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STUDY OF DEPTH-AREA-DURATION AND DEPTH-DURATION CHARACTERISTICS

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ABSTRACT

Some of the extreme storms in the contiguous areas of Saurashtra and Rajasthan forming part of the arid and semi-arid belt in India were analysed by the depth-area-duration and depth-duration techniques and their characteristics were examined. The depths of rainfall of these extreme storms were compared using the statistical estimates of rainfall over this region both over shorter and longer durations. The meteorological systems associated with these extreme rain storms have also been examined with a view to identify any common characteristic which could be useful for study of the consequent flood events.

The studies have broadly indicated that

(i) most of the severe storms in the Saurashtra and Rajasthan regions have occurredin the month of July;

(ii) the extreme storms have occured soon after the onset of monsoon over these regions namely June in Saurashtra and July in Rajasthan;

(iii) the one day rain depths of the June 1983 storm over Saurashtra region have exceeded the 10000 year return period estimates of rainfall over the Saurashtra region;

(iv) the rainfall over shorter durations (less than 24 hour) have exceeded the 50 year return period

estimates over their respective regions during the June 1983 storm over Saurashtra and July 1981 storm over Rajasthan; and

(v) the storms of June 1983 and July 1981 have comparable magnitudes, though the July 1981 storm was relatively less intense & more localised than the June 1983 storm.

From the point of view of flash flood occurrence, the magnitude of the total storm depths of June 1983 and July 1981 storms and their intensities over shorter durations have far reaching implications in terms of the magnitude of peak flood as well as volume of water to be discharged. This indicates need for review of the design flood of the hydraulic structures, existing or under construction and those being planned especially those with smaller catchment areas.

1.0 INTRODUCTION

India has a vast stretch of semi-arid belt extending from Punjab in the north to Kanyakumari in the south. While some rivers originate in this stretch, others have large parts of their catchment areas in this part of land. A number of medium and major irrigation projects have already been in operation or under construction and nearing completion. Some more are being proposed. Design flood estimation for these projects requires an indepth study of the severe and extreme storms by depth-area-duration and depth-duration techniques.

Cyclonic storms are some of the meteorological systems which cause very heavy rainfall resulting in floods. In recent years it has been noticed that very severe storms have occurred in these regions, whose 24 hour rainfall has either equaled or exceeded the normal annual rainfall. This, naturally, calls for a thorough understanding of the increasing rainfall in these areas. This report describes study of the hydrometeorological aspects of severe storms in two contiguous semi-arid areas in Saurashtra and Rajasthan and their space-time characteristics using depth-area-duration, depth-duration and statistical estimates.

2.0 REVIEW

Depth-area-duration and depth-duration techniques have been used by the India Meteorological Department, Indian Institute of Tropical Meteorology, Central Water Commission and other organisations for analysing severe and extreme storms. Some studies were also carried out on severe storms occurring over Saurashtra and Kutch and Rajasthan regions. Ramaswamy and Pareek (1976) have studied the synoptic situations associated with the exceptionally heavy rainfall over Jaipur district.

Dhar et al (1981 a, b) made depth-area-duration analysis of the severe storms which occurred in the Saurashtra and Kutch region in August 1979 and June 1980 and made an assessment of their intensity with respect to the earlier severe storms by comparing the depths over different durations for the standard areas.

Rao et al (1980, 1982) have studied the August 1979 storm on Macchu catchment by depth-area-duration method and the design storm values obtained by the moisture maximisation method were compared with those obtained by the statistical approach of return period analysis.

Sharma and Vangani (1982) analysed the 15-19 July 1979 storm in relation to the worst flash flood in the Luni basin which was reported to be having a return period of 100 years.

Mistry et al (1984) have analysed the 1983 storm over Junagadh and Rajkot districts by depth-area-duration analysis and made a comparative study with the past storms in this region. However, while carrying out the analysis, the isohyetal pattern has been extended over the sea as was done by Dhar et al. While it is true that rain occurs over sea with the same intensity as over land, if not more, however from practical point of view, these hypothetical depths could not be applied over river catchments which are land based.

Puri et al (1984) have studied the hydrometeorological aspects of the cyclonic storms over Gujarat state. Isohyetal analysis of heavy rainfalls which occurred during the period 1891 to 1970 and their depth-area-duration analysis were carried out. The study revealed that the storm of 12-14 June 1920 was the heaviest and has yielded maximum rainfall depths for 1 day, 2 day and 3 day durations. A comparative study of these depths were made with rainfall depths of 26-28 July 1927 and 21-23 June 1983 and estimated rainfall of 1 day and 2 day duration for Saurashtra and Kutch for 10000 year return period.

3.0 PROBLEM DEFINITION

Extreme floods resulting from extreme storms would have far reaching implications not only on the safety of the existing hydraulic structures but also on the planning and design of future water resources projects which may have to have also to consider the flood control aspect which has hitherto been not considered, as most of these are only irrigation projects designed for moderate floods. An additional problem which needs consideration in this connection is that the much localised intense nature of these storms gets coupled with small catchment areas. These localised extreme intense storms might cause flash floods, for which many of our design procedures are ill equipped to cater to. It is, therefore, proposed to examine the adequacy of the design storms in view of the recent storms such as those of July 1979 and July 1981 in Rajasthan; and August 1979 and June 1983 in Saurashtra and Kutch whose depths have exceeded the highest observed point rainfalls in their respective areas.

4.0 METHODOLOGY

To study the two principal characteristics of a rain storm namely intensity and areal extent, two methods of analysis normally used are the depth-duration and depth-area-duration analysis. The severity of the extreme rainfall depths observed could be ascertained by comparing them with the statistical estimates of rainfall for different durations and return period. The storm centered depth-area-duration analysis for the storms over Saurashtra were carried out considering the last closed isohyet and the coast as boundary. In case of the storms over Rajasthan, the analyses were extended upto the last closed isohyet for each duration. Depth-duration characteristics were analysed from point rainfall data at ordinary and self-recording raingauge stations in the two regions. In addition to analysing the storms by conventional means, the nature of the storms over different durations, especially the shorter durations was also examined as these are important for estimation of the peak floods.

5.0 APPLICATION

The depth-area-duration and depth-duration techniques were applied to study the area-intensity and duration-intensity characteristics of the severe storms which occurred recently in the Saurashtra and Rajasthan regions of the semi-arid areas in Western India.

5.1 Saurashtra Region

The Saurashtra region comprises of six districts namely Bhavnagar, Junagadh, Amreli, Rajkot, Jamnagar and Surendernagar. The region is an elevated plateau of about 100-200 m.a.s.l. A number of rivers flow radially outwards towards the sea from this plateau. The normal annual rainfall shown in figure 1 varies from 45 to 60 cm. Nearly 95% of this annual rainfall is received during the four monsoon months from June-September. The normal date of onset of monsoon over this region is 15th June.

The severe rain storms over this region could be attributed to the following meteorological systems.

i) Storms and depressions originating in Arabian Sea and travelling north-eastwards;

ii) storms and depressions originating in Bay of Bengal, moving over the main land and intensifying over the region due to moisture incursion from Arabian Sea.

