PROBLEMS OF RIVER FORECASTING IN INDIA

By S. K. BANERJI, *D.Sc.*, *F.N.I.*, *F.R.M.S.*, *Calcutta.*

SUMMARY

The object of river forecasting is to predict the volume of stream-flow or the height of water to be expected in a river channel, lake or reservoir.

Floods are caused by cyclonic storms or depressions which move inland from the Bay of Bengal or the Arabian Sea and the Meteorological Department normally issue warnings for all expected floods. This is comparatively easier than predicting the stages or flows in a river. Yet, an adequate river-forecasting service is a vital necessity in all flood-control plans, as are dams, levees and by-passes. For instance, in the Damodar catchment or the Mahanadi catchment, floods are due to storms from the head of the Bay of Bengal moving westwards or west-north-westwards. While moving, these cause heavy precipitation first in the lower catchment and next in the upper catchment. If no adequate warnings are given, and if the dams are already full, the flood control plan will fail. Then again, without adequate forecasting service, the dams may be left inadequately filled at the end of the monsoon for work during the following dry months.

The forecasting service has to be based on a detailed study of the characteristics of each catchment, which again require provision of data giving quantitative measurements of the condition of the rivers, and of precipitation, temperature, humidity, evaporation, transpiration and wind over the catchments. A study of the basin characteristics must be followed by a full knowledge of the meteorological data affecting the hydrological cycle. This involves a study of rainfall losses (including depression storage), surface run-off, interflow, the ground-water and surface-water hydrographs within and between storms. The rainfall and run-off relationship for each basin must be definitely established.

The development of prediction formulae based on statistical analysis of the past rainfall and river-discharge data involves:

(1) A study of the frequency distribution of precipitation over the catchments for different periods, say '3 days' or '5 days', and also the frequency distribution of river discharges for corresponding periods and their mutual correlations. Provided the statistical data constitute a fairly long series, such analysis enables us to say with an '80 per cent' chance of success that the precipitation, during a certain specified period of '3 days' or '5 days' or any other specified period, will lie between two defined limits and we could similarly say with the same chance of success that the river heights will be between two stated limits.

(2) Working out of definite prediction formulae connecting precipitation over the catchment and the river-heights for 'one-day', '2-days', '3-days' periods, which could be used to predict the expected river height for a given period from a forecast value of precipitation over the catchment during that period or a previous period. A study of correlations between rainfall and discharge data for catchments show generally that the closeness of the association between rainfall and discharge decreases as the 'period' increases. A prediction formula of this kind was given by Mahalanobis to predict the level of the Mahanadi at Naraj one day in advance in the following form:

$$H_n = 1{\cdot}54\,(R) + 0{\cdot}67\,(h) + 23{\cdot}81$$

where

H_n = predicted height at Naraj on nth day,
R = total rainfall in inches for a period of 3 consecutive days ending on the $(n-2)$th day,
h = average height in feet of the river for 3 consecutive days ending on $(n-1)$th day.

When the value of the total rainfall can be accurately estimated, the error of the height forecast will be between $\pm 1{\cdot}2$ feet. An error in the estimated rainfall will increase the error of the estimated height.

The problems of river-forecasting in India, taking into consideration all the above aspects, and the development of prediction formulae for definite catchments like the Damodar and the Mahanadi, are discussed in detail in the paper.

So far it has been generally the practice to compute values of meteorological elements for the different political divisions of the country. A map showing the division of the country in terms of catchments of the different rivers has been prepared by the Central Water Power, Irrigation and Navigation Commission. In Appendices I, II, III and IV have been given for the first time the values of (i) mean rainfall, (ii) mean temperature, (iii) the highest and lowest values of rainfall, and (iv) the highest and lowest values of temperature for each of the catchments and for each month and the year. These are the basic data for the hydrological studies of the different catchments.

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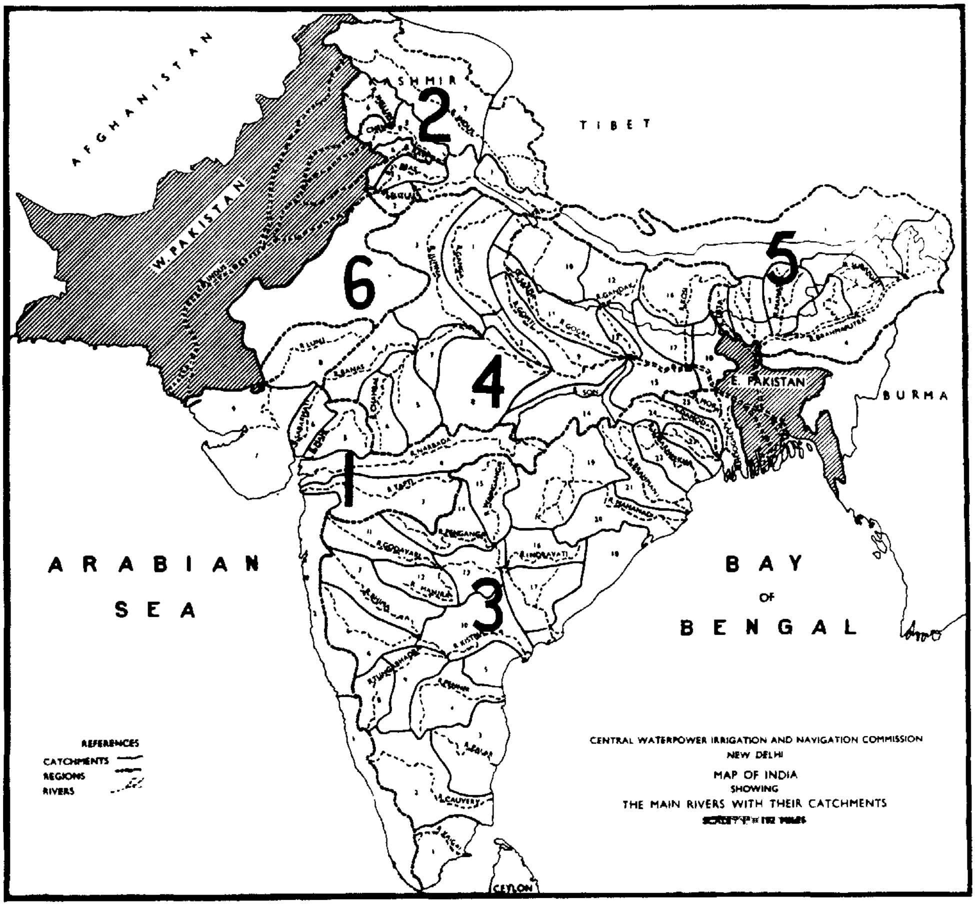
AFGHANISTAN
W. PAKISTAN
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BURMA
ARABIAN SEA
BAY OF BENGAL
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1
2
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REFERENCES
CATCHMENTS
REGIONS
RIVERS
CENTRAL WATERPOWER IRRIGATION AND NAVIGATION COMMISSION
NEW DELHI
MAP OF INDIA
SHOWING
THE MAIN RIVERS WITH THEIR CATCHMENTS

Figure A.

The object of river forecasting is to predict the volume of stream-flow or the height of water to be expected in a river channel, lake or reservoir. This subject has received a good deal of attention in countries where river projects have reached an advanced stage of development. I give in this article a review of the problems which we have to face in India. In this review use has been made of some of the materials given by Prof. Mahalanobis in his excellent report on the Mahanadi catchment and in some of the publications of the India Meteorological Department.

Heavy rainfall in catchments is associated with the movement of cyclonic storms or depressions from the Bay of Bengal or the Arabian Sea during the pre-monsoon months, April and May, the monsoon months, June to September, and the post-monsoon months, October and November. These are occasional events; the formation and movement of cyclonic storms or depressions can be seen on weather charts, and the meteorological department is able to give a warning for heavy rainfall in most cases at least 48 hours before their occurrence. This is comparatively easier than predicting the stages or flows in a river. Yet, an adequate river-forecasting service is a vital necessity in all flood-control plans, as are dams, levees and by-passes. In catchments like Damodar or Mahanadi, floods are produced by storms, which form at the head of Bay of Bengal and move westwards or west-north-westwards. While moving, these cause heavy precipitation first in the lower catchment and next in the upper catchment. If no adequate warnings are given, and if the dams are already full, the flood control plan will fail. Then again, without adequate forecasting service, the dams may be left inadequately filled at the end of the monsoon for work during the following dry months.

The forecasting service has to be based on a detailed study of the characteristics of each catchment, which again require provision of data giving quantitative measurements of the condition of the rivers, and of precipitation, temperature, humidity, evaporation, transpiration and wind over the catchments. A study of the basin characteristics must be followed by a comprehensive knowledge of the meteorological data affecting the hydrological cycle. This involves a study of rainfall losses (including depression storage), surface run-off, interflow, the ground-water and surface water hydrographs within and between storms. The rainfall and run-off relationship for each basin must be definitely established.

The first essential step is the establishment of a network of meteorological stations recording the elements mentioned above, and the installation of instruments to provide the necessary hydrograph for the river-flow as well as the underground flow. The network of precipitation-gauges has to be so arranged as to give the space-distribution of precipitation with an error not exceeding 10%. The determination of the network involves a statistical examination of the rainfall variance of the existing stations, with particular reference to the topography. With a good network the isohyetal map allows a computation of the space distribution of rainfall over a catchment to be made to a certain degree of accuracy. The accuracy increases with increase in the number of raingauge stations. In Damodar catchment, covering an area of 7,200 square miles, a network of 25 raingauge stations, gave an error in the determination of space distribution of rainfall of the order of 15 per cent. A network of 60 stations was required to bring down the error to about 10 per cent, and this is the network which has now been established in that catchment.

Storm Analysis.

For storm analysis, Thiessen constructed network by joining the stations with straight lines. If the perpendicular bisectors of these connecting lines be drawn, each station will be enclosed by a boundary midway between it and the adjacent stations. The area covered by each station can be measured and expressed as a percentage of the whole area. A weighted average rainfall for the basin can be obtained by multiplying the record of each station by the percentage of the area assigned to it and totalling these values. The method is unsatisfactory because it has no physical basis ; it is arbitrary and at the same time inflexible.

It appears that the most accurate computation of average rainfall can be made by means of the isohyetal map. By measuring the area between contours with a planimeter, the average rainfall for the basin can be readily computed. A good amount of rainfall analysis for some of the catchments in India has already been made.

A knowledge of the maximum rainfall that has occurred or is likely to occur over the catchment area as well as the maximum rate at which the run-off water will arrive at the point of outlet from the basin and the duration for which this rate will be maintained, that is the characteristics of 'peak discharges', is essential for the design of flood control reservoirs for the regulation of flood waters.

In Damodar catchment, during the period of 60 years (1891–1950), the five storms, the particulars of which are given below, caused the largest amount of precipitation.

	I Aug. 6–12, 1913	II July 31 –Aug. 7, 1943	III Aug. 8–15, 1935	IV July 29 –Aug. 3, 1917	V June 16–19, 1893
Total storm period rainfall in inches	22·0	21·8	17·9	17·4	15·9
Average rainfall per day of storm period	3·1	2·7	2·2	2·9	3·0
Maximum rainfall in 3 days ..	13·0	10·1	9·4	15·2	13·5
Highest rainfall in a day ..	4·7	6·9	5·1	7·1	8·0

Storms I and II gave the heaviest total rainfall during the storm period. Storm IV gave the highest three-day rainfall of 15 inches. Storm V gave the highest mean rainfall of 8 inches during a period of 24 hours over an area of 7,200 square miles.

The frequency distribution of storm-period rainfall irrespective of the duration of the periods is given below:

Rainfall Range in inches	1·01 to 2·00	2·01 to 3·00	3·01 to 4·00	4·01 to 5·00	5·01 to 6·00	6·01 to 7·00	7·01 to 8·00	8·01 to 9·00	9·01 to 10·00	10·01 to 11·00	11·01 to 12·00	12·01 to 13·00
Frequency ..	161	60	22	15	15	3	3	3	1	1	1	0

These have been plotted in Fig. 1 and a smooth curve drawn through the points. The curve suggests that the chance of storm period rainfall exceeding 13 inches in Damodar catchment is 1 in 200 years.

