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FORECASTING OF MONSOON RUNOFF USING DATA FROM SPECIFIC BASINS

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The water resources planning and operation activities are dependent mainly on the monsoon behaviour that being a crucial period contributing 80-90% of annual rainfall and runoff. The forecasting of monsoon runoff based upon the available runoff data upto the end of June, July, August and September coule be an important aspect for drought management and in planning and operation of surface water reservoirs. The correct and timely assessment of water resources before the beginning of their utilization period say before Rabi is a must.

For forecasting of monsoon rainfall and runoff, a methodlology based on simple regression relationships was earlier developed and was applied to the data of Mahanadi river basin at Hirakud. The methodology gave very encouraging results in forecasting the monsoon rainfall and runoff and in identifying whether the current year is going to be below normal or above normal. In order to examine the applicability of the technique for other reservoirs and rivers located in different agroclimatic regions of the country, the methodology has been applied to the runoff data of following reservoirs/river sites in the present study; (i) Bhima at Dhond, (ii) Bhima at Wodakabal, (iii) Bhima at Narsingpur,(iv)Bhima at Takali, (v) Bhima at Yadgir, (vi) Tungbhadra at Haralahalli (vii) Tungbhadra at T Ramapuram, (viii) Koyna reservoir, (ix) Gandhisagar reservoir, (x) Mahanadi at Hirakud

(xi) Chaliyar river, (xii) Kanhirpuzha river, (xiii) Koodathai river, (xiv) Punnarpuzha river, (xv) Gobindsagar at Bhakra, (xvi) Sabarmati at Dharoi, (xvii) Pong reservoir, (xviii) Malaprabha, and (xix) Jayakwadi reservoir. The catchment areas v ry from 71.77 Km^2 to 83400 Km^2 and the length of data vary from 10 years to 41 years.

The report gives the efficiency in percentage in estimation and forecasting of monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September. The report also gives the results of these relationships in identifying whether the current year is going to be below normal or above normal from runoff point of view.

1.0 INTRODUCTION

The water resources planning and operation activities are dependent mainly on the monsoon behaviour that being a crucial period contributing 80-90% of annual rainfall and runoff. The forecasting of monsoon runoff based upon the available runoff data upto the end of June, July, August and September could be an important aspect for drought management and in planning and operation of surface water reservoirs. The correct and timely assessment of water resources before the beginning of their utilization period i.e. before Rabi is a must.

IMD is forecasting rainfall in different categories of time spells. The short term forecast is done generally 48 hours in advance. It covers generally the weather over a particular area. The rainfall forecasts for one week are included in weekly bulletins and these cover various sub divisions. The forecasts upto days are generally based on the behaviour of weather systems during the past week and subsequent movement as observed on day to day synoptic charts prepared in forecasting offices.

The long term predictions in India are based on statistical associations and meteorological tele connections. The best known work in this area is that of Sir Gilbert Walker in the early years of the century. Jagannathan (1960), Rao (1964, 1972) and Das (1986) give excellent review of seasonal forecasting of rainfall in India.

In the direction of forecasting monsoon runoff not much work has been done in India. Earlier Goel (1986) made an attempt to forecast the monsoon rainfall and runoff for river Mahanadi at Hirakud based on simple regression relationships. The runoff data (1946-82) and rainfall data (1901-79) were used.

The results based on the analysis of above data indicate that for Hirakud.

(i) the efficiencies of monsoon runoff forecasts are 71%, 81% and 98% at the end of July, August and September respectively.

(ii) the efficiencies in identifying whether the current year is going to be below normal or above normal are 71%, 88%, 94% and 100% at the end of June, July, August and September respectively on the basis of 1968-82 runoff data.

(iii) the efficiencies of forecasting monsoon rainfall are 60%, 80% and 97% at the end of July, August and September respectively on the basis of 1966-79 rainfall data, and

(iv) the efficiencies of regression relationships in identifying whether the current year is going to be below normal or above normal are 62%, 62%, 63% and 93% at the end of June, July, August and September respectively on the basis of 1951-79 data and 64%, 79%, 93% and 93% on the basis of 1968-79 rainfall

data.

Since these results are based on the analysis of only one site data, it was felt appropriate to study the effectiveness of the technique for other reservoirs/rivers located in different agro climatic regions of the country also and to restrict the scope of the report for monsoon runoff forecasting only.

2.0 STATEMENT OF THE PROBLEM

For forecasting the monsoon rainfall and runoff a methodology based on simple regression relationships, was earlier developed by the author and was applied to the data of Mahanadi river basin at Hirakud. The methodology gave very encouraging results in forecasting the monsoon rainfall and runoff and in identifying whether the current year is going to be below normal or above normal. In order to examin the applicability of the technique for other reservoirs and rivers located in different agro climatic regions of the country the objectivesof the study are:

(i) To forecast the monsoon runoff on the basis of total runoff upto the end of (a) June, (b) July, (c) August and (d) September using simple regression relationships for reservoirs/rivers located in different agroclimatic regions of the country.

(ii) To judge the efficiency of these regression relationships in forecasting the magnitude of runoff for various reservoirs/rivers.

(iii) To study the effectiveness of these relationships in judging whether the current year is going to be below normal or above normal from runoff point of view.

3.0 METHODOLOGY

The methodology, developed earlier by Goel (1986), for forecasting of monsoon rainfall and runoff has been adopted for this study also. The methodology for forecasting of monsoon runoff include the following steps

(a) Plot the graph between monsoon runoff v/s total runoff upto the end of

(i) June, (ii) July, (iii) August and (iv) September

The graph may be linear or may be nonlnear. If the graph is linear then develop the relationship in original domain otherwise in log domain.

(b) Devide the data in two parts i.e. one for calibration and other for verification of forecast.

(c) Develop the following relationships

$$Y = a_1 + b_1 X_1 \quad \ldots(1)$$

$$Y = a_2 + b_2 X_2 \quad \ldots(2)$$

$$Y = a_3 + b_3 X_3 \quad \ldots(3)$$

$$Y = a_4 + b_4 X_4 \quad \ldots(4)$$

where,

Y is monsoon runoff,

X_1 is the total runoff upto the end of June,

X_2 is the total runoff upto the end of July,

X_3 is the total runoff upto the end of August,

X_4 is the total runoff upto the end of September

and a_1, b_1, a_2, b_2 etc. are coefficients which are estimated by least squares approach.

The equations to be used for the estimation of a and b are

$$b = \frac{\sum_{i=1}^{N} X_i Y_i - \sum_{i=1}^{N} X_i \quad Y_i/N}{\sum_{i=1}^{N} X_i^2 \quad [(\sum_{i=1}^{N} X_i)^2/N)} \qquad \ldots(5)$$

$$a = \bar{Y} - b \bar{X} \qquad \ldots(6)$$

where,

N is number of years of data,

Y_i is monsoon runoff of i^{th} year,

X_i is runoff data (X_1 or X_2 or X_3 or X_4) of i^{th} year.

In case of non-linear relationships Y_i and X_i are logarithmic of respective runoff.

(d) Judge the fitting of regression relationship in calibration. Efficiency of regression relationships (η) has been used as the criteria to judge the fitting of regression relationship. Efficiency (η) is computed as follows:

$$\eta = \frac{F_m}{F_o} \times 100\% \qquad \ldots(7)$$

where,

η is the efficiency of regression relationship,

F_m, is variance explained by the regression relationship or model variance;

F_m = initial variance - residual variance

F_o = initial variance

Initial variance = $\Sigma(Y_i - \bar{Y})^2$ ...(8)

Residual variance = $\Sigma(Y_i - Y_c)^2$ ...(9)

Y_c = Computed monsoon runoff

(e) Forecast the monsoon runoff after updating the paramter. The forecasting is done as follows:

Develop the relationship for n year (calibration run period using equation (1) to (4). Forecast for (n+1)th year is given by these relationships. To give forecast for (n+2)th year, develop the relationships using (n+1) year data and so on.

(f) Judge the efficiency of regression relationship given by equation (7) for the data for verification of forecast.

(g) Judge the effectiveness of the regression relationships in identifying whether the current year is going to be a below normal year or above normal year.

4.0 DESCRIPTION OF STUDY AREAS

The methodology of monsoon runoff forecasting has been applied to the runoff data of following 19 reservoirs/ rivers:

Sl.No.	Name of reservoir/river site	Catchment area(km^2)	River basin
1.	Bhima at Dhond	11660	Krishna
2.	Bhima at Wodakabal	12092	"
3.	Bhima at Narsingpur	22856	"
4.	Bhima at Takali	33916	"
5.	Bhima at Yadgir	69863	"
6.	Tungbhadra at Haralhalli	14582	"
7.	Tungbhadra at T. Ramapuram	23500	"
8.	Koyna Reservoir	891	"
9.	Gandhi Sagar Reservoir	23140	Chambal
10.	Mahanadi at Hirakud	83400	Mahanadi
11.	Chaliyar	448.15	Chaliyar
12.	Kanhirpuzha	71.77	"
13.	Kudathai	121.25	"
14.	Punnarpuzha	468.9	"
15.	Gobind Sagar at Bhakra	56876	Sutlej
16.	Sabarmati at Dharoi	5540	Sabarmati
17.	Pong reservoir	12562	Beas
18.	Malprabha dam	2176	Krishna
19.	Jayakwadi	21750	Godavari

The description of Krishna, Chambal, Mahanadi, Chaliyar, Sutlej, Sabarmati, Beas and Godavari river basins is given in subsequent sections.

4.1 The Krishna River Basin

The river Krishna rises near Mahabalesh warat 1360 m elevation from a water spring. The place is held in esteem. After flowing 1400 km it joins the bay of Bengal. Its drainage area is 258948 km of which 26.8% lies in Maharashtra, 43.8% in Karnataka and 29.4% in Andhra. The river passes through a narrow gorge from Sangameswaram, , just below the confluence of the Tungbhadra with Krishna, to Nagarjunasagar a distance of 130km. It is in this reach that two large reservoirs, the Sreesailam and the Nagarjunasagar are located.

The Chief tributaries are the Koyna, the Ghataprabha, the Malaprabha, the Tungbhadra, the Musi and the Muneru. The maximum discharge of the Krishna river is 33810 cumecs and the minimum is less than 3 cumecs. The total annual mean runoff is 57764 million cu.m.

The gross sown area is 16 million ha forming 80% the cultivable area. The percentage of irrigation is 21. Soils consist of black, red, laterite, alluvium, mixed soils and saline and alkaline soils, Rao (1979).

In most of the areas of the basin, the ground water is to be tapped from open wells. In Krishna basin good water occurs in the flood plains of the Muneru, The wyra, and the Krishna. In areas underlain by crystalline rocks like granite, the quality of water is unsuitable for domestic purposes, due to the presence of fluorides in excess of the prescribed safe limits. The basin map of Krishna basin

is given in Figure 1.

4.2 The Chambal River Basin

The Chambal rises in Vindhya ranges and flows for 965m before it joins the Yamuna. It flows through the flat fertile Malwa Plateau and then enters a gorge at Chaurasingarh. The gorge is 96 km long and stretches upto Kotah city. The river runs for another 34 km flowing through plains. The total drop between the source and outfall is 766 m and of this drop 128 km is in the gorge itself. Taking advantage of this three dams have been constructed at Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar, where 386 MW of power is generated. As the river flows much below the banks and due to poor rainfall, sever erosion has occurred over centuries and numerous deep ravines have been formed in Chambal Valley.

4.3 The Mahanadi River Basin

The Mahanadi basin lies between North latitudes 19^{o} 21' and 23^{o} 35' and east longitudes 80^{o} 30' and 84^{o} 50' (Figure 2). The basin extends over an area of 141592 sq.km. It is nearly 4.3% of the geographical area of the country.

Lying in the north-east of the Deccan Plateau, the basin covers large areas in the states of Madhya Pradesh and Orissa and only small areas in Bihar and Maharastra. The state wise distribution of the drainage basin of the river is given below:

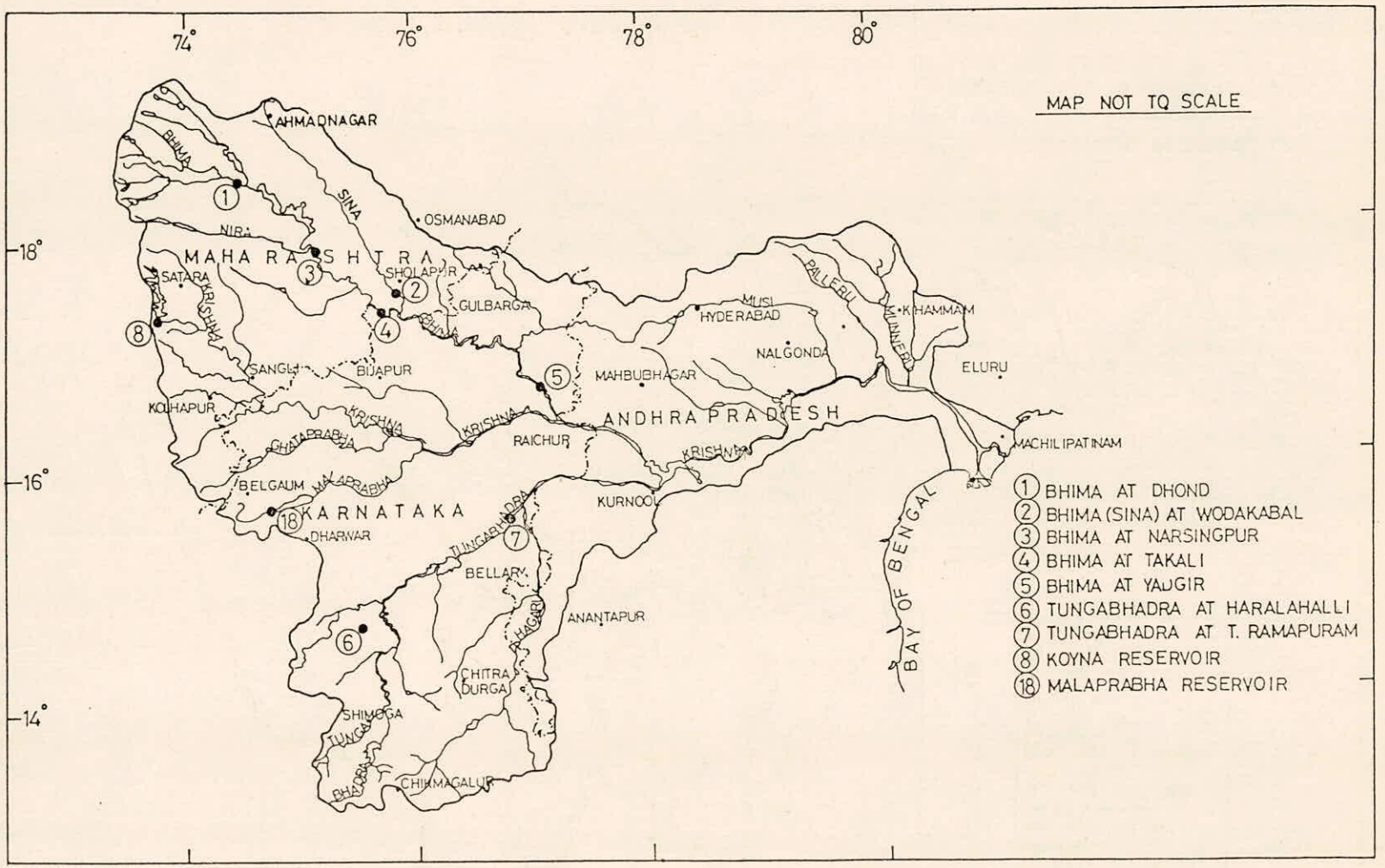
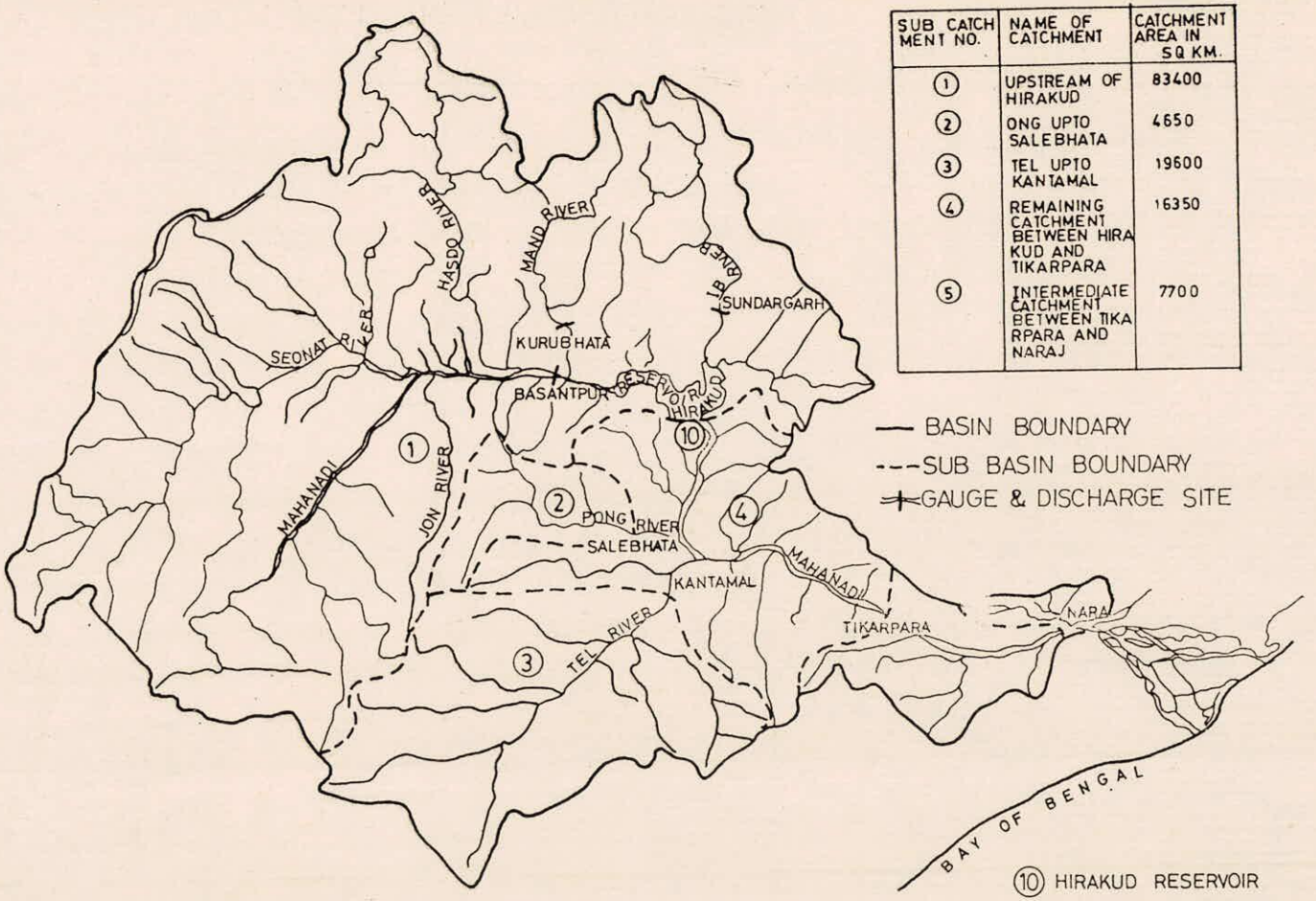


FIG. 1. THE KRISHNA RIVER BASIN



SUB CATCHMENT NO.	NAME OF CATCHMENT	CATCHMENT AREA IN SQ KM.
1	UPSTREAM OF HIRAKUD	83400
2	ONG UPTO SALEBHATA	4650
3	TEL UPTO KANTAMAL	19600
4	REMAINING CATCHMENT BETWEEN HIRAKUD AND TIKARPARA	16350
5	INTERMEDIATE CATCHMENT BETWEEN TIKARPARA AND NARAJ	7700

MAP SHOWING MAHANADI RIVERS MAIN TRIBUTARIES AND GAUGE DISCHARGE SITES.

MAP NOT TO SCALE

FIG. 2. THE MAHANADI RIVER BASIN

State	Drainage Area (Sq.Km.)
Bihar	633
Madhya Pradesh	75,138
Orissa	65,581
Maharashtra	238
Total	141,592

The Mahanadi basin is bounded on the north by the Central India hills, on the south and east by the eastern Ghats and on the west by the Maikala range. The upper basin is a saucershaped depression known as the Chattigarh. The basin is circular in shape with a diameter of about 400 km and an exit passage of about 160 km length and 60 km breadth.

There are four well defined physical regions in the basin namely (i) The northern plateau, (ii) The Eastern Ghats, (iii) The Coastal Plain, and (iv) The erosional plains of the central table land. The Northern Plateau and the Eastern Ghats are well forested hilly regions. The coastal plains stretching over the districts of Cuttack and Puri cover the large delta formed by the Mahanadi and is a fertile area well suited for intensive cultivation. The erosional plains of the Central table land are traversed by the Mahanadi and its tributaries.

4.4 The Chaliyar River Basin

Western Ghats nurse some of the major river systems of the peninsular India. Chaliyar river basin is one of them.

The Chaliyar river basin has been chosen for this study as this basin represents the general topography of Kerala and the river and its tributaries traverse all the three physiographic terrains i.e. the high lands, the mid land and the coastal low lands. Chaliyar river basin is situated between 11^{o} 5' and 11^{o} 37' North latitude; 75^{o} 48' and 76^{o} 35' East longitude in Wynad, Kozhikode and Malappuram districts of Kerala and some portion of Gudalur districts of Tamil Nadu state. The basin extends from north to south over a distance of 60 km, from east to west over a distance of about 90 km and alongwith tributaries it drains an area of 2952.87 km^2. It is bounded in the east and north by east flowing river basins Kabbani and Bhavani respectively, south by Kadalundi river and west by Arabian sea. Chaliyar river originates on the eastern slope of Elamaleri hills at an elevation of 2068 meters above mean sea level and joins the Arabian sea near Byporeport. The length of Chaliyar river is 169 km. The Chaliyar river is the third largest river of Kerala state and it is known near the mouth as Beypore river. The main tributaries of the Chaliyar river are Karimpuzha, Kuthirpuzha, Kanhirpuzha, Cherupuzha, Punnarpuzha, Mukkom, Koodathai etc. (Figure 3).

4.5 The Sutlej River Basin

The river Sutlej is a tributary of the Indus. It rises from the Mansarover lake in the Tibetan Plateau situated at an elevation of about 4500 m above mean sea

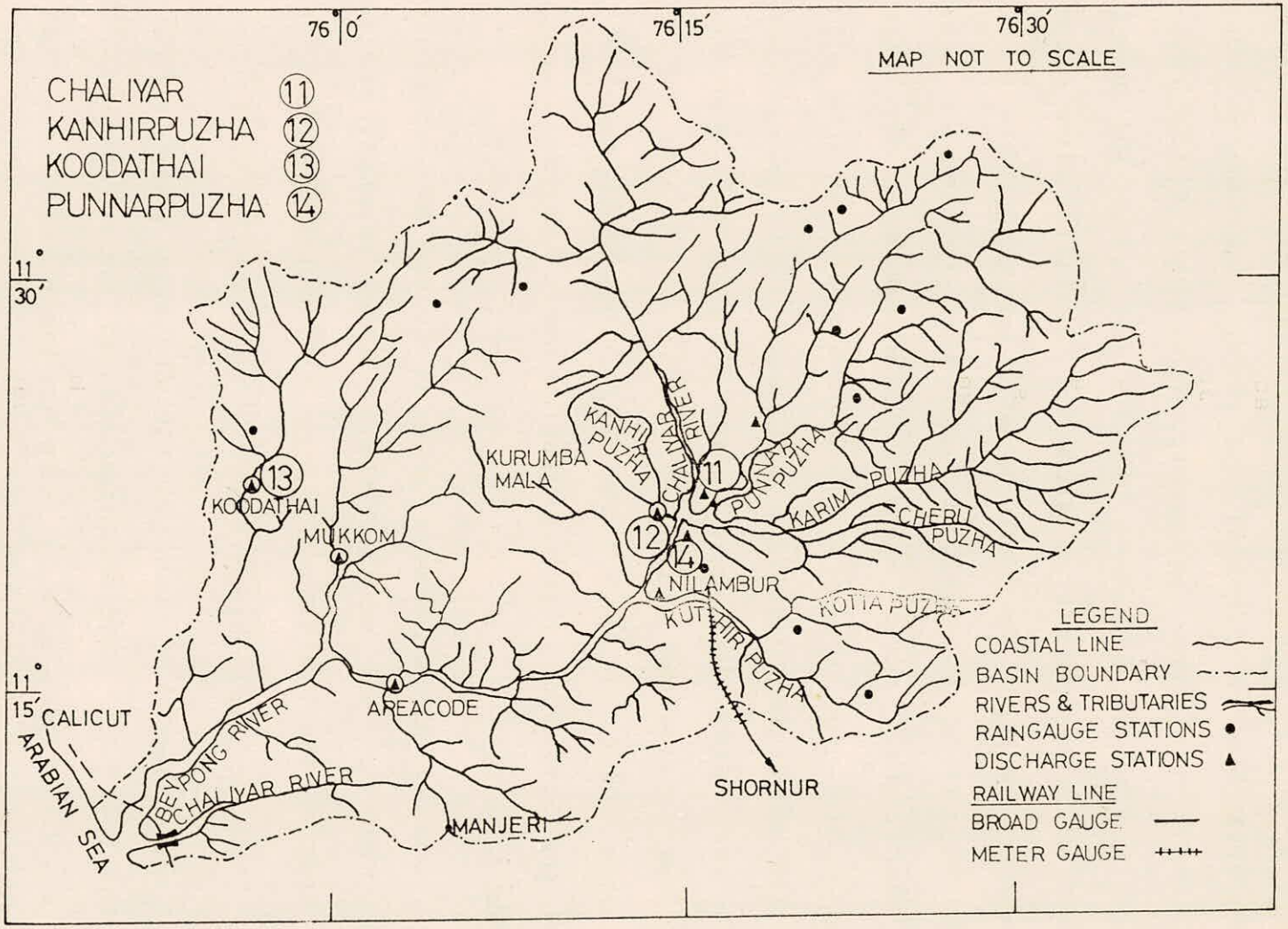


FIG. 3. THE CHALIYAR RIVER BASIN

level. It flows for a distance of about 320 km in Tibet, between Zaksar and Ladakh ranges. This plateau is formed of boulders, gravel, clay and mud in the through between the two ranges. The deposits lie in parallel and nearly horizontal beds. This part of the river is purely snow fed and the river has been able to cut a channel 1000 m deep through the plateau by means of water received from the glaciers. The banks stand almost vertical as there is no rainfall in this area. During the months of May and June, when thawing of snow takes place, this river brings in considerable discharge from this area and the water is heavily loaded with silt consisting of boulder, shingle and mud. In India, it cuts through successive Himalayan ranges carving out beautiful gorges and enters the plains near Bhakra. Its length in India upto Bhakra is about 260 km. The total catchment area of the Sutlej and its tributaries above Bhakra is about 57000 km^2.

Out of the Catchment area of 20,000 km^2 lying in India, 6700 km^2 lie in the area of heavy rainfall of 125 cm per year on the average.

4.6 The Sabarmati River Basin

The Sabarmati rises in the Aravalli hills and has a length of 300 km. The drainage area of the river is 21674 km^2 of which 19% lies in Rajasthan and the balance in Gujarat (Figure 4). Its main tributaries are the Sei from the right and the Wakul, the Harnav, the Hathmati and the Watrak on

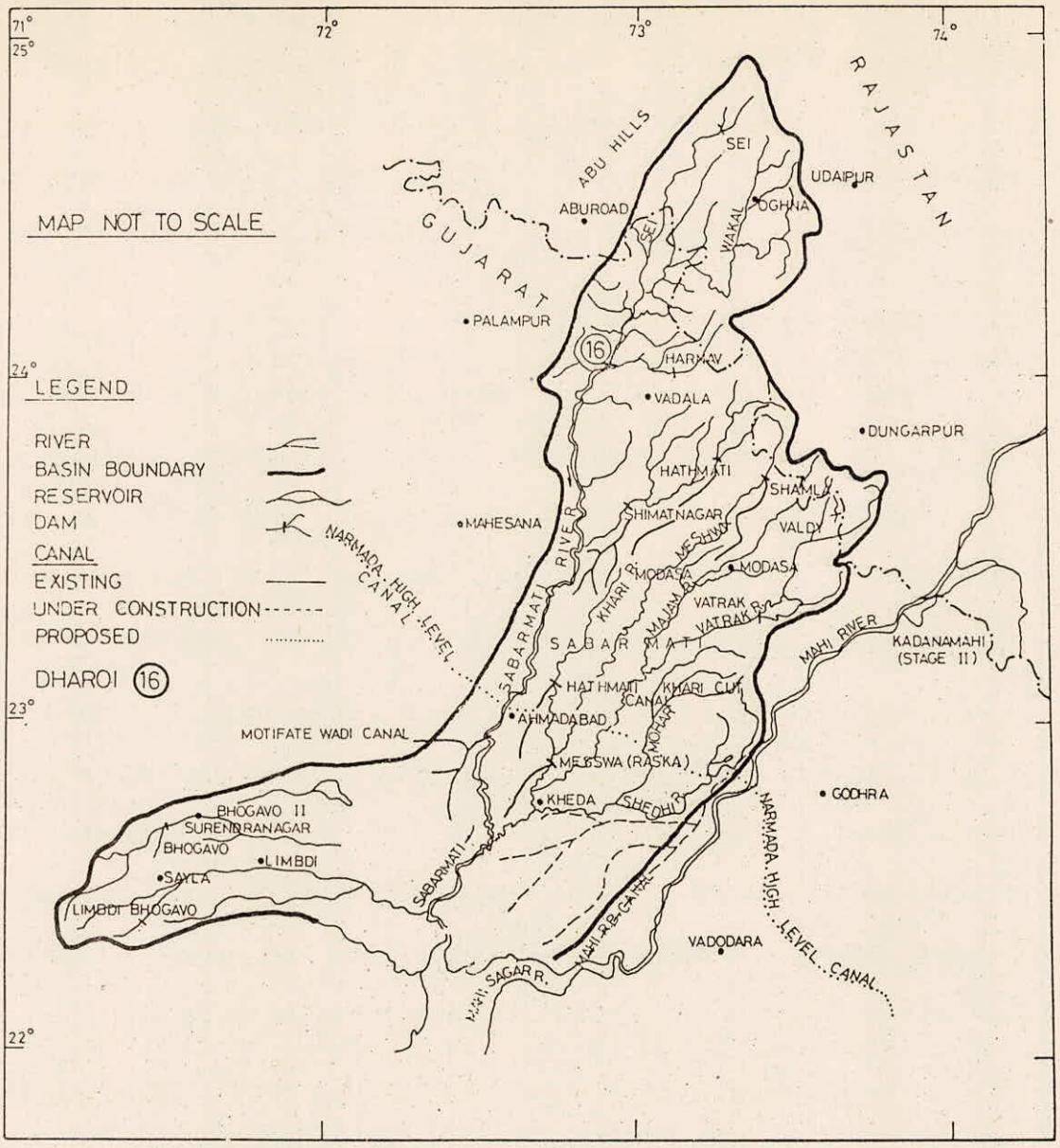


FIG. 4. THE SABARMATI RIVER BASIN

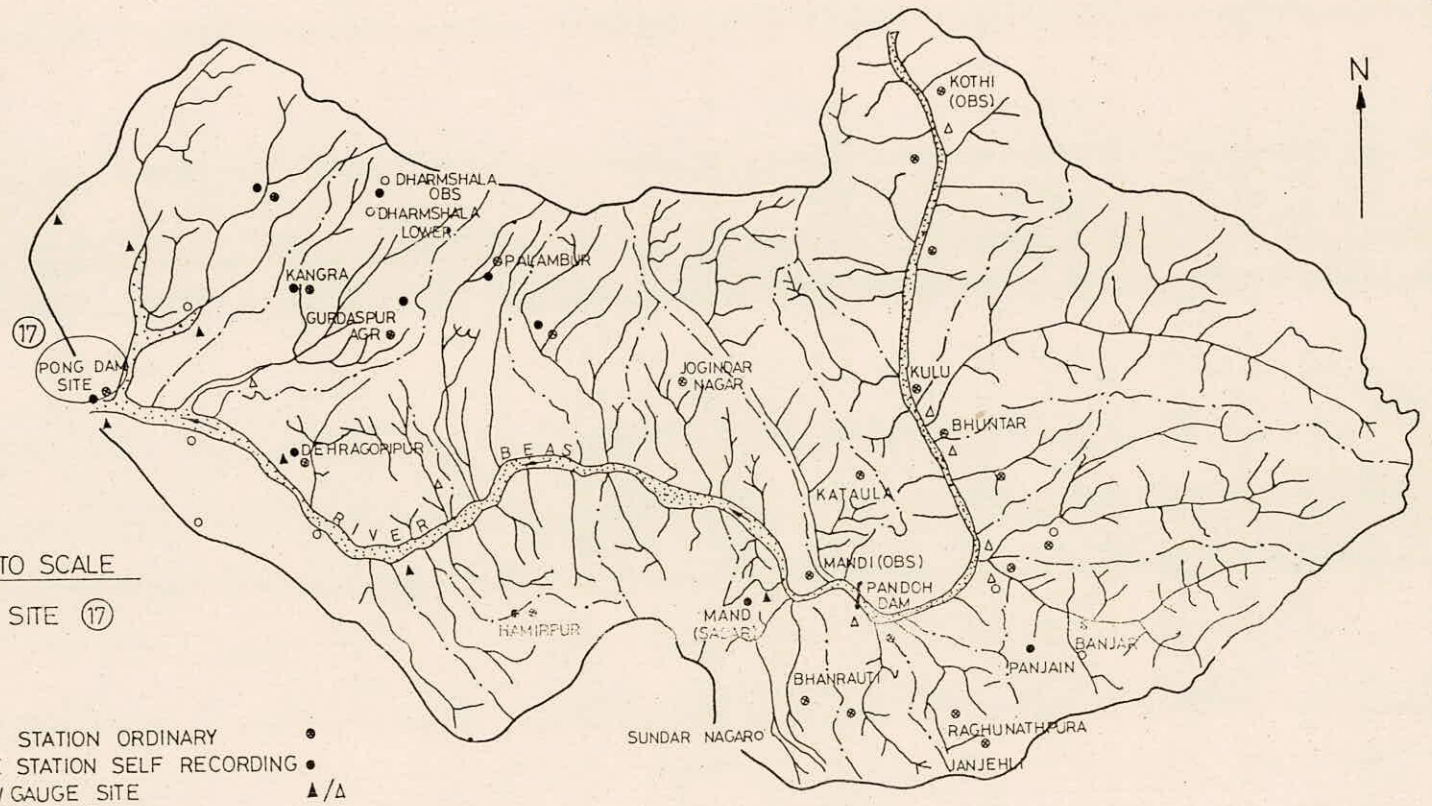
the left. At Dharoi the river passes through a gorge and later after 240 km of its course, it passes through Ahmedabad and finally falls into the Gulf of Cambay. The important tributaries are the Hathmati (1523 km^2), the Sei (946 km^2) the Wakul (1625 km^2), and the Harnav (972 km^2).

