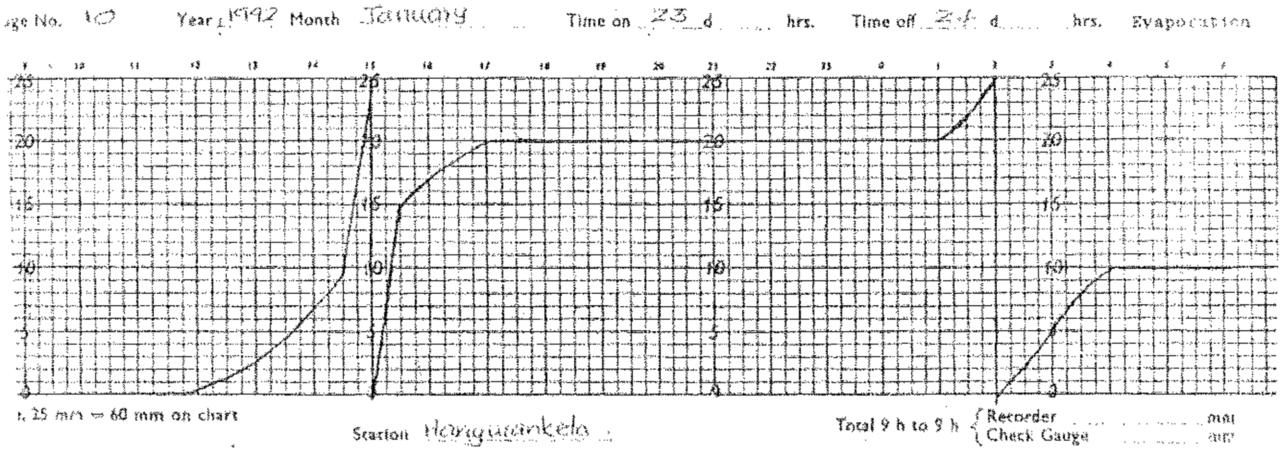
Bachelor of Biosystems Technology
Faculty of Technology
South Eastern University of Sri Lanka

BSE 11022 – Hydrology and Meteorology

Assignment 1 Professor M.M.M. Najim

1. Given recording rain gauge chart shows a rainfall event over a small tank catchment in Sri Lanka.



a) Find the total amount of rainfall
b) Find the maximum rainfall intensity, time at which it occurred and its duration.
c) The tank has a water surface area of 20 ha, a catchment area of (excluding water surface area) 5 km^2. If the water level was raised by 0.45 meters due to this rainfall event, calculate the fraction of rainfall that contributed to the runoff (neglect increase in water surface area with increasing volume for the reservoir and other losses)
d) As a student of hydrology, what does this fraction signify in terms of simple rainfall runoff relations?

2. Precipitation station X was inappropriate for part of a month during which storm has occurred. The respective precipitation totals of three surrounding stations A, B, and C were 98, 80 and 110 mm. The normal annual precipitation amounts at stations X, A, B, and C are 880. 1008, 842, and 1080 mm. Estimate the missing storm precipitation from station X.

3. Calculate the average annual rainfall amounts for stations A, B, C and D.

Year	A	B	C	D	X
1990	6.6	8.9	8.7	9.8	8.8
1991	5.5	5.7	5.6	5.0	5.6
1992	9.6	9.7	9.7	9.0	10.0
1993	14.9	16.9	16.6	16.7	16.7
1994	22.8	18.0	23.9	21.6	20.5
1995	21.4	22.7	21.7	23.0	23.4
1996	18.1	17.1	16.7	15.6	17.9
1997	18.6	17.9	16.9	18.5	16.8
1998	16.7	18.1	17.1	17.1	16.4
1999	19.3	18.7	17.9	20.3	19.3

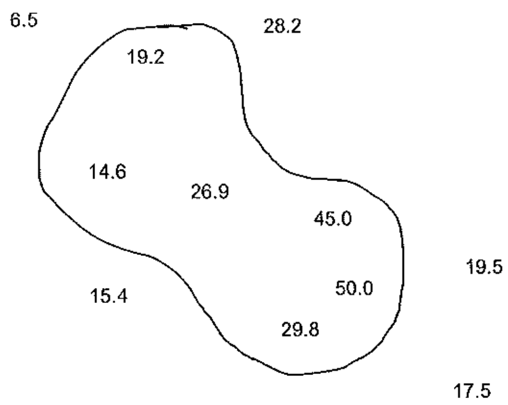
By assuming that stations A, B, C and D are closely located, estimate the missing rainfall of station X for the months of April 2000.

