Rainfall Analysis

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Learning Outcome

- At the end of this section students will be able to
  - Estimate long term mean rainfall for a new station
  - Describe the usage of a hyetograph
  - Define recurrence interval and apply the concept of recurrence interval in rainfall analysis
  - Define rainfall frequency and apply Weibull's formula to find recurrence interval
  - Calculate expected maximum and minimum rainfall

Long term mean rainfall for a new station

- Newly established station has only few years records
- Adjacent station with similar hydrologic conditions used
  - Let us assume A and B stations
  - A has long term data and B is new

- Step 1

Mean Rainfall for station A (A_{mt})

$$A_{mt} = \frac{Total\ Rain\ in\ t\ years}{t}$$

- Step 2

Mean rainfall for station A for the years in which B has data

$$A_{mB} = \frac{Amount\ of\ Rain\ for\ short\ years\ (b)\ at\ station\ A}{Number\ of\ years\ B\ has\ records\ (b)}$$

- Step 3

Mean rainfall of station B

$$B_m = \frac{Amount\ of\ Rain\ at\ station\ B}{Number\ of\ years\ (b)}$$

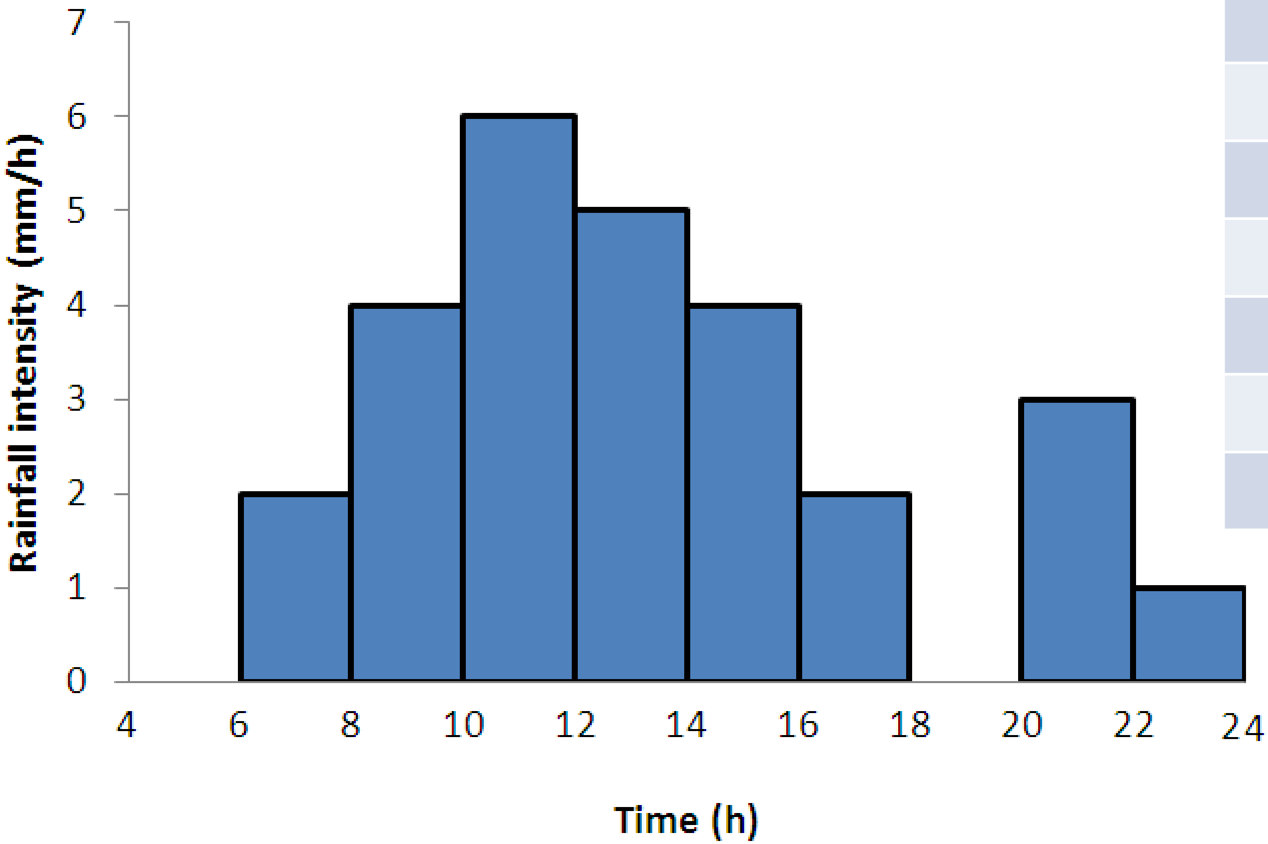
- Step 4

Long term mean rainfall of station B

$$\frac{B_{mt}}{B_m} = \frac{A_{mt}}{A_{mB}}$$

Hyetograph

- Plot of rainfall intensity and time interval.
- Used in hydrological analysis of catchment for
  - prediction of flood
  - estimation of runoff
  - Derivation of unit hydrograph
- Area under hyetogrpah is total rainfall

