizzle

Water droplets of size less than 0.5 mm and intensity less than 1 mm/h.

Glaze

When rain or drizzle comes in contact with cold ground at around 0^o c, the water drops freeze to form an ice coasting called glaze.

Sleet

When rain falls through air at sub – freezing temperature, the frozen raindrop called sleet.

Hail

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

Important considerations for setting a raingauge

- In a flat surface
- It must be placed near the ground
- Placed in an open space (area of 5.5 m x 5.5 m).
- No obstruction within 30 m.

Types of raingauge

- Non – recording Gauge
- Recording Gauge

Symon's non-recording gauge

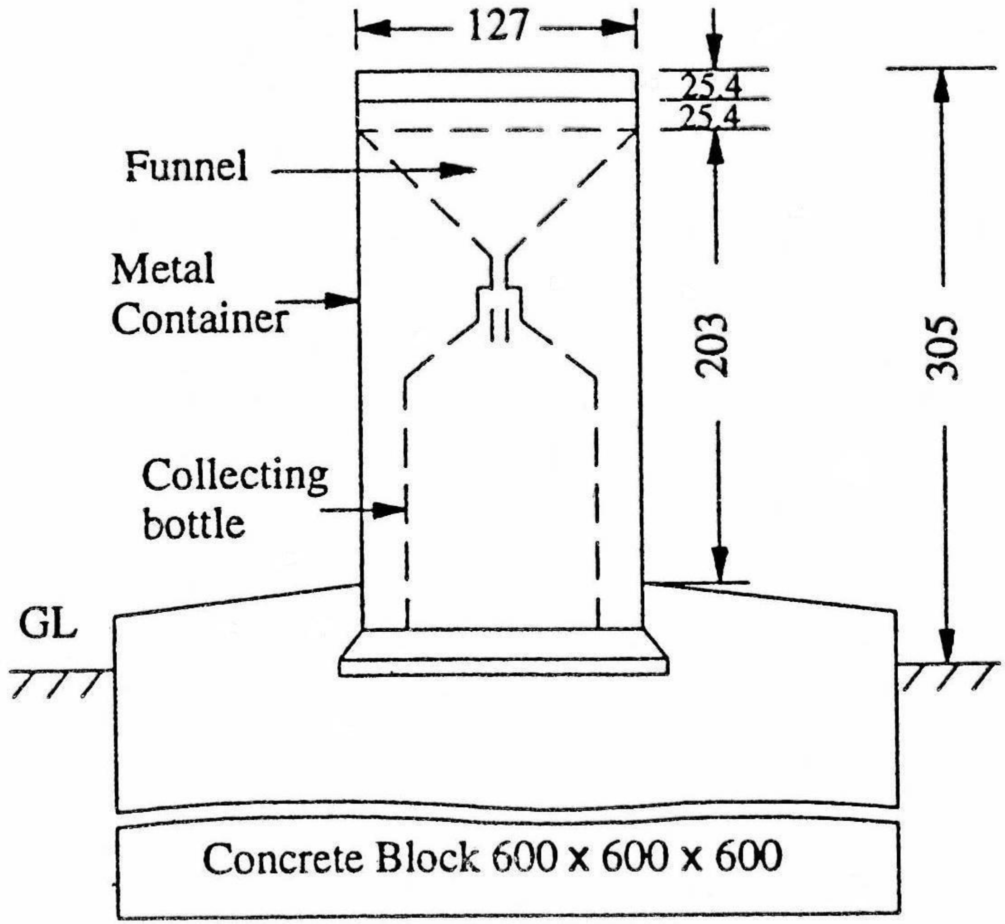


Fig. Nonrecording raingauge (Symons' gauge)

Recording Gauges

Advantage

- We can identify storm event
- We find intensity of rainfall
- We find storm duration

