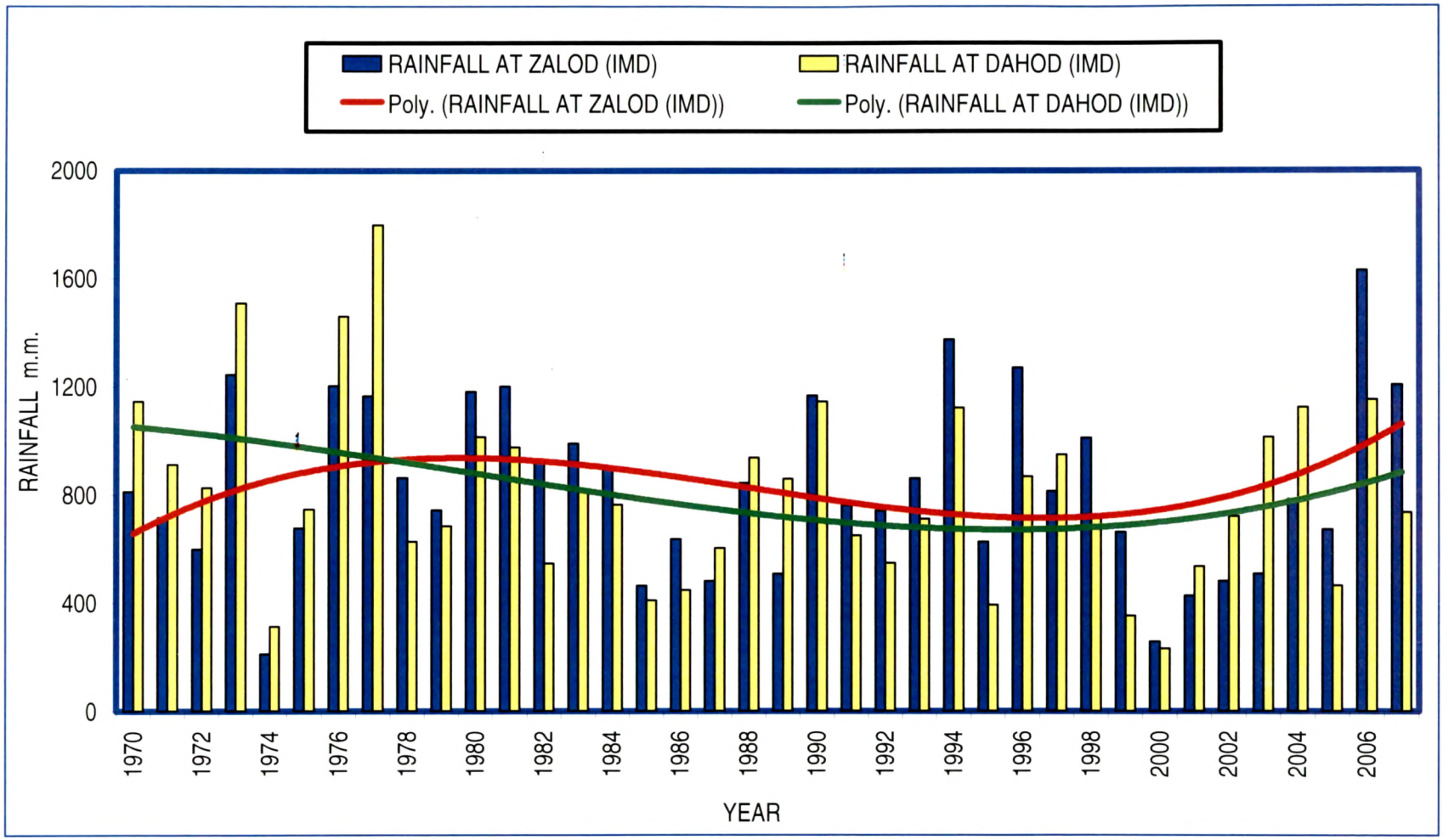
6 RAINFALL AND MORPHOMETRIC ANALYSIS

6.1 Rainfall Analysis

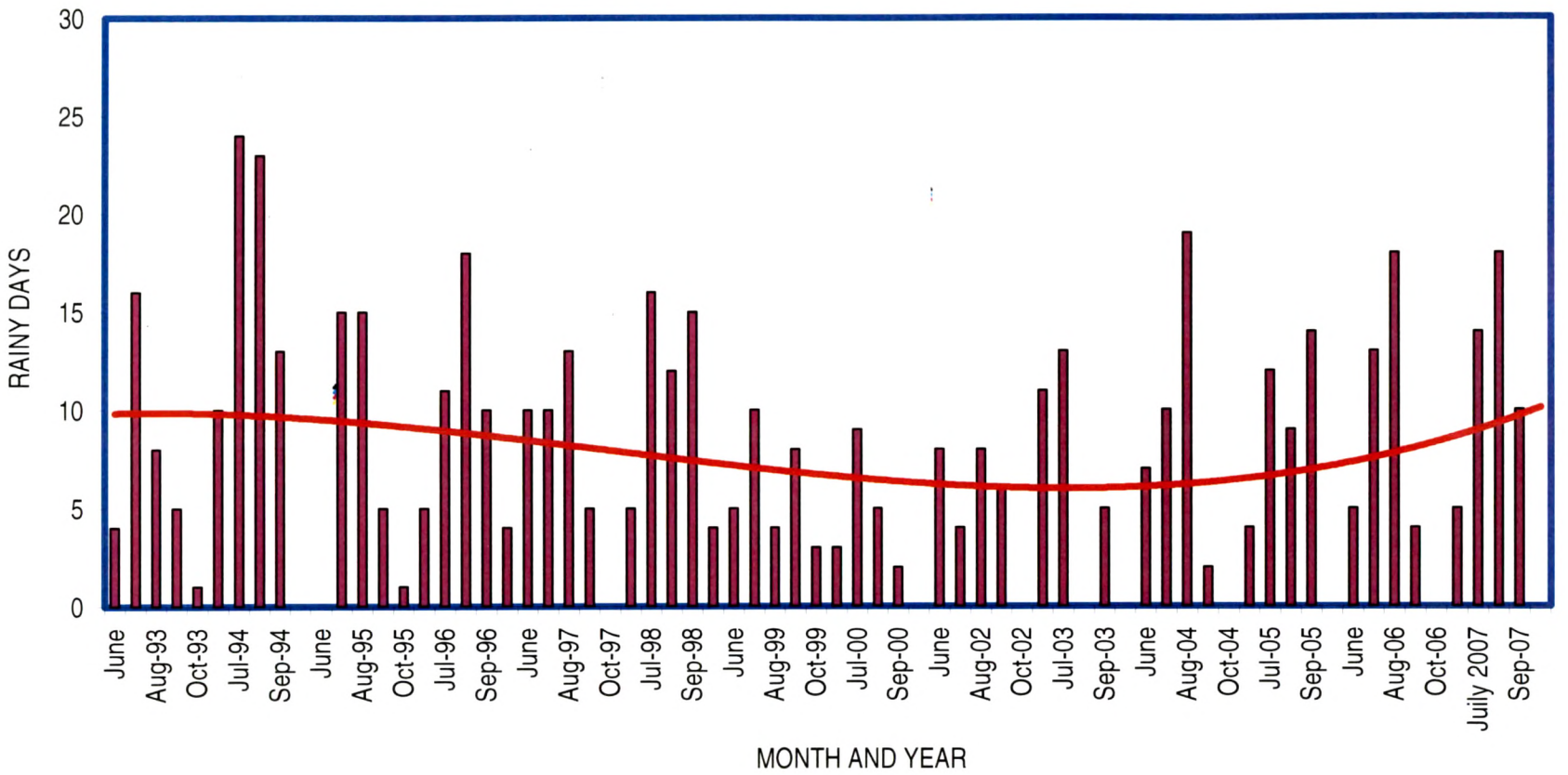
The study area comes under the influence of South-West monsoon. The long term annual rainfall of the Jhalod taluka for the first half of last century i.e. 1901 to 1950 is 1039.86 m.m. as per IMD data, however in later half of the last century the average rainfall decade vise shows varying trend with value for none of the decade crossing 1000 m.m.. The average rainfall of the period 1970-2004 works out to be 834 m.m..

There are four rain gauge stations provided and maintained by different agencies. The data available from each station is of different ranges and period. IMD data are annual values of rainfall for along period of 30 years so the overall nature