CS-37

HYDROLOGICAL ASPECTS OF DROUGHT UPTO 1987-88

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PREFACE

A most important factor in understanding droughts, often not included in definition, is that it is a supply and demand phenomenon. Though a no. of definitions of drought pertaining to various uses have been developed, however, a definition which does not include reference to water requirement or demand can be regarded as inadequate. To a hydrologist drought means below average availability of flow in streams and below average storages in reservoirs, lakes, tanks, ground water aquifers and soil moisture in soil column. The various hydrological variables which can be used to study hydrological aspects of drought include rainfall, groundwater levels, surface water storages and soil moisture.

The problem of drought in the country has been recurrent in nature. In late 80's the country has faced drought for three years in succession. Reliable estimates indicate that the drought of year 1987 is ranked second in the century, the first one being in year 1918. It has been estimated that about 1/3rd of the geographical area of the country (107 M ha) spread over 99 districts, are affected by drought. The Central Water Commission (CWC) has carried out studies in these 99 districts for identifying drought proneness.

The National Institute of Hydrology initiated drought studies in the year 1986 with the major objectives to lay emphasis on hydrological aspects of drought and to develop suitable drought indices alongwith evolving short and long term drought management strategies. In this venture the institute has already carried out studies by bringing out technical reports etc. on pertinent issues related to hydrological aspects of drought. In order to study the gravity of problem, studies have been taken up using the field data to evaluate impacts of drought. In this pursuit the institute has chosen six states namely, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra & Rajasthan. During year 1985-86 two districts in each of these states were chosen for study. This was followed by choosing four districts in each state for the year 1986-87. The present report is third study in the series where in six districts in each of these states have been taken up for ana'ysis for the year 1987-88. These districts are Anantpur, Cuddapah, Chittoor, Prakasam, Kurnool and Mehboobnagar of A.P., Jamnagar, Rajkot, Ahmedabad, Surendranagar, Amreli and Bhavnagar of Gujarat, Bijapur, Belgaum, Gulburga, Raichur, Dharwar and Bellary of Karnataka, Jhabua, Khargone, Dhar, Sidhi, Betul and Shahdol of M.P., Ahmednagar, Sholapur, Pune, Satara, Sangli and Aurangabad of Maharashtra and Banswara, Barmer, Ajmer, Udaipur, Jodhpur and Dungarpur of Rajasthan.

The Institute sent scientific teams to various states which contacted the relevant state/central govt, agencies for collecting the required data for carrying out the study. The study includes various kinds of analysis of rainfall data, stream flow data and ground water level data. Based on the analysis, inferences, highlighting the hydrological aspects of drought of 1987-88 have been drawn.

The study has been carried out by a group of scientists & scientific staff including the following : Sri V.K. Lohani, Scientist 'C', Shri N.S. Raghuwanshi, Sc. 'B', Sri Sudhir Kumar Goyal, Scientist 'B', Sri Tanveer Ahmed, R.A , Sri Avinash Agarwal, Sc. 'C', Sri R. P. Pandey, Sc, 'B' and Sri Yatveer Singh, R.A , contributed to bring this report in final form. The manuscript has been typed by Sri S.P. Modi and Sri Rajneesh Kumar Goel. The report is an attempt of the Institute to highlight the hyd ological aspects of drought as experienced in six drought prone states in recent years. Further studies with the use of more comprehensive methodologies and better aerial coverage are being taken up in the future work plan of the drought studies division of the Institute.

(SATISH CHANDRA)

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ABSTRACT

The regular monitoring of rainfall in the country started in 1875 with the establishment of India Meteorological Dept. Reliable information documents reveal that since 1800, there have 40 drought years in the country. In recent times, the country has faced three drought years in succession namely 1985, 1986 and 1987. It has been reported intensity wise the drought of year 1987 ranks second in the 20th century, the first one being in year 1918. Statistics on aerial coverage indicate that out of the country's geographical area of 328 m.ha., 107 m.ha or about one third of the area and 29 percent of the population are affected by drought.

In view of severity of drought problem and less understanding the hydrological aspects associated with the droughts, the National Institute of Hydrology started studies in the year 1986 to better understand the drought impacts from hydrology point of view. In this venture the institute started collection of field data concerning rainfall streamflow and groundwater in selected areas of study.Six states of Andhra Pradesh, Gujarat, Karnataka,Madhya Pradesh Maharashtra & Rajasthan were selected for the study. During the first year (1985-86) ,two districts in each of these six states were chosen for analysis.Analysis of rainfall, streamflow groundwater, and soil moisture data was presented in the report ' Hydrological Aspects of Drought for 1985-86'(CS-21) which was printed and circulated to various agencies. In the following year (1986-87) efforts were intensified to include 4 districts in each six states for the study. Another Report giving details of studies highlighting, Hydrological aspects of droughts in 1986-87 (CS-24) was prepared and published. This report was released by Union Minister of State of Water Resources in November, 1989.

In view of continued situation of drought the studies were further extended to the year 1987-88. For this study six districts in each of six states were chosen for analysis purpose. These districts are Cuddapah, Anantpur, Chittoor, Prakasam, Kurnool and Mehboobnagar in Andhra Pradesh; Jamnagar, Rajkot, Amreli, Bhavnagar, Surendranagar and Ahmedabad in Gujarat; Bijapur, Belgaum, Gulburga, Raichur, Ballary and Dharwar in Karnataka ; Khargone, Jhabua, Sidhi, Dhar, Betul and Shahdol in Madhya Pradesh; Ahmadnagar, Solapur, Pune, Satra, Aurangabad and Sangli in Maharashtra and Banswara, Barmer, Ajmer, Udaipur, Dungarpur and Jodhpur in Rajasthan.

The rainfall data has been subjected to various kind of analysis including monthly and seasonal departures; probability analysis, Herbst's analysis and dry spell analysis. It was found that almost all districts taken for study from Guj .arat, M.P., Rajasthan and Maharashtra showed seasonal deficiency in rainfall in 1987-88 by more than 30%. In some districts 100% deficiency in monthly rainfall was observed. In Karnataka and A.P. states, the rainfall picture was comparatively better than other four states. The probability analysis of rainfall data from 1901 to 1987 has indicated that all districts barring few exceptions had less than 80% probability of getting normal annual rainfall. Unlike previous reports,the Herbst's analysis was done taking all 12 month's data. In general 4-12 drought spells were found in these districts during the period 1951-87. The state of Gujarat seems to have had most intense latest drought spell as per Herbst's criteria. The dry spell analysis has yielded the duration of the dry spell from 21-28 days at 75 % probability level in all but few districts.

The streamflow analysis has been extended to four new sites of Godavari basin in addition to the earlier chosen sites of Krishna basin. The hydrographs during 1987-88 indicated flow close to minimum flow of last 21 years in case of five sites of Krishna. The analysis of data for Godavari was done up to 1986-87 only due to want of data and the hydrographs

showed deficient flows in 1986-87. The annual stream flow volumes were found to be deficient by more than 50% during 1987-88 for Krishna sites as compared to last 21 years' data and also for Godavari sites for 1986-87 .Statistical parameters of the flow series were evaluated to observe severity of drought years and it was found that most of the sites of Krishna observed severe droughts consecutively for three years. Such analysis for Godavari basin sites indicated moderate drought conditions. The flow series for the sites of Godavari was highly variable as compared to Krishna basin sites. The low flow index values for all sites were established. The analysis also resulted in working out annual maximum deficiency volume and duration for a particular demand level. An analysis to find drought volumes and corresponding drought duration has also been attempted in the report. In order to see effects of monsoon failure on reservoir storages attempts were made to compare storages of some selected reservoirs in some selected months of monsoon season. In most of cases storages in years 1986 and 1987 were recorded less than the previous two years.

The analysis of ground water data was restricted to 30 districts spread over six states. The data from 1976-87,in general, has been used to establish post and pre-monsoon trends. The analysis for the districts of A.P. does not show clear picture of ground water regime as a result of drought. The districts in Gujarat have been worst affected ones due to consecutive drought years. In Karnataka, the groundwater picture looked better in year 1987 as compared to previous year 1986. In Madhya Pradesh in general ground water trends (pre and post) were found declining. In Maharashtra state a mixed picture of groundwater level trends was observed with more districts showing falling post monsoon trends. More steeper declining trends were observed post monsoon levels of the districts of Rajasthan barring few exceptions. In some cases positive development in ground water balance was recorded which is attributed to the contribution of surface water irrigation project in the region.

This report is an attempt of the Institute to bring out hydrological aspects of drought which was experienced by the country during 1987 and is third such study in series. It is expected that with the study of a normal year, the Institute will be able to develop some sound base for developing a comprehensive index for characterising hydrologic drought.

1.0 INTRODUCTION

In spite of all the inconveniences that drought causes all around the world, many drought phenomena are still insufficiently understood in terms of the characterisation and impact assessment. There have been difficulties encountered in finding a generally accepted drought definition. The definitions currently in use are derived either on professional stand points (meteorology, hydrology, geography etc.), or on the economic activity affected (agriculture, power, production, water supply etc.). A most important factor in understanding drought, often not included in definitions, that it is a "supply and demand" phenomena. A definition of drought which does not include reference to water requirement or demand can be regarded as inadequate. In general terms, the chief characteristics of drought is associated with a decrease of water availability in a particular period and over a particular area for specified use(s).

In India, the problem of droughts is recurrent. Estimates indicate that about one-third of the geographical area of the country (107 m.ha.) spread over 99 districts is affected by drought.Although the regular monitoring of rainfall in the country started in 1875 with the establishment of India Meteorological Department, there is enough information published in various Gazettes highlighting the occurrences of drought from year 1800 onwards. Statistics reveal that since 1800, there have been 40 different years which experienced drought with varying degree of severity. In recent times, the country faced three drought years in succession namely, 1985, 1986 and 1987. It has been reported that intensity wise the drought of 1987 ranks second in the century, the first one being in year 1918. During the drought of 1987 about 50% of country's area was affected by drought with about 18% negative departure in monsoon rainfall all over India and about 45% negative departure in monsoon rainfall over the drought affected region (Upadhyay & Gupta, 1989). Sampath (1989) has reported that during 1987, 21 meteorological sub-divisions out of 35 recorded deficient/scanty rains leading to drought conditions. It has been further reported that these sub-divisions account for about 53% of the total food grains production in the country. A quick glance of food grains production figures indicates that during year 1987-88 the production was 138.41 million tones while in 1988-89 it was estimated to be about 172.0 million tones. The years 1985-86 through 1987-88 saw declining trend of food grains production which fell from 150.4 million tones in 1985-86 to 138.41 million tones in 1987-88. The fluctuation of food grain production clearly show dependability of agricultural activities on the rainfall.

The incidents of drought lead to reduction in stream flows, depletion of soil moisture storages, decline of reservoir and tank levels and fall in groundwater table. This in turn leads to reduced agriculture and fodder production. The drought characteristics and the associated problems vary from area to area depending upon the amount of variability of available water supplies and the demand of water for specified users.In spite of the repeated occurrence of drought in the country, the hydrological aspects of drought have not been studies to the desired extent. Such studies have a direct bearing on evolving strategies for planning judicious use of water resources.

The Institute had initiated studies to lay emphasis on hydrological aspects of droughts in year 1986-87 as these aspects were by and large neglected in past studies whatever carried out. The present report describes results of studies carried out for the year 1987-

88 with six districts chosen in each state. The report includes analysis of rainfall and groundwater level data for finding deficit of rainfall and trend of ground water tables as a result of drought incidents. The report is an attempt towards developing a comprehensive hydrological drought index for characterising drought situations.

2.0 DESCRIPTION OF STUDY AREA

In view of frequent occurrence of drought incidences over last few years, the Institute took up a task to carry out studies using field data to highlight hydrological aspects of drought as experienced in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Rajasthan. To begin with two districts in each of these states where chosen for the analysis and the study report entitled "Hydrological Aspects of Drought 1985-86" has been published. Since the droughts prevailed continuously during 1985-86, 1986-87 and 1987-88, the studies were extended with more aerial coverage. Therefore in 1986-87 , four districts in each of chosen states were selected for analysis. The study report has been published under the title 'Hydrological Aspects of Drought for 1986-87'.

The efforts of the Institute were intensified to carry out studies for year 1987-88 in which six districts in each of these six states were chosen for study purpose. It may be mentioned that the districts chosen for study are out of the ones which have been declared as drought prone in the chosen states. Salient features of these drought prone states and their location is given in Table 2.1 and Fig.2.1

The state wise list of districts chosen for study during years 1985-86, 86-87, and 87-88 are reported in Table 2.2 and for year 87-88 is presented in Fig.2.2

During the visits it was attempted to collect data pertaining to water year 1987-88 and other necessary data required for short term and long term analysis. List of departments contacted and districts visited by the scientific and technical teams is given in Appendix II-1. A brief description of the states and the districts chosen for detailed analysis is given in the following sections :

2.1 Andhra Pradesh

In Andhra Pradesh, the South West Monsoon generally sets in from early June and lasts until about the end of September, whereas the North East Monsoon occurs from October to December. The annual average rainfall in coastal Andhra Pradesh, Rayalaseema and Telangana regions is 700-1500 mm, 400-700 mm, and 700-1200 mm respectively. About 60.74 percent area of the States is under agriculture. Major crops of the States are Jowar, Bajra, Rice, Pulses, Ground nut, Cotton, Tobacco etc.

As per studies carried out by the Central Water Commission in year 1982, eight districts namely, Anantpur, Chittoor, Cuddapah, Hyderabad, Prakasam, Kurnool, Mehboobnagar and Nalgonda were declared drought prone in Andhra Pradesh (Fig. 2.2). Out of these eight drought prone districts it was decided to choose districts of Cuddapah, Anantpur, Chittoor, Prakasam, Kurnool, and Mehboobnagar for study. The locations of these six districts on state map are shown in Fig.2.3..

TABLE 2.1 : DROUGHT PRONE DISTRICTS

Sl.No.	State	Area in 1000 sq.km	Population lakhs	Major rivers streams	Normal rainfall	*Drought Prone Distt. in 1985	District in which study was done by C.W.C.	Distt. covered in this study	Remarks
1.	2.	3.	4.	5.	6.	7.	8.	9.	10
1.	Andhra Pradesh	275	535	Godavari Krishna Vansadhara Negavelli Pennar	900	Anantpur Kurnool Chittoor Cuddapah Mahboob-nagar Pakasam Rangareddy Nalgonda	Anantpur Kurnool Chittoor Cuddapah Mahboobnagar Pakasam - Nalgonda Hyderabad	Anantpur Kurnool Chittoor Cuddapah Mahboobnagar Pakasam - - -	
2.	Gujarat	196	341	Tapti Narmada	350	Ahmedabad Rajkot Kutch Amreli Jamnagar Surendra-nagar Bhavnagar Panch-mahals	Ahmedabad Rajkot Kutch Amreli Jamnagar Surendra-nagar Bhavnagar Panch-mahals Benas-Kantha Kheda Bharuch Mehsana	Ahmedabad Rajkot Amreli Jamnagar Surendranagar Bhavnagar	

* Source:District declared drought-prone under DPAP during Seventh Plan.
**Source : Brochure on Drought-March 1982", Drought Area Study and Investigation, C.W.C. and Govt. of India.

1.	2.	3.	4.	5	6.	7.	8.	9.	10.
3.	Karnataka	192	371	Sharvathi	1355	Bijapur	Bijapur	Bijapur	
				Kali		Tumkur	Tumkur		
				Natravati		Dharwar	Dharwar	Dharwar	
				Varahi		Belgaum	Belgaum	Belgaum	
				Bedthi		Kolar	Kolar	-	
				Aghanashini		Bidar	-	-	
				Krishna		Chikmaglur	Chikmaglur	-	
				Ghataprabha					
				Malaprabha		Chitra-durga	Chitra-durga		
				Bhima					
				Tungabhadra		Gulbarga	Gulbarga	Gulbarga	
				Cauvery		Bellary	Bellary	Bellary	
				Pennar		Raichur	Raichur	Raichur	
				Palar		-	Bengalore	-	
						-	Hassan	-	
						-	Mandya	-	
						-	Mysore	-	
4.	Madhya Pradesh	443	522	Narmada	1140	Betul	Betul	Betul	
				Mahanadi		Shahdol	Shahdol	Shahdol	
				Tapti		Khargone	Khargone	Khargone	
				Mahi		Dhar	Dhar	Dhar	
				Chambal		Jhabua	Jhabua	Jhabua	
				Betwa		Sidhi	Sidhi	Sidhi	
				Sone		-	Datia	-	
				Indrawati		-	Dewas	-	
						-	Khandwa	-	
						-	Shajapur	-	
						-	Ujjain		

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
5.	Maharashtra	308	623	Tapti Godavari Krishna	60-120	Ahmadnagar Sangli Jalna Dhule Aurangabad Solapur Jalgaon Nasik Satara Beed Osmanabad Pune	Ahmadnagar Sangli - - Aurangabad Solapur - Nasik Satara Beed Osmanabad Pune	Ahmadnagar Sangli - - Aurangabad Solapur - Satara Pune
6.	Rajasthan	342	343	Chambal	59	Udaipur Dungarpur Banswara Ajmer Sawai Madhopur Tonk Kota Jhalawer - - - - - - - - -	Udaipur Dungarpur Banswara Ajmer - - - - - Barmer Bikaner Churu Jaisalmer Jalore Jhunjhunun Nagaur Pali Jodhpur	Udaipur Dungarpur Banswara Ajmer - - - - - Barmer - - - - - - - Jodhpur

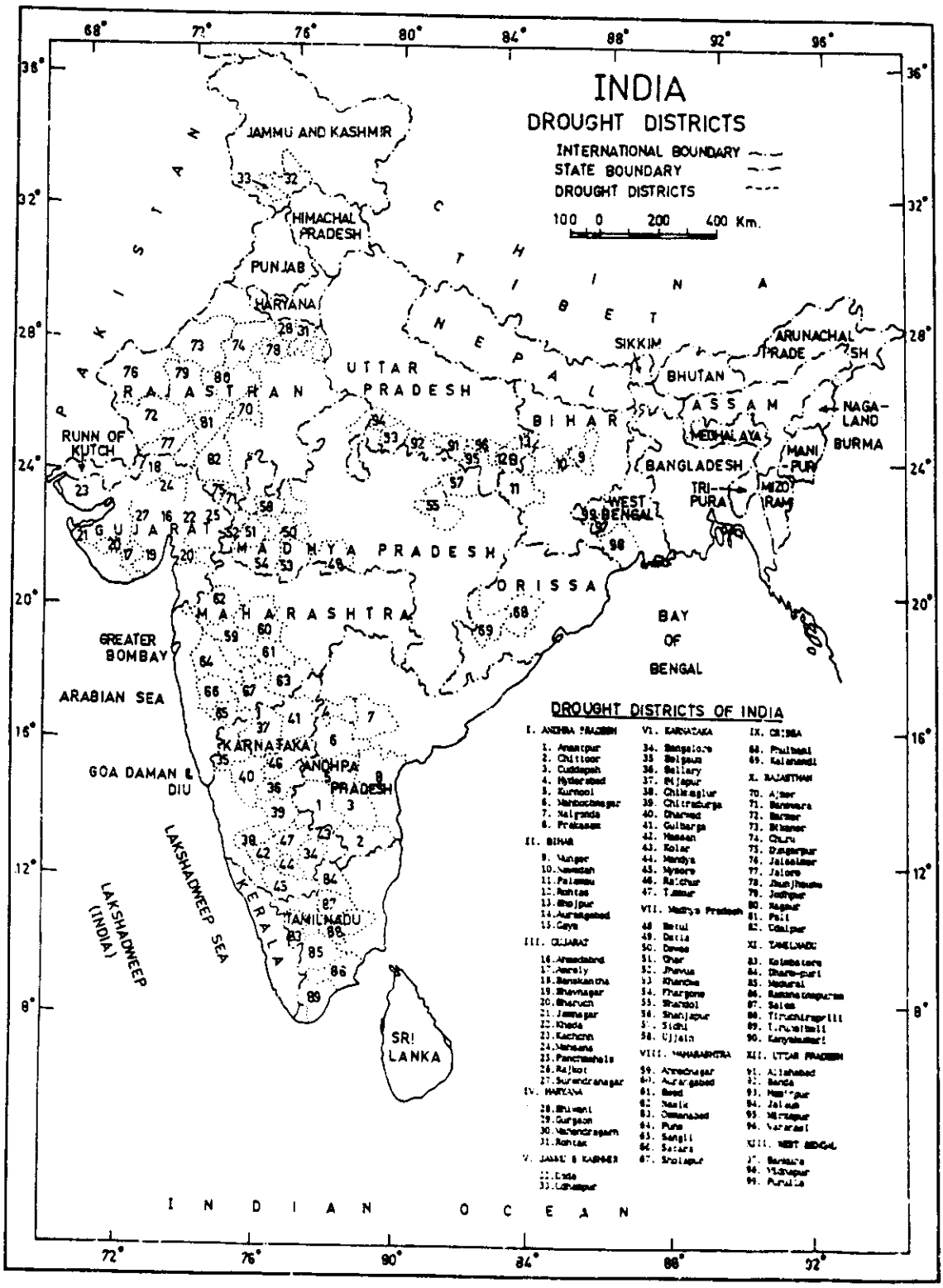


FIG. 2.1 : DROUGHT PRONE DISTRICTS IN INDIA

Table 2.2 Districts chosen for study

State	Districts taken for study in the report Hydrological Aspects of Drought		
	1985-86	1986-87	1987-88
Andhra Pradesh	Anantpur Cuddapah	Anantpur Cuddapah Chittoor Prakasam	Anantpur Cuddapah Chittoor Prakasam Kurnool Mehboobnagar
Gujarat	Rajkot Jamnagar	Rajkot Jamnagar Ahmedabad Surendranagar	Rajkot Jamnagar Ahmedabad Surendranagar Amreli Bhavnagar
Karnataka	Belgaum Bijapur	Belgaum Bijapur Gulburga Raichur	Belgaum Bijapur Gulburga Raichur Bellary Dharwar
Madhya Pradesh	Jhabua Khargone	Jhabua Khargone Dhar Sidhi	Jhabua Khargone Dhar Sidhi Betul Shahdol
Maharashtra	Ahmednagar Sholapur	Ahmednagar Sholapur Pune Satara	Ahmednagar Sholapur Pune Satara Sangli Aurangabad
Rajasthan	Barmer Banswara	Barmer Banswara Ajmer Udaipur	Barmer Banswara Ajmer Udaipur Dungarpur Jodhpur

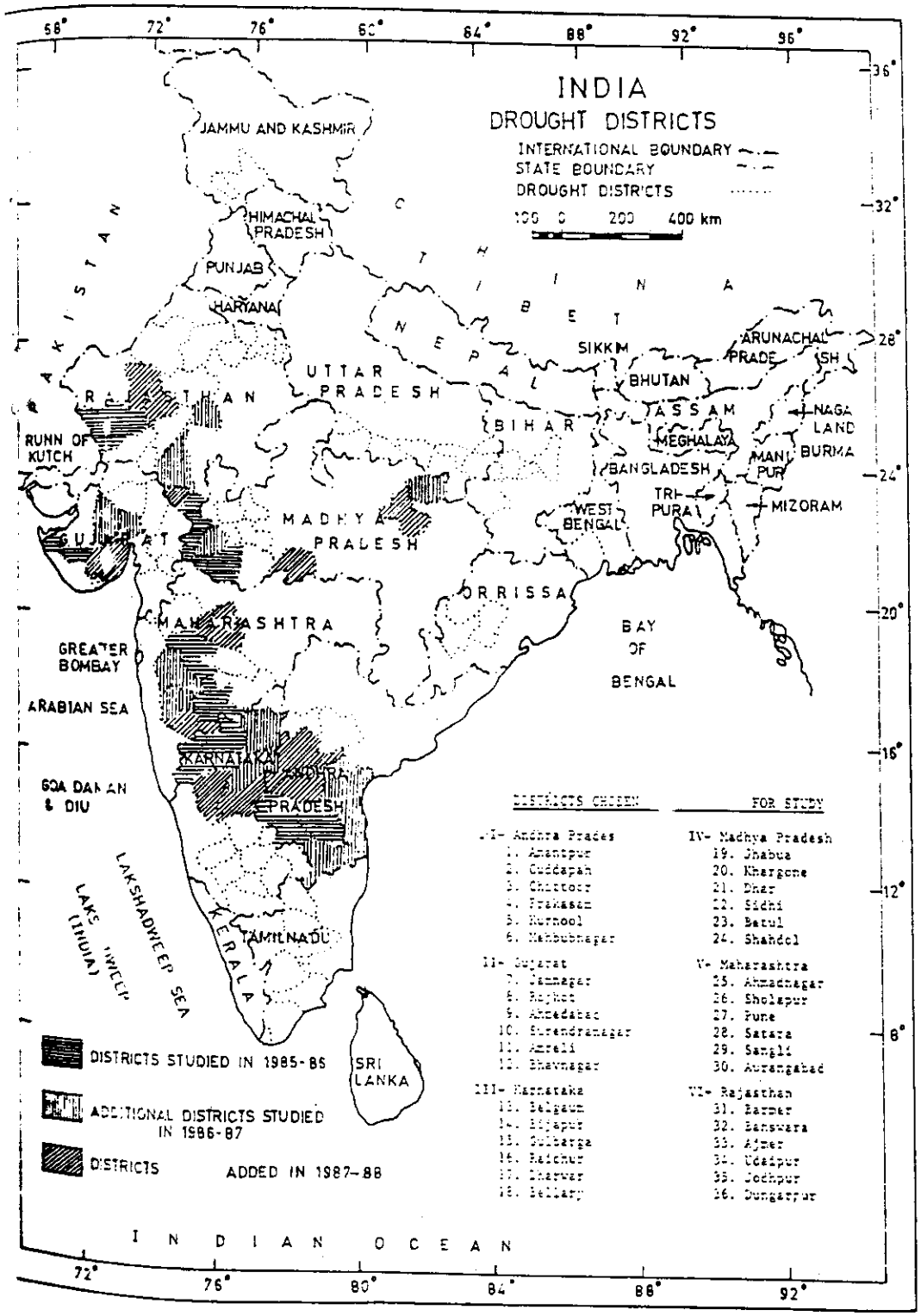


Fig. 2.2 : Districts chosen for study

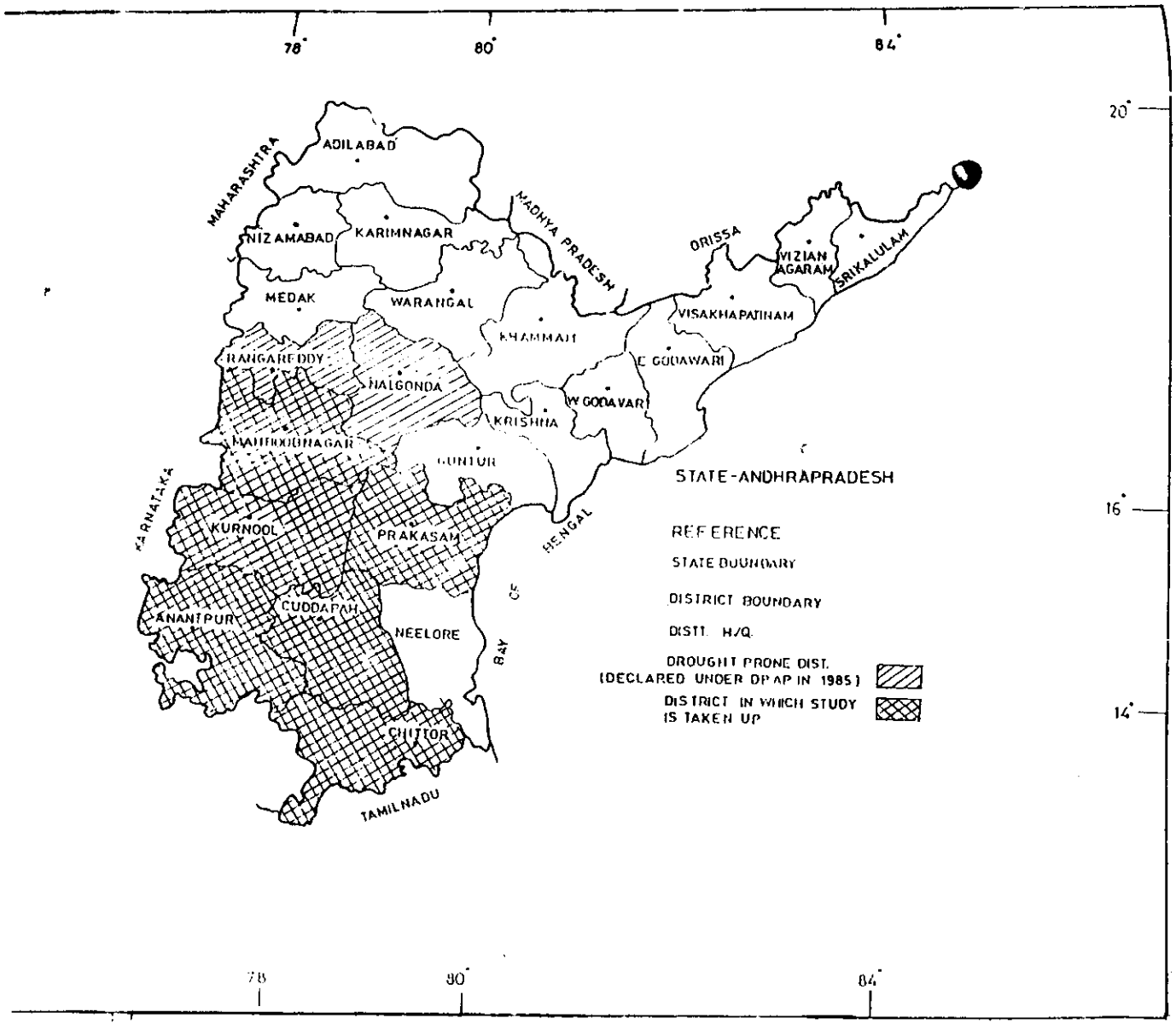


FIG. 2.3 : DROUGHT PRONE DISTRICTS IN ANDHRA PRADESH

2.2 Gujarat

In Gujarat , the average annual precipitation over different parts of the State varies widely from 300 mm in the Western half of Kutch to 1500 mm in the Southern parts of the Valsad Districts and Dengs. The monsoon usually commences by the middle of June and withdraws by the end of September. According to the figures available the irrigated area in Gujarat state was about 15% of the total cultivated area. The soils of Gujarat can be broadly classified as : Residual loamy soils, Alluvial Deep Clay soils, Alluvial clayey soils, Alluvial sandy soils, Alluvial sandy loam, coastal littoral soils and saline soils. Out of the total geographical area of 196 lakh ha of the state, about 50% is under cultivation. Among the individual crops, ground nut and cotton occupy the largest area which is about 20% each. Live-stock and poultry raising forms a very substantial part of the occupation of almost all the farms.

Central Water Commission in 1982 identified 12 districts namely, Ahmedabad, Rajkot, Kutch, Amreli, Jamnagar, Surendranagar, Bhavnagar, Panchmahals, Banas-Kantha, Kheda, Bharuch and Mehsana in Gujarat State as drought prone (Fig.2.1) out of which six districts viz. Jamnagar, Rajkot, Ahmedabad, Surendranagar, Amreli and Bhavnagar have been taken up for the study. The locations of these six districts along with other drought prone districts of the state are shown in Fig.2.4.

2.3 Karnataka

The land area of Karnataka is 19.18 M.ha. and the state's population is 37.1 M(1981 census). The net area shown in the state is 10.39 M.ha. and the net irrigated area is 2.5 M.ha. The ultimate irrigation potential in the state is estimated to be about 5.5 M.ha.

The state of Karnataka can be divided into four district regions : (i) a long narrow coastal region which receives a high (2500 mm) rainfall during the south-west monsoon season; rice is the main crop and coconuts and arecanut are also extensively grown; (ii) the western ghats or Malnad region, along narrow mountainous area to the east of the coastal belt with heavy and assured rainfall and rice, coffee, cardamum, arecanut and coconut are main crops grown; (iii) the Northern plateau, drained by the krishna, Bhima, Ghatprabha, Malprabha & Tungabhadra river; receives an average annual rainfall of 60 mm or less which is highly variable from year to year and forms the arid region of the state. The principal crops are Sorghum, pear, millet, ground nut and cotton; (iv) the southern plateau, drained by the Cauvery, Tungabhadra, Pennar and Palar rivers; rainfall is again variable and ranges from 500 mm in the North-west to 760 mm in the west, much of the irrigation in this area is from tanks and the principle irrigated crops are rice, and sugar cane, with Sorghum, pear, millet, finger millet, castor and pulses as the major rain fed crops. The state has mostly red sandy soils, black soils and mixed red and black soils.

The Central Water commission in 1982 identified 14 drought districts namely, Bijapur, Tumkur, Dharwar, Belgaum, Kolar, Chikmaglur, Chitradurga, Gulburga, Bellary, Raichur, Bangalore, Hassan, Madhya and Mysore in the State (Fig.2.1). Out of 14 districts identified as drought prone by Central Water Commission, six districts viz. Bijapur, Raichur, Gulburga, Belgaum, Bellary and Dharwar have been selected for the study. The location of these six districts along with other drought prone districts of the state is shown in Fig.2.5.

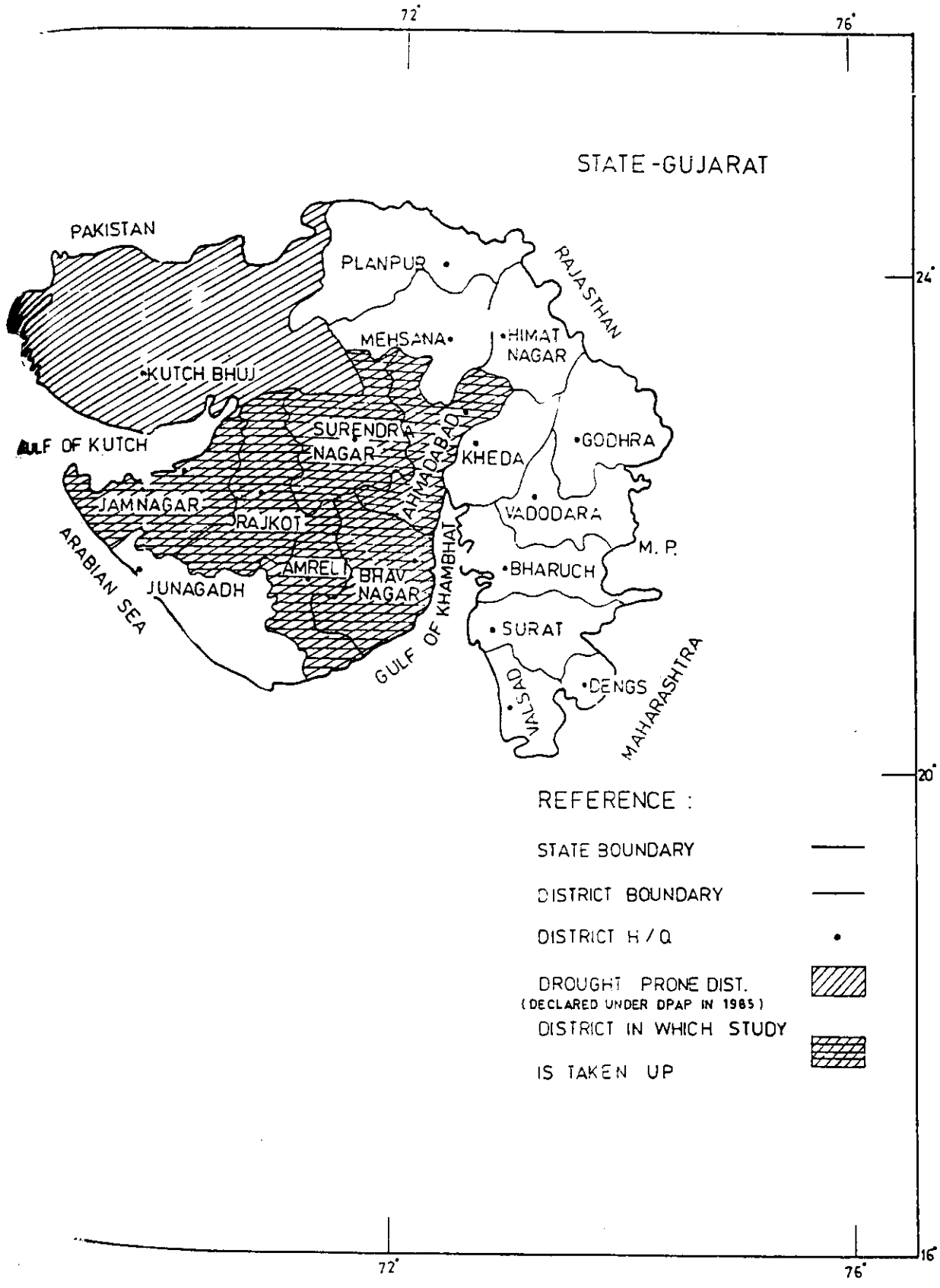


FIG. 2.4 : DROUGHT PRONE DISTT. IN GUJARAT

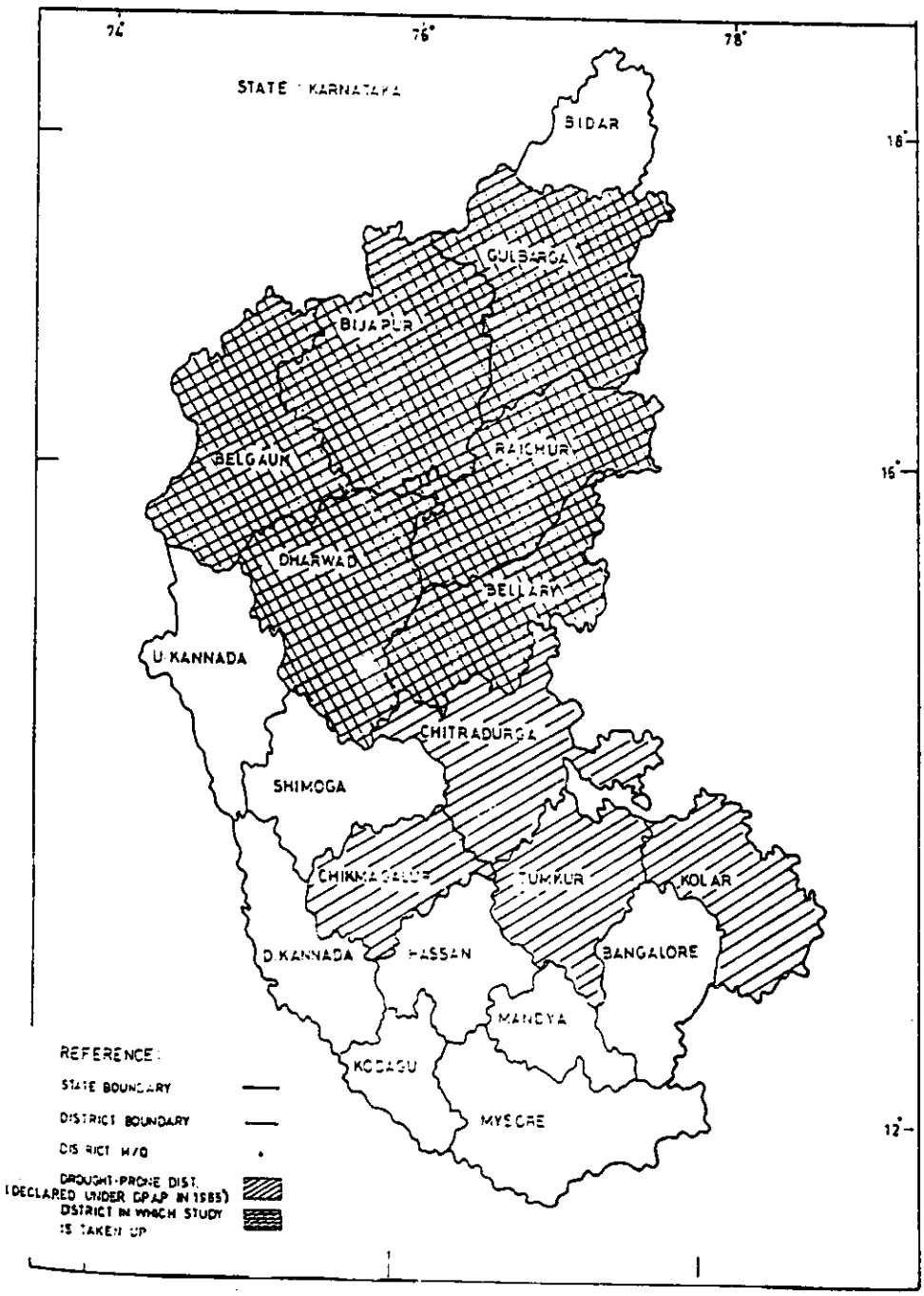


FIG. 2.5 : DROUGHT PRONE DISTT. IN KARNATAKA

2.4 Madhya Pradesh

In Madhya Pradesh monsoon generally breaks about in the middle of June and continues up to the end of September, with short dry spells in between. As a result, normally the northern portion of Madhya Pradesh receives a rainfall of about 750 mm to 85-mm and the Malwa plateau receives 750 mm to 1250 mm annually. The hilly areas of Vindhyas and Satpuras receives rainfall of 1050 to 1750 mm whereas the Baster plateau receives a maximum of 1600 to 1800 mm annually. The state of Madhya Pradesh has twelve agroclimatic zones. Broadly, it could be sub-divided into five crop zones viz., rice zone, wheat zone, wheat-rice zone, wheat-Jowar zone and cotton- Jowar zone. The main crops produced in the state are Wheat, Jowar, Rice, Grams, Maize, Ground nut, Sugarcane and Cotton. The major portion of state's economy is due to agriculture which involves nearly 80% of its population. Madhya Pradesh is however, much below the national average of 27.5% (as in 1983-84) in the field of irrigation

The Central Water Commission identified in year 1982, 11 districts namely, Betul, Shahdol, Khargon, Dhar, Jhabua, Sidhi, Datia, Dewas, Khandwa, Shahjapur and Ujjain as drought affected in State (Fig.2.1). Six districts namely Jhabua, Khargone, Dhar, Sidhi, Betul and Shahdol out of 11 drought affected districts have been taken up for the detailed analysis. The location of these six districts along with other drought affected districts in the state is shown in Fig.2.6.

2.5 Maharashtra

In Maharashtra, the coastal belt of Konkan and the wind-ward side of the Western Ghats receive an annual rainfall of over 200 to 250 cm, rainfall decreases rapidly to less than 60 cm over the western districts of Madhya Maharashtra. Parts of Dhule, Nasik, Pune, Satara and Solapur districts receive less than 50 cm. Marathwada receives 60-90 cm annually. The rainfall in 17 districts out of 27 in the state is 100 cm or less annually. Rainfall is more than 150 cm in many parts of Vidarbha. The soil over major part of the state to the east of the Western Ghats and to the west of eastern Vidarbha is of the medium black variety interspersed by long patches of deep black soil. The land utilisation pattern reveals about 60% area is under cultivation including about 8% under irrigation, 18% under forest and remaining 22% under miscellaneous land use. The dry farming area in the state accounts for nearly 70% of the geographical area of the state. Jowar and Bajra are the principal crops followed by Wheat and Sugarcane in the interior districts. Rice is the principal crop in coastal districts.

As per studies carried out by Central Water Commission in 1982, 9 districts namely, Ahmednagar, Sangli, Aurangabad, Solapur, Nasik, Satara, Beed, Osmanabad and Pune were declared as drought prone in Maharashtra (Fig.2.1). Out of these nine districts, six namely Solapur,Ahmednagar, Pune, Satara, Sangli and Aurangabad have been selected for study. The location of these districts on state map alongwith other drought affected districts is shown in Fig.2.7.

2.6 Rajasthan

Rajasthan receives rainfall from South-West monsoon. The duration of monsoon in Rajasthan is hardly three months from 15th June to 15th September. There are 12 basic types of soils viz. Desert soils,Desert rivweive soils, Alluvial serozams, Gray Brown soils, Non-calcic brown soil, Brown soils saline phase, Alluvial soil recent origin, Gray Brown alluvial soils, Yellow brown soil, Red loamy, Deep and Medium black soils and Hilly soils. Major

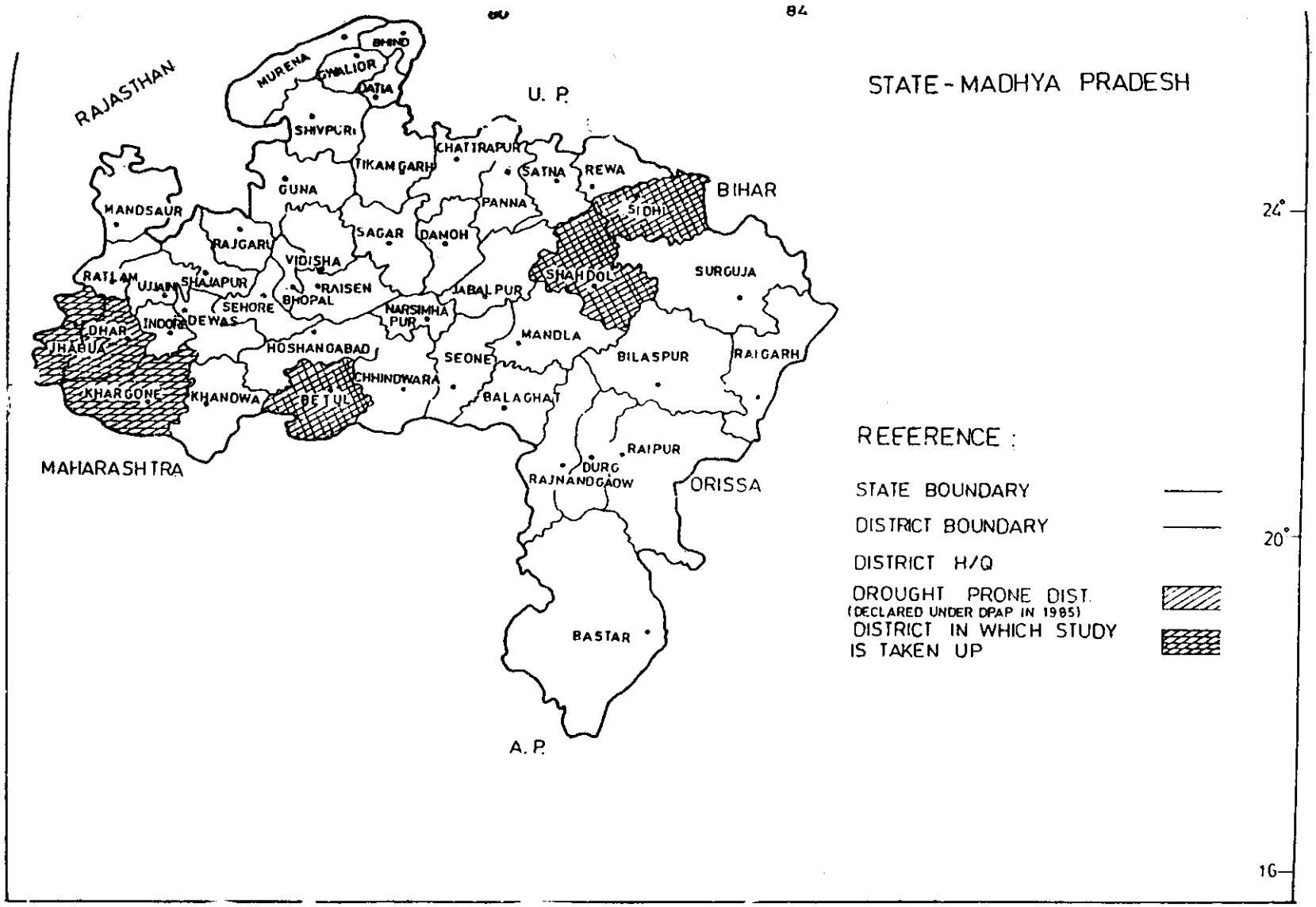


FIG. 2.6 : DROUGHT PRONE DISTT. IN MADHYA PRADESH

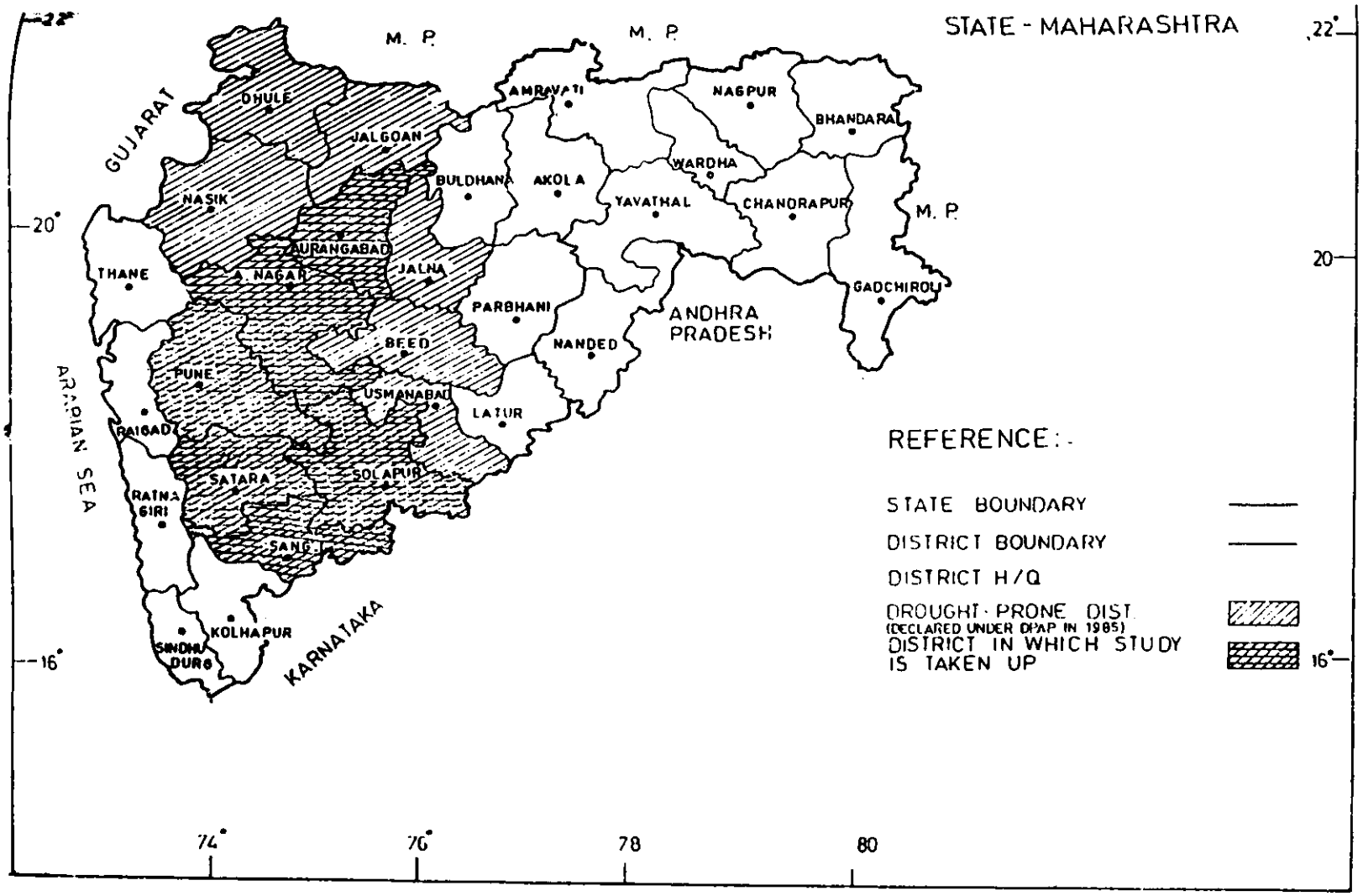


FIG. 2.7 : DROUGHT PRONE DISTTS. IN MAHARASHTRA

crops of the state are Jowar, Bajra, Maize, Pulses, Wheat etc. Major source of irrigation in drought prone areas of state is through irrigation-tanks supplemented by ground water.

