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WATER AVAILABILITY STUDY OF RIVER TAWI
J & K STATE

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PREFACE

The National Water Policy requires that water resource planning has to be done for a hydrologic unit such as a drainage basin or a sub-basin. All individual developmental projects could be formulated by the states and considered within the framework of such an overall plan for a basin or sub-basin. Keeping in view of the water resources developmental activities on the river Tawi, a tributary of Chenab system and flowing thorough heart of Jammu city, this study is made on the sub-basin as a part of its overall hydrologic studies, on the request of Govt. of J&K. The study made by W.H.R.C. Jammu basically is the modelling of rainfall-runoff process and developing flow-duration curves for different months in a year based on available long term rainfall runoff data, to ascertain the percent of time in a month a particular flow exceeded or equalled. This should be useful to the water resources deptts. in Jammu region.

The existing rainfall station network in Tawi basin is inadequate and there are several missing periods in the data. Runoff data were available only for twelve years. But for these bottlenecks the results could further improve. Installing more rainguage stations, guage, discharge and silt sites etc. and setting up hydrometeorological observatories within the basin is of urgent need for comprehensive hydrologic studies in the area.

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ABSTRACT

Water availability study, an important component of overall hydrologic study of a river is required to examine the feasibility of future planning for project purposes of water resources development works on it. The river Tawi, a major tributary of Chenab has ample water resource potential and many schemes to harness and utilise it, have been undertaken since early seventies for irrigation, flood control, hydropower and domestic purposes. The projects that were completed were planned on the basis of inadequate data and relevant informations about the river basin, needed review immediately after unprecedented flood of 1988. Therefore, on the request of Govt. of J&K water availability study of river Tawi, as part of its overall hydrologic study, has been taken up on the basis of long term up to date data collected from numerous state and central agencies as available.

With only long term available rainfall data and short duration runoff data at one site, rainfall-runoff relationships were developed for different months of a year by multiple linear regression analysis with the help of available P.C. software. With the help of these relationships, runoff series was extended to match the record length of rainfall series to develop monthly flow duration curves. In the process monthly mean areal rainfalls were calculated for three existing rainfall stations within the basin and one at outside, with due consideration of

their elevations and stations weights. Flow duration curves, so developed, indicate a particular flow is equalled or exceeded a percent of time in a month and reflect the periodical stream flow variability.

But for insufficient existing network, lack of long term discharge data, gaps and inconsistency in the available data blocks, the study could be more comprehensive. Due to these bottlnecks the results so arrived at provide for further scope of improvement. For more such future studies setting up of hydrometeorological observatories and more self recording rainguages, gauge and discharge sites etc. are of urgent needs.

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1.0 INTRODUCTION

Water availability study of a river is an important component of project hydrology, on the basis of which development of water resources of a river for various beneficial uses is thought of. Due to uneven distribution of precipitation, catchment characteristics and predominant hydrometeorological factors in the watershed, all taken as the input, there is wide degree of variation in the runoff taken as output of the hydrological system. Therefore, water availability study or assessment of river flows in different time periods and its dependability has to be carried out to conceive available water resources development projects and ascertain its success for long term operation for a particular purpose for which it was meant for.

The study aims at establishing emperical relationship of runoff with rainfall which is often the only known information in the system and work out a definite out flow pattern for the developmental strategy to follow. The river Tawi, the left bank tributary of Chenab of the Indus system and consisting catchment area of about 2168 sq km, has seen various water resources development works taken up by Govt. of J & K since last two decades. After the unprecedented flood of Sept'88 which surpassed all earlier flow records, these works now evisage review engaging attention of scientists and technochrates for a thorough hydrologic studies of the river towards which very little has been done so far. Towards this objective, this report attempts to

describe water availability study of Tawi based on about 29 years rain fall data from the existing net work.

2.0 REVIEW

Primarily because of insufficient existing network and inadequate data available, there is no comprehensive hydrological study for Tawi worth the name as yet. However, in early sixties one project report was prepared by the then CW&PC in connection with a proposed Tawi Barrage Project near Siddra village, about 10 km upstream of Jammu bridge site.

During that period there were only three rain gauge stations within the Tawi catchment. Since these few stations alone could not represent the entire catchment, data from nearby stations were also made use of. Gauge and discharge at Jammu bridge site were available from May 1955 to October 1962 only. Length of discharge data being not enough for flood frequency analysis, it was attempted to work out design flood by applying design storm of specific frequencies to unit hydrograph. Depth Duration analysis was made with sixty years storm data from 1901 to 1961 and maximum one day and two day rainfall series were subjected to frequency analysis. One day storm of 60 and 150 years return peri - ods were found to be 16.83 cm & 19.25 cm repectively. Two day storm of 60 and 150 years return periods were found to be 26.46 & 30.11 cm respectively.

To develop a Unit Hydrograph, rating curve for Tawi bridge site was drawn with available discharge records. Then with the help of this rating curve hourly gauge records from 1955 to 1962 were converted into discharges. From these generated discharges flood hydrographs were drawn and then unit hydrographs were derived. The mean unit hydrograph derived from four individual

unit hydrographs showed a peak of 1.1 lakh cusecs with peaking time 9 hours and base period 27 years. Then design unit hydrograph was developed increasing the peak by 15% to take care of hydraulic efficiency of the structure in the event of impingement of design flood. The design unit hydrograph showed a peak of 133,000 cusecs, peaking time 8 hours, base period 26 years and duration of 2 hours (as varified from S- curve).

To arrive at the design flood two hourly estimated runoff values in sequence, with reference to the unit hydrograph ordinates and estimated design floods at Siddra and Bahu Fort sites were found to be 5.14 lakh cusecs corresponding to 60 years storm and 5.92 lakh cusecs corresponding to 150 years storm respectively.

Since gauge observations were not available at the adjacent barrage site at Siddra, a relationship was developed (FIG.1) correlating gauge data available at Tawi bridge site. The equation obtained was:

$$Y = 1.7737 + 0.8269X$$

Then in the project report gauge heights at Siddra were worked out and discharges calculated assuming same discharge as that in Tawi bridge site would have been passing through Siddra site as well. The reasonability of this gauge discharge curve at Siddra was also checked by computing discharges at Siddra by Manning's equation with the suggested value of 'N' as 0.04. The variation of results from both the approaches were reported to be about 17%.FIG.2, shows the mean gauge discharge curve for Tawi river at Siddra site showing also the limit curves which afford

only 17% change of the actual value to lie beyond either of them.

The results worked out on the basis of inadequate data were deemed to be tentative and C.W. & PC felt it to be useful for project feasibility study only. It was also felt by them that the results could have been revised on the basis of cotinuous observed gauge and discharge data for more subsequent years.

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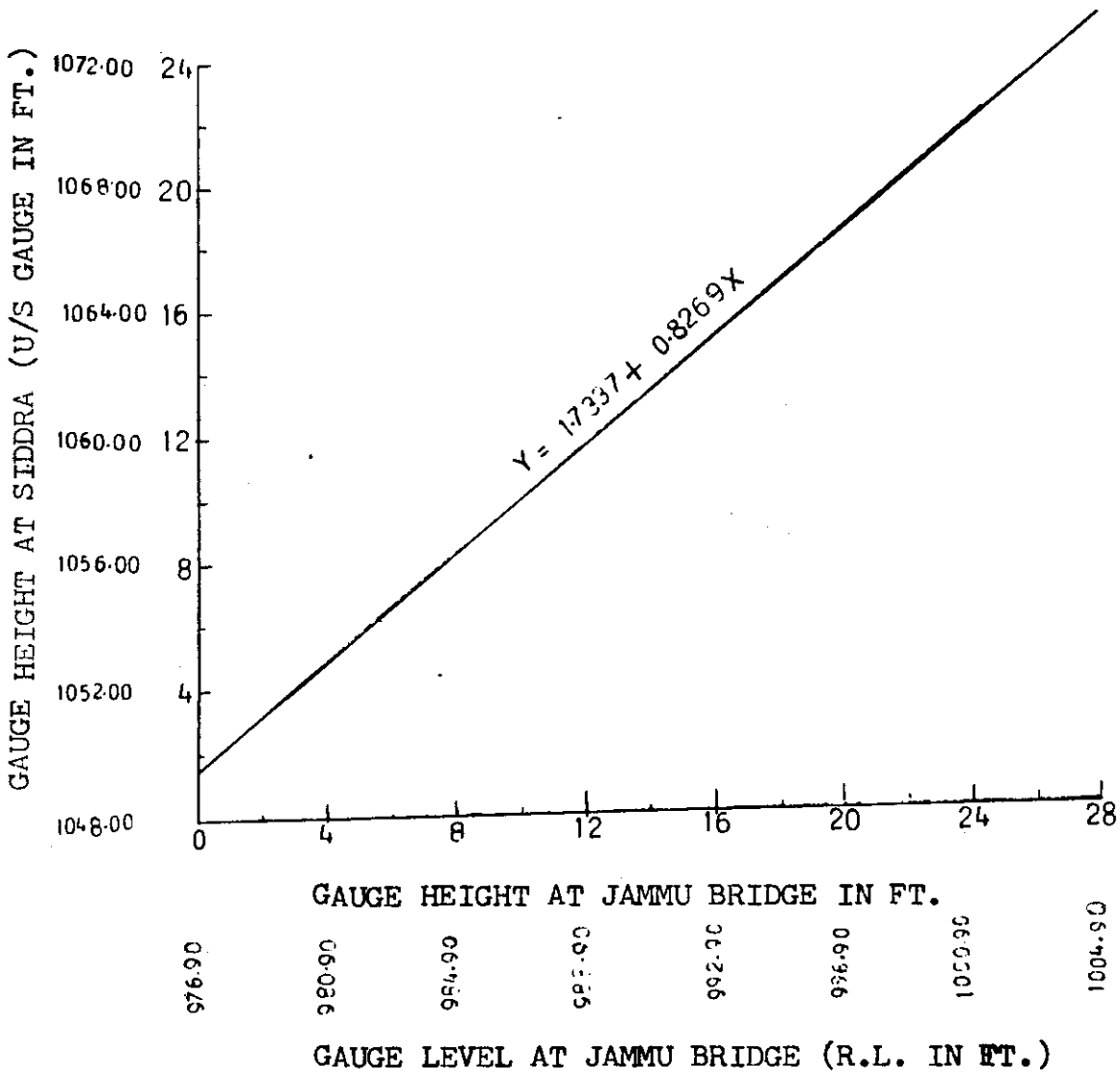