Tipping-Bucket Type

- 30.5 cm size raingauge
- Two compartment bucket size 0.1 mm/0.25 mm

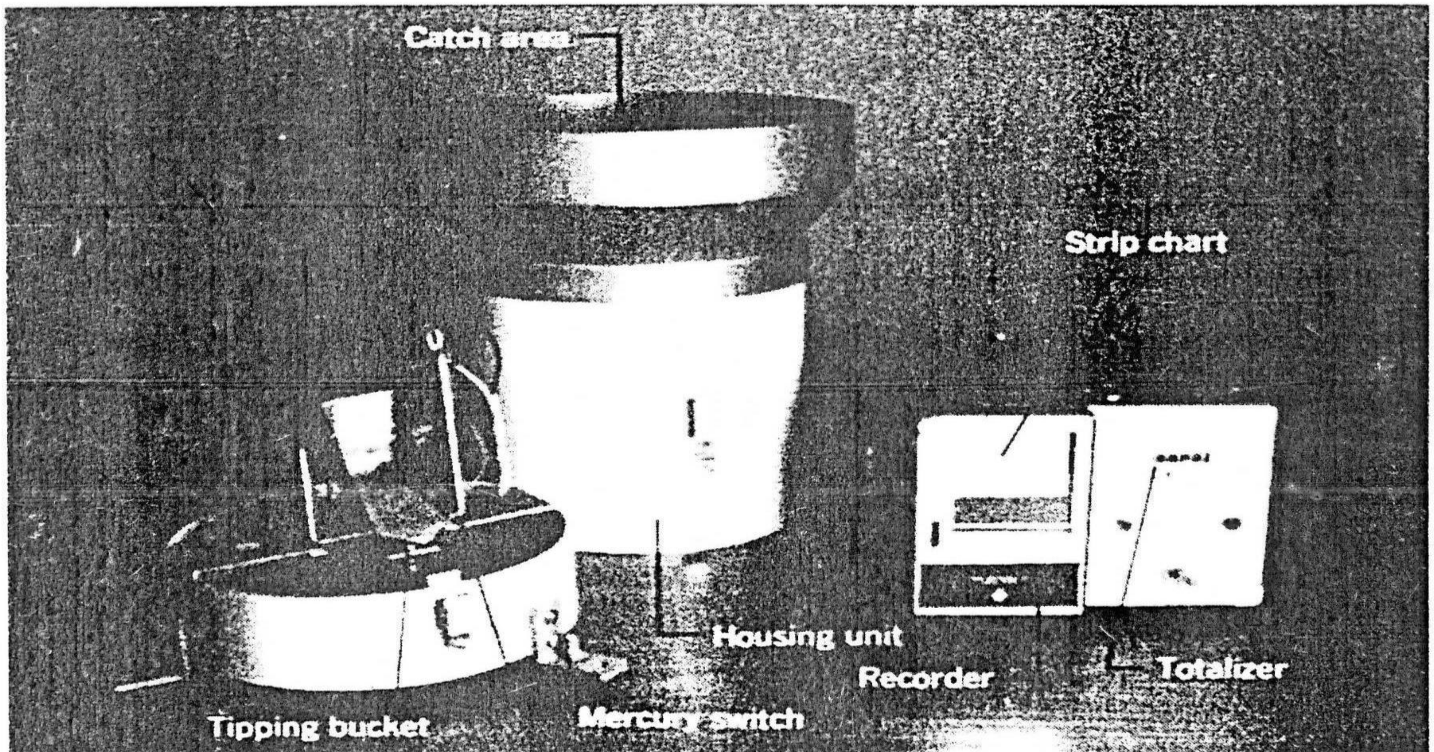


FIGURE Tipping bucket housing unit mercury switch recorder strip chart totalizer.