Central Water Commission in year 1982 identified thirteen districts namely; Udaipur, Dungarpur, Banswara, Ajmer, Barmer, Bikaner, Churu, Jaisalmer, Jalore, Jhunjhunu, Nagaur, Pali and Jodhpur in Rajasthan as drought prone (Fig.2.1). Out of these 13 districts, six districts viz.Barmer, Banswara, Udaipur, Ajmer, Jodhpur and Dungarpur have been selected for the present study. The location of six districts on state map along with other drought affected districts is shown in Fig.2.8.

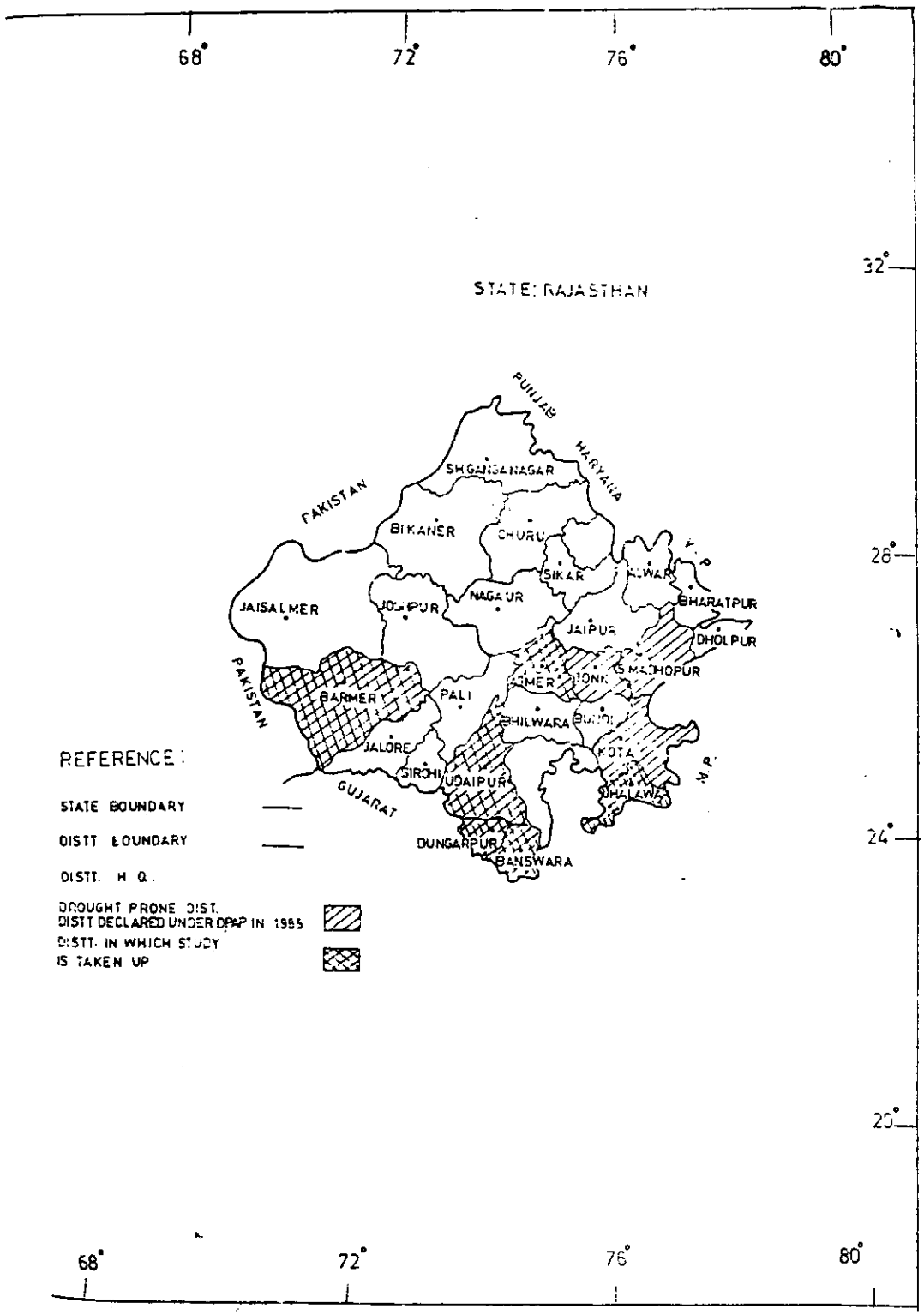


FIG. 2.8 : DROUGHT PRONE DISTTS. IN RAJASTHAN

3.0 RAINFALL ANALYSIS

3.1 General

As has already been described in chapter 2.0, Six districts from each of six selected states have been chosen for rainfall analysis.One representative raingauge station from each taluk in each district has been selected for the study. The raingauge stations selected for the study are the ones which were selected by Central Water Commission for carrying out studies for identification of drought prone areas in 1982. The rainfall analysis has been carried out with the data from year 1901-1988. The data from 1901 to 1980 have been taken from CWC reports (CWC 1982). The remaining data from 1981 to 1988 have been collected during visits of scientific and technical teams to various states.

3.2 Rainfall Departure Analysis

3.2.1 Seasonal rainfall departure

In order to see the deficiency of rainfall on seasonal basis,seasonal rainfall departure analysis has been carried out. The data from period 1970-87 have been used for this analysis. As has been said earlier that a total of 36 districts have been chosen for rainfall analysis. It may be mentioned that in the previous two reports namely : Hydrological Aspects of Drought 1985-86 (CS-21) and Hydrological Aspects of Drought 1986-87 (CS-24), the seasonal rainfall departure analysis for 23 districts upto water year 1986-87 have already been presented. Therefore, the seasonal deficiencies as experienced in the water year 1987-88 in the 23 districts have been an noted to the earlier analysis. In the remaining 13 districts (12 new ones and one Udaipur for which analysis could not be done in 1986-87 report) the seasonal rainfall deficiency analysis has been done by using the data of 1970 to 1987.

The analysis for the year 1987 has been added in this report for 23 districts covered in the previous report,Hydrological Aspects of Drought 1986-87. Seasonal normals for districts have been calculated as the summation of normals for the months (June to September or May to November as the case maybe) as provided in CWC reports. The period for calculating seasonal normals are June to September for the states of Gujarat, Maharashtra, Madhya Pradesh and Rajasthan as the south-west monsoon is active for four months in these states and May to November for Andhra Pradesh and Karnataka as the south-west and north-east ,both the monsoons are active from May to November in these two states. The major inferences that could be drawn from the seasonal analysis are as below :

a) In the state of Andhra Pradesh, in general, seasonal rainfall departure of about 10% has been experienced barring the districts of Kurnool, Prakasam and Mehboobnagar. The pattern of seasonal rainfall deficiency has been more or less similar in the case of Cuddapah & Anantpur districts which are adjoining Table 3.1. The deficiency pattern in case of Kurnool and Mehboobnagar has also matched to some extent while districts Prakasam and Chittoor show a very indefinite pattern of seasonal deficiency.

b) In the state of Gujarat all the six chosen districts experienced more than 60% deficiency in the seasonal rainfall during year 1987-88 Table 3.2. It has also been observed that all the districts in the state have been experiencing seasonal deficits of more than 20% since water year 1984-85 indicating occurrence of severe droughts in the state for years in succession.

c) The seasonal rainfall departure scene is bit different in case of Karnataka state where all but two districts have shown slightly above normal seasonal rainfall during 1987-88. Only the district of Belgaum has shown seasonal rainfall deficiency of about 20% Table 3.3. However, almost all the six districts experienced deficient seasonal rainfall in previous three years (i.e. 1984 to 1986).

d) The districts in Madhya Pradesh experienced seasonal rainfall deficiency with the extreme lying between 30 percent to 65 percent. Only one district of Sidhi which is on the eastern side of the state showed positive departure by 10 percent in seasonal rainfall.Table 3.4. The deficiency pattern in the district shows by and large scarcity of seasonal rain since 1985 in all the six districts chosen for study particularly in western districts of the state. The analysis for Shahdol could it be done due to want of data.

e) The seasonal rainfall pattern in the state of Maharashtra has been deficient in all districts during 1987-88 except Sholapur table 3.5. The districts of Ahmednagar, Satara, Pune and Sangli have recorded continuous deficient seasonal rainfall since 1984 with the extremes lying in between 15 to 60 percent. Some districts like Pune and Satara recorded continuous seasonal rainfall deficiency in last 15-16 years.

f) In case of six districts of Rajasthan, a continuous deficiency in seasonal rainfall has been experienced with the extremes lying between 20% to 65% except in the case of Banswara which recorded slight positive departure in seasonal rainfall Table 3.6. The deficiency pattern has been more or less same in the districts of Ajmer, Jodhpur, Udaipur and Barmer.

On the basis of seasonal rainfall departure it has been observed that the state of Gujarat followed by Rajasthan, Maharashtra, Madhya Pradesh experienced severe drought conditions during 1987-88.

3.2.2 Monthly rainfall departure for the year 1987-88

In order to observe deficiency in monthly rainfall during the year 1987-88, monthly departures have been worked out for 36 districts spread over six states.. The departure analysis has been done for all the taluks and district as a whole. Monthly rainfall values from June'87 to May'88 alongwith monthly normals of representative raingauges of various taluks have been considered for the analysis. Monthly rainfall values for a district from June'87 to May'88 have been taken as weighted average rainfall of all the taluks considered for analysis in the district. Monthly normals of districts have been directly taken from reports of CWC (CWC,1982). It may be mentioned that in case of some districts/taluks monthly departure analysis has been limited to some months only due to data availability constraints.The results are reported in the reports of respective state.

Table 3.1 : SEASONAL RAINFALL DEPARTURE OF SIX DISTRICTS OF ANDHRA PRADESH

District	Anantpur	Kurnool	Chittoor	Cuddapah	Mehboobnaga	Prakasham
Seasonal normalised rainfall	1300.72	622.75	752.26	646.90	713.57	690.53
Year	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure
1970		27.64	- 0.14		- 2.88	-16.10
1971		-20.68	-10.78		-26.95	-20.96
1972		-19.05	10.02		-45.99	1.38
1973		12.84	-19.02		- 3.11	-10.99
1974		10.08	- 6.20		13.37	4.87
1975		68.97	44.28		43.79	15.30
1976		-17.03	26.77		- 7.54	4.36
1977		30.07	19.84		- 1.39	- 5.85
1978		40.86	-16.06		26.26	14.72
1979		2.75	19.22		8.46	62.62
1980		-19.97	-33.48		-21.17	-14.97
1981		16.76	8.79		0.55	5.28
1982		2.06	-17.50		- 6.72	- 7.24
1983		43.76	9.01		27.74	27.90
1984		-19.99	- 0.14		-28.48	-34.53
1985		-11.53	5.85		-26.36	-25.02
1986	-65.96	-28.30	-22.62	-22.29	-43.25	-15.79
1987	-64.20	21.47	- 3.85	0.47	6.24	17.11
1988	-90.33	13.32	7.73	29.89	-30.27	-24.86
1989	-60.24	2.09	-10.56	- 8.00	4.04	-28.45

Table 3.2 : SEASONAL RAINFALL DEPARTURE OF SIX DISTRICTS OF GUJARAT

District	Ahmedabad	Rajkot	Amreli	Jamnagar	Surendranagar	Bhavnagar
Seasonal normalised rainfall	650.70	540.35	526.86	427.43	479.61	563.24
Year	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure
1970	27.57		26.50		60.80	67.80
1971	-37.34		21.36		-36.20	16.61
1972	-55.23		-56.35		-73.28	-53.92
1973	- 8.25		- 5.78		-32.05	15.74
1974	-57.23		-49.29		-71.58	-51.58
1975	71.83		-18.54		1.95	0.69
1976	104.55		9.02		13.15	63.39
1977	7.20		9.68		- 7.46	2.29
1978	- 6.65		-24.73		-36.45	-34.17
1979	0.89		26.11		45.77	20.28
1980	-31.30		21.74		- 1.26	-17.09
1981	28.60		29.22		-13.95	0.83
1982	-35.99		-35.21		-47.55	-53.94
1983	1.41		54.28		0.11	36.86
1984	-13.36		-40.45		-25.14	-27.47
1985	-17.69		-64.30		-54.71	-59.01
1986	-42.17	-55.26	-43.43	-35.51	-56.09	-57.48
1987	-71.74	-79.20	-65.26	-90.42	-79.65	-65.86
1988	22.37	77.08	88.02	56.27	6.26	31.45
1989	-100.00	-100.00	-100.00	-100.00	100.00	-100.00

Table 3.3 : SEASONAL RAINFALL DEPARTURE OF SIX DISTRICTS OF STATE KARNATAKA

District	Bijapur	Dharwar	Belgaum	Gulburga	Bellary	Raichur
Seasonal normalised rainfall	534.82	671.52	762.39	726.83	583.32	573.05
Year	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure
1970		- 1.59		2.45	24.32	2.28
1971		-11.63		-42.77	8.82	-30.61
1972		-22.78		-47.75	- 9.83	-40.36
1973		- 8.66		30.30	18.36	- 0.37
1974		12.11		31.83	14.38	10.70
1975		20.49		76.17	48.71	- 7.07
1976		-33.94		- 2.90	-51.82	-38.33
1977		- 6.77		24.97	6.66	- 8.67
1978		18.25		38.32	19.94	1.38
1979		33.55		14.73	2.14	1.30
1980		5.14		- 5.01	- 8.05	- 33.47
1981		- 7.44		50.78	40.15	20.60
1982		6.81		8.99	21.82	- 3.19
1983		-12.69		63.07	34.62	8.62
1984		-22.78		- 9.98	52.44	-21.57
1985		-43.34		-14.90	-32.92	-29.83
1986	-15.38	- 9.92	-20.31	-23.40	18.58	-16.64
1987	38.25	0.92	-21.24	12.03	15.29	5.18
1988	4.39	- 3.13	5.44	16.72	18.95	-12.36
1989	13.95	-35.27	-18.82	- 4.17	-14.65	-31.61

Table 3.4 :SEASONAL RAINFALL DEPARTURE OF SIX DISTRICTS OF STATE MADHYA PRADESH

District	Betul	Shahdol	Khargone	Dhar	Jhabua	Sidhi
Seasonal normalised rainfall	880.53	1074.83	733.68	773.60	790.70	1115.82
Year	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure
1970	20.92	- 5.08		43.00		-12.29
1971	-16.45	10.47		11.82		31.36
1972	-20.03	- 3.15		-27.21		-16.45
1973	52.28	-51.45		56.20		-28.81
1974	-18.68	-22.71		-38.47		-36.30
1975	34.48	32.36		-34.82		3.02
1976	-37.21	-63.41		31.97		-24.94
1977	-20.20	11.23		4.27		6.55
1978	-33.95	15.41		3.51		6.23
1979	-18.31	-45.90		-24.54		-44.48
1980	-22.46	-32.46		-12.63		17.71
1981	- 5.40	-26.98		32.52		3.23
1982	- 5.40	-11.03		-39.26		16.20
1983	12.22	10.37		2.16		- 3.24
1984	- 5.40	7.35		- 1.45		-18.46
1985	-20.83	- 2.05		-41.65		14.06
1986	11.23	- 5.64	-16.64	-21.46	-26.31	-31.14
1987	-46.05	-4.81	-40.56	-30.27	-33.43	8.88
1988	26.44	-14.50	- 8.79	- 3.02	31.66	-39.03
1989	-100.00	-26.62	-33.27	-27.08	-37.70	-35.25

Table 3.5 :SEASONAL RAINFALL DEPARTURE OF SIX DISTRICTS OF STATE MAHARASHTRA

District	Ahmednagar	Sangli	Aurangabad	Solapur	Satara	Pune
Seasonal normalised rainfall	431.00	423.60	604.77	456.50	941.91	865.30
Year	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure
1970		1.28	41.65		-47.31	-51.55
1971		0.00	-19.16		-57.11	-45.94
1972		-37.38	-49.13		-76.36	-58.93
1973		- 3.49	2.75		-50.47	-32.27
1974		31.53	-43.75		-52.78	-45.34
1975		58.30	7.61		-43.47	-30.00
1976		-12.61	-15.67		-44.22	-10.59
1977		- 2.77	-18.91		-52.94	-16.06
1978		7.30	-17.01		-49.00	-43.81
1979		59.02	13.79		-48.44	-41.33
1980		6.64	- 1.09		-48.44	-41.33
1981		61.81	- 2.04		-27.18	-24.04
1982		- 7.64	-37.31		-52.52	-50.10
1983		-5.09	30.02		-36.38	-25.06
1984		-24.67	-26.78		-45.21	-41.04
1985		-32.10	-40.19		-49.72	-56.43
1986	-23.78	-15.78	-20.69	-21.56	-41.45	-44.68
1987	-31.28	-11.22	-19.79	- 0.27	-51.86	-60.45
1988	-76.15	-13.05	-54.36	-21.82	-23.01	-50.77
1989	31.16	16.29	-54.28	35.79	-68.37	-46.57

Table 3.6 :SEASONAL RAINFALL DEPARTURE OF SIX DISTRICTS OF STATE RAJASTHAN

District	Udaipur	Banswara	Ajmer	Barmer	Jodhpur
Seasonal normalised rainfall	573.8	782.4	455.10	245.12	245.12
Year	Percent Departure	Percent Departure	Percent Departure	Percent Departure	Percent Departure
1970	32.51		26.34		39.04
1971	- 5.17		- 2.91		-28.77
1972	-35.22		-54.68		-40.56
1973	142.03		55.79		46.93
1974	-32.77		-21.28		-40.11
1975	27.46		91.75		98.96
1976	26.33		54.17		52.47
1977	21.38		17.85		15.00
1978	11.85		1.56		8.32
1979	-31.14		4.43		-14.87
1980	3.37		-29.11		-24.16
1981	-10.89		-16.23		-46.40
1982	-71.90		- 2.68		-34.76
1983	28.63		53.86		43.63
1984	- 2.29		-13.45		-64.57
1985	-19.60		-39.67		-45.37
1986	-23.63	18.27	-30.20	-74.05	-57.19
1987	-49.03	5.40	-47.88	-80.07	-62.41
1988	5.53	11.30	-86.66	-27.27	- 7.72
1989	0.27	-20.11		3.45	-18.85

3.3 Frequency of Rainfall

3.3.1 Probability analysis of annual rainfall

Probability is a constant characterising given set of objects or incidents in a particular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy the relative frequency of occurrence in different group intervals of annual rainfall. It is also possible to work out the percentage probability of occurrence of 75% of annual rainfall or more for identification of drought proneness of district/taluk/ tehsil.

Two taluks from each district and district as a whole have been selected for probability analysis of annual rainfall. The analysis has been carried out based on the data available from 1901 to 1987 and probability expressed both in number of years of occurrence and the percentage of years for each group interval. Group interval of 100 mm has been considered for the analysis.

The probability distribution curves have been drawn by plotting the values of percentage of cumulative probability in respect of various groups at their corresponding midpoint. The cumulative percentage have been worked out starting from the maximum rainfall group downwards adding the successive percentage. Probability graphs for two selected taluks in each district have been shown in report of respective state.

3.3.2 Probability of occurrence of rainfall equivalent to 75% of the normal rainfall

For identification of drought proneness of the district/taluk, the percentage probability of occurrence of rainfall equivalent to the 75% of normal rainfall or more has also been worked out. As per IMD criteria, an area would be classified as drought prone if probability of rainfall equivalent to 75% of normal is below 80% indicating that more than 20% of years, the area experienced scarcity of rain. Central Water Commission has carried out analysis and identified drought prone areas on this ground (CWC, 1982). Using this criteria, inferences drawn, regarding the probability of occurrence of 75% normal rainfall in all the 36 districts selected for the analysis, have been given in the state reports.

The taluks of all the districts except the ones as above showed the similar results. As such these taluks alongwith the districts as a whole are drought affected as per IMD criteria.

3.4 Excess/Deficit Rainfall Using Herbst Approach

3.4.1 Model Description

Herbst et al (1966) evolved a new method of drought analysis using monthly rainfall data, whereby it was possible to determine the duration and intensity of droughts and their months of onset and termination.

The model uses the following steps to calculate indices to evaluate onset and termination of droughts.

A. Calculation of mean monthly rainfall, MMR

From the long record of monthly rainfall, the mean rainfall for all the months (i.e. mean monthly rainfall, MMR) is calculated:

$$MMR(J) = \sum_{J=1}^{NYR} \frac{RF(I,J)}{NYR} \quad \ldots(1)$$

Here

MMR = Mean monthly rainfall
Rf = Rainfall
NYR = Number of years of record

Suffix I and J denote years and months respectively.

B. Calculation of mean annual precipitation (MAP)

Mean annual precipitation (MAP) is calculated for entire period of record.

$$MAP = \sum_{J=1}^{NMN} MMR(J) \quad \ldots(2)$$

where NMN = Number of months in a year

C. Calculation of Effective Rainfall

For calculation of drought criteria, the carry over effects from month to month is considered. For this purpose, the mean monthly rainfall for a month, say (J) is subtracted from the actual rainfall for that month (J) so that deficit or excess for that month is obtained. This deficit or excess is multiplied by a 'weighting factor' for the next month (J+1) and the product whether negative or positive, is added algebraically to the rainfall figure of that month (J+1). This sum becomes the 'Effective rainfall' (ER) for that month (J+1).

The 'weighting factor' for a month used to calculate carryover effects is derived from an empirical formula as suggested by Herbst et al (1966).

$$W(J) = 0.1^* \left[1 + \frac{MMR(J)}{1/12^*MAP}\right] \quad \ldots(3)$$

W(J) = weighting factor for j^{th} month

The carry over for j^{th} month and corresponding effective rainfall is calculated as under:

$$CO(I,J) = ER(I,J-1) - MMR(J-1) \quad \ldots(4)$$

$$ER(I,J) = RF(I,J) + CO(I,J)^*W(J) \quad \ldots(5)$$

Here CO = Carry over factor

For the first month of first year of record, the effective rainfall has been assumed as equal to monthly rainfall.

Thus for I = 1 and J = 1,

$$ER(1,1) = RF(1,1) \quad \ldots(6)$$

There upon the effective rainfall for each month of every year was calculated by allowing for the carry over effect of a surplus or deficit of rainfall in the preceding month. The process is continued to obtain the effective monthly rainfall for the full period of record.

D. Calculation of mean annual deficit

The difference of effective rainfall for a month and 'Mean Monthly Rainfall' for that month is obtained for full period of record and termed as 'Difference'.

$$DIFF(I,J) = ER(J,J) - MMR(J) \quad \ldots(7)$$

These 'differences' for various months of the record, if greater than or equal to zero, were reported as zero. Thus the 'Mean Monthly Deficits (MMD)' were based not only on those months in which a negative difference occurred, for positive differences (i.e., negative deficits) were taken as zero and thus also included in the computation. In this way 'Mean Monthly Deficit' for each month of every year was calculated:

$$MD(I,J) = 0.0; \text{ for } DIFF(,J) > 0.0 \quad \ldots(8)$$

$$MD(I,J) = DIFF(I,J); \text{ for } DIFF(I,J) < 0.0 \quad \ldots(9)$$

In this way 'Mean Monthly Deficit' for each month of every year was calculated:

$$MAD(J) = \left[\sum_{J=1}^{NMN} MD(I,J) \right]^* \frac{1}{NYR} \quad \ldots(10)$$

The summation of Mean Monthly Deficits yields

Mean annual deficit (MAD) or,

$$MAD = \sum_{J}^{NMN} MMD(J) \quad \ldots(11)$$

Here

MD = Monthly deficits or monthly differences
MMD = Mean monthly deficit
MAD = Mean annual deficit

Mean annual deficit is used in testing for onset and termination of drought.

The analysis includes establishment of another set of termination drought. This includes maximum parameters used for test of start and termination drought. This includes maximum of Mean Monthly Rainfall (MMR), the sum of two highest values of mean monthly rainfall, the sum of three nighest values of mean monthly

rainfall and so on up to the sum of mean monthly rainfall of all the months yielding a value equal to mean annual rainfall.

E Test to Determine onset of drought

From the given record, a month with a negative difference is found, while inspecting delete negative difference, the following two cases may arise.

Case (A) Delete negative difference ‹ MMMR

Case (B) Delete negative difference › MMMR

Case (A) Delete negative difference ‹ MMMR

If delete negative difference is less than MMMR, the difference of the next month is inspected and if negative is added to the negative difference of the previous month and compared with the second values on the sliding scale, (MMMR + x). If sum of these two delete negative difference exceeds (MMMR + x), the drought is deemed to have started from the previous month. In this manner the absolute value of sum of all negative differences occurring from the first month over a period of a year is tested sequentially against the twelve values of the sliding scale. If at any time the summed value of delete negative difference from the first to the J^{th} ,pmtj exceeds the value MMMR+(J-1)x, drought is deemed to have started from the first month.

Case (B) Delete negative difference › MMMR

In this case when the delete negative difference is greater than or equal to MMMR, the drought is deemed to have stated from this month.

F Tests to determine the termination of drought

Once the start of the drought is found, the program begins to search for a month with a positive difference.

A precondition to be satisfied is that at least one of the two months following the initial month with a positive difference should also have a positive difference. Once this condition is met. then only the initial month is qualified for further testing for termination of drought. Thus for further testing for termination of drought a precondition to be satisfied is that two consecutive months should have positive difference.

Once this condition is met, the following two tests are carried out for testing for termination of drought:

i) In this test the differences are algebrically summed up from the month, the drought started to the month of the termination test. If the sum became positive, the drought is deemed to have terminated otherwise second test is carried out for testing of termination.

ii) The second tests comprises of ten sequential tests. Firstly the actual rainfall values from the first to the third month of testing are mmed up and compared with the sum of three highest values of mean monthly rainfall.

If the sum of actual rainfall is higher the drought is considered to have terminated. If the sum of actual rainfall is not exceeded, then the sum of actual rainfall of first four month is compared with the sum of the four highest values of mean monthly rainfall, and so on should the drought not yet have been terminated, upto a comparison of the sum of the rainfall of the rainfall of the twelve months following and including the month from which the test commenced, with the mean annual rainfall. By this stage either the drought had been terminated, in which case it was deemed to have ended in the month from which the multiple test had been initiated or the drought conditions prevailed over this period and test for the termination recommenced at the first month with a positive difference following that from which the previous unsuccessful test had proceeded.

Once a termination had occurred testing for the start of the next drought began at the first month with a negative difference following the month in which the drought ended.

(G) Evaluation of drought index

Drought intensity is evaluated by dividing the total deficits beyond the monthly mean deficit for the period of drought (D) by the sum of the mean monthly deficits for the same period.

$$\text{Drought Intensity} = \frac{\sum_{J=UDST}^{IDEND} [MMR(J)-ER(J)] - MMD(J)}{\sum_{J=IDST}^{IDEND} [MMD(J)]} \quad \ldots(12)$$

WHERE

IDST = Month of start of drought
IDEND = Month of termination of drought

In above equation if nominator is less than 0.0 (i.e., negative), than nominator is equaled to zero for calculation of drought intensity.

Severity Index: Severity Index is defined as product of drought intensity and drought duration

$$SI = I \times D \quad ..(13)$$

This analysis has been performed for six selected drought prone districts of six selected states of A.P. Karnataka.Gujarat, Rajasthan, Maharashtra and M.P. The analysis for Shahdol district of M.P. state could not be done as the data was not available.

Monthly rainfall data for period 1951-1987 of a selected raingauge stations located at taluk headquarters of each district have been used for analysis. As has been described in earlier section the computational programme using the approach has been developed at the Institute. The analysis has yielded in monthly and overall drought intensity values.

The following inferences can be drawn from the analysis :

1) In Andhra Pradesh,drought spells were observed using Herbst's criteria. It can be observed that all districts except Chittoor fell under drought spells during year 1985-87. The districts of Cuddapah, Kurnool and Anantpur recorded similar spells of drought in intensity and duration during 1984-87. The district of Prakasam had a spell of drought in year 1987 while in the previous year the spell was not extensive. In general, all districts recorded about 12 spells of drought since 1951 till 1987. The duration of drought spells was largest in the last spell of 1984-87 in most districts.

2) In the state of Gujarat, Herbst's analysis has resulted in finding drought spells in all but one districts during years 84-87. The district of Bhavnagar, however, did not have drought spell during 84-87 and the last spell experienced in the district was during 80-83. The pattern of intensity and duration of drought in the districts of Ahmedabad and Amreli was found similar during 84-87. The highest intensity of drought was, however, found in Rajkot district. In general, all districts experienced 6-9 drought spells during the period of 1951-87.

3) In Madhya Pradesh, the analysis was restricted to five districts only due to non-availability of data of Shahdol district. All these five districts have shown over two drought spells, during 1984-87. The district of Sidhi showed maximum number of drought spells and in general 4-5 spells were found in all districts since 1951. The maximum drought intensity was found in case of Khargone district while the longest spell was observed in Betul district during 78-86.

4) In the case of the districts in Maharashtra state, four districts experienced drought spells during years 1984-87. The districts of Satara and Ahmednagar, however, did not record any drought spells during 1984-87 though drought spells were found in these districts from late 70's to early 80's. The maximum intensity of drought was recorded in the case of Satara district and the no. of drought spells varied from 4-11 in these districts during the period 1951-87. The district of Sangli experienced the longest spell of drought during 1983-84. The longest period of drought spell over the entire period was found in case of Ahmednagar district during late 70's and early 80's. The pattern of spells of drought was not matching in various districts.

5) In the state of Karnataka, all districts recorded drought spells during the period 1984 to 1987. The district of Dharwar, however, experienced the longest duration of drought spell while in Bellary the spell duration was shortest amongst all. The intensity of drought was highest in case of Bellary and lowest for the Gulbagra. In general, all the districts experienced 6 to 13 no. of drought spells during the period of 1951-87. Over the entire period, the district of Gulburga experienced longest drought spell from 1962-72 while the shortest duration drought spell was found in case of Bellary district. The pattern of drought spell was found similar in case of Raichur, Dharwar and Belgaum districts. The district of Gulburga experienced minimum no. of drought spells during the period of 1951-87.

6) In the state of Rajasthan the rainfall data analysis using Herbst approach yielded that all the six districts experienced continuous or intermittent drought spells during the period 1984-87. The intensity of drought was found higher in the case of Banswara during the year 1985, but in the subsequent years the spell did not continue in this district. Rest of the five districts experienced continuous

drought spells during 1985-87. The no. of drought spells varied from 7 to 13 during the period 1951-87. The maximum no. of drought spells were experienced in the district of Dungarpur while Ajmer had minimum no. of drought spells. The pattern of drought intensity and duration was found similar in the districts of Udaipur and Dungarpur.

3.5 Dry Spell Analysis:

Agriculture is the worst sufferer of droughts as the ultimate effects of drought results in partial or total crop failure. Out of the various growing stages of crops, some are sensitive to moisture stress known as critical growing stages. Agricultural droughts are the result of occurrence of dry spells specially during critical growth stages of crops. Therefore the analysis of dry spells (› 2 weeks) within monsoon season has significant importance specially for rain fed agriculture in the country. Therefore, an attempt has been made to identify the dry spells of two or more than two weeks duration during monsoon period (4th June to 15th September) by selecting one taluk from each of the 36 districts of six states.

The criteria for selection of dry spell is that the daily rainfall should be less than or equal to 5 mm (as a day is assumed as rainy day if daily rainfall exceeds 5 mm) occurring continuously for at least two weeks (i.e. 14 days) or more. For counting number of spells the start of monsoon season has been assumed from fourth June of (beginning of 23rd standard week) every year. The duration and time of occurrence and number of such dry spells for all the 36 districts have been presented in respective state reports. The number of dry spells have been counted starting from the monsoon season of 1981 to 1987. However, in case of some of the districts, the daily rainfall data for some of the years were not available and so the analysis could not be done.

For statistical analysis, the duration of dry spells were represented as range (in days) and no. of spells falling in that range were counted. The number of spells falling in various ranges of duration of spells were represented as percentage of total no. of spells occurring from 1981-1987 and cummulative percentage was obtained starting from the maximum duration of dry spell group downwards adding successive percentage.The probability curves have been drawn showing range of duration of dry spells on the abscissa and cummulative percentage of no. of spells as ordinates. The plots are shown in figure 3.1. Probability distribution graphs as shown in figure have been used to read the values of duration of dry spells (in days) at 75% probability level and have been given in table 3.7. It can be observed from the table that at 75% probability, the duration of dry spell ranges from 21-28 days for all the taluks selected for dry spells analysis except Mehboobnagar (Mehboobnagar), Dhar (Dhar) and Gopad Banas (Sidhi) where the duration of dry spell was expected at 75% probability ranged from 14-21 days.

This analysis is specially important from the view point of agriculture as it can give some idea about likelihood of dry spells based on which alternate arrangements can be made for providing water during critical growth stages to avoid hazardous effects on crop yields.

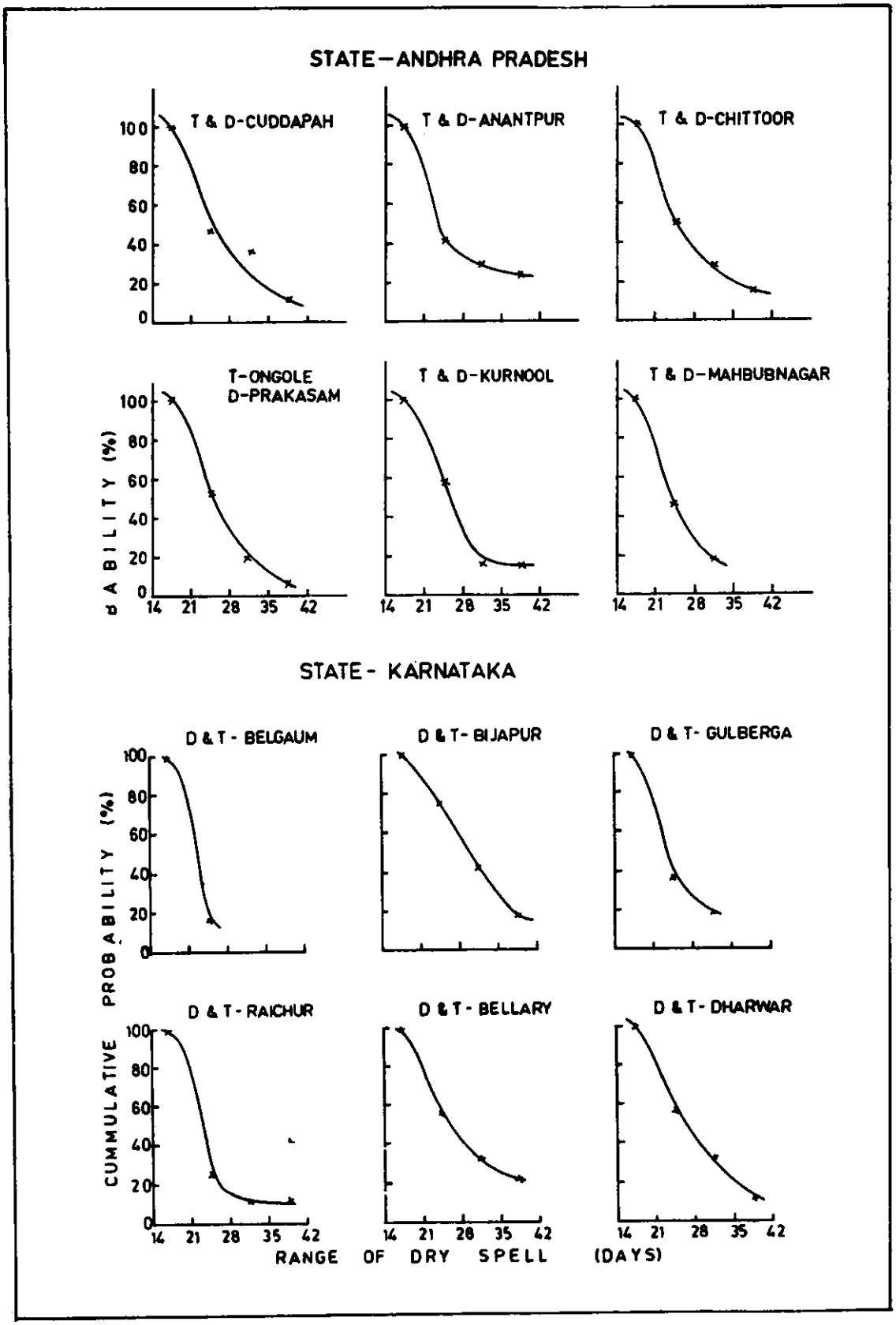


Fig. 3.1 : Probability Distribution of Dry Spells

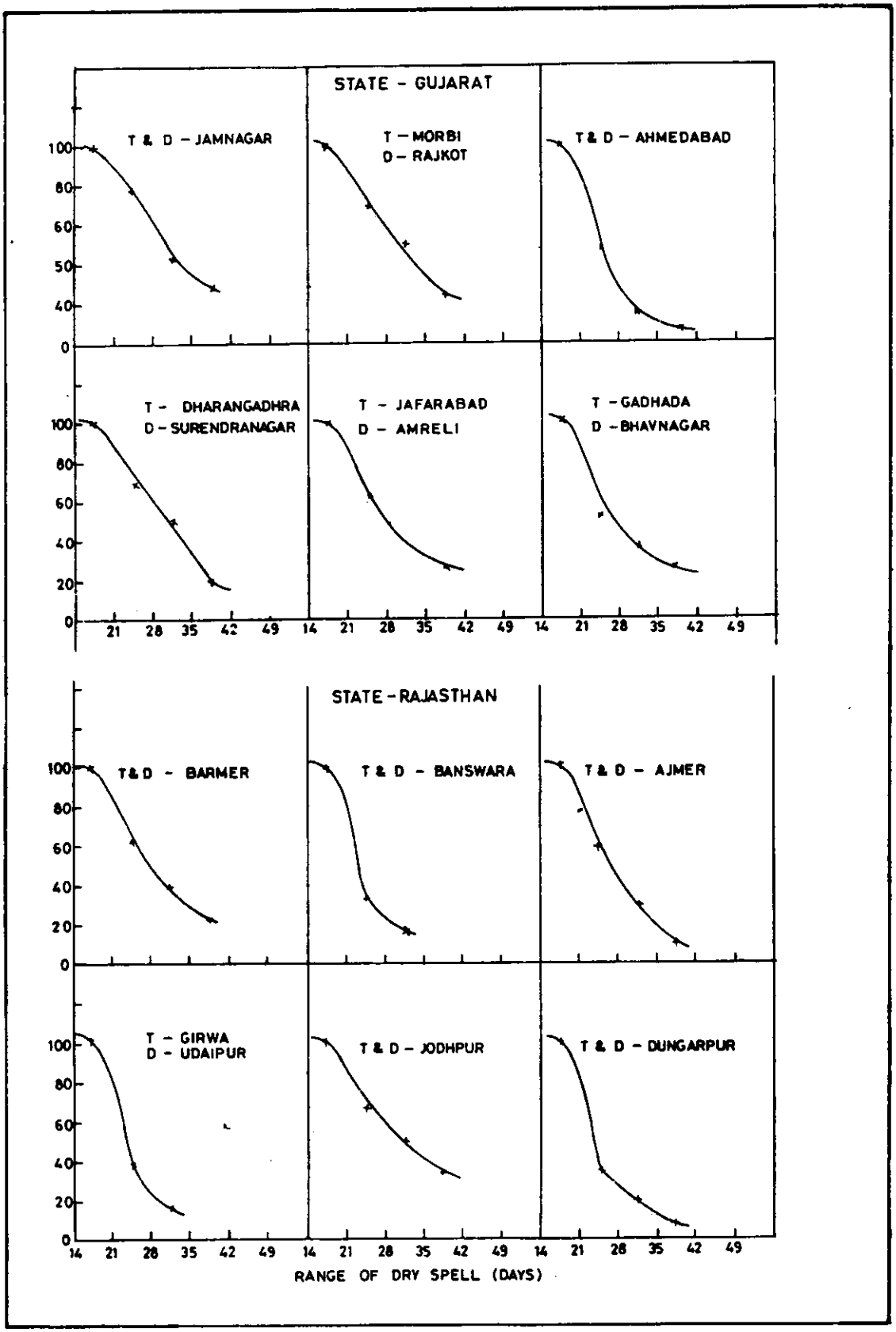


Fig. 3.2: Probability Distribution of Dry Spells

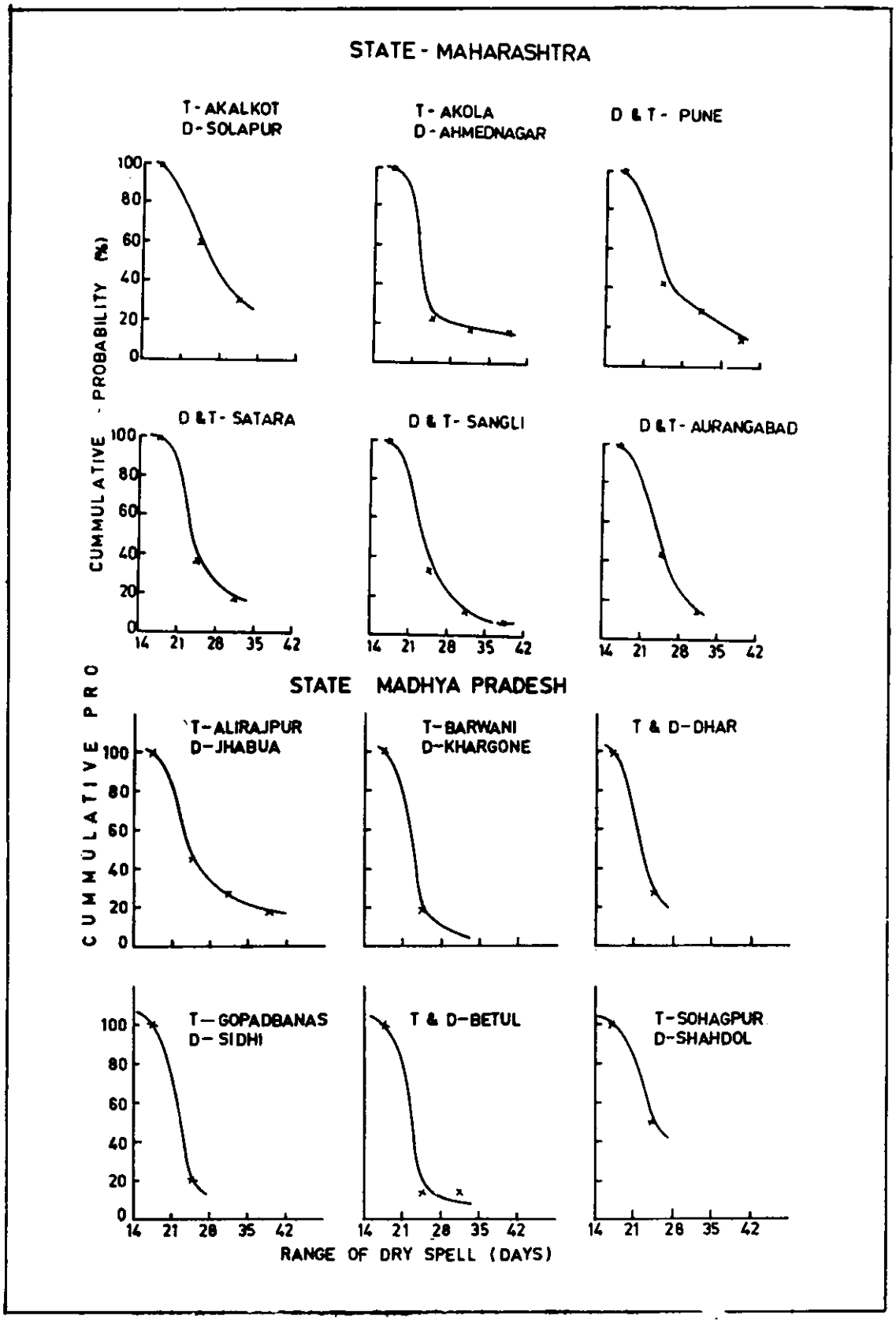


Fig. 3.3 : Probability Distribution of Dry Spells

Table 3.7 : RANGE OF DURATION OF DRY SPELLS FOR 75% PROBABILITY

S.No.	Taluk (Distt.)	State	At 75% Probability, duration of dry spells (in days)
1.	Cuddapah (Cuddapah)	A.P.	21-28
2.	Anantpur (Anantpur)	A.P.	21-28
3.	Chittoor (Chittoor)	A.P.	21-28
4.	Ongole (Prakasam)	A.P.	21-28
5.	Kurnool (Kurnool)	A.P.	21-28
6.	Mehboobnagar (Mehboobnagar)	A.P.	14-21
7.	Alirajpur (Jhabua)	M.P.	21-28
8.	Burwani (Khargone)	M.P.	21-28
9.	Dhar (Dhar)	M.P.	14-21
10.	Gopad Banas (Sidhi)	M.P.	14-21
11.	Betul (Betul)	M.P.	21-28
12.	Suhagpur (Shahdol)	M.P.	21-28
13.	Jamnagar (Jamnagar)	Gujarat	21-28
14.	Marbi (Rajkot)	Gujarat	21-28
15.	Ahmednagar (Ahmednagar)	Gujarat	21-28
16.	Dharangadhra (Surendranagar)	Gujarat	21-28
17.	Jagarabad (Amreli)	Gujarat	21-28
18.	Gadhoda (Bharngar)	Gujarat	21-28
19.	Barmer (Barmer)	Rajasthan	21-28
20.	Banswara (Banswara)	Rajasthan	21-28
21.	Ajmer (Ajmer)	Rajasthan	21-28
22.	Girwa (Udaipur)	Rajasthan	21-28
23.	Jodhpur (Jodhpur)	Rajasthan	21-28
24.	Dungarpur (Dungarpur)	Rajasthan	21-28
25.	Akolkot (Solapur)	Maharashtra	21-28
26.	Akola (Ahmednagar)	Maharashtra	21-28
27.	Pune (Pune)	Maharashtra	21-28
28.	Satara (Satara)	Maharashtra	21-28
29.	Sangli (Sangli)	Maharashtra	21-28
30.	Aurangabad (Aurangabad)	Maharashtra	21-28
31.	Belgaum (Belgaum)	Karnataka	21-28
32.	Bijapur (Bijapur)	-do-	21-28
33.	Gulburga (Gulburga)	-do-	21-28
34.	Raichur (Raichur)	-do-	21-28
35.	Bellary (Bellary)	-do-	21-28
36.	Dharwar (Dharwar)	-do-	21-28

4.0 SURFACE WATER DEFICIT

4.1 General

Estimation of the drought flows in a stream is desired for overall planning and management of water resources and also for navigation purposes. For example, accurate prediction of the rate and duration of low flows is important, to design economically many water supply and waste disposal works,to determine the required capacity of storage reservoirs for the supply of water for various uses under drought conditions and to design economically hydraulic structures in the stream especially for preventing silting of irrigation channels. The low flow analysis is also required for determining dilution requirements for water quality control in natural water courses.