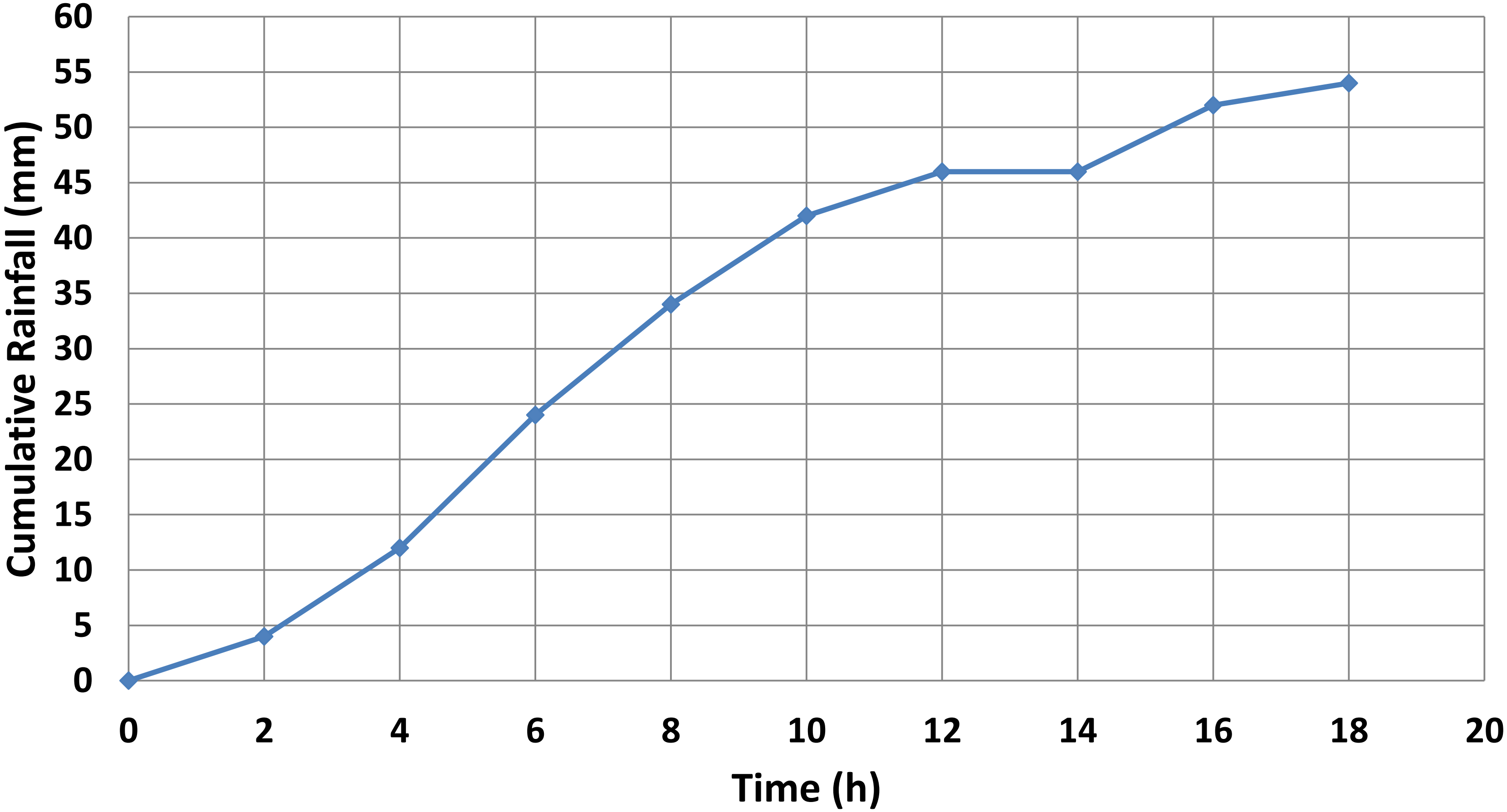


Time	Rainfall intensity
6-8	2
8-10	4
10-12	6
12-14	5
14-16	4
16-18	2
18-20	0
20-22	3
22-24	1