For the Mahanadi catchment, the absolute maximum observed intensities of average rainfall in inch per day for the whole catchment for 1, 2, 3..........10 consecutive days, based on data of heaviest rainfall during 1891-1928 are given below :

No. of days	1	2	3	4	5	6	7	8	9	10
Maximum intensities of average rainfall in inch per day ..	3·75	2·91	2·24	1·94	1·85	1·72	1·54	1·37	1·24	1·18

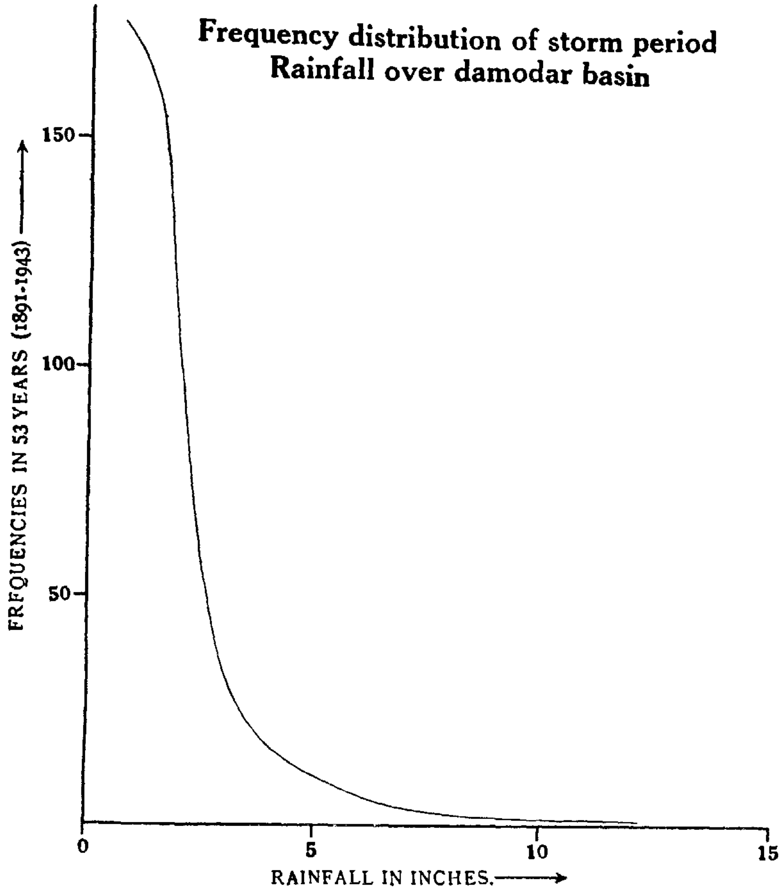


Fig. 1

These figures give an idea of the risk of maximum rainfall in Mahanadi catchment taken as a whole. The accumulated frequency distribution of rainfall intensities for the whole Mahanadi catchment based on 2–5 days' averages, July to Sept. 1891–1928 is shown below :

In excess of inches of rainfall	2 days	3 days	4 days	5 days
1·00	204	117	104	77
1·25	104	53	36	25
1·50	48	21	18	10
1·75	22	10	6	2
2·00	14	8	..	..
2·25	5	1	..	..
2·50	4	..	..	..
2·75	2	..	..	..

The figures in the following table give the probable number of occasions in one monsoon season (July–September) on which different intensities of rainfall in excess of one inch may be expected to occur continuously for periods of '2-days', '3-days', '4-days', etc. over the whole of the Mahanadi catchment.

In excess of inches of rainfall	2 days	3 days	4 days	5 days	6 days	7 days	8 days	9 days	10 days
1·00	10·0	4·7	3·9	3·3	1·6	1·5	1·2	0·9	0·8
1·20	3·9	2·1	1·3	1·3	0·7	0·5	0·1	0·2	..
1·40	2·1	1·3	0·9	0·8	0·1	0·05	..	..	..
1·60	1·3	0·7	0·7	0·4	0·03	..	..	..	..
1·80	0·7	0·5	0·2	0·05	..	..	..	..	..
2·00	0·5	0·4	0·05	..	..	..	..	..	..
2·40	0·3	0·05	..	..	..	..	..	..	..
2·80	0·1	..	..	..	..	..	..	..	..

Thus the probability of 1·2 inches of rainfall occurring continuously for 7 days over the whole of the Mahanadi catchment is once in two monsoon seasons.

It is not only necessary to analyse the space distribution of rainfall but it is also important to analyse the time distribution of rainfall throughout a storm. A 'mass-curve' is a plot of accumulated precipitation against time.

The area-depth curve, and the duration-depth curve are useful tools for storm-analysis. The area-depth curve expresses the relation between average rainfall and area for a given storm. The duration-depth curve shows the relation between accumulated average rainfall and storm duration.

The area-depth curves of storm rainfall and time-depth-area curves of maximum likely rainfall have been worked out by Mr. Satkopan for Damodar catchment with particular reference to the storm of 17th to 19th June, 1898, which, as already indicated gave 8 inches of rain over 7,200 square miles. These curves are shown in Figs. 2 and 3. Similar curves for Mahanadi catchment have been worked out from data given by Mahalanobis and are shown in Fig. 4.

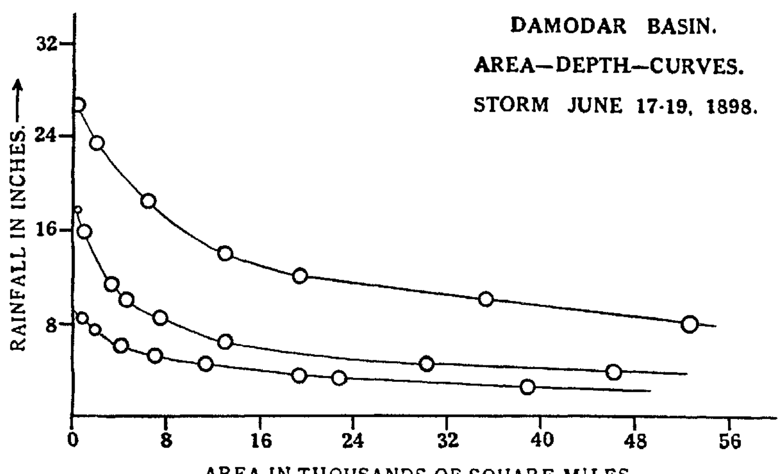


Fig. 2

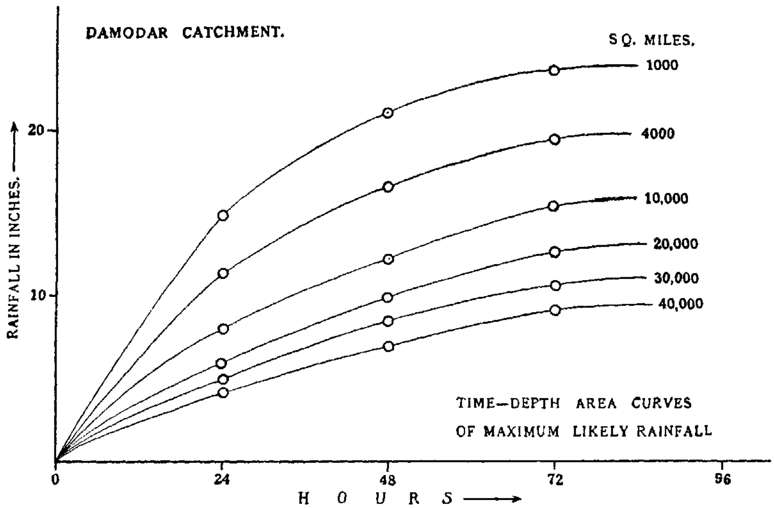


Fig. 3

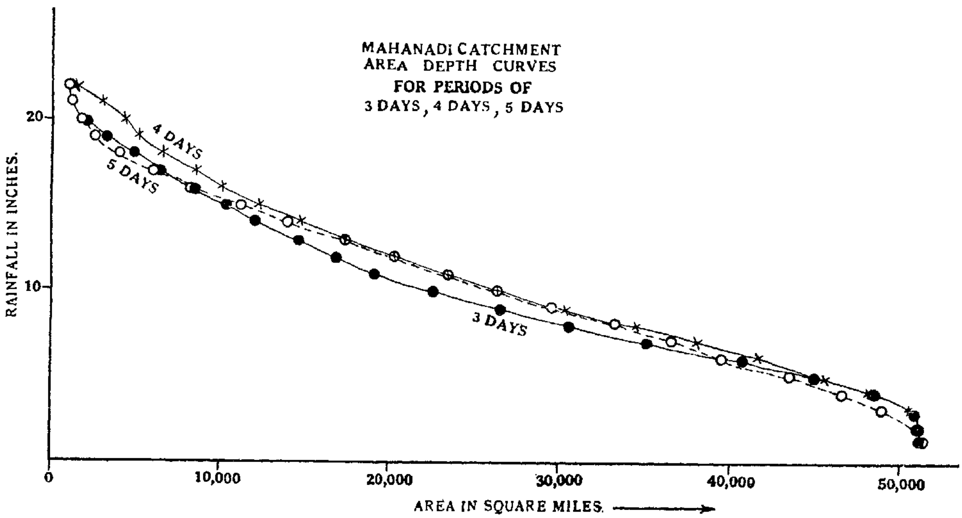


Fig. 4

Ground-water measurements.

Water stored in the ground constitutes an immense reservoir making material contribution to the stream flow. The principal direct measurement of ground water is the elevation of the ground water-table; this is determined by measuring the elevation of water surface in wells.

Basin Characteristics.

It is essential to have adequate knowledge of the basin characteristics. This would comprise:

Type of soil (rocky, sandy, clay, lava, etc.),

Land-use (forest, cultivation, range, urban, etc.),

Type of cover (brush, hardwood, evergreen, crops, etc.),
General Topography (steep slopes, flat slopes, rolling hills),
Drainage area,
River mileage,
Elevation area data, showing drainage areas above and below various elevations.

Rainfall Loss.

The difference between the volume of rainfall and the volume of run-off is the 'loss'. The loss factors cover—

(*a*) The *interception loss*, that is, the water held on the leaves, trunks and stems of plants and trees. The water so intercepted is returned to the atmosphere by evaporation.
(*b*) The loss due to field moisture, that is, the water retained within the interstices of the soil, the amount depending on the type of soil.
(*c*) Infiltration through the soil to the lower layers. A portion of this gravity water goes to the ground water-table whence it travels to the stream channels and springs. Since this underground flow ultimately goes to the stream channels, it does not constitute entirely an item of loss. A portion of the water is held by capillary action in the soil above the water-table, and returned to the atmosphere by transpiration under favourable conditions.
(*d*) Loss due to depression storage, and applies to the portion of the precipitation caught in ditches, field, puddles, and other natural or artificial storage basins. Such water remains where it collects until it evaporates into the atmosphere or percolates into the soil.

The amount of water held by foliage, crops and undergrowth will depend on—

(i) the intensity of rainfall,
(ii) wind action during and after the storm,
(iii) thickness and nature of foliage, kind of crop and nature of undergrowth,
(iv) dry and wet state of plants prior to the commencement of the rain.

The amount held up in this way has been variously estimated to be between 15 to 30 per cent of the rainfall caught in the open.

The absorption losses consist of—

(i) Evaporation,
(ii) Transpiration by plants,
(iii) Absorption by subsoil.

The loss due to evaporation and transpiration by plants will depend on the nature of the terrain, temperature (dry and wet bulb) of the air and wind, and has been estimated to lie between 20 per cent to 40 per cent of the total rainfall.

The loss due to infiltration into subsoil constitutes the principal loss and is considered to depend on—

(i) Temperature changes.
(ii) Packing of the soil surface and in-washing of fine material to pores and openings in the soil surface by rain.
(iii) Previously existing soil moisture content.
(iv) Cultivation.
(v) Perforation of the soil and subsoil due to various causes.
(vi) Shrinking and swelling of surface soils, containing colloidal particles, particularly sun-checking of the soil surface during dry periods.

For any particular catchment this loss can be indirectly estimated.

Run-off.

Run-off is divided into three classes—

Surface run-off is that portion of the run-off which travels over the soil surface to the nearest stream channel. A certain volume of water is required to provide the necessary depth to maintain surface run-off and it is called the surface detention.

It is generally agreed that sub-surface storm run-off occurs but its measurement is difficult. The inter-flow is that portion of the run-off which percolates through the upper soil to the streams without first reaching the permanent water-table. Interflow travels more slowly than does surface run-off.

Ground water flow originates from the water stored beneath the ground water-table. It is usually a continuous source of stream-flow throughout the year. Even where streams go dry during the summer months ground-water flow continues below the channel bottom. The water-level in a stream and the level of the ground water-table at the streams' edges are usually the same (see fig. 5).