2000	A	B	C	D	X
April	4.5	3.2	1.2	0.5	?

4. The precipitation falling on a Catchment area of 50 km^2 is sampled by six rain gauges. From the measurements in table, estimate the aerial rainfall for 2001. If a dam is built at the catchment outfall and a minimum discharge of 0.1 m^3/s is maintained throughout the year in the river downstream, estimate the volume of water available for supply from the reservoir. Assume the catchment is water tight and there is a total evaporation loss of 400 mm.

Rain Gauge	2001 Rainfall (mm)	Thiessen Polygon Area (km^2)
1	2052	7.8
2	1915	8.3
3	1868	10.2
4	1723	11.5
5	1640	5.4
6	1510	6.8

5. A watershed area and the surrounding rain gauge readings are given in the Figure below. The rainfall is measured in millimeters.



a. Calculate the average rainfall by arithmetic mean method.
b. Thiessen polygon areas for the above watershed are as follows. Calculate the average rainfall.

Observed rainfall (mm)	Area (km^2)*	% total area	Weighted rainfall (mm)
6.5	7		
14.6	120		
19.2	109		
26.9	120		
15.4	20		
29.8	92		
50.0	82		
45.0	76		

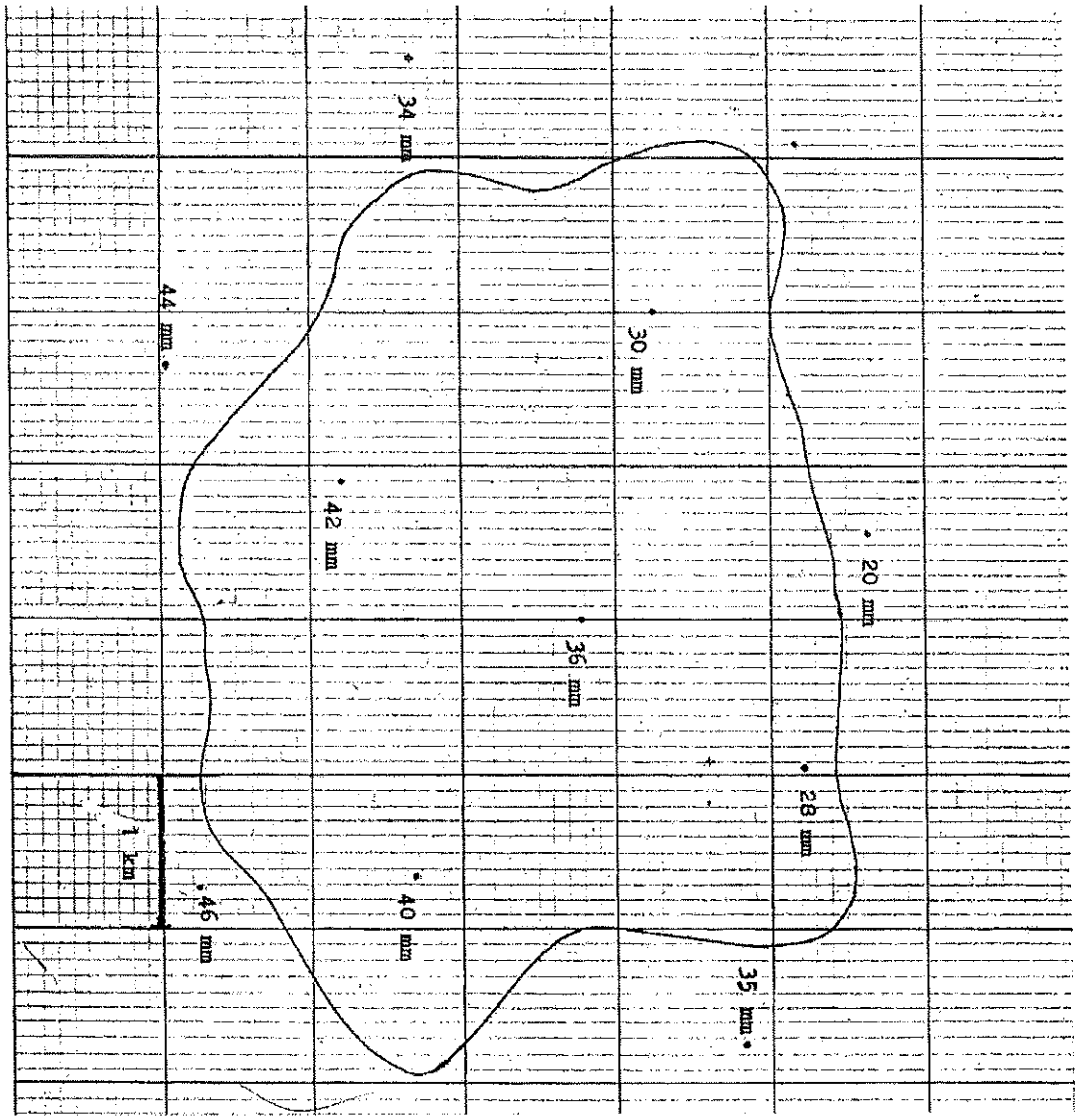
* area given is the area corresponding polygon within basin boundary