Mass Curve

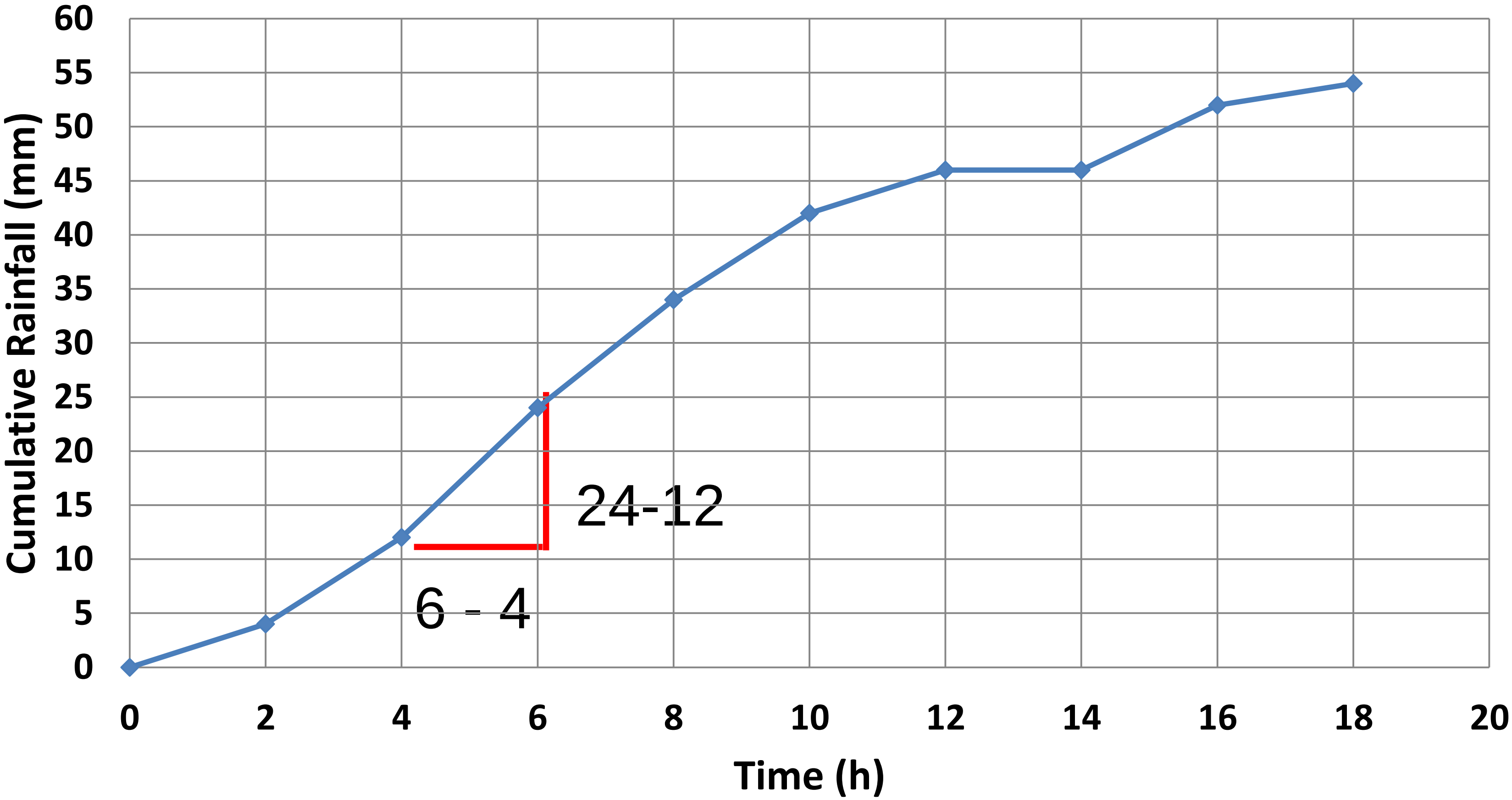
- Plot of accumulated rainfall against time

Time	Cumulative Time	Cumulative Rainfall
4-6	0	0
6-8	2	4
8-10	4	12
10-12	6	24
12-14	8	34
14-16	10	42
16-18	12	46
18-20	14	46
20-22	16	52
22-24	18	54



Cumulative Rainfall (mm)
60
55
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
Time (h)

- Can determine magnitude and duration of storm
- Slope of curve give intensity at various time
  - Considers the event from 4 – 6 hour



Intensity = (24 - 12) / (6 - 4) = 6 mm/h

Intensity-Duration-Frequency Relationship

- rainfall duration increases when intensity decreases and vice-versa
- rainfall intensity increases when return period increases and vice-versa
  - Return period (recurrence interval) : Number of years in which an event can be expected once.
  - Needed to know in designing dams, bridges, culverts etc.