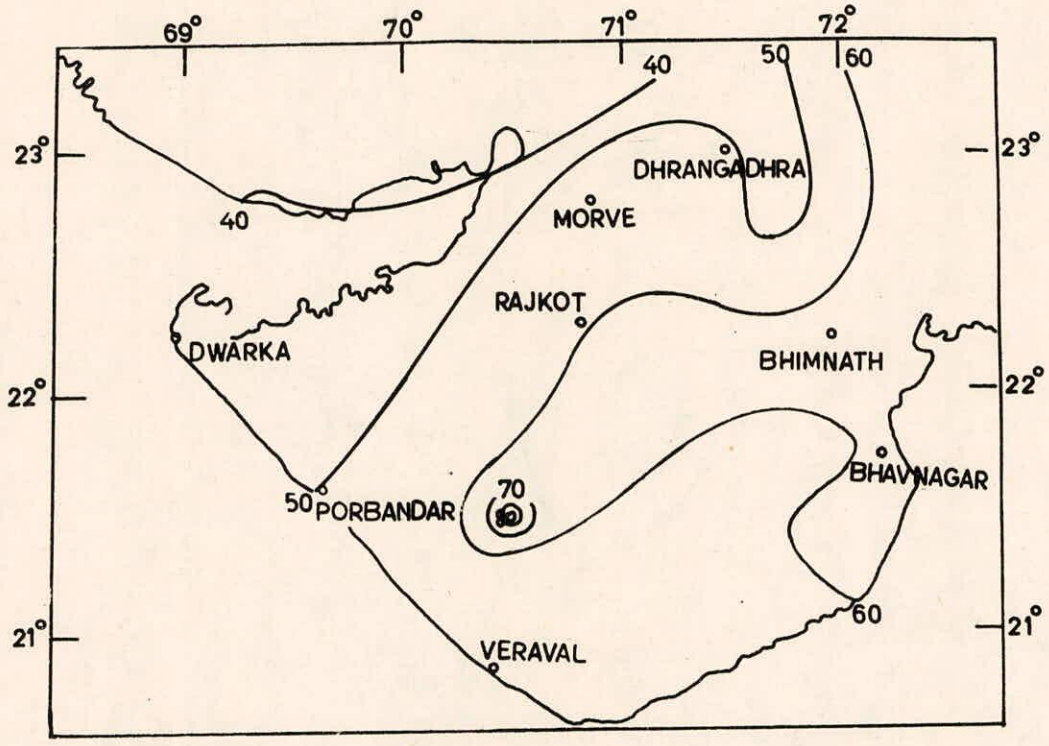

FIGURE 1 - NORMAL ANNUAL RAINFALL ISOPLETHS(Cm) - SAURASHTRA

iii) mid tropospheric lows (circulations); and

iv) trough along west coast

While the Bay of Bengal storms affect the interior and the coastal districts alike, the Arabian Sea storms affect the coastal districts more severely. Occasional heavy rains are also known to have occurred over the inland areas in association with upper air systems not traceable on surface charts.

The frequency of storms and depressions during the period 1891-1970 is shown in figure 2. Since 1979, the frequency have increased and the total storm depths in case

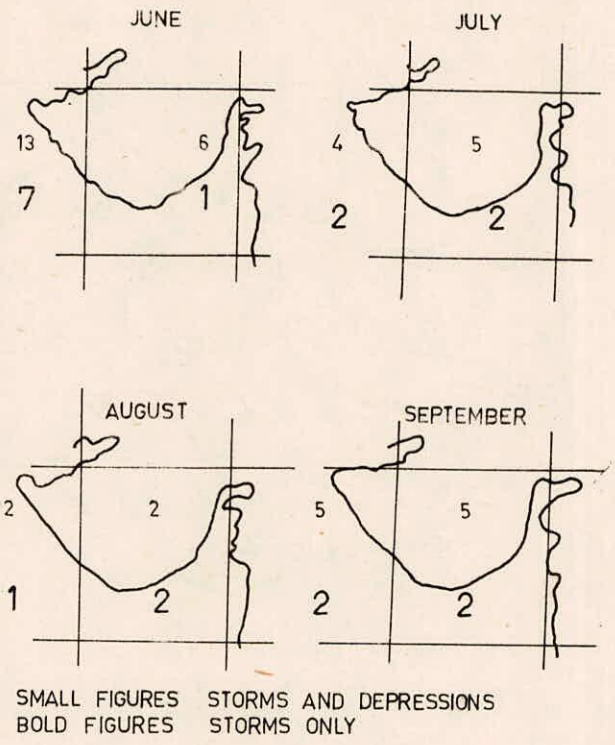

FIGURE 2 - FREQUENCY OF STORMS AND DEPRESSIONS

of some of these storms have either equaled or exceeded even the normal annual rainfall for this region.

5.1.1 Severe storms in the region

The severe storms experienced in this region in chronologic order were

i) 21-23 July 1894,

ii) 12-14 June 1920,

iii) 25-27 July 1927,

iv) 12-14 July 1950,

v) 11-13 August 1979,

vi) 28-30 June 1980,

vii) 2-4 July 1980; and

viii) 21-23 June 1983.

5.1.2 Depth-area-duration analysis of June 1983 storm

Depth-area-duration analysis of the June 1983 storm were carried out using daily rainfall data over 1,2 and 3 days duration using data of 50 stations listed by Mistry et al. (1984). The depth-area-duration curves for 1 day, 2 days and 3 days have been prepared and are shown in figure 3. From these DAD curves, rainfall depths for 1 day, 2 days and 3 days durations for different areas were obtained.

5.1.3 Comparison with other severe historical storms

The 21-23 June 1983 storm over the Saurashtra region was caused by a low pressure area which formed in the Arabian Sea and moved northwards. It was lying as a deep depression 50 km southwest of Amreli at 0830 hrs on 20th June. The deep depression moved further north over the Saurashtra region, weakened into a depression and was lying centered at 0830 hrs on 22 June about 60 km east of Rajkot. It moved further north-eastwards subsequently and became unimportant. The storm of 28-30 Jun'80 was due to remnants of a land depression, while the July 1980 storm had no trace on surface charts. Thus the three storms were due to different meteorological systems. A close examination of the isohyetal maps of June 1980, July 1980 and June 1983 storms (Figures 4 to 6), however,revealed a rather common pattern with the rain

