केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण
विभाग, जल शक्ति मंत्रालय
भारत सरकार

Central Ground Water Board

Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Sabarkantha District
Gujarat

पश्चिम मध्य क्षेत्र, अहमदाबाद
West Central Region, Ahmedabad

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास एवम् गंगा संरक्षण विभाग
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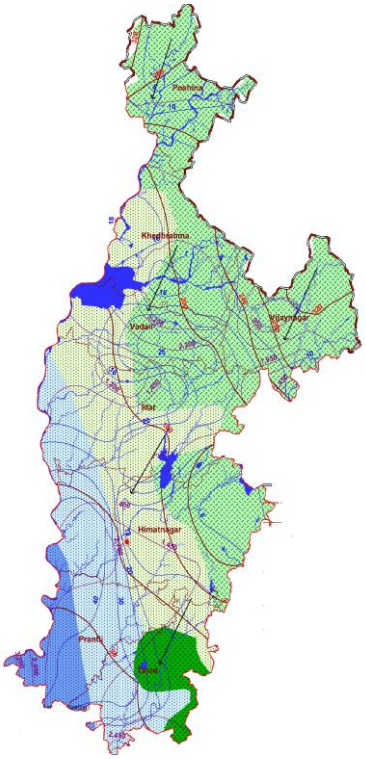
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT
AND
GANGA REJUVENATION

AQUIFER MAP AND MANAGEMENT PLAN, SABARKANTHA DISTRICT, GUJARAT STATE



CENTRAL GROUND WATER BOARD
WEST CENTRAL REGION
GUJARAT
DECEMBER-2021

भारत सरकार
जल शक्ति मंत्रालय
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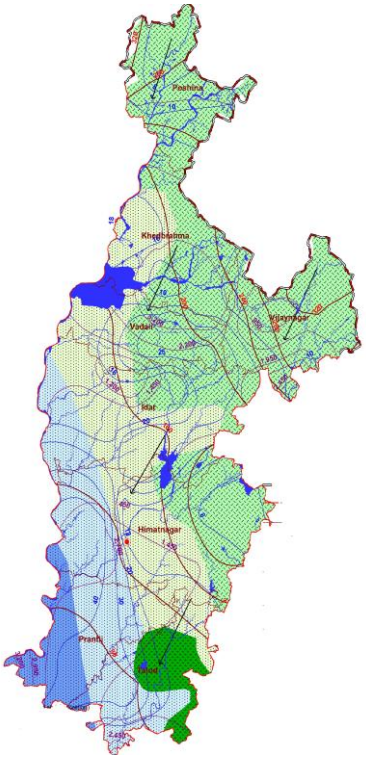

Dr. A. K. Jain,
Consultant & Scientist "D"(Retired)

CENTRAL GROUND WATER BOARD
WEST CENTRAL REGION
GUJARAT
DECEMBER-2021

AQUIFER MAP AND MANAGEMENT PLAN, SABARKANTHA DISTRICT GUJARAT STATE

CONTRIBUTORS' PAGE

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SL No.	Items	Statistics
1	General Information	
	i) Geographical area as per state territory/as per village papers (Sq. Km)	5390
	ii) Administrative Divisions *(As per Ankadiya Rooprekha 2016-17)* Number of Taluka Number of Village	 08 702
	iii) Populations (As per 2011 census)	14,04,865
	iv) Average Normal Rainfall (mm), 1981-2020	808 mm
2.	GEOMORPHOLOGY	
	Major Physiographic Units : Pediments, highly dissected plateau and hills	
	Major Drainages: Sabarmati, Vatrak, Hathmati, Meshvo, Hamav & Khari	
3.	LAND USE Area (Ha)	
	a) Cross cropped b) Net area sown c) Cultivable waste land	284889 241411 6643
4.	MAJOR SOIL TYPES**:** Sandy soils & Loam, Brown to black soils, Black cotton soils	
5.	AREA UNDER PRINCIPAL CROPS (Hectare) (2014-15) Rice - 31, Bajra-68, Wheat-918, Maize-16,Total cereals-1034, Gram- 1, other pulses-59, Total pulses-60, Total food crops- 1361, Ground nut-93, Seasam -5, Rapes and Mustard-8, Total oil seeds-439, Cotton – 861, Tobaco -38, .	
6.	IRRIGATION BY DIFFERENT SOURCES (Area in Sq Km/ no of structures)	
	Dugwells	928
	Tube wells/Borewells	1219
	Tanks/Ponds/Water conservation structures	6
	Canals	205
	Other Sources	449
	Net Irrigated area (Ha)	282157
	Rainfed area	111424
	Total	393581
7.	NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on 31-03-2017)	54
	No of Dug Wells	43
	No of Piezometers	11

8. HYDROGEOLOGY

Major Water Bearing Formation**:** Groundwater occur in unconfined to semi-confined condition in phyllite, schist & quartzite, Granite and gneiss, Deccan trap formation in weathered mantle and factures zones. Under unconfined to confined condition in alluvium along river courses, valley fills flood plain & abandoned Palaeochannel deposits.

Depth to water Level during 2019		
Period	Phreatic Aquifer (DTW)	
	Min	Max
Pre Monsoon	4.75 (Khedbrahma)	56.20 (Derol Pz)
Post Monsoon	2.60 (Sabalwad)	42.95 (Derol)

Long Term (10 Years) Water Level Trend (2008 to 2017)		
Trend	Pre-Monsoon	Post- Monsoon
Rise (m/Yr)	0.0144 (Seenavad) to 2.1743 (Kuski)	0.0325 (Matoda) to 1.7598 (Boral)
Fall (m/Yr)	0.039 (Hamirpur) to 1.5224 (Derol Pz II)	0.0517 (Ratanpur) to 0.9752 (Derol Pz II)

9. GROUND WATER EXPLORATION BY CGWB (As on 31-03-2018)

No of wells drilled (EW, OW, Pz, SH, Total)	EW: 118,OW: 18, PZ :12, SH:03, Total: 138
Depth Range(m)	20.00 m to 500.18
Discharge (Litres per minute)	12.60 to 720

10 GROUND WATER QUALITY, May 2017

Electrical Conductivity (uS/cm at 25°C)	700 – 4651
Fluoride (mg/l)	0.2– 3.0
NO_3 (mg/l)	5.0 – 230
Iron (mg/l)	0.2 – 3.0

11.

DYNAMIC GROUND WATER RESOURCES	2017	2020

	Annual Replenishable Ground Water Resources (MCM)	893.48	747.69
	Net Ground water Availability (MCM)	848.81	672.92
	Annual Groundwater draft (MCM)	594.55	509.13
	Stage of Ground Water Development (%)	70.05 (Semi critical)	75.66(Semi critical)

12	AWARENESS AND TRAINING ACTIVITY (as on 3/2017)	
	Mass Awareness Programmes organized No of Participants	Nil
	Tier II Water Management Training Programmes organized at Himatnagar, Sabarkantha district from 29 June to 03 July. The numbers of participants were 46.	one
13	EFFORTS OF ARTIFICIAL RECHARGE & RAIN WATER HARVESTING (31-3-2017)	
	Projects completed by CGWB (No & Amount spent)	Nil
	Projects under technical guidance of CGWB (Numbers)	NA

14 GROUND WATER CONTROL AND REGULATION

Category	2017	2020
Number of OE Blocks	Nil	1
Number of Critical Blocks	Nil	Nil
Number of Semi Critical Blocks	4	3
Number of Safe Blocks	4	4
Number of Saline Blocks	Nil	Nil

15 MAJOR GROUND WATER PROBLEMS AND ISSUES

i) Declining Groundwater levels/ Piezometric heads in user aquifers
ii) Increasing depth of tube wells
iii) Increasing instances of high fluoride
iv) Groundwater contamination due to unplanned construction and poor technical design of tube wells
v) Awareness amongst villagers on water conservation techniques
vi) Demand supply management

AQUIFER MAP AND MANAGEMENT PLAN, SABARKANTHA DISTRICT GUJARAT STATE

I Introduction

Aquifer Mapping is an attempt to combine a combination of geologic, geophysical, hydrologic and chemical data to characterize the quantity, quality and sustainability of ground water in aquifers. India is a vast country with a large number of distinct hydrogeological settings. The occurrence and movement of ground water in various aquifer systems are highly complex due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Two broad groups of water bearing formations have been identified depending on their hydraulic properties, 'Viz. Porous Formations which can be further classified into unconsolidated and semi consolidated formations having primary porosity, and Fissured Formations or consolidated formations which are characterized by the absence of primary porosity.

1.1 Purpose and scope

The objective of this study is to prepare Aquifer Map on 1:50,000 scale and prepare management plan for sustainable management of the resources. The report deals with the aquifer map and hydrogeological cross sections. An attempt has been made to estimate the groundwater resources and surplus ground water available for future development. It furnishes taluka wise ground water potential, which, it is hoped, that the district and taluka authorities will find useful in proper planning of their agricultural, industrial, rural and urban water supply schemes.

The main scope of study is summerised below.

i. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality) with geo-referencing information and identification of principal aquifer units.

ii. Periodic long term monitoring of ground water regime (water levels and water quality) for creation of time series data base and ground water resource estimation.

iii. Quantification of groundwater availability and assessing its quality.

iv. To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.

v. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, information dissemination, education, awareness and training.

vi. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management

vii. Develop sustainable ground water management plan through public participation.

1.2 Location and Areal Extent

The district derives its name from the Sabarmati River that separates Sabarkantha from the neighboring districts. Sabarkantha District is situated in North Eastern part of Gujarat State. Sabarkantha district is surrounded by Rajasthan state to the northeast, Banaskantha and Mehsana districts to the west, Gandhinagar to the south and Aravalli District to the South - East. It is a border district in the eastern part of the Gujarat and is situated between 23°14'and 24°30' North latitudes and 72°43' and 73°26' East longitudes, covered by toposheets no. 45D, H, 46A and E of Survey of India. It has total an area of 5390 sq.km (Source: Gujarat Government Website https://sabarkantha.gujarat.gov.in).

1.3 Administrative units, Accessibility & Population

The district consist of 08 talukas namely Himmatnagar, Idar, Khedbrahma, Prantij, Talod, Poshina,Vadali and Vijaynagar.The administrative Map of the district is given in **Fig.-1.1 & 1.2** . The administrative headquarters of the district is Himmatnagar, about 80 km from Ahmedabad. August 2013 Sabarkantha district was bifurcated into two separate districts. The newly formed district was named Aravalli. District is divided in 4 Revenue Sub-Divisions & 8 Talukas. There are 6 Municipalities in the District. Poshina, Khedbrahma&Vijaynagar Talukas are mainly tribal Talukas. These Talukas are hilly and forest areas. Remaining Talukas are mainly flat areas.

According to the 2011 census, the total population of Sabarkantha district is 1404865 persons out of which population of male and female are 720128 and 68737 respectively (Table 1.1). The District is predominantly rural with around 83.12% of the population residing in rural areas. The sex ratio is better in rural areas with 955 females per 1,000 males as against 933 females per 1,000 males in urban area.

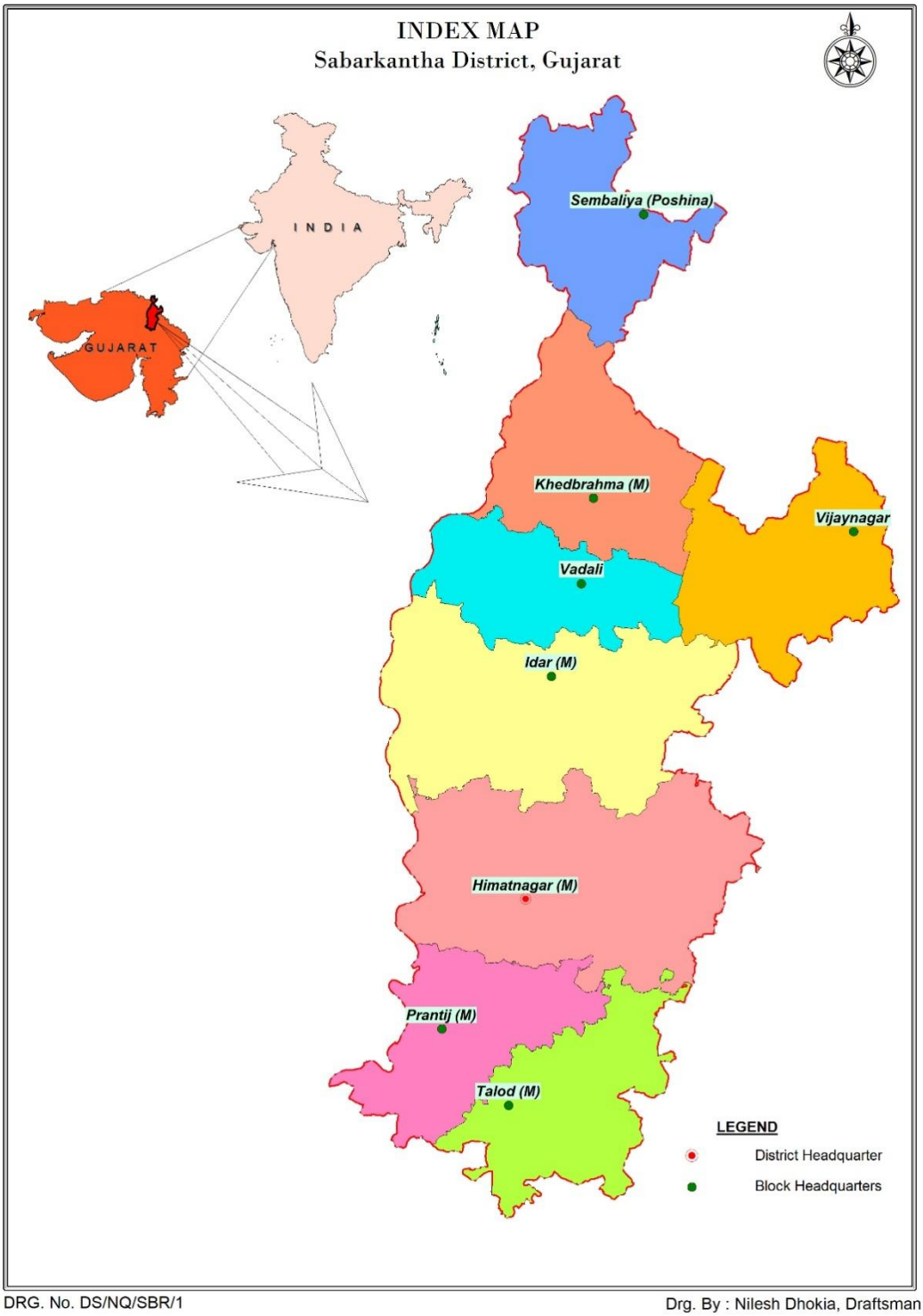


Fig.1.1 Index map of Sabarkantha district, Gujarat.

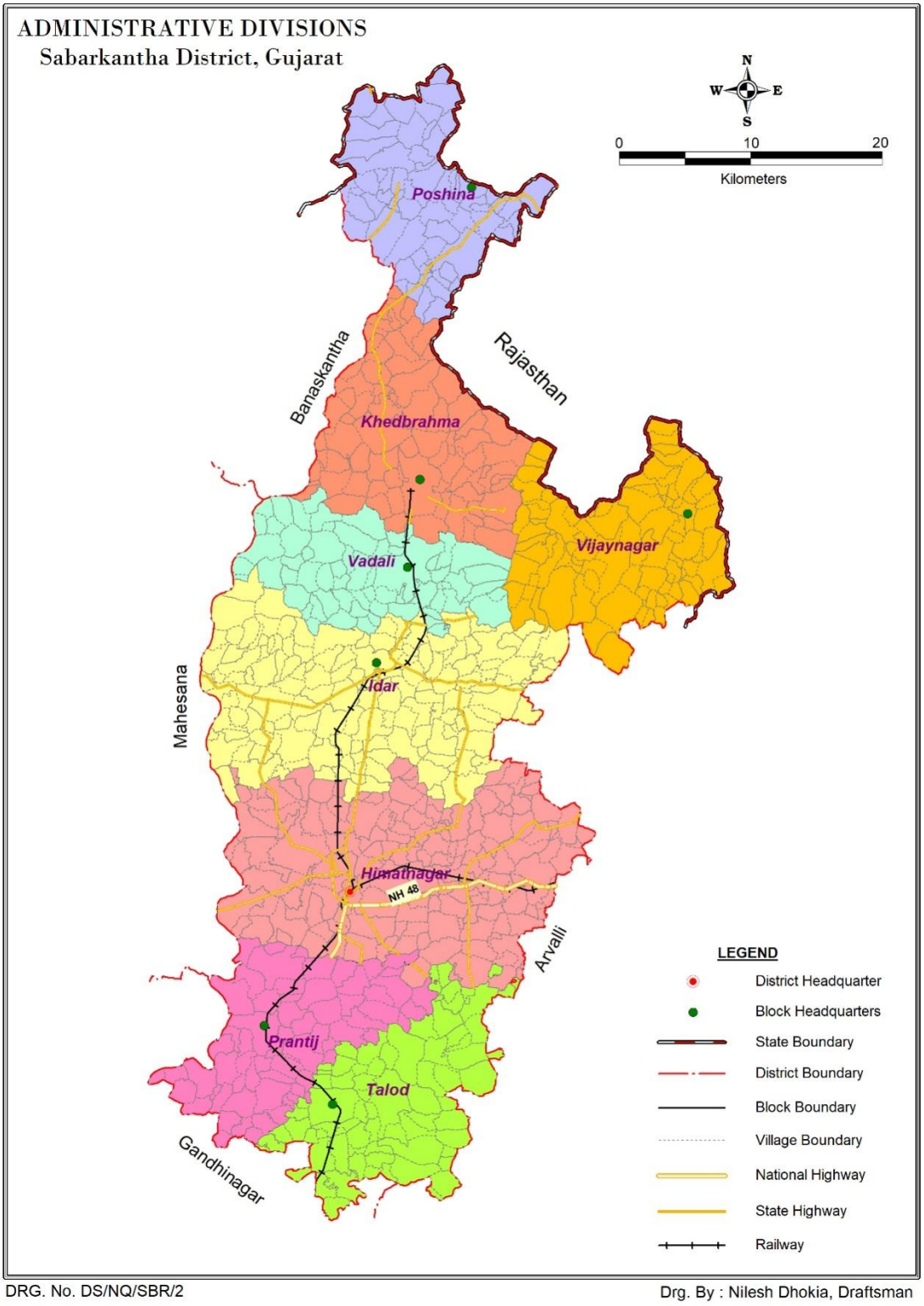


Fig.1.2 Administrative division of Sabarkantha district, Gujarat

Table:1.1 Demographic Profile (Gender based)

Sr. No.	Taluka	Total population			Rural population			Urban population		
		Total	Male	Female	Total	Male	Female	Total	Male	Female
1	Himmat nagar	340289	176415	163874	239056	123749	115307	101233	52666	48567
2	Idar	264195	135730	128465	221889	113790	108099	42306	21940	20366
3	Khedbrahma	163966	82988	80978	138965	70215	68750	25001	12773	12228
4	Poshina	130937	65911	65026	130937	65911	65026	0	0	0
5	Prantij	161279	83566	77713	137683	71473	66210	23596	12093	11503
6	Talod	154424	79739	74685	136126	70252	65874	18298	9487	8811
7	Vadali	85880	43817	42063	65234	33227	32007	20646	10590	10056
8	Vijaynagar	103895	51962	51933	97817	48826	48991	6078	3136	2942
	Total	1404865	720128	684737	1167707	597443	570264	237158	122685	114473
Source: Ankadiya Rooprekha Sabarkantha										

The total number of SC and ST family members in the district are 1,25,462 and 3,28,243 respectively. In Khedbrahma & Poshina (Table1.2), the ST populace is to the tune of 15.91% (of total population in the district), highest of all the talukas, followed by Vijaynagar (05.86%). In case of SC population, the maximum persons are in Idar taluka (03.00%) followed by Himatnagar (02.43%). Other tehsils have less than 01% of SC population.

Table :1.2 Demographic Profile (Category based)

S. No.	Taluka	SC	ST	OBC / General	No. of HH	Total Population
1	Himatnagar	33848	6668	285153	66731	325669
2	Idar	41759	14344	201801	54823	257904
3	Khedbrahma & Poshina	8696	220964	63483	49560	293143
4	Prantij	13190	601	147488	32503	161279
5	Talod	11874	464	142086	30913	154424
6	Vadali	11216	3693	77448	19264	92357
7	Vijaynagar	4879	81509	17507	20881	103895
Total		125462	328243	1103890	274675	1388671
Source: Censes of India website www.censusindia.gov.in						

1.4 Previous work

Systematic hydrogeological surveys were carried by Geological Survey of India between 1965 and 1968 (I-lurthy 1965-67, G-. Balsubrahmanian 1 967-68) and between 1979 and 1981 by Central Ground Water Board (R.N. Meshram 1980-81 and Arun Kumar, 1979-80). For systematic hydrogeological surveys 3,500 sq.km. area has been covered by Geological Survey of India and 4,600 sq.km. area has been covered by Central. Ground Water Board.

Area recovered under systematic hydrogeological surveys is 736 sq.km. Prior to 1969, Exploratory Tubewell Organisation carried out some drilling in the district. From May 1969 to April 1970, Geological Survey of India drilled five exploratory boreholes. During the period of 1990 to 1992 in exploratory drilling programme of CGWB, drilled 14 EW and 9 OW in the taluka of Bhiloda, Idar , Khedbrahamma and Poahina.

II Physiography and Drainage

2.1 Physiography

Physiographically, the district can be divided in to two zones i.e. the hilly regions and the plains (Fig. 2.1). The hilly ranges cover the northern and eastern part of the district where as the plains, showing the undulating topography, are confined towards west and southwest. Hilly area shown the high relief formed by the long narrow steep sloped and flat topped. Aravalli ridges which are intervened by narrow longitudinal valleys and presented as denudation hills and structural hills. The hilly tract known as Poshina Patti area covers Khedbrahma, Vijaynagar and parts of Idar talukas. The highest elevation is about 682.75m amsl towards west of Vijaynagar. The hill ranges are aligned roughly in NE – SW and N – S direction. Near the peripheries of the ridges, there are prominent round hills and mounds of granites near Idar. Southern and western parts of the district are mostly plain and sandy area covers the Parntij, Himmatnagar, and parts of Idar talukas.

2.2 Drainage

Sabarmati, the major river of the district, flows from north to south, along the western border of the district originating from the hill ranges of the Rajasthan (Fig. 2.2). The area is mainly drained by the south westerly flowing river, namely the Hathmati, the Khari, the Meshwa, the Majham and the Vatrak.