- Return period is related with intensity, duration and frequency by

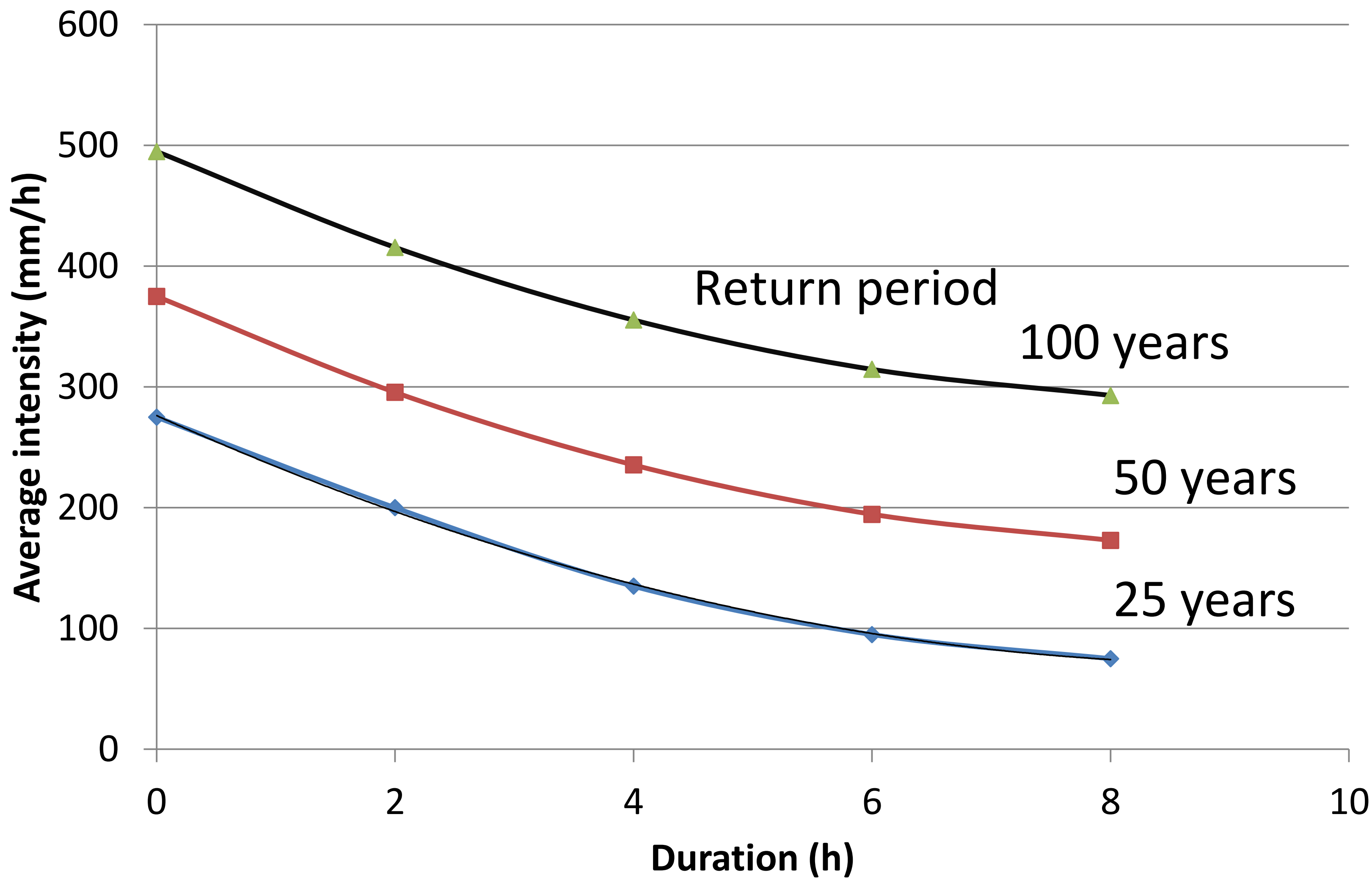
$$i = \frac{K\,T^{a}}{(t+b)^{d}}$$

i – average rainfall intensity (cm/h)

t – duration of rainfall (h)