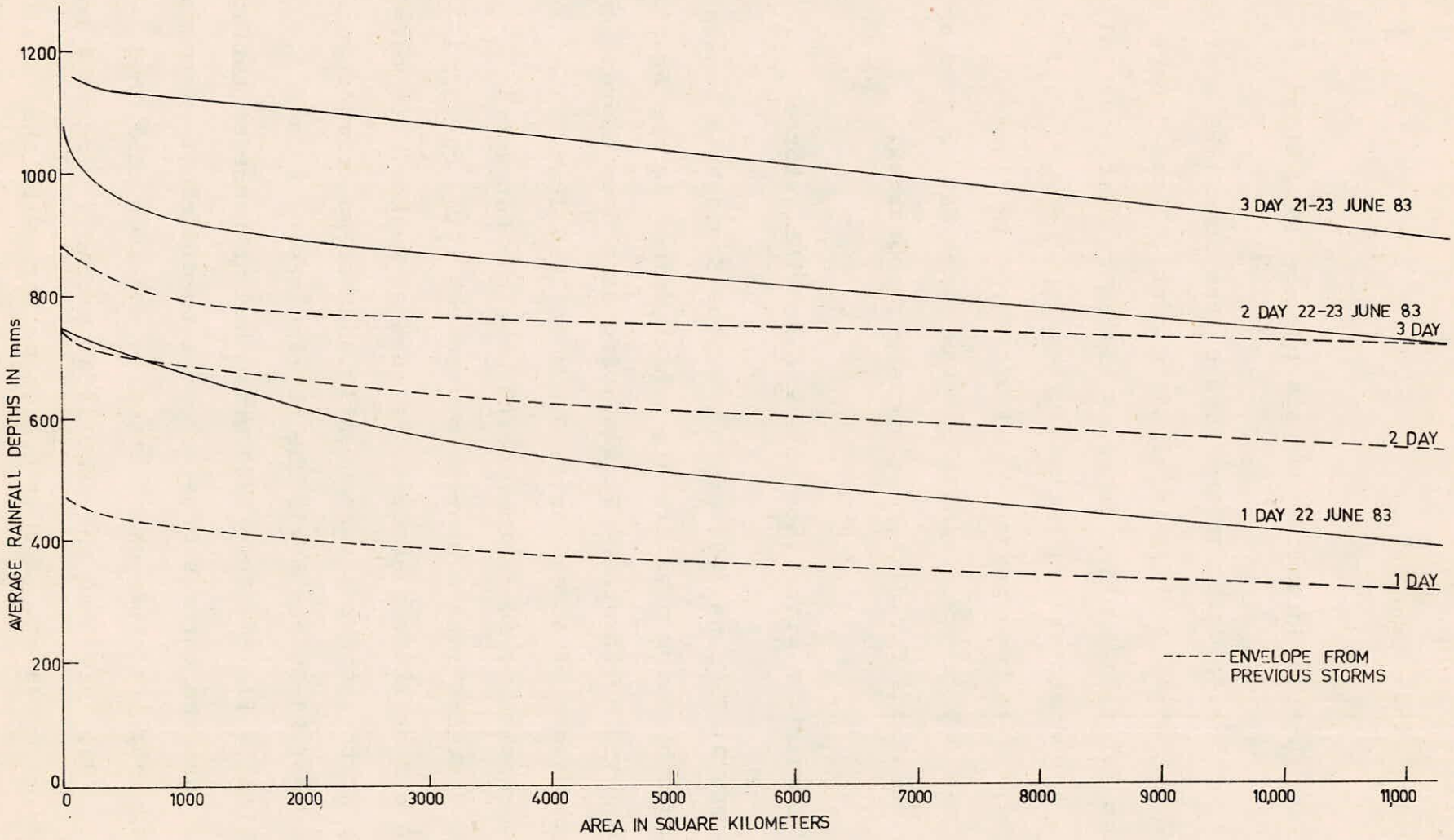

FIGURE 3 - DEPTH-AREA-DURATION CURVES, 21 to 23 JUNE 1983 STORM AND ENVELOPE VALUES

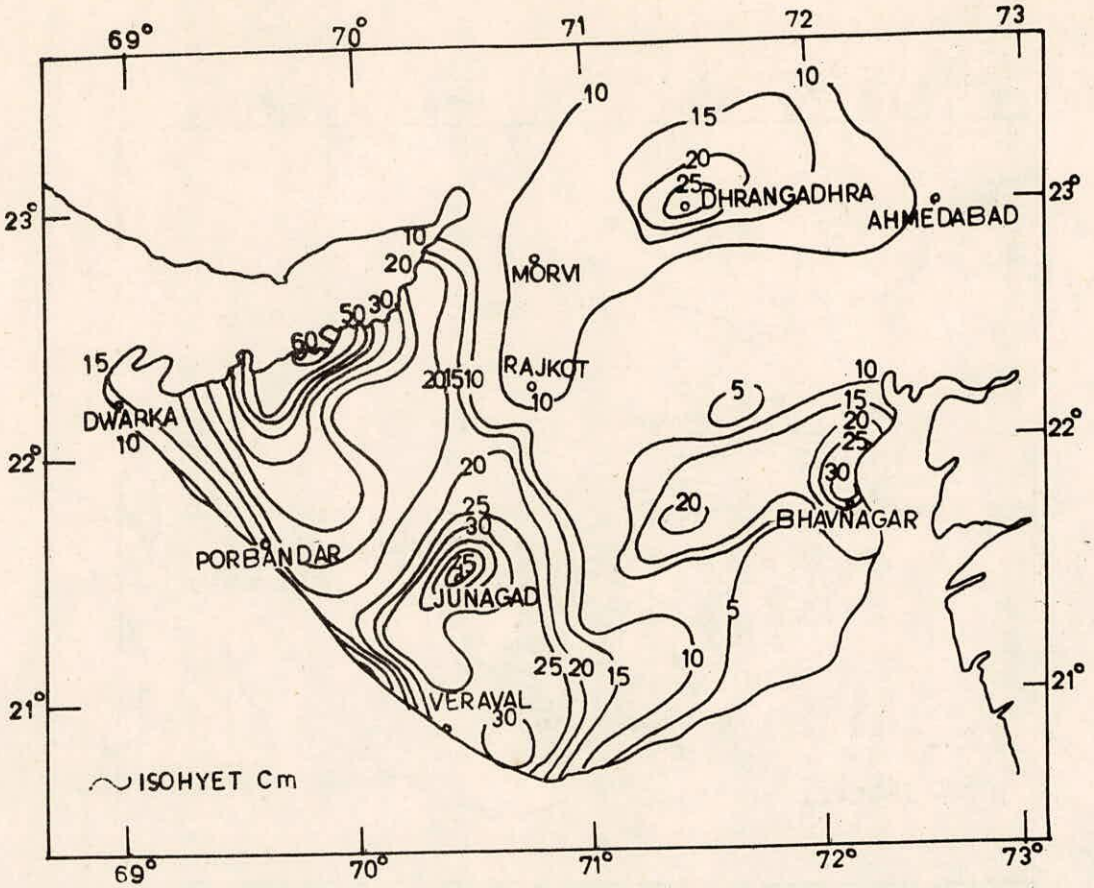

FIGURE 4 - 28-30 JUNE 1980 RAINSTORM OVER SAURASHTRA

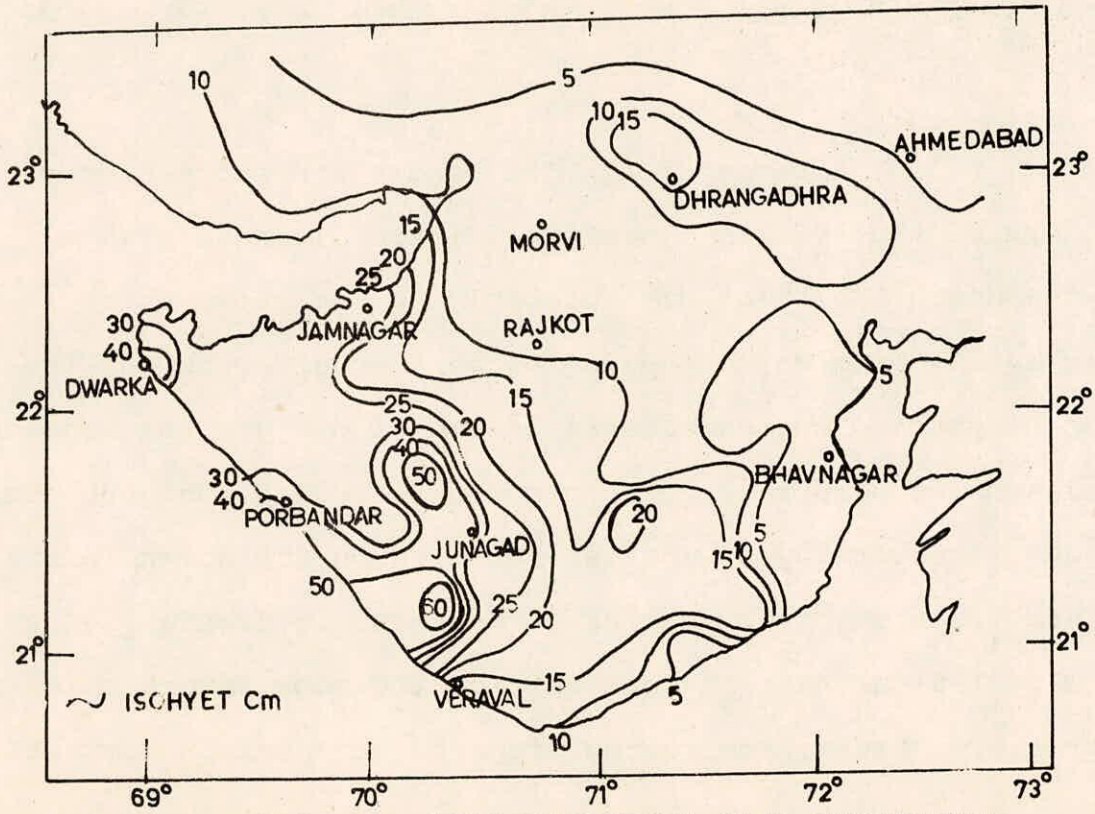

FIGURE 5 - 2-4 JULY 1980 RAINSTORM OVER SAURASHTRA

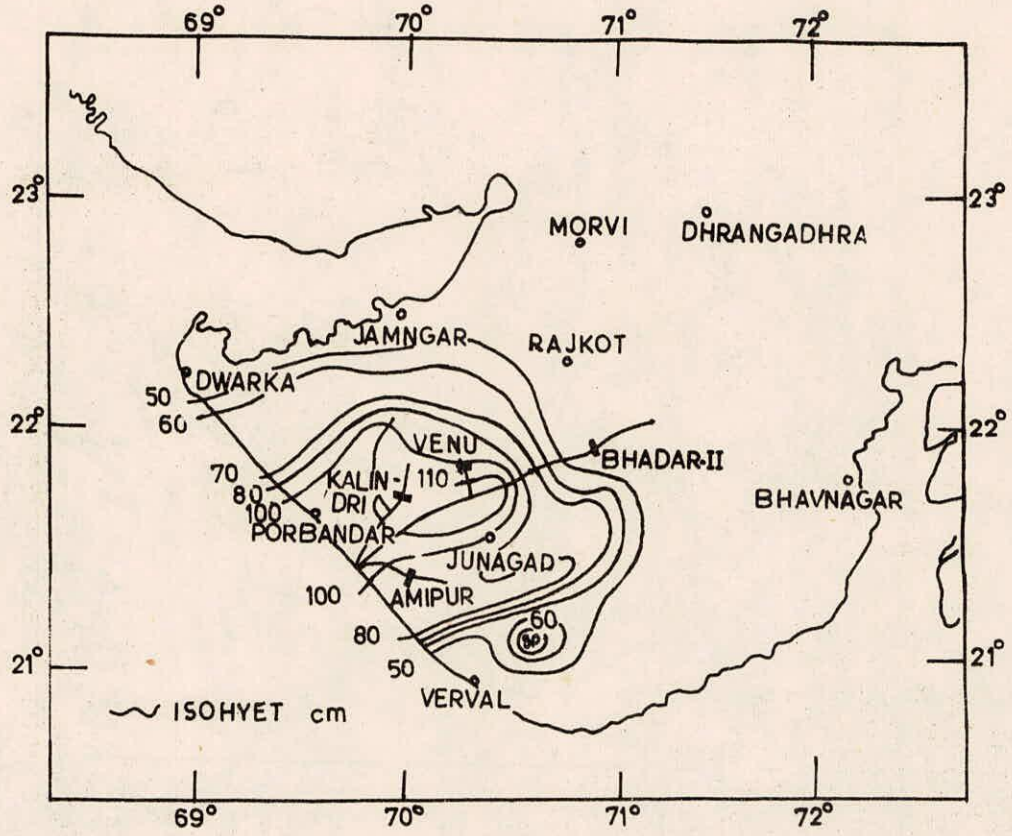

FIGURE 6 - 21-23 JUNE 1983 RAINSTORM OVER SAURASHTRA

centre in Junagadh district. The centre and storm isohyetal pattern of the August 1979 storm (Figure 7), however, is in the north. This was due probably to the storm track originating from Bay of Bengal being further north and the time of storm occurrence being in the middle of the monsoon season. The occurrence of storm centre around Junagadh could be due to orography as is also revealed by the normal annual rainfall pattern over the region as shown in figure 1. Dhar et al.(1981 a) have on the basis of the most severe rain storms over Saurashtra region prepared an envelope curve of

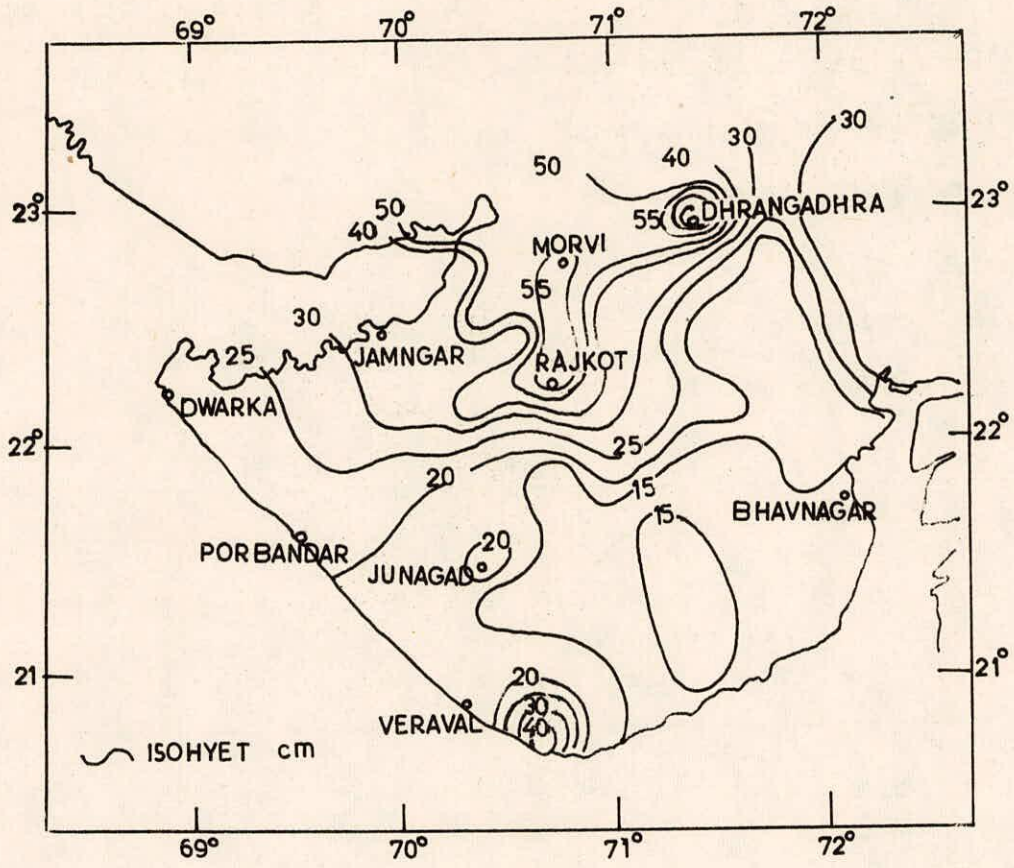

FIGURE 7 - ISOHYETAL MAP OF THE 10-12 AUGUST 1979 RAINSTORM OVER MACHHU BASIN

rain depths over different areas. These envelope values come mostly from the 25-27 July 1927 storm with centre at Dakor-Ahmedabad, which was due to a depression that moved over Gujarat from Bay of Bengal. However, the 1 day envelope depths over 600 km^2 and above were contributed by the 21-23 July 1894 storm, which again was a Bay of Bengal storm. After comparison of the depth-area-duration values of June 1980 and July 1980 storms with the envelope values (Table 1), Dhar et al.(1981) concluded that the rainfall depths of the 1980 storms were certainly less than the envelope depths

over all durations.

Puri et al.(1984) have noticed that though the storm of 12-14 June 1920 was the heaviest storm during the period 1891-1970, its depths were lower than those of the July 1927 or June 1983 storms.

Table 1 - Depth-Area-Duration Statistics of Rain Depths of Severe most Rain Storms in 1980 and Envelope Rain Depths *

Area in sq.miles	Area in sq. km.	Rain Depths (cm) June 1980 1 day 29 June	2 days 29-30 June	3 days 28-30 June	July 1980 1 day 2 July	2 days 2-3 July	3 days 2-4 July	Envelope 1 day	2 days	3 days
Point Value		42.0	43.0	61.0	47.0	63.0	68.0	45.7 b	74.9 b	84.1 b
100	259	41.2	42.8	60.8	43.5	61.0	64.0	45.2 b	71.8 b	82.5 b
