PROCESSING AND ANALYSIS OF PRECIPITATION DATA

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OBJECTIVES

This lecture describes the processing of precipitation data. Methods of mean areal precipitation estimation in plain and mountainous areas are explained with illustrative example to enable participants to achieve the capability of carrying out the analysis themselves.

INTRODUCTION

It is common experience that the precipitation data in its raw form would contain many gaps and inconsistent values. As such preliminary processing of precipitation data is essential before it is put to further use in analysis. Processing of the data has two major objectives. One is to evaluate the data for its accuracy and the other is to prepare the data in a form appropriate for subsequent analysis. Manual scrutiny for the carrying out processing has obvious limitations. Computerized processing and analysis has several advantages over the manual scrutiny and analysis.

PROCESSING SYSTEM

The processing system consists of a series of steps and procedures. The efficiency, economy and speed of the system would depend upon the type of storage devices, the quality of machines and software (computer programmes). The methodology for executing the various steps involved in the processing system is briefly described.

Preliminary Scrutiny

Before the precipitation data is stored on computer compatible devices for computer processing, it becomes necessary to carry out preliminary checks, manual scrutiny etc. The reports received from manually observed stations by telephone or other communication channels are checked by a repeat back system.

Improper registering of data includes entering data against wrong time and date, alteration of figures etc. The official at receiving station could check the reasonableness of report by judging the report based on past experience and statistics of the station and region to which the station belongs.

Some of the climatological parameters used for checking the values of normal rainfall, highest observed rainfall or value of rainfall, corresponding to 25, 50 or 100yr. return period.

Checking reasonableness of a daily reported precipitation

For example, daily precipitation reported from a station is 360.6 mm and its precipitation statistics of the reporting station are:

(i)   Normal monthly rainfall of the corresponding month   :350.0 mm

(ii)   Mean maximum 1 day rainfall (($\bar{x}$))   :   210.6 mm

(iii)   Standard deviation (σ) of maximum 1 day rainfall   :   50.0 mm

(iv)   Highest observed 1 day rainfall   : 285.3 mm

(v)   100-year return period value of 1 day maximum rainfall   :   300.0 mm

(vi)   Probable maximum precipitation value of 1 day rainfall   :   370.8 mm

The reported daily rainfall value of 360.6 mm is more than the normal monthly rainfall of the corresponding month and is, therefore, doubtful but not reasonable. The reasonableness is checked with other statistics. The value is compared with the mean 1 day maximum rainfall

and the highest observed value. The reported value is more than the mean 1 day maximum and the corresponding to $(\bar{x}+\sigma)$ and $(\bar{x}+2\sigma)$ are computed. They are 260.6 mm and 310.6 mm, respectively.

The reported daily value is compared with the 1 day Probable maximum precipitation (PMP) value, which is 370.8 mm. The value is less than the PMP and is, therefore, reasonable and is further checked by spatial consistency.

STORAGE OF PRECIPITATION DATA: DATA BANK

In India, precipitation data collected by central and state organizations is generally stored only in the form of printed record. The data are, however, transferred to computers by the office of Additional Director General of Meteorology (Research), India Meteorological Department (IMD), Pune. Precipitation and other meteorological data can be obtained from IMD Pune on the payment basis.

Format of daily precipitation data

The daily rainfall data were punched in 31 card format as shown in Figure1 (a) until 1970 and was switched over to 24 card format as shown in Figure 1(b) since 1971.

In the 31 card format, the data of 12 months for each day are punched on each card together with station related information, year and date. In the 24 card format, each month's rainfall data are punched on 2 cards, 16 days data on the first card, 15 days data and monthly total on the second card.

Format of hourly rainfall data

Data of hourly rainfall recorded at the self recording rain gauges maintained by either India Meteorological Department or other organizations were not published in printed form. India Meteorological Department, however, stores data of self recording rain gauge in the digital forms. The data format is shown in Figure 1C.

The first card contains besides station code, year, month, date and card number, data of hourly rainfall corresponding to 1st to 16th hour. The second card contains besides station code and other details, data of hourly rainfall, time of maximum rainfall occurrence and total rainy duration in the day given in hours and minutes.

FIG. 1 (a)   31 CARD DAILY RAINFALL DATA FORMAT

FIG. 1 (b)   24 CARD DAILY RAINFALL DATA FORMAT

FIG. 1 (c)   HOURLY RAINFALL DATA FORMAT

Quality Control

Quality control is a pre-requisite before the precipitation data are used either in an operational system for flood forecasting or achieved for climatological purposes. The basic objective of the quality control procedure is to detect and if possible correct errors in observational data at the earliest stage possible in the flow of data from local data source to the centralized database.

Source and types of data errors

Measurement errors have been classified by WMO (1982) into various groups.

(a) Errors built into instruments
(b) Errors involved in regarding instruments and transmitting or recording data
(c) Errors due to improper instrument exposure or to the lack of representativeness of the instrument site to the area for which it is to be used as an index
(d) Errors occurring during the processing of the data.

Most of the errors described above could be further sub classified as

(i)   Systematic errors, and
(ii) Random errors

(i)   *Systematic errors*

Systematic errors are essentially due to malfunctioning of instrument, wrong exposure conditions and/or lack of knowledge of observer. WMO (1982) listed the following errors for which adjustment needs to be made to get a near accurate estimate of precipitation from a measured precipitation report.