Fig. 1 : GAUGE CORRELATION BETWEEN JAMMU AT TAWI BRIDGE AND SIDDRA SITES

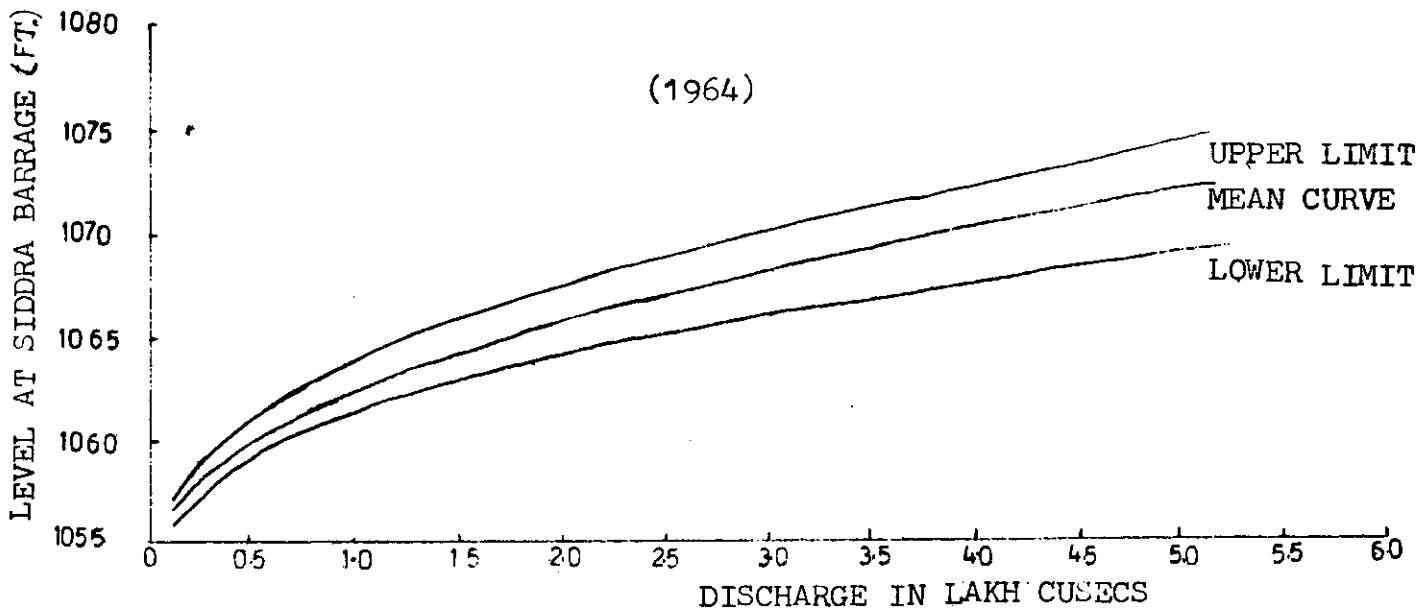

Fig. 2 : MEAN GAUGE DISCHARGE CURVE FOR TAWI RIVER AT SIDDRA WITH POSSIBLE VARIATION IN LOWER AND UPPER LIMITS

3.0 STATEMENT OF THE PROBLEM

The increasing demand of the development of Tawi water for beneficial uses of about 18 lakh population of the districts of Jammu, Udhampur and Doda calls for systematic hydrologic studies for the river for planning effective water resources development schemes. Since last two decades few minor schemes for irrigation, hydropower and domestic water supply which are of lift type have come up. Major development work like flow scheme on Tawi was also conceived in sixties but could not be taken up for want of sufficient data to carry out appropriate analysis and studies. To begin with, water availability study is one of such studies made in this report on the basis of available data with the various state and central agencies, as described in Chapter 5. This study is intended to develop **FLOW DURATION CURVES** for the different months,

With the help of Flow Duration Curves, which are developed on the basis of long term data, the percent of time a particular flow in a particular month was equalled or exceeded could be seen. Thus flows corresponding to different dependabilities of flows required for different project purposes can be worked out.In this case, however, only 13 years short period discharge data at Tawi bridge site was available. This was used to develop rainfall-runoff relationship using data of rainfall and runoff for concurrent periods. This relation was used for extending the runoff series based on long term rain fall series. The analysis of water availability is described in detail in chapter 6.

4.0 DESCRIPTION OF STUDY AREA

The Tawi river catchment is a part of Chenab basin in Western Himalayas. The basin is contained in between 32-35'to 33-5' North Latitude and 74-35'to 75-45' East Longitude (FIG.3). The catchment is of about 2168 sq. km. and falls mostly within the districts of Jammu, Udhampur and a small portion of Doda. In the present study the area upto Jammu has been considered.

4.1 GENERAL

The river catchment area is about 1885 sq. km. Number of rainfall stations within the catchment are Jammu, Udhampur, Ramnagar, Chenani, Katra, Kowpota and Barmin (Fig.4). All are non recording raingauge stations. Out of them data of about three stations viz. Jammu, Udhampur and Chenani are mostly continuous and available for the period of analysis.

4.2 TOPOGRAPHY

The upper part of the basin is covered by hard granite intrusive rocks and the lower part by loose and soft siwalic rocks. The average hieght of the basin is 2200 m varying from 400 m. to 4000 m. above mean sea level. The slope of the basin is from East to West in upper part, while North-East to South-East in the lower part. Out of total area of 1162,000 hect. in the three comprising districts of Jammu, Udhampur and Doda, forest comprises of about 31% and rest being barren,fallow grazing or cultivable waste.

4.3 CLIMATE

In the Tawi basin July and August are generally the wetest months with about 55% rainfall and November is the least rainy month with about 2-3% of total rainfall. Tawi experiences heavy