of variation of yearly rainfall is studied using these data. River gauging Department provided hourly and daily data for different sites but the period for which it is available is short, around one decade. These data are used to know pattern of rainfall, rainy days in a each month of monsoon.

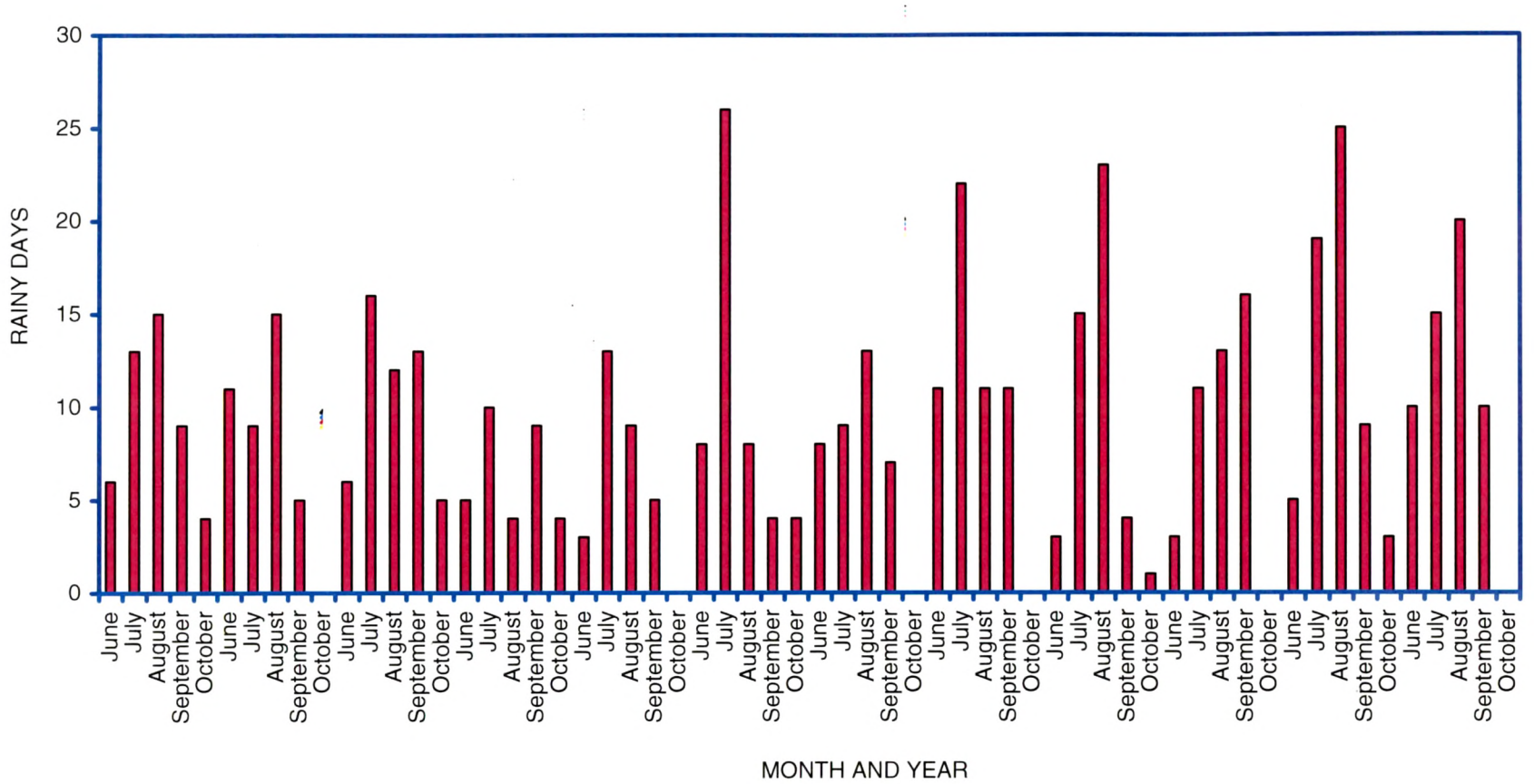
Reports on the "Behaviour of Subsoil Water Table in the Command Area of Machhannala Water Resources Project in Panchmahal District" of Soils, Drainage and Reclamation Circle, Narmada and Water Resources & Water Supply Department, Gujarat State also contains some analysis of rainfall with an annual value of rainfall for a period of around one decade. These data have been used for statistical analysis along with other data. Drought analysis was also carried out.