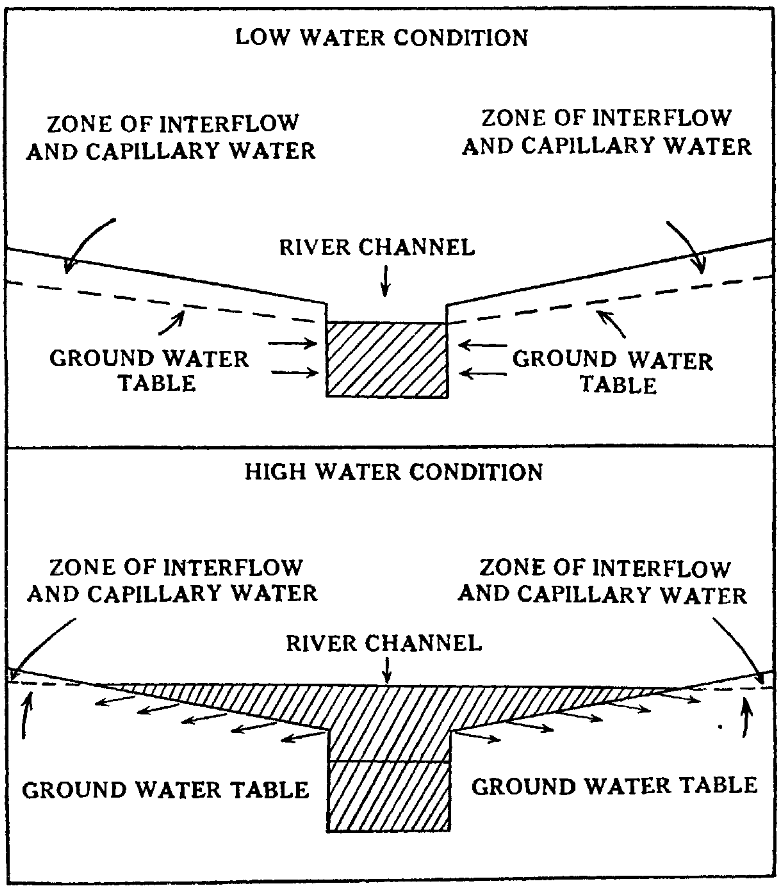


Fig. 5

As rainfall percolates to the ground water-table, the elevation of the water-table is increased, and consequently there is a corresponding increase in discharge to the stream. When the stream has crested and begins to fall below the level of the water-table, the increase in ground water flow becomes apparent.

A further source of stream flow is precipitation over the channel itself.

Khosla has given an empirical relationship connecting the mean monthly temperature (T_m) expressed in degrees Fahrenheit and monthly evaporation (L_m) in inches in the following form :—

$$L_m = \frac{1}{9 \cdot 5}(T_m - 32)$$

where T_m is $> 40°$F.

For $T_m < 40°$F., he has given the following figures as the evaporation loss :—

T_m	40°	30°	20°	10°	0°	F.
L_m	0·84	0·70	0·60	0·50	0·40	Inches.

The corresponding rainfall (P_m) and run-off (R_m) relationship is expressed in the form, $R_m = P_m - L_m$.

For Mahanadi river at Sambalpur for the year 1932 (catchment area 32,000 square miles), the following figures have been given :—

Month	Precipitation in inches	Temp. in°F.	Calculated loss in inches.	Calculated run-off in inches	Actual surface run-off in inches
July	19·78	80·9	5 15	14·63	6·77
August	11·01	82·3	5·29	5·72	8·46
September ..	11·25	83·6	5·43	5·82	5·62

The annual precipitation is 52·02 inches, mean temperature 80·1°F., the calculated run-off is 26·17 inches, while the actual is 25·78 inches.

While as shown by Khosla there is general agreement between the annual value of the calculated run-off and the observed run-off, the variation between the monthly values is considerable. When applied to short periods the relationship is more complicated than the empirical one given by Khosla.

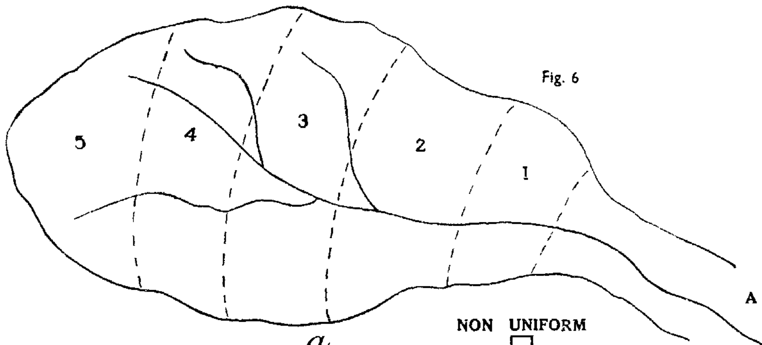
Hydrograph Analysis.

We have discussed so far the disposal of the rain water up to the time it reaches the stream-channels. The behaviour of the 'run-off' after reaching the channels is an important factor in determining the resultant river stages, and must be known fully for the purpose of river-forecasting.

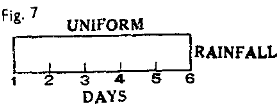
The method of building up the hydrograph at the head-waters by dividing the catchment into a large number of equal strips, from each of which the storm water flows with a uniform velocity, and working out the discharge reaching the head-waters at successive intervals of time is now well recognized.

Essentially the method is as follows:—

Fig. 6 represents a hypothetical drainage basin, which has five sub-areas, marked 1, 2, 3, 4, 5. The numbers indicate the length of time in days required for a small volume of water to travel from the sub-area to the outlet station at A. Fig. 7 represents rainfall at a steady 2 units per hour for four days. The run-off from the sub-area is assumed to have the same pattern as the rainfall. Adding the run-offs from the sub-areas (each delayed by the time necessary to travel from basin to outlet) the outflow at A will appear as shown in fig. 8. Figs. 9 and 10 demonstrate a similar process with a non-uniform rainfall-time pattern. These simple examples show the typical shape of a hydrograph resulting from the variable time required for water to reach the outlet from the different portions of the basin. When the velocity of the surface run-off over the different strips is known accurately it is possible to make a detailed mathematical analysis of the form of the hydrograph which will result therefrom. A hydrograph is a plot of discharge at a station against the time of occurrence. When such a record is available, it is highly instructive to check up the calculated hydrograph with the actual one.



a.



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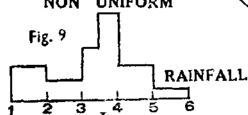

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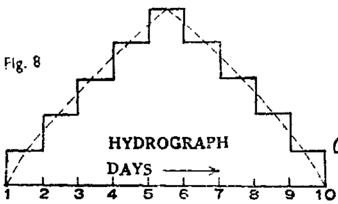

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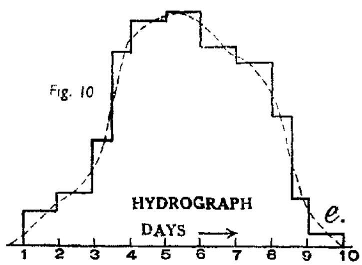

e.

If the velocity of flow of water were the only factor influencing the shape of the streamflow hydrograph the problems would be comparatively simple. The factor which introduces a complication is the channel storage. Throughout the period of the rise, this factor has the effect of deducting a portion of the flow. Fig. 11 shows a hydrograph for Mahanadi river. Each hydrograph can be divided into three parts. The first part, the ascending limb, starts with the beginning of run-off, and extends to a point near crest, where equilibrium between inflow and outflow begins to be approached. The crest covers a period during which inflow and outflow are in equilibrium. During this period, the aggregate flow from the various sub-areas is at its greatest value. Included in the crest is a small portion of the descending limb of the hydrograph during which surface run-off still occurs. The end of surface run-off is generally believed to occur at the point of inflexion where the descending limb of the hydrograph changes from concave downward to concave upward, the remaining portion of the hydrograph representing only the outflow from the channel storage. Mathematically it can be shown that no such definite point of change need exist under all conditions.

The analysis of the stream-flow hydrograph is a preliminary to the development of forecasting procedures. It serves to determine the volume of run-off resulting from a storm, to separate that run-off into its components of (*a*) surface run-off,

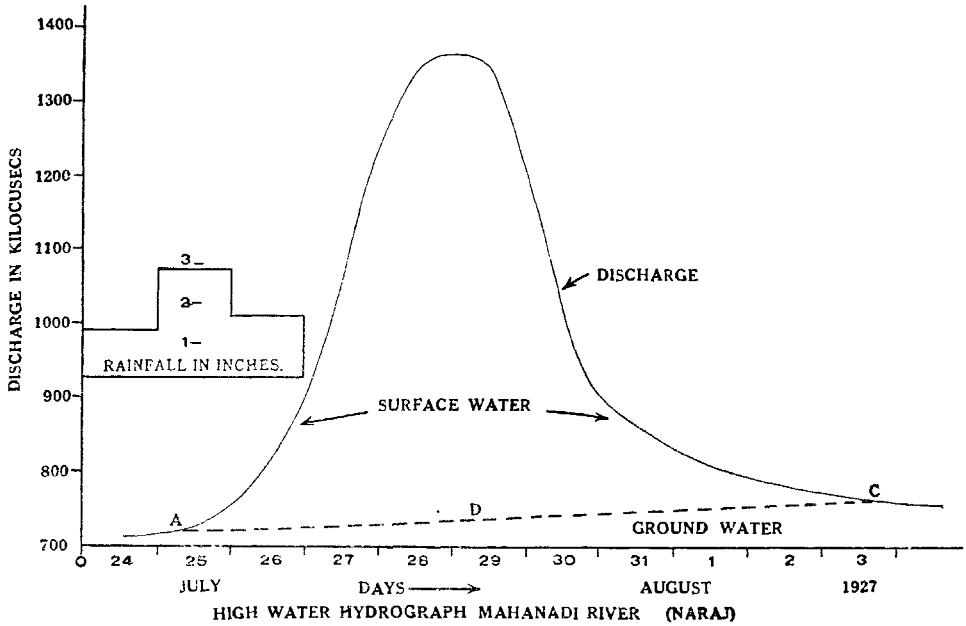

Fig. 11

(*b*) ground water run-off, and (*c*) interflow, and to establish certain physical characteristics of the stream under consideration. For Mahanadi catchment divided into five strips, Mahalanobis has given the following figures for the velocity of surface run-off:—

Section	Lag in hours	Equivalent distance from Naraj in miles	Average velocity of flow	
			Miles per hour	Feet per second
M—I ..	43·8	96	2·19	3·21
M—II ..	49·1	200	4·07	5·97
M—III ..	76·0	308	4·05	5·94
M—IV ..	80·8	318	3·95	5·79
M—V ..	100·0	408	4·08	5·98

Excepting in M—I, the mean velocity is of the order of 4 miles per hour. The comparatively low velocities of 2·2 miles per hour in M—I is explained by the fact that the gradient in this section is very small. With these figures, the hydrograph will have very nearly the form given in the illustrative example.

Stream-flow separation.

The simplest procedure for separating the run-off from a given storm is to draw a straight line *AC* from the point of rise to the time at which the surface run-off is believed to have ended. Another method is to extend the recession existing prior to the storm onward to a point under the crest of the current storm and then draw a line to the time of end of surface run-off outflow. (*ADC*, fig. 11.)

Recession Curves.

The separation of stream flow into its three components or between two or more closely spaced storms requires more advanced procedures involving the use of recession curves. The recession curve expresses the normal shape of the falling limb of the hydrograph. The ground water hydrograph should be drawn below the total hydrograph and the surface run-off ordinates computed (total flow *minus* ground water flow) for the determination of surface run-off recession. The recession curves obtained in this manner should agree with all other recession of records for the basin. In other words, at any given flow, the rate of decrease of flow is constant. This conception provides another approach for the development of recession curves. During periods of natural recession, values of flow at any instant may be plotted against the flow at a fixed time later (say 24 hours). The points thus plotted will fall on or near a smooth curve, which expresses the stream-flow recession for the basin. It has been suggested that the recession may be expressed by the equation.

$$Q = Q_0 \cdot K^t,$$

where Q_0 equals the initial flow and Q equals the flow at time t later and K is a recession constant always less than one. If this equation is true the recession will plot as a straight line on semi-logarithmic paper.

River Forecasting Methods.

We may divide forecasting problems into two parts. The first is the prediction of out-flow hydrograph of the headwater basins within the river district. The second is the task of translating these flows from the headwater stations on down-streams. This is extremely difficult work for any basin of more than 1,000 square mile drainage area.

For the purpose of the forecasts we require the rainfall run-off relations under different conditions. The concept of run-off as a remainder after the loss has been subtracted from the rainfall has been already discussed. If a correlation involving the total loss (rainfall *minus* surface run-off) can be developed, the procedure becomes relatively simple. Ground water accretion may be subtracted from the total loss, leaving a net loss consisting mainly of interception, depression storage and soil moisture losses. A few typical rainfall run-off relationships are shown in fig. 12.

The rainfall run-off relation provides the necessary first step for each forecast. The second step is to distribute the run-off with time according to the observed characteristics of each individual basin. This is accomplished by the application of the unit hydrograph principle, developed by Sherman, to each of the head-water areas, as well as to each of the ungauged local areas to the down stream reaches. Once the flows from each sub-area of the basin are predicted, the final job of the forecaster is to combine these flows successively into forecasts for all points on the downstream. For each of our large river basins, these forecasting relations will have to be developed by graphical correlations.

All these calculations involve a forecast of the expected precipitation over the catchment. This is determined by the computation of the expectation from an analysis of the past rainfall data to which is superposed any rainfall anomaly determined from an analysis of weather charts.

An analysis of the past rainfall data enables one to say with an 80 per cent chance of success the limits within which rainfall will lie during any specified period. From the 60 years' rainfall series, 1891–1950, one could work out the frequency distribution of different rainfall amounts, for monthly periods, or fortnightly periods. Taking 80 per cent of the area enclosed by these frequency curves (treated as probability curves) one could specify two limits, within which rainfall could be stated to lie with an 80 per cent chance of success.

