UNIT-I

ADDITIONAL ANSWER SHEET
S.S.N. COLLEGE OF ENGINEERING & TECHNOLOGY
(Affiliated to J.N.T. University, Kakinada)

Signature of Invigilator

18/9/14:-

W R E
water Resources engineering.

water:- The clear liquid falls from the sky as rain and that is in seas, rivers, lakes etc.

resources: It means re use (or) re produce

Ex:- sun light, wind, water etc

The main resources are
(1) Rain fall
(2) ground water

Engineering:- It means managing of these two is called as Engineering
It means how to produce of rain water, how to produce of ground water, how to behave, how to maintanance

W R E means water resources Engineering.
It means of ~~storage of to~~ how to produce of water, how to storage of water, how to maintanance of water, how to regulate. These and all u can study of water

water resources structures are classified as

(1) water storage structures
Ex:- Dams, reservoirs, small irrigation works

(2) Diversion head works (change the direction of water)
Ex:- weir (Anicuts), Barrages

(3) Canal regulator works (regulation of water (or) control of water)
Ex:- canal fall (or) canal drop, Head regulator, flow cross regulator, outlets

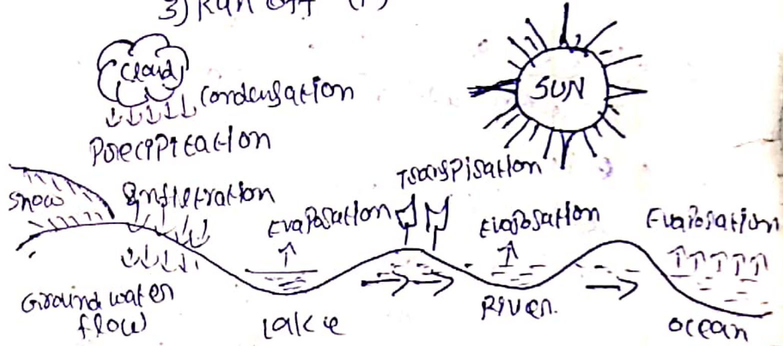
(4) cross drainage works (Above flow of water and below drainage water flow)
Ex:- Aqueduct, siphon Aqueduct, level crossing, inlet & outlet

water direction
below water flow drainage
(or) inlet
drainage (below)

Hydrology:-
Hydro logy
water study
It means study of water is called as "Hydrology"

Hydrology is the science which deals with study of water in above the surface of earth, including that in the automosphere and below the surface of the earth

Hydrological cycle:-
It means the constant circulation of water earth to atmosphere and come back to the water atmosphere to earth.
These water circulation system is known as Hydrologic cycle
The hydrologi cycle consist of following process
1) Evaporation and Transpiration (E)
2) Precipitation (P)
3) Run off (R)



1) Evaporation.
→ In ocean more amount of water will be evaporated
→ River some small amount of water will be evaporated
→ Lakes again some small amount of water will be evaporated
The water will transfer to the automosphere is called as Evaporation.

2) Transpiration:-
loss of water from the leaves and plants due to photosynthesis process is called as transpiration

2) Precipitation:-

Precipitation means rain-fall

It means falls of moisture form the automosphere to the earth surface in any form.

It is two types

(a) Liquid precipitation (i,e) rain-fall

(b) frozen precipitation

(a) snow (b) Hail

(c) sleet (d) freezing rain.

(3) Run off:-

The rainfall falls on ground some water is infiltrated some water evaporated, remaining water will move to lakes, after that river, and again move oceans is called as run off

It means changing possition of water and water flows one place to another place is called as Runoff

1) surface runoff

2) subsurface run off

3) Ground water flow (or) base flow

(1) surface runoff:-

The water will flow on the surface of the earth

Ex:- streams (వాగు సెలయేరు), rivers,

2) sub surface runoff:-

The rain water falls on ground some amount of water will absorb the soil surface and remaining water will reach on ground water table.

The soil surface absorb some amount of water that water will flow one place to another place. , water will absorb the plants and finally these reaches the streams and rivers.

3) Ground water flow (or) base flow:-

The rain water (precipitation) will infiltrated to the ground percolates indown side and meet the ground water

These ground water which ultimately connected to the ocean

The water will flowing below the water table is known as Ground water flow.

The hydrologic cycle may be expressed by the following simplified equation

Precipitation (rainfall) = Evaporation + Runoff

$$P = E + R$$

Engineering hydrology and it's applications:-

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Precipitation:- (or rainfall)

It is the general term for all forms of moisture emanating from the clouds and falling to the ground.

Essential requirements for precipitation occur

→ Some mechanism is required to cool the air to cause condensation (small water particles combined each other to make big particle) and droplet growth

→ The cooling of air more amount of rainfall will occur

Types of precipitation:-

(1) Cyclonic precipitation
2) Convective "
3) Orographic "
(4) Precipitation due to turbulent ascent

(1) Cyclonic precipitation:-

The cyclonic precipitation is came lifting of air masses in low pressure area. It means lifting the surface air (or) low pressure air lifted to upper.

The cyclonic precipitation in two types
(a) Frontal precipitation
(b) Non-Frontal "

(a) Frontal precipitation:-

The border region b/w two adjacent air masses (cool air, hot air, edges) having different characteristics such as temperature & humidity. So the cold air will ~~absorbing~~ combining to warm air. The warm air will cools (having some weight) will move from down side causing precipitation.

(b) Non-frontal precipitation:-

The cold air having some weight will be stable in one place. The warm air is moving (because of less wt) will meets cold air masses.

The warm air become cool will move at down of altitude precipitation is occur.

(2) Convective precipitation:-

The convective precipitation is occur on natural process.

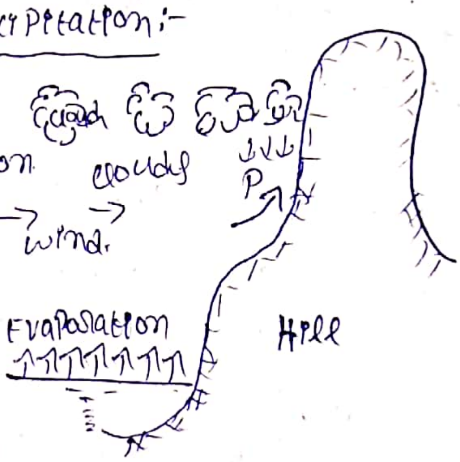
The warm air surrounding became a cool because of difference in temperature, unequal heating of the surface, unequal cooling at the top of the air layer.

* In this case air is forced to pass over a denser colder air masses

* In this sudden rain fall is occur.

(3) Orographic precipitation:-

As it reaches higher evaporation. The clouds contact with hill precipitation is occur



(4) Precipitation due to turbulent ascent:-

The air masses forced to rise up due to grater friction of earth surface. after it's travel over ocean

This air rises becaus of increase the friction ultimately precipitation occurs

Ex:- winter rain fall in "madras state" is mainly due to this process.

Forms of Precipitation:-

Drizzle:-
when the size of water droplets is under 0.5mm intensity is < 1 mm per hour

Rain:- when the size of the drops is more than 0.5mm. The upper size of water drop is generally 6.25mm (or) greater than it's break up fall through rain

Glaze:-
The size of water droplet under 0.5 mm. intensity is < 1 mm per hour but the glaze precipitation is coming to contact with cold objects.

Sleet:-
The extreme cold rain drops cooled to the ice stage with falling through air. because suddenly falldown temperature

Snow:- precipitation is falls in the form of ice crystals.

Snow flakes:-
No of ice crystals combined together form snow flakes (particles)

~~Measure melt~~.