(a)   error due to the systematic wind field deformation above the gauge orifice

(b)   error due to the wetting loss on the internal walls of the collector

(c)   error due to evaporation from the container (generally in hot climates)

(d)   error due to the wetting loss in the container when it is emptied

(e)   error due to blowing and drifting snow

(f)   error due to splashing in and out of water, and

(g)   random observational and instrumental errors.

The first six errors listed above are systematic and are listed in order of general importance. The net error due to blowing and drifting snow and due to splash in and out of water can be either negative or positive while net systematic errors due to the wind field and other factors are negative.

Since for liquid precipitation the errors listed at (e) and (f) above are near zero, the general model for adjusting the data from most gauges take the form

$$Pk = XPc = K (Pg + \Delta P1 + \Delta P2 + \Delta P3) \hspace{3cm} (1)$$

where

Pk =   adjusted precipitation amount

K =   adjustment factor for the effects of wind field deformation

Pc =   the amount of precipitation caught by the gauge collector

Pg =   the measured amount of precipitation in the gauge

$\Delta P1$ =   adjustment for the wetting loss in the internal wells of the collector

$\Delta P2$ =   adjustment for wetting loss in the container after emptying

$\Delta P3$ =   adjustment for evaporation from the container

For further details of adjustment WMO (1982) may be referred. The data needed to make the adjustments include wind speed, drop size, precipitation intensity, air temperature, humidity and other characteristic of the gauge site.

(ii)   ***Random errors***

Some of the random errors could arise due to spilling of the water when transferring it to the measuring jar, leakage into or out of the receiver, observational error etc. The others which could be due to observer are

(i)   misreading and transposing digits,

(ii)   misrecording because of faulty memory,

(iii)   recording the data at the wrong place on the recording sheet,

(iv)   misplacing the decimal point,

(v)   making readings at improper interval,

(vi)   incorrect dating of the report,

(vii)   making an estimate of the precipitation in some case because of non-availability or other problems with the gauge,

(viii) incorrectly reading or communicating the data to a reporting centre etc.

It may, therefore, appear that automation may be solution to reduce the error. However even without human intervention chances of erroneous reading may be possible because of

(a)   evaporation from gauge

(b)   overflowing gauge

(c)   mechanical or electrical mal-functions

ESTIMATION OF MISSING DATA

While retrieving data for climatological purpose or inputting data in real time, one often comes across missing data situations. Since blank in a data set is read as zero by computer, necessary software for identifying the blanks and marking them appropriately need to be developed.

Data for the period of missing rainfall data could be filled using estimation technique. The length of period up to which the data could be filled is dependent on individual judgment. Generally, rainfall for the missing period is estimated either by using the normal ratio method or the distance power method.

Normal ratio method

In the normal ratio method, the rainfall RA at station A is estimated as a function of the normal monthly or annual rainfall of the station under question and those of the neighbouring stations for the period of missing data at the station under question.

$$R_A = \frac{\sum_{i=1}^{n} \frac{NR_A}{NR_i} x R_i}{n} \tag{2}$$

where RA   is the estimated rainfall at station A

Ri   is the rainfall at surrounding station

NRA   is the normal monthly or seasonal rainfall at station A

NRi   is the normal monthly or seasonal rainfall at station i

n   is the number of surrounding stations whose data used for estimation

Example

The observed rainfall at the estimator stations B, C and D are:

Station	B	C	D
Rainfall (mm)	98.9	120.5	110.0

The normal monthly, seasonal or annual rainfall at the estimated stations :

Station	A	B	C	D
Monthly rainfall (mm)	331.3	290.8	325.9	360.5

The rainfall at station A is:

$$P_A = \frac{\dfrac{331.3x98.9}{290.8} + \dfrac{331.3x120.5}{325.9} + \dfrac{331.3x110.0}{360.5}}{3}$$

$$= \frac{1.14x98.0 + 1.02x120.5 + 0.92x110}{3} = 112.3mm$$

Distance power method

In this method, the rainfall at a station is estimated as a weighted average of observed rainfall at the neighbouring stations. The weights are taken as equal to the reciprocal of the distance of some power of distance of the estimator stations.

$$R_A = \frac{\sum_{i=1}^{n} \dfrac{R_i}{D_i^2}}{\sum_{i=1}^{n} \dfrac{1}{D_i^2}} \qquad (3)$$

where RA and Ri has the same notation as in Eq. (2) and Di is the distance of estimator station from the estimated station. The procedure for estimating rainfall data by this technique is indicated through an example (Figure 2a).

If A, B, C, D are the location of stations discussed in the example of normal ratio method, the distance of each estimator station (B, C and D) from the station (a) whose data is to be estimated is computed with the help of the coordinates using the formulae

$$Di = [(x - x_i)^2 + (y - y_i)^2]$$ (4)

where x and y are the coordinates of the station whose data is estimated and x_i and y_i are the coordinates of stations whose data are used in estimation.

The weights $1/D_i^2$ are computed for each station and the rainfall at the station A is estimated as follows.