Weighing – Becket Type

Natural Syphon Type

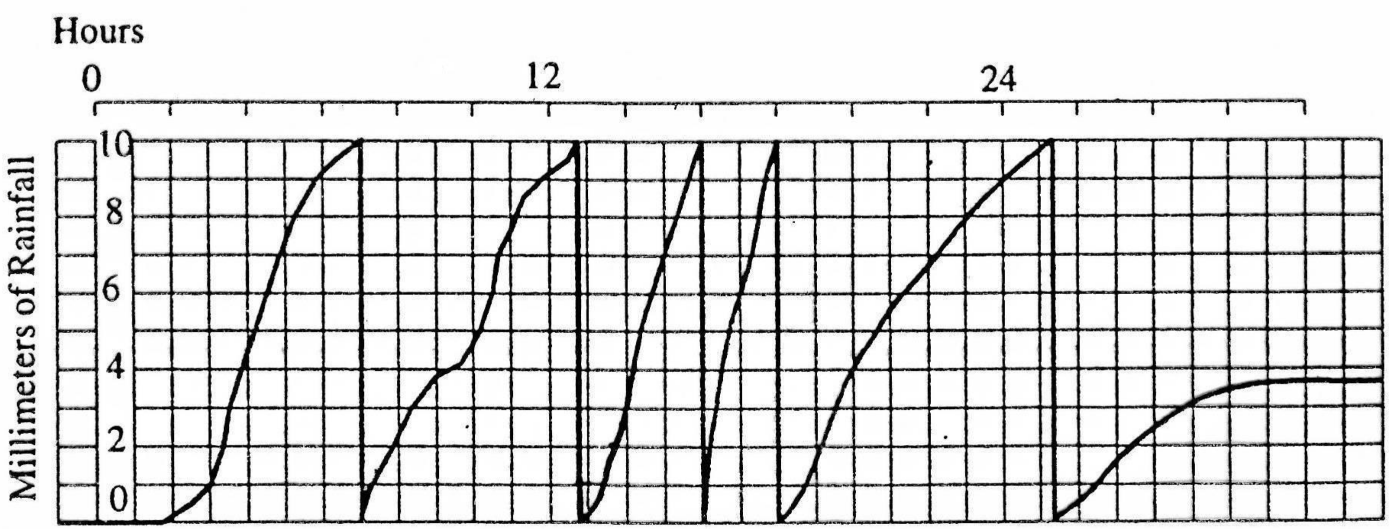


Fig. Recording from a natural syphon–type gauge (schematic)

Raingauge Network

World Meteorological Organization (WMO) recommends the following densities.

1. Flat regions : ideal – 1 station for 600 – 900 Km^2
   acceptable – 1 station for 900 - 3000 Km^2

2. Mountains regions : ideal – 1 station for 100 – 250 Km^2
   acceptable - 1 station for 250 – 1000 Km^2

3. Arid and Polar Zones : 1- station for 1500 – 10,000 Km^2

Adequacy of Raingauge Stations

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

where,
N = optimal number of stations,
ϵ = allowable degree of error in the estimate of the mean rainfall, and
C_v = coefficient of variation of the rainfall values at the existing m stations (in per cent).
If there are ***m*** stations in the catchment each recording rainfall values P_1, P_2, ..., P_p..... P_m in a known time, the coefficient of variation C_v is calculated as:

$$C_v = \frac{100 \times \sigma_{m-1}}{\overline{P}}$$

where, standard deviation =

$$\sigma_{m-1} = \sqrt{\frac{\sum_{1}^{m}\left(p_i - \overline{p}\right)^2}{m-1}}$$

P_i = precipitation magnitude in the i^{th} station

$$\overline{P} = \frac{1}{m}\left(\sum_{1}^{m} P_i\right) = \text{mean precipitation}$$

In calculating optimal number of stations N it is usual to take ϵ = 10%. It is seen that if the value of ϵ is small, the number of raingauge stations will be more.

Example A catchment has six raingauge stations. In a year, the annual rainfalls recorded by the gauges are as follows:

Station	A	B	C	D	E	F
Rainfall	82.6	102.9	180.3	110.3	98.8	136.7

For a 10% error in the estimation of the mean rainfall, calculate the optimum number of stations in the catchment.

Solution

For this data,

m = 6

$\overline{P} = 118.6$

$\sigma_{m-1} = 35.04$

$\epsilon = 10$

$$C_v = \frac{100 \times 35.04}{118.6} = 29.54$$

$$N = \left(\frac{29.54}{10}\right)^2 = 8.7$$

Provide 9 stations

Estimation of Missing Data

Given the annual precipitation values, P_1, P_2, P_3, ... P_m at neighboring M stations 1,2,3, ..., M respectively, it is required to find the missing annual precipitation P_x at a station X not included in the above M stations. Further, the normal annual precipitations N_1, N_2, ..., N_i ... at each of the above (M+1) stations including station X are known.