4.7 The Beas River Basin

The river Beas is principal tributary of river Sutlej in Indus basin (Figure 5). The river Beas originates in the Upper Himalayas from Beas Kund near Rohtang Pass at a height of about 3960 m and flows in the east westerly direction till it emerges in the plain at the Pong dam site.

The total length of the Beas river upto its Confluence with Sutlej is about 395 km and the length upto Pong dam is 230 km. The total area of the Beas catchment upto Pong dam is 12560 km^2 out of which about 777 km^2 is under permanent snow. Pandoha diversion dam is also situated on the river Beas at about 140 Km upstream of Pong dam.

The average river bed slope upto Larji is 30 m/km. Below Larji the river slope flattens sharply and in the vicinity of the Pong dam it is of the order of 1.0 m/km. The upstream part of the catchment is bowl shaped with mountain ranges on both north and east. The catchment area of 7284 km downstream of the Pandoh dam is fan shaped and produces the high floods. The catchment area consists scientifically managed forest, degraded forest, cultivated land and uncultivated weathered rocks.



MAP NOT TO SCALE

PONG DAM SITE (17)

LEGEND

RAIN GAUGE STATION ORDINARY	●
RAIN GAUGE STATION SELF RECORDING	●
DISCHARGE / GAUGE SITE	▲/△
EVAPORIMETRE SITE	o
BEAS CATCHMENT BOUNDARY	—
SUB CATCHMENT BOUNDARIES OF KHADS AND TRIBUTORIES	— —
RIVER	
KHADS AND TRIBUTORS	

FIG. 5. BEAS DAM AT PONG (RIVER BEAS CATCHMENT)

4.8 The Godavari Basin

The Godavari rises in the Nasik district of Maharashtra and after flowing 1465 km joins the Bay of Bengal in Andhra Pradesh. It has a catchment area of 312812 km^2 of which 48.6% lies in Maharashtra, 20.7% in Madhya Pradesh, 1.4% in Karnataka, 5.5% in Orissa and 23.8% in Andhra Pradesh. It is the largest of the Peninsular rivers and is held in reverence as 'Vridha Ganga' or 'Dakshina Ganga'. The delta of the river consists of a wide belt of river borne alluvium and gradually extending into the sea. It pierces through the Eastern Ghats flowing through a narrow gorge 130 km from the sea.

The Jayakwadi project (Paithan Dam) is on river Godavari in Dist. Aurangabad (Maharashtra). The catchment area upto Paithan Dam is 21750 km^2. The annual rainfall is of the order of 100 cm per annum. The catchment map of Godavari basin is given in Figure 6.

All these 19 sites have been shown on the map of India in Figure 7.

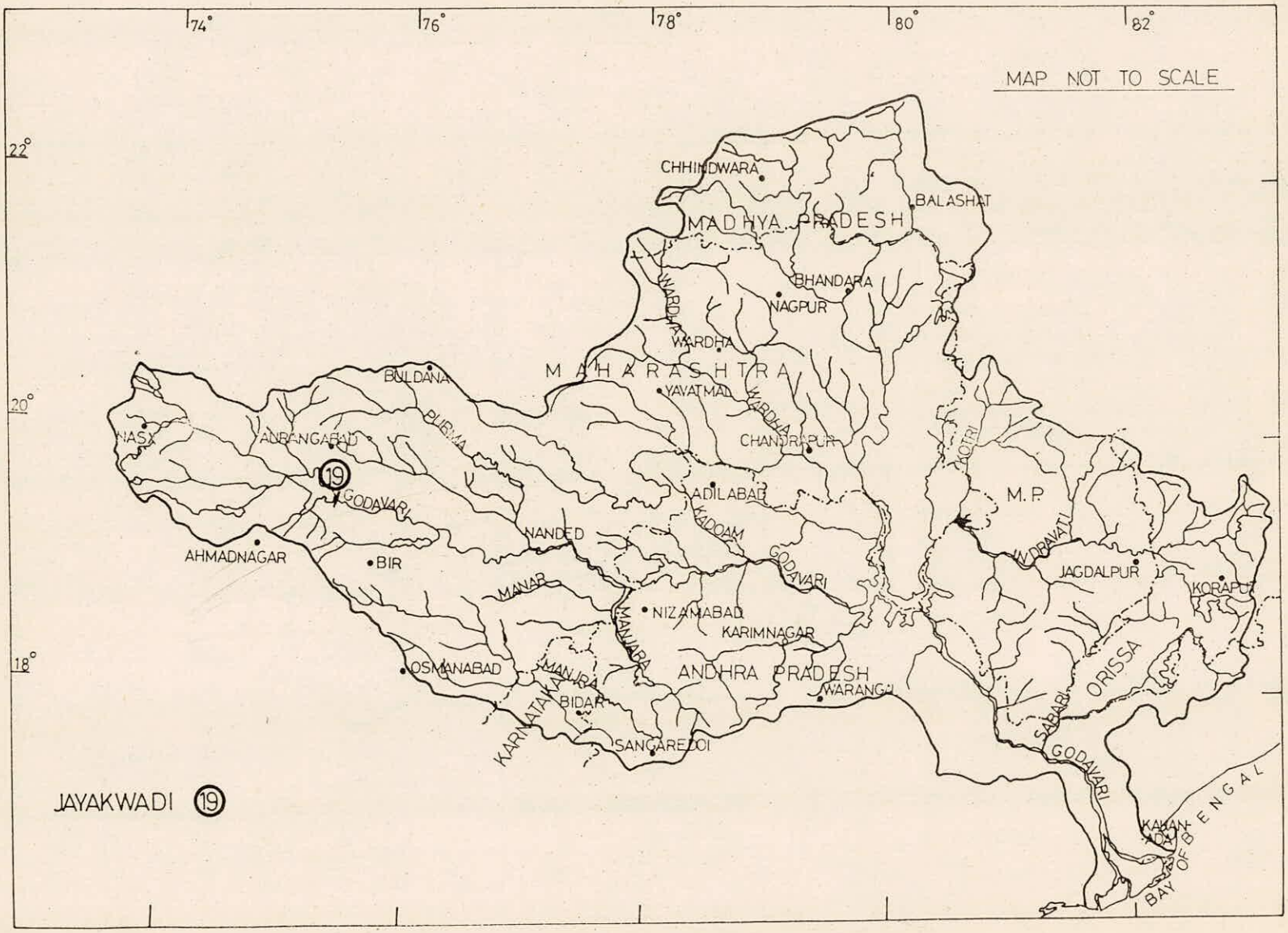


FIG. 6. THE GODAVARI RIVER BASIN

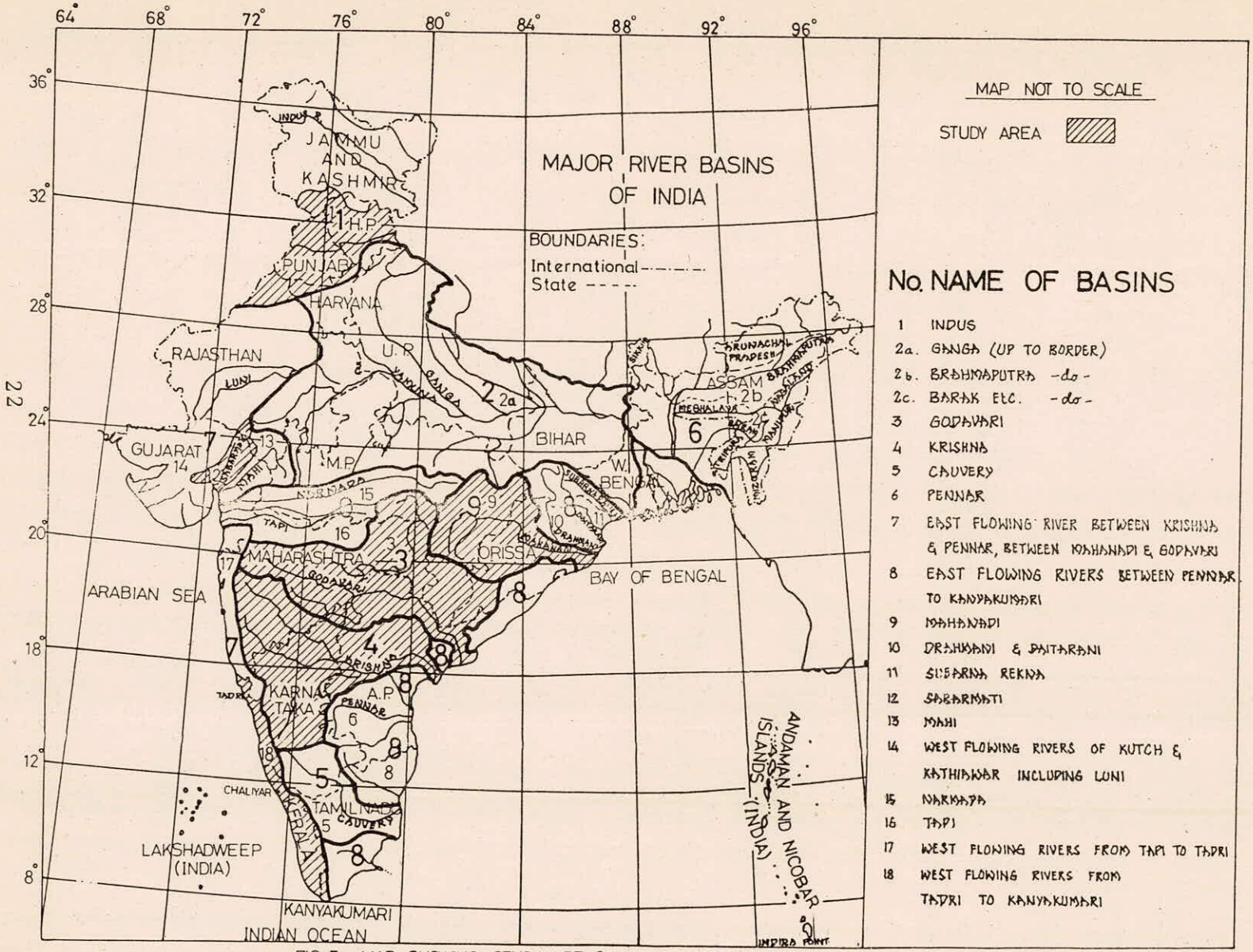


FIG. 7. MAP SHOWING STUDY AREAS

5.0 DATA USED

The monthly runoff data for various sites have been used. The length of data, and units of runoff are given below in Table-1.

TABLE - 1

DATA USED FOR VARIOUS SITES

S.NO.	Name of reservoir/ river site	Length of Data Years	Period	Unit of runoff
1.	Bhima at Dhond	18	1968-85	Cumec days
2.	Bhima at Wodakabal	21	1965-85	Cumec days
3.	Bhima at Narsingpur	19	1967-85	Cumec days
4.	Bhima at Takali	18	1966-83	Cumec days
5.	Bhima at Yadgir	21	1965-85	Cumec days
6.	Tungbhadra at Haralahalli	19	1967-85	Cumec days
7.	Tungbhadra at T. Ramapuram	20	1966-85	Cumec days
8.	Koyna Reservoir	21	1963-83	M.C.M. days
9.	Gandhisagar Reservoir	26	1961-86	T.A.F.
10.	Mahanadi at Hirakud	39	1944-82	M.M.
11.	Chaliyar	14	1965-78	Cumec days
12.	Kanhirpuzha	14	1965-78	Cumec days
13.	Koodathai	14	1965-78	Cumec days
14.	Punnarpuzha	14	1965-78	Cumec days
15.	Gobindsagar at Bhakra	28	1960-87	Cusec days
16.	Sabarmati at Dharoi	41	1935-75	Cusec days
17.	Pong Reservoir	13	1974-86	Cusec days
18.	Malprabha Reservoir	10	1975-85	M.C.M.
19.	Jayakwadi reservoir	12	1974-85	M.C.M.

The runoff for monsoon months i.e. for june, July, August, September and October and monsoon total are given in table 2-20 for various sites.

TABLE-2

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS FOR BHIMA AT DHOND (1968-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1968	1243.6	0.0	20947.3	3603.5	3547.3	29341.7
1969	537.6	19907.8	40818.4	19067.5	889.2	81220.5
1970	969.4	17926.5	24069.6	13181.4	2983.1	59130.0
1971	8858.0	19736.6	20159.1	14978.6	11740.6	75472.9
1972	87.2	22278.3	7712.2	3282.8	196.8	33557.3
1973	413.9	32657.8	19806.6	26718.0	4835.8	84432.1
1974	1009.9	10548.6	16492.6	9819.7	10349.5	48220.3
1975	2292.4	17058.5	26531.5	16489.0	10105.4	72476.8
1976	10280.0	28362.4	43385.0	10699.7	1139.8	93866.9
1977	1921.2	24194.3	13932.6	10603.5	1360.5	52012.1
1978	3937.2	10323.9	24331.6	11482.0	1321.9	51396.6
1979	1019.0	9072.2	32662.8	14060.8	3093.3	59928.1
1980	6054.0	24381.1	28048.4	9016.3	1955.2	69455.0
1981	874.0	30679.4	24362.7	8555.0	2319.7	66790.8
1982	327.5	3954.8	24148.2	2818.7	1213.1	32462.3
1983	304.3	7844.1	34490.5	12775.8	4740.1	60154.8
1984	896.2	23253.6	14831.5	6091.5	3433.7	48506.5
1985	589.5	7718.1	15270.9	1096.6	2291.4	26966.5

TABLE-3

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS
FOR BHIMA AT WODAKABAL (1965-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1965	712.1	1560.5	4551.9	1718.6	205.6	8748.7
1966	540.8	642.3	262.6	3746.8	341.6	5534.1
1967	445.8	4485.2	891.3	6632.8	2718.1	15173.2
1968	484.6	1383.5	160.4	2106.4	3161.3	7296.2
1969	1337.0	3491.5	5729.8	15232.6	1333.9	27124.8
1970	688.0	693.1	2158.5	13829.3	3483.5	20852.4
1971	593.0	30.9	5008.9	4849.1	4496.6	14978.5
1972	119.8	31.9	36.8	980.3	36.2	1205.0
1973	674.0	3076.4	4777.5	2862.6	4726.6	16117.1
1974	618.6	378.2	2476.1	3307.9	6860.2	13641.0
1975	110.6	869.4	2714.3	9366.0	9576.0	22636.3
1976	778.0	185.3	1257.8	645.0	161.0	3027.1
1977	702.3	736.8	265.6	318.2	1002.2	3025.1
1978	3268.0	1193.6	362.6	2152.7	1833.6	8810.5
1979	0.3	521.0	185.5	8202.7	1861.1	10770.6
1980	2877.6	206.8	3611.2	2370.0	894.6	9960.2
1981	859.4	25.7	90.4	4464.2	945.9	6385.6
1982	152.4	111.0	8.7	821.3	184.9	1278.3
1983	110.0	1702.0	1252.8	20907.0	5948.8	29920.6
1984	0.0	503.5	72.5	733.8	5093.0	6402.8
1985	340.7	159.2	56.2	572.6	1229.5	2358.2

TABLE-4

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS
FOR BHIMA AT NARSINGPUR (1967-85)

	RUNOFF					
YEAR	JUNE	JULY	ALG.	SEPT.	OCT.	MONSOON
1967	587.4	30692.2	29695.1	8407.6	3944.6	73326.9
1968	1427.3	13708.2	29859.7	3861.2	8622.1	57478.5
1969	937.4	29420.6	55868.3	30245.9	1658.4	118130.6
1970	1134.7	19734.8	26027.6	20610.9	4411.4	71919.4
1971	6132.5	20311.4	18285.0	24960.0	13284.7	82973.6
1972	157.6	21482.5	7532.5	5052.1	319.1	34543.8
1973	1016.0	34735.3	19194.2	27819.3	8763.8	91528.6
1974	651.4	8488.4	16723.2	10977.5	24074.9	60915.4
1975	2046.7	18190.7	28857.4	20512.1	15669.8	85276.7
1976	13719.0	29809.9	60000.0	14766.0	1959.1	120254.0
1977	1260.2	14301.4	19759.7	19364.4	4130.0	58815.7
1978	1704.9	9939.4	29070.8	20710.8	4779.8	66205.7
1979	311.2	2407.2	38926.2	23843.2	8190.2	73678.0
1980	1552.4	29943.1	37972.5	11168.5	2418.0	83054.5
1981	5546.2	32920.7	23065.7	17754.8	2094.5	86381.9
1982	4825.9	88.3	20947.5	1630.5	1149.9	28642.1
1983	452.4	4940.2	45998.5	17968.6	4289.2	73648.9
1984	3737.9	26550.3	17574.8	2159.6	5684.4	55707.0
1985	527.5	9218.0	16759.4	78.4	910.7	27494.0

TABLE-5

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS
FOR BHIMA AT TAKALI (1966-83)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1966	1676.9	14825.3	22942.4	10033.0	2125.8	51603.4
1967	1422.2	25649.2	41730.3	17205.9	11989.1	97996.7
1968	1472.2	12168.5	25006.9	6416.7	14149.7	59214.0
1969	2341.0	23450.5	52124.0	33876.5	3309.5	115101.5
1970	1066.6	18992.7	24593.4	27560.3	6504.6	78717.6
1971	5134.0	18349.4	15763.5	32072.1	19281.1	90600.1
1972	42.0	17453.4	7333.2	5248.1	571.6	30648.3
1973	1058.8	33829.9	18162.8	31386.0	13010.1	97447.6
1974	939.5	8082.2	15893.9	17397.7	36084.3	78397.6
1975	1544.7	17710.8	29215.7	25483.9	41887.3	115842.4
1976	11997.5	27157.7	70420.7	14186.7	2283.7	126046.3
1977	3000.0	10358.1	17226.5	17796.6	6263.2	54644.4
1978	1659.9	8616.2	25469.5	22763.4	7451.2	65960.2
1979	122.8	1772.4	39765.9	40838.8	12397.2	94897.1
1980	1199.5	25890.7	35846.4	9407.1	3430.7	75774.4
1981	7901.6	26316.7	27808.5	33693.1	5769.6	101489.5
1982	4303.7	480.1	17960.3	2794.3	2695.0	28233.4
1983	344.1	4027.7	44393.1	26662.4	7969.5	83396.8

TABLE-6

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS
FOR BHIMA AT YADGIR (1965-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1965	3034.2	37113.2	44997.1	21607.2	2612.4	109364.1
1966	4587.9	10877.4	28628.5	29580.0	5745.7	79419.5
1967	2631.5	27594.2	58643.8	42627.5	29186.5	160683.5
1968	2414.1	15825.3	27780.1	14288.4	31108.0	91415.9
1969	3010.9	26090.2	60132.8	74160.3	7344.2	170738.4
1970	3630.9	19918.8	35784.5	50342.3	15610.7	125287.2
1971	6623.6	21256.8	26661.4	35967.8	31515.6	122025.2
1972	196.5	17413.8	7866.2	9911.8	1060.2	36448.5
1973	1196.5	37796.2	28817.8	36362.2	48425.8	152598.5
1974	4115.6	10869.0	22199.4	21372.9	59738.2	118295.1
1975	2554.5	42481.3	40784.7	45466.9	91309.7	222597.1
1976	12533.1	32804.7	72874.9	22771.4	4556.2	145540.3
1977	9972.1	8925.5	26468.9	21622.7	15327.6	82316.8
1978	5816.8	12546.8	41261.9	41789.4	23337.4	124752.3
1979	1135.2	2222.9	40669.8	57260.2	24450.0	125738.1
1980	4938.5	24301.5	42883.0	15999.4	6997.0	95119.4
1981	11781.8	25559.7	30958.3	55463.8	18380.4	142144.0
1982	3501.7	6083.8	17645.8	11796.1	5329.1	44356.5
1983	2330.6	6019.1	52618.8	70209.0	36663.3	167840.8
1984	2417.8	28695.0	23525.2	7593.8	21620.4	83852.2
1985	3160.2	10178.7	20312.2	2320.3	8490.6	44460.0

TABLE-7

obs
OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS FOR TUNGBHADRA AT HARALAHALLI (1967-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1967	906.1	23414.9	27871.7	9728.1	7345.7	69266.5
1968	3387.3	22162.7	23517.8	8814.1	7205.2	65087.1
1969	2483.2	30857.8	25660.6	14815.0	9646.4	83463.0
1970	5425.3	22684.2	35368.5	15275.0	15351.5	94104.5
1971	15271.9	21906.2	15597.6	9186.8	6876.5	68839.0
1972	1862.8	25868.4	12896.4	7639.0	6162.0	54428.6
1973	10213.9	26451.4	23273.9	8775.9	5120.5	73835.6
1974	1310.9	20642.2	24109.0	10297.9	8248.4	64608.4
1975	12152.4	23450.7	37209.4	21251.8	10539.1	104603.4
1976	1703.1	14063.3	16019.5	9678.2	3150.6	44614.7
1977	4842.9	24849.7	12493.5	13168.9	10440.5	65795.5
1978	11327.4	33376.7	54036.5	18508.2	8353.2	125622.0
1979	3563.8	11624.9	27578.4	8836.5	4751.8	56355.4
1980	11111.7	40278.2	32631.0	15052.3	7786.6	106859.8
1981	5063.4	15428.5	37797.3	11905.2	7374.7	77569.1
1982	4953.3	12665.5	41262.4	7601.6	5429.7	71912.5
1983	2529.9	18877.0	28017.5	12900.1	7589.7	69914.2
1984	8272.9	25600.1	19955.7	9392.0	10543.9	73764.6
1985	9594.8	12941.6	23199.2	5954.4	7145.4	58835.4

TABLE-8

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS FOR TUNGBHADRA AT T RAMAPURAM (1966-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1966	223.7	627.1	505.1	3806.5	2121.7	7284.1
1967	307.9	429.1	238.0	679.4	2354.9	4009.3
1668	631.1	189.9	185.6	2695.7	6426.4	10128.7
1969	527.3	373.9	1245.7	861.0	2499.3	5507.2
1970	321.6	342.9	1225.2	3895.3	4086.5	9871.5
1971	232.9	175.0	652.9	2018.7	5670.8	8750.3
1972	745.8	192.8	204.8	2767.7	1507.8	5418.9
1973	995.4	338.6	1628.3	2938.2	3852.1	9752.6
1974	319.1	278.5	604.5	3765.1	4861.2	9828.4
1975	125.1	1368.3	1976.2	5464.2	8467.3	17401.1
1976	257.2	207.6	1096.8	708.5	508.8	2778.9
1977	898.5	299.0	1552.9	835.5	4337.5	7923.4
1978	116.9	932.0	887.4	5177.1	2318.7	9432.1
1979	108.4	152.4	505.4	4020.8	1586.1	6373.1
1980	182.2	205.0	641.5	1417.5	1251.3	3697.5
1981	236.9	271.2	983.6	9956.0	3174.2	14621.9
1982	210.0	272.6	532.8	2448.4	1690.4	5154.2
1983	850.5	78.2	661.0	2044.2	3248.3	6882.2
1984	3.6	1065.5	350.8	738.5	1271.2	3429.6
1985	5.9	158.0	311.0	815.2	884.8	2174.9

TABLE-9

OBSERVED MONTHLY AND MONSOON FLOWS IN MCM FOR KOYNA RESERVOIR (1963-83)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1963	84.0	1679.0	1498.0	309.0	76.0	3646.0
1964	299.0	1155.0	2131.0	551.0	223.0	4359.0
1965	249.0	2667.0	834.0	234.0	35.0	4019.0
1966	113.0	1642.0	737.0	475.0	69.0	3036.0
1967	151.0	2006.0	1230.0	404.0	109.0	3900.0
1968	92.0	1093.0	1123.0	156.0	107.0	2571.0
1969	60.0	1988.0	1449.0	623.0	48.0	4168.0
1970	247.0	1521.0	1552.0	621.0	131.0	4072.0
1971	909.0	1223.0	920.0	116.0	168.0	3336.0
1972	139.0	1461.0	561.0	182.0	5.0	2348.0
1973	195.0	1797.0	1174.0	690.0	170.0	4026.0
1974	89.0	1205.0	1231.0	249.0	211.0	2985.0
1975	471.0	1395.0	1500.0	628.0	190.0	4184.0
1976	603.0	1856.0	1293.0	532.0	20.0	4304.0
1977	217.0	1890.0	952.0	704.0	144.0	3907.0
1978	698.0	1301.0	1859.0	585.0	72.0	4515.0
1979	402.0	915.0	1748.0	221.0	136.0	3422.0
1980	567.0	1680.0	1630.0	334.0	98.0	4309.0
1981	153.0	1629.0	1422.0	293.0	117.0	3614.0
1982	151.0	1135.0	1597.0	191.0	113.0	3187.0
1983	339.0	1125.0	1481.0	383.0	110.0	3438.0

TABLE-10

OBSERVED MONTHLY AND MONSOON FLOWS IN TAF FOR GANDHISAGAR RESERVOIR (1961-86)

	RUNOFF					
YEAR	JUNE	JULY	ALG.	SEPT.	OCT.	MONSOON
1961	14.4	574.6	815.3	3316.5	1252.2	5973.0
1962	15.3	832.2	608.6	1241.7	1198.2	3896.0
1963	189.7	694.4	2297.0	330.0	110.8	3621.9
1964	232.5	516.7	607.6	470.4	81.1	1908.3
1965	6.9	330.2	315.4	370.9	20.2	1043.6
1966	39.1	346.8	589.1	250.2	8.0	1233.2
1967	192.2	183.6	248.6	1323.0	31.1	1978.5
1968	673.9	1346.1	2168.1	116.4	80.8	4385.3
1969	367.0	712.1	4232.4	2187.6	131.9	7631.0
1970	638.4	276.3	837.3	1747.8	128.8	3628.6
1971	236.3	2228.9	1708.0	1975.9	383.0	6532.1
1972	93.9	655.2	1169.7	314.3	48.7	2281.8
1973	45.0	4349.8	3482.5	7352.4	436.4	15666.1
1974	55.7	392.3	3794.5	309.8	578.6	5130.9
1975	161.6	468.2	1702.2	2239.2	322.7	4893.9
1976	162.6	726.8	4244.7	2818.5	109.2	8061.8
1977	241.0	680.9	1883.6	2367.8	178.1	5351.4
1978	113.1	816.6	3776.1	676.7	123.8	5506.3
1979	74.1	161.3	1635.9	75.1	64.9	2011.3
1980	436.1	481.8	1125.7	761.9	385.5	3191.0
1981	78.5	381.2	1879.7	351.2	92.3	2782.9
1982	29.8	291.8	1249.0	175.6	35.3	1781.5
1983	52.2	325.3	1061.9	795.2	187.8	2422.4
1984	33.4	162.8	5195.1	387.9	24.9	5804.1
1985	15.4	41.7	1294.1	281.6	875.7	2508.5
1986	82.0	3473.6	4142.4	154.1	63.3	7915.4

TABLE-11

OBSERVED MONTHLY AND MONSOON FLOWS IN M M FOR HIRAKUD RESERVOIR (1946-82)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1946	34.7	156.4	366.2	105.6	39.3	702.2
1947	1.0	123.5	209.3	179.8	40.6	554.2
1948	7.3	92.3	240.4	92.8	113.1	545.9
1949	7.5	78.2	223.5	111.2	59.4	479.8
1950	10.0	140.6	245.7	86.3	12.9	495.5
1951	4.4	27.2	169.5	48.7	29.1	278.9
1952	8.4	96.6	177.9	224.7	30.9	538.5
1953	2.7	118.8	186.5	69.6	20.3	397.9
1954	4.2	26.7	63.3	123.5	20.5	238.2
1955	12.0	90.6	109.2	154.3	74.0	440.1
1956	36.3	169.6	194.1	64.1	29.4	493.5
1957	1.4	71.2	148.3	46.5	5.0	272.4
1958	5.3	171.8	106.3	148.8	71.8	504.0
1959	3.7	75.0	217.8	204.9	32.7	534.1
1960	7.5	95.7	266.1	59.4	54.4	483.1
1961	81.0	331.2	227.4	358.6	86.3	1084.5
1962	7.2	48.7	90.3	66.5	15.7	228.4
1963	11.5	73.4	162.1	164.3	31.8	443.1
1964	19.9	187.8	259.9	103.5	61.2	632.3
1965	5.4	46.7	46.2	67.0	13.6	178.9
1966	32.0	66.5	125.2	24.3	10.8	258.8
1967	7.0	82.7	246.8	111.6	20.6	468.7
1968	7.3	66.2	167.0	40.5	21.2	302.2
1969	4.2	72.4	151.7	53.8	15.8	297.9
1970	21.2	156.5	207.0	121.9	29.0	535.6
1971	69.4	155.6	201.5	102.0	37.1	565.6
1972	1.8	63.6	107.5	82.0	21.1	276.0
1973	1.4	125.2	179.0	190.4	112.6	608.6
1974	3.2	42.6	125.6	14.8	17.6	203.8
1975	5.6	101.5	220.2	98.9	57.9	484.1
1976	1.8	79.4	191.9	92.9	9.9	375.9
1977	23.8	115.9	170.2	110.9	28.1	448.9
1978	13.1	82.0	222.7	84.1	18.5	420.4
1979	2.5	34.0	92.3	9.8	14.4	153.0
1980	33.4	143.9	121.4	217.8	19.7	536.2
1981	4.3	62.8	133.0	76.0	27.4	303.5
1982	3.7	30.5	170.4	56.2	18.8	279.6

TABLE-12

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS FOR CHALIYAR RIVER (1965-78)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1965	35.6	209.5	122.3	80.9	140.1	588.6
1966	98.7	400.6	254.8	64.8	52.7	871.6
1967	160.8	658.1	391.6	213.3	100.0	1523.8
1968	118.0	451.3	298.6	321.5	100.0	1289.5
1969	138.8	217.8	194.8	68.8	68.2	688.3
1970	371.3	140.1	135.6	45.8	67.2	759.9
1971	85.2	185.5	46.4	20.8	37.4	375.2
1972	267.8	513.5	372.5	97.2	43.2	1294.1
1973	17.5	394.5	381.9	145.8	98.5	1038.1
1974	77.6	155.8	311.3	131.7	96.9	773.0
1975	9.7	245.3	327.2	127.3	37.2	746.7
1976	155.2	274.5	144.2	133.5	126.6	833.9
1977	254.6	311.8	344.9	174.6	127.3	1213.2
1978	192.6	431.5	596.3	203.7	154.2	1578.4

TABLE-13

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS
FOR KANHIRAPUZHA RIVER (1965-78)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1965	4.6	46.2	15.9	10.7	34.3	111.7
1966	16.7	97.5	53.3	27.1	23.4	218.0
1967	26.2	187.5	129.5	84.7	39.1	467.1
1968	16.9	95.1	51.2	43.3	8.9	215.5
1969	16.1	35.2	48.5	13.5	16.9	130.2
1970	157.3	73.4	66.8	44.6	35.5	377.6
1971	7.1	42.5	12.7	5.0	14.0	81.2
1972	37.3	53.6	33.1	8.0	4.0	136.1
1973	1.8	64.5	79.9	24.6	19.1	190.0
1974	80.2	58.1	86.9	26.3	23.3	274.8
1975	0.8	27.9	30.9	11.4	4.5	75.6
1976	18.8	54.8	18.5	21.3	15.0	128.4
1977	32.2	71.6	79.4	19.7	7.5	210.3
1978	26.2	86.0	146.9	20.2	10.7	290.0

TABLE-14

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS FOR KOODATHAI RIVER (1965-78)

YEAR	RUNOFF JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1965	9.1	132.0	139.3	26.1	40.2	346.7
1966	33.3	335.7	216.1	28.0	37.1	650.2
1967	46.3	451.0	107.3	2.6	7.7	614.8
1968	67.0	231.1	164.3	84.7	32.0	579.1
1969	82.5	196.6	184.4	46.7	57.6	567.8
1970	144.8	91.8	37.6	30.5	51.4	356.2
1971	22.4	126.4	66.0	21.7	36.3	272.8
1972	90.2	123.1	107.3	24.4	13.1	357.9
1973	11.1	195.5	116.1	95.3	41.7	459.7
1974	120.0	134.5	170.4	87.4	81.1	593.5
1975	2.8	60.4	70.0	36.1	27.0	196.4
1976	82.1	148.0	64.3	77.3	75.1	446.7
1977	216.8	310.9	281.4	92.0	43.3	944.4
1978	178.1	351.7	321.5	99.5	110.1	1060.9