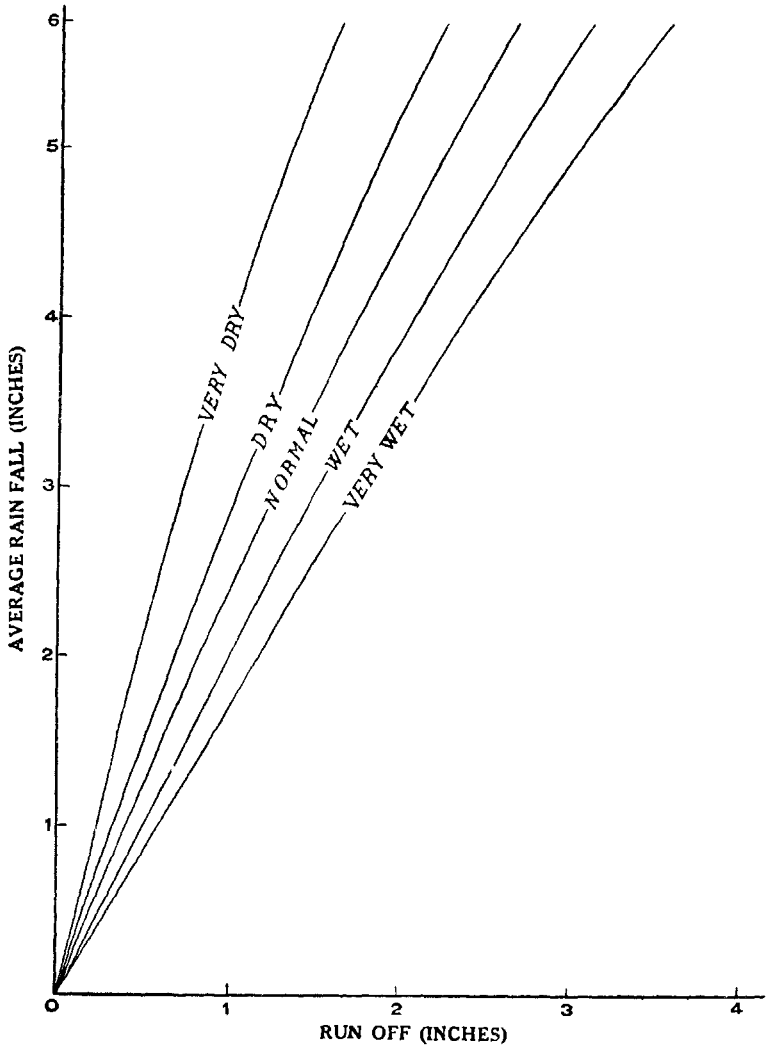

Fig. 12

Figs. 13, 14 give the frequency curves for the Damodar and Mahanadi catchments for rainfall of different intensities for each of the months of July, August and September. From an examination of these curves one could say with an eighty per cent chance of success that in the Damodar catchment, rainfall on any day in July will lie between 0·15 and 1·00, in the month of August between 0·15 and 1·00, and in the month of September between 0·10 and 0·75 inch. Similarly for the Mahanadi catchment, one could say with the same chance of success that rainfall on any day in July will lie between 0·20 and 1·00, on any day in August between 0·20 and 1·25 and on any day in September between 0·20 and 0·75 inch.

Forecasts of this nature, which are based on analysis of past rainfall data constitute standing forecasts. To this must be added any abnormality in the rainfall which can be deduced from an analysis of the current weather charts.

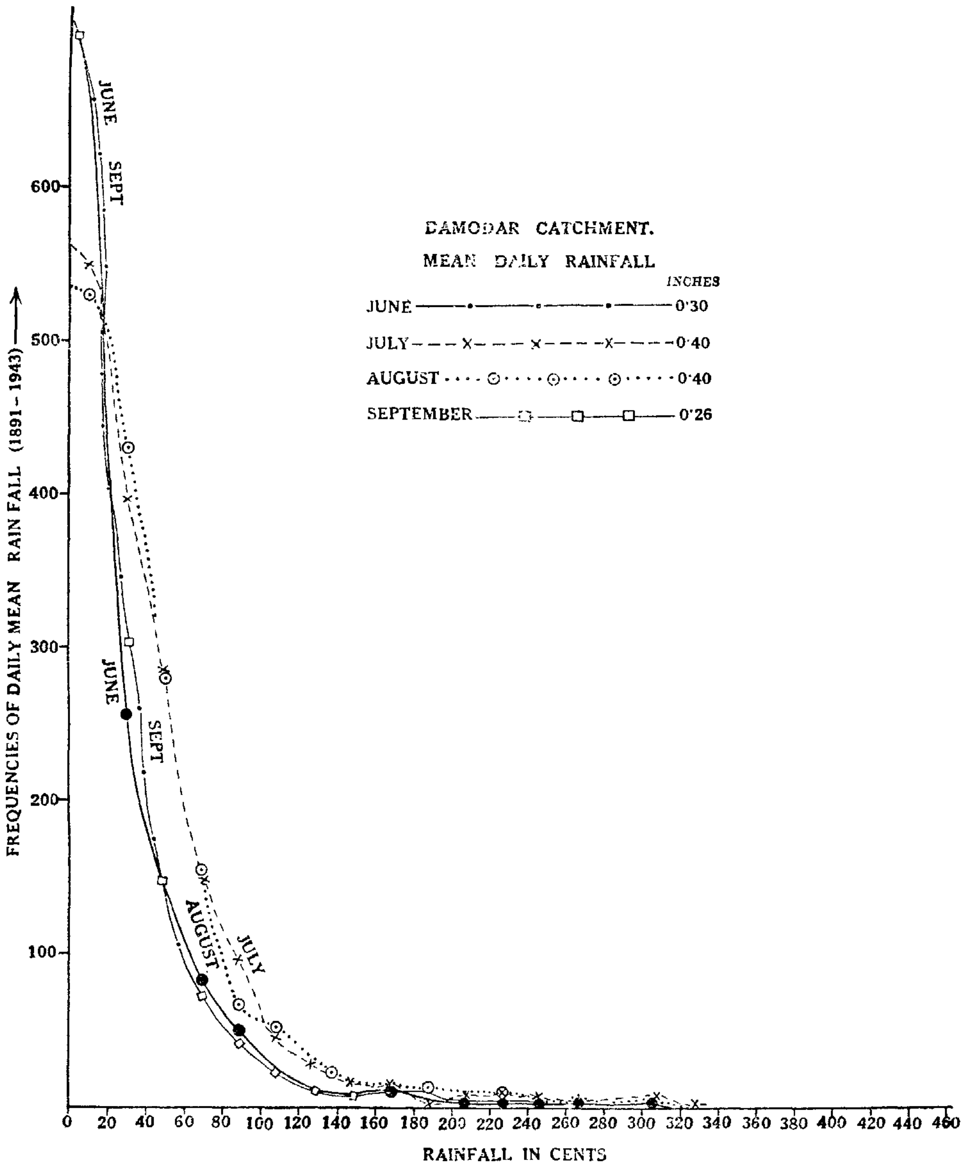

Fig. 13

The correlations between rainfall in the catchment and the river discharges may be utilized to work out prediction formulae.

One such formula to predict the river stage 24 hours ahead has been given by Mahalanobis for the Mahanadi catchment. He observed that in the Mahanadi catchment, it usually requires at least 3 consecutive days of heavy rainfall to produce a flood and that it requires about 2·3 days for the rainfall to make itself felt at Naraj. We therefore take the total rainfall in 3 consecutive days ended two days previously, that is on the $(p-2)$th day. The previous state of the river has also to be taken

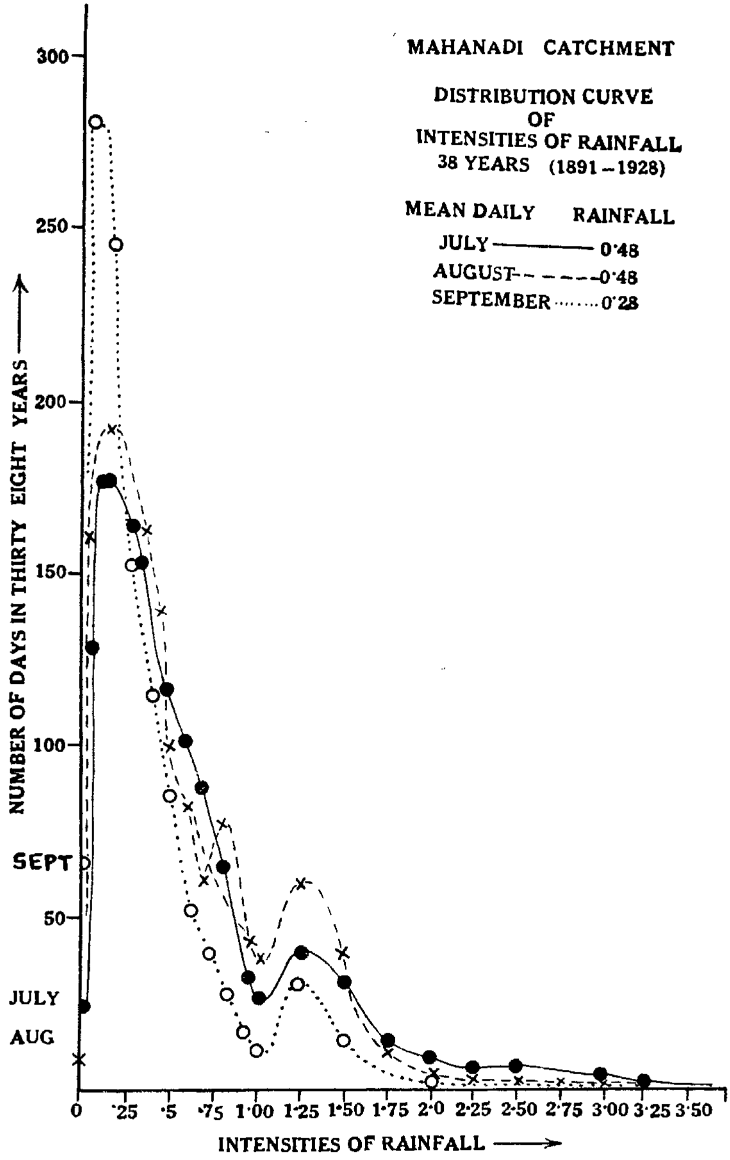

Fig. 14

into consideration, and this is done by taking the height of the river at Naraj for 3 consecutive days ending on the day of the forecast, that is, on the $(p-1)$th day. We have the two factors—

R = total rainfall in inches for a period of 3 consecutive days ended on the $(p-2)$th day.

G = average height in feet of the river for 3 consecutive days ended on the $(p-1)$th day.

The following partial correlation coefficients were obtained.

Between N (height at Naraj) and R (rainfall)	..	$0{\cdot}455 \pm {\cdot}033$
Between N (height at Naraj) and G (gauge)	..	$0{\cdot}771 \pm {\cdot}016$
Between R (rainfall) and G (gauge) ..	..	$0{\cdot}041 \pm {\cdot}040$

These give the following regression equation—

$$N = 1{\cdot}54(R)+0{\cdot}67(G)+23{\cdot}81$$

where N is the predicted height at Naraj.

The value of the multiple correlation coefficient is 0·88, which is quite high. This equation will allow individual forecasts to be made within 1·2 feet on an average for floods above 83 feet at Naraj.

From the statistical analysis of past rainfall data and river discharge data, similar prediction formulae can be worked out, and these are of great value in river forecasting.

Rainfall and Temperature Data for the different river catchments of India.

So far it has been the practice to compute the mean values, the highest and the lowest values of the different meteorological elements for the different political divisions of the country.

The natural division of the country is, however, in terms of the catchments of the different rivers. A map of the country showing the catchments of the different rivers has recently been prepared by the Central Water Power Irrigation and Navigation Commission. A copy of this map is given as Frontispiece to this paper (Fig. A).

The country has been divided into six regions, and all catchments in each region has been serially numbered. This is rather an artificial classification. Each catchment is defined by the number of the region followed by its serial number. A more rational system of assigning number to each catchment would be to take the value of the latitude in full degrees just south of the catchment followed by the value of the longitude in full degrees just west of the catchment, and to take the four figures to define the catchment. Thus, for Damodar catchment the number would be 2284. When so expressed the geographical co-ordinates of any station in the catchment can be represented by x, y, where $22+x$ and $84+y$ are the latitude and longitude of the station.

For each of the river catchments I had had the following elements calculated :—

(1) Mean values of monthly and annual rainfall.
(2) Mean values of monthly and annual temperature.
(3) The highest and the lowest values of rainfall for each month and the year.
(4) The highest and the lowest values of temperature for each month and the year.

These are the basic data which are essential for the hydrological studies of each of the catchments and are given in Appendices I, II, III and IV. The catchment numbers in these tables are those given in the map in fig. A.

The following explanatory notes are offered in respect of these appendices :—

(1) *Mean monthly rainfall and the mean annual rainfall for each catchment.*

The means are based on the data of all rain gauges—(under the Meteorological Department and Provincial Governments) in each catchment. The latest normals (the 1940) prepared by the Meteorological Department from all available past data have been used.