Measurement of rainfall:-

Rainfall is the source of all water used for irrigation purposes

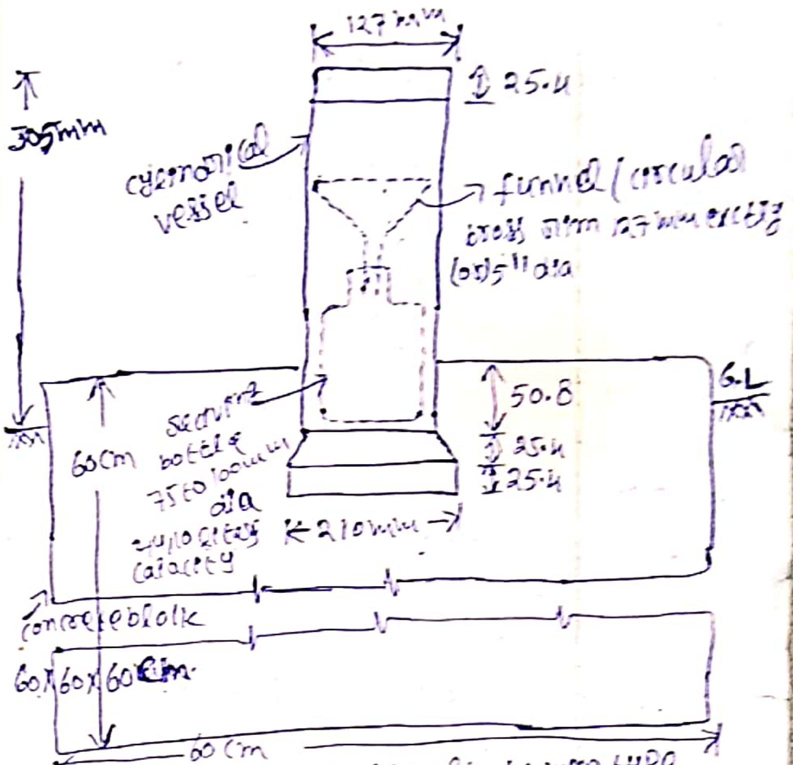
The amount of precipitation is expressed as centimeters (or) inches which falls on ground surface and is measured by rain gauges

1) Non-automatic rain-gauges
2) Automatic rain gauges

(1) Non-automatic rain gauges:-

This is also called as non recording rain-gauge

Ex:- symon's rain gauge. Is the instrument prescribed by use at all Government rain-gauge stations through out India



* symon's rain gauge is most common type non automatic rain gauge and is used to meteorological department of Government of India.
* It consist of cylindrical vessel 127mm (or) 5" in diameter with a base enlarged to 210 mm (or) 8" dia
* The top section is a funnel provided with circular cross dim 127mm (or) 5" dia
* The funnel shank is inserted in the neck of a receiving bottle which is 75 to 100mm or (3to4") dia
* The bottle capacity is about 75-100mm of rain should be measure 3or4 times in a day ~~on day of heavy rainfall~~
* when the rainfall is collected to the bottle. a man comes daily 8:30 A.M (in India) and collected water in the bottle by pouring into standard graduated measuring jar
* The rain gauge set up having in concrete block 60x60x60cm
* The rim should be provided 305 mm above the ground level

The rain fall is exceeded. The capacity of bottle. That a day. Two are 3 intermediate readings may be taken. sum. of these all recordings

* The final recording. reading 8:30 A.m. is taken

* when the rain fall on a given day. exceeded 2.5mm) Than That day is called. rainy day.

The selecting of site for raingauge station

* The rain gauge set up should kept in open place.

* The distance b/w The rain gauge and object should at least twice The hight of The object

* should never kept side (or) top of the hill

* should be kept away from high winds

(2) ~~Not~~ Automatic rain gauge:-

The rain fall is measured automatically

The rain gauge readings are recorded automatically

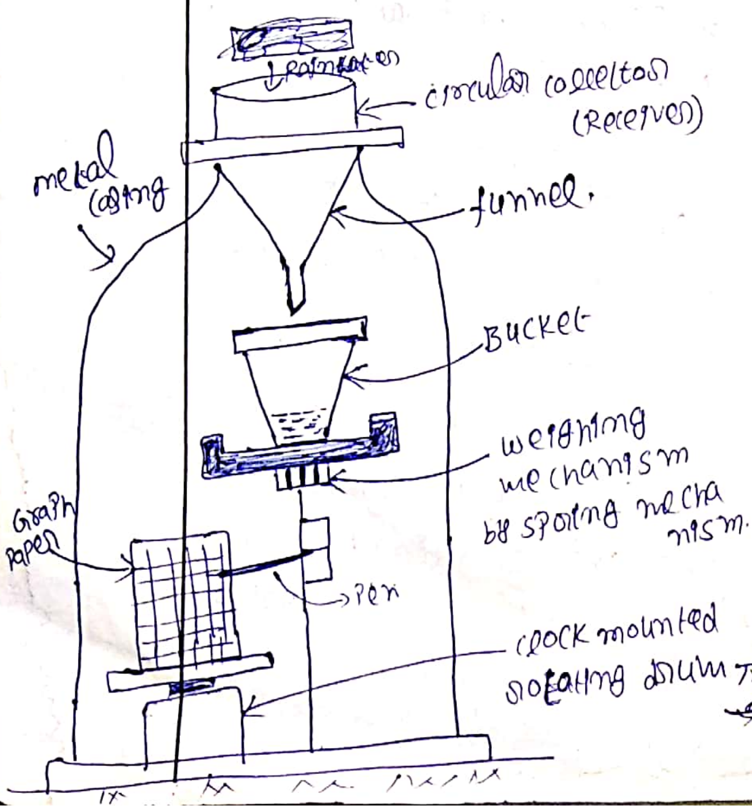
There are 3 types of rain gauges

(a) weighing bucket rain-gauge.

(b) Tipping bucket 11

(c) Float type 11

(a) weighing bucket rain-gauge:-



* It is a self recording rain gauge is used to measure the rain fall at short period of time

* This is the most commonly used type of the raingauge system.

* It consists of receiving bucket supported by a spring (or) any other weighing mechanism

* The moment of bucket due to increasing of weight is transmitted to a pen

* The pen will move Then recorded in a clock driven chart (It mean the drum moving in clock wise and recorded)

~~* The graph is chart is replaced after the pen~~ ~~reaching the upper surface (top of the chart)~~

~~* They are putting the pen~~ * The rotating drum. one revolution ~~* The pen after that~~ completes 24 hours or some time 7 days depending upon gauge.

* After graph chart is replaced. This much of time.

* The water will comes out ~~automatically~~ (syphoning occurs) and pen automatically reaches upper surface of graph zero line.