200	518	40.6	42.6	60.2	40.9	59.0	61.6	43.7 b	70.8 b	81.6 b
500	1295	38.9	41.8	57.9	36.4	55.2	57.6	41.7 a	67.8 b	79.4 b
1000	2590	36.4	40.5	53.7	32.4	51.0	54.2	39.3 a	65.0 b	77.0 b
5000	12950	23.0	30.7	36.6	21.3	34.0	40.0	30.3 a	53.4 b	68.2 b
10000	25900	16.4	24.1	30.5	14.2	24.4	32.2	24.8 a	45.6 b	61.6 b
20000	51800	10.7	16.7	24.3	8.9	16.9	23.9	21.6 b	37.3 b	49.9 b

a= Of 21-23 July 1894 storm; b = of 25-27 July 1927 storm; *= Dhar etal 1981.

From a comparison of the values over different areas and different durations in Table 2 and comparison of DAD curves in figure 3, it may be seen that the rain depths of June 1983 storm are much higher than the envelope depths over all durations and all areas.

Table 2 - Comparison of 1, 2 and 3 Day Envelope Depths Over Saurashtra With 21-23 June 1983 Storm Depths

Storm/Envelope depths (cm)

Area in km^2	Envelope			June 1983		
	1 day	2 days	3 days	1 day 22	2 days 22-23	3 days 21-23
500	44.0	71.5	85.0	71.0(1.61)	96.0(1.34)	113.0(1.33)
1000	42.5	69.0	82.0	68.0(1.60)	92.0(1.33)	112.0(1.37)
2000	40.5	66.5	77.0	61.5(1.52)	88.5(1.33)	111.0(1.44)
5000	36.5	61.0	75.0	50.5(1.38)	83.0(1.36)	103.0(1.37)
10000	32.5	55.0	72.0	42.0(1.29)	74.0(1.35)	91.0(1.26)

Figures in brackets indicate ratios of June 1983 storm depths to envelope depths.

5.1.4 Other special features of the June 1983 storm

Besides being the severe most storm on record, the June 1983 storm has other important features as indicated by the characteristics of the storm rainfall depths over shorter durations.

It may be seen from the figure 3 that the 1 day, 2 day and 3 day depth-area-curves are almost parallel to each other indicating that the rainfall was almost uniformly intense over large area on all the three days. For examining the intensity over shorter durations, the depth-duration values of 14 recording raingauge stations in the Saurashtra region given by Mistry et al. (1984) have been made use of (Table 3). It is seen from these values that excepting for five recording rain gauges in the vicinity of the rain storm centre, the intensity of rainfall beyond 24 hours of duration over a number of recording raingauges is not pronounced. It is, therefore, apparent that the information from the daily depths does not represent the true nature of occurrence of storm which might have been widespread only for 24-30 hours during 22-23 June.