If the normal annual precipitations at various stations are within about 10% of the normal annual precipitation at station X, then a simple arithmetic average procedure is followed to estimate P_x. Thus

$$P_x = \frac{1}{M}\left[P_1 + P_2 + \ldots + P_m\right]$$

If the normal precipitations vary considerably, then Px is estimated by weighing the precipitation at the various stations by the ratios of normal annual precipitations. This method, known as the normal ratio method, gives P_x as

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

Test for Consistency of Record

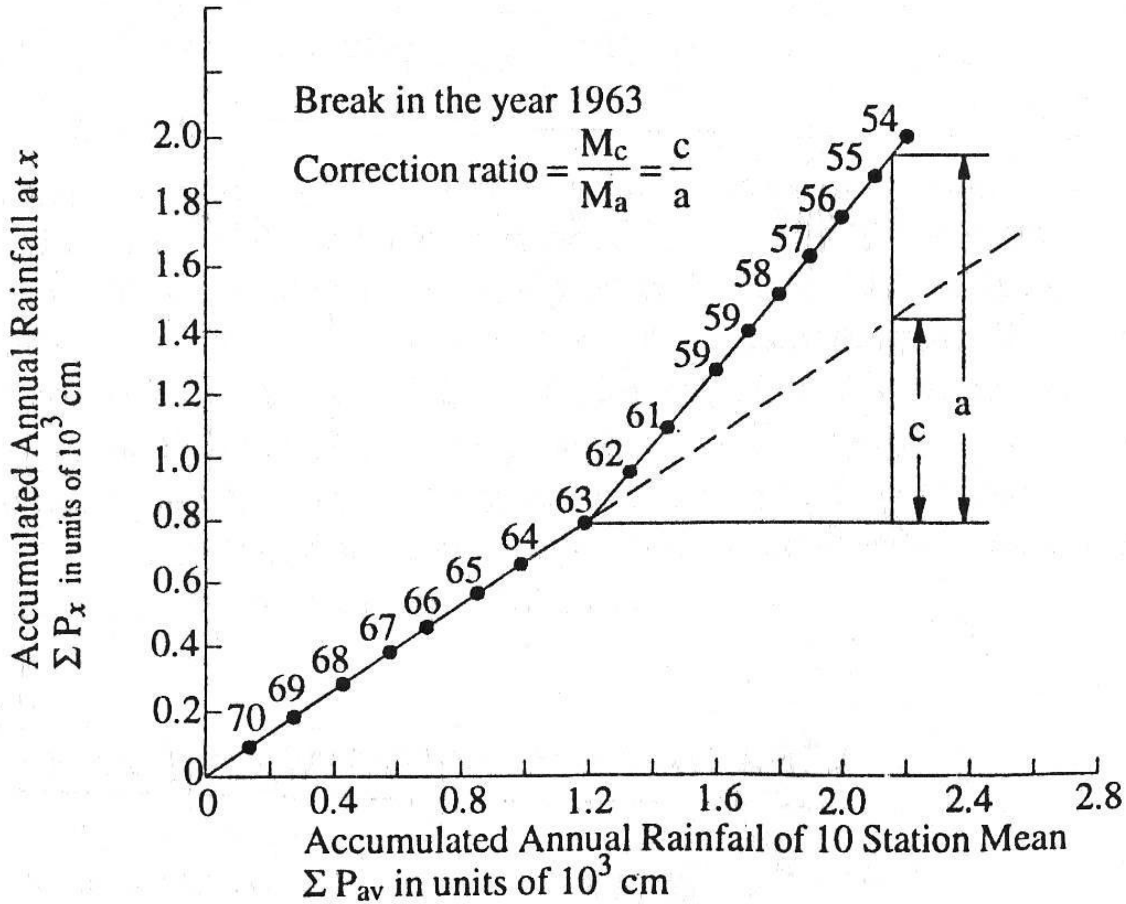


Fig. 2.7 Double–mass curve

$$P_{cx} = P_x \frac{M_c}{M_a}$$

Where 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

Arithmetic Average Method

$$\overline{P} = \sum_{i=1}^{n} P_i / n$$

$\overline{P}$ = average precipitation depth (mm or in.).