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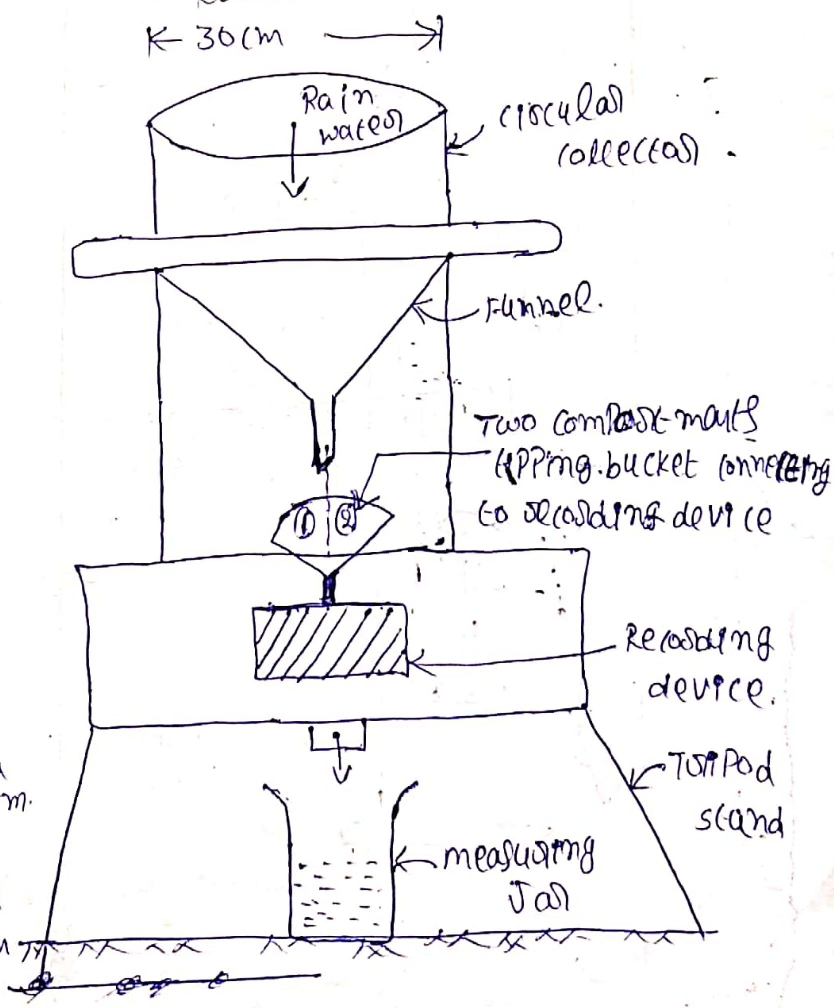
(b) Tipping bucket rain-gauge:-

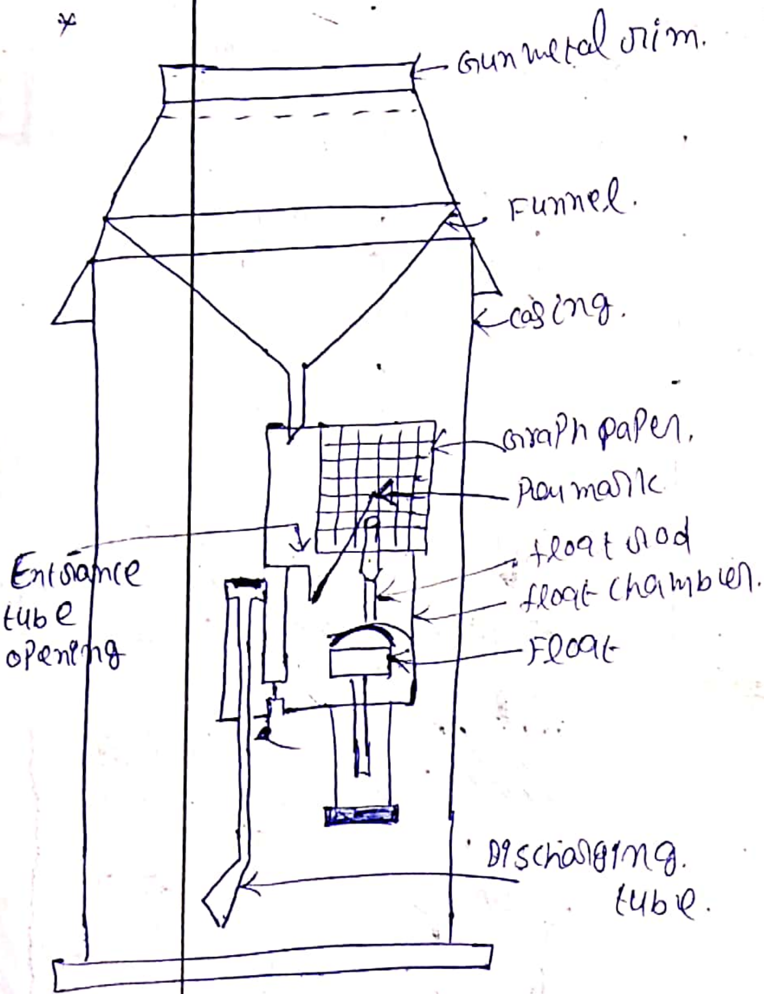


3

* It consists of 30cm diameter of a sharp edge receiver at the end of the receiver is provided a funnel.
* The pair of buckets are pivoted (arranged) under the funnel.
* In such a way that one bucket receives 0.25mm of precipitation. gets filled. after that the ~~buckets moves~~ water moves in the reservoir (or) measuring jar. and moving the second bucket will ~~come move on the~~ will come on the place of first bucket.
* There are rotating
* Tipping buckets completes ~~to~~ an electric circuit causing a pen to mark on a revolving drum.
* The moment of tipping bucket can transmitted electronically over distance.

(c) Float type rain gauge station:-

*



* It is similar to the weighing bucket type rain gauge.
* A funnel receives the water which is collected in a rectangular container.
* A float is provided at bottom of container
* A float is raised as the water level rises in the container. These moment being recorded by a pen moving on a recording drum.
* When water level rises in container so the float touches the top and releases the water. Thus all the water in the box is drained out.

Rain Gauge Network:-

The design of network rain gauges in a given catchment before to collect the necessary precipitation data.

The rain gauge density (or) Network density is defined as the ratio of total area of catchment to the total number of ~~rain~~ gauges in the catchment.

The optimum No of rain gauge stations (N) is given by

$$N = \left[\frac{C_v}{P}\right]^2$$

C_v = coefficient of variation of the rainfall values of existing station.

$$C_v = \frac{S_x}{\bar{x}} \times 100$$

S_x = standard deviation.

$\bar{x}$ = mean of rain fall

P = error in estimating mean rain fall

1) A catchment has five raingauge station In a year the annual rainfall recorded by the gauges are 78.8 cm, 90.2 cm, 98.6 cm, 102.4 cm and 70.4 cm, for a 6% error in the ~~[illegible]~~ estimation of mean rainfall; determine the additional number of gauges needed

Sol

$(\bar{x}) = \frac{1}{n} \sum x_i$

mean rainfall (x̄) = sum of annual rainfall / no of raingauge stations

mean rain fall $= \dfrac{78.8+90.2+98.6+102.4+70.4}{5}$

$= 88.08$ cm.

Standard deviation of the rainfall is given by

$$S_x^2 = \frac{\sum (x_i - \bar{x})^2}{n-1}$$

$$= \frac{[(78.8-88.08)^2 + (90.2-88.08)^2 + (98.6-88.08)^2 + (102.4-88.08)^2 + (70.4-88.08)^2]}{(5-1)}$$

$= 179.732$

$S_x = 13.41$

Hence $C_v = \dfrac{S_x}{\bar{x}} \times 100$

$= \dfrac{13.41}{88.08} \times 100 = 15.22$

[∵ C_v = coefficient of variation of the rainfall]

$N = \left[\dfrac{C_v}{P}\right]^2$

$= \left[\dfrac{15.22}{6}\right]^2$

$= 6.43 \cong 7$

Additional no of stations $= 7 - 5$

$= 2$

(2) There are four rain gauge stations existing in the catchment of a river. The avg rainfall values at these stations are 800, 620, 400 and 540 mm respectively.

(a) Determine the optimum No of rain gauges in the catchment if it is desired to limit the error in the mean value of rain fall in the catchment to 10%.

(b) How many more gauges will then be required to be installed.

Sol Mean rainfall $\bar{x} = \frac{1}{n}\sum x_i$

$$= \frac{800+620+400+540}{4}$$

$$= 590$$

$S_x^2 = \cancel{\frac{(x_i-\bar{x})^2}{}}$

standard deviation of the rain fall. is given by

$$S_x^2 = \frac{(x_i-\bar{x})^2}{n-1}$$

$$= \frac{(800-590) + (620-590)^2 + (400-590)^2 + (540-590)^2}{4-1}$$

$$= 27866.67$$

$$S_x = \sqrt{27866.67} = 166.93$$

Hence $CV = \frac{S_x}{x} \times 100$

$$= \frac{166.93}{590} \times 100 = 28.293$$

$$N = \left[\frac{CV}{P}\right]^2$$

$$= \left[\frac{28.293}{10}\right]^2 = 8.$$

(b) Additional gauges required to be installed.