TABLE-15

OBSERVED MONTHLY AND MONSOON FLOWS IN CUMEC-DAYS FOR PUNNARPUZHA RIVER (1965-78)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1965	14.0	28.0	26.3	20.0	69.7	158.1
1966	40.4	79.4	70.5	20.1	22.8	233.3
1967	76.4	641.0	266.4	160.9	108.6	1253.2
1968	18.0	432.9	465.1	72.1	74.9	1063.0
1969	47.5	138.4	167.5	91.2	116.0	560.6
1970	126.5	141.5	146.5	105.7	144.1	664.4
1971	37.2	91.4	69.3	39.7	57.2	294.8
1972	63.8	127.7	115.0	64.9	38.4	409.7
1973	18.3	158.3	161.5	102.7	83.9	524.6
1974	62.4	95.6	156.5	88.2	78.2	480.9
1975	11.6	65.1	99.3	88.7	41.4	306.1
1976	61.9	146.4	120.8	128.5	110.3	567.8
1977	56.5	145.9	192.2	83.9	53.3	531.8
1978	50.4	128.7	218.2	67.2	38.3	502.8

TABLE-16

OBSERVED MONTHLY AND MONSOON FLOWS IN CUSEC-DAYS
FOR GOBINDSAGAR AT BHAKRA (1960-86)

	RUNOFF					
YEAR	JUNE	JULY	ALG.	SEPT.	OCT.	MONSOON
1960	26897.0	49107.0	47610.0	25319.0	8027.0	156960.0
1961	38203.0	50066.0	54736.0	35960.0	11880.0	190845.0
1962	30420.0	36867.0	38088.0	29962.0	10271.0	145608.0
1963	39347.0	44796.0	45537.0	23728.0	9667.0	163575.0
1964	25428.0	26795.0	56135.0	29922.0	11110.0	149390.0
1965	27448.0	41417.0	28938.0	12077.0	7061.0	116941.0
1966	40764.0	45074.0	51011.0	20029.0	7191.0	164069.0
1967	28082.0	50751.0	53861.0	23923.0	8229.0	164846.0
1968	39627.0	43461.0	39044.0	17204.0	7492.0	146828.0
1969	40064.0	47306.0	50800.0	22408.0	8056.0	168634.0
1970	17847.0	32558.0	39225.0	25532.0	8670.0	123832.0
1971	35721.0	37817.0	57511.0	20973.0	8365.0	160387.0
1972	25190.0	36419.0	32292.0	21530.0	7530.0	122961.0
1973	52628.0	54444.0	47158.0	29178.0	9663.0	193071.0
1974	16978.0	33182.0	35098.0	14325.0	6330.0	105913.0
1975	39034.0	43684.0	53460.0	30104.0	10616.0	176898.0
1976	27556.0	51364.0	40067.0	20330.0	8474.0	147791.0
1977	18803.0	50652.0	47444.0	31709.0	13006.0	161614.0
1978	44021.0	58066.0	69785.0	33856.0	15087.0	220815.0
1979	36449.0	52695.0	42937.0	21213.0	10296.0	163590.0
1980	38755.0	53929.0	40863.0	20443.0	11219.0	165209.0
1981	28299.0	52511.0	50640.0	20719.0	11017.0	163186.0
1982	40571.0	54830.0	51901.0	22752.0	10375.0	180429.0
1983	36555.0	48779.0	58623.0	35623.0	13824.0	193404.0
1984	40331.0	38291.0	43185.0	25576.0	9616.0	156999.0
1985	32550.0	43133.0	51590.0	29162.0	18084.0	174519.0
1986	41740.0	59284.0	53889.0	23297.0	12081.0	190291.0

TABLE-17

OBSERVED MONTHLY AND MONSOON FLOWS IN CUSEC-DAYS
FOR SABARMATI AT DHAROI (1935-75)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1935	333.0	2684.0	500.0	2818.0	436.0	6771.0
1936	495.0	155.0	386.0	337.0	124.0	1497.0
1937	103.0	6136.0	997.0	1671.0	376.0	9283.0
1938	1804.0	1264.0	808.0	206.0	59.0	4161.0
1939	15.0	321.0	760.0	1140.0	57.0	2293.0
1940	1287.0	582.0	607.0	135.0	65.0	2676.0
1941	678.0	7077.0	11981.0	709.0	151.0	20596.0
1942	637.0	11528.0	5485.0	6872.0	323.0	24845.0
1943	797.0	18460.0	6800.0	2752.0	399.0	29208.0
1944	990.0	9858.0	4209.0	14017.0	440.0	29514.0
1945	333.0	14653.0	8524.0	1784.0	320.0	25614.0
1946	33.0	864.0	6406.0	2491.0	223.0	10017.0
1947	9.0	370.0	4346.0	3389.0	123.0	8237.0
1948	5.0	404.0	264.0	164.0	74.0	911.0
1949	24.0	812.0	910.0	274.0	69.0	2089.0
1950	4.0	5280.0	2141.0	16503.0	1673.0	25601.0
1951	80.0	2041.0	1922.0	219.0	42.0	4304.0
1952	5.0	372.0	1767.0	576.0	209.0	2929.0
1953	77.0	218.0	133.0	810.0	309.0	1547.0
1954	768.0	5573.0	1871.0	9021.0	2072.0	19305.0
1955	292.0	151.0	4565.0	12256.0	1080.0	18344.0
1956	383.0	7246.0	8111.0	5278.0	5233.0	26251.0
1957	918.0	2251.0	1502.0	370.0	68.0	5109.0
1958	27.0	3245.0	321.0	929.0	429.0	4951.0
1959	4.0	781.0	2583.0	12335.0	1373.0	17076.0
1960	60.0	1715.0	3298.0	789.0	282.0	6144.0
1961	68.0	1606.0	989.0	11994.0	1094.0	15753.0
1962	7.0	2953.0	2589.0	1748.0	450.0	7747.0
1963	145.0	958.0	3165.0	4138.0	586.0	9012.0
1964	134.0	1720.0	5400.0	1347.0	406.0	9007.0
1965	10.0	1720.0	1191.0	346.0	2614.0	5881.0
1966	661.0	1518.0	339.0	705.0	39.0	3262.0
1967	166.0	4887.0	2518.0	3497.0	654.0	11742.0
1968	8.0	3481.0	1367.0	330.0	135.0	5321.0
1969	65.0	1133.0	886.0	502.0	33.0	2619.0
1970	635.0	186.0	4852.0	6069.0	1132.0	12874.0
1971	49.0	2887.0	1377.0	1794.0	145.0	6252.0
1972	279.0	1271.0	838.0	198.0	14.0	2600.0
1973	34.0	1987.0	13377.0	27688.0	2833.0	45919.0
1974	1981.0	611.0	1933.0	290.0	259.0	5074.0
1975	156.0	3567.0	5489.0	6956.0	1836.0	18004.0

TABLE-18

OBSERVED MONTHLY AND MONSOON FLOWS IN CUSEC-DAYS FOR PONG RESERVOIR (1974-86)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1974	10566.0	33113.0	50623.0	13494.0	5393.0	113189.0
1975	18444.0	44375.0	56680.0	36647.0	11282.0	167428.0
1976	17303.0	55681.0	51820.0	24935.0	9668.0	159457.0
1977	14899.0	63390.0	58533.0	32300.0	9405.0	178527.0
1978	19570.0	66918.0	79926.0	25483.0	6380.0	198277.0
1979	13407.0	30842.0	27931.0	7244.0	2880.0	82304.0
1980	11591.0	35023.0	30529.0	7775.0	2620.0	87538.0
1981	6977.0	44676.0	34857.0	5832.0	2852.0	95194.0
1982	10382.0	19631.0	39272.0	5553.0	2861.0	77699.0
1983	8502.0	16548.0	35098.0	27654.0	3801.0	91603.0
1984	11057.0	21861.0	29588.0	14995.0	2743.0	80244.0
1985	3838.0	26233.0	52672.0	19540.0	9871.0	112154.0
1986	12773.0	36999.0	47462.0	7756.0	4758.0	109748.0

TABLE-19

OBSERVED MONTHLY AND MONSOON FLOWS IN MCM FOR MALAPRABHA RESERVOIR (1976-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1976	153.9	323.0	203.8	140.6	28.0	849.4
1977	364.6	4330.1	171.3	151.1	83.4	5100.5
1978	232.3	295.9	516.8	218.6	63.8	1327.4
1979	85.5	167.6	569.2	146.9	65.4	1034.7
1980	94.7	424.0	469.0	136.6	56.2	1180.6
1981	58.3	527.9	388.2	187.1	55.3	1216.8
1982	53.3	398.5	1274.1	104.2	44.9	1875.0
1983	375.0	312.0	423.4	126.4	44.4	1281.2
1984	79.0	508.0	202.0	109.0	103.0	1001.0
1985	42.1	167.2	310.3	57.1	90.7	667.4

TABLE-20

OBSERVED MONTHLY AND MONSOON FLOWS IN MCM FOR JAYAKWADI RESERVOIR (1974-85)

	RUNOFF					
YEAR	JUNE	JULY	AUG.	SEPT.	OCT.	MONSOON
1974	41.0	49.0	251.0	306.0	294.0	941.0
1975	66.0	213.0	1185.0	1694.0	728.0	3886.0
1976	702.0	2321.0	3420.0	665.0	75.0	7183.0
1977	380.0	1597.0	580.0	643.0	106.0	3306.0
1978	110.0	320.0	239.0	461.0	134.0	1264.0
1979	92.0	141.0	1180.0	1456.0	360.0	3229.0
1980	445.0	720.0	1880.0	484.0	122.0	3651.0
1981	115.0	843.0	767.0	935.0	214.0	2874.0
1982	201.0	111.0	518.0	273.0	163.0	1266.0
1983	116.0	331.0	648.0	1700.0	375.0	3170.0
1984	165.0	311.0	433.0	358.0	188.0	1455.0
1985	60.0	62.0	258.0	70.0	115.0	565.0

6.0 ANALYSIS AND RESULTS

Graphical plots of monsoon runoff v/s total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for various sites indicate that linear relationships given by equation 1-4 are good enough to try.

6.1 Bhima at Dhond

a. Using equations 1-9 and 1968-77 runoff data the following relationships have been developed:

Sl. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 54179.95+3.184\times Q_{June}$	0.434×10^{10}	0.312×10^{10}	28.2%
2.	$Q_{mon} = 28627.89+1.559\times Q_{June+July}$	0.434×10^{10}	0.187×10^{10}	57.0%
3.	$Q_{mon} = 10776.92+1.149\times Q_{June+July+Aug.}$	0.434×10^{10}	0.685×10^{9}	84.2%
4.	$Q_{mon} = 5788.2 +0.982\times Q_{June+July+August+Sept.}$	0.434×10^{10}	0.172×10^{9}	96.0%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1968-77 are plotted in Figure 8.

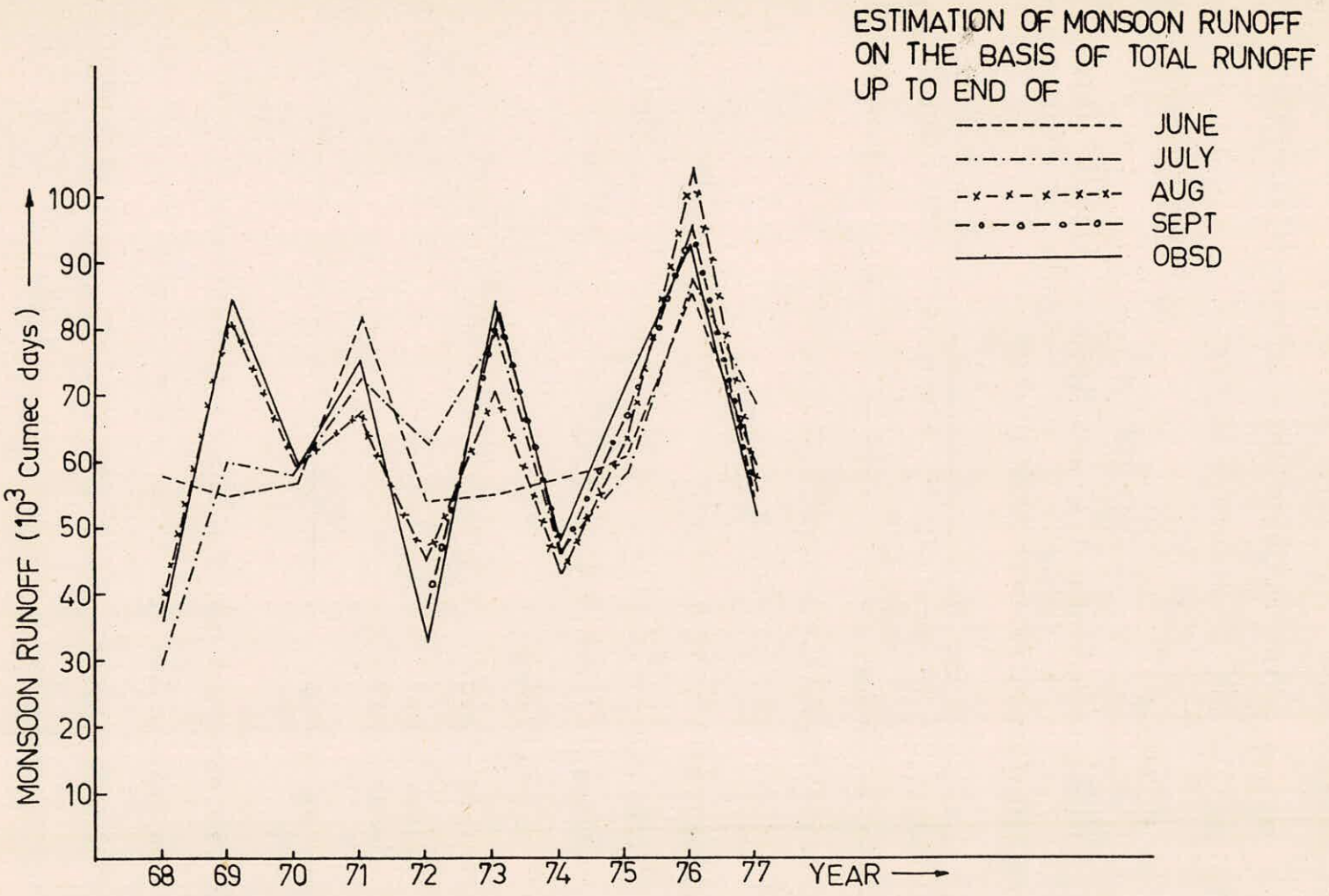


FIG. 8. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1968 – 77) FOR BHIMA AT DHOND.

c. Monsoon runoffs for 1978-85 period have been forecasted after updating the parameters. The effficiency of the regression relationships are as given below:

Sl. No.	Forecast of monsoon runoff on the basis of total runoff upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.236×10^{10}	0.175×10^{10}	26.1%
2.	July	0.236×10^{10}	0.135×10^{10}	42.6%
3.	August	0.236×10^{10}	0.345×10^{9}	85.4%
4.	September	0.236×10^{10}	0.369×10^{8}	98.4%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1978-85 are plotted in Figure 9.

e. Out of 8 years (1978-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 6 years, 7 years, 8 years and 8 years at the end of June, July, August and September respectively.

The normal monsoon runoff, observed monsoon runoff and forecasted monsoon runoff from drought point of view are given in Table 21.

Comment on the Results:

The results are pretty good inspite of the short length of data.

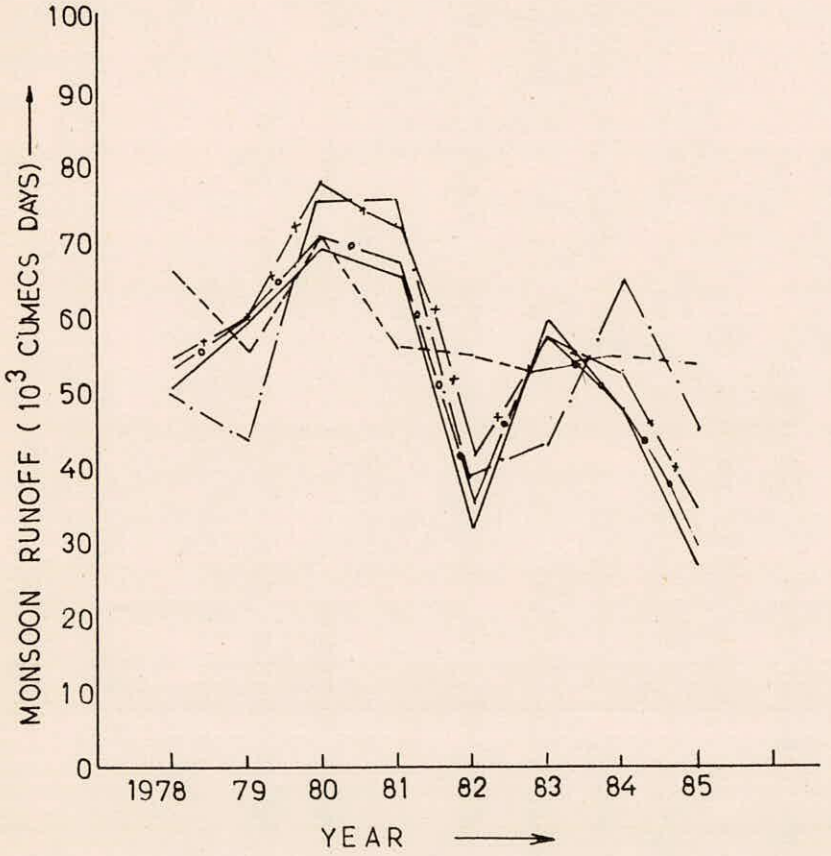


FIG 9 FORCASTING OF MONSOON RUNOFF FOR THE PERIOD (1978-85) FOR BHIMA AT DHOND

TABLE-21

FORECASTING OF MONSOON RUN OFF 1978-85 FROM DROUGHT POINT OF VIEW FOR BHIMA AT DHOND

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUN OFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUN OFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1978	62973	51396.6 -	66716.0-	50860.0+	55119.9-	54961.6 -
1979	61920	59928.1 -	56279.9-	44453.2-	59577.3-	61273.5 -
1980	61754.62	59455.0 +	71778.1+	76051.0+	77775.2+	71689.7 +
1981	62346.9	66790.8 +	56164.9-	76627.7+	73834.9+	68471.4 +
1982	62664.38	32462.3 -	55682.6-	39662.8-	42871.0-	35758.2 -
1983	60650.9	60154.8 -	53195.5-	43338.8-	57692.9-	59712.9 -
1984	60619.9	48506.5 -	55672.4-	65946.6+	53635.8-	48594.0 -
1985	59907.0	26966.5 -	54179.7-	45300.0-	35428.1-	28581.3 -

Note :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. - ve sign shows runoff is below normal.
3. + ve sign shows runoff is above normal.

6.2 Bhima at Wodakabal

a. Using equations 1-9 and 1965-74 runoff data the following relationships have been developed.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon}=232.11+20.656*Q_{June}$	$0.525x10^9$	$0.169x10^9$	67.9%
2.	$Q_{mon}=7231.61+2.654*Q_{June+July}$	$0.525x10^9$	$0.337x10^9$	35.8%
3.	$Q_{mon}=4463.68+1.791*Q_{June+July+Aug.}$	$0.525x10^9$	$0.216x10^9$	58.9%
4.	$Q_{mon}=2506.47+1.022*Q_{June+July+Aug.+Sept.}$	$0.525x10^9$	$0.460x10^8$	91.2%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July , (iii) August and (iv) September for the period 1965-74 are plotted in Figure 10.

c. Monsoon runoffs for 1975-85 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

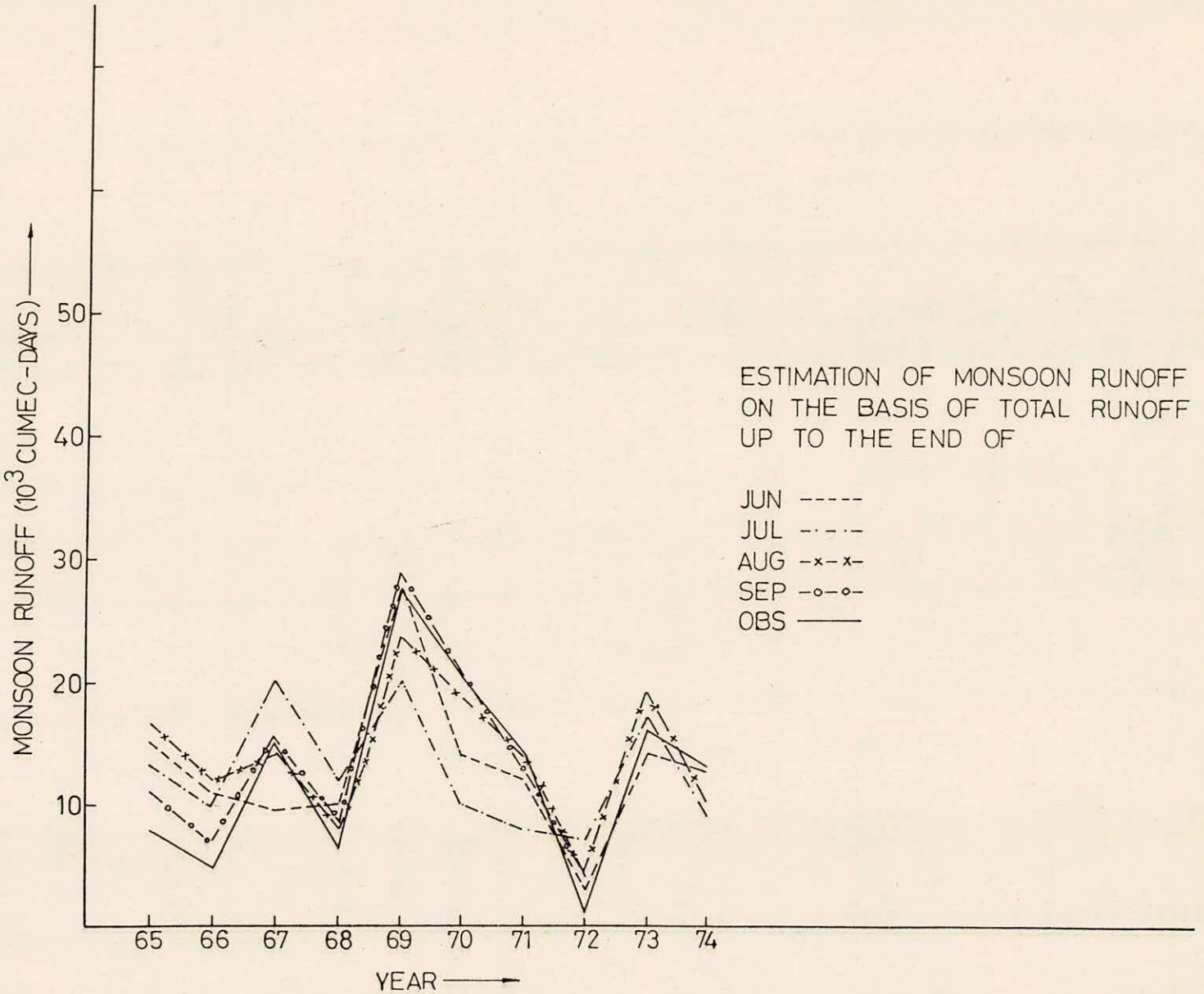


FIG. 10 ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1965-74) FOR BHIMA AT WODAKABAL

Sl. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.939×10^9	0.206×10^{10}	-118.9%
2.	July	0.939×10^9	0.906×10^9	3.6%
3.	August	0.939×10^9	0.747×10^9	20.4%
4.	September	0.939×10^9	0.804×10^8	91.4%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv)September for the period 1975-85 are plotted in Figure 11.

e. Out of 11 years (1975-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to below normal or above normal for 1 year, 7 years, 7 years and 11 years at the end of June, July, August and September respectively.

The normal monsoon runoff, observed monsoon runoff and forecasted monsoon runoff from drought point of view are given in Table 22.

Comment on the Resuts:

The results are very poor. This may be because of (i) measurement error in discharge (ii) short sample length

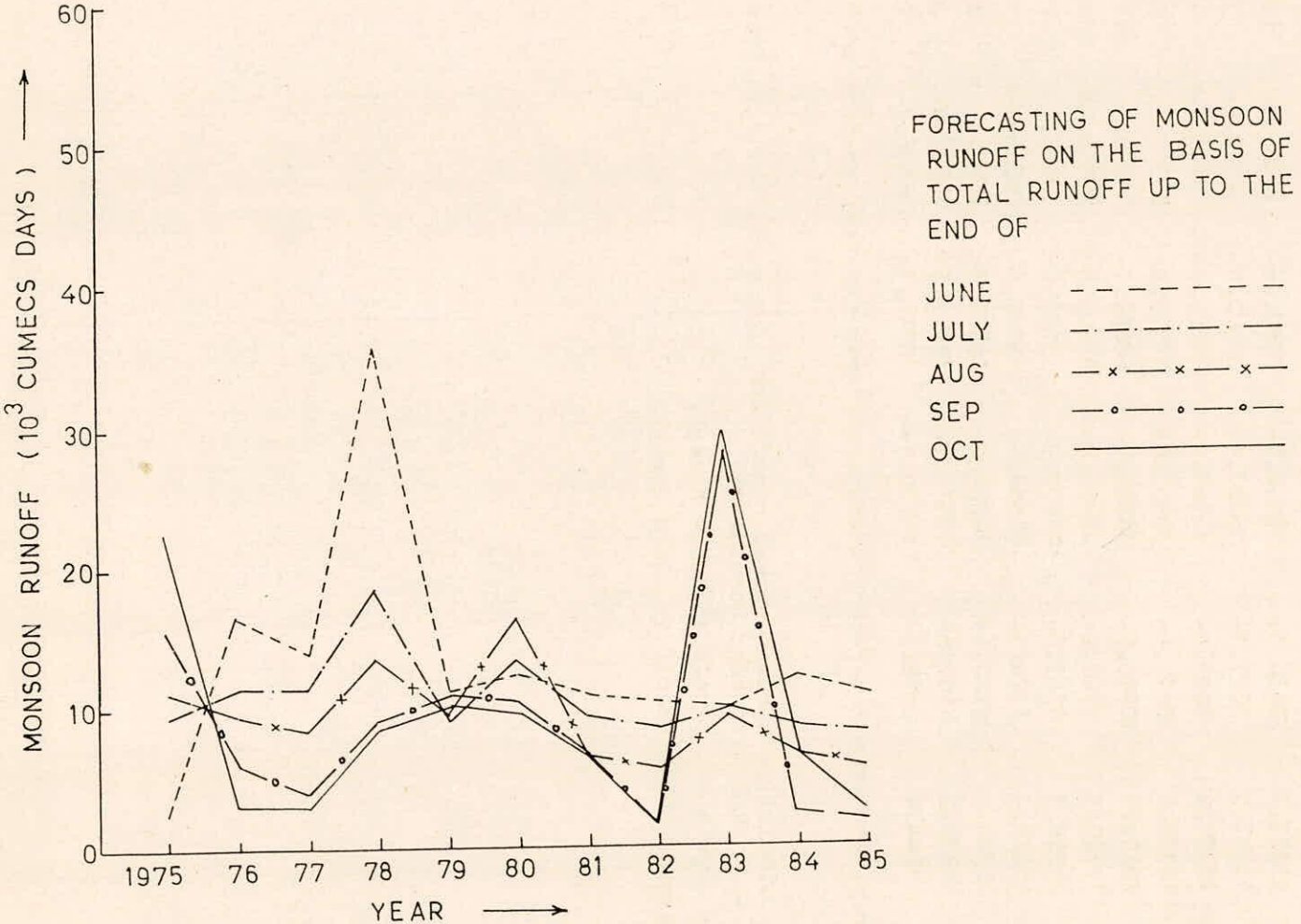


FIG. 11. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1975-85) FOR BHIMA AT WODAKABAL

TABLE-22

FORECASTING OF MONSOON RUN OFF (1975-1985) FROM DROUGHT POINT OF VIEW FOR BHIMA AT WODAKABAL

YEAR	NORMAL	OBSERVED	FORECASTING MONSOON RUNOFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUN OFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1975	13067.1	22636.3+	2516.7-	9832.5-	11080.2-	15854.1+
1976	13937.0	3027.1-	16363.4+	11520.9-	9987.8-	5772.8-
1977	13027.8	3025.1-	14101.0+	11668.5-	7945.2-	4357.6-
1978	12258.4	8810.5-	35493.8+	18779.0+	13307.2+	9646.3-
1979	12012.1	10770.6-	11886.0-	8887.7-	5093.1-	11736.0-
1980	11929.3	9960.2-	12483.8+	13908.4+	16531.4+	11842.5-
1981	11806.3	6385.6-	11807.9+	9679.6-	6466.1-	7676.2-
1982	11487.4	1278.3-	11586.4+	8225.5-	5305.3-	2691.1-
1983	10920.2	29920.6+	10634.2-	10687.3-	9577.3-	28575.9+
1984	11920.2	6402.8-	12375.1+	8984.3-	6657.0-	2632.1-
1985	11644.4	2358.2-	11750.1+	8744.3-	6596.7-	2846.9-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

and (iii) variability of flow. A critical examination of flows reveals that monsoon flows at Wodakabal are much lesser than the flows at Dhond while there is no diversion in between. This makes the reliability of discharge data at Wadakbal doubtful.

6.3 Bhima at Narsingpur

a. Using equations 1-9 and 1967-76 runoff data the following relationships have been developed.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 69574.91+3.617* Q_{June}$	$0.629x10^{10}$	$0.421x10^{10}$	33.0%
2.	$Q_{mon} = 32332.5+1.859* Q_{June+July}$	$0.629x10^{10}$	$0.308x10^{10}$	51.0%
3.	$Q_{mon} = 26310.55+0.976* Q_{June+July+Aug.}$	$0.629x10^{10}$	$0.135x10^{10}$	78.5%
4.	$Q_{mon} = 15343.88+0.887* Q_{June+July+August+Sept.}$	$0.629x10^{10}$	$0.415x10^{9}$	93.4%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1967-76 are plotted in Figure 12.

c. Monsoon runoffs for 1977-85 period have been forecasted after updating the parameters. The efficiency of

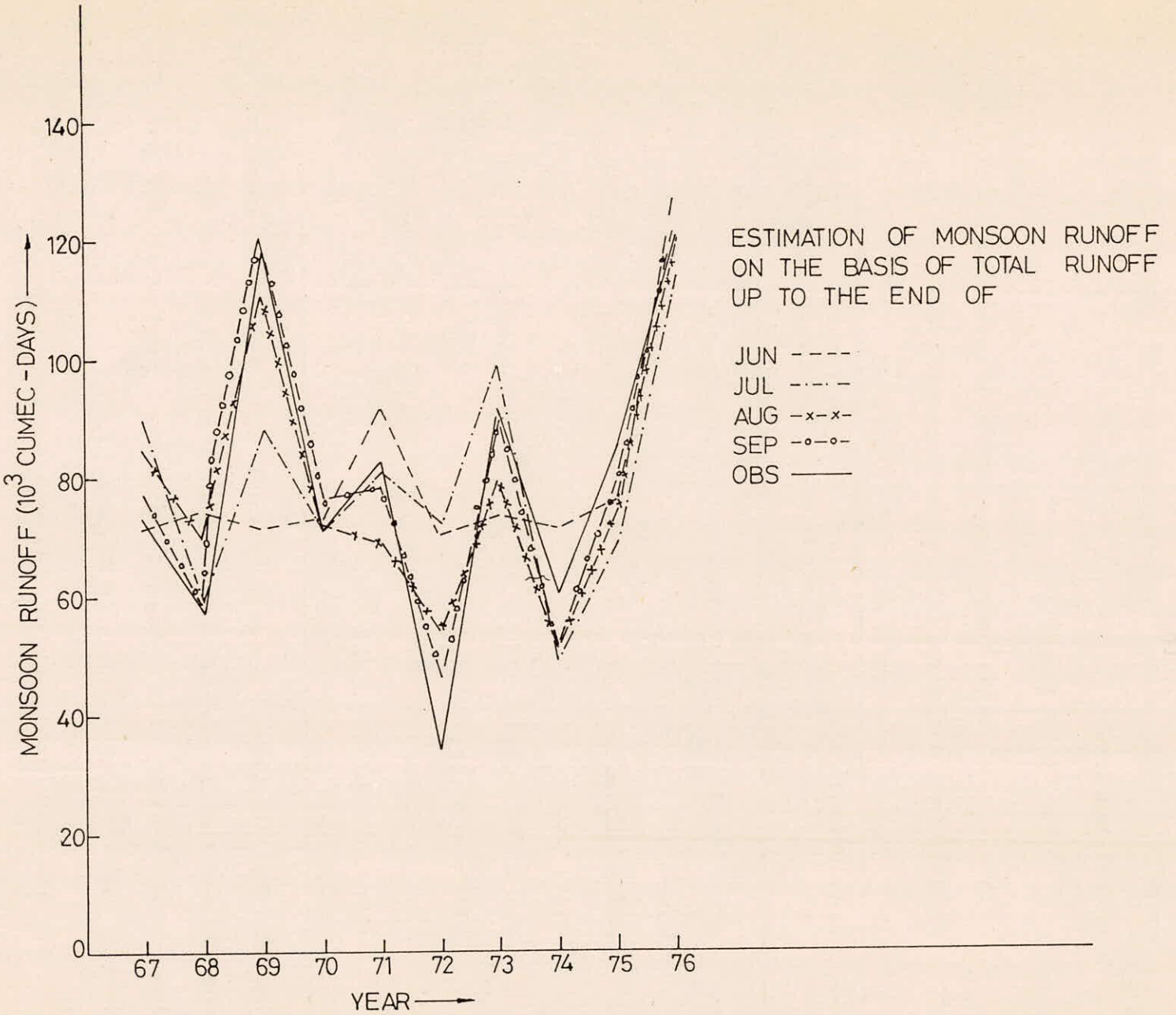


FIGURE 12. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1967-76) FOR BHIMA AT NARSINGPUR

the regression relationships are as given below:

Sl. No.	Forecast of monsoon runc on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.558×10^{10}	0.585×10^{10}	-4.9%
2.	July	0.558×10^{10}	0.458×10^{10}	17.8%
3.	August	0.558×10^{10}	0.139×10^{10}	75.1%
4.	September	0.558×10^{10}	0.268×10^{9}	95.2%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1977-85 are plotted in Figure 13.

e. Out of 9 years (1977-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 6 years, 8 years, 9 years and 8 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 23.