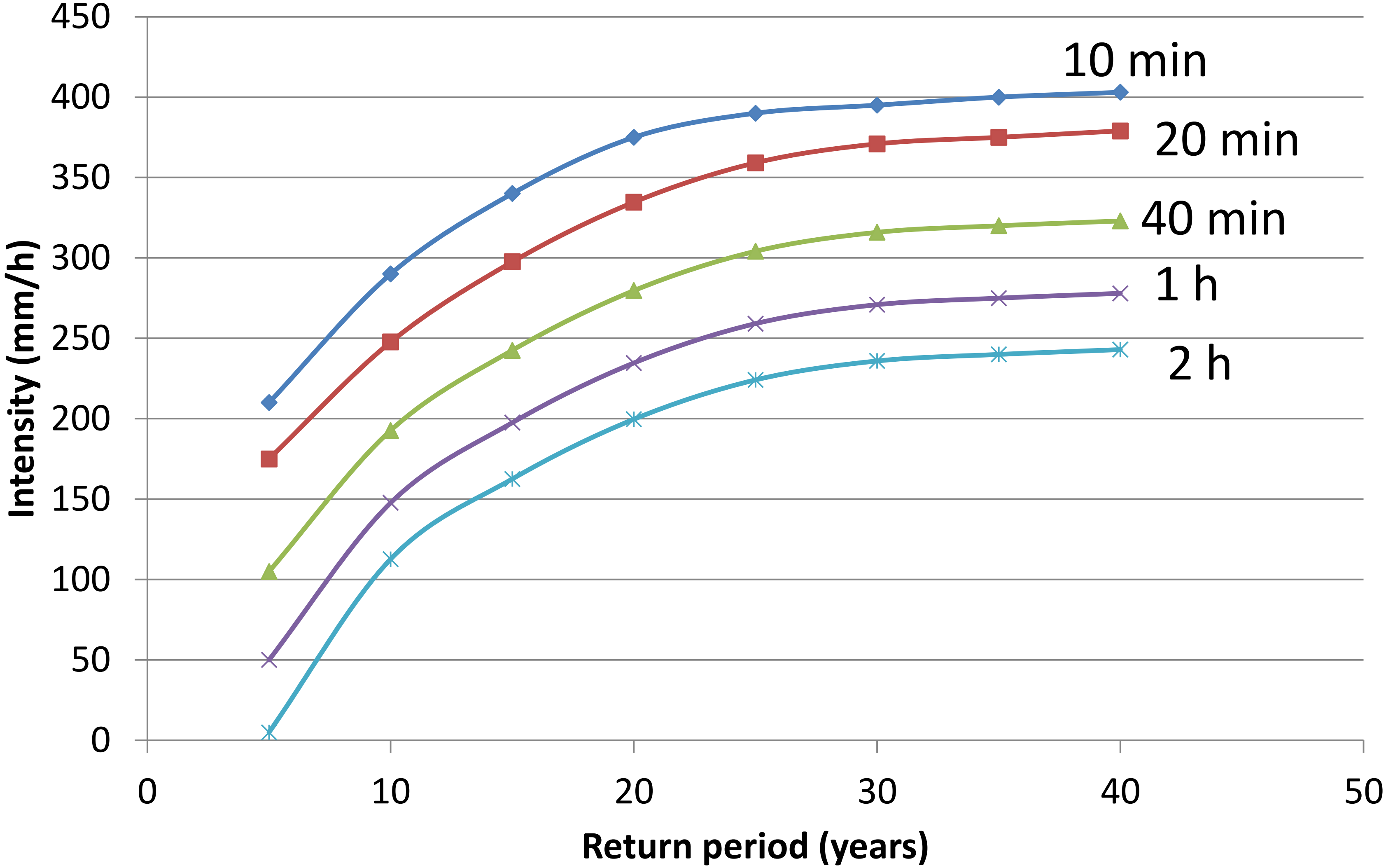
T – return period (year)

K, a, b and d are constants (depend on geographical location)



600
500
400
300
200
100
0
Average intensity (mm/h)
0
2
4
6
8
10
Duration (h)
Return period
100 years
50 years
25 years

- What will be the intensity for a shorter period
  - 10 minutes, 20 minutes, 40 minutes, 1 hour, 2 hour events (for 5 year return period)
    - 10 min > 20 min> 40 min > 1 h > 2 h
  - What will happen to intensity if return period increase (10 min for return periods 5, 10, 20, 25 etc. years)
    - Intensity will increase


Intensity (mm/h)
Return period (years)
10 min
20 min
40 min
1 h
2 h
0
50
100
150
200
250
300
350
400
450
0
10
20
30
40
50

- For a given catchment (watershed), runoff generated will change with intensity of rainfall (Area is same, vegetation is same)
- When intensity changes runoff volume and rate changes. Therefore, we have to consider intensity in designing structures.
- For soil conservation return period – 10 years, culverts – 25 years, bridges – 500 – 1000 years

Rainfall frequency

- Design of hydraulic structures, flood control structures, soil conservation structures, drains, culverts etc. are based on probability of occurrence of extreme rainfall events.