Graph 6.1 Annual Rainfall - Jhalod & Dahod



Graph 6.2 Rainy Days - Jhalod

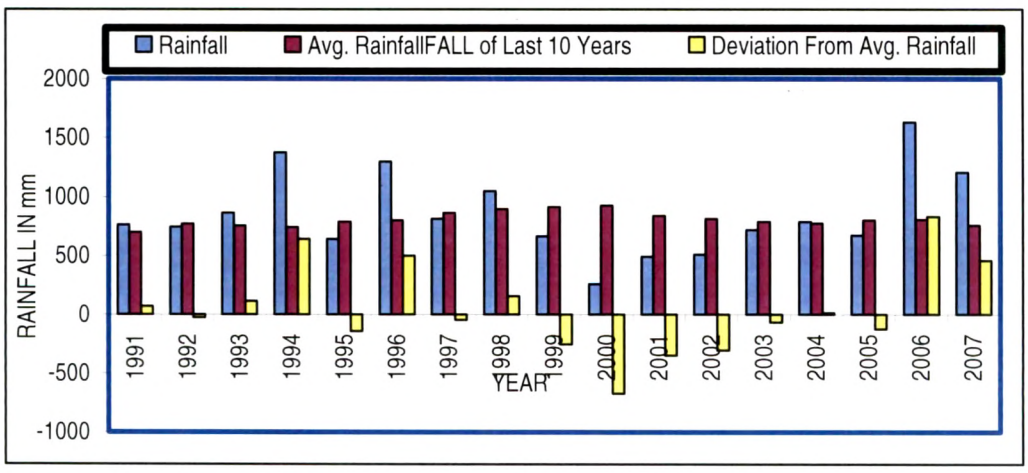


Graph 6.3 Rainy Days - Dahod

6.1.1 Analysis of Rainfall Pattern and Characteristics

Table – 6.1 Rainfall Pattern – Jhalod

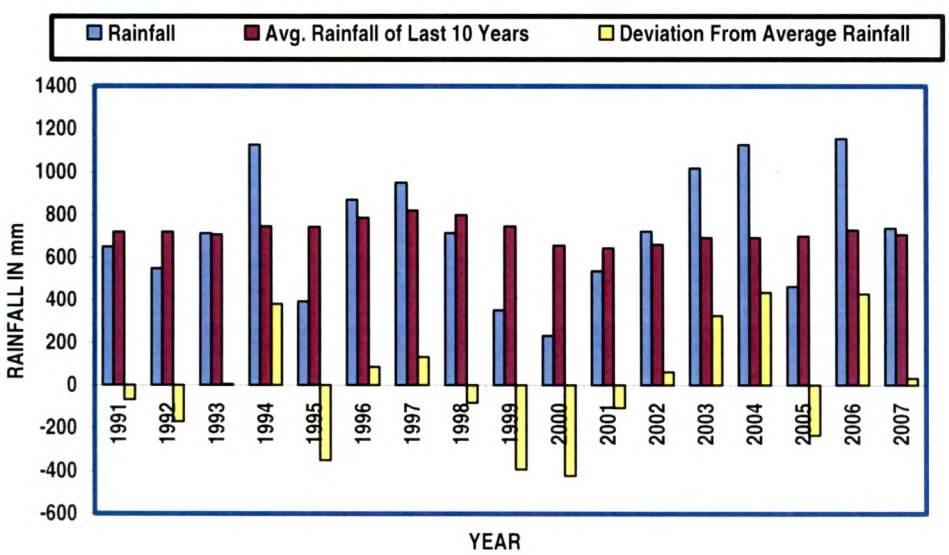
Year	Rainfall (Jhalod)	Avg. Rainfall Of Last 10 Years	Deviation From Avg, Rainfall
----	(m.m.)	(m.m.)	(m.m.)
1991	761	812.508	66
1992	742	768.508	-26.508
1993	862	750.408	111.592
1994	1376	737.508	638.492
1995	641	784.388	-143.388
1996	1297	800.688	496.312
1997	814	863.881	-49.881
1998	1050	897.081	152.919
1999	660	913.881	-253.881
2000	257	929.381	-672.381
2001	488	838.28	-350.28
2002	506	810.98	-304.98
2003	718	787.38	-69.38
2004	785.1	772.98	12.12
2005	672	798.5	-126.5
2006	1631	803.1	827.9
2007	1208	754.61	453.39