Station	Distance from Station A	$1/D_i^2$	Rainfall (mm)	Weighted Rainfall (mm)
B	28	1.27×10^{-3}	98.9	125.6×10^{-3}
C	17.7	3.19×10^{-3}	120.5	384.6×10^{-3}
D	42.5	0.55×10^{-3}	110.6	60.5×10^{-3}
	Total	5.01×10^{-3}		570.7×10^{-3}
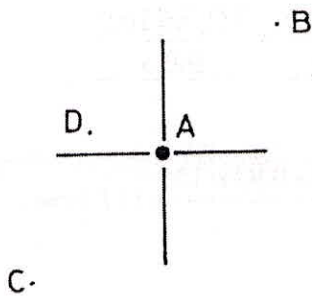
FIG. 2 (a)
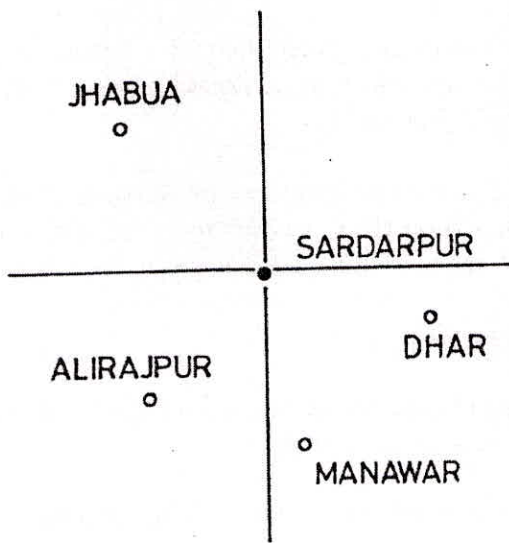
FIG. 2 (b)

Rainfall at station A $= = \dfrac{570.7x10^{-3}}{5.01x10^{-3}} = 113.9mm$

Internal consistency check

The internal consistency or self consistency checks are applied by using statistical information based on historical data of the station and current data in case of short duration rainfall. Example for checking the data by the internal consistency is given below:

Example: Hourly rainfall data reported at a station are as follows:

Hours	1	2	3	4	5	6
Rainfall	8.0	10.8	85.8	28.5	19.8	15.0

The hourly rainfall reported during 3rd hour is suspected though it could not be ruled out. When the 3 hourly total 1-3 hours is reported, the value in 3rd hour could be checked. If the 3 hourly total reported is 54.1 mm it could be seen that the value is 50.5 mm less than the three hourly total computed from the reported hourly data which is 104.6. Thus the value in the 3rd hour is 35.3 mm and not 85.8 mm as reported in the first place.

When the 6 hour total 117.4 mm is reported, the value of 35.3 mm is confirmed for the 3rd hour. Further checking for the erroneous value is carried out similarly.

Spatial consistency checks

Spatial consistency checks for precipitation data are carried out by relating the observations from surrounding stations for the same duration with the rainfall observed at the station. This is achieved by interpolating the rainfall at the station under question with rainfall data of neighbouring stations (Figure 2b). An example of spatial consistency check is given below.

Data reported at a group of five stations is as follows:

Station	Jhabua	Sardarpur	Dhar	Manawar	Alirajpur

Rainfall(mm)	132.1	10.3	103.3	125.7	149.8

During the quality control process, the data at Sardarpur is identified as doubtful. The data at Sardarpur is checked by spatial consistency check. The rainfall data at Sardarpur is estimated using the distance power method and compared with the observed value. From the four quadrants around Sardarpur (Figure 2b) on nearest from each quadrant is selected for the estimation of rainfall at Sardarpur.

Using the reference coordinate system, the distance of each of the estimator stations from Sardarpur is determined and the rainfall at Sardarpur is estimated using the Eq.(3).

Sl. No.	Station	Distance from Sardarpur (km)	$1/D_i^2$	R/D_i^2
1.	Jhabua	42	5.67×10^{-4}	.075
2.	Dhar	39	6.57×10^{-4}	.068
3.	Alirajpur	75	1.78×10^{-4}	.027
		Total	14.02×10^{-4}	.170

The estimated rainfall in Sardarpur in 121.3 mm and is very much different from the observed value. Therefore reported value is rejected and replaced by the estimated value.

Adjustment of data

To obtain homogeneity among and within measurements of precipitation, adjustment of data becomes necessary. Adjustment on data has two principal objectives. First is to make the record homogeneous with a given environment and the second is to eliminate or reduce extraneous influences by correcting for change in gauge location or exposure. Adjustment for these errors is made by 'Double Mass Analysis'.

Double mass analysis is a graphical method for identifying and adjusting inconsistencies in a station's data by comparing with the trend of reference stations' data. As the name itself implies, a double mass curves both axis are accumulated precipitation values. Usually, the accumulated seasonal or annual precipitation values of reference station or stations is taken as abscissa and those of the station under test as ordinate (Figure 3)

A change in the regime of the rain gauge such as change in exposure, change in location is revealed by a change in the slope of the straight line fit as shown in Figure 4. The other records are adjusted by multiplying the precipitation values by the ratio of the slope of the later period to the slope of the earlier period.

