केन्द्रीय भूमि जल बोर्ड

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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

Bhavnagar District
Gujarat

पश्चिम मध्य क्षेत्र, अहमदाबाद
West Central Region, Ahmedabad

ACKNOWLEDGEMENT

I would like to take an opportunity to thank Shri G. Krishnamurthy, Regional Director, CGWB, West Central Region, Ahmedabad and Shri Sanjeev Mehrotra, Scientist-D, CGWB, West Central Region, Ahmedabad, Gujarat for offering such opportunity of detailed study of the district. I am very much delighted to express my deep sense of gratitude and regards to my respected colleagues/ seniors Dr. A. K. Jain Scientist-D (Retired), Sh Ramesh Jena, Scientist-B, Sh L N Damodra, Scientist-B, Sh Satyendra Kumar, Scientist-B, Sh Ankit Vishwakarma, Scientist-B, Sh Kamar Ujjam Khan, Scientist-B, Sh Gajanan Ramteke, Scientist-B , Sh Saddam Husain, AHg, Sh Subhash Singh, AHg, Sh Abdurrahman, AHg, and Sh Avinash Chandra STA (HG), WCR, Ahmedabad for their valuable and meticulous guidance and support duringthe study.

I am deeply thankful to Smt Puja Mehrotra, Scientist-D, Dr. H. B. Meena Asst Chemist, Smt Adiba Khan STA (Chem), and all other scientists of chemical team for timely analysis of the water samples of the district.

I would like to extend my gratitude to Shri Neelesh Dokia, Draftsman, for suggested map preparation. The help and co-operation of all Scientists, staffs, MTS of CGWB, WCR, Ahmedabad is greatly recognizable.

Last but not least, I would like to acknowledge my family members for their unselfish sacrifices, constant blessing and moral support at every stage in my life.

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AQUIFER MAP AND MANAGEMENT PLAN
BHAVNAGAR DISTRICT
GUJARAT

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AQUIFER MAPPING AND MANAGEMENT PLAN OF BHAVNAGAR DISTRICT

1.1 Introduction

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological, and quality data is integrated to characterize the quantity, quality, and sustainability development of ground water in aquifers. 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.

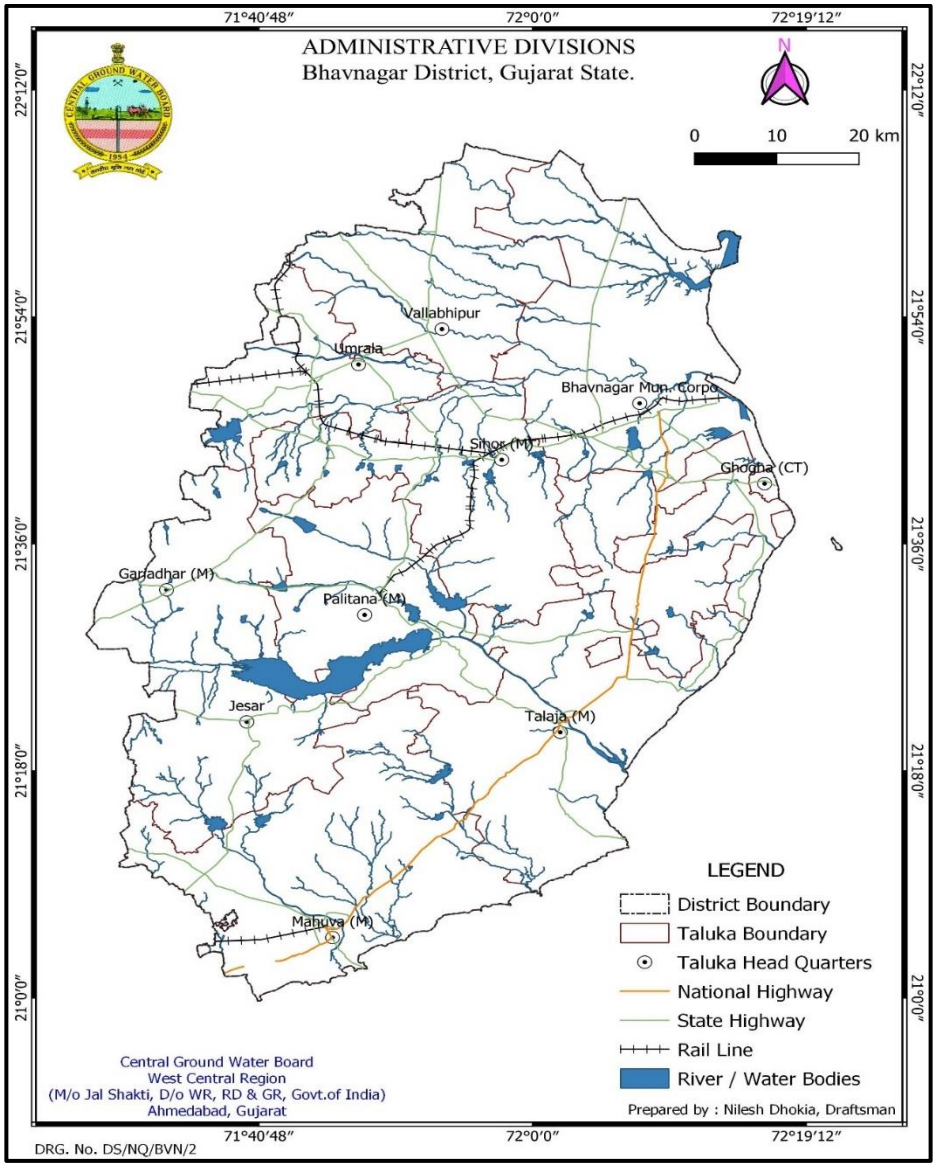


Figure 1 Administrative map of Bhavnagar district

1.2 Objective

The aquifer mapping implemented is primarily based on the existing data that are collected, compiled, analysed and interpreted from available sources. In order to represent the heterogeneity of ground water system, the complexity of aquifer system on map is simplified based on the availability of data for generation of information to be depicted in Aquifer maps broadly representative of the area. The data gap analysis carried out helped in to propose/generate additional data from new data-collection activities such as exploratory drilling, geophysical investigations, water level measurements and groundwater quality analysis. By integrating and analysing the existing data and the data generated, regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2-D and 3 –D aquifer dispositions and maps of the potentiometric head were generated. Theses maps were utilized for defining the aquifer geometry and assessment of ground water resources and planning possible interventions for improvement in groundwater scenario.

1.3 Scope of the Study

Scope of the study is limited to the extent defining the geometry of aquifer system in space i.e., lateral and vertical disposition of aquifer system, based on existing available data. Defining characteristics of aquifer system wherever available and its significance in development and management of ground water resources in terms of quantity and quality of groundwater of the area depicting ground water regime in Two- and Three-dimension form for understanding & quantification of ground water resources in space, demand and supply of ground water and its use in the area. Identification of issues related with development and use of ground water to meet the competing water demand and its depiction for addressing the issue. Groundwater management strategies for addressing the issues by introducing management intervention (on demand and supply side) into the system. Finally, it is the user, whose participatory approach and perspective of ground water development, use and management based on available Aquifer information system as a stakeholder is envisaged.

1.4 Approach and Methodology

Methodology involves creation of database for each of the principal aquifer. Delineation of aquifer, Aquifer Geometry and their characteristics, integration of Hydrogeological, geophysical, geological, hydrochemical data on GIS platform, identification of issues, manifestation of issues and formulation of strategies to address the issues by possible interventions at local and regional level.

The activities of the Aquifer Mapping can be grouped as follows

1.4.1 Data Compilation & Data Gap Analysis

One of the important aspects of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were collected from the available sources, analysed, examined, synthesized and interpreted. Predominantly non-computerized data was converted into computer-based GIS data sets and on the basis of available data, data gaps were identified.

1.4.2 Data Generation

There is a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, remote sensing, and hydrogeological surveys to delineate multi aquifer system.

1.4.3 Aquifer Map Preparation

On the basis of integration of data generated from various studies aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out details of Aquifers, these are termed as Aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities (i.e., quality & quantity).

1.4.4 Aquifer Management Plan Formulation

A suitable strategy for sustainable development of the aquifer in the area has been formulated. All the above activities under the ground National Aquifer Mapping programme is depicted/elaborated in presented in **Figure 2**.

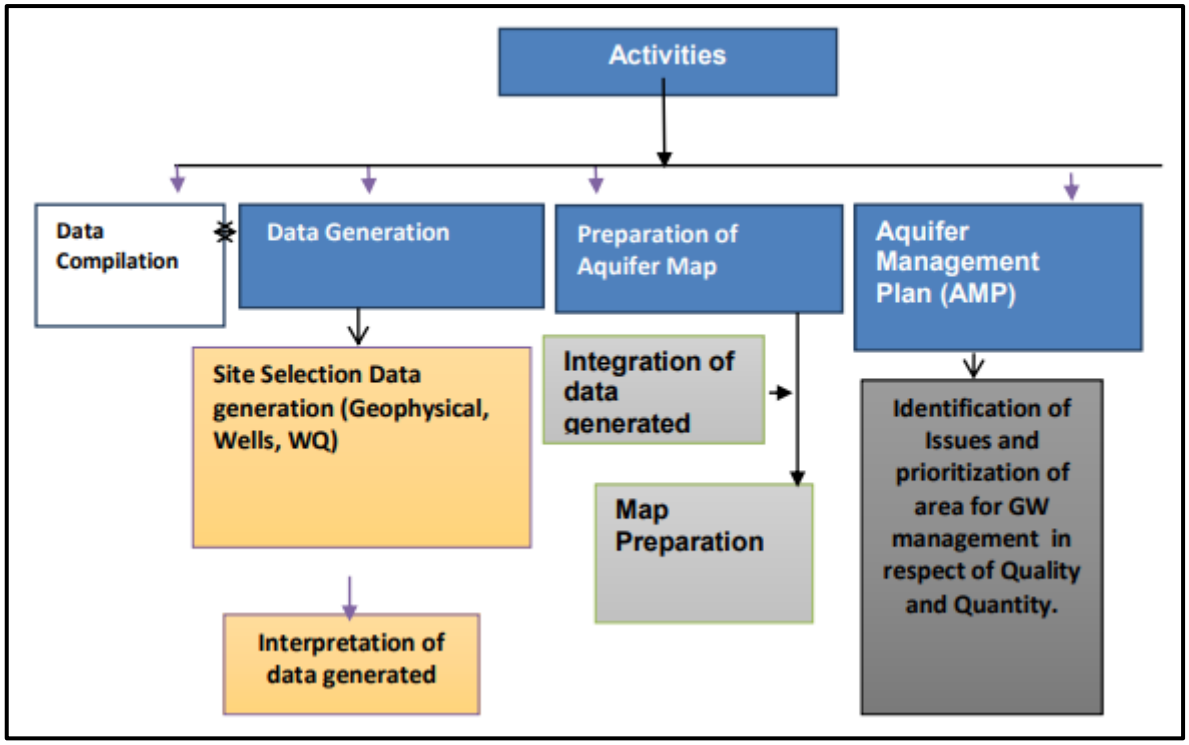


Figure 2 Activities under National Aquifer Mapping Programme

Activities:
Step 1: No activity needed
Step 2: Data generation
Step 3: Aquifer map preparation
Step 4: Preparation of management plan

1.5 Location and Areal Extent

Bhavnagar district has the area of 9980.9 Sq. km and is located in southern part of the Saurashtra Region of Gujarat State. It lies between north latitude 21°18' and 22°18' and east longitudes 71°15' and 72°18'. It falls in the Survey of India (SOI) degreesheets 41O and 46 C. District Bhavnagar is bounded by Surendranagar and Ahmedabad districts of Gujarat in the north, Rajkot and Amreli districts of Gujarat in the west, Arabian Sea and part of Amreli district in the south and the Gulf of Cambay (Gulf of Khambhat) in the east.

1.6 Administrative units, Accessibility, and Population

Administratively, the district is divided into ten talukas viz., Bhavnagar, Gariyadhar, Ghogha, Jesar, Mahuva, Palitana, Sihor, Talaja, Umarala, and Vallabhipur, having total of 693 villages.

The administrative Map of the district is given in **Figure 1**. The Botad taluka from the Bahvnagar district is now become the district itself in 15 August 2013. Gadhada taluka which was in Bhavnagar district previously, is now in Botad district. Mahuva taluka is divided into two talukas, i.e., Mahuva and Jesar taluka. The district headquarter, Bhavnagar, is connected with Ahmedabad through a National Highway NH751. The district is also connected by broad gauge railway line.

Table 1 Area details of parted talukas Jesar and Mahuva

Taluka Name	Total village (2015)	Total Village Panchayat (2015)	Total Geographic Area (Sq. Km) (2015)	Population (Census 2011)

Jesar	42	40	490.13	84785
Mahuva	118	114	1255.61	407259

Source: District Human Development Plan (Moving from DHDR to DHDP)

Table 2 Taluka Wise Population, Population Density and area in Km^2 as per Census- 2011
Source: District Human Development Plan (Moving from DHDR to DHDP)

S. No	Taluka Name	Total Geographic Area (Sq. Km)	Total Forest Area (Sq. Km)	No. of Villages	Total Population	Population		Population Density (Per Sq. Km)
						Urban	Rural	
1	Bhavnagar	1039.68	11.35	60	787319	643263	144056	757
2	Ghogha	437.85	8.28	47	100377	12208	88769	231
3	Gariyadhar	484.33	0.73	49	114887	33949	80938	244
4	Jesar	490.13	69.67	42	34785	---	84785	167
5	Mahuva	1255.61	26.39	118	407259	98519	308740	351
6	Palitana	734.74	39.16	81	210566	64497	146069	313
7	Sihor	720.87	46.03	79	212236	60574	151662	294
8	Umrala	407.33	0.87	43	86323	15604	70719	212
9	Vallabhipur	593.39	11.35	57	80192	15852	64340	135
10	Talaja	869.72	23.56	117	325667	54611	271056	374

1.7 Previous Work

The study area has been under intensive study by CGWB since 1974. The detailed hydrogeological study carried out by various officers of the department is mentioned below. Systematic Hydrogeological Survey was carried out by shri D.S.K.Rao during FSP 1974 – 77, then by Mandhekar S.M and Pandey A.R in the year 1975 – 77. Later Shri R.C.Jain carried out Systematic Hydrogeological survey during 1983-84. Shri. Arun Kumar and Shri A.Dey carried out during 1883-85 & 1987 – 89 respectively.

Reappraisal Hydro geological surveys were carried out by Shri. A.B.Kawade and Srivastava.N.K during 1984-85 & 1985 – 86 respectively. Exploratory drilling was carried out in Shetrunji Basin during 1981 – 85.

PHYSIOGRAPHY AND DRAINAGE

2.1 Physiography/Geomorphologic Features and Land Forms

The Physiography of the study area features coastal marshes and sandy areas fringing the Gulf of Cambay to the hilly areas of Palitana, and Sihor in the northwest. In the north-western part, hilly upland area ranging between 100 and 296 m AMSL and the slope of the area is towards east. The height of the hill ranges in the south and southwest covering Palitana and Sihor talukas generally ranges in height between 305 and 457 m AMSL. The Shetrunji hills lying southwest of Palitana have the highest elevation of 501 m AMSL. The Geomorphological map of the district is shown in **Figure 3**. These hill ranges lie almost parallel to the coast.

The various geomorphic units occurring with the area classified into two groups:

- Those formed by Quaternary/Tertiary formation that includes alluvial plain, salt flat, valley fill, coastal plain, coastal ridge, coastal depression and piedmont zone.I
- Those formed by Deccan trap that includes pediment, dissected hilly terrain, moderately dissected pediplain and denudational hill.

The Alluvial Plain occupies two prominent patches – one in the area south of Shetrunji river and joining the piedmont zone and the other in the Vallbhipur-Umrala region which merges with the salt flats in the west. The drainage in this region is angular, relatively poor and often intersected by lineaments. It comprises of gravel, sand, silt and clay. Though the groundwater development possibility is large in the alluvial plains, however, its quality is unlikely to the potable.

The Salt Flat is the study area is characterised by a thin layer of salt admixed with clay forming flat and extensive surface.

The Piedmont zone exists adjoining dissected hilly terrain. One towards south of Shetrunji river and the other north of Sihor. The contact of piedmont zone with dissected hilly terrain in both the localities appears to be faulted.

The Pediment exists towards the north of Shetrunji river extending northward up to Botad taluka and from Gariyadar taluka in the west to Palitana in the east.

The dissected Hilly Terrain consists of elongated hill ranges of basaltic lava flows representing highly rugged topography. The lava flows are intruded with dykes trending NE-SW, ENE-WSW and NW-SE. The dissected hilly terrain is located in the southwestern, eastern and north-eastern part of Shetrunji river and acts as a basin divide. In regions of moderately dissected Pediplain, numerous dykes exist trending NW-SW, ENE-WSW and NNW – SSE. Drainage is mostly dendritic and stream flows are in southerly and south-easterly directions. There are two denudational hills viz near Palitana and near Mitiala with topographic heights measuring 431 and 473 m amsl.

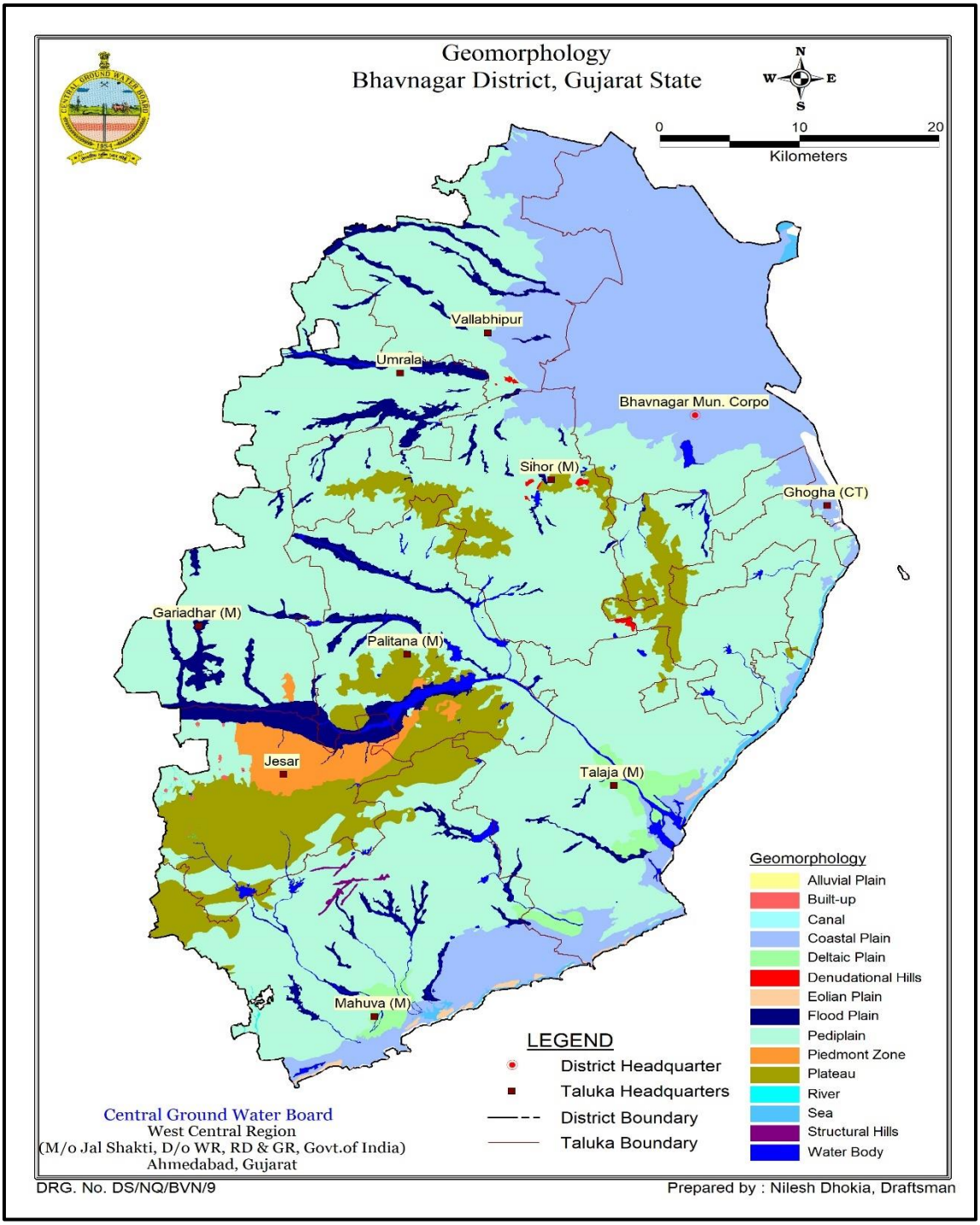


Figure 3 Geomorphological map of Bhavnagar distict, Gujarat state

2.2 Drainage

Bhavnagar district is drained by a number of rivers, namely Shetrunjiriver and its tributaries viz., Kalubhar, Ghelo, Vagad, Kalbi, Padala, Keri, Goma, Utavli, Dhantarvadi, Surajvadi, Melan and Bagad (**Figure 4**). Most streams are ephemeral. The drainage is south-easterly except in Mahuva taluka, where it is drained by southerly flowing streams. Shetrunji is the main river that flows towards Southeast and meets with the Arabian Sea. The river Shetrunji drains the south-central of the district covering Gariadhar, Palitana and Talajatalukas. Originating in the Dundhi hills in the Gir, it enters the district about 1.5 km north of Karjala and flows almost towards east and northeast to east of Palitana and takes a southeasterly turn afterward and debouches in the Gulf of Cambay near Sultanpur. The total length of the river is the district is about 98 km.

The other important rivers that drain the central and northern part of the districts include the Kalubhar, Ghelo, Vagad etc. The above rivers have generally easterly and southeasterly flow and debouch in the marshy land adjoining the Gulf of Cambay in the north-eastern part of the district. The Kalubhar has a total flow length of 45 km, the Ghelo 72 km and the Vagad 38 km in the district. A number of rivers/streams originate and flow in a southerly direction in the southern part of the district south of Shetrunji basin-divide and debouches in the Gulf of Cambay. Important among them are Dhantarvadi, Nadhi, Surajvadi, Nandh, Malan Nadi and Bagad Nadi.

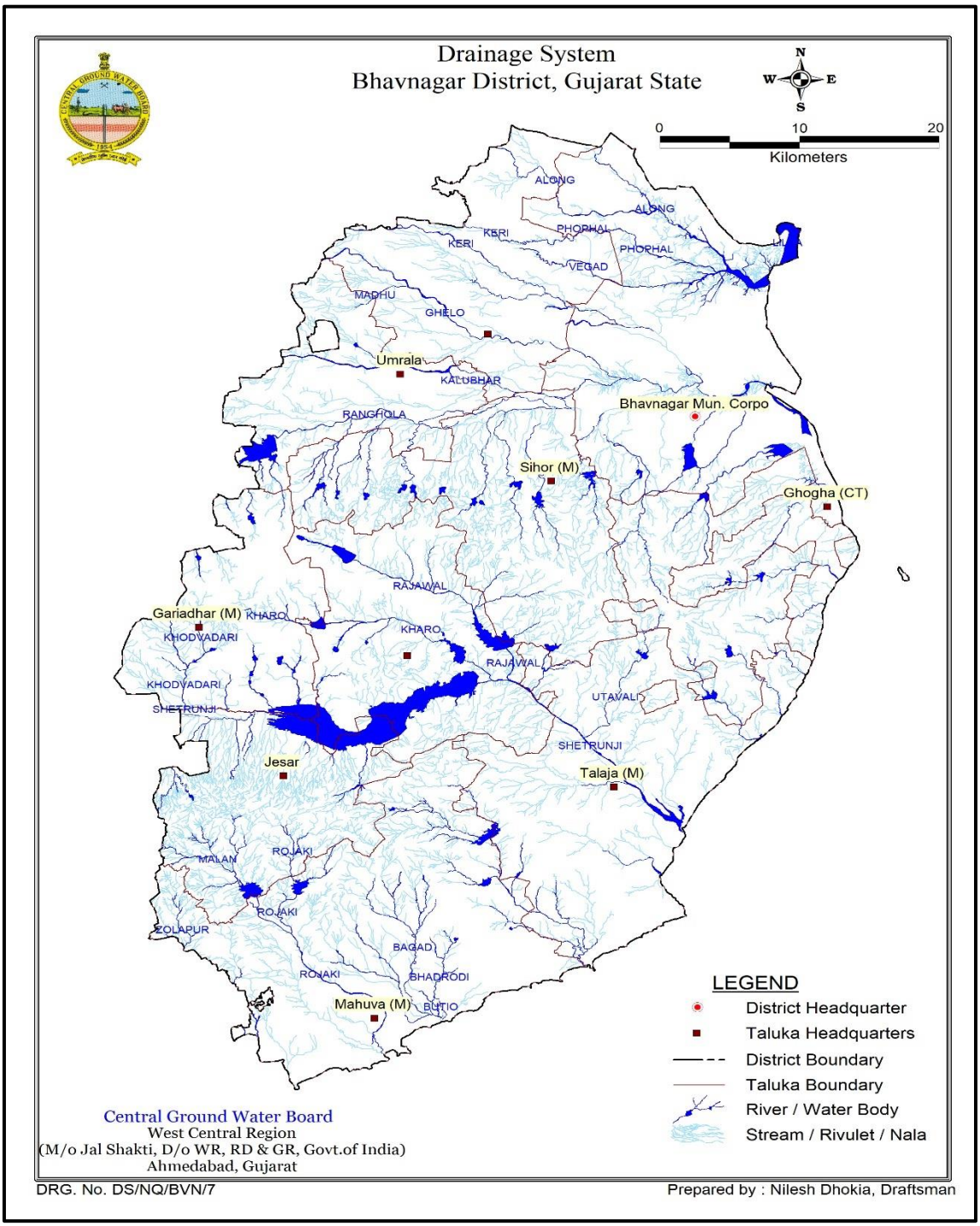


Figure 4 Drainage map of Bhavnagar district, Gujarat state

SOIL, LANDUSE, AGRICULTURE, IRRIGATION AND SURFACE WATER RESOURCES

3.1 Soil

The soils of the district may be broadly classified into following categories

i) Medium black soils
ii) Alluvial soils
iii) Alkaline soils

Medium black soils are wide spread and are found in all the talukas of the district (**Figure 5**). They are more productive and are rich in lime, magnesium and alumina and poor in phosphorous, nitrogen and organic matters. They can retain considerable moisture and are much suitable for agriculture.

Alluvial soils are found along the Shetrunji river covering parts of Gariyadhar and Palitana taluka. Soils in this area are less productive as they are saline. Alkaline soils are found in the parts of Gariyadhar taluka. They consist of both productive and non-productive soils.

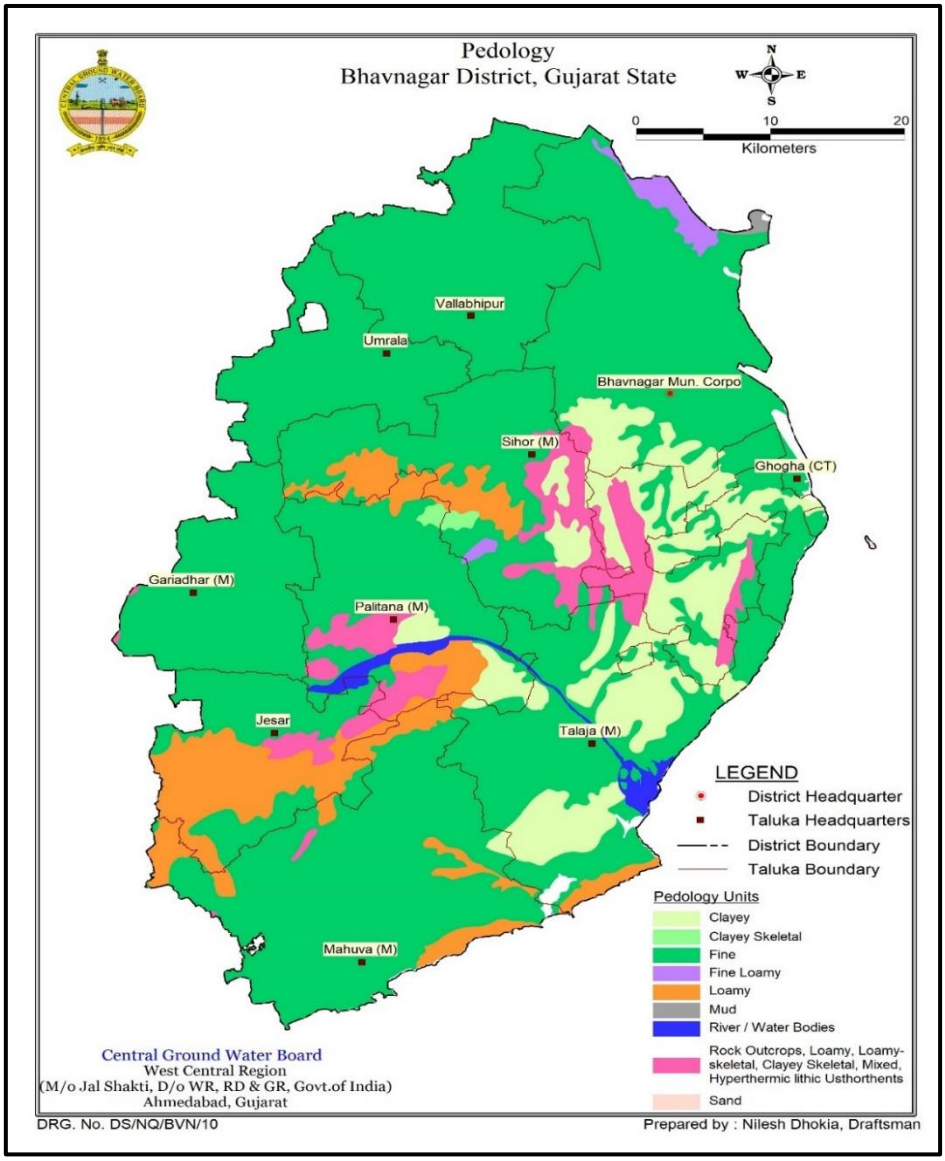


Figure 5 Map showing the soil texture in Bhavnagar district of Gujarat district

3.2 Land Use

As per *Seasons & Crops Record*, 833400 hectares of land, excluding all type of forest & hilly terrain areas, is accounted for land use record. Brief account of land use classification for Bhavnagar district is given in **table 3**. The land use/land cover map of the district is given in **Figure 6**.