In order to study the effects of drought on streamflow, it is desirable that the hydrologic studies be carried out on river basins for which local singularities are eliminated. General experience indicates that the percentage deficit of rainfall in drought prone area is comparatively low as compared to the percentage deficit in streamflow. The impact of drought on hydrologic regime can be well analysed by studying the effects on streamflow quantity resulting in reduction of reservoir levels, depletion of soil moisture and groundwater regimes. This chapter deals with the analysis of surface water deficit, low flow analysis, maximum drought volume and duration analysis.

4.2 Stream Flow Data

The studies done for 1985-86, 1986-87 were continued with additional data for year 1987-88 for the same sites of Krishna basin except Harallahalli as were chosen for the studies of previous two years. In addition to this, four sites of Godavari basin, namely Ashwi, Chass, Karodi and Saigoan were also chosen for the analysis of streamflow drought for the year 1986-87. Since the flow data for year 1987-88 could not be made available the analysis for Godavari river sites was restricted upto the data of 86-87. The basin maps showing location of sites and details of tributaries of Krishna and Godavari basins are given in Fig.4.1 and 4.2 respectively. The general description of Krishna and Godavari basin is given in following sections :

4.2.1 General description of Krishna basin :

Krishna basin lies between 13°30′to 18°44′N latitude to 73°12′ to 81°36′ 10″ E longitude, covering parts of Maharashtra, Karnataka and Andhra Pradesh state. The climate of basin is characterised by a hot summer and general dryness during the major part of the year except during South-west monsoon. The rainy season generally commences in the month of June and lasts till October or so, with the withdrawal of the monsoon by about the first week of October the day temperature increases slightly. However, the night temperatures decreases steadily with the day after the withdrawal of monsoon. The Krishna basin comes under the influence of south-west monsoon and this season lasts over the basin till the end of September. Rainfall of about 564.88 mm which forms 72.08 percent of the total annual rainfall in the basin is received during the south-west monsoon season. The basin also received some rainfall during north-east monsoon season and estimates indicate that about 17.64% of total annual rainfall over the basin is received during north-east monsoon season. Evapotranspiration losses in the basin vary between 90 mm to 220 mm from winter to summer months.

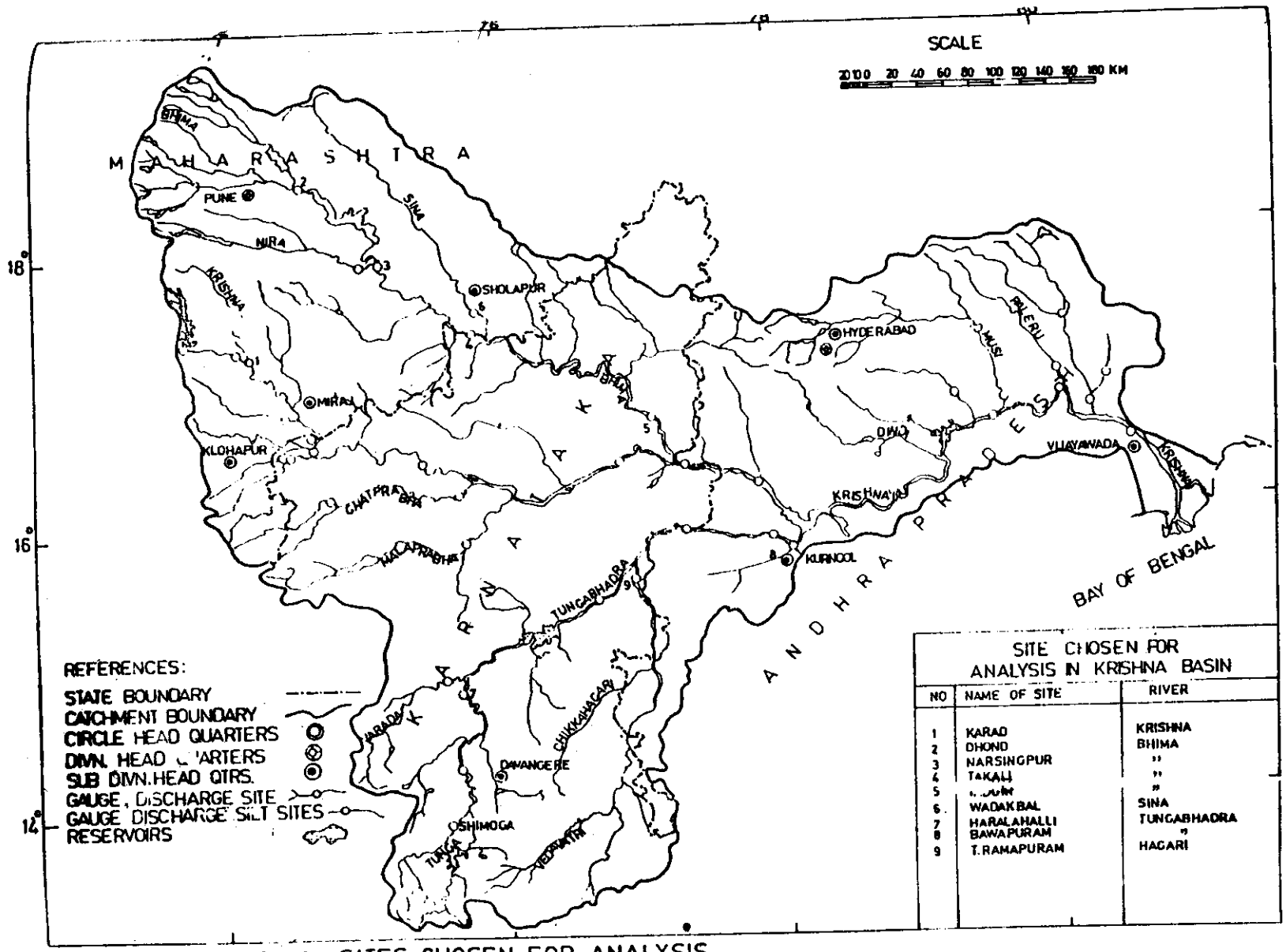


FIG. 4·1 - SITES CHOSEN FOR ANALYSIS

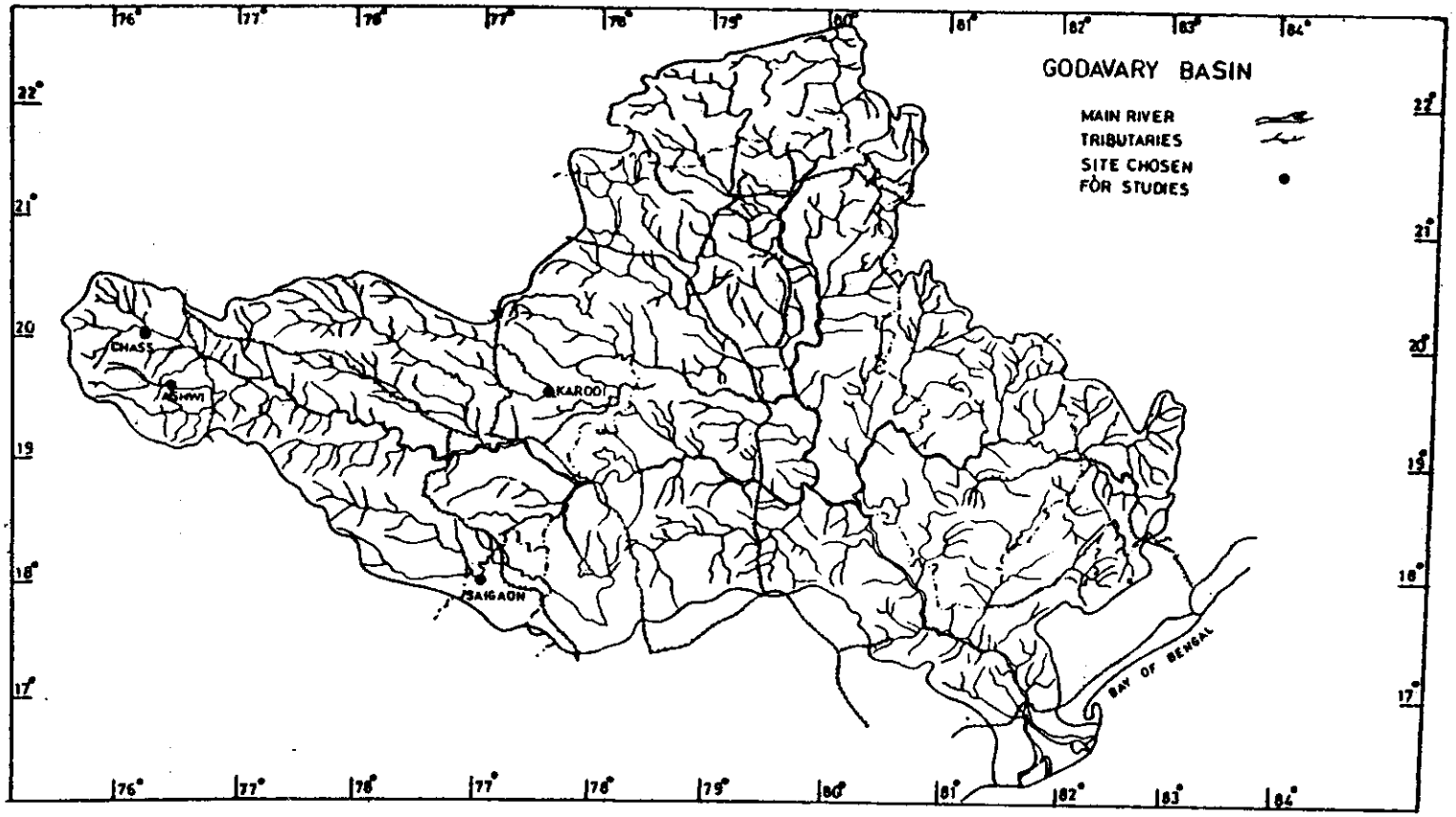


FIG. 4-2 - SITES CHOSEN FOR ANALYSIS

The details of sites chosen for the study are given in Table 4.1

Table 4.1 Details of sites chosen for stream flow studies in **Krishna Basin.**

Sl. No.	Name of Site	Distt.	State	Stream	Catchment area(Km)
1.	Karad	Satara	Maharashtra	Krishna	5,462
2.	Dhond	Poona	-do-	Bhima	11,660
3.	Narsingpur	Sholapur	-do-	-do-	22,865
4.	Takali	-do-	-do-	-do-	33,916
5.	Wadakwal	-do-	-do-	-do-	12,092
6.	Yadgir	Gulburga	Karnataka	-do-	69,863
7.	T.Ramapuram	Bellary	-do-	Tungabhadra	23,500
8.	Bawapuram	Kurnool	Andhra Pradesn	-do-	67,180

4.2.2 General description of Godavari basin

The Godavari basin extends over an area of 312,812 sq.km. which is nearly 10 percent of the total geographical area of the country.The basin lies between east longitude 73°6 and 83°7 and north latitude 16°16 and 22°36, and covers large area in the state of Andhra Pradesh, Madhya Pradesh and Maharashtra, in addition to smaller areas in Karnataka and Orissa. In spite of its large catchment area, the discharge is not very impressive because of moderate nnnual average rainfall in the basin. The basin has 4 distinct seasons, viz.(i) the cold weather; (ii) the hot weather;(iii) the south-west monsoon and (iv) the post-monsoon. The cold weather season in the entire basin, from mid October to mid Feb. is generally pleasant, the western and the north-eastern regions being colder that the rest of the basin. In the hot weather, the heat is unbearable in the entire basin. The south-west monsoon sets in by mid-June and ends by mid-October. During this period, the basin receives about 88% of its total annual rainfall. After south-west monsoon, the weather gradually improves and becomes cool and pleasant. The annual rainfall in the basin varies from 600 mm to 1100 mm. January and February months are almost entirely dry in the Godavari basin, the rainfall during these two months being less than 15 mm. During the next three months, upto end of May, it varies from 50 mm to about 200 mm, in most parts of the basin.

Table 4.2 Details of sites chosen for stream flow studies in Godavari Basin.

Sl. No.	Name of Site	Distt.	State	Stream	Catchment area(Km)
1.	Ashwi	Ahmednagar	Maharashtra	Godavari	1819.90
2.	Chass	-do-	-do-	-do-	5229.95
3.	Karodi	Yeotmal	-do-	Penganga	5160.92
4.	Saigoan	Bidar	Karnataka	Godavari	9958.74

As can be seen from Table 4.1, out of 18 districts selected for studies in the states of Andhra Pradesh, Karnataka and Maharashtra (the states in which part of Krishna and Godavari basin fall) only districts of Satara, Pune, Sholapur in Maharashtra, Gulburga and Bellary in Karnataka and Kurnool in Andhra Pradesh are included in the study of surface water deficit analysis of Krishna Basin. Likewise the district of Ahmadnagar in Maharashtra falling in Godavari basin is the one for which other kinds of analysis have been done.

4.3 Hydrograph Analysis

The magnitude of low flows can be presented in many ways. For water resources engineers and scientists, the hydrograph of river flow gives an immediate feel for the position of water at the site under consideration. Therefore,hydrographic analysis can be used as one of the methods of stream flow deficit analysis. In this analysis hydrographs for mean, minimum and for the years 1985-86, 1986-87 and 1987-88 were compared for the chosen sites of Krishna and Godavari basins.

4.3.1 Hydrographic analysis for Krishna basin.

The monthly flow hydrographs at the sites chosen were plotted for the year of 1985-86, 1986-87 and 1987-88. In order to compare the flows with the dis-continuous values of mean and minimum flows recorded during last 21 years (1967-88), flow hydrographs have been drawn at all eight chosen sites. These are shown in Fig.4.3 through 4.5. The hydrographs illustrate a marked difference between the response of river flows in 1985-86, 1986-87 and 1987-88 and mean flows for chosen sites. All the chosen sites were affected by drought situations in the years 1985-86, 1986-87 and 1987-88. Out of eight sites, the site of T.Ramapuram shows closer runoff volume to mean runoff volume for the year 1987-88, whereas sites of Dhond, Yadgir, Takali, Narsinghpur and Karad show closer runoff volume to their 21 years minimum runoff volume. During the year 1987-88 the runoff volume oft he sites of Wadakwal and Bawapuram is in closer agreement with the previous two years runoff volumes. Another observation from the hydrographs is that the response of hydrographs for all chosen sites is poorest in the year 1987-88 as compared to year 1985-86 and 1986-87 which indicates more severity in streamflow deficiency during 1987-88.

4.3.2 Hydrographic analysis for Godavari basin:

The monthly flow hydrographs for the four sites of Godavari, namely, Ashwi, Chass, Karodi and Saigoan were drawn for the years 1985-86 and 1986-87. These flow hydrographs were compared with the discontinuous values of mean as well as minimum flows observed during 1972-87 for Ashwi and Chass and 1968-87 for Karodi and Saigoan sites (as per data available status) and are shown in Fig.4.6 and 4.7. The hydrographs illustrate a marked difference between the response of river flows in 1985-86 and 1986-87, and mean flows for all the chosen sites. It can be observed that all the sites were affected by drought during 1985-86 and 1986-87. Out of four sites, the sites of Ashwi and Chass show similar patterns of runoff volume for the years 1985-86 and 1986-87 with significant difference as compared to minimum and mean runoff volumes. The site of Saigoan shows that in year '86-87, the actual runoff volume was close to the minimum flows as os last 20 years contrary to years 1985-86. Whereas the runoff volume at site Karodi during 1986-87 was more than runoff volume during 1985-86. From this

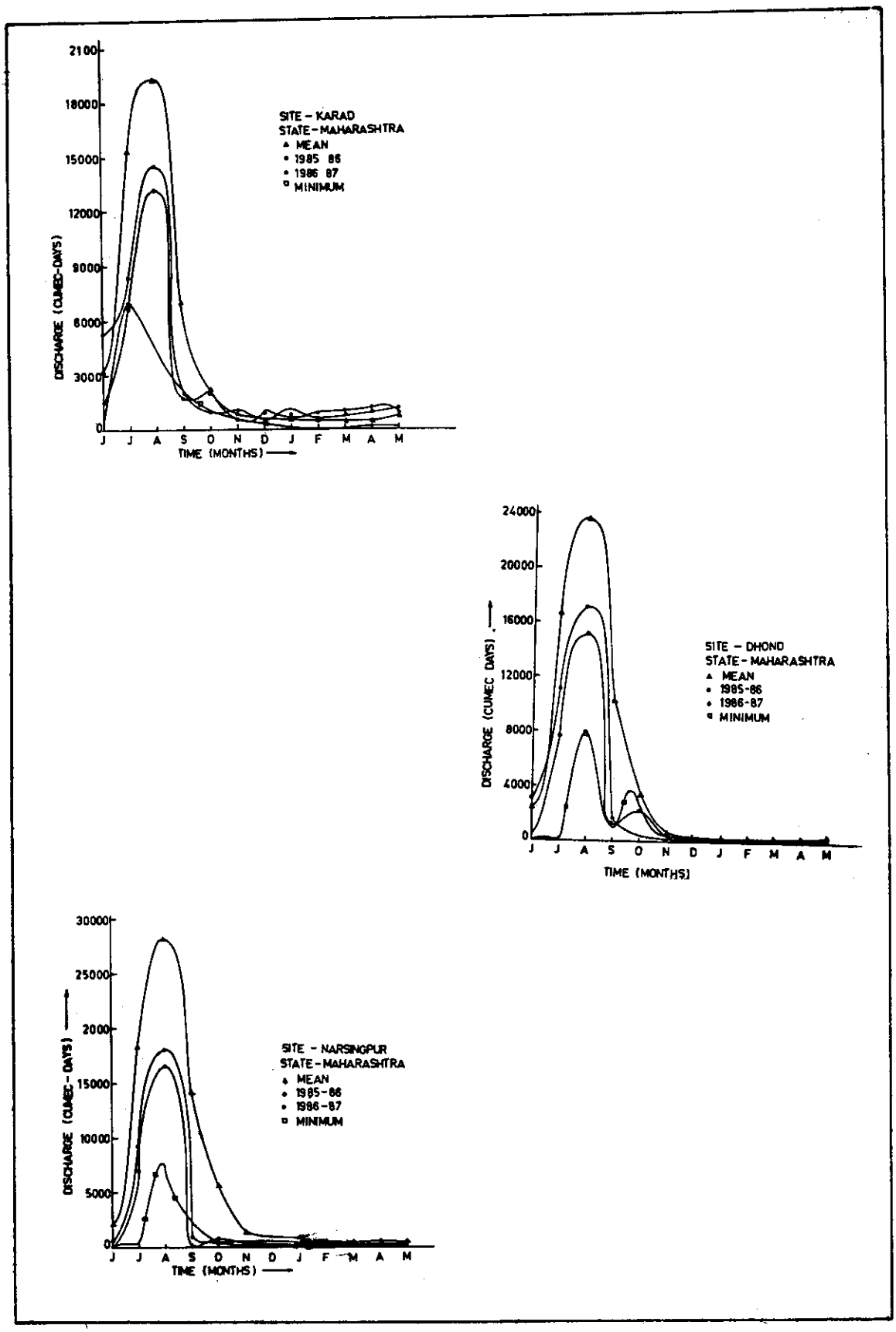


FIG. 4.3 : FLOW HYDROGRAPH FOR KARAD, DHOND AND NARSINGPUR

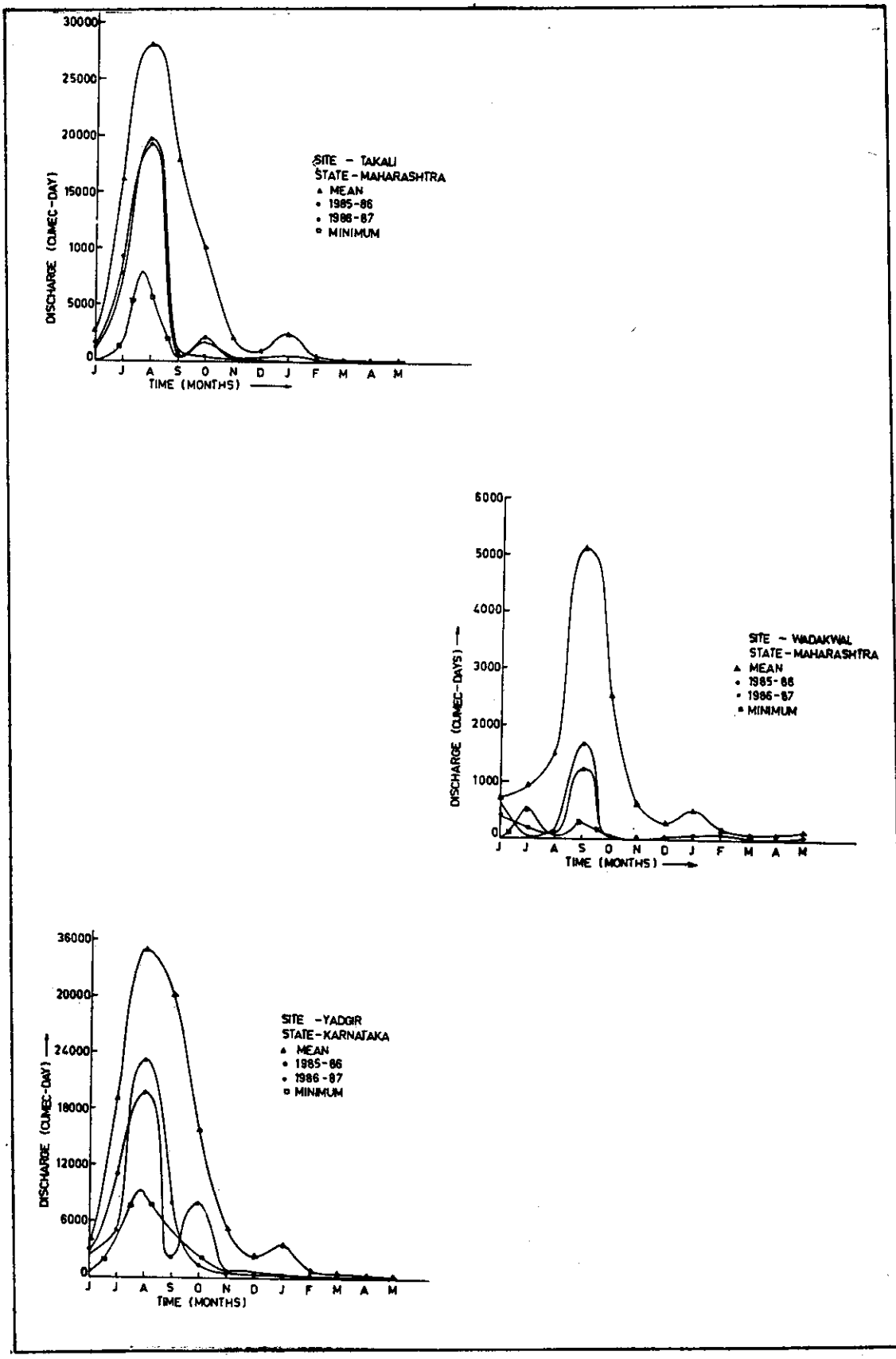


FIG. 4.4 : FLOW HYDROGRAPH FOR TAKALI, WADAKWAL AND YADGIR

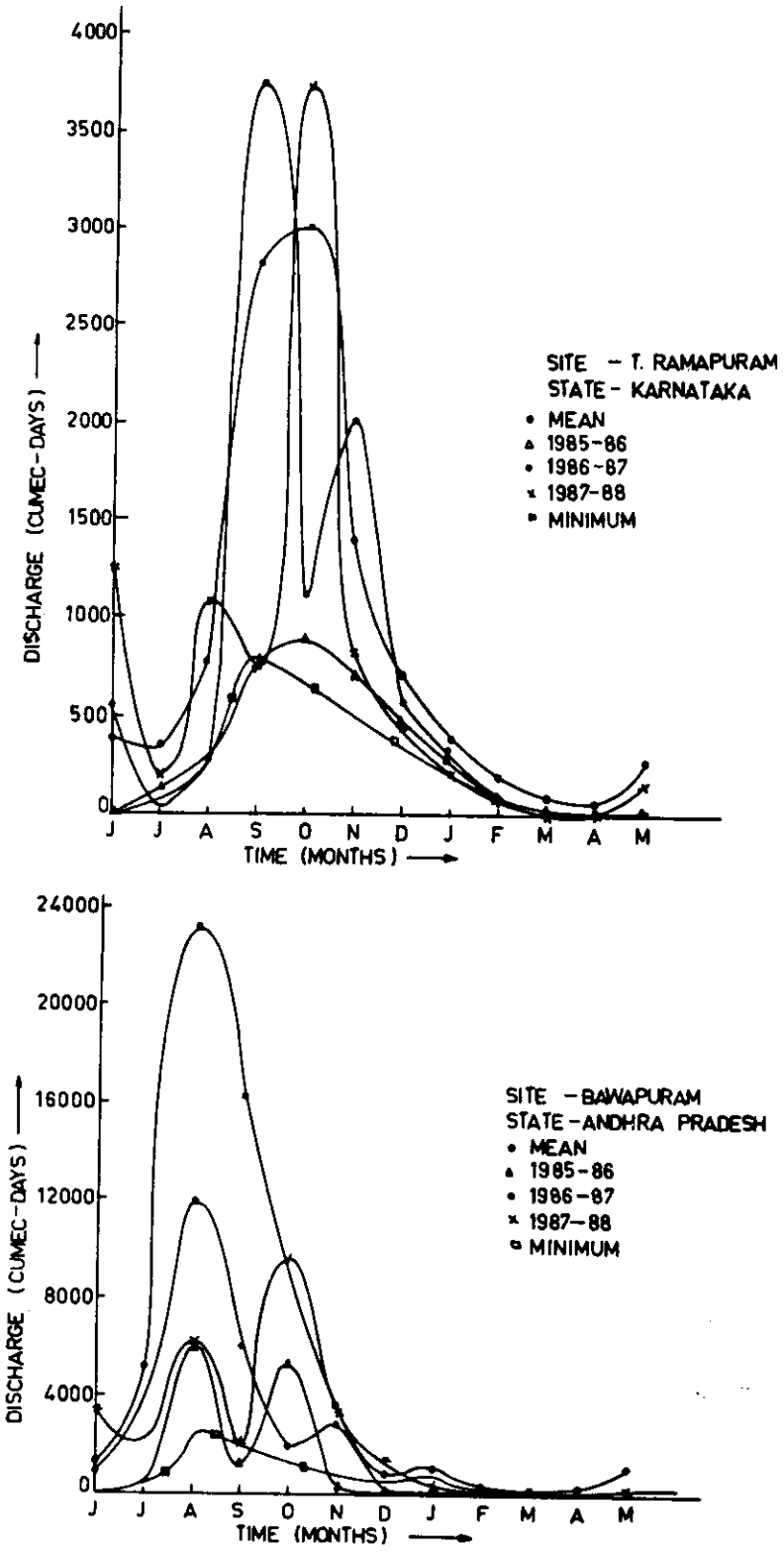
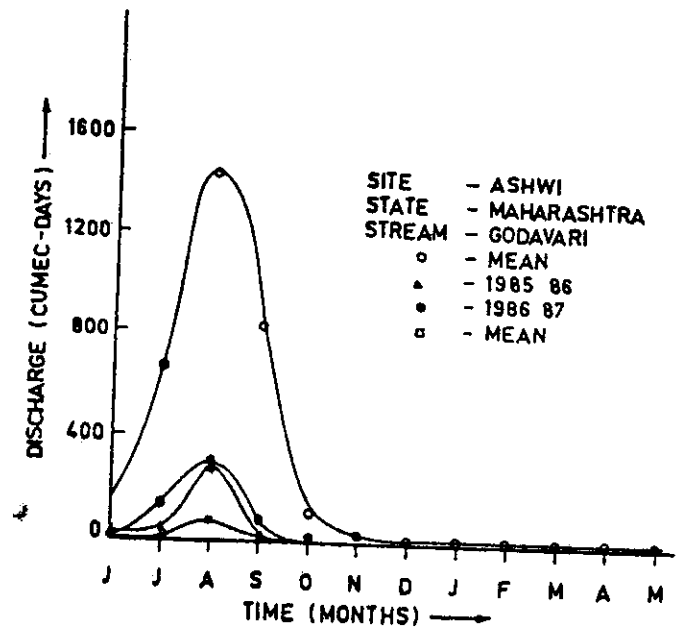


Fig. 4.5 : Flow Hydrograph for T. Ramapuram and Bawapuram



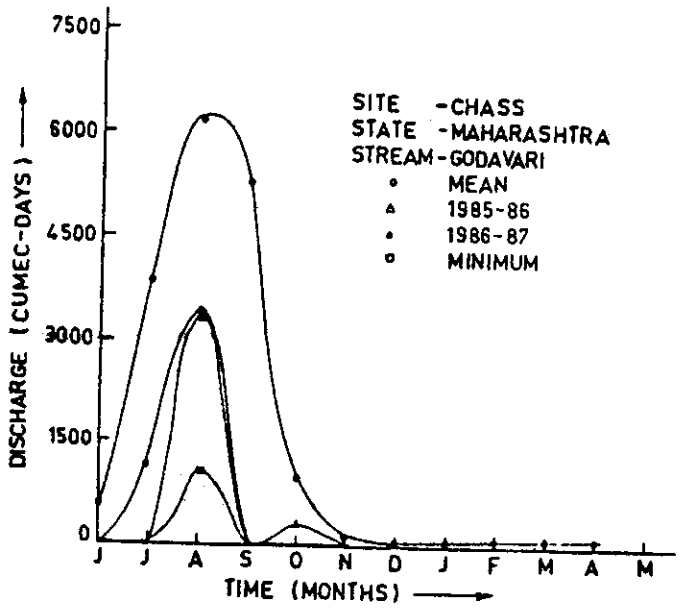
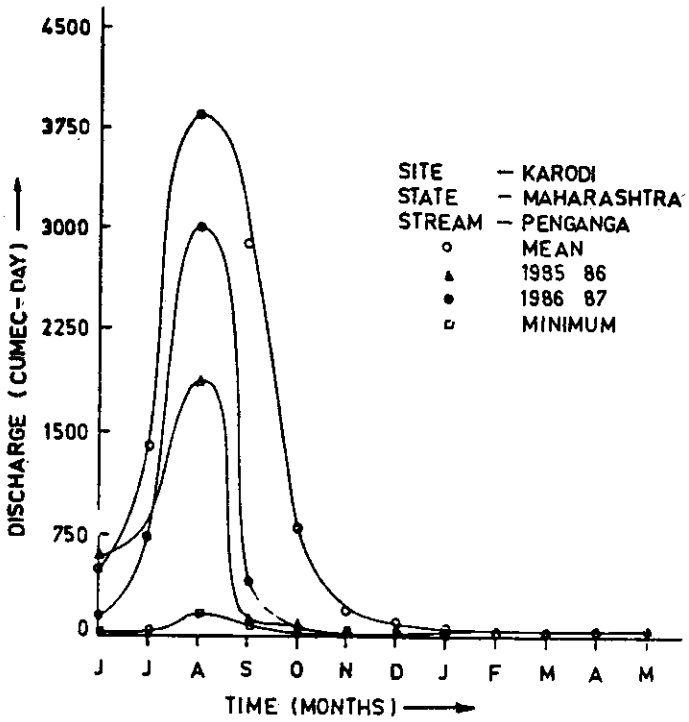


Fig. 4.6 : Flow Hydrograph for Ashwi and Chass



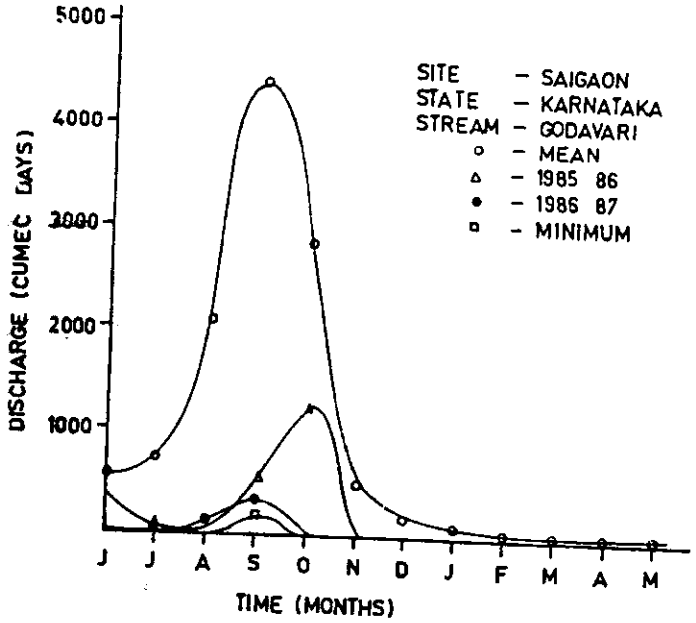


FIG. 4.7 : FLOW HYDROGRAPH FOR KARODI AND SAIGAON

analysis, it can be inferred that the site of Saigoan was the worst affected by drought in the year 1986-87.

4.4 Simple Indices

There are many simple indices those can be used to see immediate effect of drought on streamflow. In the following section some such simple indices namely departure or numerical index and indices based on statistics of observed stream flow data are developed for the selected sites of Krishna and Godavari river basins.

4.4.1 Departure Analysis

A commonly used index to see the effects of drought on streamflow is to compare runoff depth or volume for a given duration i.e. fortnight,month or a year with long term mean or standard period normal value for the same duration. It has been suggested that if the runoff is found to be less than 75% of normal runoff at a site, the year would be considered as drought year and if it occurs in 25 or more than 25% of years, then the area would be considered as drought prone. Drought is classified as severe drought and moderate drought depending upon percentage departure of runoff volumes as given below (CWC,1982):

Percentage departure	50% -	Severe
Percentage departure	25-50%	Moderate

4.4.1a Departure analysis for Krishna basin :

The results of the deviation of annual flows during '87-88 from long term average flow for the chosen sites are given in Table 4.3. As evident from the Table, the annual flows for the year 1985-86 for all chosen sites were deficient by more than 25% of normal flow indicating year 1985-86 as drought year. In the year,1986-87, all sites except Karad and T.Ramapuram showed annual deficiency of more than 25 percent. However, during year 1987-8 again all sites except T.Ramapuram showed annual deficiency of more than 25%. The classification of drought based on above criteria (moderate and severe drought) during years 1985-86, 1986-87 and 1987-88 for all the chosen sites of Krishna basin is given in Table 4.4.

TABLE 4.3: DEVIATION OF ANNUAL FLOWS FROM LONG TERM AVERAGE FLOWS

Sl. No.	Year	% Departure Karad	Dhond	Narsing-pur	Takali	Yadgir	Wadak-wal	Bawpu-ram	T.Rama-puram
1.	1967-68	56.21	-47.31	11.05	34.35	41.84	37.57	-11.65	-48.97
2.	1968-69	-32.06	44.84	-14.41	-19.89	-49.56	-35.20	14.43	22.44
3.	1969-70	58.93	5.72	73.86	47.15	47.15	133.98	23.97	-13.33
4.	1970-71	20.16	35.22	7.18	7.92	7.92	80.98	79.98	17.49
5.	1971-72	- 0.73	38.81	22.74	5.94	5.94	30.11	-17.40	19.44
6.	1972-73	-43.69	52.40	-48.42	-68.41	-68.41	-89.31	-60.29	-32.30
7.	1973-74	14.80	- 6.43	-37.67	38.21	38.21	44.05	7.06	19.03
8.	1974-75	-23.94	36.84	- 1.37	12.74	12.74	24.97	7.15	21.57
9.	1975-76	21.06	70.98	33.02	111.09	111.09	110.87	163.63	173.89
10.	1976-77	59.87	- 2.11	78.16	24.42	24.42	-74.22	-82.70	-54.50
11.	1977-78	5.80	- 5.14	1.20	-16.36	-16.36	-37.67	-36.17	3.30
12.	1978-79	18.84	10.69	1.49	14.68	14.68	-11.83	109.94	22.93
13.	1979-80	9.39	25.49	17.80	23.96	23.96	25.70	-32.00	-13.21
14.	1980-81	25.12	20.75	22.80	-18.22	-18.22	-13.25	60.30	-39.16
15.	1981-82	-12.29	-49.26	30.30	27.19	27.19	-44.55	22.97	70.13
16.	1982-83	-36.38	11.74	-56.03	-58.58	-58.58	-86.45	-10.87	- 3.60
17.	1983-84	-17.89	-11.70	10.88	44.84	44.84	156.62	-14.54	-14.64
18.	1984-85	-18.11	-51.10	-15.36	-26.46	-26.46	-44.15	-29.88	-52.61
19.	1985-86	-34.37	-39.43	-57.27	-62.30	-62.30	-80.09	-77.31	-63.75
20.	1985-87	-21.08	-72.98	-61.01	-64.37	-64.37	-77.31	-61.76	-16.91
21.	1987-88	-49.66		-94.32	-65.73	-65.73	-51.00	-54.84	-17.02

Table 4.4 :Drought classification in nine sites of Krishna basin from 85-87.

Year	Name of site Karad	Dhond	Narsingh-pur	Takali	Yadgir	Wadak-wal	Bawa-puram	T.Rama-puram	Haral-ahalli
1985-86	M	S	S	S	S	S	S	S	M
1986-87	N	M	S	S	S	S	S	N	M
1987-88	S	S	S	S	S	S	S	N	D.N.A.

M- moderate, S-severe, N-normal, D.N.A.-data not available

The discrepancy in the average annual flow volumes of various sites as reported in earlier report (CS-24) and the present one is due to the reason that in these reports long term average flows for all sites were calculated on the basis of data of last 20 and 21 years(1967-87 and 1967-88), respectively while in the report (CS-21) the data from year 1965-66 (or from 1966-67 in some cases) were taken for computing long term average flows. As has been stated earlier that the catchments of some sites fall in the selected districts of analysis in the states of Maharashtra, A.P. and Karnataka. In view of this, the deviations of annual flows from long term flows were compared with the annual rainfall departure of the corresponding district. A summary of comparison is shown in table 4.5.

4.5 : Comparison between Deviation of Annual Flows From Long Term Average Flow and Annual Rainfall Deficit During 1987-88

Name of Site	State	District	% Departure in Stream-flow	% Departure Annual Rainfall
Karad	M.S.	Satara	-49.66	-24.56
Dhond	M.S.	Pune	-72.58	-37.14
Narsinghpur	M.S.	Sholapur	-94.32	- 0.27
Takali	M.S.	Sholapur	-82.62	- 0.27
Yadgir	Karnataka	Gulburga	-65.73	-14.26
Wadakwal	M.S.	Sholapur	-51.00	- 0.27
Bawapuram	A.P.	Kurnool	-54.84	27.27
T.Ramapuram	Karnataka	Bellary	-17.02	20.18

It can be observed from Table 4.5 that in general less deficiency in rainfall has resulted in a more deficient stream flows which is cohesive with the general understanding. Even some cases have been observed where slight positive deviation in rainfall have still yielded less than normal flows. This may be due to two reasons : 1) Annual rainfall values are based on the district as a unit whereas streamflow values are based on basin scale, and only a part of district is covered by the sub-basin. 2) due to occurrence of continuous three year drought conditions in the basin.

4.4.1 b Departure analysis for Godavari basin :

The results of the deviation of annual flows from long term average flow for chosen sites are given in Table 4.6. It can be seen from Table 4.6 that during years 1985-86 and 1986-87 annual flows for all the chosen sites were deficient by more than 50% from the long term average flows. Therefore, all the chosen sites of Godavari basin were affected by severe drought condition during 1985-86 , 1986-87.

For the year 1986-87, the deficiency in the stream flow was recorded as 83.03, 73.76, 52.92 and 95.65 percent for the sites of Ashwi, Chass, Karodi and Saigoan respectively. During the same period, annual rainfall deficiency of Ahmednagar district of Maharashtra was recorded as 23.78 percent in which part of basins of Ashwi and Chass are falling. The annual rainfall values for the districts of Yeotmal in Maharashtra and Bidar in Karnataka were not available for comparison in which Karodi and Saigoan sites of basin fall. During year 1986-87, the site of Saigoan showed the highest negative departure followed by Ashwi, Chass and Karodi. However, in the previous year, the highest departure was recorded at the site of Ashwi followed by Saigoan, Chass and Karodi. Since flow data for year 87-88 could not by obtained, the analysis for the 87-88 drought could not be included at this stage.

4.4.2 Based on statistics of data

Another method to observe effects of drought on streamflow can be by measuring discharge in terms of number of standard deviation below the mean value. Drought has been classified on the basis of statistical parameters,

i.e. mean and standard deviation of the observed stream flow series ( ).Based on this criterion, the severe drought is considered when average annual volume

TABLE 4.6: DEVIATION OF ANNUAL FLOWS FROM LONG TERM AVERAGE FLOWS

S.No.	Year	% Departure Ashwi	Chass	Karodi	Saigoan
1.	1968-69			- 60.81	- 33.88
2.	1969-70			+ 7.04	+ 58.34
3.	1970-71			+ 99.75	+131.26
4.	1971-72			- 65.14	+ 23.62
5.	1972-73	- 86.07	- 46.35	- 63.15	- 89.62
6.	1973-74	+104.97	+ 57.20	+ 45.03	+ 34.10
7.	1974-75	- 66.22	- 76.23	- 66.76	- 28.47
8.	1975-76	- 10.65	- 18.13	+121.86	+137.01
9.	1976-77	+269.53	+172.81	+ 21.52	- 50.64
10.	1977-78	+ 23.04	- 8.80	+ 5.52	- 58.16
11.	1978-79	- 63.20	- 60.27	+19.87	- 29.32
12	1979-80	+ 35.70	- 59.78	+ 50.63	- 32.45
13.	1980-81	+ 72.77	- 10.64	+ 16.22	- 20.46
14.	1981-82	+ 42.59	+ 27.55	- 16.72	- 24.01
15.	1982-83	- 53.99	- 66.93	- 91.67	- 77.12
16.	1983-84	- 40.34	+277.60	+175.29	+318.34
17.	1984-85	- 56.12	- 36.05	- 85.47	- 83.88
18.	1985-86	- 89.22	- 78.19	- 60.08	- 78.96
19.	1986-87	- 83.03	- 73.76	- 52.92	- 95.65

of streamflow during the year under consideration is lower than the mean value of the series by at least one standard deviation. Whereas moderate drought is considered when an annual volume of stream flow is lower than mean volume of the series by 0.6 standard deviation.

4.4.2(a) Drought classification based on statistics of data for Krishna basin.

The average annual stream flow volume for all the chosen sites of Krishna basin along with their statistical parameters i.e. mean, standard deviation, coefficient of variation are given in Table 4.7. Classification of drought conditions as per above criterion of the selected sites of Krishna basin using statistical properties of observed series during 1984-87 is given in Table 4.8. It is evident from the table that in the year 1984-85 only T. Ramapuram site was affected by severe drought conditions. However, in subsequent years by and large all the sites were facing severe drought conditions. For example, in the year 1985-86, all the selected sites of Krishna basin were subjected to severe drought conditions. In 1986-87, the sites of Dhond, Narsinghpur, Takali, Yadgir, Wadakwal were affected by severe drought, whereas the sites of Karad and T Ramapuram experienced normal year and Bawapuram had moderate drought conditions. During the year 1987-88, the sites experiencing severe drought included Karad, Dhond, Narsinghpur, Takali and Yadgir while Wadakwal and Bawapuram showed moderate drought conditions. In case of T.Ramapuram site normal conditions were

Table 4.7 : Annual mean flows in cumec-Days and their statistics for Krishna basin

Year	Karad	Dhond	Narsingpur	Takali	Yadgir	Wadakwal	Bawapuram	T.Remapuram
1967-68	6612.76		6419.36	8689.80	14326.88	1386.02	4816.52	446.80
1968-69	2875.95	2485.17	4947.14	5180.51	8124.27	652.80	6239.08	1072.18
1969-70	6782.00	6832.03	10050.40	9907.81	14863.61	2357.28	6758.89	758.90
1970-71	5086.95	4987.12	6195.60	6835.47	10901.58	1823.36	9812.51	1028.85
1971-72	4201.94	6378.27	7095.13	7797.92	10701.49	1310.85	4502.84	1045.94
1972-73	2383.60	2886.15	2981.36	2637.92	3189.89	107.60	2164.84	592.75
1973-74	4859.69	7188.81	7958.42	8595.97	13960.25	1451.28	5837.18	1042.30
1974-75	3219.64	4413.30	5701.18	7365.12	11388.00	1259.07	5841.76	1064.52
1975-76	5124.94	6455.03	7689.31	10763.71	21322.52	2124.51	14373.35	2396.55
1976-77	6767.71	8265.30	10298.60	10805.16	12568.06	259.65	942.82	398.34
1977-78	4478.84	4617.09	5849.99	5447.42	8448.04	627.91	3479.66	904.59
1978-79	5030.96	4474.14	5866.84	6029.99	11584.11	838.28	11445.81	1076.46
1979-80	4630.87	5221.51	6809.59	8800.77	12521.25	1266.47	3707.25	759.90
1980-81	5296.90	5919.33	7098.59	6482.65	8259.64	873.96	8739.85	532.72
1981-82	3712.64	5705.20	7531.99	8885.67	12847.64	560.56	6704.41	1489.80
1982-83	2693.03	2817.88	2541.20	2543.08	4183.21	136.50	4859.28	844.10
1983-84	3475.45	5270.95	6409.77	7231.52	14630.41	2585.39	4658.76	747.44
1984-85	3466.31	4164.99	4892.25	5226.45	7427.75	562.64	3822.65	414.89
1985-86	2778.14	2306,55	2469.81	2724.20	3807.01	200.49	1236.77	317.40
1986-87	3340.68	2856.80	2253.68	2743.61	3598.21	228.51	2084.46	727.50
1987-88	2130.55	1293.31	328.31	1124.06	3460.67	493.65	2461.79	726.57
Mean	4233.13	4716.94	5780.40	6467.56	10100.69	1007.46	5451.92	875.64
S.D.	1407.91	1835.74	2535.31	2864.36	4754.35	746.22	3395.57	453.20
C.V.	0.33	0.38	0.43	0.44	0.47	0.74	0.62	0.51

observed. It can also be observed from the Table 4.7 that during year 1987-88 about five sites experienced flows which were deficient by more than 1.5 times thestandard deviation of long term flow values which was not the case in earlier years. Therefore, year 1987-88 experienced a rather severe drought than during earlier years. However, in general it can be concluded that during three consecutive year (85-87) most of the selected sites were subjected drought conditions. The results of drought classification based on the criteria as discussed in the present section are coherent with the results of departure analysis except one or two cases as presented earlier.

4.4.2(b) Drought classification based on statistics of data for Godavari basin.

The statistical parameters, i.e.mean, standard deviation coefficient of variation and observed average stream flow series for the chosen sites of Godavari basin are given in Table 4.9. The classification of drought using above criterion for the selected sites of Godavari basin is given in Table 4.10. It can be seen from the table that during year 1984-85 only Saigoan site was affected by severe drought while the other sites showed normal or moderate drought conditions. In the following two years (1985-86 and 1986-87) all the selected sites experienced moderate drought conditions as per this criteria. These results are not quite coherent with the results of departure analysis as presented earlier for Godavari basin. This may be due to fact that the average annual stream flow series of various sites of Godavari basin shows a high value of coefficient of variation (Cv) and in such cases only when the flow go down to nil, the conditions will become severe drought conditions which may not be the case in the present analysis. This has been demonstrated by Zvi (1987). It can be seen that for Krishna basin the Cv lies in the range of 0.33 to 0.74 while for Godavari it has a range of 0.74 to 1.26.Therefore,a range of Cv may need to be established for using this criterion for drought classification.

Table 4.8 : Classification of Drought based on statistics of data for Krishna.

Year	Karad	Dhond	Narsingh-pur	Takali	Yadgir	Wadakwal	Bawa-puram	T.Rama-puram
1984-85	N	N	N	N	N	N	N	S
1985-86	S	S	S	S	S	S	S	S
1986-87	N	S	S	S	S	S	M	N
1987-88	S	S	S	S	S	M	M	N

N- Normal water year, S-Severe drought, M-Moderate drought

Table 4.9 Annnual average flows of Godavari basin in cumec-days and their statistics.