DISAGGREGATION OF DAILY DATA

For hydrological analysis, rainfall data of shorter duration is required. The net work of recording rain gauge in India being small in comparison to that of daily (non-recording) rain gauge, therefore some times it becomes necessary to convert the daily rainfall into shorter period intervals either manually or by using appropriate computer routines. The information of shorter interval rainfall is used together with information of daily rainfall from nearby non-recording (daily) gauge.

Mass curve

Mass curve is a graphical display of accumulated rainfall vs. time. Mass curve of accumulated rainfall at (non-recording) daily stations and recording station are prepared by plotting the accumulated rainfall values against time for the storm duration under analysis.

A comparison of the mass curves of the recording rain gauge stations with those of the non-recording stations would help in deciding which recording rain gauges or group of gauges could be considered as representative of which of the non-recording rain gauge for the purpose of distributing daily rainfall into hourly rainfall.

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The procedure for distribution of daily rainfall at non-recoding rain gauge stations into hourly rainfall is explained with the help of an example.
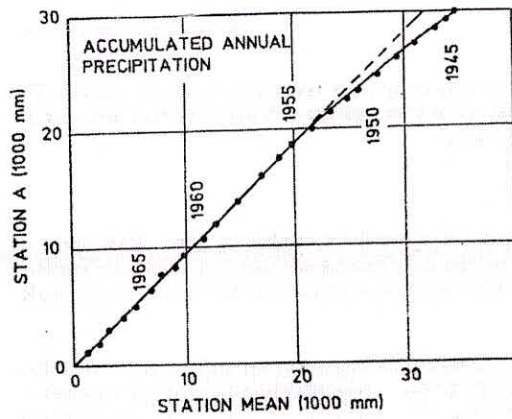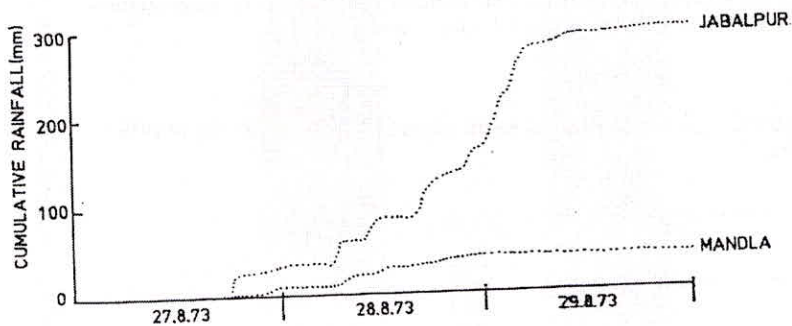

FIG. 3 DOUBLE MASS ANALYSIS

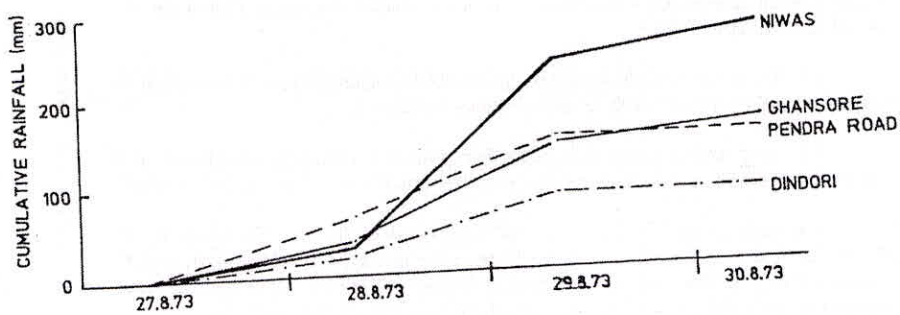FIG. 4 HOURLY RAINFALL MASS CURVE

FIG. 5 DAILY RAINFALL MASS CURVE

Example:

Daily rainfall data (mm) of four stations for the period 28th August to 30th August 1973 is given below:

	28-8-73	29-8-73	30-8-73
Pendra Road	65.3	80.8	1.1
Dindori	23.2	58.4	1.0
Ghansore	42.0	98.0	20.6
Niwas	30.4	203.0	33.4

Hourly rainfall data of two self-recording rain gauge stations is given in Table 1 for the period 27-29 August 1973.

The hourly rainfall data at each of the two SRRG stations is plotted on a graph to prepare the mass curve of hourly rainfall as shown in Figure 4.

The daily rainfall data at each of the four stations is cumulated and plotted on a graph as shown in Figure 5. The points are joined to form the mass curve of daily rainfall.

The mass curves of daily rainfall are compared with those of hourly rainfall to determine which of the daily rain-gauge stations are represented by which of the SRRG stations. It may be seen that the daily rainfall stations at Pendra Road and Dindori and represented by Mandla while Jabalpur represents Niwas and Ghansore stations.

For converting the daily rainfall into hourly rainfall, the hourly rainfall from 0800 hr to 0800 hr for consecutive days is cumulated and the rainfall during hour is expressed as a ratio of the total rainfall during 24 hours (0800 to 0800). These ratios are used to distribute the daily rainfall for the corresponding duration at those rain gauge stations, which are represented by

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the SRRG. The daily rainfall distributed for 1 day, i.e. corresponding to 28-29 August 1973 is given in Table 2.