Table 3 Bhavnagar District Land use classification

Land use Classification 2019-20 (Area in 00 Hectare)		
Total Geographical Area		8334
Total Reporting Area		6768
Total Forest		305
Not available for cultivation	Land put to Non-agricultural uses	575
	Total Barren and Unculturable Land	134
Other uncultivated land excluding fallow land	Pasture and other Grazing	430
	Land under miscellaneous	02
	Culturable Waste	481
Fallow Land	Other Fallows	12
	Current Fallows	232
Net area sown		4597
Area sown more than once		861
Gross Cropped area		5458

Source: Agriculture Directorate Govt. of Gujarat

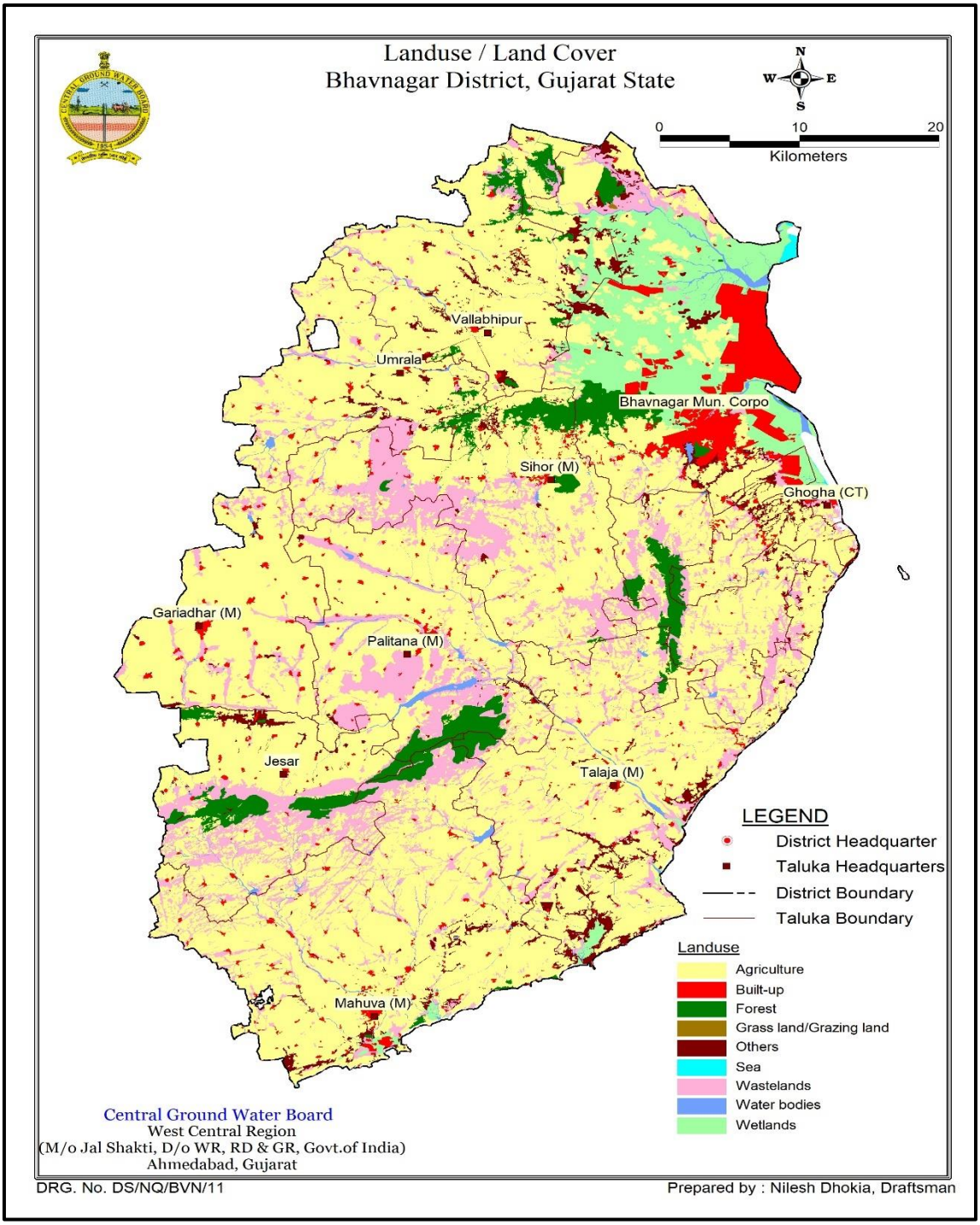


Figure 6 Land use/Land Cover map of Bhavnagar district, Gujarat state

3.3 Agriculture

Bhavnagar district is primarily an agricultural district with cotton, groundnut and wheat as the predominant crops. The other major crops cultivated are Bajra, Sesame, pearl millet, green gram etc. It is interesting to note that the Taluka wise cropping intensity and intensity of irrigated cropping is more than 100% for every Taluka of the district. The crop is divided into two major parts for statistical purpose namely Food and Non-Food crops. The main food crops of the district are Bajra, Wheat and Maize. The main non-food crops are Cotton, Groundnut, Til and Fodder.

3.3.1 Crop Calendar

Month of sowing and harvesting of various crops in the district for the year 2017-18 are given below.

Table 4 Crop calendar of Bhavnagar

S. No.	Crop	Season	Month of sowing	Time of Harvesting
1	Groundnut	Kharif	May-June	Oct-Nov
2	Cotton	Kharif	May-June	Feb-March
3	Sesamum	Kharif	June-July	Oct-Nov
4	Kharif Bajri	Kharif	June-July	Oct-Nov
5	Wheat	Rabi	Oct-Nov	Feb-March
6	Onion	Rabi	Oct-Nov	March-April
7	Cumin	Rabi	Oct-Nov	March-April
8	Coriander	Rabi	Oct-Nov	March-April
9	Sorghum	Rabi	Oct-Nov	Jan-Feb
10	Gram	Rabi	Oct-Nov	Jan-Feb
11	Sugarcane	Rabi	Oct-Nov	Feb-March
12	Moong	Summer	Feb-March	May-June
13	Summer Bajri	Summer	Feb-March	May-June
14	Summer Groundnut	Summer	Jan-Feb	May-June

Source: Pradhan Mantri Fasal Bima Yojana, Ministry of Agriculture and Farmers Welfare

3.4 Irrigation

The irrigated area is broadly classified into four classifications namely irrigation by (a) canal, (b) tank, (c) well (including tubewell) and (d) other sources (like Khettalavadi, Boribandh, Checkdam etc.). The detailed description of Irrigation classification of Bhavnagar district is given in table below.

Table 5 Irrigation classification of Bhavnagar district (Source wise)

Source Wise Irrigation- 2019-2020 (Area '00' Hectare)								
	Canal			Tank	Wells		Other Sources	Total
	Canals Govt.	Canals Private	Total		Tubewells	Other Wells		
Net Area Irrigated	564	0	564	120	230	779	0	1693
Gross Area Irrigated	862	0	862	209	320	1097	0	2489

Source: Agriculture Directorate Govt. of Gujarat

Table 6 Irrigation classification of Bhavnagar district (Crop wise)

Crop Wise Irrigation- 2019-2020 (Area '00' Hectare)		
Sr. No	**Crop**	**Irrigation Area**

1	Total Cereals	248
2	Total Pulses	64
3	Total Spices and Condiments	14
4	Total Fruits	261
5	Total Vegetables	279
6	Total oil seed	89
7	Total Fiber crops	1203
8	Total Fodder crops	331
9	Total non-food crops	1623

Source: Agriculture Directorate Govt. of Gujarat

3.5 Irrigation Projects: Major, Medium and Minor

In the talukas covering under Bhavnagar district, as such no major or medium scheme exists.

3.6 Surface Water Resources

The study area has only one major irrigation scheme namely Shetrunji. Lot of check dams and percolation tanks have been constructed within the study area for the past five years by the state government departments. A medium irrigation dam has been constructed on Shetrunji River near Rajasthali village, about 8 km south of Palitana town. In addition to the above, two minor irrigation dams have been constructed at Manadavada on Rajaval River and Sonpart on Kharo Nadi. The Kallubhar dam that exists in Gadhada taluka across the Kallubar river is also an important minor irrigation dam. The details regarding the catchment area and reservoir level in given in **Table 7**.

Table 7 Classification of Surface water resources, Bhavnagar district, Gujarat state

Sr. No	Irrigation Dams	River	Catchment area at dam site in Km2	Full Reservoir Level in m
1	Shetrunji Dam	Shetrunji River	4317.0	54.84
2	Rajaval Dam	-	287.0	56.75
3	Kharo Dam	Kharo Nadi	241.06	54.12
4	Kallubar Dam	Kallubar River		47.00

CLIMATOLOGY

The area is characterised by tropical climate. Four seasons exists viz. Hot season from March to May, Monsoon season June to September, Post-monsoon season from October to November and Cold season from December to February. The climatological map is given in **Figure 7** and the data is given in **table 8**.

Table 8 Climatological data of Bhavnagar district, Gujarat state

Climatological Data								
Station: Mhauva					**District:** Bhavnagar			
Altitude: 9 mAMSL					**HA** 10	0.7479511		
Latitude: 21º 05' N					**Longitude:** 71$^{0^{o}}$47' E			
Month	**Max Temp (Deg.C)**	**Min Temp (Deg.C)**	**Humidity (%)**	**Wind Spd. Kmpd**	**Sunshine (Hours)**	**Solar Rad. (MJ/m2/d)**	**Eto (mm/d)**	**Rainfall (mm)**
January	30.3	14.1	52.5	129.2	9.70	18.3	4.0	0.7
February	32.2	15.8	51.5	145.4	10.30	21.2	4.9	0.2
March	34.9	19.1	56.0	168.7	9.90	22.9	5.9	6.6
April	36.2	22.2	60.0	204.6	10.50	25.4	6.9	0.1
May	35.6	24.1	70.5	296.2	10.30	25.5	7.0	0.3
June	33.9	25.8	78.5	346.5	7.40	21.0	5.7	112.1
July	31.7	25.0	85.0	312.3	4.00	15.9	4.1	228.4
August	31.0	24.3	86.5	244.1	4.30	16.0	3.8	141.0
September	32.4	23.2	81.5	166.9	6.20	18.0	4.2	114.5
October	35.2	22.0	64.0	131.0	9.40	20.6	5.0	12.7
November	33.8	19.5	56.5	113.1	9.70	18.7	4.2	4.2
December	31.6	16.2	55.5	114.9	9.50	17.3	3.7	1.2
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**622.0**
Average	**33.2**	**20.9**	**66.5**	**197.7**	**8.4**	**20.1**	**4.9**	**51.8**

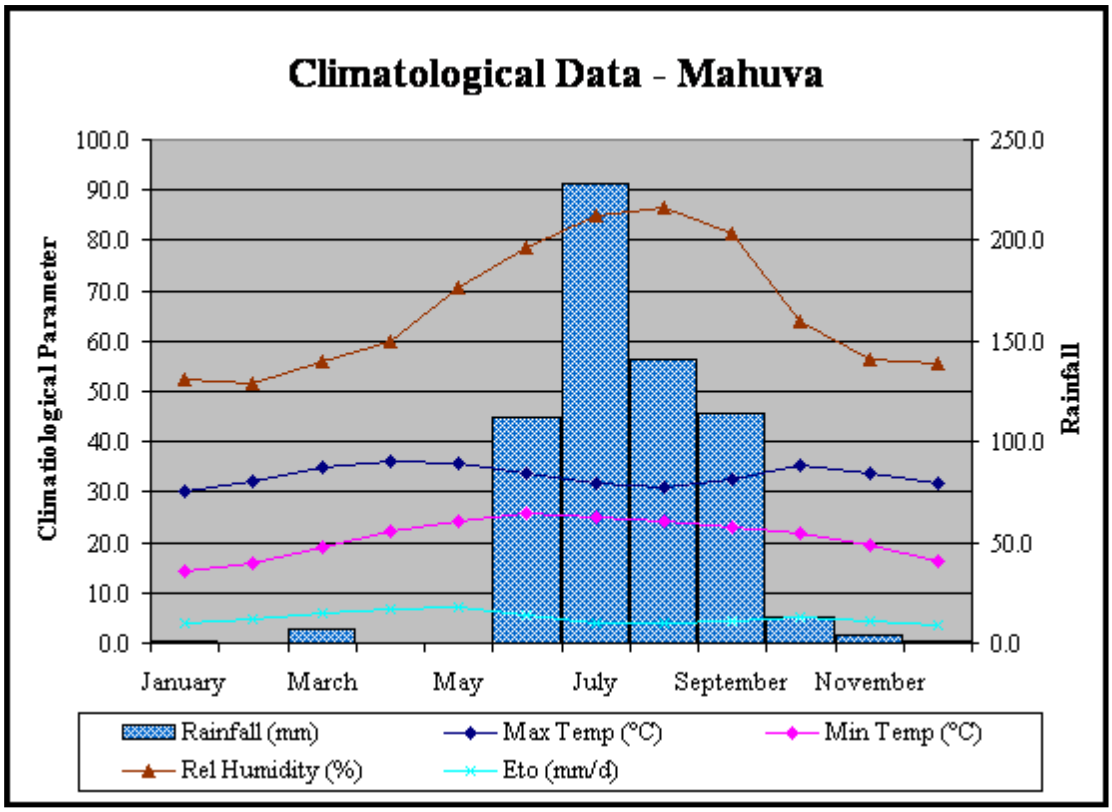


Figure 7 Climatological map of Bhavnagar district, Gujarat state

4.1 Rainfall

The average annual rainfall in the area is about 648.7 mm. Rainfall distribution map is given in **Figure 8** and table of that distribution is in **Table 9**.

Table 9 Annual Rainfall Data for the period 1987–2021

Station / Year	Bhavnagar	Gariadhar	Ghogha	Jesar	Mahuva	Palitana	Sihor	Talaja	Umrala	Vallabhipur
1987	105	189	141	183	286	152	259	214	116	262
1988	761	812	627	883	1256	631	807	538	609	678
1989	573	619	544	689	549	514	619	400	478	560
1990	736	560	851	1011	455	580	755	460	524	634
1991	348	170	380	338	298	241	436	325	264	327
1992	608	968	590	642	513	539	440	710	561	561
1993	446	620	490	745	677	468	512	685	341	318
1994	788	614	675	576	887	675	811	574	691	700
1995	585	221	600	447	297	367	575	366	351	469
1996	637	312	558	590	384	399	478	339	275	318
1997	563	533	671	870	551	657	540	472	669	642
1998	770	363	653	1175	761	560	700	522	541	543
1999	423	248	510	648	309	391	423	388	412	369
2000	173	260	362	451	303	243	349	184	279	227
2001	621	455	507	665	515	572	656	428	523	689
2002	831	642	767	509	596	865	888	649	473	510
2003	537	528	797	506	580	702	497	559	754	558
2004	549	318	718	591	552	617	485	411	480	594
2005	947	630	927	1132	1157	1020	1068	898	846	1235
2006	1033	514	663	754	682	766	926	879	582	840
2007	1371	643	914	1147	954	867	1070	856	1141	1050
2008	997	566	655	818	544	694	845	811	712	680
2009	519	251	460	461	494	462	438	374	448	245
2010	952	618	595	822	763	714	865	842	651	882
2011	687	414	612	686	585	667	582	634	465	594
2012	532	251	443	361	259	446	353	354	416	515
2013	1324	685	917	817	1055	830	983	969	773	851
2014	651	359	516	420	542	354	458	466	596	540
2015	672	366	451	675	592	627	554	493	682	581
2016	668	604	631	753	778	639	499	697	542	660
2017	659	370	503	546	750	735	471	637	566	613
2018	483	178	433	528	745	406	371	615	352	379
2019	1184	502	932	425	873	729	754	617	961	1002
2020	886	470	452	608	768	542	440	432	833	941
2021	904	597	768	586	830	664	460	458	621	599
Min.	-	170	362	-	259	241	349	184	264	227
Max.	-	968	932	-	1157	1020	1070	969	1141	1235

Table 10 Average Annual Rainfall Data for the Period 1987-2021

Station / Year	Bhavnagar	Gariadhar	Ghogha	Jesar	Mahuva	Palitana	Sihor	Talaja	Umrala	Vallabhipur
1980-2011	-	481	630	-	583	590	650	555	542	589
1992-2011	-	486	636	-	605	612	657.4	579.05	559.75	601.2
2001-2011	-	507.2	692.3	-	674.7	722.4	756.4	667.4	643.2	716.1
2011-2020	775	420	589	582	694.7	597.5	546.5	591.4	618.6	667.6

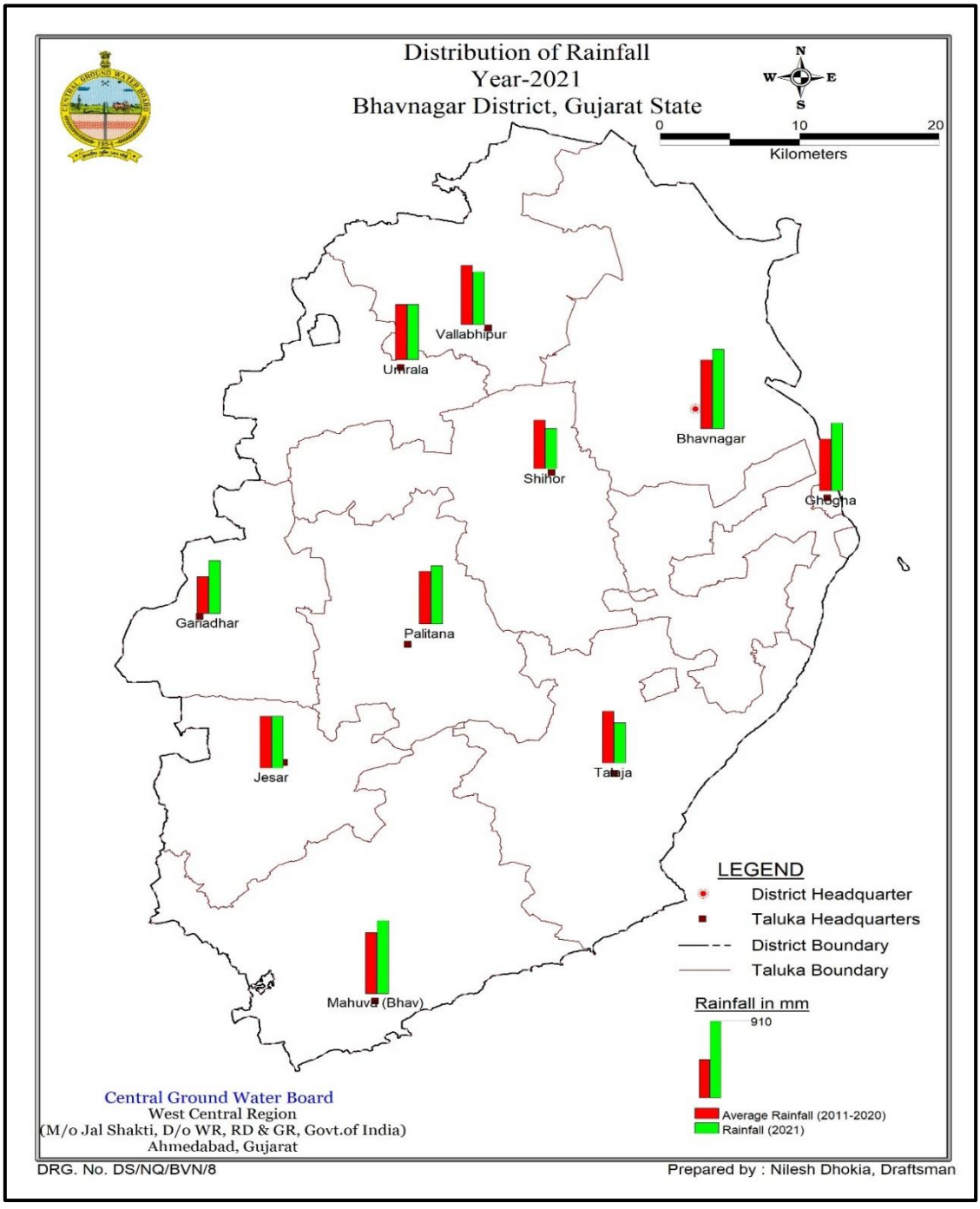


Figure 8 Rainfall distribution map of Bhavnagar distict, Gujarat state

Table 11 Summary of Drought Analysis (1981-2000) - Taluka: Kallubhar, Umralla Taluka.

No of Years	(1981 – 2000) 20 yrs	Type of Drought	Year of Occurrence	Frequency in %
Average	458.9	No Drought	1981, 83, 84,88,89,90,92,94,97 & 98.	50
Standard Deviation	225.78	Mild	1985,86,95 & 99	20
Coefficient of Variation %	49.20	Normal	1982,1991 & 1993	15
Highest Rainfall mm	1073	Severe	1987,1996 & 2000	15
Lowest Rainfall mm	116	Most Severe	Nil	0

Drought analysis carried out from the rainfall data over a period of 20 years revealed that, the average annual rainfall is 491.58 mm with the highest and the lowest rainfall of 1178 and 196 mm during 1988 and 1987 respectively. The area experienced severe drought during 1987. The coefficient of variation and standard deviation for the rainfall period 1981–2000 was 53.44 % and 262.63.

Though the average annual rainfall is 459 mm/yr. as observed in the table above, the field survey year i.e., 2005 – 06 experienced annual rainfall of about 924 mm which is nearly 50 % more than the normal annual rainfall.

4.2 Temperature

The temperature of the study is varying from 25.7 to 41 ° C during the period March to May. As most of the study area comes within Bhavnagar district, the temperature statistics pertaining to Bhavnagar has been taken for discussion. The coldest month is January wherein the temperature varies between 12.6 to 28.6 ° C. The hottest month is May where the temperature varies between 21.6 to as high as 44.5 (**Table 12**)

Table 12 Showing the Minimum and Maximum Temperature of the study area.

Sr. No	Year	January		May	
		Min	Max	Min	Max
1	2001	12.6	28.6	N.A	39.8
2	2002	28.3	N.A	26.9	41.1
3	2003	28.8	15.5	23.6	40.0
4	2004	31.6	9.5	21.6	44.5
5	2005	29	10.4	27.9	42.8

Source: Statistical Abstract of Gujarat state – 2006.

4.3 Humidity

The relative humidity is about 60 % during monsoon season. During other seasons the air remains relatively dry with relative humidity ranging from 20-30%.

4.4 Wind Velocity

Winds are generally light but become more forceful during the late summer and monsoon season. Winds blow mainly from directions between north-west and north-east during October to April and mostly from the South-West and West during the South-west monsoon season.

GEOLOGY

The generalised geological succession is given in the following table: Geologically, 80% of the area is covered by Basalts and the remaining 20 % by alluvial formation and mudflats.

Table 13 Geological succession of Bhavnagar district, Gujarat state

Era	Age	Formation	Lithology
Quaternary	Recent to Sub-Recent	Surface Soil/ Alluvium	Thick beds of calcareous clay, intercalated with layers of trap sand.
--Unconformity--			
Tertiary	Lower Eocene to Upper Cretaceous	Deccan trap	Basalt as stratified lava flows comprising amygdalolidal basalt, fine grained porphyritic basalt and basaltic/doleritic dykes.

5.1 General Geology and Structures

The Deccan trap lave flows is the most extensive geological formation and covers more than 80 % of the study area. In the eastern part, quaternary formation overlies the deccan traps.

5.1.1 Deccan Trap

The Deccan trap encompasses all the intrusive and extrusive acid and basic volcanic formations belonging to upper cretaceous to Paleocene (lower Eocene) age. Deccan traps form highly rugged, undulating to hilly topography and are exposed in the highest reaches, in the western and northern parts rock cut surfaces, nalla courses. In the plain terrain, 1 – 2 m of soils and weathered part cover these formations.

Deccan traps in this area is represented by basalts, both massive and amygdaloidal or vesicular type, dolerite flows, ash beds, basaltic and doleritic dykes. Massive basalt is dark grey or steel grey in colour, very fine grained and compact of basaltic composition.

5.1.2 Dyke

The study area is also characterized by numerous dykes that cut across the prominent feature of the landscape. These dykes vary in thickness/width from less than a metre to more than 15 metres. Number of dykes are traceable for very long distances and are both straight linear and arcuate type, have cut across nature and seams to follow well defined fractures. Fedden (1984) concluded that majority of basaltic flows were derived from fissure eruption, now represented by dykes.

Major part of the district, about 82%, is covered by Deccan Trap lava flows. The trap rock is mostly basalt and dolerite, though, trachytes are also found. at places. The Deccan Trap occurs in the form of lava flows with thickness of individual flows ranging from few meters to more than 30 m. Each individual lava flow can be sub divided into three distinct units - (1) greyish red clay and reddish clayey vesicular basalt, (2) vesicular and amygdaloidal basalt and (3) jointed and massive basalt.

The top of the individual flow is often marked by greyish red to reddish brown clayey material. The thickness of this horizon varies from few centimetres to few metres, at places clayey horizons up to 20 m thickness have also been observed. These horizons are insitu product of weathering and baking of basalt representing a time gap between two successive lava flows. The Vesicular/Amygdaloidal horizons range in thickness from few meters to as much as 10 m. Vesicles were formed due to escape of gas bubbles from the upper part of the flow during cooling of lava. The vesicles are generally filled with secondary minerals like calcite, zeolites and quartz. The lower most horizon of each flow is represented by jointed and massive basalt. This horizon is fine to medium grained, compact dark greenish to grey in colour and forms 60 to 70% of the

flow unit. The upper part of this horizon is often jointed and fractured. At places, the massive basalt is underlain by thin pipe amygdaloidal unit. The lava flows are generally horizontal in disposition. However, in at places, they are found to be dipping by about 7° towards SSE and SSW direction.

The Deccan Trap lava flows have been intruded by a large number of basic and acidic dykes. The basic dykes are generally composed of basalt and dolerite, whereas, the acidic dykes are generally composed of rhyolite and felsite. The doleritic dykes are generally porphyritic in nature. In Saurashtra Region, the dykes generally 2 to 5m thick, but dykes of as much as 250m thickness are also encountered. An acidic dyke, the Kankrej Dyke, is observed north of Shetrunji River near Kankrej. These dykes appear to be structurally controlled are generally oriented in three main directions, i.e., ENE-WSW, E-W and NE-SW.

The joints in Deccan traps are also quite well developed at places. Columnar jointing is also quite common. Principal joint directions observed are N-S, E-W, NE-SW, and NW-SW. The Faults are generally not seen within the basalt out crops, however, there are indications several faults lying below the overlying formations. An east-west trending faults has been observed south of Shetrunji River near trap-alluvium contact. The Deccan traps in the study area include layers of lava flows such as basalt, dolerite, felsite etc.

5.1.3 Quaternary Formations

The Quaternary formations in the area are represented by clays (fuller's earth), marls, limestones. This formation overlies deccan traps.

5.1.4 Recent to Sub-Recent Formations

The recent and sub-recent formations in the district are sand dunes, coastal & beach sands, tidal mud flats, coral reefs occurring in the coastal areas and fresh water alluvium occurring mainly along the rivers and streams.

The alluvium mainly occurs in the central parts of the district along the Shetrunji River. Here it has a thickness ranging from few meters to about 50 m. The alluvium which primarily rests of the basalt mainly comprise of the sand and clays along with the carbonate nodules (kankar) and weathered pieces of basalt. Weathering of basalt has also given rise to black cotton soils and generally it is difficult to distinguish between insitu weathering product of basalt and alluvium.

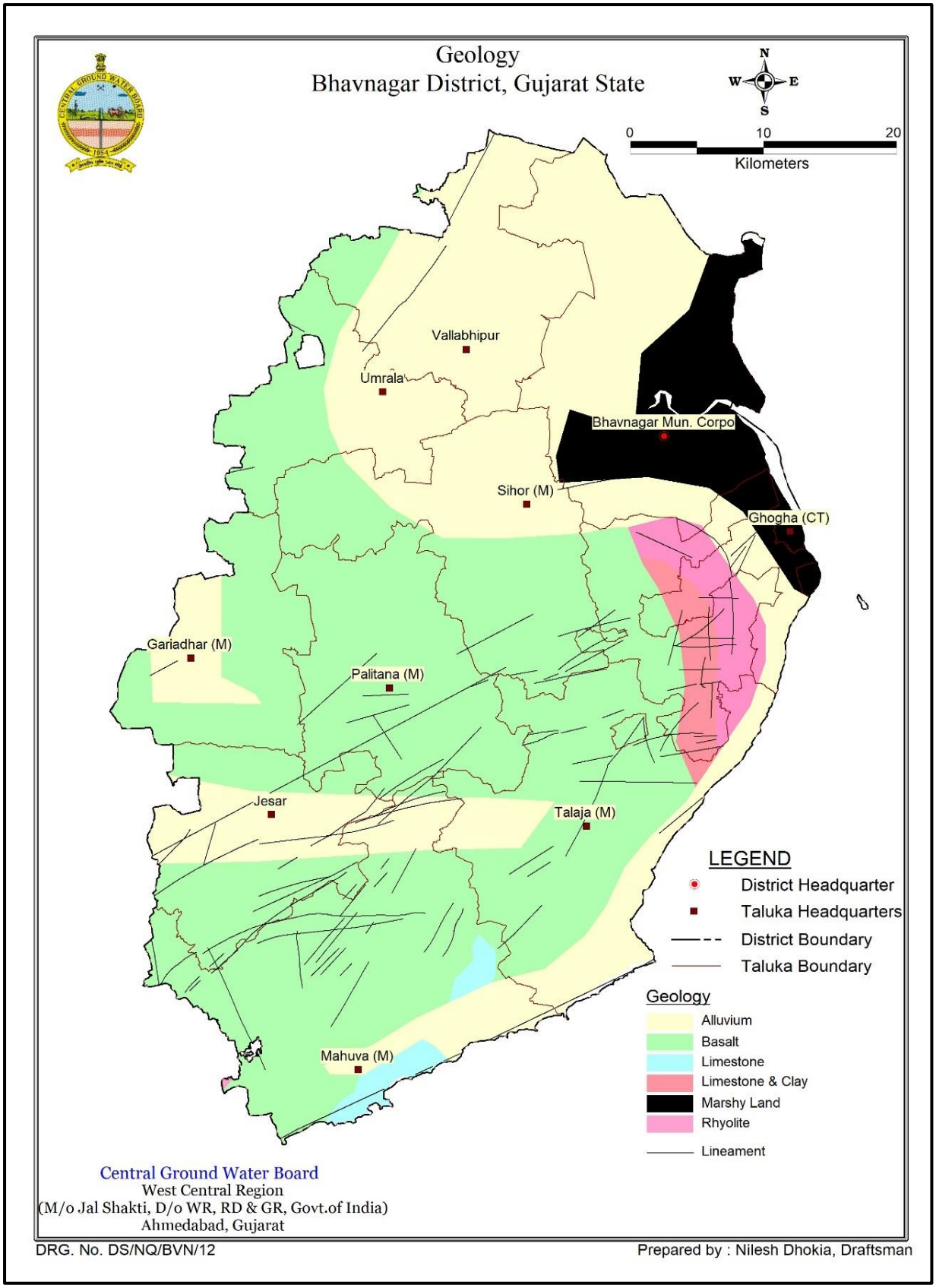


Figure 9 Geological map of Bhavnagar district, Gujarat state

HYDROGEOLOGY

The Deccan trap and Quaternary formations form the aquifer within the district. Groundwater occurs under water table and semi-confined conditions. Dug and dug cum bore well are common structures used for groundwater extraction.

6.1 Quaternary Formation

The area around Panvi in the east has shallow to moderately thick quaternary formation (Post – Miocene) overlying thick Deccan trap. It constitutes about 5 % of the total area covered and consists of clays, marl, chert and sand gravel.