Comment on the Results:

The results show that monsoon flows can be forecasted with 75.1% and 95.2% reliability at the end of August and September respectively. The results are satisfactory.

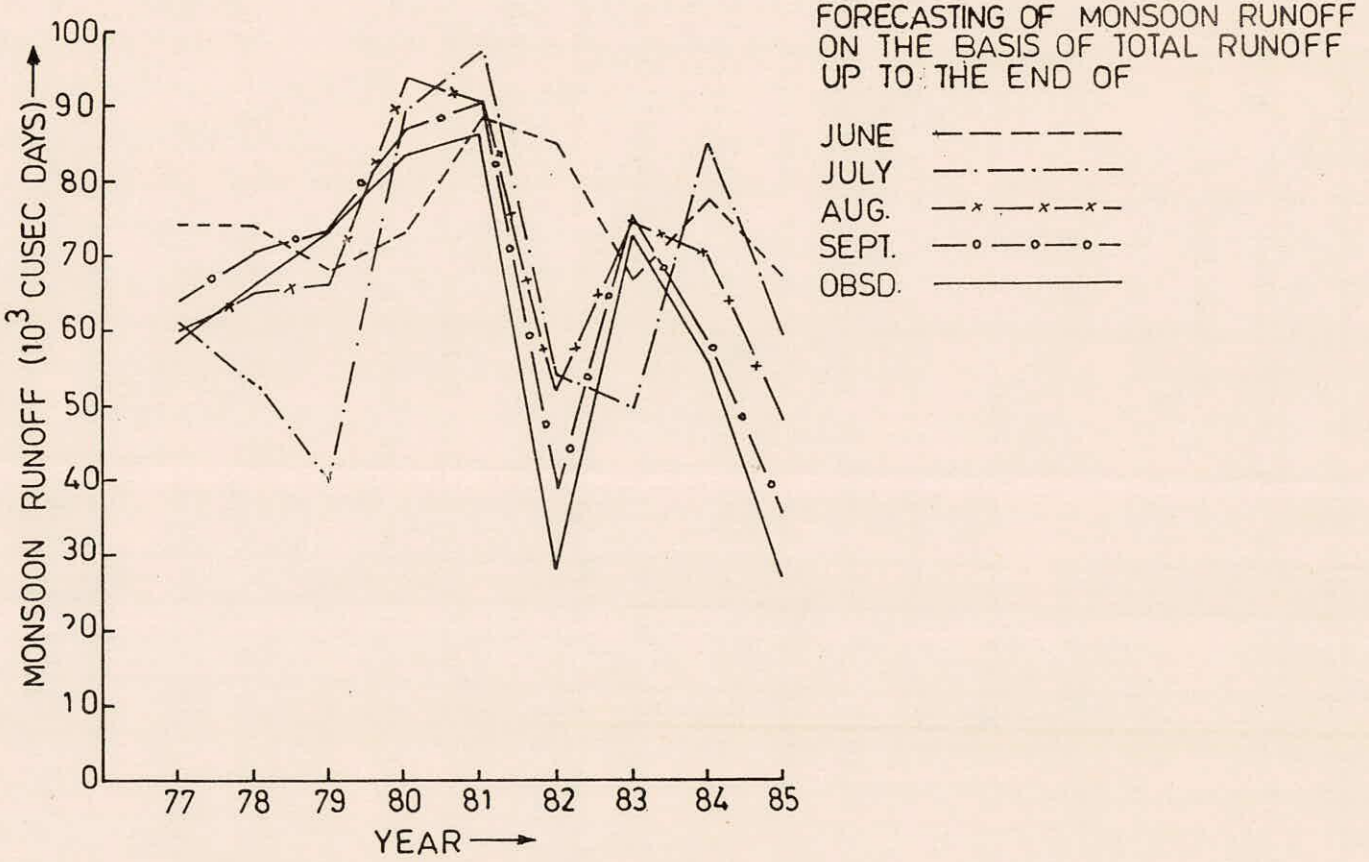


FIG.13. -FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1977-85) BHIMA AT NARSINGPUR

TABLE-23

FORECASTING OF MONSOON RUN OFF (1977-1985) FROM DROUGHT POINT OF VIEW FOR BHIMA AT NARSINGHPUR

YEAR	NORMAL	OBSERVED	FORECASTING MONSOON RUNOFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1977	79634.7	58815.7-	74133.0-	61261.5-	60784.1-	64850.1-
1978	77742.1	66205.7-	74226.0-	53480.3-	65704.1-	70191.2-
1979	76780.7	73678.0-	68236.6-	40421.5-	66732.6-	73502.2-
1980	76542.0	83054.5+	73419.0-	89505.7+	94377.2+	87202.8+
1981	77007.2	86381.9+	88835.4+	97870.0+	90259.5+	90095.3+
1982	77632.2	28642.1-	85925.4+	54802.4-	52081.1-	39176.5-
1983	74570.3	73548.9-	67947.4-	50224.7-	74355.6-	75371.6+
1984	74516.1	55707.0-	77939.9+	85789.4+	70726.1-	57700.5-
1985	73471.1	27494.0-	67677.8-	59100.7-	47966.2-	35557.4-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

6.4 Bhima at Takali

Using equations 1-9 and 1966-75 runoff data the following relationships have been developed:

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon} =68708.55+7.695* Q_{June}	0.691×10^{10}	0.594×10^{10}	14.1%
2.	Q_{mon} =41058.01+1.954* $Q_{June+July}$	0.691×10^{10}	0.503×10^{10}	27.2%
3.	Q_{mon} =27545.98+1.174* $Q_{June+July+Aug.}$	0.691×10^{10}	0.328×10^{10}	52.5%
4.	Q_{mon} =17283.08+0.964* $Q_{June+July+Aug.+Sept.}$	0.691×10^{10}	0.178×10^{10}	74.3%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1966-75 are plotted in Figure 14.

c. Monsoon runoffs for 1976-83 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

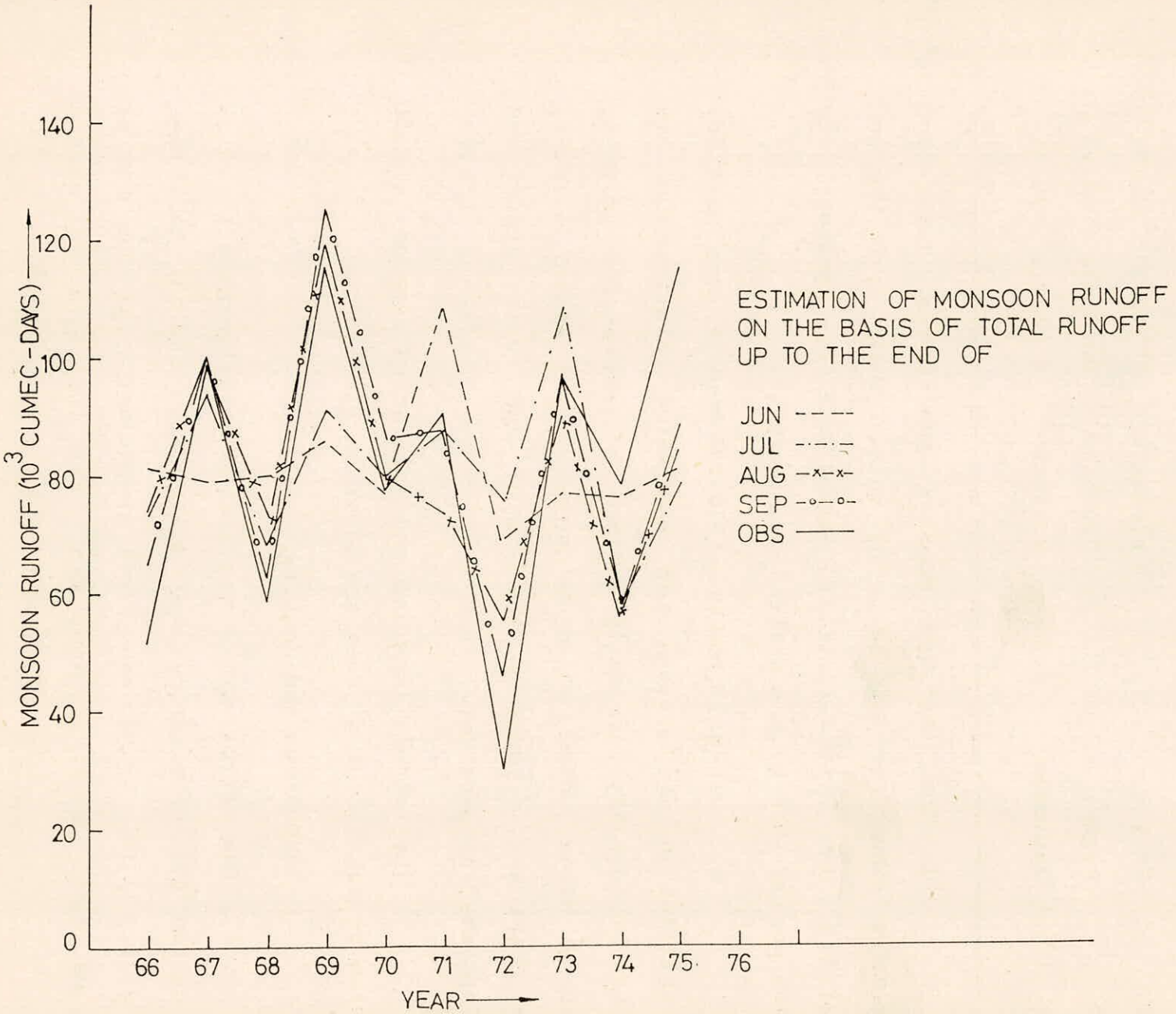


FIG. 14 ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1966-75) FOR BHIMA AT TAKALI

S. No.	Forecast of monsoon runoff on the basis of totalrun-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.688×10^{10}	0.709×10^{10}	-3.1%
2.	July	0.688×10^{10}	0.543×10^{10}	21.0%
3.	August	0.688×10^{10}	0.289×10^{10}	58.0%
4.	September	0.688×10^{10}	0.525×10^{9}	92.4%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1976-83 are plotted in Figure 15.

e. Out of 8 years (1976-83) runoff data used for verification of forecast the regression relationships are able to identify correcatly whether the current year is going to be below normal or above normal for 4 years, 5 years, 6 years and 7 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 24.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 14.1%, 27.2%, 52.5%, 74.3% and -3.1%, 21.0%, 58.0% and 92.4% respectively at the end of June, July, August and September. This indicates that monsoon

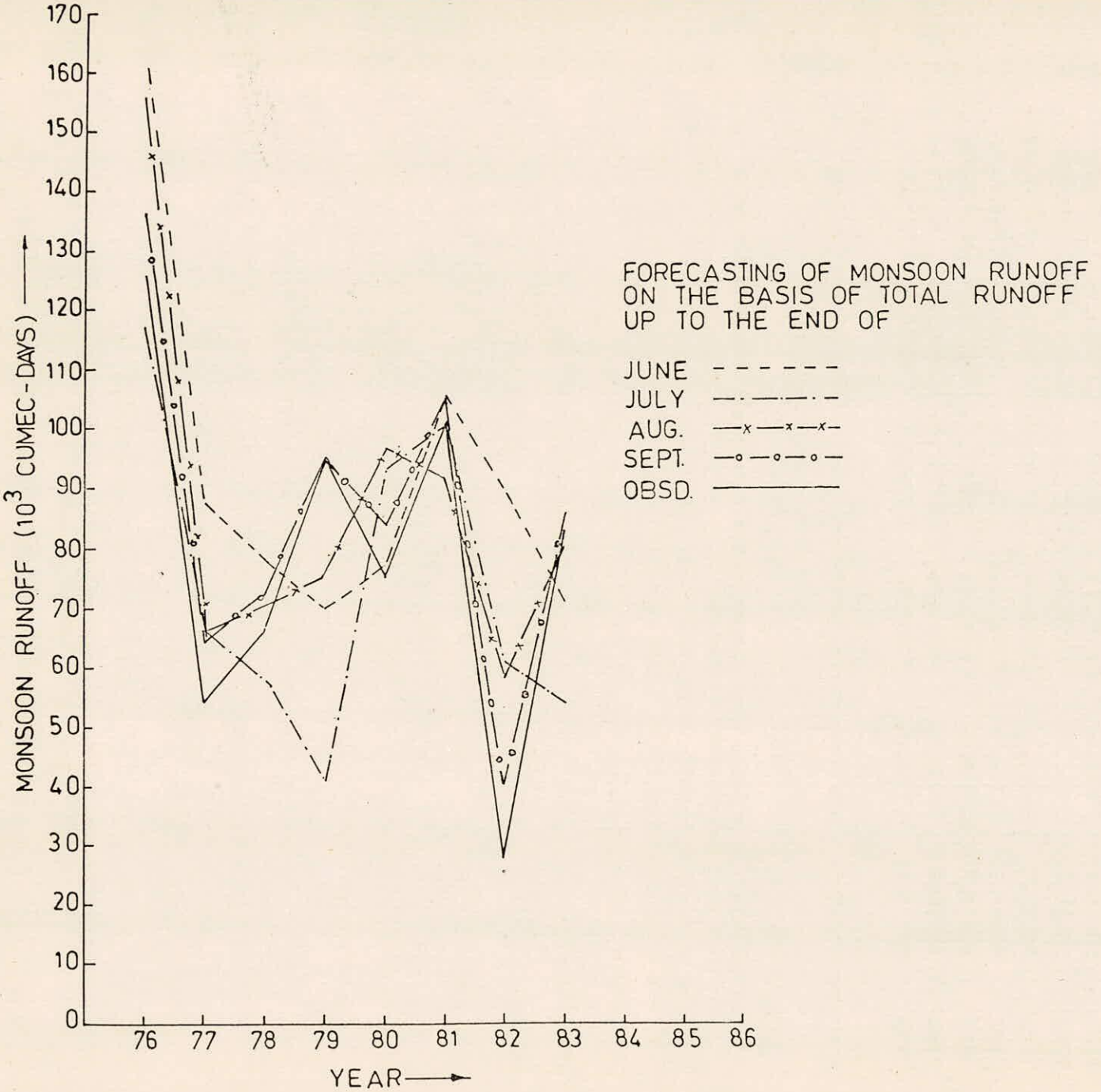


FIG. 15 - FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1976-83) FOR BHIMA AT TAKALI.

TABLE-24

FORECASTING OF MONSOON RUNOFF (1976-1983) FROM DROUGHT POINT OF VIEW FOR BHIMA AT TAKALI

YEAR	NORMAL	OBSERVED	FORECASTING MONSOON RUNOFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1976	81556.9	126046.3+	161029.3+	117567.3+	156188.1+	136590.2+
1977	85601.4	54644.4-	87479.9+	66329.6-	66583.5-	64505.3-
1978	83021.6	65960.2-	78412.4-	57534.8-	69713.6-	72500.6-
1979	81709.2	94897.1+	69995.6-	41069.0-	74878.2-	94279.4+
1980	82651.2	75774.4-	77497.5-	93713.9+	96026.2+	84881.5+
1981	82192.7	101489.5+	106452.4+	101567.5+	93379.1+	105926.8+
1982	83398.8	28233.4-	90242.3+	61757.3-	58872.6-	40970.5-
1983	80153.8	83396.8+	71605.7-	54903.3-	80396.5+	86332.5+

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

flows can be forecasted with good reliability only at the end of September. This may be because of short sample length.

6.5 Bhima at Yadgir

a. Using equations 1-9 and 1965-74 runoff data the following relationships have been developed:

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon} =102749.6+4.494* Q_{June}	0.148×10^{11}	0.142×10^{11}	3.8%
2.	Q_{mon} =51550.3+2.54* $Q_{June+July}$	0.148×10^{11}	0.982×10^{10}	33.5%
3.	Q_{mon} =30458.5+1.442* $Q_{June+July+Aug.}$	0.148×10^{11}	0.527×10^{10}	64.3%
4.	Q_{mon} =29986.9+0.928* $Q_{June+July+Aug.+Sept.}$	0.148×10^{11}	0.360×10^{10}	75.6%

b. Theobserved monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1965-74 are plotted in Figure 16.

c. Monsoon runoffs for 1975-85 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

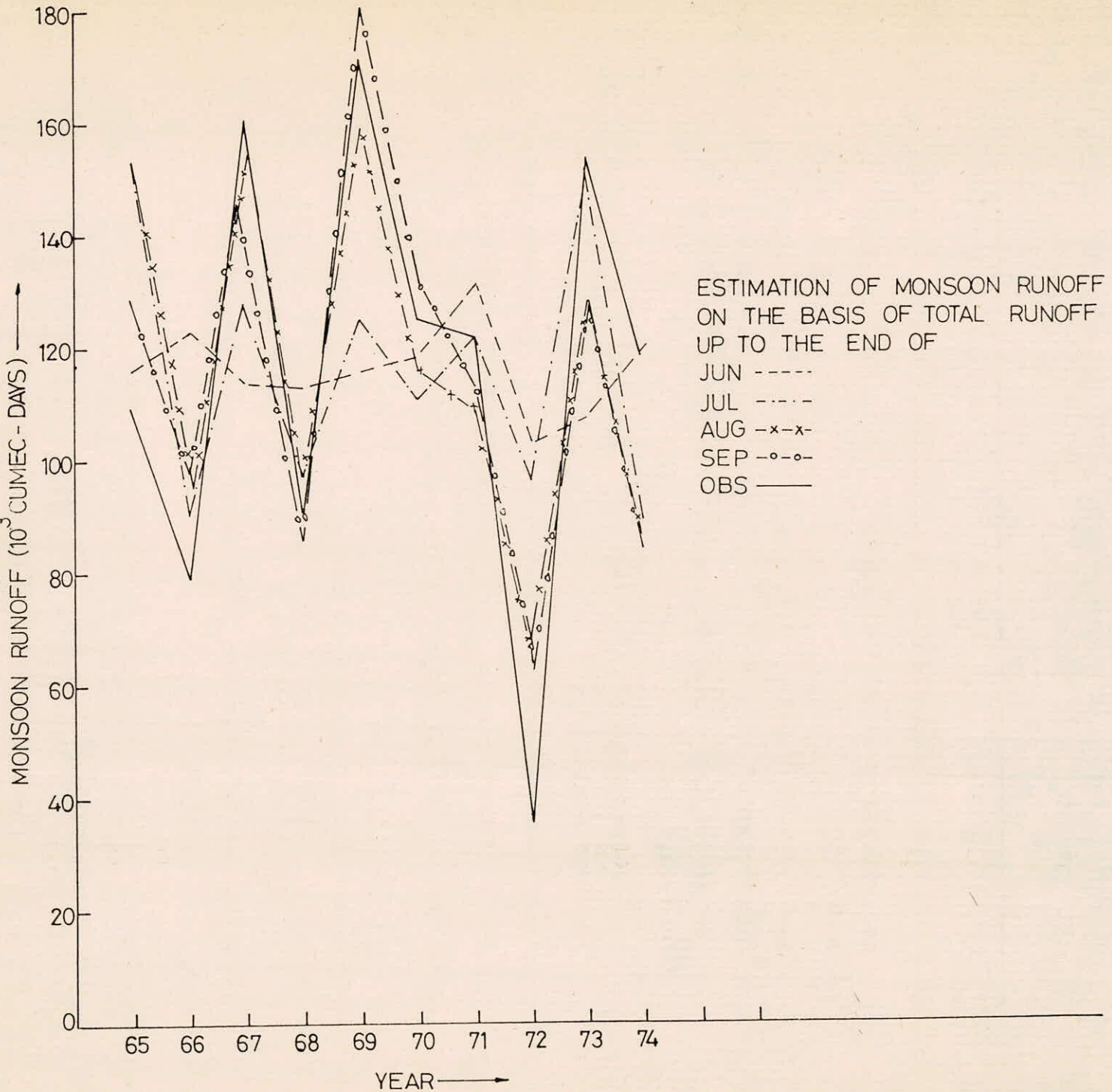


FIG. 16. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1965-74)
FOR RUMA AT YADGIR

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.307×10^{11}	0.323×10^{11}	-5.1%
2.	July	0.307×10^{11}	0.279×10^{11}	9.2%
3.	August	0.307×10^{11}	0.199×10^{11}	35.1%
4.	September	0.307×10^{11}	0.688×10^{10}	77.6%

d. The observed monsson runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1975-85 are plotted in Figure 17.

e. Out of 11 years (1975-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current ;year is going to be below normal or above normal for 5 years, 6 years, 7 years and 11 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 25.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 3.8%, 33.5%, 64.3%, 75.6% and -5.1%, 9.2%, 35.1% and 77.6% respectively at the end of June, July, August and september. The results are very poor.

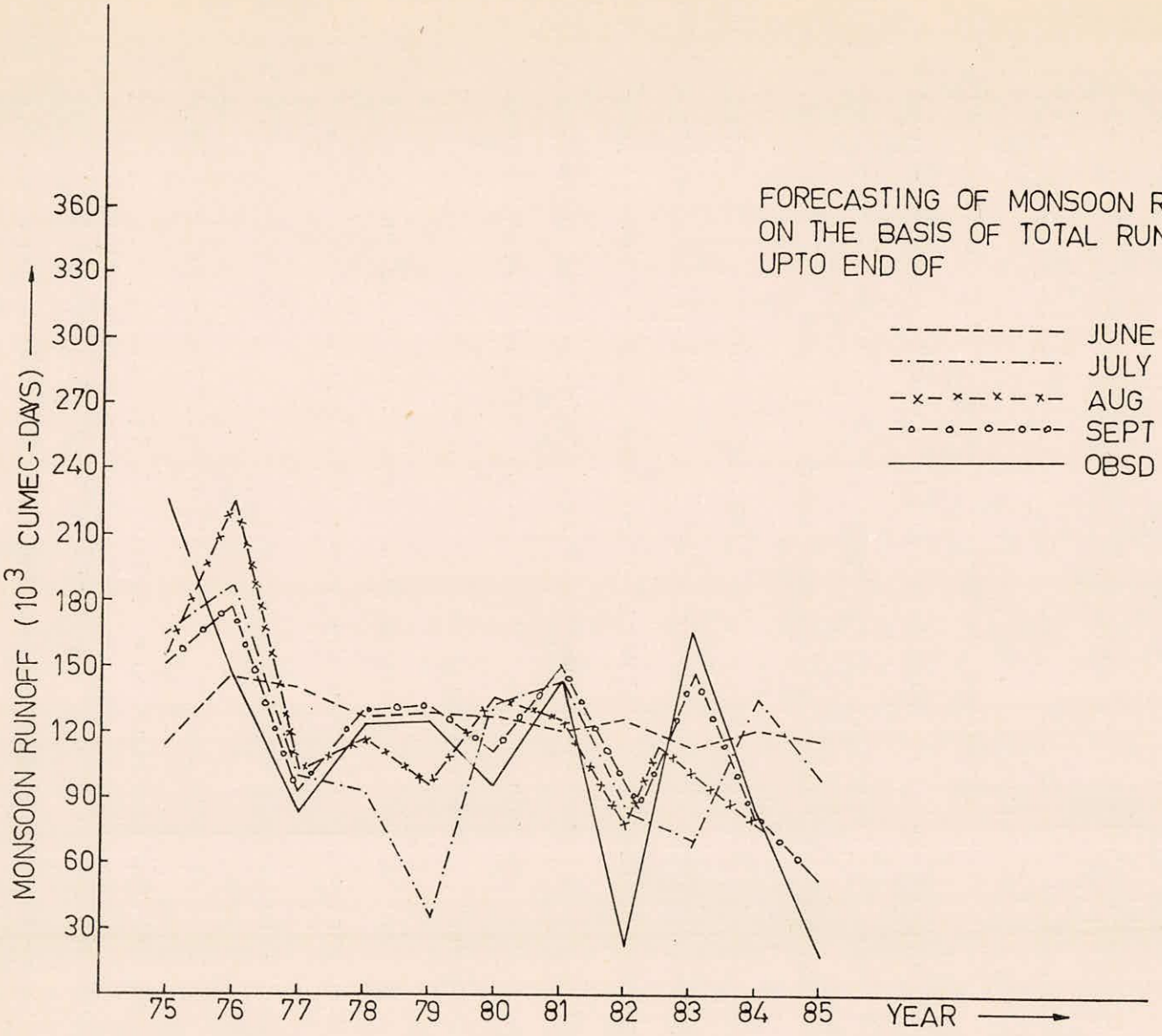


FIG.17 FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1975 85) FOR BHIMA AT YADGIR

TABLE-25

FORECASTING OF MONSOON RUN OFF (1975-1985) FROM DROUGHT POINT OF VIEW FOR BHIMA AT YADGIR

YEAR	NORMAL	OBSERVED	FORECASTING MONSOON RUN OFF IN CUMEC DAY ON THE BASIS OF TOTAL RUN OFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1975	116627.5	222597.1+	114025.2-	165941.2+	154211.7+	151821.6+
1976	126261.1	145540.3+	148990.6+	188042.3+	224620.7+	174690.1+
1977	127867.7	82316.8-	140891.0+	98478.1-	101037.9-	93511.9-
1978	124363.8	124752.3+	124166.4-	94702.5-	117199.0-	127984.1+
1979	124391.6	125738.1+	124821.7+	55313.4-	97630.1-	127679.8+
1980	124481.3	95119.4-	124375.7-	131759.4+	135250.8+	113738.7-
1981	122646.2	142144.0+	120611.5-	146080.9+	127853.1+	150126.6+
1982	123793.1	44356.5-	123246.6-	88663.1-	79512.2-	60913.5-
1983	119380.0	167840.8+	117346.3-	78746.5-	117870.2-	157728.9+
1984	121930.5	83852.2-	121157.4-	133352.5+	112162.6-	82712.1-
1985	120026.6	44460.0-	119137.9-	99809.7-	82690.5-	53886.0-

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

The critical examination of flows reveals that the flows at Yadgir are not virgin.

6.6 Tungbhadra at Haralahalli

a. Using equations 1-9 and 1967-76 runoff data the following relationships have been developed:

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q'_{mon} =63584.7+1.59* Q_{June}	0.286×10^{10}	0.225×10^{10}	21.3%
2.	Q_{mon} =27010.1+1.582* $Q_{June+July}$	0.286×10^{10}	0.174×10^{10}	39.1%
3.	Q_{mon} =5166.4+1.468* $Q_{June+July+Aug.}$	0.286×10^{10}	0.165×10^{9}	94.3%
4.	Q_{mon} =-2219.7+1.158* $Q_{June+July+Aug.+Sept.}$	0.286×10^{10}	0.481×10^{8}	98.3%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) september for the period 1967-76 are plotted in Figure 18.

c. Monsoon runoffs for 1977-85 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

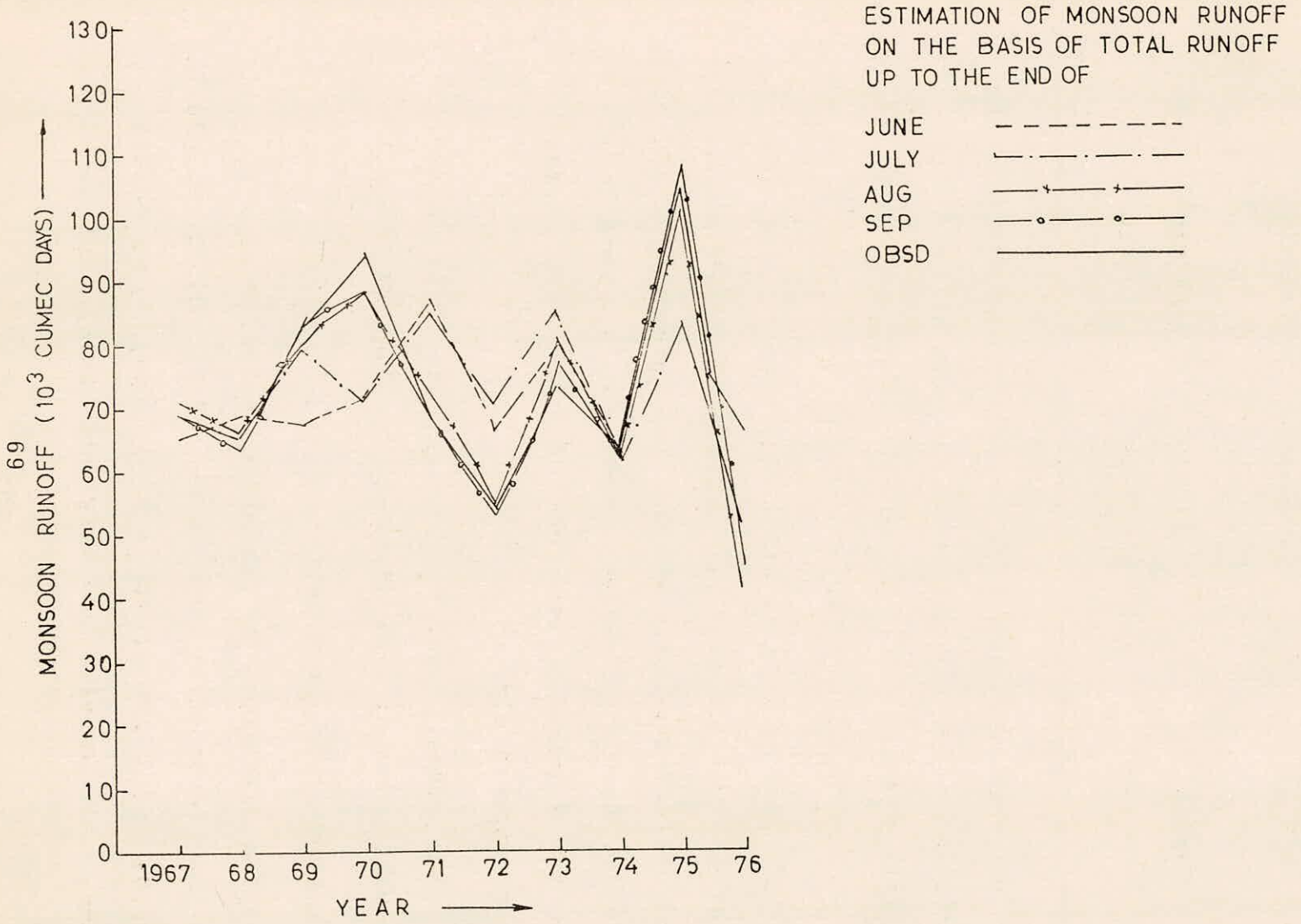


FIG. 18. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1967-76) FOR TUNGABHADRA AT HARALAHALLI.

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.476×10^{10}	0.342×10^{10}	28.2%
2.	July	0.476×10^{10}	0.200×10^{10}	57.9%
3.	August	0.476×10^{10}	0.344×10^{9}	92.8%
4.	September	0.476×10^{10}	0.101×10^{9}	97.9%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1977-85 are plotted in Figure 19.

e. Out of 9 years (1977-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 6 years, 6 years, 8 years and 9 years at the end of june, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 26.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 21.3%, 39.1%, 94.3% and 28.2%, 57.9%,92.8% and 97.9% at the end of june, July, August and September. The results are very good inspite of the short

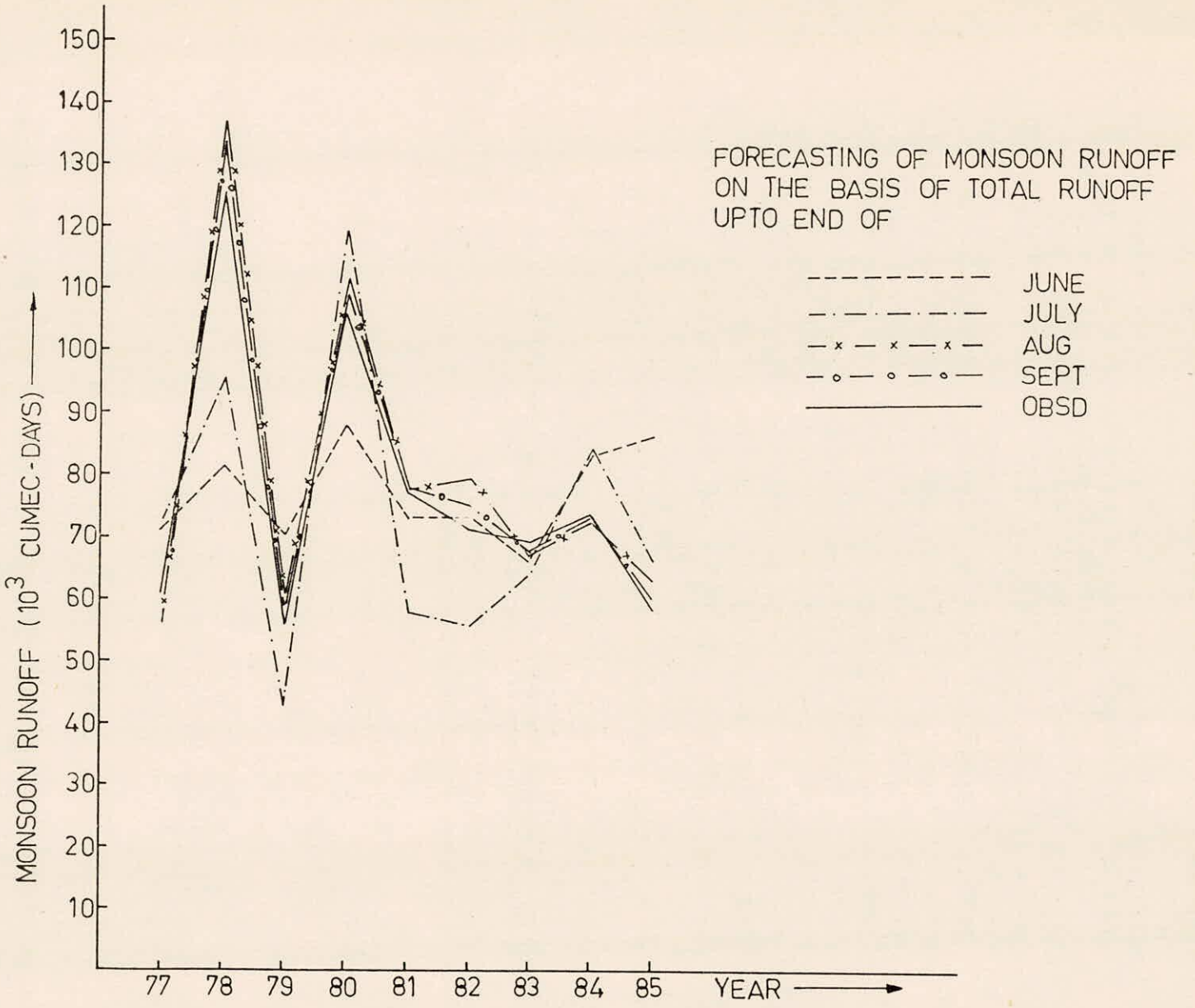


FIG. 19 FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1977 85) FOR TUNGBHADRA AT HARLAHALLI

TABLE-26

FORECASTING OF MONSOON RUN OFF (1977-85) FROM DROUGHT POINT OF VIEW FOR TUNGBHADRA AT HARALHALLI

YEAR	NORMAL	OBSERVED	FORECASTING MONSOON RUN OFF IN CUMEC DAY ON THE BASIS OF TOTAL RUN OFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1977	72285.0	65795.5-	71285.0-	73983.8+	56762.7-	61881.4-
1978	71695.1	125622.0+	81173.3+	96693.3+	137547.7+	133218.3+
1979	76189.0	56355.4-	70375.3-	43722.7-	59986.2-	58697.8-
1980	74663.3	106859.8+	88609.2+	119373.6+	111651.8+	109341.7+
1981	76963.1	77569.1+	73935.3-	58951.0-	78777.2+	78199.4+
1982	77003.5	71912.5-	73875.0-	56500.5-	79448.5+	74227.6-
1983	76685.3	69914.2-	66756.8-	64665.8-	67303.1-	69669.5-
1984	76287.0	73764.6-	83419.7+	84363.5+	72892.9-	70591.8-
1985	76146.8	58835.4-	86394.7+	66503.4-	63055.8-	58606.0-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

length of data.