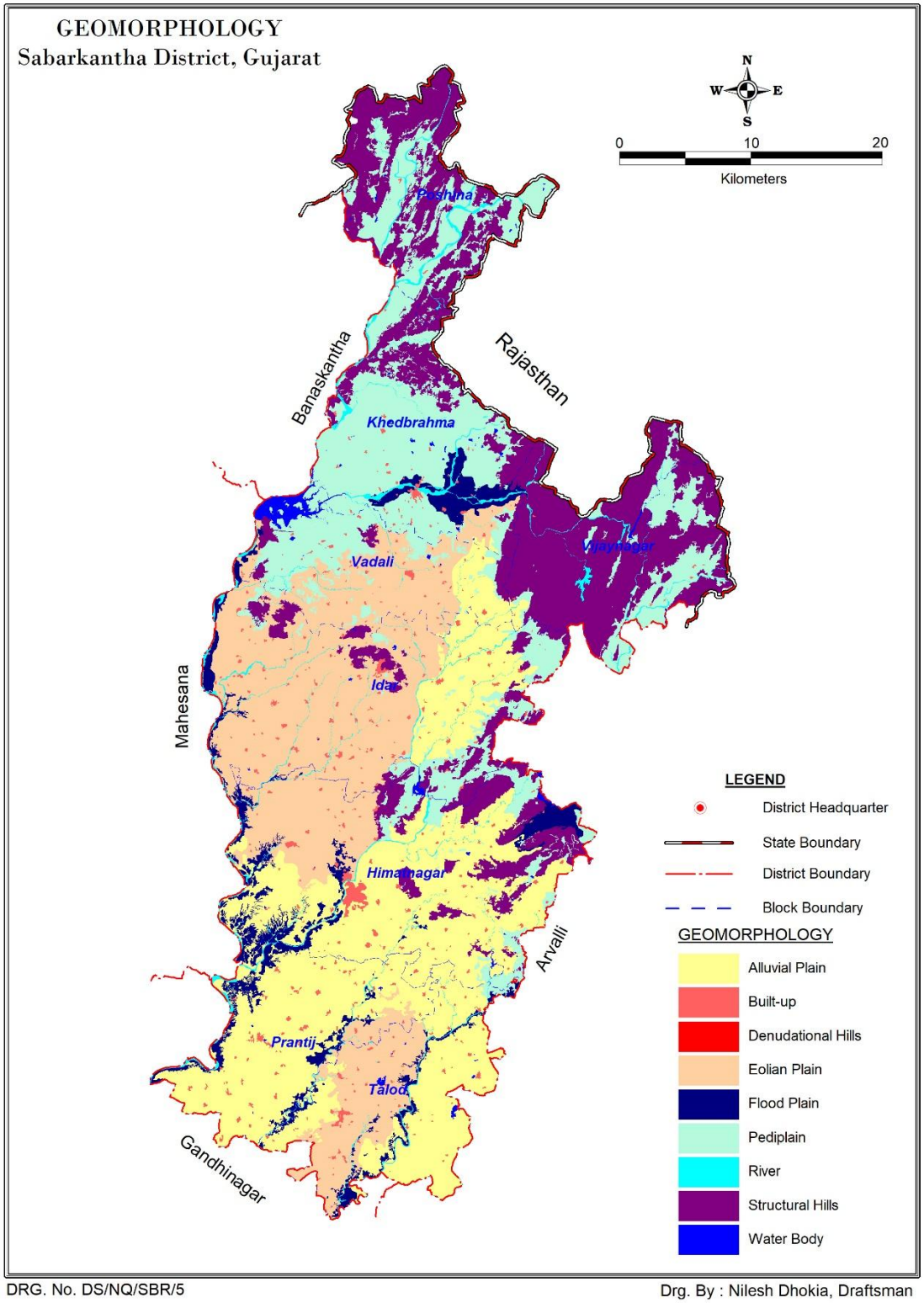


Fig.2.1 Physiographic division of Sabarkantha district

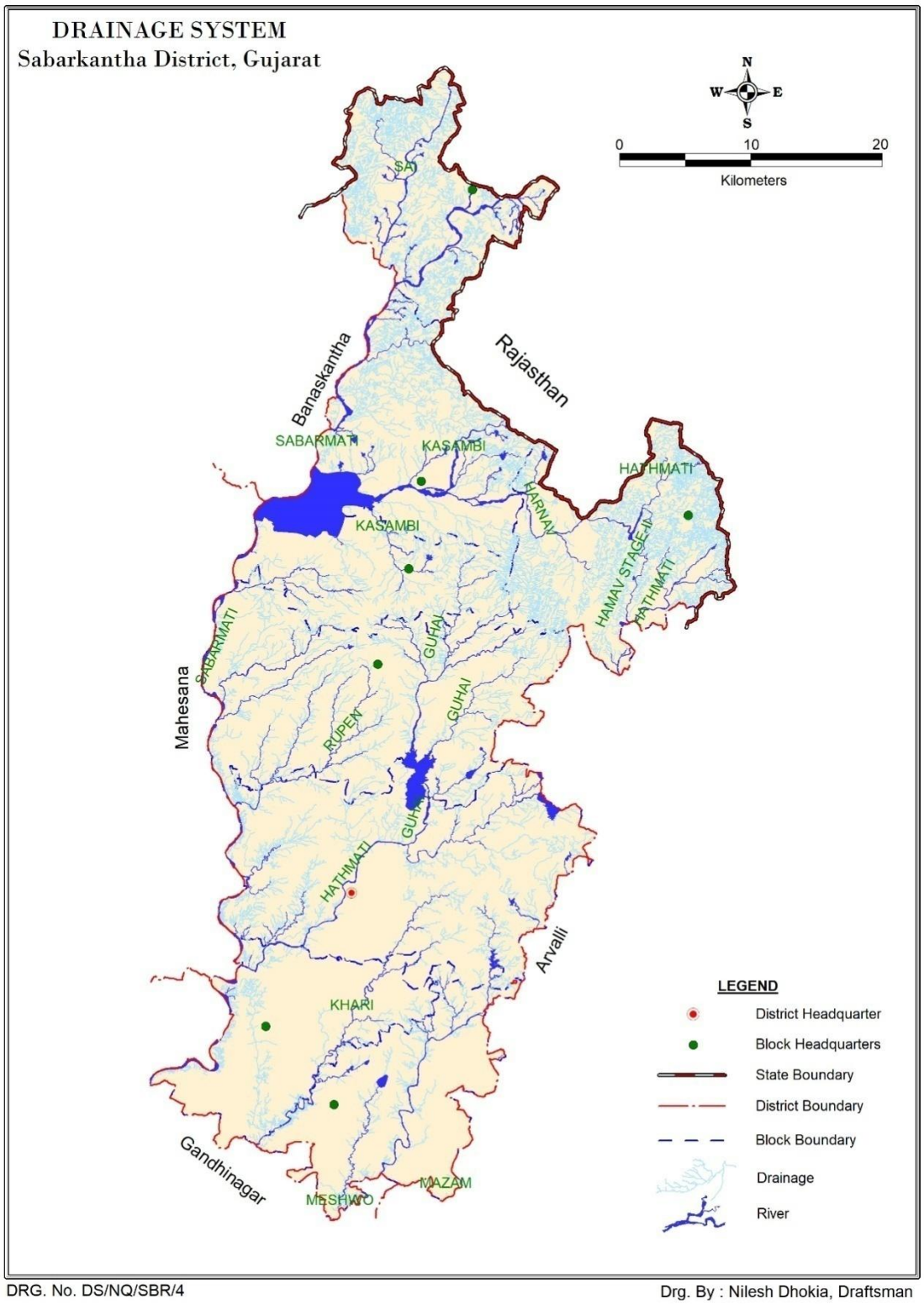


Fig.2.2 Drainage map of Sabarkantha district

III Soil, Land use, Agriculture, Irrigation and Surface water resources.

3.1 Soil

The soils of Sabarkantha district may be divided into three soil classes. a. Sandy loamy; b. Sandy loam, clay loam & clay; and c. Sandy clay loam, shallow in depth (Table 3.1 & Fig. 3.1). The texture of the soil is generally sandy loam to clay loam. The agro-climatic conditions provide a range of potentialities for growing crops like maze, potatoes, pulses, and fruits apart from cereals, millets and oilseeds. Soils are medium deep and fertile.

Table:3.1 Soil classification of the district.

Soil Class	Districts
Sandy loamy	Himatnagar, Prantij, Talod
Sandy loam, clay loam and clay	Idar, Khedbrahma, Vadali
Sandy clay loam , shallow in depth	Vijaynagar
Source: Comprehensive District Agriculture Plan	

3.2 Land Use/ land cover

Average cropping intensity in the district is about 120%. Net sown area is reported as about 59% of the total geographical area. Cultivable waste land is 1.6% of the total geographical area. About 6% of the total geographical area is either barren or not fit for agriculture. Overall 70% of the geographical area may be termed as Gross Cropped Area (Table3.2). Land cover of the district is shown in Fig. 3.2.

Table:3.2 Land use pattern (Area in Ha.)

#	Name of Block	Geographical Area	Area under Agriculture				Area under Other Uses		
			Gross Cropped Area (1)	Net Sown Area (2)	Area Sown more than once (1-2)	Cropping Intensity (%)	Barren / Not Fit for Crops	Pastures	Cultivable Waste Land
1	Himatnagar	77391	64455	54120	10335	119.09	4799	4070	1383
2	Idar	81458	67281	58278	9003	115-44	3579	3351	793
3	Khedbrahma & Poshina	83743	33874	33034	840	108.59	4623	1498	2249
4	Prantij	40936	39608	30120	9488	131.50	3536	2895	337
5	Talod	44079	36310	29866	6444	121.57	3935	3200	400
6	Vadali	33219	27135	23235	3900	116.78	2225	2664	599
7	Vijaynagar	45796	16226	12758	3468	127.18	1425	125	882
Total		406622	284889	241411	43478		24122	17803	6643
Source: C-DAP, Sabarkantha									

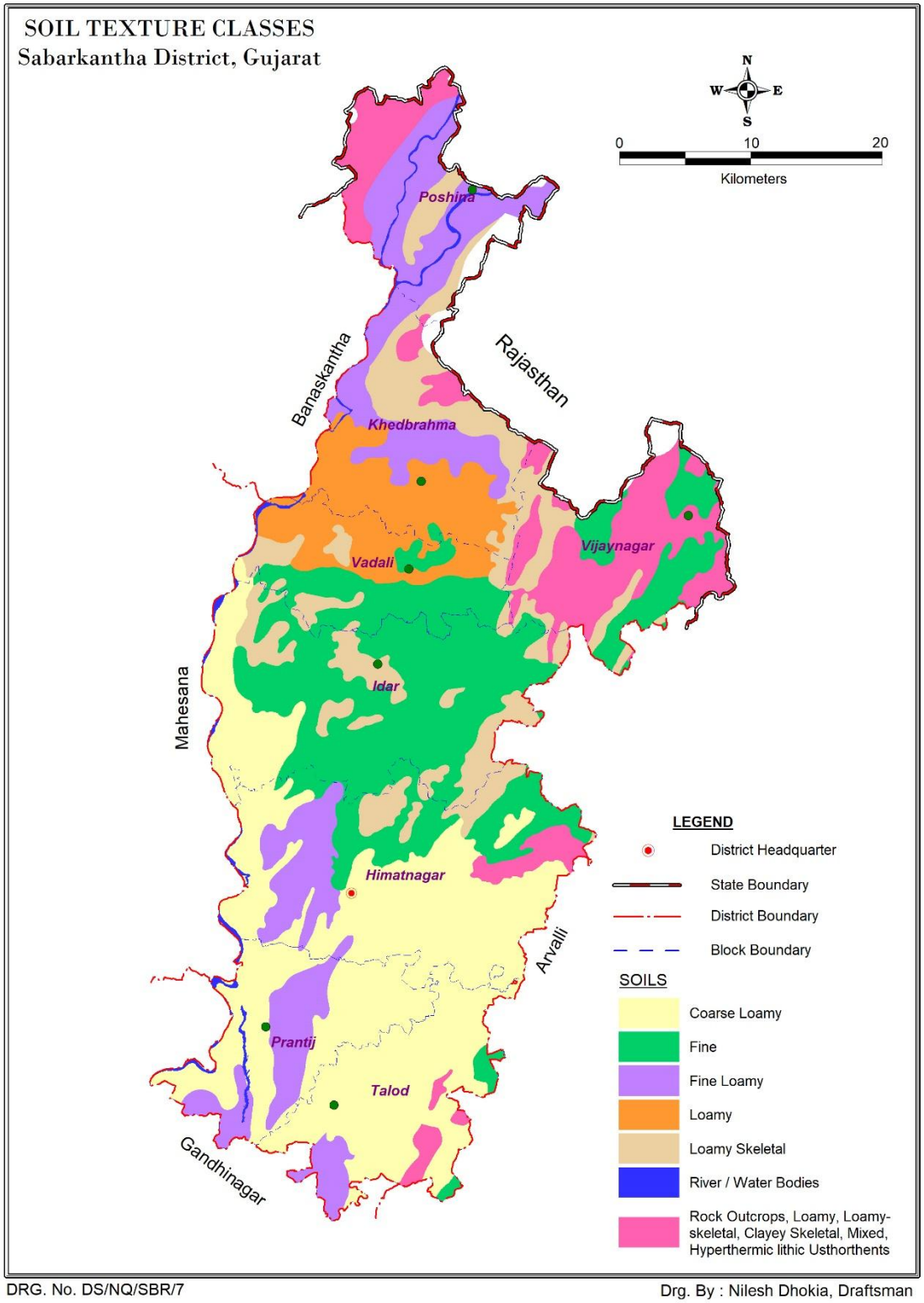


Fig.3.1 Soil Classification in Sabarkantha District

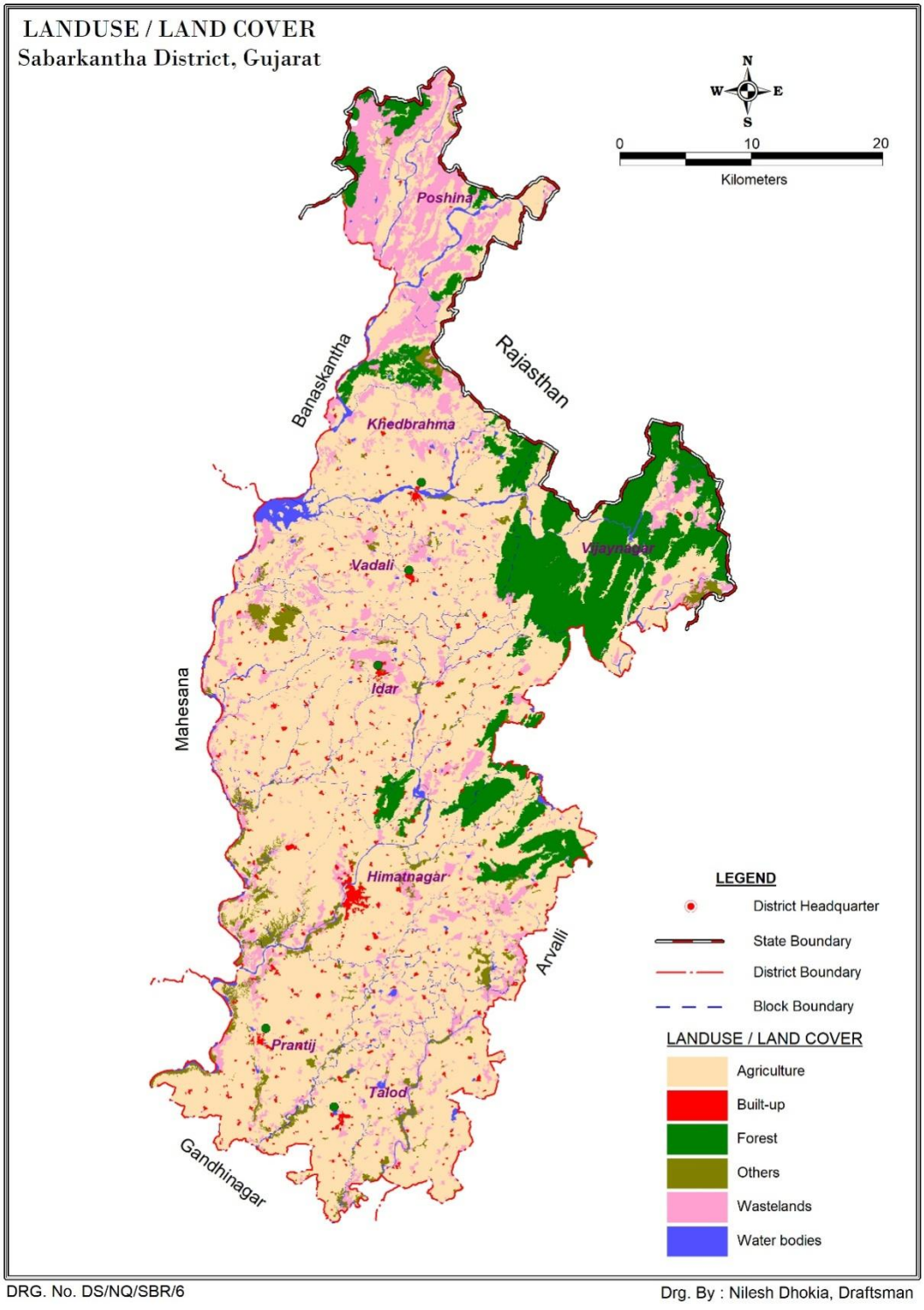


Fig.3.2 Land cover

3.3 Irrigation:

The district has good resource of surface and area is drained by major rivers viz. Sabarmati, Hathmati, and Harnav. The district also has good numbers of water reservoirs/dams like Dharoi, Hathmati, Vanaj, Guhai, Harnav 1 & 2. The prestigious Sujalam Suflam project also benefits the district and has helped in improving the water table and out flow of the tube wells. The main source of irrigation is from ground water through wells (76.88%), though 28.10% area has access to canals irrigation. Twenty six per cent of the cultivated area is irrigated.

3.4 Agriculture:

About 70% of the geographical area of the state is Gross Cropped Area. Gross Irrigated Area under agriculture in the district is 2,82,157 Ha. and Gross Rainfed Area under agriculture in the district is 1,11,424 Ha. All the summer crops are cropped only as irrigatedcrops. In Rabi season, wheat is dominating crop, whereas in kharif season; cotton, castor and maize are dominating crop. Horticulture and other crops are still gaining popularity. As may be observed in the following table, Gross area under horticulture plantation is 33,590 Ha. This forms about 8.53% of the total gross area under agriculture.

3.5 Surface Water Availability

Major sources of surface irrigation are uneven in space and time. Nearly 80% of the rainfall occurs in 3-4 months. Surface water availability across the seasons in the Sabarkantha district is shown in the following table 3.3. Total water availability across the seasons in the district is 325.87 MCM. This has paved the way for flood irrigation. Surface irrigation in the district is found to be common during all seasons.

3.6 Command Area:

The area which can be irrigated from a scheme and is fit for cultivation is known as Culturable Command Area. The cultivable area excludes forest and barren land from the Gross Command Area. Area under canal command and irrigate different sources is given in Table 3.4. Total irrigated and rainfed area are 282157 Ha and 111424 Ha respectively in the district (Table 3.5).

Table:3.3 Surface Water Availability in MCM

S. No.	Block	Kharif	Rabi	Summer	Total
1	Himatnagar	23	59.91	19	101.91
2	Idar	17.25	57.4	16	90.65
3	Khedbrahma & Poshina	9.2	20.25	0	29.45
4	Prantij	17.45	32.91	3	53.36
5	Talod	4.5	11.7	0	16.2
6	Vadali	7	14.2	0.5	21.7
7	Vijaynagar	3.8	8.8	0	12.6
Total		82.2	205.17	38.5	325.87

Source: District Irrigation records, Sabarkantha

Table: 3.4 Status of the command area in Ha.

S. No.	Block	Information of Canal Command			Information on the other Services Command			Total Area	
		Total Area	Developed Area	Undeveloped Area	Total Area	Developed Area	Undeveloped Area	Developed Command	Undeveloped Command
1	Himatnagar	29756	29756	-	0	0	-	29756	-
2	Idar	15153	15153	-	0	0	-	15153	-
3	Khedbrahma & Poshina	2198	2198	-	0	0	-	2198	-
4	Prantij	7781	7781	-	0	0	-	7781	-
5	Talod	0	0	-	2325	2325	-	2325	-
6	Vadali	8579	8579	-	0	0	-	8579	-
7	Vijaynagar	1561	1561	-	0	0	-	1561	-
Total		65028	65028	-	2325	2325	-	67353	-

Table:3.5 Irrigated and rainfed area in Agriculture in Sabarkantha district (area in Ha)

Block	Kharif			Rabi			Summer			Total		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
Himatnagar	37505	19080	56585	30293	0	30293	2525	0	2525	70323	19080	89403
Idar	27570	33570	61140	25700	2125	27825	4220	0	4220	57490	35695	93185
Khedbrahma&Poshina	8000	26195	34195	13750	400	14150	9895	0	9895	31645	26595	58240
Prantij	20286	2134	22420	11634	0	11634	1683	0	1683	33603	2134	35737
Talod	17305	4710	22015	9978	0	9978	6188	0	6188	33471	4710	38181
Vadali	15760	11035	26795	15470	40	15510	5720	0	5720	36950	11075	48025
Vijaynagar	1850	11915	13765	9585	220	9805	7240	0	7240	18675	12135	30810
Sabarkantha District Total	128276	108639	236915	116410	2785	119195	37471	0	37471	282157	111424	393581

Source: Department Of Agriculture, Agriculture Statistic of state ,Agri State

IV HYDROMETEOROLOGY

Sabarkantha district is located in east of *Gujarat*, comes under normal rainfall areas in Gujarat, having sub-tropical climate with moderately low humidity. The main seasons prevailing in the district are (a) monsoon - mid of June to October, (b) winter - November to February, and (c) summer – March to June. Climatological data is as given below in Table 4.1. and shown in Fig. 4.1.

Table 4.1: Climatological Data of Idar station in Sabarkantha district

Climatological Data								
Station:	Idar				District:	Sabarkantha		
Altitude:	219	m AMSL			HA	10	**0.7479511**	
Latitude:	$23^0$50'	N			Longitude:	$73^0$02'	E	
Month	**Max Temp (Deg.C)**	**Mini Temp (Deg.C)**	**Humidity (%)**	**Wind Spd. Kmpd**	**Sunshine (Hours)**	**Solar Rad. (MJ/m2/d)**	**Eto (mm/d)**	**Rainfall (mm)**
January	33.2	13.1	33.0	127.5	8.9	16.6	3.7	0.0
February	38.4	17.0	28.5	129.2	9.5	19.4	4.5	0.0
March	43.9	21.1	25.5	134.6	10.1	22.8	5.8	0.0
April	46.8	21.8	26.5	140.0	10.8	25.6	7.0	0.0
May	48.5	27.5	37.5	161.6	11.4	27.1	7.8	0.0
June	47.2	23.9	57.0	184.9	8.7	23.1	6.8	8.0
July	39.6	23.3	71.5	136.4	5.3	17.9	4.5	177.9
August	36.4	23.3	81.0	105.9	5.4	17.6	3.9	149.2
September	37.4	22.7	69.5	93.3	7.9	20.2	4.5	551.5
October	40.2	23.4	41.5	88.0	9.6	20.3	4.5	0.0
November	35.8	16.3	33.0	105.9	9.3	17.5	3.9	0.0
December	31.0	11.5	35.0	114.9	8.9	15.8	3.5	0.0
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**886.6**
Average	**39.9**	**20.4**	**45.0**	**126.9**	**8.8**	**20.3**	**5.0**	**73.9**

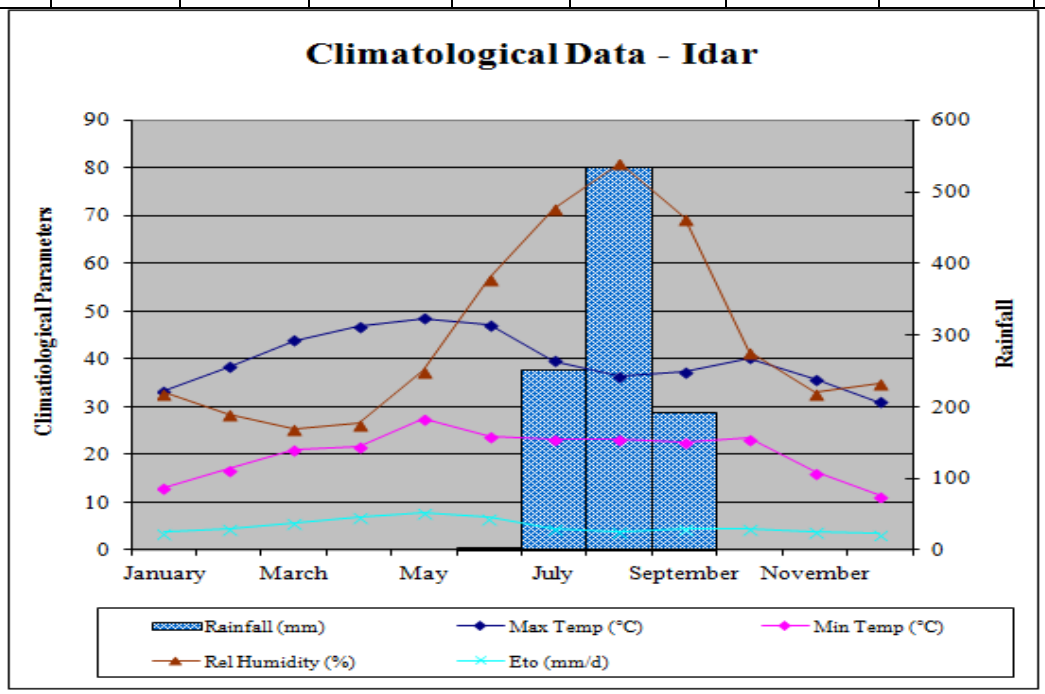


Fig 4.1: Climatological data analysis of Sabarkantha district

4.1 Rainfall

Sabarkantha district receives much of its rainfall from the south-west monsoon during the period between June & October; its maximum intensity being in the month of July & August. Total rainy days ranges from 20 to 30 days/year. Long term annual rainfall data of 7 taluka from year 1981-2020 are statistically analyzed and presented in table No 4.2.

Rainfall	% Departure
Excess	Percentage departure of realised rainfall from normal rainfall is + 20% or more.
Normal	Percentage departure of realised rainfall from normal rainfall is between - 19 % to + 19 %.
Deficient	Percentage departure of realised rainfall from normal rainfall is between – 20 % to - 59 %.
Scanty	Percentage departure of realised rainfall from normal rainfall is between – 60 % to - 99 %.
No Rain	Percentage departure of realised rainfall from normal rainfall is– 100 %

Table 4.2 - Statistical Analysis of Rainfall Data *Rainfall in mm*

Name of the Taluka	Rainfall 2020	Average Annual RF (1981-2020)	Departure % (Year 2020)	Highest RF - Year		Lowest RF - Year	
				Year	Rainfall	Year	Rainfall
Himatnagar	797	798.275	-0.16	2006	1590	1987	165
Idar	1072	901.925	18.86	2007	2077	1987	218
Khedbrahma	965	813.20	18.67	2006	1640	1987	204
Prantij	1034	810.775	27.53	1997	1608	1987	223
Talod	1085	786.675	37.90	1997	1608	1987	223
Vadali	870	816.25	6.60	2006	1781	1987	218
Vijaynagar	986	807.975	22.20	2006	1625	1987	310

4.2 DROUGHT ANALYSIS

Drought frequency was computed for the 7 taluka of the Sabarkantha district (**Table 4.3.a, b, c & d, Table 4.4**). These frequencies area based on the agriculture definition of drought which takes into account the negative departures of annual rainfall from mean annual rainfall as given below. Rainfall, Departure and Cumulative Departure are presented in **Fig. 4.2a, b, c & d**.