Year	Ashwi	Chass	Karodi	Saigoan
1968-69			321.07	627.14
1969-70			876.96	2502.09
1970-71			1636.53	2193.80
1971-72			285.53	1172.73
1972-73	37.72	796.94	301.85	98.37
1973-74	555.32	2335.16	1188.27	1272.14
1974-75	91.49	353.02	272.29	678.46
1975-76	242.06	1216.00	1817.71	2248.32
1976-77	1001.142	4052.56	995.60	468.14
1977-78	333.35	1354.67	864.56	396.83
1978-79	99.67	590.17	982.09	670.38
1979-80	367.65	597.31	1234.11	640.69
1980-81	468.62	1327.36	952.17	754.43
1981-82	386.32	1892.80	682.26	720.83
1982-83	124.64	491.33	68.17	216.96
1983-84	161.62	5609.25	2255.42	3968.40
1984-85	118.87	949.87	118.96	152.83
1985-86	29.20	323.96	326.99	199.52
1986-87	45.97	389.69	385.67	41.23
Σ x	4063.64	22282.15	15566.21	18023.34
Mean	270.90	1485.47	819.27	948.59
S.D.	262.13	1506.46	611.00	973.80
Cv	0.96	1.01	0.74	1.26

Table 4.10 Classification of Drought based on statistics of **data for Godavari**

Year	Ashwi	Chass	Karodi	Saigon
1984-85	N	N	M	S
1985-86	M	M	M	M
1986-87	M	M	M	M

Normal water year, S- Severe drought, M- Moderate drought

Low Flow Analysis

In low flow analysis it is important to consider magnitude and duration of low flow as well as the frequency of occurrence of low flow. The magnitude of low flow is the quantity of water through a given section of a stream for a specified period of time. It determines the amount of water available for use. The duration depends on natural conditions as well as man made effects and may reflect some specified water use practices. The duration also depends on period of water deficits tolerable to the user or

some other requirements. The probability of being equaled or exceeded of particular magnitude in any given year is called as frequency of flow flow. Many techniques for low flow analysis have been developed over years for investigating different aspects of low flow regime. The low flow analysis included in the present section covers flow duration curves, frequency analysis of low flow spells, annual maximum low flow spell analysis and drought intensity.

4.5.1 Flow duration curve

Flow duration curves show the relationship between any given discharge and the percentage of time that the discharge is exceeded. The low flow data are normally specified in terms of the magnitude of low flow for a given time interval within a year or a season. The curve is a very simple, but useful device for illustrating the flow characteristics of a stream throughout the range of discharge, without regard to the sequence of occurrence.

4.5.1(a) Flow duration curve for Krishna basin

The flow duration curve were developed for 10, 30, 90 and 360 days period for all the selected sites of Krishna basin using 21 years daily flow data and are shown in Fig.4.8 through 4.11. These flow duration curves are used to define low flow index (LFI) as the 10 days average flow which is exceeded 95% of time of the duration of series, or

Low Flow Index (LFI) = $(Q_{10})_{95}$

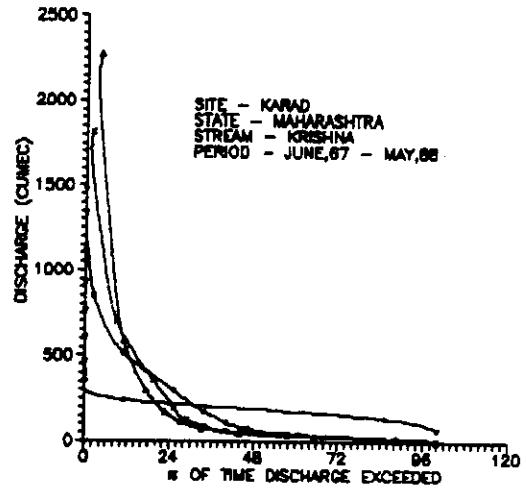
The low flow index values for all the chosen sites of Krishna basin are given in Table 4.11. These values of LFI can be used for estimating the water availability for planning strategies in drought conditions.

Table 4.11 Low Flow Index for Krishna basin :

Sl. No.	Site	Period of analysis	L.F.I. ($10^{-4}m^3/km^2$)
1.	Karad	1967-87	1.170
2.	Dhond	1968-88	1.539
3.	Narsinghpur	1967-88	1.275
4.	Takali	-do-	0.239
5.	Wadakwal	-do-	0.275
6.	Yadgir	-do-	0.293
7.	T.Ramapuram	-do-	0.598
8.	Bawapuram	-do-	0.819

4.5.1.(b) Flow duration curve for Godavari basin :

The flow duration curve for 10, 30, 90 and 360 days period for all the chosen sites using daily flow data have been constructed and shown in fig.4.12, and 4.13. The low flow index values are defined in earlier section were determined for all the selected



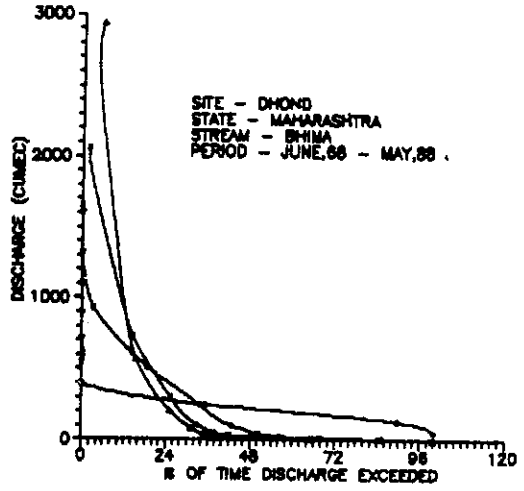
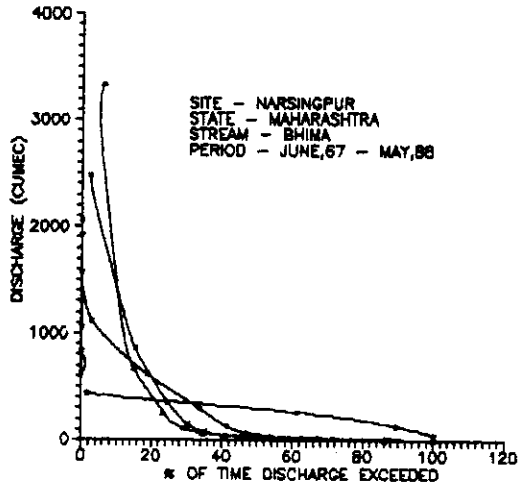


Fig. 4.8: Flow Duration Curves for Karad and Dhond



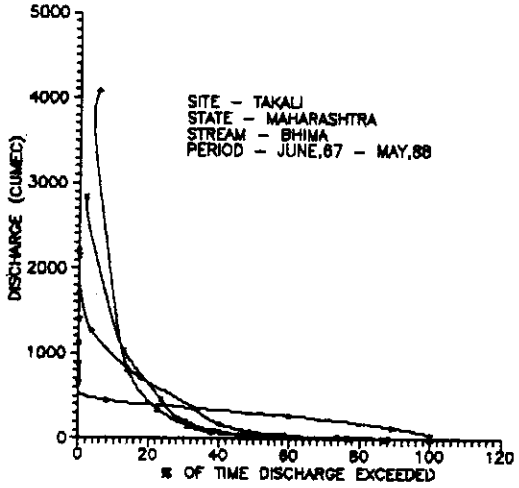
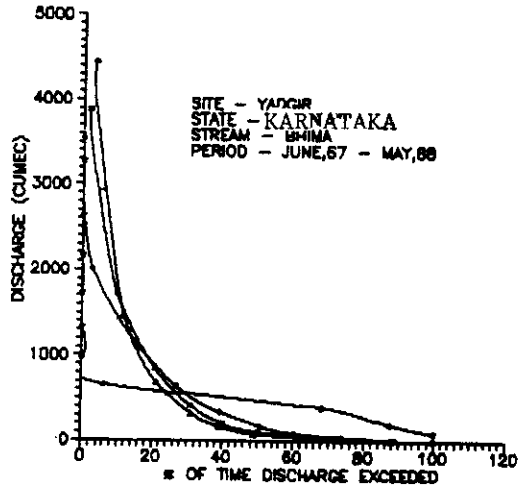


Fig. 4.9 : Flow Duration Curves for Narsingpur and Takali



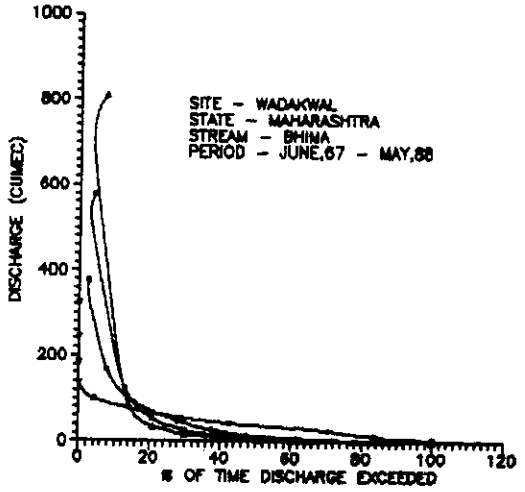
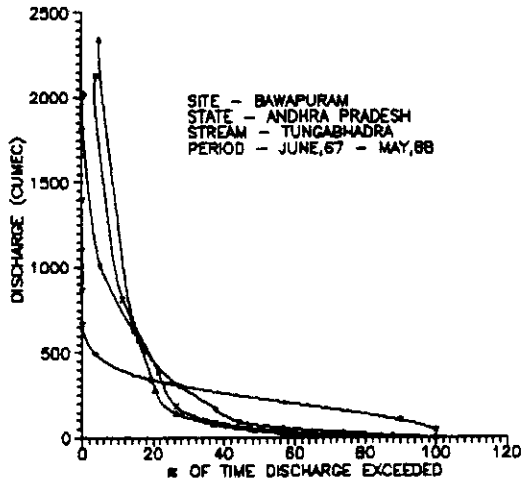


Fig. 4.10 : Flow Duration Curves for Wadakwal and Yadgir



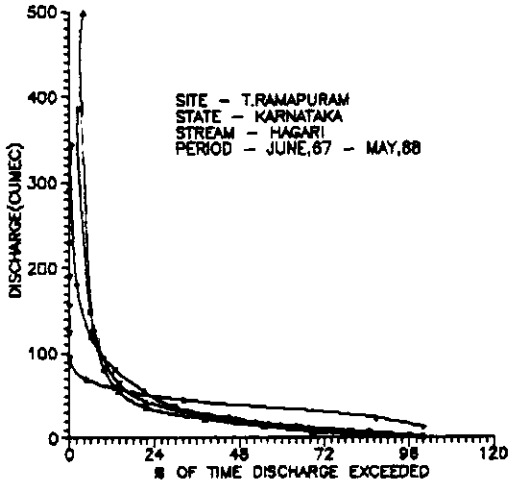
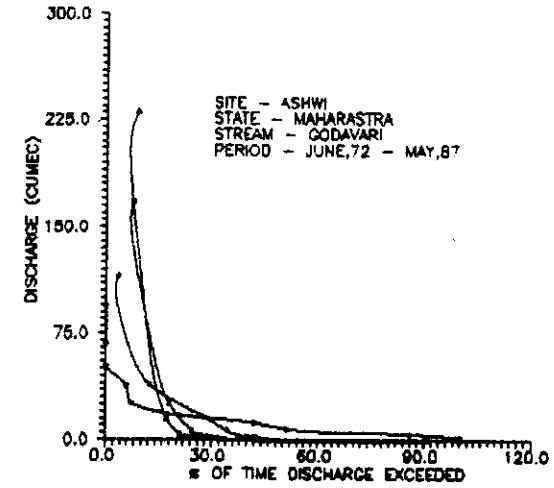


Fig. 4.11 : Flow Duration Curves for T. Ramapuram and Bawapuram



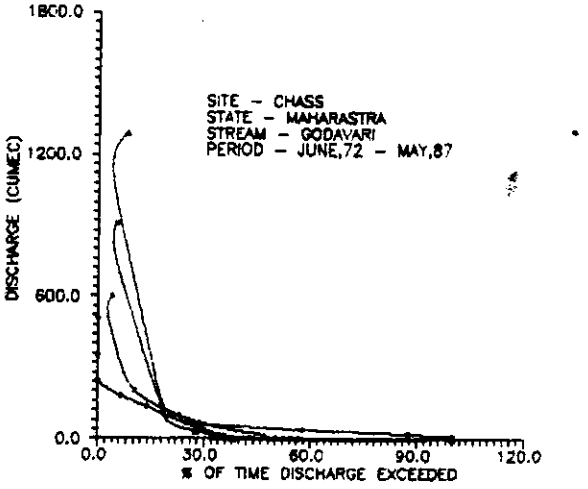
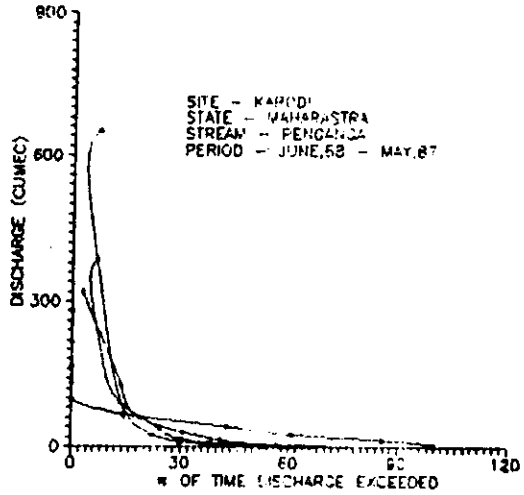


Fig. 4.12 : Flow Duration Curves for Ashwi & Chass



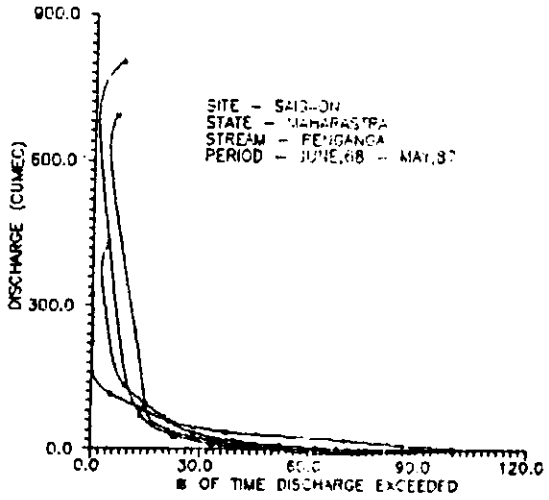


Fig.4.13:

Flow Duration Curves for Karodi & Saigoan

sites and are given in Table 4.12 alongwith period of analysis.

Table 4.12 Low flow index for Godavari basin :

Sl. No.	Site	Period of analysis	L.F.I. ($10^{-4}m^3/km^2$)
1.	Ashwi	1972-87	3.022
2.	Chass	1972-87	1.147
3.	Karodi	1968-87	1.065
4.	Saigoan	1968-87	0.552

4.5.2 Analysis of low flow spells

While the flow duration curve gives the duration below any specified flow, it provides no information about the length of consecutive periods below this flow, or how large a deficit has been built up. Two streams with similar flow duration curves may exhibit very different low flow sequences, for instance a sluggish stream may spend the time below the 20% flow duration values in a few long spells whereas a responsive stream may divide the time into many short spells below the same threshold. Therefore, it may be required to carry out frequency analysis of deficit duration and deficit volumes corresponding to a selected threshold level. The frequency of spell durations and deficiency volume can be expressed in two ways : {(Institute of Hydrology (1980)}:

i) Frequency per 100 years of an event

ii) Proportion of years in which a deficit duration or volume is expressed

4.5.2.1 Analysis for frequency of spell duration and frequency of deficiency volume

In the drought report of 1985-86 (CS-21) the procedure of analysis for frequency of spell duration and deficiency volume has already been described. Analysis for frequency of spell duration and deficiency volume have been carried out on annual basis for all the chosen sites of Krishna basin. The daily flow data have been used to compute long term average daily flow (ADF) at a particular site. Different spells of deficit volume and corresponding duration were computed by considering various demand levels as 10%, 30%, 50%, 70%, and 90% of the computed average daily flow (ADF). Using these results, various frequency curves for deficit volume and deficit duration were plotted and are shown in Fig.4.14 through 4.17 and Fig. 4.18 to 4.21 for frequency of deficit volume and frequency of deficit duration, respectively. These curves show the frequency of deficiency volume and also frequency of deficiency duration per 100 years at different demand levels.

Similar analysis for frequency of spell duration and frequency of deficiency volume per 100 years have also been carried out for all the chosen sites of Godavari basin by taking into consideration various demand levels as 10%, 30%, 50%, 70% and 90% of the average daily flow (ADF). Frequency curves for the selected sites are shown in Fig.4.22 and 4.23 and Fig. 4.24 and 4.25 for deficit volume and deficit duration respectively.

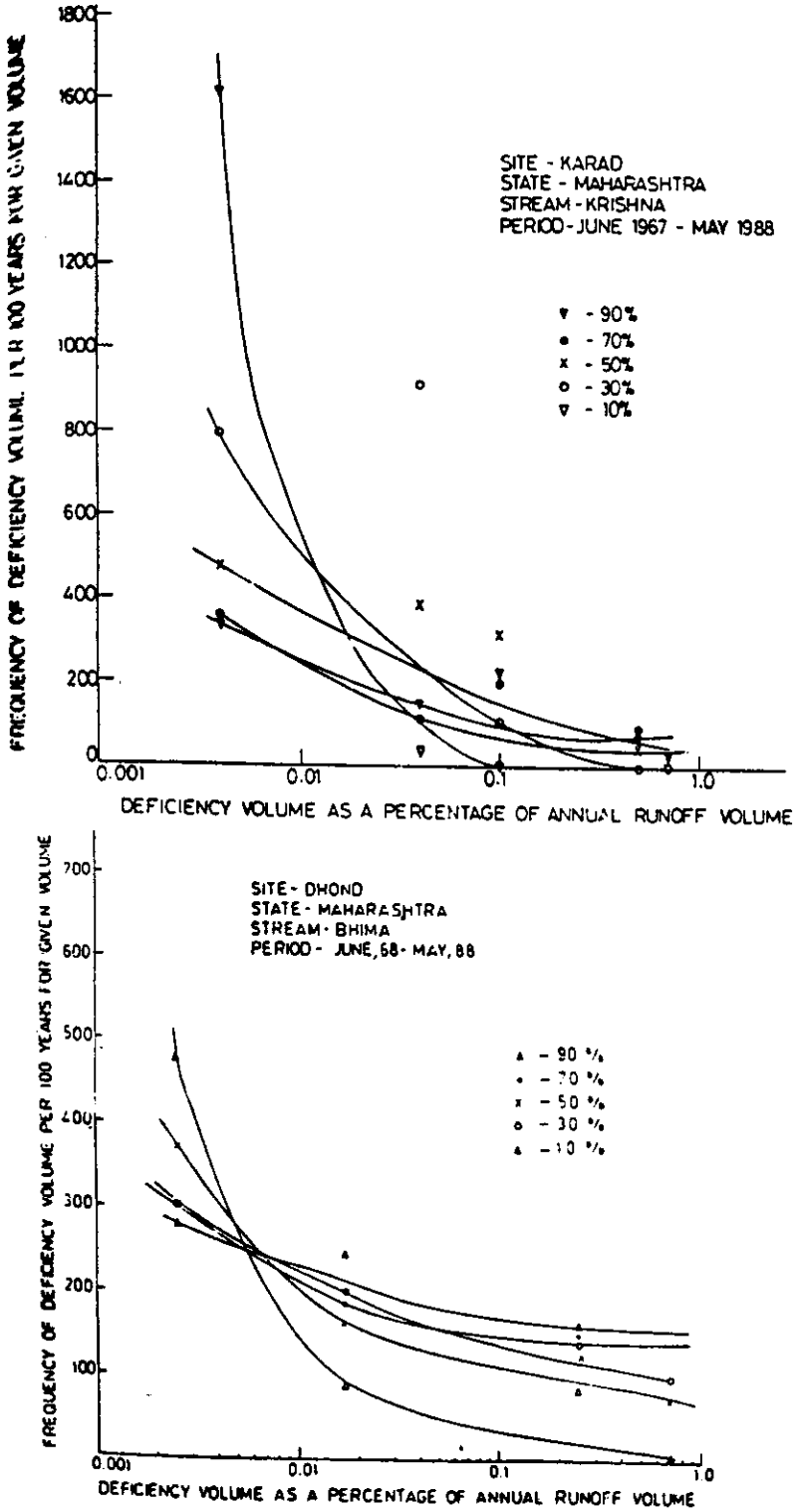


Fig.4.14 : Frequency of Deficiency Volume for Karad & Dhond

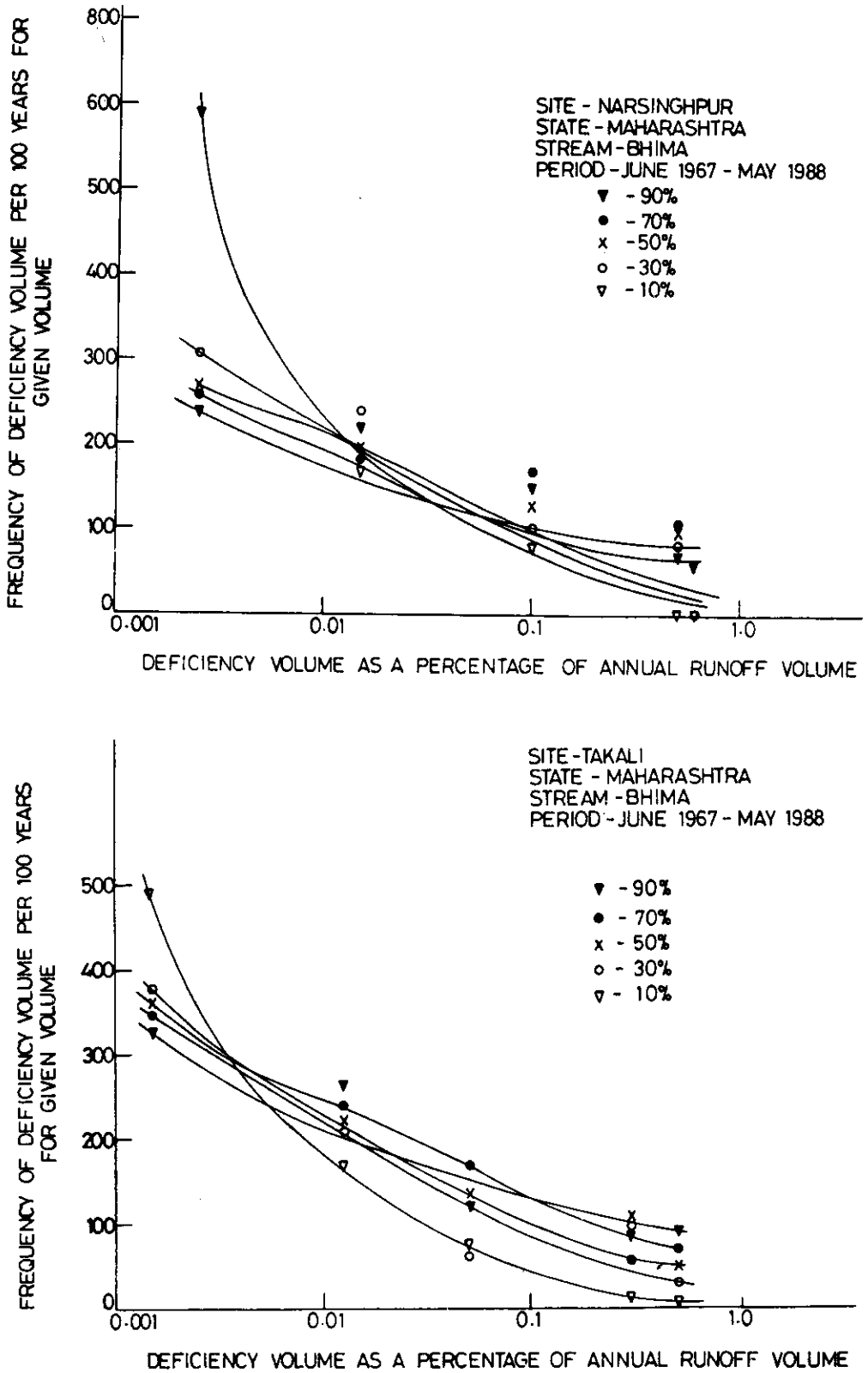
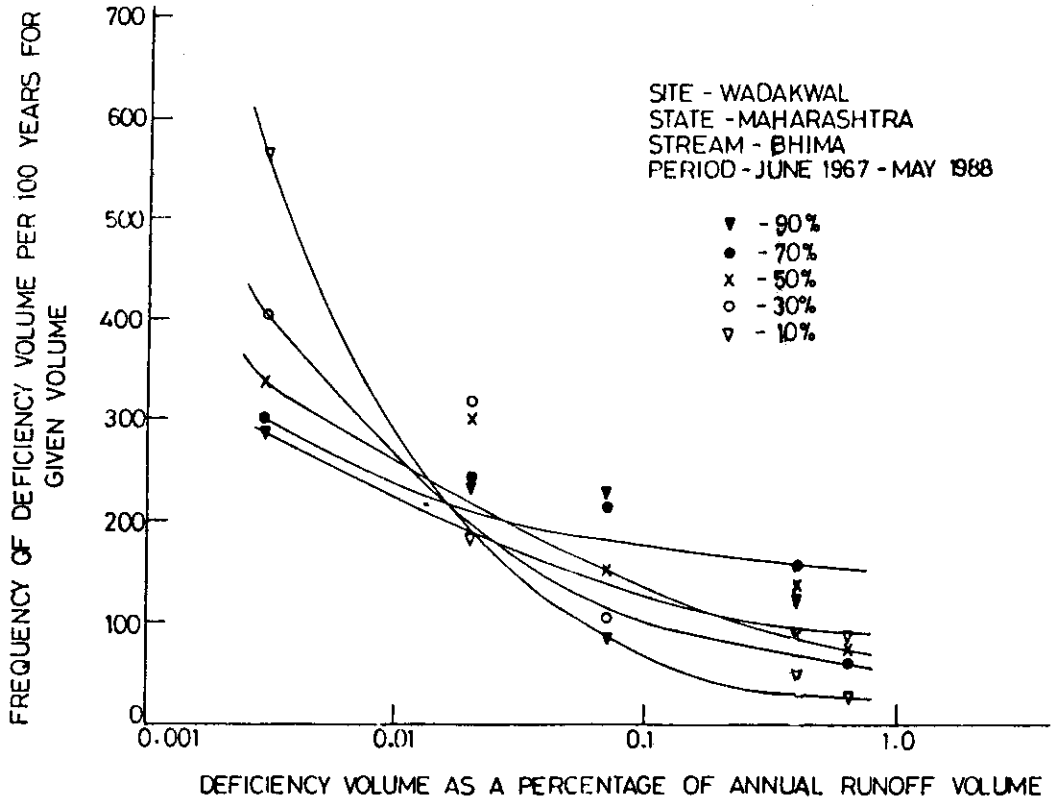


Fig. 4.15 : Frequency of Deficiency Volume for Narsingpur & Takali



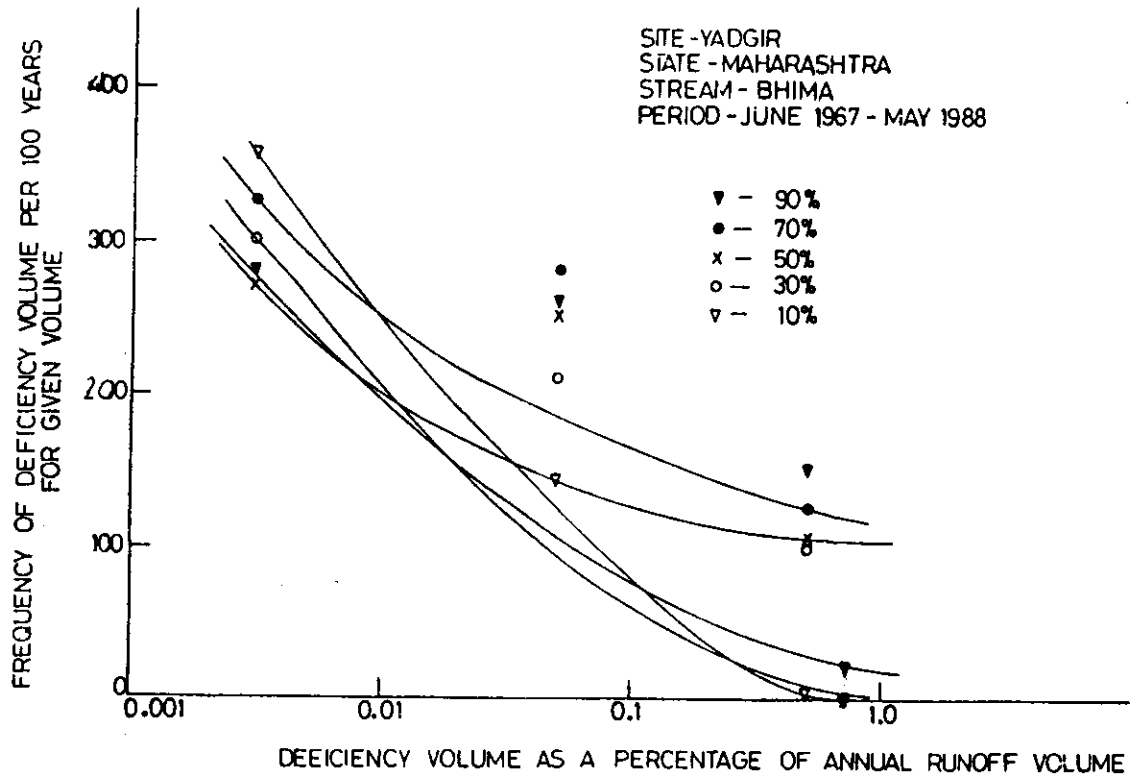
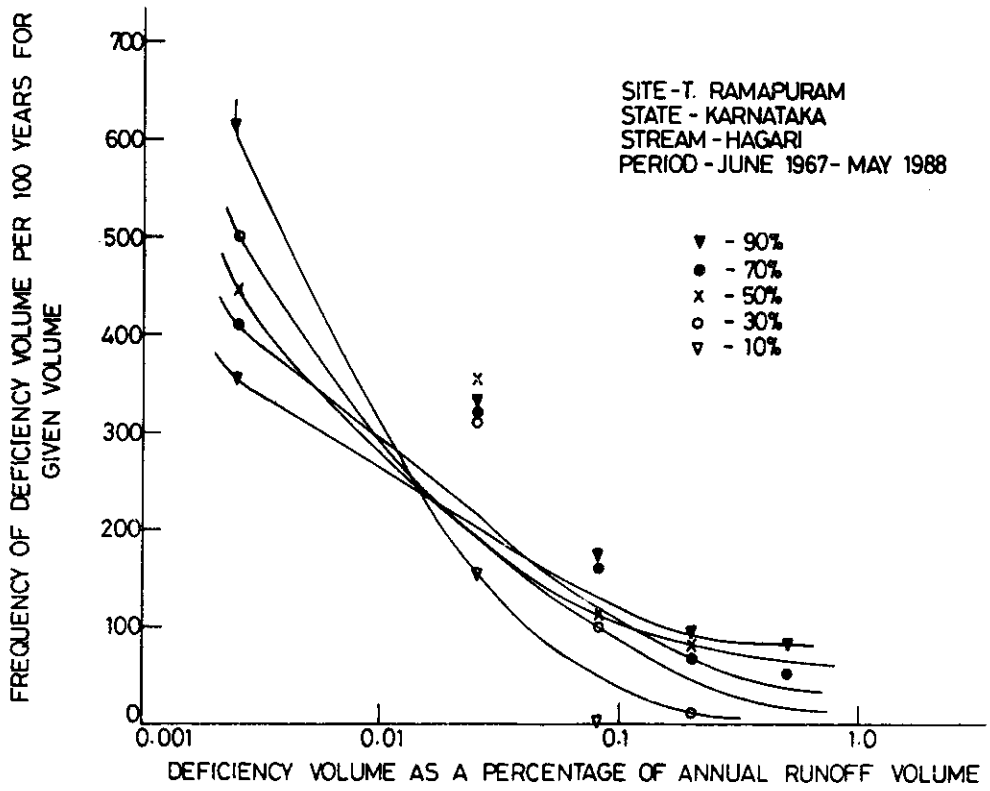


Fig. 4.16 : Frequency of Deficiency Volume for Wadakwal & Yadgir



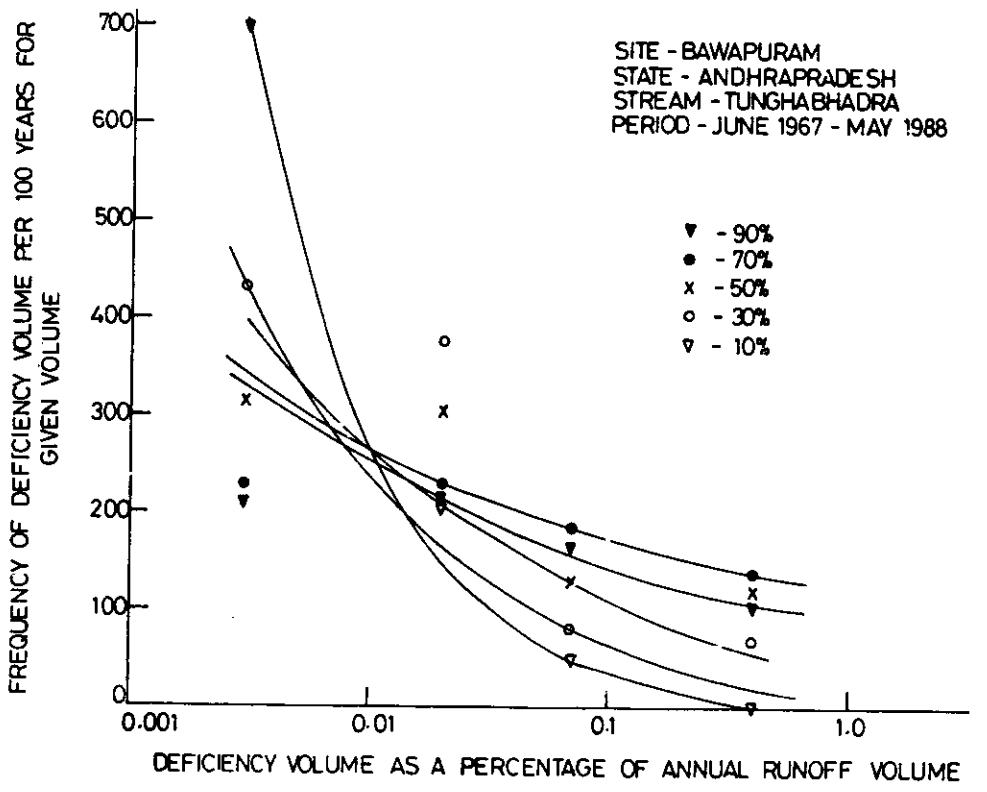
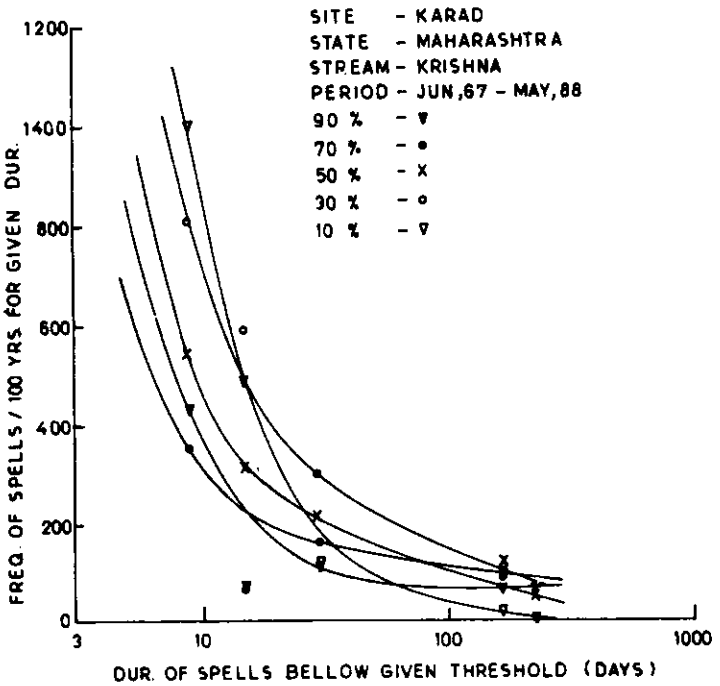


Fig. 4.17 : Frequency of Deficiency Volume for T. Ramapuram & Bawapura



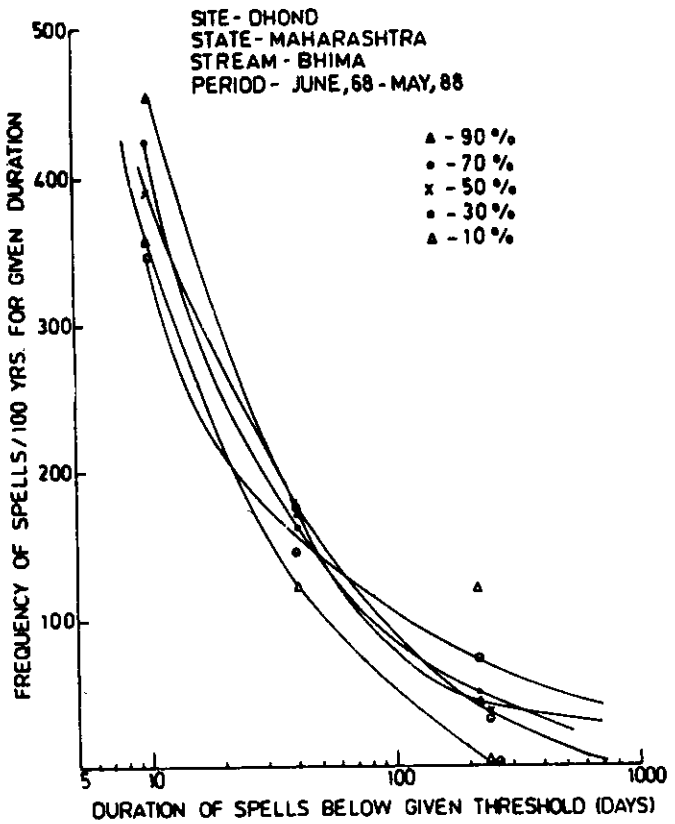


Fig. 4.18 : Frequency of Spell Duration for Karad & Dhond

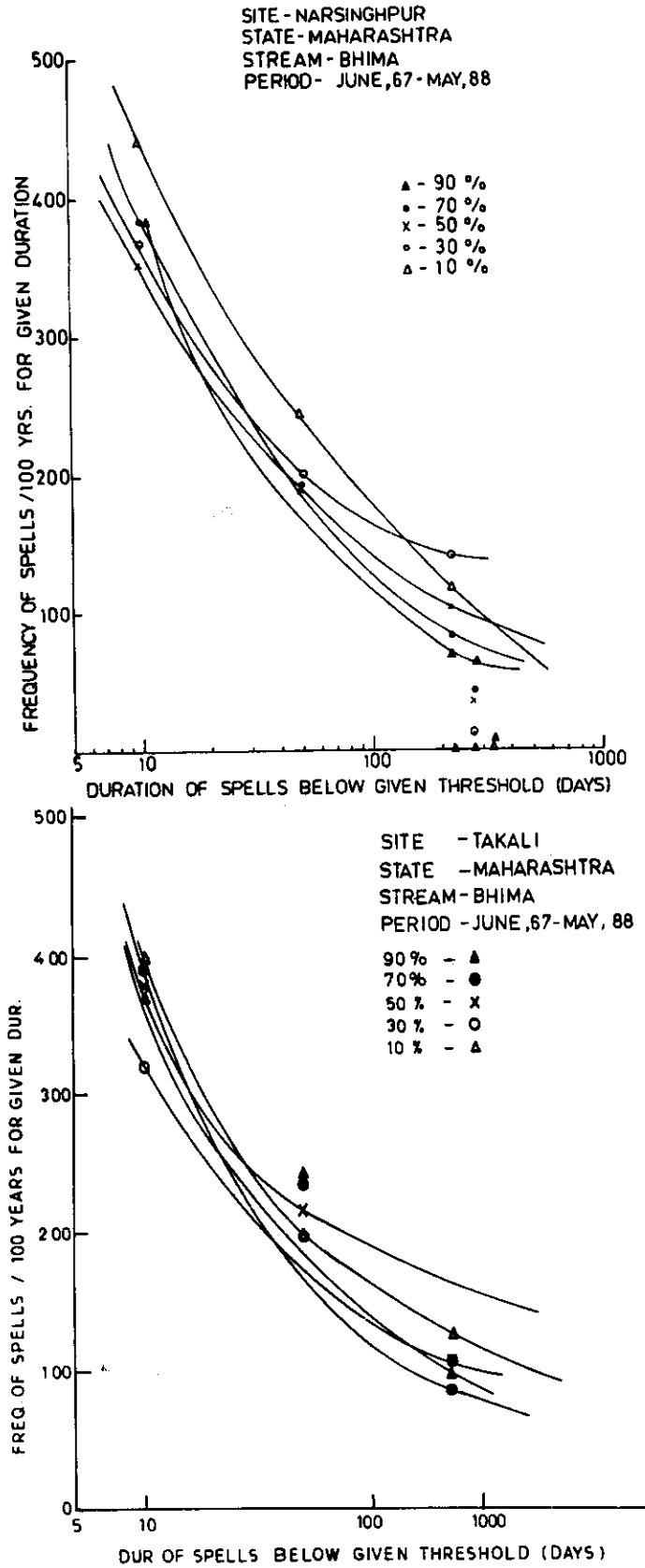


Fig. 4.19 : Frequency of Spell Duration for Narsingpur & Takali

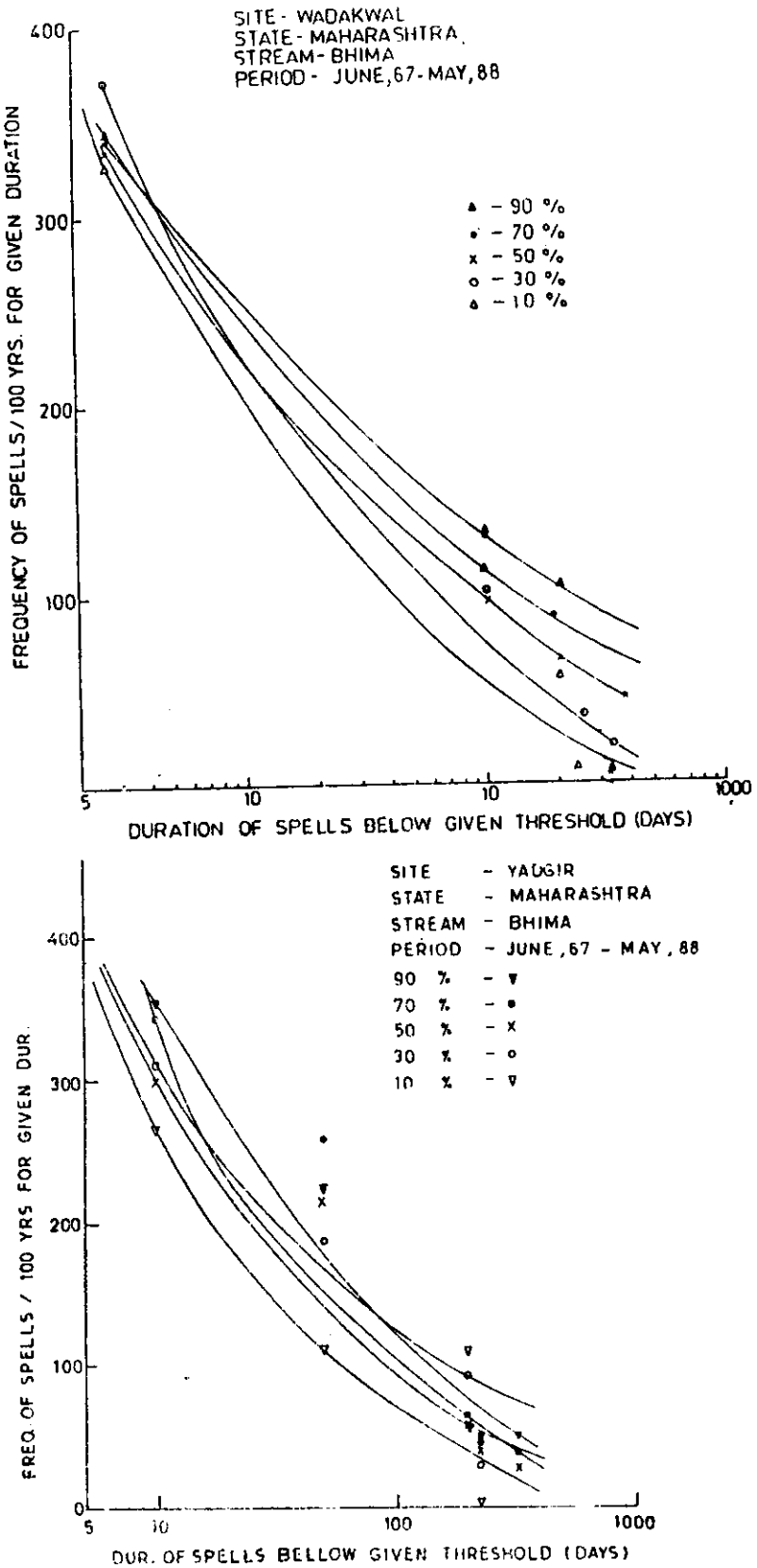


Fig.4.20 : Frequency of Spell Duration for Wadakwal & Yadgir

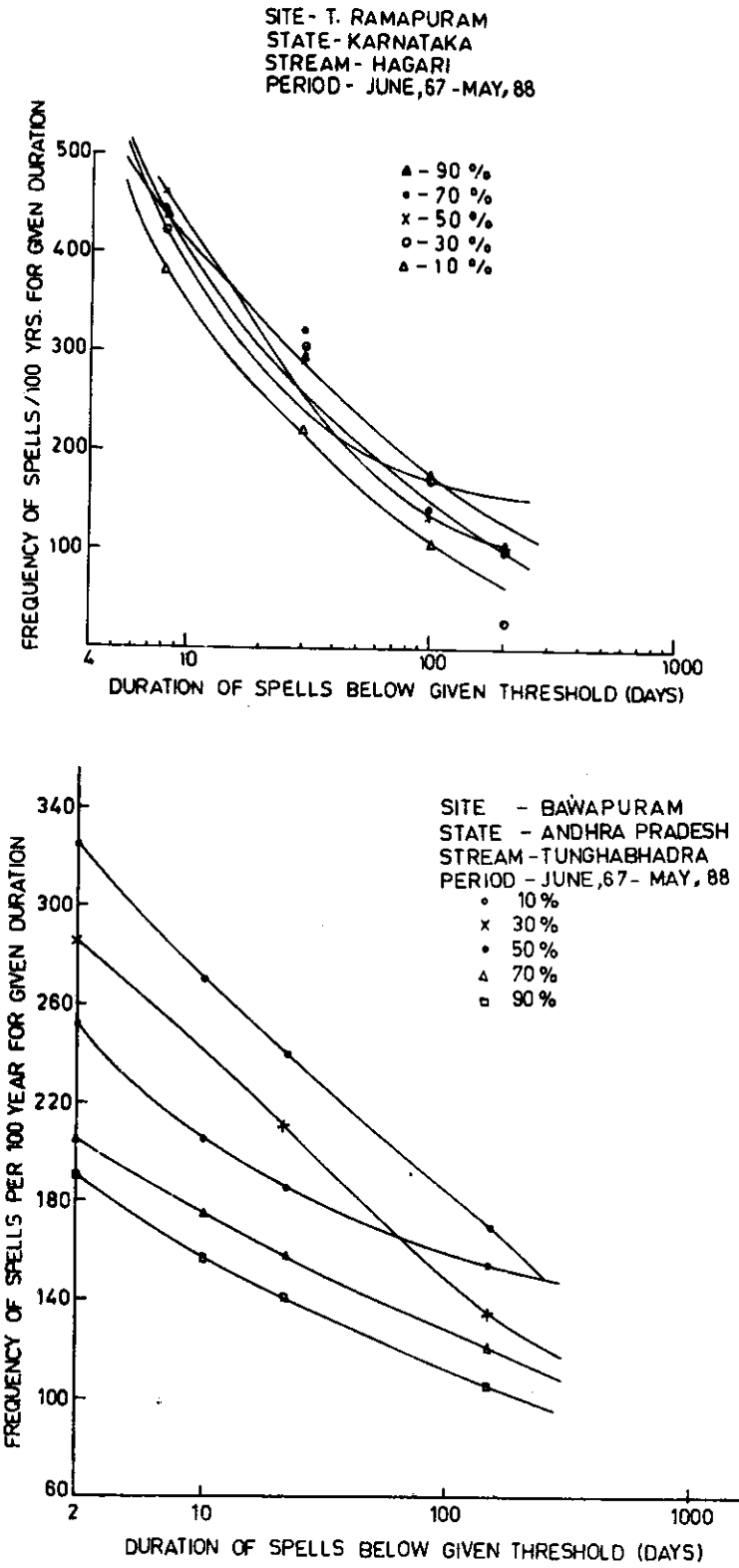
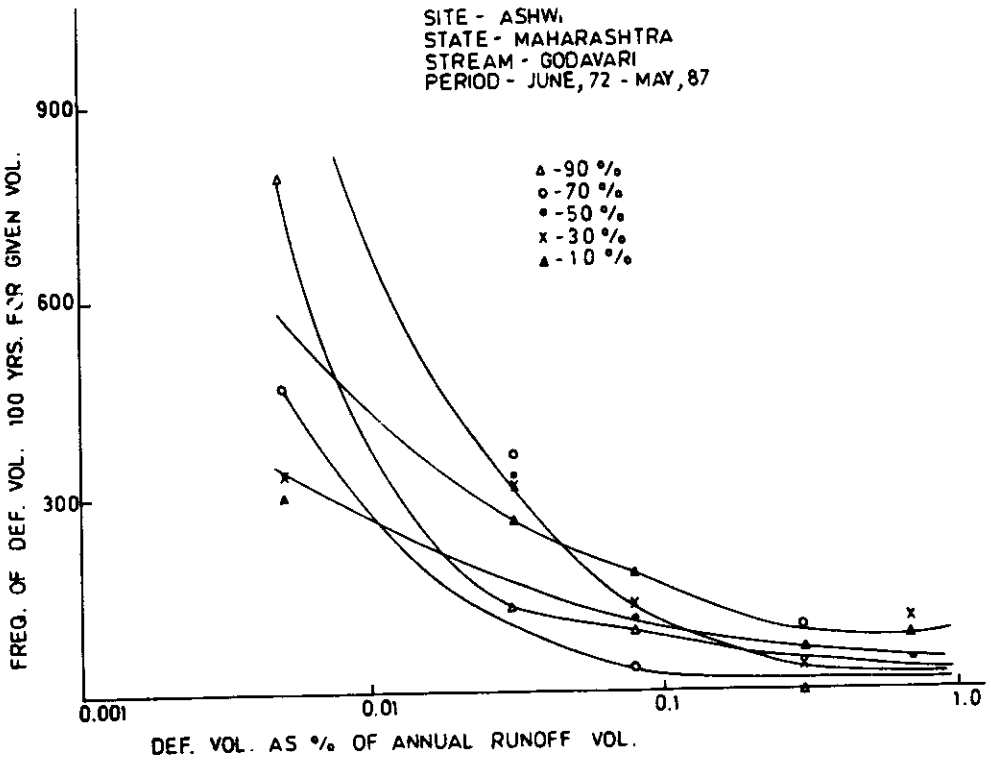