6.7 Tungbhadra at T Ramapuram

Using equations 1-9 and 1966-75 runoff data the following relationships have been developed.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon} =10439.08-3.711* Q_{June}	0.126×10^9	0.117×10^9	7.4%
2.	Q_{mon} =3698.5+5.827* $Q_{June+July}$	0.126×10^9	0.938×10^8	25.8%
3.	Q_{mon} =4000.5+2.786* $Q_{June+July+Aug.}$	0.126×10^9	0.717×10^8	43.3%
4.	Q_{mon} =1360.7+1.613* $Q_{June+July+Aug.+Sept.}$	0.126×10^9	0.298×10^8	76.4%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1966-75 are plotted in Figure 20.

c. Monsoon runoffs for 1976-85 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

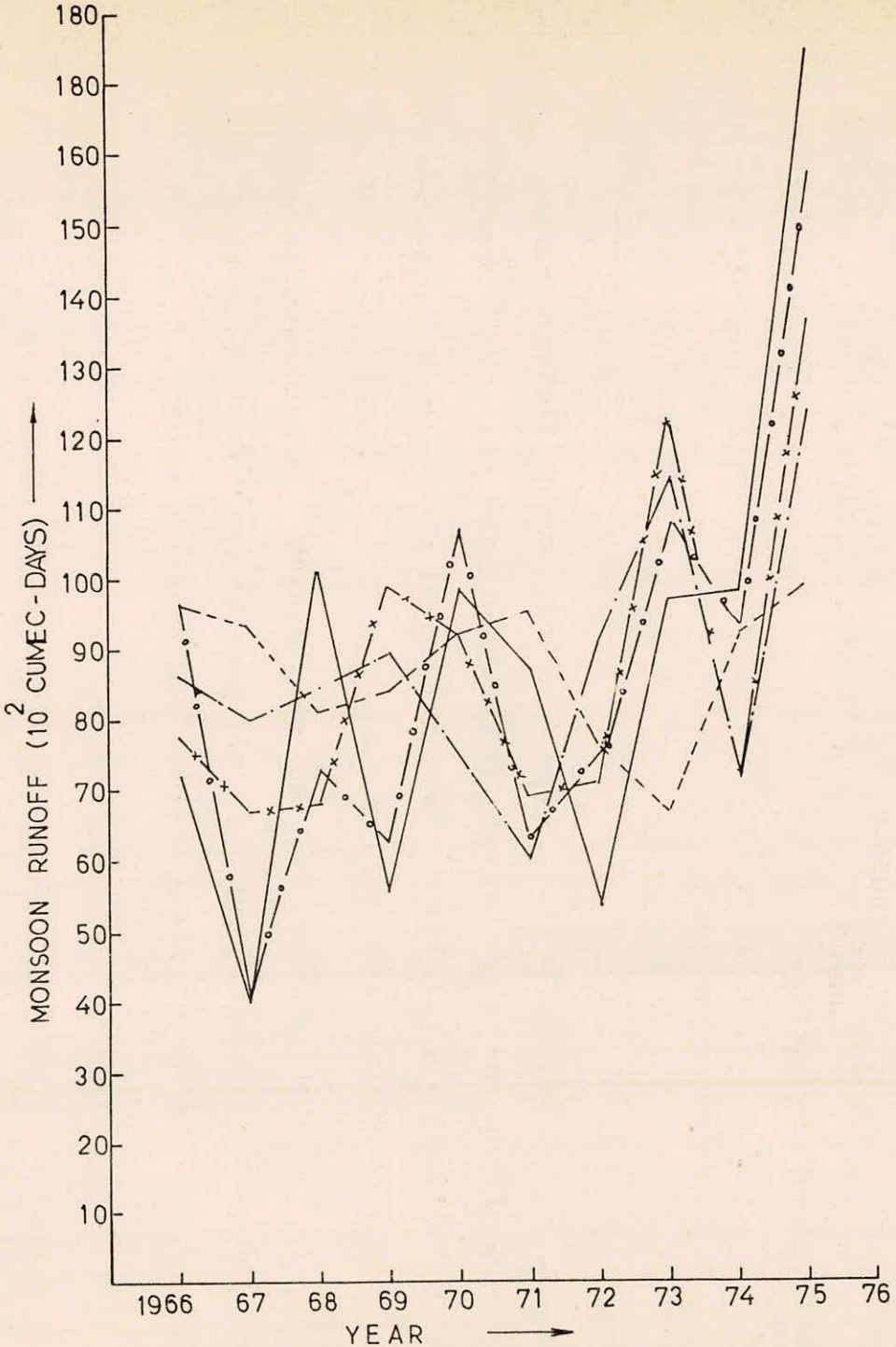


FIG. 20. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1966-75) FOR

S. No.	Forecast of monsoon runoff on the basis of total runoff upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.171×10^9	0.188×10^9	-9.9%
2.	July	0.171×10^9	0.155×10^9	9.7%
3.	August	0.171×10^9	0.130×10^9	24.0%
4.	September	0.171×10^9	0.487×10^8	71.6%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the perioid 1976-85 are plotted in Figure 21.

e. Out of 10 years (1976-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 5 years, 6 years, 8 years and 9 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 27.

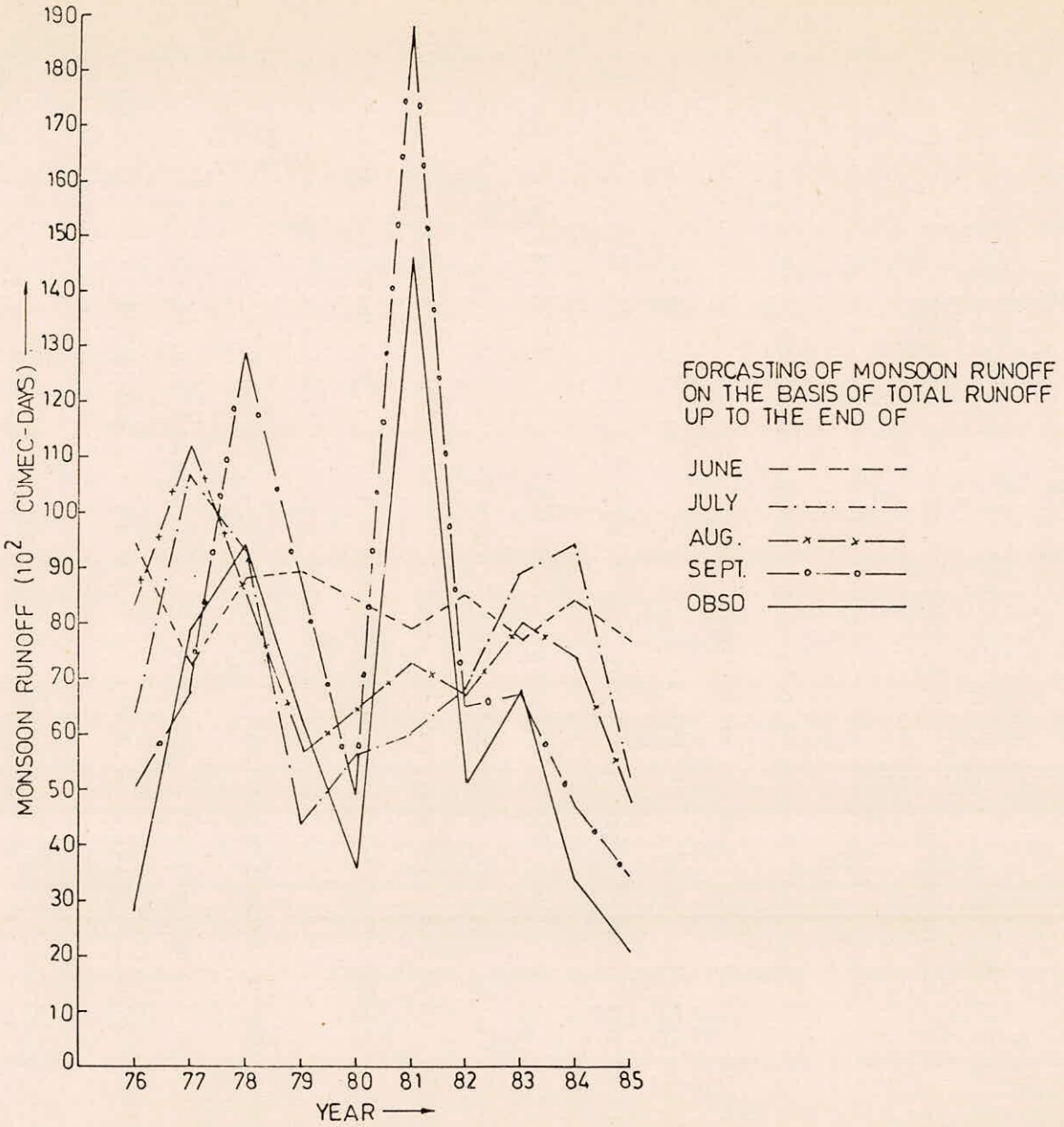


FIG. 21. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1976-85) FOR TUNGBHADRA AT TRAMAPURAM.

TABLE-27

FORECASTING OF MONSOON RUN OFF (1976-85) FROM DROUGHT POINT OF VIEW FOR TUNGBHADRA AT T RAMAPURAM

YEAR	NORMAL	OBSERVED	FORECASTING MONSOON RUNOFF IN CUMEC DAY ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1976	8795.2	2778.9-	9484.6+	6406.9-	8351.1-	5022.4-
1977	8248.2	7323.4-	7246.3-	10784.1+	11275.0+	6847.9-
1978	8221.2	9432.1+	8849.0+	9360.1+	8578.9+	12972.0+
1979	8314.3	6373.1-	8969.4+	4414.5-	5700.7-	8686.3+
1980	8175.6	3697.5-	8473.5+	5662.3-	6459.5-	4972.1-
1981	7877.1	14621.9+	7942.2+	6070.5-	7371.8-	18847.7+
1982	8298.6	5154.2-	8521.9+	6837.9-	6658.4-	6508.2-
1983	8113.7	6882.2-	7743.4-	8908.8+	8002.0-	6625.8-
1984	8045.3	3429.6-	8466.8+	9457.8+	7497.9-	4726.5-
1985	7802.3	2174.9-	7746.4-	5232.4-	4737.9-	3437.4-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 7.4%, 25.8%, 43.3%, 76.4% and 9.9%, 9.7%, 24.0% and 71.6% respectively at the end of June, July, August and september. The results are very poor. The flows at T Ramapuram were further investigated and it was found that flows are not virgin and affected by the upstsream structures as the flows at T Ramapuram are much lesser than the flows at Haralhalli while the catchment area upto T Ramapuram is much larger than Haralahalli.

6.8 Koyna Reservoir

a. Using equations 1-9 and 1963-72 runoff data the following relationships have been developed:

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 3509.6+0.153* Q_{June}$	$0.437x10^7$	$0.436x10^7$	0.3%
2.	$Q_{mon} = 2341.3+0.641* Q_{June+July}$	$0.437x10^7$	$0.354x10^7$	19.1%
3.	$Q_{mon} =-130.35+1.193* Q_{June+July+Aug.}$	$0.437x10^7$	$0.318x10^6$	92.7%
4.	$Q_{mon} =-7.74+1.030* Q_{June+July+Aug.+Sept.}$	$0.437x10^7$	$0.345x10^5$	99.2%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1963-72 are plotted in Figure 22.

c. Monsoon runoffs for 1973-83 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below.

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.316×10^7	0.216×10^7	31.7%
2.	July	0.316×10^7	0.144×10^7	54.4%
3.	August	0.316×10^7	0.484×10^6	84.7%
4.	September	0.316×10^7	0.443×10^5	98.6%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1973-83 are plotted in Figure 23.

e. Out of 11 years (1973-83) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 7 years, 11 years, 9 years and 11 years at the end of June, July, August and September respectively.

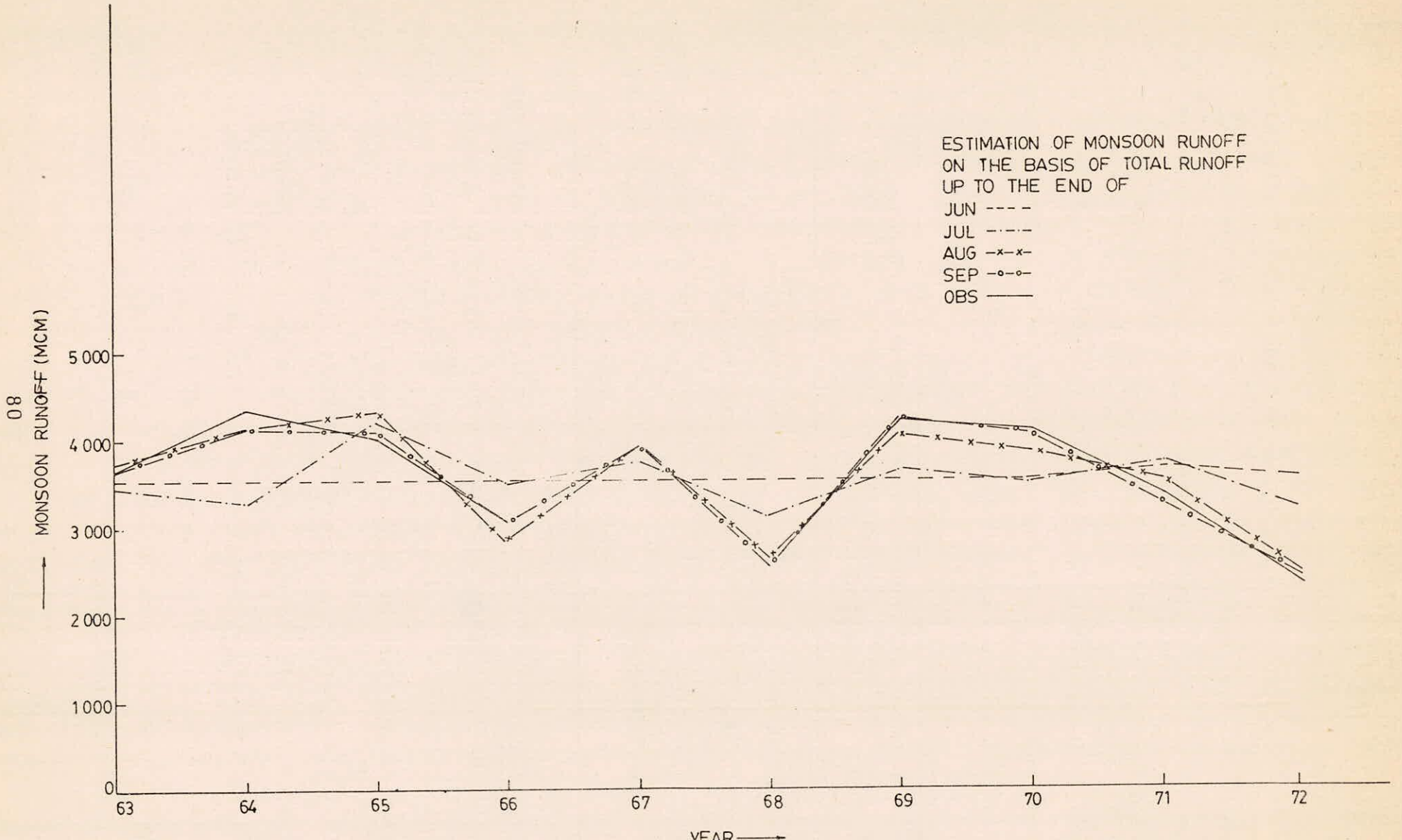


FIG. 22. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1963-72) FOR KOYNA RESERVOIR

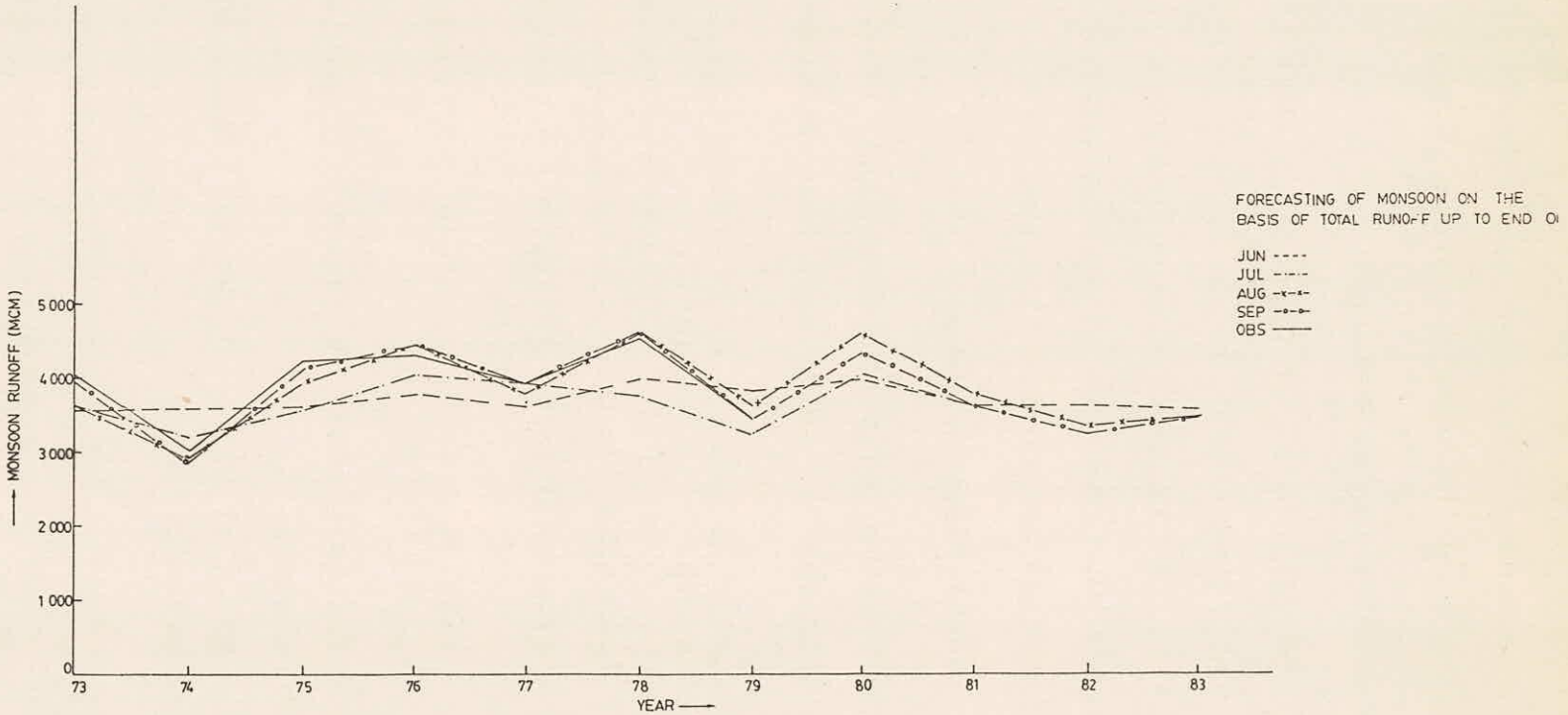


FIG.23. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1973-83) FOR KOYNA RESERVOIR

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 28.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 0.3%, 19.1%, 92.7%, 99.2% and 31.7%, 54.4%, 84.7% and 98.6%. The results are very good and indicate that monsoon flows can be predicted with good reliability even at the end of August.

6.9 Gandhi Sagar Reservoir

a. Using equations 1-9 and 1961-75 runoff data the following relationships have been developed:

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 4796.25-0.722* Q_{June}$	$0.184x10^9$	$0.183x10^9$	0.2%
2.	$Q_{mon} = 1446.44+2.852* Q_{June+July}$	$0.184x10^9$	$0.495x10^8$	73.0%
3.	$Q_{mon} = 328.68+1.565* Q_{June+July+Aug.}$	$0.184x10^9$	$0.397x10^8$	78.4%
4.	$Q_{mon} = 222.67+1.023* Q_{June+July+Aug.+Sept.}$	$0.184x10^9$	$0.221x10^7$	98.8%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1961-75 are plotted in Figure 24.

TABLE-28

FORECASTING OF MONSOON RUNOFF (1973-83) FROM DROUGHT POINT OF VIEW FOR KOYNA

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN MCM ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1973	3545.5	4026.0+	3539.4+	3618.2+	3646.7+	3963.9+
1974	3589.1	2985.0-	3571.8-	3195.8-	2910.1-	2853.2-
1975	3538.8	4184.0+	3602.6+	3558.9+	3924.8+	4115.3+
1976	3588.4	4304.0+	3757.7+	4031.1+	4421.2+	4420.9+
1977	3639.5	3907.0+	3606.1-	3812.1+	3572.6-	3875.0+
1978	3657.4	4515.0+	3957.9+	3735.1+	4545.5+	4567.1+
1979	3711.0	3422.0-	3816.4+	3234.9-	3600.4-	3396.2-
1980	3694.0	4309.0+	3934.5+	3985.8+	4555.9+	4325.5+
1981	3728.1	3614.0-	3574.3-	3638.5-	3740.5+	3607.1-
1982	3722.1	3187.0-	3575.3-	3235.2-	3364.6-	3184.7-
1983	3695.4	3438.0-	3741.1+	3374.6-	3425.1-	3439.0-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

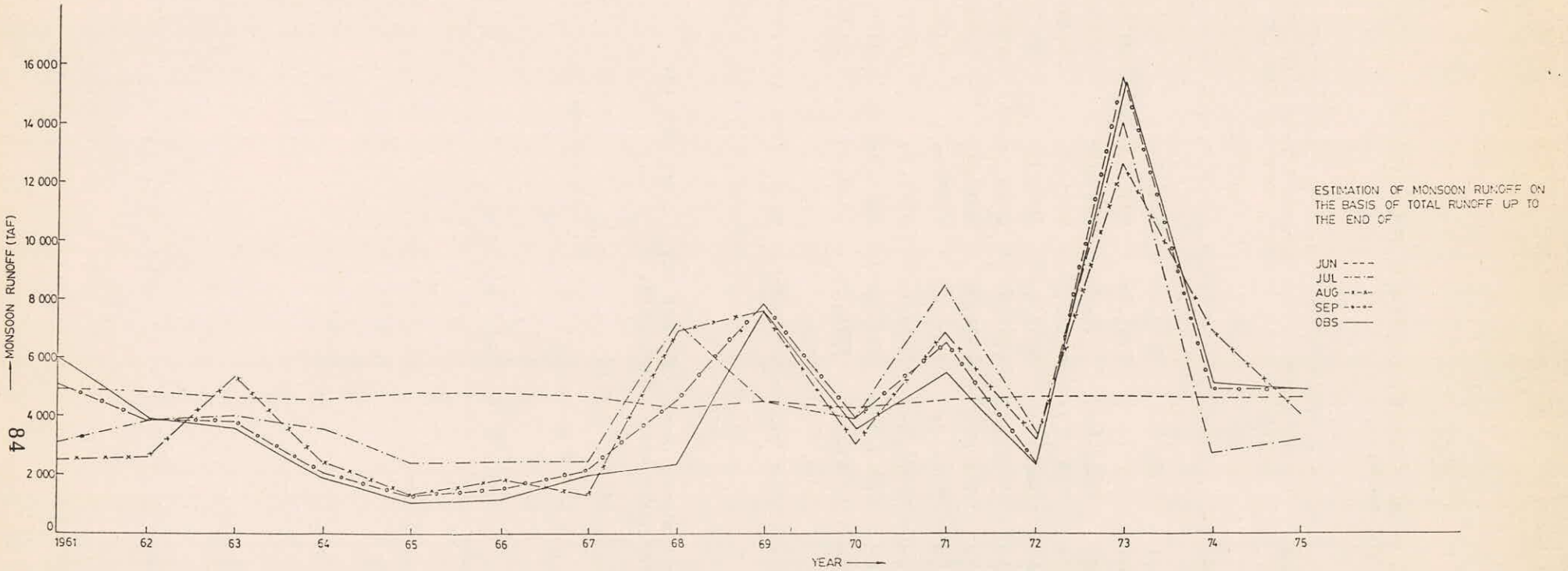


FIG.24ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1961-75) FOR GANDHISAGAR RESERVOIR

c. Monsoon runoffs for 1976-86 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.574×10^8	0.589×10^8	-2.5%
2.	July	0.574×10^8	0.481×10^8	16.2%
3.	August	0.574×10^8	0.285×10^8	50.5%
4.	September	0.574×10^8	0.854×10^6	98.5%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1976-86 are plotted in Figure 25.

e. Out of 11 years (1976-86) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 5 years, 7 years, 10 years and 11 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 29.

Comment on the Results:

The efficiency of regression relationships in cali-

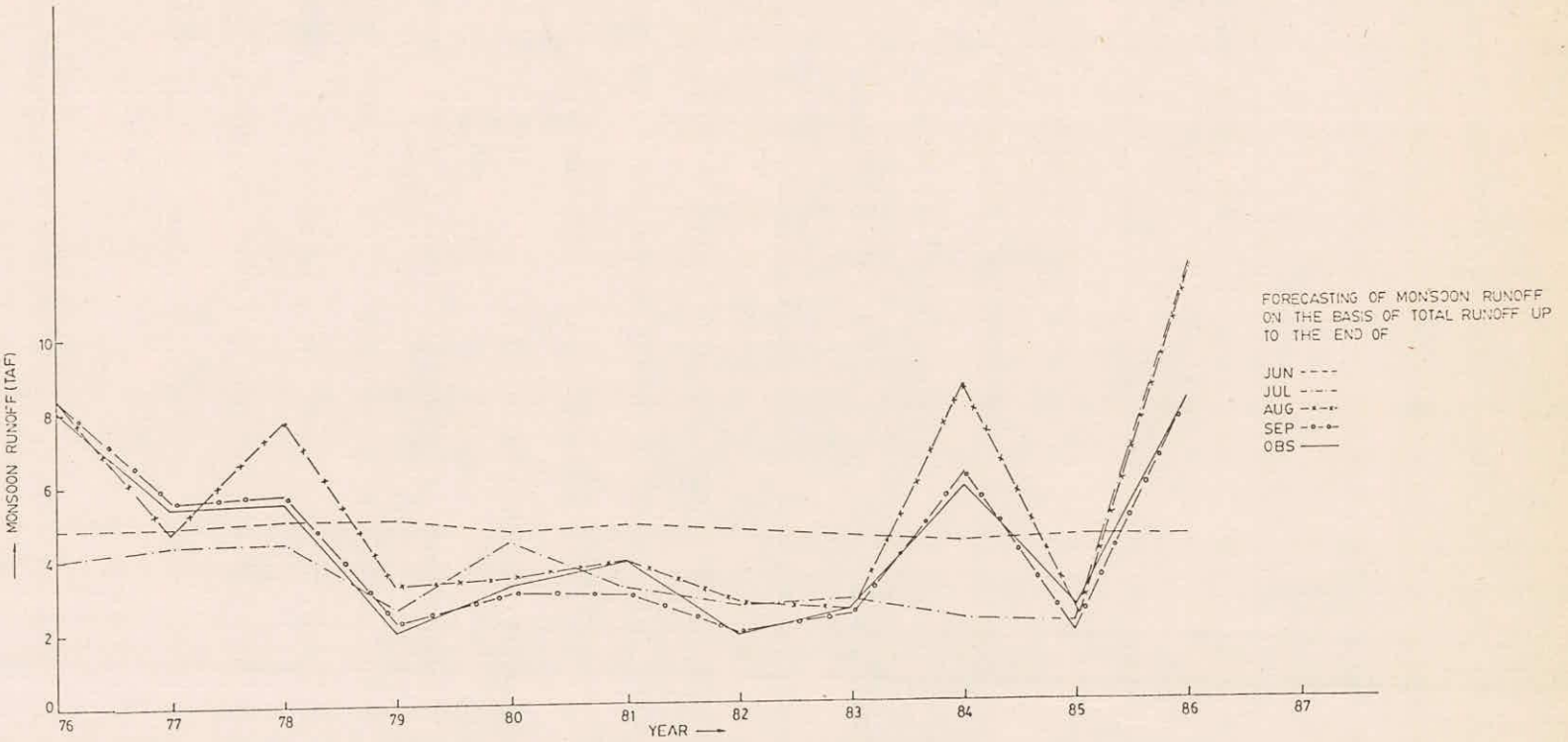


FIG25 FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1976-87) FOR GANDHI SAGAR RESERVOIR

TABLE-29

FORECASTING OF MONSOON RUNOFF (1976-86) FROM DROUGHT POINT OF VIEW FOR GANDHI SAGAR

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN M.A.F ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1976	4653.6	8061.8+	4678.9 +	3983.0-	8363.5+	8358.2+
1977	4866.6	5351.4+	4825.6 -	4340.3-	4703.0-	5490.0+
1978	4895.1	5506.3+	4968.2+	4424.2-	7694.3+	5696.6+
1979	4929.0	2011.3-	5039.6+	2558.1-	3229.9-	2193.1-
1980	4775.5	3191.0-	4673.6-	4421.0-	3406.2-	3051.1-
1981	4696.3	2782.9-	4804.8+	3070.5-	3843.4-	2943.4-
1982	4605.1	1781.5-	4700.1+	2662.5-	2613.3-	1973.0-
1983	4476.8	2422.4-	4473.8-	2760.7-	2355.6-	2456.8-
1984	4387.5	5804.1+	4334.3-	2221.2-	8454.2+	6073.1+
1985	4446.5	2508.5-	4430.4-	2090.9-	2240.5-	1833.5-
1986	4369.0	7915.4+	4329.6-	11592.6+	11481.0+	8174.2+

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

bration and forecasting are 0.2%, 73.0%, 78.4%, 98.8% and -2.5%, 16.2%, 50.5% and 98.5% respectively at the end of June, July, August and September. The results are poor. This may be because of short sample length. The parameters of the regression relationships are also highly unstable.