P_i = precipitation depth at gage (within the topographic basin), (mm or in.)

n = total number of gauging stations within the topographic basin

Thiessen Polygon Method

$$W_i = A_p/A$$

Where,

W_i = weighted area, dimensionless
A_p = area of the polygon within the topographic basin (km^2)
A = total area (km^2)

The average precipitation using the Thiessen method is

$$\overline{P} = \sum_{i=1}^{n} W_i P_i$$

where,

$\overline{P}$ = average precipitation (mm)
P_i = gage precipitation for polygon i
n = total number of polygons

Isohyetal Method

$$\overline{P} = \sum_{i=1}^{n} W_i P_i$$

Where,

$\overline{P}$	=	isohyetal average precipitation (mm)
P_i	=	isohyetal cell average precipitation (mm)
W_i	=	Ai/A; Ai – area of cell (km^2)
A	=	total area (km^2)
n	=	total number of cells

Example :

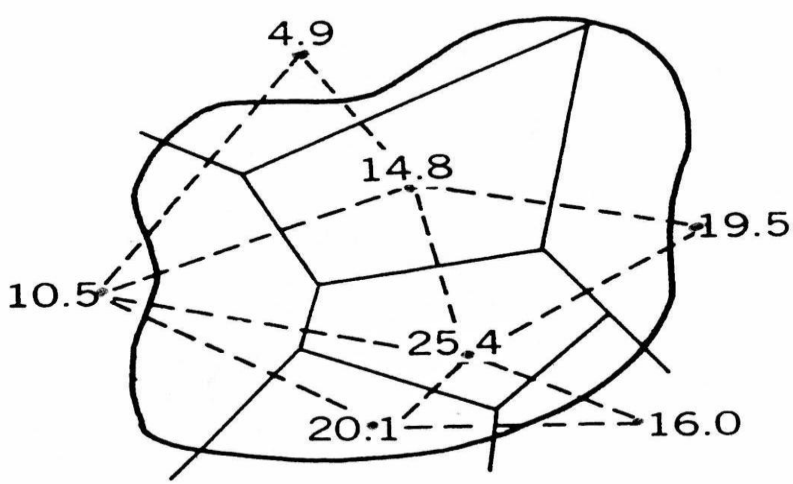
For the following watershed, estimate using three methods the average precipitation. The watershed in figure.

Solution

a. Arithmetic average (add those within the watershed)