Fig.4.21 : Frequency of Spell Duration for T.Ramapuram & Bawapuram



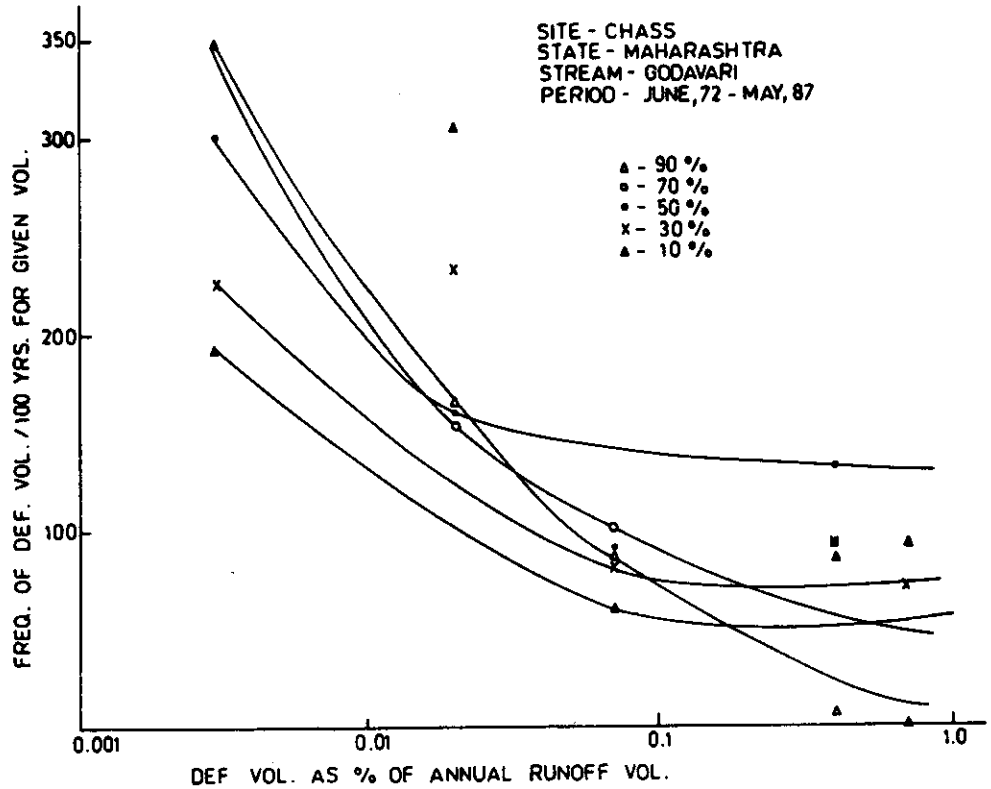
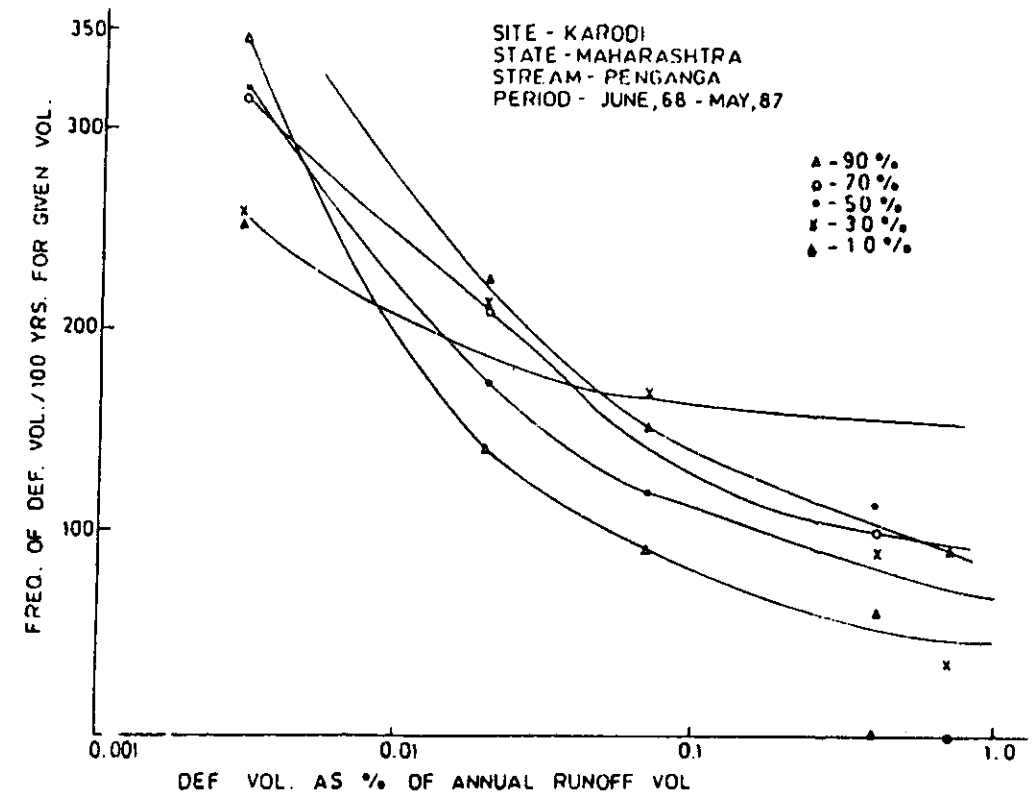


Fig.4.22 : Frequency of Deficiency Volume for Ashwi & Chass



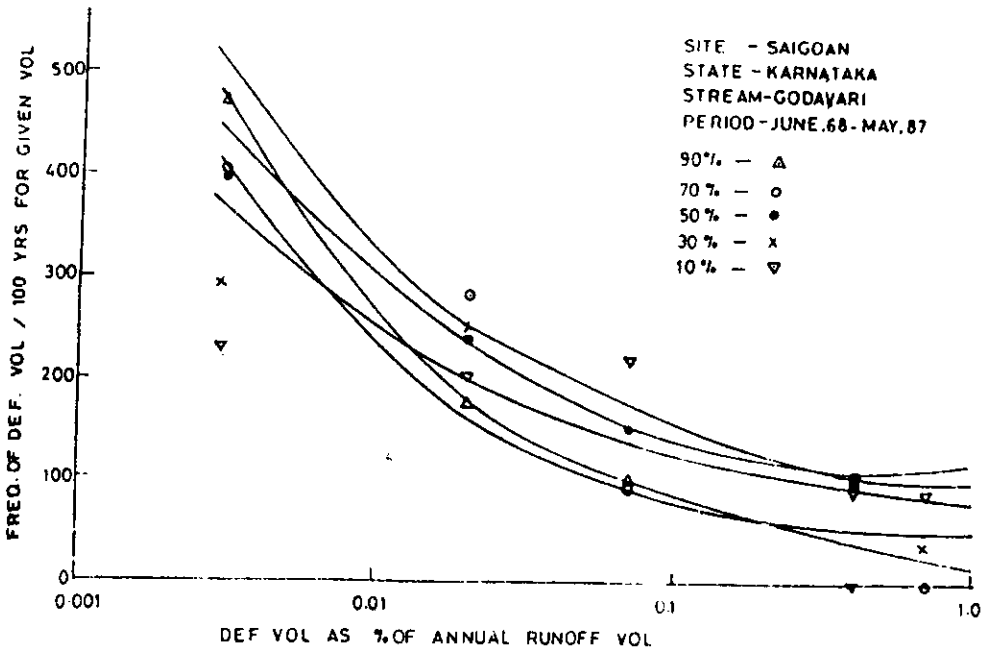
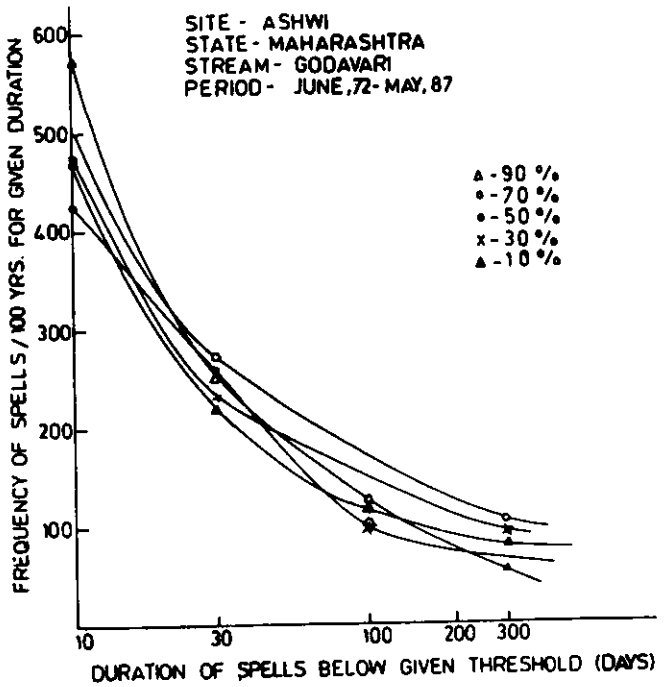


Fig. 4.23 : Frequency of Deficiency Volume for Karodi & Saigoan



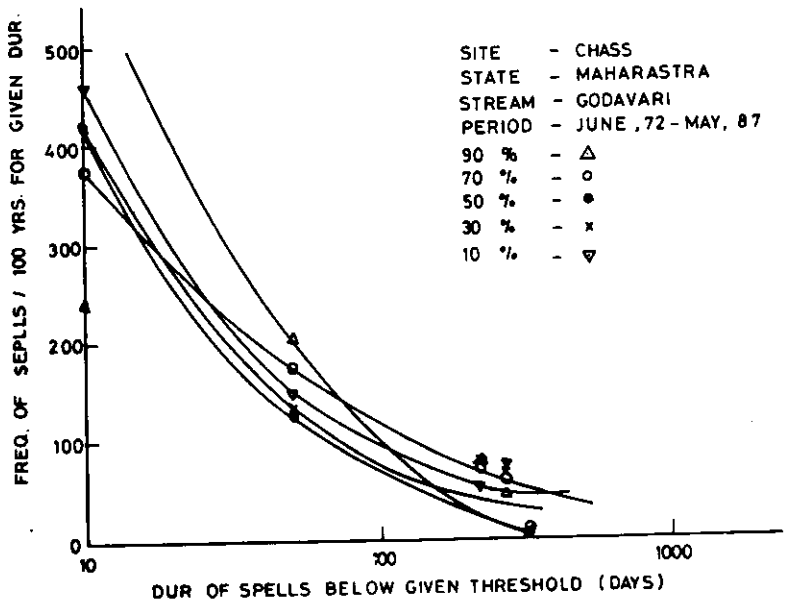
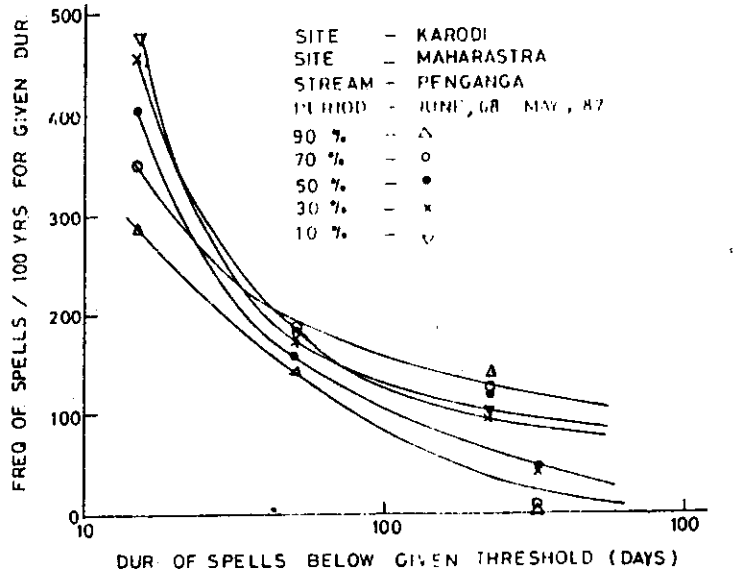


Fig.4.24 : Frequency of Spell Duration for Ashwi & Chass



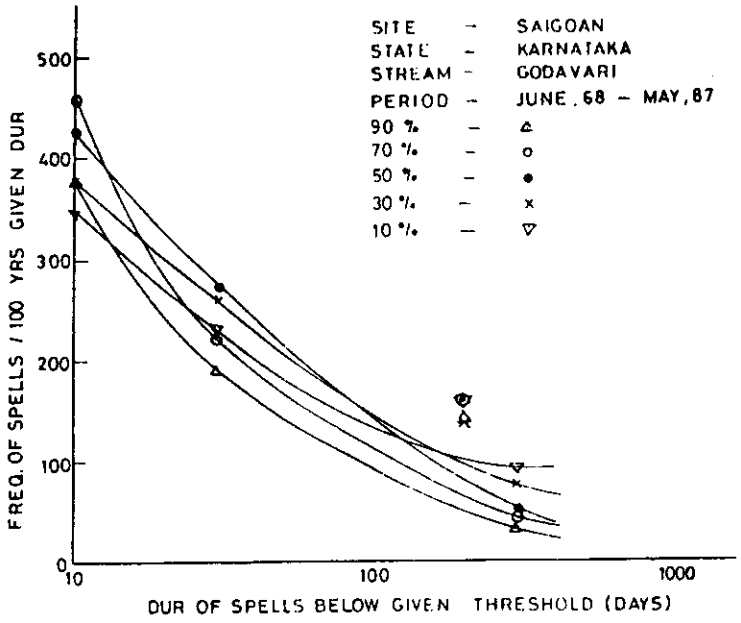


Fig. 4.25 : Frequency of Spell Duration for Karodi & Saigoan

4.5.2.2 Analysis of annual maximum duration and volume of low flow spell

Based on the procedure mentioned in CS-21, the analysis of annual maximum deficit volume of low flow spell and annual maximum deficit duration of low flow spells have been carried out for all the chosen sites corresponding to demand level as 10%, 30%, 50%, 70% and 90% of average daily flow (ADF). The results of analysis of annual maximum deficit volume and duration are presented in Table 4.13 through 4.20 and Table 4.21 to 4.28 respectively for the chosen sites of Krishna basin. Due to inclusion of flow data of the year 1987-88 into flow series, the average daily flow values have changed slightly. The values of maximum deficient volume and duration at different demand level are comparable to the values of previous years. It may, however, be mentioned that the maximum deficient volume or duration are not representing maximum drought volume or duration. The values of maximum deficit volume and maximum deficit duration are the highest values in the series of deficient volume and duration in a year.

Similar analysis of annual maximum deficit volume of low flow spell and annual maximum deficit duration of low flow spell for the chosen sites of Godavari basin have been carried out at different demand levels, i.e. 10%, 30%, 50%, 70% and 90% of average daily flow. The sample results of annual maximum volume and annual maximum duration are given in Table 4.29 through 4.32 and Table 4.33 to 4.36 respectively. The values of annual maximum deficit volume and duration for the sites of Ashwi and Karodi higher for the year 1985-86 than the year 1986-87, while in case of sites of Chass and Saigoan the values of annual maximum deficit volume and annual maximum deficit duration were higher for year 1986-87 than the year 1985-87 at all demand levels.

In order to see the effect of monsoon, the analysis has been performed using daily flow data of monsoon period (1st June - 31st Oct.) for all the chosen sites. The daily flow data of five months have been used for computation of average daily flow (ADF). The average daily flow values for all sites decreased with the inclusion of flow data for year 1987-88.

At different demand level of ADF, maximum deficit volume and maximum deficit duration were computed. The table 4.37 through 4.44 show the maximum deficit volume and Table 4.45 through 4.52 show maximum deficit duration for all the chosen sites of Krishna basin. The maximum deficit volume and maximum deficit duration of valuesare comparable with the values of previous years. Also, similar analysis has been carried out for the chosen sites of Godavari basin by considering daily flow data of monsoon months i.e. 1st June - 31st Oct. The results of maximum deficit volume and maximum deficit duration are shown in Table 4.53 through 4.56 and Table 4.57 through 4.60 respectively. The maximum deficit volumes for the sites of Ashwi and Karodi are higher for the year 1985-86 than those of year 1986-87, while for the sites of Chass and Saigoan, maximum deficit volumes are high for the year 1986-87 than those of year 1985-87. Also, maximum deficit duration for all the sites except Ashwi are higher for the year 1986-87 than those of year 1985-86.

Based on the calculations of maximum deficit volume and maximum deficit duration, drought intensity was worked out for all the selected sites of Krishna basin. It has been observed that by and large maximum deficit volume has corresponded to maximum deficit duration barring few situations. The results of drought intensity for Krishna basin are presented in Table 4.61 through 4.68. The drought intensity values for all the sites at various demand levels are higher, for the years 1985, 1986 and 1987 than those

TABLE 4.13 ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: KARAD AVERAGE DAILY FLOW : 138.62 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	185.20	1453.58	3105.78	4824.48	6831.97
1968 - 69	543.69	4369.87	13946.80	20313.13	26717.26
1969 - 70	393.07	3494.00	11625.72	16875.48	27157.57
1970 - 71	175.89	1174.01	12914.51	19309.70	25653.41
1971 - 72	174.53	1107.88	2324.49	19139.32	25719.19
1972 - 73	228.91	799.26	4056.43	21334.27	28320.62
1973 - 74	167.43	897.24	3328.86	15503.91	21477.37
1974 - 75	199.33	2848.32	11659.12	17521.74	23458.75
1975 - 76	180.15	1090.01	4903.98	16449.19	22272.72
1976 - 77	186.05	2387.79	5671.59	19068.74	25666.93
1977 - 78	254.41	1476.46	8417.20	14153.93	19258.76
1978 - 79	185.68	1331.00	10331.23	17244.01	23398.61
1979 - 80	180.71	3541.96	9643.53	14994.11	20380.71
1980 - 81	234.16	2094.04	7570.65	14499.96	19822.86
1981 - 82	151.33	1184.46	7731.02	17061.70	23548.98
1982 - 83	155.49	610.03	7544.23	15441.83	21430.10
1983 - 84	95.30	741.91	4446.32	16831.04	23512.38
1984 - 85	95.78	443.69	2081.85	14285.92	20357.37
1985 - 86	108.36	487.55	1046.51	7449.56	20132.79
1986 - 87	122.88	527.55	2223.01	12233.77	17921.64
1987 - 88	142.78	707.76	2644.24	8866.63	12581.57

TABLE 4.14 ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: DHOND AVERAGE DAILY FLOW : 154.95 cumecs
PERIOD OF ANALYSIS : JUN 1968- MAY 1988

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1968 - 69	2819.58	9737.54	16831.41	23938.1	31055.43
1969 - 70	2191.03	9747.58	17061.25	24374.69	31688.56
1970 - 71	2556.06	9464.42	16468.19	23471.94	30475.71
1971 - 72	2290.71	8846.41	15478.30	22342.78	29129.62
1972 - 73	2486.78	10164.89	17917.34	25726.85	33536.36
1973 - 74	1793.77	8038.47	14597.12	21197.99	27798.88
1974 - 75	323.42	6180.54	12265.48	18560.51	24911.34
1975 - 76	1323.34	6837.53	12537.52	19003.79	25511.71
1976 - 77	655.94	7517.72	14776.97	22091.06	29895.79
1977 - 78	1440.30	6435.87	11974.54	17552.74	23211.52
1978 - 79	1227.13	6782.37	14495.45	22742.06	30272.65
1979 - 80	1342.51	7214.70	14116.04	21101.15	28104.92
1980 - 81	1424.14	8793.32	16039.19	23290.86	30619.64
1981 - 82	1884.45	8228.17	14773.41	21374.39	30032.67
1982 - 83	2362.44	8442.54	14578.61	23828.13	31350.47
1983 - 84	538.23	6901.73	13854.44	20796.32	28041.44
1984 - 85	1807.05	8460.28	15154.14	22531.77	29597.52
1985 - 86	2468.91	9605.32	16673.93	23793.36	30960.94
1986 - 87	1926.28	6642.18	17655.40	25332.95	33018.50
1987 - 88	2254.66	9419.96	16229.31	23047.07	30243.78

TABLE 4.15: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: NARSINGHPUR AVERAGE DAILY FLOW : 189.02 cumecs
PERIOD OF ANALYSIS : JUN 1967 - MAY 1988

PERIOD: YEAR		VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967	68	1596.96	7542.41	13742.08	20088.72	26439.91
1968	69	2320.45	10363.56	18785.72	27360.03	35962.12
1969	70	1807.83	9215.81	18554.83	28229.83	37675.78
1970	71	2038.60	10126.13	18404.18	26721.20	35216.73
1971	72	2146.44	9925.09	18044.53	26233.87	34445.20
1972	73	3102.07	10856.75	18681.73	26541.92	40907.31
1973	74	1595.06	8452.25	16251.52	24129.35	32093.18
1974	75	385.56	6489.91	13718.40	21283.42	28950.89
1975	76	1348.46	7668.74	14755.67	22476.18	30314.79
1976	77	1688.40	7980.63	17909.54	26834.10	36198.32
1977	78	141.43	2524.84	10108.67	16564.74	23177.72
1978	79	1917.49	8479.07	15826.44	23428.94	31103.28
1979	80	1357.57	6035.07	12235.95	18942.19	25785.84
1980	81	1674.75	10585.59	19267.51	28036.33	36982.01
1981	82	1081.49	4405.72	17237.43	26147.38	35369.80
1982	83	1607.62	9943.53	19964.13	29150.68	38337.23
1983	84	571.51	8580.14	17924.46	26506.13	35087.79
1984	85	879.84	9058.21	17148.41	25249.42	35035.25
1985	86	929.86	10978.06	19910.88	28870.60	37830.31

TABLE 4.16: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: TAKALI AVERAGE DAILY FLOW : 211.35 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR		VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967 -	68	1597.15	7818.64	14328.34	20838.04	27347.72
1968 -	69	2305.57	10345.70	19814.89	29182.52	38608.89
1969 -	70	1996.75	9689.41	18232.56	26728.97	35225.41
1970 -	71	2256.11	10924.02	20093.79	29376.37	38849.73
1971 -	72	2200.59	10569.78	19534.10	28592.43	37680.66
1972 -	73	3327.52	12417.16	21078.67	34996.95	45691.50
1973 -	74	1867.29	9247.42	17295.14	26143.65	34956.04
1974 -	75	845.61	7263.98	15116.93	23342.34	31764.57
1975 -	76	1596.33	7946.16	15334.94	23236.24	31538.57
1976 -	77	1436.85	10239.30	19981.79	29999.39	40362.63
1977 -	78	154.32	5198.34	12216.07	19450.24	26781.71
1978 -	79	1929.58	8891.69	16910.62	25203.47	33654.01
1979	80	1028.65	6787.39	13716.83	21115.92	28657.91
1980 -	81	2113.09	11982.28	21648.39	31455.45	41600.84
1981 -	82	873.72	9078.44	17258.06	25599.03	33968.64
1982 -	83	2307.83	11316.34	19826.03	28382.95	36963.95
1983 -	84	1051.34	9755.04	19956.10	29467.02	38977.96
1984 -	85	576.29	10325.89	19254.50	28218.06	37597.63
1985 -	86	4111.54	14161.94	24024.03	33915.30	43837.28
1986 -	87	4031.48	14541.55	24889.40	35286.09	45727.06
1987	88	3038.54	9812.06	16809.48	23882.42	30983.98

TABLE 4.17: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: WADAKWAL AVERAGE DAILY FLOW : 33.08 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	106.12	746.51	1308.83	1876.51	2445.45
1968 - 69	409.77	1645.18	2958.22	4281.08	5609.06
1969 - 70	188 88	1082.15	2159.33	3713.83	5026.49
1970 - 71	262.45	1343.21	2610.99	3958.38	5343.35
1971 - 72	349.49	1529.47	2840.08	4202.32	5590.73
1972 - 73	689.86	2037.16	3412.88	4788.93	7380.07
1973 - 74	287.23	1356.76	2564.18	3843.77	5189.55
1974 - 75	253.56	1229.92	2435.80	3712.24	5021.65
1975 - 76	133.26	658.25	1885.83	3102.35	4368.02
1976 - 77	585.34	2182.19	3743.72	5432.01	7072.67
1977 - 78	214.34	1116.66	2128.81	3187.43	4273.63
1978 - 79	369.57	1520.22	2773.37	4057.89	5358.50
1979 - 80	133.42	762.39	1727.70	2781.84	3889.78
1980 - 81	364.62	1207.74	2069.40	2936.04	3802.67
1981 - 82	442.23	1846.76	3217.83	4600.49	5989.21
1982 - 83	622.12	1934.07	3263.26	4599.81	5940.42
1983 - 84	316.80	1426.66	2678.89	3986.06	5322.69
1984 - 85	569.00	1861.83	3202.89	4542.19	5889.22
1985 - 86	405.15	2207.12	3749.50	5297.55	6847.38
1986 - 87	278.44	1460.07	3925.33	5547.56	7181.60
1987 - 88	453.62	1538.61	2839.18	3743.98	4852.75

TABLE 4.18: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: YADGIR AVERAGE DAILY FLOW : 331.07 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	1998.66	11764.87	22071.32	32590.08	43237.52
1968 - 69	3669.94	15608.20	28486.21	43393.09	57892.11
1969 - 70	3003.75	14025.84	27481.69	41526.23	55656.22
1970 - 71	3154.63	15702.73	29595.60	43954.29	58526.54
1971 - 72	3376.08	15711.98	29205.00	43079.42	57091.40
1972 - 73	6046.28	19223.70	37464.95	53952.07	70505.62
1973 - 74	2574.59	13362.30	25682.11	38414.36	51560.68
1974 - 75	1554.85	9585.97	22825.94	35312.04	48330.00
1975 - 76	1692.74	9832.74	20983.42	32911.84	45475.75
1976 - 77	3288.21	16044.96	31052.47	46514.39	62595.41
1977 - 78	442.91	7549.81	15060.05	22608.49	41791.91
1978 - 79	2399.43	11831.41	22754.61	34295.57	50246.47
1979 - 80	2175.49	9707.20	19946.13	31182.13	42733.30
1980 - 81	3626.82	17518.27	32561.41	47868.67	63644.24
1981 - 82	2190.26	12014.42	24299.31	37037.88	52275.71
1982 - 83	4513.99	17091.87	30056.41	43184.11	56360.77
1983 - 84	2578.66	14376.93	27691.38	41638.64	55891.16
1984 - 85	2300.70	16305.97	30015.86	43862.43	58024.02
1985 - 86	5849.36	20601.81	35738.27	50999.35	66337.16
1986 - 87	4493.03	19245.25	32951.54	53266.41	69356.47
1987 - 88	3207.72	14576.29	25288.97	36123.65	47011.34

TABLE 4.19: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: T.RAMAPURAM AVERAGE DAILY FLOW : 28.75 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY1988

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	0%	70%	90%
1967 - 68	37.13	687.57	152.45	2489.71	3652.11
1968 - 69	53.31	309.44	715.29	1221.09	1715.33
1969 - 70	21.36	348.79	715.58	1392.68	1972.80
1970 - 71	42.54	468.61	1522.49	2358.05	3202.01
1971 - 72	110.69	697.27	1376.10	2119.60	2894.86
1972 - 73	139.93	684.55	1597.00	2319.35	3043.92
1973 - 74	62.22	484.46	1120.10	2043.72	3025.97
1974 - 75	67.86	465.10	1084.25	1748.15	2452.83
1975 - 76	22.35	183.51	577.91	1032.77	1544.69
1976 - 77	59.20	506.85	1374.37	2453.36	3674.31
1977 - 78	53.41	410.09	1082.39	2045.47	3003.75
1978 - 79	45.49	540.63	1084.06	1636.52	2608.20
1979 - 80	34.15	327.96	860.90	2114.36	3099.71
1980 - 81	71.06	519.57	1117.63	1726.79	2352.74
1981 - 82	18.16	327.51	991.12	1566.99	2921.21
1982 - 83	91.74	586.21	1154.42	1952.82	2732.92
1983 - 84	57.86	322.62	1429.43	2361.75	3391.01
1984 - 85	186.30	837.36	1578.39	2680.17	3674.51
1985 - 86	227.26	926.54	1680.87	2439.95	3204.21
1986 - 87	247.00	964.64	1719.47	2602.44	3727.23
1987 - 88	261.16	1046.40	1965.46	2897.05	3833.32

TABLE 4.20: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELL

SITE: BAWAPURAM AVERAGE DAILY FLOW : 179.04 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	928.94	6373.23	15204.35	23296.82	31426.54
1968 - 69	783.14	3268.70	6537.50	14454.96	21115.78
1969 - 70	454.95	2410.64	6909.18	14991.26	22077.21
1970 - 71	374.63	3641.86	7476.30	17331.11	24576.50
1971 - 72	289.10	2763.69	7769.77	17344.38	24617.57
1972 - 73	1823.81	7991.55	14507.42	22318.50	29745.79
1973 - 74	773.09	6523.62	12697.15	19287.07	26374.01
1974 - 75	758.64	5560.96	12799.76	21484.71	29004.25
1975 - 76	459.47	3993.79	8578.12	13751.94	24796.64
1976 - 77	1543.20	6843.28	15718.88	23274.24	34275.77
1977 - 78	1614.47	7372.20	15291.32	22857.66	30305.59
1978 - 79	530.67	7257.52	13531.78	19726.46	25921.11
1979 - 80	1287.10	5288.70	13455.85	20034.85	26623.37
1980 - 81	701.49	2828.17	10765.47	22030.61	28977.21
1981 - 82	1959.58	9055.59	16173.98	23343.27	30615.40
1982 - 83	2190.22	8929.82	15917.42	22986.79	30097.80
1983 - 84	1746.60	8988.78	16956.64	24455.70	31989.09
1984 - 85	2467.80	10447.45	18115.04	25813.64	33512.20
1985 - 86	2027.48	6723.95	11450.52	16177.10	35724.75
1986 - 87	2348.15	9871.61	16981.91	24143.39	31321.29
1987 - 88	2165.74	7231.21	14148.53	20024.67	25937.41

TABLE 4.21 : ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: KARAD AVERAGE DAILY FLOW : 138.62 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	31.00	59.00	61.00	76.00	113.00
1968 - 69	55.00	130.00	228.00	231.00	231.00
1969 - 70	40.00	101.00	189.00	190.00	243.00
1970 - 71	20.00	37.00	222.00	228.00	229.00
1971 - 72	21.00	42.00	46.00	235.00	236.00
1972 - 73	18.00	23.00	73.00	252.00	252.00
1973 - 74	22.00	31.00	66.00	200.00	205.00
1974 - 75	30.00	93.00	210.00	213.00	215.00
1975 - 76	22.00	40.00	90.00	208.00	211.00
1976 - 77	20.00	88.00	104.00	238.00	238.00
1977 - 78	39.00	50.00	163.00	182.00	185.00
1978 - 79	24.00	47.00	202.00	222.00	222.00
1979 - 80	23.00	151.00	190.00	194.00	195.00
1980 - 81	22.00	78.00	157.00	192.00	192.00
1981 - 82	20.00	51.00	165.00	234.00	234.00
1982 - 83	16.00	25.00	167.00	216.00	216.00
1983 - 84	11.00	26.00	95.00	241.00	241.00
1984 - 85	11.00	17.00	53.00	219.00	219.00
1985 - 86	12.00	18.00	25.00	133.00	232.00
1986 - 87	11.00	17.00	60.00	205.00	206.00
1987 - 88	15.00	23.00	60.00	134.00	134.00

TABLE 4.22: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: DHOND AVERAGE DAILY FLOW : 154.95 cumecs
PERIOD OF ANALYSIS : JUN 1968- MAY 1988

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1968 - 69	215.00	225.00	229.00	229.00	230.00
1969 - 70	175.00	236.00	236.00	236.00	236.00
1970 - 71	209.00	226.00	226.00	226.00	226.00
1971 - 72	200.00	214.00	214.00	219.00	219.00
1972 - 73	225.00	249.00	252.00	252.00	252.00
1973 - 74	188.00	210.00	213.00	213.00	213.00
1974 - 75	77.00	192.00	202.00	204.00	205.00
1975 - 76	173.00	179.00	193.00	210.00	210.00
1976 - 77	93.00	233.00	235.00	237.00	244.00
1977 - 78	142.00	176.00	180.00	180.00	183.00
1978 - 79	134.00	183.00	220.00	243.00	243.00
1979 - 80	160.00	221.00	224.00	226.00	226.00
1980 - 81	154.00	233.00	234.00	234.00	239.00
1981 - 82	191.00	210.00	213.00	213.00	238.00
1982 - 83	193.00	198.00	198.00	240.00	242.00
1983 - 84	74.00	206.00	224.00	224.00	230.00
1984 - 85	191.00	216.00	216.00	228.00	228.00
1985 - 86	200.00	227.00	229.00	231.00	232.00
1986 - 87	144.00	155.00	247.00	248.00	248.00
1987 - 88	166.00	219.00	220.00	220.00	226.00

TABLE 4.23: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: NARSIGHPUR AVERAGE DAILY FLOW : 189.02 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	VOLUME IN CUMECS DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	129.00	163.00	164.00	168.00	168.00
1968 - 69	191.00	222.00	223.00	227.00	228.00
1969 - 70	142.00	200.00	233.00	249.00	250.00
1970 - 71	171.00	216.00	220.00	220.00	224.00
1971 - 72	187.00	211.00	216.00	217.00	218.00
1972 - 73	202.00	206.00	207.00	208.00	256.00
1973 - 74	155.00	192.00	207.00	210.00	212.00
1974 - 75	68.00	187.00	196.00	202.00	203.00
1975 - 76	112.00	176.00	202.00	206.00	208.00
1976 - 77	129.00	189.00	233.00	237.00	247.00
1977 - 78	14.00	77.00	168.00	173.00	176.00
1978 - 79	168.00	180.00	199.00	203.00	203.00
1979 - 80	116.00	124.00	175.00	180.00	182.00
1980 - 81	151.00	227.00	231.00	233.00	237.00
1981 - 82	81.00	102.00	232.00	237.00	242.00
1982 - 83	136.00	203.00	243.00	243.00	243.00
[illegible]	74.00	205.00	227.00	227.00	227.00
1984 - 85	102.00	214.00	214.00	215.00	230.00
1985 - 86	70.00	236.00	237.00	237.00	237.00
1986 - 87	152.00	214.00	214.00	248.00	280.00
1987 - 88	167.00	169.00	225.00	225.00	225.00

TABLE 4.24: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: TAKALI AVERAGE DAILY FLOW : 211.35 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	120.00	154.00	154.00	154.00	154.00
1968 - 69	155.00	198.00	221.00	223.00	223.00
1969 - 70	140.00	197.00	201.00	201.00	201.00
1970 - 71	170.00	215.00	218.00	220.00	224.00
1971 - 72	158.00	209.00	213.00	215.00	215.00
1972 - 73	162.00	204.00	206.00	253.00	253.00
1973 - 74	124.00	183.00	193.00	205.00	208.00
1974 - 75	88.00	176.00	189.00	198.00	200.00
1975 - 76	114.00	172.00	180.00	192.00	199.00
1976 - 77	92.00	228.00	234.00	239.00	245.00
1977 - 78	17.00	154.00	170.00	173.00	175.00
1978 - 79	138.00	177.00	194.00	199.00	201.00
1979 - 80	58.00	128.00	172.00	177.00	180.00
1980 - 81	127.00	225.00	230.00	234.00	240.00
1981 - 82	77.00	187.00	196.00	198.00	198.00
1982 - 83	131.00	201.00	202.00	203.00	203.00
1983 - 84	100.00	203.00	225.00	225.00	225.00
1984 - 85	59.00	210.00	212.00	213.00	219.00
1985 - 86	205.00	232.00	234.00	234.00	235.00
1986 - 87	206.00	244.00	245.00	247.00	247.00
1987 - 88	153.00	164.00	167.00	168.00	168.00

TABLE 4.25: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: WADAKWAL AVERAGE DAILY FLOW : 33.08 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	38.00	85.00	85.00	86.00	86.00
1968 - 69	165.00	197.00	199.00	200.00	201.00
1969 - 70	95.00	159.00	164.00	198.00	199.00
1970 - 71	109.00	176.00	200.00	207.00	212.00
1971 - 72	143.00	192.00	203.00	208.00	212.00
1972 - 73	206.00	207.00	208.00	208.00	253.00
1973 - 74	120.00	178.00	187.00	194.00	202.00
1974 - 75	98.00	172.00	190.00	197.00	199.00
1975 - 76	46.00	92.00	178.00	188.00	193.00
1976 - 77	197.00	235.00	237.00	248.00	248.00
1977 - 78	70.00	148.00	157.00	162.00	166.00
1978 - 79	150.00	185.00	192.00	196.00	197.00
1979 - 80	51.00	128.00	154.00	164.00	171.00
1980 - 81	118.00	130.00	131.00	131.00	131.00
1981 - 82	158.00	204.00	209.00	209.00	210.00
1982 - 83	195.00	200.00	202.00	202.00	203.00
1983 - 84	103.00	178.00	195.00	201.00	204.00
1984 - 85	189.00	197.00	202.00	203.00	204.00
1985 - 86	135.00	232.00	234.00	234.00	235.00
1986 - 87	95.00	153.00	245.00	247.00	247.00
1987 - 88	156.00	166.00	167.00	167.00	168.00

TABLE 4.26 : ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: YADGIR AVERAGE DAILY FLOW : 331.07 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	79.00	153.00	158.00	160.00	161.00
1968 - 69	160.00	192.00	197.00	218.00	220.00
1969 - 70	133.00	180.00	211.00	213.00	214.00
1970 - 71	158.00	203.00	214.00	218.00	222.00
1971 - 72	150.00	200.00	208.00	211.00	212.00
1972 - 73	195.00	200.00	247.00	250.00	250.00
1973 - 74	112.00	174.00	189.00	196.00	201.00
1974 - 75	92.00	125.00	184.00	193.00	198.00
1975 - 76	90.00	147.00	172.00	187.00	191.00
1976 - 77	128.00	223.00	230.00	236.00	245.00
1977 - 78	30.00	113.00	114.00	114.00	170.00
1978 - 79	117.00	155.00	172.00	176.00	196.00
1979 - 80	97.00	131.00	167.00	173.00	176.00
1980 - 81	157.00	223.00	231.00	232.00	236.00
1981 - 82	107.00	179.00	189.00	194.00	223.00
1982 - 83	181.00	195.00	197.00	199.00	199.00
1983 - 84	135.00	189.00	205.00	213.00	216.00
1984 - 85	140.00	200.00	207.00	213.00	214.00
1985 - 86	219.00	225.00	230.00	231.00	232.00
1986 - 87	145.00	207.00	207.00	243.00	243.00
1987 - 88	113.00	160.00	163.00	164.00	165.00

TABLE 4.27: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: T.RAMAPURAM AVERAGE DAILY FLOW : 28.75 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	31.00	119.00	148.00	157.00	170.00
1968 - 69	36.00	70.00	81.00	81.00	88.00
1969 - 70	22.00	69.00	69.00	99.00	103.00
1970 - 71	35.00	97.00	145.00	146.00	147.00
1971 - 72	65.00	111.00	119.00	133.00	136.00
1972 - 73	65.00	97.00	125.00	126.00	126.00
1973 - 74	52.00	72.00	102.00	145.00	180.00
1974 - 75	46.00	85.00	104.00	120.00	124.00
1975 - 76	14.00	43.00	72.00	84.00	90.00
1976 - 77	44.00	99.00	156.00	191.00	205.00
1977 - 78	44.00	73.00	111.00	158.00	172.00
1978 - 79	41.00	94.00	95.00	97.00	143.00
1979 - 80	22.00	72.00	106.00	165.00	174.00
1980 - 81	34.00	76.00	105.00	107.00	110.00
1981 - 82	18.00	70.00	97.00	103.00	165.00
1982 - 83	43.00	97.00	101.00	130.00	151.00
1983 - 84	34.00	57.00	143.00	172.00	183.00
1984 - 85	93.00	126.00	132.00	169.00	174.00
1985 - 86	98.00	130.00	132.00	132.00	133.00
1986 - 87	93.00	129.00	133.00	153.00	191.00
1987 - 88	106.00	157.00	162.00	162.00	164.00

TABLE 4.28: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: BAWAPURAM AVERAGE DAILY FLOW : 179.04 cumecs
PERIOD OF ANALYSIS : JUN 1967- MAY 1988

PERIOD YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967 - 68	66.00	148.00	226.00	226.00	228.00
1968 - 69	66.00	73.00	98.00	185.00	187.00
1969 - 70	40.00	67.00	108.00	150.00	179.00
1970 - 71	36.00	105.00	109.00	202.00	203.00
1971 - 72	28.00	81.00	129.00	201.00	205.00
1972 - 73	139.00	168.00	181.00	206.00	208.00
1973 - 74	80.00	147.00	177.00	185.00	197.00
1974 - 75	66.00	132.00	183.00	210.00	210.00
1975 - 76	46.00	117.00	137.00	149.00	195.00
1976 - 77	135.00	153.00	211.00	211.00	244.00
1977 - 78	127.00	163.00	202.00	208.00	208.00
1978 - 79	45.00	165.00	173.00	173.00	173.00
1979 - 80	108.00	118.00	182.00	184.00	184.00
1980 - 81	53.00	61.00	134.00	194.00	194.00
1981 - 82	158.00	198.00	200.00	201.00	205.00
1982 - 83	168.00	192.00	197.00	198.00	199.00
1983 - 84	136.00	189.00	209.00	210.00	211.00
1984 - 85	164.00	214.00	215.00	215.00	215.00
1985 - 86	130.00	132.00	132.00	132.00	232.00
1986 - 87	150.00	198.00	200.00	200.00	201.00
1987 - 88	139.00	142.00	164.00	165.00	166.00

Table 4.29 : Annual maximum deficiency volume of low flow spells

SITE: ASHWI AVERAGE DAILY FLOW : 8.90 cumecs
PERIOD OF ANALYSIS : JUN 1972- MAY 1987

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1972 - 73	205.08	669.77	1134.47	1599.15	2064.35
1973 - 74	114.03	523.53	888.52	1254.33	1621.10
1974 - 75	162.00	544.08	926.88	1309.67	1692.45
1975 - 76	140.52	518.74	897.98	1277.20	1656.43
1976 - 77	74.59	435.35	772.20	1110.48	1448.76
1977 - 78	132.91	460.50	788.09	1115.69	1443.28
1978 - 79	149.11	474.92	800.74	1518.67	2042.31
1979 - 80	120.15	428.92	755.89	1076.37	1503.24
1980 - 81	127.74	590.83	1028.06	1466.04	1904.02
1981 - 82	170.58	594.31	1018.05	1441.79	1865.53
1982 - 83	119.70	507.91	871.12	1234.32	1893.11
1983 - 84	[illegible]	570.23	992.60	[illegible]	1822.27
1984 - 85	200.05	609.55	1019.49	1569.75	2027.15
1985 - 86	237.25	755.35	1273.46	1792.09	2311.97
1986 - 87	205.15	650.26	1095.36	1540.47	1985.57

TABLE 4.30: ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: CHASS AVERAGE DAILY FLOW : 48.81 cumecs
PERIOD OF ANALYSIS : JUN 1972- MAY 1987

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1972 - 73	677.32	2102.59	4688.70	6621.60	8880.72
1973 - 74	995.13	3156.78	5337.88	7732.17	10025.56
1974 - 75	953.79	3033.64	5126.53	7226.46	9339.50
1975 - 76	948.48	2984.47	5345.00	7613.17	9961.21
1976 - 77	795.74	3346.19	5727.29	8134.95	10555.12
1977 - 78	766.19	3463.68	5934.34	8422.90	10917.96
1978 - 79	830.39	2601.16	4377.87	6154.57	11204.63
1979 - 80	791.24	2530.11	4316.58	6103.04	11162.84
1980 - 81	1042.37	3336.99	5857.23	8333.53	10814.71
1981 - 82	1074.46	3371.31	5688.73	8013.68	10353.17
1982 - 83	1089.47	3394.48	5732.28	8090.38	10464.69
1983 - 84	4.91	401.72	1464.93	2495.05	3529.83
1984 - 85	1008.60	3228.75	5460.31	7699.81	9947.82
1985 - 86	1105.18	3341.82	5588.32	7857.02	10131.60
1986 - 87	1339.66	4056.13	6786.68	9520.37	12259.50

TABLE 4.31 : ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: KARODI AVERAGE DAILY FLOW : 26.92 cumecs
PERIOD OF ANALYSIS : JUN 1968- MAY 1987

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1968 - 69	349.09	1377.20	2583.27	3821.00	5076.53
1969 - 70	337.47	1346.28	2587.37	3798.76	5161.36
1970 - 71	290.25	1280.66	2413.51	3612.50	4833.53
1971 - 72	458.83	1589.07	2767.17	3951.65	5150.76
1972 - 73	443.52	1443.22	3193.82	4587.84	5997.48
1973 - 74	330.16	1339.63	2433.99	3560.00	4697.08
1974 - 75	449.73	1577.25	2737.43	3915.49	5094.57
1975 - 76	293.81	1214.15	2267.89	3374.61	4499.20
1976 - 77	415.69	1410.00	2420.66	3432.83	4450.04
1977 - 78	266.34	1153.06	2097.69	3059.06	4028.19
1978 - 79	250.80	798.80	1359.68	1925.00	2490.31
1979 - 80	318.35	1228.31	2192.07	3161.18	4133.82
1980 - 81	314.04	1644.79	2936.89	4248.68	5617.71
1981 - 82	457.20	1505.36	2643.91	3836.26	5063.42
1982 - 83	401.34	1246.62	3186.59	4516.41	6494.28
1983 - 84	304.42	1316.76	2435.49	3596.55	4777.61
1984 - 85	473.83	1620.15	2800.03	3998.32	5209.34
1985 - 86	226.91	1590.55	3071.08	4566.77	6063.52
1986 - 87	184.22	1650.70	2974.29	4307.86	5780.12

TABLE 4.32 : ANNUAL MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: SAIGAON AVERAGE DAILY FLOW : 31.17 cumecs
PERIOD OF ANALYSIS : JUN 1968- MAY 1987

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1968 - 69	377.73	1421.47	2586.22	3820.07	5066.79
1969 - 70	315.27	1250.09	2267.41	3657.53	4804.54
1970 - 71	309.53	1259.71	2398.87	3640.32	4944.20
1971 - 72	386.96	1388.51	2542.64	3767.36	5034.69
1972 - 73	636.25	1932.87	3925.81	5588.11	7233.80
1973 - 74	277.42	885.86	2528.07	3698.01	4957.84
1974 - 75	277.42	885.86	2519.50	3753.06	5046.05
1975 - 76	285.37	1130.00	2185.41	3288.08	4470.22
1976 - 77	496.11	1730.07	3411.08	4951.11	6502.71
1977 - 78	254.67	802.06	2317.88	3374.50	4440.48
1978 - 79	461.60	1598.82	2817.64	4048.11	5289.28
1979 - 80	248.30	1393.15	2474.95	3586.96	4709.04
1980 - 81	384.28	1863.21	3259.93	4715.52	6195.87
1981 - 82	408.45	1647.57	2899.25	4185.39	5488.25
1982 - 83	616.43	2127.45	3627.13	5135.70	6844.25
1983 - 84	299.70	1210.54	2458.76	3716.32	5000.94
1984 - 85	631.60	1974.73	3451.33	4884.18	6317.93
1985 - 86	697.42	2127.24	3576.67	5029.13	6487.14
1986 - 87	766.27	2309.95	3869.30	5427.74	6986.17

TABLE 4.33: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: ASHWI AVERAGE DAILY FLOW : 8.90 cumecs
PERIOD OF ANALYSIS : JUN 1972- MAY 1987