6.10 Mahanadi at Hirakud

a. Using equations 1-9 and 1944-65 runoff data the following relationships have been developed.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 360.75+8.513* Q_{June}$	$0.760x10^6$	$0.283x10^6$	62.7%
2.	$Q_{mon} = 218.22+2.070* Q_{June+July}$	$0.760x10^6$	$0.154x10^6$	79.6%
3.	$Q_{mon} = 67.38+1.318* Q_{June+July+Aug.}$	$0.760x10^6$	$0.120x10^6$	84.2%
4.	$Q_{mon} = 9.135+1.076* Q_{June+July+Aug.+Sept.}$	$0.760x10^6$	$0.113x10^5$	98.5%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1946-65 are plotted in Figure 26.

c. Monsoon runoffs for 1966-82 period have been forecasted after updating the parameters. The efficiency

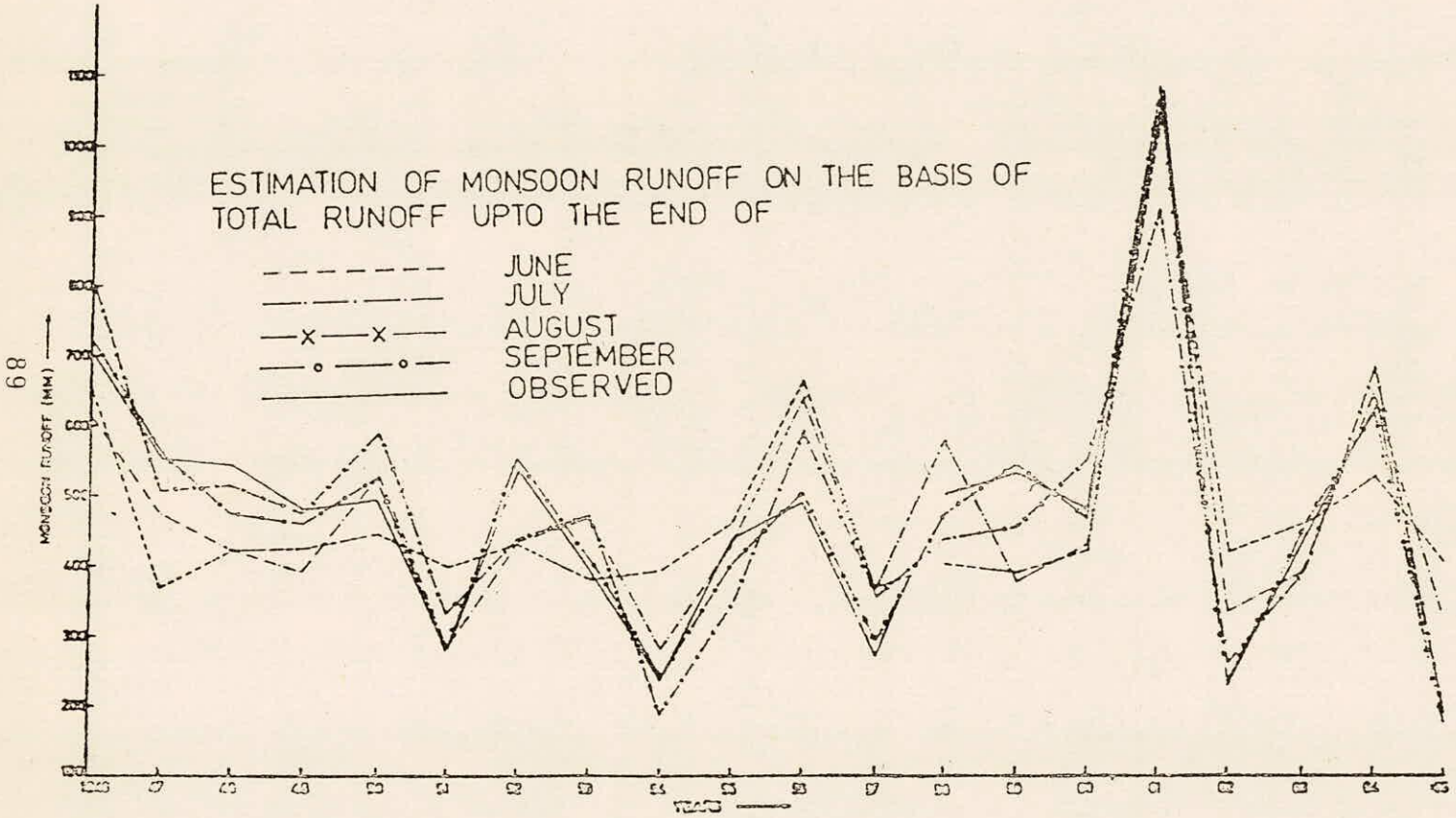


FIG.26. - ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1946-65) FOR MAHANADI AT HIRAKUD

of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.390×10^6	0.448×10^6	-15.10%
2.	July	0.390×10^6	0.114×10^6	70.8%
3.	August	0.390×10^6	0.724×10^5	81.4%
4.	September	0.390×10^6	0.836×10^4	97.9%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1966-82 are plotted in Figure 27.

e. Out of 17 years (1966-82) runoff data used for verification of forecast the regression relationships are abel to identify correctly whether the current year is going to be below normal or above normal for 12 years, 15 years, 16 years and 17 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought pointof view are given in Table 30.

Comment on the Results:

The efficiency of monsoon runoff forecasts are 71%, 81% and 98% at the end of July, August and September respectively. The relationships are also good enough in identifying

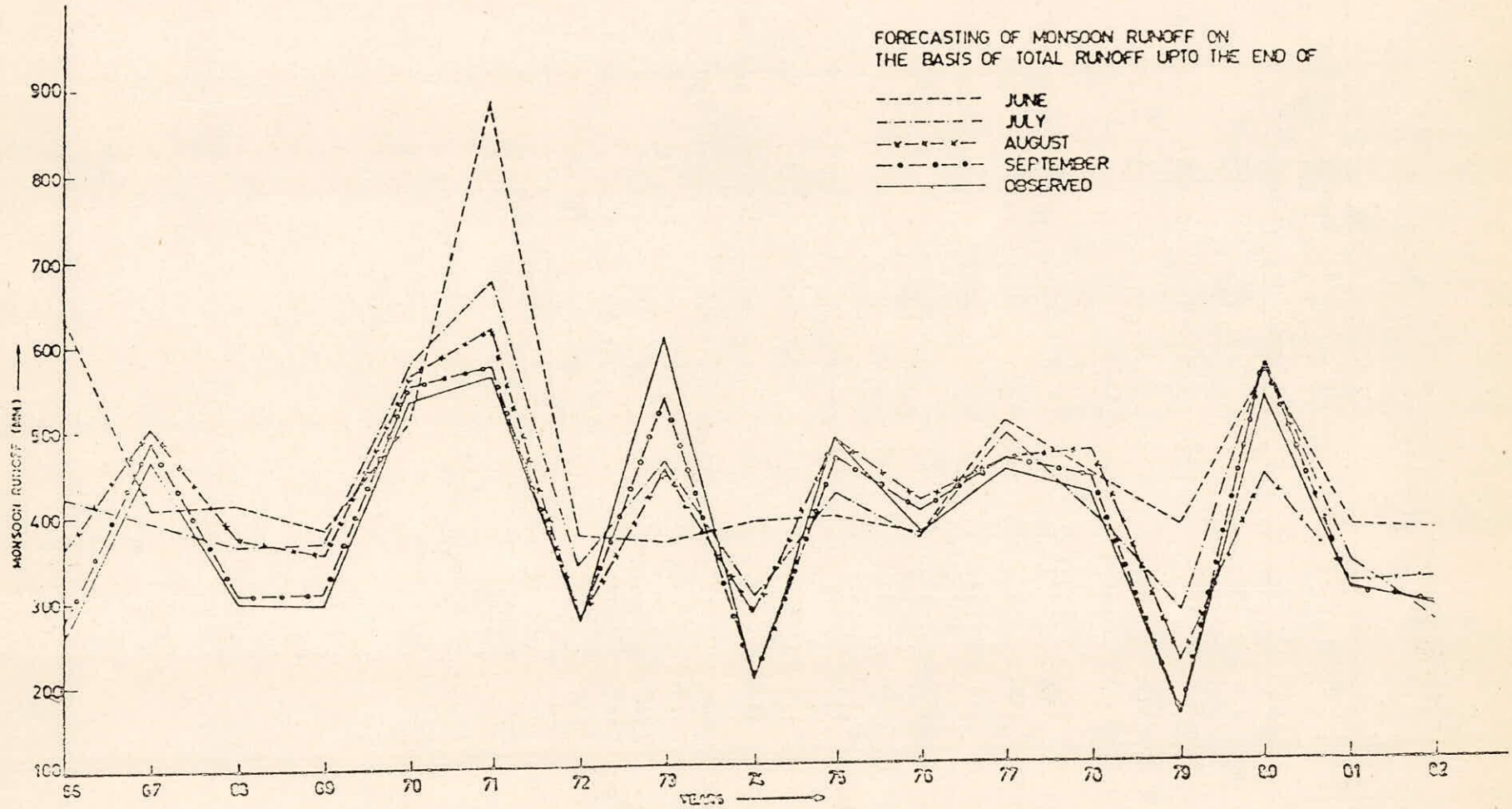


FIG. 27- FORECASTING OF MONSOON RUNOFF FOR THE PERIOD(1966-82)FOR MAHANADI AT HIRAKUD

TABLE - 30

FORECASTING OF MONSOON RUNOFF (1966-82) FROM DROUGHT POINT OF VIEW FOR MAHANADI AT HIRAKUD

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN MM ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1966	476.3	258.9-	633.2+	422.1-	362.3-	276.0-
1967	465.9	468.8+	409.6-	395.2-	506.8+	490.5+
1968	466.0	302.2-	415.0-	365.3-	376.5-	309.1-
1969	458.9	297.7-	385.8-	368.1-	356.0-	309.8-
1970	452.2	535.5+	512.3+	578.9+	565.7+	552.2+
1971	455.5	565.7+	886.7+	675.8+	620.7+	575.1+
1972	459.8	276.0-	374.7-	339.6-	277.0-	279.1-
1973	453.0	608.5+	366.9-	462.0+	454.7+	539.4+
1974	458.5	203.9-	390.2-	300.6-	280.3-	205.5-
1975	449.7	484.0+	396.1-	423.2	487.3+	466.4+
1976	450.9	375.8-	376.9-	370.9-	413.3-	401.5-
1977	448.5	448.8+	508.7+	493.9+	462.3+	460.3+
1978	448.5	420.4-	442.8-	399.0-	472.6+	439.4-
1979	447.6	152.9-	379.1-	277.2-	213.5-	151.9-
1980	439.0	536.2+	560.6+	571.3+	443.3+	563.7+
1981	441.7	303.5-	380.7-	334.4-	309.4-	301.5-
1982	437.9	279.8-	374.2-	262.7-	315.4-	284.9-

Note: IN CALCULATING MONSOON NORMAL RUNOFF FOR A YEAR ALL THE DATA PRIOR TO THAT YEAR STARTING FROM 1946 HAVE BEEN CONSIDERED

2. -VE SIGN SHOWS RUNOFF IS BELOW NORMAL

3. +VE SIGN SHOWS RUNOFF IS ABOVE NORMAL

whether the current year is going to be below normal or above normal from runoff point of view.

6.11 Chaliyar river

a. Using equations 1-9 and 1965-74 runoff data the following relationships have been developed

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon}= 820.26+0.729* Q_{June}	0.116×10^7	0.111×10^7	4.8%
2.	Q_{mon} = 212.35+1.507* $Q_{June+July}$	0.116×10^7	0.271×10^6	76.7%
3.	Q_{mon} = 88.28+1.154* $Q_{June+July+Aug.}$	0.116×10^7	0.879×10^5	92.5%
4.	Q_{mon} = 76.31+!.005* $Q_{June+July+Aug.+Sept.}$	0.116×10^7	0.923×10^4	99.2%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1965-74 are plotted in Figure 28.

c. Monsoon runoffs for 1975-78 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below.

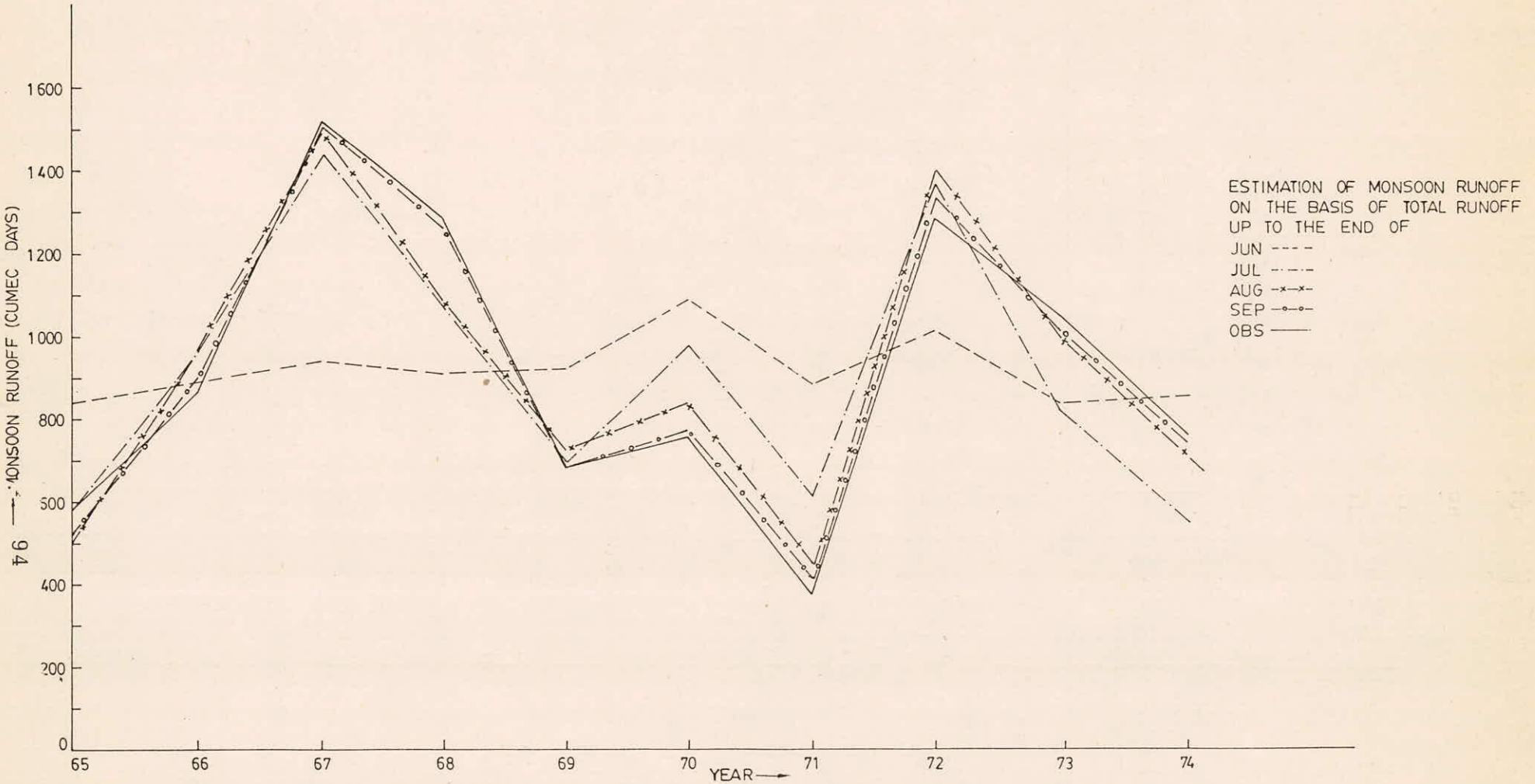


FIG.28. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1965-74) FOR CHALIYAR

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.564×10^6	0.425×10^6	24.7%
2.	July	0.564×10^6	0.213×10^6	62.2%
3.	August	0.564×10^6	0.169×10^5	97.0%
4.	September	0.564×10^6	0.105×10^5	98.1%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1975-78 are plotted in Figure 29.

e. Out of 4 years (1975-78) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 3 yearas, 4 years, 4 years and 4 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 31.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 4.8%, 76.7%, 92.5%, 99.2% and 24.7%, 62.2%, 97.7% and 98.1% respectively at the end of June, July, August and September. The results are very good

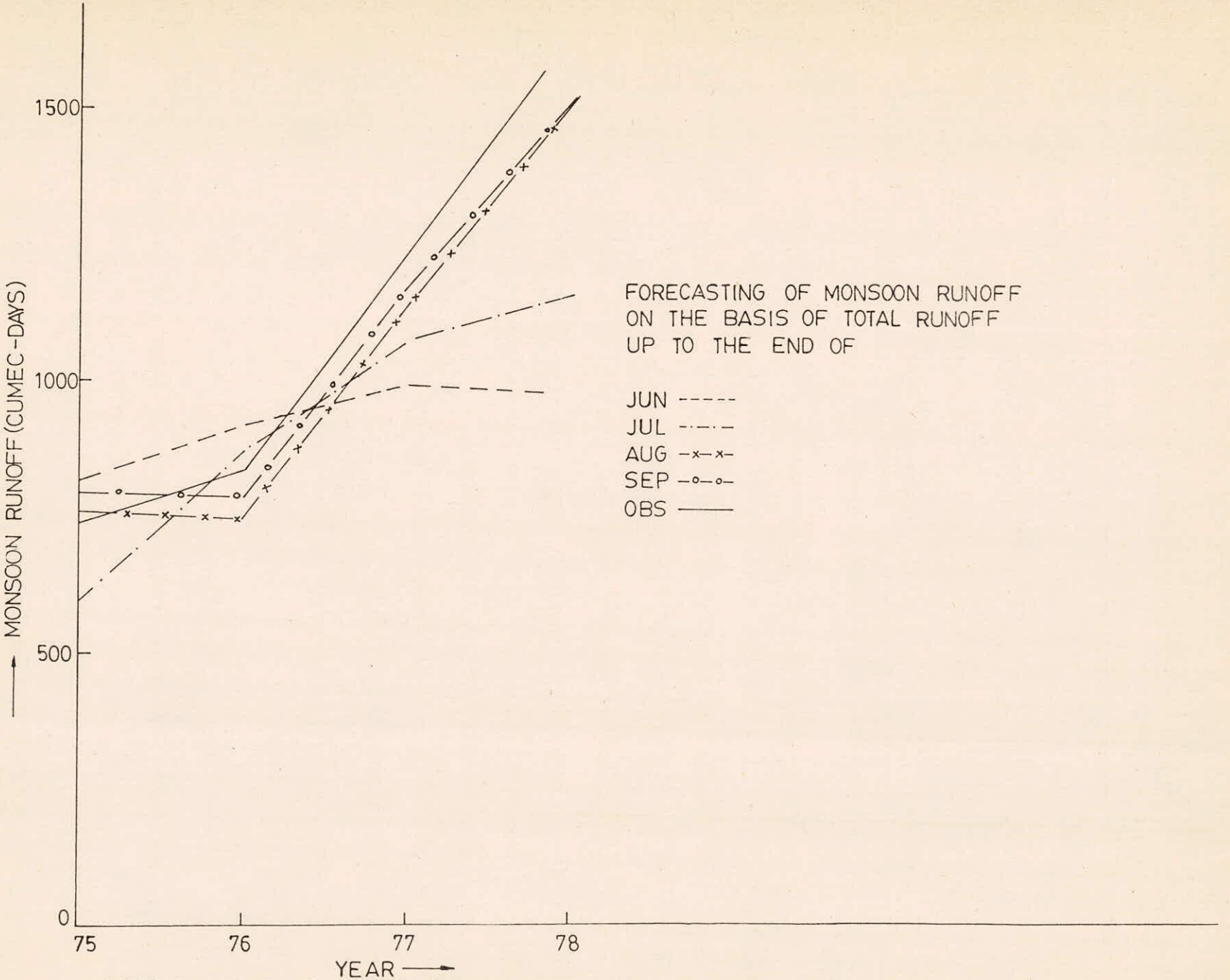


FIG29. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1975-78) FOR CHALIYAR

TABLE-31

FORECASTING OF MONSOON RUN OFF (1975-78) FROM DROUGHT POINT OF VIEW FOR CHALIYAR

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1975	920.2	746.7-	827.3-	596.6-	760.1-	789.4-
1976	904.4	833.9-	928.4+	874.9-	748.9-	782.5-
1977	898.5	1213.2+	998.1+	1068.3+	1143.8+	1167.3+
1978	922.7	1578.4+	976.0+	1168.5+	1510.1+	1515.7+

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

inspite of the short sample length.

6.12 Kanhirpuzha River

a. Using equations 1-9 and 1965-74 runoff data the following relationships have been developed.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 169.07+1.405* Q_{June}$	$0.136x10^6$	$0.947x10^5$	30.5%
2.	$Q_{mon} = 21.92+1.774* Q_{June+July}$	$0.136x10^6$	$0.133x10^5$	90.2%
3.	$Q_{mon} = 0.11+1.299* Q_{June+July+Aug.}$	$0.136x10^6$	$0.212x10^4$	98.4%
4.	$Q_{mon} = 10.17+1.059* Q_{June+July+Aug.+Sept.}$	$0.136x10^6$	$0.806x10^3$	99.4%

b.The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1965-74 are plotted in Figure 30.

c. Monsoon runoffs for 1975-78 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

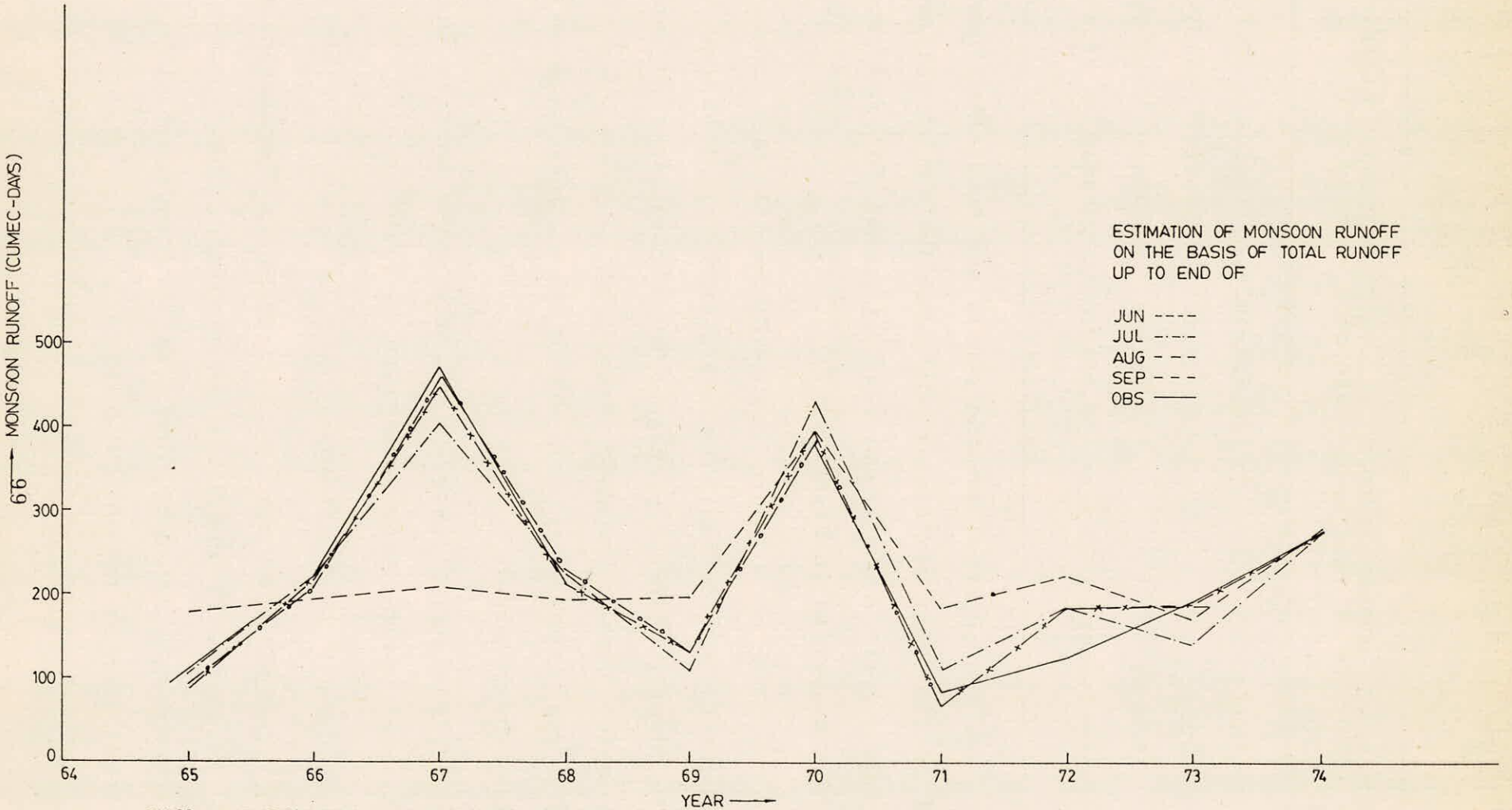


FIG.30. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1965-74) FOR KANHIRPUZHA

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.351×10^5	0.218×10^5	37.8%
2.	July	0.351×10^5	0.558×10^4	84.1%
3.	August	0.351×10^5	0.277×10^4	92.1%
4.	September	0.351×10^5	0.494×10^3	98.6%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1975-78 are plotted in Figure 31.

e. Out of 4 years (1975-78) runoff data used for verificatioin of forecast the regression relaationships are able to identify correctly whether the current year is going to be below normal or above normal for 3 years, 4 years, 4 years and 4 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 32.

Comment on the Results

The efficiency of relationships in forecasting are 37.8%, 84.1%, 92.1% and 98.6% respectively. This indicates that Kanhirpuzha monsoon flows can be forecasted with good efficiency even at the end of July.

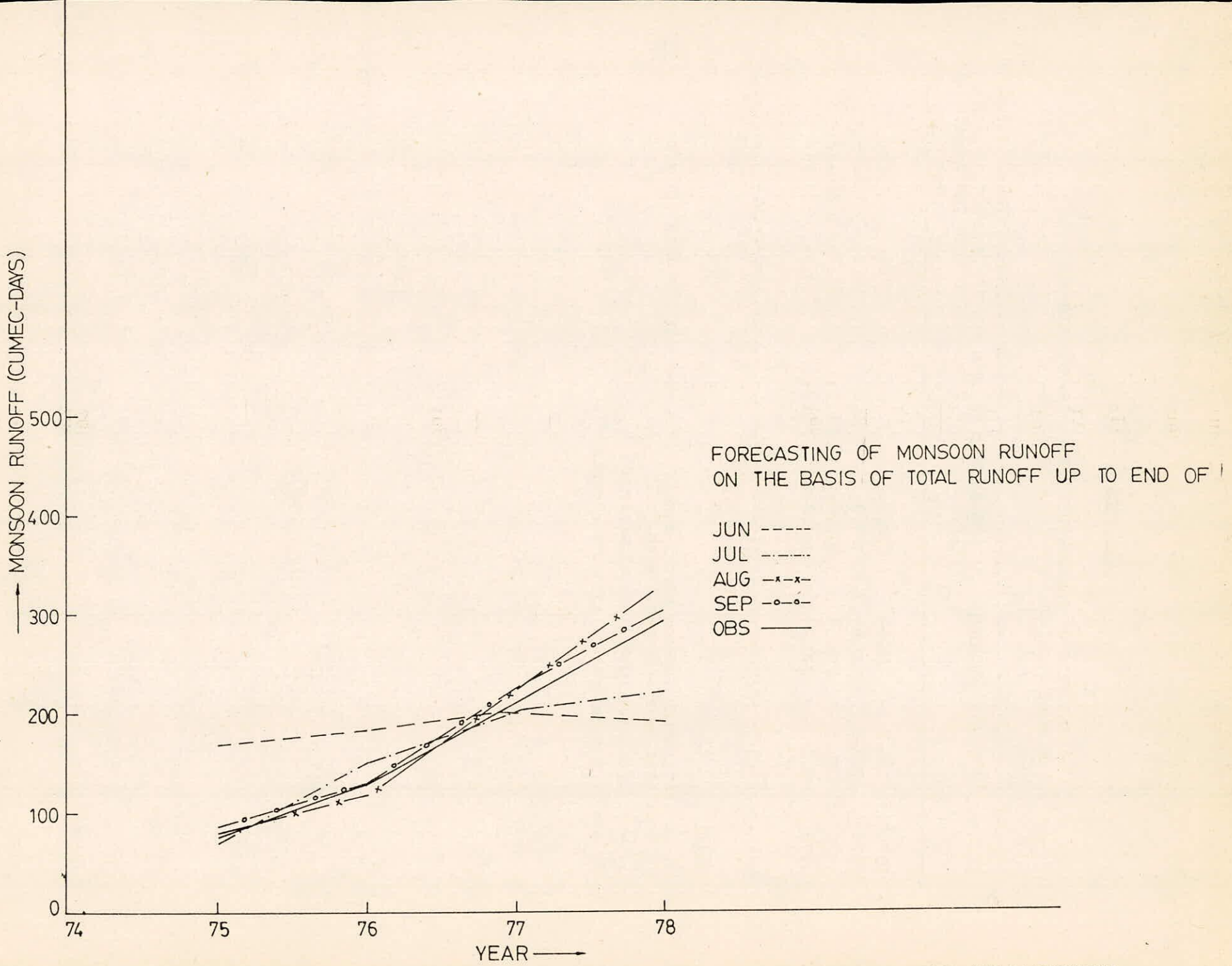


FIG.31. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1975-78) FOR KANHIRPUZHA

TABLE-32

FORECASTING OF MONSOON RUN OFF (1975-78) FROM DROUGHT POINT OF VIEW FOR KANHIRPUZHA

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1975	220.2	75.6-	170.2-	72.8-	77.3-	85.4-
1976	207.0	128.4-	184.9-	152.6-	119.2-	128.7-
1977	200.5	210.3+	200.9+	204.1+	238.2+	224.1+
1978	201·2	290.0+	192.1-	219.7+	333.7+	304.4+

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

6.13 Koodathai River : a. Using equations 1-9 and 1965-74 runoff data the following relationships have been developed

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 465.47+0.230* Q_{June}$	$0.169x10^6$	$0.168x10^6$	0.6%
2.	$Q_{mon} = 210.10+1.020* Q_{June+July}$	$0.169x10^6$	$0.629x10^5$	62.8%
3.	$Q_{mon} = 100.09+0.961* Q_{June+July+Aug.+September}$	$0.169x10^6$	$0.201x10^5$	88.1%
4.	$Q_{mon} = 42.05+0.995* Q_{June+July+Aug.+Sept.}$	$0.169x10^6$	$0.399x10^4$	97.6%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1965-74 are plotted in Figure 32.

c. Monsoon runoffs for 1975-78 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	$0.646x10^6$	$0.330x10^6$	48.8%
2.	July	$0.646x10^6$	$0.840x10^5$	87.0%
3.	August	$0.646x10^6$	$0.199x10^5$	96.9%
4.	September	$0.646x10^6$	$0.604x10^4$	99.1%

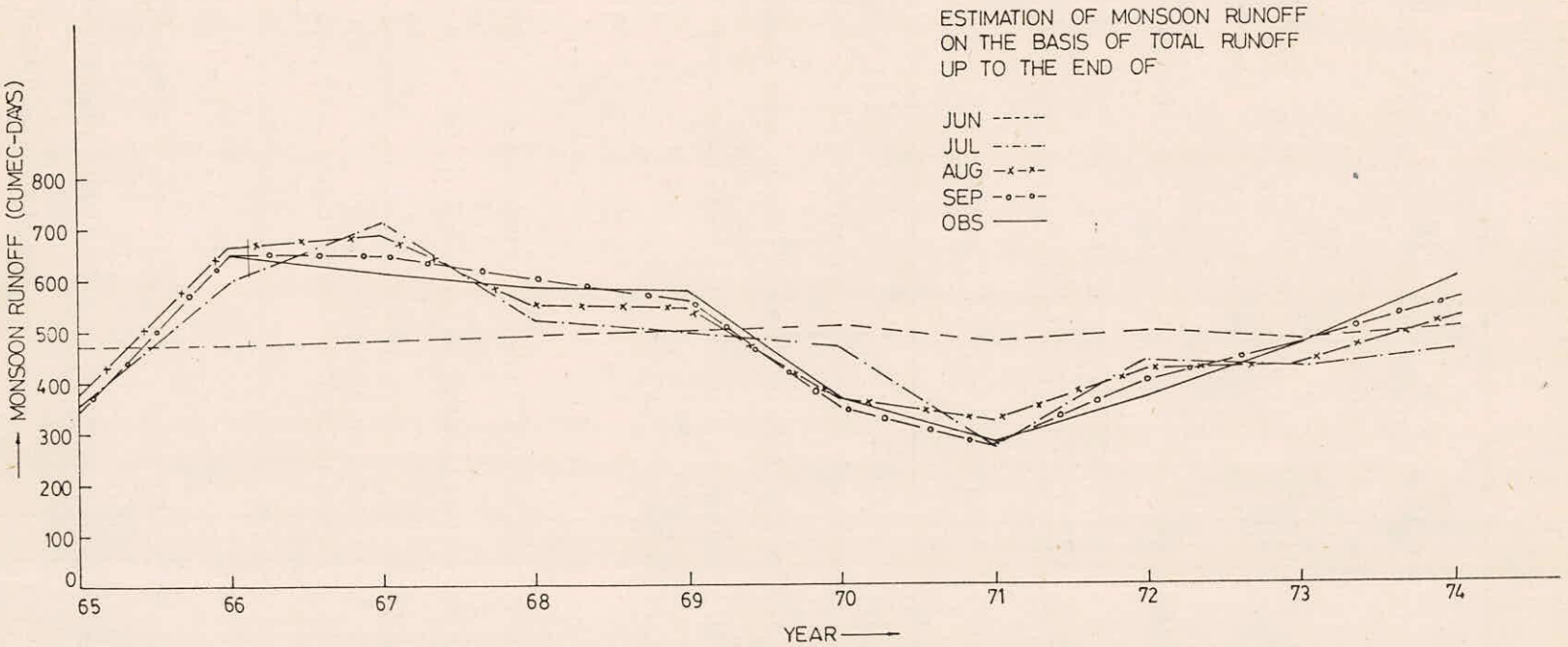


FIG. 32. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1965-74) FOR KOODATHAI

d. The observed monsoon runoff and forecasted monsoon runoff of the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1975-78 are plotted in Figure 33.

e. Out of 4 years (1975-78) runoff data used for verification of forecast the regression relationships are able to identify correcatly whether the current year is going to be below normal or above normal for 3 years, 4 years, 4 years and 4 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 33.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 0.6%, 62.8%, 88.1%, 97.6% and 48.8%, 87.0%, 96.9% and 99.1% respectively at the end of June, July, August and September. The results are good.

6.14 Punnarpuzha River

a. Using equations 1-9 and 1965-74 runoff data the following relationships have been developed.