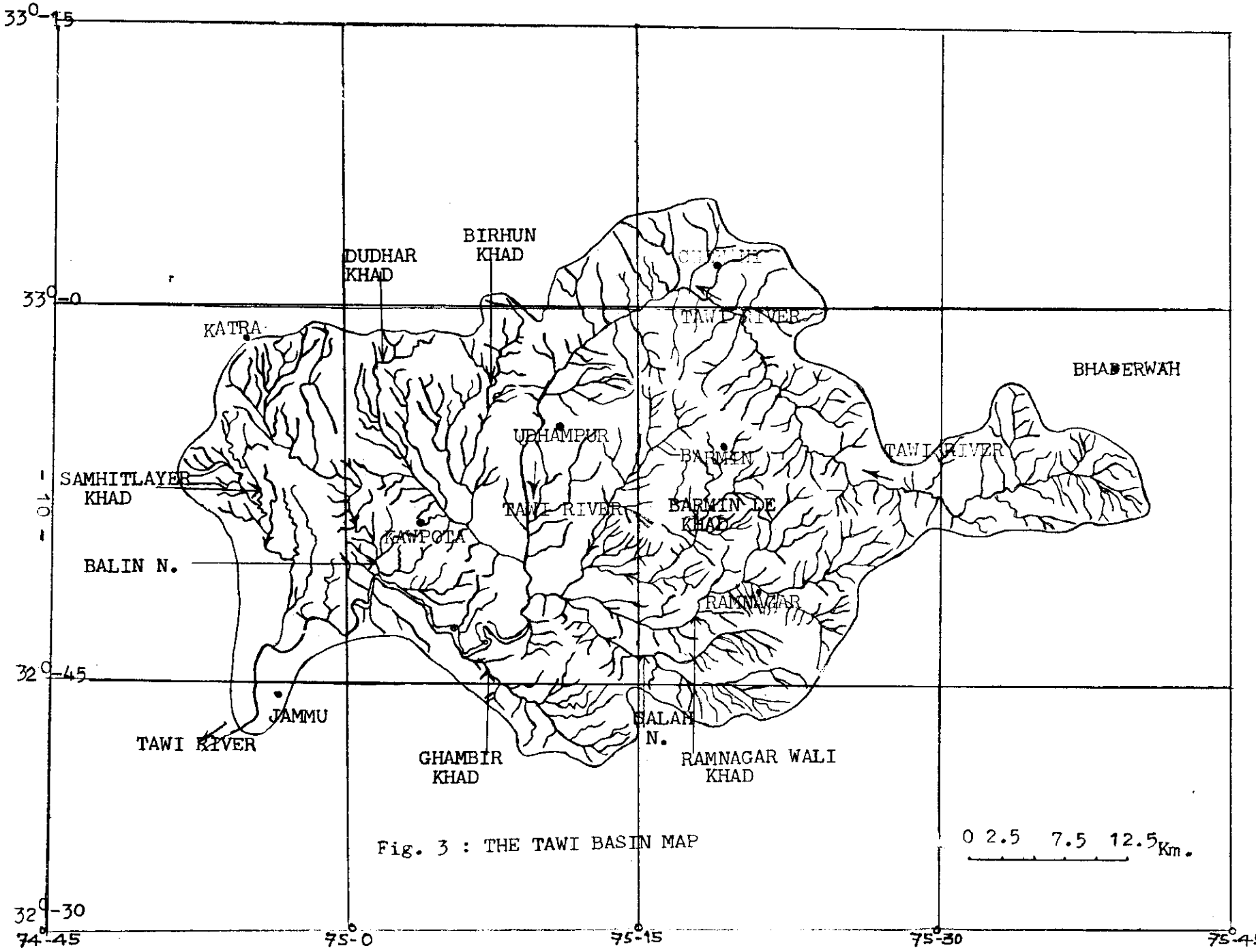

Fig. 3 : THE TAWI BASIN MAP

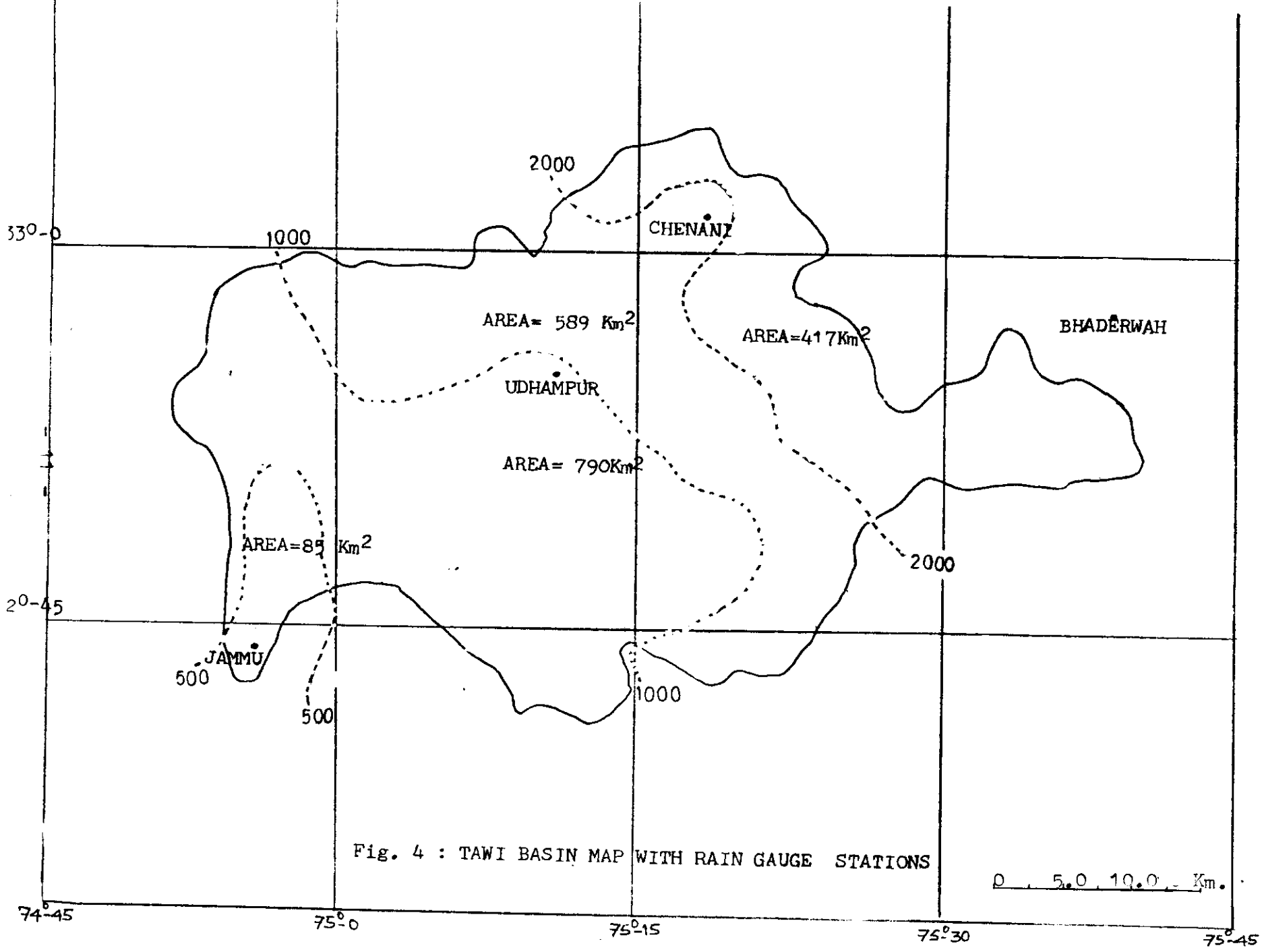

Fig. 4 : TAWI BASIN MAP WITH RAIN GAUGE STATIONS

flood in July & August. Monsoon starts from 1st July with heavy thunder showers and up to mid September. Normal annual rainfall varies from 111cm. to 150cm. within the basin.

4.4 WATER RESOURCES

The river Tawi is endowed with vast water resources with irrigation, domestic water and power potentials which are yet to be assessed in details The river of about 141 km. length up to the point it enters Pakistan, originates from Himalayan Kalikundi Glacier. its part is snow fed while the lower part is predominantly rainfed. It has nine major tributaries carrying discharge mostly in mosoon period only. The maximum discharge of tawi was 4.3 lakh cusecs in september, 1988 at Jammu and minimum discharge was about 300-400 cusecs. Low water is experienced during the month of October, November and December. But there is rise of water level in March during the early summer snow melting in Kalikundi valley.

5.0 DATA

There is no systematic network of rainfall observations in Tawi basin. However from 1951,state departments installed non recording rain gauges at places where some development works were planned. After completion of such works or giving up some of them after study due to various technical reasons,most of the observations were either discontinued or are not being properly maintained. Daily and monthly rainfall data for Jammu & Udhampur are available at Air Force stations and collected from 1961 to 1989.Monthly normal rainfalls for stations Chenani,Bhaderawah are also available for the period from 1961 to 1989 under consideration. Considering the availability of data, three stations viz Jammu, Udhampur and Chenani within Tawi basin have been taken to be representative of the area having contour elevation up to 2000m. Small portion of the basin has area under elevation of over 2000m for which the nearby rainfall station Bhaderawah is considered to be repersentative. Monthly rainfall data for these four stations for 29 years from 1961 to 1989 are collected for the study. However, there are gaps in data for stations Udhampur and Chenani. These missing recordsare estimated and gaps filled up by Normal Ratio Method.

Monthly discharge data for 12 years(1977-1989) at Jammu bridge site maintained by Central Water Commission, Jammu are also collected and made use of in the analysis. The status of availability of data is given in Annexure-1.

ANNEXURE-1

RAINFALL AND DISCHARGE DATA AVAILABLE

Rainfall Data

Station	Period
Jammu (I.A.F)	January 1961 to December 1990
Udhampur(IRR & F.C)	January 1961 to December 1972,
	1973,1974 calculated by N.R method
	1981 to 1986
Udhampur(I.A.F)	1975 to 1980, 1987 to 1989
Chenani	1961 to 1973
	1974 to 1989- calculated by N.R method
Bhaderwah	1961 to 1989
	(1961 to 1967)-IMD publication
	(1968 to 1989)-C.W.C. publication

Discharge Data

Station	Period
Jammu Bridge	1977 to 1989 from CWC publication

6.0 METHODOLOGY

Study of water availability of a river at certain location is necessary for various activities related to water resources development. The present study is carried out to see the availability of surface water at Jammu bridge site of Tawi river, where only some run off data is available. The basic steps involved in the study are:

(i) Processing and analysis of rainfall and runoff data,preparation of mean monthly areal rainfall series for representative stations.