ESTIMATION OF MEAN AREAL PRECIPITATION

Precipitation observations from gauges are point measurements and is characteristic of the precipitation process, exhibits appreciable spatial variation over relatively short distance. An accurate assessment of mean areal precipitation is a pre-requisite and basic input in the hydrological analysis.

Numerous methods of computing areal rainfall from point raingauge measurements have been proposed. Some of the well known methods are described in text books of Hydrology (Chow, 1964; Linsley et al., 1958) and in Manual of Hydrometeorology of IMD etc. The most commonly used methods are

1.   Arithmetic average

2.   Thiessen polygon method, and

3.   Isohyetal method

The choice of the method is dependent on the quality and nature of data, importance of use and required precision, availability of time and computer. Some of the commonly used methods and other computerized methods are described below:

Arithmetic average

The simplest technique for computing the average precipitation depth over a catchment area is arithmetic average of the values at gauges within the area for the time period of concern. If the gauges are relatively uniformly distributed over the catchment and the values are not greatly different from the average value, this technique will yield reliable results.

Thiessen Polygon

The Thiessen Polygon method is used with non-uniform stations spacing and gives weights to stations precipitation data according to the area which is closer to that station than to any other station. This area is found by drawing the perpendicular bisector of the line joining the nearby station so that the polygons are formed around stations. The polygons thus formed around each station are the boundaries of the effective area assumed to be controlled by station. The area governed by each station is planimetered and expressed as a percentage of total area. Weighted average precipitation for the basin is computed by multiplying each station precipitation amount by its assigned percentage of are and totaling. An example is given in Figure 6.

The weighted average precipitation is given by

$$\overline{P} = \frac{\sum_{i=1}^{n} P_i W_i}{\sum_{i=1}^{n} W_i} \tag{5}$$

Where $\overline{P}$ is the average catchment precipitation, Pi is the precipitation at station 1 to n, Wi the weights of respective station. An example of Thiessen network and computation of mean areal precipitation estimating using Thiessen weights is given below:

Example:

Estimation of mean areal catchment rainfall by Thiessen Polygon Method

Sl.No.	Station	Station Weight	Rainfall (mm)	Weighted rainfall (mm)
1	Sohela	.06	262.0	15.7
2	Bijepur	.12	521.0	62.5
3	Padampur	.42	177.0	74.3
4	Paikmal	.28	338.0	94.6
5	Binka	.04	158.0	6.3
6	Bolangir	.08	401.6	32.1

Weighted catchment rainfall = 285.5 mm

The advantage of this method is that the stations outside the catchment may also be used for assigning weights of marginal station within the catchment. The disadvantage, however, is that it assumes the precipitation between two stations varies linearly and does not make allowances for variation due to orography. Also, whenever a set of stations are added to or removed from the network, new set of polygons have to be drawn. If a few observations are missing it would be convenient to estimate the missing data than to construct new set of polygons.

Isohyetal Method

The isohyetal method employs the area encompassed between isohyetal lines. Rainfall values are plotted at their respective stations on a suitable base map and lines of equal rainfall, called isohyets are drawn. In regions of little or no physiographic influence, the drawing of isohyetal contours is relatively simple matter of interpolation in which the degree of smoothness of contours and of profiles which may be drawn or inferred from their spacing of stations and the quality and variability of the data. In regions of pronounced orography, where the precipitation in influenced by topography, the analyst should take into consideration the orographic effects, storm orientation etc to adjust or interpolate between station values. The modern computers equipped with plotters have the ability to draw isohytel maps. Analysts, however, prefer to carry out the analysis manually after getting the values plotted on the maps. Figure 7 shows an isohyetal map drawn using few stations.

The average depth of precipitation is computed by measuring the area between successive isohyets and determining the total volume and dividing by total area. The average depth is given by the relation