Graph - 6.4: Rainfall Pattern - Jhalod (Average Rainfall)

Table – 6.2 Rainfall Pattern - Dahod

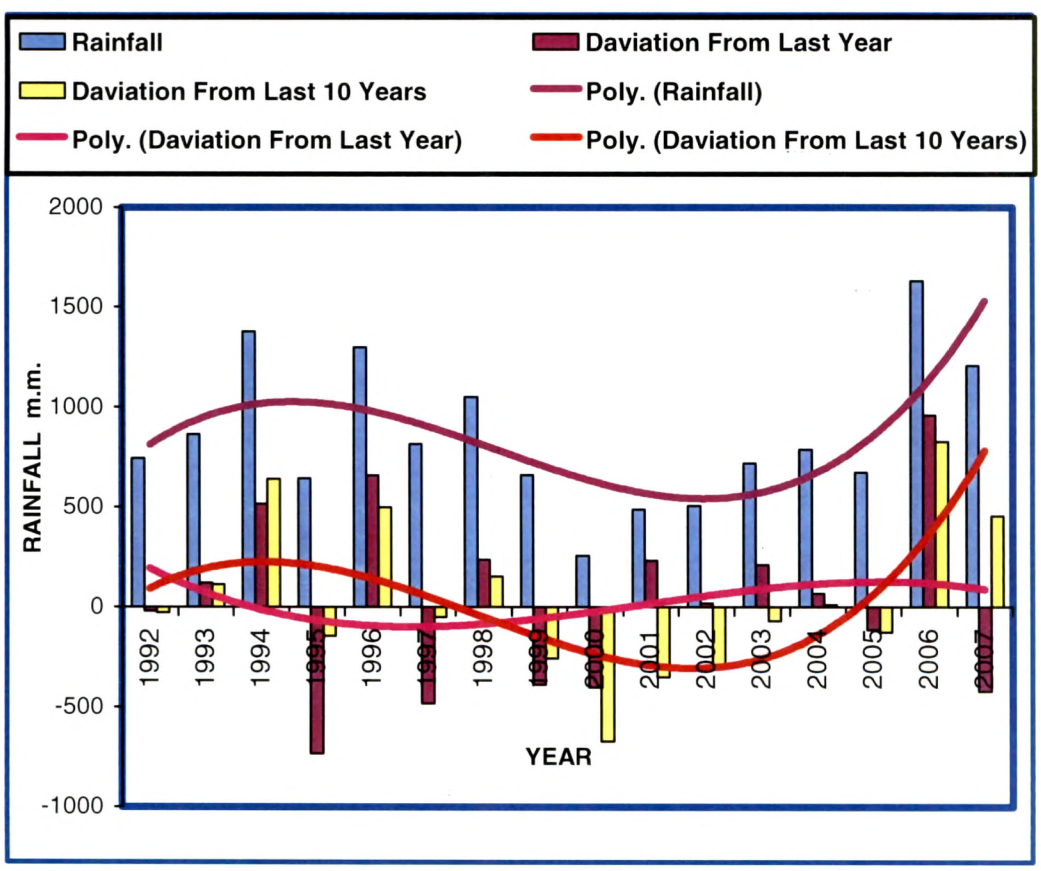
Year	Rainfall (Dahod)	Avg. Rainfall Of Last 10 Years	Deviation From Avg, Rainfall
----	(m.m.)	(m.m.)	(m.m.)
1991	650	718.855	-68.855
1992	549	719.155	-170.155
1993	712	708.155	3.845
1994	1124	744.055	379.945
1995	392	742.355	-350.355
1996	869	784.45	84.55
1997	950	819.05	130.95
1998	715	796.73	-81.73
1999	352	745.83	-393.83
2000	231	654.4	-423.4
2001	536	643	-107
2002	722	660.3	61.7
2003	1015	690.6	324.4
2004	1125	690.7	434.3
2005	463	697.8	-234.8
2006	1154	726.3	427.7
2007	736	704.9	31.1



Graph - 6.5 Rainfall Pattern - Dahod (Average Rainfall)