Departure from annual mean (%)			Type of Drought
0.1	to	25.0	Mild Drought
25.1	to	50.0	Normal Drought
50.1	to	75.0	Severe Drought
75.1	to	100.0	Most severe Drought (rare drought)

Table: 4.3a Rainfall, Departures, Cumulative Departures and type of Drought in Idar and Himmatnagar talukas

Year	Taluka Idar			
	Rainfall	Departure	Cumulative Departures	type of Drought
1981	768	-0.1485	-0.15	Mild
1982	716	-0.2061	-0.35	Mild
1983	1005	0.1143	-0.24	
1984	1024	0.1353	-0.10	
1985	600	-0.3348	-0.44	Normal
1986	327	-0.6374	-1.08	Sever
1987	218	-0.7583	-1.84	Most Sever
1988	886	-0.0177	-1.85	Mild
1989	781	-0.1341	-1.99	Mild
1990	981	0.0877	-1.90	
1991	812	-0.0997	-2.00	Mild
1992	814	-0.0975	-2.10	Mild
1993	733	-0.1873	-2.28	Mild
1994	1620	0.7962	-1.49	
1995	315	-0.6507	-2.14	Sever
1996	760	-0.1574	-2.30	Mild
1997	1097	0.2163	-2.08	
1998	986	0.0932	-1.99	
1999	534	-0.4079	-2.39	Normal
2000	367	-0.5931	-2.99	Sever
2001	753	-0.1651	-3.15	Mild
2002	332	-0.6319	-3.78	Sever
2003	921	0.0211	-3.76	
2004	709	-0.2139	-3.98	Mild
2005	1159	0.2850	-3.69	
2006	1759	0.9503	-2.74	
2007	2077	1.3029	-1.44	
2008	809	-0.1030	-1.54	Mild
2009	743	-0.1762	-1.72	Mild
2010	1112	0.2329	-1.49	
2011	1020	0.1309	-1.35	
2012	1104	0.2240	-1.13	
2013	1121	0.2429	-0.89	
2014	1029	0.1409	-0.75	
2015	1010	0.1198	-0.63	
2016	865	-0.0409	-0.67	Mild
2017	1290	0.4303	-0.24	
2018	763	-0.1540	-0.39	Mild
2019	1085	0.2030	-0.19	
2020	1072	0.1886	0.00	
Mean	901.925			

	Taluka Himmatnagar			
Year	Rainfall	Departure	Cumulative Departures	type of Drought
1981	829	0.0385	0.04	
1982	519	-0.3498	-0.31	Normal
1983	976	0.2226	-0.09	
1984	925	0.1587	0.07	
1985	521	-0.3473	-0.28	Normal
1986	292	-0.6342	-0.91	Sever
1987	165	-0.7933	-1.70	Most Sever
1988	899	0.1262	-1.58	
1989	761	-0.0467	-1.63	Mild
1990	998	0.2502	-1.38	
1991	758	-0.0505	-1.43	Mild
1992	583	-0.2697	-1.70	Normal
1993	683	-0.1444	-1.84	Mild
1994	1204	0.5083	-1.33	
1995	426	-0.4663	-1.80	Normal
1996	669	-0.1619	-1.96	Mild
1997	1025	0.2840	-1.68	
1998	1102	0.3805	-1.30	
1999	421	-0.4726	-1.77	Normal
2000	420	-0.4739	-2.24	Normal
2001	578	-0.2759	-2.52	Normal
2002	431	-0.4601	-2.98	Normal
2003	905	0.1337	-2.84	
2004	499	-0.3749	-3.22	Normal
2005	1206	0.5108	-2.71	
2006	1590	0.9918	-1.72	
2007	1305	0.6348	-1.08	
2008	569	-0.2872	-1.37	Normal
2009	578	-0.2759	-1.64	Normal
2010	691	-0.1344	-1.78	Mild
2011	867	0.0861	-1.69	
2012	644	-0.1933	-1.89	Mild
2013	1245	0.5596	-1.33	
2014	880	0.1024	-1.22	
2015	830	0.0397	-1.18	
2016	740	-0.0730	-1.26	Mild
2017	1318	0.6511	-0.61	
2018	902	0.1299	-0.48	
2019	1180	0.4782	0.00	
2020	797	-0.0016	0.00	Mild
Mean	798.275			

Table:4.3b Rainfall, Departures, Cumulative Departures and type of Drought in Khedbrahmma and Prantiz talukas

Year	Taluka Khedbrahma			
	Rainfall	Departure	Cumulative Departures	type of Drought
1981	784	-0.0359	-0.04	Mild
1982	899	0.1055	0.07	
1983	1012	0.2445	0.31	
1984	1011	0.2432	0.56	
1985	475	-0.4159	0.14	Normal
1986	358	-0.5598	-0.42	Sever
1987	204	-0.7491	-1.17	Sever
1988	889	0.0932	-1.07	
1989	792	-0.0261	-1.10	Mild
1990	1148	0.4117	-0.69	
1991	626	-0.2302	-0.92	Mild
1992	851	0.0465	-0.87	
1993	886	0.0895	-0.78	
1994	1381	0.6982	-0.08	
1995	481	-0.4085	-0.49	Normal
1996	648	-0.2031	-0.70	Mild
1997	925	0.1375	-0.56	
1998	850	0.0453	-0.51	
1999	315	-0.6126	-1.13	Sever
2000	444	-0.4540	-1.58	Normal
2001	613	-0.2462	-1.83	Mild
2002	362	-0.5548	-2.38	Sever
2003	889	0.0932	-2.29	
2004	497	-0.3888	-2.68	Normal
2005	914	0.1240	-2.55	
2006	1640	1.0167	-1.54	
2007	975	0.1990	-1.34	
2008	571	-0.2978	-1.64	Normal
2009	571	-0.2978	-1.93	Normal
2010	831	0.0219	-1.91	
2011	1372	0.6872	-1.22	
2012	970	0.1928	-1.03	
2013	1127	0.3859	-0.65	
2014	703	-0.1355	-0.78	Mild
2015	1061	0.3047	-0.48	
2016	726	-0.1072	-0.58	Mild
2017	1156	0.4215	-0.16	
2018	502	-0.3827	-0.54	Normal
2019	1104	0.3576	-0.19	
2020	965	0.1867	0.00	
Mean	813.2			

Year	Taluka Prantiz			
	Rainfall	Departure	Cumulative Departures	type of Drought
1981	812	0.0015	0.00	
1982	939	0.1582	0.16	
1983	1098	0.3543	0.51	
1984	886	0.0928	0.61	
1985	474	-0.4154	0.19	Normal
1986	393	-0.5153	-0.32	Sever
1987	223	-0.7250	-1.05	Sever
1988	1005	0.2396	-0.81	
1989	444	-0.4524	-1.26	Normal
1990	1140	0.4061	-0.86	
1991	795	-0.0195	-0.88	Mild
1992	555	-0.3155	-1.19	Normal
1993	569	-0.2982	-1.49	Normal
1994	1220	0.5047	-0.98	
1995	535	-0.3401	-1.32	Normal
1996	694	-0.1440	-1.47	Mild
1997	1608	0.9833	-0.48	
1998	1394	0.7193	0.23	
1999	397	-0.5103	-0.28	Sever
2000	416	-0.4869	-0.76	Normal
2001	285	-0.6485	-1.41	Sever
2002	397	-0.5103	-1.92	Sever
2003	851	0.0496	-1.87	
2004	758	-0.0651	-1.94	Mild
2005	1335	0.6466	-1.29	
2006	1416	0.7465	-0.54	
2007	1489	0.8365	0.29	
2008	904	0.1150	0.41	
2009	596	-0.2649	0.14	Normal
2010	854	0.0533	0.20	
2011	715	-0.1181	0.08	Mild
2012	599	-0.2612	-0.18	Normal
2013	1137	0.4024	0.22	
2014	939	0.1582	0.38	
2015	830	0.0237	0.40	
2016	452	-0.4425	-0.04	Normal
2017	836	0.0311	-0.01	
2018	415	-0.4881	-0.50	Normal
2019	992	0.2235	-0.28	
2020	1034	0.2753	0.00	
Mean	810.775			

Table: 4.3c Rainfall, Departures, Cumulative Departures and type of Drought in Vadali and Vijainagar talukas

Year	Taluka Vadali			
	Rainfall	Departure	Cumulative Departures	type of Drought
1981	768	-0.0591	-0.06	Mild
1982	716	-0.1228	-0.18	Mild
1983	1005	0.2312	0.05	
1984	1024	0.2545	0.30	
1985	600	-0.2649	0.04	Normal
1986	327	-0.5994	-0.56	Sever
1987	218	-0.7329	-1.29	Sever
1988	886	0.0855	-1.21	
1989	781	-0.0432	-1.25	Mild
1990	981	0.2018	-1.05	
1991	812	-0.0052	-1.05	Mild
1992	814	-0.0028	-1.06	Mild
1993	733	-0.1020	-1.16	Mild
1994	1620	0.9847	-0.17	
1995	315	-0.6141	-0.79	Sever
1996	760	-0.0689	-0.86	Mild
1997	1097	0.3440	-0.51	
1998	986	0.2080	-0.31	
1999	534	-0.3458	-0.65	Normal
2000	367	-0.5504	-1.20	Sever
2001	753	-0.0775	-1.28	Mild
2002	332	-0.5933	-1.87	Sever
2003	811	-0.0064	-1.88	Mild
2004	631	-0.2270	-2.11	Mild
2005	1165	0.4273	-1.68	
2006	1781	1.1819	-0.50	
2007	1052	0.2888	-0.21	
2008	531	-0.3495	-0.56	Normal
2009	794	-0.0273	-0.58	Mild
2010	980	0.2006	-0.38	
2011	1149	0.4077	0.02	
2012	591	-0.2760	-0.25	Normal
2013	1075	0.3170	0.06	
2014	792	-0.0297	0.03	Mild
2015	884	0.0830	0.12	
2016	563	-0.3103	-0.19	Normal
2017	1073	0.3145	0.12	
2018	556	-0.3188	-0.20	Normal
2019	923	0.1308	-0.07	
2020	870	0.0658	0.00	
Mean	816.25			

Year	Taluka Vijaynagar			
	Rainfall	Departure	Cumulative Departures	type of Drought
1981	649	-0.1968	-0.20	Mild
1982	548	-0.3218	-0.52	Normal
1983	828	0.0248	-0.49	
1984	1102	0.3639	-0.13	
1985	580	-0.2822	-0.41	Normal
1986	571	-0.2933	-0.71	Normal
1987	310	-0.6163	-1.32	Sever
1988	787	-0.0260	-1.35	Mild
1989	673	-0.1671	-1.51	Mild
1990	1178	0.4580	-1.06	
1991	907	0.1226	-0.93	
1992	720	-0.1089	-1.04	Mild
1993	790	-0.0222	-1.07	Mild
1994	1440	0.7822	-0.28	
1995	690	-0.1460	-0.43	Mild
1996	795	-0.0161	-0.45	Mild
1997	924	0.1436	-0.30	
1998	1119	0.3849	0.08	
1999	471	-0.4171	-0.33	Normal
2000	644	-0.2029	-0.54	Mild
2001	310	-0.6163	-1.15	Sever
2002	400	-0.5049	-1.66	Sever
2003	833	0.0310	-1.63	
2004	638	-0.2104	-1.84	Mild
2005	868	0.0743	-1.76	
2006	1625	1.0112	-0.75	
2007	756	-0.0643	-0.82	Mild
2008	477	-0.4096	-1.23	Normal
2009	545	-0.3255	-1.55	Normal
2010	852	0.0545	-1.50	
2011	1184	0.4654	-1.03	
2012	711	-0.1200	-1.15	Mild
2013	1076	0.3317	-0.82	
2014	1034	0.2797	-0.54	
2015	834	0.0322	-0.51	
2016	789	-0.0235	-0.53	Mild
2017	917	0.1349	-0.40	
2018	673	-0.1671	-0.56	Mild
2019	1085	0.3429	-0.22	
2020	986	0.2203	0.00	
Mean	807.975			

Table: 4.3d Rainfall, Departures, Cumulative Departures and type of Drought in Talod Taluka

Year	Taluka Talod			
	Rainfall	Departure	Cumulative Departures	type of Drought
1981	812	0.032192456	0.03	
1982	939	0.193631423	0.23	
1983	1098	0.395747926	0.62	
1984	886	0.126259256	0.75	
1985	474	-0.39746401	0.35	Normal
1986	393	-0.500429021	-0.15	Sever
1987	223	-0.716528427	-0.87	Sever
1988	1005	0.27752884	-0.59	
1989	444	-0.435599199	-1.02	Normal
1990	1140	0.449137191	-0.58	
1991	795	0.010582515	-0.56	
1992	555	-0.294498999	-0.86	Normal
1993	569	-0.276702577	-1.14	Normal
1994	1220	0.550831029	-0.59	
1995	535	-0.319922458	-0.91	Normal
1996	694	-0.117805955	-1.02	Mild
1997	1608	1.044046144	0.02	
1998	1343	0.707185305	0.73	
1999	459	-0.416531605	0.31	Normal
2000	375	-0.523310134	-0.21	Sever
2001	421	-0.464836178	-0.68	Normal
2002	352	-0.552547113	-1.23	Sever
2003	813	0.033463629	-1.20	
2004	802	0.019480726	-1.18	
2005	1197	0.521594051	-0.65	
2006	1379	0.752947532	0.10	
2007	1074	0.365239775	0.46	
2008	796	0.011853688	0.48	
2009	578	-0.265262021	0.21	Normal
2010	766	-0.026281501	0.18	Mild
2011	706	-0.10255188	0.08	Mild
2012	517	-0.342803572	-0.26	Normal
2013	896	0.138970985	-0.12	
2014	845	0.074141164	-0.05	
2015	859	0.091937585	0.04	
2016	613	-0.220770966	-0.18	Mild
2017	811	0.030921283	-0.15	
2018	418	-0.468649697	-0.61	Normal
2019	972	0.235580132	-0.38	
2020	1085	0.379222678	0.00	
Mean	786.675			

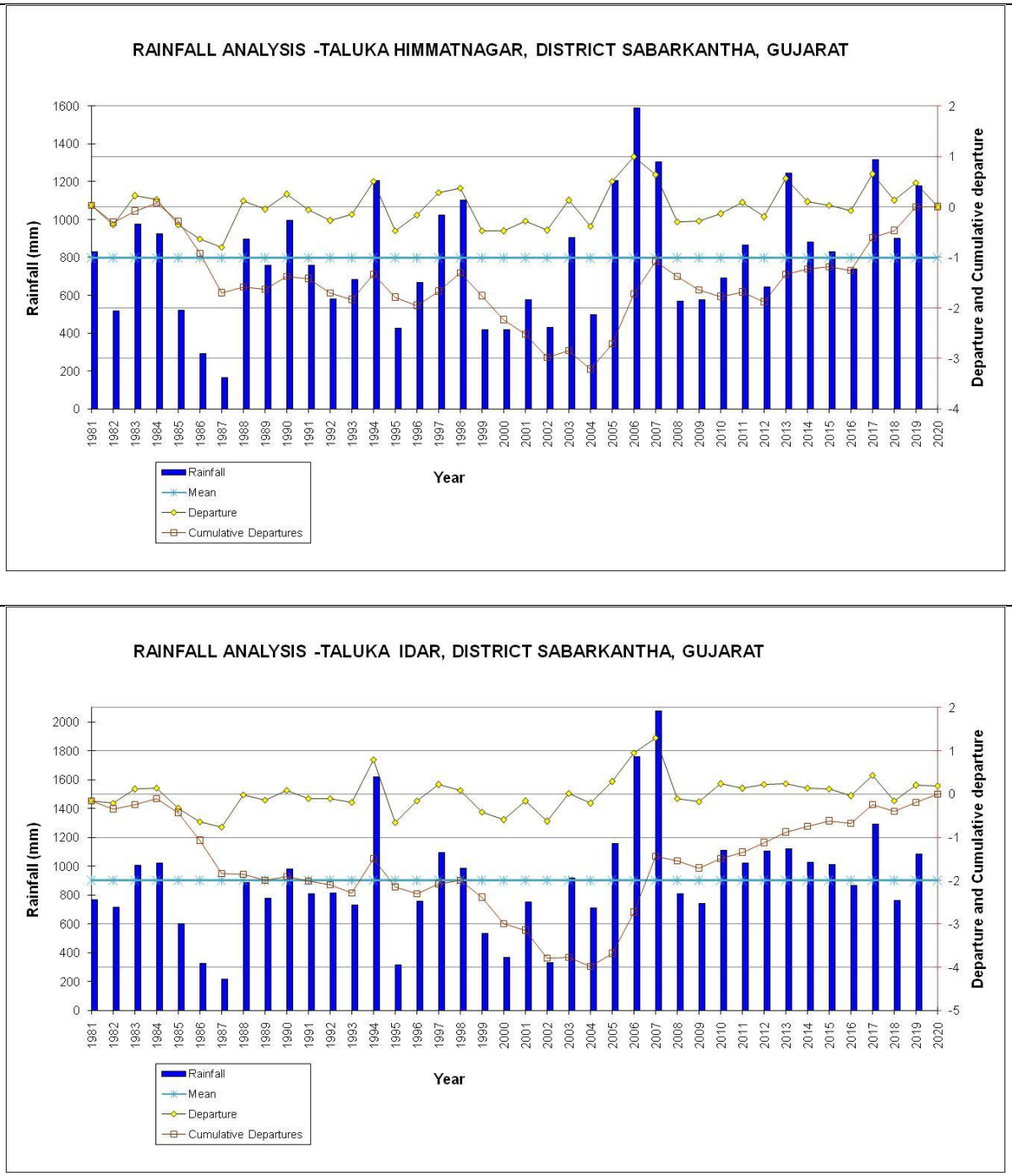
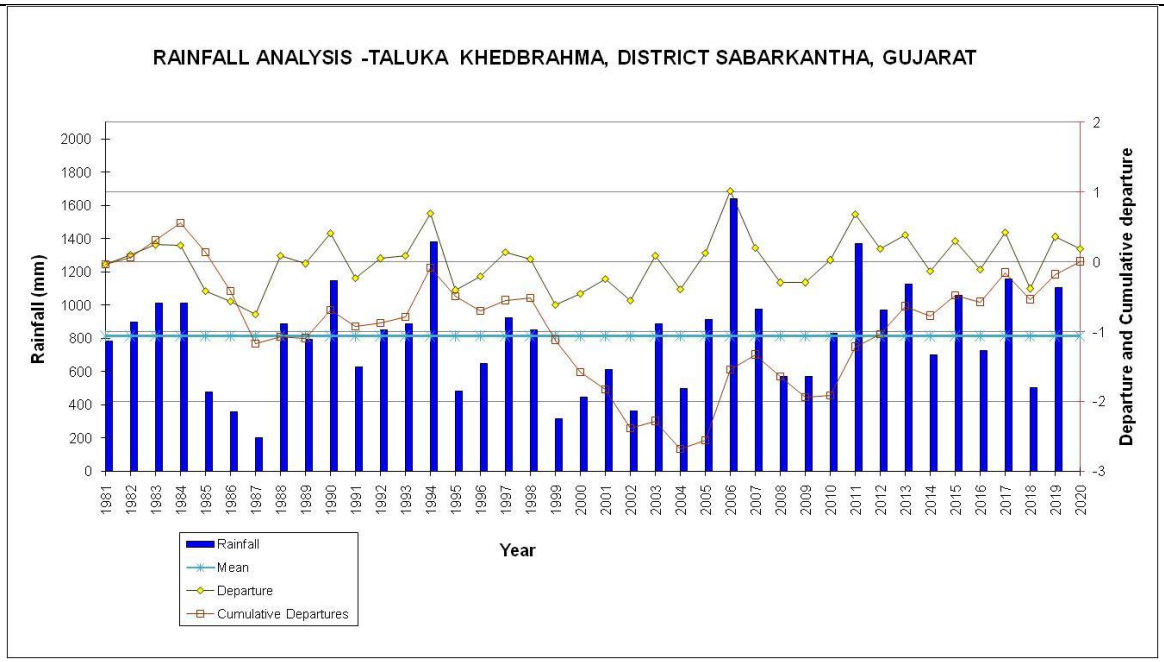


Fig: 4.2a Rainfall, Mean, Departure & Cumulative departure at Himmatnagar and Idar talukas



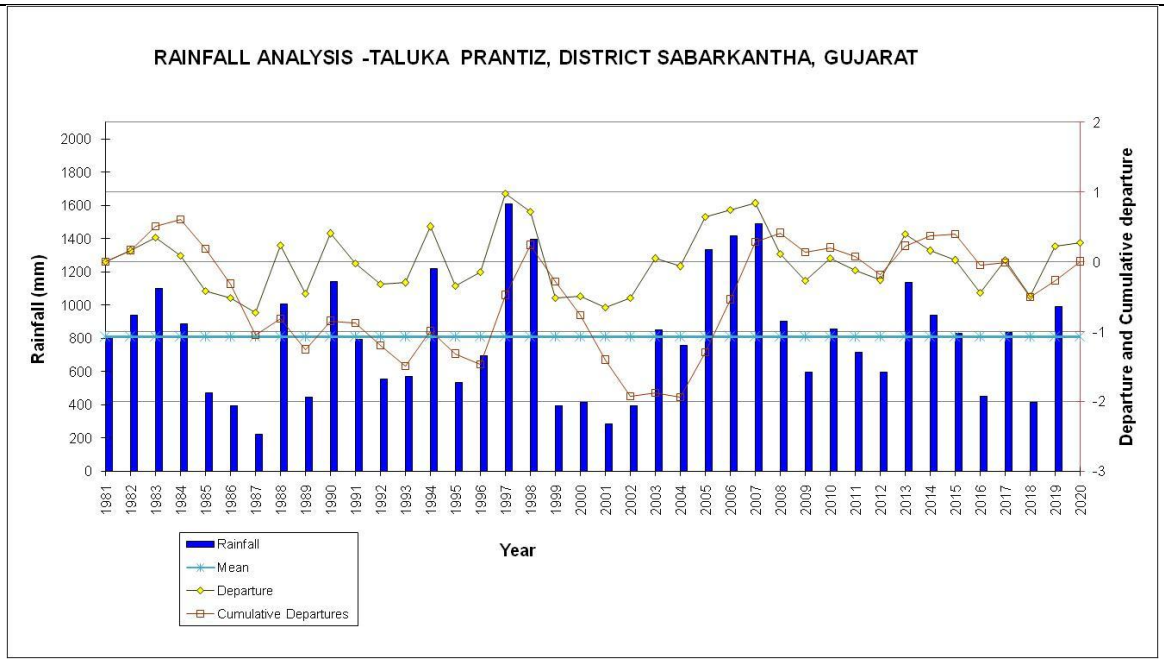
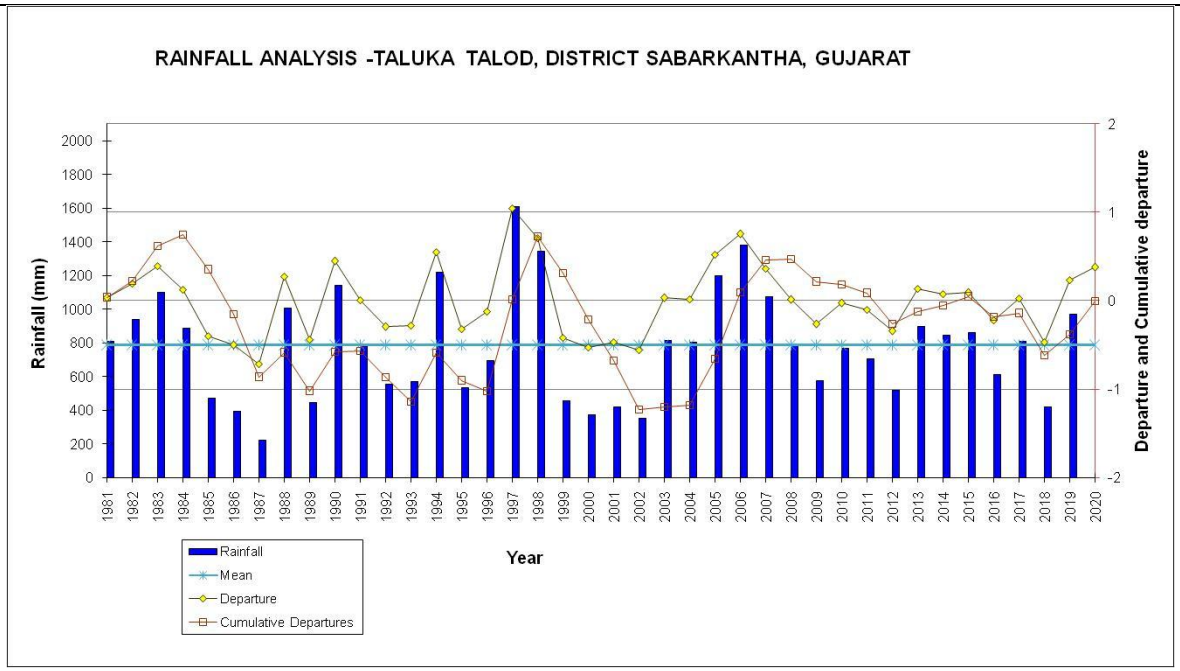


Fig:4.2b Rainfall, Mean, Departure & Cumulative departure at Khedbrahmma and Prantiz talukas



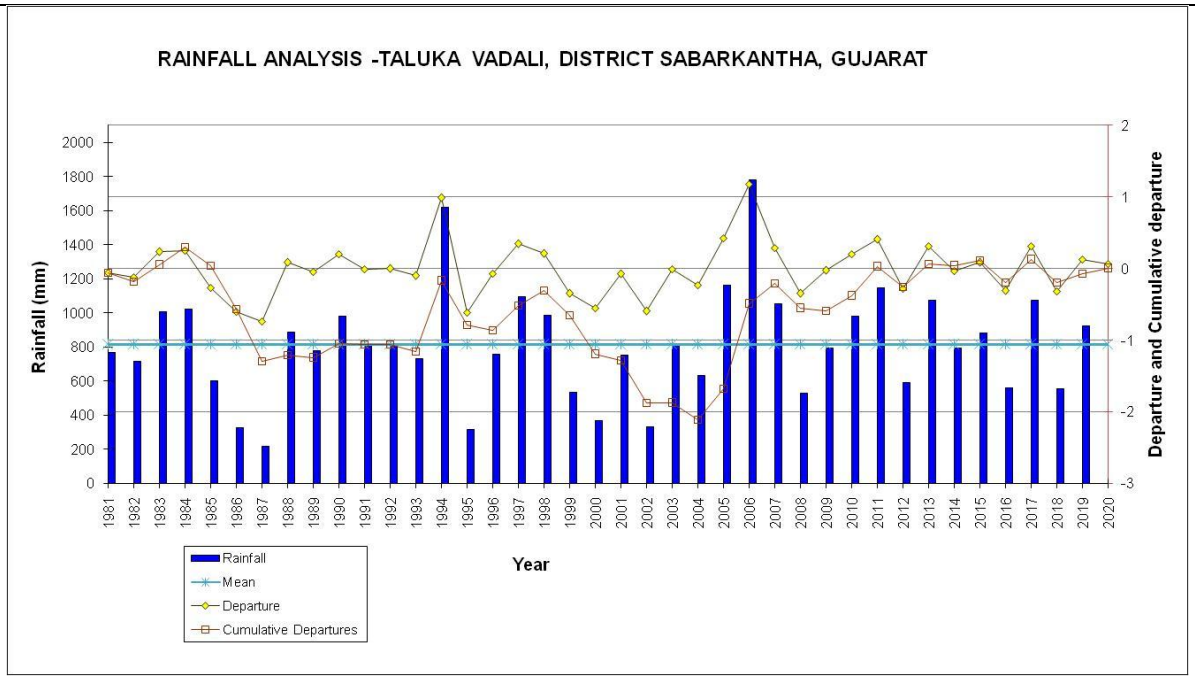


Fig: 4.2c Rainfall, Mean, Departure & Cumulative departure at Talod and Vadali talukas

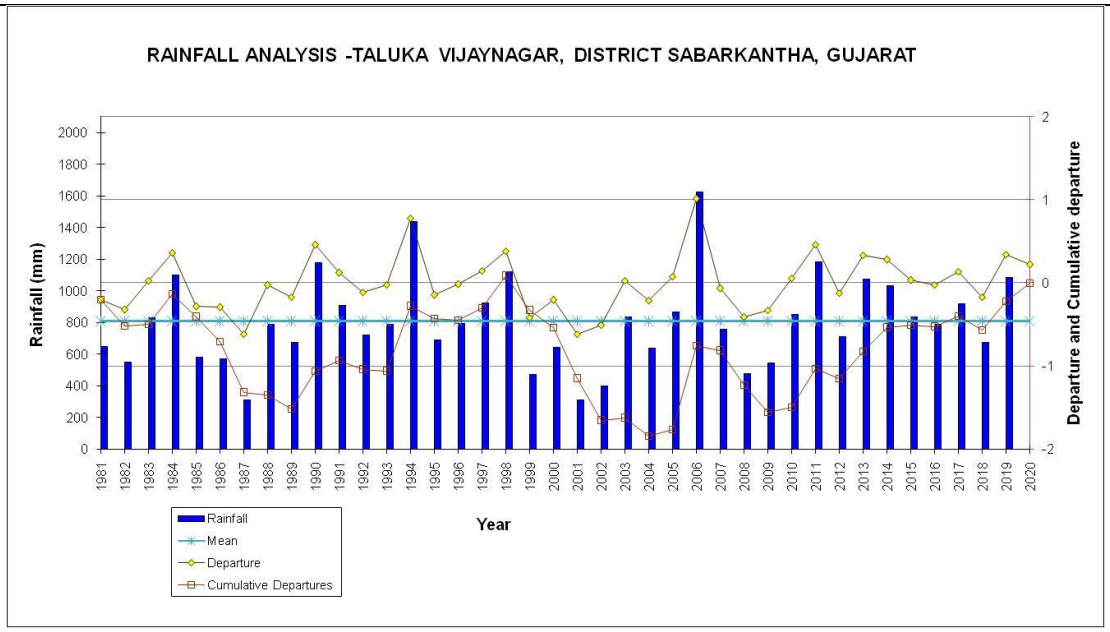


Fig: 4.2d Rainfall, Mean, Departure & Cumulative departure at Vijainagar taluka.