= 8 - Existing 4 gauges

= 8 - 4 = 4 No's Ans

Computation of Average rainfall over a basin:-

In order to compute the average rainfall over a basin (or) catchment area of rainfall is measured at number of rain-gauge stations suitably located in the area:

The computations of average rainfall (or) precipitation may done by the following methods

(1) Arithmatic average method

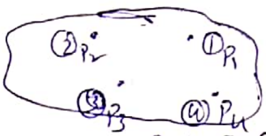
(2) Thiessen Polygon method (weighted mean method)

(3) Isohyetal method

(4) Grid Point method.

(1) Arithmatic average method:-

* It is the simplest method of estimating the average of rainfall
* The arithmatic average method is most approximate method.
* The rainfall intensity and duration varies from place to place
* The rainfall is recorded by each of rain-gauge stations



$$\frac{P_1+P_2+P_3+P_4}{4}$$

$$P_{av} = \frac{P_1+P_2+P_3+\cdots P_n}{n}$$

where $P_1, P_2, P_3 \cdots P_n$ etc are the precipitations of rain fall

n = number of rain gauge stations

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

Ex:-

Station No	1	2	3	4	5
Precipitation (mm)	12.6	18.8	14.8	10.4	16.2

Determine the average of precipitation on Arithmatic average method.

Sol $P_{av} = \frac{12.6+18.8+14.8+10.4+16.2}{5}$

$= \frac{72.8}{5} = 14.6$ mm.

$\left[\because P_{av} = \frac{P_1+P_2+P_3+\cdots P_n}{n}\right]$

(2) Thiessen Polygon method:-

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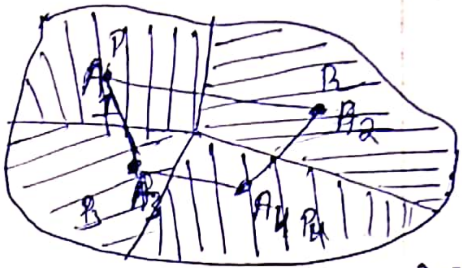
* Thiessen Polygon method is a more common method.
* Thiessen Polygon method is also called weighted mean method.
* This method is more accurate than the arithmatic average method



* Join the rain gauge stations A, B, C, D etc by straight lines
* Construct a perpendicular bisectors of each of these lines
* Find the area of each of these Polygons shown hatched.
* Multiply the area of each Thiessen Polygon by the precipitation value (or) rain gauge value of enclosed station.

$$P_{av} = \frac{A_1P_1 + A_2P_2 + \cdots A_nP_n}{A_1+A_2+\cdots A_n}$$

$$= \frac{\Sigma(A \times P)}{\Sigma A}$$

Ex:-

Rain gauge station	A	B	C	D
Area of Thiessen Polygon	45 sq km	38 sq.km	30 sq.km	40 sq.km
Precipitation	30.8mm	34.6 mm	32.6 mm	24.6 mm

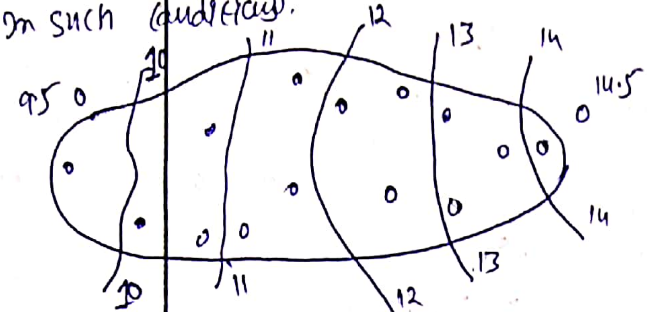
Determine avg of precipitation by using Thiessen Polygon method

Sol:- $P_{av} = \frac{(45 \times 30.8)+(38 \times 34.6)+(30 \times 32.6)+(40 \times 24.6)}{45+38+30+40}$

$= \frac{4663}{153} = 30.5$

(3) Isohyetal method:-

* The isohyetal method is most accurate in such conditions.



Procedure:-

* The rainfall values is recorded at various rain-gauge stations, prepare the isohyetal map causing the rainfall over the area
* measure the area b/w two successive isohyets with the help of planimeter.
* multiply each of these areas by the average of two rainfalls b/w the isohyets
* the average rainfall is then computed from the expression.

$$P_{av} = \frac{\Sigma A \times \left[\frac{P_1+P_2}{2}\right]}{\Sigma A}$$

Ex:-

Isohyets	Area b/w isohyets (A) (sq.km)
9	
	22
10	
	80
11	
	105
12	
	98
13	
	78
14	
	16
15	

Isohyets	Area b/w isohyets A (sq.km)	Average precipitation $\frac{1}{2}(P_1+P_2)$	Product $A \times \left[\frac{P_1+P_2}{2}\right]$
9			
	22	$\frac{9+10}{2} = 9.5$	22×9.5=209
10			
	80	$\frac{10+11}{2} = 10.5$	80×10.5=840
11			
	105	11.5	1208
12			
	98	12.5	1225
13			
	78	13.5	1053
14			
	16	14.5	232
15			4767
sum	399		

$$P_{av} = \frac{\Sigma A \left[\frac{P_1+P_2}{2}\right]}{\Sigma A}$$

$$= \frac{4767}{399} = 11.92 \text{ cm}$$

* The isohyetal method gives better results than the previous two methods
* The major drawback of the method is that a separate isohyet is required to be drawn for each storm.
* If monthly rainfall is to be computed by the isohyetal method. Then each month each year, one set of isohyet is to be drawn.
* Due to work is increased.

(4) Grid Point method:-

* In this method all the grid stations are marked on the map
* on this map drawn a suitable scale a uniform rectangle
* The average precipitation of the grid corresp is then multiplied by the area of the grid. It gives the average volume of the grid
* The sum of all such products devided by the total area of basin will gives average precipitation for the area.

(1) Arithmatic Average method:-

Ex:-

Station No	1	2	3	4	5	6	7	8	9
precipitation cm	58	61	69	56	84	86	69	79	71

Determine the average of precipitation. on Arithmatic average method?

Sol:- we know that

$$P_{av} = \frac{P_1+P_2+P_3+\dots\dots P_n}{n}$$

so

$$P_{av} = \frac{P_1+P_2+P_3+P_4+P_5+P_6+P_7+P_8+P_9}{9}$$

$$= \frac{58+61+69+56+84+86+69+79+71}{9}$$

$$= \frac{633}{9}$$

$$= 70.34\ cm.$$

(2) Thiessen Polygon method:-

Ex:-

Rain gauge station	Area of Thiessen polygon (A) cm^2	observed precipitation. P (cm)
A	3.26	58
B	0.39	63
C	1.61	71
D	2.04	69
E	2.46	86
F	0.84	81
G	3.91	84
H	5.09	56
I	0.41	53
J	3.94	69
K	2.06	61
L	4.40	79

Determine the average of precipitation. by using Thiessen polygon method?

Sol:-
we know that

$$P_{av} = \frac{A_1P_1+A_2P_2+\dots\dots A_nP_n}{A_1+A_2\dots\dots A_n}$$

$$P_{av} = \frac{(3.26\times58)+(0.39\times63)+(1.61\times71)+(2.04\times69)+(2.46\times86)+(0.84\times81)+(3.91\times84)+(5.09\times56)+(0.41\times53)+(3.94\times69)+(2.06\times61)+(4.40\times79)}{3.26+0.39+1.61+2.04+2.46+0.84+3.91+5.09+0.41+3.94+2.06+4.40}$$

$$P_{av} = \frac{2324.3}{30.41}$$

$$= 76.4\ cm.$$

(3) Isohyetal method:-

Ex:-

Isohyets (cm)	Area of enclosed b/w Isohyets (A) cm^2
86	
	0.43
85	
	5.20
80	
	4.00
75	
	5.04
70	
	5.85
65	
	4.53
60	
	4.09
55	
	1.27
50	

Determine the average of rainfall by using Isohyetal method ?