$$\overline{P} = \sum_{i=1}^{n} P_i / n$$

$$\overline{P} = \frac{14.8 + 25.4 + 20.1}{3} = 20.1\ mm$$

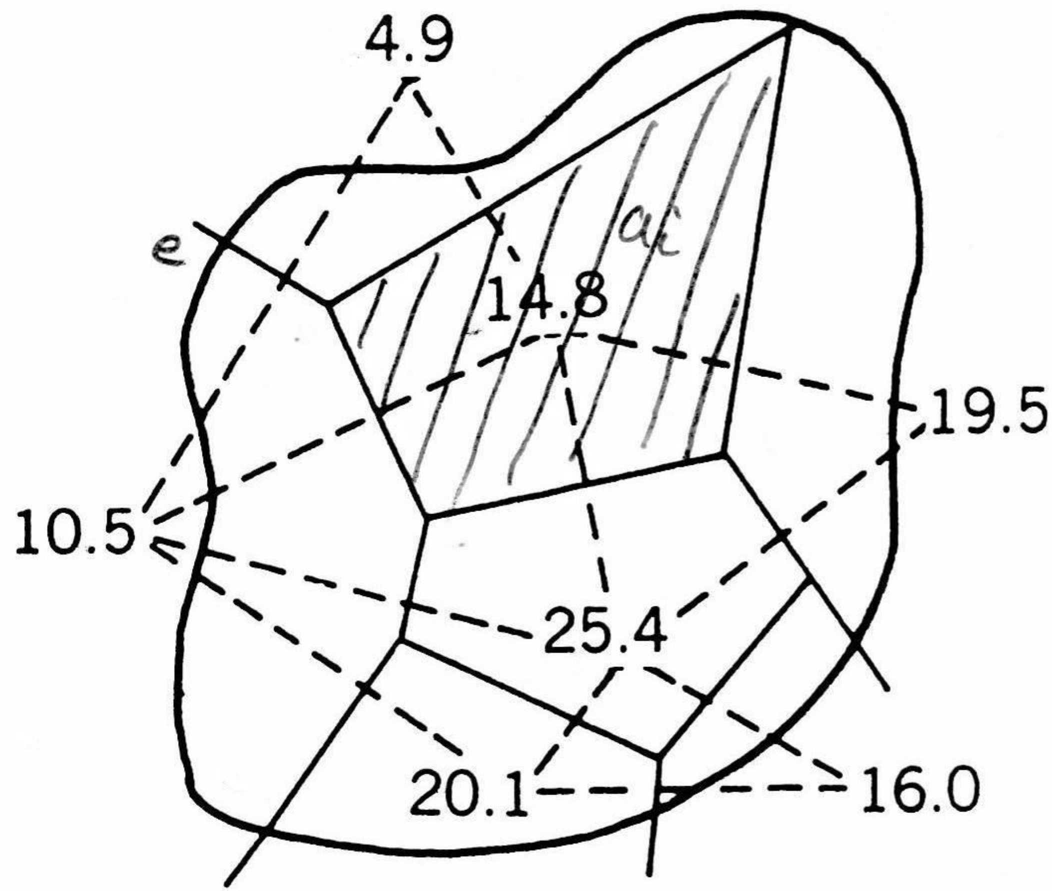


Thiessen Method

b. Thiessen method

$$\overline{P} = \sum_{i=1}^{n} W_i P_i$$

OBSERVED PRECIPITATION (P_i)	WEIGHTED AREA (W_i) $= \frac{a_i}{A}$	W_iP_i (mm)
14.8	0.29	4.3
19.5	0.16	3.1
4.9	0.07	0.3
10.5	0.19	2.0
25.4	0.15	3.8
20.1	0.12	2.4
16.0	0.02	0.3
	$\overline{P}$	= 16.2 mm



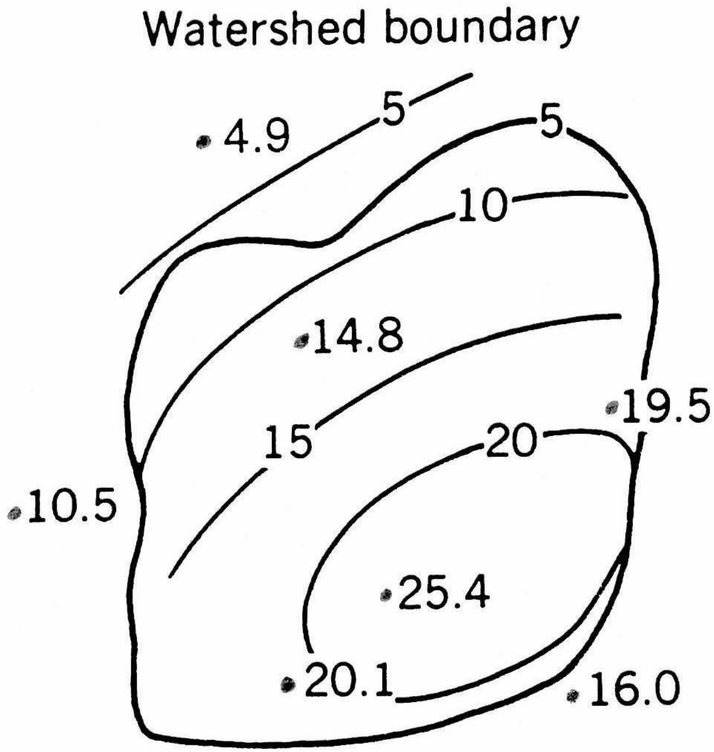
Thiessen
Method

c. **Isohyetal method**

$$\overline{P} = \sum_i W_i P_i$$

ISOHYET (mm)	WEIGHTED AREA (W_i)	AVERAGE PRECIPITATION (P_i)	W_iP_i (mm)
>20	0.30	22.7*	6.8
10	0.58	15.0	8.7
5	0.12	7.5	0.9
			$\overline{P}$ = 16.4 mm