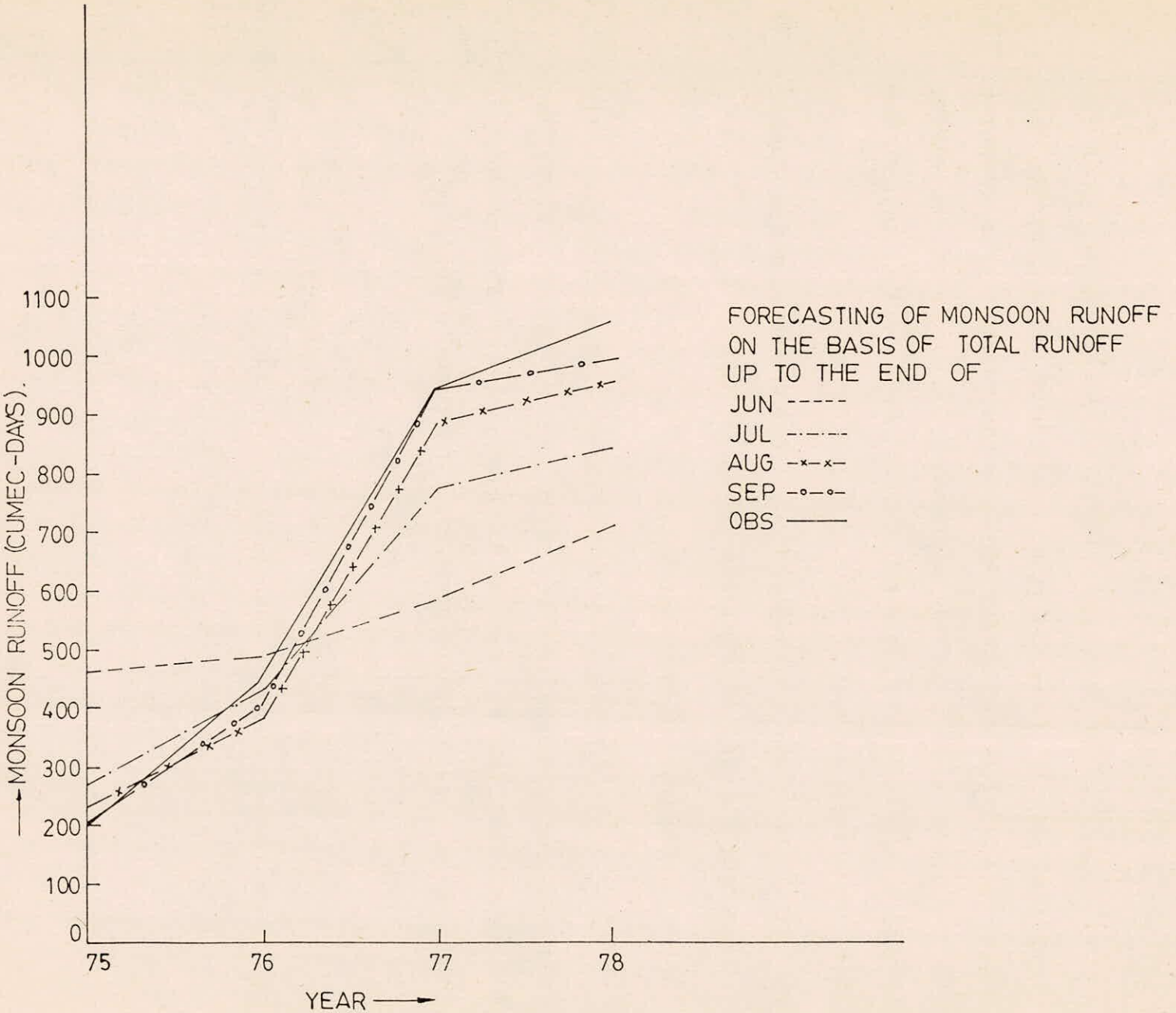


FIG.33. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1975-78) FOR KOODATHAI

TABLE-33

FORECASTING OF MONSOON RUNOFF (1975-78) FROM DROUGHT POINT OF VIEW FOR KOODATHAI

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1975	479.8	196.4-	466.1-	274.6-	228.1-	210.6-
1976	454.0	446.7-	475.9+	436.0-	377.3-	410.0-
1977	453.4	944.4+	586.9+	770.9+	885.5+	944.9+
1978	491.2	1060.9+	701.6+	842.7+	957.9+	993.9+

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon} = 423.33+2.793* Q_{June}	0.111×10^7	0.103×10^7	7.3%
2.	Q_{mon} = 149.32+1.701* $Q_{June+July}$	0.111×10^7	0.851×10^5	92.3%
3.	Q_{mon} = 96.24+1.146* $Q_{June+July+August}$	0.111×10^7	0.313×10^5	97.2%
4.	Q_{mon} = 56.63+1.047* $Q_{June+July+Aug.+Sept.}$	0.111×10^7	0.966×10^4	99.1%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1965-74 are plotted in Figure 34.

c. Monsoon runoffs for 1975-78 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.691×10^5	0.263×10^5	62.0%
2.	July	0.691×10^5	0.688×10^4	90.0%
3.	August	0.691×10^5	0.125×10^5	81.9%
4.	September	0.691×10^5	0.416×10^4	94.0%

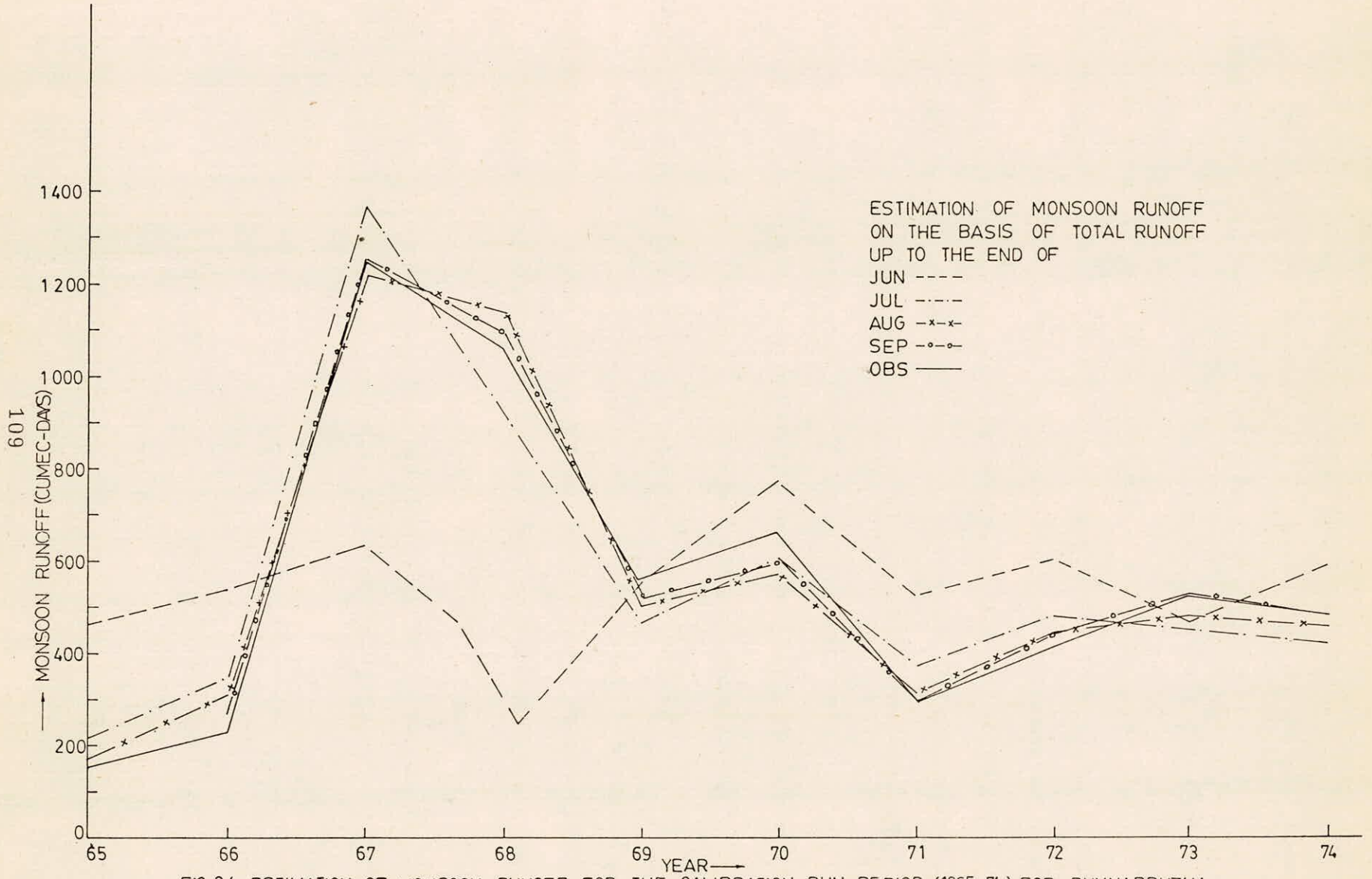


FIG. 34. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1965-74) FOR PUNNARPUZHA

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (August), and (September) for the period 1975-78 are plotted in Figure 35.

e. Out of 4 years (1975-78) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 3 years, 3 years, 1 years and 2 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 34.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 7.3%, 92.3%, 97.2%, 99.1% and 62.0%, 90.0%, 81.9% and 94.0% respectively at the end of June, July, August and September. The results are good.

6.15 Gobing Sagar at Bhakra

a. Using equations 1-9 and 1960-79 runoff data the following relationships have been developed:

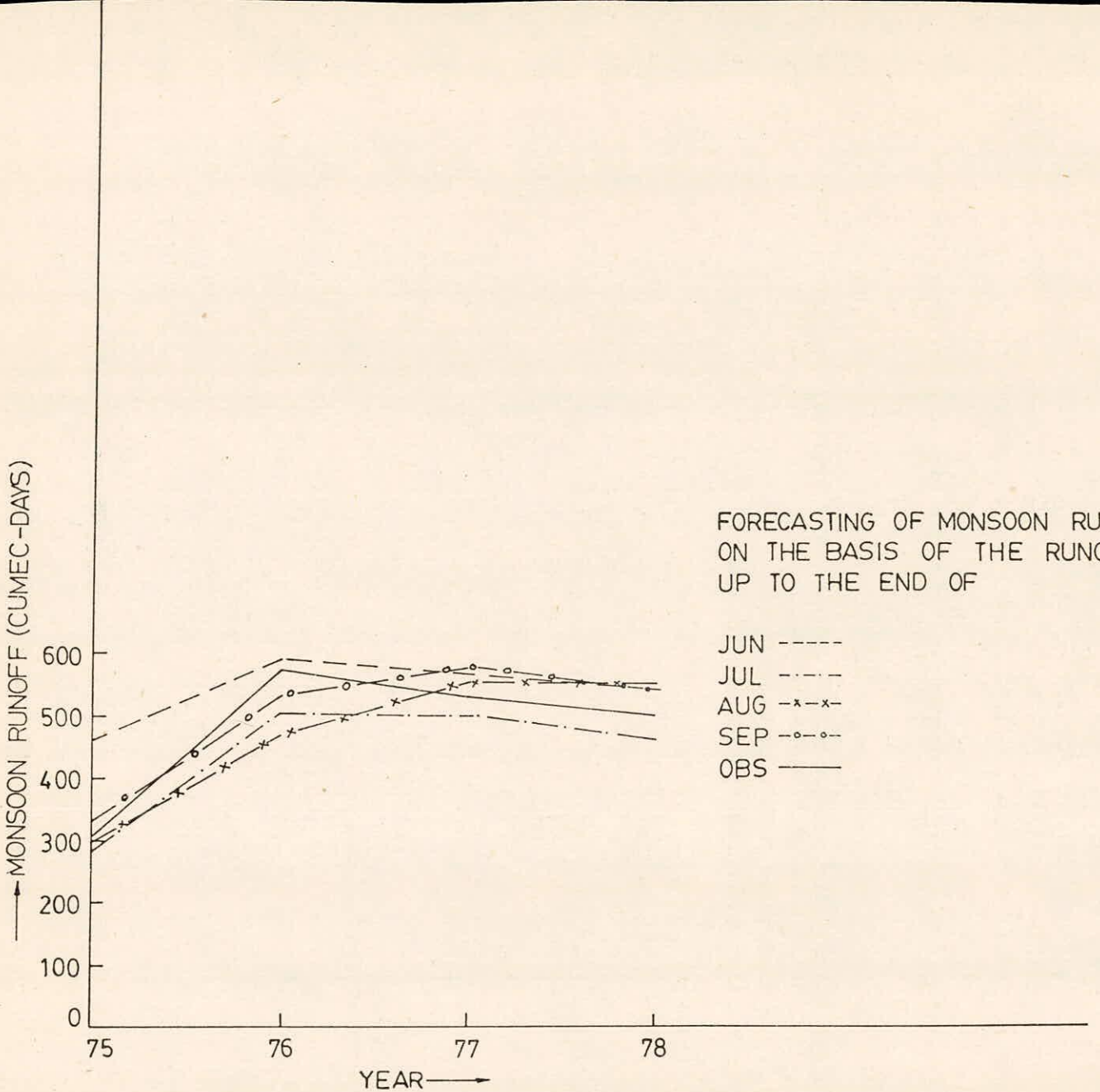


FIG.35 FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1975-78) FOR PUNNARPUZHA

TABLE-34

FORECASTING OF MONSOON RUN OFF (1975-78) FROM DROUGHT POINT OF VIEW FOR PUNNARPUZHA

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUN OFF IN CUMEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1975	564.2	306.1-	455.7-	278.8-	297.9-	333.8-
1976	540.7	567.8+	589.3+	506.2-	474.2-	533.0-
1977	543.0	531.8-	569.8+	501.6-	556.8+	558.1+
1978	542.1	502.8-	547.3-	464.4-	557.9+	541.5-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon} = 87278.3+2.149* Q_{June}	0.141×10^{11}	0.618×10^{10}	56.3%
2.	Q_{mon} = 44749.8+1.463* $Q_{June+July}$	0.141×10^{11}	0.420×10^{10}	70.3%
3.	Q_{mon} = 10007.7+1.193* $Q_{June+July+Aug.}$	0.141×10^{11}	0.696×10^{9}	93.1%
4.	Q_{mon} = 996.7+1.056* $Q_{June+July+Aug.+Sept.}$	0.141×10^{11}	0.518×10^{8}	99.6%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1960-79 are plotted in Figure 36.

c. Monsoon runoffs for 1980-87 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.289×10^{10}	0.179×10^{10}	38.0%
2.	July	0.289×10^{10}	0.123×10^{10}	57.3%
3.	August	0.289×10^{10}	0.400×10^{9}	86.2%
4.	September	0.289×10^{10}	0.756×10^{8}	97.4%

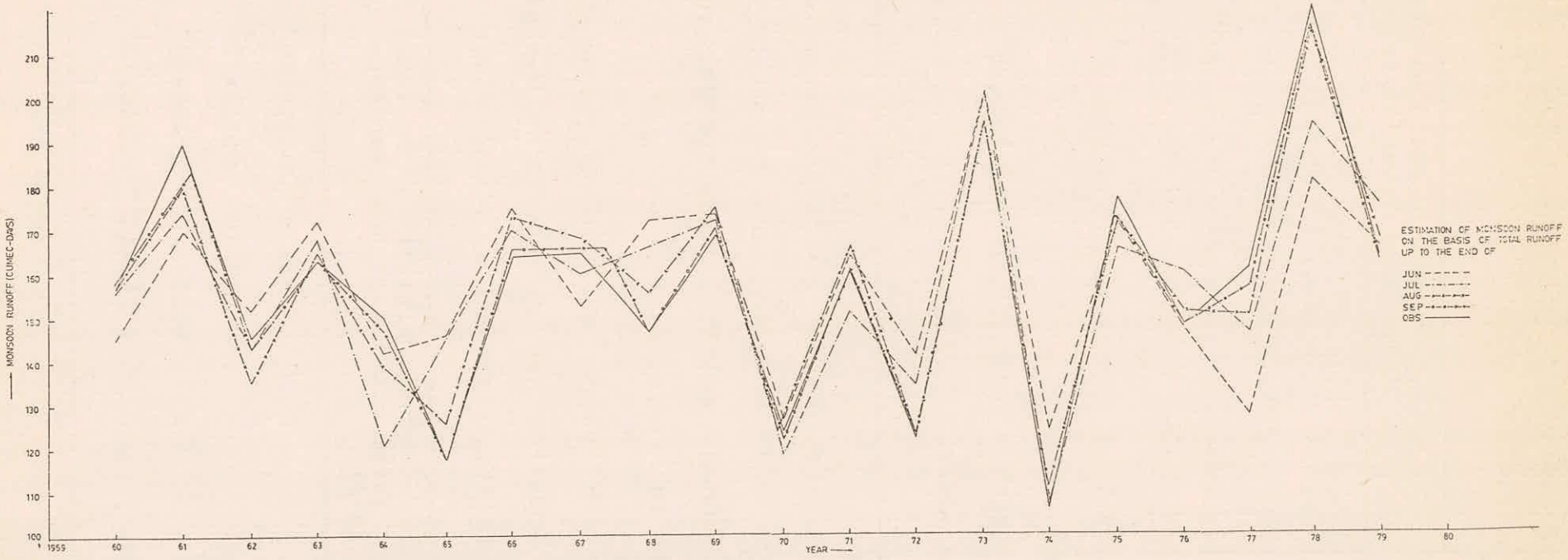


FIG.36 ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1960-79) FOR GOBIND SAGAR AT BHAKRA

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1980-87 are plotted in Figure 37.

e. Out of a year (1980-87) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 4 years, 6 years, 7 years and 7 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 35.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 56.3%, 70.3%, 93.1%, 99.6% and 38.0%, 57.3%, 86.2% and 97.4% respectively at the end of June, July, August and September. The results are good.

6.16 Sabarmati at Dharoi

a. Using equations 1-9 and 1935-64 runoff data the following relationships have been developed:

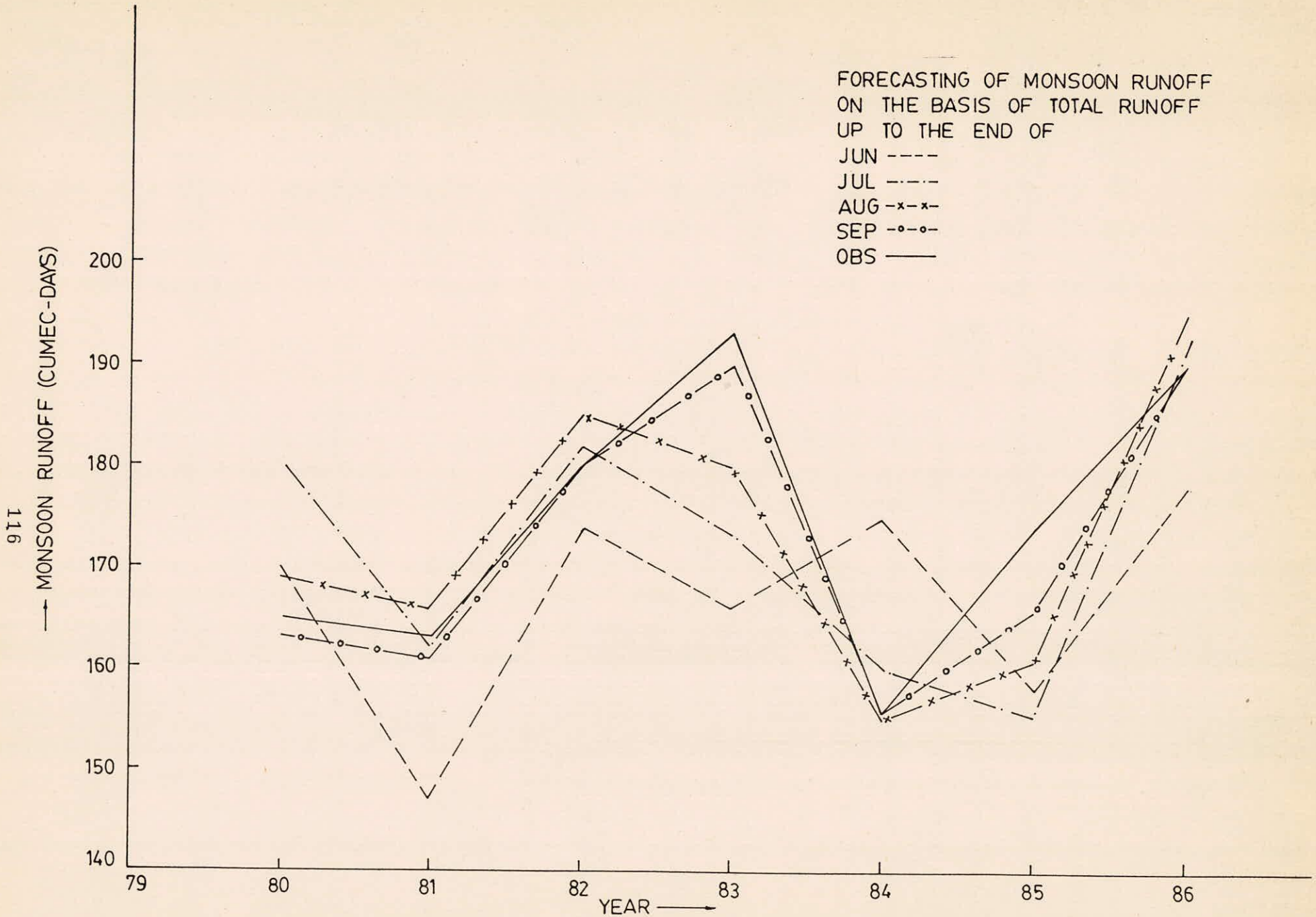


FIG. 37. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1980-86) FOR GOBIND SAGAR AT BHAKRA

TABLE-35

FORECASTING OF MONSOON RUN OFF (1980-86) FROM DROUGHT POINT OF VIEW FOR GOBIND SAGAR AT BHAKRA

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUN OFF IN CUSEC DAYS ON THE BASIS OF TOTAL RUNOFF DATA THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1980	157228.4	165209.0+	170562.8+	180346.5+	169329.3+	163610.1+
1981	157608.4	163186.0+	147919.2-	162086.3+	166630.8+	161807.2+
1982	157861.9	180429.0+	174480.4+	182839.9+	185207.4+	180883.4+
1983	158843.1	193404.0+	166395.8+	168403.2+	180782.9+	190856.9+
1984	160283.1	156999.0-	175880.3+	159971.2-	155188.6-	156872.3-
1985	160151.8	174519.0+	158338.4-	155610.6-	161889.5+	166490.8+
1986	160704.3	190291.0+	178164.6+	192671.8+	195404.2+	190142.2+

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

S. No.	Relationships	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 10330.39++3.888* Q_{June}$	$0.259x10^{10}$	$0.250x10^{10}$	3.4%
2.	$Q_{mon} = 5401.89+1.549* Q_{June+July}$	$0.259x10^{10}$	$0.100x10^{10}$	61.3%
3.	$Q_{mon} = 3547.52+1.549* Q_{June+July+Aug.}$	$0.259x10^{10}$	$0.810x10^{9}$	68.7%
4.	$Q_{mon} = 113.6+1.046^{*} Q_{June+July+Aug.+Sept.}$	$0.259x10^{10}$	$0.245x10^{8}$	99.1%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1935-64 are plotted in Figure 38.

c. Monsoon runoff for 1965-75 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total runoff upto the end of	Initial variance	Residual variance	Efficiency
1.	June	$0.164x10^{10}$	$0.178x10^{10}$	-8.7%
2.	July	$0.164x10^{10}$	$0.167x10^{10}$	-2.1%
3.	August	$0.164x10^{10}$	$0.703x10^{9}$	57.1%
4.	September	$0.164x10^{10}$	$0.774x10^{7}$	99.5%

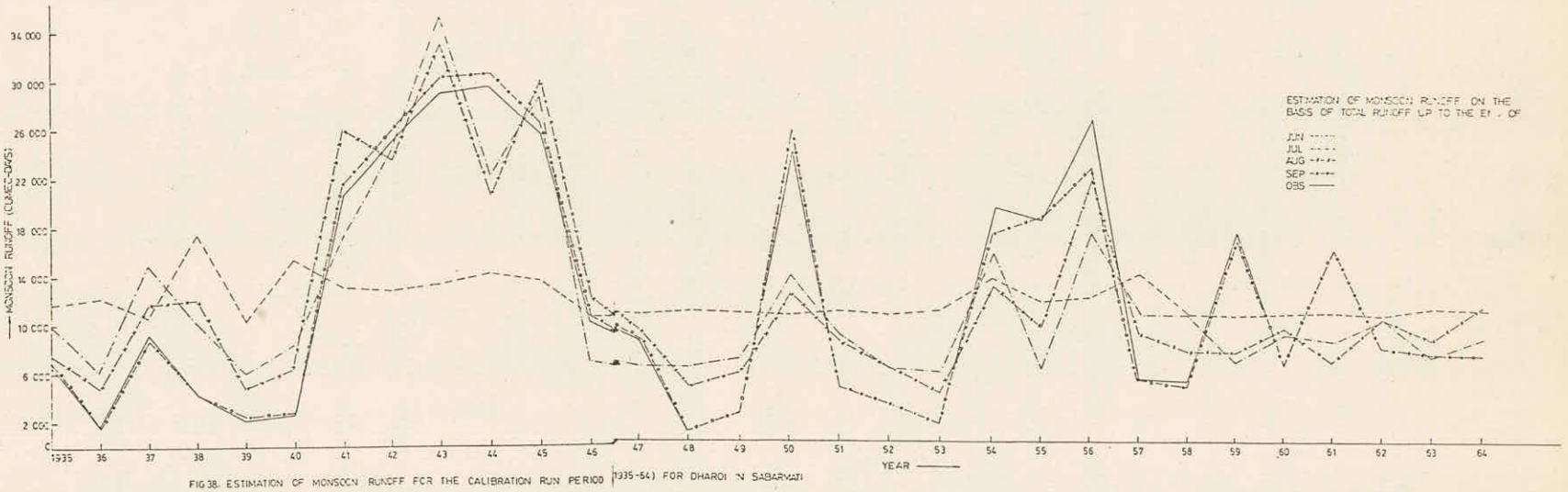


FIG 38. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1935-64) FOR DHAROI IN SABARMATI

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1965-75 are plotted in Figure 39.

e. Out of 11 years (1965-75) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 6 years, 9 years, 10 years and 11 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 36.

Comment on the Results

The efficiency of regression relationships in calibration and forecasting are 3.4%, 61.3%, 68.7%, 99.1% and -8.7%, -2.1%, 57.1%, and 99.5% respectively at the end of June, July, August and September. The results are poor. The flows for Sabarmati at Dharoi are highly variable. The reliability of the flow data could not be further investigated because of non-availability of the required data.

6.17 Pong Reservoir

a. Using equations 1-9 and 1974-83 runoff data the following relationships have been developed:

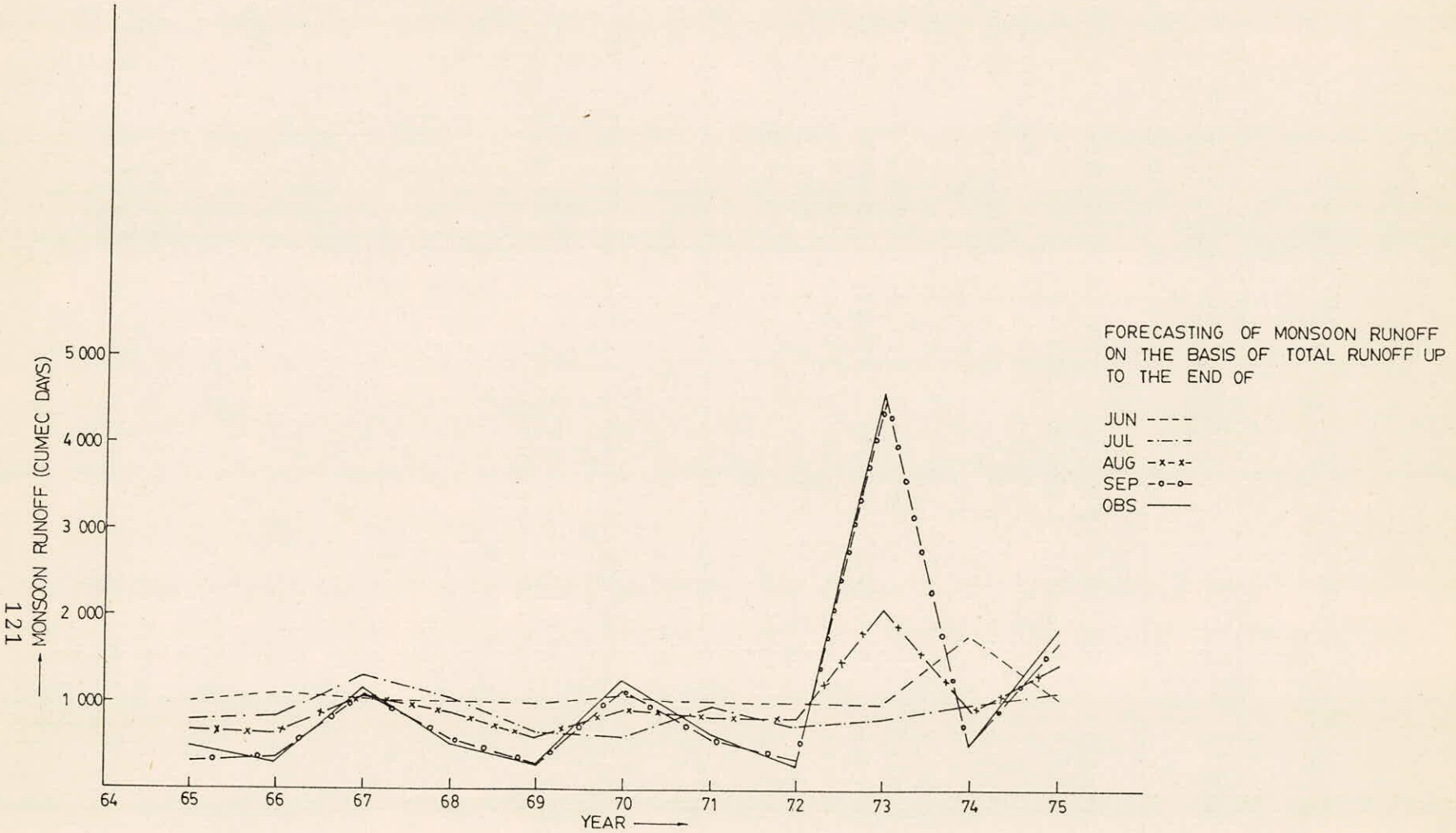


FIG. 39. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1965-75) FOR SABARMATI AT DHAROI

TABLE-36

FORECASTING OF MONSOON RUNOFF (1965-75) FROM DROUGHT POINT OF VIEW FOR SABARMATI AT DHAROI

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN CUSEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1965	11693.0	5881.0-	10369.5-	8081.7-	6865.8-	3530.9-
1966	11505.5	3262.0-	12834.2+	8693.9-	6363.4-	3614.8-
1967	11247.9	11742.0+	10651.5-	13045.5+	12047.0+	11767.6+
1968	11262.9	5321.0-	10045.0-	10519.1-	8899.0-	5634.6-
1969	11088.1	2619.0-	10045.8-	6761.2-	5587.5-	2919.6-
1970	10846.2	12874.0+	12131.1+	6001.0-	9633.5-	12435.8+
1971	10902.5	6252.0-	9697.0-	9576.7-	8144.3-	6579.4-
1972	10776.8	2600.0-	10564.4-	7317.2-	5847.3-	2902.5-
1973	10561.6	45919.0+	9270.8-	7905.3-	20971.6+	45087.2+
1974	11468.2	5074.0-	16166.6+	9875.7-	8559.8-	5191.4-
1975	11308.4-	18004.0+	11126.3-	11438.5+	14635.5+	17107.3+

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	Q_{mon} = 7831.9+8.910* Q_{June}	0.188×10^{11}	0.564×10^{10}	70.0%
2.	Q_{mon} = 14182,74+2.047* $Q_{June+July}$	0.188×10^{11}	$0.307.10^{10}$	83.7%
3.	Q_{mon} = 3718.59+1.279* $Q_{June+July+Aug.}$	0.188×10^{11}	0.115×10^{10}	93.9%
4.	Q_{mon} = -1786.7+1.063* $Q_{June+July+Aug.+Sept.}$	0.188×10^{11}	0.327×10^{8}	99.8%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (September) for the period 1974-83 are plotted in Figure 40.

c. Monsoon runoffs for 1984-86 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total runoff upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.220×10^{10}	0.654×10^{10}	-196.6%
2.	July	0.220×10^{10}	0.143×10^{10}	35.0%
3.	August	0.220×10^{10}	0.252×10^{9}	88.5%
4.	September	0.220×10^{10}	0.276×10^{8}	98.7%

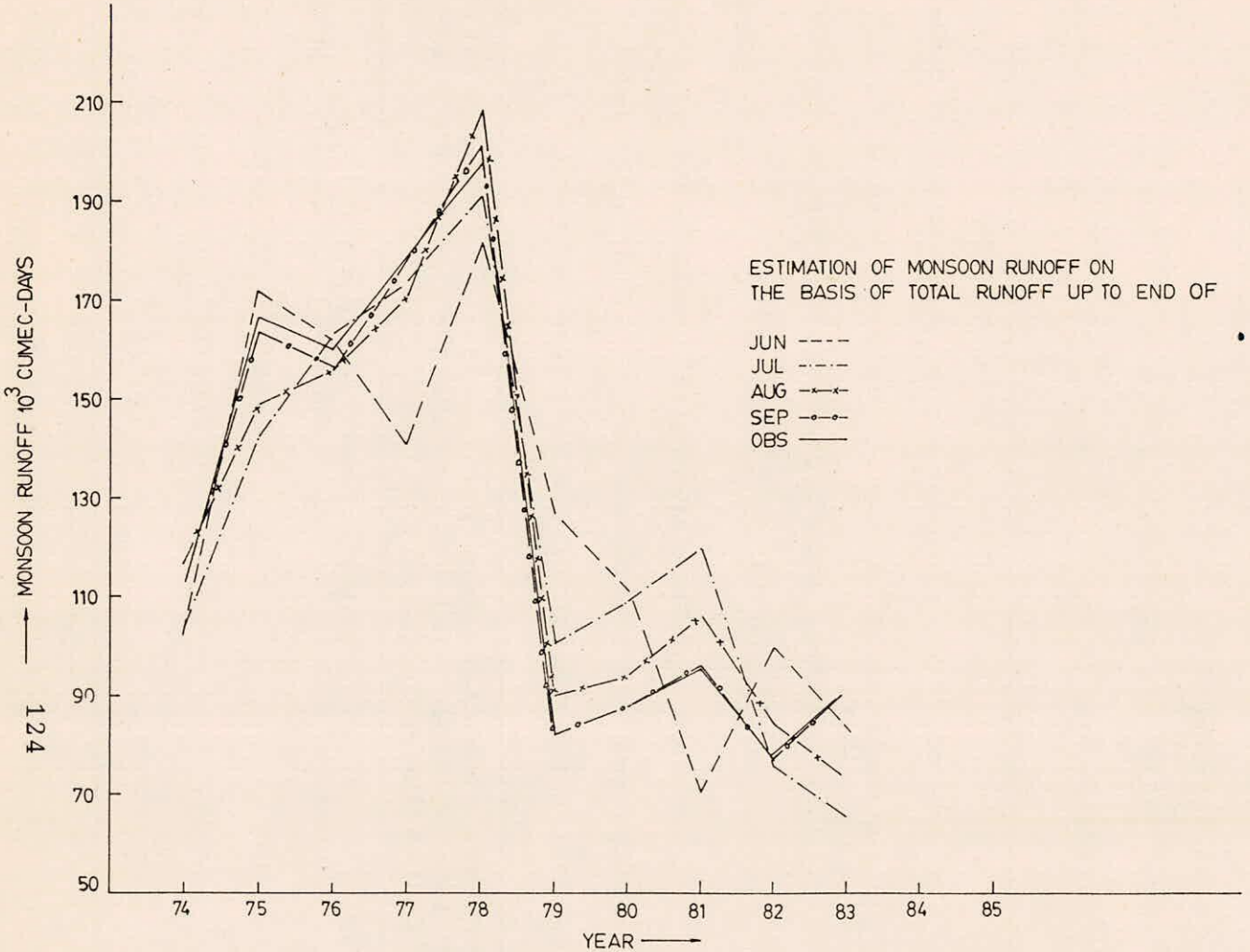


FIG. 40. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1974 - 83) FOR PONG

d. The observed monsoon runoff and forecasted mon soon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August and (iv) September for the period 1984-86 are plotted in Figure 41.

e. Out of 3 years (1984-86) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 2 years, 2 years and 3 years and 3 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 37.