Groundwater in these formations occurs under unconfined conditions. The occurrence and movement of groundwater is controlled by primary as well as secondary porosity.

6.2 Dykes/Lineaments

The presence of many dykes and lineaments in the study area are suggestive of large-scale tectonic disturbances experienced in the past. Dykes generally form linear hills and are demarcated due to relief. The subsurface dykes and fracture do appear in the form of lineament. The dykes in general do not form the aquifer, unless highly fractured and thus mostly act as groundwater barrier. The associated fracture zone and the basaltic formation adjacent to dykes have comparatively higher porosity.

6.3 Deccan Trap

Deccan trap basalt occupies a major part of the district and forms the most extensive aquifer system. It generally forms a poor aquifer due to compactness and poor primary porosity. However, the upper weathered parts, which at places are up to 20 m thick, form good aquifer in the district. At deeper levels, the secondary porosity developed as a result of tectonic activities, in the form of joints, and fractures, shear zones, form repository of groundwater at many places. Amygdaloidal horizons within basalt also form potential aquifers at places. The dykes, both basaltic and doleritic, play an important role in occurrence and movement of groundwater. At places, the dykes are highly weathered and themselves form potential aquifers. At other places where the dykes are more compact, they act as subsurface barrier for the groundwater flow and well-constructed upstream of these dykes have good yields.

6.4 Alluvium

The alluvium forms very potential aquifer, particularly in the central part. The wells in alluvium range in depth from 4 to 50 m bgl. Drilling of horizontal bores in the wells to increase the yields is quite common. Such horizontal bores generally have 2.5 to 5 cm of diameter and extend laterally to 10 to 15 m. The yield of wells ranged between 10 and 820 m^3/day.

DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities (**Table 14**).

Table 14 Brief activities showing data compilation and generations

Sr.No	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification	Compilation of Existing data on groundwater.	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters Including fluoride.
3	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to Administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

7.1 Data Generation

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs and Electrical logs of Exploratory wells studies carried out and used in prepare a hydro geological cross section, Fence diagram and 3D Model. The data has been analysed using Rockworks 16 software and is presented below in the Hydrogeological cross sections A-A' to E-E' and Solid Model of the district showing the depiction of Aquifer Groups and Aquitard up to 200 m. The stratigraphic sections depicting unconfined aquifer, Confined Aquifer for alluvium and weathered aquifer & fractured aquifer for Basaltic rock are placed at **Figures (11 to 14)**. Fence Diagram and 3D Solid Model of district is depicted in **Figure 15** and **Figure 16**, respectively.

Table 15 Data integration in respect to Bhavnagar district

Type of Data & source	No of Wells
Aquifer Disposition	
CGWB	**14**
Long term Fluctuation	
CGWB+GWRDC	**70+81**
Decadal Analysis water Level	
CGWB+GWRDC	**40+87**
Analysis of water Quality	
CGWB	**78**

7.2 Conceptualization of Aquifer system in 2D

A total of 31 exploratory wells and piezometers lithologs are utilized to decipher the subsurface geometry of the aquifer by using Rockworks 16 software prepared hydro geological cross sections, Fence diagram and 3D Model up to the depth of 200 mbgl. And six hydrogeological cross sections (2D) are drawn in different direction to cover entire area as per the availability of data point in the district and represented in figure 11 (A-A') to figure 16 (F-F').

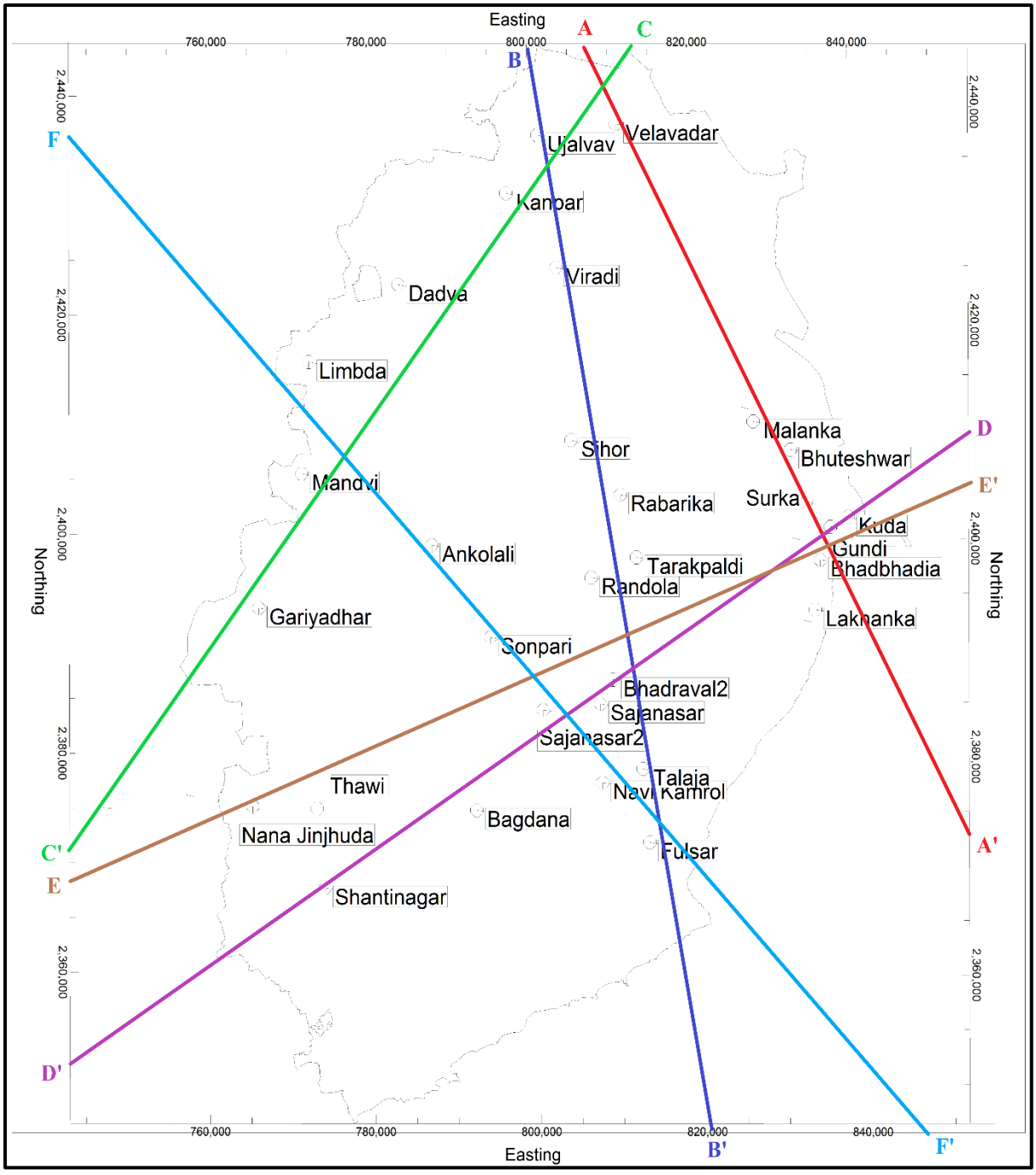


Figure 10 Map showing drawn section lines

1. Section A-A' (Figure 11)- Section is drawn roughly NW-SE direction and in between Velavadar and Lakhanka passing through Malanka, Bhuteshwar, Surka, Kuda, Gundi, and Bhadbhadia. Section is represented Stratigraphically; from section it is deciphered that Soft rock formation forms the major aquifer system in the district and rested on the hard rock (fractured/weathered) along drawn section line.

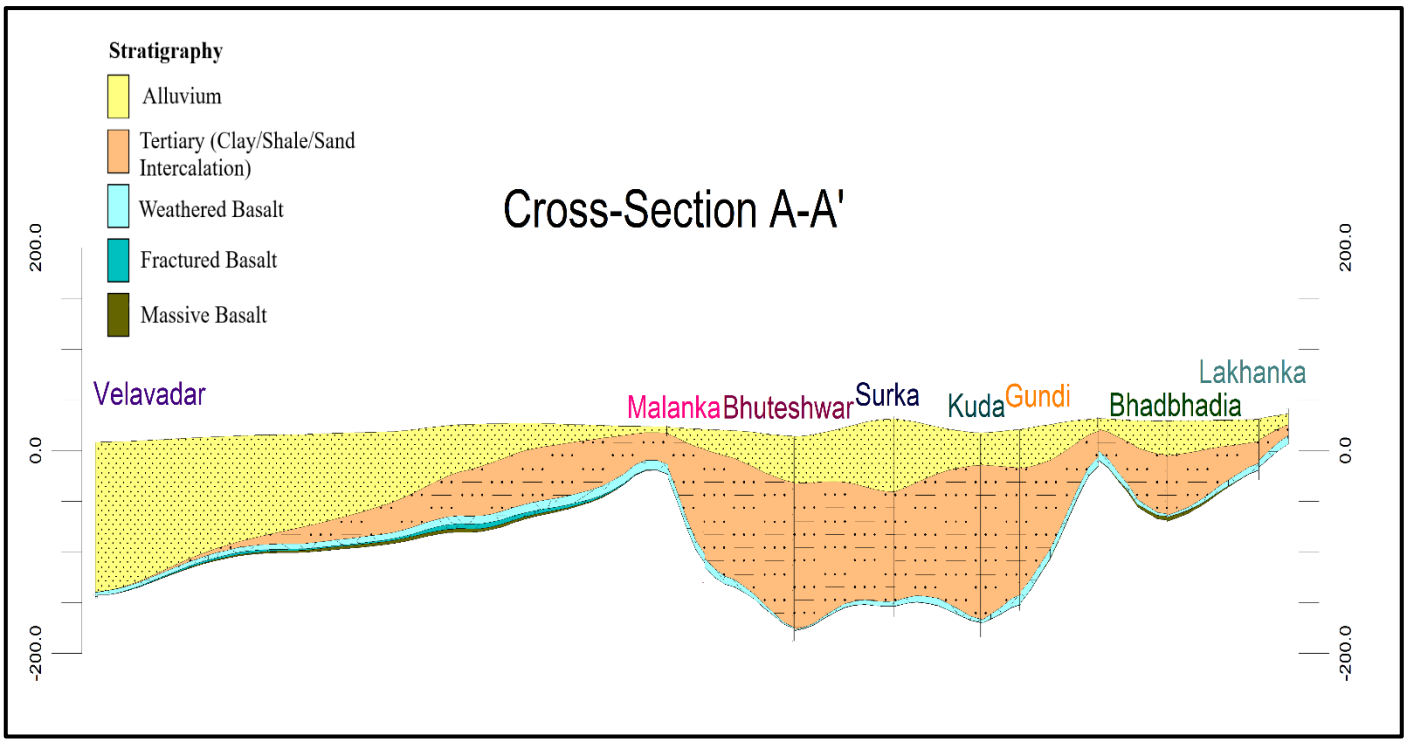


Figure 11 Hydrogeological cross section between Velavadar and Lakhanka (A-A')

2. Section B-B' (Figure 12)- Section is drawn roughly NW-SE direction and in between Ujalvav and Fulsar passing through Viradi, Sihor, Rabarika, Tarakpaldi, Randola, Bhadraval2, and Talaja. Section is represented Stratigraphically; from section it is deciphered that Soft rock and hard rock (fractured/weathered) formation forms the major aquifer system in the district and rested on the hard rock (fractured/weathered) along drawn section line. The Alluvium forms an aquifer system in Ujalvav and Viradi village and Hard rock formation (weathered & fractured) forms the major aquifer system in rest of

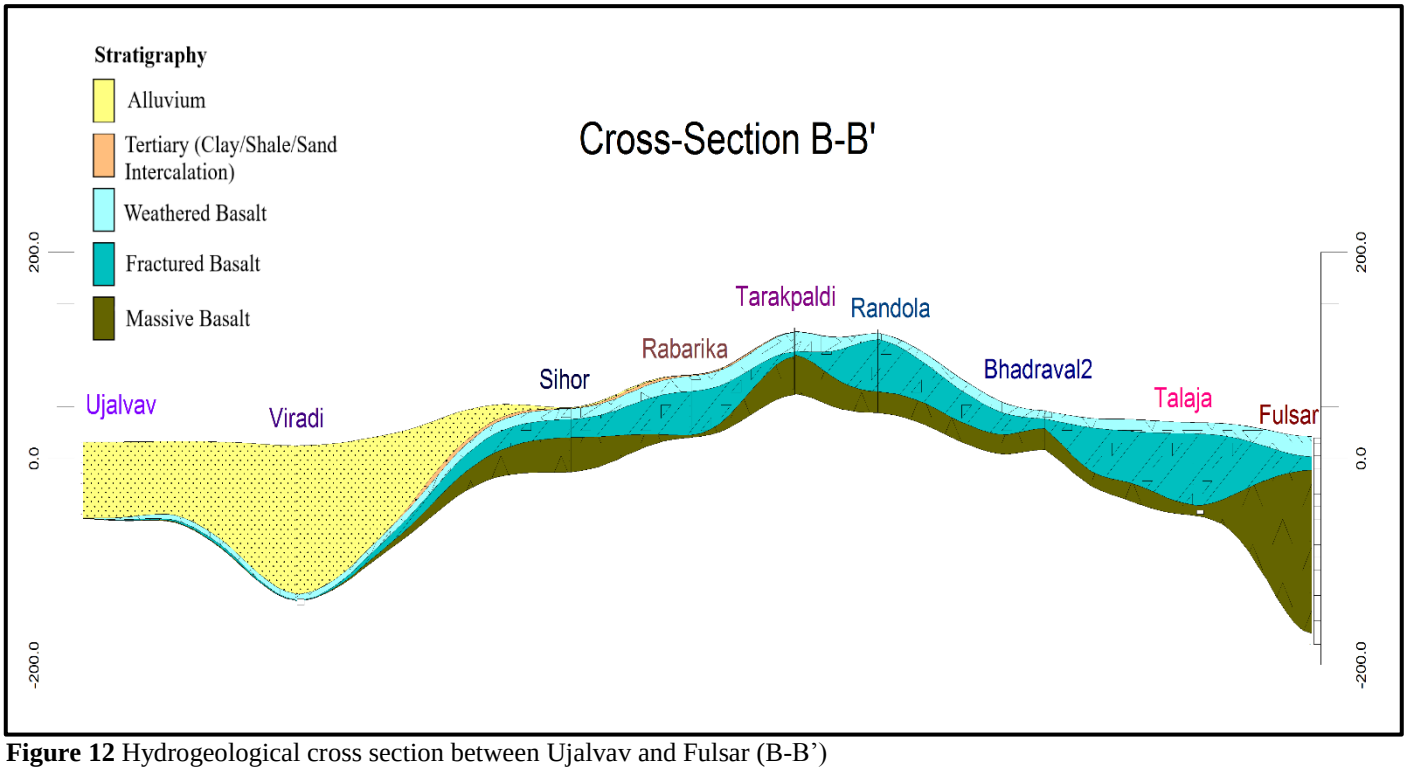


Figure 12 Hydrogeological cross section between Ujalvav and Fulsar (B-B')

the villages along drawn section line.

3. Section C-C' (Figure 13)- Section is drawn roughly NE-SW direction and in between Velavadar and Thawi, passing through Ujalvav, Kanpar, Dadva, Limbda, Mandvi, and Gariyadhar. Section is represented Stratigraphically, from section it is deciphered that Alluvium forms an aquifer system in Velavadar, Ujalvav, and Kanpar village of Bhavnagar district and Hard rock formation (weathered & fractured) forms the major aquifer system in rest of the areas along the drawn section line. The alluvium and hard rock (weathered/ fractured) rested on hard rock (weathered/fractured) and massive rock respectively, along

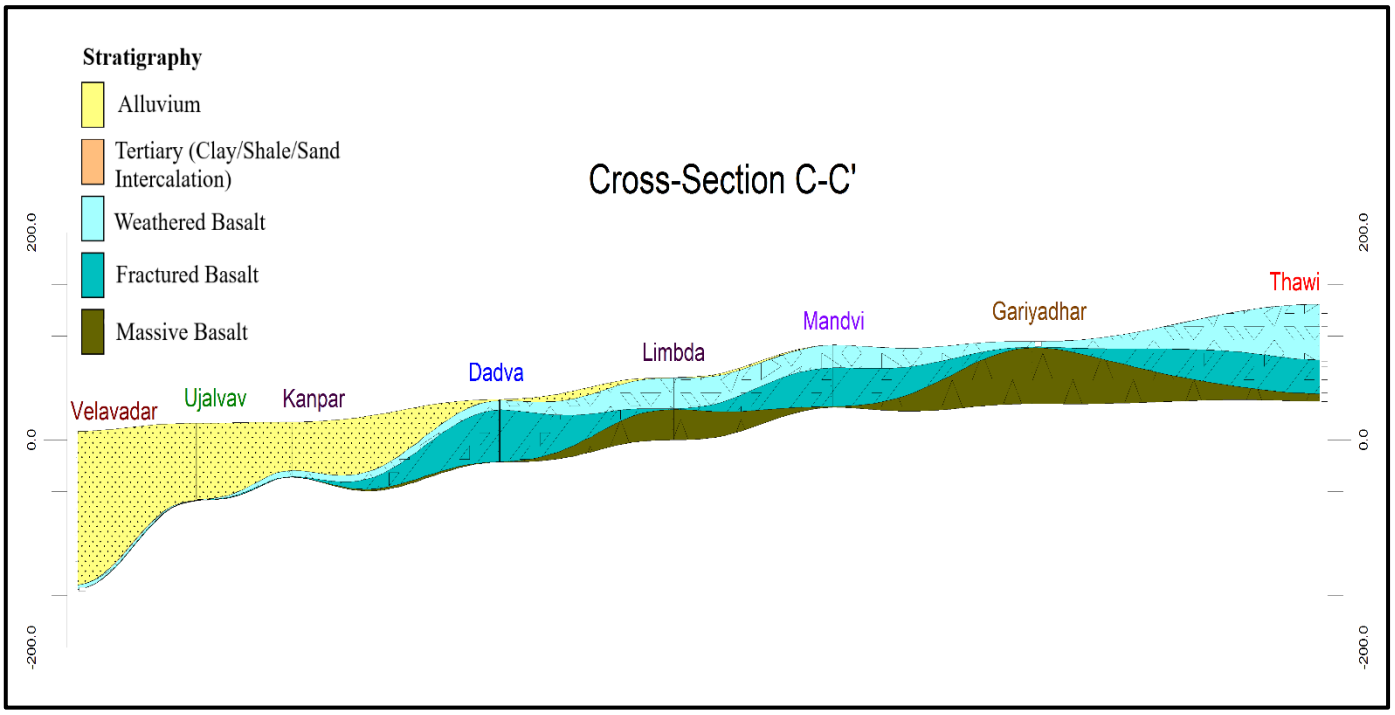


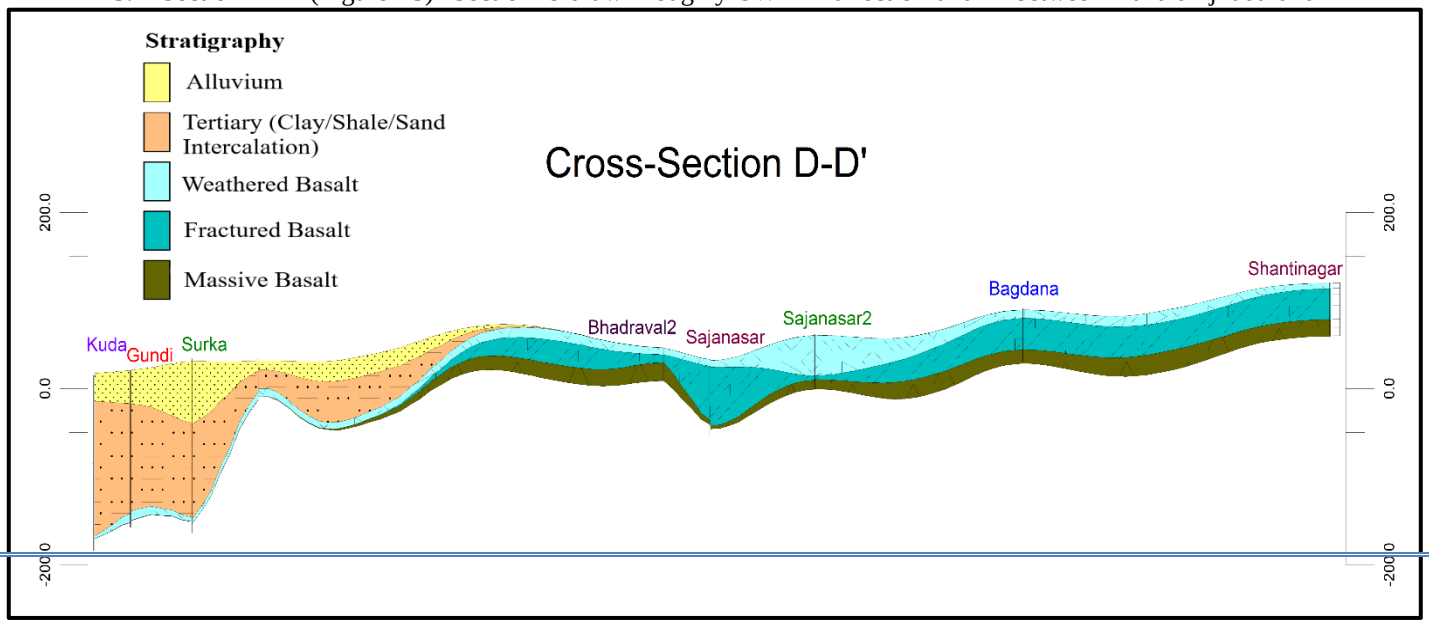
Figure 13 Hydrogeological cross section between Velavadar and Thawi (C-C')

drawn section line.

4. Section D-D' (Figure 14)- Section is drawn roughly NE-SW direction and in between Kuda and Shantinagar, passing through Gundi, Surka, Bhadrawal2, Sajanasar, Sajanasar2, and Bagdana. Section is represented Stratigraphically; from section it is deciphered that Hard rock formation (weathered & fractured) forms the major aquifer system in the district and Alluvium forms an aquifer system in Kuda, Gundi, and Surka village. The alluvium and hard rock (weathered/ fractured) rested on hard rock (weathered/fractured) and massive rock respectively, along drawn section line.

Figure 14 Hydrogeological cross section between Kuda and Shantinagar (D-D')

5. Section E-E' (Figure 15)- Section is drawn roughly SW-NE direction and in between Nana Jinjhuda and



Kuda, passing through Thawi, Sonpari, Randola, Tarakpaldi, Bhadbhadia, and Gundi. Section is represented Stratigraphically; from section it is deciphered that Hard rock formation (weathered & fractured) forms the major aquifer system in the district and Alluvium forms an aquifer system in Bhadbhadia, Gundi, and Surka village. The alluvium and hard rock (weathered/ fractured) rested on hard rock (weathered/fractured) and massive rock respectively, along drawn section line.

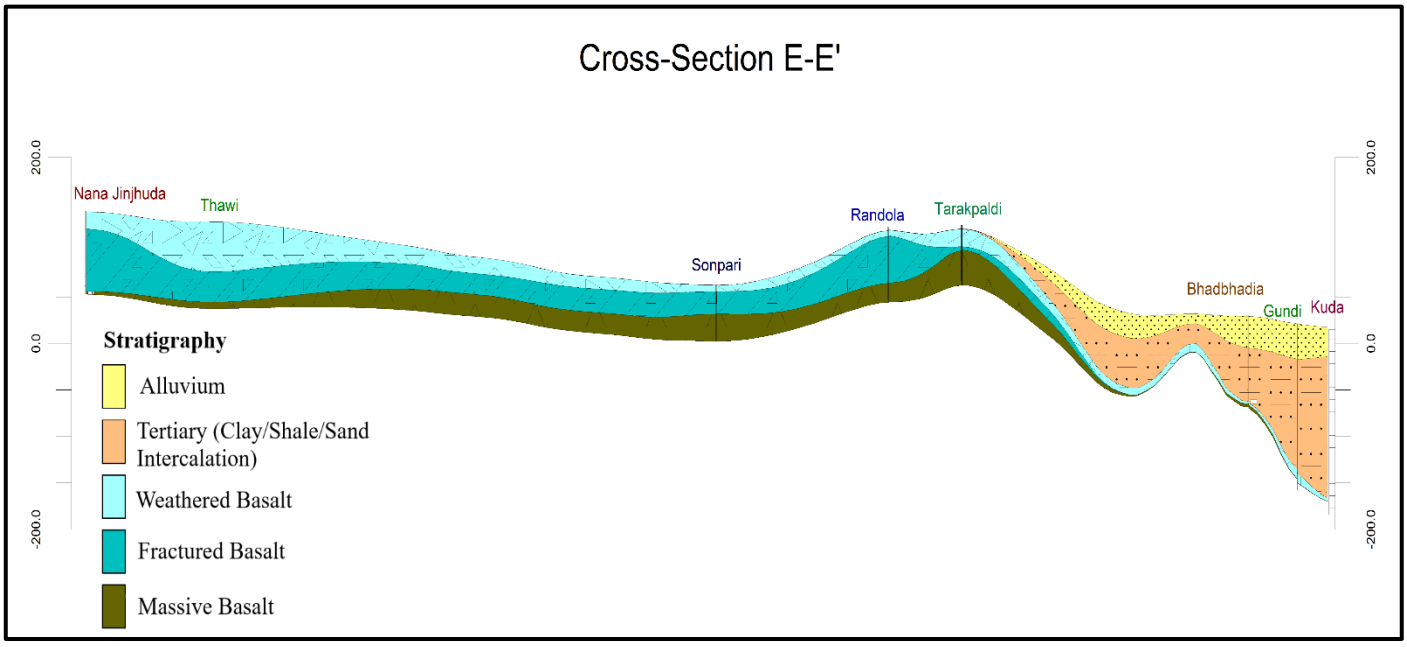


Figure 15 Hydrogeological cross section between Nana Jinjhuda and Kuda (E-E')

6. Section F-F' (Figure 16)- Section is drawn roughly NW-SE direction and in between Limbda and Fulsar, passing through Mandvi, Ankolali, Sonpari, Sajanasar2, Sajanasar, Navi Kamrol, and Talaja. Section is represented Stratigraphically; from section it is deciphered that hard rock formation (weathered & fractured) forms the major aquifer system in the district and rested on massive rock along drawn section line.

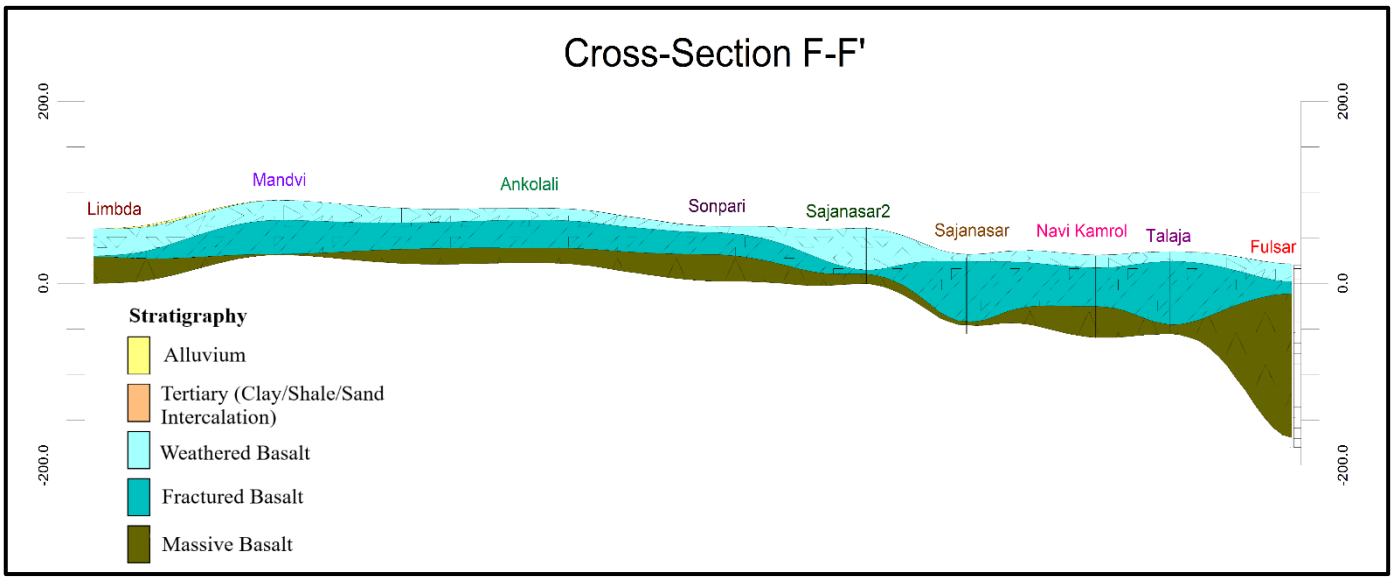


Figure 16 Hydrogeological cross section between Limbda and Fulsar (F-F')