*(25.4 + 20)/2 = 22.7

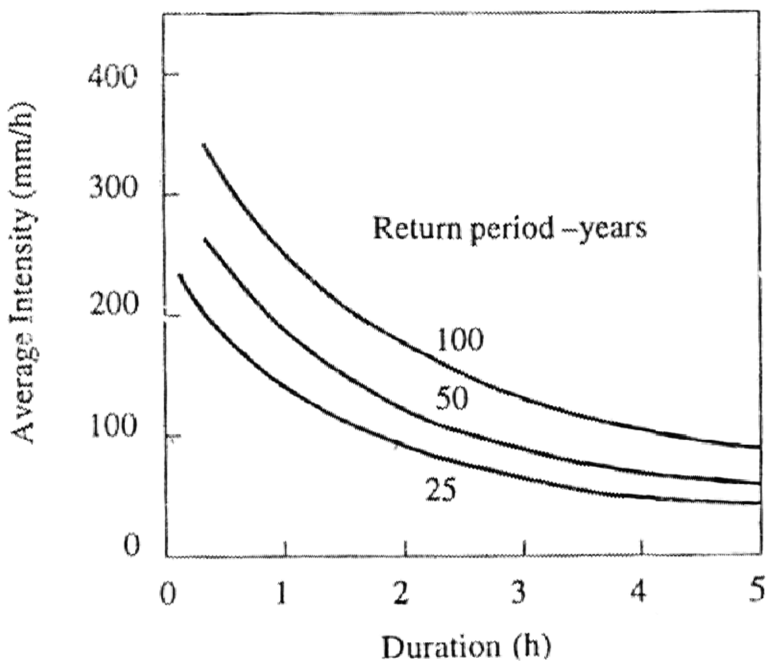


Isohyetal Method

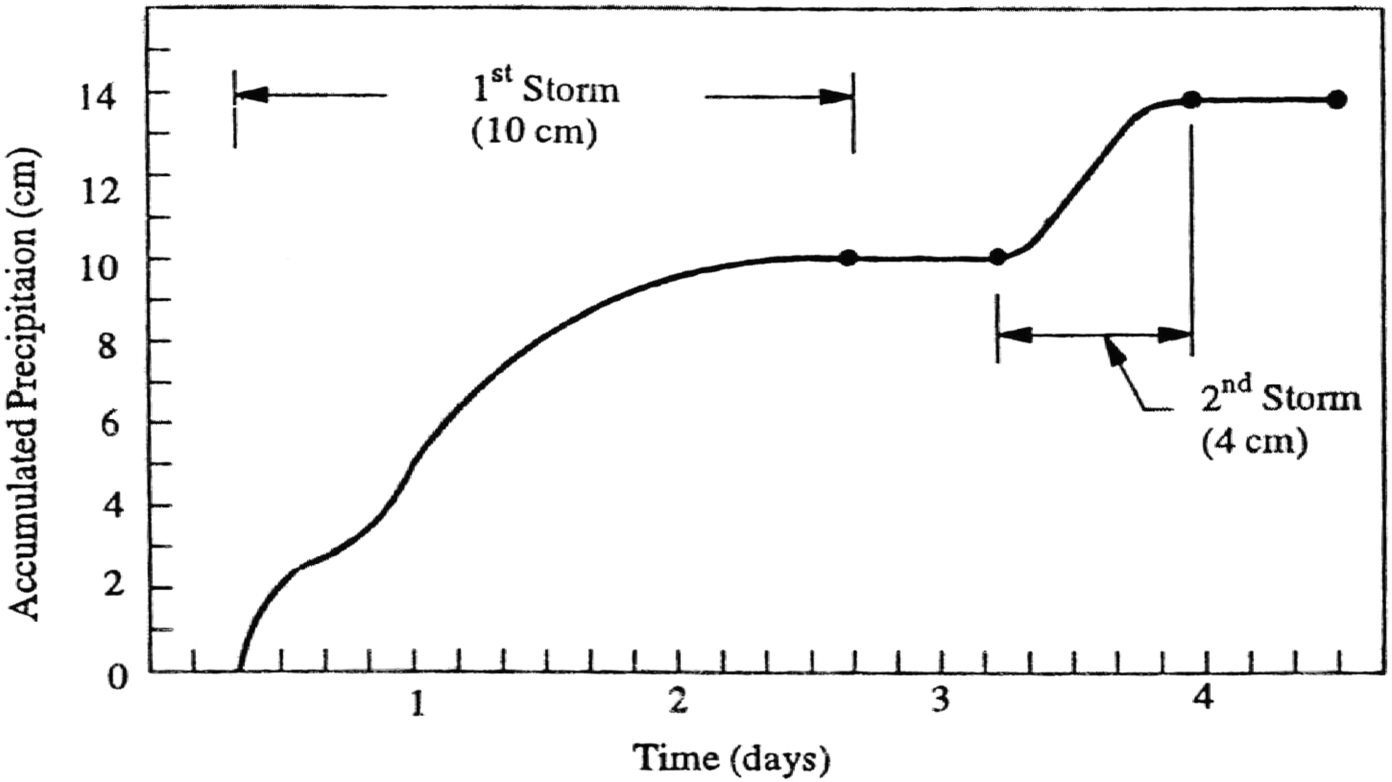
Intensity – Duration – Frequency relationship