Table – 6.3 Rainfall Characteristics – Jhalod

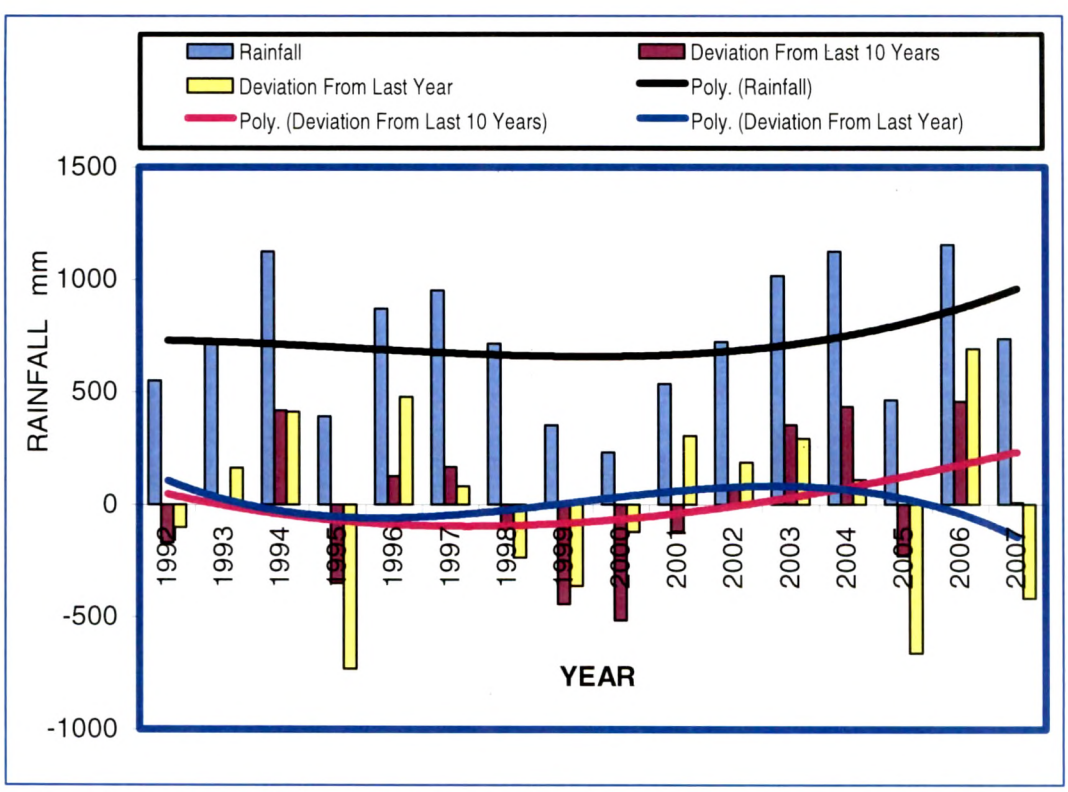
Year	Rainfall	Deviation from Last 10 Yrs.	Deviation from Last Year	Year	Rainfall	Deviation from Last 10 Yrs.	Deviation from Last Year
	(m.m.)	(m.m.)	(m.m.)		(m.m.)	(m.m.)	(m.m.)
1992	742	-26.508	-19	2000	257	-672.381	-403
1993	862	111.592	120	2001	488	-350.28	231
1994	1376	638.492	514	2002	506	-304.98	18
1995	641	-143.388	-735	2003	718	-69.38	212
1996	1297	496.312	656	2004	785.1	12.12	67.1
1997	814	-49.881	-483	2005	672	-126.5	-113.1
1998	1050	152.919	236	2006	1631	827.9	959
1999	660	-253.881	-390	2007	1208	453.39	-423



Graph - 6.6 Rainfall Characteristics - Jhalod

Table – 6.4 Rainfall Characteristics – Dahod

Year	Rainfall	Deviation From Last 10 Yrs.	Deviation From Last Year	Year	Rainfall	Deviation From Last 10 Yrs.	Deviation From Last Year
	(m.m.)	(m.m.)	(m.m.)		(m.m.)	(m.m.)	(m.m.)
1992	549	-169.855	-101	2000	231	-514.83	-121
1993	712	-7.155	163	2001	536	-118.4	305
1994	1124	415.845	412	2002	722	79	186
1995	392	-352.055	-732	2003	1015	354.7	293
1996	869	126.645	477	2004	1125	434.4	110
1997	950	165.55	81	2005	463	-227.7	-662
1998	715	-104.05	-235	2006	1154	456.2	691
1999	352	-444.73	-363	2007	736	9.7	-418