Comment on the Results:

The efficiency of regression relationships in calibraton and forecasting are 70.0%, 83.7%, 93.9%, 99.8% and 196.6%, 35.0%, 88.5%, 98.7% respectively at the end of June, July, August and September respectively. The monsoon runoff forecasts on the basis of June flows are highly unreliable. The forecasts based on total flow upto the end of August and September are good.

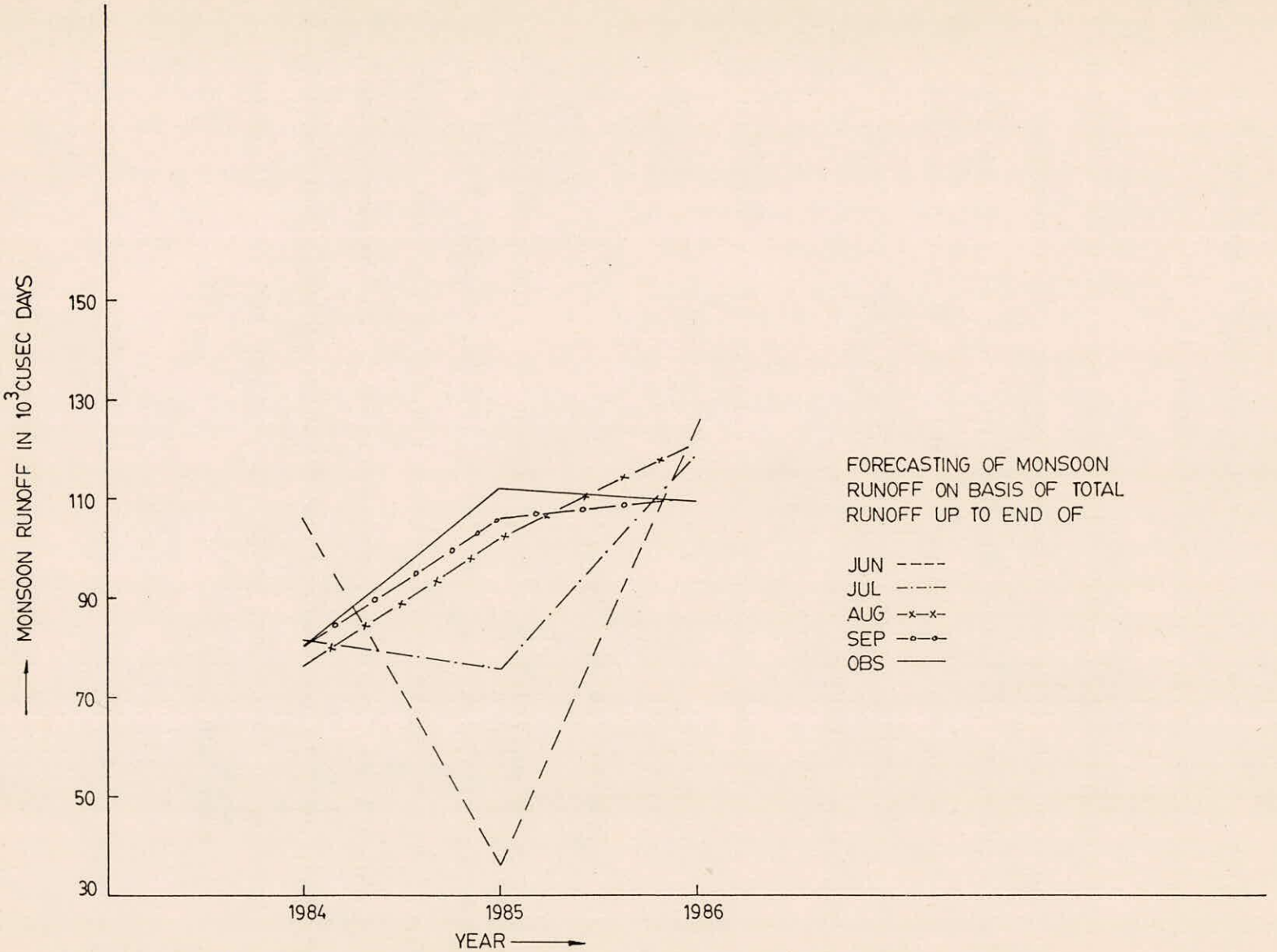


FIG. 41. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1984-86) FOR PONG

TABLE-37

FORECASTING OF MONSOON RUNOFF (1984-1986) FROM DROUGHT POINT OF VIEW FOR PONG

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN CUSEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1984	125121.6	80244.0-	106349.8-	80244.0-	76226.6-	80596.9-
1985	121041.8	112154.0-	36971.1-	112154.0-	102676.6-	106929.8-
1986	120301.1	109748.0-	124036.8+	109748.0-	121852.4+	110229.8-

NOTE:

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

6.18 Malprabha Reseravoir

a. Using equations 1-9 and 1976-82 runoff data the following relationships have been developed:

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon}=274.85+10.226*$ Q_{June}	$0.133x10^{8}$	$0.520x10^{7}$	61.0%
2.	$Q_{mon}=821.68+0.910*$ $Q_{June+July}$	$0.133x10^{8}$	$0.610x10^{6}$	95.4%
3.	$Q_{mon}=204.71+1.004*$ $Q_{June+July+Aug.}$	$0.133x10^{8}$	$0.123x10^{5}$	99.9%
4.	$Q_{mon}=42.98+1.008*$ $Q_{June+July+Aug.+September}$	$0.133x10^{8}$	$0.981x10^{3}$	99.99%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i)

June, (ii) July, (iii) August, and (iv) September for the period 1976-82 are plotted in Figure 42.

c. Monsoon runoffs for 1983-85 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total runoff upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.177×10^7	0.810×10^7	-357.2%
2.	July	0.177×10^7	0.215×10^6	87.9%
3.	August	0.177×10^7	0.454×10^4	99.7%
4.	September	0.177×10^7	0.431×10^4	99.8%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1983-85 are plotted in Figure 43.

e. Out of 3 years (1983-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 2 years , 3 years, 3 years and 3years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 38.

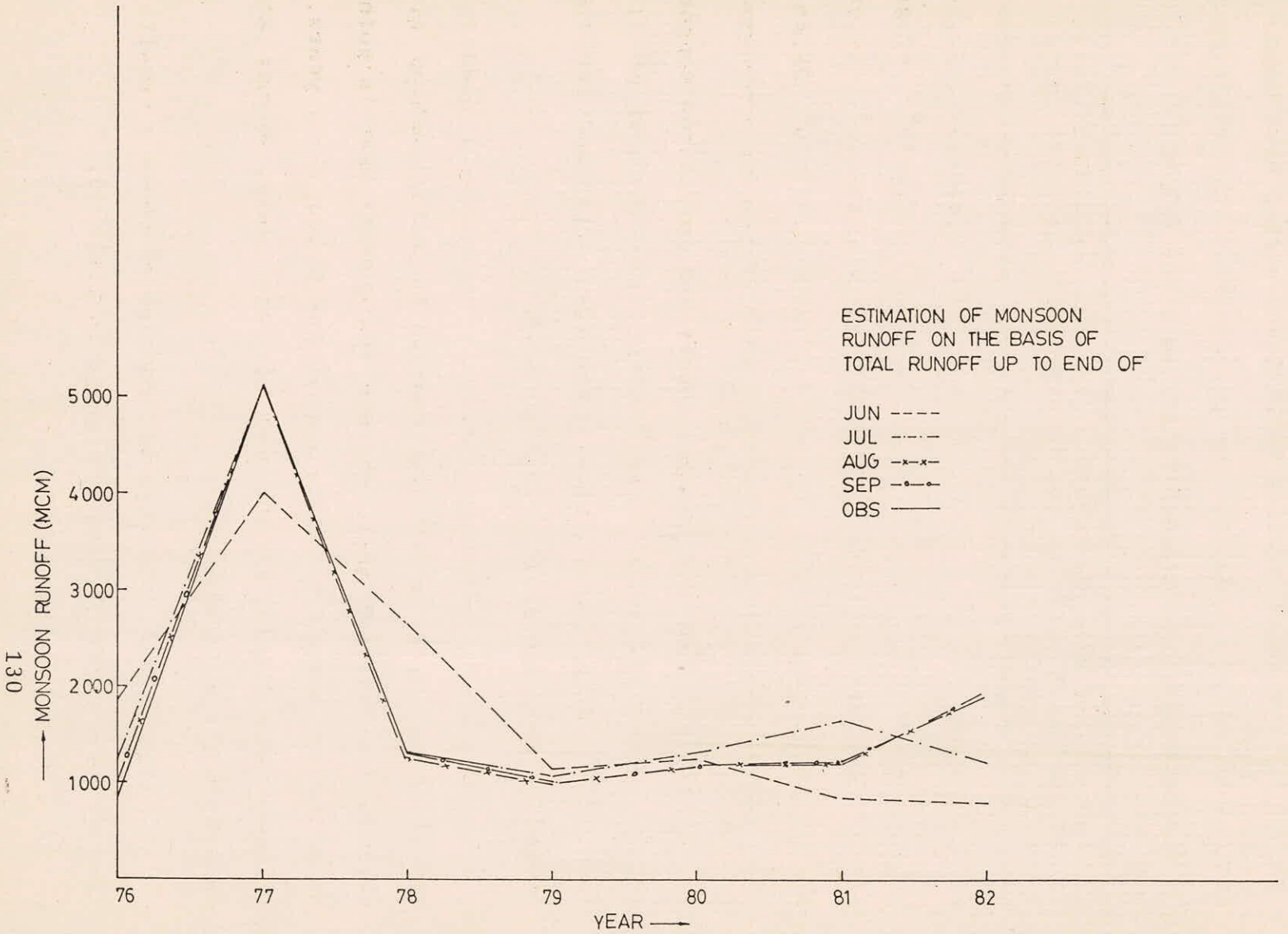


FIG. 42. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1976-82) FOR MALPRABHA

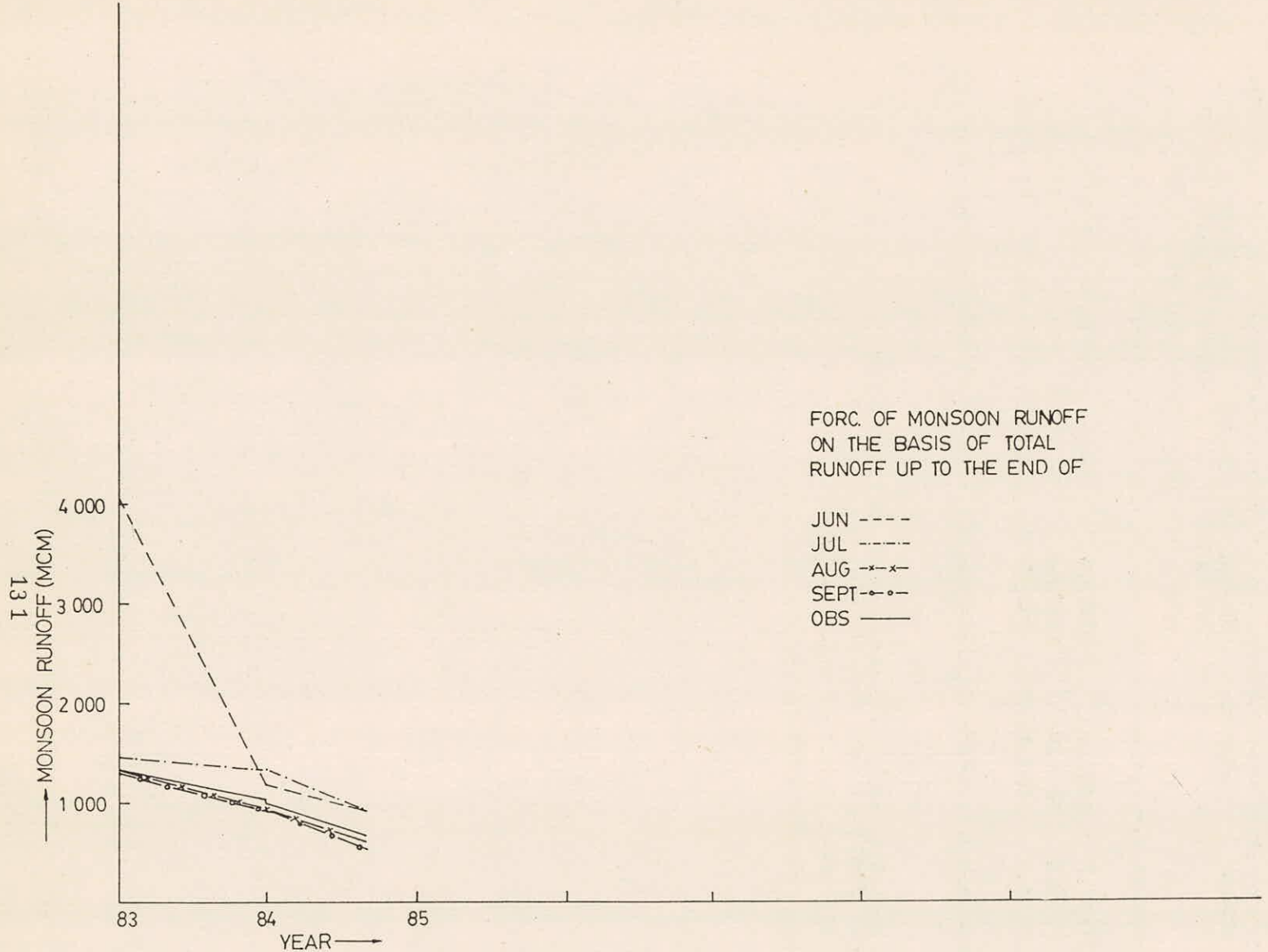


FIG.43. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1983-85) FOR MALPRABHA

TABLE-38

FORECASTING OF MONSOON RUNOFF (1983-85) FROM DROUGHT POINT OF VIEW FOR MALPRABHA

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN CUSEC DAYS ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1983	1797.7	1281.2-	4109.6+	1446.9-	1319.7-	1289.7-
1984	1733.2	1001.0-	1177.6-	1333.2-	991.7-	946.7-
1985	1651.8	667.4-	934.5-	945.3-	721.9-	631.5-

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

Comment on the Results:

The efficiency of regression relationships in calibration and forecasting are 61.0%, 95.4%, 99.7%, 99.99% and -357.2%, 87.9%, 99.7% and 99.8% respectively at the end of June, July, August and September. The forecasts based on July, August, and September are very good inspite of short sample length.

6.19 Jayakwadi Reservoir

a. Using equations 1-9 and 1974-81 runoff data the following relationships have been developed.

S. No.	Relationship	Initial variance	Residual variance	Efficiency
1.	$Q_{mon} = 1726.26+6.419* Q_{June}$	$0.254x10^8$	$0.899x10^7$	64.7%
2.	$Q_{mon} = 1779.9+1.483* Q_{June+July}$	$0.254x10^8$	$0.931x10^7$	63.4%
3.	$Q_{mon} = 1247.97+0.926* Q_{June+July+Aug.}$	$0.254x10^8$	$0.312x10^7$	87.7%
4.	$Q_{mon} = 326.57+0.976* Q_{June+July+Aug.+Sept.}$	$0.254x10^8$	$0.310x10^6$	98.8%

b. The observed monsoon runoff and estimated monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and September for the period 1974-81 are plotted in Figure 44.

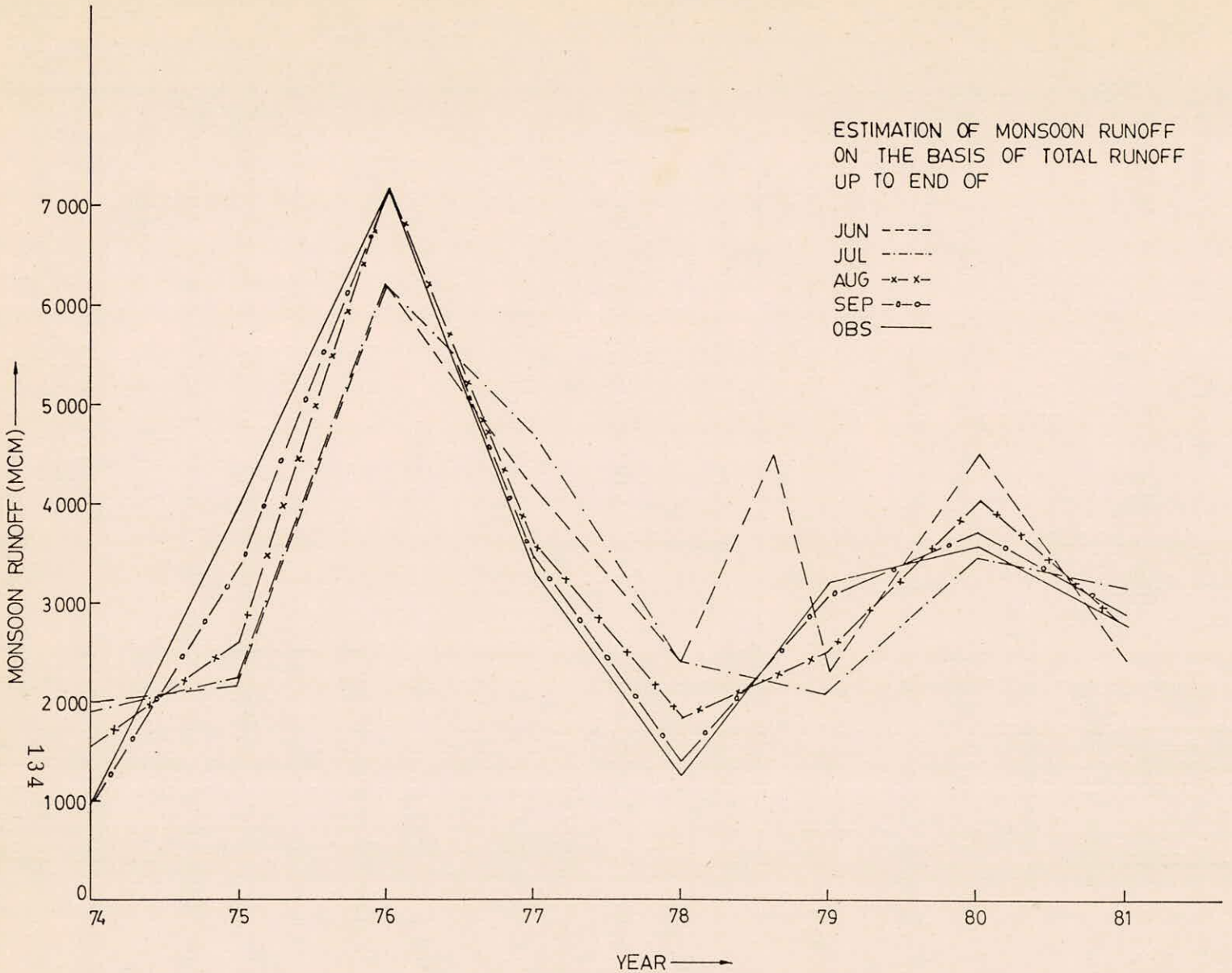


FIG.44. ESTIMATION OF MONSOON RUNOFF FOR THE CALIBRATION RUN PERIOD (1974-81) FOR JAYAKWADI

c. Monsoon runoffs for 1982-85 period have been forecasted after updating the parameters. The efficiency of the regression relationships are as given below:

S. No.	Forecast of monsoon runoff on the basis of total run-off upto the end of	Initial variance	Residual variance	Efficiency
1.	June	0.123×10^8	0.714×10^7	42.1%
2.	July	0.123×10^8	0.420×10^7	65.9%
3.	August	0.123×10^8	0.295×10^7	76.1%
4.	September	0.123×10^8	0.711×10^5	99.4%

d. The observed monsoon runoff and forecasted monsoon runoff on the basis of total runoff upto the end of (i) June, (ii) July, (iii) August, and (iv) September for the period 1982-85 are plotted in Figure 45.

e. Out of 4 years (1982-85) runoff data used for verification of forecast the regression relationships are able to identify correctly whether the current year is going to be below normal or above normal for 3 years, 3 years, 3 years and 3 years at the end of June, July, August and September respectively.

The normal, observed and forecasted monsoon runoff from drought point of view are given in Table 39.

Comment on the results:

The efficiency of regression relationships in cali-

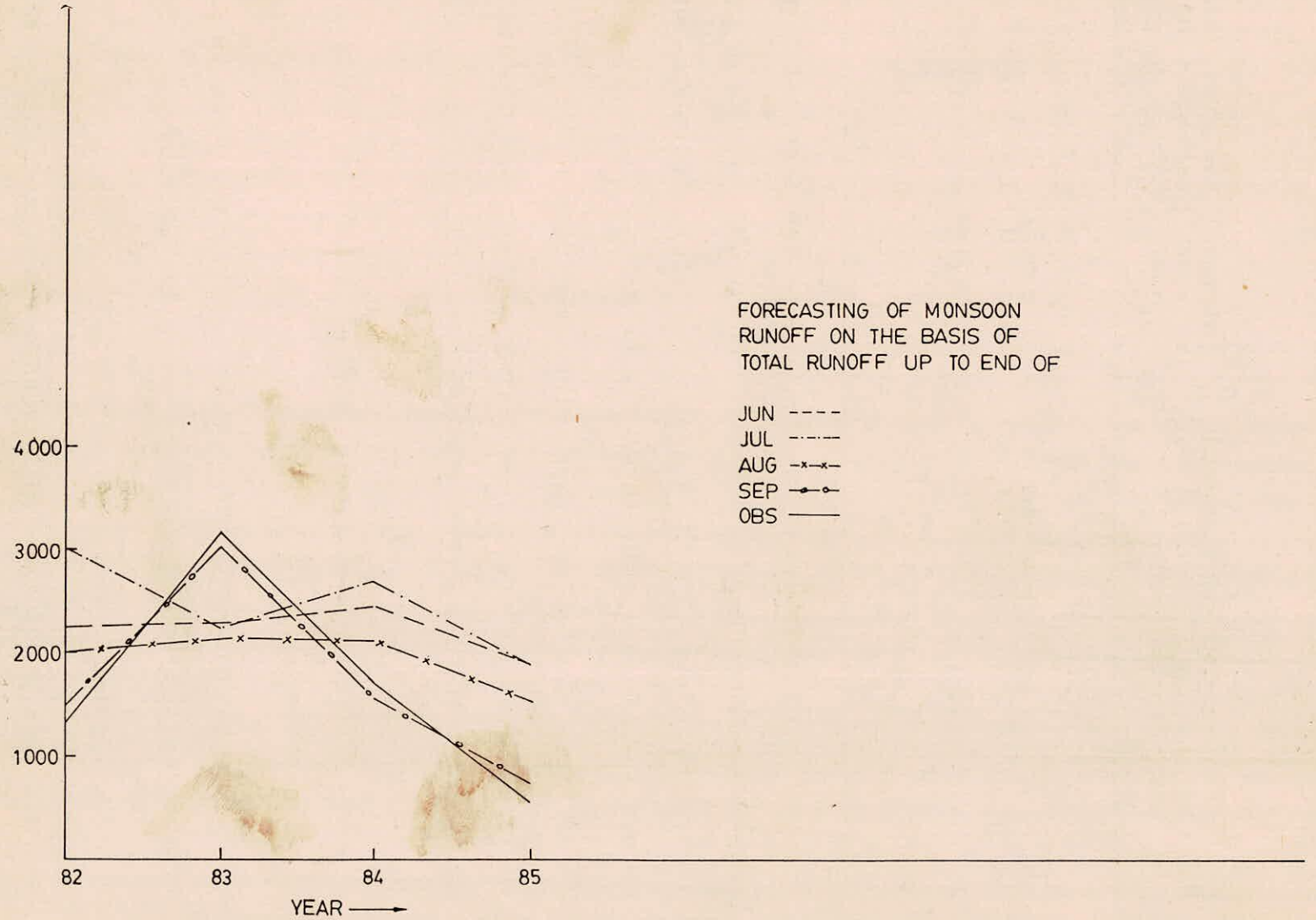


FIG.45. FORECASTING OF MONSOON RUNOFF FOR THE PERIOD (1982-85) FOR JAYAKWADI

TABLE-39

FORECASTING OF MONSOON RUNOFF (1982-85) FROM DROUGHT POINT OF VIEW FOR JAYAKWADI

YEAR	NORMAL	OBSERVED	FORECASTED MONSOON RUNOFF IN MCM ON THE BASIS OF TOTAL RUNOFF UPTO THE END OF			
			JUNE	JULY	AUGUST	SEPTEMBER
1982	3291.7	1266.0-	3016.5-	2242.6-	2016.6-	1403.2-
1983	3066.6	3170.0+	2255.9-	2295.3-	2146.6-	3039.3-
1984	3077.0	1455.0-	2685.1-	2448.1-	2103.0-	1549.1-
1985	2929.5	565.0-	1880.8-	1788.5-	1522.1-	727.2-

NOTE :

1. In calculating monsoon normal runoff for a year all the data prior to that year have been considered.
2. -ve sign shows runoff is below normal.
3. +ve sign shows runoff is above normal.

bration and forecasting are 64.7%, 63.4%, 87.7%,98.8% and 42.1%, 65.9%, 76.1% and 99.4% respectively at the end of June, July, August, September and October. The results are good.

The results of forecasting of monsoon flows for various rivers/reservoirs are summarized in Table 40.

TABLE-40

FORECASTING OF MONSOON FLOWS FOR VARIOUS RIVERS/RESERVOIRS

Sl. No.	Name of River / Reservoir	C.A. (Km^2)	Length of data		Efficiency in % in Estimation of monsoon runoff on the basis of total runoff upto the end of				Length of data		Efficiency in % in forecasting of monsoon runoff on the basis of total runoff upto the end of				
			Years	Period	June	July	Aug.	Sept.	Years	Period	June	July	Aug.	Sept.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Bhima at Dhond	11,660	10	1968-77	28.2	57.0	84.2	96.0	8	1978-85	26.1	42.6	85.4	98.4	
2.	Bhima at Wodakabal	12,092	10	1965-74	67.9	35.8	58.9	91.2	11	1975-85	-118.9	3.6	20.4	91.4	Not virgin
3.	Bhima at Narsingpur	22,856	10	1967-76	33.0	51.0	78.5	93.4	9	1977-85	-4.9	17.8	75.1	95.2	
4.	Bhima at Takali	33,916	10	1966-75	14.1	27.2	52.5	74.3	8	1976-83	-3.1	21.0	58.0	92.4	
5.	Bhima at Yadgir	69,863	10	1965-74	3.8	33.5	64.3	75.6	11	1975-85	-5.1	9.2	35.1	77.6	Not virgin
6.	Tungbhadra at Haralhalli	14,582	10	1967-76	21.3	39.1	94.3	98.3	9	1977-85	28.2	57.9	92.8	97.9	
7.	Tungbhadra at Tramapuram	23,500	10	1966-75	7.4	25.3	43.3	76.4	10	1976-85	-9.9	9.7	24.0	71.6	Not virgin
8.	Koyna Reservoir	896	10	1963-72	0.3	19.1	92.7	99.2	11	1973-83	31.7	54.4	84.7	98.6	
9.	Gandhi Sagar Reservoir	23,140	15	1961-75	0.2	73.0	78.4	98.8	11	1976-86	-2.5	16.2	50.5	98.5	
10.	Mahanadi at Hirakud	83,400	20	1946-65	62.7	79.6	84.2	98.5	17	1966-82	-15.11	70.76	81.4	97.9	
11.	Ghaliyar	448.15	10	1965-74	4.8	76.7	92.5	99.2	4	1975-78	24.7	62.2	97.0	98.1	
12.	Kanhirpuzha	71.77	10	1965-74	30.4	90.2	98.4	99.4	4	1975-78	37.8	84.1	92.1	98.6	
13.	Kooda Thai	121.25	10	1965-74	0.6	62.8	88.1	97.6	4	1975-78	48.8	87.0	96.9	99.1	
14.	Punnarpuzha	468.9	10	1965-74	7.3	92.3	97.2	99.1	4	1975-78	62.0	90.00	81.9	94.0	
15.	Gobindsagar at Bhakra	56876	20	1960-79	56.3	70.3	93.1	99.6	8	1980-87	38.0	57.3	86.2	97.4	
16.	Sabarmati at Dharoi	5540	30	1935-64	3.4	61.3	68.7	99.1	11	1965-75	-8.7	-2.1	57.1	99.5	
17.	Pong Reservoir	12562	10	1974-83	70.0	83.7	93.9	99.8	3	1984-86	-196.6	35.0	88.5	98.7	
18.	Malprabha	2176	7	1976-82	61.0	95.4	99.7	99.99	3	1983-85	-357	87.9	99.7	99.8	
19.	Jayakwadi	21750	8	1974-1981	64.7	63.4	87.7	98.8	4	1982-85	42.1	65.9	76.1	99.4	

7.0 SUGGESTIONS FOR FURTHER WORKS

Keeping in view the comments received from the members of the working group, on the report, the methodology developed for monsoon flow forecasting may further be refined along the following lines by future workers.

i) The 95% confidence limits for the regression relationships can also be estimated. Haan (1977) gives details for the computation of confidence limits on regression line and individual estimates.

ii) Statistical distribution and significance of fitted parameters should also be tested in order to make the analysis more sound. Hann (1977) is a good reference for the same.

iii) Suitability of multiple regression relationships correlating monsoon flows with flow, rainfall and catchment characteristics etc. should be explored and comparison between simple and multiple regression relationships be made.

iv) Criteria may be developed to test the consistency between parameters of successive relationships.

v) The gradation of the efficiency of regression relationships in estimation and forecasting, as very good, good satisfactory or poor is a somewhat subjective criteria. A more quantitative criteria could be developed for this purpose.

vi) Suitable methodology should be developed to deal with non-virgin flows, as in some cases, there will be diversion schemes upstream of the gauge-discharge site which will vitiate the flow conditions at G-D site. As the catchment area increases the flow conditions will get affected more due to further additions in diversion. In such cases it may be desirable to forecast the monsoon rainfall first and from the rainfall corresponding runoff may be obtained with suitable corrections for upstream diversion schemes. This needs further investigation using appropriate field data.

8.0 CONCLUSIONS

The technique for monsoon flow forecasting based on regression relationships has been applied to the data of 19 reservoirs/river sites. The catchment areas for these reservoirs/river sties-varied from 71.77 km^2 to 83400 km^2. The length of data also varies from 10 years to 41 years. Based on the analysis of these data following conclusions can be drawn.

1. The technique for monsoon flow forecasting based on regression relationships is a simple approach and gives quite accurate forecast of monsoon flows at the end of August and September.
2. For application of the technique the flows should be virgin.
3. For better application of the technique the data length should be adequate preferably more than 30 years. The parameters of the regression relationships obtained from the small samples are generally not stable.
4. The efficiency of forecast should increase with the increase in drainage area of the river basin as the flows will be more stable. This is not appearing from the analysis of the data. This may be because of (i) possible diversions in the basin as the drainage area increases.(ii)short sample length.

The results and conclusions are based on the analysis of data of only 19 sites. Out of 19 sites only two sites are having data for more than 30 years. In order to arrive at definite conclusion the data of other river basins and reservoirs should be analysed on the similar lines.

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