Table 4. 4: Drought frequency analysis of rain gauge stations Himmatnagar, Idar, Khedbrahma, Prantiz, Talod, Vadali and Vijaynagar.

Station	Mild Drought		Normal Drought		Severe Drought		Most severe Drought	
	Year	Frequency (%)	Year	Frequency (%)	Year	Frequency (%)	Year	Frequency (%)
Himmatnagar	1989, 1991, 1993, 1996, 2010, 2012, 2016 2020	20	1982, 1985, 1992, 1995, 1999, 2000, 2001, 20002, 2004, 2008, 2009,	27.5	1986	2.5	1987	2.5
Idar	1981, 1982, 1988, 1989, 1991, 1992, 1993, 1996, 2001, 2004, 2008, 2009, 2016, 2018	35	1985, 1999	5	1986, 1995, 2000, 2002	10	1987	2.5
Khedbrahma	1981, 1989, 1991, 1996, 2001, 2014, 2016	17.5	1985, 1995, 2000, 2004, 2008, 2009, 2018	17.50	1986, 1987, 1999, 2002	10	-	-
Prantiz	1991, 1996, 2004, 2011	10	1985, 1989, 1992, 1993, 1995, 2000, 2009, 2012,	25	1986, 1987, 1999, 2001,	12.5	-	-

			2016, 2018		2002			
Talod	196, 2010, 2011, 2016	10	1985, 1989, 1992, 1993, 1995, 1999, 2001, 2009, 2012, 2018	25	1986, 1987, 2000, 2002	10	-	-
Vadali	1981, 1982, 1989, 1991, 1992, 1993, 1996, 2001, 2003, 2004, 2009, 2014	30	1985, 1999, 2008, 2012, 2016, 2018	15	186, 1987, 1995, 2000, 2002	12.5	-	-
Vijaynagar	1981, 1988, 1989, 1992, 1993, 1995, 1996, 2000, 2004, 2007, 2012, 2016, 2018	32.5	1982, 1985, 1986, 1999, 2008, 2009	15	1987, 2001, 2002	7.5	-	-

The following conclusions can be drawn from the classification of drought and frequency of their occurrence.

1. The district as a whole has drought frequency in the range of 45% (Khedbrahma & Talod) to 57.5% (Vadali) with district average of 50.71%. This shows that the district is drought affected almost every alternate year.
2. The frequency of occurrence of mild and normal drought in the district is about 40.71%. This shows that the district is affected by such draughts almost ones in three years.
3. The severe and most severe drought conditions prevailed during 8.9% of the years, i.e., about once in eleven years.
4. The frequency of occurrence of severe drought in the district varies from 2.5% (Himmatnagar) to 12.5% (Prantiz and Vadali). The district average is 9.29%. This reveals that the district was affected by severe drought once in 10 to 11 years. Year 1987 is most severe drought conditions prevailed in some parts (Idar & Himmatnagar) of the district.

V: GEOLOGY

Geologically, Sabarkantha district is the manifestation of diverse geological extension from Lower Proterozoic to Holocene. The stratigraphy of Sabarkantha district is presented in table

9. The oldest formation in the area is Aravallis Supergroup comprises of various meta-sediments belongs to Lower Proterozoic. The rock types encountered in the area are sedimentary, meta-sedimentary, volcanic and metamorphic rocks. Among the different rock types, the rocks of Aravallis and Delhi Super group cover a large area in the northern and eastern part of the district. The regional stratigraphic is established by the Geological Survey of India is as follows. (Fig 03: Geological map of Sabarkantha district)

The Aravalli Supergroup

The rocks of the Aravalli Supergroup occupy by mainly the easternpart of the district and are represented by the Goran and the Samlaji Formation of the Jharol Group and Kadana formation of the Lunavada Group. These comprises of highly folded Phyllite, chlorite-mica schist, quartzite, garnetiferous mica schist, calc-amphibolite schist, feldspathic-mica schist and metagraysubwacke.

At places, serpentinite and talc-carbonate rocks of the Rakhabdev Ultramafic suite are seen. Around Vadali, Khedbrahma and Golwada many hills of Calc-gneiesses trend north, north-east to south, south west. These are generally complicated in their formation and bending. General strikes is NNE-SSW and dip is steep. At places, gneisses are intruded by aplite veins. Crystalline dolomites occur as an intercalated sequence within the meta sediments and constitutes an important lithological unit. They have restricted occurrence at Bhanmer, Kendon valley and Jesangpur. Dolomitic limestone occurs as a narrow band within mica schist around Bamanwada and Sunak.

The quartzites are fine grained to medium grained and thin bedded. The quartzites occur as scattered isolated outcrops near Meru, Bhanmer and Kheradi. Mica schists, chlorite schist and biotite gneisses are exposed east of Golwada. Phyllites are thinly foliated and hard to friable.

Delhi Supergroup

The northern part of the district is mainly occupied by the rocks belonging to the Kelwara and Antalia Formation of Gogunda group and Todgarh Formation of the Kumbhargarh Group of the Delhi Supergroup. They comprises of quartzite, biotite schist, calc-biotite schist, phyllite, calc-gneiss, calc-schist, marble and biotite gneiss/migmatite.

The rocks belonging to Aravalli and Delhi Super groups are strongly deformed under atleast three phases of deformation. The regional trend of the beds and foliation vary from NNE – SSW to NE – SW with steep dips on either side. Epidiorite, hornblende schist, amphibolites, pyroxene granulite and gabbro of the Phulad Ophiolite suites are found north of the Songarh. The area in the north is intruded by the Sendra – Ambaji granite. Godhra granite (CA 955 Ma) is exposed in the central part, granite, quartz vein and quartz porphyry, quartz vein and dolerite belonging belonging to the Malani Igneous suite are observed around Idar.

Himmatnagar Formation

Conglomerate, variegated sandstone, shale, clay stone, and chert belonging to the Himmatnagar formation of Mesozoic age are found in and around Himmatnagar. They are exposed up to Arsodia, in south they occur as scattered outcrop, especially near Wantra, Viravada etc on the hill top.

The conglomerate are not always seen at the base of the Himmatnagar formation. It is however well exposed in the river cuttings near Arsodia. The pebbles in the conglomerate are mostly of quartzites pebbles. Near Arsodia, between the basal conglomerate and Himmatnagar sandstone, there are several band of variegated clays.

Sandstones are generally loosely aggregated, but at several places it is also compact. There are several bands of shale with in sandstones.

Lameta formation

Lameta formation, consisting of variegated clay, banded chert and limestone of upper cretaceous age are seen in the southern and southeastern part of the district.

Deccan Traps

Basaltic flows with associated minor inter trappean horizons, grouped under the Deccan traps are limited to the southern and south-western parts in the Meshwo and Mazum river sections. These are of “aa” and pahoe-hoe” type lava flows. Basalts flow also occupy the the area east and north east of Kapadvanj, south of Bayad and north of Dabha and it is also exposed along the Vatrak river section north of Thalpore.

Matanomadh formation, consisting of ferruginous sandy beds, sandstone, clay laterite and conglomerate of Palaeocene age are found exposed in the western part of the district. Laterites have supposed to be originated from the weathering of coarse grained granites and Himmatnagar sandstones. Laterite has varying proportions of limonitic and aluminous ingredients.

Alluvium

Rest of the area occupied by the windblown sands of the Akhaj formation, flood plain and channel fill deposits of Varahi formation of Holocene. Alluvium mainly composed of medium to coarse sand, gravel, cobble and boulders with clay are present in the southern part of the district. Alluvium also found in patches along the Meshwa and Majhan river, north-east of Nawagam, south-west of Bheswara, west of Varngam, south of Khilori and also in patches along the Vatrak river section.

Aeolian sand are brownish yellow, fine to medium grained, sub rounded to rounded and unconsolidated sand occupies the area between the Meshwo and Majham rivers and also between the Vatrak and Meshwa river. It also covers the area lying between Varagam and Bheswara around Nanawara, west of Meghraj, east of Majham rivers and to a small extent to the east of Vatrak river. The general range of thickness of Aeolian sand is 5 to 18m but to the south of Balisana, it increases up to 35m.

Table :5.1 Stratigraphy of Sabarkantha District (After GSI)

Geological Age	Supergroup	Group	Formation	Lithology
Holocene			Varahi Formation	Flood plain and channel fill deposits
			Katpur Formation	Flood plain and channel fill deposits
			Jantral Formation	Sand sheet and sand dune deposits
Palaeocene			Mata no madh Formation	Ferruginous sandy beds, sandstone, clay, laterite and conglomerate.
Cretaceous to Eocene	Deccan Traps		Basalts	Porphyritic and amygdaloidal basalt flow with intertrappean sediments
Upper Cretaceous			Lameta Formation	Varigated clay, banded chert and limestone
Lower Cretaceous			Himmatnagar Formation	Conglomerate, variegated sandstone, shale, claystone and chert
Upper Proterozoic		Malani Igneous Suite		Olivine Dolerite
			Idar Granite	Granite, Quartz porphyry, quartzitic vein
			Godhra Granite	Granite
Middle Proterozoic			Sendra - Ambaji Granite	Granite and leucogranite with quartzo - feldspathic veins
			Phulad Ophiolite Suite	Epidorite, hornblende schist, amphibolite, pyroxene granulite and gabbro
Lower to Middle Proterozoic	Delhi Supergroup	Kumbhalgarh Group	Todgarh Formation	Calc-gneiss, calc-schist, calc-gneiss, impure marble, calcitic marble, biotite schist, calc-biotite schist, biotite gneiss/migmatite
		Gogunda Group	Kelwara Formation	Biotite schist, calc-biotite schist and phyllite
			Antalia Formation	Quartzite and quartz sericite schist, biotite schist and calc-biotite schist
Lower Proterozoic	Aravallies Supergroup	Lunavada Group	Kadana Formation	Mica schist and metasubgraywacke, quartzite
		Intrusive	Rakhabdev Ultramafic suite	Serpentinite and talc-carbonate rock
		Jharol Group	Samlaji Formation	Garnetiferous mica schist, quartzite, calc-amhibolite, feldspathised mica schist
			Goran Formation	Phyllite, chlorite-mica schist, quartzite

VI SUBSURFACE GEOLOGY- DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

6.1 Data Integration:

In order to establish the three dimensional disposition of the aquifer systems in the area, the existing data of lithological logs of Exploratory wells and Electrical logs interpretations of CGWB and State Ground Water Departments (GWRDC) were used to construct 3-D physical model.

A total of validated 52 lithologs of exploratory wells and piezometers constructed by CGWB and GWRDC, State Gujarat falling in Sabarkantha district (Table 6.1) were utilised to decipher the subsurface geometry of the aquifer with the help of ROCKWORKS software. Lithological information were analysed and generated 5 no. of cross sections, 3-D map along with panel diagram (Fig. 6.3, 6.4 & 6.5).

Table 6.1: Data integration

Type of data & source	No. Of Well
Aquifer disposition	
CGWB	52 EW
GWRDC, Govt. Of Gujart	-
Total	52
Water level	
CGWB	28
GWRDC, Govt. Of Gujart	73
Total	101
Analysis of Water Quality	
CGWB	22
GWRDC, Govt. Of Gujart	63
Total	85

6.2 Conceptualization of Aquifer Disposition in 3D and 2D cross Sections:

Hydrogeologic sections are synthesized based on the lithological logs and electrical logs and delineated data of aquifer boundaries was imported in ROCKWORKS software to synthesized the aquifer disposition in 2D and 3D. Hydrogeological sections in 5 no. along the section lines A-A' to E-E' are presented in Fig.6.1.

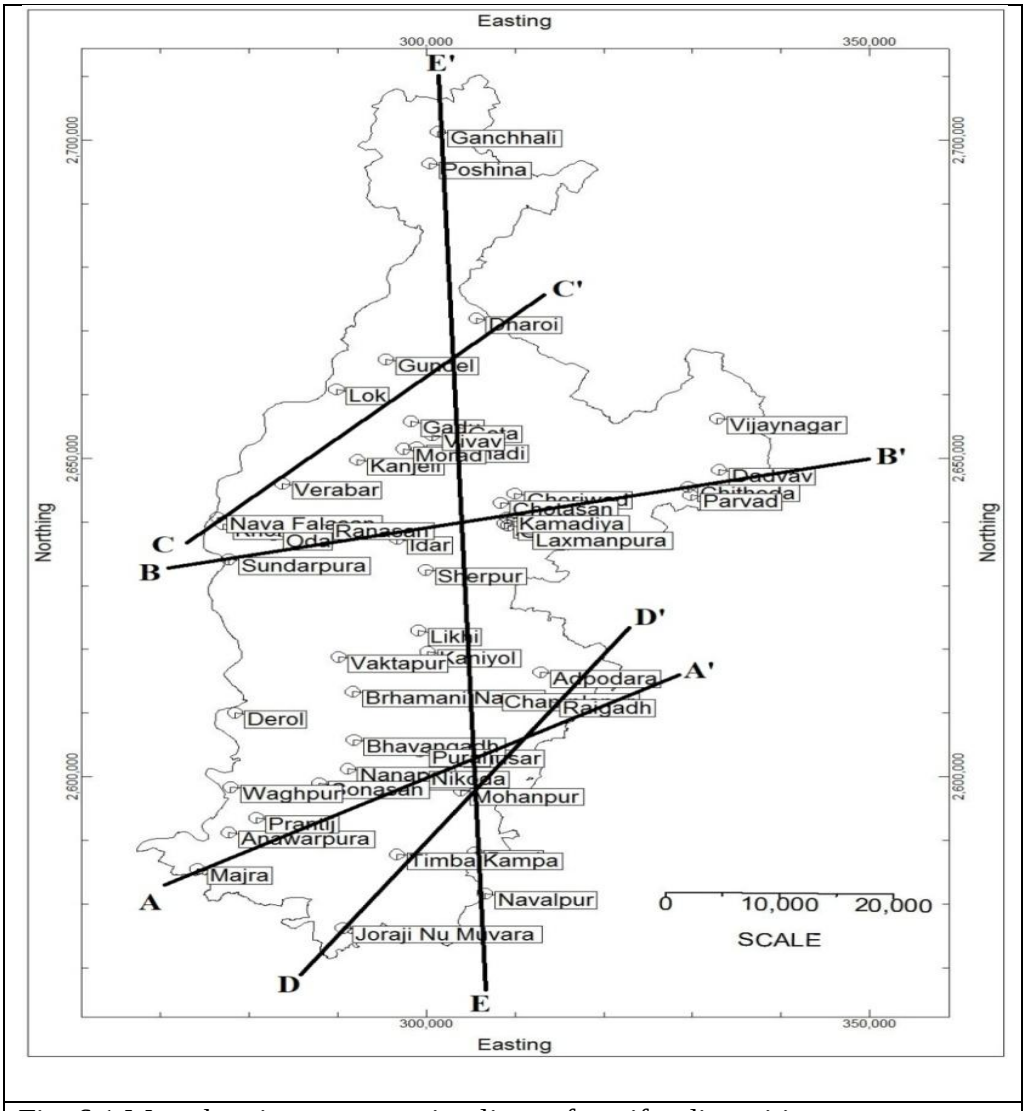


Fig. 6.1 Map showing cross section lines of aquifer disposition.

About 10 layers are delineated in the depth representing Aquifer groups I and II in the unconsolidated formation under unconfined to semi-confined conditions as shown in Fence and 3D diagram (Fig 6.2 & 6.3).

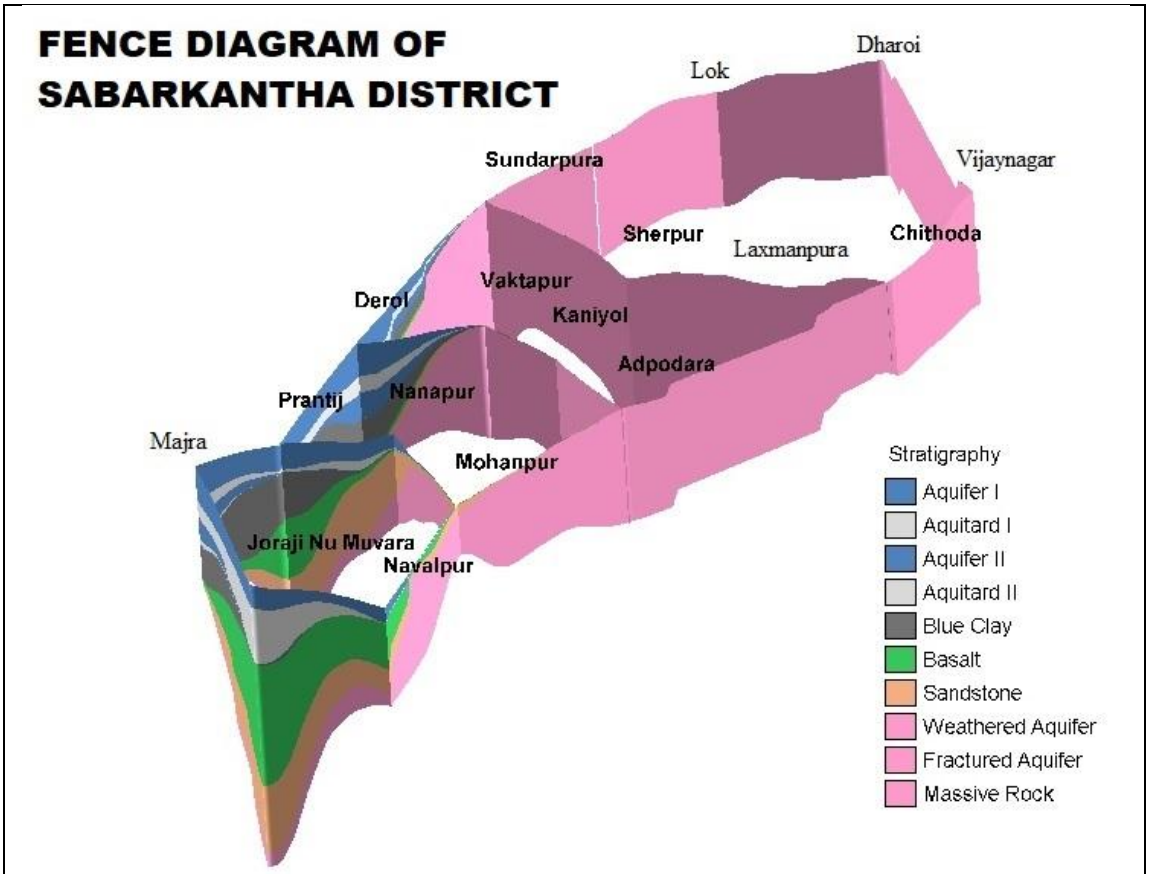


Fig. 6.2 Fence diagram of Sabarkantha district

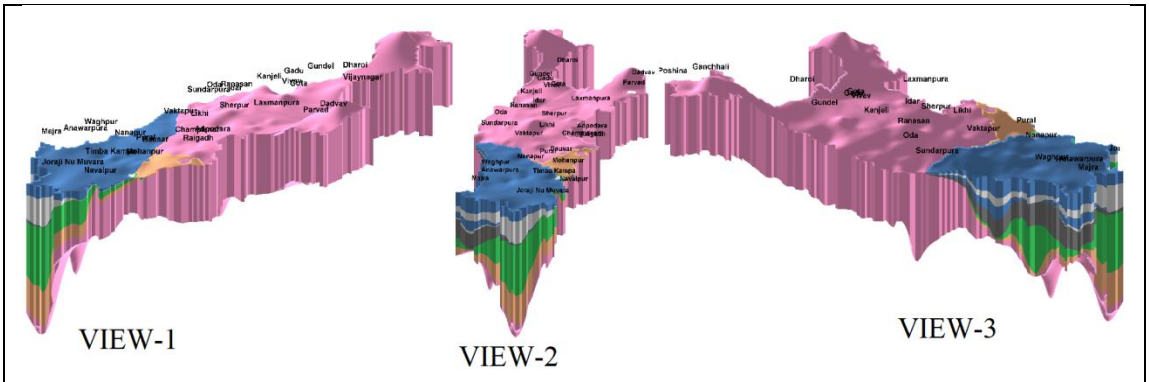


Fig. 6.3 3Dimensional disposition of aquifers in Sabarkantha district.

Alluvium formation is underlain by Basalt and Sandstone formation. Meatasediments are disseminated 3 dimensionally as weathered at top followed by fractured rock forms unconfined aquifer. Disposition of different layers of formation forming aquifers are shown in cross section A-A' to E-E' in Fig 6.4, 6.5 and 6.6. Details of aquifer characteristics are given in Table 6.2 and 6.3.