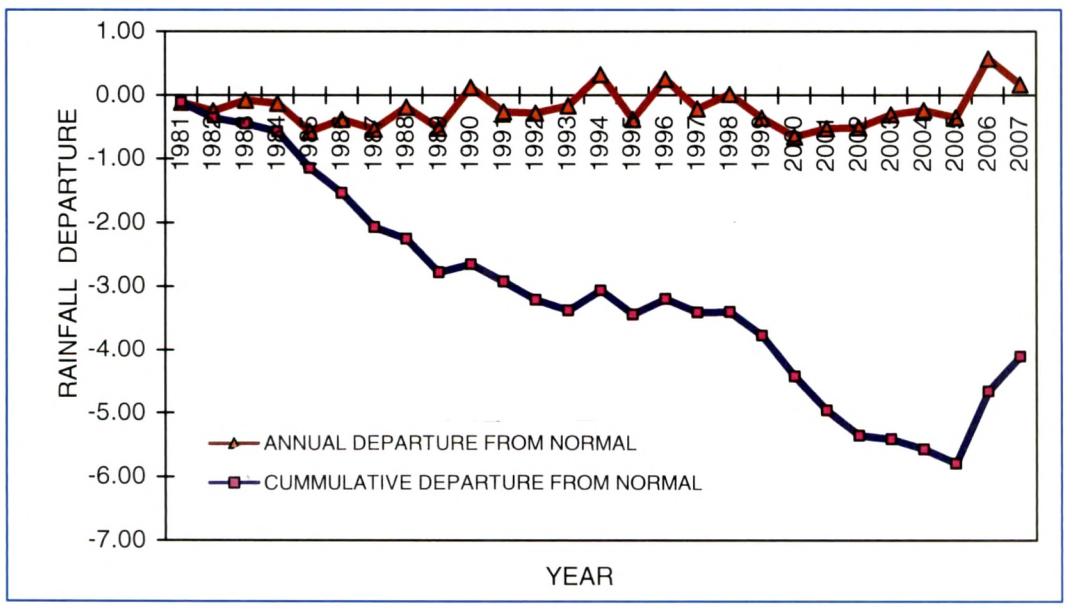


Graph - 6.7 Rainfall Characteristics - Dahod

6.1.2 Drought Analysis

Table – 6.5 Drought Analysis – Jhalod

Year	Rainfall Jhalod	Annual Departure From Normal	Cumulative Departure From Normal	Year	Rainfall Jhalod	Annual Departure From Normal	Cumulative Departure From Normal
	(m.m.)				(m.m.)		
1981	919	0.2	0.2	1995	641	-0.4	-2.97
1982	782	0.02	0.22	1996	1297	0.25	-2.72
1983	951	-0.05	0.17	1997	814	-0.22	-2.94
1984	904	-0.13	0.04	1998	1050	-0.14	-3.08
1985	442	-0.56	-0.52	1999	660	-0.36	-3.44
1986	639	-0.38	-0.9	2000	356	-0.66	-4.1
1987	483	-0.54	-1.44	2001	488	-0.53	-4.63
1988	846	-0.19	-1.63	2002	506	-0.51	-5.36
1989	500	-0.52	-2.15	2003	718	-0.31	-5.42
1990	1168	0.12	-2.03	2004	785.1	-0.24	-5.58
1991	761	-0.37	-2.4	2005	672	-0.35	-5.80
1992	742	-0.29	-2.69	2006	1631	0.57	-4.66
1993	862	-0.19	-2.88	2007	1208	0.16	-4.11
1994	1376	0.31	-2.57				

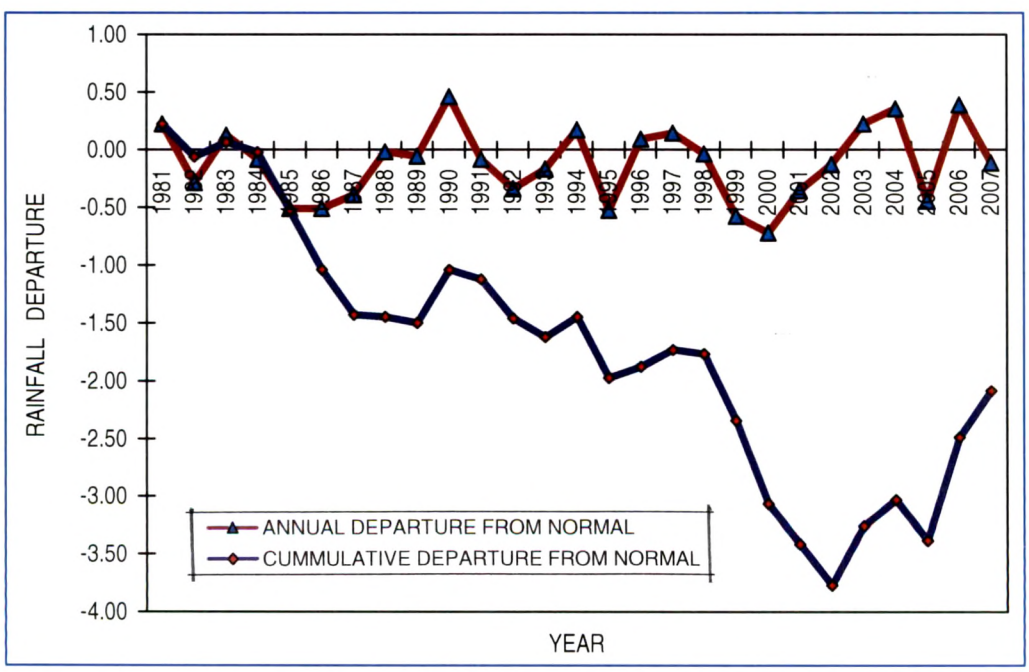


Graph - 6.8 Drought Analysis - Jhalod

6.1.3 Drought Analysis - Dahod

Table – 6.6 Drought Analysis – Dahod

Year	*Rainfall Jhalod*	Annual Departure From Normal	Cumulative Departure From Normal	Year	*Rainfall Jhalod*	Annual Departure From Normal	Cumulative Departure From Normal
	(m.m.)				(m.m.)		
1981	1014	-0.12	-0.12	1995	394	-0.38	-3.47
1982	592	-0.25	-0.37	1996	907	0.25	-3.22
1983	934	-0.09	-0.46	1997	950	-0.22	-3.44
1984	759	-0.13	-0.59	1998	800	0.01	-3.43
1985	409	-0.57	-1.16	1999	352	-0.37	-3.8
1986	406	-0.39	-1.55	2000	290	-0.66	-4.46
1987	505	-0.54	-2.09	2001	536	-0.53	-4.99
1988	815	-0.19	-2.28	2002	722	-0.72	-3.06
1989	783	-0.52	-2.8	2003	1015	-0.35	-3.42
1990	1212	0.12	-2.68	2004	1125	-0.13	-3.77
1991	761	-0.27	-2.95	2005	463	0.22	-3.26
1992	549	-0.29	-3.24	2006	1154	0.36	-3.03
1993	692	-0.17	-3.41	2007	736	-0.44	-3.39
1994	975	0.32	-3.09				



Graph - 6.9 Drought Analysis – Dahod

6.1.4 Discussion on Rainfall Analysis

Study of rainfall data indicates that during 8 of the last 10 years the annual rainfall in the taluka has been below long term rainfall. Rainfall is highly erratic. The number of rainy days in each month ranges from 4 to 14 in Jhalod and between 6 to 12 in Dahod.

As per the drought analysis Jhalod Taluka suffered mild drought for 8 years, normal drought for 7 years and severe drought for 6 years in total 27 years analysed. The Dahod Taluka suffered mild drought for 8 years, normal drought for 3 years and severe drought for 7 years in total 27 years analysed. Both the taluka were having no drought condition for only around 22 % years in 27 years analysed.