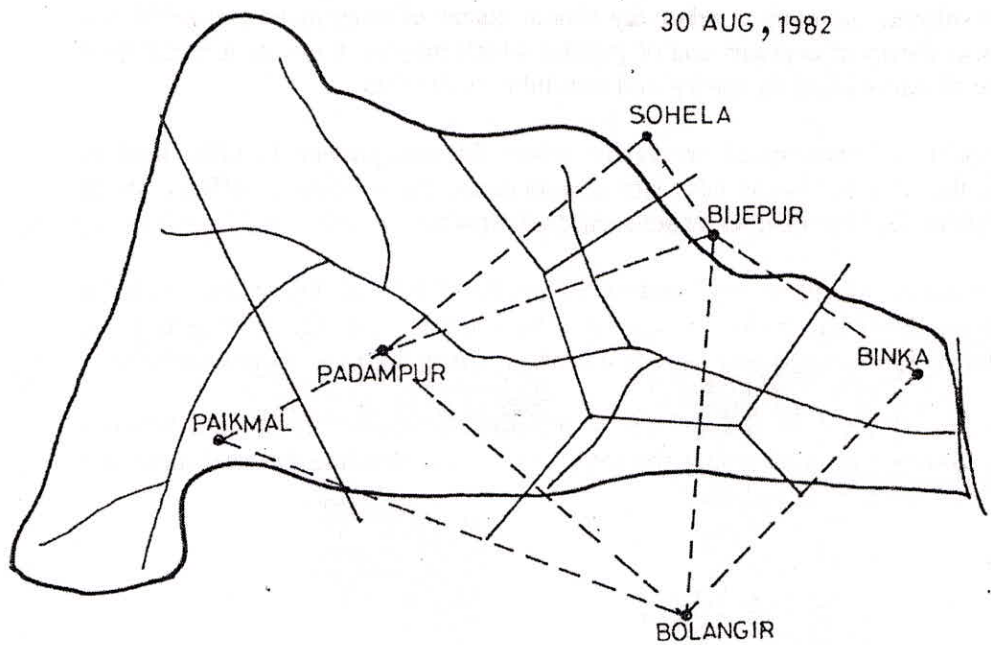$$\overline{P} = \frac{\sum_{i=1}^{n} P_i A_i}{\sum_{i=1}^{n} A_i} \tag{6}$$
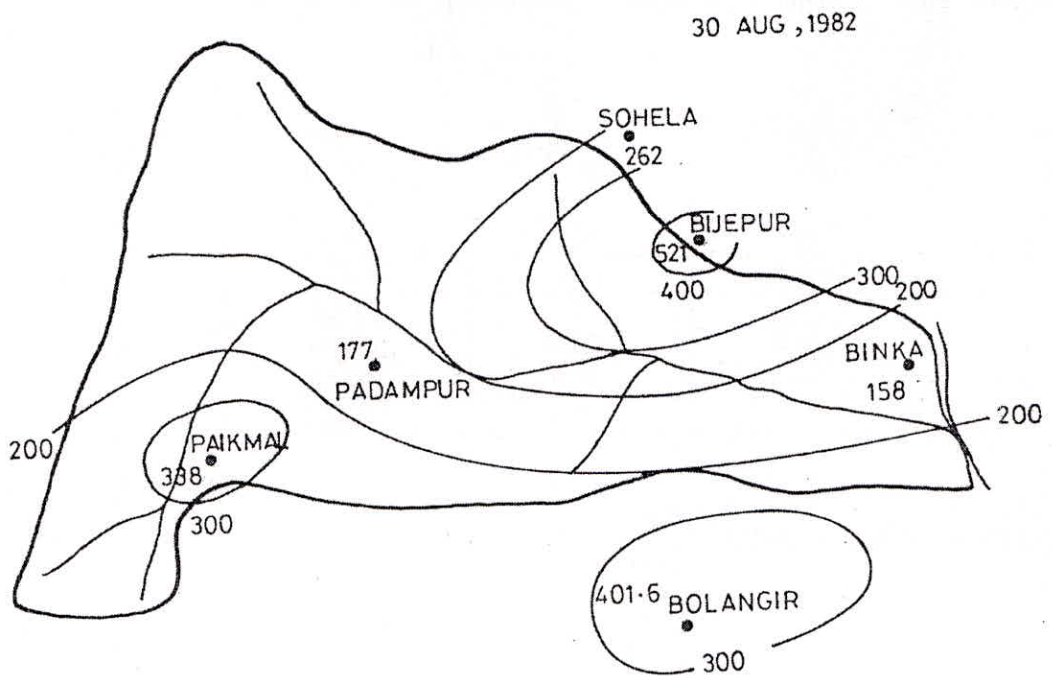
FIG. 6-THIESSEN POLYGON METHOD

FIG. 7 – ISOHYETAL ANALYSIS

where Ai is the area between successive isohyets; $\overline{P}$ and Pi have the same notation as given above section. A typical isohyetal map and example of the mean areal precipitation computation is given below. Estimation of mean areal catchment rainfall by Isohyetal Method

Isohyetal range (mm)	Average value (mm)	Area (km^2)	Volume (10^{5}m^3)
521.0 - 500.0	510.5	70	357.4
500.0 – 300.0	400.0	530	2120.0
338.0 – 300.0	319.0 .	100	319.0
200.0 – 300.0	250.0	2080	5200.0
158.0 – 200.0	179.0	2820	5047.8
		5600	**13044.2**

$$\text{Average catchment rainfall} = \frac{13044.2}{5600} = 232.9 mm$$

ESTIMATION OF MEAN AREAL PRECIPITATION IN MOUNTAINOUS AREAS

Precipitation data which exhibits appreciable spatial variation over relatively short distance is often used as areal estimate for use as input in hydrological models. Several methods are commonly used for estimating average precipitation over a specific area, such as a drainage basin. The choice of the method, is generally, dependent on the quality and nature of data, the importance of its use and required precision of the result.

Any method of areal estimation such as isohyetal, Thiessen weights etc involves implicity of explicity, inference concerning the depth of precipitation at all points in the area of interest. Estimation of mean areal precipitation in mountainous areas by these conventional methods does not yield the desired results because of the influence of orography, aspect storm

orientation, etc on the precipitation in areas with pronounced orography. A better way of estimating areal rainfall in mountainous regions is through the use of isopercental technique.