Further, from an examination of the maximum intensities over 1,2,3, 6,12 and 24 hours, it is seen that out of the five recording raingauges in the vicinity of the rain storm centre, namely Porbandar, Fodarness Dam, Venu II, Uben and Kalindri, Venu II has the highest 1 hour depth, Bhadar Dam has the highest 2 hours depth and Uben the highest 3,6 and 12 hours depths. The highest 6 hours depth at Amipur Dam is very close to the corresponding value at Uben. The 48 and 72 hours depths are, however, highest at Kalindri followed by Fodarness Dam and Porbandar Airport. Thus, except for the 2 hours value, the maximum rainfalls over all other time durations have been recorded at one or the other among the

Table 3 - 50 year Return Period* and Maximum Rain Depths of June 83**, August 1979 for Different Durations

Rain depths (mm)

	Duration (in hours)								
	1	2	3	6	9	12	24	48	72
50 yr	100	-	200	240	260	280	360	-	-
Venu II Dam site	93	143	176	217.5	259	380	536	878	986
Porbandar (AP)	-	-	131.4	240.2	315.8	352	619.8	853.4	1036.7
Uben Dam site	83	138	208	277.5	345	416	618.5	800	867.5
Kalindri Dam site	65	96	135	196	276	361	525	927	1156
Fodarness Dam	64	112	153	205	295	372	575	768	1142
Amipur Dam site	60	106	160	276	346	400	522	603.5	760
Jetpur	60	107	120	160	200	240.5	420	635.5	663
Keshod	-	-	38	-	138	-	300	-	522
Bhadar Dam site	87	173	182	221	244	271	429	635.5	520
Veraval	-	-	100	157	208	256	331	474	512
Phophal Dam site	60	85	95	115	140	170	270	425	480
Hiran II Dam site	34	46.5	66.5	56	101.5	111.5	173.5	308	406

Table 3 - continued

	Duration (in hours)								
	1	2	3	6	9	12	24	48	72
Sankroli Dam	44	63	89	157.5	218.5	269.5	368	462.5	-
Khambha	23	25	33	48	65	75	121	-	-
Aug.1979 storm as recorded at Rajkot	-	-	159	249.5	293.6	339	532.1	554.1	-
Ratio of highest point rainfall to 50 yr value	0.93	-	1.04	1.16	1.33	1.49	1.72	-	-

* Source: Harihara Iyer and Tripathi (1974)

** Source:Mistry et al.(1984)

five stations at the centre of the storm. The rain centre is located over Junagadh district not only on daily basis but also for shorter durations of 1 to 6 hours.

5.1.5 Comparison with the statistical estimate of extreme rainfall depths

Harihara Iyer et al. (1974) have prepared maps of 2,5,10,25 and 50 year return period values of rainfall for 15 min, 30 min, 45 min, 1 hour , 3 hrs, 6 hrs, 9 hrs, 12 hrs and 24 hrs durations using Gumbel's extreme value distribution.

Using Gumbel's distribution over a 30 year series, Rao et al. (1982) have estimated the 1 day rainfall for return period of 50, 100, 500, 1000, 5000 and 10000 years for ten stations in and around the catchment of Machhu. The highest value of 700 mm has been estimated at Bhuj for 10000 year return period. The one day point rainfall depth of 736 at Manavdar and 711 mm at Junagadh on 22 June 1983 was higher than the 10000 years value at Bhuj which gives an indication of the magnitude of the June 1983 storm.

In Table 3, the 50 year return period values of 1 hr, 3 hrs, 6 hrs, 12 hrs (Harihara Iyer and Tripathi, 1974) are given. Comparing these with the rainfall recorded for the corresponding durations at the stations in the Saurashtra region, it may be seen that the maximum rainfall for 1 hr is less than that for the 50 year return period, while it is more at all other durations by 16 to 72 percent, the percentage increasing with time duration.

From these comparisons, it may be seen that the storm which has exceeded the 10000 year return period over 24 hours and longer durations and the 50 yr value over shorter durations would have effect on not only the peak flood magnitude but also on the volume of water to be discharged within a short period of time, which is a typical characteristic of the flash floods.

5.2 Rajasthan Region

The Rajasthan region has been divided by the India Meteorological Department into two sub divisions viz., West and East Rajasthan. West Rajasthan is an arid region with scanty and highly variable rainfall. East Rajasthan is partly arid and partly semi-arid. The normal annual rainfall in East Rajasthan is 704 mm (based on 1950 normals) as compared to 586 mm in West Rajasthan. Jhalawar has the highest normal annual rainfall 1000 mm (Figure 8). The variability of annual rainfall varies from 30 percent in the south east to as high as 80 percent in the West. Nearly 90 percent of the annual rainfall is received in the south west monsoon season from June to September and first July is the normal date of onset of monsoon over this region.

The severe rain storms over this region are mainly due to:

i) local thunderstorms resulting from low level convergence and high level divergence, and

ii) remnants of the Bay of Bengal cyclones which

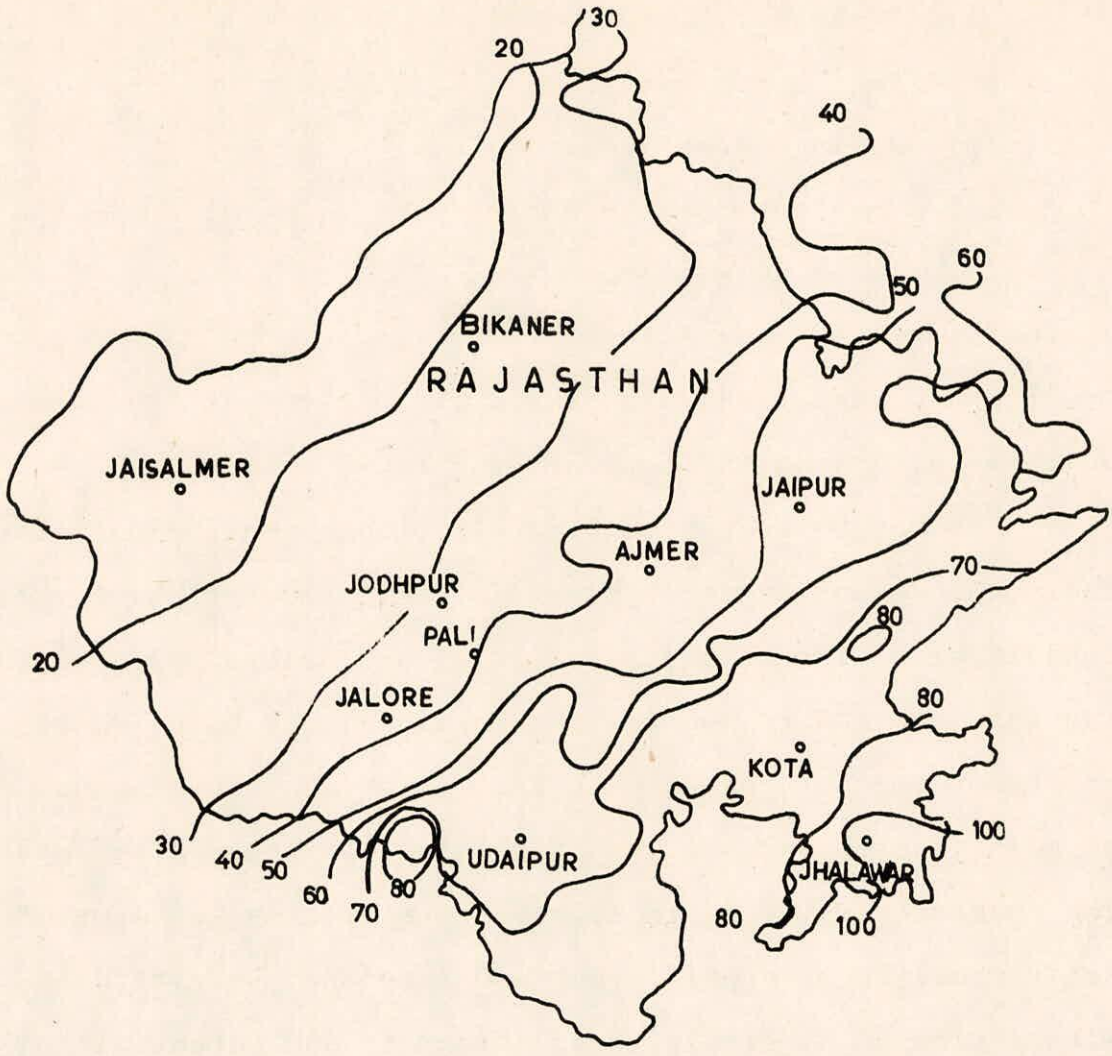

FIGURE 8 - NORMAL ANNUAL RAINFALL ISOPLETHS(CM)- RAJASTHAN

dissipate over Rajasthan after traversing the main land

Occasionally, Arabian Sea storms moving north or north eastwards also cause severe rain over this region. The heavy rain in these cases, however, is generally concentrated on the southern slopes of Aravalis.