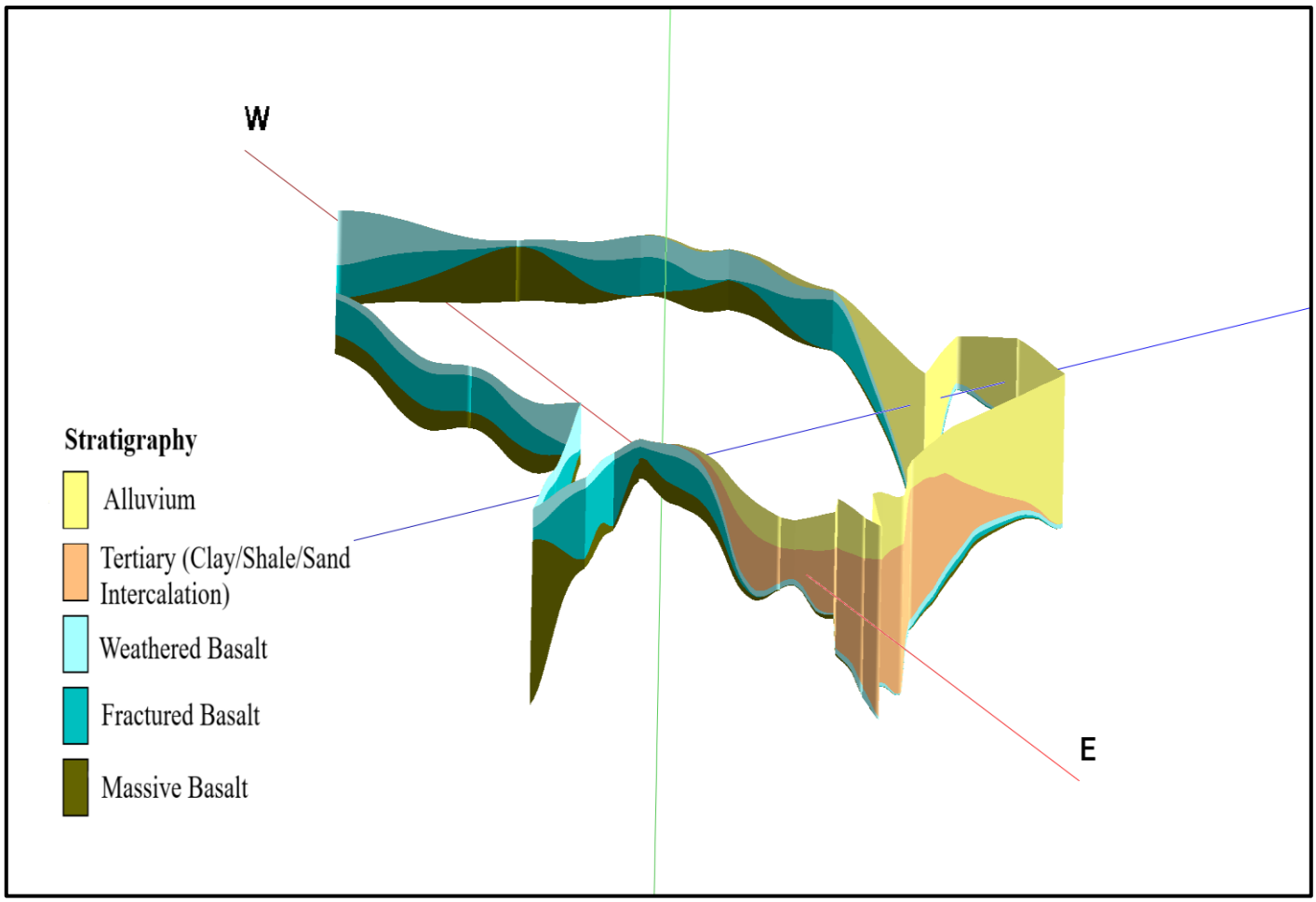


Figure 17 Fence diagram of Bhavnagar district

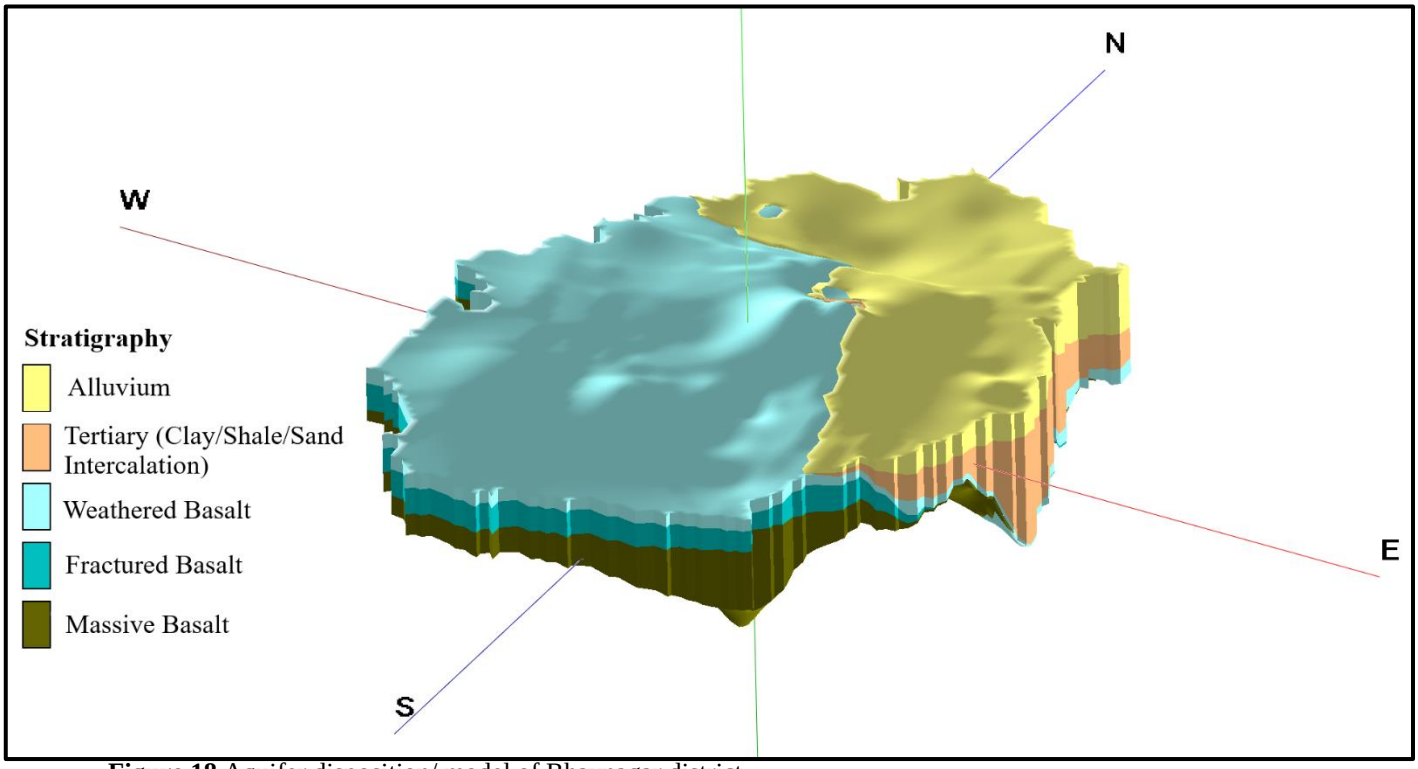


Figure 18 Aquifer disposition/ model of Bhavnagar district

Table 16 Aquifer characterization and disposition of Bhavnagar district

Aquifer Characterisation and Disposition (Bhavnagar)										
Stratigraphy	**Aquifer Nomenclature**	**Lithological**	**Depth of occurrence**	**Thickness**	**Water Level (mbgl)**	**Quality**	**Discharge**	**Transmissivity**	**Nature of Aquifer**	**Remarks**
						EC				
		Characteristics	**Aquifer**	**Range**	**Range**	**Range**	**Range**	**Range**		
			(mbgl)	**(m)**	**(mbgl)**	**mg/l**	**lps**	**m^2/day**		
Quaternary	**Alluvium**	sand and clays along with the carbonate nodules (kankar).	0 to 148	3 to 62	3.5 to 77.11	940 to 4106	2 to 7		Phreatic to confined	Good to brackish quality
Tertiary	**Clay/Shale/Sand Intercalation**	Thick bed of clay and shale intercalated with the lenses of sand.	40 to 200	13 to 34	7.0 to 23.53	2531 to 41178	1.1 to 3.93	22.19 to 84.67	Phreatic to confined	Good to Saline quality
	Weathered Basalt	Basalts, both massive and amygdoidal or vesicular type, dolerite flows, ash beds,basaltic and dolerite dykes.	0 to 200	4 to 34	3.25 to 13.3	1400 to 4106	2 to 12		Phreatic to confined	Good to brackish quality
	Fractured Basalt		5 to 86	14 to 52	4.29 to 37.72	680 to 2960	0.3 to 6	7.41 to 39.88	Semi-confined	Good quality

GORUNDWATER SCENARIO

8.1 Quaternary Formation

The area around Panvi in the east has shallow to moderately thick quaternary formation (Post – Miocene) overlying thick Deccan trap. It constitutes about 5 % of the total area covered and consists of clays, marl, chert and sand gravel.

Groundwater in these formations occurs under unconfined conditions. The occurrence and movement of groundwater is controlled by primary as well as secondary porosity. Table below shows the statistics of the dugwells of Vallabhipur taluka that exists within the quaternary formation.

The yield of the dugwells ranged between 170 m^3/day to 800 m^3/day. Lateral bores are also drilled in the dugwells to enhance the yield.

8.2 Dykes/Lineaments

The presence of many dykes and lineaments in the study area are suggestive of large-scale tectonic disturbances experienced in the past. Dykes generally form linear hills and are demarcated due to relief. The subsurface dykes and fracture do appear in the form of lineament. The dykes in general do not form the aquifer, unless highly fractured and thus mostly act as groundwater barrier. The associated fracture zone and the basaltic formation adjacent to dykes have comparatively higher porosity.

8.3 Deccan Trap

Deccan trap basalt occupies a major part of the district and forms the most extensive aquifer system. It generally forms a poor aquifer due to compactness and poor primary porosity. However, the upper weathered parts, which at places are up to 20 m thick, form good aquifer in the district. At deeper levels, the secondary porosity developed as a result of tectonic activities, in the form of joints, and fractures, shear zones, form repository of groundwater at many places. Amygdaloidal horizons within basalt also form potential aquifers at places. The dykes, both basaltic and doleritic, play an important role in occurrence and movement of groundwater. At places, the dykes are highly weathered and themselves form potential aquifers. At other places where the dykes are more compact, they act as subsurface barrier for the groundwater flow and well-constructed upstream of these dykes have good yields.

The groundwater in basalt occurs under phreatic to confined conditions. The groundwater is generally tapped through dug wells varying in depth from 5 to 30 m. At places, dug-cum-bored wells are also constructed by drilling bores below the bottom of dug wells. The yield of dug wells and dug-cum-bored wells in basalt generally range from 100 to 500 m^3/day. During Rabi (post monsoon) season these wells sustain intermittent pumping of 15 minutes to 12 hours, however, during summer, the yield of these wells is considerably diminished. The vesicular & amygdaloidal horizons within basalt at places may have yields of up to 1000 m^3/day.

The dykes occurring in the district form aquifers at places wherever they are highly fractured. The wells in such dykes range in depth between 5 and 25 m and the yield of wells range between 15 and 600 m^3/day.

8.4 Alluvium

The alluvium forms very potential aquifer, particularly in the central part. The wells in alluvium range in depth from 4 to 50 m bgl. Drilling of horizontal bores in the wells to increase the yields is quite common. Such horizontal bores generally have 2.5 to 5 cm of diameter and extend laterally to 10 to 15 m. The yield of wells ranged between 10 and 820 m^3/day.

8.5 Basalt

The **basalts** are moderately weathered to 2 – 5 m bgl. The groundwater occurs within the less to moderately jointed basalts. The yield of the dugwells in the basaltic terrain is 200 – 250 m3/day. The sp. Yield

varied between 0.3 % to 14 % with an aquifer transmissivity varying between 2 and 250 m2/day. At places, highly productive zones are encountered and are attributed to the secondary porosity developed by fracturing or interflow zones. The groundwater quality is generally good with the EC varying between 300 and 2000 µS/cm.

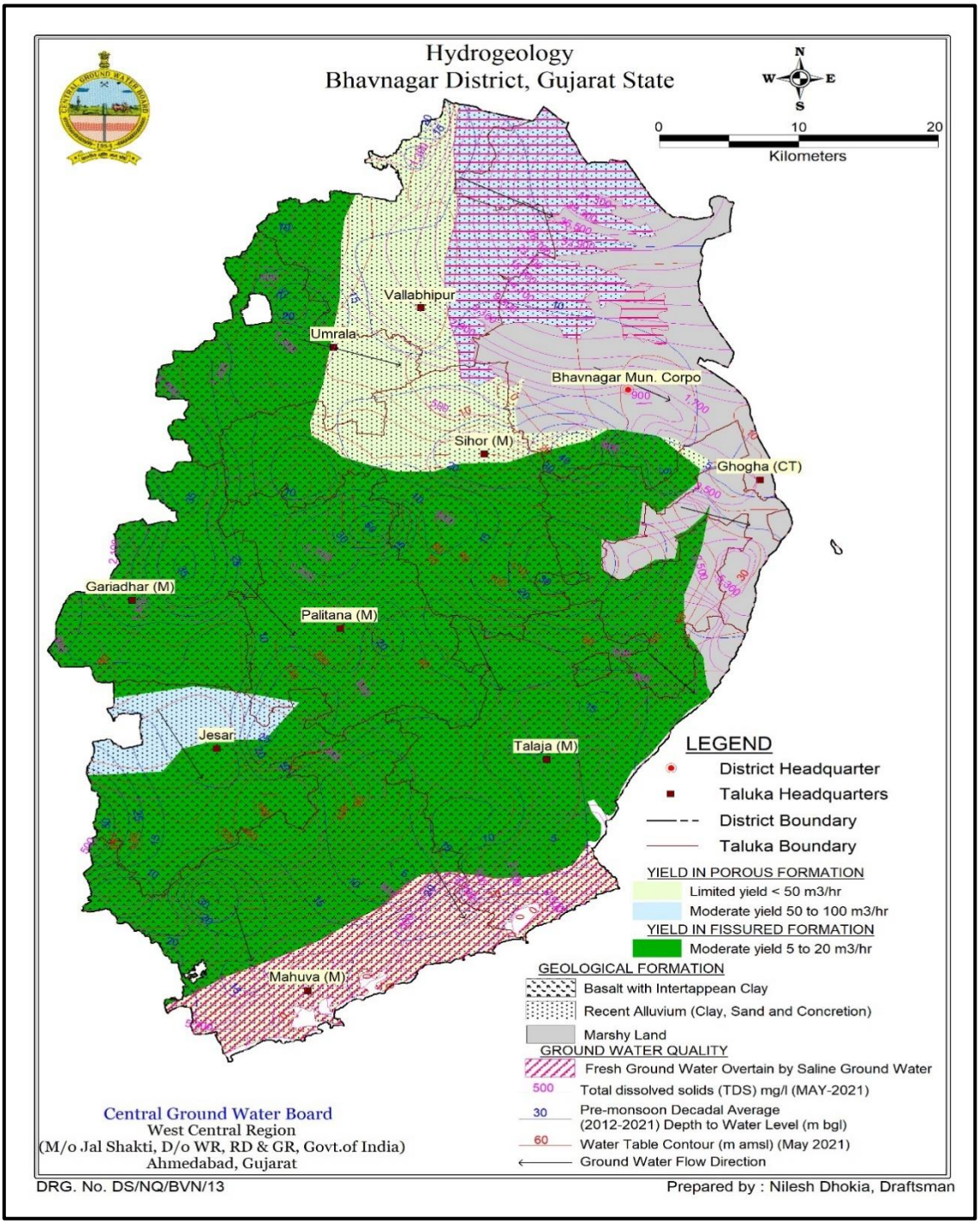


Figure 19 Map showing the Hydrogeological setup of Bhavnagar District

GROUNDWATER REGIME MONITORING

Ground water regime monitoring is the basic component of groundwater management, and it is carried out in Bhavnagar district four times a year, during January, May, August and November through 42 National Hydrograph Network Stations (NHS) and also for NAQUIM studies Pre-Monsoon and Post-Monsoon (2021). Depth to water level map of pre monsoon and post monsoon period and annual fluctuation of water level are prepared with data of NHS.

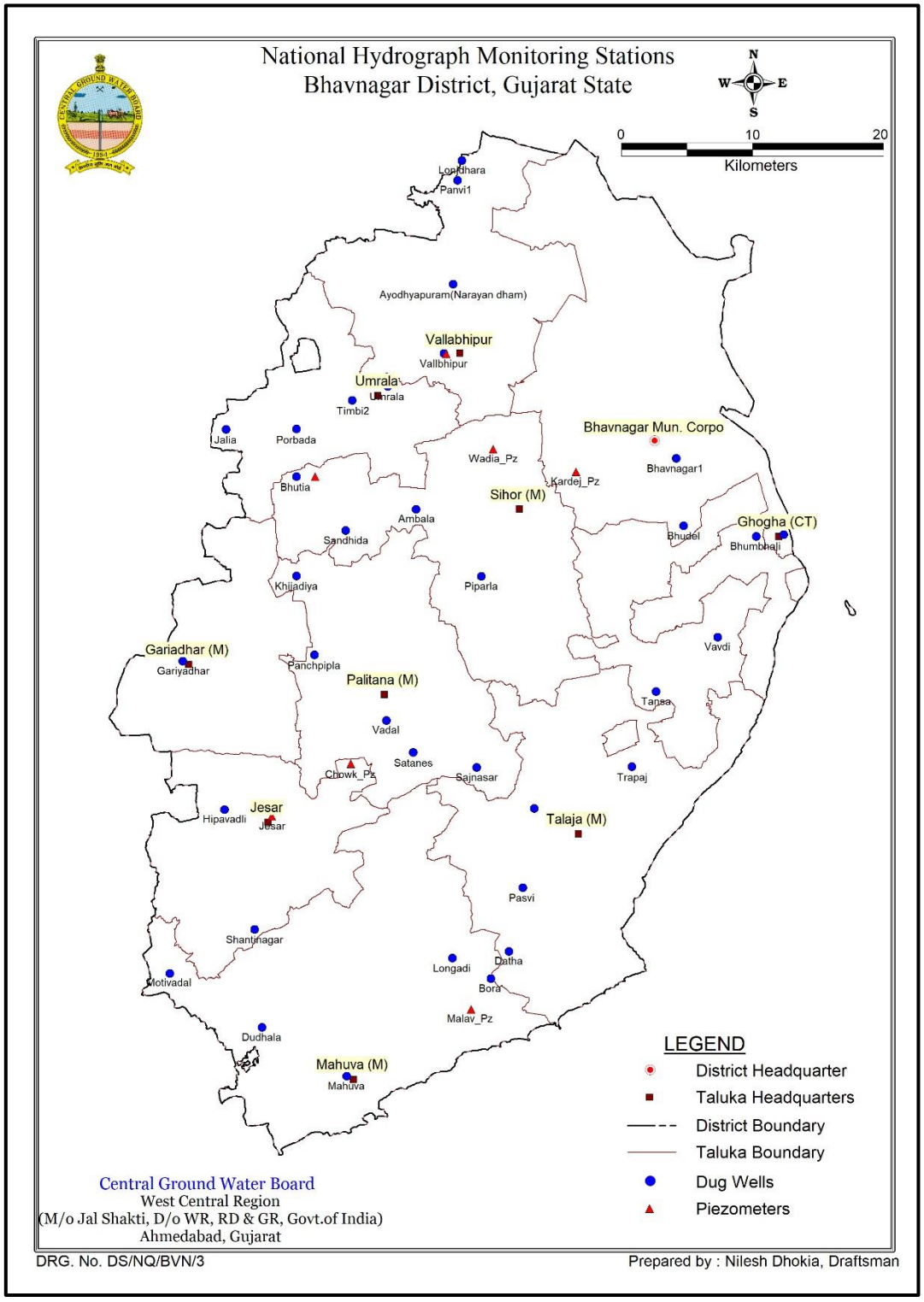


Figure 20 National Network of Hydrograph Stations of Bhavnagar District

9.1 Behaviour of Water Levels

The behaviour of water levels was studied based on the water level data collected from the National Network of Hydrograph Stations (NNHS). The water level data of May 2021 and November 2021 was used for preparing the depth to water level maps. The seasonal fluctuation in water levels was calculated between May and November 2021. Total 167 nos. of monitoring stations including 87 nos. monitoring station of Gujarat Water Resources Development Corporation (GWRDC) were taken during preparation of maps.

9.1.1 Depth to Water Level (Pre-monsoon)

Pre monsoon depth to water levels of Bhavnagar district is shown in the (**Figure 19**), which depict that water levels in most part of the district ranges in between 05m bgl to 20m bgl. Small patch in boundary region of Bhavnagar-Ghogha, Sihor-Palitana, and Gariyadhar-Umrala taluka shows deeper water level of more than 20 m bgl. Bhavnagar taluka shows small patch of water level deeper than 40m bgl. Shallow water level is observed in patches in almost all talukas of the district.

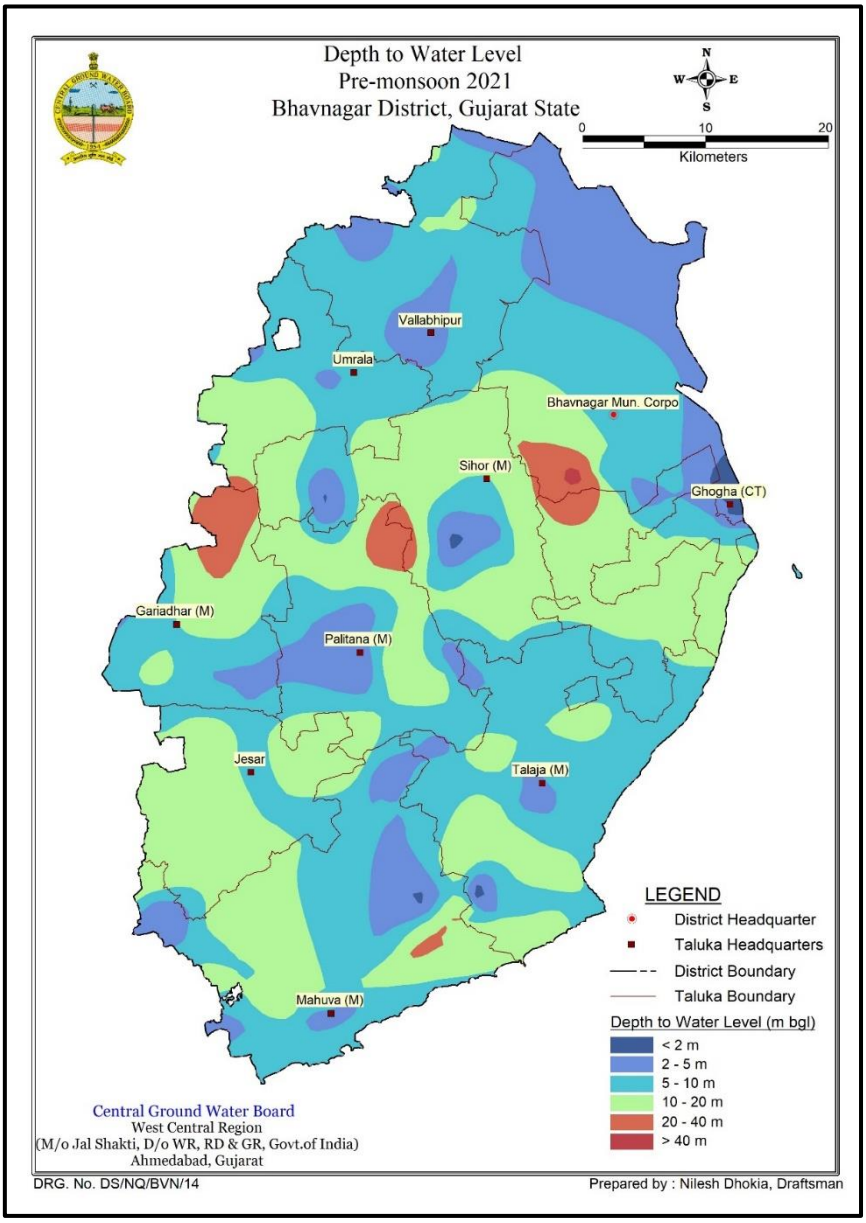


Figure 21 Pre-monsoon (May 2021) depth to water level of Bhavnagar District

9.1.2 Depth to Water Level (Post-monsoon)

Post-monsoon water level as shown below in map for the period of November, 2021 (**Figure 20**) shows that shallow water level up to 5.0 m bgl are observed in most part of the district which reflect good recharge were taken place due to rainfall. Water level between 5m bgl to 10m bgl is observed in patches in almost all talukas of the district. Small patch in boundary region of Bhavnagar-Sihor, Palitana-Jesar, Mahuva-Talaja, and in Ghogha taluka shows water level between 10m bgl to 20 m bgl. Bhavnagar taluka shows small patch of water level deeper than 40m bgl.

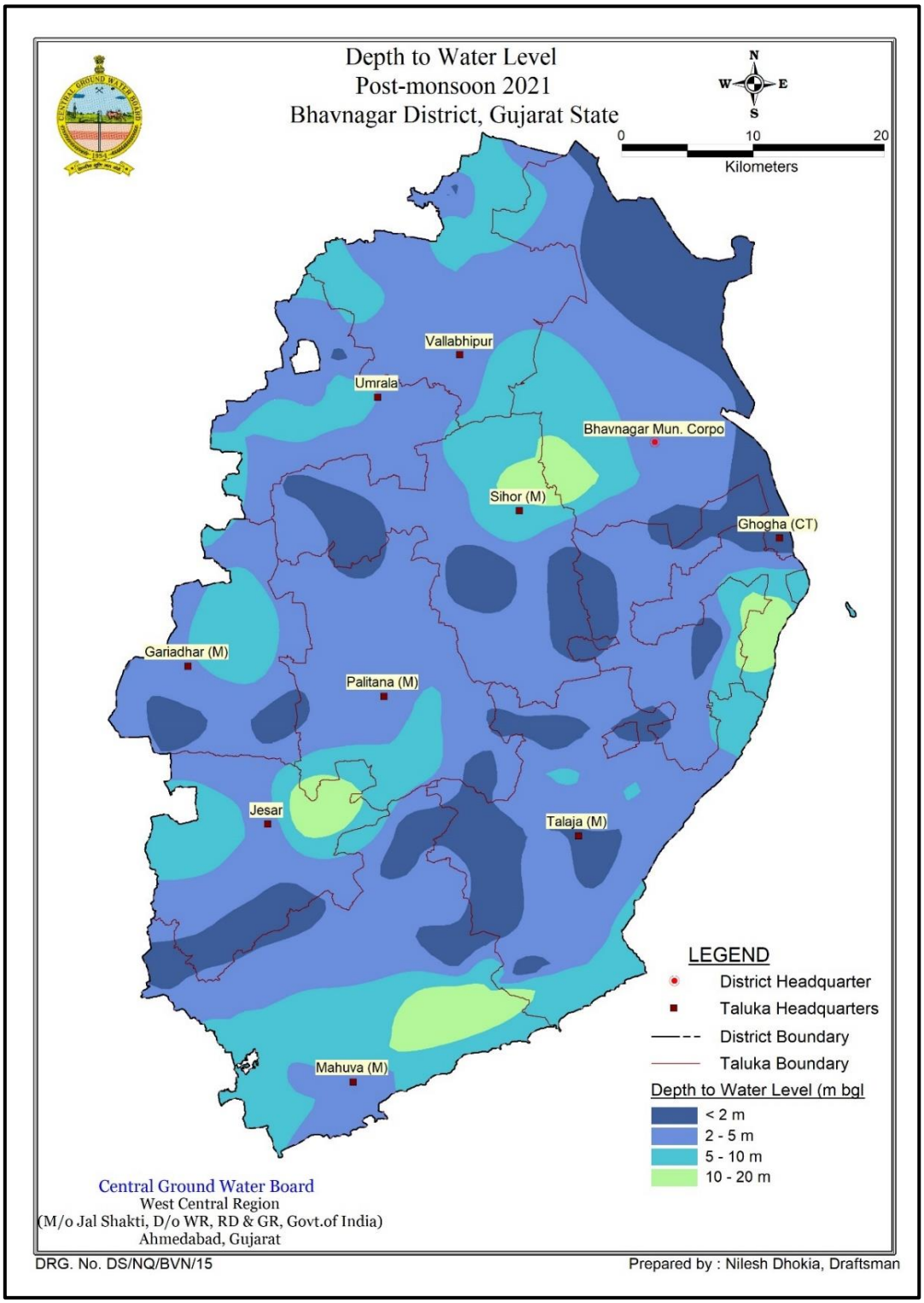


Figure 22 Post-monsoon (November 2021) depth to water level of Bhavnagar District

9.1.3 Water level Fluctuation

The fluctuation of water levels between Pre-monsoon (May, 2021) and Post Monsoon (November, 2021) shows in **Figure 21**. Most parts of the district have registered rise in water levels i.e., >4m. Major area of Vallabhipur and Bhavnagar taluka shows water level rise up to 4m. A few localized pockets in Sihor, Palitana, Jesar, Talaja taluka, and most part of district boundary also indicate water level rise up to 4m.