6.2 Morphometric Analysis

The drainage map of the Machhan Catchment was prepared using topo sheets 46-I and 46-J. This map was digitized using software Auto Cad. Length of each stream was found, streams are classified and tabulated. Area was measured with the help of digital plannimeter and various morphometric features of the basin found for analysis. The procedure followed is as under:

- Total catchment area and catchment area up to gauging site calculated.
- Stream orders found out with the help of Strahler's method. The length of each stream is found.
- Bifurcation Ratio for each subsequent stream order found out.
- Drainage Density and frequency for the basin worked out.
- Total relief, relief ratio, total stream length and main stream length have been found out.

Classification of area in watershed is done as per norms of, Department of Agriculture and Co-operative, Government of India. According to it the area can be given nomenclature 5E2A4a1b. (Refer table 6.9). Table 6.7 and 6.8 gives number and lengths of different order streams.

6.2.1 Terminology Related To Morphology Of Basin

1. **Morphometry:** Measurement of the shape or geometry of any natural form is termed as Morphometry. (Reference: Strahler Arthur N., "Physical Geography")

2. **Stream order:** Stream order is a rank numbers given to the different drains. There are several methods of ranking proposed by different scientists. As per the Strahler's method, first-order stream includes "fingertip" streams receiving no tributary. Second-order Stream includes those which are formed by the junction of two first-order streams and only receive first-order tributaries. Third-order Stream includes those which are formed by the junction of two second-order streams and only receives first and second-order tributaries, and so on.(Reference : Mitchell Colin W., "Terrain Evaluation".)

3. **The Bifurcation Ratio:** For any consecutive pair of orders is assessed as the total number of streams of the lower order divided by the total number in the higher order. Where rock and structure are simple and do not form narrow elongated basis, bifurcation ratios seem to be stable and generally range between 3 to 5.The pattern of runoff in basins seems to reflect this ratio.(Reference :Strahler Arthur N.)

$$R_b = \frac{N_u}{N_{u+1}}$$

4. **Drainage Density:** It is defined as the ratio of total length of all streams of the catchment divided by basin area, indicates the drainage efficiency of the basin. The higher the value, quicker is the runoff and lesser is the infiltration and other losses. Low drainage density catchments give a larger period of surface runoff and more loss of rainfall.

   Thus,

$$DrainageDensity = D_d = \frac{L_s}{A}$$

   Where L_s is the total length (km) of all streams in a basin and A the drainage area in km^2 .It is expressed in km/km^2.

   In a topographical map drainage channels of all types are clearly visible. When a lower order stream joins a higher order stream, the order remains the same as that of higher order. (Reference: Patra K.C., "Hydrology and water resources engineering")

5. **Drainage Frequency :** It is the number of streams per unit area of the basin. This value chiefly depends on the drainage network and topographical features of area.

6. **Main stream length :** It is the length of the main stream having maximum length.

7. **Total Relief (H) :** It is the maximum vertical distance between the lowest and the highest points of a watershed.

8. **Relief Ratio :** It is the total relief of watershed divided by the maximum length of the watershed.

Table – 6.7 Numbers of Different Order Streams

	Number of Streams						
	Stream Order						Total Streams
Zone No.	First	Second	Third	Fourth	Fifth	Sixth	of All Orders
1	74	12	3	1	0		
2	53	10	3	0	0		
3	53	13	4	1	0		
4	84	18	3	1	0		
5	126	23	5	3	0		
6	44	13	1	0	1		
7	28	6	0	0	0		
8	9	1	0	1	0		
9	44	9	5	1	0		
10	3	1	0	0	1		
11	131	29	5	1	0		
12	32	9	2	0	0		
13	8	2	0	0	0	1	1319
14	26	5	1	0	0		
15	31	8	1	1	0		
16	67	18	4	1	0		
17	21	6	2	0	0		
18	20	5	1	0	0		
19	16	4	1	0	0		
20	31	5	2	0	0		
21	47	13	3	1	0		
22	29	8	1	1	0		
23	21	4	0	0	0		
24	27	7	2	0	0		
Total	**1025**	**229**	**49**	**13**	**2**	**1**	

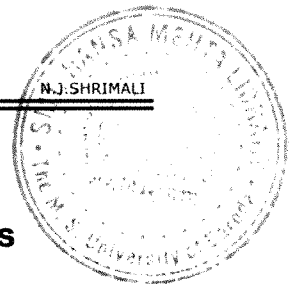


Table – 6.8 Lengths of Different Order Streams

	Stream Order				
Zone No.	First	Second	Third	Fourth	Fifth
	Length in km				
1	42.38	13.16	13.035	2.69	0
2	27.565	12.14	7.105	0	0
3	24.585	7.725	2.435	2.4	0
4	40.155	12.07	6.905	6.575	0
5	68.555	14.79	8.5	5.785	0
6	23	8.54	3.115	0	8.32
7	14.915	5.845	0	0	0
8	5.89	1.91	0	6.12	0
9	29.165	8.58	7.095	5.71	0
10	1.6	0.745	0	0	1.435
11	80.61	18.015	10.32	13.075	0
12	19.64	9.9	1.73	0	0
13	8.645	4.425	0	0	0
14	13.91	7.94	2.93	0	0
15	26.665	14.93	0.5	3.37	0
16	38.06	13.57	7.3	2.42	0
17	16.785	3.65	6.95	0	0
18	15.825	5.83	0.45	0	0
19	7.05	3.725	2.01	0	0
20	20.215	5.63	8.93	0	0
21	30.585	8.535	5.445	2.6	0
22	18.5	6.395	1.49	8.29	0
23	13.35	1.85	0	0	0
24	13.375	7.985	1.445	0	0
TOTAL	**601.025**	**197.885**	**97.69**	**59.035**	**9.755**