5.2.1 Severe storms in the region

Some of the severe rain storms on record were

i) 26-28 July 1920

ii) 9-11 September 1924

iii) 23-25 August 1964

iv) 7-9 September 1973

v) 16-18 July 1979

In recent years, a severe storm occurred around Jaipur city on 18 to 20 July, 1981 and caused flash flood in Amanishah Ka Nalla which drains through Jaipur city.

As may be seen from figure 8, the normal annual rainfall over Jaipur and the three districts through which the Luni river drains namely Ajmer, Pali and Jalore have rainfall ranging from 400 to 500 mm. The maximum 1 day point rainfall depths of some of the rain storms listed above were equal to or more than the normal annual rainfall of these districts. The characteristics of these severe rainstorms in terms of their magnitudes, areal extent and frequency were studied with a view to ascertain their intensity and potential to cause flash floods.

5.2.2 Depth-area-duration analysis of September 1924 and July 1981 storms

An attempt has been made to trace the history of some of these storms listed above and link them to the Bay of Bengal and Arabian Sea storms or land depressions. However, none of these have been associated with such systems. In the case of July 1979 and July 1981 storms, a closed isobar could be seen over Rajasthan region and in case of September 1924 storm only a falling pressure indication was available

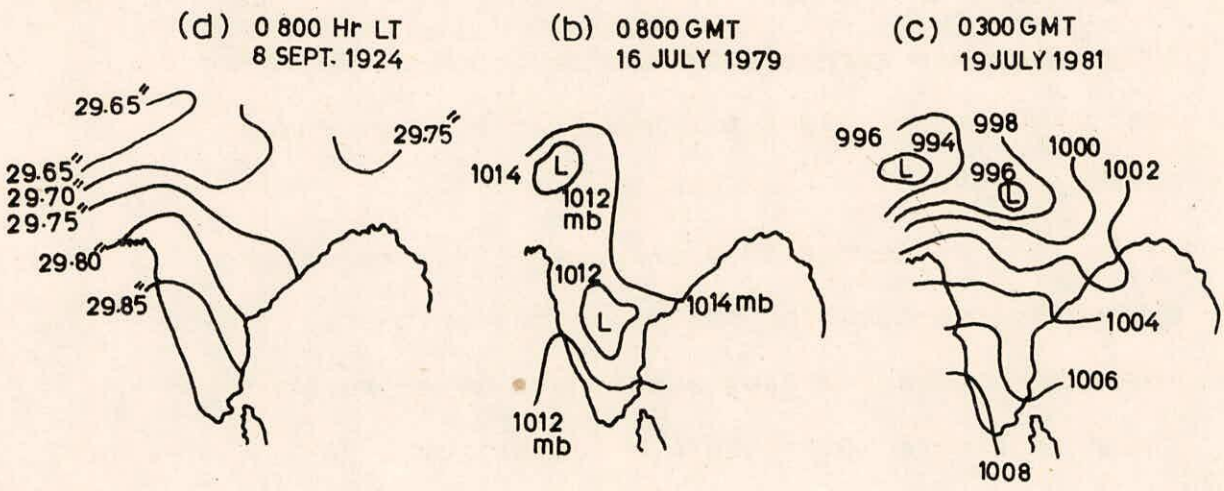

FIGURE 9 a to c - SURFACE ISOBARIC MAPS

(figures 9 a to 9c).

Ramaswamy and Pareek (1976) based on isobaric analysis of surface pressure and streamline analysis of upper wind data for a number of storms, have concluded that the exceptional cases of heavy rainfall were not associated with deep cyclonic systems or with strong upper winds in the field of cyclonic circulation or with large pressure deficiencies. It was reported that in many cases, the heavy rainfall was associated with only one closed odd isobar at sea level or with only one closed isobar drawn at 2 mb interval. The surface isobaric maps of 16 July 1979 and 19 July 1981 as may be seen in figures 9b and 9c were in confirmity with the findings of Ramaswamy

and Pareek (1976).

The available information on daily rainfall in various storms suggested that the September 1924 and July 1981 storms were severe in the Jaipur district and the July 1979 storm was severe over the Luni basin. Depth-duration analysis of the 1979 storm were reported by Sharma and Vangani (1982).

The September 1924 and July 1981 storms were analysed by depth-area-duration method. The depth-area-duration curves for 1 day, 2 days and 3 days were prepared and are shown in figure 10. Rainfall depths for 1 day, 2 days and 3 days durations derived from these DAD curves for different areas are shown in Table 4.

Table 4 - Depth-Area-Duration Statistics of September 1924 and July 1981 Rain Storms Over Jaipur District

Area in sq.km.	Average rainfall depths (cm)					
	September 1924			July 1981		
	1day	2days	3days	1day	2days	3days
	10 Sept	10-11 Sept	9-11 Sept	19 July	18-19 July	18-20 July
Point	42.5	44.2	47.5	59.0	79.9	92.0
100	42.0	44.0	46.5	58.5	78.5	91.0
200	41.2	43.0	45.0	57.5	77.0	89.5
500	39.5	41.2	42.7	55.3	72.5	86.3
1000	36.5	39.8	41.2	51.5	66.2	81.0
2000	32.5	37.5	38.8	45.2	60.0	73.3
5000	25.5	32.5	35.0	38.8	52.2	62.5
10000	16.2	23.8	28.0	33.5	45.0	55.5