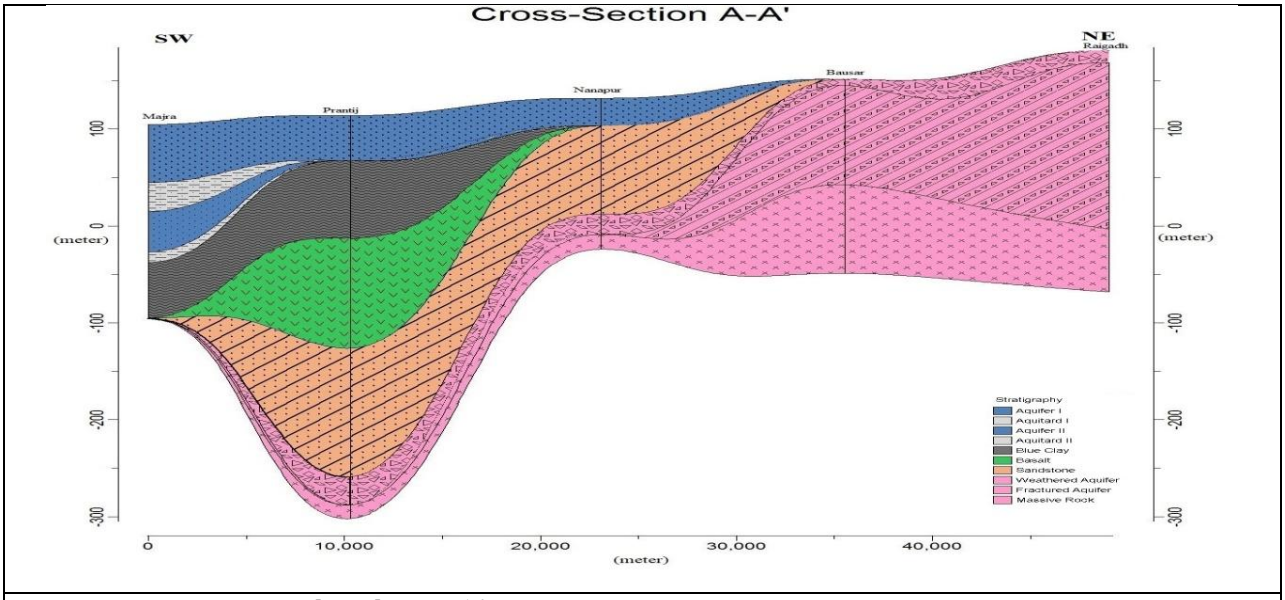


Fig. 6.4.1 Cross section along line A-A'

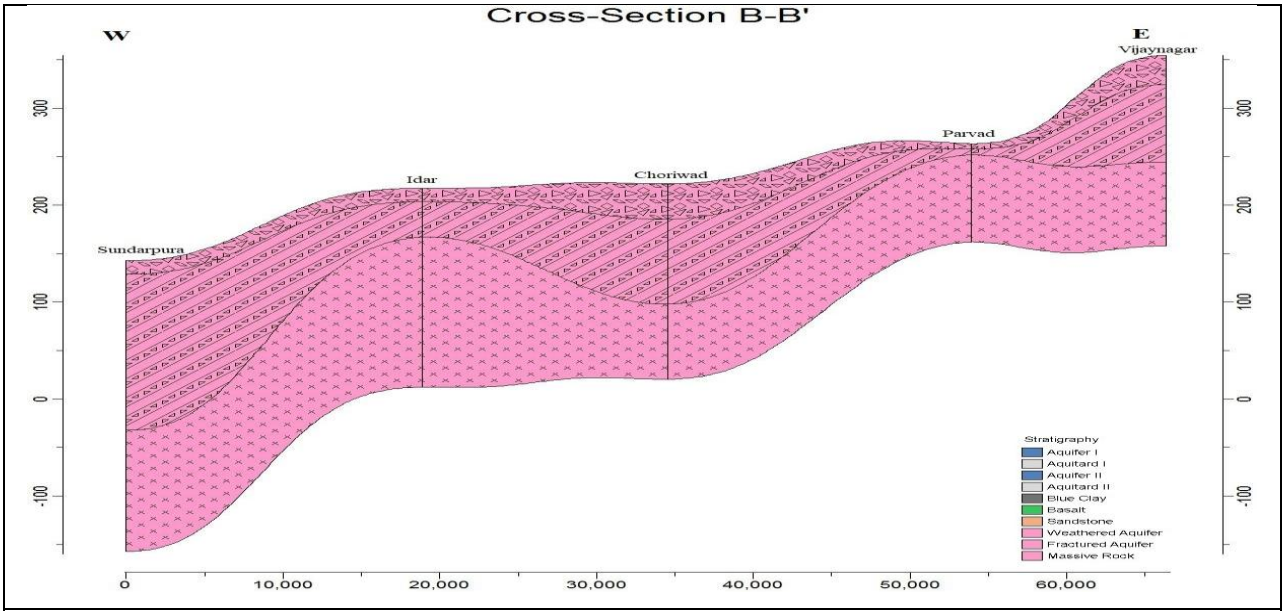


Fig. 6.4.2 Cross section along line B-B'

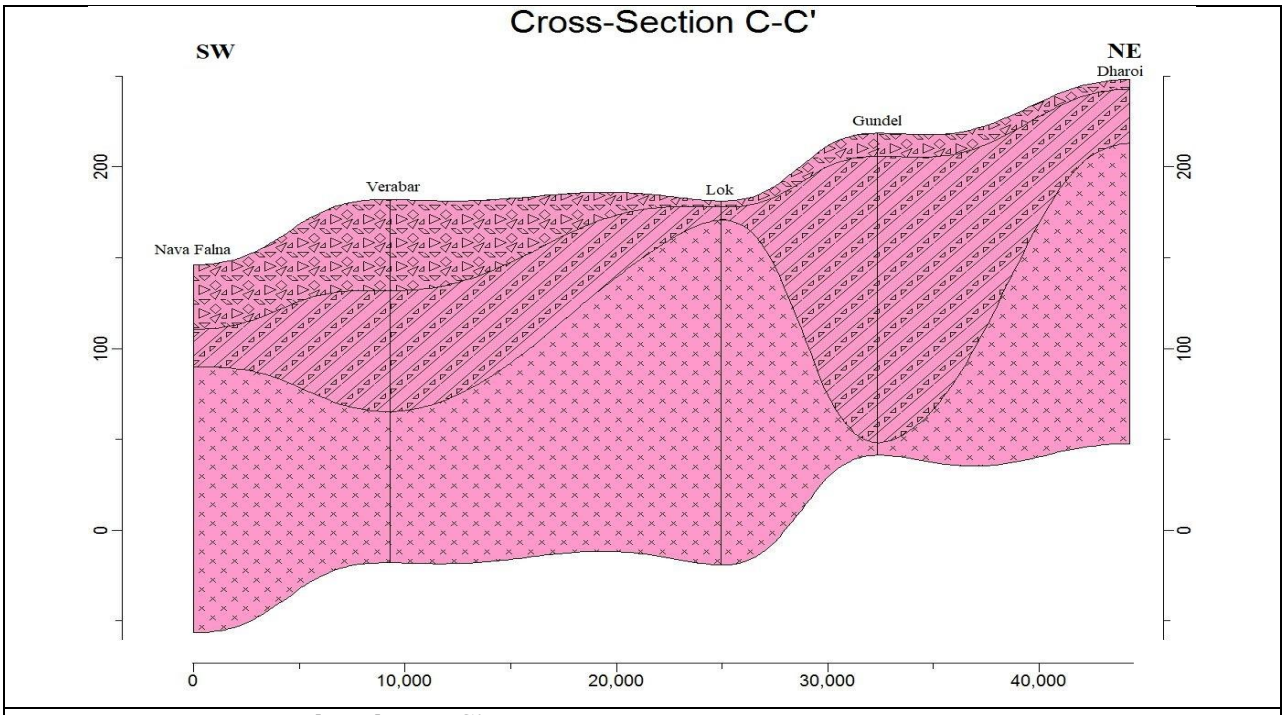


Fig. 6.5.1 Cross section along line C-C’

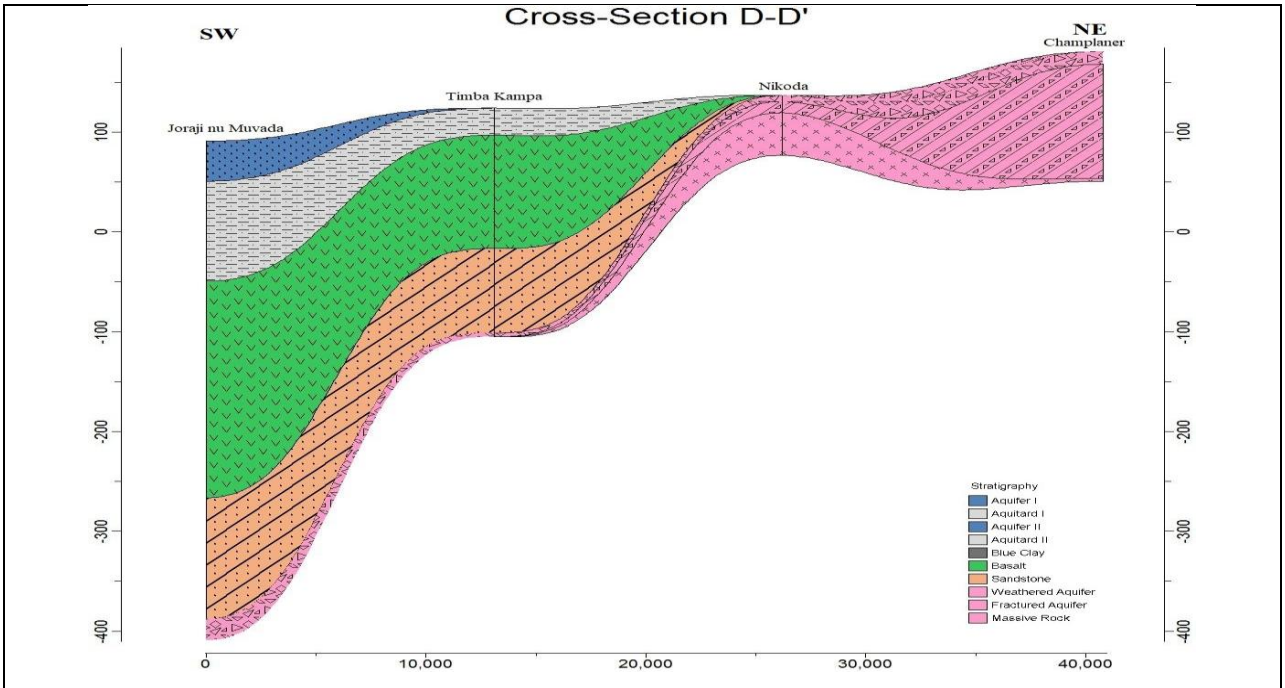


Fig. 6.5.2 Cross section along line D-D’.

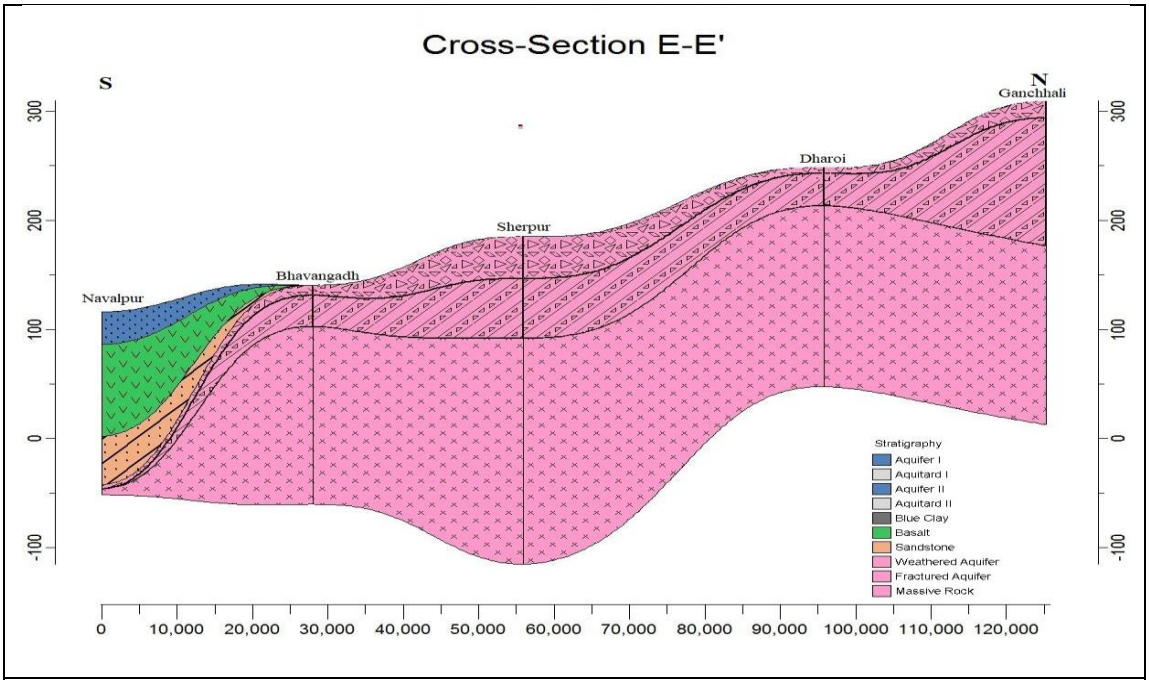


Fig. 6.6 Cross section along line E-E'.

Table: 6.2 Aquifer Disposition and quality of water Sabarkantha District

Stratigraphy	Aquifer	Lithological character	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level Range (m)	TDS mg/l
Holocene	**Younger Alluvium**	Pediments, Sand dunes, Flood Plain	0 to 60	25 to 60	2 to 20	500 to 3000
	Alluvium		90 to 135	2 to 40	8 to 50	700 to 3000
Cretaceous	**Basalt**	Basalts	27 to 357	80 to 200	-	-
Lower Cretaceous	**Sandstone**	Sandstone	30 to 300	40 to 80	14 to 37	550 to 1200
Proterozoic	**Weathered Granite**	Granite & Granodiorite	0 to 50	3 to 35	5 to 20	500 to 2500
	Fractured Granite, Meta Sediment	Granite, Calc-Gneiss, Granodiorite, Phyllite, Mica schsit	5 to 149	12 to 135	10 to 25	300 to 3600

Table : 6.3 Aquifer parameters and quality of Groundwater

Formation	Aquifer	Depth to water level in m bgl	Duration of test in minutes	Pumping Discharge in LPS	Drawdown in m	Transmissivity	Specific yield/storability	Electrical conductivity (EC) in µS/cm
Combined -Alluvium, Basalt and sandstone	Unconfined to Semi-confined	10 to 12		2 to 19	6.09 to 24.53	55 to 85	-	-
Granite weathered/Fractured	Unconfined	6.60 to 8.30	1000	5 to 15	5 to 16.66	80 to 286	0.0015 to 0.0016	532 to 959
Granite Fractured/Massive	Confined(Tapped deep fracture)	4.6	500	3.1	34.7	3 to 7	-	1073
Meta sediments-Calc-Gneiss	Confined (Tapped deep fracture at 198 m bgl)	9.85	440	5.4	27.79	12	2.90E-05	571
Phyllite	Unconfined predominantly	7.44 to 10.95	450 to 1000	3.11 to 5.56	36.68 to 48.50	6 to 17	0.00094 to 0.016	917 to 1280

(Values presented based on aquifer performance test)

VII HYDROGEOLOGY

Groundwater occurs both in alluvium and hard rock. Major area of the district is covered by hard rock aquifer, covering a large area in the northern, eastern and southern-western part along with a small patch at central part of the district. Though ground water occurs in all types of formation, but the most productive aquifer are Himmatnagar sandstone, Quarternary sediments (Alluvium) and Deccan traps (Fig. 7.1).

(a) Quartzite, phyllite and schist:

Among the different types of aquifer, quartzite, phyllite and schist occupy the maximum area in the district. In these formations, groundwater occurs under unconfined condition in weathered portion and in fissures, joints and other weak planes. The movement of groundwater is controlled by the extent of weathering, fissures, fractures and joints. Large diameter dug wells are exist in these formation. In general, yield of the open wells tapping these formations are poor, except those located near streams and tanks. Yield of the wells ranges from 5 to 350 m^3/day.

(b) Granite and granite gneiss:

Granite and granite gneisses are occur as water bearing formation in the northern part of the district and also in a few scattered areas in the central and southern parts. Groundwater occurs under unconfined to semi-confined condition in weathered and fissured zones. Depth of weathered zone is highly variable and extent down to a depth of 30m and at places it has been noticed upto 40m depth. Rarely, the thickness of saturated weathered zones tapped in dugwell exceeds 5m. Depth of dugwell ranges between 8 and 24m while dug cum bore well is around 58m. Yield of wells tapping granite ranges from 5 to 25 m^3/day.

(c) Himmatnagar sandstones:

Himmatnagar sandstone occurs as water bearing formation in the western and south western part of the district. Groundwater occurs under unconfined to confined condition. Coarse grained, gritty sandstones occurring in the middle part of the Himmatnagar series form potential aquifer. The complete sequence and the maximum thickness (82m) of Himmatnagar series was encountered in the borehole at Ilol. Here four beds of sandstones have been alternate with shales. The thickness of Himmatnagar series varies from 40m at

Timba Kampa to 82m at Ilol. The yield of the dug well and dug cum bore well varies from 342 to 1752 m^3/day and in tube it ranges from 163 to 864m^3/day.

(d) Deccan Trap:

Deccan Trap occurs as water bearing formation in the southern and southern part of the district. In the Deccan traps, groundwater occurs in weathered portion and in weak planes like fissures and joints under unconfined condition. As the weathering thickness extent Deccan trap gives rise to clayey black soil which is impervious and does not yield much water. Weathered zone varies from a few meters to about 20m. As the traps form gentle mounds, the water table is deeper. Depth of dug well is up to 30.10m bgl and dug-cum-borewell extents below to a depth of 60.96 m bgl. The yield of wells tapping Deccan traps ranges from a few cubic meter to 30m3/day. The uppermost trappeans flow is highly jointed and brittle. It has been encountered in the boreholes at Mohanpur, Ghari, Fatehpur, Mota and Timba Kampa and the maximum thickness is about 200m as met at Timba Kampa Borehole. The upper part of the flow is potential due to the thick weathered zone and joints, fractures and secondary partings down below.

(e) Sandstone s and Limestones of Bagh beds/ Lameta

Sandstone and limestones of Bagh beds occur in a small area in the southern part of the district. The sandstones are fine grained and compact. So, potentiality is poor. The limestones are massive, compact and poorly jointed and also very poor yielding. Very few dugwell are being constructed tapping these formations. Generally large diameter dug wells are occur tapping these formations and the diameter ranges from 4 to 6 m because of the poor yield of tapped formation.

(f) Alluvium and blown sand aquifer:

Alluvial and blown sand aquifers mainly occur in the south western part of the district and also occur as small scattered patches along different streams. Alluvium is an important formation with regard to the development of ground water in view of occurrence of highly permeable granular beds in some areas. Groundwater occur both under unconfined and confined condition. Reasonably thick alluvium has been encountered in the boreholes at Derol, Balisana, Nawalpur, Pusri and Nananpur. The thickness of alluvium ranges from 73m (Balisana) to 28.35m (Nananpur). Within

alluvium highly permeable, granular beds occur at Derol, Balisana, Nawalpur and Pusri. In the north-eastern and central part the district, small scattered patches of alluvium occur near rivers and streams constituting aquifer of very limited nature which consist of pebbles with little sand up to 10m thick. Yield of dugwell ranges between 12 to 1062 m^3/day while tube well yield as high as 6720 m^3/day with a low to medium of vary wide range. Fine to medium grained, unconsolidated sand comprises the aquifer materials in the blown sand and it occurs as water bearing formation in the southern part of the district. The yield of the dug well located in blown sand ranges between 6.4 to 90 m^3/day.

7.1 Groundwater Regime:

Since 1969, Central Ground Water Board, as a part of its national programme, has established a network of observation wells in the state of Gujarat and UT of Daman and Diu for periodic monitoring of water levels and the variation in quality of groundwater. At present a total of 1039 National Hydrograph Network monitoring Stations including 43 open wells and 11 Piezometers in Sabarkantha. The ground water scenario of the district is presented here.

Unconfined Aquifer

Unconfined aquifer is the most extensive aquifer occurring in the different hydrogeological units in the district with thickness ranging from 2 m to 60 m bgl.

Depth to Water Level during pre monsoon period (Fig.-7.2) in 73% area (Table 7.1) falls in the range of 10 to 20 m bgl, in most part of the district, 12% area in the range of 20 to 30 mbgl in isolated patchs in the central and southern part of the area whereas 2% area falls in the water level more than 30 m bgl in the small isolated patch in Prantij taluka of southern part of district. Shallower water level in the range of 5 to 10 m bgl observed in 13% area of district in the form of isolated patches scattered in whole district. Central part of the district comprises part of Dhanera, Tharad, Lakahni, Deesa, Kankrej, Planpur and Vadgaon are observed in deep water levels of more than 40 m bgl. The shallow water level 2 to 10 m bgl is observed in isolated patches in western part and hilly region of eastern part.

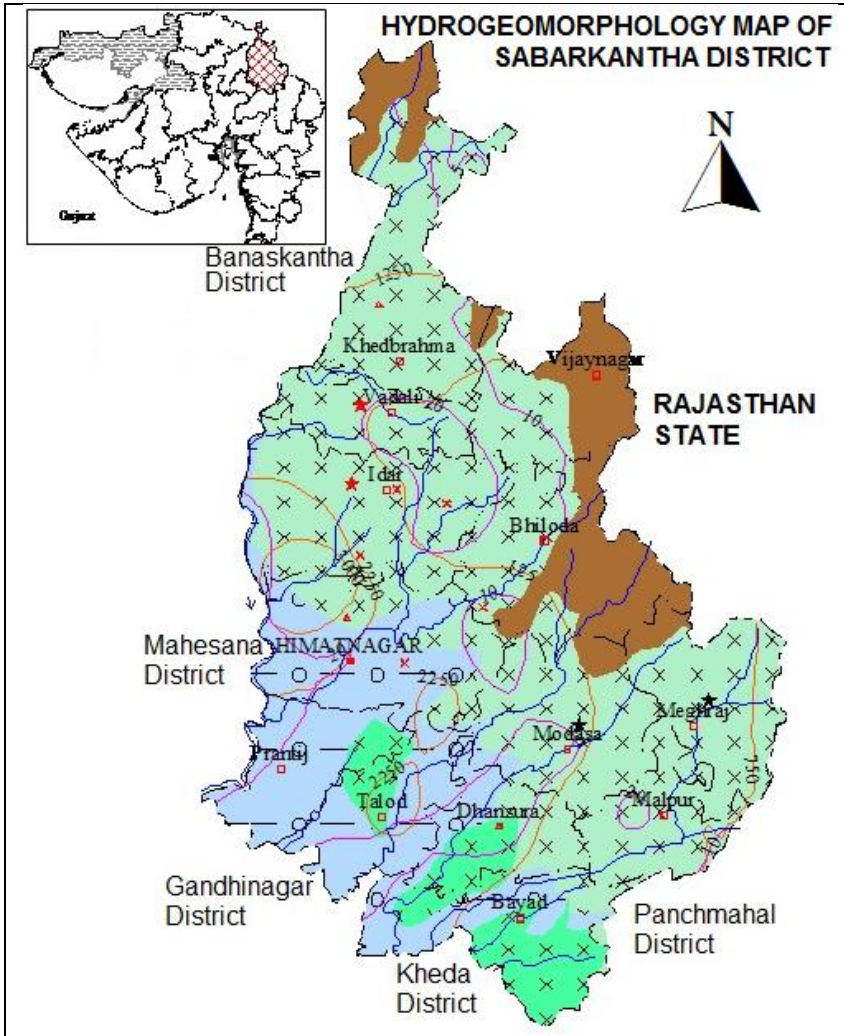


Fig 7.1: Hydrogeological map of Sabarkantha district.

Legend

Rock type	Wells Feasible	Rigs Suitable	Depth of Well (m)	Discharge (lpm)	Artificial Recharge Structure Suitable
Soft Rock Aquifer	Dug Well Tubewell	Manual Direct Rotary, Reverse Rotary	10-25 50-100	200-300 400-800	Percolation Tanks/ Ponds, Recharge Wells,
Hard Rock Aquifer	Dug Well Borewell	Manual Down the Hole Hammer (DTH)	10-20 50-100	60-200 60-240	Percolation Tanks/ Ponds, Recharge Wells, Check Dams, Nalla Bunds.
Hard Rock Aquifer	Dug Well Borewell	Manual Down the Hole Hammer (DTH)	10-25 100-200	80-150 100-300	Percolation Tanks/ Ponds, Recharge Wells, Check Dams, Nalla Bunds.
Hilly Areas	Not Suitable				Check Dam, Nalla Bund, Gully Plug
20	Pre-monsoon Decadal mean (1993-2000) Depth to Water Level (mbgl)		2000	Electrical Conductivity (µS/cm at 25° C)	
	Fluoride > Maximum Permissible Limit (1.5 mg/l)			Nitrate > Maximum Permissible Limit (100 mg/l)	
	Over Exploited Taluka			Dark Taluka	
	Drainage			District/Taluka HQ	

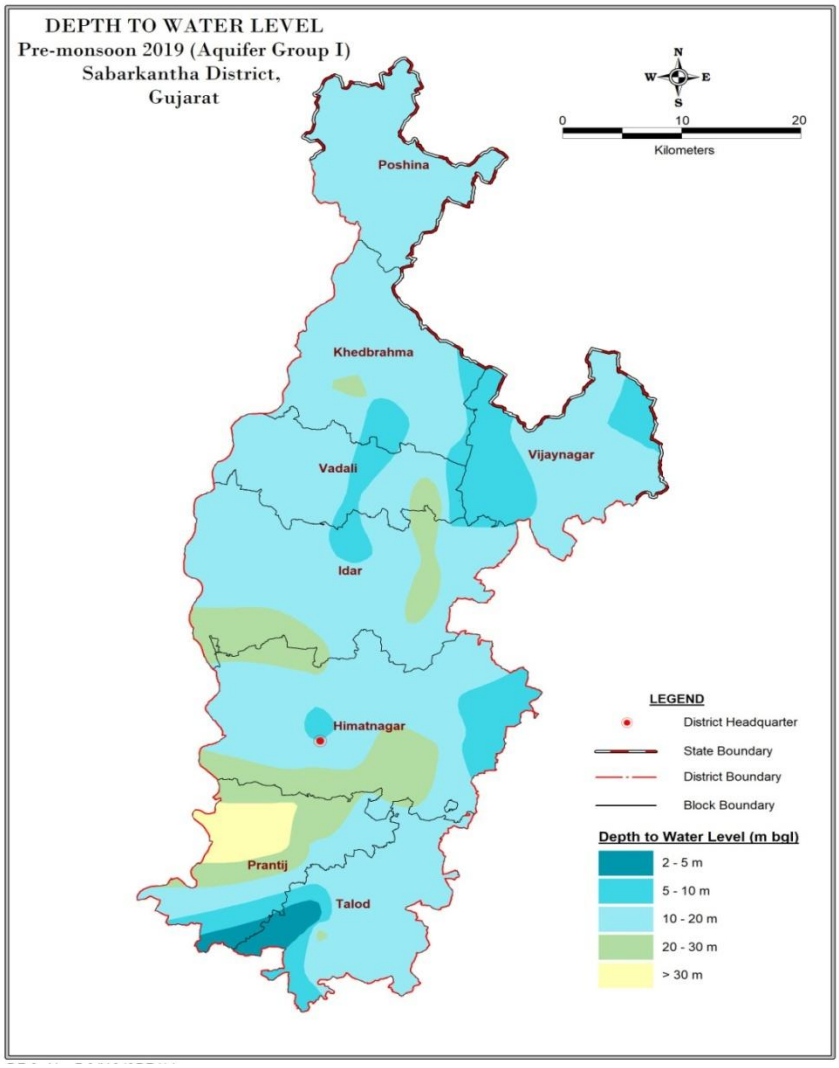


Fig. 7.2 Depth to water level in m bgl for the period of pre-monsoon 2018

Table: 7.1 Percentage area covered by depth to water level in different season of monsoon year 2019

Sr. no.	DTWL range in m	Pre-monsoon (% area)	Post- monsoon (% Area)
1	<2	0	5
2	2-5	2	24
3	5-10	13	44
4	10-20	71	22
5	20-30	12	3
6	>30	2	2

During post monsoon period (Fig.- 7.3), 24% area falls in the water level range of 2 to 5 m bgl, 44% area in the range of 5 to 10 mbgl, 22% area in 10 to 20 and deeper water level in the range of 20 to 30 m bgl and more than 30 is observed in 2 to 35 area in Prantij taluka of the district. The shallow water level < 2 m bgl is observed in isolated patche in the hilly region in the northern part of the district.

7.2 Water Table configuration

Water table map for the period of Pre-monsoon and Post-monsoon 2019 shows the groundwater level with reference to the mean sea level (Fig. 7.4, 7.5) and Water table ranges 340 m to 70 m MSL. Groundwater flow direction in general from north east to south direction and following surface topography of the area. Ground water flow is steep in the north east part of the area whereas it becomes gentler in southern direction.