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

T = return period

P = Plotting position (Probability)

- Frequency analysis is done to obtain relation between magnitude of events and probability.

$$P = \left(\frac{m}{n+1}\right)100$$

Weibull's Formula

P = Probability or plotting position (%)

m = rank number (after arranging in descending order)

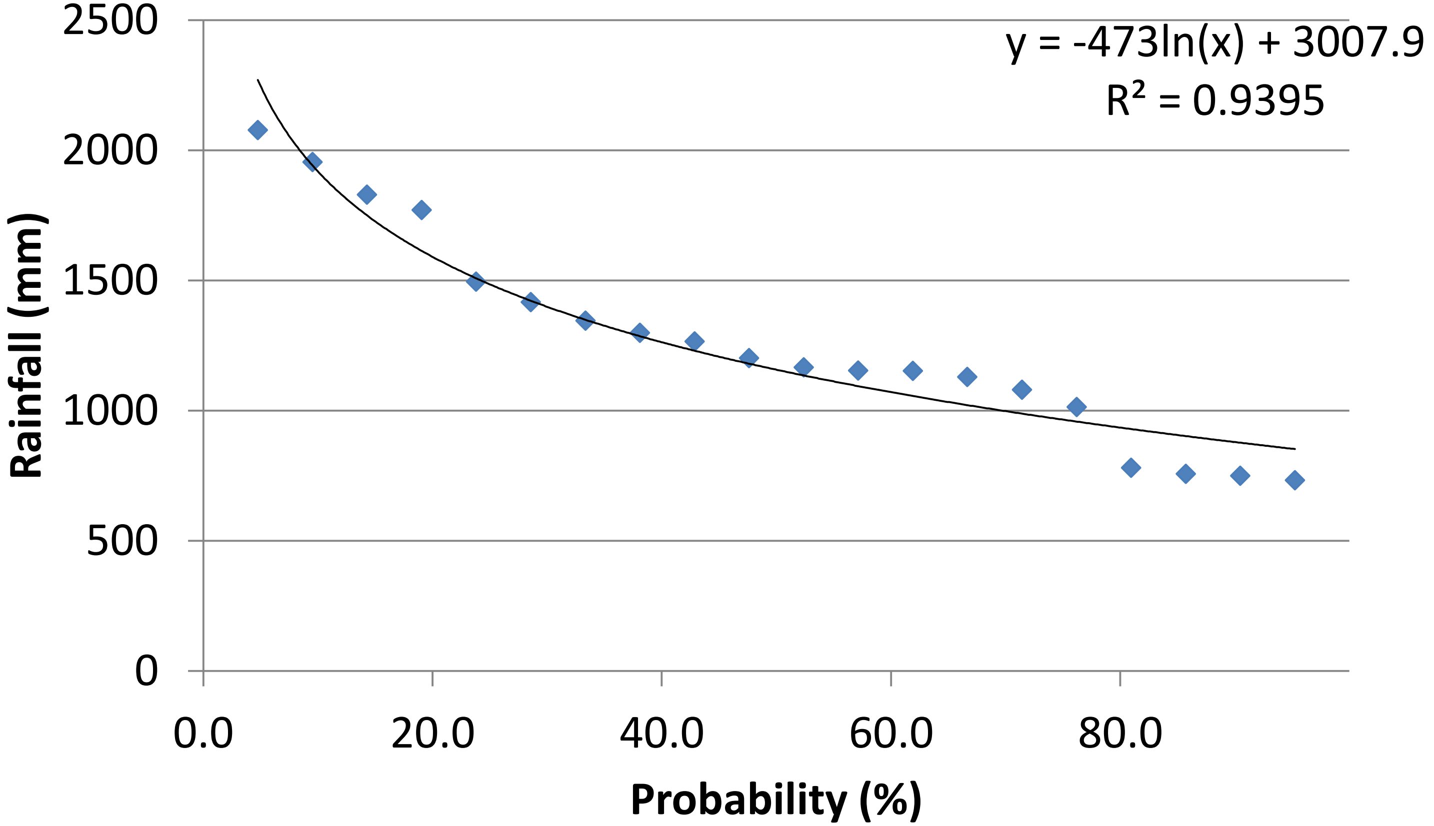
n = total number of events

- There are many formulas to calculate P (Gumbel, Hazen, Blom etc.)