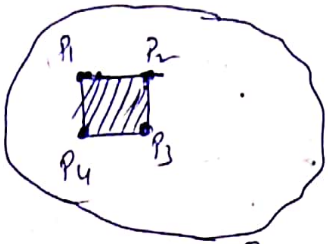
Sol :-

Isohyets (cm)	Area of enclosed b/w Isohyets (A) cm^2	Average of precipitation $\frac{1}{2}(P_1+P_2)$	Product $A \times \left[\frac{P_1+P_2}{2}\right]$
86			
	0.43	$\frac{86+85}{2} = 85.5$	$0.43 \times 85.5 = 36.80$
85			
	5.20	$\frac{85+80}{2} = 82.5$	$5.20 \times 82.5 = 429$
80			
	4.00	77.5	310
75			
	5.04	72.5	365
70			
	5.85	67.5	395
65			
	4.53	62.5	283
60			
	4.09	57.5	235
55			
	1.27	52.5	66.80
50			
sum	30.41		2121.00

$$P_{av} = \frac{\Sigma A \left[\frac{P_1+P_2}{2}\right]}{\Sigma A}$$

$$= \frac{2121.0}{30.41}$$

$$\cong 69.7\ cm$$



$$A \times \left[\frac{P_1+P_2+P_3+P_4}{4}\right]$$

This is volume of the grid

$$(V) = A \times \left[\frac{P_1+P_2+P_3+P_4}{4}\right]$$

$$\text{Avg precipitation} = \frac{A \times \left[\frac{P_1+P_2+P_3+P_4}{4}\right]}{\Sigma A}$$

A = Area of the rec cangee

ΣA = Area of the basin (total catchment area).

Frequency of rain fall :-

~~The frequency of rain fall is~~

The variation of rain fall in specified period. randomly variable of rain fall and mathematically theory of probability is applicable.

Ex:- suppose in 1 hour duration of rain fall rainfall is falling fastly after that 1/2 an hour rainfall is falling slowly and 1 hour after 45 min rain falling slowly and 1 hour rain falling is very slow this is changing frequency of rainfall

* The design of hydraulic structures, such as flood control structures, soil conservation structures, waste water systems, drains & culverts etc. design by probability of occurence of rainfall and run off

Ex:- Let us assume maximum 24 hours rainfall data for 30 years, recorded at a station

* The highest ~~rain fall~~ value of 24 hours rainfall in 30 years its frequency. occurs in 30 years

Ex:- suppose in 30 years highest rainfall 1 time occurs so frequency $\frac{30}{1} = 30$

It means next 30 years highest rain fall occurs

suppose in 30 years highest rain fall 2 times 50 cm, 50 cm occurs

It means frequency $\frac{30}{2} = 15$

~~next~~ It means next 15 years maximum rain fall occurs.

suppose in 1970 50 cm rain fall occurs again in 1990 again 50 cm rainfall occurs the difference b/w 1970 to 1990 is called as recurrence interval.

This recurrence interval is also known as return period is given by

$$T = 1/P_{ro}$$

Where P_{ro} is the probability of occurence.

* ~~The frequency analysis at various stations~~ events are 7 water head

P_{ro} is calculated by using these formulas

(i) California formula : $P_{ro} = \frac{m}{n}$ (or) $T = \frac{N}{m}$

(ii) Hazen formula : $P_{ro} = \frac{2m-1}{2N}$ (or) $T = \frac{2N}{2m-1}$

(iii) weibull formula : $P_{ro} = \frac{m}{N+1}$ (or) $T = \frac{N+1}{m}$

out of these, weibull formula is most widely used

$$\text{The frequency of rainfall } (F) = 100\, P_{ro} = \frac{1}{T} \times 100$$

(Rainfall)

(* The frequency analysis, various events are arranged in descending order of magnitude, (low to high) and each event (rain fall) is assigned a number m, with m=1 for the first entry, m=2 for the second entry. so the last entry m=n

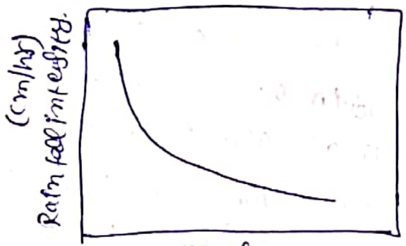
N = number of years)

Intensity - duration ~~freq~~ Analysis

The greater intensity of rain fall, shorter the length of time

It means the duration of rain fall will be more the maximum intensity is decreases

(rain fall is falling on ground more water The time duration of rain fall is less, but the duration of rainfall high the small amount of rain fall is falling on ground)



Sherman gave the following relation ship b/w intensity and duration.

$$i = \frac{a}{(t+b)^n}$$

where i = intensity of rainfall (cm/hr)

t = time in min (time duration)

a, b, n = Constants to be determined for the area.

* The above curve represented by a hyperbolic
* The rain fall is more the time will be less
* the rain fall is less the time will be more
* the rain fall is plotted against the duration.
* The world largest recorded of rain fall. lie on (or) Just under a straight line whose eqn. is

$$R = 16.6 D^{0.475}$$

where.
R = Rainfall (inches), D = Duration (hours)

Rain fall recorded on region is less, extracted from more than a million stations years of data, lie close the line of eqn

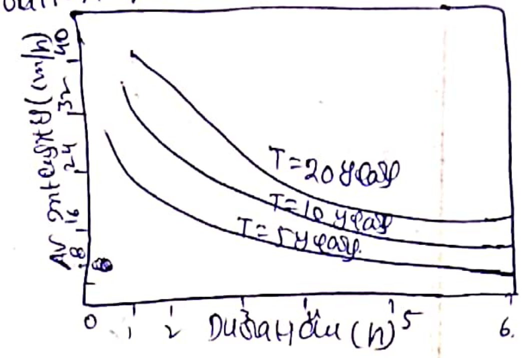
$$R = 106 D^{0.46}$$

R in mm. and D in hours

Intensity duration frequency Relationship

It means the intensity of rain fall is more the duration period will be less

The intensity of rainfall is less The duration period will be more.



The intensity duration and frequency (Return period) can be expressed by the following

$$i = \frac{KT^x}{(t+b)^n}$$

where x, b, and n = Constants for the catchment

T = Return period

Typical values of the constants K, b, n and x are given in the table.

These values are based on studies conducted by the central soil and water conservation research and training institute, Dehradun.

Typical values of constants K, b, n and x.

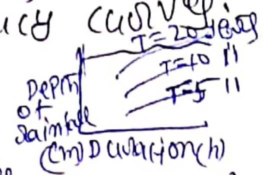
S.N	Place in India	Values of Constants			
		K	b	n	x
1	Bellary	6.16	0.5	0.694	0.972
2	Bhopal	6.93	0.5	0.189	0.878
3	Chandigarh	5.82	0.4	0.160	0.750
4	Nagpur	11.45	1.25	0.156	1.032
5	Raipur	4.68	0.15	0.139	0.928

Sherman gave the following relations

$i = \frac{KT^x}{t^n}$ and $i = \frac{40\,T^{0.27}}{(t+T)^{0.7}}$

Depth duration frequency curves

The intency of rainfall $i = \frac{KT^x}{(t+b)^n}$ is converted ix t and result are plotted depth duration frequency curves



Probable maximum precipitation (PMP)

* For safe design of hydraulic structure, even a 50 year or 100 year precipitation
* The probable of maximum precipitation commonly known as (PMP)
* For this stage precipitation resulting from the most critical rain fall occur but it is measured this stage also
* once the rainfall measured on critical stage and construct the structure. ~~by using~~ There is no risk
* For the determination (or) estimation of PMP, the knowledge of an experienced hydro-meteorologist is required.
* Last 40 years there has been increasing of these science.
* Hydrometeorology, has been largely developed in USA.
* The PMP can be estimated by maximising the different parameters like humidity, temperature, wind velocity and

There are two approaches for determining PMP.