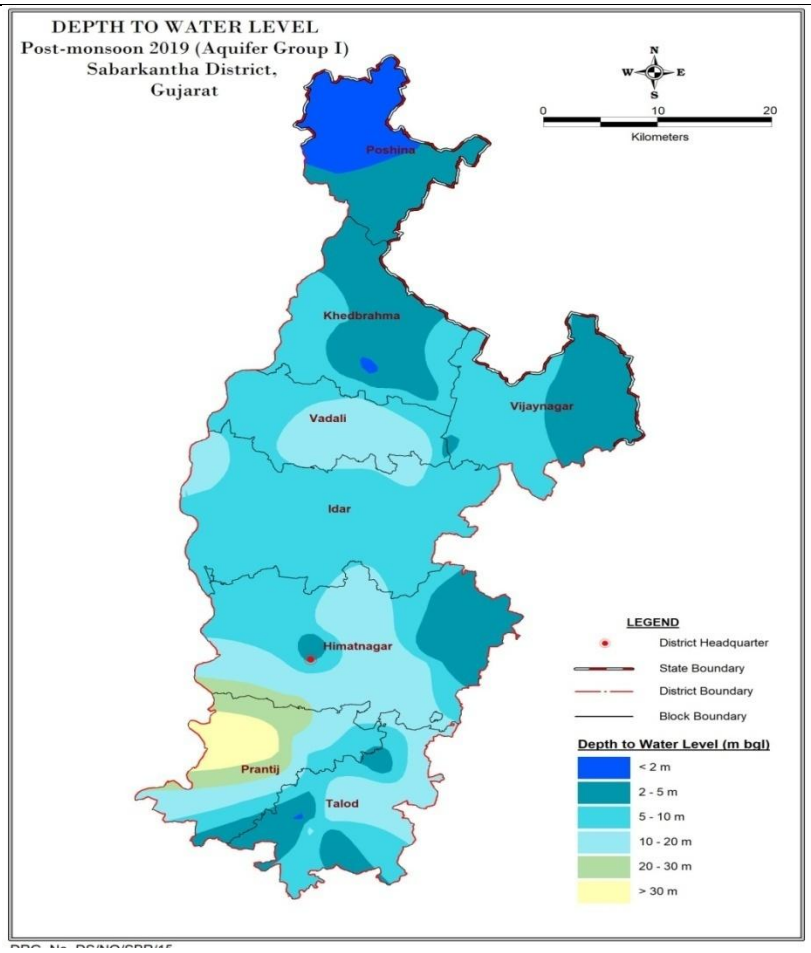


Fig. 7.3 Depth to water level in m bgl for the period of post-monsoon 2018

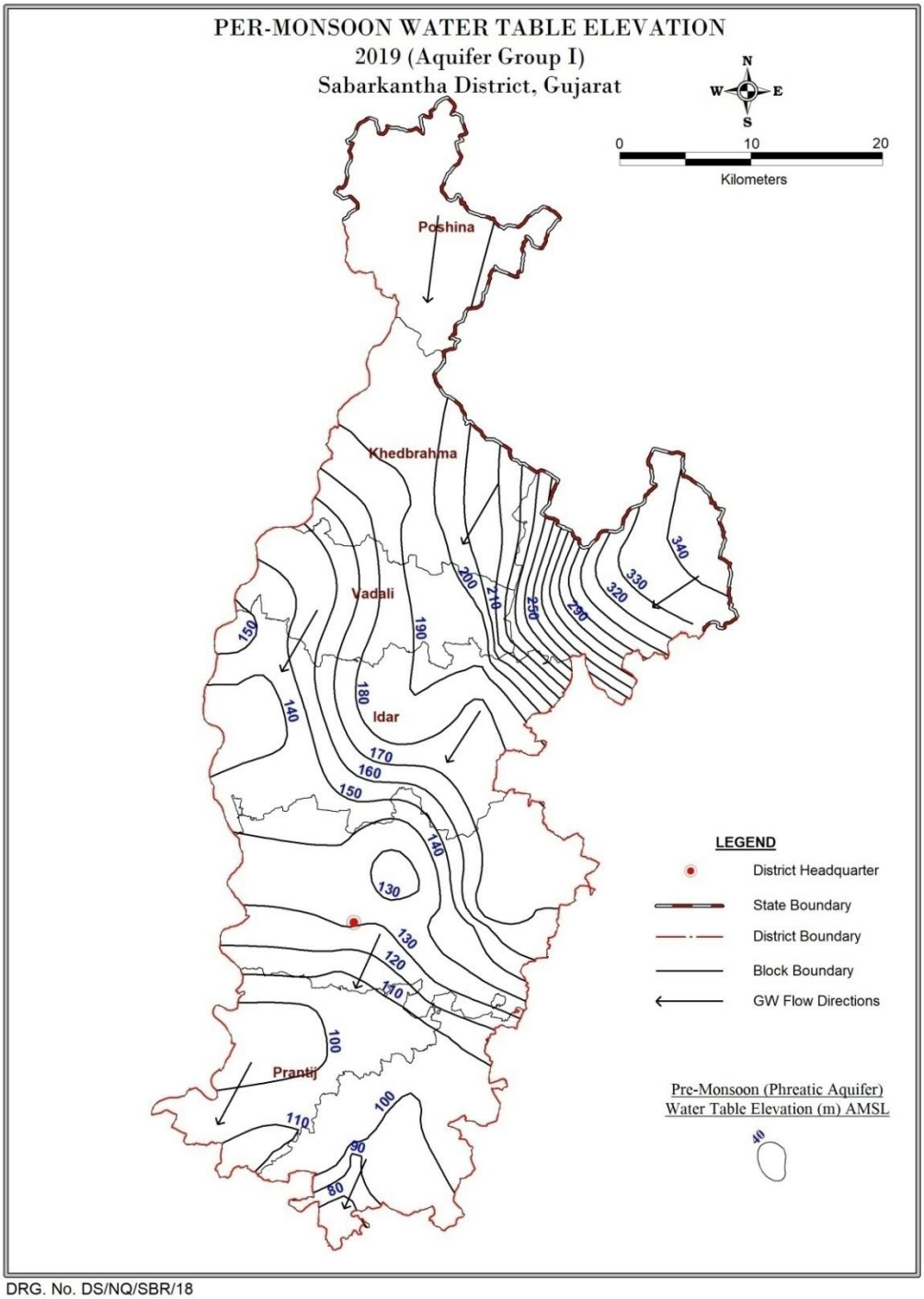


Fig. 7.4 Water table configuration in m MSL for the period of Pre-monsoon 2021.

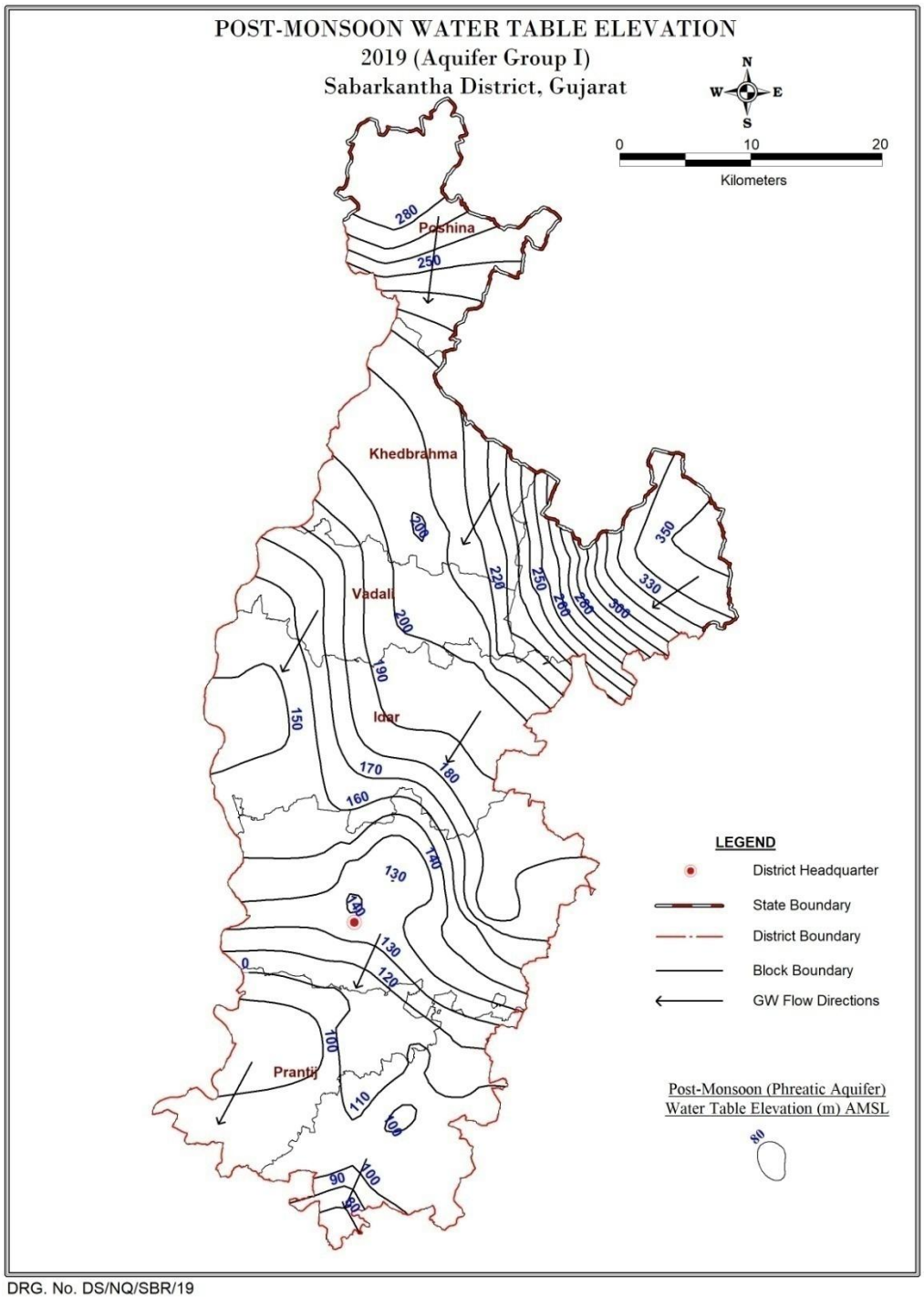


Fig. 7.5 Water table configuration in m MSL for the period of Post-monsoon 2021.

7.3 Long Term Water Level Trends: Rise and fall of water levels.

Groundwater level trends are observed in different period of time at the monitoring stations maintained by CGWB are shown in Fig 7.6 to 7.9. And data is given in table 7.2. Overall rises of water level is observed in unconfined aquifer and are estimated between 0.0088 m/year (Wadali) to 1.042 m/year (Choriwad) in different period of time. Declines of water level is observed in unconfined aquifer are between 0.1034 m/year (Boriya) to 0.7054 m/year (Derol) in different period of time. Groundwater trends of some selected monitoring stations are given in Table 10.1 and location shown in Fig.10.1. Hydrograph of selected stations area shown in Fig. 10.2 to 10.5.

Table : 7.2 Groundwater trends for the period of 2010 to 2020 in Sabarkantha district

Sr. No.	Location	Pre-monsoon			Post-monsoon			All seasons		
		Data Points	Rise (m/year)	Fall (m/year)	Data Points	Rise (m/year)	Fall (m/year)	Data Points	Rise (m/year)	Fall (m/year)
1	Anwarpura Pz	10		0.1305	9	0.1085		35		0.1226
2	Atarsumba	8	0.2588		7	0.3003		30	0.3269	
3	Bhadreshwar	9	0.1057		11	0.4827		38	0.2945	
4	Boriya	8		0.1461	8		0.2368	30		0.1034
5	Chandap_DW	6			7	0.2098		25		
6	Chandap_Pz	11		0.1797	10		0.1298	42		0.1152
7	Choriwad	11	0.8852		11	1.1001		44	1.0420	
8	Derol Pz-II	10		0.9359	9		1.0867	35		0.7054
9	Dhansura1	11	0.2121		10	0.1858		41	0.2975	
10	Gadada	6			7	0.5590		25		
11	Gadha	11	0.0549		11	0.0647		43	0.3563	
12	Harsol1	11		0.0143	10		0.2626	41	0.0186	
13	Himmatnagar_Pz	11	0.0544		11	0.2158		40	0.1917	
14	Idar	11		0.0936	11		0.2257	44		0.1592
15	Jhaloti	8		0.1303	10		0.1158	38	0.0243	
16	Kesharpura	6			7		0.7505	25		
17	Khedbrahma_Pz	7	0.0264		11	0.0737		38	0.0362	
18	Kherwada	6			7		0.0264	24		
19	Mathasuliya	6			7	0.5562		25		
20	Medasana	6			7		0.3383	25		
21	Meghraj_1	5			7		0.5368	24		
22	Modasa	11	0.2806		11	0.1487		44	0.2159	
23	Panvath/porvad	6			8		0.1763	27	0.0511	
24	Poshina2	10	0.1609		10	0.0754		42	0.1317	
25	Ratanpur	8		0.6016	8	0.5938		30	0.0220	
26	Revas	11	0.8202		11	0.8313		44	0.9720	
27	Silwad	11	0.5693		11	0.6284		44	0.5922	
28	Umadpura	6			7	0.9825		25		
29	Varvada	6			7	0.7931		28	0.2450	
30	Vijaynagar	9	0.3724		7		0.1996	33		0.1127
31	Vijaynagar_Pz	10	0.2455		10	0.0359		36	0.1254	
32	Wadali	9		0.0341	8	0.2798		35	0.0088	
33	Waliampura Pz	10		0.6340	9		0.3078	35		0.3881

Alluvium Formation

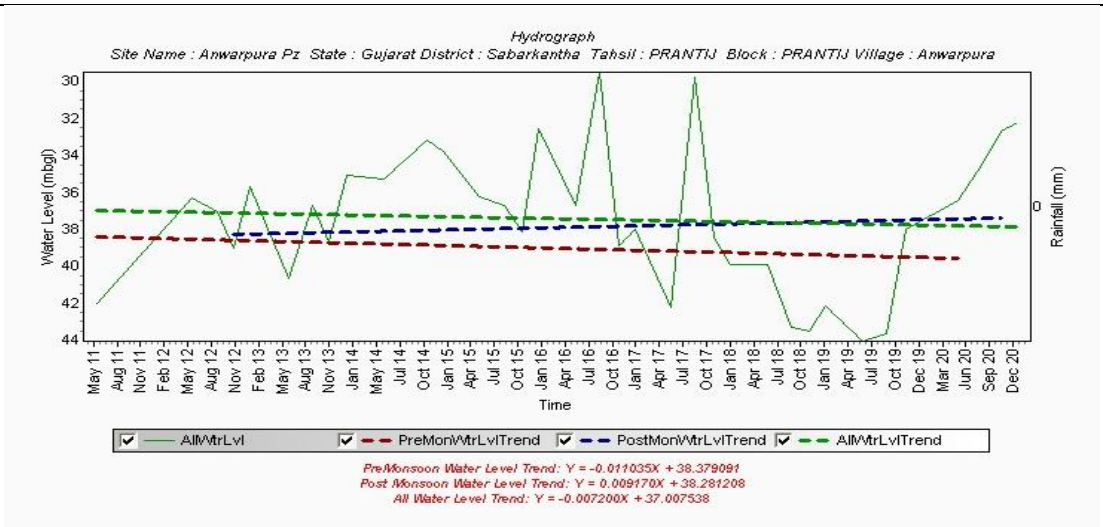


Fig.7.6 Hydrograph at station Anwarpura in Alluvium formation.

Sandstone

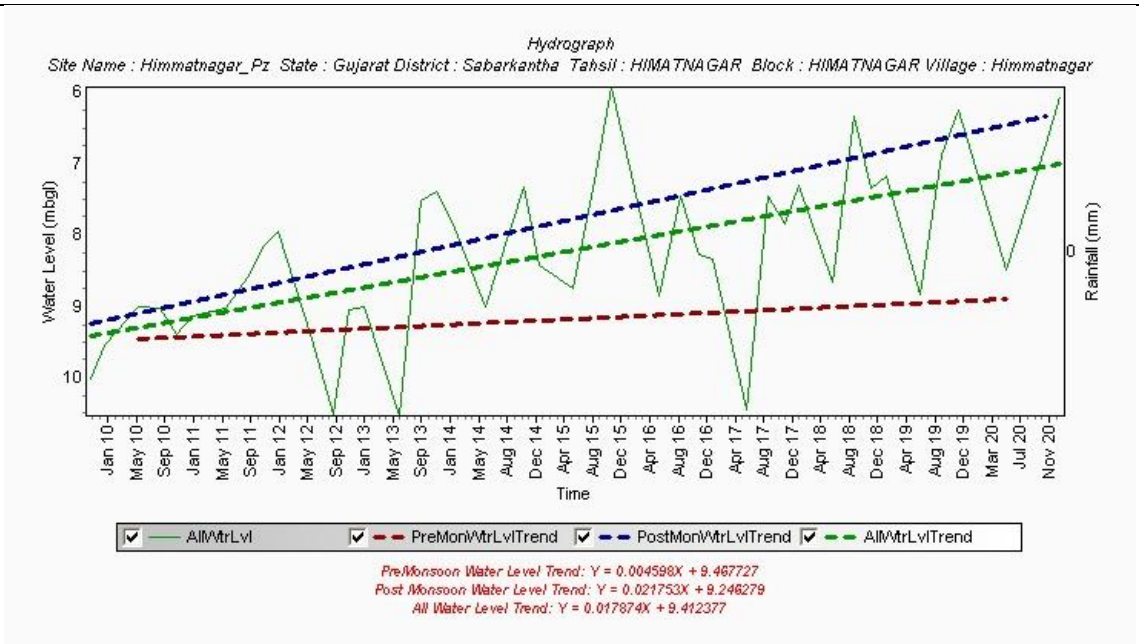
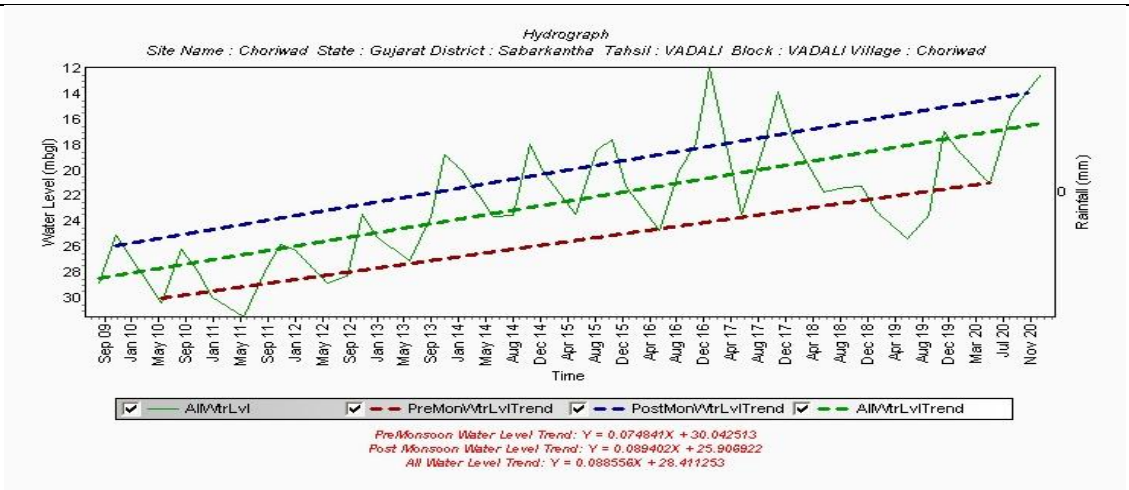


Fig.7.7 Hydrograph at station Himmatnagar in sandstone formation.

Granite



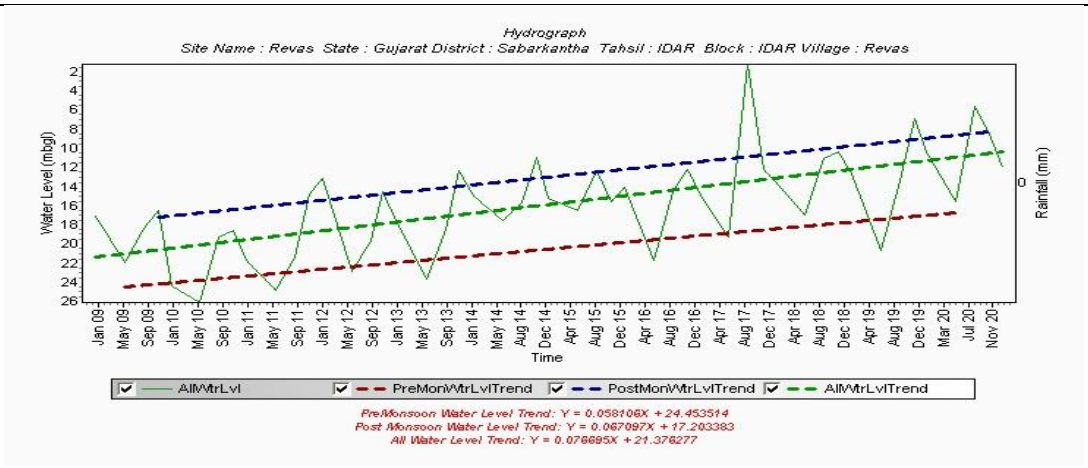


Fig. 7.8 Hydrograph at station Choriwad and Rewas in Granite formation.

Meta-sediments:

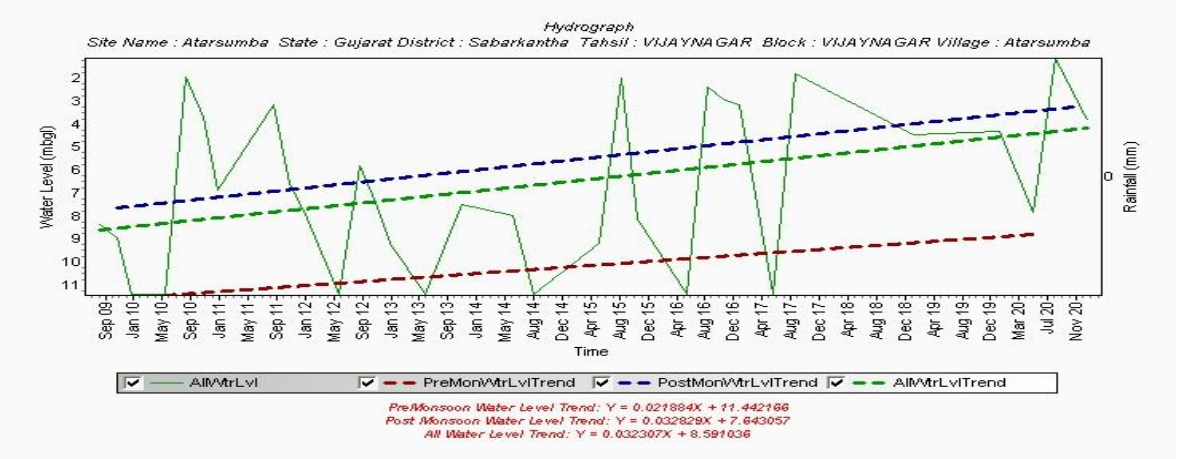


Fig.7.9 Hydrograph at station Atarsumba in Meta-sediments formation.

VIII Hydrochemistry

Variation in chemical quality of ground water is due to hydrogeological factors controlled by rock types, depicting aerial distribution of various water quality features. In terms of electrical conductance (EC), measure of total dissolved salts in ground water is varying in between 700 to 4651 µS/cm during May 2019. The chloride content of the district also vary with in 28 to 1205 mg/l. Nitrate content in the district is very high varying within 5 to 230 mg/l. Iron is the heavy metal that found in the groundwater of the district is varying from 0 to 3.145mg/l. The maximum value found at Boriya (3.145 mg/l) of Talod taluka is unsuitable for drinking purpose comparing to BIS 2017: IS10500 as limit set for 0.3 mg/l only. In other chemical ion, total hardness in terms of $CaCO_3$, is found above the BIS maximum permissible limit of 600 mg/l at 12 places of the district vary within 230 to 1800 mg/l found unsuitable for drinking purpose.

The range analytical result of major ions of representative samples collected during various surveys and exploration works along with NHS data are compiled and the range of major constituents and parameters are given below in table 8.1. EC, Flouride and Nitrate concentration map is shown in Figure 8.1, 8.2 & 8.3.

Table 8.1: Summarised chemical data of Sabarkantha district

Sr No	Parameter	Minimum	Maximum
1	pH	7.64	8.58
2	EC	700	4651
3	TDS	469	3116.17
4	TH	230	1800
5	Ca	36	402
6	Mg	12	312
7	Na	24	360
8	K	0.4	26.9
9	CO3	0	72
10	HCO3	317	854
11	Cl	28	1205
12	NO3	5	230
13	SO4	2.56	278.59
14	F	0.2	3
15	Alk	259.84	700
16	Fe	0	3.145

**All values are in mg/l except pH and EC in µS/cm at 25°C*

8.1 Electrical Conductivity (EC):

EC value ranges from 700 at village Megraj, Taluka Modasa to 4651 µS/cm at Silwad village of Khedbrahma Taluka. But EC in Gadha1, Khedbrahma1, Ramgarh and Silwad is found 3171 µS/cm, 3700 µS/cm, 3783 µS/cm and 3587 µS/cm respectively of the district are not under permissible limit. It is represented in below Fig 8.1.

8.2 Fluoride:

Fluoride value ranges from 0.2 mg/l at Matoda village of Khedbrahma taluka to 3.0 mg/l at Kesarpura Village of Vadali Taluka. Fluoride concentration in Sabarkantha district is under permissible limit except Kesharpura village. The Fluoride Map of Sabarkantha district is given in Figure 8.

8.3 Nitrate:

Nitrate value ranges from 5 mg/l at Megraj village of Modasa taluka to 230 mg/l at Revas Village of Idar Taluka. At most of the places Nitrate concentration is beyond permissible limit. The Nitrate Map of Sabarkantha district is given in Figure 9.