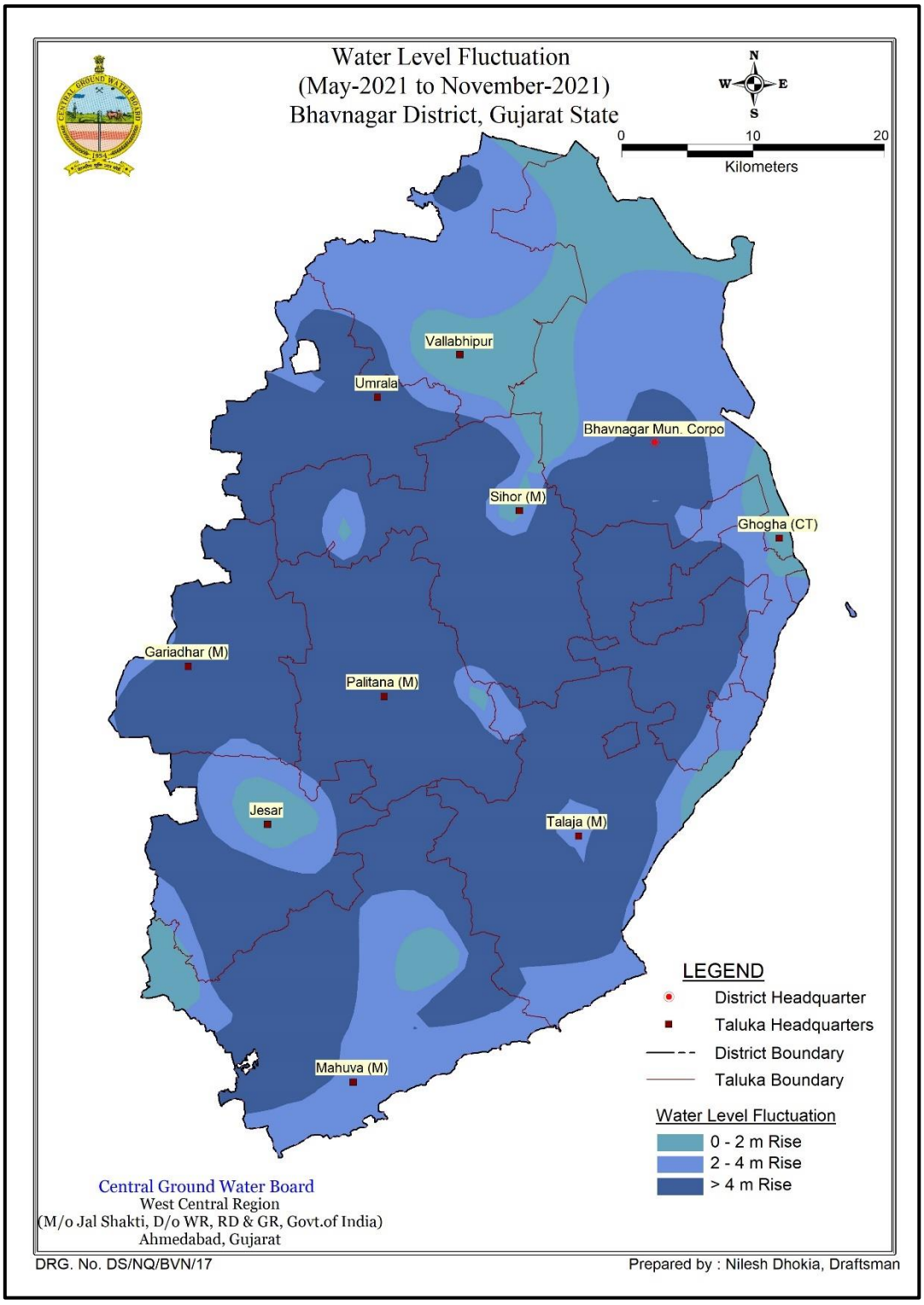


Figure 23 Water Level Fluctuation Bhavnagar District

9.1.4 Decadal water level trend

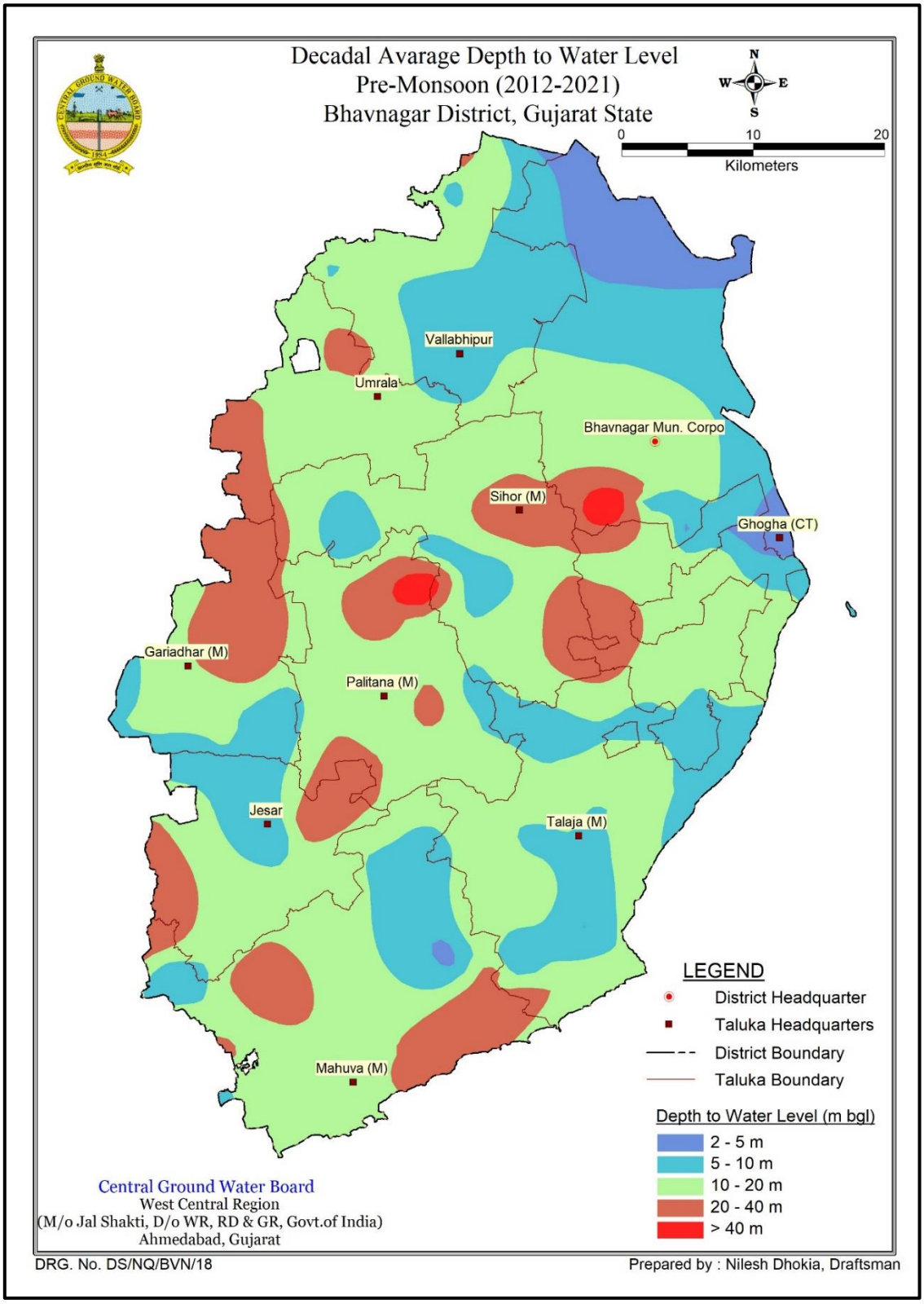


Figure 24 Ground water decadal trend Pre-monsoon (2012-2021), Bhavnagar district, Gujarat

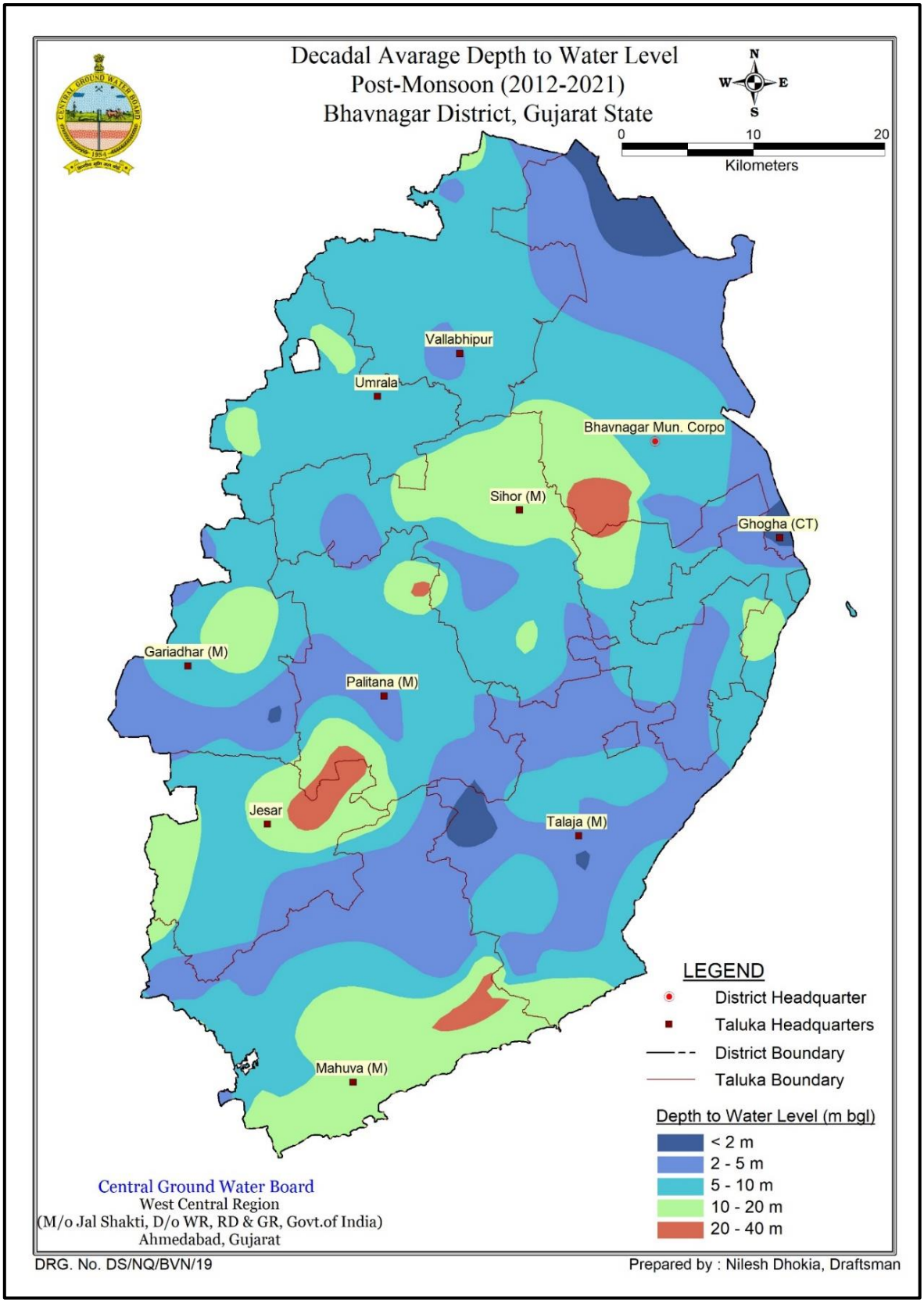


Figure 25 Ground water decadal trend Post-monsoon (2012-2021), Bhavnagar district, Gujarat

9.2 Decadal water level trend and Hydrograph

From the analysis of the water level trend of the Botad district from 2012 to 2021, it 1s observed that, during pre-monsoon, the water level has a rise of 0.089127 m/yr (Tansa) to 0.923064 m/yr (Timbi) and also has a fall of 0.027672 m/yr (Porbada) to 0.61704 m/yr (Bhumbhali). Similarly, from the analysis of the post-monsoon data of 2012 to 2021, the water level has a rise of 0.084790 m/yr (Ghogha) to 1.52 m/yr. (Mahuva) and there is no fall in water level trend in post-monsoon season in the district. Pre-monsoon and Post-monsoon long-term rising and declining trend of water level of various hydrograph stations established by CGWB are also studied in graphic form. Majority of the hydrographs are showing rising trends during the pre-monsoon period and there is no falling trend in post monsoon period. However, falling trend in few hydrographs is also observed in pre-monsoon season.

Table 17 Decadal Water level trend (2012-2021) Bhavnagar District

Long Term Water Level Trend (2012-2021)									
Sr. No	**District**	**Taluka**	**Location**	**Pre-Monsoon**			**Post-Monsoon**		
				Data Point	**Rise (m/year)**	**Fall (m/year)**	**Data Point**	**Rise (m/year)**	**Fall (m/year)**
1	Bhavnagar	Bhavnagar	Bhumbhali	10		0.061704	10	0.104724	
			Kardej	10	0.183132		10	0.511152	
2	Bhavnagar	Ghogha	Ghogha	10	0.295224		10	0.084792	
			Tansa	10	0.089172		10	0.619092	
3	Bhavnagar	Gariyadhar	Gariyadhar	10	0.837648		10	0.787356	
4	Bhavnagar	Mahuva	Mahuva	10	0.787224		10	1.520052	
			Motivadal	10	0.776244		10	0.161364	
5	Bhavnagar	Palitana	Khijadiya	10		0.046308	10	0.466956	
			Palitana	10	0.3171		10	0.439476	
6	Bhavnagar	Sihor	Ambala	10	0.25398		10	1.125144	
			Sandhida	10		0.060036	10	0.104748	
7	Bhavnagar	Umrala	Porbada	10		0.027672	10	0.496788	
			Timbi	10	0.923064		10	0.547368	
8	Bhavnagar	Vallabhipur	Panvi	10	0.575964		10	0.170256	
			Vallabhipur	10	0.242388		10	0.222048	
9	Bhavnagar	Talaja	Datha	10	0.557736		10	0.163968	
			Talaja	10	0.10134		10	0.634728	
Minimum					**0.089172**	**0.027672**		**0.084792**	
Maximum					**0.923064**	**0.061704**		**1.520052**	