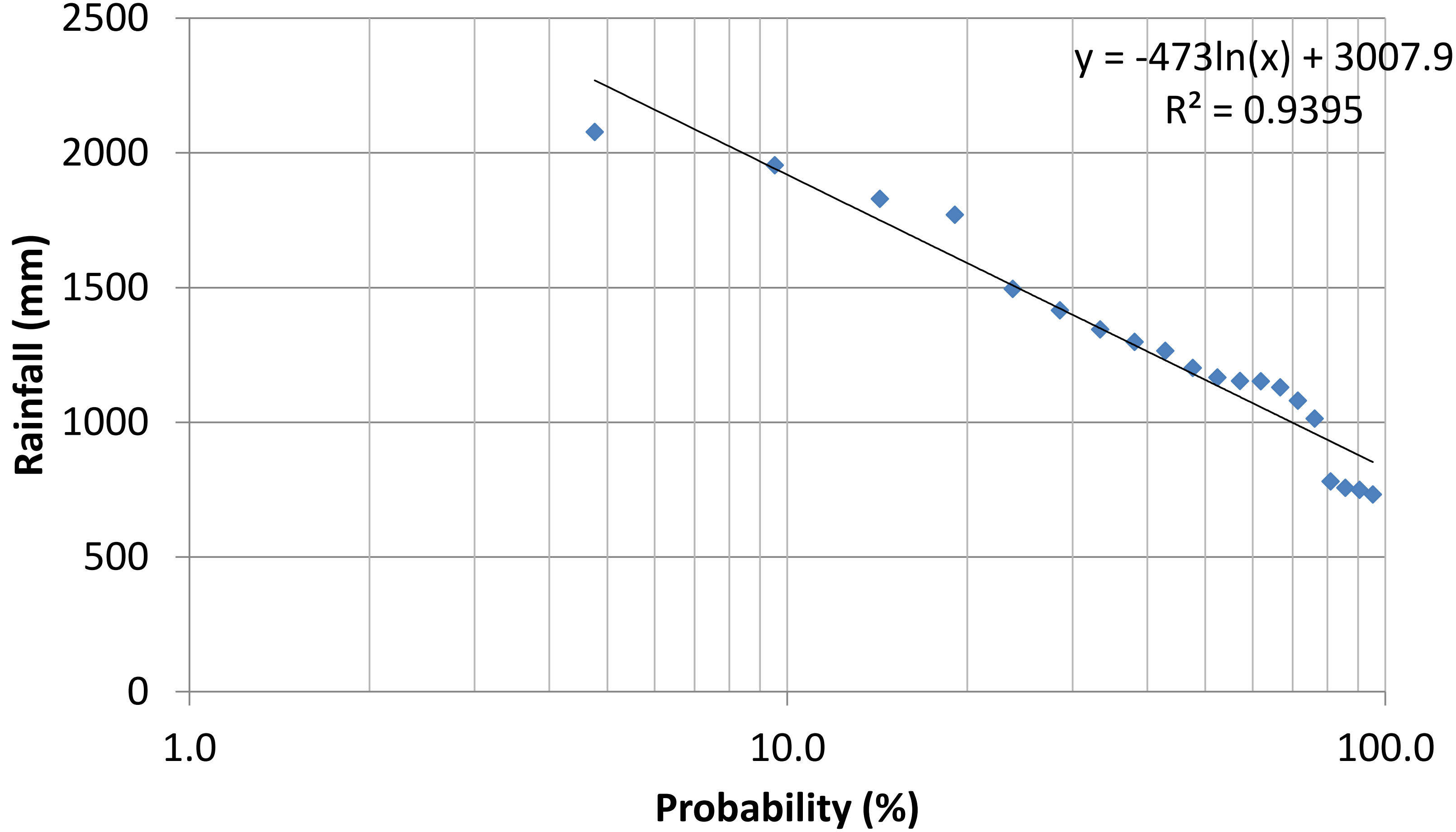
Procedure

- Arrange rainfall data in ascending order
- Assign rank number starting from 1
- Calculate plotting position
- Plot plotting position on log scale (X axis) and corresponding rainfall on Y axis (Use semi log sheet)
- Draw the curve – Rainfall frequency curve
- Using calculation, can find recurrence interval

Rainfall	Rank No.	Plotting Position	Recurrence Interval
2077.7	1	4.8	21.0
1954.1	2	9.5	10.5
1829.2	3	14.3	7.0
1770	4	19.0	5.3
1495.7	5	23.8	4.2
1416.1	6	28.6	3.5
1344.9	7	33.3	3.0
1298.2	8	38.1	2.6
1265	9	42.9	2.3
1202.2	10	47.6	2.1
1166.4	11	52.4	1.9
1153.69	12	57.1	1.8
1152.5	13	61.9	1.6
1129.6	14	66.7	1.5
1080.25	15	71.4	1.4
1014.3	16	76.2	1.3
780.5	17	81.0	1.2
756.6	18	85.7	1.2
749.1	19	90.5	1.1
732.8	20	95.2	1.1



y = -473ln(x) + 3007.9
R² = 0.9395
2500
2000
1500
1000
500
0
Rainfall (mm)
0.0
20.0
40.0
60.0
80.0
Probability (%)



y = -473ln(x) + 3007.9
R² = 0.9395
2500
2000
1500
1000
500
0
Rainfall (mm)
1.0
10.0
100.0
Probability (%)