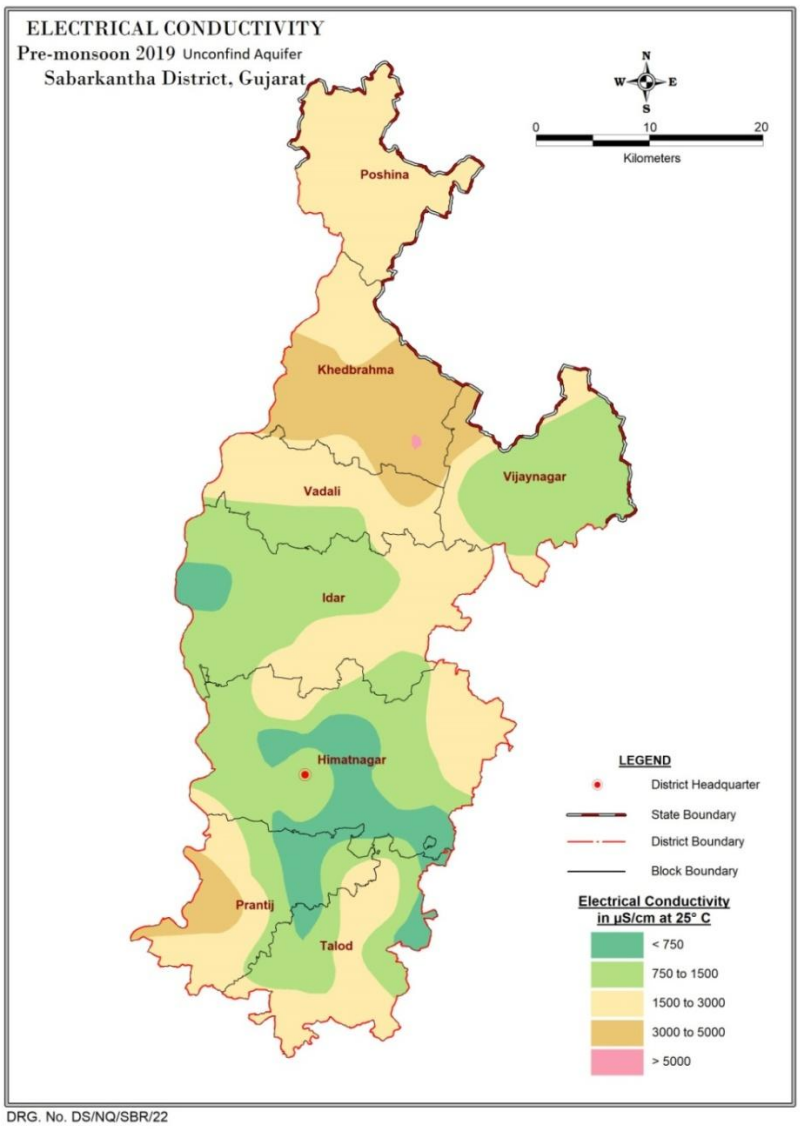


Fig.8.1 Iso Electrical conductivity of the groundwater in the unconfined aquifer year May 2019.

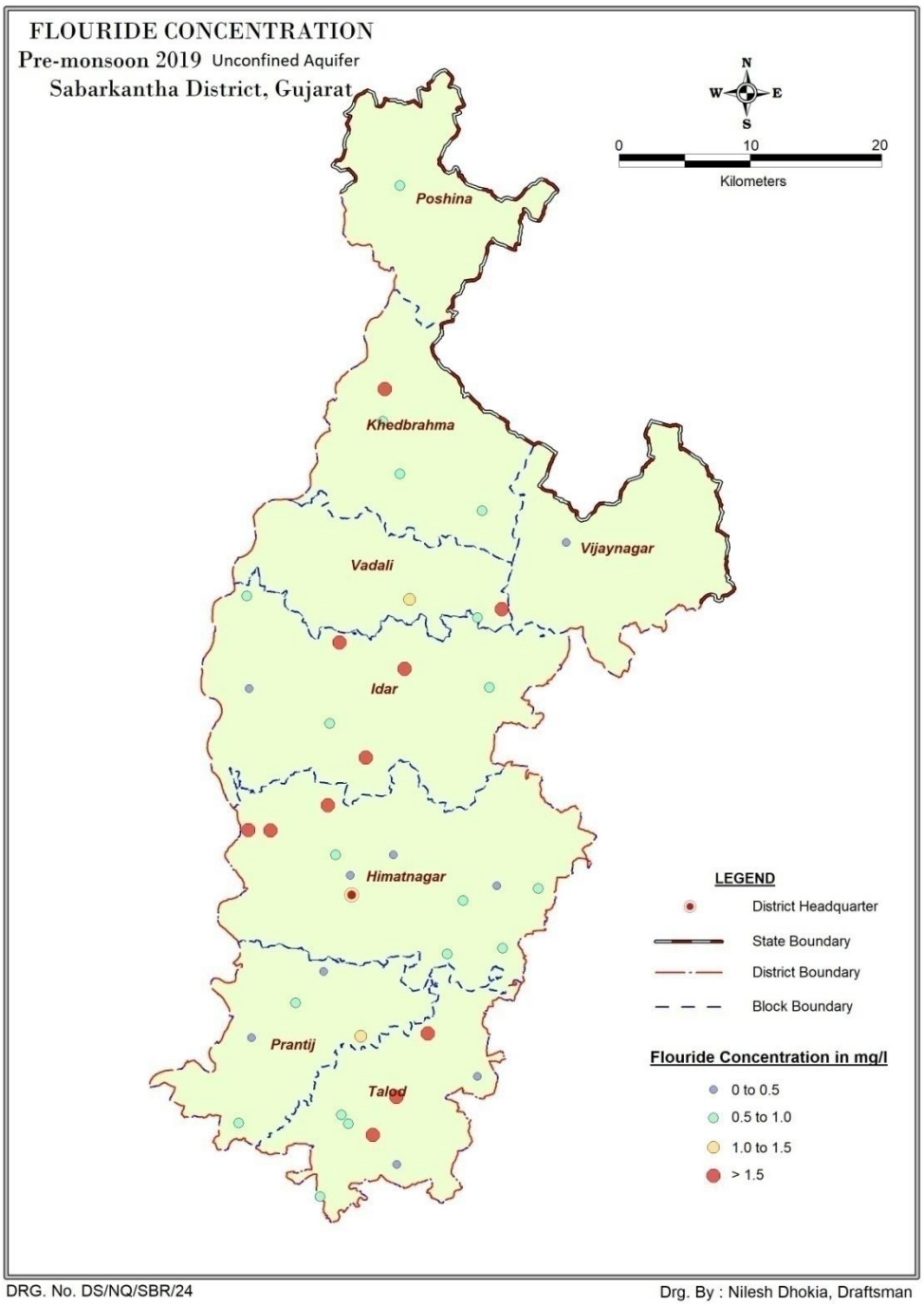


Fig. 8.2 Concentration of Fluoride in unconfined aquifer in Sabarkantha District

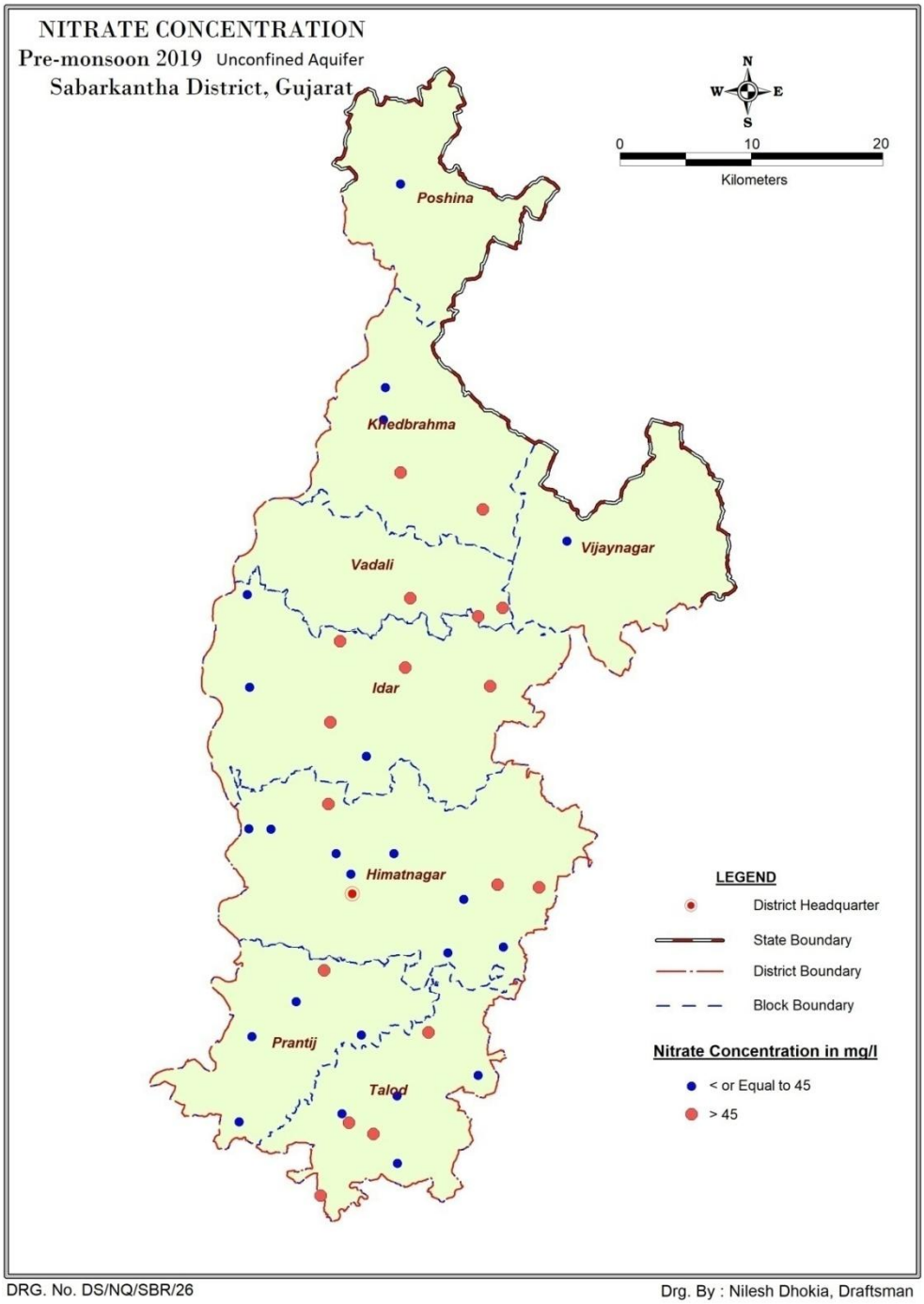


Fig. 8.3 Concentration of Nitrate in unconfined aquifer in Sabarkantha District

IX Ground Water Resources

The ground water resources of the district as per GWRE 2017 and 2020 are presented in Table no 9.1 & 9.2. Out of 8 talukas, 4 talukas are categorised as semi-critical and rest are in safe category in year 2017 whereas in year 2020 Prantiz taluka falls in over-exploited category and rest of talukas are same category as in year 2017 (Fig 9.1 & 9.2).

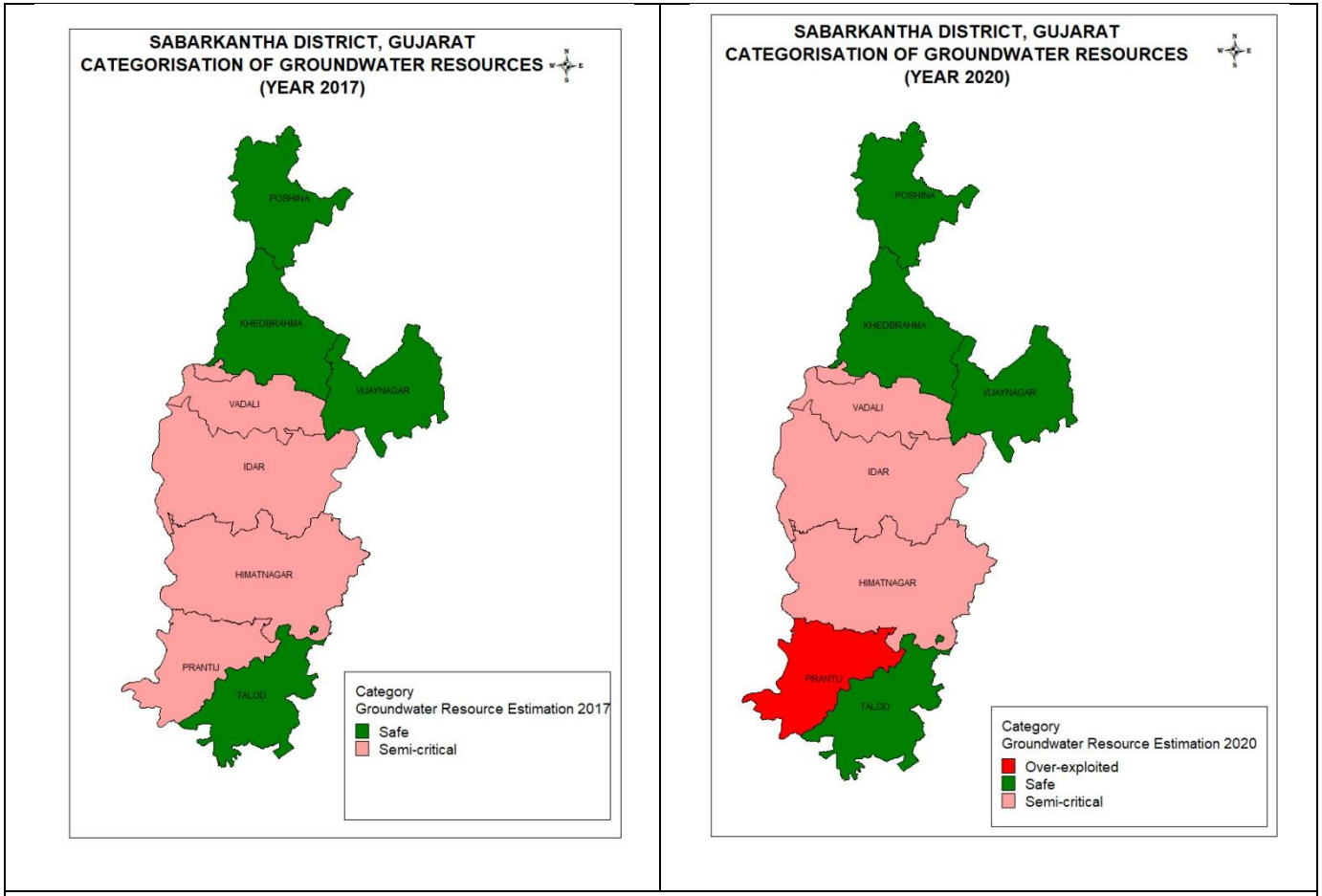


Fig.9 Category of Groundwater resources in year 2017 and 2020.

Table: 9.1 Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2017)

District : Sabarkantha

Sr. No.	Taluka	ANNUAL REPLENISHABLE GROUND WATER RESOURCE (mcm)					Natural Discharge during non-monsoon season (mcm) (5 % of 7)	Net Annual Ground Water Availability (mcm) (7- 8)	ANNUAL GROUND WATER DRAFT (mcm)			Projected Demand for Domestic and Industrial uses upto 2025 (mcm)	Ground Water Availability for future irrigation (mcm) {(9)-(10+13)}	Stage of Ground Water Development (%) (12/9) * 100	Category
		Monsoon		Non Monsoon		Total Annual Ground Water Recharge (3+4+5+6)			Irrigation	Domestic And Industrial uses	Total (10 + 11)				
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Himatnagar	150.99	37.23	0.00	15.62	203.84	10.19	193.65	115.19	5.65	120.84	6.43	72.02	62.40	Safe
2	Idar	123.02	26.91	0.00	9.40	159.34	7.97	151.37	115.50	4.39	119.88	4.99	30.88	79.20	Semi critical
3	Khedbrahma	50.76	15.47	0.00	3.39	69.61	3.48	66.13	35.00	2.71	37.71	3.09	28.04	57.03	Safe
4	Poshina	24.46	3.43	0.00	1.22	29.11	1.46	27.65	11.24	2.19	13.42	2.49	13.92	48.54	Safe
5	Prantij	134.89	15.90	0.00	7.31	158.10	7.90	150.19	112.03	2.68	114.71	3.05	35.11	76.38	Semi critical
6	Talod	76.43	13.36	0.00	2.90	92.68	4.63	88.05	63.56	2.56	66.12	2.92	21.57	75.10	Semi critical
7	Vadali	16.21	32.68	0.00	46.47	95.36	4.77	90.60	66.42	1.43	67.84	1.62	22.56	74.89	Semi critical
8	Vijaynagar	70.71	10.05	0.00	4.68	85.44	4.27	81.17	52.29	1.72	54.01	1.96	26.92	66.54	Safe
District Total		**647.47**	**155.01**	**0.00**	**91.00**	**893.48**	**44.67**	**848.81**	**571.23**	**23.32**	**594.55**	**26.55**	**251.03**	**70.05**	**Semi critical**

Table:9.2 Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2020)

Assessment Unit Name	Total Area of Assessment Unit (Ha)	Recharge Worthy Area(Ha) Fresh	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources- Monsoon Season	Recharge from Other Sources- Non Monsoon Season	Total Annual Ground Water (Ham) Recharge- Fresh	Total Natural Discharges (Ham)-Fresh	Annual Extractable Ground Water Resource (Ham)-Fresh	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)-Fresh	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%) Fresh	Categorization Fresh
HIMATNAGAR	77322	77322	11725.74	1684.72	2136.12	15546.58	1554.66	13991.92	10269.90	7.30	499.67	10776.86	549.91	3164.82	77.02	semi_critical
IDAR	80732	78506	9879.32	1561.13	3253.75	14694.2	1469.43	13224.77	10332.80	0.00	527.59	10860.39	580.64	2311.33	82.12	semi_critical
KHEDBRAHMA	38930	38040	4146.12	766.41	1362.75	6275.28	627.53	5647.75	3302.90	0.00	287.73	3590.62	316.65	2028.21	63.58	safe
POSHINA	36056	32211	3489.92	208.11	380.57	4078.6	407.86	3670.74	1506.80	0.00	231.90	1738.70	255.22	1908.72	47.37	safe
PRANTIJ	39956	39956	6942.16	631.67	623.91	8197.74	819.77	7377.97	8694.30	0.00	0.00	8694.30	0.00	0.00	117.84	over_exploited
TALOD	42852	42852	6446.83	761.49	3454.42	10662.74	1066.27	9596.47	5572.90	0.00	0.00	5572.90	0.00	4023.57	58.07	safe
VADALI	33886	33886	3842.67	1049.24	1566.08	6457.99	645.8	5812.19	5168.20	0.00	0.00	5168.20	0.00	643.99	88.92	semi_critical
VIJAYNAGAR	45605	35024	3835.55	1110.19	3910.36	8856.1	885.61	7970.49	4233.30	0.00	277.65	4510.95	305.57	3431.62	56.60	safe

X GROUNDWATER RELATED ISSUES

In Sabarkantha district, The diverse physiographic, climatic, topographic and geologic conditions have given rise to diversified ground water situations in different parts of the district. Area at present is significantly exploited for groundwater and effect of excessive groundwater exploitation are noted in alluvium and semi-consolidated aquifers. Due to overexploitation of ground water in district the water levels have assumed a declining trend, which in addition to the investments, deepening of wells, entails higher lifting cost. There are two main groundwater issues are observed as below.

10.1 Declines of water levels

Over exploitation of groundwater has lead to depletion of groundwater resources. Declines of water levels are observed in the talukas of Prantiz, Himmatnagar, Idar and Vadali. In comparison of groundwater resourced Prantiz taluka turned into overexploited taluka as per GRE 2020 from semi-critical in GWRE 2017.

10.1.1 Groundwater level Trends:

An overall decline of water levels are observed in unconfined aquifer and are estimated between 0.1034 m/year (Boriya) to 0.7054 m/year (Derol) in different period of time. Groundwater trends of some selected monitoring stations are given in Table 7.2 and Hydrographs shown in Fig.7.6 to 7.9.

10.2 Quality of Groundwater:

Electrical conductivity more than 3000µS/cm are observed in parts of Khedbrahmma and Prantiz taluka. Fluoride concentration >1.5 ppm is observed in Idar taluka and adjoining area of Himmatnagar taluka where area is underlain by Granite. Talod taluka which is mostly underlain by alluvial formation is also identified Fluoride more than 1.5 ppm.

XI MANAGEMENT STRATIGIES

The population of Sabarkantha district is predominantly dependent on agriculture and allied activities for their livelihood. The gross cropped area in the district is 4,27,171 Ha. (3,93,581 Ha. is under agricultural crops and 33,590 Ha. is under horticultural crops). About 3,15,188 Ha. of the area under crop is irrigated area while 1,11,983 Ha. of area is rainfed area (District irrigation Plan 2016-2020).

The major source of irrigation in the district is constituted by canal which forms the surface irrigation sources. The various canal based source of surface irrigation are Dharoi, Hathmati, Meshvo, Vanaj, Vatrak, Guhai, Vaidi, Harnav 1 & 2. Besides this there is a ground water source that also prevails in the district. Under ground water sources there are dugwells and tube wells as major source. The benefits to be accrued out of groundwater based irrigation and domestic supply.

There is not much scope for further development of ground water resources in major parts of the district. Thus, there is an urgent need for augmentations and judicious management of ground water resources. The following measures are required to be done for the groundwater management in concerned.

- Adoption of Micro irrigation system (MIS).
- Diverting surplus run-off during monsoon into ponds, percolation tanks. Spreading canal/basins, abandoned dugwells etc.
- Augmentation of Ground water Recharge through Rain water Harvesting and Artificial Recharge.
- Artificial recharge/micro irrigation to be taken up on large scale with active community participation.
- Shift towards water efficient cropping pattern as per locally available water
- Cooperative irrigation scheme as already existing in the area should be encouraged/rationalised at PRI level.

In the area covered by alluvium terrain, scope exists for augmenting the ground water resources through the artificial recharge. Large scale artificial recharge schemes may not be feasible due to non availability of source of non-committed surface water. However, small and cost effective

measures like contour bunding, nalla plugging, small check dams may be quite effective in increasing the ground water recharge in the portion of the hard rock area of the district. Ground water recharge through percolation tank, recharge shaft is also feasible in the alluvium area and may be adopted at local level. This is a cost effective method to enhance the availability of ground water and improve the ground water quality.

11.1 Management plan

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy. The study suggests notable measures for sustainable groundwater management, which involves a combination of various measures given below.

1. Supply side measures
2. Demand side measures
3. Regulatory measures
4. Institutional measures

11.1.1 SUPPLY SIDE INTERVENTIONS

ARTIFICIAL RECHARGE TO GROUND WATER AND WATER CONSERVATION PLAN

IDENTIFICATION OF RECHARGE AREA

Various water bearing geological formations occurring in the district have been categorized broadly in three hydrogeological units, namely, unconsolidated alluvial deposits, consolidated rock units of igneous and meta sediments and semi consolidated units of other sedimentary rocks. The thickness of available unsaturated zone (below 6 m bgl) is computed on basis of Post monsoon (2009-18) decadal average depth to water level map and decadal water level trend map of Sabarkantha district (Fig 11.1 & 11.2). Based on the decadal average depth to water level of post monsoon period (2009-18) data and long term trend of ground water level (2009-18) (Fig.11.3) four categories were identified in fresh area as follows.

i)Area showing declining trend > 0.10 cm / year and water level between 6-9 m bgl.

ii) Area showing declining trend 0 to 0.10 cm / year and water level between 6 -9 m bgl.

iii)Area showing declining trend > 0.10 cm / year and water level between > 9 m bgl.

iv) Area showing declining trend 0 to 0.10 cm / year and water level between > 9 m bgl.

As per the Master plan for Artificial Recharge to Groundwater in India -2020, A total of 1703 sq. km area spread over mostly in taluka of Talod, Prantiz, Himmatnagar, Idaar, and Khedbrahmma (Fig. 11.3).

Sub-Surface Storage Space and Water Requirement

The thickness of available unsaturated zone (below 6 mbgl) is considered for computing the volume of unsaturated zone for recharge. The product of the area and thickness provides the volume of unsaturated zone below 6m bgl which is of the order of 9950.73 MCM (Table 11.1). The product of specific yield and the unsaturated volume provide the volume available for recharge and is of the order of 398.03 MCM. Considering the efficiency of the artificial recharge structures as 75%, the volume of water required to saturate has been worked out and is found to be 529.38 MCM (Table 11.2).

Source Water Availability

The availability of source water, one of the prime requisites of artificial recharge has been adopted as per data of Narmada, Water Resources, Water Supply & Kalpsar Department, Government of Gujarat (www.guj-nwrws.gujarat.gov.in), which has adopted basin approach. Broadly, the data of each basin takes into account of committed runoff, provision for future planning and surplus water available. Considering the various types of artificial recharge structures constructed up to 2020, as per data provided by the State Water Resources Department an additional 15 MCM of surplus surface water is provisioned for artificial recharge through recharge shafts and existing 84 defunct tube wells which can be used as injection wells (Table 11.3).