Table – 6.9 Classification of Watershed Area (5E2A4a1b)

Notation	Description	Reference
5	Region	Drainage merging in to Arabian sea
E	Basin	Mahi
2	Catchment	Mahi
A	Sub Catchment	Anas
4	Watershed	Machhan
a	Sub Watershed	30 Km^2 to 50 Km^2
1	Mini Watershed	15 Km^2 to 30 Km^2
b	Micro Watershed	5 Km^2 to 15 Km^2

6.2.2 Discussion on Morphometric Analysis

The study area represents undulating topography with maximum altitude 378 m. above M.S.L. to minimum 218 m. above M.S.L. Total relief, which is maximum vertical distance between lowest and highest points of a basin works out to be 160 m.

Morphometric analysis suggests that the Machhan basin contains numerous drains of stream orders ranging from 1 to 6 with 6^{th} order stream as Machhan River itself. The total length of first order drain is 601.05 k.m., second order stream is 197.885 k.m., third order stream 97.69 k.m., fourth order stream 59.035 and fifth order stream 9.755 k.m. Total stream length works out to be 992 km. Maximum length of first order stream is 80.61 k.m. which is in zone 11, second order stream 18.015 k.m. in zone 11, third order stream 13.035 k.m. in zone 1, 4^{th} order stream 13.075 k.m. in zone 11 and 5^{th} order stream as 8.32 k.m. in zone 6.

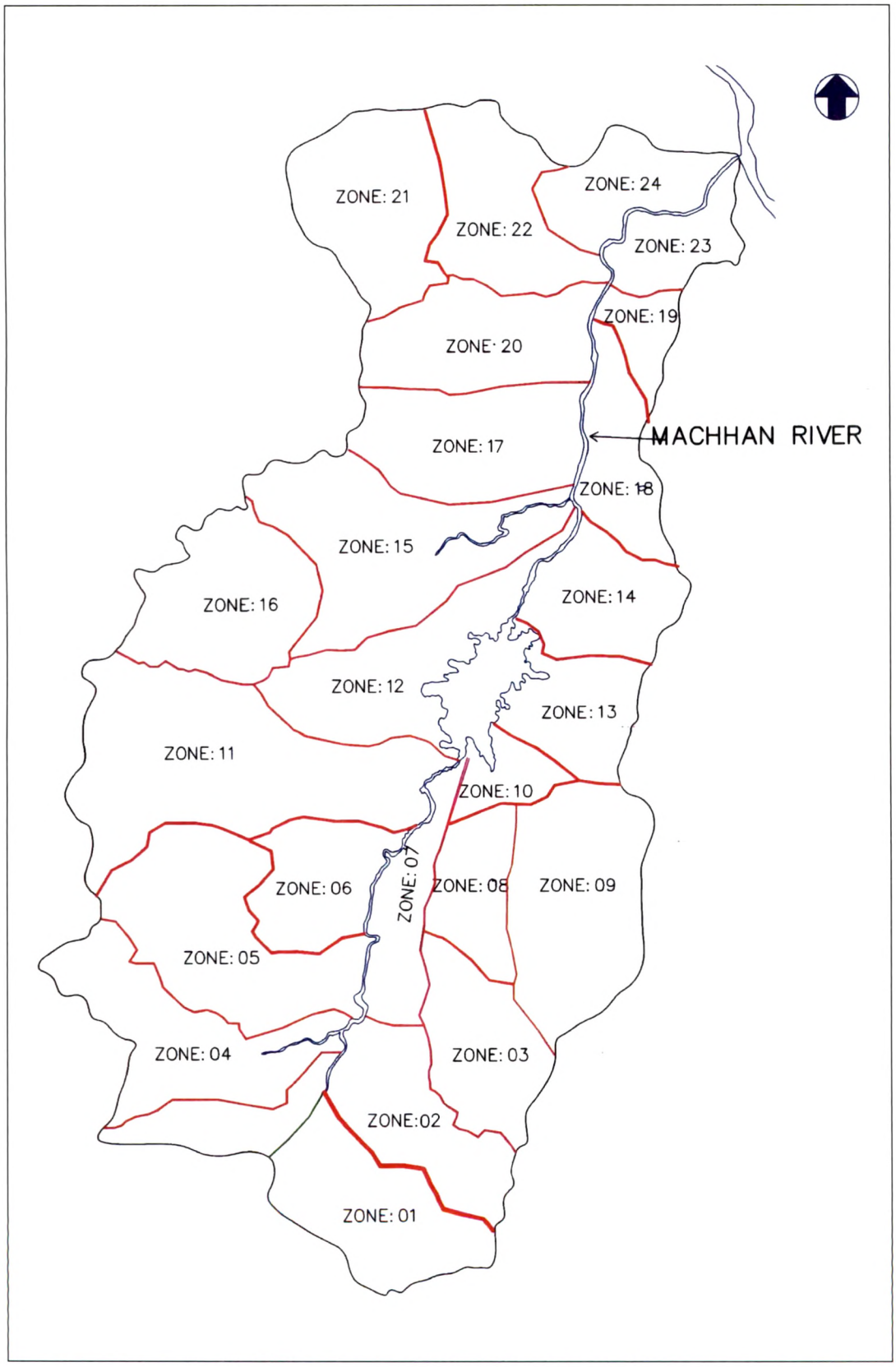


Figure – 6.1 Zones in Machhan River Basin

Figure - 6.2 Different Order Streams in Machhan River Basin

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