c. Following table gives the areas enclosed by different isohyets. Calculate the average rainfall.

Isohyets (mm)	Area enclosed** (km^2)	Net area (km^2)	Average rainfall (mm)	Precipitation volume
50	13			
40	90			
30	206			
20	402			
10	595			
< 10	626			

** Within watershed boundary

6. Find the areal precipitation by arithmetic mean, Thiessen polygon and Isohyetal methods for the area given and comment on the difference if any.



Assignment 1.

1.

a) Rain event 01 - 11:45 to 17:00

45 mm

Rain event 02 - 1:00 to 4:00

15 mm.

Total rainfall = 45 + 15 mm = 60 mm

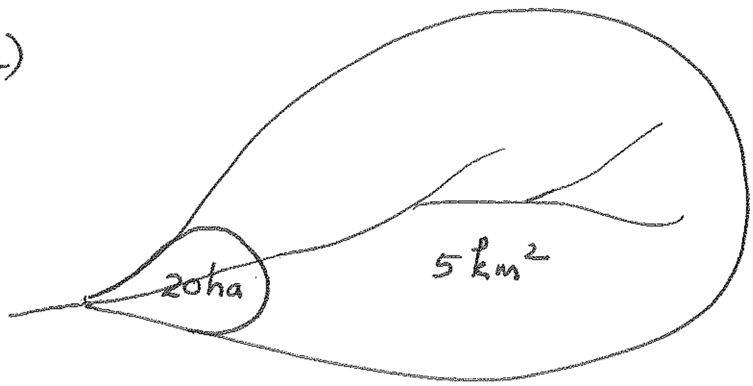
b) Maximum Rainfall 14:30 to 15:30

30 mm.

$$\text{Intensity} = \frac{\text{Amount of rainfall}}{\text{duration}}$$

$$= \frac{30 \text{ mm}}{1 \text{ h}} = 30 \text{ mm/h}$$

c)



60 mm fall on the watershed

Water level raised by rainfall = 0.45 m

Quantity of water contributed to the increase in water level } $= 0.45 \text{m} \times 20 \times 10000 \text{ m}^2$

$= 90{,}000 \text{ m}^3$

Total volume of rainfall $= \frac{60}{1000} \text{m} \times (5 \text{km}^2 + 20 \text{ha})$

$= \frac{60}{1000} \times (5 \times 10^6 + 20 \times 10^4)$

$= 312{,}000 \text{ m}^3$

Percentage of rainfall contributed to runoff $\Big\} = \dfrac{90\,000}{320\,000} \times 100$

$= \underline{\underline{28.1\ \%}}$

d) Only 28.1 % of rainfall has contributed to runoff (effective rainfall)

71.9 % of rainfall is loss

This catchment could be a densely forested catchment.