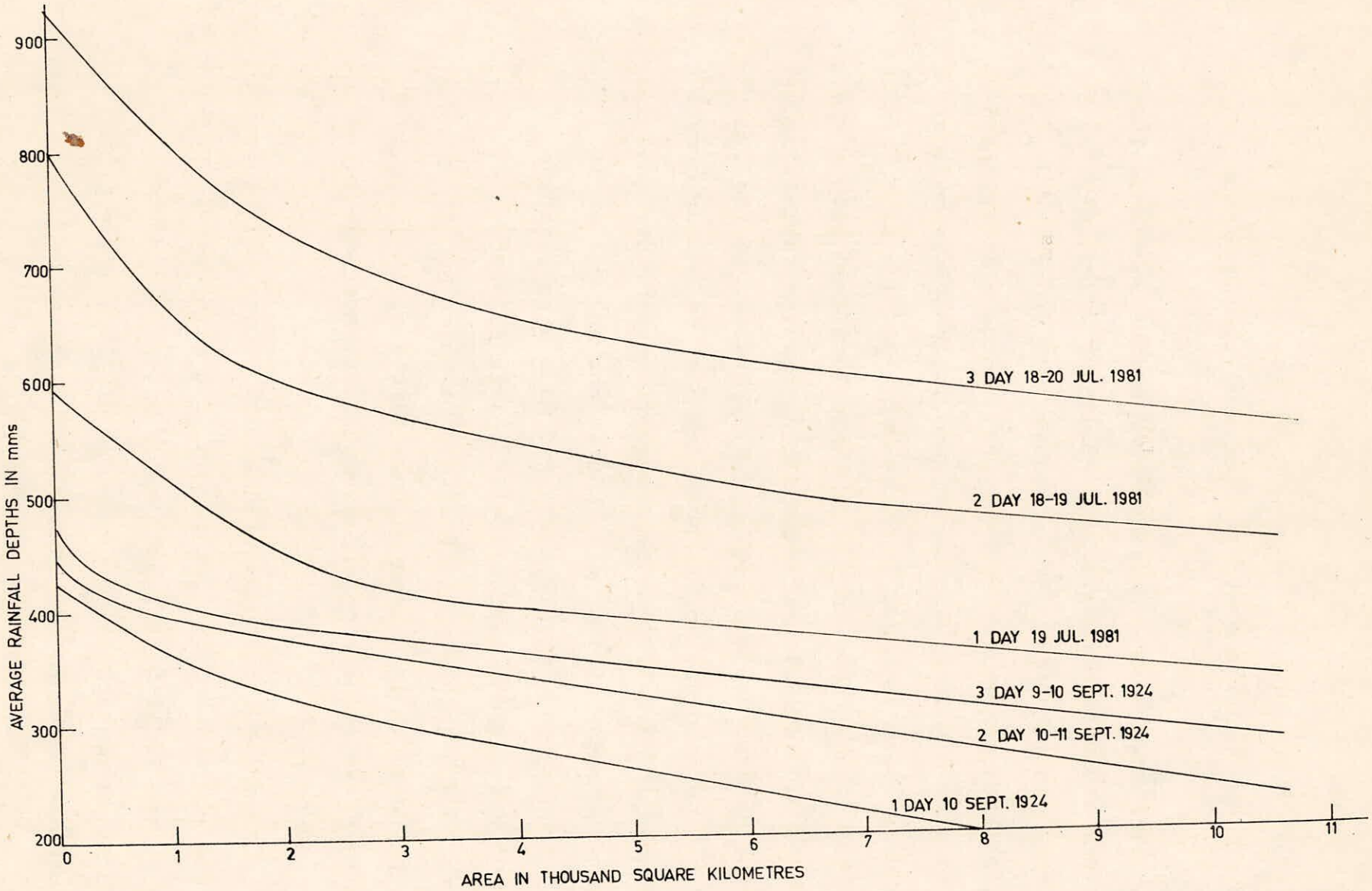

FIGURE 10 - DEPTH-AREA-DURATION CURVES 9 TO 11 SEPT 1924 AND 18 TO 20 JULY 1981 STORMS

5.2.3 Depth-Duration characteristics of the severemost historical storms

From a cursory look at the DAD curves in figure 10 and storm isohyetal maps in figures 11 and 12, it may be seen that the September 1924 and July 1981 storms have similar characteristics; that is, the centre of heavy rainfall is very close to Jaipur city and is towards east. While it is very close to Dausa in September 1924 and Kanota in July 1981. Also, the rain storms were localised with a small area of heavy rainfall and rainfall decreasing rapidly away from the centre. This might be due, probably, to the isolated hillocks to the north and north east of Jaipur city. The depths of July 1981 storm, however, were higher than thoseof September 1924 over all durations and all areas.

Sharma and Vangani (1982) had made a comparative study of total storm depths of 15-19 July 1979 storm with the previous highest spells from storms which occurred over the region. It was noted that depths of the July 1979 storm were the highest recorded at Bilara, Borunda, Pali, Ajmer and Erinpura.

Comparing the depths of July 1979 storm with those of September 1924 and July 1981 over a five day period, it may be seen from Table 5 that the depths of July 1979 storm are fairly comparable with those of July 1981 while those of September 1924 are the lowest of the three.