Expected maximum and minimum rainfall

$$T = \frac{n}{(m - 0.5)}$$

Hazen Formula

T – recurrence interval

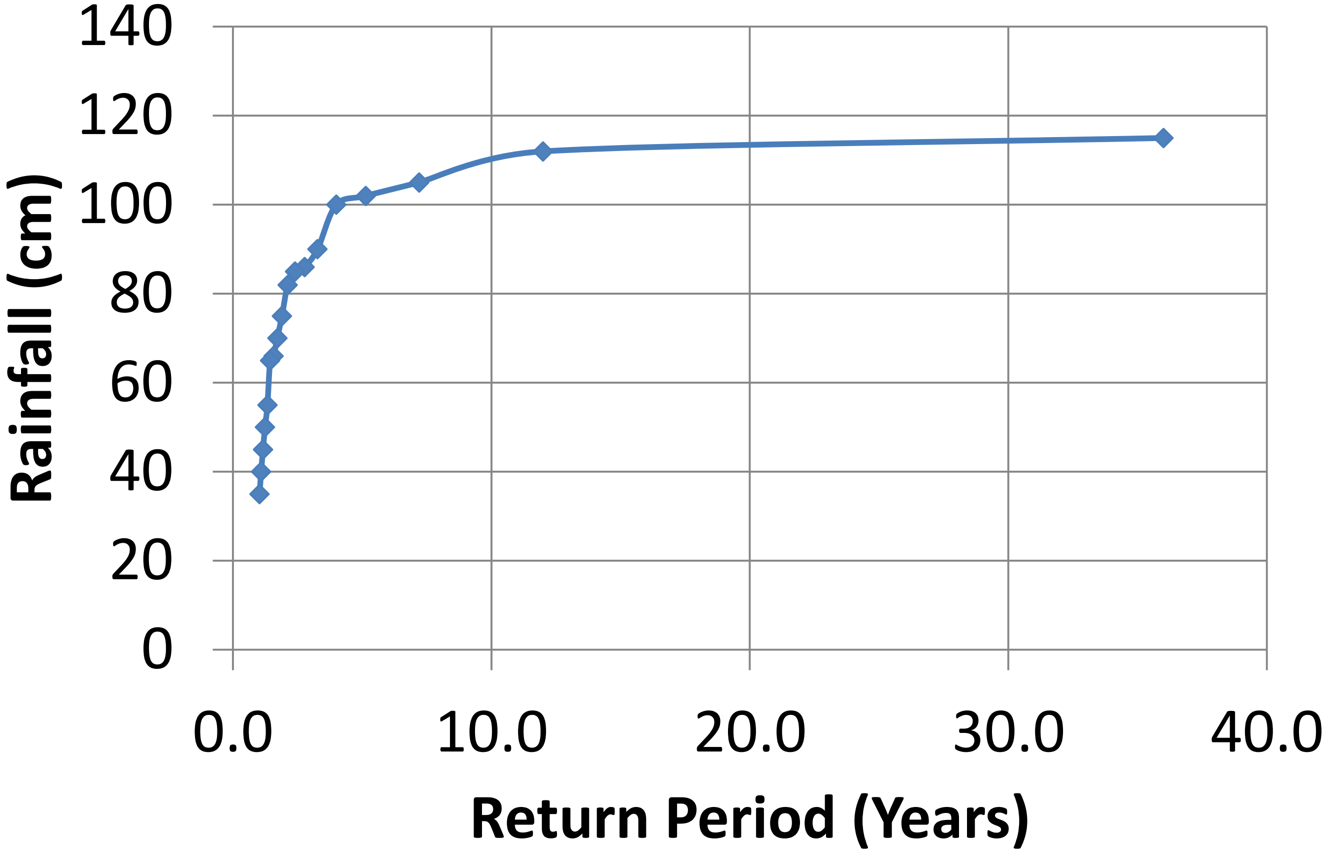
n – total events

m – rank number

- Arrange observed rainfall in descending order (ascending order for minimum rainfall)
- Assign rank number
- Calculate recurrence interval
- Plot recurrence interval (X axis) and rainfall (Y axis)
- Draw curve and predict expected maximum or minimum rainfall using graph

Rainfall	Rank	Recurrence Interval
115	1	36.0
112	2	12.0
105	3	7.2
102	4	5.1
100	5	4.0
90	6	3.3
86	7	2.8
85	8	2.4
82	9	2.1
75	10	1.9
70	11	1.7
66	12	1.6
65	13	1.4
55	14	1.3
50	15	1.2
45	16	1.2
40	17	1.1
35	18	1.0

Expected Maximum



Rainfall	Rank	Recurrence Interval
35	1	36.0
40	2	12.0
45	3	7.2
50	4	5.1
55	5	4.0
65	6	3.3
66	7	2.8
70	8	2.4
75	9	2.1
82	10	1.9
85	11	1.7
86	12	1.6
90	13	1.4
100	14	1.3
102	15	1.2
105	16	1.2
112	17	1.1
115	18	1.0

Expected Minimum