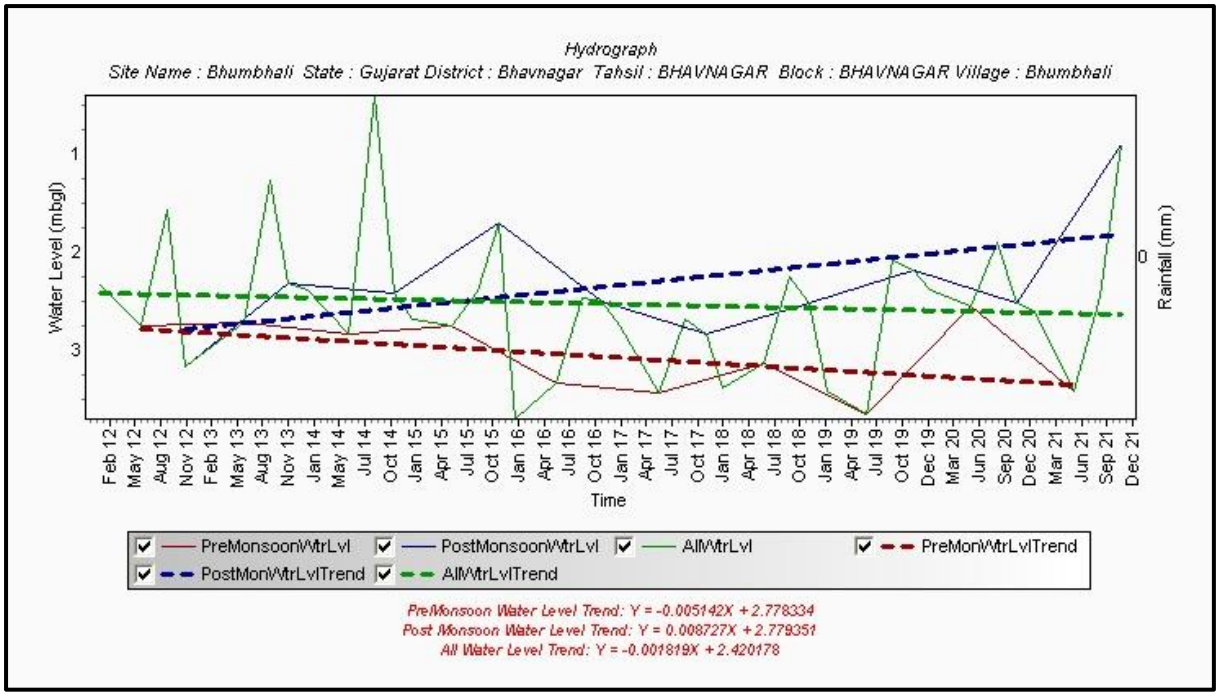


Figure 26 Hydrograph of Bhumbhali NHS well in Bhavnagar District

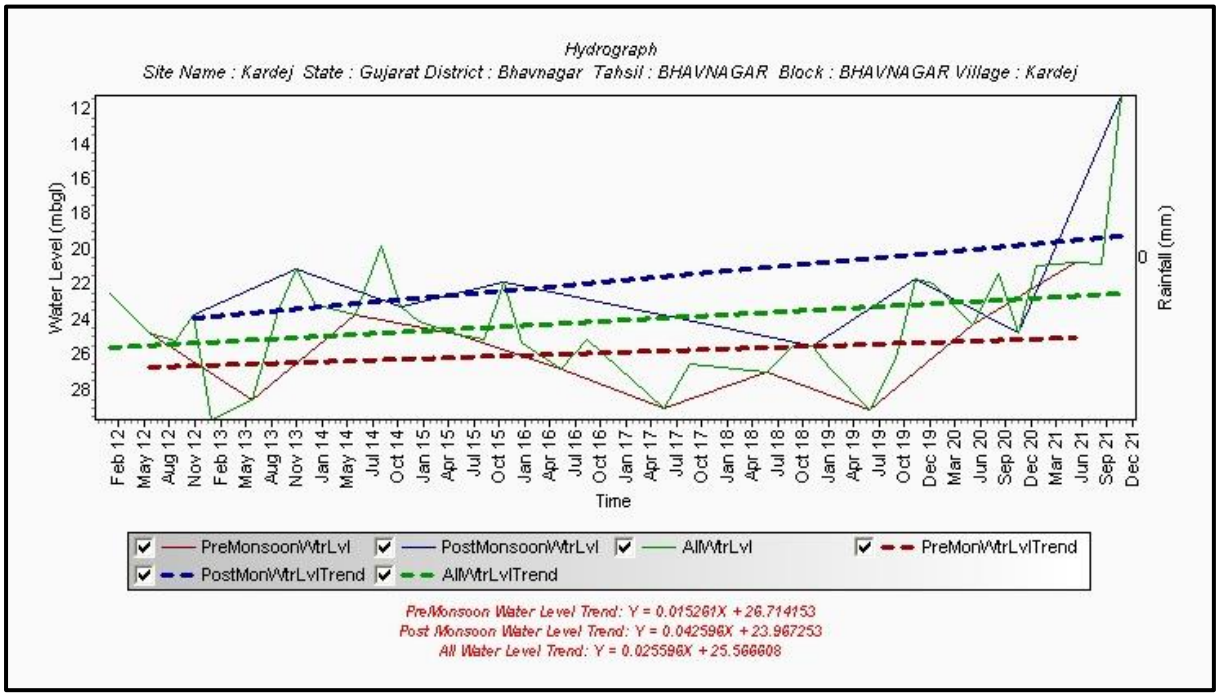


Figure 27 Hydrograph of Kardej NHS well in Bhavnagar District

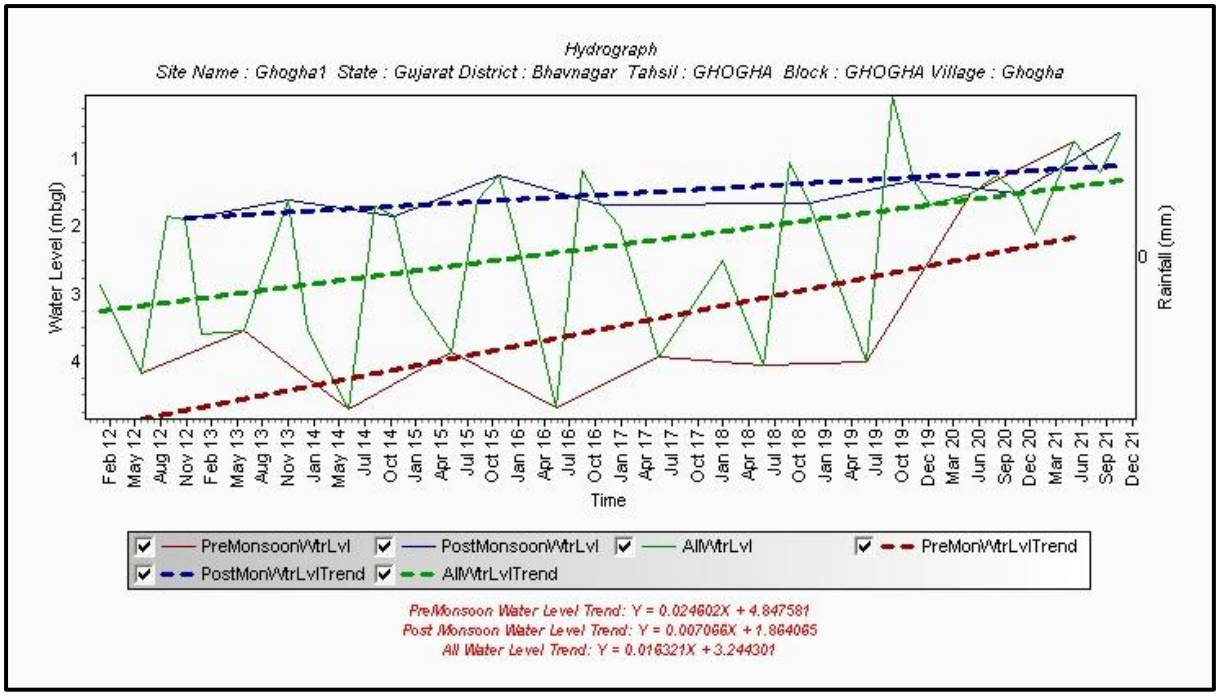


Figure 28 Hydrograph of Ghogha NHS well in Bhavnagar District

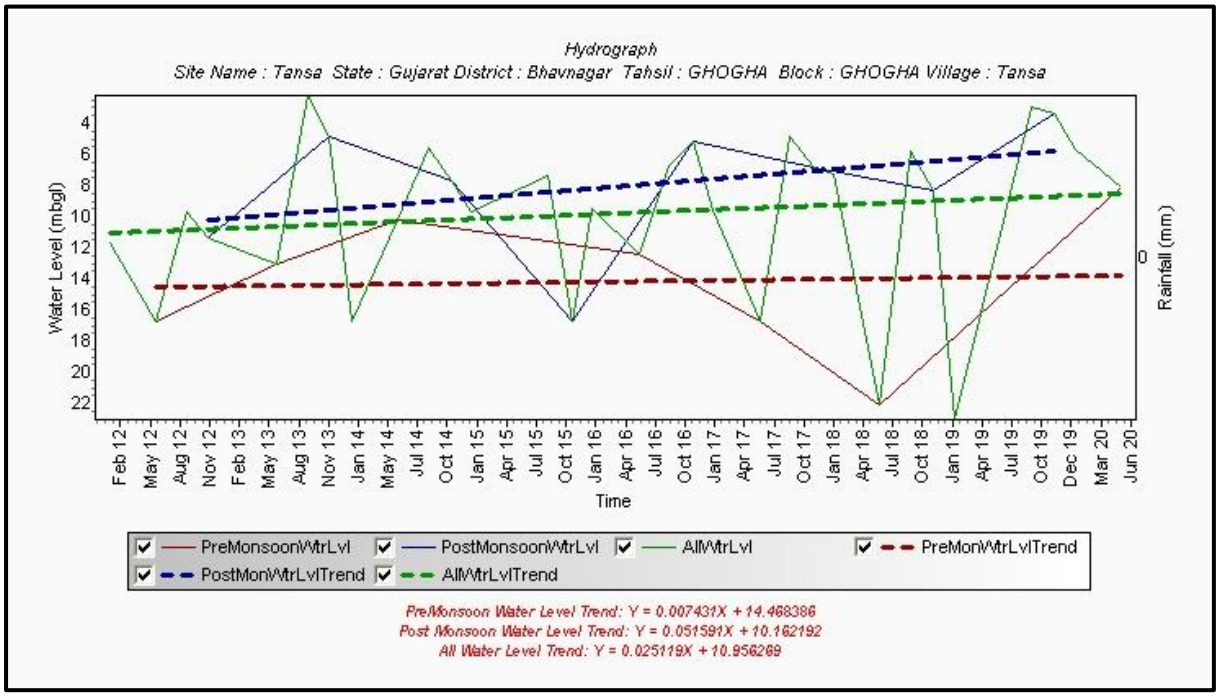


Figure 29 Hydrograph of Tansa NHS well in Bhavnagar District

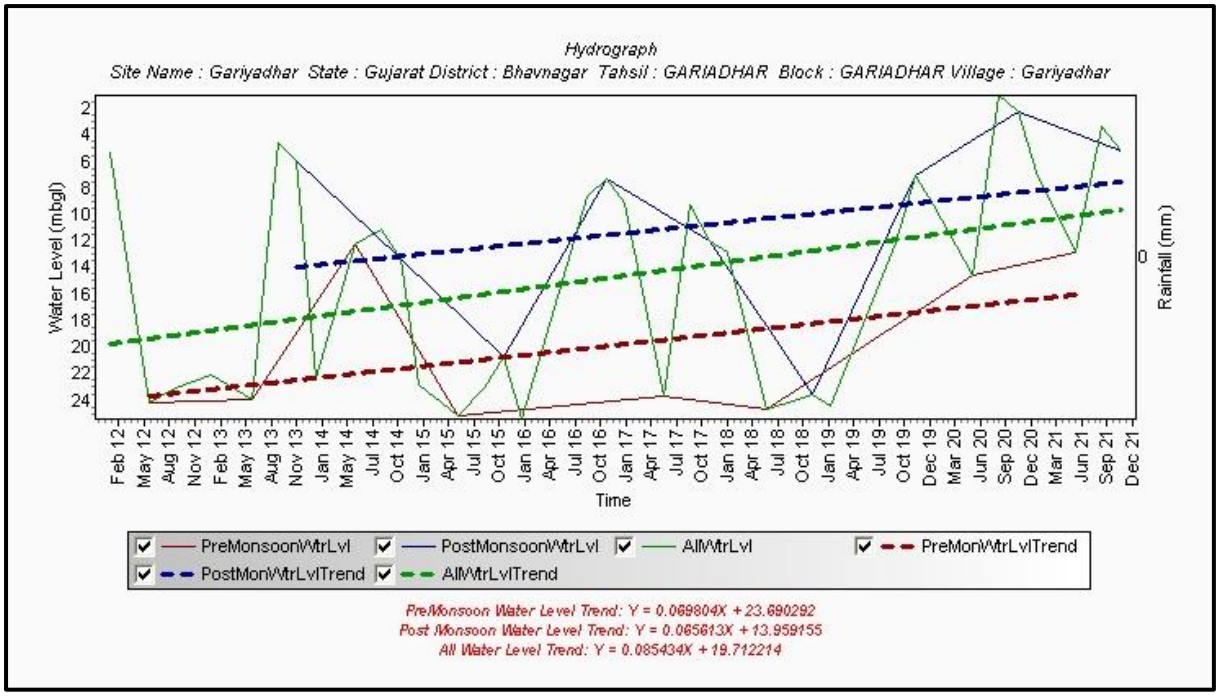


Figure 30 Hydrograph of Gariyadhar NHS well in Bhavnagar District

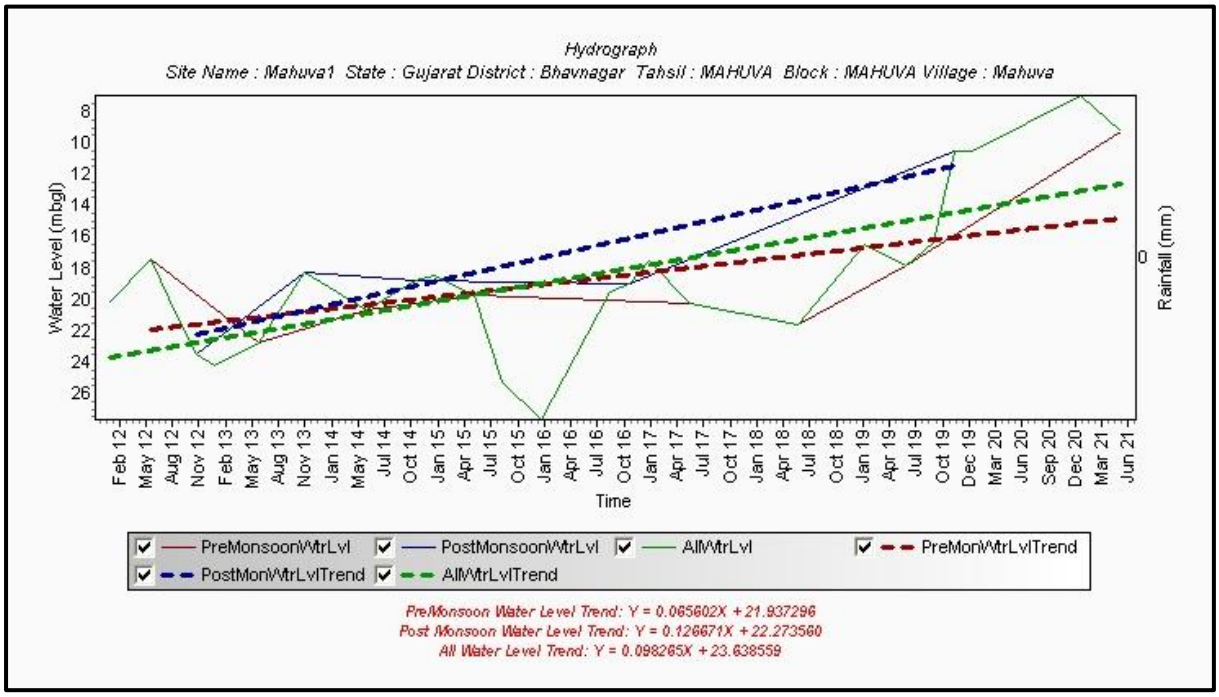


Figure 31 Hydrograph of Mahuva NHS well in Bhavnagar District

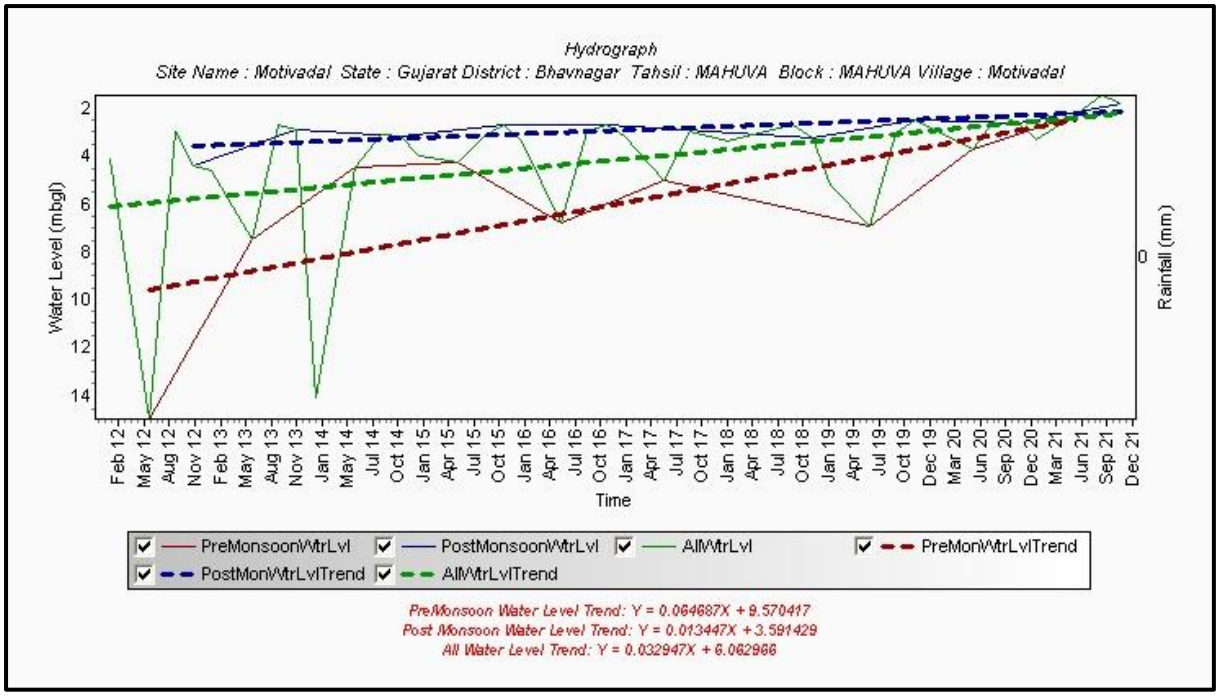


Figure 32 Hydrograph of Motivadal NHS well in Bhavnagar District

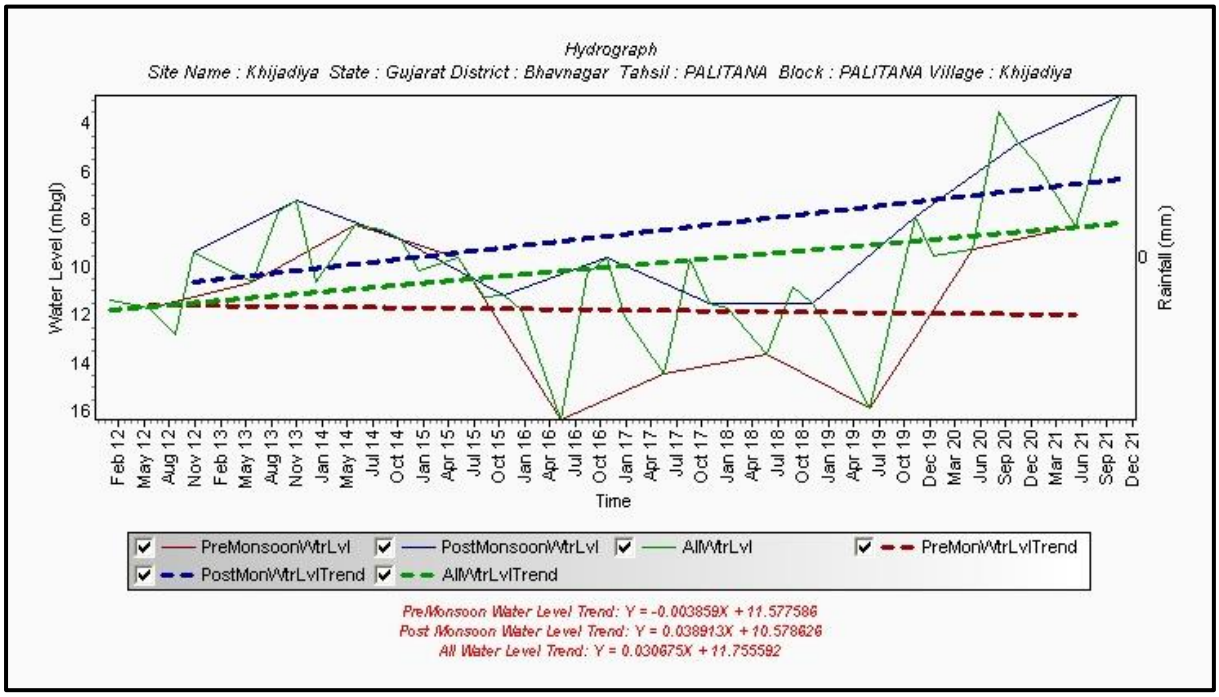


Figure 33 Hydrograph of Khijadiya NHS well in Bhavnagar District

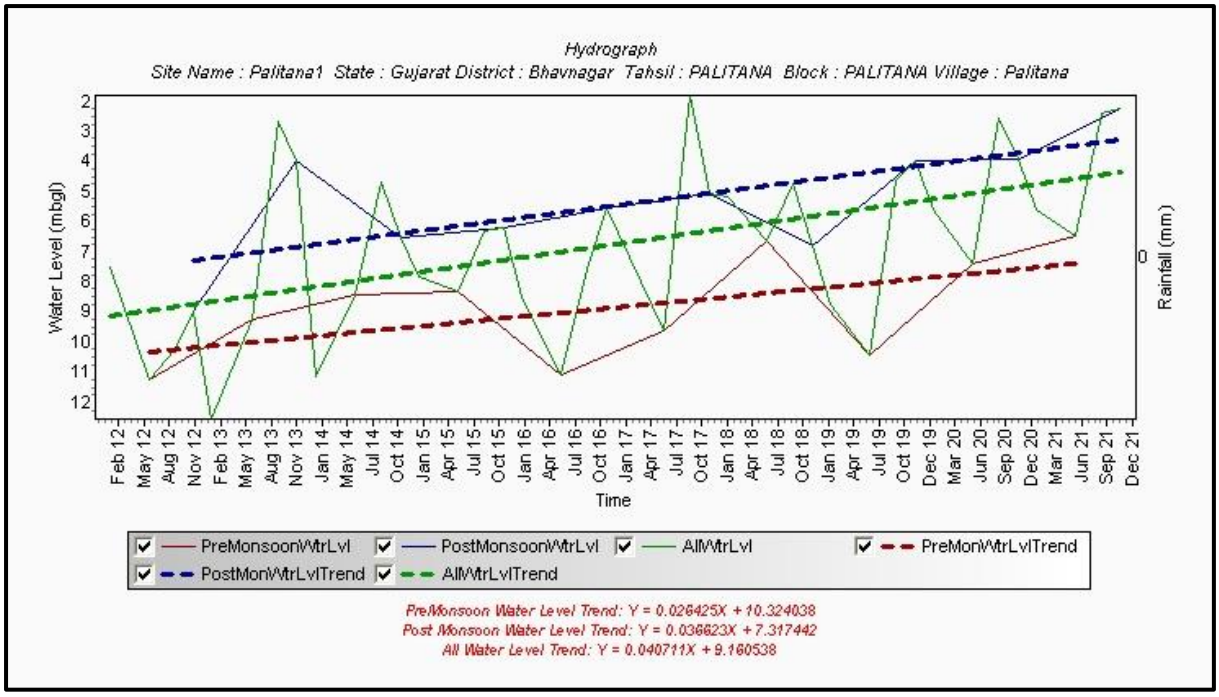


Figure 34 Hydrograph of Palitana NHS well in Bhavnagar District

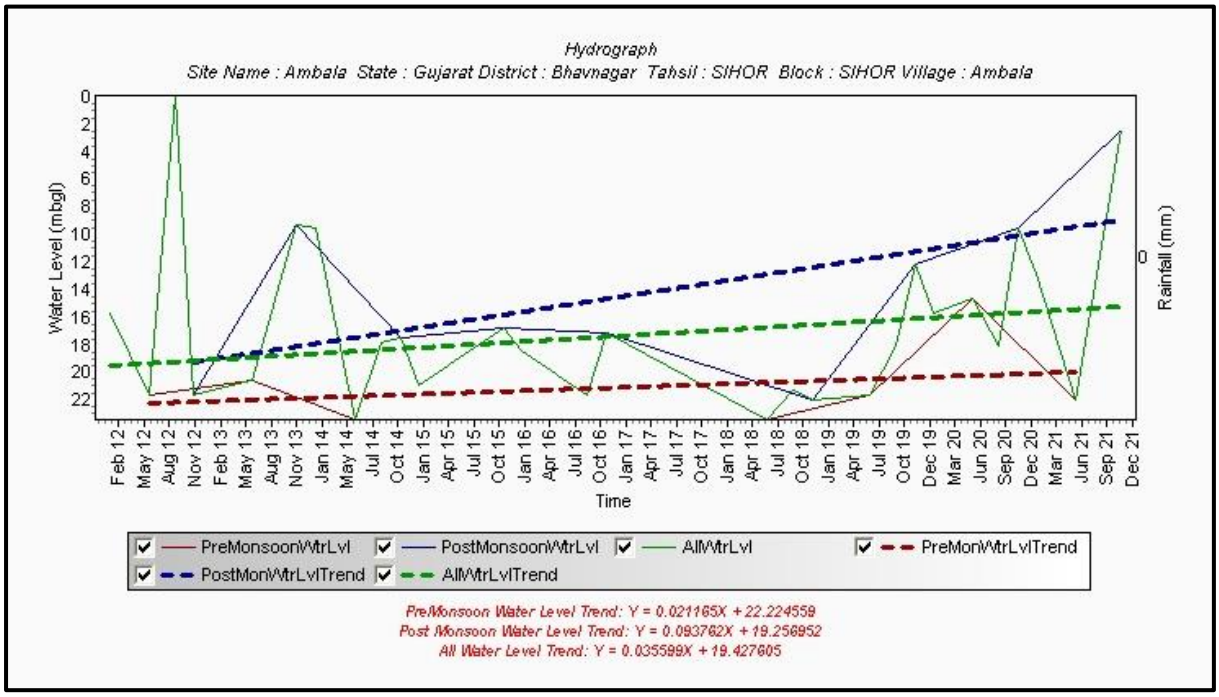


Figure 35 Hydrograph of Ambala NHS well in Bhavnagar District

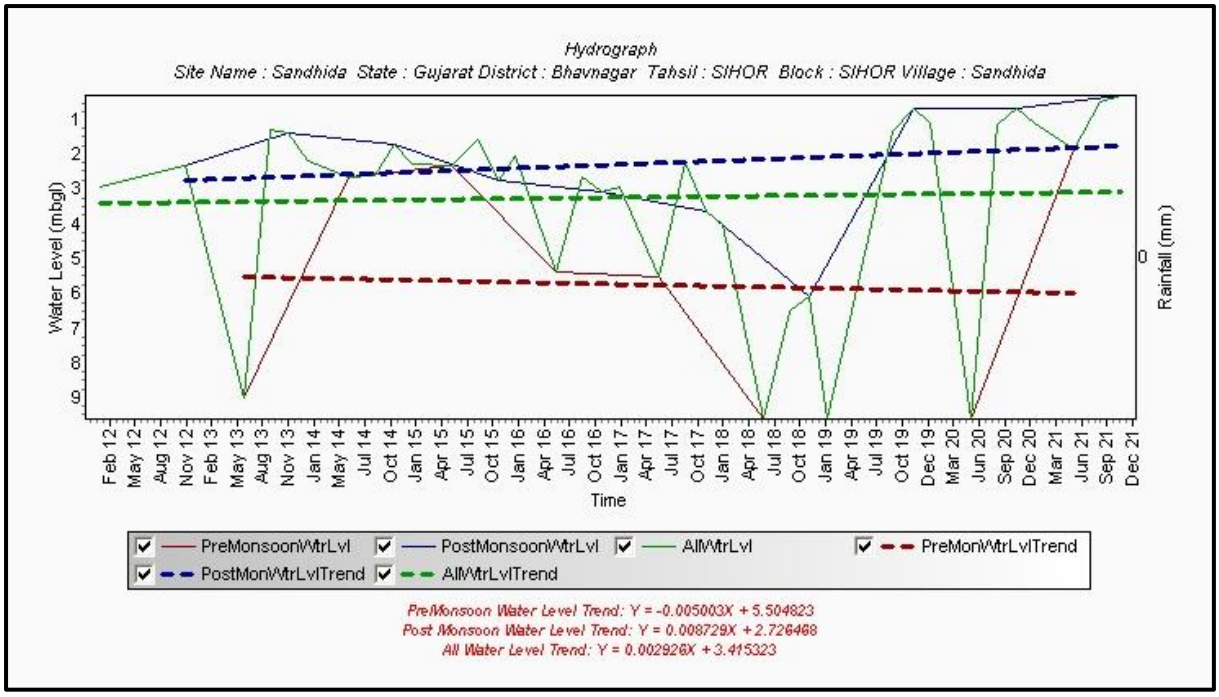


Figure 36 Hydrograph of Sandhida NHS well in Bhavnagar District

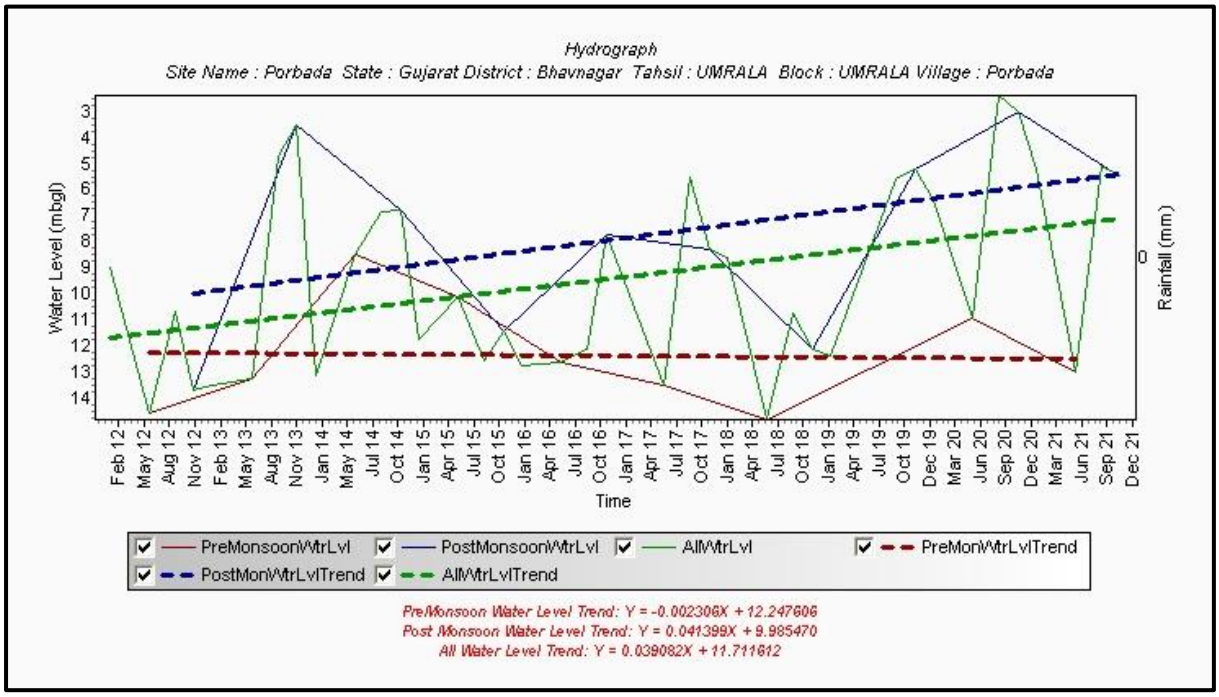


Figure 37 Hydrograph of Porbada NHS well in Bhavnagar District

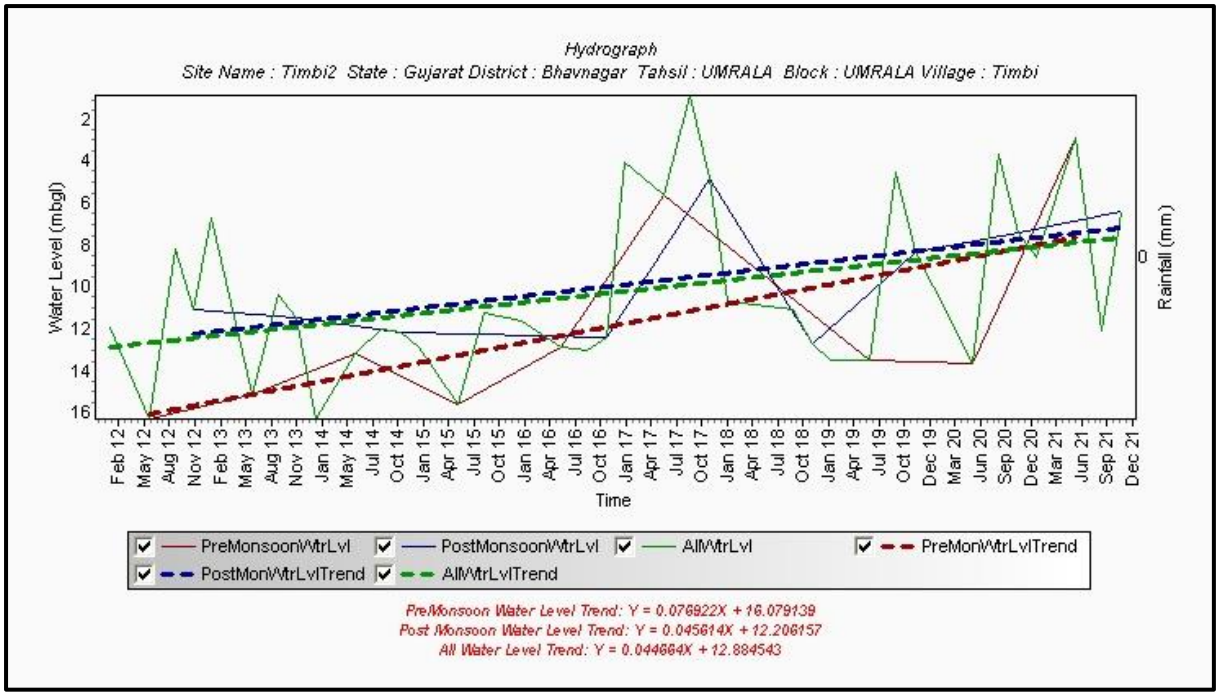


Figure 38 Hydrograph of Timbi2 NHS well in Bhavnagar District

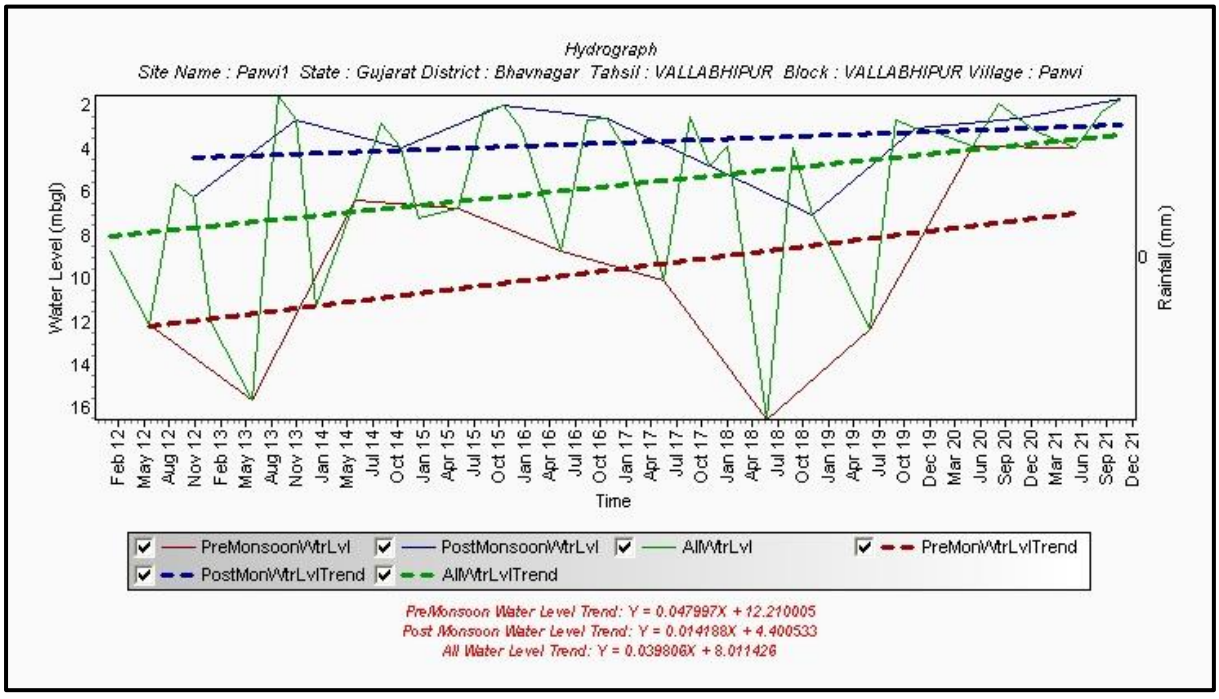


Figure 39 Hydrograph of Panvi NHS well in Bhavnagar District

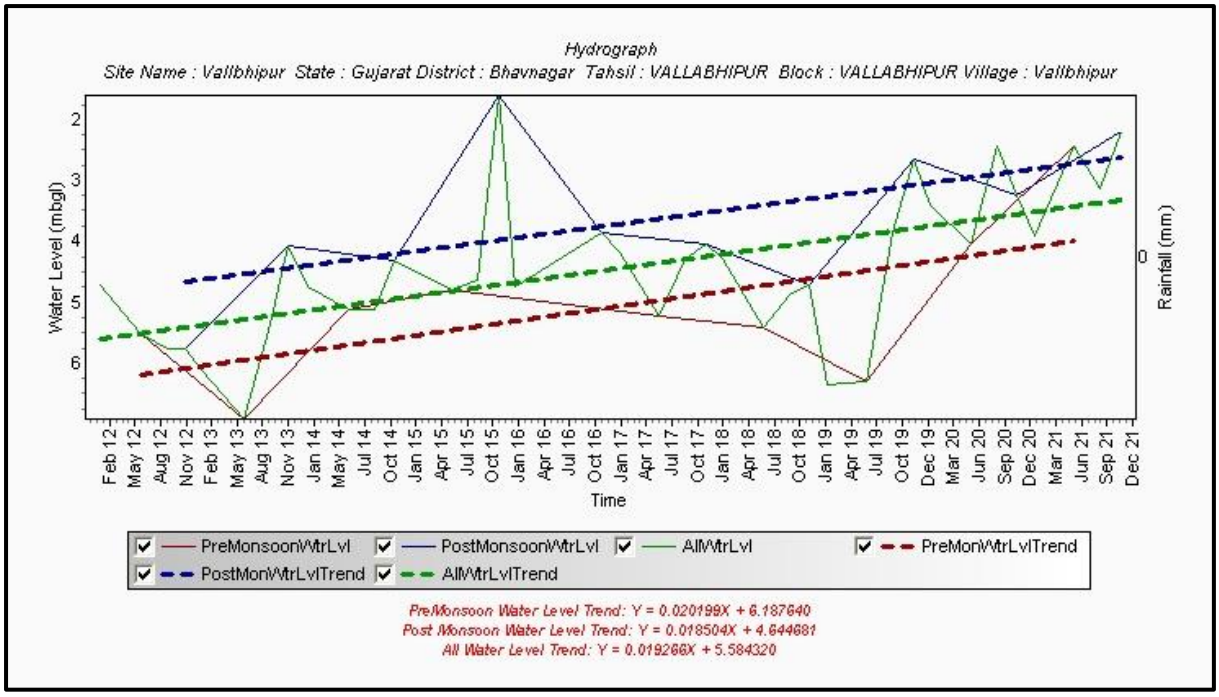


Figure 40 Hydrograph of Vallabhipur NHS well in Bhavnagar District

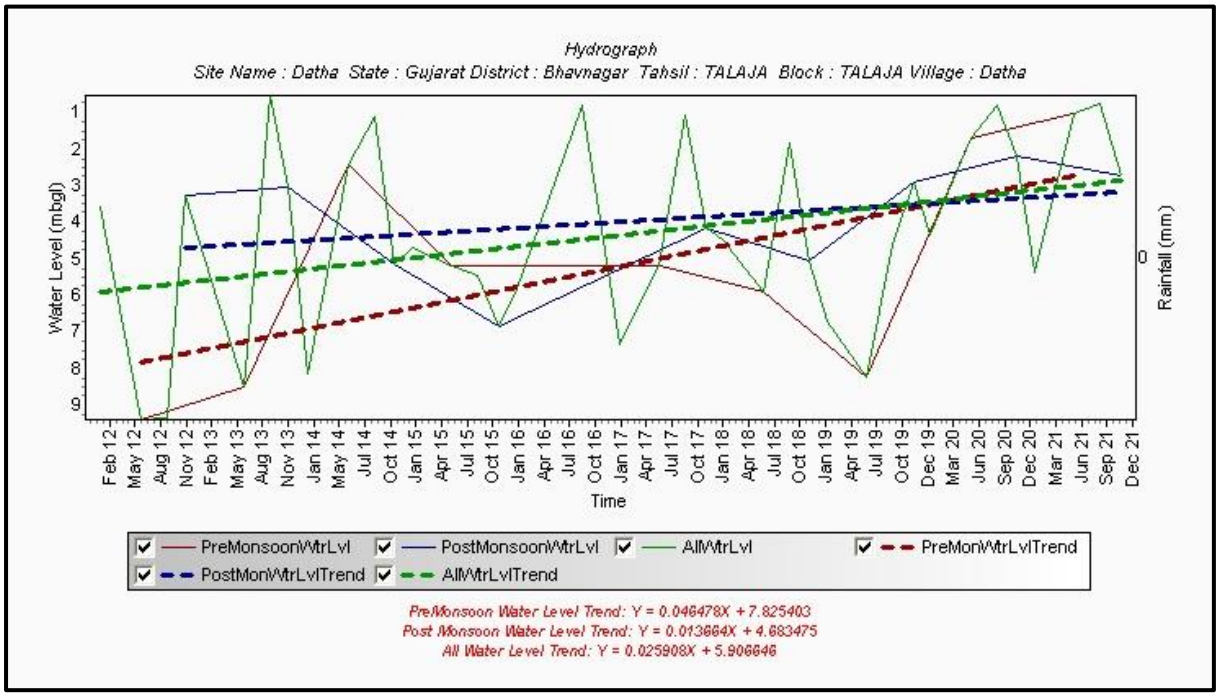


Figure 41 Hydrograph of Datha NHS well in Bhavnagar District

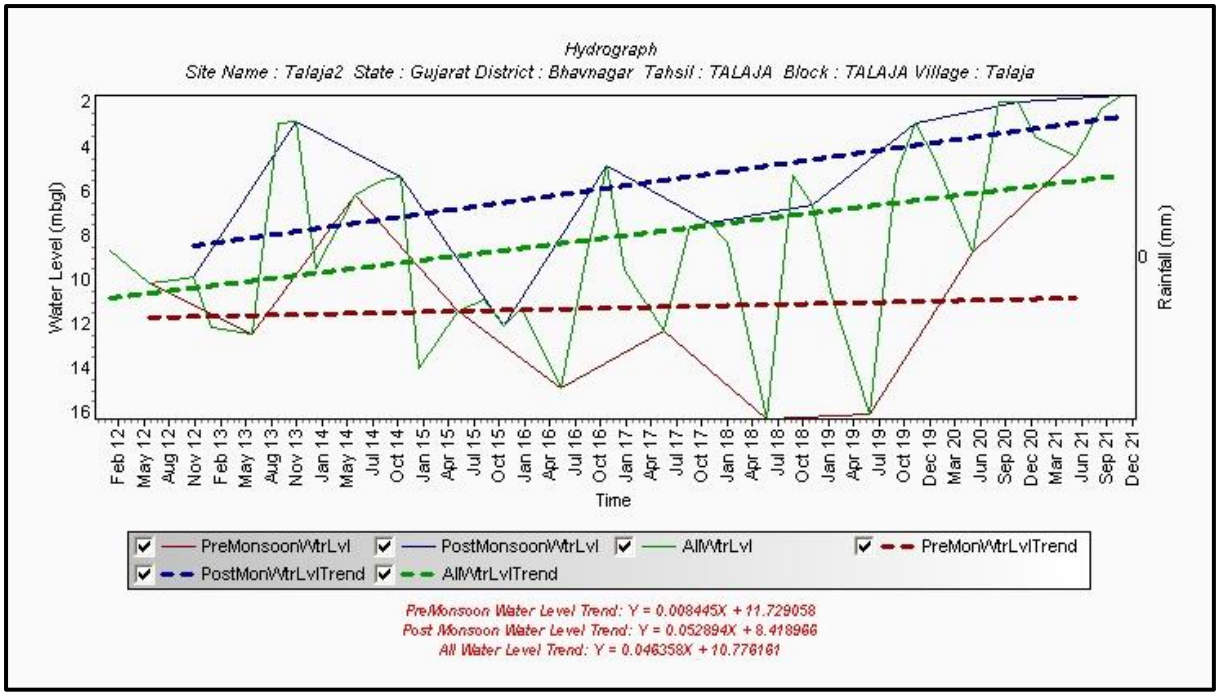


Figure 42 Hydrograph of Talaja NHS well in Bhavnagar District

9.3 Water Table and Groundwater Movement

The elevation of water table in Pre-monsoon 2021 is observed higher along eastern boundary of Jesar, southern side of Palitana, and along SE boundary of Sihor taluka. The above areas show dome shape water table contour elevation from where the flow direction is towards all the sides. The highest water table contour elevation is observed in Palitana taluka i.e., 240 amsl to 130 amsl (**Figure 43**). Northern area of district i.e., Vallabhipur, Bhavnagar, Umrala, and northern part of Sihor taluka exhibit lower water table contour elevation. Similarly, eastern side of Mahuva, Talaja, and Ghogha taluka shows lower water table contour elevation. The overall trend of flow direction of the district is towards SE direction.

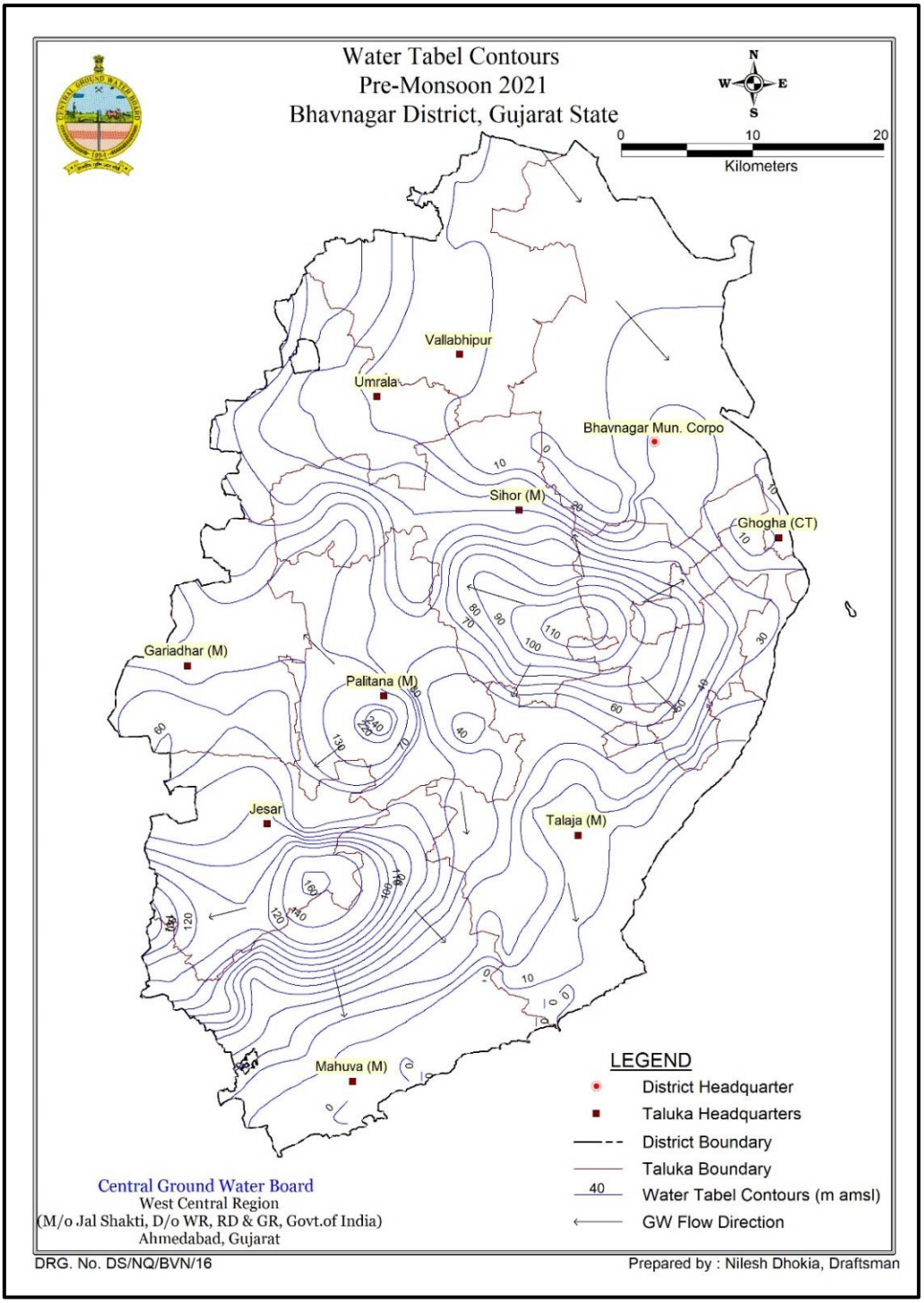


Figure 43 Water level contour map (Pre-monsoon_2021)

GROUND WATER RESOURCE POTENTIAL

The ground water resources of the district were calculated as on May 2021 in collaboration with the Government of Gujarat using the GEC-2015 methodology suggested by Ground Water Resource Estimation Committee (GWRE-2017). These resources were computed after reorganization of the districts, talukas of the district are considered as Assessment Unit (AU) and total area of 6693.9 km^2 are taken as area of assessment of the district including 10 talukas. Computed resource is presented in tabulated (**Table 19**) and graphically represented as below.