Isopercental technique

In this method, the mean annual or mean seasonal rainfall mps of the catchment of region are prepared taking care of the likely influence, which the orography exerts on rainfall. The storm rainfall values are expressed as percentages of the seasonal or annual normal rainfall at the rain gauge station as given below:

Stations	Storm rainfall (mm) (30-8-1982)	Normal annual Rainfall (mm)	Storm rainfall as percentage of annual normal
1. Paikmal	338.0	1728.0	19.6
2. Padampur	177.0	1302.0	13.6
3. Bijepur	521.0	1237.0	42.1
4. Sohela	262.00	1247.0	21.0
5. Binka	158.0	1493.0	10.6
6. Bolangir	401.6	1440.0	27.9

Isopercental lines are drawn and an overlay is prepared on a transport sheet. This overlay is superimposed on seasonal isohyetal map (Figure 8). The various points at which the isopercentals cross the seasonal isohyetal pattern are marked and isohyetal values are multiplied by the percentage value to obtain a new set of points and the corresponding values. An isohyetal map is prepared (Figure 9) using these values which incorporate the characteristics of storm isohyetal pattern and seasonal isohyetal pattern which is supposed to be governed by the orography of the region. To illustrate the method an example is given below:
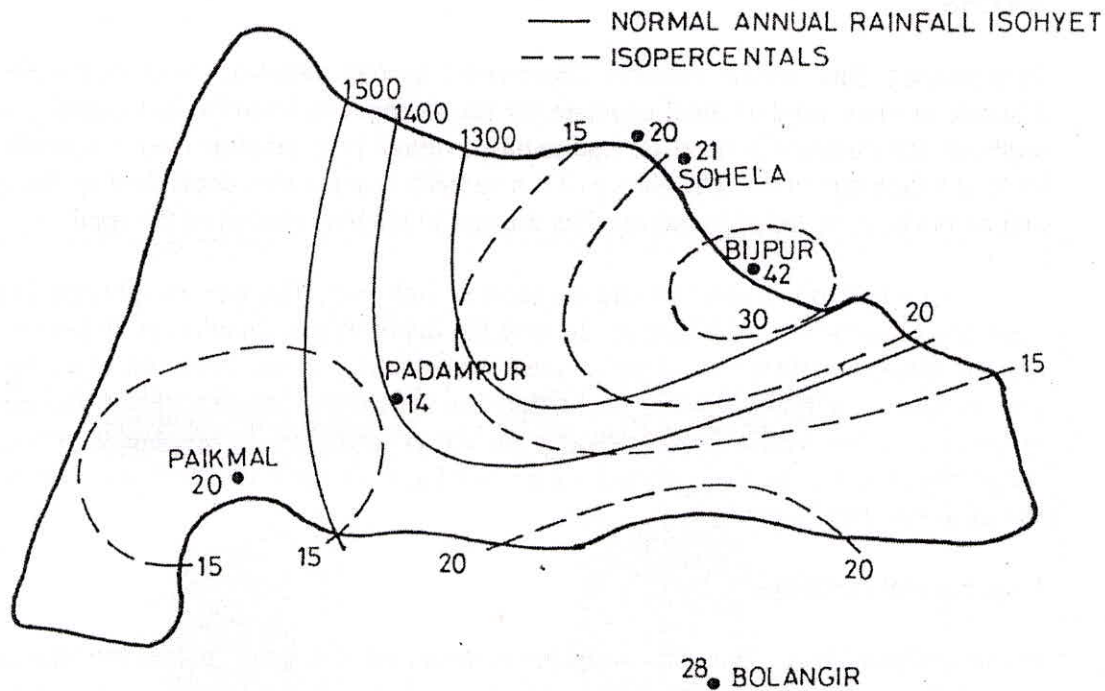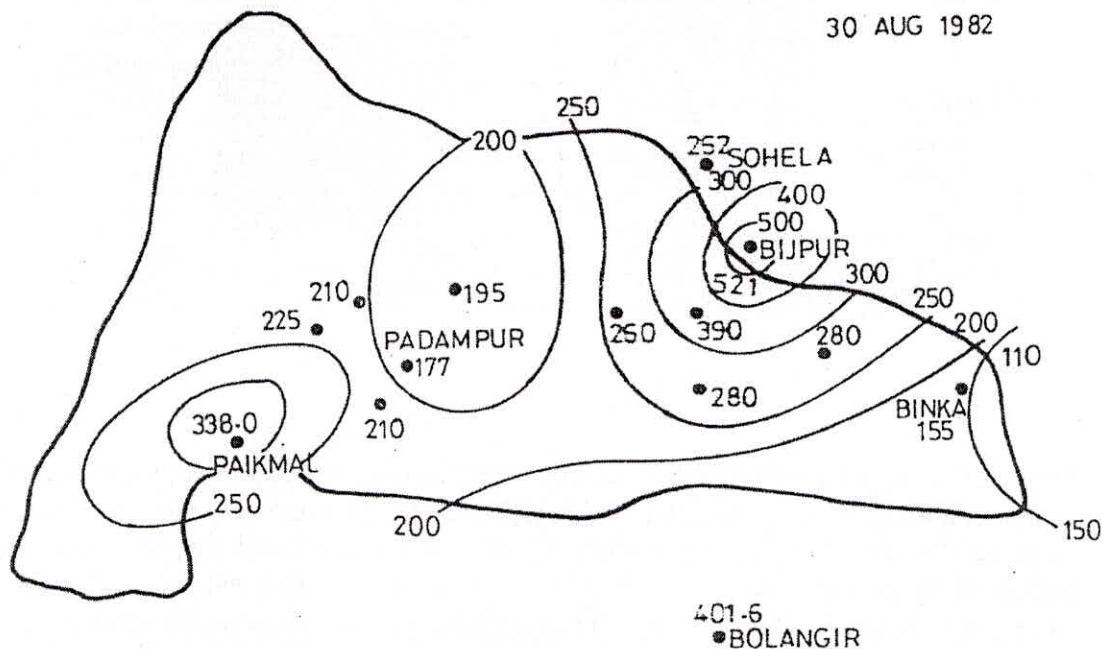
FIG. 8 - ISOPERCENTAL MAP