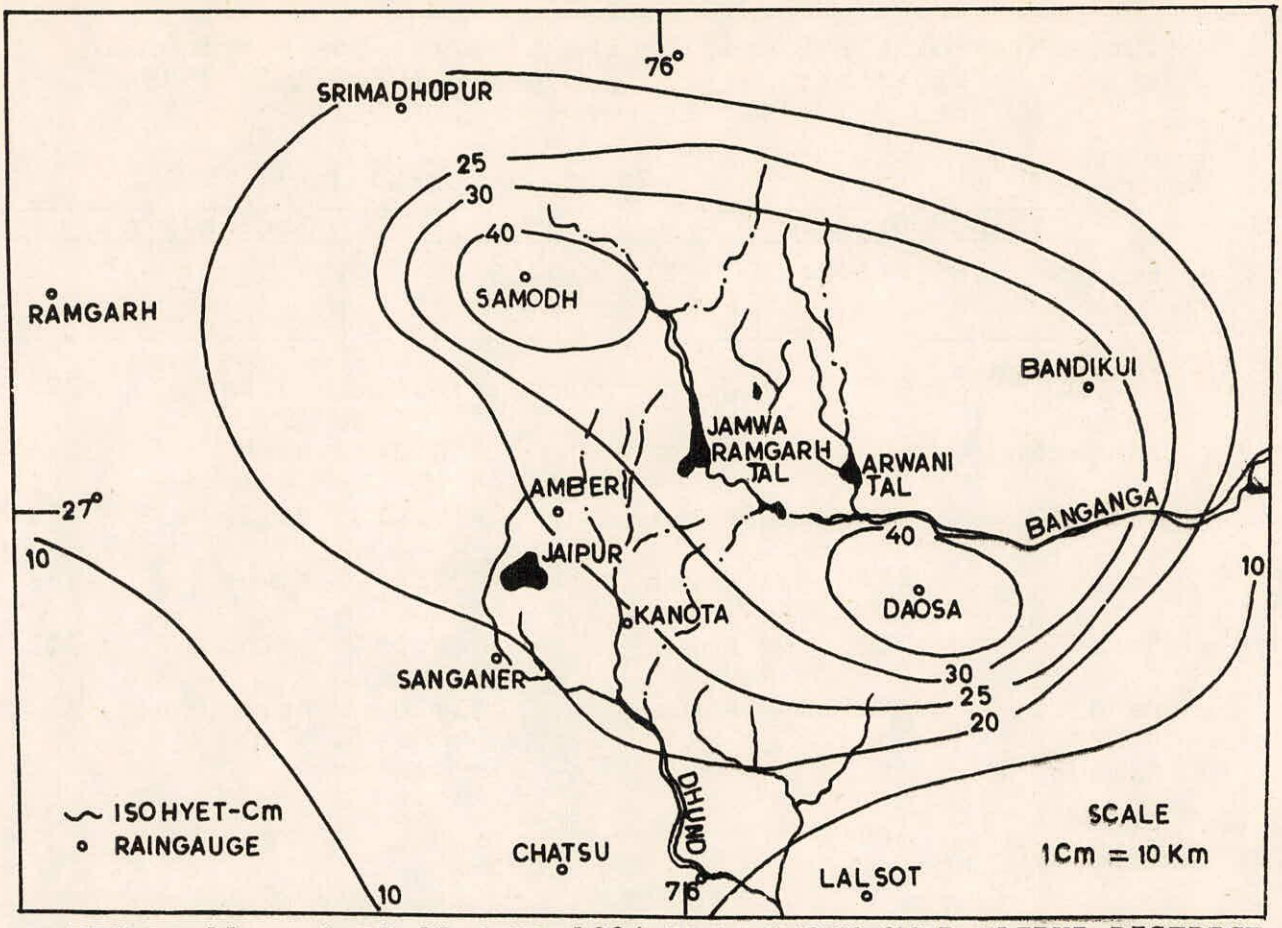

FIGURE 11 - 9 TO 11 SEPT.1924 RAIN STORM OVER JAIPUR DISTRICT

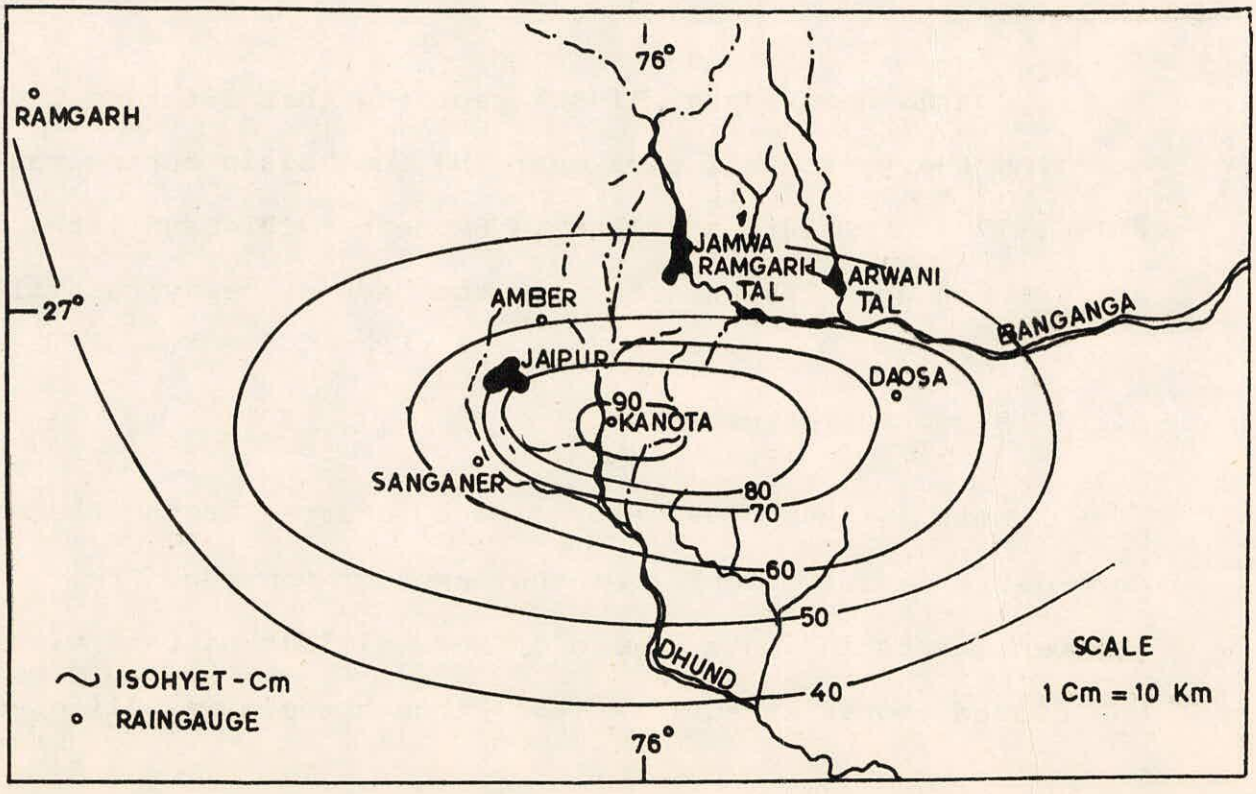

FIGURE 12 - 18 TO 20 JULY 1981 RAIN STORM OVER JAIPUR DISTRICT

Table 5 - Point Rainfall Depths of Raingauge Stations in Rajasthan for the September 1924, July 1979 and July 1981 Storms

Rainfall depths (mm)					
Jaipur District				Luni basin	
8-12 September 1924		17-21 July 1981		15-19 July 1979	
Jaipur	220.2	Jaipur City	836.4	Bailara	773.0
Sanganer	150.4	Sanganer	658.0	Barunda	843.0
Chomu	255.0	Kanota	919.4*	Pali	514.5
Dausa	484.1	Dausa	697.7*	Ajmer	432.0
Amber	315.5	Amber	540.0*	Jodhpur	442.0
Bandikui	391.2	Ramgarh	421.0	Erinpura	398.0
Samodh	484.4				
Ajmer	368.8				

* Depths refer to 18-20 July 1981 (3 days)

Sharma and Vangani (1982) reported that 16th and 17th were the heavy rainfall days over the Luni basin during the July 1979 storm. 10th and 11th in September 1924 and 18th and 19th in July 1981 storms were the days of heavy rainfall.

5.2.4 Synoptic features

Both 1979 and 1981 storms have occurred around the same dates in July soon after the onset of monsoon. The weather charts indicate a more or less similar pattern with one closed isobar at surface level though there was difference

in prevailing pressure in the two storms. These were known to have occurred due to low level convergence and moisture feed from Arabian Sea. The pattern was similar in 1924 also, though the storm occurred in September. However, because of lesser intensity of the storm as indicated by the absence of closed isobars over the region, the moisture feed from the Arabian Sea might have been less and, therefore, resulted in comparatively lesser rainfall.

5.2.5 Short duration rainfall analysis

There was no autographic raingauge in the Jaipur area in 1924 and also in and around Luni basin in 1979. Jaipur Airport at Sanganer has an autographic raingauge which was flooded during peak rain period in July 1981. However, the three hourly rainfalls recorded manually were available. From the available information of SRRG data and the three hourly rainfall it was noticed that the maximum rainfall has occurred between 6.30 hours and 9.30 hours on 19 July 1981. In Table 6, the 3, 6, 9, 12 and 24 hours rainfall depths of this storm are compared with the corresponding 50 year return period values over this region. The ratio of the maximum recorded rainfall to the 50 year value has also been given.

Table 6 - 50 Year Return Period* and Maximum Rain Depth of July 1981 Storm for Different Durations

	3	6	9	12	24
50 Year return period value* (mm)	100	150	170	175	180
Sanganer Jaipur A.P. (mm)	159.8	246.8	273.2	284.8	382.3
Ratio of max. rainfall to 50 yr value	1.60	1.65	1.61	1.68	2.12

* Source : Harihara Iyer and Tripathi (1974)

It is seen from the values of these ratios that the maximum depths of July 1981 storm recorded over shorter durations exceed the 50 yr return period over all durations by more than 60 percent upto 12 hrs and by about 110 percent for 24 hr duration.

From the daily rainfall and hourly rainfall pattern it was further noticed that the rainfall over the Rajasthan region was generally of less than 48 hours duration though it was recorded as corresponding to two observational days.

6.0 RESULTS

From the foregone discussion in sections 5.1 and 5.2 certain similarities and characteristics among the storms occurring over Saurashtra and Rajasthan region have been noticed which are discussed as follows:

6.1 Time of Occurrence of Storms

The normal dates of onset of monsoon in Saurashtra and Rajasthan are 15th June and 1st July respectively. The severe storms whose rain depths have exceeded the previous highest rainfall have occurred in the months of June and July respectively in Saurashtra and Rajasthan suggesting the possibility of occurrence of severe storms soon after the onset of monsoon over these areas.Considering the severe storms over Saurashtra and Rajasthan together, there were more number of severestorms in the month of July.

6.2 Meteorological Systems Responsible for the Severe Storms

The common meteorological systems causing heavy rainfall over both Saurashtra and Rajasthan were

i) the remnants of Bay of Bengal storms receiving moisture feed from Arabian Sea, and

ii) local low pressure systems either in mid troposphere

orat surface level caused by low level convergence and upper level divergence.

The effect of Arabian Sea storms was, however, more pronounced over Saurashtra region than over Rajasthan.

6.3 Depth-Area-Duration Characteristics

A comparison of the depth-area-duration characteristics of severe storms over Saurashtra and Rajasthan as given in Tables 2 and 4 reveals that the storms of Saurashtra region were more wide spread and intense than those of Rajasthan.

6.4 Statistical Frequency of the Storms

Though no statistical estimates of severe storms over Rajasthan were available for durations more than 24 hours, the 24 hours depths seem to have the same order of frequency as of the storm over Saurashtra region which has exceeded the 10000 yr estimates.

Over shorter durations, the depths which occured during the June 1983 storm over Saurashtra and July 1981 storm over Rajasthan were found to be higher than the 50 yr return period estimates (Based on short period data).

The total rainfall computed from self-recording rain gauge data at Sanganer (Jaipur AP) for the 19th July 1981 storm does not match the heavy rainfall at Kanota. Working on similar percentages of maximum short duration rainfall

as of Sanganer, the maximum short duration rainfall at Kanota would be very high as compared to maximum rainfall over corresponding duration in Saurashtra region.

7.0 CONCLUSIONS AND RECOMMENDATIONS

From the study of the extreme storms in the semi-arid regions of Saurashtra and Rajasthan it could be broadly summarised that

i) Severe storms generally occur in the month of July.

ii) The highest ever extreme rain storms in Saurashtra and Rajasthan occurred immediately after the onset of monsoon.

iii) The rainfall depths in the July 1981 and June 1983 storms have exceeded the envelope values of all previous storms over all areas in the respective regions.

iv) The depths of storm over Saurashtra region were more heavy and wide spread than over Rajasthan and exceeded the 10000 yr estimate

v) The maximum rainfall recorded over shorter duration during the July 1981 and June 1983 storms were more than the 50 yr return period estimates for the corresponding durations.

vi) The maximum depths of rainfall over shorter duration in the storm centre at Kanota in July 1981 storm over Rajasthan could be more than the maximum depths of corresponding duration in the storm centre for June 1983 over Saurashtra.

As has been indicated earlier, the heavy rainfall concentrated

over a small area and during a short time duration, which is very conducive for causing flash floods in small and medium catchments. The existing network of self-recording raingauges in Rajasthan is not adequate and some of the intense rainfall events might go unnoticed until they culminate in flash floods. With more data accumulating since the study of Harihara Iyer and Tripathi in 1974, the statistical estimates of short duration rainfall need to be updated and could probably be extended to 100 yr recurrence interval. The existing ordinary raingauge network also need strengthening so as to provide a better coverage of rainfall records to estimate the average areal rainfall more realistically.

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