Table 18 Taluka wise Ground Water resources, Availability, Utilization and Stage of Ground Water Development

Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2020)															
Taluka	ANNUAL REPLENISHABLE GROUND WATER RESOURCE (mcm)					Total Natural Discharge (mcm)	Annual extractable Ground water Resource (mcm)	ANNUAL GROUND WATER DRAFT (mcm)				Projected Demand for Domestic uses upto 2025 (mcm)	Net Ground Water Availability for future use (mcm)	Stage of Ground Water Extraction (%)	Category
	Monsoon		Non-monsoon		Total Annual Ground Water Recharge			Irrigation	Industrial use	Domestic use	Total				
	Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources											
Bhavnagar	49.37	11.82	0	13.44	74.63	3.73	70.9	17.51	0	0	17.51	0	53.39	24.7	safe
Gariadhar	60.14	4.03	0	5.33	69.5	3.47	66.02	34.14	0	0	34.14	0	31.88	51.71	safe
Ghogha	40.7	6.14	0	6.73	53.57	2.68	50.89	26.57	0	0	26.57	0	24.32	52.21	safe
Jesar	65.45	6.61	0	7.43	79.49	3.97	75.51	24.32	0	0	24.32	0	51.19	32.21	safe
Mahuva	136.51	10.35	0	16.27	163.13	8.16	154.97	73.52	0	0	73.52	0	81.46	47.44	safe
Palitana	134.12	7.24	0	12.57	153.92	7.7	146.23	56.62	0	0	56.62	0	89.61	38.72	safe
Sihor	170.78	6.27	0	7.65	184.7	9.24	175.47	60.69	0	0	60.69	0	114.78	34.59	safe
Talaja	103.43	9.76	0	22.14	135.33	6.77	128.56	79.09	0	0.65	79.74	0.71	48.76	62.02	safe
Umrala	47.55	4.71	0	9.28	61.53	3.08	58.46	35.57	0	0	35.57	0	22.89	60.85	safe
Vallabhipur	41.3	3.29	0	4.63	49.22	2.46	46.76	13.96	0	0	13.96	0	32.81	29.85	safe
Total	849.35	70.22	0.00	105.47	1025.03	51.25	973.78	421.98	0	0.65	422.63	0.71	551.08	43.4	Safe

Note: The Annual Groundwater Draft (mcm) for Domestic and Industrial uses (2017)

Taluka	ANNUAL GROUND WATER DRAFT (mcm)			Projected Demand for Domestic and Industrial uses up to 2025 (mcm)
	Irrigation	Domestic And Industrial uses	Total	
Bhavnagar	26.793	5.23	32.02	14.86
Gariadhar	32.722	1.96	34.68	2.23
Ghogha	26.309	1.26	27.57	1.91
Jesar	26.377	1.24	27.61	8.53
Mahuva	71.858	7.5	79.36	4.35
Palitana	57.298	3.82	61.12	4.01
Sihor	66.061	3.52	69.58	6.15
Talaja	75.174	5.4	80.58	1.63
Umrala	34.51	1.43	35.94	1.51
Vallabhipur	13.881	1.17	15.05	1.41
District Total	430.98	32.54	463.52	46.59

10.1 Ground Water Recharge

Total Annual Ground Water Recharge from Rainfall and other sources for both monsoon and non-monsoon season for the district is 1025.03 mcm. And ground water recharge in talukas varies from 49.22 mcm (Vallabhipur taluka) to 184.7 mcm (Sihor taluka).

10.2 Net Ground Water Availability

Annual Extractable Ground Water Resource/ Net Ground Water Availability of the district is 973.78 mcm which computed after deducting total natural discharge of 51.25 mcm from total annual ground water recharge.

10.3 Annual Ground Water Draft

The gross ground water draft for all uses (i.e., Irrigation, Domestic and Industrial uses) in the district is 422.63 mcm. The existing gross ground water extraction for all uses varies from 13.96 mcm (Vallabhipur taluka) to 79.09 mcm (Talaja taluka). According to annual groundwater draft, 2017, approximately 93% of ground water extraction are used for Irrigational purposes, remaining 7% are being extracted mainly for Domestic and Industrial purposes.

10.4 Projected demand for Domestic and Industrial use up to 2025

As per the annual Ground Water Resource Potential, 2017, the total Projected demand of ground water for Domestic and Industrial uses in the district is 46.59 mcm. Projected demand for domestic uses varies from 1.41 mcm (Vallabhipur taluka) to 14.86 mcm (Bhavnagar taluka).

10.5 Ground water Availability for future Irrigation

Net ground water availability for future use in the district is 551.08 mcm. Taluka wise it varies from 22.89 mcm (Umrala taluka) to 114.78 mcm (Sihor taluka).

10.6 Stage of Ground Water Extraction

As per the Ground Water Resource Estimation (GWRE-2017), the stage of Ground Water extraction of the district is 43.4% which categorized as Safe. Whereas in taluka it varies varies from 24.7% (Bhavnagar taluka) to 62.02% (Talaja taluka) and all the 10 talukas of the district are categorized as SAFE.

HYDROCHEMISTRY

Groundwater in the district is in general potable and fresh, both in phreatic and confined aquiferswithin 200 m depth.

The chemical quality of groundwater in shallow aquifer of the district has been analysed based on the water samples collected during National Hydrographs Monitoring Stations (NHS) and NAQUIM in May 2021 form CGWB and

Chemical data from Gujarat Water Resources Development Corporation (GWRDC) were also incorporated, and presented in **Table 20**. The ground water is in general alkaline in nature.

Table 19 Statistical Analysis of Chemical Constituents of Ground Water in Bhavnagar District, May 2021.

Constituents	Minimum	Maximum	Average
pH	7.18	9	8.19
EC (uS/cm)	542	16000	2444.15
Alkalinity (mg/l)	70	1350	413.08
TH (mg/l)	70	3850	545.06
TDS (mg/l)	363	10720	1637.64
CO_3 (mg/l)	0	300	41.38
HCO_3 (mg/l)	73	1257	419.82
Cl (mg/l)	28	5213	411.29
SO_4 (mg/l)	5	1083	135.27
NO_3 (mg/l)	6.38	2352	121.94
Ca (mg/l)	12	640	84.41
Mg (mg/l)	0	559.36	81.24
Na (mg/l)	2.6	2096.2	312.01
K (mg/l)	0.02	63	2.24
F (mg/l)	0.21	2.75	69
SiO_2 (mg/l)	15.04	101	53.73
SAR	0.06	39.45	6.9

11.1 Hydrogen Ion Concentration (pH)

The pH is an indicator of acidity of the water. The shallow ground water in the district is generally alkaline with pH more than 7. The value of pH ranges between 7.18 (Bhavnagar1 site) & 9.0 (Malvav village) in the district.

11.2 Iso Conductivity Map

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit and permissible limit of Total Dissolve Solid (TDS) are 500 mg/l and 2000 mg/l respectively.

Iso conductivity Map of the district shown below in (**Figure 44**), EC in the district is mostly lie within Permissible limit. Most of the area of Vallabhipur taluka shows TDS value above permissible limit. Small patches of TDS value above permissible limit are visible in Sihor-Palitana boundary, Palitana Gariadhar taluka, and Mahuva taluka. The TDS value above 5000 mg/l is exhibited in southern section of mahuva taluka.

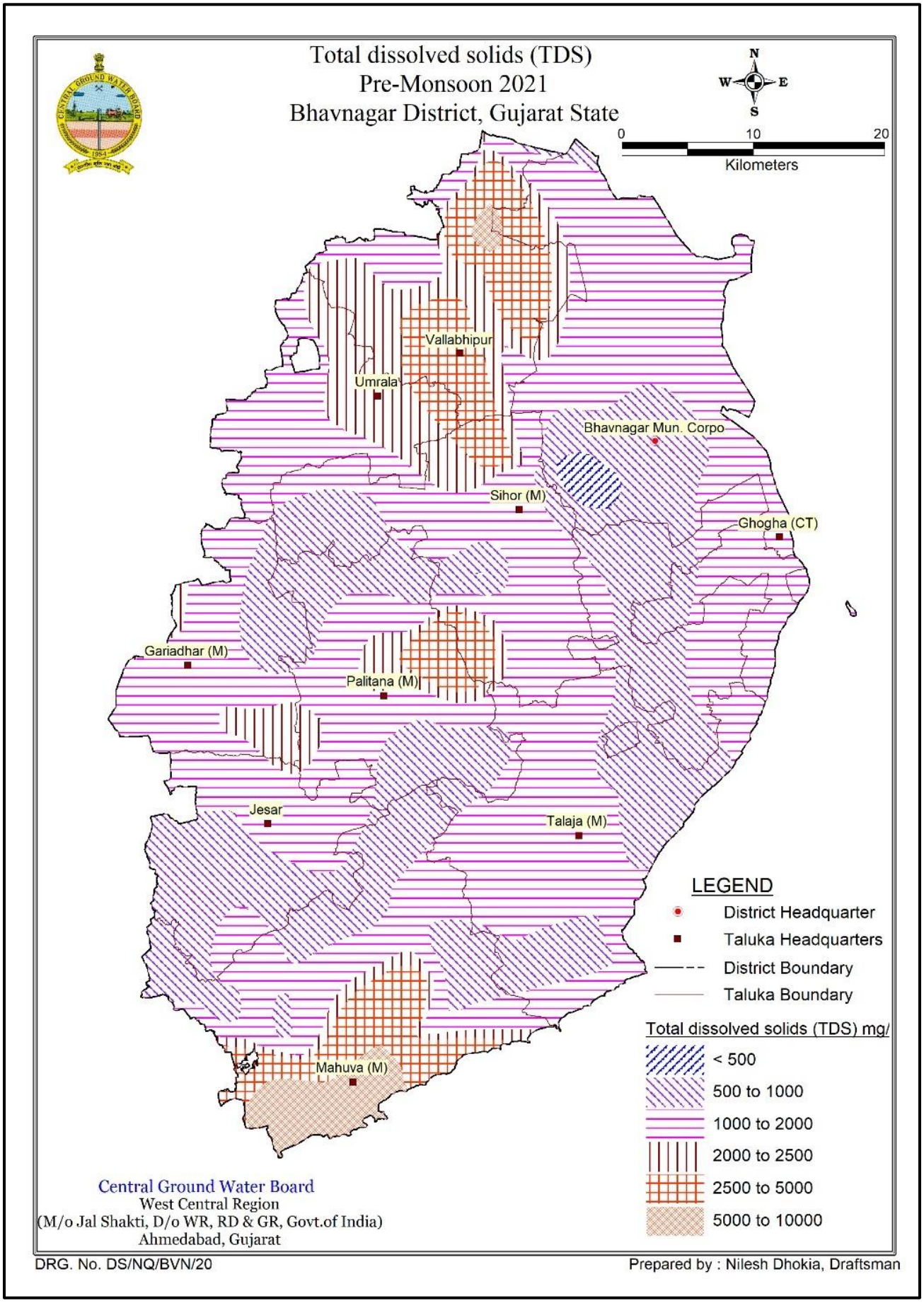


Figure 44 Map showing Taluka wise Total Dissolved Solid (TDS) values of Bhavnagar District.

11.3 Electrical conductivity (EC)

The electrical conductivity is a measurement of how easily a material allows electric current to flow through. The electrical conductivity of ground water varies from 542 mg/l (Kardej village) to about 16000 mg/l (Devaliya village).

11.4 Carbonate (CO3) and Bicarbonate (HCO3)

Carbonate and bicarbonate anions contribute to alkalinity due to their basic nature. The carbonate concentration in district are varies in between zero mg/l (38 locations) to 300 mg/l (Padrod village). Similarly, Bicarbonate concentration in district are varies in between 73 mg/l (Timbi2) to 1257 mg/l (Umrala village).

11.5 Map of Chloride (Cl)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit and permissible limit of Chloride (mg/l) are 250 mg/l and 1000 mg/l respectively. It is depicted from the map shown in **Figure 45**, A very small patches in Mahuva and Vallabhipur taluka shows Cl concentration is more than permissible limit.

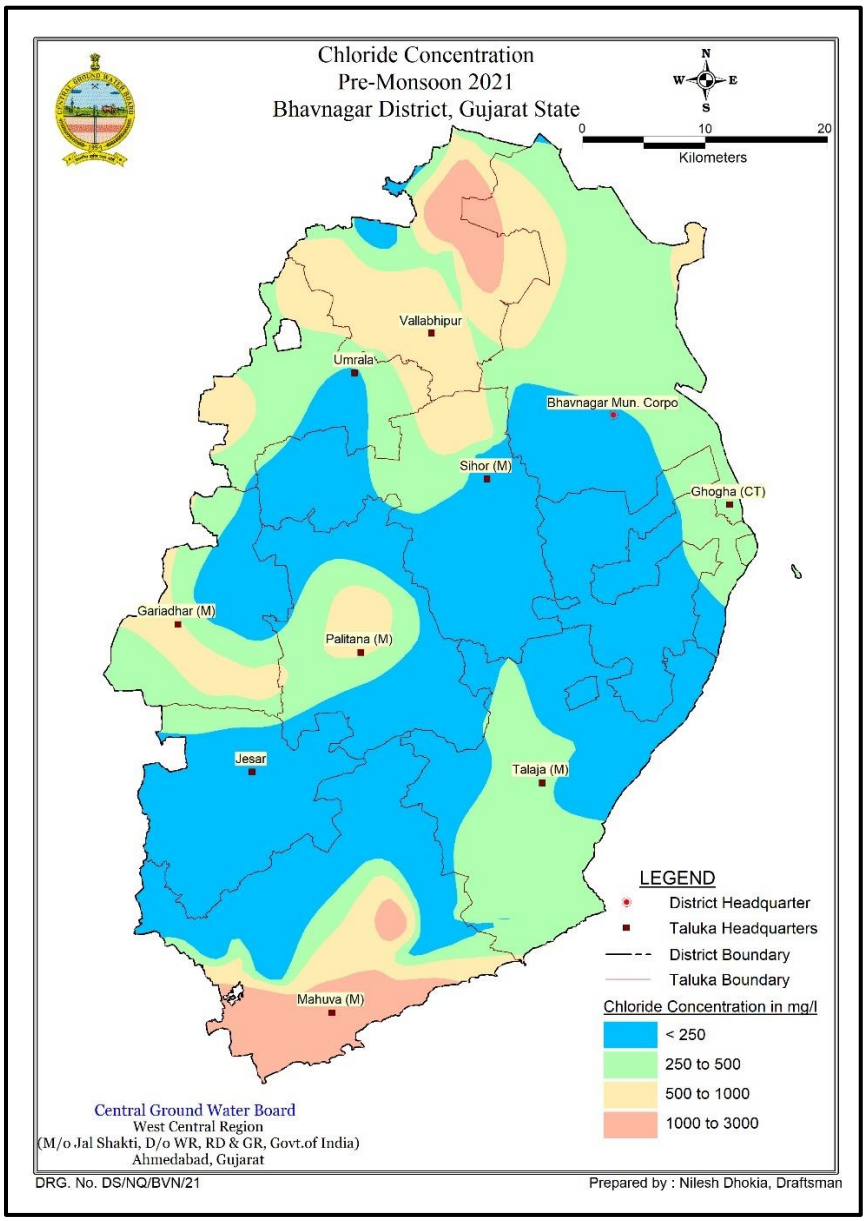


Figure 45 Map showing Taluka wise Chloride (Cl) concentration in Bhavnagar District.

11.6 Nitrate (NO_3)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit is 45 mg/l (maximum) and there is no relaxation in permissible limit.

Nitrate concentration in the ground water in district varies between 6.38 mg/l (Longadi village) and 2352 mg/l (Randola village). Majority of the stations show nitrate concentration above acceptable limit (**Figure 46**). All the stations of Bhavnagar taluka show nitrate concentration below 45 mg/l.

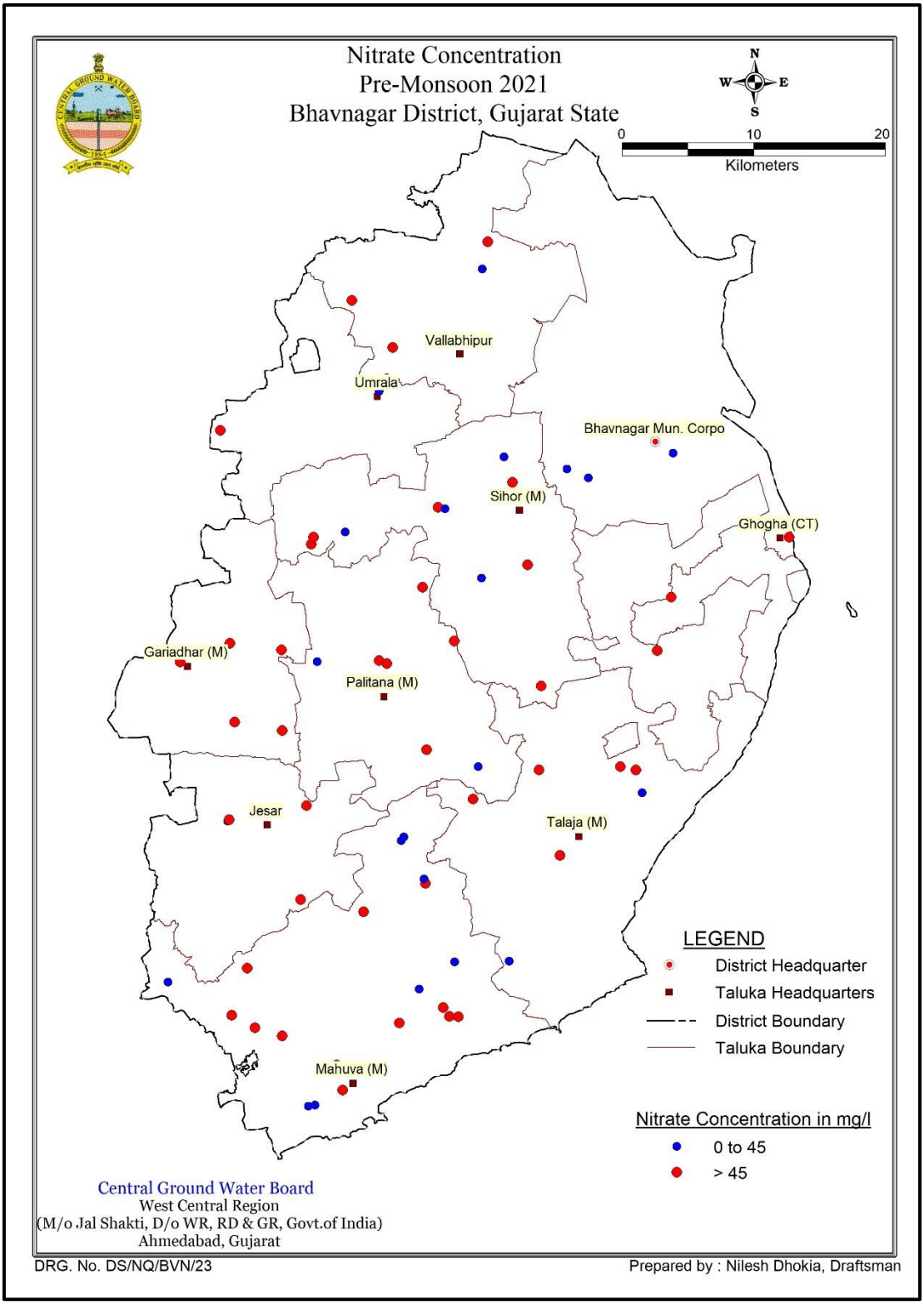


Figure 46 Map showing Taluka wise Nitrate (NO3) concentration in Bhavnagar District.

11.7 Sulphate (SO4)

In the district, Sulphate concentration varies from 5 mg/l (Kardej village) to 1083 mg/l (Bhavani Nagar location).

11.8 Fluoride (F)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Fluoride (mg/l) are 1 mg/l and 1.5 mg/l respectively. Fluoride concentration in Bhavnagar district varies in between 0.21 mg/l (Dharai village) and 2.75 mg/l (Bora village). There are 03 isolated locations where Fluoride concentration is more than permissible limit as presented in **Figure 47**.

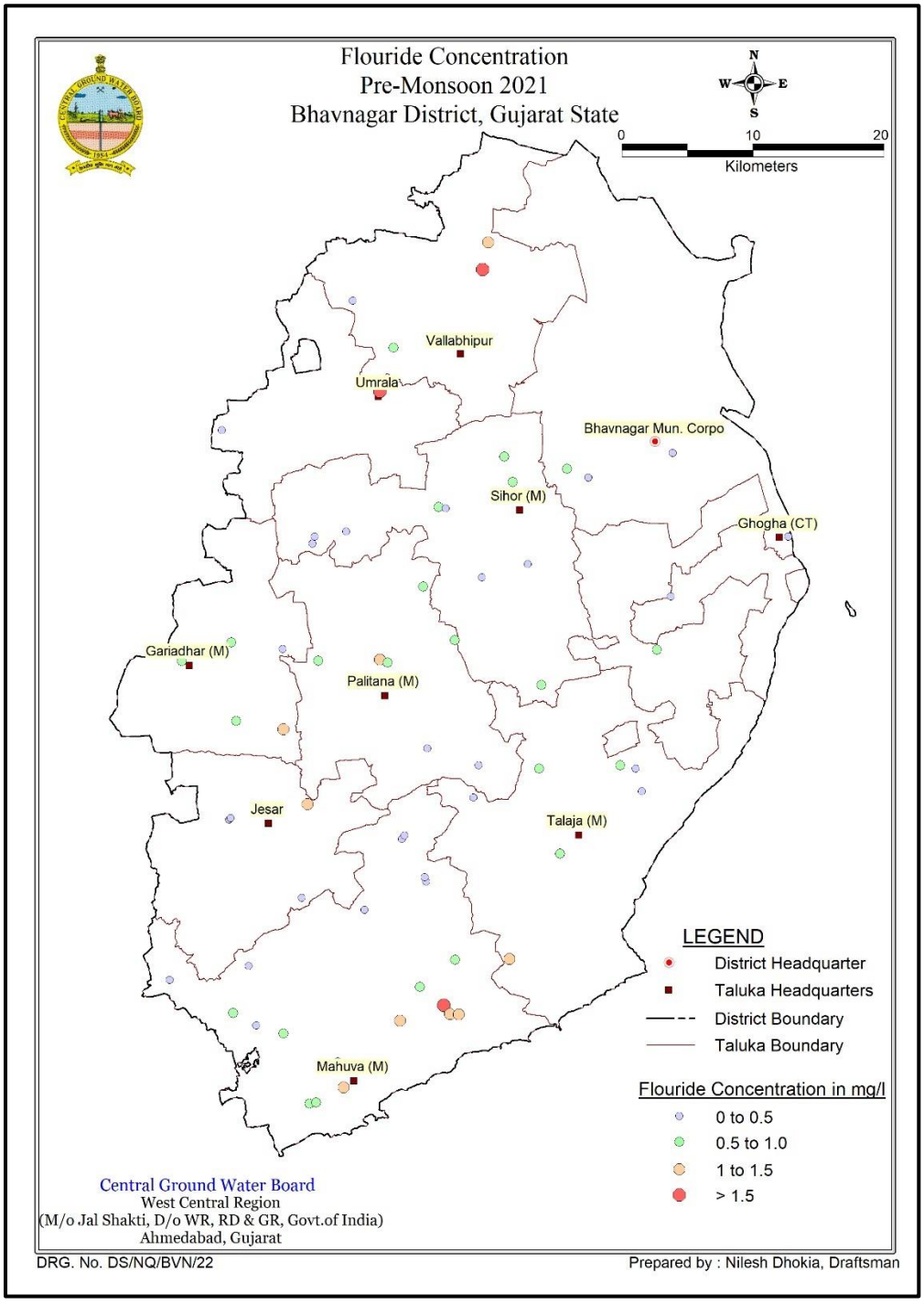


Figure 47 Map showing Taluka wise Fluoride (F) concentration in Bhavnagar District.

11.9 Calcium (Ca)

Calcium concentration in district varies between 12 mg/l (Bora village) and 640 mg/l (Devaliya village). The concentration of calcium is found within permissible limits in the district (permissible limit as per BIS norms is 200 mg/l) except 03 location i.e., Jalia, Varal, and Devaliya village.

11.10 Magnesium (Mg)

The Concentration of Magnesium in areas ranges from zero mg/l (Varal village) to 559.36 mg/l (Randola village). In 17 locations namely Kajavadar, Bhavani Nagar, Jalia, Padroad, Palitana, Talaja2, Satapada, Moti Dharai, Gariyadhar, Senjadiya, Bhandaria, Dudhala, Varal, Dharai, Dudadhar, Devaliya, Randola, the concentration of Magnesium is more than maximum permissible limits of 100 mg/l (as per BIS norms).

11.11 Sodium (Na)

Sodium concentration in the district varies between 2.6 mg/l (Kukad village) and 2096.2 mg/l (Bhavani Nagar site).

11.12 Potassium (K)

The concentration of Potassium in shallow ground water ranges from 0.02 mg/l (Umrala village) to 63 mg/l (Ghogha site).

SUSTAINABLE GROUNDWATER DEVELOPMENT AND MANAGEMENT

12.1 Groundwater related issue:

12.1.1 Low Ground water development

As per GWRE 2020 the total ground water resources of the district are in order of 102503.1 Ham/year and utilizable resources are 97377.93 Ham/year. The net annual drafts of 42263.25 Ham/year leaves a balance of 55114.68 Ham/year of ground water available for future development.

Low Ground water Development: Stage of Ground water development of the district is 43.43%, however talukas wise it ranges from 24.7% (Bhavnagar taluka) to 62.02% (Talaja taluka).

12.1.2 Pollution (Geogenic and Anthropogenic)

Ground water in both shallow and deeper Aquifers is Potable and fit for domestic, drinking, irrigation and other industrial purposes and Occurrence of Fluoride and Nitrate beyond acceptable limit (As per the BIS standards [IS 10500: 2012] for drinking water) in Shallow aquifers identified in localized isolated villages.

12.1.3 Sustainability

Groundwater in these formations occurs under unconfined conditions. The occurrence and movement of groundwater is controlled by primary as well as secondary porosity. The yield of the dugwells ranged between 170 m3/day to 800 m3/day. Lateral bores are also drilled in the dugwells to enhance the yield.

The groundwater in basalt occurs under phreatic to confined conditions. The groundwater is generally tapped through dug wells varying in depth from 5 to 30 m. At places, dug-cum-bored wells are also constructed by drilling bores below the bottom of dug wells. The yield of dug wells and dug-cum-bored wells in basalt generally range from 100 to 500 m^3/day. The dykes occurring in the district form aquifers at places wherever they are highly fractured. The wells in such dykes range in depth between 5 and 25 m and the yield of wells range between 15 and 600 m^3/day.

12.1.4 Reasons for Issues

The groundwater related issues in Bhavnagar district are

- In Bhavnagar district, the overall stage of groundwater development is moderate (68.04 %), however, there is constraint of quality in the coastal areas and low yield in inland hard rock areas. Rapid urbanization and concurrent industrial activities are affecting ambient hydrogeological regime lately.
- District receives monsoon rainfall of 580 mm during SW monsoon, large number of artificial recharge structure are present in the district. The structures need maintenance at regular interval so as to reap the benefit for Time to come.
- There are relatively high ground water development along coastal zones, which also have limited thickness of good quality aquifer system. Sustainable groundwater management strategy to conserve existing resources and preventive actions to control contamination of freshwater resources are essential. Periodic monitoring of ground water should be mandatory

12.2 Management Strategies

As per the estimate of ground water resources and irrigation potential, there exists a scope for further development of ground water resources in major parts of the district. As per GWRE 2017 all the ten (10) talukas of the district are under **safe** category. Stage of Ground water development of the district is 43.4%, however taluka wise it ranges from 24.7% (Bhavnagar village) to 62.02% (Talaja village).

Thus, further ground water development could be augmented in a judicious way.

12.3 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.

- Ground water development Plan
- Supply side measures
- Demand side measures
- Regulatory measures
- Institutional measures

12.3.1 Ground water Development Plan

To elevate the stage of ground water development to 46.04% in all blocks, 5840 nos. of Dug wells (15m depth) are proposed as feasible extraction structures **Table 21**. The extraction structures will result as expected annual ground water draft of 2920 Ham which will create 6488.89 Ha additional irrigation potential in the district.

Table 20 Feasible Extraction structures to elevate the Stage of GW development to 46.04% (Hard Rock)

Extraction / Talukas	Feasible Extraction structures to elevate the Stage of GW development to 46.04%		G.W Draft from Extraction structures (ham)	Additional Irrigation Potential Created (Ha)
	DW	Total		
Bhavnagar	183	183	92	203.33
Gariadhar	565	565	283	627.78
Ghogha	463	463	232	514.44
Jesar	250	250	125	277.78
Mahuva	1174	1174	587	1304.44
Palitana	386	386	193	428.89
Sihor	617	617	309	685.56
Talaja	1549	1549	775	1721.11
Umrala	417	417	209	463.33
Vallabhipur	238	238	119	264.44
District	5840	5840	2920	6488.89

12.3.2 Supply side interventions

As per Master Plan 2020, surplus surface water of 20 mcm non committed is allocated to suggest artificial recharge in district of Bhavnagar. To harvest the surface water the artificial recharge structures are proposed to recharge the aquifer. Expected annual Groundwater recharge is 2043.2 Ham through Recharge Shaft of total 667 nos. are recommended for harvesting the part of available runoff and to recharge the Groundwater as in **Table 22**.

Table 21 Proposed Artificial Recharge and WUE Interventions in Bhavnagar District

Recharge / Talukas	Artificial Recharge through Recharge Shaft	Additional Recharge fromRecharge interventions (ham)
Bhavnagar	31	94.8
Gariadhar	58	177.4
Ghogha	47	143.7
Jesar	37	113.4
Mahuva	125	382.4
Palitana	70	215.7
Sihor	89	273.1
Talaja	141	430.9
Umrala	43	135.6
Vallabhipur	25	76.4
District	667	2043.4

12.3.3 Demand side intervention

Feasible extraction structures are proposed to elevate the stage of ground water development to 46.04%, to avoid further exploitation demand side management is also recommended to restrict the stage of ground water development to 45.06%. An area of 421.98 Ha is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding), and 2986 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Conservation of water from on-farm activities, WUE measures and farm ponds is 944.13 ham.

- **Farm Ponds**

A farm pond is a large hole dug out in the earth, usually square or rectangular in shape (**Figure 48**), 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.