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

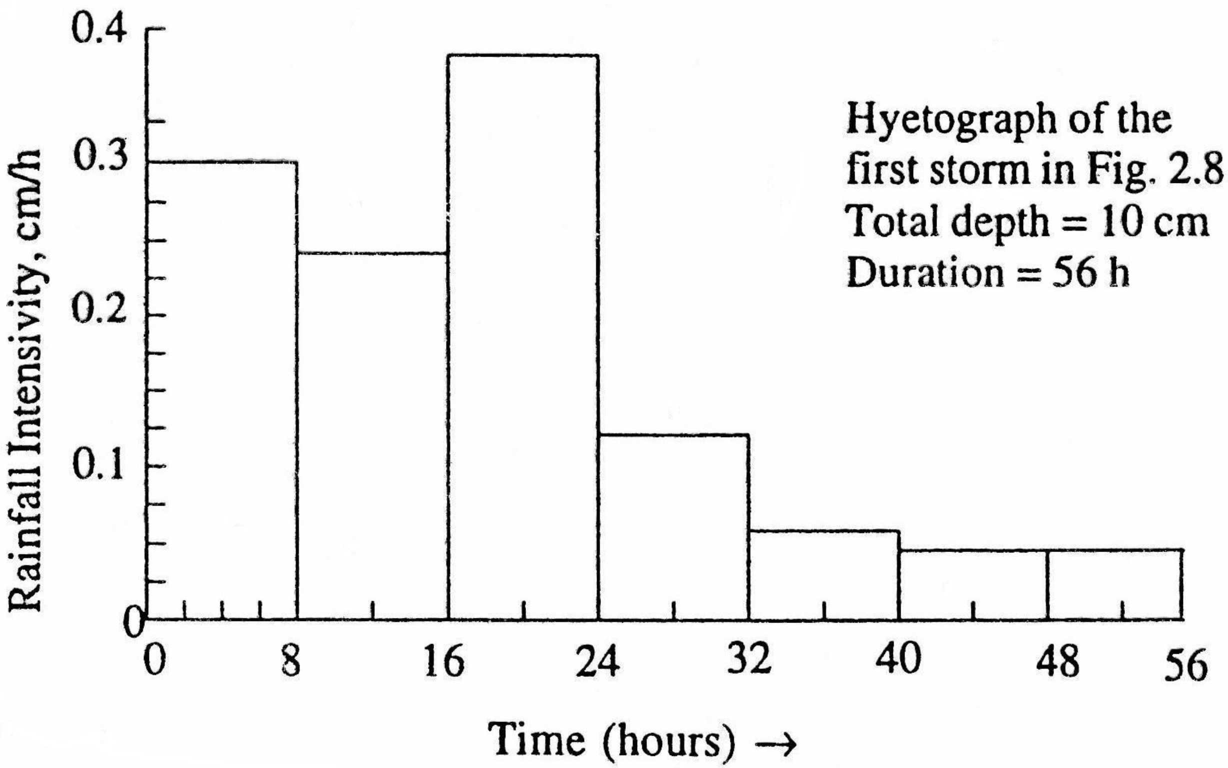
where K, x, a and n are constants for a given catchment.



Mass Curve of Rainfall



Hyetograph



Hyetograph of the
first storm in Fig. 2.8
Total depth = 10 cm
Duration = 56 h
Rainfall Intensivity, cm/h
0.4
0.3
0.2
0.1
0
0
8
16
24
32
40
48
56
Time (hours) →