(2) *Mean monthly and annual temperatures for each catchment.*

Mean temperature $\frac{1}{2}$ (mean maximum temperature + Mean minimum temperature) has been worked out with the data of the relevant observatories, for each catchment (1940 normals). For catchments without any observatory, data of the nearest observatories have been used.

(3) *Highest and lowest monthly and annual temperatures for each of the catchments.*

For each catchment the mean temperature for each month and year has been worked out from the observatories in or near the catchment. The data for 30 years 1911–1940, have generally been used. The highest value for each month and year for these 30 values have been given as the highest value for the catchment. A similar procedure has been followed for picking out the lowest values.

(4) *Highest and the lowest annual rainfall for each catchment.*

The data for the period 1911–1940 (generally) of selected representative stations in each catchment have been used. For each catchment the monthly and annual rainfall based on data of these stations were worked out and the highest and lowest monthly and annual rainfall figures were picked out from these values.

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APPENDIX I

Rainfall

(1) *Mean Monthly and Annual Rainfall (in inches) for each catchment*

Catchment Nos. refer to the map given in Fig. A

Region.	Catchment No.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1	01	0·66	0·67	1·56	4·23	7·70	23·55	25·99	15·69	5·46	11·29	6·63	1·67	108·11
1	02	0·09	0·06	0·06	0·31	1·11	22·32	37·72	22·84	11·97	4·02	0·91	0·13	101·55
1	03	0·34	0·26	0·23	0·17	0·41	5·71	9·46	6·43	8·15	1·73	0·74	0·30	31·58
1	04	0·41	0·47	0·37	0·26	0·40	6·58	15·23	12·23	7·60	1·77	0·61	0·27	46·20
1	05	0·06	0·06	0·09	0·05	0·31	4·83	12·47	8·90	5·56	0·84	0·26	0·05	33·49
1	06	0·06	0·08	0·06	0·04	0·31	3·82	11·29	7·71	4·35	0·40	0·19	0·04	28·33
1	07	0·09	0·08	0·06	0·03	0·29	3·83	9·01	4·85	3·32	0·69	0·22	0·06	22·50
1	08	0·10	0·15	0·11	0·07	0·35	1·57	4·89	5·71	2·51	0·24	0·09	0·08	15·81
1	09	0·07	0·12	0·06	0·07	0·20	1·59	7·06	3·58	2·12	0·34	0·09	0·06	15·35
2	01	1·6	1·7	1·3	0·9	0·9	3·1	10·0	10·0	4·8	0·5	0·2	0·8	35·8
2	02	1·04	0·98	0·71	0·50	0·48	1·81	5·80	5·26	2·92	0·29	0·09	0·48	20·36
2	03	1·82	1·74	1·35	0·71	0·77	2·83	10·41	10·46	4·06	0·41	0·17	0·87	35·59
2	04	2·10	1·99	1·58	0·82	0·75	2·53	10·17	10·58	3·70	0·45	0·19	0·98	35·85
2	05	2·0	1·9	1·6	1·0	1·0	3·6	11·6	11·6	5·7	0·6	0·3	0·9	41·8
2	06	3·90	4·19	4·67	4·06	2·55	2·39	5·56	5·81	2·72	1·31	0·59	2·02	39·83
2	07	2·93	2·99	4·37	3·55	2·28	1·00	1·37	1·62	1·10	0·94	0·45	1·45	24·05
3	01	1·50	0·84	1·08	2·15	2·04	1·38	1·41	2·20	2·66	6·91	7·19	3·55	32·92
3	02	0·93	0·45	0·61	1·93	3·36	2·67	3·44	4·28	4·72	7·22	6·03	2·72	38·62
3	03	0·94	0·37	0·37	0·96	2·29	2·18	3·09	4·51	0·51	7·46	7·65	2·78	38·10
3	04	0·24	0·17	0·19	0·72	1·76	2·26	2·85	3·60	5·17	4·69	3·03	0·61	25·30
3	05	0·42	0·37	0·27	0·58	1·46	2·24	3·34	3·80	5·08	7·47	5·84	1·05	31·91
3	06	0·09	0·07	0·25	1·14	1·72	5·99	9·29	6·70	5·76	4·11	1·40	0·28	36·80
3	07	0·13	0·12	0·16	0·54	0·92	4·75	6·38	4·37	6·03	2·95	1·24	2·58	27·84
3	08	0·12	0·11	0·33	1·81	3·22	10·28	19·08	10·77	5·15	5·57	2·17	0·49	59·19
3	09	0·08	0·12	0·16	1·04	2·57	2·15	2·24	2·88	4·71	4·29	1·84	0·31	22·40
3	10	0·19	0·40	0·36	0·86	1·38	3·99	5·85	5·46	6·14	3·87	1·83	0·27	30·60
3	11	0·19	0·12	0·14	0·22	0·70	5·63	8·06	5·91	6·61	2·19	0·93	0·23	30·93
3	12	0·11	0·92	0·39	1·09	0·74	6·81	10·63	8·29	7·45	2·47	0·83	0·31	39·97
3	13	0·19	0·85	0·47	0·78	0·70	6·81	13·46	10·06	7·62	2·74	0·77	0·22	44·67
3	14	0·35	0·48	0·41	0·49	0·56	6·80	11·18	8·19	6·83	2·02	0·85	0·32	38·50
3	15	0·34	0·92	0·59	0·63	0·50	8·52	18·45	14·71	8·32	2·41	0·59	0·30	56·27
3	16	0·29	0·72	0·65	1·24	1·61	8·71	18·26	17·40	10·92	3·50	0·81	0·17	63·36
3	17	0·17	0·51	0·55	1·40	2·23	6·45	11·68	10·23	8·24	4·96	1·69	0·23	48·36
3	18	0·28	0·71	0·64	1·08	2·61	5·59	7·11	7·66	7·84	7·34	3·11	0·49	44·46
3	19	0·39	0·99	0·54	0·68	0·75	8·61	15·98	14·70	8·05	2·46	0·61	0·20	53·15
3	20	0·41	0·99	0·80	0·95	2·46	9·38	14·72	14·17	9·43	4·57	1·37	0·19	59·46
3	21	0·63	1·34	1·03	1·16	3·04	9·11	14·86	13·92	8·89	4·42	1·16	0·19	59·83
3	22	0·62	1·43	1·05	1·09	3·15	8·83	13·32	13·00	8·16	3·75	0·73	0·19	55·06
3	23	0·43	1·25	1·20	1·48	4·35	10·28	13·14	12·85	7·92	4·29	0·78	0·13	57·11
3	24	0·47	1·19	0·96	1·03	3·34	8·77	12·02	12·18	7·95	3·55	0·54	0·16	52·17
3	25	0·38	1·02	1·15	1·85	5·41	10·30	11·81	11·51	8·46	3·87	0·68	1·14	56·57
4	01	1·33	1·33	0·79	0·44	0·89	4·70	12·93	12·64	6·79	1·01	0·17	0·57	43·99
4	02	0·60	0·51	0·26	0·18	0·32	3·55	10·86	10·59	6·04	1·40	0·19	0·30	34·80
4	03	0·67	0·62	0·42	0·25	0·45	2·49	7·77	7·65	4·39	0·61	0·12	0·35	25·31
4	04	0·13	0·06	0·07	0·06	0·35	4·63	10·36	9·39	5·64	0·88	0·40	0·10	32·07
4	05	0·30	0·21	0·15	0·13	0·41	4·20	11·90	10·68	5·56	0·73	0·46	0·25	34·96
4	06	0·29	0·26	0·22	0·13	0·39	2·65	7·71	7·73	3·17	0·38	0·13	0·22	23·29
4	07	0·50	0·41	0·21	0·15	0·30	3·52	10·77	10·61	5·57	0·99	0·25	0·27	33·54
4	08	0·54	0·49	0·28	0·19	0·35	4·79	13·94	12·81	6·83	1·17	0·49	0·30	42·19
4	09	0·68	0·71	0·35	0·20	0·56	4·64	12·30	11·65	7·31	1·83	0·25	0·29	40·78
4	10	0·8	0·7	0·4	0·2	0·7	5·5	14·4	13·8	8·6	2·2	0·3	0·3	47·9
4	11	0·76	0·95	0·48	0·30	1·12	6·49	14·49	13·74	8·48	1·97	0·20	0·34	48·79
4	12	0·5	0·8	0·5	0·6	2·2	7·5	13·0	12·6	9·2	2·6	0·4	0·2	50·1
4	13	0·47	0·72	0·40	0·46	1·90	7·63	13·78	12·48	9·45	2·17	0·30	0·17	49·99
4	14	0·80	1·11	0·54	0·32	0·76	5·99	14·13	14·19	7·78	2·07	0·57	0·27	48·54
4	15	0·60	0·86	0·51	0·49	1·86	6·97	12·15	12·10	8·53	2·56	0·42	0·27	47·19
4	16	0·4	0·8	0·9	1·3	3·5	8·8	12·4	12·4	9·2	2·1	0·4	0·2	52·4
4	17	0·37	0·57	0·44	0·79	2·95	8·10	13·13	12·09	9·47	2·44	0·29	0·13	50·43
4	18	0·39	0·68	0·71	1·44	5·24	11·83	14·41	12·92	11·45	3·83	0·38	0·09	63·35
5	01	0·1	0·3	0·7	1·7	2·6	3·9	3·5	3·4	2·5	1·1	0·2	0·1	20·1
5	02	0·6	1·3	2·7	7·0	10·5	15·7	14·4	12·9	10·1	4·6	0·9	0·3	81·0
5	03	0·4	1·1	1·5	3·1	8·0	14·8	15·9	14·9	11·2	5·0	0·9	0·2	77·0
5	04	0·73	1·49	2·82	7·23	11·89	17·35	18·62	16·01	12·28	4·83	0·86	0·36	94·16
5	05	0·5	1·4	2·0	4·2	11·0	20·1	21·7	20·4	15·2	6·9	1·3	0·3	105·0
6	01	0·23	0·28	0·20	0·15	0·29	1·02	3·07	3·50	1·25	0·18	0·05	0·14	10·37