2. $P_x = ?$ $\quad N_x = 880$ mm

$P_A = 98$ mm $\quad N_A = 1008$ mm

$P_B = 80$ mm $\quad N_B = 842$ mm

$P_C = 110$ mm $\quad N_C = 1080$ mm

$$P_x = \frac{1}{3}\left(\frac{P_A}{N_A} N_x + \frac{P_B}{N_B} N_x + \frac{P_C}{N_C} N_x\right)$$

$$= \frac{1}{3}\left(\frac{98 \times 880}{1008} + \frac{80 \times 880}{842} + \frac{110 \times 880}{1080}\right)$$

$$= \frac{1}{3}\left(85.56 + 83.61 + 89.63\right)$$

$$= \underline{\underline{86.27 \text{ mm}}}$$

3. Average annual rainfall of the stations

A = 15.35

B = 15.37

C = 15.48

D = 15.66

X = 15.54

$$\left.\begin{array}{l}\text{Average annual rainfall} \\ \text{of station A}\end{array}\right\} = \frac{6.6 + 5.5 + 9.6 + 14.9 + 22.8 + 21.4 + 18.1 + 18.6 + 16.7 + 19.3}{10}$$

$= 15.35$

$P_x = ?$	$N_x = 15.54$
$P_A = 4.5$	$N_A = 15.35$
$P_B = 3.2$	$N_B = 15.37$
$P_C = 1.2$	$N_C = 15.48$
$P_D = 0.5$	$N_D = 15.66$

$$P_x = \frac{1}{4}\left(\frac{N_x}{N_A}P_A + \frac{N_x}{N_B}P_B + \frac{N_x}{N_C}P_C + \frac{N_x}{N_D}P_D\right)$$

$$= \frac{1}{4}\left(\frac{15.54}{15.35} \times 4.5 + \frac{15.54}{15.37} \times 3.2 + \frac{15.54}{15.48} \times 1.2 + \frac{15.54}{15.66} \times 0.5\right)$$

$$= \frac{1}{4}\left(4.56 + 3.24 + 1.20 + 0.50\right)$$

$$= \underline{\underline{2.38}}$$

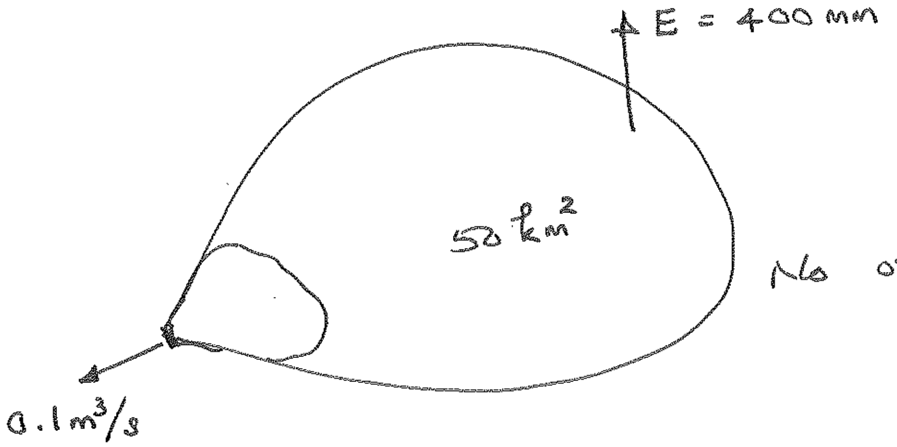
4.

$$P = \frac{(P_1 \times A_1) + (P_2 A_2) + (P_3 A_3) + (P_4 A_4) + (P_5 A_5) + (P_6 A_6)}{A_1 + A_2 + A_3 + A_4 + A_5}$$

$$= \frac{(2052 \times 7.8) + (1915 \times 8.3) + (1868 \times 10.2) + (1723 \times 11.5) + (1640 \times 5.4) + (1510 \times 6.8)}{7.8 + 8.3 + 10.2 + 11.5 + 5.4 + 6.8}$$

$$= \frac{16005 + 15894 + 19053 + 19814 + 8856 + 10268}{50}$$

$$= \underline{\underline{1797.8 \text{ mm}}}$$



No other loss.