(i) meteorological approach
(ii) stastical approach.

PMP can also be estimated from the following equation.

$$PMP = \bar{P} + K\sigma$$

where
$\bar{P}$ = mean of annual maximum rainfall series

σ = standard deviation of the series

K = frequency factor,

maximum and minimum rainfall:-

* The magnitude (or) of maximum rainfall and minimum rainfall with in specified time period can be determined by the use of frequency formula given by Hazen.

$$T = \frac{2N}{2m-1} = \frac{N}{m-0.5}$$

where T = recurrence interval.

m = rank number.

ADDITIONAL ANSWER SHEET
S.V.V.S.N. ENGINEERING COLLEGE, ONGOLE.
(Affiliated to Acharya Nagarjuna University)

Signature of invigilator

R13 batch Newly implemented topics

(జల సంబంధిత data)
Hydrological data:-

Already before classes we have to study of hydrological cycle in that hydrological we are studying in
(i) Evaporation (E) & Transpiration (t)
(ii) Precipitation (P)
(iii) Run off (R)

in that run off we are studying in surface run off, subsurface run off and ground water run off these all are components will give an information about climate.

These information will be required for finding the hydrological data, meteorology and geology is also required.

The hydrological data will be depending on
(1) weather and climate records
(2) precipitation data
(3) stream flow data
(4) Evaporation and transpiration data
(5) Infiltration characteristics of the area.
(6) Ground water characteristics
(7) Physical and Geological characteristics

(1) weather and climate records:-

weather and climate records helps to giving the data about temperature, humidity, radiation, wind etc

(2) precipitation data:-

The precipitation data helps to predicting run off volume.
(అంచనా)
(Precipitation data ద్వారా ఎంత వాటర్ ప్రవహించింది [illegible] అని తెలుసుకోవడానికి ఉపయోగపడుతుంది)

It is also helpful in estimating the water-budget-equation for the basin
(ఒక వర్షపాతం [illegible] తెలుస్తే ఆ వర్షం [illegible] water budget equation లో వాడడానికి ఉపయోగపడుతుంది)

(3) Stream flow data:-

(కొలత)

This helps to planning of reservoirs, design of spillways, bridges, culverts.

(ఒక రివర్‌లోని వాటర్ ఎంత ప్రవహిస్తుంది అనేది తెలుసుకుంటే దాని బట్టి ఏ type of structure కట్టి water store చేయాలి అలాగే height ఎంత కట్టాలి అనేది కూడా తెలుస్తుంది)

(4) Evaporation and transpiration data:-

The data is required for determining

(i) water budget for ~~a~~ the river basin

(ఒక river లోని మొత్తం వాటర్ utilise చేసుకోవాలి అనేది ఈ డేటా ద్వారా తెలుసుకోవచ్చు)

(ii) Reservoir capacity for water resources development

(ఒక reservoir ~~water~~ లో ఎంత water save చేయాలి అనేది ఈ డేటా ద్వారా తెలుసుకోవచ్చు)

(iii) Evaporation suppression technique

(Evaporation తగ్గించడానికి ఏమి చేయాలో ఈ డేటా ద్వారా తెలుసుకోవచ్చు)

(5) Infiltration characteristics of the area.

This data helps in determining rainfall excess (or) not of ~~a~~ particular area, and run off water in that area.

(6) Ground water characteristics:-

This helps to estimate the ground water in particular area.

(భూమిలో ఉండే జలాల పరిమాణాలు)

(7) Physical and Geological characteristics:-

This data helps to determine run off pattern and silt load movement

(భూమిపైన & భూమిలోపల జరిగే చర్యలు అంటే భూమిపైన surface మీద నుండి water ఏ speed లో move అవుతుంది అలాగే ఎంత మట్టిని తనతో తీసుకెళ్తుంది water తనతో ఈ data ద్వారా తెలుసుకోవచ్చు)

Water budget :-

(a) Global water budget :-

Water is the most important natural resource which is vital for all forms of life ([illegible]) on the earth

([illegible] life [illegible] water [illegible])

→ The total quantity of water in the world is roughly 1360 million cubic kilometers ($M\,km^3$; $1\,M\,km^3 = 10^{15}\,m^3$)

→ The total amount of water 97.2% is having in seas and oceans
([illegible]) ([illegible])

~~→ 0.31% is available as~~

→ while about 2.1% is frozen in ice caps

→ 0.31% is available as deep ground water.

→ so thus $97.2 + 2.1 + 0.31 = 99.6\%$ of total water is of no use to man

(Write a table 4.1 in page No 105 B.C Punmia)

see back side I am writing a table

(b) India's water Budget :-
([illegible])

→ India has a Geographical area of nearly 3.3 million square kilometers.

→ Normally annual ([illegible]) rain fall varies from 100 mm to 11000 mm.

→ The annual average rainfall over the country is 1170 mm depth which is nearly $4000\,km^3$ of the total precipitation

([illegible] 1170 mm depth [illegible] 1170 mm height [illegible] $4000\,km^3$ [illegible])

→ In our country the water will be flowing through the river is estimated to be $1800\,km^3$

→ Central water commission (CWC) indicate that the water resources utilisable through surface structures is about $690\,km^3$ only

([illegible] structures [illegible] $690\,km^3$ [illegible] utilise [illegible])

→ In our country Ground water is utilisable about $450\,km^3$

($450\,km^3$ [illegible] (ground water) [illegible])

→ The total moisture is having in atmosphere has 770 million ha-m during June to september and 340 million ha-m in other months

Global moisture (తేమ) 770 m-ha-m ఉత్పత్తి అవుతుంది [illegible] atmosphere లో ఉండి ఈ June నుండి September వరకు [illegible] ~~[illegible]~~ 340 m-ha-m లో ఉత్పత్తి [illegible] atmosphere లో ఉంటుంది.

→ In ~~moisture content~~ 25 to 30% of moisture content comes back as rain fall.

Table 4.1 Estimated Earth's water inventory

Location	Water volume, M km^3 (= 1×10^{15} m^3)	% of total water
(1) Fresh water (lakes)	0.125	
(2) Rivers	0.00125	
(3) Soil moisture	0.065	0.621
(4) Ground water (a) < 0.8 km deep (b) > 0.8 km deep	 4.125 4.125	
(5) Saline lakes and inland seas	0.105	0.008
(6) Atmosphere	0.013	0.001
(7) Polar ice caps, glaciers and snow	29.2	2.1
(8) Seas and snow	1320.0	97.25
Total	1360 M km^3 (= 1.360×10^{18} m^3)	100.00

UNIT-I Problems

Pg No 130 (Punmia)

(1) The ordinates (in mm) of a rainfall mass curve for a storm, which commenced at 06.30 hours; recorded by self recording raingauge at 15 minutes interval are as under.

0, 12.4, 22.1, 35.1, 52.7, 63.7, 81.9, 109.2, 123.5, 132.6, 143.3, 146 and 146 Construct the hyetograph of this storm for a uniform interval of 15 minutes.