FIG. 9 - ISOHYETAL MAP DRAWN BY ISOPERCENTAL METHOD

Estimation of mean areal precipitation by Isopercental Technique

Isohyetal range (mm)	Mean value (mm)	Area covered (km^2)	Volume (km^2 x mm)
110-150	130	80	10400
150-200	175	600	105000
177-200	188.5	600	113100
200-250	225	3370	758250
250-300	275	620	170500
300-400	350	230	80500
400-500	450	90	40500
500-421	510.5	10	5105
		5600	**1283355**

Average rainfall depth = 229.2 mm

REMARKS

It is very well recognized that the areal precipitation estimates derived on the basis of point rainfall observations from a network of sparsely and unevenly distributed precipitation gauges could only be regarded as an index of rainfall. Even with an ideal gauge coverage, the catch from the gauges cannot be considered to be accurate because of wind influence and other exposure conditions.

Radar sensed echo intensity reflected by precipitation could provide useful areal estimates of precipitation over areas with few or no precipitation gauges. Precipitation observed by a dense network of precipitation gauge specially set up for the purpose on a temporary basis could be related to echo intensities as sensed by radar to develop reasonable relationships for the area of interest.

Table 1: Hourly rainfall data of Mandla and Jabalpur

Hours	Mandla			Jabalpur		
	27.8.73	28.8.73	29.8.73	27.8.73	28.8.73	29.8.73
1	0.0	0.0	0.0	0.0	0.0	23.5
2	0.0	0.0	0.0	0.0	0.0	30.5
3	0.0	0.0	0.0	0.0	0.3	10.2
4	0.0	0.0	0.0	0.0	0.5	30.8
5	0.0	0.0	0.0	0.0	0.1	16.9
6	0.0	0.0	0.0	0.0	1.0	1.9
7	3.0	1.7	0.0	0.0	24.4	0.6
8	0.0	9.0	0.0	0.0	0.2	3.1
9	0.0	2.3	0.5	0.0	0.0	5.3
10	0.9	0.0	0.4	0.0	0.0	3.8
11	0.0	1.5	0.1	0.0	23.8	0.8
12	0.0	5.5	0.0	0.0	1.3	1.5
13	0.0	0.0	0.0	0.0	0.2	0.0
14	0.0	0.0	0.0	0.0	0.0	0.3
15	0.0	0.0	0.0	0.0	0.1	0.9
16	0.0	2.5	0.3	0.0	0.6	1.5
17	0.2	1.5	0.4	0.0	29.0	0.4
18	2.1	0.8	0.3	0.0	11.0	0.5
19	0.7	3.4	0.0	25.7	7.1	0.1
20	0.3	0.6	0.0	0.0	0.4	0.5
21	0.1	2.5	0.0	0.1	2.7	0.7

22	0.1	0.0	0.0	1.0	6.8	0.0
23	4.7	0.0	0.0	6.0	20.6	0.0
24	0.0	0.0	0.0	1.3	0.0	0.0

Table 2: Daily rainfall distributed into hourly rainfall (28-29 August 1982)

Hour	Pendra Road		Dindori		Niwas		Ghansore	
	28//8/1982	29//8/1982	28//8/1982	29//8/1982	28//8/1982	29//8/1982	28//8/1982	29//8/1982
1		0.0		0.0		21.5		10.5
2		0.0		0.0		28.0		13.7
3		0.0		0.0		9.3		4.5
4		0.0		0.0		28.2		13.7
5		0.0		0.0		13.4		7.5
6		0.0		0.0		1.7		0.8
7		0.0		0.0		0.5		0.2
8		0.0		0.0		2.8		1.3
9	8.9		6.4		0.0		0.0	
10	0.0		0.0		0.0		0.0	
11	5.6		4.1		21.9		10.7	
12	21.8		13.8		1.0		0.5	

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13	0.0		0.0		0.2		0.1	
14	0.0		0.0		0.0		0.0	
15	0.0		0.0		0.1		0.0	
16	9.7		7.0		0.5		0.2	
17	6.5		4.7		26.6		13.3	
18	2.5		1.8		10.1		4.9	
19	13.7		9.9		6.5		3.1	
20	2.4		1.7		0.4		0.2	
21	9.7		7.0		2.4		1.1	
22	0.0		0.0		6.1		2.9	
23	0.0		0.0		18.9		9.1	
24	0.0		0.0		0.0		0.0	

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