(ii) Establishing rainfall,runoff relationship on daily, 10 daily,monthly,seasonal or annual basis depending upon the availibility of rainfall & runoff data for concurrent period of at least 10 to 15 years.

(iii) Extension of runoff series using long term rainfall data with the help of rainfall-runoff relationship.

(iv) Estimation of water availability for different probability levels

(v) Plotting Flow Duration Curve for different months.

From the available rainfall data for 29 years at four representative stations, mean monthly areal rainfall for the whole year for the basin is derived taking into consideration of station weights assigned to the respective stations at different contour elevation ranges of the basin.

With the short period runoff data (converted to depth unit) at Jammu site rainfall-runoff relationship of the form $RO_i=a+bP_i+cP_{i-1}$ is developed by multiple linear regression.

Where ROi= Runoff of current month

Pi= Mean monthly areal rainfall of current month.

Pi-1= Mean monthly areal rainfall of preceeding month

'a'is a constant and b, c are Regression co-efficients evaluated from known values of ROi and Pi by multiple linear regression.

The constant 'a'is normally negative indicating the initial loss and the values of b & c are less than unity.

From the regretted equation, the short period runoff data is extended to the earlier period based on long term rainfall data and runoff series is prepared. From this runoff series of each month under consideration,percent probability'p' of a flow magnitude equalled or exceeded is worked out as follows:-

$$P = (m/N+1)*100 \quad \text{----------(6.1)}$$

Where m = rank of runoff values arranged in decending order with first rank assigned to highest value

n = No of years of record

This gives availability of discharges for various dependability levels as may be required for various project purposes.

Then the plot of discharge 'RO'against 'P' for each month is made which gives a set of Flow Duration Curves. Flow duration Curve is a popular method of studying the stream flow variability and indicates a particular flow is equalled or exceeded a percent of time in a month. This is also known as discharge frequency curve.

7.0 APPLICATION AND RESULT

Rainfall data of four raingauge stations in the Tawi catchment i.e. Jammu representing portion of basin area of up to 500 m elevation, Udhampur representing area between elevation 500-1000m, Chenani representing area of 1000-2000m elevation and Bhaderawah representing basin area of elevation more than 2000m,for the period from 1961 to 1989 are used for analysis. The gaps in data blocks for Chenani for the periods 1961,1962 & from 1979 to 1989 are filled up by Normal Ratio Method:-

$$Pa = \frac{N(P1/N1 + P2/N2 + P3/N3)}{n} \qquad \text{----- (7.1)}$$

where

Pa = monthly rainfall at station A

Na = normal rainfall at station A

n = No. of surrounding stations considered

N1, N2, N3 = normal rainfall of stations 1, 2 & 3 respectively

P1, P2, P3 = monthly rainfall of stations 1, 2 & 3 respectively

The areas repersented by different stations are marked in Fig.4and stations weights are calculated as proportion of the area represented by a station to the total basin area. The stations weights are 0.0447,0.4186,0.312 and 0.221 for Jammu, Udhampur, Chenani & Bhadherwah respectively. With these station weights Mean Areal Rainfalls for each month from February to December for each year are calculated.

With Mean Monthly Areal Rainfall known, the short period

runoff data from 1977 to 1988 are used to carry out multiple Linear Regression as in chapter 6. The computer program 'MULTI.FOR'is executed in PC - 386 and values of constant a, and coefficients b & c are found out for the months February to December (Table 7.1).After the evaluation of a, b & c eleven rainfall- runoff relationships for the months Feb. to Dec. are obtained. With the help of these relationships monthly runoff series for eleven months is extended from 1961 to 1976 and also for the year 1989 to make the series complete.

Now to develop Flow Duration Curves runoff series is arranged in descending order,assigned ranks 1,2,3 to 29 accordingly and percentage probability 'P' is calculated from equation 6.1. Then Flow Duration Curves for each of the eleven months under consideration are drawn plotting runoff versus percent probability shown in Fig.5 to Fig.15.

Availability of dependable flows in different months are presented in TABLE 7.2.

TABLE : 7.1

AVAILABILITY OF DEPENDABLE FLOWS

AND COMPUTED COEFFICIENTS

MONTH	CORRELATION COEFF. r	COEFF. OF DETERMINATION r^2	REGRESSION COEFF. a	b	c
Feb.	0.246	0.061	29.49	0.19	0.05
Mar.	0.80	0.646	25.81	0.71	-0.63
Apr.	0.859	0.738	-25.05	0.56	0.15
May	0.941	0.886	-8.34	0.54	0.24
Jun.	0.599	0.359	2.42	0.30	0.18
Jul.	0.759	0.575	-133.6	1.03	0.38
Aug.	0.569	0.324	32.58	0.83	0.12
Sep.	0.930	0.865	-10.16	0.75	0.12
Oct.	0.788	0.620	10.18	0.42	0.09
Nov.	0.574	0.330	7.96	0.15	0.08
Dec.	0.699	0.489	3.59	0.23	0.15

TABLE : 7.2

MONTHLY RUN-OFF AND PERCENT PROBABILITY FROM FEB. TO DEC.

	Water available in cumec.									
% Proba-bility	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
60	34.52	26.47	21.00	22.00	22.65	102.00	168.30	46.47	16.61	8.00	10.00
70	31.33	17.72	12.86	16.00	20.00	95.20	153.63	35.39	12.89	7.85	5.56
80	21.00	12.39	6.27	11.00	16.81	61.87	127.87	26.00	10.91	6.56	3.18
90	17.00	2.55	1.74	7.90	9.27	51.75	77.04	17.00	7.00	6.21	2.54