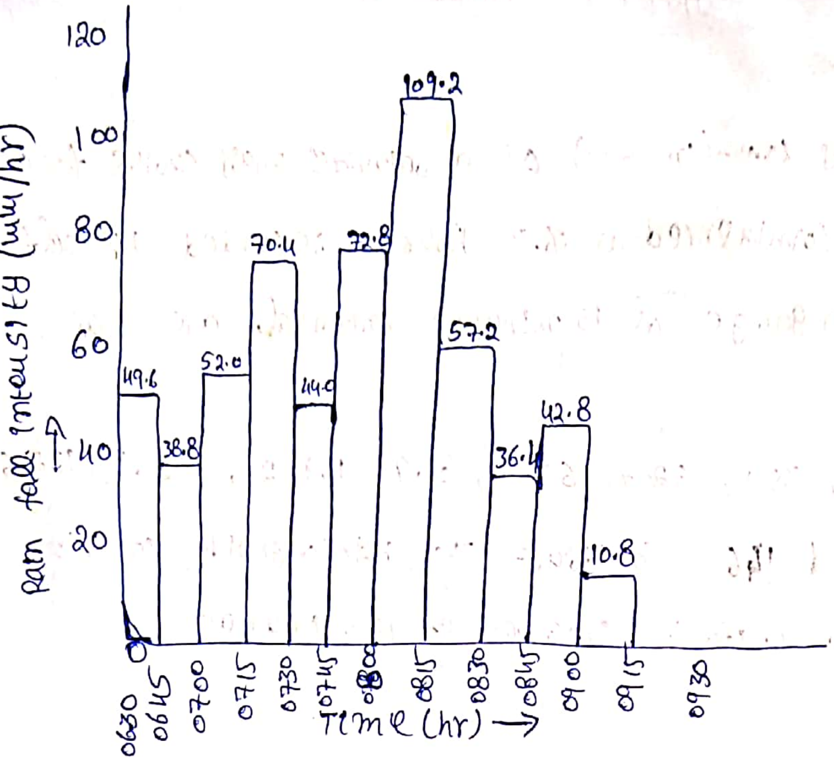
Sol:

Time	Cumulative rainfall (mm)	Rainfall in successive 15 min interval (mm)	Rainfall intensity (mm/h)
06.30	0	–	–
06.45	12.4	12.4 − 0 = 12.4	12.4 × 4 = 49.6
07.00	22.1	22.1 − 12.4 = 9.7	9.7 × 4 = 38.8
07.15	35.1	35.1 − 22.1 = 13.0	13 × 4 = 52
07.30	52.7	17.6	70.4
07.45	63.7	11.0	44.0
08.00	81.9	18.2	72.8
08.15	109.2	27.3	109.2
08.30	123.5	14.3	57.2
08.45	132.6	9.1	36.4
09.00	143.3	10.7	42.8
09.15	146	2.7	10.8
09.30	146	0.0	0.0

Note: [∵ Time duration of every 15 min interval]

∴ the rain fall in successive 15 min. but Rainfall intensity is 1 hour

∴ so 4 × 15 min = 60 min = 1 hour (4 × Rainfall in successive 15 min)



Pg No 131 (BC Punmia)

(2) In the above example. compute the maximum rainfall intensities for duration of 15, 30, 45, 60, 90 and 120 minutes and plot the intensity duration graph

Sol

Time	Cumulative Rain fall (mm)	Rainfall in any possible time interval of					
		15 min	30 min	45 min	60 min	90 min	120 min
06.30	0						
06.45	12.4	12.4−0 = 12.4	—				
07.00	22.1	22.1−12.4 = 9.7	22.1				
07.15	35.1	13.0	9.7+13.0 =22.7	35.1			
07.30	52.7	17.6	13.0+17.6 = 30.6	30.6+9.7 = 40.3	52.7		
07.45	63.7	11.0	28.6	28.6+13.0 = 41.6	41.6+9.7 =51.3		
08.00	81.9	18.2	29.2	46.8	46.8+13.0 =59.8	81.9	
08.15	109.2	27.3	45.5	56.5	74.1	74.1+22.7 =96.8	
08.30	123.5	14.3	41.6	59.8	70.8	70.8+30.6 =101.4	123.5
08.45	132.6	9.1	23.4	50.7	68.9	97.5	97.5+22.7 =120.2
09.00	143.3	10.7	19.8	34.1	61.4	90.6	90.6+30.6 =121.2
09.15	146.0	2.7	10.4	22.5	36.8	82.3	110.9
09.30	146.0	0.0	2.7	13.4	22.5	64.1	93.3

15 min + 15 min = 30 min column values are coming
30 min + 15 min = 45 min " " "
45 min + 15 min = 60 min " " "

15 min to 60 min we take 15 min interval but
60 min to 120 min we take 30 min interval so
in 90 min column we can leave 2 boxes at a time.
60 min + 30 min = 90 min. column values are coming

In the above table we should take the maximum values
of the each interval. This denote the maximum rainfall
depth for the respective durations.
Thus the maximum rainfall depth of 15 min, 30 min, 45 min,
60 min, 90 min and 120 min. duration are respectively
27.3, 45.5, 59.8, 74.1, 101.4 and 123.5 mm

1 hour = 60 min

∴ max intensity for 15 min duration.

$i_{15} = 27.3/0.25 = 109.2$ mm/h

$\frac{15}{60} = 0.25$

max intensity for 30 min duration

$i_{30} = 45.5/0.5 = 91$ mm/h.

$\frac{30}{60} = 0.5$

max intensity for 45 min duration.

$i_{45} = 59.8/0.75 = 79.7$ mm/h.

$\frac{45}{60} = 0.75$

max intensity for 60 min duration.

$i_{60} = 74.1/1 = 74.1$ mm/h

$\frac{60}{60} = 1$

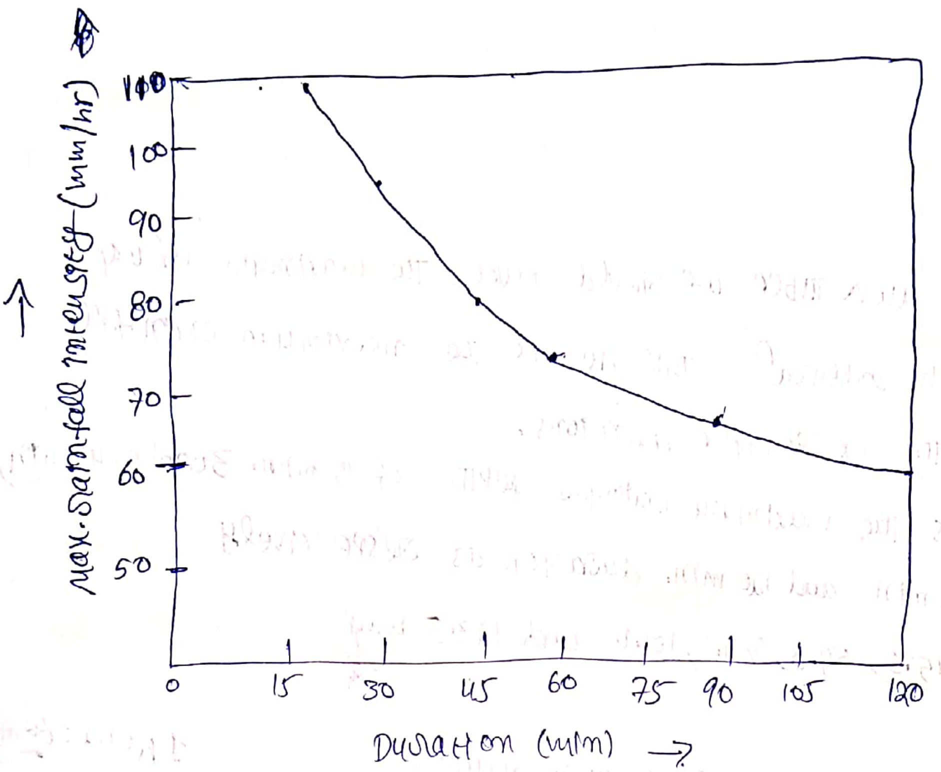
~~max intensity~~

Max intensity for 90 min duration

$$i_{90} = 101.4/1.5 = 67.6 \text{ mm/h}$$

Max intensity for 120 min duration

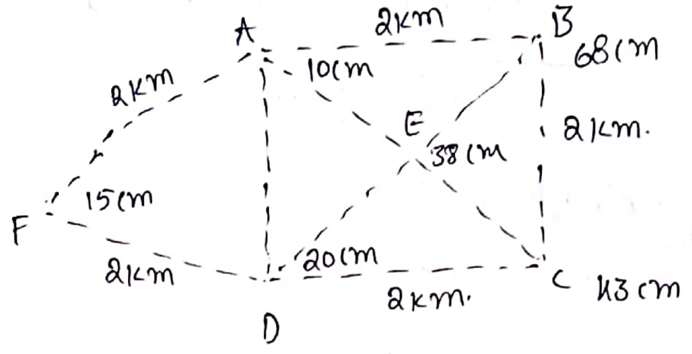
$$i_{120} = 123.5/2 = 61.75 \text{ mm/h}$$