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1972 - 73	261.00	261.00	261.00	261.00	263.00
1973 - 74	145.00	205.00	205.00	206.00	206.00
1974 - 75	214.00	215.00	215.00	215.00	215.00
1975 - 76	212.00	213.00	213.00	213.00	213.00
1976 - 77	124.00	189.00	190.00	190.00	190.00
1977 - 78	183.00	184.00	184.00	184.00	184.00
1978 - 79	183.00	183.00	183.00	250.00	262.00
1979 - 80	169.00	173.00	180.00	180.00	197.00
1980 - 81	180.00	244.00	246.00	246.00	246.00
1981 - 82	237.00	238.00	238.00	238.00	238.00
1982 - 83	153.00	204.00	204.00	204.00	245.00
1983 - 84	222.00	232.00	233.00	233.00	233.00
1984 - 85	230.00	230.00	231.00	256.00	257.00
1985 - 86	291.00	291.00	291.00	292.00	292.00
1986 - 87	250.00	250.00	250.00	250.00	250.00

TABLE 4.34: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: CHASS AVERAGE DAILY FLOW : 48.81 cumecs
PERIOD OF ANALYSIS : JUN 1972- MAY 1987

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1972 - 73	146.00	146.00	198.00	198.00	212.00
1973 - 74	220.00	222.00	225.00	234.00	236.00
1974 - 75	212.00	214.00	215.00	216.00	217.00
1975 - 76	207.00	210.00	228.00	234.00	238.00
1976 - 77	188.00	243.00	244.00	247.00	248.00
1977 - 78	175.00	252.00	254.00	255.00	256.00
1978 - 79	180.00	182.00	182.00	182.00	262.00
1979 - 80	172.00	183.00	183.00	183.00	263.00
1980 - 81	234.00	236.00	253.00	254.00	255.00
1981 - 82	233.00	237.00	238.00	239.00	241.00
1982 - 83	234.00	238.00	241.00	243.00	244.00
1983 - 84	5.00	70.00	100.00	106.00	106.00
1984 - 85	227.00	228.00	229.00	230.00	231.00
1985 - 86	228.00	230.00	231.00	233.00	233.00
1986 - 87	277.00	279.00	280.00	280.00	280.00

TABLE 4.35: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: KARODI AVERAGE DAILY FLOW : 26.92 cumecs
PERIOD OF ANALYSIS : JUN 1968- MAY 1987

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1968 - 69	168.00	201.00	226.00	232.00	234.00
1969 - 70	166.00	196.00	225.00	225.00	244.00
1970 - 71	143.00	201.00	219.00	226.00	228.00
1971 - 72	195.00	217.00	220.00	220.00	222.00
1972 - 73	184.00	186.00	256.00	261.00	262.00
1973 - 74	155.00	198.00	207.00	210.00	212.00
1974 - 75	196.00	214.00	216.00	219.00	219.00
1975 - 76	136.00	189.00	202.00	208.00	209.00
1976 - 77	176.00	187.00	188.00	188.00	189.00
1977 - 78	119.00	172.00	177.00	180.00	180.00
1978 - 79	100.00	104.00	105.00	105.00	114.00
1979 - 80	143.00	178.00	180.00	180.00	181.00
1980 - 81	132.00	237.00	242.00	244.00	253.00
1981 - 82	174.00	205.00	219.00	223.00	228.00
1982 - 83	157.00	157.00	247.00	247.00	281.00
1983 - 84	134.00	201.00	212.00	218.00	220.00
1984 - 85	208.00	218.00	221.00	224.00	225.00
1985 - 86	148.00	272.00	277.00	278.00	278.00
1986 - 87	109.00	245.00	247.00	248.00	264.00

TABLE 4.36: ANNUAL MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: SAIGAON AVERAGE DAILY FLOW : 31.17 cumecs
PERIOD OF ANALYSIS : JUN 1968- MAY 1987

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1968 - 69	152.00	178.00	195.00	199.00	201.00
1969 - 70	135.00	160.00	165.00	184.00	184.00
1970 - 71	126.00	170.00	194.00	205.00	212.00
1971 - 72	146.00	174.00	190.00	202.00	204.00
1972 - 73	208.00	208.00	257.00	264.00	264.00
1973 - 74	96.00	98.00	188.00	188.00	203.00
1974 - 75	96.00	98.00	192.00	202.00	209.00
1975 - 76	111.00	152.00	172.00	181.00	193.00
1976 - 77	184.00	201.00	245.00	248.00	249.00
1977 - 78	87.00	88.00	168.00	171.00	171.00
1978 - 79	166.00	192.00	196.00	199.00	200.00
1979 - 80	101.00	167.00	176.00	180.00	180.00
1980 - 81	129.00	217.00	231.00	236.00	238.00
1981 - 82	139.00	197.00	202.00	209.00	209.00
1982 - 83	203.00	240.00	242.00	242.00	242.00
1983 - 84	101.00	147.00	195.00	205.00	207.00
1984 - 85	213.00	216.00	229.00	230.00	230.00
1985 - 86	226.00	232.00	233.00	233.00	234.00
1986 - 87	247.00	248.00	250.00	250.00	250.00

TABLE 4.37 MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: KARAD AVERAGE DAILY FLOW : 285.54 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967	256.34	2094.09	3723.48	5379.61	7035.75
1968	[illegible]	1400.66	2657.04	[illegible]	[illegible]
1969	338.36	2344.49	4201.61	7129.39	9756.36
1970	299.35	1098.07	1897.58	2738.77	7038.19
1971	38.01	1000.30	2270.21	3601.47	5281.38
1972	379.08	2743.28	5352.12	10318.93	14342.52
1973	106.62	800.13	1713.49	2684.33	4188.04
1974	192.13	1947.45	3832.01	5716.58	7601.14
1975	300.55	1309.45	2440.33	3525.38	4610.44
1976	220.33	1554.35	3033.62	4518.43	6003.24
1977	125.28	1055.53	2291.44	3949.33	5449.03
1978	147.66	990.63	1947.70	6788.68	9723.88
1979	299.33	1718.85	3146.55	4574.25	6001.95
1980	224.77	1593.24	4659.51	7716.72	10800.55
1981	210.59	1444.70	3239.17	5009.52	6779.87
1982	390.56	1428.98	5373.72	8924.96	12429.94
1983	153.94	1408.86	2897.23	4603.24	6370.87
1984	197.49	869.31	1687.85	4249.89	7898.86
1985	128.83	1029.60	2682.10	5262.70	12084.91
1986	160.54	1281.65	3912.32	10019.01	13928.55
1987	189.91	1654.01	3695.78	6156.17	8775.52

TABLE 4.38 MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: DHOND AVERAGE DAILY FLOW : 340.20 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1968	1088.63	4145.45	7272.31	10402.12	13531.93
1969	385.32	2662.26	4635.40	7951.20	10688.94
1970	360.83	1554.06	4593.64	6906.97	9220.31
1971	141.56	980.67	1875.18	2759.69	3960.58
1972	997.73	3552.56	6274.13	9678.12	12874.20
1973	539.27	2961.00	5591.03	8108.48	10625.94
1974	680.49	2486.59	4323.65	6170.98	9103.31
1975	95.98	1474.54	2954.25	4851.72	6952.68
1976	326.95	1852.97	4228.54	7021.48	9538.94
1977	274.91	1560.98	5886.31	9252.27	12654.23
1978	186.36	1841.93	3951.14	6124.10	8301.35
1979	412.15	2317.25	4222.35	6145.49	8166.30
1980	270.25	1732.30	3459.45	5347.75	7628.35
1981	171.08	1476.62	2936.55	6678.80	8856.05
1982	562.73	4530.96	8069.00	11607.04	15145.08
1983	659.99	3119.08	6148.52	9039.91	11965.59
1984	254.56	1555.30	4395.34	6572.60	8749.85
1985	425.76	2495.21	5818.41	13290.94	18523.10
1986	704.11	2901.22	5350.63	13694.98	18393.56
1987	517.16	2544.46	4449.56	8142.23	10727.72

TABLE 4.39: MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: NARSINGPUR AVERAGE DAILY FLOW : 407.78 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967	524.95	1974.17	6702.41	9698.50	16692.48
1968	309.91	1555.94	3631.08	7353.04	10778.42
1969	483.12	2283.60	5399.38	8580.10	11760.01
1970	175.06	2922.26	5858.31	8794.35	11730.39
1971	219.41	1630.77	3180.35	4729.92	8242.74
1972	1231.74	4086.23	7560.14	11148.64	14808.74
1973	489.85	2714.42	5324.34	8809.25	11908.40
1974	795.12	3123.22	5488.36	8992.85	11928.89
1975	184.25	1961.74	4135.57	6650.81	9251.98
1976	234.67	1862.68	4940.05	8734.23	12648.96
1977	454.07	1802.13	3345.54	4895.12	12157.59
1978	61.74	2113.98	5362.17	8705.99	12057.42
1979	1047.74	5624.56	9947.07	14699.12	19784.64
1980	453.38	1911.30	4210.56	6657.26	9103.96
1981	193.17	1794.87	4319.36	6766.06	9282.67
1982	1719.44	5715.72	9712.00	14047.63	19924.33
1983	696.20	4329.80	7592.08	10854.34	17241.49
1984	447.33	1833.80	3220.26	5297.62	7336.53
1985	1589.33	5369.35	9202.52	19988.65	26132.01
1986	802.66	3742.98	12279.45	17825.31	23371.17
1987	1814.80	9711.74	16848.37	37667.98	49004.32

TABLE 4.40: MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: TAKALI AVERAGE DAILY FLOW : 451.46 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967	566.10	2095.01	4375.50	6542.50	12684.93
1968	363.06	1802.71	5844.07	8823.69	11803.32
1969	521.20	2670.74	4928.03	7271.28	10618.58
1970	239.09	3380.73	6811.81	10242.90	13673.98
1971	174.02	1426.84	3098.16	6319.47	8757.34
1972	1561.90	4902.69	8243.48	11693.71	15634.96
1973	396.84	3004.33	5713.08	8421.83	11130.58
1974	596.00	3145.87	6480.28	9821.08	13161.87
1975	162.10	2479.18	5327.87	8381.62	12283.72
1976	316.02	1916.98	5262.22	9459.61	13839.62
1977	867.20	1787.18	3486.26	5225.32	7031.16
1978	81.88	1308.36	6500.76	10383.30	14265.85
1979	1608.79	6836.03	11711.78	17570.37	23439.33
1980	335.15	1838.29	5962.84	8852.17	11741.51
1981	150.93	995.08	2678.69	4554.24	6778.51
1982	1455.00	5902.50	10319.14	14992.28	19598.06
1983	1391.68	5153.58	8945.83	12812.41	20416.97
1984	349.01	2317.95	4123.79	5972.86	13181.26
1985	1276.93	5131.75	9185.62	13303.87	18687.74
1986	690.07	3936.13	7104.61	10355.11	13605.61
1987	985.29	3917.52	14656.71	35785.32	47523.24

TABLE 4.43: MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: T.RAMAPURAM AVERAGE DAILY FLOW : 46.25 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967	39.47	202.05	842.04	1450.44	2067.69
1968	17.75	421.86	839.08	1264.55	3186.40
1969	10.55	167.28	594.12	1077.26	1567.48
1970	10.10	148.56	312.72	1118.34	1580.81
1971	20.05	419.08	1295.02	2053.47	2811.92
1972	18.87	237.47	553.12	1693.03	2457.77
1973	4.52	66.54	345.83	601.84	1091.50
1974	22.15	389.34	794.36	1219.75	1645.22
1975	27.82	327.77	951.34	1441.56	1931.78
1976	42.15	203.03	665.80	1063.53	1736.62
1977	10.45	263.30	556.65	852.63	1582.88
1978	44.62	364.19	687.92	1011.65	1335.38
1979	53.89	570.20	1504.81	2337.26	3169.70
1980	82.34	422.81	1100.19	1797.56	2571.88
1981	32.90	265.60	715.56	1161.68	1658.91
1982	74.22	327.87	586.86	1463.61	2175.81
1983	59.54	470.18	920.25	1377.84	1840.31
1984	179.54	568.01	956.49	1344.96	1733.43
1985	150.94	736.95	1264.86	1801.33	2337.79
1986	120.04	550.03	966.26	1382.48	3256.60
1987	89.85	334.72	640.82	967.62	1300.60

TABLE 4.44 : MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: BAWAPURAM AVERAGE DAILY FLOW : 362.89 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1967	779.42	4039.47	7394.49	10805.64	14216.79
1968	849.69	3648.66	7060.73	10563.68	14119.99
1969	382.66	1326.17	8624.63	12959.90	17241.99
1970	45.86	1468.33	6204.38	10447.01	14996.39
1971	145.91	2618.00	6977.99	11042.34	15106.69
1972	152.41	1990.97	7716.51	13549.01	24463.98
1973	97.96	1133.40	5183.61	9117.21	13139.09
1974	948.42	3969.17	7893.91	16479.65	22213.29
1975	472.28	3670.73	7419.82	11048.71	14677.59
1976	678.52	4741.93	12936.29	18960.24	24984.19
1977	740.82	2622.60	4655.39	6780.16	15122.89
1978	614.53	4008.63	7202.05	10395.47	13588.89
1979	1113.90	5282.76	9274.54	17071.61	22369.79
1980	329.84	1543.87	3079.98	7869.82	10555.20
1981	898.69	3578.60	6475.18	9409.93	12458.19
1982	617.78	2237.20	4284.04	6316.22	11569.49
1983	562.11	3091.17	5628.15	8168.37	10729.29
1984	819.60	3754.07	6822.06	9870.33	12918.59
1985	1867.25	6133.93	0416.02	14698.10	23947.69
1986	1534.11	5695.90	9646.69	13757.36	19529.09
1987	866.04	2680.49	5200.75	7780.31	12441.74

TABLE 4.45 : MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: KARAD AVERAGE DAILY FLOW : 285.54 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	12.00	28.00	29.00	29.00	29.00
1968	9.00	25.00	28.00	37.00	38.00
1969	14.00	37.00	41.00	46.00	46.00
1970	12.00	16.00	18.00	19.00	48.00
1971	7.00	21.00	23.00	24.00	30.00
1972	20.00	40.00	46.00	67.00	71.00
1973	6.00	15.00	17.00	21.00	26.00
1974	8.00	33.00	33.00	33.00	33.00
1975	12.00	17.00	19.00	19.00	19.00
1976	19.00	25.00	26.00	26.00	26.00
1977	11.00	21.00	22.00	26.00	27.00
1978	14.00	19.00	20.00	51.00	52.00
1979	21.00	25.00	27.00	30.00	32.00
1980	18.00	28.00	53.00	54.00	54.00
1981	9.00	21.00	31.00	31.00	38.00
1982	16.00	25.00	54.00	61.00	62.00
1983	11.00	27.00	29.00	30.00	31.00
1984	11.00	13.00	15.00	37.00	46.00
1985	8.00	21.00	30.00	41.00	64.00
1986	10.00	25.00	36.00	68.00	69.00
1987	10.00	30.00	43.00	45.00	46.00

TABLE 4.46 : MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: DHOND AVERAGE DAILY FLOW : 340.20 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1968	32.00	45.00	46.00	46.00	46.00
1969	23.00	29.00	29.00	40.00	41.00
1970	17.00	18.00	34.00	34.00	34.00
1971	8.00	13.00	13.00	13.00	18.00
1972	36.00	40.00	40.00	46.00	47.00
1973	19.00	34.00	37.00	37.00	37.00
1974	25.00	27.00	27.00	29.00	34.00
1975	8.00	21.00	26.00	30.00	31.00
1976	18.00	25.00	32.00	37.00	37.00
1977	16.00	24.00	48.00	50.00	50.00
1978	13.00	31.00	31.00	32.00	32.00
1979	28.00	28.00	28.00	29.00	32.00
1980	18.00	22.00	27.00	28.00	32.00
1981	9.00	19.00	26.00	32.00	35.00
1982	22.00	52.00	52.00	52.00	52.00
1983	25.00	35.00	42.00	43.00	43.00
1984	8.00	17.00	32.00	32.00	32.00
1985	17.00	29.00	48.00	76.00	77.00
1986	26.00	36.00	36.00	69.00	70.00
1987	20.00	28.00	30.00	38.00	38.00

TABLE 4.47: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: MARSIMOUR - AVERAGE DAILY FLOW : 407.78
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	18.00	19.00	36.00	37.00	54.00
1968	9.00	24.00	27.00	42.00	42.00
1969	13.00	37.00	39.00	39.00	39.00
1970	11.00	36.00	36.00	36.00	36.00
1971	9.00	19.00	19.00	19.00	26.00
1972	35.00	41.00	44.00	44.00	45.00
1973	16.00	29.00	32.00	38.00	38.00
1974	27.00	29.00	29.00	36.00	36.00
1975	16.00	24.00	28.00	31.00	33.00
1976	15.00	25.00	43.00	48.00	48.00
1977	15.00	18.00	21.00	23.00	47.00
1978	6.00	25.00	41.00	41.00	42.00
1979	35.00	53.00	53.00	60.00	63.00
1980	15.00	20.00	30.00	30.00	30.00
1981	9.00	22.00	30.00	30.00	31.00
1982	49.00	49.00	49.00	52.00	62.00
1983	23.00	40.00	40.00	40.00	56.00
1984	17.00	17.00	23.00	25.00	25.00
1985	48.00	48.00	48.00	75.00	76.00
1986	25.00	36.00	68.00	68.00	68.00
1987	47.00	87.00	88.00	139.00	139.00

TABLE 4.48: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: TAKALI AVERAGE DAILY FLOW : 451.46 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	17.00	19.00	24.00	24.00	42.00
1968	10.00	19.00	33.00	36.00	38.00
1969	13.00	25.00	25.00	37.00	38.00
1970	15.00	38.00	38.00	38.00	38.00
1971	7.00	17.00	19.00	27.00	27.00
1972	37.00	40.00	42.00	43.00	44.00
1973	14.00	30.00	30.00	30.00	30.00
1974	24.00	31.00	37.00	37.00	37.00
1975	11.00	26.00	33.00	34.00	41.00
1976	14.00	26.00	45.00	48.00	49.00
1977	14.00	18.00	20.00	21.00	21.00
1978	8.00	15.00	43.00	43.00	43.00
1979	39.00	54.00	54.00	65.00	65.00
1980	12.00	21.00	32.00	32.00	32.00
1981	5.00	18.00	20.00	21.00	24.00
1982	37.00	48.00	49.00	51.00	52.00
1983	41.00	42.00	42.00	43.00	60.00
1984	10.00	20.00	21.00	22.00	44.00
1985	40.00	44.00	45.00	46.00	50.00
1986	20.00	34.00	36.00	36.00	36.00
1987	27.00	35.00	77.00	130.00	130.00

TABLE 4.49 : MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: WADAKWAL AVERAGE DAILY FLOW : 67.97 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	16.00	25.00	26.00	26.00	27.00
1968	29.00	35.00	37.00	43.00	43.00
1969	10.00	22.00	36.00	36.00	36.00
1970	6.00	9.00	21.00	21.00	35.00
1971	56.00	58.00	59.00	59.00	59.00
1972	55.00	72.00	99.00	99.00	99.00
1973	17.00	21.00	24.00	25.00	27.00
1974	21.00	31.00	32.00	34.00	35.00
1975	15.00	36.00	36.00	36.00	36.00
1976	30.00	52.00	54.00	60.00	60.00
1977	25.00	27.00	41.00	41.00	41.00
1978	7.00	31.00	32.00	66.00	66.00
1979	41.00	54.00	54.00	54.00	54.00
1980	10.00	42.00	57.00	59.00	59.00
1981	35.00	41.00	76.00	80.00	82.00
1982	59.00	66.00	88.00	88.00	113.00
1983	27.00	27.00	27.00	27.00	27.00
1984	44.00	44.00	44.00	53.00	54.00
1985	39.00	39.00	46.00	48.00	90.00
1986	50.00	86.00	87.00	90.00	90.00
1987	23.00	23.00	32.00	46.00	47.00

TABLE 4.50: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: YADGIR AVERAGE DAILY FLOW : 690.09 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	17.00	18.00	24.00	45.00	45.00
1968	14.00	20.00	35.00	35.00	43.00
1969	8.00	27.00	28.00	30.00	35.00
1970	3.00	35.00	38.00	38.00	41.00
1971	5.00	10.00	17.00	17.00	21.00
1972	40.00	40.00	40.00	41.00	58.00
1973	12.00	30.00	30.00	31.00	31.00
1974	3.00	13.00	30.00	30.00	37.00
1975	6.00	25.00	30.00	44.00	44.00
1976	10.00	23.00	36.00	45.00	46.00
1977	10.00	15.00	18.00	20.00	21.00
1978	6.00	18.00	23.00	29.00	29.00
1979	36.00	36.00	58.00	58.00	68.00
1980	7.00	19.00	25.00	34.00	34.00
1981	8.00	9.00	12.00	17.00	19.00
1982	35.00	38.00	40.00	40.00	40.00
1983	24.00	24.00	24.00	24.00	24.00
1984	24.00	24.00	25.00	33.00	38.00
1985	15.00	41.00	42.00	43.00	52.00
1986	23.00	30.00	35.00	55.00	59.00
1987	18.00	40.00	44.00	59.00	71.00

TABLE 4.51: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: T.RAMAPURAM AVERAGE DAILY FLOW : 46.25 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	15.00	25.00	57.00	65.00	67.00
1968	14.00	44.00	46.00	46.00	90.00
1969	6.00	20.00	52.00	53.00	53.00
1970	11.00	17.00	22.00	50.00	50.00
1971	10.00	51.00	82.00	82.00	82.00
1972	11.00	32.00	35.00	69.00	75.00
1973	2.00	10.00	30.00	34.00	36.00
1974	10.00	41.00	45.00	46.00	46.00
1975	17.00	36.00	53.00	53.00	53.00
1976	10.00	26.00	43.00	43.00	64.00
1977	10.00	31.00	32.00	32.00	53.00
1978	17.00	35.00	35.00	35.00	35.00
1979	28.00	54.00	90.00	90.00	90.00
1980	30.00	42.00	72.00	75.00	80.00
1981	16.00	27.00	41.00	45.00	50.00
1982	25.00	28.00	31.00	77.00	77.00
1983	26.00	47.00	49.00	50.00	50.00
1984	42.00	42.00	42.00	42.00	42.00
1985	34.00	56.00	58.00	60.00	60.00
1986	30.00	45.00	45.00	45.00	90.00
1987	24.00	31.00	34.00	36.00	36.00

TABLE 4.52: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: BAWAPURAM AVERAGE DAILY FLOW : 362.89 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1967	25.00	46.00	47.00	47.00	47.00
1968	28.00	46.00	48.00	49.00	49.00
1969	13.00	14.00	57.00	59.00	59.00
1970	4.00	26.00	58.00	59.00	62.00
1971	8.00	39.00	56.00	56.00	56.00
1972	10.00	31.00	79.00	82.00	100.00
1973	4.00	18.00	52.00	55.00	56.00
1974	34.00	43.00	52.00	79.00	79.00
1975	20.00	41.00	50.00	50.00	50.00
1976	33.00	53.00	83.00	83.00	83.00
1977	25.00	27.00	29.00	30.00	54.00
1978	24.00	44.00	44.00	44.00	44.00
1979	36.00	55.00	55.00	73.00	73.00
1980	14.00	19.00	22.00	37.00	37.00
1981	28.00	36.00	40.00	42.00	42.00
1982	20.00	24.00	28.00	28.00	40.00
1983	17.00	34.00	35.00	35.00	36.00
1984	27.00	40.00	42.00	42.00	42.00
1985	58.00	59.00	59.00	59.00	79.00
1986	44.00	54.00	56.00	57.00	63.00
1987	25.00	27.00	33.00	37.00	47.00

TABLE 4.53: MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: ASHWI AVERAGE DAILY FLOW : 20.70 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1972	96.05	298.91	659.05	1454.92	1914.46
1973	31.39	101.77	177.10	298.25	401.75
1974	54.16	249.93	591.10	839.50	1087.90
1975	60.17	188.51	316.85	445.19	813.05
1976	46.63	166.69	320.95	534.84	738.44
1977	71.88	259.36	451.15	649.62	851.47
1978	68.46	225.78	489.70	696.70	924.09
1979	61.60	203.04	446.55	632.85	1153.15
1980	53.74	192.54	333.30	474.06	617.55
1981	66.24	198.72	331.20	463.68	596.16
1982	106.15	333.85	561.55	814.09	1066.63
1983	65.01	282.14	485.00	687.86	890.72
1984	97.68	296.40	495.12	693.84	892.56
1985	153.73	481.30	813.45	1148.79	1485.96
1986	73.26	230.58	389.85	680.92	879.64

TABLE 4.54: MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: CHASS AVERAGE DAILY FLOW : 112.67 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1972	495.46	1586.77	3191.30	4649.35	6136.64
1973	274.82	1191.98	2048.30	2904.61	3765.14
1974	299.02	925.26	3530.90	5071.73	7032.57
1975	491.50	1528.09	2564.69	3601.29	4637.88
1976	301.02	1041.57	1857.96	2725.29	3937.09
1977	400.39	1339.79	2335.55	3372.83	4454.50
1978	405.03	1512.90	2632.54	3790.51	5026.65
1979	405.03	1512.90	2632.54	3790.51	5026.65
1980	227.82	1150.89	2370.55	3598.43	4837.84
1981	357.36	1078.47	1799.58	2520.69	3241.80
1982	832.73	2545.36	4258.00	5970.64	7702.58
1983	28.64	664.76	1290.83	1921.80	3436.25
1984	191.98	1364.98	2446.64	3528.31	4609.98
1985	663.40	2038.01	3412.63	4787.25	7012.47
1986	725.61	2251.74	3790.43	5347.00	6924.44

TABLE 4.55 MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: KARODI AVERAGE DAILY FLOW : 61.48 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1968	184.44	553.31	922.18	1305.86	1711.61
1969	128.61	386.82	645.03	1008.63	1450.81
1970	11.70	78.72	257.91	553.81	873.50
1971	290.29	986.33	2285.92	3299.91	4386.12
1972	135.87	678.64	1296.70	2197.04	2992.70
1973	83.07	255.21	427.35	1212.15	1581.02
1974	169.64	513.92	1146.60	1773.69	3085.57
1975	98.37	295.10	491.83	688.56	885.29
1976	153.70	463.63	945.61	1498.88	2102.44
1977	79.92	252.68	474.01	810.94	1107.34
1978	49.18	211.41	541.00	885.28	2258.31
1979	122.96	368.87	614.79	871.89	1263.38
1980	72.17	400.19	908.75	1435.51	1984.22
1981	121.74	450.82	1292.93	1895.42	2501 24
1982	238.87	718.40	1903.31	3896.77	5114.05
1983	129.96	457.00	788.98	1120.97	1452.95
1984	219.85	1979.25	3602.29	5225.32	6848.36
1985	128.60	881.38	1692.89	2504.41	3540.97
1986	116.99	754.87	1448.93	2298.05	3160.98

TABLE 4.56: MAXIMUM DEFICIENCY VOLUME OF LOW FLOW SPELLS

SITE: SAIGAON AVERAGE DAILY FLOW : 68.66 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	VOLUME IN CUMEC DAYS AT % ADF 10%	30%	50%	70%	90%
1968	101.98	490.39	967.57	1456.22	1950.54
1969	56.55	374.62	713.82	1071.39	1442.13
1970	30.26	285.44	745.91	1153.07	1565.00
1971	365.24	1158.71	1968.24	3748.37	4860.59
1972	274.29	882.52	1648.21	2362.23	5051.88
1973	103.71	440.45	783.72	1208.55	1619.60
1974	105.88	526.10	1738.99	2549.12	3359.26
1975	68.66	276.35	509.00	777.64	1065.99
1976	70.4[illegible]	484.68	990.96	1754.38	2497.35
1977	120.88	421.62	737.44	1273.14	2540.59
1978	34.56	193.56	784.36	1328.96	2992.64
1979	153.74	623.78	1776.30	2517.78	3259.26
1980	323.87	1007.01	1803.41	2609.37	3419.51
1981	158.44	667.77	1203.08	1738.60	4324.95
1982	312.21	1190.49	2090.93	2997.19	3903.44
1983	185.37	556.11	926.85	1297.59	1668.33
1984	248.72	839.16	1570.78	2353.46	3167.21
1985	159.10	1060.11	1854.01	2656.17	5680.72
1986	283.15	1264.79	2116.12	2967.45	3818.78

TABLE 4.57: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: ASHWI AVERAGE DAILY FLOW : 20.70 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1972	49.00	49.00	68.00	111.00	111.00
1973	17.00	17.00	20.00	25.00	25.00
1974	28.00	43.00	60.00	60.00	60.00
1975	31.00	31.00	31.00	31.00	45.00
1976	29.00	29.00	39.00	46.00	48.00
1977	44.00	46.00	47.00	48.00	49.00
1978	38.00	38.00	50.00	50.00	53.00
1979	30.00	34.00	45.00	45.00	65.00
1980	32.00	34.00	34.00	34.00	35.00
1981	32.00	32.00	32.00	32.00	32.00
1982	55.00	55.00	55.00	61.00	61.00
1983	33.00	49.00	49.00	49.00	49.00
1984	48.00	48.00	48.00	48.00	48.00
1985	79.00	80.00	81.00	81.00	82.00
1986	38.00	38.00	39.00	48.00	48.00

TABLE 4.58: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: CHASS AVERAGE DAILY FLOW : 112.67 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1972	47.00	49.00	64.00	66.00	66.00
1973	30.00	38.00	38.00	38.00	39.00
1974	27.00	28.00	68.00	69.00	77.00
1975	46.00	46.00	46.00	46.00	46.00
1976	30.00	35.00	37.00	39.00	47.00
1977	40.00	43.00	45.00	48.00	48.00
1978	39.00	49.00	50.00	52.00	57.00
1979	39.00	49.00	50.00	52.00	57.00
1980	24.00	42.00	53.00	55.00	55.00
1981	32.00	32.00	32.00	32.00	32.00
1982	76.00	76.00	76.00	76.00	77.00
1983	10.00	27.00	28.00	28.00	41.00
1984	23.00	48.00	48.00	48.00	48.00
1985	61.00	61.00	61.00	61.00	77.00
1986	67.00	68.00	69.00	70.00	70.00

TABLE 4.59: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: KARODI AVERAGE DAILY FLOW : 61.48 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1968	30.00	30.00	30.00	33.00	62.00
1969	21.00	21.00	33.00	35.00	36.00
1970	2.00	14.00	18.00	26.00	26.00
1971	50.00	58.00	82.00	83.00	85.00
1972	39.00	49.00	51.00	64.00	65.00
1973	14.00	15.00	20.00	30.00	30.00
1974	28.00	31.00	51.00	51.00	61.00
1975	16.00	16.00	17.00	20.00	21.00
1976	25.00	37.00	44.00	48.00	50.00
1977	14.00	21.00	23.00	24.00	25.00
1978	8.00	17.00	28.00	28.00	59.00
1979	20.00	22.00	30.00	31.00	32.00
1980	20.00	32.00	42.00	43.00	43.00
1981	26.00	28.00	49.00	49.00	50.00
1982	39.00	39.00	69.00	99.00	99.00
1983	26.00	27.00	27.00	27.00	27.00
1984	45.00	132.00	132.00	32.00	132.00
1985	25.00	66.00	66.00	66.00	77.00
1986	29.00	52.00	67.00	70.00	71.00

TABLE 4.60: MAXIMUM DURATION OF LOW FLOW SPELLS

SITE: SAIGAON AVERAGE DAILY FLOW : 68.66 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD: YEAR	DURATION IN DAYS AT % ADF 10%	30%	50%	70%	90%
1968	21.00	34.00	35.00	36.00	36.00
1969	16.00	24.00	29.00	34.00	37.00
1970	7.00	19.00	29.00	30.00	30.00
1971	57.00	58.00	59.00	81.00	81.00
1972	43.00	45.00	52.00	52.00	87.00
1973	21.00	25.00	25.00	28.00	30.00
1974	18.00	30.00	59.00	59.00	59.00
1975	10.00	16.00	18.00	21.00	21.00
1976	21.00	36.00	38.00	54.00	55.00
1977	21.00	25.00	26.00	33.00	51.00
1978	10.00	18.00	38.00	40.00	66.00
1979	25.00	36.00	54.00	54.00	54.00
1980	53.00	58.00	58.00	59.00	59.00
1981	28.00	38.00	39.00	39.00	75.00
1982	49.00	62.00	66.00	66.00	66.00
1983	27.00	27.00	27.00	27.00	27.00
1984	43.00	43.00	57.00	57.00	59.00
1985	29.00	57.00	58.00	59.00	98.00
1986	42.00	62.00	62.00	62.00	62.00

TABLE 4.61 DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : KARAD AVERAGE DAILY FLOW : 285.54 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF				
	10%	30%	50%	70%	90%
1967	21.36	74.78	128.39	185.50	242.61
1968	19.78	56.02	94.89	121.71	209.37
1969	24.16	63.36	102.47	154.98	212.09
1970	24.94	68.62	105.42	144.14	159.95
1971	15.43	47.63	98.70	150.06	176.04
1972	18.95	68.58	116.35	154.01	202.00
1973	17.77	53.34	100.79	127.82	161.07
1974	24.01	59.01	116.12	173.22	230.33
1975	25.04	77.02	128.43	185.54	242.65
1976	11.59	62.17	116.67	173.78	230.89
1977	11.38	50.26	104.15	151.89	201.81
1978	10.54	52.13	97.38	133.11	186.99
1979	14.25	68.75	116.53	152.47	187.56
1980	12.48	56.90	87.91	142.90	200.01
1981	23.39	68.79	104.48	161.59	178.41
1982	24.41	57.15	99.51	146.31	200.48
1983	13.99	52.18	99.90	153.44	205.51
1984	17.95	66.87	112.52	114.86	171.71
1985	16.10	49.02	89.40	128.35	188.82
1986	16.05	51.26	108.67	147.33	201.86
1987	18.99	55.13	85.94	136.80	190.77

TABLE 4.62 DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : DHOND AVERAGE DAILY FLOW : 340.20 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF				
	10%	30%	50%	70%	90%
1968	34.01	92.12	158.09	226.13	294.16
1969	16.75	91.80	159.84	198.78	260.70
1970	21.22	86.33	135.10	203.14	271.18
1971	17.69	76.20	144.24	212.28	220.03
1972	27.71	88.81	156.85	210.39	273.91
1973	28.38	87.08	151.10	219.14	287.18
1974	27.21	92.09	160.13	212.79	267.74
1975	11.99	70.21	114.77	161.72	224.28
1976	18.16	74.11	132.14	189.76	257.80
1977	17.18	65.04	122.63	185.04	253.08
1978	14.33	59.41	127.45	191.37	259.41
1979	14.71	82.75	150.79	211.91	255.19
1980	15.01	78.74	128.12	190.99	238.38
1981	19.00	77.71	112.94	208.71	253.03
1982	25.57	87.13	155.17	223.21	291.25
1983	26.39	89.11	146.39	210.23	278.26
1984	31.82	91.48	137.35	205.39	273.43
1985	25.04	86.04	117.05	174.88	240.55
1986	27.08	80.58	148.62	198.47	262.76
1987	25.85	90.87	148.31	214.26	282.30

TABLE 4.63 : DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : NARSINGPUR AVERAGE DAILY FLOW : 407.78 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF 10%	30%	50%	70%	90%
1967	29.16	103.90	42.56	262.12	309.12
1968	34.43	64.83	134.48	175.07	256.62
1969	37.16	61.71	138.44	220.00	301.55
1970	15.91	81.17	162.73	244.28	325.84
1971	24.37	85.83	167.38	248.94	317.02
1972	35.19	99.66	171.82	253.37	329.08
1973	30.61	93.60	166.38	231.82	313.37
1974	29.44	107.69	189.25	249.78	331.35
1975	11.51	81.73	147.69	214.54	280.36
1976	15.64	74.50	114.88	191.96	263.52
1977	30.27	100.11	159.31	212.83	258.67
1978	10.29	84.55	130.78	212.34	287.08
1979	29.93	106.12	187.68	244.98	314.04
1980	30.22	95.56	140.35	221.90	303.46
1981	21.46	81.58	143.97	225.53	299.44
1982	35.09	116.64	198.20	270.14	321.36
1983	30.26	108.24	189.80	271.35	307.88
1984	26.31	107.87	140.01	211.90	293.46
1985	33.11	111.86	191.71	266.51	343.84
1986	32.10	103.97	180.59	262.13	343.69
1987	38.61	111.62	191.45	270.99	352.54

TABLE 4.64 : DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : TAKALI AVERAGE DAILY FLOW : 451.46 cumecs
BASE PERIOD : 1st June - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF 10%	30%	50%	70%	90%
1967	33.3	110.26	182.31	272.60	302.00
1968	36.30	94.87	177.09	245.10	310.61
1969	40.09	106.82	197.12	196.52	279.43
1970	15.93	88.96	179.25	269.55	359.84
1971	24.86	83.93	163.06	234.05	324.34
1972	42.21	122.56	196.27	271.94	355.34
1973	28.34	100.14	190.43	280.72	371.01
1974	24.83	101.47	175.14	265.43	331.99
1975	14.73	95.35	161.45	246.51	299.60
1976	22.57	73.73	116.93	197.07	282.44
1977	27.65	99.28	174.31	248.82	334.81
1978	10.23	87.22	151.18	241.47	331.76
1979	41.25	126.59	216.88	270.31	360.60
1980	27.92	87.53	186.33	276.63	366.92
1981	30.18	55.28	133.93	216.86	282.43
1982	39.32	122.96	210.59	293.96	376.88
1983	33.94	122.70	212.99	297.96	340.28
1984	34.90	115.89	196.37	271.49	299.57
1985	31.92	116.63	204.12	289.21	373.75
1986	34.50	115.76	197.35	287.64	377.93
1987	36.49	111.92	190.34	275.27	365.56

TABLE 4.67 DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : WADAKWAL AVERAGE DAILY FLOW : 67.97 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF 10%	30%	50%	70%	90%
1967	6.74	15.83	28.62	42.22	54.04
1968	2.93	15.34	27.75	40.64	54.24
1969	4.62	11.83	25.20	38.80	52.39
1970	2.89	13.45	21.68	35.27	44.31
1971	5.68	18.92	32.11	45.70	59.30
1972	6.00	18.92	31.91	45.50	59.10
1973	4.03	16.06	27.21	39.41	50.68
1974	3.25	13.55	26.71	38.61	50.92
1975	4.60	17.01	30.60	44.19	57.79
1976	5.06	15.94	28.68	38.04	52.38
1977	5.24	18.22	26.58	40.17	53.77
1978	2.18	10.42	24.30	36.68	50.27
1979	6.74	19.59	33.18	46.77	60.37
1980	2.20	12.26	24.85	37.43	51.02
1981	5.84	18.85	31.35	43.52	56.57
1982	6.13	19.21	30.45	44.04	57.50
1983	6.52	20.12	33.71	47.30	60.90
1984	6.79	20.39	33.98	54.22	57.62
1985	6.07	19.66	31.81	44.48	57.03
1986	6.23	19.32	32.55	45.66	59.25
1987	6.77	20.36	28.33	36.83	49.63

TABLE 4.68 DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : YADGIR AVERAGE DAILY FLOW : 690.09 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF 10%	30%	50%	70%	90%
1967	64.48	191.25	242.57	393.36	531.38
1968	64.07	152.86	259.52	397.54	506.35
1969	46.27	139.80	269.75	380.58	452.21
1970	11.77	106.90	235.44	373.46	497.08
1971	25.80	117.89	204.40	342.42	431.30
1972	56.94	194.95	332.97	459.50	420.00
1973	63.25	167.14	305.16	428.91	566.92
1974	14.61	101.44	189.11	327.12	430.16
1975	54.54	122.13	231.43	335.18	473.20
1976	68.41	90.67	177.16	271.95	403.43
1977	52.12	150.15	248.89	354.03	469.97
1978	11.44	106.61	210.15	305.06	443.08
1979	49.59	165.29	311.82	449.84	538.12
1980	56.60	118.55	225.08	331.79	469.81
1981	56.00	172.46	221.36	224.58	331.11
1982	35.76	138.41	270.88	408.90	546.92
1983	53.34	191.36	329.37	467.39	605.41
1984	60.00	198.02	326.48	357.41	546.11
1985	49.30	127.35	261.84	392.95	543.25
1986	46.65	164.78	263.95	396.47	503.13
1987	69.00	126.36	234.50	322.12	509.65

TABLE 4.67 DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : T. RAMAPURAM AVERAGE DAILY FLOW : 46.25 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	10%	DROUGHT 30%	INTENSITY IN 50%	CUMEC AT % ADF 70%	90%
1967	2.63	8.08	14.77	22.31	30.86
1968	1.26	9.58	18.24	27.49	35.40
1969	1.75	8.36	11.42	20.32	29.57
1970	0.91	8.73	14.21	22.36	31.61
1971	2.00	8.21	15.79	25.04	34.29
1972	1.71	7.42	15.80	24.53	32.77
1973	2.26	6.65	11.52	17.70	30.31
1974	2.21	9.49	17.65	26.51	35.76
1975	1.63	9.10	17.94	27.19	36.44
1976	4.21	7.80	15.48	24.73	27.13
1977	1.04	8.49	17.39	26.64	29.86
1978	2.62	10.40	19.65	28.90	38.15
1979	1.92	10.55	16.72	25.96	35.21
1980	2.74	10.06	15.28	23.96	32.14
1981	2.05	9.83	17.45	25.81	33.17
1982	2.96	11.70	18.93	19.00	28.25
1983	2.29	10.00	18.78	27.55	36.80
1984	4.27	13.52	22.77	32.02	41.27
1985	4.43	13.15	21.80	30.02	38.96
1986	4.00	12.22	21.47	30.72	36.18
1987	3.74	10.79	18.84	26.87	36.12

TABLE 4.68 :DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : BAWAPURAM AVERAGE DAILY FLOW : 362.89 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	10%	DROUGHT 30%	INTENSITY 50%	IN CUMEC AT 70%	% ADF 90%
1967	31.17	87.81	157.32	229.90	302.48
1968	30.34	79.31	147.09	215.58	288.16
1969	29.43	94.72	151.30	219.65	292.23
1970	11.46	56.47	106.97	177.06	241.97
1971	18.23	67.12	124.60	197.18	269.76
1972	15.24	64.22	97.67	165.23	244.63
1973	24.49	62.96	99.68	165.76	234.62
1974	27.89	92.30	151.80	208.60	281.18
1975	23.61	89.53	148.39	220.97	293.55
1976	20.56	89.47	155.85	228.43	301.01
1977	29.63	97.13	160.53	226.00	280.05
1978	25.60	91.10	163.68	236.26	308.83
1979	30.94	96.05	168.62	233.85	306.43
1980	23.56	81.25	139.99	212.69	285.27
1981	32.09	99.40	161.87	224.04	296.62
1982	30.88	93.21	153.00	225.57	289.23
1983	33.06	90.91	160.80	233.38	298.03
1984	30.35	93.95	162.43	235.00	307.58
1985	32.19	103.96	176.84	249.12	303.13
1986	34.86	105.47	172.26	247.35	309.09
1987	34.64	99.27	157.59	210.27	264.71

of previous three to four years, indicated that all the sites during 1985-87 were affected by the drought conditions.

Drought intensity as a ratio of maximum deficit volume to maximum deficit duration has also worked out for the selected sites of Godavari basin. The results of drought intensity for the sites of Godavari basin are given in Table 4.69 to 4.72. The values of drought intensity for the year 1985-86 and 1986-87 are comparable. Also, barring a few cases, these values are higher for 1985-86 and 1986-87 than those of previous years indicating that during 1985-87 all selected sites were subjected to drought conditions.

4.6 Analysis of Annual Maximum Drought Volume and Duration

In the analysis of flow duration curve the percentage of time that any flow is equaled or exceeded can be found out However, since all flows are lumped together in such a curve without regard to time sequence of occurrence the extent of remedial measures required to deal with the problem can not be assessed in this way. It is for this purpose analysis of drought volume is required. A drought volume can be defined with reference to some demand level as the storage volume required at the beginning of drought incident to prevent flow from falling below the demand level for the duration of the drought. The computation for working out annual maximum drought volume & duration for Narsingpur site at 10% ADF level for year 1987-88 are shown in Table 4.73. As can be seen for each spell of deficit flow a series of flow values are generated by summing the deficit and surplus volumes. As soon as negative value of summation is obtained, the drought spell is taken to be discontinued. Similar analysis is carried out for next spell of deficit/surplus volume. The maximum deficit volume of all spells and its duration is taken as the maximum drought volume for the period of analysis. As shown in Table 4.73 the first drought spell has a maximum drought volume of 796.73 cumec days and the corresponding duration of 47 days. The next spell was identified with the drought volume of 900.77 cumec days and corresponding duration of 90 days. The third spell during the period had drought volume of 3352.45 cumec days with a drought duration of 220 days. Therefore, in the entire period of analysis during 1987-88 the maximum annual drought volume was found as 3352.45 cumec days with the corresponding drought duration of 220 days. This implies that in the beginning of this drought spell an extra storage of 3352.45 cumec days will be required for preventing the flow from falling below the demand level of 10% ADF for 220 days. Similar analysis was attempted at various demand levels and various sites of Krishna and Godavari basin. The maximum drought volume at various demand levels for three years in case of Krishna basin (1985-86 to 1987-88) and two years for Godavari basin (1985-87) are given in Table 4.74 and 4.75 respectively.The corresponding duration are listed in Table 4.76 and 4.77.

In order to see the relative intensities of drought,ratio of maximum drought volume and corresponding duration have been worked out. These are shown in Table 4.78 as can be seen from the Table that Karad, Bawapuram and T. Ramapuram sites have higher values of drought intensity in the year 1987-88 in comparison to previous years value. It is also evident that the values for the years 1985-86, 1986-87 and 1987-88 are comparable at all demand levels, which indicates that during all the years drought was dominated at all selected sites. The drought intensity also determined for the selected sites of Godavari basin given in Table 4.79.

All the sites of Godavari basin have higher drought intensity in the year 1985-86 in comparison to that of year 1985-86

TABLE 4.69 DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS

SITE : ASHWI AVERAGE DAILY FLOW : 20.70 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	DROUGHT INTENSITY IN CUMEC AT % ADF				
	10%	30%	50%	70%	90%
1972	1.96	6.10	9.69	13.10	17.24
1973	1.84	5.98	8.85	11.93	16.07
1974	1.93	5.81	9.85	13.99	18.13
1975	1.94	6.08	10.22	14.36	18.06
1976	1.60	5.74	8.22	11.62	15.38
1977	1.63	5.63	9.59	13.93	17.37
1978	1.80	5.94	9.79	13.93	17.43
1979	2.05	5.97	9.92	14.06	17.74
1980	1.67	5.66	9.80	13.94	17.64
1981	2.07	6.21	10.35	14.49	18.63
1982	1.93	6.07	10.21	13.34	17.48
1983	1.97	5.75	9.89	14.03	18.17
1984	2.03	6.17	10.31	14.45	18.59
1985	1.94	6.01	10.04	14.18	18.12
1986	1.92	6.06	9.99	14.18	18.32

TABLE 4.70 : DROUGHT INTENSITY IN DIFFERENT LOW FLOW SPELLS
SITE : CHASS AVERAGE DAILY FLOW : 112.67 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

Period Year	Drought Intensity in Cumec at % ADF				
	10%	30%	50%	70%	90%
1972	10.54	32.88	49.86	70.44	92.97
1973	9.16	31.36	53.90	76.43	96.54
1974	11.07	33.04	51.92	73.50	91.33
1975	10.98	33.21	52.75	73.26	100.82
1976	10.03	29.75	50.21	69.97	83.76
1977	10.00	31.15	51.90	70.26	92.80
1978	10.38	30.87	52.65	72.89	88.18
1979	10.38	30.87	52.65	72.89	88.18
1980	9.19	27.40	44.72	65.42	87.96
1981	11.16	33.70	56.23	73.77	101.30
1982	10.95	33.49	56.02	70.56	100.03
1983	2.36	24.62	46.10	68.63	83.81
1984	8.34	28.43	50.97	73.50	96.24
1985	10.87	33.41	52.94	72.47	91.07
1986	10.83	33.11	54.93	76.38	93.92

Table 4.71 : Drought intensity in different low flow spells

Site: Kurlodi Average Daily Flow : 61.48 cumecs
Base period : 1st June - 31st October

Period Year	10%	Drought 30%	Intensity in 50%	Cumec at 70%	ADF 90%
1968	6.14	18.44	30.73	39.57	27.60
1969	6.12	18.42	19.54	28.81	40.30
1970	5.85	5.62	14.32	21.30	33.59
1971	5.80	17.00	27.87	39.75	51.60
1972	3.43	13.84	25.42	34.32	46.04
1973	5.93	17.01	21.30	40.40	52.70
1974	6.05	16.57	22.48	34.77	50.52
1975	6.14	18.44	28.93	34.42	42.15
1976	6.14	12.53	21.49	31.22	40.04
1977	5.70	12.03	20.60	33.78	44.29
1978	6.14	12.43	19.32	31.61	38.27
1979	6.14	16.76	26.49	28.12	39.48
1980	3.60	12.50	21.63	35.38	45.67
1981	4.98	16.10	26.38	38.68	50.02
1982	5.12	14.42	27.58	39.36	51.68
1983	4.99	16.92	29.22	41.51	53.81
1984	4.88	14.99	27.29	39.58	51.88
1985	5.14	15.35	25.64	37.94	45.98
1986	4.03	14.51	21.62	32.82	44.52

Table 4.72 : Drought intensity in different low flow spells

SITE : SAIGAON AVERAGE DAILY FLOW : 68,66 cumecs
BASE PERIOD : 1st JUNE - 31st OCTOBER

PERIOD YEAR	10%	DROUGHT 30%	INTENSITY 50%	IN CUMEC AT % ADF 70%	90%
1968	4.85	14.42	27.64	40.45	54.18
1969	3.53	15.60	24.61	31.51	38.97
1970	4.32	15.02	25.72	38.43	52.16
1971	6.40	19.97	33.36	46.27	60.00
1972	6.37	19.61	31.69	45.42	58.06
1973	4.93	17.61	31.34	43.16	53.98
1974	5.88	17.53	29.47	43.05	56.93
1975	6.86	17.27	28.27	37.03	45.40
1976	3.35	13.46	26.07	32.48	49.81
1977	5.75	16.86	28.36	38.58	45.34
1978	3.45	10.75	20.64	40.27	45.34
1979	6.14	17.32	32.89	62.94	60.35
1980	4.22	17.36	31.09	48.32	57.95
1981	5.65	17.57	30.84	29.46	57.66
1982	6.37	19.20	31.68	45.41	59.14
1983	6.86	20.59	34.32	48.05	61.79
1984	5.78	19.51	27.55	41.28	53.68
1985	5.48	18.59	31.96	45.01	57.96
1986	6.74	20.39	34.13	47.86	61.59

Table No.4.73 Computation of annual maximum volume and duration for Narsinghpur at 10% ADF for year 1987-88

Date	Days below	Days	Drought	Net deficit at end of each component cumec-days	Drought volume	Maximum drought duration (days)
1 June						
		29				
29 June			-517.49	517.49		
		1				
30 June			- 6.14	511.08		
		17				
17 July			-275.65	-786.73		
		6				
23 July			907.82	-121.09	786.73	47
		15				
8 August			-242.00	242.00		
		2				
10 August			46.70	195.30		
		1				
11 August			-5.13	200.43		
		1				
12 August			10.37	190.06		
		6				
18 August			- 75.66	265.72		
		2				
20 August			90.11	175.61		
		45				
4 October			-725.16	900.77		
		6				
10 October			270.08	630.69		
		8				
18 October			-108.42	739.11		
		7				
25 October			992.04	-252.93	900.77	
		4				
29 October			- 26.27	26.27		
		1				
30 October			1.23	25.04		
		21				
20 November			-346.63	371.67		
		1				
21 November			2.66	369.01		
		22				
13 December			-308.29	677.30		
		4				
17 December			130.13	547.17		
		167				
31 May			-2805.28	3352.45	3352.45	220

Table 4.74 : Maximum drought volume for the selected sites of Krishna basin during 1985-88.