APPENDIX II

Temperature

Mean Monthly and Annual Temperatures (degrees Fahrenheit) for each catchment

Catchment Nos. refer to the map given in Fig. A

Region.	Catchment No.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1	01	79·9	80·8	82·0	84·3	83·7	79·9	78·7	79·0	79·6	80·2	80·3	80·1	80·8
1	02	76·6	76·4	79·5	82·9	84·9	81·9	79·9	79·5	79·5	81·3	80·8	78·2	80.1
1	03	70·5	73·8	81·7	88·8	92·2	87·5	81·5	80·2	80·8	80·1	74·2	70·0	80·1
1	04	67·3	70·7	78·5	86·5	91·3	87·8	81·3	80·1	80·5	78·8	72·1	67·4	78·5
1	05	68·1	71·6	79·1	87·7	90·9	87·9	81·3	79·8	79·5	79·9	73·7	68·7	79·1
1	06	69·2	72·1	80·0	88·3	92·7	91·5	85·7	83·1	84·1	83·6	77·1	71·1	81·6
1	07	68·1	70·8	78·0	84·0	88·0	88·1	84·2	82·1	82·2	82·1	76·7	70·3	79·5
1	08	63·0	65·5	76·6	86·1	92·3	91·9	86·7	83·5	84·0	81·1	72·5	65·4	79·1
1	09	65·9	70·1	78·5	85·5	88·9	88·5	84·5	82·4	83·3	83·3	75·9	68·1	79·6
2	01	29·0	34·0	45·0	55·0	63·0	67·0	63·0	62·0	58·0	52·0	40·0	31·0	50·0
2	02	55·3	59·3	69·7	81·1	89·9	92·8	88·8	87·1	84·9	77·7	66·2	57·5	75·9
2	03	55·3	59·3	69·7	81·1	89·9	92·8	88·8	87·1	84·9	77·7	66·2	57·5	75·9
2	04	53·4	58·1	66·5	76·4	87·1	90·4	86·1	84·5	83·3	76·3	64·7	56·0	73·6
2	05	56·5	59·9	69·1	79·5	89·1	92·5	87·3	84·7	83·5	77·7	67·1	58·5	75·5
2	06	41·1	44·1	53·1	61·9	70·7	78·3	80·3	78·3	73·3	63·7	53·3	44·4	61·9
2	07	21·0	24·1	35·2	47·3	57·6	65·9	71·9	71·4	63·4	51·4	38·7	28·4	48·0
3	01	77·8	79·9	83·3	86·3	87·3	86·3	85·5	84·9	84·4	82·6	80·3	78·1	83·1
3	02	74·0	77·3	81·5	84·5	84·4	81·2	79·6	79·3	79·3	78·3	75·6	73·5	79·0
3	03	75·4	77·8	81·5	86·4	90·3	89·2	86·9	85·6	84·8	81·8	78·0	75·5	82·8
3	04	76·1	80·4	85·8	90·9	93·3	89·8	86·2	85·4	84·5	82·6	78·1	75·2	84·0
3	05	75·7	79·7	84·8	89·9	92·9	89·6	85·9	85·1	84·3	82·2	77·8	74·9	83·6
3	06	71·8	75·3	80·7	84·8	85·2	79·6	76·1	75·8	76·2	77·3	73·5	70·7	77·3
3	07	71·4	75·2	81·0	87·3	88·8	83·3	79·1	78·3	78·4	78·6	73·7	70·3	78·9
3	08	71·7	75·5	79·7	82·7	82·0	76·6	74·1	74·3	75·0	75·7	73·0	70·7	75·9
3	09	74·4	78·9	84·3	87·6	86·7	82·0	79·3	78·9	78·9	78·6	75·3	72·9	79·8
3	10	74·1	78·2	83·0	88·9	91·8	87·0	82·4	81·6	81·6	80·5	76·0	72·8	81·6
3	11	70·5	74·2	81·4	87·5	90·2	84·3	79·2	78·1	78·3	78·0	72·6	69·0	78·6
3	12	72·3	76·3	83·0	87·1	89·4	82·6	77·5	76·3	76·5	77·3	73·4	70·9	78·6
3	13	72·7	77·1	83·6	89·4	93·5	87·8	81·5	81·4	80·8	79·5	73·9	70·5	81·0
3	14	70·5	74·7	82·8	90·6	95·4	89·3	82·0	81·0	81·8	79·6	73·0	68·7	80·8
3	15	68·0	72·0	80·1	88·0	92·8	87·3	80·1	79·1	80·0	77·7	71·0	66·8	78·6
3	16	66·8	71·7	79·4	85·7	90·0	84·7	78·1	78·1	78·5	76·2	69·7	64·9	77·0
3	17	66·1	71·3	79·3	85·0	88·1	83·1	77·4	77·1	77·6	75·5	69·5	64·3	76·2
3	18	71·6	75·7	80·9	84·8	87·6	86·0	82·7	82·5	82·5	80·6	75·4	70·9	80·1
3	19	66·8	71·1	79·3	87·1	92·3	87·1	79·9	79·6	80·1	77·7	70·3	65·3	78·1
3	20	70·6	75·1	82·1	87·2	90·0	87·1	83·2	83·0	83·4	81·7	75·0	69·5	80·7
3	21	67·0	71·5	79·7	86·6	88·8	86·0	81·6	81·2	81·4	78·7	71·7	66·1	78·4
3	22	65·7	70·1	78·9	86·6	89·4	86·6	82·5	81·9	81·9	78·8	71·1	65·1	78·2
3	23	66·8	71·4	80·0	87·9	89·1	87·1	84·2	83·7	83·9	81·0	73·2	67·0	79·7
3	24	64·8	69·0	78·7	86·3	87·9	86·0	82·9	82·3	82·5	79·4	71·6	65·3	78·1
3	25	65·2	69·6	79·2	86·1	86·3	86·0	83·9	83·6	83·9	81·1	73·3	66·1	78·7
4	01	57·5	61·0	70·8	81·3	88·5	89·3	84·6	82·9	81·6	75·8	66·1	58·7	74·8
4	02	59·7	64·3	75·1	85·7	93·2	93·1	86·6	84·4	83·0	78·8	68·7	60·9	77·8
4	03	56·8	61·5	71·5	82·3	91·1	93·1	88·1	86·0	84·5	77·9	66·8	58·9	76·5
4	04	63·7	67·5	76·8	85·9	92·5	90·0	82·6	80·1	80·7	78·6	70·3	64·4	77·8
4	05	63·2	67·7	76·4	85·7	93·3	90·9	82·9	80·7	81·0	78·3	69·8	66·3	78·0
4	06	61·5	65·1	74·7	84·3	90·9	89·9	83·7	81·1	81·2	78·5	69·7	62·9	77·0
4	07	59·6	63·8	73·1	83·5	91·9	91·7	84·4	82·2	81·7	76·7	67·1	60·7	76·4
4	08	61·6	65·9	76·5	86·6	93·5	92·0	84·3	82·2	82·4	78·4	69·1	62·2	77·9
4	09	60·0	64·4	75·0	85·4	91·4	90·9	85·8	84·3	83·9	78·6	68·7	61·1	77·5
4	10	35·0	39·0	49·0	59·0	64·0	66·0	62·0	61·0	59·0	54·0	43·0	35·0	52·0
4	11	60·1	64·5	74·6	84·5	89·7	88·8	85·3	84·2	83·9	79·2	69·5	61·8	77·2
4	12	36·0	41·0	53·0	63·0	64·0	67·0	64·0	63·0	62·0	57·0	46·0	40·0	54·0
4	13	61·1	64·9	75·2	84·3	87·5	86·9	84·9	84·1	83·8	79·7	70·3	62·6	77·1
4	14	61·6	66·0	75·4	85·2	92·5	90·1	82·9	81·2	81·2	76·6	67·8	61·5	76·8
4	15	64·2	66·3	76·9	86·2	89·1	87·9	84·8	83·9	83·7	79·7	70·3	62·7	78·0
4	16	35·0	37·0	43·0	47·0	52·0	56·0	59·0	58·0	54·0	47·0	41·0	40·0	48·0
4	17	61·7	65 3	74·5	83·1	85·3	85·1	84·3	83·9	83·5	79·6	70·9	63·5	76·7
4	18	62·1	65·9	77·0	82·0	83·5	83·7	83·9	83·7	83·1	79·4	71·3	64·1	76·6
5	01	21·0	26·0	37·0	45·0	48·0	54·0	51·0	51·0	48·0	43·0	32·0	25·0	40·0
5	02	60·7	63·9	69·0	73·4	77·6	80·5	81·3	81·5	80·5	76·9	69·8	62·5	73·2
5	03	63·3	66·6	64·6	79·1	79·4	80·9	82·1	82·4	81·5	78·5	71·7	64·9	75·5
5	04	62·3	65·5	72·3	76·8	79.4	82·1	83·3	83·3	82·2	78·4	70·8	63·8	75·0
5	05	62·2	65·3	72·7	78·8	81·1	82·1	82·9	83·1	82·0	78·5	71·1	64·9	75·5
6	01	59·0	63·4	73·7	84·2	92·3	93·9	89·7	86·8	85·8	80·4	69·8	61·4	78·4

APPENDIX III

Highest and Lowest Monthly and Annual Rainfall (in cents) for each Catchment*

Catchment Nos. refer to the map given in Fig. A

Region No.	Catchment No.	Highest—1. Lowest—2.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1	01	1	0191	0182	0373	0630	2585	4277	5284	3916	1663	1965	0951	0424	14211
1	01	2	0000	0000	0003	0041	0165	1566	0859	0928	0261	0278	0121	0000	8532
1	02	1	0100	0116	0036	0271	1486	3886	6820	4469	2676	1937	0448	0144	16157
1	02	2	0000	0000	0000	0000	0000	0990	1502	1202	0417	0007	0000	0000	7113
1	03	1	0278	0134	0187	0180	0326	1287	1851	1363	1400	0893	0617	0898	4992
1	03	2	0000	0000	0000	0000	0000	0035	0404	0185	0116	0003	0000	0000	1704
1	04	1	0435	0177	0210	0171	0307	1277	2572	2427	1685	0793	0450	0223	6483
1	04	2	0000	0000	0000	0000	0000	0089	0727	0694	0207	0000	0000	0000	3213
1	05	1	0105	0072	0050	0043	0467	1699	3029	2473	1542	0801	0235	0047	5667
1	05	2	0000	0000	0000	0000	0000	0003	0082	0041	0017	0000	0000	0000	1089
1	06	1	0045	0072	0062	0036	0419	1249	4815	2361	2055	0574	0169	0113	6557
1	06	2	0000	0000	0000	0000	0000	0000	0137	0026	0000	0000	0000	0000	803
1	07	1	0077	0038	0197	0025	0395	1242	1989	1575	1906	0856	0164	0077	4619
1	07	2	0000	0000	0000	0000	0000	0000	0033	0061	0026	0000	0000	0000	918
1	08	1	0156	0120	0144	0085	0361	0622	1883	2335	1645	0584	0083	0105	5845
1	08	2	0000	0000	0000	0000	0000	0005	0069	0060	0006	0000	0000	0000	959
1	09	1	0063	0099	0108	0027	0549	0519	2428	1513	2215	0694	0100	0105	4591
1	09	2	0000	0000	0000	0000	0000	0000	0002	0007	0000	0000	0000	0000	318
2	01	1	0815	0525	0828	0539	0424	0986	1711	2167	1569	0726	0235	0420	6468
2	01	2	0028	0022	0034	0028	0011	0116	0339	0416	0121	0000	0000	0000	3084
2	02	1	0492	0453	0318	0266	0295	0350	1537	1082	1549	0455	0109	0206	4426
2	02	2	0000	0000	0000	0000	0000	0000	0114	0054	0004	0000	0000	0000	1115
2	03	1	0711	0397	0704	0428	0209	0669	2158	1591	1309	0674	0155	0568	6207
2	03	2	0003	0008	0000	0000	0001	0009	0169	0378	0033	0000	0000	0000	1967
2	04	1	0919	0757	0965	0536	0319	0950	2855	2279	1861	0549	0227	0336	8307
2	04	2	0013	0019	0006	0019	0008	0021	0326	0901	0052	0000	0000	0000	2782
2	05	1	1458	0977	1512	0719	0483	0934	2401	1854	1525	0571	0468	0930	8005
2	05	2	0094	0053	0066	0058	0005	0044	0409	0544	0100	0000	0000	0002	4266
2	06	1	1173	0961	1147	0985	0631	0575	0970	1501	0700	0763	0327	1282	5520
2	06	2	0031	0078	0155	0131	0027	0033	0266	0334	0022	0000	0000	0000	3200
2	07	1	0397	0553	0767	0479	0380	0237	0238	0268	0181	0226	0114	0397	2486
2	07	2	0019	0025	0032	0033	0001	0006	0013	0006	0001	0000	0000	0000	565
3	01	1	0674	0402	0385	0457	0477	0249	0519	0597	0462	1652	1935	1641	4367
3	01	2	0000	0000	0002	0021	0043	0003	0007	0034	0029	0219	0251	0040	2432
3	02	1	0436	0204	0211	0507	0883	0502	0716	0716	0769	1719	1407	0858	4685
3	02	2	0000	0000	0000	0065	0124	0122	0122	0133	0074	0201	0114	0021	2654
3	03	1	0713	0363	0365	0731	0902	0354	0917	0826	0867	1977	1951	1497	6344
3	03	2	0000	0000	0000	0000	0032	0066	0130	0169	0190	0040	0078	0000	2545
3	04	1	0285	0230	0199	0387	0600	0433	0846	1199	1140	1175	1200	0534	4010
3	04	2	0000	0000	0000	0001	0012	0110	0049	0067	0101	0005	0008	0000	1506
3	05	1	0421	0225	0395	0655	0413	0567	0863	0687	1013	1701	1857	0475	4395
3	05	2	0000	0000	0000	0000	0000	0039	0053	0047	0107	0015	0000	0000	1612

* For Kosi (4/16) lowest rainfall have been obtained as $\frac{1}{3}$ (twice Gandak value + Tista value) except for annual figure where it is the same value as that of Gandak. For Brahmaputra (5/1), Subansri (5/2) and Chenab (2/5) the values of lowest rainfall are taken as $\frac{1}{3}$ of the mean rainfall for the corresponding months or year estimated earlier.