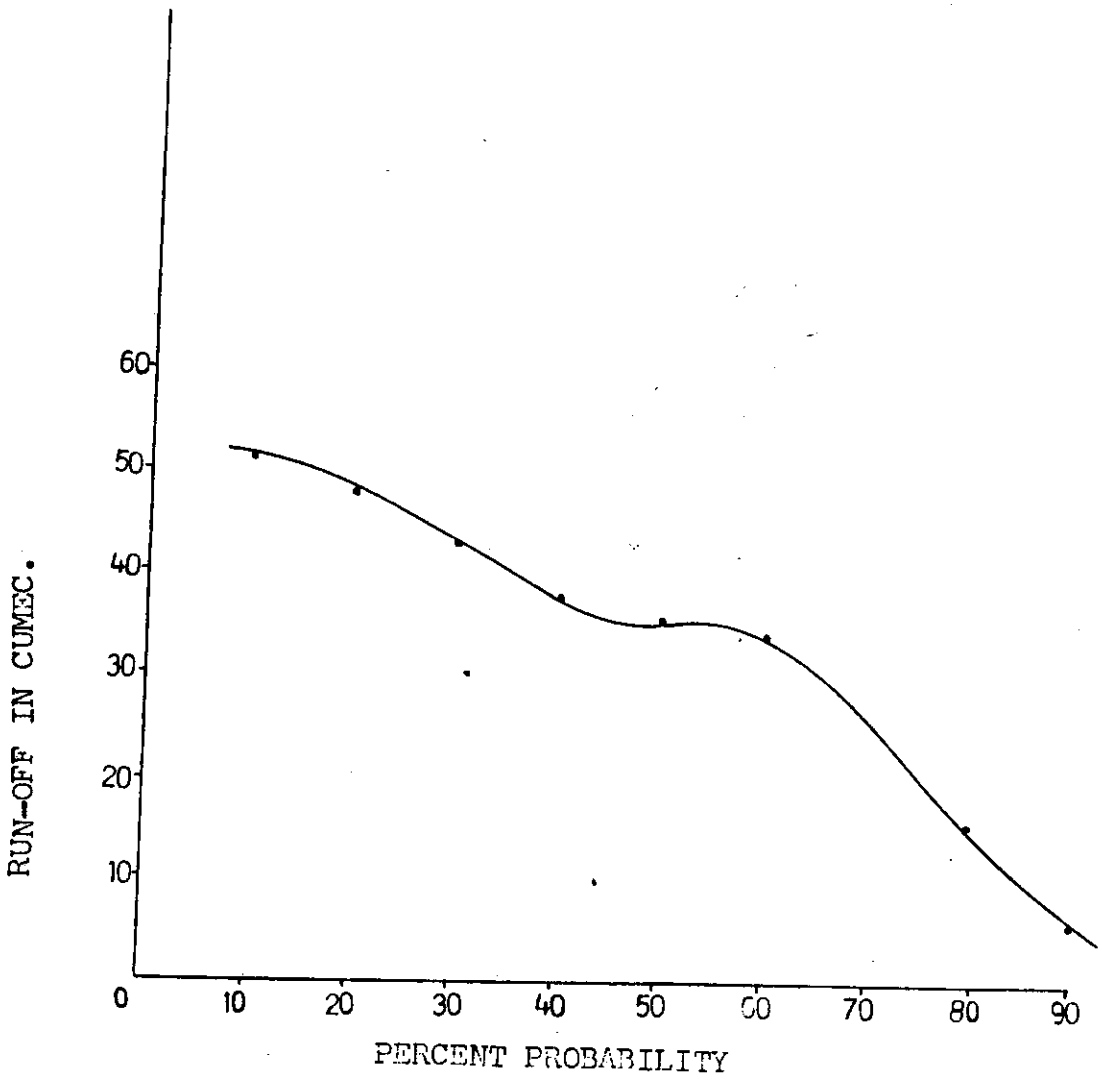

Fig. 5 : FLOW DURATION CURVE FOR FEBRUARY

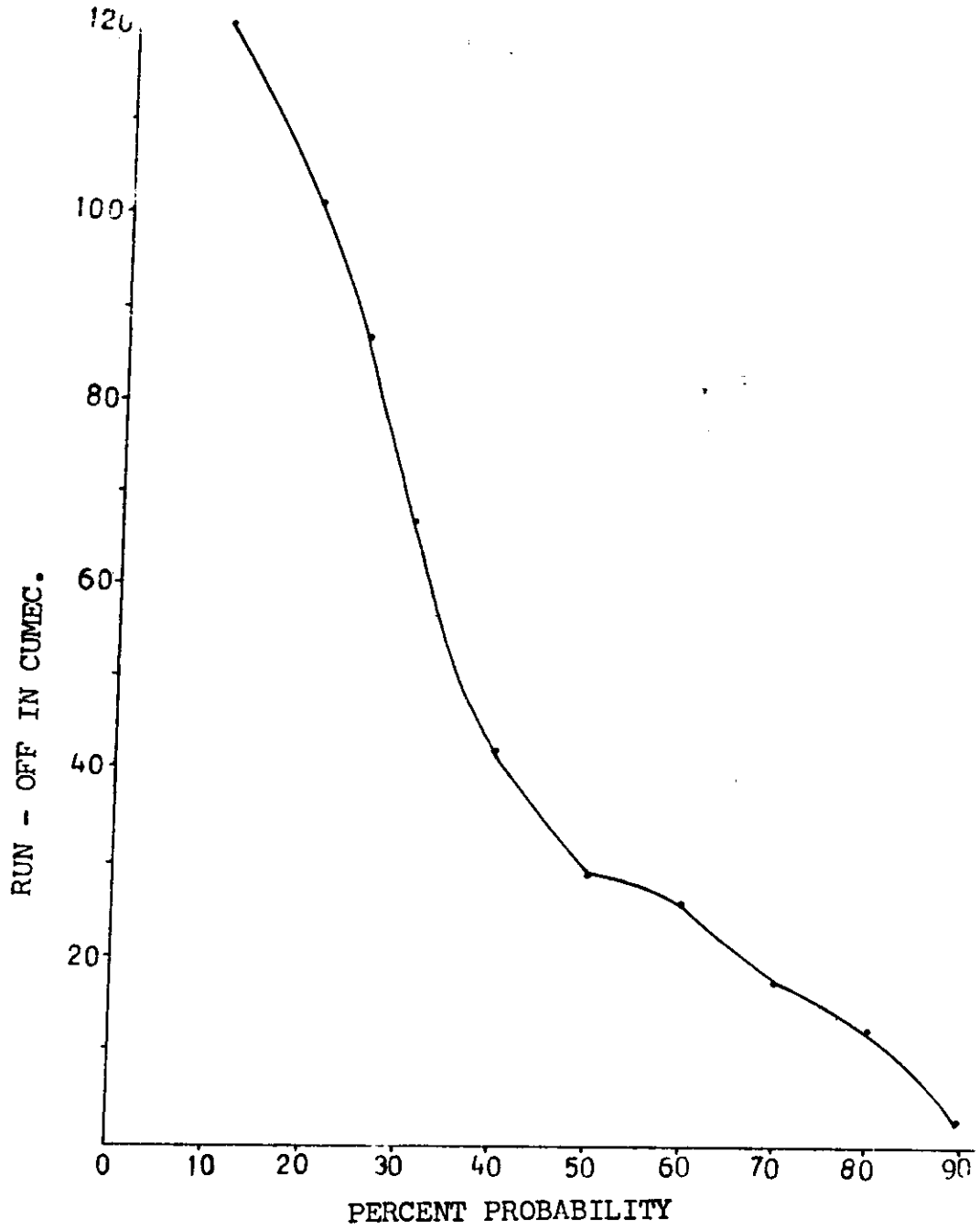

Fig. 6 : FLOW DURATION CURVE FOR MARCH

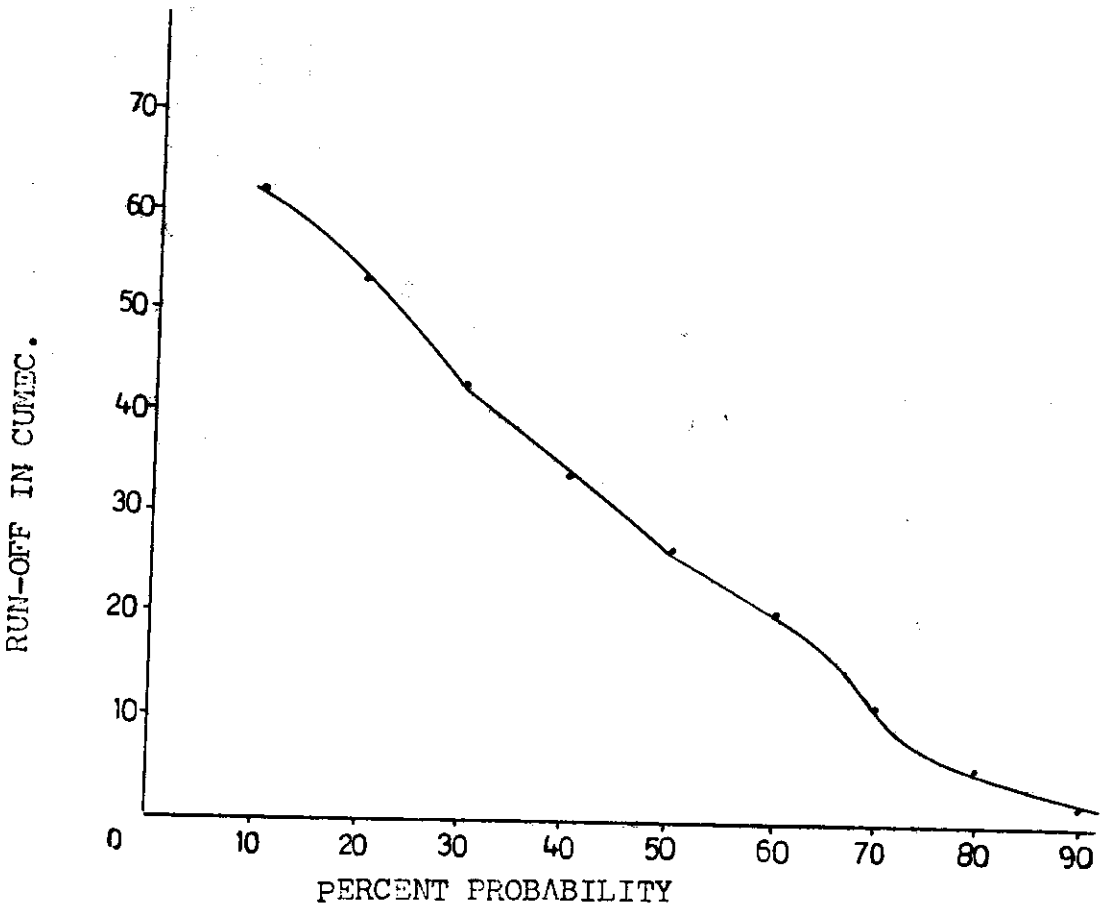

Fig. 7 : FLOW DURATION CURVE FOR APRIL

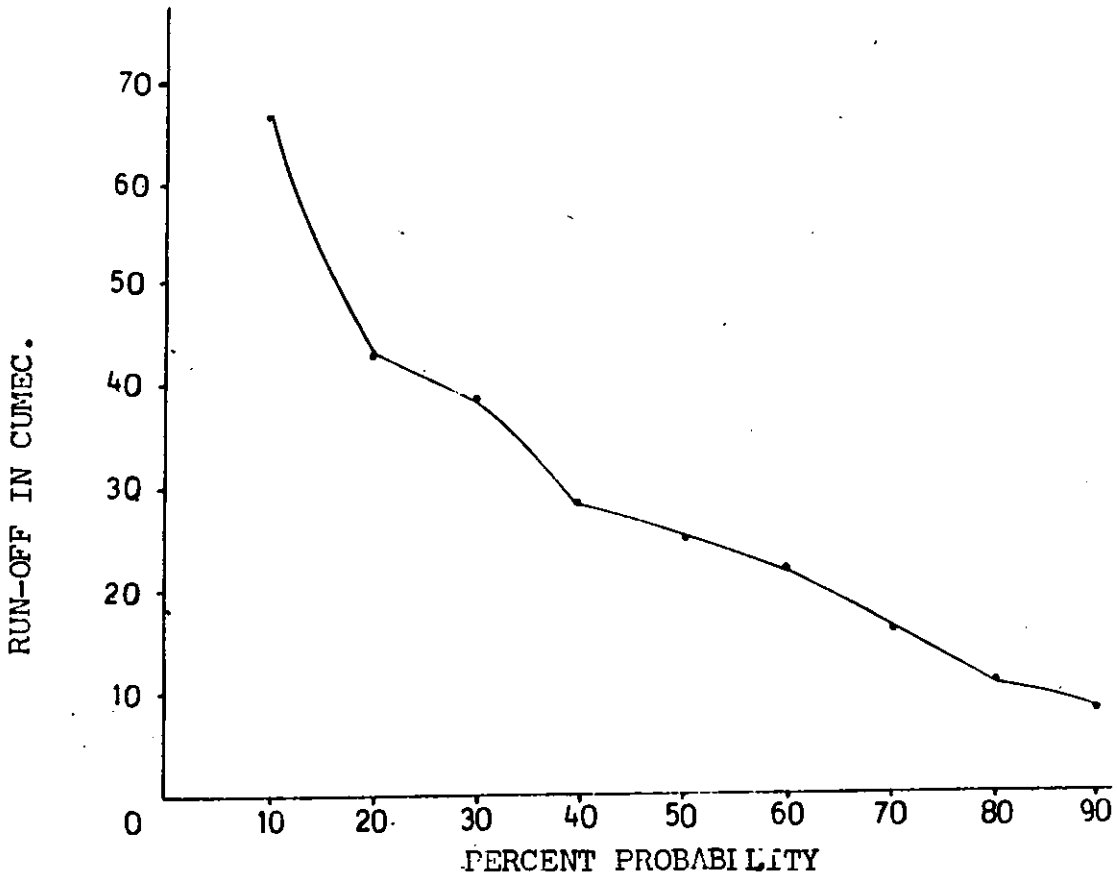

Fig. 8 : FLOW DURATION CURVE FOR MAY

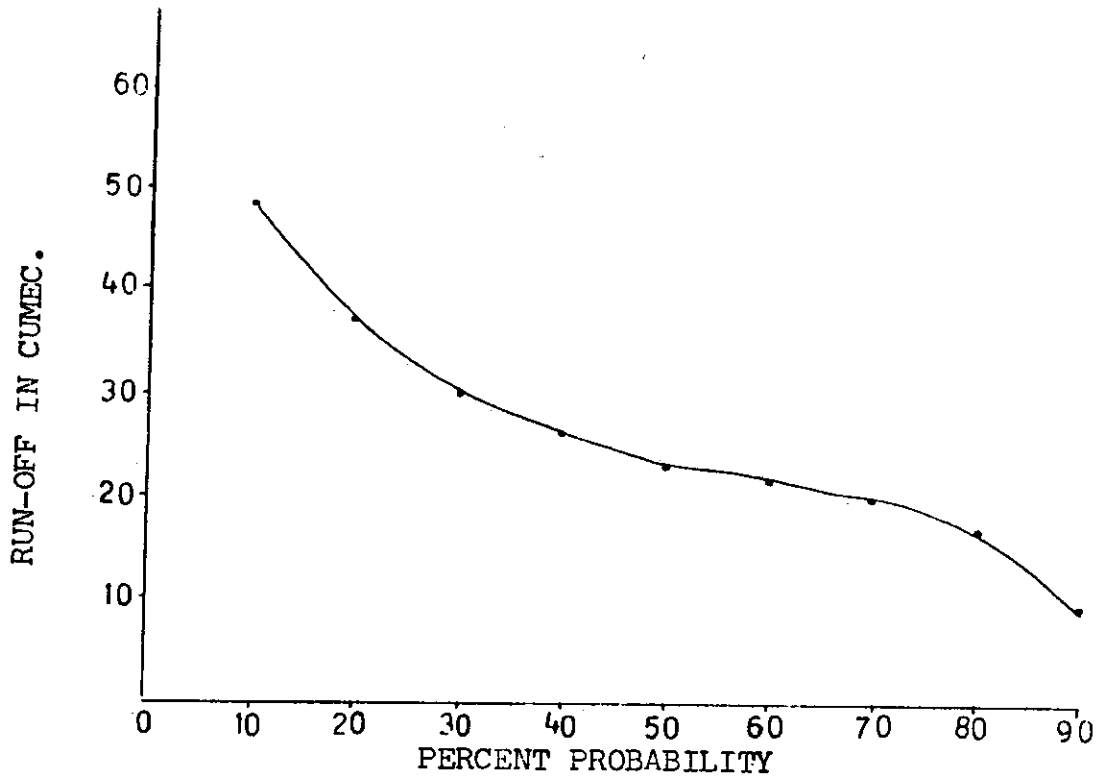

Fig. 9 : FLOW DURATION CURVE FOR JUNE

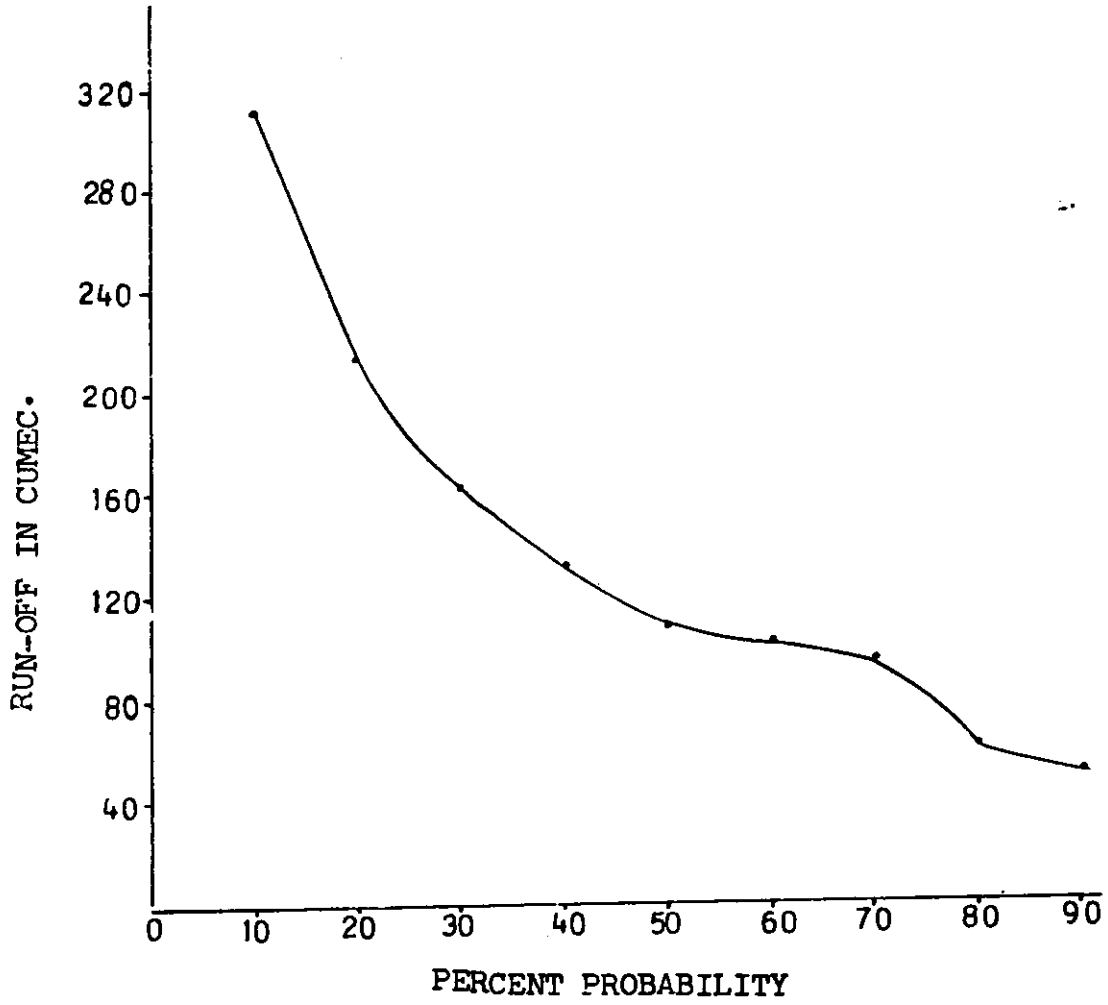

Fig. 10 : FLOW DURATION CURVE FOR JULY

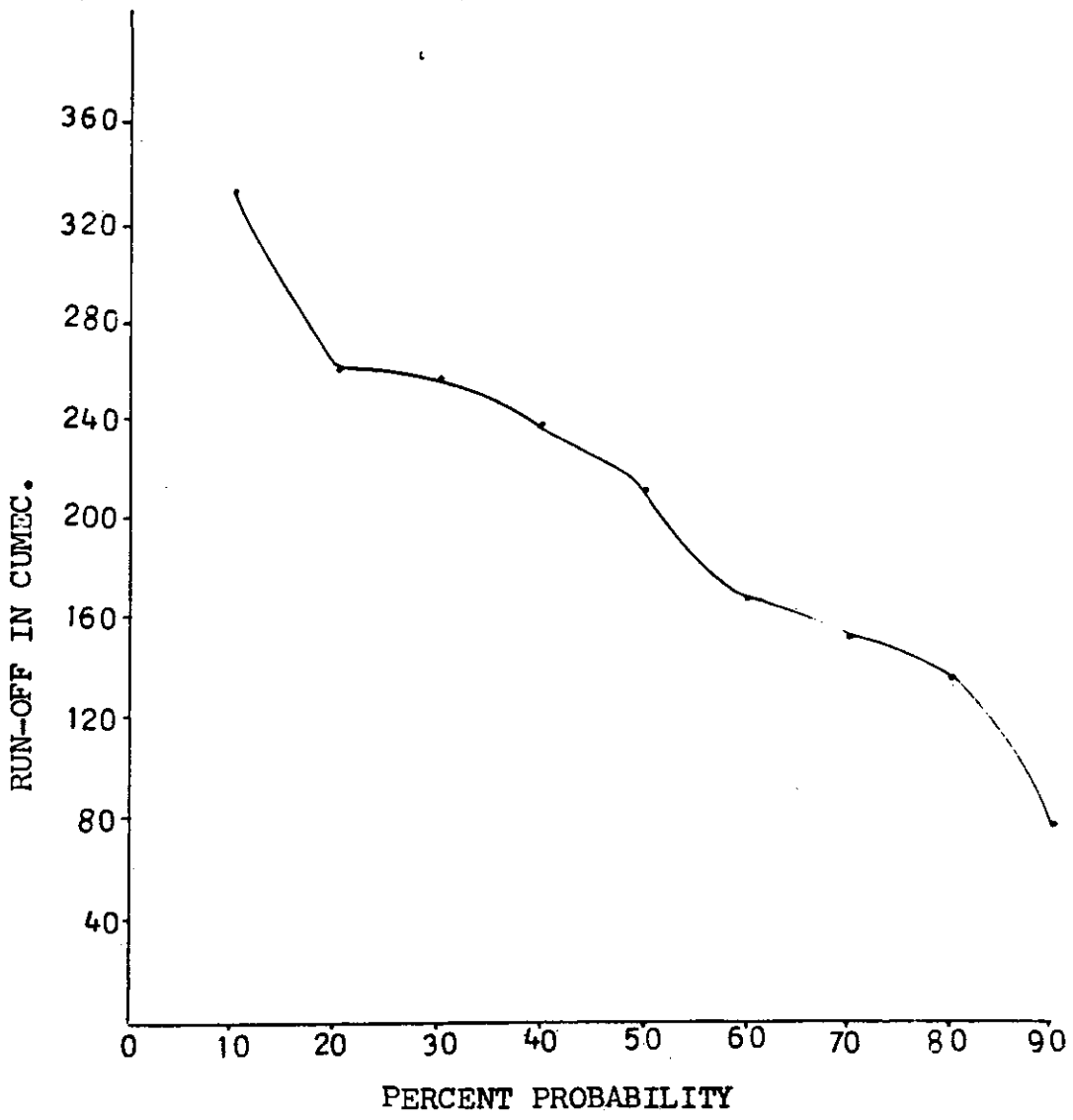

Fig. 11 : FLOW DURATION CURVE FOR AUGUST

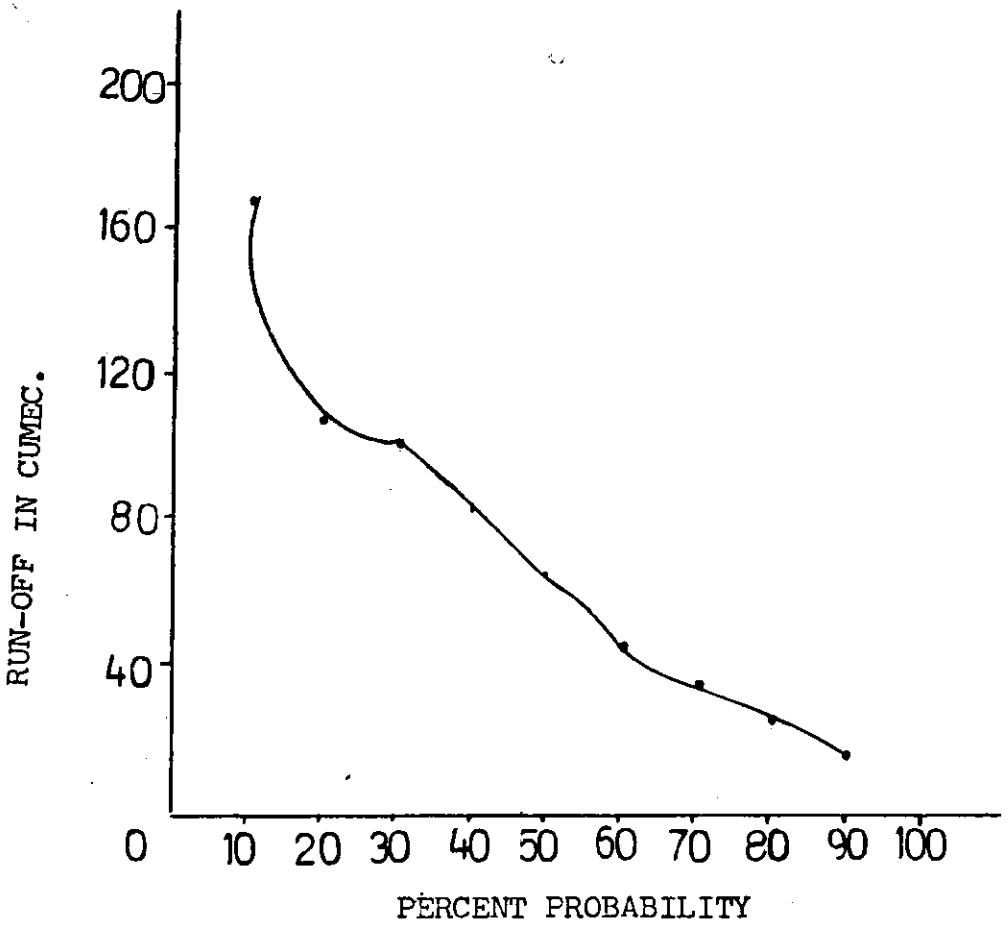

Fig. 12 : FLOW DURATION CURVE FOR SEPTEMBER

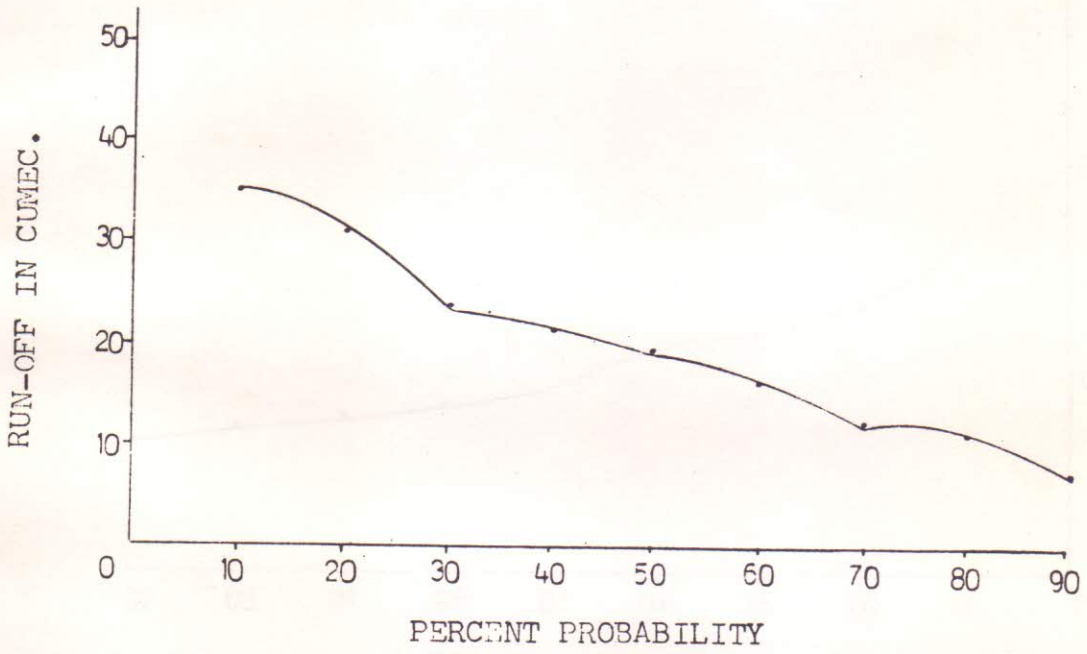