Site	Year	Maximum Drought Volume in cumec-day at % ADF 10%	30%	50%	70%	90%
Karad	1985-86	108.35	1084.49	7360.68	14713.80	22269.37
	1986-87	122.87	1244.41	7780.38	15402.03	23083.45
	1987-88	142.77	2171.98	8074.82	15279.51	22713.00
Dhond	1985-86	2639.71	9605.32	17136.7	25927.23	34749.57
	1986-87	2787.36	10092.03	18544.56	27128.75	35750.72
	1987-88	2662.55	9419.96	16382.21	24712.81	35520.86
Narsingpur	1985-86	2249.91	12910.01	23716.55	34889.44	45340.84
	1986-87	4018.56	14134.06	24700.70	35286.02	45871.31
	1987-88	3352.45	16814.97	30651.48	44488.00	58324.52
Takali	1985-86	4406.16	14875.85	26836.20	38816.58	50821.58
	1986-87	4283.49	14541.55	25081.56	36822.56	48573.93
	1987-88	3038.54	10155.49	25188.99	40660.05	56131.24
Yadgir	1985-86	5849.36	20601.81	35738.27	52385.59	71057.96
	1986-87	5772.13	21343.93	37234.65	53266.41	70341.62
	1987-88	4250.19	14676.78	26946.03	43292.28	67526.63
Wadakwal	1985-86	689.65	2207.12	3749.50	6045.47	8461.09
	1986-87	692.40	2304.52	3925.33	5909.00	8191.36
	1987-88	453.62	1627.61	3062.32	4507.18	5955.99
Bawapuram	1985-86	2762.83	10929.42	19166.84	30902.60	43927.87
	1986-87	2882.13	9871.61	16981.91	25156.14	33800.02
	1987-88	2470.98	8288.41	14862.08	21863.94	29634.11
T.Ramapuram	1985-86	227.26	926.54	1680.87	3537.54	5636.52
	1986-87	248.51	964.64	1734.20	2649.72	3727.23
	1987-88	261.16	1046.40	1965.46	2959.69	4051.29

Table 4.75 : Maximum drought volume for the selected sites of Godavari basin during 85-88.

Site	Year	Maximum Drought Volume in cumec-day at % ADF 10%	30%	50%	70%	90%
Ashwi	1985-86	237.25	775.35	1274.23	1924.08	2573.93
	1986-87	205.15	660.34	1176.64	1722.78	2372.63
Chass	1985-86	1105.18	3544.54	6314.53	9116.27	12146.69
	1986-87	1339.66	4056.13	6786.68	9520.07	12253.50
Karodi	1985-86	244.33	1590.55	3071.08	4566.77	6063.52
	1986-87	354.71	1650.70	2974.29	4423.24	5911.28
Saigoan	1985-86	697.42	2127.24	3576.67	5569.32	7844.62
	1986-87	766.27	2918.17	5193.49	7468.82	9744.14

Table 4.76 : Maximum Drought Duration for the selected sites of Krishna basin during 1985-88

Site	Year	Maximum Drought Duration in day at % ADF 10%	30%	50%	70%	90%
Karad	1985-86	12	224	228		273
	1986-87	11	204	274	276	278
	1987-88	15	204	218	267	269
Dhond	1985-86	222	227	283	284	285
	1986-87	228	239	277	277	279
	1987-88	218	219	268	270	365
Narsingpur	1985-86	282	285	286	286	286
	1986-87	244	279	280	280	280
	1987-88	220	365	365	365	365
Takali	1985-86	228	282	283	284	284
	1986-87	240	244	277	278	278
	1987-88	153	216	365	365	365
Yadgir	1985-86	219	225	230	282	282
	1986-87	201	239	241	243	275
	1987-88	149	183	187	365	365
Wadakwal	1985-86	226	232	243	365	365
	1986-87	241	245	245	345	345
	1987-88	162	212	218	219	219
Bawapuram	1985-86	226	229	231	365	365
	1986-87	193	198	200	249	365
	1987-88	160	163	189	217	217
T.Ramapuram	1985-86	98	130	132	365	365
	1986-87	113	129	149	186	191
	1987-88	106	157	162	189	190

Table 4.77 : Maximum Drought Duration for the selected sites of Godavari basin during 1985-86

Site	Year	Maximum Drought Duration in day at % ADF 10%	30%	50%	70%	90%
Ashwi	1985-86	291	291	365	365	365
	1986-87	250	290	290	365	365
Chass	1985-86	228	272	287	287	365
	1986-87	277	279	280	280	280
Karodi	1985-86	214	272	277	278	278
	1986-87	233	245	247	275	277
Saigoanl	1985-87	266	232	233	365	365
	1986-87	247	365	365	365	365

Table 4.78: Drought Intensity for selected sites of Krishna basin.

	Drought Intensity in cumec at 10% ADF				
Site	Year	10%	30%	50%	70%	90%
Karad	1985-86	9.02	4.68	32.28	54.09	81.57
	1986-87	11.17	6.10	28.39	55.80	83.03
	1987-88	9.51	10.64	37.04	57.22	84.43
Dhond	1985-86	11.89	42.31	60.55	91.29	121.92
	1986-87	12.22	42.22	69.94	97.93	128.13
	1987-88	12.21	43.01	61.12	91.52	97.31
Narsingpur	1985-86	7.97	45.29	82.92	121.99	158.53
	1986-87	16.46	50.65	88.21	126.02	163.82
	1987-88	15.23	46.06	83.97	121.88	159.79
Takali	1985-86	19.32	52.75	94.82	136.67	178.94
	1986-87	17.84	59.59	90.54	132.45	174.72
	1987-88	19.85	47.01	69.01	111.39	153.78
Yadgir	1985-86	26.70	91.56	155.38	185.76	251.97
	1986-87	28.71	89.30	154.50	219.20	255.78
	1987-88	28.52	80.20	144.09	118.60	185.00
Wadakwal	1985-86	3.05	9.51	16.02	16.56	23.18
	1986-87	2.87	9.40	16.02	17.12	23.74
	1987-88	2.80	7.67	14.04	20.58	27.96
Bawapuram	1985-86	12.22	47.72	82.97	84.66	120.35
	1986-87	14.93	49.85	84.90	101.02	92.60
	1987-88	15.44	50.84	78.63	100.75	136.56
T.Ramapuram	1985-86	2.31	7.12	12.73	9.69	15.44
	1986-87	2.19	7.47	11.63	14.24	19.51
	1987-88	2.46	6.66	12.46	15.65	21.32

Table 4.79 : Drought Intensity for selected sites of Godavari basin.

Site	Year	Drought intensity in cumec at % ADF 10%	30%	50%	70%	90%
Ashwi	1985-86	0.81	2.66	3.49	5.27	7.05
	1986-87	0.82	2.27	4.05	4.71	6.50
Chass	1985-86	4.84	13.03	22.00	31.76	33.27
	1986-87	4.83	14.53	24.23	34.00	43.76
Karodi	1985-86	1.14	5.84	11.08	16.42	21.81
	1986-87	1.52	6.73	12.04	16.08	21.34
Saigoan	1985-86	3.08	9.16	15.35	15.25	21.49
	1986-87	3.10	7.99	14.22	20.46	26.69

4.7 Analysis of Reservoir Storages

In order to see, the impact of failure of monsoon on storages of the reservoirs, an attempt has been made to compare the storages in some selected reservoirs in the states of Andhra Pradesh, Karnataka, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan. For this purpose, the live storages and corresponding reservoir levels in some selected months have been plotted against time. The weekly reservoir level data as supplied by Central Water Commission from 1984 till 1987 have been used for the analysis. Table 4.80 give the details of reservoirs selected for this study. Fig.4.27 through Fig.4.32 shows the position of storages during 1984 to '87 in the selected states. The inferences which can be drawn from these figures are as below :

(1) In Andhra Pradesh two reservoirs namely, Nagarjunasagar and Sri Sailam both on Krishna basin have been selected. It can be seen from Fig.4.27 that in case of Sri Sailam reservoir the pre and post monsoon storages were least in year 1987 as compared to previous two years. In case of Nagarjunasagar the storages in the month of May and August were minimum during year 1987 as compared to years 1985 and '86. However, the storage by the end of Nov.in 1987 was better than year 1986. Keeping in view the storage position, the drought impacts in 1987 were more or less similar in 1986 and 1987 with few exceptions.

(2) In the state of Gujarat the Kadana reservoir on Mahi river was chosen for analysis. The storage position as indicated in Fig.4.28(a) show that the impacts of rainfall failure have been more or less same on reservoir storages during year 1986 and 87 with the months of May and Aug.showing little difference The live storage in the reservoir at the mid of Oct.,'87 was 114% to the last year's storage. Based on these results, it can be inferred that drought impacts on reservoir storages were more pronounced during year 1986.

(3) In the state of Karnataka the reservoir data of Tungabhadra and Ghatprabha have been chosen for analysis. Both the reservoir have shown less storage value during year 1987 as compared to previous three years. The storages by the end of Nov. in Tungabhadra reservoir during 1987 was 6.3% of previous year storage for the same

period. In case of Ghatprabha the storage by Nov.87 was 57% of previous year storage. This indicates that the reservoir storages were affected more during year 1987 as compared to previous two-three years. (Fig.4.28(b) & 4.29(a).

(4) In case of Maharashtra four reservoirs namely ; Jayakwadi, Khadakwasla,Koyana and Bhima have been selected for storage analysis. As can be observed from fig.4.29(b) & 4.31(a) that all the reservoirs showed more deficient storages during year 1987 as compared previous 2-3 years, except Jayakwadi reservoir.

Table 4.80 Details of Reservoirs selected for storage Analysis

Sl.No.	Name of Reservoir	State	Basin
1.	Nagarjunasagar	Andhra Pradesh	Krishna
2.	Sri Sailam	Andhra Pradesh	Krishna
3.	Tungabhadra	Karnataka	Krishan
4.	Ghatprabha	Karnataka	Krishna
5.	Kadana	Gujarat	Mahi
6.	Gandhisagar	Madhya Pradesh	Chambal
7.	Tawa	Madhya Pradesh	Narmada
8.	Jayakwadi	Maharashtra	Godavari
9.	Khadakwasla	Maharashtra	Krishna
10.	Koyana	Maharashtra	Krishna
11.	Bhima	Maharashtra	Krishna
12.	Rana Pratap Sagar	Rajasthan	Chambal

The Koyana reservoir showed worst impact of drought on storages as compared to previous years out of all four reservoirs. The live storage in Koyana, Khadakwasla, Bhima and Jayakwadi during mid Oct.'87 were 80%, 49%, 92% and 152% respectively to previous year's storages.

(5) In case of Madhya Pradesh two reservoirs namely Gandhinagar and Tawa falling in Chambal and Narmada basins respectively have chosen for storage analysis. As can be observed from fig.4.32(a) that in Gandhinagar reservoir during May 1986 the live storage was recorded lower than that of May 1987 and also than that of previous years. On the other hand, live storage during Aug. and Oct. 87 were lower than previous years. The storage during Oct. 87 in Gandhisagar reservoir was 55% to previous year' same time storage. In case of Tawa (Fig.4.31(b) the May,'84 live storage was lower than the consecutive three years. The Oct.'87 storage in Tawa reservoir was 102% to the same time storage during previous year's storages.

(6) In case of Rajasthan, Rana Pratap Sagar reservoir in Chambal basin has been selected for storage analysis. As can be seen from Fig.4.32(b) that live storage during May'86 was lower than the other years. However, during Aug. and Oct.'87 the live storages were recorded lower than the previous years. The Oct.'87 live storage was 31% to the previous year's Oct.live storage which indicates reservoir storage was severely affected by the drought conditions during 1987.

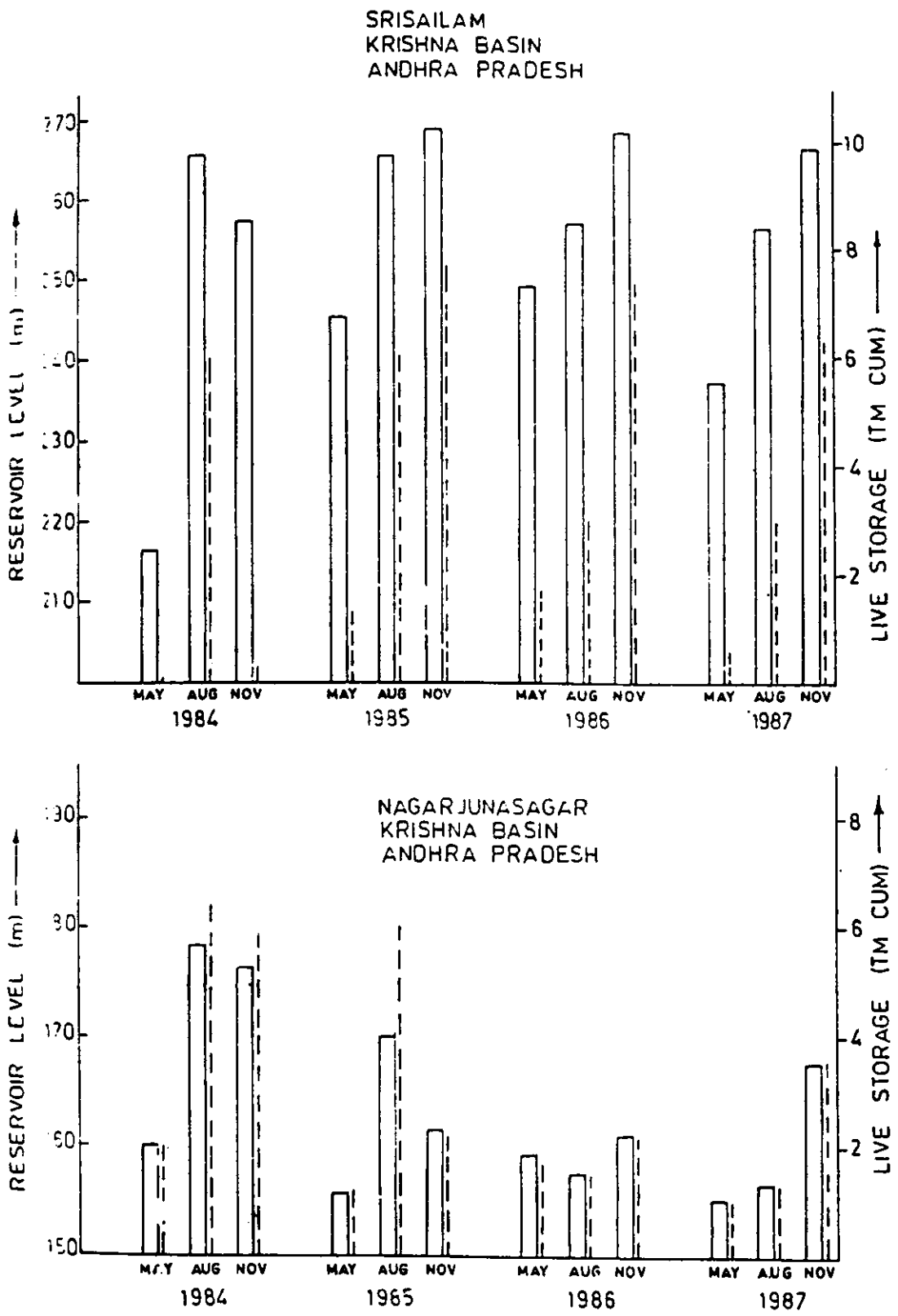


FIG. 4.26 : RESERVOIR LEVELS AND STORAGES FOR SRISAILAM AND NAGARJUNASAGAR

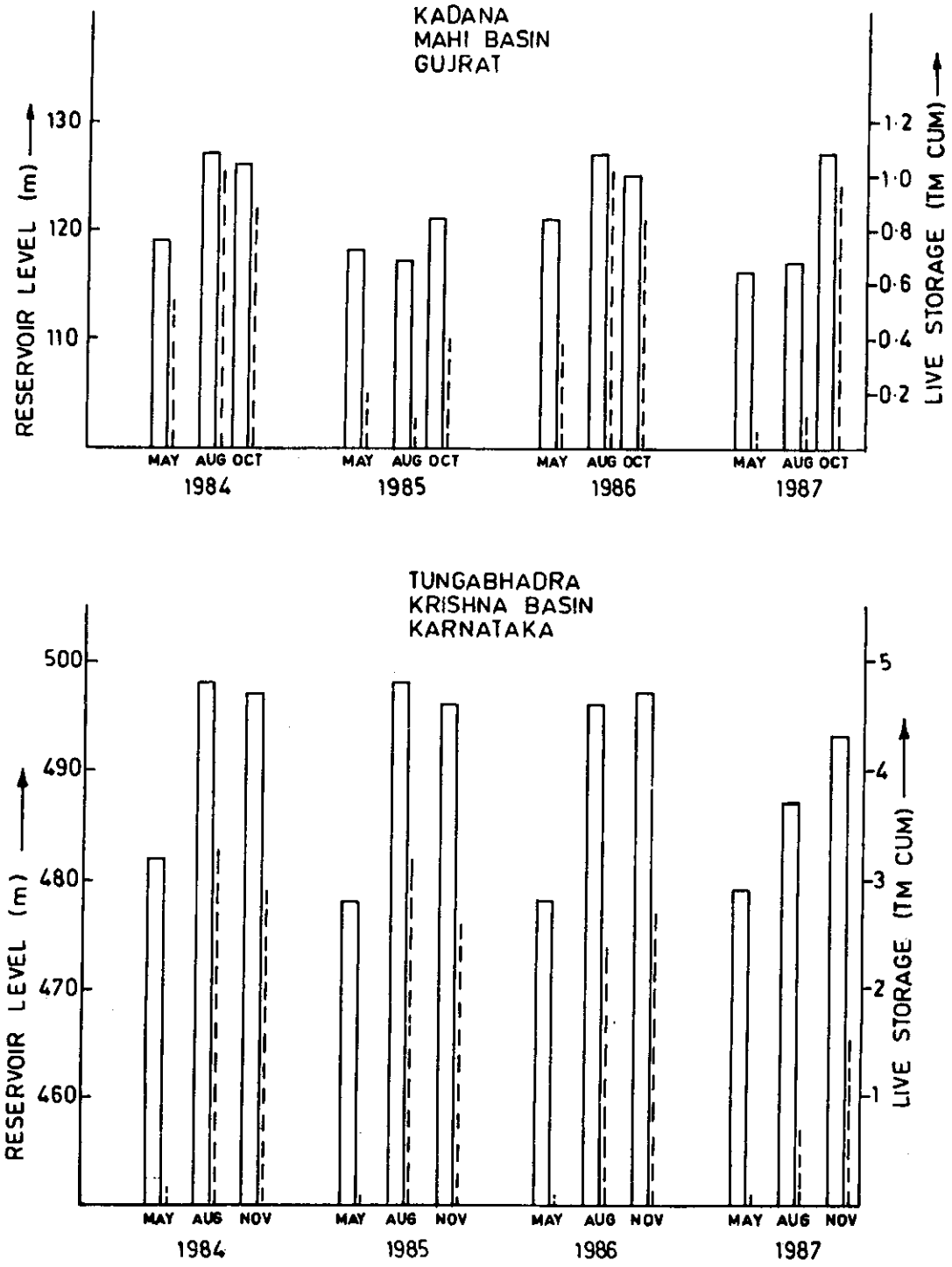


FIG. 4.27 : RESERVOIR LEVELS AND STORAGES FOR KADANA AND TUNGABHADRA

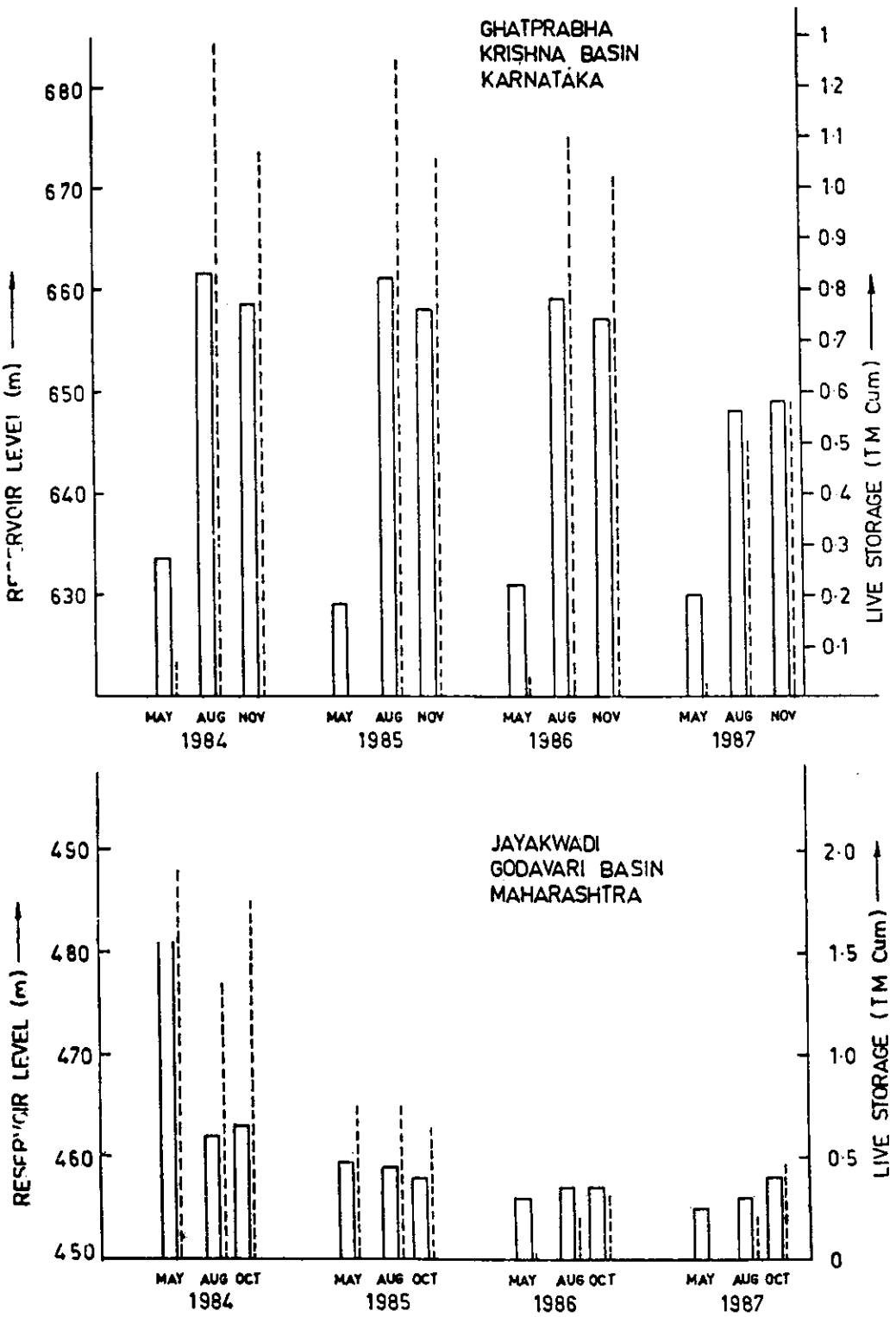


FIG. 4.29 : RESERVOIR LEVELS AND STORAGES FOR GHATPRABHA AND JAYAKWADI

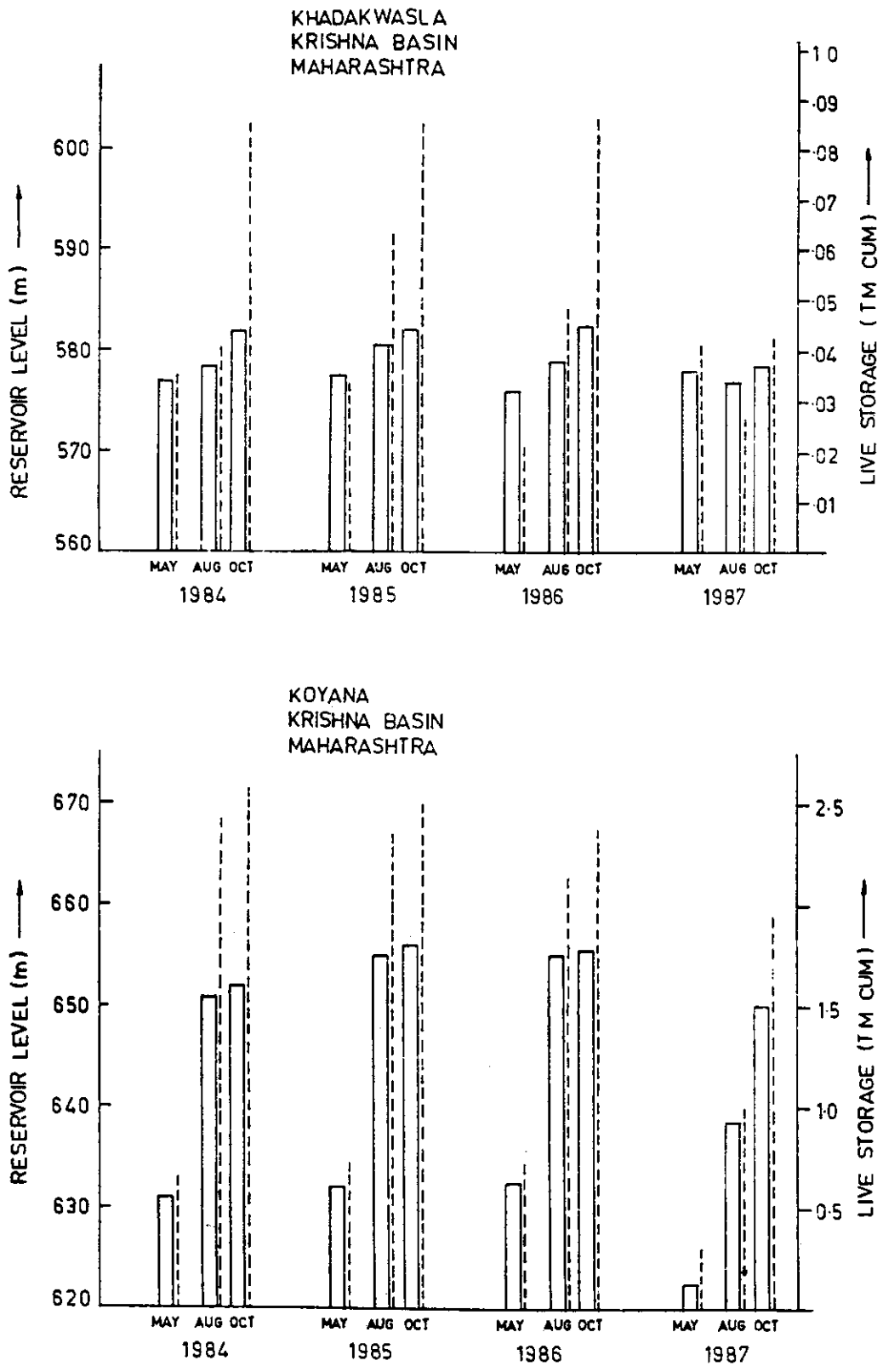


FIG. 4.29 : RESERVOIR LEVELS AND STORAGES FOR KHADAKWASLA AND KOYANA.

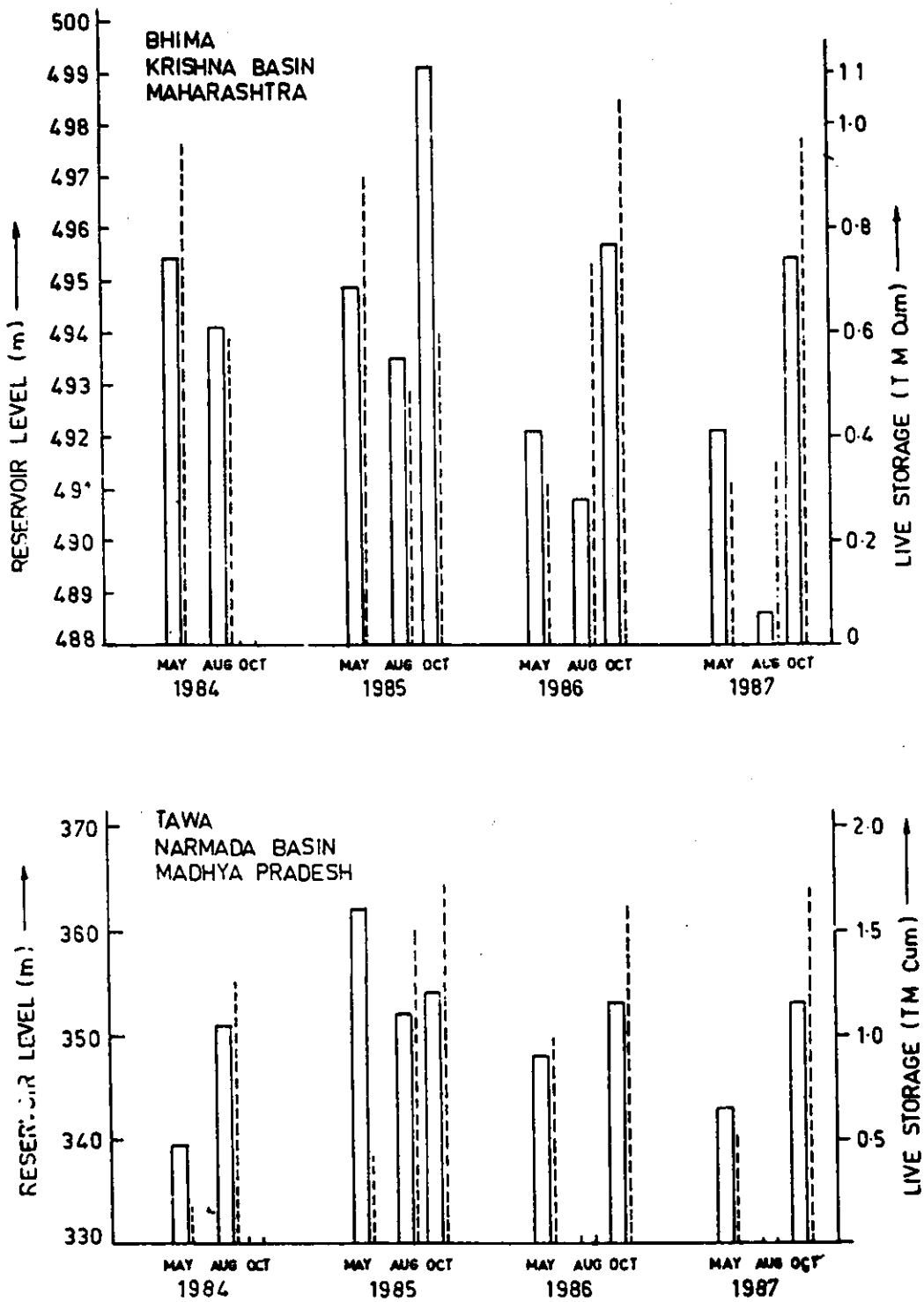


FIG. 4.30 : RESERVOIR LEVELS AND STORAGES FOR BHIMA AND TAWA

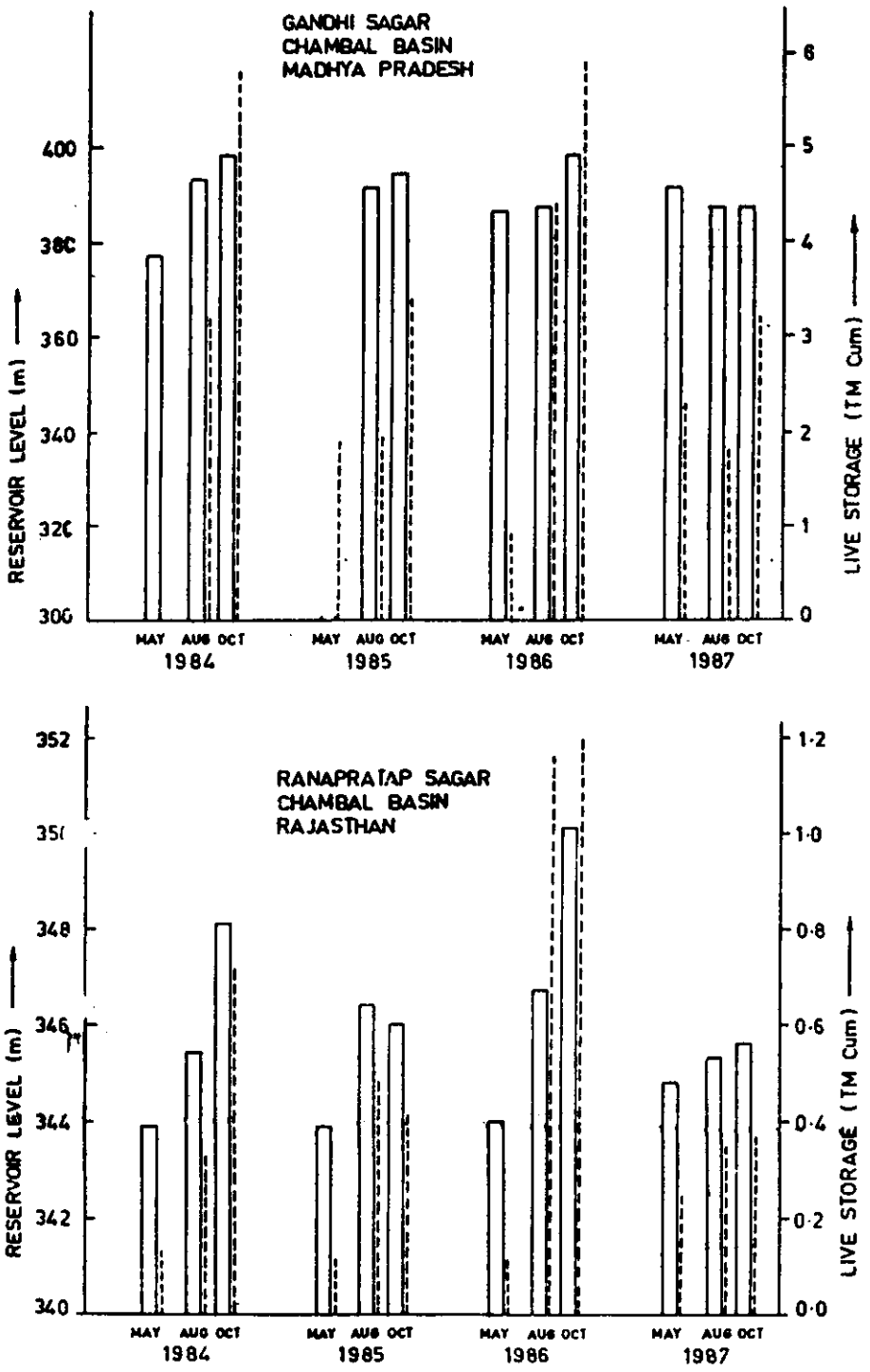


FIG. 4.31 : RESERVOIR LEVELS AND STORAGES FOR GANDHI SAGAR AND RANAPRATAP SAGAR

5.0 Ground Water Deficit

5.1 General

The main objective of groundwater management is to ensure that groundwater will be available at an appropriate time and in an appropriate quantity and quality to meet the most important demands of society. The measurement of groundwater levels and their evaluation can play an important role in management of this underground resource of water. The fluctuations of water table reflect the effects of infiltration of precipitation and of discharge of groundwater to streams and lakes or withdrawal of water from wells. Usually the change in ground water storage is a seasonal phenomenon.

However, during the period of scarcity of rains or droughts, more dependence comes on ground water storages and steep decline in groundwater levels are experienced. Because of improper management of groundwater aquifers after development, numerous undesirable consequences such as the depletion of aquifers and groundwater mining emerge, especially during drought years. Statistics recently compiled on the use of ground water and surface water show that in a number of states ground water is being over exploited in certain pockets resulting in a fall in the water table. During droughts, due to deficiency of rainfall and higher rate of evapotranspiration, the demand for irrigation gets enhanced, thereby the water level goes down. This results in increased use of energy for pumping water from greater depths involving higher expenditure. As a policy, the withdrawal of groundwater should be restricted to average annual recharge. This will conserve water for over exploitation during drought periods.

Therefore, there is a long standing need to better understand the relationship between precipitation and groundwater levels. The relationship can be developed by carrying out statistical analysis of precipitation data and well level measurements. Besides, information regarding well abstractions should be available for evaluating effects on water table only due to reduced precipitation.

In order to see the effects of scarce rainfall as experienced during three successive drought years (1985-1987) on groundwater regime, statistical analysis of groundwater level data viz.a viz precipitation has been carried out for 36 districts (six in each chosen state of A.P., Gujarat, M.P., Maharashtra, Karnataka and Rajasthan). However, due to non-availability of abstraction data, the effects of withdrawal could not be introduced in the analysis.

5.2 Groundwater level analysis

As has already been discussed in Chapter 2, attempts were made to collect the groundwater level fluctuation data from six states with six districts in each state. The information regarding period of data used , no. of observation wells and the source of data is given in Table 5.1. As can be observed from the Table that about 5-14 wells evenly distributed over the district were chosen for the analysis keeping in view data availability constraints. The locations of the wells on the district map have already been shown in the figures presented in Chapter 2. The ground water level analysis was attempted with the help of quarterly/seasonal data depending upon the frequency of the data collection by the concerned state/central agency. Appendix V.1 gives the various observation wells spread over 30 districts chosen in six drought prone states with their latitude and longitude. In general, the analysis has been carried out for ground water level data from 1976-87.

TABLE 5.1 - STATUS OF GROUNDWATER DATA

S.NO.	STATE	NAME OF DISTRICT	DATA AVAILABLE	NO.OF WELL TAKEN	SOURCE OF DATA AVAILABILITY
1.	Andhra Pradesh	Chittoor	1977-88(time in a year)	6	C.G.W.B.
		Prakasam	1977-88 -do-	7	C.G.W.B.
		Kurnool	1977-88 -do-	4	C.G.W.B.
		Mehboobnagar	1981-88 -do-	10	C.G.W.B.
2.	Gujarat	Ahmedabad	1979-88(time in a year)	6	C.G.W.B.
		Jamnagar	1979-88 -do-	10	-do-
		Rajkot	1979-88 -do-	5	-do-
		Surendranagar	1979-88 -do-	8	-do-
		Amreli	1979-88 -do-	6	-do-
		Bhavnagar	1979-88 -do-	8	-do-
3.	Karnataka	Belgaum	1976-88(Five times in a year)	6	State Ground Water Board
		Bijapur	1976-88 -do-	7	-do-
		Gulburga	1976-88 -do-	10	-do-
		Raichur	1976-88 -do-	8	-do-
4.	Madhya Pradesh	Dhar	1976-88(Pre & Post)	5	State Ground Water Board
		Khargone	1975-88 -do-	14	-do-
		Jhabua	1975-88 -do-	11	-do-
		Betul	1975-88 -do-	3	-do-
		Shahdol	1975-88 -do-	7	-do-
5.	Mahara-shtra	Ahmednagar	1976-88(Pre & Post)	7	G.W.Survey & Dev. Agency
		Pune	1976-88 -do-	8	-do-
		Satara	1976-88 -do-	8	-do-
		Solapur	1976-88 -do-	8	-do-
		Aurangabad	1977-88 -do-	10	-do-
		Sangli	1976-88 -do-	10	-do-
6.	Rajasthan	Ajmer	1976-88(Four times in a year)	5	C.G.W.B.
		Banswara	1979-88 -do-	7	-do-
		Barmer	1979-88 -do-	10	-do-
		Udaipur	1981-88 -do-	7	-do-
		Jodhpur	1978-88 -do-	5	-do-

The water levels in the wells have ben calculated with respect to mean sea level and for each district average ground water level has been calculated using Thiessen method. The Thiessen weight of all wells considered in each district was established and groundwater level calculated with respect to mean sea level by Thiessen weight gave average ground water level for the district. An example of groundwater level calculation for the district of Surendranagar in Gujarat state is presented in Appendix V.2. It can be observed that the Thiessen weight for the wells in the district were 0.115, 0.133, 0.134. 0.120, 0.151, 0.073, 0.136 and 0.139 and average levels for these wells were computed

with respect to MSL. Based on these values, average ground water level for the district was obtained. Similar computations were done for all districts and average quarterly/seasonal values were derived. The values so obtained were plotted against each year to derive trend in ground water fluctuation. The trend was established for two period namely, pre-monsoon and post monsoon. In order to see the trend in the rainfall, the seasonal rainfall was also plotted in the same graph showing the ground water level fluctuations. For this purpose, the seasonal rainfall from June to September was used for M.P., Maharashtra, Gujarat, and Rajasthan while the rainfall from May to November was used for the states of A.P. and Karnataka. A simple regression line was fitted to show the trend of rainfall in order to see the effect of deficit in water levels.The plot showing trends of seasonal rainfall and average ground water fluctuations for Surendranagar is shown in Fig.5.1(b). As has already been mentioned that due to non availability of data the effects caused due to over exploitation of ground water during drought periods could not be introduced in the study and it is presumed that decline in the ground water level is caused solely due to failure of rainfall. Also a district has been taken as a unit for analysing ground water levels. Ideally, a hydrogeological boundary will need to be established for such an analysis. However, it has ben presumed that the district has no inflow or outflow of ground water into/from its aquifer. Based on the analysis, following inferences can be drawn :

(a) In Andhra Pradesh, six districts namely Anantpur, Cuddapah, Chittoor, Prakasam, Mehboobnagar and Kurnool were chosen for the study of pre-monsoon and post monsoon ground water levels and seasonal rainfall fluctuations. The pre-monsoon and post-monsoon groundwater levels alongwith seasonal rainfall fluctuations for these districts are shown in respective state report for the year 1987-88. In case of Anantpur and Cuddapah only rainfall trend for the year 1987-88 has been established due to non-availability of ground water data. However, based on the rainfall trend it can be inferred that for both of these districts the groundwater regime might have improved due to better rainfall conditions as compared to previous two years. However, this can be verified only after receipt of data. In case of Chittoor and Prakasam districts declining trends in seasonal rainfall have been observed. This has led to decline in groundwater levels, in case of Chittoor district. However, for Prakasam district positive departure in seasonal rainfall value has been observed and relatively the groundwater trend have shown rising trend as compared with the last year. In Mehboobnagar and Kurnool district the rainfall show declining trend with both positive departure in Kurnool and negative departure in Mehboobnagar. The pre and post water level trends show decline for Mehboobnagar district while for Kurnool these trends show rising behaviur.

(b) In case of Gujarat, pre and post monsoon levels have been analysed forsix districts of Jamnagar, Rajkot, Ahmedabad, Surendranagar, Bhavnagar and Amreli. The seasonal rainfall fluctuation for these districts are shown in respective state report. The seasonal rainfall in all six districts was deficient by more than 50%. It was observed from figures that during the year 1987-88 the rainfall trend for all districts have more declining trend than that of previous years. The deficiency of seasonal rainfall have also shown similar trend. As a result the ground water table has been recorded falling in all the districts. The trend lines of pre and post monsoon for year 1987-88 have shown greater effects on water table as a result of monsoon failure as compared to previous years. The district of Jamnagar followed by Rajkot and Amreli showed highest rate of decline in post monsoon groundwater levels for 1987-88. The pre monsoon level was observed falling at highest rate in the district of Surendranagar followed

by Jamnagar. The district of Ahmedabad recorded lowest rate of decline in pre

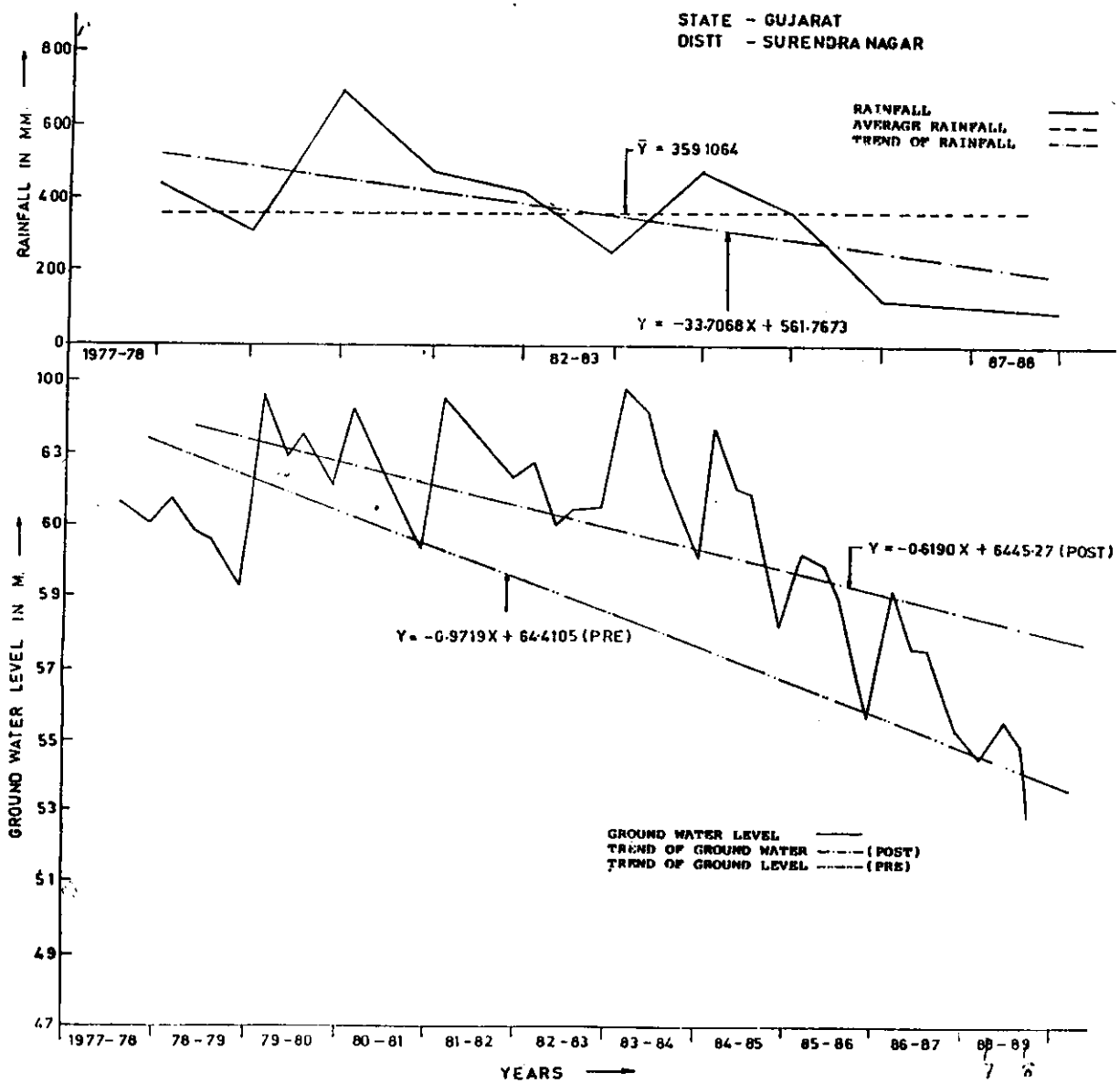


FIG. 5.1: -GROUND WATER LEVEL FLUCTUATIONS AND RAINFALL AND TREND ANALYSIS

and post water table levels. As in the case of rainfall, the ground water regime also seems to get worstly affected in six chosen districts of Gujarat.