Annual rainfall = 1797.8 mm

Loss as Evaporation = 400 mm

Runoff = 1797.8 − 400

= 1397.8 mm

Total amount of runoff = $1397.8 \text{ mm} \times 50 \text{ km}^2$

$= \frac{1397.8}{1000} \text{ m} \times 50 \times 10^6 \text{ m}^2$

$= 698,900 \times 10^2 \text{ m}^3$

Total amount of flow released downstream of dam } $= 0.1 \text{ m}^3/\text{s} \times 60 \times 60 \times 24 \times 36$

$= 3,153,600 \text{ m}^3$

Amount of water stored in the reservoir $\Big\} = (698,900 \times 10^2 - 31,536 \times 10^2)$

$= \underline{\underline{667,364 \times 10^2 \ m^3}}$

5.

a. Average rainfall (Arithmetic mean method) $= \dfrac{19.2 + 14.6 + 26.9 + 45.0 + 50.0 + 29.8}{6}$

$= \underline{\underline{30.92 \text{ mm.}}}$

b. Average rainfall by Thiessen Polygon method.

$$= \frac{\sum_{i=1}^{n} P_i A_i}{\sum_{i=1}^{n} A_i}$$

$$= \frac{P_1 A_1 + P_2 A_2 + P_3 A_3 + P_4 A_4 + P_5 A_5 + P_6 A_6 + P_7 A_7 + P_8 A_8}{A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8}$$

$$= \frac{(6.5 \times 7) + (14.6 \times 120) + (19.2 \times 109) + (26.9 \times 120) + (15.4 \times 20) + (29.8 \times 92) + (50 \times 82) + (45 \times 76)}{7 + 120 + 109 + 120 + 20 + 92 + 82 + 76}$$

$= \underline{\underline{28.26 \text{ mm}}}$

c. Average rainfall by Isohyetal method

$$\text{Average Rainfall} = \frac{(55 \times 13) + (45 \times 77) + (35 \times 116) + (25 \times 196) + (15 \times 193) + (5 \times 31)}{626}$$

$$= \underline{\underline{25.86 \text{ mm}}}$$

6.

Steps.

1. Connect 36 mm site with 42 mm, 40 mm, 35 mm 28 mm, 20 mm and 30 mm sites.
2. Connect 42 mm to 30 mm; 30 mm to 20 mm; 20 mm to 28 mm; 28 mm to 35 mm; 35 mm to 40 mm; 40 mm to 42 mm
3. Connect 42 mm to 46 mm, 40 mm, 30 mm, 34 mm, 44 mm
4. Connect 40 mm to 46 mm, 46 mm to 44 mm, 44 mm to 34 mm, 34 mm to 30 mm
5. Draw Perpendicular bisectors to each side of each triangle
6. Construct the polygons
7. Measure the area based on the scale.

Rain gauge	Area (Number of small squares)	Area (km^2)
42 mm	377	3.77
36 mm	326	3.26
28 mm	196	1.96
34 mm	47	0.47
44 mm	16	0.16
46 mm	76	0.76
40 mm	357	3.57
35 mm	38	0.38
30 mm	369	3.69
20 mm	91	0.91
		~~8.56~~ 18.93

$$\text{Average Rainfall} = \frac{(42 \times 3.77) + (36 \times 3.26) + (28 \times 1.96) + (34 \times 0.47) + (44 \times 0.16) + (46 \times 0.76) + (40 \times 3.57) + (35 \times 0.38) + (30 \times 3.69) + (20 \times 0.91)}{18.93}$$

$$= \underline{\underline{35.58 \text{ mm}}}$$

Isohytal Method.

Range	Average	Area (small squares)	Area (km^2)
45 - 40	42.5	584	5.84
40 - 35	37.5	628	6.28
35 - 30	32.5	363	3.63
30 - 25	27.5	309	3.09
25 - 20	22.5	63	0.63
			19.47

$$\text{Average Rainfall} = \frac{(42.5 \times 5.84) + (37.5 \times 6.28) + (32.5 \times 3.63) + (27.5 \times 3.09) + (22.5 \times 0.63)}{19.47}$$

$$= 35.995 = \underline{\underline{36 \text{ mm}}}$$