Fig. 13 : FLOW DURATION CURVE FOR OCTOBER

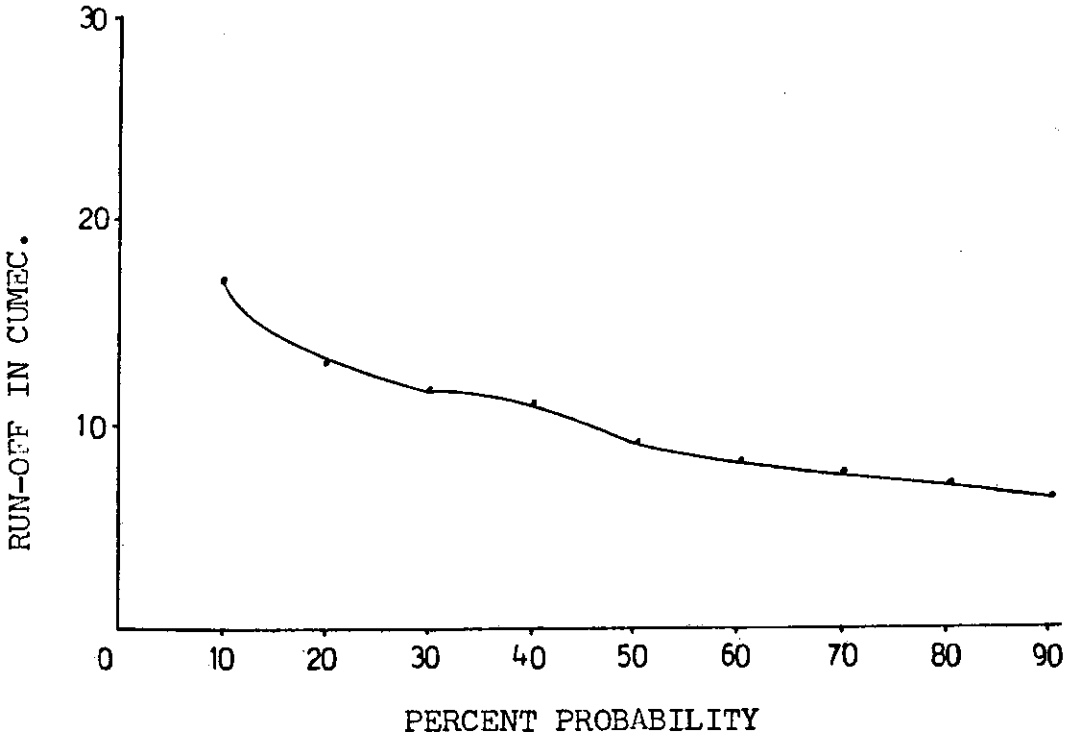

Fig. 14 : FLOW DURATION CURVE FOR NOVEMBER

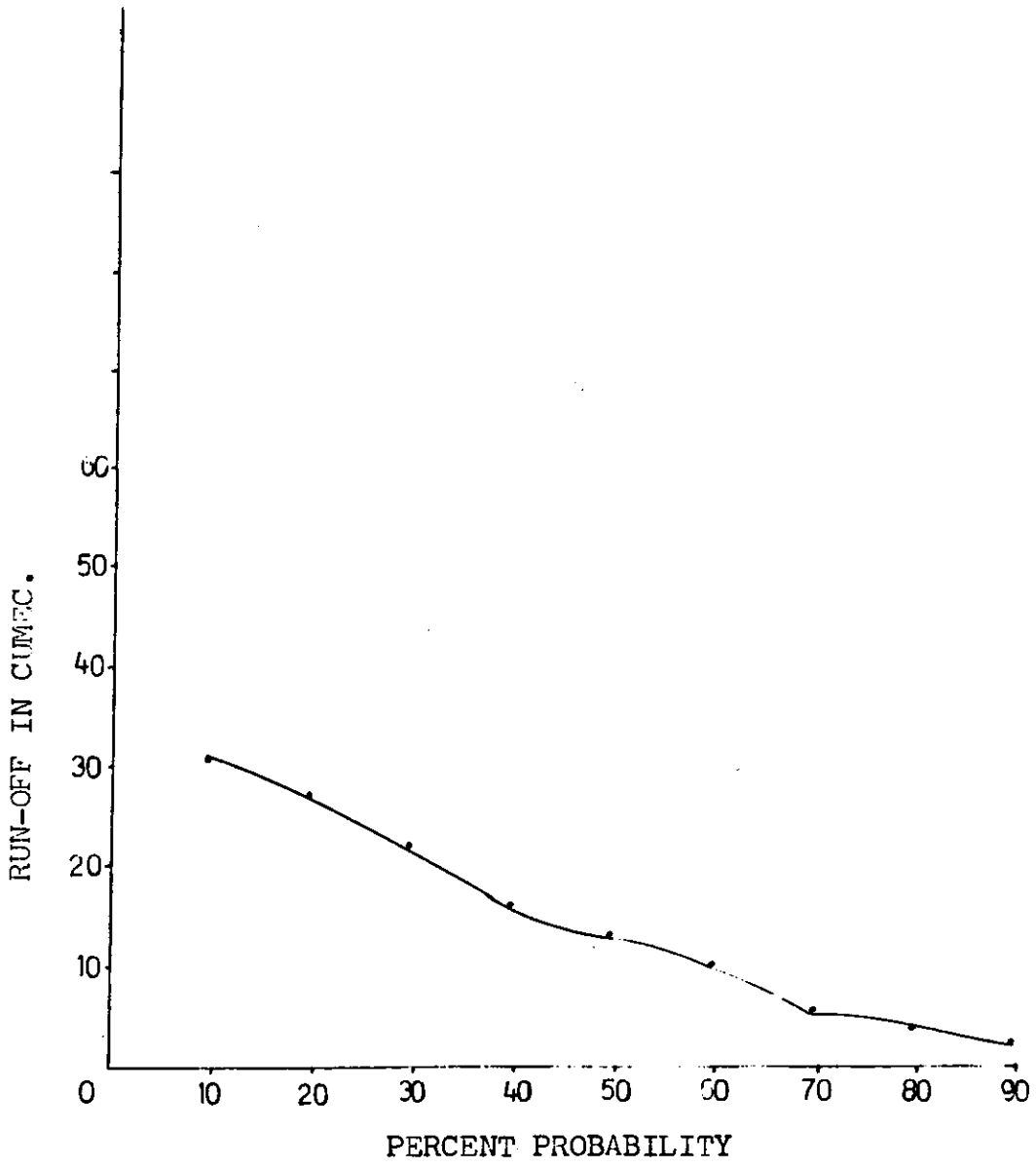

Fig. 15 : FLOW DURATION CURVE FOR DECEMBER

8.0 CONCLUDING REMARKS

Comprehensive hydrologic modelling for Tawi is yet to be seen, because informations about the catchment and river characteristics to estimate various model parameters are not available. Like in most other cases, long period rainfall data,that too with many gaps, is the only available information for Tawi. The existing network is inadequate with only 3 ordinary rain gauges in the basin. With the basin elevation ranging from 400m to 4000m in a catchment area of 2168sq.km a systematic network design with installation of more self Recording Rain Gauges is of urgent need. Discharge data for a short period of 13 years at Jammu site is only available and the Rainfall-Runoff Relationships had to be developed extending the runoff series for another 16 years. Moreover, missing gaps in rainfall series for Chenani is more than 56% Though the gaps have been filled up with available technique described in chapter-7, the applicability of the technique in such cases exceeds the acceptable limit.

Rainfall-Runoff relationship as derived and described in chapter-7, were also tried from a Bivariate Linear relationship of the form $Yi = a.Xi^{b}$, but plot of the relation and the results were found to be unsatisfactory.

Consistency of rainfall data was checked by Double Mass Curve Analysis. Inconsistancy was observed beyond the concurrent period of availability of actual runoff data, and relationships could not be improved further even if corrections would have been applied. Coefficients of determination as shown in the Table 7.1 are less than 90% in many cases which indicates the relationships do not explain the variability of rainfall and runoff

satisfactorily.This may be due to inadequate existing network, missing data gaps, lack of hydrometeorological similarity within the influence area of a rain gauge or interbasin distribution of total precipitation by subsurface flow.

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