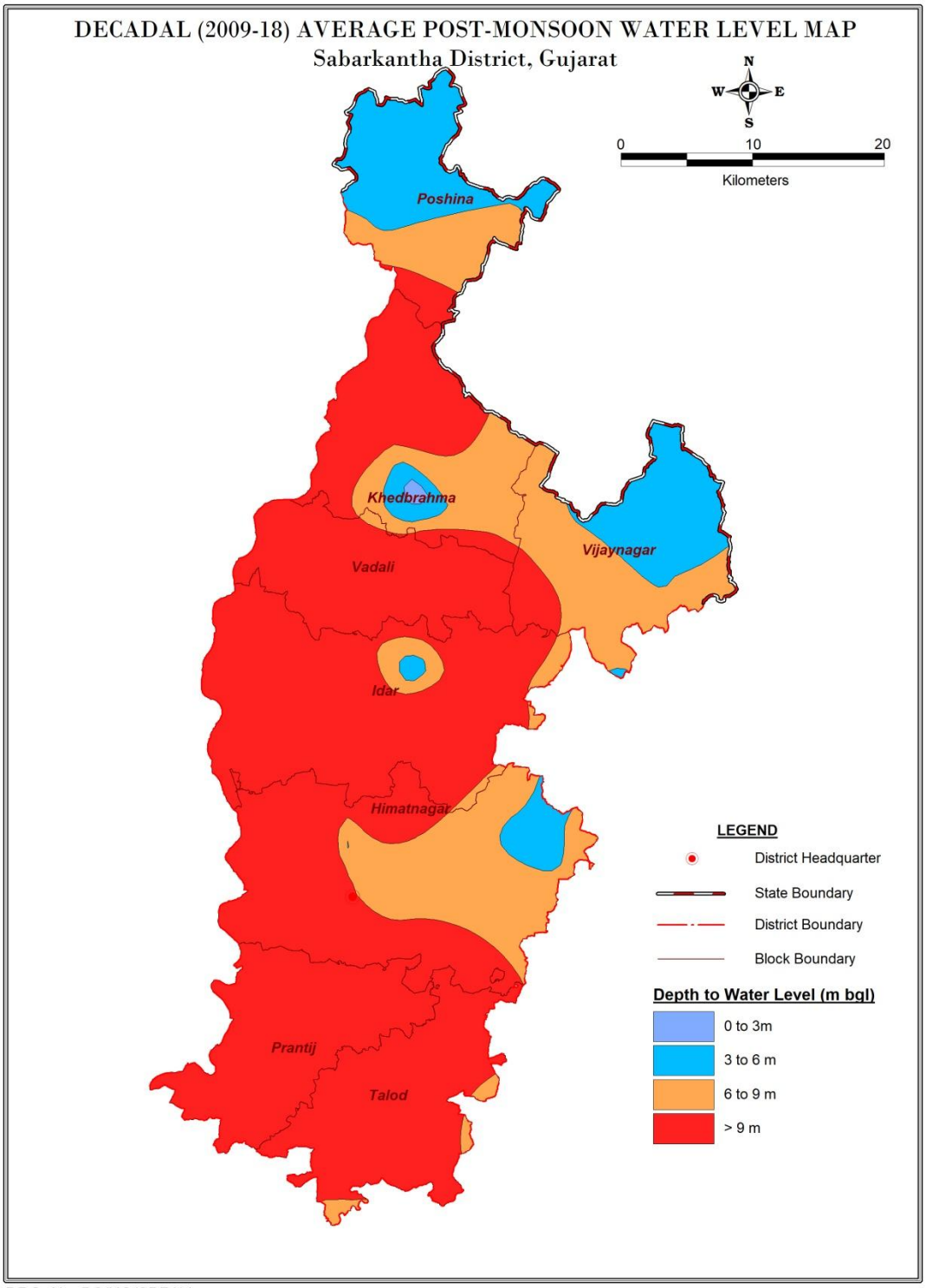


Fig.11.1 Post- monsoon decadal average depth to water level

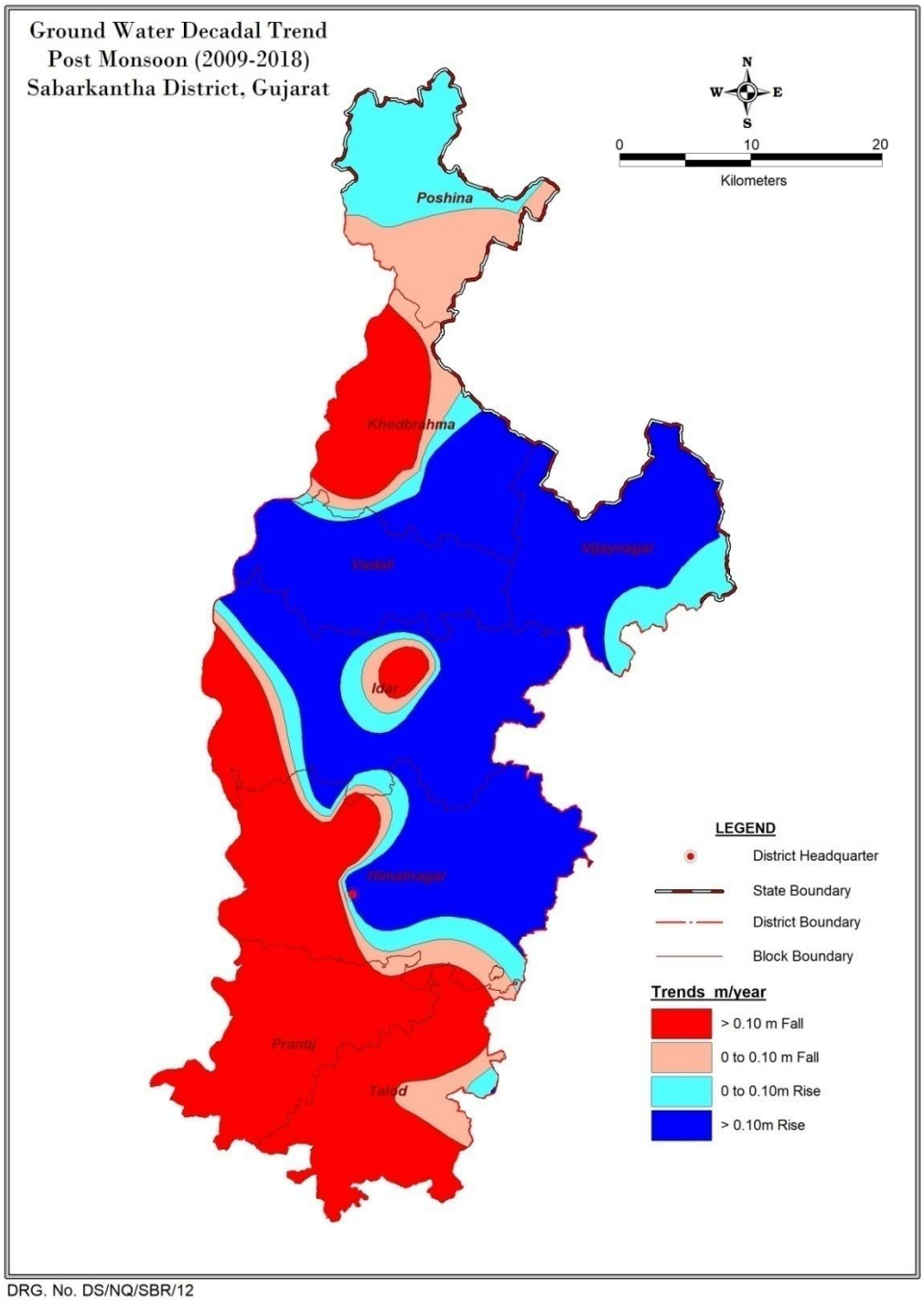


Fig.11.2 Pre-monsoon decadal water level trends.

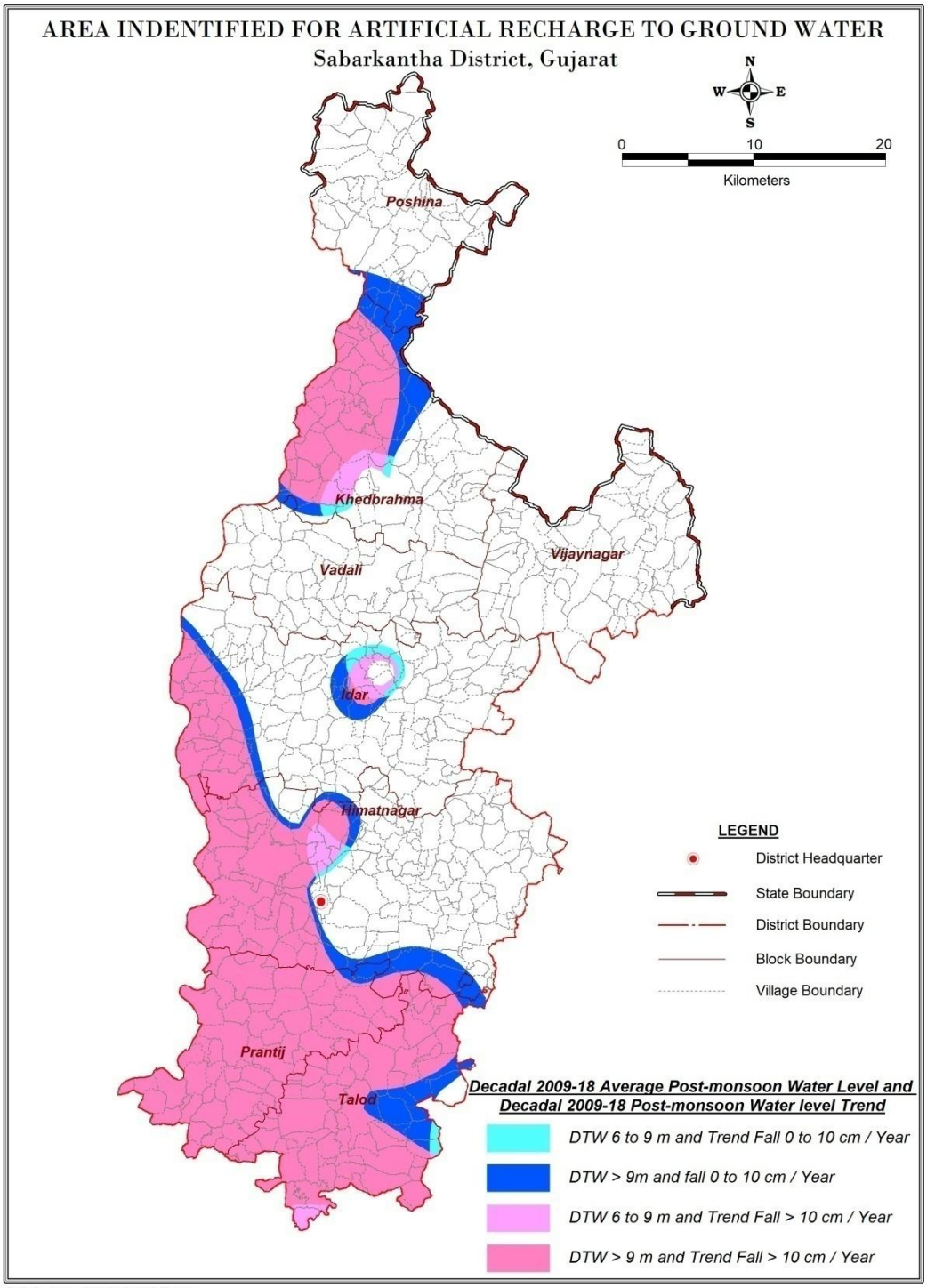


Fig.11.3 Suitable recharge area.

Table 11.1 Computation of suitable recharge area in sq. Km. and volume in MCM

Taluka	Trends		Suitable area for Artificial Recharge (km^2)						Volume of Unsaturated zone MCM
	0.00 to 0.10	> 0.10	0.00 to 0.10	0.00 to 0.10	> 0.10	> 0.10	Total AR Area	Total Area As per Map (Block)	
			Decadal WL_6 to 9m	Decadal WL_> 9m	Decadal WL_6 to 9m	Decadal WL_> 9m			
			3	6	3	6			
Himatnagar	67.22	295.05	2.99	64.23	17.15	277.90	362.27	856.05	2113.2
Idar	59.24	146.34	11.59	47.65	15.95	130.39	205.58	789.54	1150.86
Khedbrahma	56.90	209.55	6.47	50.43	23.05	186.50	266.45	502.10	1510.14
Poshina	31.79	0.00		31.79			31.79	388.54	190.74
Prantij	9.36	402.20		9.36		402.20	411.56	411.57	2469.36
Talod	62.89	361.55	4.45	58.44	9.05	352.50	424.44	434.31	2506.14
Vadali	1.80	0.00		1.80			1.80	364.97	10.8
Vijaynagar	0.00	0.00					0.00	481.24	0
TOTAL			**25.50**	**263.70**	**65.20**	**1349.49**	**1703.89**	**4228.33**	**9951.24**

Table : 11.2 Volume of water required for recharge in MCM

Block	Volume of unsaturated zone available	Specific yield factor	Volume of water required for recharge
Himatnagar	2113.2	0.1	211.32
Idar	1150.86	0.02	23.0172
Khedbrahma	1510.14	0.0199	30.051786
Poshina	190.74	0.0155	2.95647
Prantij	2469.36	0.023	56.79528
Talod	2506.14	0.1	250.614
Vadali	10.8	0.02	0.216
Vijaynagar	0	0.03	0
Total	9951.24		574.970736

Farm ponds:

A farm pond is a large hole dug out in the earth, usually square or rectangular in shape (Fig. 11.4), which harvests rainwater and stores it for future use. It has an inlet to regulate inflow and an outlet to discharge excess water. The pond is surrounded by a small bund, which prevents erosion on the banks of the pond. The size and depth depend on the amount of land available, the type of soil, the farmer's water requirements, the cost of excavation, and the possible uses of the excavated earth. Water from the farm pond is conveyed to the fields manually, by pumping, or by both methods.

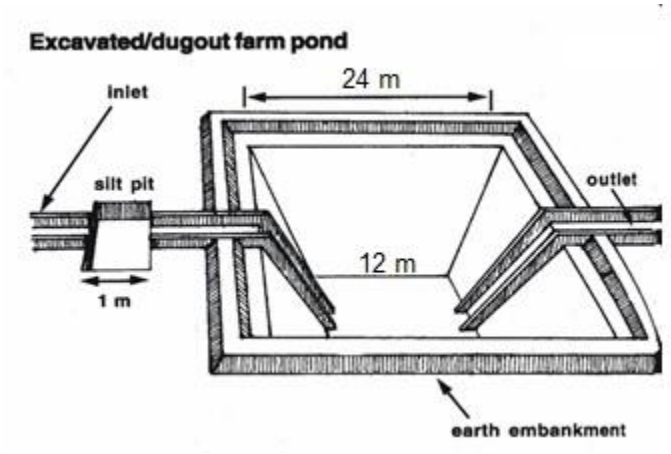


Fig. 11.4: Thematic diagram of Farm pond

Advantages of Farm Ponds

- They provide water to start growing crops, without waiting for rain to fall.
- They provide irrigation water during dry spells between rainfalls. This increases the yield, the number of crops in one year, and the diversity of crops that can be grown.
- Bunds can be used to raise vegetables and fruit trees, thus supplying the farm household with an additional source of income and of nutritious food.
- Farmers are able to apply adequate farm inputs and perform farming operations at the appropriate time, thus increasing their productivity and their confidence in farming.
- They check soil erosion and minimize siltation of waterways and reservoirs.
- They supplies water for domestic purposes and livestock
- They promote fish rearing.
- They recharge the ground water.
- They improve drainage.
- The excavated earth has a very high value and can be used to enrich soil in the fields, levelling land, and constructing farm roads

It is proposed to construct 6115 farm ponds as per the specification (24 x 12 x 3 m). Considering

1.5 fillings can accommodate 7.93 MCM of runoff rainfall. Farm ponds can be constructed in the village at feasible location. Dimension of the farm pond depends on land holdings (Table 11.3).

Recharge shaft with the pond /tanks (for enhancing recharge from above structures by 30%) Recharge capacity 3 ham (0.03 mcm) are estimated 416 no. GWR, Gujarat State referred 84 no. defunct abandoned well through recharge can be done as Recharge Wells in alluvial area and Recharge capacity 3 ham (0.03 mcm) is considered.

Table-: 11.3 Proposed Artificial Recharge and WUE Interventions in Sabarkantha District

Block	Recharge Shaft (Nos.)	Recharge Wells (Nos.)	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)	Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)	
						DW	TW
Himatnagar	85	17	2175	1500	1000	2700	300
Idar	78	16	3500	0	2500	-	-
Khedbrahma	49	10	1250	0	250	1670	150
Poshina	38	7	185	15	100	1040	15
Prantij	40	8	3500	850	1000	-	-
Talod	43	9	1500	235	400	-	-
Vadali	36	7	1000	300	600	-	-
Vijaynagar	47	10	1500	300	265	425	8
Total	**416**	**84**	**14610**	**3200**	**6115**	**5410**	**465**

11.1.2 DEMAND SIDE INTERVENTION

Along with development plan to prevent Over Exploitation, water conservation activities like on farm activities, farm ponds and Micro irrigation system (Sprinkler/drip) are recommended in the district. By these activities, groundwater extraction can be developed up to 65% i.e. under safe category.

Water use efficiency/Water conservation activities by application of on-farm activities, farm pond and Micro irrigation system:

14610 Ha area is proposed for on farm activities (Laser leveling/Bench terracing/Contour banding) and 3200 Ha area is proposed for Micro irrigation system (Sprinkler/drip) in

Table: 11.4 Projected Status of Groundwater Resource after implementation of GW Management Plan, Sabarkantha District (Gujarat)

Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures (in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Himatnagar	19365	523.5	159	20047.5	12084	643.58	1590	13030.43	62.40	70.04	66.01	65.00	3180
Idar	15137	632	0	15769	11988	949.56	0	11038.44	79.20	79.20	71.28	70.00	0
Khedbrahma	6613	302	92.5	7007.5	3771	139.96	925	4556.04	57.02	70.03	66.70	65.02	1850
Poshina	2765	153.5	63.9	2982.4	1342	42.48	639	1938.52	48.54	70.03	68.08	65.00	1278
Prantij	15019	494	0	15513	11471	612.33	0	10858.68	76.38	76.38	70.65	70.00	0
Talod	8805	306	0	9111	6612	234.18	0	6377.82	75.09	75.09	71.22	70.00	0
Vadali	9060	229	0	9289	6784	280.90	0	6503.11	74.88	74.88	70.99	70.01	0
Vijaynagar	8117	321	30.55	8468.55	5401	202.10	305.5	5504.40	66.54	70.04	66.34	65.00	611
Total	**84881**	**2961**	**345.95**	**88187.95**	**59453**	**3105.08**	**3459.5**	**59807.42**	**70.04**	**73.21**	**68.91**	**67.50**	**6919.00**

Sabarkantha district (Table 11.3). Ground water conservation of 3105 ham through WUE measures & farm ponds activities is expected for the district.

11.2 Ground Water Development Plan

As per GWRE 2017 total 04 no talukas of Sabarkantha district are under safe category and other 4 are under Semi critical catogory. Ground water stage of development ranges from 48.54 % (Poshina) to 66.54 % (Vijaynagr) in safe talukas. To elevate the stage of ground water development to 70% in 4 talukas 5410 no dug wells (20 m depth) and 465 no Tube wells (60 to 70 m depth area are proposed as feasible extraction structures (Table 11.4). The extraction structures will result in additional ground water draft of 3460 ham which will create 6919 Ha additional irrigation potential for the district and same as tabulated below (Table 11.5).

Table:11.5 Summary of Interventions, Expected Benefits

Interventions Recommended	
Recharge Shaft (Nos)	416
Recharge Wells (Nos.)	84
On-farm Activities	14610 ha
Water Use Efficiency (WUE) Measures	3200 ha
Farm Ponds	6115
Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)	DW - 5410
	TW- 465
Expected Benefits	
Expected Annual Recharge	3306.95 ham
Conservation from On-farm Activities, WUE Measures & Farm Ponds	3105.08 ham
Total Recharge/ Saving	**6412.03 ham**
Additional Irrigation Potential Created (Ha)	6919.0 ha

XII CONCLUSIONS AND RECOMMENDATIONS

12.1 Summary and Conclusions

1. The district derives its name from the Sabarmati River that separates Sabarkantha from the neighbouring districts. Sabarkantha District is situated in North Eastern part of Gujarat State. District has a geographical area of 5390 km^2 and comprises 8 talukas.
2. According to the 2011 census, the total population of Sabarkantha district is 1388671 persons out of which population of male and female are 7,11,845 and 6,76,826 respectively. The District is predominantly rural with around 82.92% of the population residing in rural areas.
3. Physiographically, the district can be divided in to two zones i.e. the hilly regions and the plains. The hilly ranges cover the northern and eastern part of the district where as the plains, showing the undulating topography, are confined towards west and southwest.
4. Sabarmati, the major river of the district, flows from north to south, along the western border of the district originating from the hill ranges of the Rajasthan (Fig. 2.2). The area is mainly drained by the south westerly flowing river, namely the Hathmati, the Khari, the Meshwa, the Majham and the Vatrak.
5. Average cropping intensity in the district is about 120%. Net sown area is reported as about 59% of the total geographical area.
6. Surface water availability across the seasons in the Sabarkantha district is 325.87 MCM. Total irrigated and rainfed area are 282157 Ha and 111424 Ha respectively in the district
7. The district has a semi-arid to arid climate. It is characterised by hot summer, cold winter, meagre rainfall and general dryness except during monsoon season. The average' annual rainfall (1981 to 2020) is ranges from 786.675 to 901.925 mm. The district as a whole has drought frequency in the range of 45% (Khedbrahma & Talod) to 57.5% (Vadali) with district average of 50.71%. This shows that the district is drought affected almost every alternate year.
8. Geologically, Sabarkantha district is the manifestation of diverse geological extension from Lower Proterozoic to Holocene. The rock types encountered in the area are sedimentary, meta-sedimentary, volcanic and metamorphic rocks.

9. Pre-Cambrian hard rocks, infratrapean sandstone of cretaceous age, Deccan trap basalt and Quaternary alluvium form aquifers in the district. Ground water occurs, both under phreatic and semi-confined conditions.

10. Groundwater occurs both in alluvium and hard rock. Major area of the district is covered by hard rock aquifer, covering a large area in the northern, eastern and southern-western part along with a small patch at central part of the district. Though ground water occurs in all types of formation, but the most productive aquifer are Himmatnagar sandstone, Quarternary sediments (Alluvium) and Deccan traps.

11. The movement of groundwater is controlled by the extent of weathering, fissures, fractures and joints. Yield of the open wells tapping quartzite and phyllite formations are poor, except those located near streams and tanks. Yield of the wells ranges from 5 to 350 m^3/day. Depth of dugwells tapped in granite formation ranges between 8 and 24m while dug cum bore well is around 58m. Yield of wells tapping granite ranges from 5 to 25 m^3/day. The thickness of Himmatnagar series varies from 40m at Timba Kampa to 82m at Ilol. The yield of the dug well and dug cum bore well varies from 342 to 1752 m^3/day and in tube it ranges from 163 to 864m^3/day. The yield of wells tapping Deccan traps ranges from a few cubic meter to 30m3/day. The uppermost trappean flow is highly jointed and brittle. Alluvial and blown sand aquifers mainly occur in the south western part of the district and also occur as small scattered patches along different streams.
12. Yield of dugwell ranges between 12 to 1062 m^3/day while tube well yield as high as 6720 m^3/day with a low to medium of vary wide range. Fine to medium grained, unconsolidated sand comprises the aquifer materials in the blown sand and it occurs as water bearing formation in the southern part of the district. The yield of the dug well located in blown sand ranges between 6.4 to 90 m^3/day.
13. Depth to Water Level during pre monsoon period 2019 (Fig.-7.2) falls in 73% area (Table 7.1) in the range of 10 to 20 m bgl, in most part of the district. The shallow water level 2 to 10 m bgl is observed in isolated patches in western part and hilly region of eastern part.

14. Water table map for the period of Pre-monsoon and Post-monsoon 2019 shows the groundwater level with reference to the mean sea level and Water table ranges 340 m to 70 m MSL. Groundwater flow direction in general from north east to south direction and following surface topography of the area. Ground water flow is steeper in the north east part of the area whereas it becomes gentler in southern direction
15. Electrical conductivity more than 3000µS/cm is observed in parts of Khedbrahmma and Prantiz taluka. Fluoride concentration >1.5 ppm is observed in Idar taluka and adjoining area of Himmatnagar taluka where area is underlain by Granite. Talod taluka which is mostly underlain by alluvial formation is also identified Fluoride more than 1.5 ppm.
16. Over all stage of development of the district is 73.94% (GW Resources 2020) and is categorized as semi-critical. One taluka Prantiz, categorised as over-exploited. Three talukas are categorized as sem-critical namely Himmatnagar (70.02%), Idar (82.12%) and Vadali (82.92%). Four talukas are categorized as safe with stage of development ranging between 47.37% (Poshina) to 63.58% (Khedbrahmma).
17. An overall decline of water level is observed in unconfined aquifer and ranges between 0.1034 m/year (Boriya) to 0.7054 m/year (Derol) in different period of time.
18. Electrical conductivity more than 3000µS/cm is observed in parts of Khedbrahmma and Prantiz taluka. Fluoride concentration >1.5 ppm is observed in Idar taluka and adjoining area of Himmatnagar taluka where area is underlain by Granite. Talod taluka which is mostly underlain by alluvial formation is also identified Fluoride more than 1.5 ppm.

12.2 Recommendations

1. From the conclusions drawn, it is evident that not much scope exists for development of ground water resources to increase the irrigation potential in the district. Keeping in mind the existing scenario, recommendations are accordingly made out for development, augmentation and management of ground water resources.

2. **Supply side management**: An area of 1704 Km^2 has been identified for artificial recharge of groundwater to unconfined aquifer. The volume of water required for artificial recharge to fully saturate aquifer (below 6 m bgl) in each taluka areas is around 575 MCM.

    i. Pond Recharge and conservation of Rainwater: In the district 416 no. of Recharge shaft with the pond /tanks (for enhancing recharge from above structures by 30%) Recharge capacity 3 ham (0.03 mcm) are estimated. Available 84. No. tube wells (Gujarat State) in district can be used as recharge tube well.

    ii. It is proposed to construct 6115 farm ponds as per the specification (24 x 12 x 3 m). Considering 1.5 fillings can accommodate 7.93 MCM of runoff rainfall.

3. **Demand side management**:

    Water use efficiency/Water conservation activities by application of on-farm activities, farm pond and Micro irrigation system:

    Conjunctive use of available water resources and optimising the utilization per unit of water have became the crucial need in agriculture and horticulture sectors and micro irrigations methods with particularly Sprinkler/drip irrigation method is recommended.

    14610 Ha area is proposed for on farm activities (Laser leveling/Bench terracing/Contour banding) and 3200 Ha area is proposed for Micro irrigation system (Sprinkler/drip) in Sabarkantha district. Ground water conservation of 3105 ham through WUE measures & farm ponds activities is expected for the district.

4. To elevate the stage of ground water development to 70% in 4 talukas 5410 no dug wells (20 m depth) and 465 no Tube wells (60 to 70 m depth area are proposed as feasible extraction structures.