APPENDIX III (*continued*)

Highest and Lowest Monthly and Annual Rainfall (in cents) for each Catchment

Catchment Nos. refer to the map given in Fig. A

Region No.	Catchment No.	Highest—1. Lowest—2.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
3	06	1	0056	0077	0024	0406	0360	0854	3159	1523	1208	0992	0860	0166	7148
3	06	2	0000	0000	0000	0000	0012	0118	0199	0193	0111	0038	0000	0000	1873
3	07	1	0167	0124	0236	0266	0497	0890	1108	0715	1219	0712	0564	0097	4173
3	07	2	0000	0000	0000	0003	0000	0096	0135	0085	0048	0029	0000	0000	1527
3	08	1	0092	0221	0141	0428	0648	1076	1544	1557	0879	1162	0673	0146	6017
3	08	2	0000	0000	0000	0002	0057	0056	0167	0084	0031	0018	0000	0000	2016
3	09	1	0177	0210	0156	0327	0695	0618	0733	0976	1034	1279	0986	0237	4199
3	09	2	0000	0000	0000	0029	0080	0063	0068	0105	0105	0051	0000	0000	1897
3	10	1	0137	0311	0283	0425	0450	0775	1078	0835	1050	1075	0575	0171	4854
3	10	2	0000	0000	0000	0003	0002	0108	0276	0281	0316	0083	0003	0000	2015
3	11	1	0247	0107	0212	0187	0537	1315	1234	0973	1346	0811	0561	0160	4135
3	11	2	0000	0000	0000	0000	0000	0073	0184	0081	0025	0005	0000	0000	1286
3	12	1	0227	0159	0227	0181	0457	1037	1293	1303	1623	0625	0508	0090	5317
3	12	2	0000	0000	0000	0000	0000	0097	0300	0120	0285	0000	0000	0000	2080
3	13	1	0243	0335	0272	0496	0461	1265	1696	1245	1369	0673	0343	0183	5582
3	13	2	0000	0000	0000	0000	0000	0037	0415	0349	0189	0006	0000	0000	1906
3	14	1	0299	0284	0329	0380	0440	1655	2342	1666	1518	1077	0360	0120	5569
3	14	2	0000	0000	0000	0000	0000	0173	0596	0333	0173	0003	0000	0000	2537
3	15	1	0373	0309	0237	0423	0423	1921	2612	2799	1698	1001	0372	0290	7614
3	15	2	0000	0000	0000	0000	0000	0120	0503	0586	0253	0000	0000	0000	3105
3	16	1	0405	0457	0202	0645	0710	1682	2036	2391	1562	0968	0561	0092	7831
3	16	2	0000	0000	0000	0009	0000	0104	0871	0661	0228	0021	0000	0000	3095
3	17	1	0130	0376	0239	0427	0691	1653	2270	1973	1527	1120	0412	0181	7429
3	17	2	0000	0000	0000	0019	0012	0196	0690	0796	0290	0000	0000	0000	3389
3	18	1	0206	0336	0385	0272	1006	1540	1745	3041	1666	1625	1769	0121	10628
3	18	2	0000	0000	0000	0003	0026	0117	0324	0339	0326	0104	0001	0000	2894
3	19	1	0568	0435	0319	0259	0477	1869	2279	2557	1425	0732	0503	0145	7162
3	19	2	0000	0000	0000	0005	0000	0191	0572	0915	0344	0000	0000	0000	3971
3	20	1	0300	0373	0309	0257	0612	2138	2381	2163	1452	1470	0912	0075	8115
3	20	2	0000	0000	0000	0000	0021	0281	0638	0835	0491	0037	0000	0000	4566
3	21	1	0334	0413	0443	0295	0713	1971	3164	2431	1370	1031	0823	0106	7381
3	21	2	0000	0015	0000	0000	0053	0257	0677	0808	0347	0007	0000	0000	4878
3	22	1	0341	0678	0532	0215	0936	1961	2693	2265	1472	1465	0655	0190	7569
3	22	2	0000	0002	0000	0006	0043	0162	0415	0820	0395	0003	0000	0000	4283
3	23	1	0197	0492	0655	0269	0869	2068	2282	2153	1707	1542	0479	0105	7359
3	23	2	0000	0006	0000	0007	0092	0389	0627	0673	0456	0020	0000	0000	4454
3	24	1	0247	0537	0698	0331	0844	2121	1984	1826	1362	1454	0520	0184	7484
3	24	2	0000	0001	0000	0023	0124	0429	0494	0705	0336	0009	0000	0000	4403
3	25	1	0145	0494	0685	0597	1063	2368	1924	2108	1463	1521	0500	0122	8147
3	25	2	0000	0005	0000	0044	0235	0643	0556	0525	0355	0016	0000	0000	4077
4	01	1	0513	0516	0478	0178	0354	1551	2461	2302	2412	0643	0296	0304	7288
4	01	2	0000	0000	0001	0001	0005	0060	0312	0693	0116	0000	0000	0000	2869
4	02	1	0245	0397	0161	0118	0303	1782	2131	1888	1605	0852	0269	0184	5740
4	02	2	0000	0000	0000	0000	0000	0027	0123	0285	0109	0000	0000	0000	2108

APPENDIX III (*continued*)

Highest and Lowest Monthly and Annual Rainfall (in cents) for each Catchment

Catchment Nos. refer to the map given in Fig. A

Region No.	Catchment No.	Highest—1. Lowest—2.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
4	03	1	0252	0328	0246	0156	0235	0746	1510	1428	1457	0418	0106	0167	4952
4	03	2	0001	0000	0000	0001	0000	0026	0095	0229	0025	0000	0000	0000	1095
4	04	1	0196	0096	0073	0047	0453	1299	1933	2420	1264	0583	0320	0152	5572
4	04	2	0000	0000	0000	0000	0000	0005	0317	0277	0088	0000	0000	0000	1489
4	05	1	0129	0211	0108	0135	0238	0999	2467	3088	1188	0703	0488	0239	6263
4	05	2	0000	0000	0000	0000	0000	0022	0437	0426	0079	0000	0000	0000	2309
4	06	1	0138	0148	0128	0098	0432	0700	1425	2009	1253	0351	0119	0178	5218
4	06	2	0000	0000	0000	0000	0000	0018	0188	0163	0018	0000	0000	0000	1174
4	07	1	0235	0198	0289	0073	0201	1013	2339	2478	1708	0789	0445	0134	5530
4	07	2	0000	0000	0000	0000	0000	0001	0107	0211	0033	0000	0000	0000	1217
4	08	1	0327	0299	0148	0139	0173	1021	2130	2747	1379	0501	0405	0216	5775
4	08	2	0000	0000	0000	0000	0000	0088	0477	0583	0229	0000	0000	0000	2737
4	09	1	0287	0380	0177	0192	0243	1128	2353	1986	1594	0480	0309	0231	6233
4	09	2	0000	0000	0000	0000	0000	0041	0220	0366	0221	0000	0000	0000	2631
4	10	1	0275	0293	0243	0167	0427	1579	2623	2459	2190	0492	0529	0146	7678
4	10	2	0000	0000	0000	0000	0000	0175	0471	0495	0163	0000	0000	0000	2644
4	11	1	0373	0391	0302	0137	0348	1806	2537	2883	1654	0466	0323	0277	7437
4	11	2	0000	0000	0000	0001	0004	0110	0458	0661	0232	0000	0000	0000	3511
4	12	1	0265	0351	0269	0442	1127	1502	2119	2020	1920	0506	0421	0150	6854
4	12	2	0000	0000	0000	0000	0133	0342	0761	0709	0214	0000	0000	0000	3433
4	13	1	0159	0179	0291	0249	0555	1851	3298	2460	1863	0664	0267	0153	7083
4	13	2	0000	0000	0000	0000	0009	0137	0517	0534	0187	0000	0000	0000	2845
4	14	1	0509	0378	0242	0121	0212	1269	2670	2585	1472	0638	0309	0183	5445
4	14	2	0000	0000	0000	0000	0000	0081	0276	0593	0160	0000	0000	0000	3025
4	15	1	0278	0310	0288	0211	0588	1862	1994	2292	1697	1153	0315	0212	7007
4	15	2	0000	0000	0000	0001	0031	0181	0480	0768	0260	0006	0000	0000	3592
4	16	1	0350	0409	0510	1225	2524	5214	5031	4417	4205	3463	1134	0233	16357
4	16	2	0000	0000	0006	0051	0267	1391	0720	1945	1077	0029	0000	0000	11300
4	17	1	0094	0207	0365	0571	0672	1989	2711	3432	2327	1697	0529	0131	7704
4	17	2	0000	0000	0000	0000	0037	0324	0425	0537	0212	0000	0000	0000	3851
4	18	1	0203	0221	0468	0723	1733	2435	2526	3306	2103	1342	0421	0172	9479
4	18	2	0000	0000	0000	0005	0093	0416	0751	0556	0251	0006	0000	0000	3109
5	01	1	0205	1645	1164	0835	0887	1164	1296	1206	0824	1195	0482	0536	5963
5	01	2	0000	0024	0055	0132	0002	0187	0502	0351	0237	0000	0000	0000	4063
5	02	1	0354	0553	1283	1559	2535	4205	4609	3569	4875	2187	0507	0361	18633
5	02	2	0039	0063	0049	0257	0619	1521	1719	1022	1281	0085	0003	0000	11734
5	03	1	0307	0430	1033	1481	2542	2776	3357	2635	1491	0927	0292	0284	11126
5	03	2	0000	0005	0001	0269	0627	0896	0629	0586	0275	0011	0000	0000	6211
5	04	1	0187	0439	0684	1118	1696	2528	2705	1998	1828	1115	0515	0178	10350
5	04	2	0001	0017	0049	0231	0570	1146	0966	0820	0654	0093	0006	0000	7664
5	05	1	0156	0391	0526	0970	1709	4223	4868	3955	3480	2440	0652	0251	15751
5	05	2	0000	0000	0000	0009	0525	1035	1632	1296	0933	0012	0000	0000	9520
6	01	1	0113	0165	0225	0123	0179	0273	0794	0901	0732	0233	0029	0117	2716
6	01	2	0000	0000	0000	0001	0000	0007	0025	0027	0002	0000	0000	0000	384

APPENDIX IV.

APPENDIX

Highest and Lowest Monthly

Catchment Nos. refer to the

Region.	Catchment.	January.		February.		March.		April.		May.		June.	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	01	81·1	78·2	81·9	79·2	84·0	81·5	85·5	83·1	84·9	80·6	81·7	78·7
1	02	79·4	74·1	78·6	74·7	82·5	77·4	85·1	80·7	87·1	83·7	84·2	80·2
1	03	73·7	67·2	77·1	71·4	85·4	78·2	91·3	84·7	93·9	85·8	92·5	82·2
1	04	70·3	63·4	74·1	67·8	82·0	75·7	89·7	82·6	93·2	83·3	92·7	81·9
1	05	70·9	64·1	74·3	68·2	83·1	76·3	91·3	84·4	93·1	88·3	89·4	82·3
1	06	73·3	64·4	75·7	68·1	86·1	76·0	91·2	84·3	94·9	86·1	94·9	87·7
1	07	72·0	64·4	74·3	67·6	82·1	74·3	86·2	81·3	89·6	84·0	90·5	85·6
1	08	67·9	58·8	71·9	62·8	81·4	71·3	89·8	81·4	94·6	83·3	95·2	87·2
1	09	70·8	60·8	75·4	65·2	81·4	74·7	88·5	82·2	91·3	85·0	90·7	83·2
2	01	46·8	36·5	48·8	37·6	55·5	44·7	63·6	51·4	71·4	57·1	97·2	63·1
2	01	58·9	51·1	63·1	55·1	75·6	64·8	88·3	74·0	96·3	82·4	98·1	88·0
2	02	58·9	51·1	63·1	55·1	75·6	64·8	88·3	74·0	96·3	82·4	98·1	88·0
2	03	58·9	51·1	63·1	55·1	75·6	64·8	88·3	74·0	96·3	82·4	98·1	88·0
2	04	57·4	49·7	59·4	53·4	72·8	63·8	81·3	71·1	92·6	79·9	93·7	85·9
2	05	60·5	53·3	65·2	55·7	76·1	63·6	88·9	72·8	96·6	81·2	97·6	86·1
2	06	44·9	28·0	50·7	31·6	58·3	43·6	67·9	52·1	77·5	62·6	81·6	69·5
2	07	28·5	14·4	30·2	16·7	44·6	30·3	51·5	41·2	63·2	48·9	70·4	59·1
3	01	80·7	77·0	82·5	77·9	85·6	81·5	88·1	84·9	90·2	84·9	88·1	84·5
3	02	76·6	72·4	79·4	74·6	83·1	79·7	86·1	82·6	87·1	81·7	84·1	79·8
3	03	77·9	73·7	79·9	74·8	83·8	79·0	87·2	83·9	92·9	86·9	92·3	86·0
3	04	79·1	73·4	82·3	77·5	87·9	83·7	93·2	87·6	96·3	89·3	92·6	85·8
3	05	78·7	73·1	81·5	76·7	87·1	82·5	92·2	86·8	95·7	89·1	92·7	85·7
3	06	74·5	69·3	77·1	72·0	82·5	76·9	86·5	82·0	86·5	81·3	83·3	77·2
3	07	75·8	69·3	78·1	72·1	83·7	78·3	89·9	84·1	91·4	84·5	86·8	79·1
3	08	73·9	67·8	77·8	70·8	81·9	75·5	83·7	78·4	84·3	75·1	78·0	70·7
3	09	77·7	70·7	81·1	76·1	86·3	81·7	89·2	85·7	88·7	80·0	84·3	79·8
3	10	77·5	70·4	84·4	71·9	86·8	81·8	93·1	84·5	95·9	87·3	92·0	81·1
3	11	74·3	67·7	77·3	71·5	84·5	77·9	91·9	83·1	94·1	83·1	89·3	79·6
3	12	77·7	69·7	80·1	74·0	87·4	81·3	93·0	82·1	93·5	84·3	87·7	77·1
3	13	77·5	69·7	80·3	74·4	86·9	81·7	92·7	83·1	98·5	86·8	94·5	82·1
3	14	74·6	67·0	78·4	71·4	85·7	79·3	93·2	83·3	98·6	86·6	96·0	82·8
3	15	73·5	64·0	74·6	65·7	88·4	75·9	90·9	80·7	96·9	81·6	93·7	81·3
3	16	71·7	64·1	74.8	68·1	82·5	78·0	88·1	80·4	94·4	81·0	89·2	78·3
3	17	72·1	64·9	74·8	68·1	82·3	77·5	88·1	79·7	94·4	81·0	89·2	78·3
3	18	75·4	68·8	77·7	73·9	82·6	79·4	86·8	82·6	90·7	83·8	89·6	82·8
3	19	69·9	63·0	74·1	68·6	83·3	76·4	90·6	82·1	97·4	85·1	94·8	80·1
3	20	73·6	67·6	76·5	72·8	84·1	79·6	89·3	84·9	92·8	86·5	92·0	81·5
3	21	69·1	62·5	73·1	66·3	83·6	75·3	89·3	81·3	94·5	83·3	92·5	80·0
3	22	69·4	61·8	72·2	67·7	81·8	75·7	89·9	81·5	93·5	82·9	92·5	81·2
3	23	71·3	64·2	74·6	69·1	84·7	77·4	91·7	80·1	93·0	84·5	92·5	82·7
3	24	68·0	61·5	71·6	66·8	82·7	74·5	89·8	82·5	91·9	84·0	91·7	79·8
3	25	68·1	62·7	72·6	67·7	83·4	76·7	89·3	81·9	90·3	83·6	88·3	82·1
4	01	60·6	54·6	64·6	59·3	75·7	66·8	87·7	76·1	95·8	83·0	96·0	86·1
4	02	64·6	57·9	67·8	62·9	79·7	71·0	91·0	80·6	98·2	85·3	98·7	88·1
4	03	61·2	53·8	68·3	58·6	78·3	67·5	89·8	77·3	98·0	83·4	98·1	87·3
4	04	68·1	60·0	72·6	64·7	81·4	73·3	89·9	81·6	94·9	82·6	94·2	84·3
4	05	68·1	59·9	73·9	64·4	84·1	69·6	93·1	82·0	99·2	85·9	98·7	84·5
4	06	67·1	57·7	70·7	62·5	79·7	70·5	88·7	79·7	94·1	81·3	94·2	85·3
4	07	64·6	54·8	67·6	59·2	80·7	70·5	92·1	79·3	99·3	84·8	99·5	87·3
4	08	69·1	58·8	69·2	64·0	80·5	72·8	90·8	81·3	97·4	84·4	97·6	82·8
4	09	63·8	57·9	67·4	62·6	79·7	71·1	90·3	80·8	97·4	84·7	96·8	86·5
4	10	47·1	35·2	48·3	40·1	50·5	45·6	63·6	52·7	69·8	66·5	71·8	60·1
4	11	63·7	57·9	66·7	62·3	78·3	70·3	87·3	80·9	94·1	84·7	94·3	84·1
4	12	56·6	47·9	57·1	51·7	65·4	56·1	71·2	65·1	75·7	89·9	77·5	74·3
4	13	64·5	59·7	69·3	62·0	81·3	72·3	89·7	81·8	92·7	84·7	93·2	82·8
4	14	67·3	57·8	68·4	63·6	79·7	72·5	89·7	81·2	96·9	84·3	96·3	84·9
4	15	66·0	60·2	70·2	65·4	82·1	74·6	90·4	83·2	93·5	81·0	94·4	83·1
4	16	45·1	37·4	46·0	41·3	53·5	44·9	58·3	51·2	61·6	56·3	63·4	59·8
4	17	63·5	58·8	67·4	62·1	77·6	70·3	85·9	78·8	88·5	83·1	88·6	82·3
4	18	64·5	59·8	68·5	63·5	77·5	68·9	84·7	77·2	85·8	81·5	85·4	81·3
5	01	28·6	16·9	29·5	23·3	38·3	26·4	44·7	34·1	51 3	40·9	58·7	47·3
5	02	63·2	58·6	66·8	61·9	74·0	66·4	76·8	70.9	81·1	73·9	82·7	78·1
5	03	65·9	60·9	69·1	64·9	78·4	70·5	85·3	74·1	82·0	77·0	83·1	78·4
5	04	64·7	60·3	68·6	63·7	76·2	68·8	80·4	72·7	81·9	77·8	83·5	80·0
5	05	66·2	59·8	68·4	63·9	76·2	69·2	81·6	25·5	83·2	79·3	84·3	80·4
6	01	63·0	55·4	68·5	59·3	79·6	69·0	90·2	79·3	96·8	83·6	97·1	90·1