(c) In the state of Karnataka the groundwater level analysis was restricted to only four districts namely Bijapur, Belgaum, Gulburga and Raichur. The analysis for Dharwar and Bellary could not be done due to lack of data. The seasonal rainfall deficiency figures in the four districts indicate that except Belgaum everywhere there has ben some positive departure from normal seasonal rainfall. This is also evident from the rainfall trends which show relatively less rate of decline as compared to previous years. For the districts of Bijapur, Gulburga and Raichur the post monsoon water table trends have shown relatively less rate of decline during '87-'88 as compared to previous years, which may be attributed to occurrence of rainfall. The pre monsoon levels have also shown rather less rate of decline in water table during 1987-88 as compared with previous years. However, in case of Belgaum district due to deficiency of rainfall the groundwater level trend did not undergo significant change though the post monsoon scenario was relatively better than previous year. The trends of water table and seasonal rainfall in respect of four districts are shown in respective state report.

(d) In Madhya Pradesh groundwater level analysis for five districts namely Jhabua, Khargone, Dhar, Shahdol and Betul has been carried out. Due to non-availability of data for Sidhi district, it could not be included in the study. All districts have experienced seasonal rainfall deficiency during '87-'88 ranging from 33-43%.The rainfall trends have also indicated continuous decline of seasonal rainfall as the rate of decline during '87-'88 has increased as compared to previous year. As a result all district except Shahdol have indicated a falling trend in pre and post monsoon water table levels and in most of the cases the rate of decline have been more than the previous year. In case of Shahdol district for which rainfall analysis was not done the pre and post water table trends have shown slightly positive slope of trend lines. The continuous decline in water table levels can be attributed to continued deficient seasonal rainfall and over pumpage of groundwater for various usages. The trends of water table and seasonal rainfall in respect of five districts are shown in respective state report.

(e) In case of Maharashtra districts of Ahmednagar, Sholapur, Satara, Pune, Aurangabad and Sangli have been chosen for groundwater table and seasonal rainfall analysis. The seasonal rainfall figures for year 1987-88 show deficient picture in all districts except Sholapur. The seasonal deficiency has been in the range of 9-60%. The rainfall trends for all the districts have shown declining trend over years except in case of Satara district. The rate of decline has increased in case of Pune and Sholapur,however, the district of Ahmednagar experienced relatively less decline rate as compared to previous year. The water table analysis has indicated that the water table (post monsoon) has been falling for the districts of Satara, Pune, Aurangabad and Sangli. However, the districts of Ahmednagar and Sholapur showed rather positive trend in post monsoon water table positions; indicating rise in post monsoon water table levels over years. The pre monsoon water table levels have shown declining trend for all the six districts with the rate of decline being little less than the previous year. The trends of water table levels along with seasonal reainfall for all the six districts are shown in respective state report.

(f) The groundwater table analysis was restricted to five districts (Banswara, Barmer, Ajmer, Udaipur and Jodhpur) in the state of Rajasthan. The district of Dungarpur was not included in the study due to non availability of data. The seasonal rainfall values for all districts except Banswara showed deficient rainfall with the extremes lying

between 47-66%. Due to such severe deficient rainfall in the monsoon season of '87 the rainfall trends have also shown steeper decline as compared to previous year. The analysis of post monsoon levels have indicated that in case of Ajmer, Udaipur and Jodhpur districts higher rate of decline in post monsoon levels were obtained. However, the districts of Banswara and Barmer showed slightly positive trend in post monsoon groundwater table levels, though the rate of rise was less as compared to previous year forBarmer district. In case of Banswara district slightly higher rate of rise in post monsoon levels have been observed during 1987-88 as compared to previous year, which can be attributed to slight positive departure in the seasonal rainfall. The analysis of pre monsoon water table levels have shown declining trend in all districts except Barmer. The rate of decline has been observed higher in all cases except Banswara as compared with the previous year. In case of Barmer district, however, the trend of pre monsoon levels shows positive slopes, however, the rate of rise has reduced as compared to previous year 1986-87. The trends in water table levels and seasonal rainfall for all the chosen five districts are shown in respective state report.

The analysis of groudwater levels based on the water table fluctuation data of post 10-12 years has yielded in knowing the ground water level trends (pre and post) as a result of seasonal rainfall departure. In most cases the water table has been recorded falling or the ratre of recharge was found lesser in 1987-88 as compared to previous year. The continuous decline in water table is certainly attributed to failure of monsoon due to which the draft of ground water also gets increased because of increase in demand. The rise in water table as found in some cases can be attributed to the positive groundwater imbalances created by surface water irrigation projects as has been observed in case of Barmer district.Better analysis to correlate rainfall failure and groundwater regime can be done by taking into account the well abstraction data, which has not been done in the present case due to non-availability.

6.0 CONCLUSIONS

6.1 Rainfall

i. The analysis of daily, monthly and annual rainfall data have been presented for classifying drought situation over 36 districts spreading over six drought prone states of the country. The rainfall data have been collected from various central and state government organisations and published reports.

ii. In the present report the normal rainfall values for district as a whole have been worked out as the algebraic summation of taluk normal values, which are taken from the reports of CWC. At each taluk headquarters, one raingauge station have been chosen and generally 3 to 14 number of taluk have been considered per district for rainfall analysis.

iii) The results of seasonal departure of rainfall indicate that almost all districts chosen for study in the states of Gujarat, M.P., Maharashtra, and Rajasthan experienced rainfall deficiency greater than 30%. However, in the states of A.P., and Karnataka some positive departures have been experienced. These deficit figures are coherent with the rainfall deficiency map issued by IMDfor the year 1987-88. However, the results for Karnataka and A.P.need to be checked in detail.

iv) In some districts like Jodhpur & Barmer (Rajasthan), Belgaum (Karnataka), Satara, Sangli, Aurangabad, Ahmednagar, and Pune (Maharashtra), Khargone (M.P.) and Rajkot, Jamnagar and all districts of Gujarat experienced deficiency in seasonal rainfall continuously for the last 4-5 years.

v) The analysis of monthly rainfall data of 1987-88 (June '87 to May '88) indicate that most of the districts in the states of Gujarat, M.P., Maharashtra and Rajasthan show deficiency in monthly rainfall during monsoon season. Even in some cases 100% deficient rainfall have been observed in these states. In case of Karnataka and A.P. state the monthly departure picture is not as bad as in the case of other 4 states. Even some positive values of departures have been noticed in some months in these states.

vi) Two taluks from each district and district as a whole have been selected for probability analysis of annual rainfall data from 1901 to 1987. Based on the analysis the group range of rainfall for districts/taluks at 75% or more probability level was established. It has been observed that the group range of rainfall in most of the districts of Rajasthan, M.P., A.P., Gujarat, Karnataka and Maharashtra was from 200-300 mm, 500-600 mm, 500-600 mm, 300-400 mm, 400-500 mm and 400-500 mm respectively. The probability of occurrence of 75% of the normal rainfall was also found for all the districts. This analysis has indicated that almost all district except few less than 80% probability of getting 75% of normal rainfall with the lower extremes lying for the districts of Surendranagar and Amreli (59% and 57% respectively). The districts of Chittoor, Prakasam, Dharwar, Satara and Betul showed probability values more than 80% with the upper highest value of 87% for the district of Chittoor.

vii) The report describes analysis of monthly rainfall data by Herbst (1966) approach. It may be mentioned that the analysis presented in this report has taken into consideration the rainfall of all the 12 months of the year contrary to previous where only monsoon months were considered. Since the approach takes into

account carry over effects month to month, the analysis presented herein should get more accurate results.

viii) It has been observed that the districts chosen for study experienced 4-13 number of drought spells during the period 1951 to 1987. In case of the districts of A.P. the number of drought spells varied from 7 to 12 and the intensity of latest spell was about 0.8 in most of the cases. The state of Gujarat experienced drought spells from 5 to 10 with the intensity of the latest spell going upto 1.8. In case of Karnataka state no. of spells varied from 6 to 13 and the intensity of latest spell was upto about 1.0. The no. of spells varied from 3 to 7 in case of M.P. with the intensity of latest spell going upto about 0.7. In case of Maharashtra no. of spells ranged 4 to 11 and the intensity of latest spell was of the order of 1.0. The state of Rajasthan shows the range of spells from 7 to 12 with the intensity of the latest spell going upto 1.2.

ix) From the Herbst analysis it has been observed that the districts of Gujarat and M.P. showed drought spells during 1984 to 1987. While the other states of A.P., Karnataka, Maharashtra and Rajasthan had drought spells during 1984 to 1987 in all but one district. From the point of intensity of latest spell the severity order of drought has been in the order of Gujarat, Rajasthan, Maharashtra, M.P., Karnataka and A.P.

x) The dry spell analysis has been done for one representative taluk from each district for rainfall data of monsoon period. The daily rainfall data for the monsoon period from 1981 to 1987 have been used for the dry spell analysis. An attempt was made to find out the duration of dry spell at the 75% probability occurrence. The results indicate that for all the taluks the dry spell range comes to 21-28 days except one taluk each of Mahbubnagar (A.P.), Dhar and Sidhi (M.P.) districts. The analysis assumes importance in view of the fact that the occurrence of dry spell has significant effect on the growth of the crops.

xi) From the rainfall analysis point of view the severity in descending order of hydrological droughts during 1981-83 can be taken as Gujarat, Rajasthan, Maharashtra, Madhya Pradesh, Andhra Pradesh and Karnataka. This conclusion is purely based on the analysis presented in the report for six districts of the respective states chosen for study and has scope for improvement in the light of other relevant informations.

6.2 Surface Water Deficit:

i) Surface water deficit analysis for nine sites of Krishna basin except Harallahalli for which data of year 1987-88 was not available, has been carried out with the additional data for the year 1987-88. Also, four sites of Godavari basin namely, Ashwi, Chass, Karodi and Saigoan have been included for analysis of 1986-87 drought in the present study. The data for the year 1987-88 have not been available at the time of analysis. The major portion of these two basins fall in the states of Maharashtra, Karnataka, A.P. Out of 18 districts selected for analysis of rainfall and groundwater deficit in these states,only district of Satara, Pune, Sholapur in Maharashtra, Gulburga and Bellary in Karnataka and Kurnool in Andhra Pradesh are covered in the study of surface water deficit of Krishna basin and one district of Ahmednagar in Maharashtra is covered in the analysis of Godavari basin.

ii) The monthly flow hydrographs at the chosen sites for the years 1985-86, 1986-87 and 1987-88 were compared with the long term mean and minimum hydrographs. Out of eight sites of Krishna, five sites namely, Dhond, Yadgir, Takali, Narsinghpur and Karad showed closer runoff volume to their 21 years' minimum runoff volume, whereas two sites of Bewapuram and Wadakawal showed similar pattern of hydrograph during 1985-86, 1986-87 and 1987-88. The rest one site of T.Ramapuram showed closer runoff volume to mean runoff volume of the year 1987-88. In case of Godavari, out of four chosen sites, two sites of Ashwi and Chass illustrated similar pattern of runoff for the years 1985-86 and 1986-87 with significant difference with minimum and mean flow hydrographs. During years 1986-87 the site at Saigoan showed runoff hydrograph closer to minimum flow hydrograph. The site of Karodi showed more runoff volume during 1986-87 in comparison with that of year 1985-86. With this analysis it can be inferred that most of the sites experienced deficient flow conditions during 87-88 (for Krishna basin) and 86-87 (for Godavari basin).

iii) The results of departure analysis indicated that during year 1987-88 all chosen sites of Krishna experienced flows deficient by more than 50% of long term average flow except T.Ramapuram site. Also during 1985-86 and 1986-87 all the chosen sites of Godavari basin experienced flows deficient by more than 50%. The results of departure analysis indicate severe deficiency of flows at the chosen sites of Krishna and Godavari during 1987-88 and 1986-87, respectively

iv) The statistical parameters of observed data series i.e.mean standard deviation and coefficient of variation were computed for defining criterion for severeand moderate drought conditions. During year 1985-86 all the sites of Krishna basin experienced severe drought. In the year 1986-87, only sites at Dhond, Narsinghpur, Takali, Yadgir and Wadakwal experienced severe drought conditions. In years 1987-88, the sites at Karad, Dhond, Narsinghpur, Takali, Yadgir experienced severe drought conditions. Therefore, it can be concluded that during consecutive three years (1985-87) most of the selected sites of Krishna basin were subjected to severe drought conditions. In case of Godavari, during years 1985-86 and 1986-87 all the chosen sites had experienced moderate drought conditions according to statistical criterion of classification. This may be due to highly variable annual flow series with C range from 0.74-1.26. Therefore, a range of C may need to be established for using this statistical criteria for drought classifications.

v) The flow duration curves for all the sites were established and were used for determining the value of low flow index as the 10 days average flow which is exceeded 95% of time of the duration of series. This index is used as a measure of stream's low flow potential in hydrologic studies. The LFI values are helpful in planning any water resources project for making assessment of water availability. The low flow index value can be correlated with catchment characteristics, i.e. area, geology, climate, stream density land use etc. in order to develop, prediction formulae for ungauged catchments.

vi) The frequency curves for deficiency volume and deficiency duration per 100 years at different threshold levels were developed by using daily flow data. These curves are useful for deciding the required storage in the reservoirs in order to meet the demands taken as some percentage of long term mean which is helpful in planning drought management strategies.

vii) The values of annual maximum deficiency volume and annual maximum deficiency duration have been worked out for all the chosen sites at different demand levels, as a percentage of ADF. These values are comparable to the values of previous two years. The values of annual maximum deficit volume and annual maximum deficit duration are the highest values in the series of deficit volume, duration in a year. These values however, do not represent maximum drought volume. In order to see the effect of drought on monsoon flow, maximum deficiency volume and duration have been worked out at different threshold levels by using data of flow of monsoon period (1 June - 31 October) at all the sites. The drought intensity as a ratio of maximum deficiency volume to maximum deficiency duration have also determined. The values of drought intensity for all the sites at different demand levels are higher for the years 1985-87 than those of previous 3-4 years indicating that all sites during 1985-87 were subjected to drought conditions.

viii) An attempt has been made to compare storages of some selected reservoirs located in the chosen states for the period of 1984 to 87. For this purpose, the live storages as built during 1984 to 87 were plotted during the selected months of monsoon. In case of A.P. and Karnataka, these storages were taken for the months of May, Aug. and Nov. while for the rest four states, the storages at the end of May, Aug., and Oct. were considered.

ix) The analysis of storage data for Nagarjunasagar and Sri Sailam reservoirs in A.P. indicated drought impacts of the similar order during year 1986-87. In Gujarat the storage indicated more impacts of drought on Kadana reservoir storages during 1986. The analysis of storages of Tungabhadra and Ghat prabha reservoirs indicated more severe impact of drought during 1987 as comparedto previous 2-3 years. In the state of Maharashtra, the analysis of storages for four reservoirs namely, Jayakwadi, Khadakwasla, Koyana and Bhima showed deficient storages during 1987 as comparedto previous 2 - 3 years with the exception of Jayakwadi. In M.P. the reservoirs of Gandhisagar and Tawa showed less live storages during Aug. & Oct. months of 1987 for the Gandhisagar reservoir, while in Tawa the Oct.87 storages was also similar to the previous year storages. In Rajasthan, the storages in R.P.Sagar reservoir were recorded less during Aug. & Oct. months as comparedto previous years indicting more impacts of drought during 1987 as on previous years.

6.3 Groundwater Deficit

i) An attempt has been made to see the effects of scarce rainfall on groundwater regime by carrying out statistical analysis of groundwater level data. Due to want of data, the analysis was restricted to 30 districts only. The data from 1976-87 was used for the purpose of analysis. Efforts have also been made to correlate the trend of seasonal rainfall over last 10-11 years with the trends of pre or post groundwater levels.

ii) In Andhra Pradesh, out of six districts chosen for analysis, the results indicated slightly improved rainfall for districts of Anantpur and Cuddapah resulting in better groundwater regime. However, for Chittoor district, decline in groundwater level has been observed due to continuous declining in rainfall. For the other two districts of Kurnool and Mehboobnagar rising/declining trends have been experienced. The analysis somehow does not show the clear cut behaviour of water table as a result of deficiency excess of rainfall which may be attributed to over withdrawal of water from groundwater during period of scarcity.

iii) In Gujarat, the seasonal rainfall was deficient by more than 50% during 1987-88. As a result, the groundwater table has also shown falling trend in all districts over last 10-12 years. The district of Jamnagar seems to have faced severe decline in water table which was followed by Rajkot and Amreli. The overall picture of groundwater regime looks to be worst affected by drought in case of Gujarat state.

iv) In Karnataka, the analysis of only four districts was taken up where the seasonal rainfall showed positive trends in all except Belgaum district. The rate of decline of water table was found less as compared to previous year in all except Belgaum district.

v) The groundwater level analysis in M.P. indicated that due to seasonal deficit of rainfall/ ranging from 33-43%, the groundwater levels have also been falling. In case of Shahdol district, due to non availability of rainfall data, the analysis for Shahdol district could not be completed and therefore, the rising trend of rainfall can not be commenced upon, rainfall data are available.

vi) In Maharashtra, analysis in all the six districts was carried out where the seasonal rainfall picture for 1987-88 showed deficient amount in the range of 9.60% except in case of Sholapur. The rate of decline in watertable was found increasing in Pune and Sholapur. However, Ahmednagar experienced relatively less declining rate as compared to previous year. The analysis of post monsoon levels indicated declining trends for districts of Satara, Pune, Aurangabad and Sangli.

vii) Analysis for five districts in Rajasthan indicated that with the seasonal rainfall deficit of 47-66%, steeper declining trends in post monsoon levels were observed. However, the district of Banswara and Barmer showed slightly positive trend in post monsoon levels.

viii) The continuous falling of water table can certainly be attributed to continuous deficient rainfall for three years. However, due to non inclusion of well draft information, the exact correlation can not be established. Some realistic values of well draft information can help achieve the objective to develop the correlation between rainfall failure and groundwater levels.

ix) The positive trends in groundwater levels as obtained in some cases can be attributed to positive development in groundwater balance caused by surface irrigation projects as has been the case of Barmer district.

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APPENDIX-II

LIST OF OFFICES AND PLACES FROM WHERE DATA AND INFORMATION WERE COLLECTED

ANDHRA PRADESH **PLACE**	
Hyderabad	Irrigation Office State Ground Water Board Office Bureau of Economics of Statistics Panchavat Raj and Rural Development Dept. of Agriculture CWC, P.H.E.D.
Mahbooh Nagar	Irrigation Office Deputy Director,Agriculture Planning Office
Prakasam	Irrigation Circle Office Deputy Director,Agriculture Dy.Director,Water Management Panchayat Raj Office
Anantpur	Irrigation Circle Office D.P.A.P.Division I.B.C., D.R.D.A.Office District Planning Office Agricultural Research Station
Chittoor	Irrigation Circle Office Chittoor Irrigation Office, Madanpalli A.P.I.D.C., Madanpalli D.R.D.A. Chittoor
Cuddapah	Irrigation Circle Office D.R.D.A. Office
GUJARAT **PLAC**	
Gandhinager	Secretary and Commissioner (RD) Govt. of Gujarat Chief Engineer (Panchayat),Guharat Secretary Irrigation,Gujarat Superintending Engnineer,Gandhinagar Panchayat, Irrigation Circle Chief Engineer, Gujarat Irrigation Deptt. Director,Gujarat Water Resources Development Corpn. Secretary, Gujarat Revenue Department Secretary, CAD, Gujarat Water Supply & Sewerage Board.
Rajkot	Zilla Panchayat Raj, Rajkot Deputy Director, Agriculture

	Superintending Engineer, Minor Irrigation Rajkot Circle
	Soil Officer, Soil Survdey Deptt.
	Superintending Engineer, P.H.E.D. Irrigation Department
Ahmedabad	W.R.I., Bhadra Fort
	Director, Agriculture Gujarat State
	Eastern Gauging Division, Central Water Commission
	Geohydrologist, Ground Water Division
	Flood Control Cell
	Additional Director of Agricultural Sciences
	Deputy Director, Central Flood Forecasting Division, Central Water Commission
KARANATAKA	
PLACE	
Bangalore	Director,Deptt. of Mines and Geology Govt. of Karanataka
	Director,C.G.W.B.,South-Western Region
	Director,DPAP/Rural Deveopment
	Chief Engineer, W R D O
	Director, Bureau of Economics & Statistics
	Chief Engineer, Minor Irrigation
	Director,Deptt. of Revenue
	Director, Deptt. of Agriculture, Govt.of Karanataka
	Directorate of Survey Settlement & Land Records
	Directorate of State, Ground Water Cell, R C Road
	C E, Public Health Engg. & PWD Govt. of Karanataka
	Central Water Commission
Kolar	E.E., Minor Irrigation
	Deputy Commissioner (Special)
	DRDA, Soil Conservation Deptt
	Irrigation Deptt.
Tumkar	E.E.,Minor Irrigation
	Deputy Commissioner(Special)
	DRDA, Soil Conservation Deptt.,
	Irrigation Deptt.
Chitradurga	E.E. Minor Irrigation
	Incharge of the DPDA Projects
	DRDA, Soil Conservation Deptt.
	Irrigation Deptt.
Belgaum	E.E., Minor Irrigation
	Incharge of the DPAP Projects
	DRDA, Soil Conservation Deptt.
	Irrigation Deptt

	Asstt. Geologist, SGWC, Belgaum
Dharwad	E.E., Minor Irrigation DRDA Soil Conservation Deptt. Irrigation Deptt.
Mysore	DRDA, Soil Conservation Deptt Irrigation Deptt.,
MADHYA PRADESH PLACE	
Bhopal	Engineer in Chief Irrigation Deptt Director (D&H) Bodhi, Central Design Organisation Chief Engineer,State Ground Water Survey Board Deputy Commissioner, Rural Development Commission Additional Director,Department of Agriculture Deptu Director Statistics, Deptt. of Agriculture Chief Engineer., Public Health Engineering Satpura Regional Meteorological Centre of IMD Superintending Engineer/Executive Engineers/ Asstt. Engineers, Narmada Tapti Basin, Irrigation Deptt. Bhopal Superintending Engineer, Narmada Control Authority Regional Director, Central Groundwater Board.
Dhar **Jhabua**	District Collector District Statistical Officer
Khargone **Betul**	Dupdt.Land Records
Shahdol **Sidhi**	Superintending Engineer(Irrigation Circle) Deputy Director, Agriculture Asstt. Geo-Hydrologist Executive Engineer, Public Health Engg. Div.
MAHARASHTRA PLACE	
Bombay	Irrigation Department, Maharashtra Deptt of Forest and Revenue Secretary, Rural Development Department of Agriculture
Pune	Asstt. Director, Ground Water Survey and Development Agency under Deptt. of Rural Development

	Met. Gr.I, Drought Research Unit, IMD Pune
	Superintending Engineer, Poona Irrigation Circle
	Directorate of Agriculture
	C.E.(Irrigation), Zilla Parishad
	Pune Gauging Division, CWC
Aurangabad	Chief Engineer, Aurangabad,Irrigation Circle
	Executive Engineer, Aurangabad Irrigation Circle
	Superintending Engineer Jayakwadi Project Stage-I, Aurangabad Irrigation Circle Deptt.
Solapur	Krishi Vidhyapeth, under All India Coordinated Dry Land Farming Project of ICAR,Salapur
	Zilla Parishad
	DRDA
	Chief Geologists
	Agronomist and Agricultural Meteorologist, N.A.P.P. Scarcity Zone, Mahatma Phule Krishi Vidhyapeth
Beed	Senior Geologist
	GSDA
	Collector's office
	Zilla Parishad
	E.E., Irrigation Department
Parbhani	Agriculture Meteorology Deptt., Marathwada Agricultural University,
	Collector's office & Zilla Parishad
Ahmadnagar	Zilla Parishad, Collector's office
Satara	Collector's office , GSDA, Zilla Parishad
Sangli	Collector's office, Zilla Parishad.
RAJASTHAN PLACE	
Jaipur	Chief Engineer,Irrigation Department
	Dy. Director (Hydrology), Rajasthan Irrigation Deptt.
	Supdt. Engineer (Special Schemes) Rajasthan Irrigation Deptt.,
	Director, Irrigation Research, Rajasthan Irrigation Deptt.
	Agronomist (Irrigation) Rajasthan Irrigation Deptt.
	Directorate of Agriculture, Rajasthan
	S.E.(Soil Conservation), Deptt. of Agriculture, Rajasthan.
	Secretary, Special Schemes Organisation Rajasthan
	Secretary, Relief Rajasthan
	Deptt. of Economics & Statistics, Rajasthan
	Directorate of Evaluation, Rajasthan
	Public Health Engg. Deptt., Rajasthan
	Soil Survey Officer, Rajasthan

Ajmer	Central Water Commission Field Office
Udaipur	Central Ground Water Board, Regional Office
Banswara	Irrigation Department
Dongarpur	Agricultural Department
Barmer	Soil Conservation
Jodhopur	District Rural Development Authority (DRDA)
	Land Record Office
	Ground Water Deptt.
	Central Arid Zone Research Institute
	Chief Engineer. Rajasthan State Ground Water Department.

LIST OF OBSERVATION WELL

STATE-GUJARAT
DISTT-JAMNAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	W.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	41F-3A1	SARMESOR	22 26 00	69 03 00	8.905	591	0.0385
2.	41F-3C1	SALAYA	22 18 00	69 37 00	3.491	557	0.0549
3.	41F-3D1	OED	22 25 30	69 4 -5	12.280	594	0.0589
4.	41F-4A1	DKHAMADIN	22 15 00	69 17 00	4.525	517	0.0512
5.	41F-4B1	DHATIYA	22 05 00	69 17 00	27.095	720	0.0710
6.	41F-4C2	BHADTHOR	22 05 00	69 33 00	15.159	667	0.0660
7.	41G-1D1	AMBARDI	21 54 00	69 52 0	74.020	2589	0.2552
8.	41J-2B1	DHROL	22 34 00	70 30 00	25.010	2474	0.2439
9.	41G-1C2	KAWAL	21 55 40	69 17 30	3.999	720	0.0710
10.	41J-3A1	JAMNAGAR	22 27 30	70 04 45	11.405	1110	0.1094

STATE-GUJARAT
DISTT-RAJKOT

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	W.L.OF M.P.(Mts)	AREA INFLUENCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	41I-4C1	MALIYA	22 01 30	70 45 30	10.20	1548	0.1209
2.	41J-2D1	MANKENEK	22 37 00	70 52 00	90.00	2055	0.1643
3.	41J-3D1	RAJKOT	22 1 30	70 45 00	12.90	2[illegible]	0.3244
4.	41K-2B1	UPLETA	21 45 20	70 17 1[illegible]	41.04	1369	0.1076
5.	41K-1C3	GONDAL	21 59 31	70 44 30	126.90	2252	0.2028

LIST OF OBSERVATION WELL

STATE-GUJARAT
DISTT-AMRELI

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	410-1B1				159.755		0.1176
2.	410-2A1				120.455		0.2200
3.	410-2B1				121.375		0.1412
4.	410-3A2				147.076		0.2529
5.	41L-1C2				12.250		0.0824
6.	41P-1B1				3.555		0.2059

STATE-GUJARAT
DISTT-BHAVNAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	410-1D1				10.505		0.3048
2.	410-2D1				48.455		0.0588
3.	410-2D2				32.355		0.1604
4.	410-3C2				1[illegible].110		0.1123
5.	410-4D1				[illegible].145		0.1123
6.	40C-1A1				1[illegible].370		0.0802
7.	40C-2B1				14.740		0.0555
8.	40C-3A2				11.700		0.1177

STATE-ANDHRA PRADESH
DISTT-ANANTPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	AN-AN-02	JALLIAPALLI	14 44 22	77 41 00	435.540	4404.10	0.2302
2.	AN-RP-01	PINCUPUR	13 50 00	77 30 00	629.000	1677.20	0.0877
3.	AN-KE-03	TALUPULA	14 14 31	78 15 38	405.900	2819.20	0.1474
4.	AN-DV-01	PEDAPURAM	14 20 00	78 45 20	365.248	4723.00	0.2469
5.		MADEKSIRA	13 57 00	77 12 30	895.900	1199.60	0.0627
6.	AN-KD-01	GOLLA	14 26 00	77 12 40	503.300	4306.90	0.2251

STATE-ANDHRA PRADESH
DISTT-CUDDAPAH

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	CU-LR-02	LAKKIREDDY-PALLE	14 10 55	78 42 00	361.480	890.41	0.0583
2.		KAYACHOTI	14 07 00	78 47 00	351.470	3833.25	0.2525
3.	CU-BE-01	BADVEL	14 45 00	79 05 55	157.960	4006.24	0.2606
4.	CU-KP-01	PALAGIRI/ KAMALPURAM	14 27 45	79 20 45	182.490	2687.61	0.1748
5.	CU-IM-03	REGADIPALLY	14 42 30	78 08 30	218.998	1591.72	0.1035
6.	CU-CU-02	CUDDEDULA PALLE	14 23 30	78 48 30	165.742	2311.18	0.1503

STATE-ANDHRA PRADESH
DISTT-CHITTOOR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	2	SRIKALAHASTHI	13 45 20	79 42 05	205.690	3371	0.2225
2.	7	MADANAPALLI	13 32 54	78 30 0[illegible]	677.160	1579	0.1042
3.	9	CHADRAGIRI	13 35 48	79 20 00	206.375	2277	0.1503
4.	14	PUNGANUR	13 21 36	78 34 3[illegible]	729.730	1973	0.1302
5.	17	PUTTUR	13 26 30	79 35 00	146.530	2580	0.1703
6.	22	SATYAVEDU	13 25 42	79 57 12	060.453	1458	0.0962
7.	23	PALMANUR	13 12 33	78 44 3[illegible]	673.500	1215	0.0802
8.	25	CHITTOOR	13 12 24	79 06 0[illegible]	301.800	699	0.0461

STATE-ANDHRA PRADESH
DISTT-PRAKASAM

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	7	MARKAPUR	15 44 18	79 16 28	158.070	5604	0.3220
2.	8	DARSI	15 48 06	79 40 48	104.415	2072	0.1190
3.	14	PODILI	15 36 00	79 37 00	083.510	1549	0.0890
4.	17	ONGOLI	15 31 24	80 06 36	010.285	2332	0.1340
5.	19	KANIGIRI	15 24 00	79 30 30	103.435	1549	0.0890
6.	21	KANDUKURU	15 13 30	79 55 12	013.485	1532	0.0880
7.	23	PAMURU	15 05 30	79 24 45	113.454	2767	0.1590

LIST OF OBSERVATION WELL

STATE-RAJASTHAN
DISTT-BARMER

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	40D-2B	BARMER	25 44 10	71 23 50	213.410	2027.04	C.0714
2.	40D-4D1	GUDA	25 11 45	71 43 15	47.765	2179.77	C.0768
3.	4CN-3B1	SISUKALAN	26 16 30	71 18 20	243.390	2558.23	C.0901
4.	40D-3A1	CHONTAN	25 26 30	71 04 00	166.350	3494.21	C.1231
5.	40D-2A1	KALURI	25 42 43	72 03 30	101.900	6395.72	C.2253
6.	40D-2B2	NIMRI	25 29 00	71 17 00	187.560	2950.19	C.1030
7.	4CP-1A1	SIHANIYA	24 55 55	71 09 30	49.680	1562.72	C.0551
8.	4CJ-4A1	SUNDRA	26 05 45	70 13 10	115.540	3211.85	C.1131
9.	4CN-3B5	SARAN KA TALA	26 16 30	71 30 45	231.740	2112.64	C.0744
10.	4CN-3D2	UNDU	26 20 30	71 44 55	230.040	1893.76	C.0667

STATE-RAJASTHAN
DISTT-BANSWARA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	46I-3A1	ARTHUNA	23 29 45	74 06 00	153.730	736.05	0.1461
2	46I-2B1	BANSWARA	23 32 00	74 27 00	213.100	923.80	0.1834
3.	46I-2C2	BHUNGARA	23 41 00	74 31 00	240.325	747.59	0.1484
4.	46I-1B1	DUNGARIA	23 51 30	74 27 30	194.610	410.01	0.0814
5.	46I-1B2	GANORA	23 46 00	74 15 10	179.720	577.16	0.1146
6.	46I-2C1	KERIA BERI	23 31 00	74 39 00	337.275	383.03	0.0760
7.	46I-4B1	KUSHALGARH	23 12 00	74 27 00	292.725	1259.37	0.2500

LIST OF OBSERVATION WELL

STATE-RAJASTHAN
DISTT-JAIPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	45K-[illegible]A1	[illegible]PIN	25 44 00	74 05 00	[illegible]44.42	869	0.0503
2.	45G-[illegible]02	[illegible]PET	25 19 00	73 56 00		2220	0.1285
3.	45K-[illegible]A1	PAILMAGRA	25 02 00	74 07 00		966	0.0559
4.	45H-[illegible]02	MAVLI	24 47 00	73 59 00	497.33	2124	0.1229
5.	45H-[illegible]01	[illegible]HUKANA	24 37 00	73 45 00	491.01	5020	0.2905
6.	45H-[illegible]02	SUKADA	24 09 00	73 50 00		3572	0.2067
7.	45H-[illegible]01	KISHANGDEV	24 05 00	73 41 00	331.55	2502	0.1452

STATE-RAJASTHAN
DISTT-AJMER

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	45J-[illegible]01	KISHAN GARH	26 37 00	74 57 00	435.65	1837	0.2167
2.	45J-[illegible]02	PUSHKAR	26 30 00	74 34 00	480.66	1307	0.1542
3.	45J-[illegible]01	BANDANWARA	26 09 00	74 42 00	416.12	2261	0.2667
4.	45J-[illegible]01	BEAWAR	26 06 00	74 20 00	447.93	1413	0.1666
5.	45G-[illegible]01	KEKRI	25 58 00	75 10 00	356.50	1660	0.1958

LIST OF OBSERVATION WELL

STATE-RAJASTHAN
DISTT- JODHPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1	45B-3D6	[illegible]	26 24 05	72 56 45	255.605		0.2634
2	45B-2D1	OSIAN	26 43 30	72 55 00	329.50		0.2055
3	45A-4E1	PHALODI	27 07 40	72 22 00	233.90		0.2948
4	[illegible]	[illegible]	26 26 00	73 45 10	306.08		0.1113
5	45B-3B2	SHERGARH	26 19 45	72 16 00	239.20		0.1250

V-1-8/15

LIST OF OBSERVATION WELL

STATE-MADHYA PRADESH
DISTT-DHAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		BADNAWAR			550.350	1098	0.1340
2.		SARDARPUR			530.000	1480	0.1806
3.		KUKSHI			195.310	1464	0.1786
4.		MANAWAR			195.340	1859	0.2268
5.		DHAR			537.350	2297	0.2800

LIST OF OBSERVATION WELL

STATE-MADHYA PRADESH
DISTT-JHABUA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		KATHIWADA	22 30 00	74 12 00	220.690	813.00	0.0904
2.		UDAIGARH	22 32 00	74 35 00	402.980	883.00	0.0978
3.		KATHIWAD	22 08 00	74 16 00	322.170	1133.00	0.1671
4.		DUNGRIPADA	22 03 00	74 22 00	264.165	246.00	0.0363
5.		ALIRAJPUR	22 18 00	74 22 00	279.230	621.00	0.0916
6.		RANAPUR	22 40 00	74 53 00	351.735	874.00	0.1289
7.		NAGPUR	22 17 00	74 33 00	250.705	425.00	0.0627
8.		BHAMEL	23 08 00	74 41 00	395.745	279.00	0.0411
9.		THANOLA	23 02 00	74 35 00	398.180	589.00	0.0868
10.		RALIYAWAN	22 58 00	74 47 00	398.690	819.00	0.1208
11.		UMARKOT	22 44 00	74 49 00	498.355	519.00	0.0765

STATE-MADHYA PRADESH
DISTT-KHARGONE

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		BHASANER	21 44 00	75 31 00	267.250	1507	0.1117
2.		SISTAN	21 43 00	75 43 00	309.410	1317	0.0976
3.		BALKAWADA	22 00 00	75 32 00	216.930	928	0.0688
4.		SEGAON	21 51 00	75 21 00	270.360	661	0.0490
5.		SENDHWA	21 14 00	75 05 00	397.675	1314	0.0974
6.		KHETIYA	21 40 00	75 36 00	199.940	851	0.0631
7.		RAJPUR	21 56 00	75 03 00	234.900	611	0.0453
8.		BARWANI	22 02 00	74 52 00	179.095	924	0.0685
9.		DHAWA	22 06 00	75 19 00	162.670	517	0.0383
10.		BHIKANGAON	21 52 00	75 56 00	276.515	905	0.0671
11.		ZIRNA	21 39 00	75 59 00	263.150	1485	0.1101
12.		BARWAHA	22 16 00	76 04 00	188.680	1075	0.0797
13.		BARWAHA	22 24 00	75 53 00	240.285	642	0.0476
14.		MAHESHWAR	22 16 00	75 35 00	156.675	753	0.0558

LIST OF OBSERVATION WELL

STATE-MADHYA PRADESH
DISTT- BETUL

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1	42	MULTAI			757.360		0.2525
2	4	BHAINSDEHI			824.45		0.3267
3	25	BETUL			647.345		0.420

STATE-MADHYA PRADESH
DISTT- SHAHDOL

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	18	KHAIRAHA	23 03 00	81 26 00	504.011		0.2124
2.	25	JAISINGHNAGAR	23 41 30	81 23 30	503.016		0.1327
3.	32	BUDAWA	24 13 00	81 24 45	306.825		0.0973
4.	34	JAMUNIHA	23 17 45	81 47 30	522.271		0.1947
5.	40	BANDHAWABARA	23 18 00	81 14 30	471.277		0.0825
6.	43	SASTARA	23 24 00	80 58 15	450.793		0.1416
7.	49	TALA	23 43 00	81 02 00	472.329		0.1328

STATE-MAHARASTRA
DISTT-AHMADNAGAR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	BM-15	SUPA	18 57 35	74 32 20	710.36	5958	0.3497
2.	GV-22A	SAIKHINDI	19 38 10	74 08 15	630.48	1291	0.0758
3.	GV-29C	TELEGAON	19 41 40	74 17 45	594.51	1071	0.0629
4.	GB-31B	TAKALI	19 55 00	74 23 00	509.14	355	0.0208
5.	GV-32B	APEGAON	19 55 15	74 37 20	521.64	489	0.0287
6.	GV-10C	BCTA	19 15 20	74 08 50	683.53	2122	0.1246
7.	GV-12B	KOKANA	19 00 00	74 20 00	434.81	3991	0.1246
8.	GV-13C	MALI-SAMBHULG	19 26 05	74 58 10	692.07	1758	0.1032

STATE-MAHARASTRA
DISTT-SOLAPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	BM-112	WADEGAON	17 26 00	75 14 15	486.23	1601.60	0.1066
2.	BM-111	DIKSAL	17 24 25	75 31 40	474.08	1508.45	0.1004
3.	SA-40	KANDALGAON	17 43 25	75 07 15	466.46	1186.81	0.0790
4.	BM-132	MUSTI	17 43 46	76 04 50	480.18	2311.29	0.1539
5.	SA-35	KALMAN	17 55 45	75 46 45	493.90	1239.32	0.0825
6.	SA-20	PANDE	18 14 30	75 14 00	542.68	2065.54	0.1375
7.	SA-27	KUSLAM	18 16 50	75 46 25	562.50	1505.10	0.1002
8.	BN-138	JEUR	17 28 38	76 05 30	440.54	1795.57	0.1195
9.	SA-29	UPLAI	17 55 00	75 29 30	493.90	1807.32	0.1203

LIST OF OBSERVATION WELL

STATE-MAHARASTRA
DISTT-PUNE

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA BY WELL(Sq.Km.)	INFLUINCED AREA WEIGHT
1.	BM-1	OTTUR	19 16 00	73 59 00	661.40	1578	0.1009
2.	BM-20	KHED (RAJGURU-NAGAR)	18 51 10	73 52 50	609.76	1871	0.1196
3.	BM-19	DHAMARI	18 47 20	74 05 50	640.24	2351	0.1503
4.	BM-40	BAMBOLI	18 40 09	73 30 11	591.46	1972	0.1261
5.	BM-55	KATRAJ	18 26 30	73 51 30	667.68	1836	0.1175
6.	BM-56	MARGASANI	18 17 00	73 44 30	673.78	1916	0.1225
7.	BM-75	PANDARE	18 08 45	74 27 55	580.30	2987	0.1910
8.	BM-78	INDAPUR	18 07 00	75 01 40	515.27	1128	0.0721

STATE-MAHARASTRA
DISTT-SATARA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA BY WELL(Sq.Km.)	INFLUINCED AREA WEIGHT
1.	SM-22	NAIGON	18 06 30	73 58 00	626.52	728	0.0694
2.	KR-3	MAHABALE-SHWAR	17 55 30	73 39 40	1356.71	728	0.0694
3.	BM-34	ADARKI-TE	17 55 44	74 13 02	640.22	1455	0.1387
4.	KR-5	KOREGAON	17 41 45	74 09 45	653.96	1152	0.1098
5.	KR-4	SATARA	17 41 00	73 59 30	712.56	1273	0.1214
6.	BM-101	PALSHI	17 40 20	74 41 00	636.52	1819	0.1734
7.	KR-23	CHITALA	17 25 02	74 30 00	657.01	1152	0.1098
8.	KR-15	YERAWAL	17 22 30	73 56 30	609.23	2163	0.2061

LIST OF OBSERVATION WELL

STATE-MAHARASTRA
DISTT-AURANGABAD

	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	GP-10	NIPANI	19 49 30	75 27 14	553.96		0.1404
2.	GV-43	MANJRI	19 43 05	74 57 03	501.52		0.0731
3.	GV-40	PALASWADI	20 03 30	75 03 05	522.31		0.1011
4.	GV-44	KANNAD	20 15 20	75 08 30	620.42		0.1011
5.	GV-52	AKATWADE	19 30 17	75 26 30	452.13		0.0562
6.	TE-136	AMKHEDA	20 35 35	75 36 45	376.52		0.0506
7.	GP-5	SILLOD	20 18 00	75 39 06	618.90		0.1011
8.	GV-338	VAIJAPUR	19 55 42	74 43 30	533.53		0.0731
9.	GP-158	MANDI	20 38 45	75 52 45	318.59		0.1348
10.	GV-33	THERGAON	19 33 08	75 34 31	472.56		0.1685

STATE-MAHARASTRA
DISTT-SANGLI

	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.	KR-32	PALUS	17 05 15	74 27 25	586.41		0.1122
2.	KR-34	ALTE	17 09 59	74 32 50	608.84		0.1225
3.	KR-37	KUCHI	17 03 40	74 51 50	663.10		0.1020
4.	KR-37	RANJANI	16 58 10	74 56 35	609.75		0.1055
5.	KR-43	SHIRALA	16 59 03	74 07 40	603.65		0.1020
6.	KR-48	TANDULWADI	16 55 35	74 17 20	556.40		0.0476
7.	BM-103	UMBARGAON	17 32 30	74 57 48	571.64		0.0544
8.	BM-113	KHARSUNDI	17 20 35	74 46 40	707.31		0.1225
9.	BM-108	ANTRAI	17 10 10	75 13 00	603.65		0.1225
10.	BM-121	UTAGI	17 11 58	75 30 10	516.76		0.1088

LIST OF OBSERVATION WELL

STATE-KARNATAKA
DISTT-BIJAPUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		BADAMI	15 54 00	75 37 00	593.95	2467	0.1457
2.		BILGI	16 26 51	75 36 55	555.75	3393	0.1988
3.		MALAPUR	16 21 26	75 16 34	561.00	1852	0.1085
4.		MUDDEBIHAL	16 20 14	76 08 06	548.10	2692	0.1577
5.		SHIVANGI	16 48 47	75 59 12	570.95	3148	0.1844
6.		HUNGUND	16 03 38	76 03 26	570.70	2385	0.1397
7.		RUGI	17 05 15	75 57 00	468.90	1113	0.0652

STATE-KARNATAKA
DISTT-BELGAUM

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		ATHANI	16 43 45	75 03 37	564.00	1529.51	0.1136
2.		CHIKKODI	16 25 25	74 35 25	643.00	1721.70	0.1279
3.		ANKALAGI	16 01 30	74 41 45	670.00	2824.23	0.2098
4.		LONDA	15 26 58	74 29 48	610.00	3038.10	0.2257
5.		RAIBHAG	15 29 40	74 46 35	664.00	1835.85	0.1364
6.		KARI KATTI	15 43 55	75 01 30	655.00	2511.41	0.1866

LIST OF OBSERVATION WELL

STATE-KARNATAKA
DISTT-RAICHUR

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		DEODURGA	16 25 00	76 56 30	4[illegible]0.00	1751	0.1250
2.		RAICHUR	16 13 00	77 21 30	416.00	2335	0.1667
3.		LINGARAGUR	16 09 30	76 31 30	5[illegible]0.00	1985	0.1417
4.		KASHTAGI	15 45 30	76 11 10	6[illegible]2.00	1401	0.1000
5.		TURVIHAL	15 4[illegible] 15	76 36 00	4[illegible]0.00	2685	0.1917
6.		YELBURGA	15 37 00	76 01 00	6[illegible]9.00	1517	0.1083
7.		GANGAVATHY	15 25 00	76 31 30	420.00	1050	0.0750
8.		HASALATHI	15 18 30	76 19 00	470.00	1283	0.0916

STATE-KARNATAKA
DISTT-GULBERGA

SL. NO.	WELL NO.	WELL NAME	LAT.	LONG.	R.L.OF M.P.(Mts)	AREA INFLUINCED BY WELL(Sq.Km.)	AREA WEIGHT
1.		AFZALPUR	17 16 30	26 13 00	399.00	915	0.0566
2.		ALAND	17 00 35	76 34 30	504.00	2068	0.1279
3.		CHINCHOLI	17 27 50	77 25 30	40[illegible].00	1513	0.0936
4.		CHITTAPUR	17 07 30	77 05 00	42[illegible].00	818	0.0506
5.		GULBERGA	17 20 30	76 49 30	45[illegible].50	2015	0.1246
6.		JEWARGI	17 00 30	76 47 00	415.00	1764	0.10[illegible]1
7.		SADAM	17 10 45	77 17 30	4[illegible].00	1030	0.0637
8.		SHAHAPUR	16 42 00	76 50 00	410.00	1499	0.0927
9.		MUDNUR	16 36 30	76 29 30	5[illegible].00	1799	0.1113
10.		YADGIV	16 45 00	77 07 00	3[illegible].00	2747	0.1699

APPENDIX - V-2

AVERAGE GROUNDWATER LEVEL (IN METRES) FROM M.S.L. FOR DISTRICT SURENDRANAGAR, GUJARAT

Sl. No.	Name of Obs. Well	R.L. of M.F.	Area Influenced by well	Area Weight	1987-88 Aug.	Nov.	Jan.	May
1.	DASADA	28:170	1201	0.1150	6.94*	7.18	7.64	8.10
					21.23**	20.99	20.53	20.07
					2.44***	2.42	2.36	2.30
2.	HALVAD	44.750	1389	0.1330	23.50	22.05	23.37	23.43
					21.07	22.52	21.20	21.14
					2.80	2.99	2.81	2.81
3.	DHAGANDHRA	50.955	1399	0.1340	21.90	19.60	21.50	22.70
					29.05	31.35	29.45	28.25
					3.89	4.20	3.94	3.78
4.	LAKHTAR	43.125	1253	0.1200	10.52	11.00	11.00	10.66
					32.60	32.12	32.12	32.46
					3.91	3.85	3.85	3.89
5.	SALAYA	50.5000	1567	0.1500	9.24	10.35	11.00	10.28
					41.26	40.15	39.50	40.22
					6.23	6.06	6.96	6.07
6.	SURENDRA-NAGAR	66.966	762	0.0730	9.83	8.67	10.50	8.13
					15.13	58.29	56.46	58.83
					4.17	4.25	4.12	4.29
7.	LIMDI	43.685	1420	0.1360	10.40	8.90	9.50	11.79
					35.28	34.78	34.18	31.89
					4.52	4.73	4.64	4.35
8.	CHOTILA	205.270	1452	0.1390	18.00	11.03	11.05	19.00
					187.27	194.24	194.22	186.27
					26.03	26.99	26.99	25.89
					53.99	55.49	55.69	53.56

* Observed groundwater level from measuring point
** Groundwater level calculated with respect to mean sea level (M.S.L.)
*** Groundwater level calculated with respect to M.S.L. multiplied by Area weight (Thiessen Weight).

The analysis for the year 1977-78 to 1986-87 is given in CS-24.