This graph shows the max intensity duration curve for the given storm.

spect

3) Find the mean precipitation for the mean area as shown in figure below by Thiessen polygon method. The area is composed of a square plus an equilateral triangular plot of side 2km. Rain-fall readings are in cm at the various stations indicated



sol:-

Rain Gauge station	Area of Thiessen polygon. (A) (km or mm)	precipitation (P) (mm)	A x P (mm²)
A	2×10^6 mm	100 mm.	$2\times10^6\times100 = 2\times10^8$ mm
B	2×10^6 mm	680 mm.	$2\times10^6\times680 = 2\times10^8\times6.8$ ($\frac{\cancel{680}}{100\times6.8}$)
C	2×10^6 mm.	430 mm.	$2\times10^6\times430 = 2\times10^8\times4.3$ ($\frac{\cancel{430}}{100\times4.3}$)
D	2×10^6 mm	200 mm.	$2\times10^6\times200 = 2\times10^8\times2$ ($\frac{\cancel{200}}{100\times2}$)
E	2×10^6 mm	380 mm.	$2\times10^8\times3.8$
F	2×10^6 mm	150 mm.	$2\times10^8\times1.5$

precipitation (P) = 10 cm Area = 2 km.

1 cm = 10 mm. 2 kilo meter.

$P = 10\times10$ mm 1 kilo = 1000 mm

$= 100$ mm. 1 meter = 1000 mm

$2\times1000\times1000$

$= 2\times10^3\times10^3$

$= 2\times10^6$

Average of precipitation

$$P_{av} = \frac{\Sigma P_1A_1 + \Sigma P_2A_2 + \dots \Sigma P_nA_n}{A_1 + A_2 + \dots A_n}$$

(or)

$$P_{av} = \frac{\Sigma P_iA_i}{\Sigma A}$$

$$= \frac{2\times10^8 + (2\times10^8\times6.8)+(2\times10^8\times4.3)+(2\times10^8\times2)+(2\times10^8\times3.8)+(2\times10^8\times1.5)}{(2\times10^6)+(2\times10^6)+(2\times10^6)+(2\times10^6)+(2\times10^6)+(2\times10^6)}$$

$$= \frac{[2+(2\times6.8)+(2\times4.3)+(2\times2)+(2\times3.8)]\,10^8}{[2+2+2+2+2+2]\times10^6}$$

$$= \frac{[38.8]\times10^8 \ mm^2}{12\times10^6 \ \cancel{mm}}$$

$$= \underline{323.33 \ mm}$$

Roll no 216 (Bc Purnima) and Roll no 261 (SK Sarraf)

(4) Precipitation station X was in operative part of a month during which a storm occurred. The respective storm at there surrounding stations A, B and C were 107, 89 and 122 mm. The normal annual precipitation amounts of stations ~~X, A, B and C~~ X, A, B, and C are respectively 978, 1120, 935 and 1200 mm. Estimate the storm precipitation for station X

Sol :- Average annual precipitation at X = 978 mm.

$\therefore$ 10% of $N_x = \frac{978}{10} = 97.8$ mm

The maximum permissible annual ppt. at either of the three stations for taking.

$978 + 97.8$ mm $= 1075.8$ mm < 1120 and 1200 mm (given)

Hence the annual precipitation A and C, 1120 and 1200 is more than 10% of N_x.

So weighted mean should be taken.

Note :- $\left[P_x = \frac{P_1+P_2+P_3}{3} \right.$ [Provided $N_1, N_2,$ and N_3 differ less within 10% of N_x.

Arithmatic average method is used]

$$P_x = \frac{1}{3}\left[P_1 \frac{N_x}{N_1} + P_2 \frac{N_x}{N_2} + P_3 \cdot \frac{N_x}{N_3}\right]$$ [provided any of N_1, N_2 and N_3 differs from N_x by more than 10%]

So $$P_x = \frac{1}{3}\left[P_1 \frac{N_x}{N_1} + P_2 \frac{N_x}{N_2} + P_3 \frac{N_x}{N_3}\right]$$

or $$P_x = \frac{1}{3}\left[P_a \frac{N_x}{N_a} + P_2 \frac{N_x}{N_b} + P_3 \frac{N_x}{N_c}\right]$$

Putting various given values, we get

$$P_x = \frac{1}{3}\left[107\left[\frac{978}{1120}\right] + 89\left[\frac{978}{935}\right] + 122\left[\frac{978}{1200}\right]\right]$$

$$= \frac{1}{3}\left[93.5 + 93.1 + 99.4\right]$$

$$= \frac{1}{3}\left[286\right] = 95.3 \text{ mm}$$

(5) The isohyetal map for 24 hour storm gave the areas enclosed between different isohyets, as follows.

Isohyets in mm	21	20	19	18	17	16	15	14	13	12
Enclosed area in sq. km	543	1345	2030	2545	2955	3280	3535	3710	3880	3915

Determine the average depth of rainfall over the basin.

Sol :-

~~The computations for calculating average rainfall by using the formula~~ $$P = \frac{P_1A_1 + P_2A_2 + \cdots}{A_1 + A_2 + \cdots}$$ ~~are easily done in a tabular form, as shown in table given below~~

Scanned by CamScanner

Isohyet mm (1)	Area between each isohyet and basin boundary in km^2 (2)	Net incremental area between two isohyet i.e. A_1, A_2, A_3 in km^2 (3)	Avg rainfall on the incremental areas i.e. avg of two isohyets i.e P_1, P_2, P_3 in mm (4)	Rainfall volume on incremental areas i.e P_1A_1, P_2A_2, P_3A_3 ...... (3) x Col(4) in $mm.km^2$
21	543	543	21	543x21 = 11,403
20	1345	1345-543 = 802	$\frac{21+20}{2} = 20.5$	802x20.5 = 16,441
19	2030	2030-1345 = 685	$\frac{20+19}{2} = 19.5$	13,357
18	2545	515	18.5	9,527
17	2955	410	17.5	7,175
16	3280	325	16.5	5,362
15	3535	255	15.5	3,952
14	3710	175	14.5	2,537
13	3880	170	13.5	2,295
12	3915	35	12.5	437
	Σ	3915		72,486

$$\text{Avg PPT over the basin} = \frac{\Sigma PA}{\Sigma A} = \frac{72486}{3915} \text{ mm}$$

$$= 18.51 \text{ mm} \quad \text{Ans}$$

$$\left[\because P_{av} = \frac{\Sigma A\left[\frac{P_1+P_2}{2}\right]}{\Sigma A}\right]$$

Pg No 137 (BC Punmia)

(5) The rainfall data recorded at a rain gauge station are given below.

year.	Rainfall. (cm)	year	Rainfall (cm)	year	rainfall (cm)	year	Rainfall (cm)