and Annual Temperature (°F.)

map given in Fig. A

July.		August.		September.		October.		November.		December.		Annual.	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
80·5	77·3	79·9	78·0	80·7	77·8	81·2	78·5	81·3	79·2	81·1	77·3	81·2	79·7
85·8	78·7	81·1	76·7	81·1	78·5	84·3	79·0	83·7	78·4	80·3	75·9	81·2	79·5
84·0	80·1	81·3	79·4	82·9	79·1	83·7	77·6	77·5	70·6	72·5	68·6	81·2	78·9
83·4	79·1	81·1	77·9	82·3	78·3	81·6	75·9	74·8	68·2	69·4	64·8	79·4	76·7
82·8	78·7	82·3	77·7	81·5	78·7	83·1	77·7	76·3	71·7	71·4	65·3	80·1	77·7
89·7	82·5	86·3	81·1	89·4	81·2	87·4	79·7	80·3	71·4	74·7	66·9	83·1	79·7
86·5	82·3	84·5	81·1	84·4	80·3	85·3	79·5	79·3	71·2	73·2	67·0	80·6	78·3
90·4	83·0	87·1	80·9	89·7	81·0	84·7	76·7	75·0	66·4	68·3	61·8	81·0	76·4
87·8	82·4	85·3	80·6	85·4	81·1	86·5	79·9	78·8	68·8	70·6	63·8	81·7	77·8
67·1	63·1	64·6	61·7	65·0	59·3	60·4	53·1	53·7	45·5	49·6	39·1	57·1	53·6
94·0	83·5	92·0	84·1	89·8	80·9	81·5	74·0	69·4	52·3	60·2	54·6	78·9	73·7
94·0	83·5	92·0	84·1	89·8	80·9	81·5	74·0	69·4	52·3	60·2	54·6	78·9	73·7
94·0	83·5	92·0	84·1	89·8	80·9	81·5	74·0	69·4	52·3	60·2	54·6	78·9	73·7
88·5	83·7	87·7	82·3	85·8	80·1	78·3	73·2	66·9	60·4	58·5	53·1	78·9	72·0
91·8	83·1	88·9	82·3	86·0	80·6	81·0	71·4	71·3	62·4	61·5	55·2	78·5	73·0
82·7	75·9	80·9	74·9	76·6	68·7	66·7	59·0	54·9	45·6	47·7	36·5	62·8	57·7
74·4	66·6	73·5	68·4	66·9	59·9	55·2	45·0	41·8	28·8	31·4	18·8	49·9	45·7
86·9	83·3	86·3	83·9	86·5	83·4	84·6	81·2	82·4	79·4	79·8	77·6	84·2	82·8
89·4	78·8	80·4	78·8	80·8	78·2	80·1	76·9	77·7	74·6	75·3	71·9	80·1	78·4
89·1	84·5	89·1	84·2	86·3	82·9	84·0	79·8	79·7	76·6	77·3	71·9	83·5	81·7
88·7	84·8	87·4	83·4	86·5	82·4	85·0	80·5	79·8	73·3	77·0	73·0	84·6	82·7
88·5	84·3	86·7	83·3	86·2	82·3	84·1	80·6	81·1	75·9	77·2	72·9	84·3	82·1
77·3	74·7	77·7	79·1	79·3	74·5	78·9	74·0	76·1	70·5	72·7	64·9	78·2	75·1
81·4	77·4	79·3	76·2	81·4	76·7	81·3	75·0	77·3	70·1	72·6	66·9	80·2	77·4
74·7	70·3	76·5	70·5	77·1	71·4	77·4	70·6	74·3	69·5	73·1	67·0	76·6	72·5
81·3	77·5	80·1	76·7	80·6	77·3	80·7	76·0	67·7	73·1	75·7	70·9	80·5	78·3
85·3	81·1	84·2	80·3	83·5	79·9	83·0	79·2	78·7	73·7	75·6	71·6	82·9	80·2
81·4	77·4	79·5	76·1	83·9	76·1	82·4	75·3	76·4	69·3	71·5	66·4	80·6	78·2
79·9	75·3	78·4	75·5	78·5	75·4	81·0	75·9	77·0	70·8	74·4	68·7	80·3	77·4
84·3	80·1	83·1	78·9	83·6	79·2	83·7	77·5	78·1	70·4	73·7	68·2	82·7	79·4
83·9	79·9	82·7	79·4	83·5	79·8	82·8	76·7	76·4	70·2	70·9	66·5	81·5	78·6
88·1	77·6	80·4	77·1	80·8	75·1	79·6	72·2	73·1	66·9	68·7	64·1	79·5	75·1
79·1	75·8	79·4	76·0	80·0	77·1	78·3	75·0	74·5	66·3	68·0	73·3	78·2	74·9
79·1	75·7	78·4	76·0	79·5	77·1	77·9	74·9	74·5	66·3	67·9	63·3	77·7	74·9
83·8	81·5	83·9	81·7	83·9	81·3	82·3	79·4	79·7	73·6	73·1	69·6	80·9	79·2
86·6	78·8	81·3	78·0	81·8	79·2	79·8	76·3	73·7	67·9	67·6	63·6	79·4	76·5
85·4	81·1	84·7	81·6	84·4	82·1	83·1	79·6	78·1	71·7	71·3	61·2	81·4	78·8
83·3	79·1	81·9	79·0	83·4	78·5	81·1	74·6	77·8	67·6	67·4	62·6	79·7	75·5
84·7	80·9	82·8	80·7	83·0	80·3	80·4	76·6	73·9	68·9	66·9	63·1	79·1	76·4
86·1	83·3	84·9	82·7	85·1	82·6	83·2	79·1	76·9	68·1	69·0	62·2	80·7	77·9
84·1	80·6	82·7	80·4	83·7	79·9	80·5	76·7	74·5	68·8	66·7	62·6	78·6	75·7
85·4	83·4	85·0	82·1	85·8	82·7	83·3	79·7	76·9	71·6	67·7	64·0	79·8	77·9
90·5	82·3	87·0	81·5	85·1	79·9	80·0	74·5	69·5	63·3	61·9	56·6	77·3	73·8
93·4	83·3	88·4	82·6	87·6	82·1	82·4	77·6	72·2	65·5	64·8	58·9	79·7	76·2
94·5	84·4	92·4	83·6	88·7	81·8	82·5	75·8	71·3	64·1	63·2	57·3	80·0	75·2
88·1	80·2	83·3	92·4	85·3	78·2	82·4	75·7	76·2	68·0	68·1	62·5	79·4	75·6
92·9	81·4	87·6	79·5	90·1	79·3	85·9	76·2	76·1	67·6	69·1	61·7	82·7	77·0
88·5	80·9	85·2	79·5	86·8	79·3	81·8	75·4	72·5	65·5	66·3	60·7	79·1	74·8
95·6	83·2	91·8	80·9	89·5	79·7	85·0	73·7	74·1	62·0	65·5	57·7	81·4	75·4
89·3	80·9	85·1	80·8	85·9	80·9	88·2	75·9	72·1	65·3	65·5	60·1	79·4	75·7
92·1	83·7	86·7	80·5	86·4	82·1	81·3	74·7	71·7	66·4	63·6	59·4	79·0	75·9
65·8	61·7	64·7	60·4	64·3	58·1	62·6	59·0	55·5	45·4	50·4	38·0	56·9	53·8
88·6	83·1	86·9	82·3	86·6	81·7	81·5	77·3	72·0	67·0	63·6	59·3	78·4	75·9
77·5	72·3	77·3	74·5	76·6	71·9	72·8	64·8	62·6	56·5	54·6	50·3	66·9	64·9
87·5	83·1	86·6	82·7	87·5	82·8	83·2	78·3	73·7	66·0	66·3	60·6	79·4	76·2
88·3	80·8	83·9	80·1	85·5	80·4	81·3	75·1	71·1	65·1	64·3	58·9	78·6	75·6
87·3	83·7	85·2	82·6	86·6	82·6	83·2	78·7	74·5	69·7	66·1	61·3	79·5	77·3
64·5	61·1	64·8	60·9	62·7	55·5	58·6	53·7	52·4	46·0	47·2	41·0	55·8	52·9
86·2	82·3	84·9	82·1	85·3	81·8	82·7	77·1	73·7	68·5	64·8	60·8	77·4	75·4
85·3	81·5	84·7	81·0	87·5	81·7	82·4	77·3	74·2	69·6	66·0	62·3	77·1	75·4
61·5	55·0	59·3	51·7	56·7	45·2	51·9	35·9	37·3	28·1	29·8	16·7	43·8	36·9
83·7	79·0	84·7	79·6	82·3	77·3	81·1	73·8	72·6	67·5	83·8	60·7	74·0	72·2
84·1	80·3	84·0	81·1	83·5	79·7	81·7	76·4	75·5	68·0	67·3	62·6	76·3	74·4
85 4	81·6	85·5	82·1	83·9	80·8	81·9	75·7	74·9	67·9	66·5	61·5	76·1	74·2
85·3	80·3	84·9	80·7	83·7	80·7	81·7	73·4	74·9	69·7	67·1	63·0	77·0	74·8
93·1	86·0	90·1	82·3	90·1	82·3	83·8	77·5	73·0	65·3	64·4	57·0	80·9	76·2