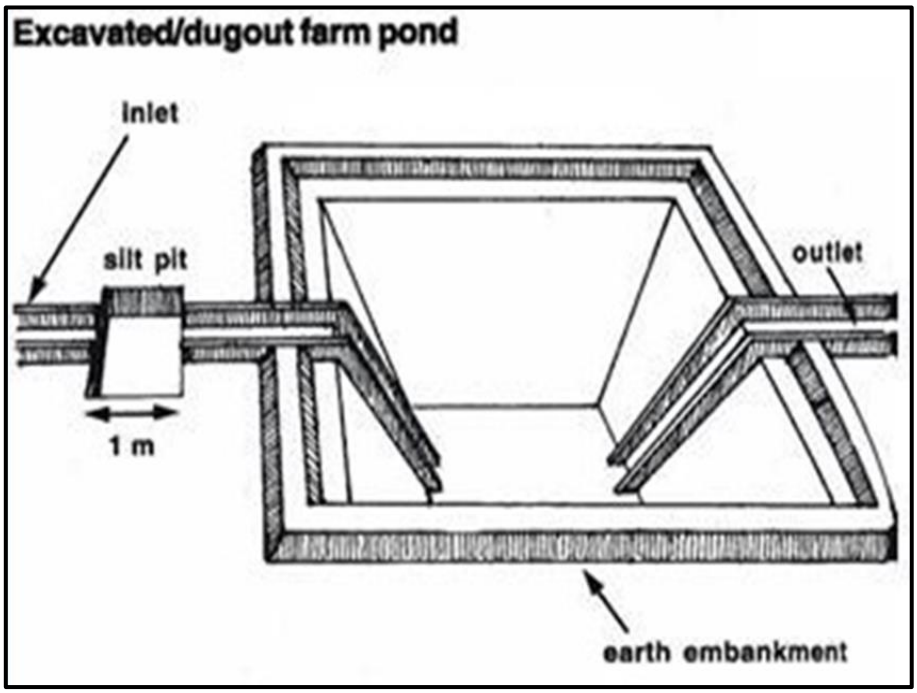


Figure 48 Schematic diagram of Farm Pond

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 supply water for domestic purposes and livestock
- They promote fish rearing.
- They recharge the ground water.
- The excavated earth has a very high value and can be used to enrich soil in the fields, levelling land, and constructing farm roads.

Table 22 Projected Stage Groundwater Resource and Management plan of Bhavnagar District

Projected Status of Groundwater Resource after implementation of GW Management Plan, Bhavnagar District (Gujrat)																
Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from RTRWH (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 Supplemental irrigation (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 & Recharge measures (in %)	Projected stage of GW development after all interventions & import of water from distant source	Additional Irrigation Potential Created (Ha)
Bhavnagar	7090.21	94.8	0	24	7208.80	1751	0	43.57	92	1798.93	24.70	25.90	25.28	24.95		203.33
Gariadhar	6602	177.4	0	71	6850	3414	0	82	283	3614	51.71	55.40	54.14	52.76		627.78
Ghogha	5088.88	143.7	0	60	5292.77	2656.8	0	66.59	232	2821.71	52.21	56.09	54.77	53.31		514.44
Jesar	7551	113.4	0	33	7697	2432	0	53	125	2504	32.21	33.72	33.01	32.53		277.78
Mahuva	15497	382.4	0	153	16033	7352	0	177	587	7762	47.44	50.73	49.57	48.41		1304.44
Palitana	14623	215.7	0	50	14889	5662	0	100	193	5755	38.72	39.90	39.21	38.65		428.89
Sihor	17547	273.1	0	80	17900	6069	0	126	309	6251	34.59	36.18	35.45	34.92		685.56
Talaja	12856	430.9	0	201	13489	7974	0	200	775	8549	62.02	67.00	65.43	63.38		1721.11
Umrala	5846	135.6	0	54	6036	3557	0	61	209	3704	60.85	63.82	62.75	61.38		463.33
Vallabhipur	4676	76.4	0	31	4784	1396	0	35	119	1479	29.85	32.18	31.42	30.93		264.44
Total	97377.93	2043.20	0.00	759.2	100180.33	42263.25	0.00	944.13	2920	44239.12	43.40	46.04	45.06	44.16		6488.89

CONCLUSION AND RECOMMENDATIONS

- Artificial recharge structures like recharge shaft is proposed in the district to encounter needed surface runoff.
- To elevate the stage of ground water development to 46.04% in district, 5840 no. of Dug wells (15 m depth) are proposed as feasible extraction structures.
- The extraction structures will result as expected annual ground water draft of 2920 Ham which will create 6488.89 Ha additional irrigation potential in the district.
- To prevent Over Exploitation, water conservation activities like on farm and farm pond activities are recommended.
- 421.98 Ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 2986 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water.
- Ground water return flow of 759.2 Ham is expected from irrigation of fields in the district.
- 944.13 ham conservation of ground water through WUE measures, on farm activities & farm ponds is expected for the district.
- As a conservation measure, farmers should be encouraged and educated to adopt modern irrigation techniques like drip, sprinkler irrigation etc. to effect minimum withdrawal and maximum utilisation of groundwater.
- The water quality in general is good. However higher EC, Nitrate and fluoride concentration is observed in isolated pockets. Ground water in such areas may be used after blending with surface water. In areas where ground water has higher concentration of Nitrate is observed, necessary sanitation measures should be adopted.
- Taking into consideration of tribal domination and drought prone area, the ‘Mass Awareness Programme’ and 'Water Management Training Programme' should be organized in regular basis in the district for awareness on the depletion of groundwater resources and quality problems.
- Present supply side interventions are suggested based on availability 20 MCM non committed source of water is referred by State Government (Reference Master Plan of Artificial recharge 2020). Proposed enhancements of present Groundwater development stage are subjected to implementation of recharge interventions, availability of cultivable land and yield of Groundwater structures.
- These interventions also need to be supported by regulation, so that the ground water resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought. IEC activities and capacity building activities needs to be aggressively propagated to establish the institutional framework for participatory ground water management.

Annexure-I- Pre-monsoon_2021 Depth to water level data of Bhavnagar District

STATE	DISTRICT	GOVT. AGENCY	SITE_NAME	AQUIFER_TY	LONGITUDE	LATITUDE	WATER_LEVEL
Gujarat	Bhavnagar	CGWB	Hipavadli	Unconfined	71.61	21.38	0.00
Gujarat	Bhavnagar	CGWB	Jesar_Pz	Unconfined	71.67	21.37	4.93
Gujarat	Bhavnagar	CGWB	Ambala	Unconfined	71.84	21.71	21.96
Gujarat	Bhavnagar	CGWB	Ayodhayapuram	Unconfined	71.89	21.96	7.16
Gujarat	Bhavnagar	CGWB	Bhavnagar1	Unconfined	72.15	21.77	3.92
Gujarat	Bhavnagar	CGWB	Bhudel	Unconfined	72.16	21.69	3.82
Gujarat	Bhavnagar	CGWB	Bhumbhali	Unconfined	72.24	21.68	3.41
Gujarat	Bhavnagar	CGWB	Bhutia	Unconfined	71.70	21.75	22.30
Gujarat	Bhavnagar	CGWB	Bora	Unconfined	71.93	21.19	20.94
Gujarat	Bhavnagar	CGWB	Chowk Pz	Unconfined	71.76	21.43	0.00
Gujarat	Bhavnagar	CGWB	Datha	Unconfined	71.95	21.22	1.03
Gujarat	Bhavnagar	CGWB	Dudhala	Unconfined	71.66	21.14	7.80
Gujarat	Bhavnagar	CGWB	Gariyadhar	Unconfined	71.57	21.54	12.84
Gujarat	Bhavnagar	CGWB	Ghogha1	Unconfined	72.28	21.68	0.74
Gujarat	Bhavnagar	CGWB	Jalia	Unconfined	71.62	21.80	10.59
Gujarat	Bhavnagar	CGWB	Khijadiya	Unconfined	71.70	21.64	8.29
Gujarat	Bhavnagar	CGWB	Kundheli	Unconfined	71.98	21.38	21.65
Gujarat	Bhavnagar	CGWB	Longadi	Unconfined	71.88	21.21	1.84
Gujarat	Bhavnagar	CGWB	Mahuva1	Unconfined	71.77	21.10	9.31
Gujarat	Bhavnagar	CGWB	Malvav_Pz	Unconfined	71.91	21.16	0.00
Gujarat	Bhavnagar	CGWB	Motivadal	Unconfined	71.55	21.20	2.29
Gujarat	Bhavnagar	CGWB	Palitana1	Unconfined	71.82	21.53	6.48
Gujarat	Bhavnagar	CGWB	Palitana2	Unconfined	71.84	21.52	0.00
Gujarat	Bhavnagar	CGWB	Panchpipla	Unconfined	71.72	21.55	0.01
Gujarat	Bhavnagar	CGWB	Panvi1	Unconfined	71.89	22.08	3.94

Gujarat	Bhavnagar	CGWB	Pasvi	Unconfined	71.97	21.29	14.00
Gujarat	Bhavnagar	CGWB	Piparla	Unconfined	71.92	21.64	1.72
Gujarat	Bhavnagar	CGWB	Porbada	Unconfined	71.70	21.80	12.98
Gujarat	Bhavnagar	CGWB	Sajnasar	Unconfined	71.91	21.43	2.23
Gujarat	Bhavnagar	CGWB	Sandhida	Unconfined	71.76	21.69	1.83
Gujarat	Bhavnagar	CGWB	Satanes	Unconfined	71.84	21.44	6.55
Gujarat	Bhavnagar	CGWB	Shantinagar	Unconfined	71.65	21.25	12.72
Gujarat	Bhavnagar	CGWB	Talaja2	Unconfined	72.02	21.37	4.40
Gujarat	Bhavnagar	CGWB	Tansa	Unconfined	72.13	21.51	0.00
Gujarat	Bhavnagar	CGWB	Timbi2	Unconfined	71.77	21.83	2.88
Gujarat	Bhavnagar	CGWB	Trapaj	Unconfined	72.10	21.43	9.91
Gujarat	Bhavnagar	CGWB	Umrala	Unconfined	71.81	21.85	6.12
Gujarat	Bhavnagar	CGWB	Vadal	Unconfined	71.81	21.48	3.14
Gujarat	Bhavnagar	CGWB	Vallabhipur1	Unconfined	71.88	21.88	3.08
Gujarat	Bhavnagar	CGWB	Vallbhipur	Unconfined	71.88	21.88	2.44
Gujarat	Bhavnagar	CGWB	Vavdi	Unconfined	72.20	21.57	12.13
Gujarat	Bhavnagar	NAQUIM	Amargadh	Unconfined	71.87	21.71	14.76
Gujarat	Bhavnagar	NAQUIM	Bapada	Unconfined	72.11	21.40	6.46
Gujarat	Bhavnagar	NAQUIM	Bhadara	Unconfined	71.68	21.13	12.89
Gujarat	Bhavnagar	NAQUIM	Bhandaria	Unconfined	71.63	21.48	1.65
Gujarat	Bhavnagar	NAQUIM	Bhanvadia	Unconfined	71.71	21.28	12.50
Gujarat	Bhavnagar	NAQUIM	Bhavani Nagar	Unconfined	71.75	21.07	2.56
Gujarat	Bhavnagar	NAQUIM	Devaliya	Unconfined	71.72	21.06	6.96
Gujarat	Bhavnagar	NAQUIM	Dharai	Unconfined	71.85	21.31	4.84
Gujarat	Bhavnagar	NAQUIM	Dudadhar	Unconfined	71.77	21.94	6.21
Gujarat	Bhavnagar	NAQUIM	Ghanghali	Unconfined	71.95	21.77	11.03
Gujarat	Bhavnagar	NAQUIM	Italia	Unconfined	71.92	21.98	4.95
Gujarat	Bhavnagar	NAQUIM	Kajavadar	Unconfined	71.97	21.65	3.64
Gujarat	Bhavnagar	NAQUIM	Kardej 1	Unconfined	72.05	21.75	21.42

Gujarat	Bhavnagar	NAQUIM	Kardej 2	Unconfined	72.02	21.76	21.28
Gujarat	Bhavnagar	NAQUIM	Khari	Unconfined	71.78	21.27	5.89
Gujarat	Bhavnagar	NAQUIM	Kudada	Unconfined	71.91	21.39	3.75
Gujarat	Bhavnagar	NAQUIM	Kukad	Unconfined	71.24	21.49	9.93
Gujarat	Bhavnagar	NAQUIM	Malvav	Unconfined	71.88	21.15	21.51
Gujarat	Bhavnagar	NAQUIM	Moorchand	Unconfined	71.18	21.56	14.24
Gujarat	Bhavnagar	NAQUIM	Mota Asrana	Unconfined	71.62	21.15	9.69
Gujarat	Bhavnagar	NAQUIM	Mota Khutawada	Unconfined	71.64	21.21	9.72
Gujarat	Bhavnagar	NAQUIM	Moti Dharai	Unconfined	71.93	22.01	10.56
Gujarat	Bhavnagar	NAQUIM	Nawasarod	Unconfined	71.85	21.63	1.67
Gujarat	Bhavnagar	NAQUIM	Padroad	Unconfined	71.82	21.15	5.02
Gujarat	Bhavnagar	NAQUIM	Palitana	Unconfined	71.81	21.54	2.30
Gujarat	Bhavnagar	NAQUIM	Paravadi	Unconfined	71.62	21.57	12.42
Gujarat	Bhavnagar	NAQUIM	Rajapara	Unconfined	71.71	21.39	11.95
Gujarat	Bhavnagar	NAQUIM	Randola	Unconfined	71.89	21.57	10.64
Gujarat	Bhavnagar	NAQUIM	Ratanpar	Unconfined	71.83	21.35	3.24
Gujarat	Bhavnagar	NAQUIM	Sajnasar	Unconfined	71.99	21.42	7.32
Gujarat	Bhavnagar	NAQUIM	Sakhada	Unconfined	72.01	21.33	4.44
Gujarat	Bhavnagar	NAQUIM	Sarvedi	Unconfined	71.72	21.67	12.08
Gujarat	Bhavnagar	NAQUIM	Satapada	Unconfined	71.68	21.47	2.57
Gujarat	Bhavnagar	NAQUIM	senjadiya	Unconfined	71.81	21.89	5.56
Gujarat	Bhavnagar	NAQUIM	Sihor	Unconfined	71.96	21.74	20.44
Gujarat	Bhavnagar	NAQUIM	Tana	Unconfined	71.68	21.56	9.95
Gujarat	Bhavnagar	NAQUIM	Ukharla	Unconfined	72.14	21.61	11.21
Gujarat	Bhavnagar	NAQUIM	Umarla	Unconfined	72.08	21.43	12.10
Gujarat	Bhavnagar	NAQUIM	Varal	Unconfined	71.99	21.52	10.00
Gujarat	Bhavnagar	NAQUIM	Zadakala	Unconfined	71.62	21.37	19.32

Annexure-II- Post-monsoon_2021 Depth to water level data of Bhavnagar District

STATE	DISTRICT	GOVT. AGENCY	SITE_NAME	AQUIFER_TY	LONGITUDE	LATITUDE	WATER_LEVEL
Gujarat	Bhavnagar	CGWB	Hipavadli	Unconfined	71.61	21.38	0.00
Gujarat	Bhavnagar	CGWB	Jesar_Pz	Unconfined	71.67	21.37	4.19
Gujarat	Bhavnagar	CGWB	Ambala	Unconfined	71.84	21.71	2.35
Gujarat	Bhavnagar	CGWB	Ayodhayapuram	Unconfined	71.89	21.96	4.37
Gujarat	Bhavnagar	CGWB	Bhavnagar1	Unconfined	72.15	21.77	3.40
Gujarat	Bhavnagar	CGWB	Bhudel	Unconfined	72.16	21.69	0.50
Gujarat	Bhavnagar	CGWB	Bhumbhali	Unconfined	72.24	21.68	0.90
Gujarat	Bhavnagar	CGWB	Bhutia	Unconfined	71.70	21.75	0.00
Gujarat	Bhavnagar	CGWB	Bora	Unconfined	71.93	21.19	9.44
Gujarat	Bhavnagar	CGWB	Chowk Pz	Unconfined	71.76	21.43	0.00
Gujarat	Bhavnagar	CGWB	Datha	Unconfined	71.95	21.22	2.74
Gujarat	Bhavnagar	CGWB	Dudhala	Unconfined	71.66	21.14	0.00
Gujarat	Bhavnagar	CGWB	Gariyadhar	Unconfined	71.57	21.54	5.20
Gujarat	Bhavnagar	CGWB	Ghogha1	Unconfined	72.28	21.68	0.60
Gujarat	Bhavnagar	CGWB	Jalia	Unconfined	71.62	21.80	8.07
Gujarat	Bhavnagar	CGWB	Khijadiya	Unconfined	71.70	21.64	2.82
Gujarat	Bhavnagar	CGWB	Kundheli	Unconfined	71.98	21.38	1.48
Gujarat	Bhavnagar	CGWB	Longadi	Unconfined	71.88	21.21	1.05
Gujarat	Bhavnagar	CGWB	Mahuva1	Unconfined	71.77	21.10	0.00
Gujarat	Bhavnagar	CGWB	Malvav_Pz	Unconfined	71.91	21.16	0.00
Gujarat	Bhavnagar	CGWB	Motivadal	Unconfined	71.55	21.20	1.80
Gujarat	Bhavnagar	CGWB	Palitana1	Unconfined	71.82	21.53	2.25
Gujarat	Bhavnagar	CGWB	Palitana2	Unconfined	71.84	21.52	3.20
Gujarat	Bhavnagar	CGWB	Panchpipla	Unconfined	71.72	21.55	-0.35
Gujarat	Bhavnagar	CGWB	Panvi1	Unconfined	71.89	22.08	1.65
Gujarat	Bhavnagar	CGWB	Pasvi	Unconfined	71.97	21.29	0.00

Gujarat	Bhavnagar	CGWB	Piparla	Unconfined	71.92	21.64	-0.20
Gujarat	Bhavnagar	CGWB	Porbada	Unconfined	71.70	21.80	5.53
Gujarat	Bhavnagar	CGWB	Sajnasar	Unconfined	71.91	21.43	1.55
Gujarat	Bhavnagar	CGWB	Sandhida	Unconfined	71.76	21.69	0.30
Gujarat	Bhavnagar	CGWB	Satanes	Unconfined	71.84	21.44	9.73
Gujarat	Bhavnagar	CGWB	Shantinagar	Unconfined	71.65	21.25	0.70
Gujarat	Bhavnagar	CGWB	Talaja2	Unconfined	72.02	21.37	1.68
Gujarat	Bhavnagar	CGWB	Tansa	Unconfined	72.13	21.51	0.00
Gujarat	Bhavnagar	CGWB	Timbi2	Unconfined	71.77	21.83	6.40
Gujarat	Bhavnagar	CGWB	Trapaj	Unconfined	72.10	21.43	5.20
Gujarat	Bhavnagar	CGWB	Umrala	Unconfined	71.81	21.85	4.60
Gujarat	Bhavnagar	CGWB	Vadal	Unconfined	71.81	21.48	4.00
Gujarat	Bhavnagar	CGWB	Vallabhipur1	Unconfined	71.88	21.88	3.18
Gujarat	Bhavnagar	CGWB	Vallbhipur	Unconfined	71.88	21.88	2.20
Gujarat	Bhavnagar	CGWB	Vavdi	Unconfined	72.20	21.57	0.90
Gujarat	Bhavnagar	NAQUIM	Amargadh	Unconfined	71.87	21.71	3.73
Gujarat	Bhavnagar	NAQUIM	Bapada	Unconfined	72.11	21.40	8.06
Gujarat	Bhavnagar	NAQUIM	Bhadara	Unconfined	71.68	21.13	9.63
Gujarat	Bhavnagar	NAQUIM	Bhandaria	Unconfined	71.63	21.48	0.57
Gujarat	Bhavnagar	NAQUIM	Bhanvadia	Unconfined	71.71	21.28	1.30
Gujarat	Bhavnagar	NAQUIM	Bhavani Nagar	Unconfined	71.75	21.07	1.86
Gujarat	Bhavnagar	NAQUIM	Devaliya	Unconfined	71.72	21.06	5.14
Gujarat	Bhavnagar	NAQUIM	Dharai	Unconfined	71.85	21.31	3.88
Gujarat	Bhavnagar	NAQUIM	Dudadhar	Unconfined	71.77	21.94	5.99
Gujarat	Bhavnagar	NAQUIM	Ghanghali	Unconfined	71.95	21.77	7.30
Gujarat	Bhavnagar	NAQUIM	Italia	Unconfined	71.92	21.98	2.90
Gujarat	Bhavnagar	NAQUIM	Kajavadar	Unconfined	71.97	21.65	2.45
Gujarat	Bhavnagar	NAQUIM	Kardej 1	Unconfined	72.05	21.75	10.87
Gujarat	Bhavnagar	NAQUIM	Kardej 2	Unconfined	72.02	21.76	17.54

Gujarat	Bhavnagar	NAQUIM	Khari	Unconfined	71.78	21.27	2.58
Gujarat	Bhavnagar	NAQUIM	Kudada	Unconfined	71.91	21.39	1.71
Gujarat	Bhavnagar	NAQUIM	Kukad	Unconfined	71.24	21.49	5.80
Gujarat	Bhavnagar	NAQUIM	Malvav	Unconfined	71.88	21.15	19.52
Gujarat	Bhavnagar	NAQUIM	Moorchand	Unconfined	71.18	21.56	5.52
Gujarat	Bhavnagar	NAQUIM	Mota Asrana	Unconfined	71.62	21.15	
Gujarat	Bhavnagar	NAQUIM	Mota Khutawada	Unconfined	71.64	21.21	4.32
Gujarat	Bhavnagar	NAQUIM	Moti Dharai	Unconfined	71.93	22.01	6.44
Gujarat	Bhavnagar	NAQUIM	Nawasarod	Unconfined	71.85	21.63	1.11
Gujarat	Bhavnagar	NAQUIM	Padroad	Unconfined	71.82	21.15	
Gujarat	Bhavnagar	NAQUIM	Palitana	Unconfined	71.81	21.54	4.34
Gujarat	Bhavnagar	NAQUIM	Paravadi	Unconfined	71.62	21.57	6.44
Gujarat	Bhavnagar	NAQUIM	Rajapara	Unconfined	71.71	21.39	8.84
Gujarat	Bhavnagar	NAQUIM	Randola	Unconfined	71.89	21.57	4.43
Gujarat	Bhavnagar	NAQUIM	Ratanpar	Unconfined	71.83	21.35	0.91
Gujarat	Bhavnagar	NAQUIM	Sajnasar	Unconfined	71.99	21.42	4.96
Gujarat	Bhavnagar	NAQUIM	Sakhada	Unconfined	72.01	21.33	3.67
Gujarat	Bhavnagar	NAQUIM	Sarvedi	Unconfined	71.72	21.67	3.96
Gujarat	Bhavnagar	NAQUIM	Satapada	Unconfined	71.68	21.47	1.69
Gujarat	Bhavnagar	NAQUIM	senjadiya	Unconfined	71.81	21.89	3.21
Gujarat	Bhavnagar	NAQUIM	Sihor	Unconfined	71.96	21.74	15.41
Gujarat	Bhavnagar	NAQUIM	Tana	Unconfined	71.68	21.56	
Gujarat	Bhavnagar	NAQUIM	Ukharla	Unconfined	72.14	21.61	4.97
Gujarat	Bhavnagar	NAQUIM	Umarla	Unconfined	72.08	21.43	2.55
Gujarat	Bhavnagar	NAQUIM	Varal	Unconfined	71.99	21.52	3.32
Gujarat	Bhavnagar	NAQUIM	Zadakala	Unconfined	71.62	21.37	5.56

Annexure-II- Pre-monsoon_2021 Water quality data of Bhavnagar District

STATE	District	Location	Lat.	Long.	Source	pH	EC	TDS	CO3	HCO3	Cl	NO3	S04	F	Alkalinity	Ca	Mg	TH	Na	K	SiO2	SAR
Gujarat	Bhavnagar	Tana	21.56	71.68	DW	8.28	1000	670	42	305	50	55.8	58	0.31	320	88	46.208	410	40	0.1	57.96	0.86
Gujarat	Bhavnagar	Kajavadar	21.65	71.97	DW	7.89	1950	1307	0	354	248	141.2	201	0.35	290	168	109.44	870	44	0.1	67.12	0.65
Gujarat	Bhavnagar	Kudada	21.39	71.91	DW	7.91	1490	998	0	232	128	186	232	0.45	190	108	80.256	600	61.6	0.1	50.66	1.09
Gujarat	Bhavnagar	Khari	21.27	71.78	DW	8.3	1290	864	24	134	142	205.6	125	0.36	150	76	75.392	500	66.2	0.1	63.24	1.29
Gujarat	Bhavnagar	Sarvedi	21.67	71.72	DW	7.88	1090	730	0	476	50	66	29	0.4	390	60	43.776	330	92	0.1	57.78	2.2
Gujarat	Bhavnagar	Bhanvadia	21.28	71.71	DW	8.31	1210	811	42	329	78	80.8	83	0.43	340	48	65.664	390	98.2	0.1	68.14	2.16
Gujarat	Bhavnagar	Mota Khutawada	21.21	71.64	DW	8	1725	1156	0	439	170	146.6	141	0.41	360	68	94.848	560	137.8	0.1	60.62	2.53
Gujarat	Bhavnagar	Sajnasar	21.42	71.99	DW	7.77	2280	1528	0	451	305	245.6	133	0.79	370	168	97.28	820	145	0.1	57.98	2.2
Gujarat	Bhavnagar	Bhadara	21.13	71.68	DW	8.48	1310	878	60	512	28	94.8	15	0.72	520	28	48.64	270	168.2	0.1	66.46	4.45
Gujarat	Bhavnagar	Satapada	21.47	71.68	DW	8.36	3440	2305	48	696	546	151.8	163	1.09	650	68	145.92	770	431.2	0.1	45.1	6.76
Gujarat	Bhavnagar	Rajapara	21.39	71.71	DW	8.6	2680	1796	114	1232	35	48.2	38	1.5	1200	16	26.752	150	530.8	0.1	18.04	18.84
Gujarat	Bhavnagar	Varal	21.52	71.99	DW	7.97	3000	2010	0	305	319	666	253	0.62	250	240	158.08	1250	133.2	0.16	66.1	1.64
Gujarat	Bhavnagar	Bhandaria	21.48	71.63	DW	7.83	3050	2044	0	561	546	64.2	219	0.64	460	116	148.352	900	275	0.17	40.96	3.99
Gujarat	Bhavnagar	Kukad	21.49	71.24	DW	8.13	850	570	0	244	71	60.8	59	0.33	200	76	53.504	410	2.6	0.2	44.12	0.06
Gujarat	Bhavnagar	Ratanpar	21.35	71.83	DW	8.28	742	497	24	256	43	13.6	42	0.43	250	44	43.776	290	36.2	0.2	35.26	0.92
Gujarat	Bhavnagar	Ukharla	21.61	72.14	DW	7.89	1290	864	0	293	113	83.4	175	0.32	240	108	60.8	520	52	0.2	56.04	0.99
Gujarat	Bhavnagar	Randola	21.57	71.89	DW	8.52	5350	3585	150	244	213	2352	27	0.71	450	80	559.36	2500	75.8	0.2	64.5	0.66
Gujarat	Bhavnagar	Nawasarod	21.63	71.85	DW	7.8	1040	697	0	403	71	77.6	30	0.92	330	60	38.912	310	95	0.2	70.02	2.35
Gujarat	Bhavnagar	Paravadi	21.57	71.62	DW	8.28	1644	1101	48	342	135	183.4	123	0.49	360	124	63.232	570	110	0.2	60.04	2
Gujarat	Bhavnagar	Sakhada	21.33	72.01	DW	8.27	2252	1509	42	488	305	101.2	136	0.64	470	68	89.984	540	270	0.2	67.94	5.05
Gujarat	Bhavnagar	Sihor	21.74	71.96	DW	8.28	2000	1340	42	537	241	93.8	66	0.51	510	40	41.344	270	335	0.2	49.26	8.86

Gujarat	Bhavnagar	Ghanghali	21.77	71.95	DW	8.32	4015	2690	180	610	780	7.8	105	0.92	800	100	60.8	500	676	0.2	38.66	13.14
Gujarat	Bhavnagar	Kardej	21.75	72.05	DW	8.36	542	363	24	171	43	17.6	5	0.4	180	36	29.184	210	26.8	0.3	28.22	0.8
Gujarat	Bhavnagar	Moorchand	21.56	71.18	DW	8.17	902	604	0	220	57	102.2	81	0.61	180	68	29.184	290	57.4	0.3	58.44	1.47
Gujarat	Bhavnagar	Dharai	21.31	71.85	DW	8.36	2050	1374	54	805	92	35.8	103	0.48	750	56	177.536	870	70.4	0.3	50.66	1.04
Gujarat	Bhavnagar	Mota Asrana	21.15	71.62	DW	7.9	1118	749	0	305	92	130.2	75	0.86	250	72	46.208	370	80.4	0.3	68.94	1.82
Gujarat	Bhavnagar	Italia	21.98	71.92	DW	8.49	3425	2295	84	1013	418	13.8	134	1.58	970	28	24.32	170	708	0.3	44.94	23.61
Gujarat	Bhavnagar	Padroad	21.15	71.82	DW	8.47	6120	4100	300	1037	745	81	578	1.24	1350	60	133.76	700	1078.8	0.3	21.32	17.73
Gujarat	Bhavnagar	Kardej	21.76	72.02	DW	8.27	622	417	24	207	57	14.8	6	0.55	210	32	29.184	200	49.6	0.4	29.34	1.52
Gujarat	Bhavnagar	Zadakala	21.37	71.62	DW	8.43	1080	724	54	366	57	40	22	0.41	390	56	53.504	360	81.4	0.4	49.8	1.87
Gujarat	Bhavnagar	Amargadh	21.71	71.87	DW	8.3	1740	1166	42	342	241	60.2	150	0.89	350	56	36.48	290	273.8	0.5	62.16	6.99
Gujarat	Bhavnagar	Panchpipla	21.54	71.72	DW	8.16	1535	1028	0	403	284	36	65	0.64	330	40	61	350	210	0.56	56	4.87
Gujarat	Bhavnagar	Bapada	21.40	72.11	DW	8.28	1410	945	36	305	191	37	88	0.28	310	104	63.232	520	80.8	0.6	39.36	1.54
Gujarat	Bhavnagar	Malvav	21.15	71.88	DW	8.04	1320	884	0	232	277	51.8	27	1.21	190	20	21.888	140	235	0.6	18.58	8.64
Gujarat	Bhavnagar	Lonjdhara	22.10	71.89	DW	8.48	1445	968	72	317	213	77	28	1.72	380	32	49	280	238	0.69	89	6.19
Gujarat	Bhavnagar	Moti Dharai	22.01	71.93	DW	8.39	8550	5729	120	732	2128	142	361	1.49	800	80	145.92	800	1578	0.7	56.12	24.26
Gujarat	Bhavnagar	Umarla	21.43	72.08	DW	8.06	1106	741	0	293	106	101.4	51	0.66	240	72	72.96	480	29.6	0.8	61.6	0.59
Gujarat	Bhavnagar	Bhavani Nagar	21.07	71.75	DW	8.03	11300	7571	0	549	2872	83.6	1083	1.16	450	200	109.44	950	2096.2	0.8	18.46	29.57
Gujarat	Bhavnagar	Vadal	21.45	71.85	DW	8.02	990	663	0	281	107	85	56	0.45	230	60	51	360	75	0.81	75	1.72
Gujarat	Bhavnagar	Talaja2	21.37	72.02	DW	8.08	2000	1340	0	232	476	86	128	0.37	190	84	141	790	113	0.86	96	1.75
Gujarat	Bhavnagar	Gariyadhar	21.54	71.56	DW	7.83	2595	1739	0	244	525	153	284	0.65	200	88	146	820	231	0.87	91	3.51
Gujarat	Bhavnagar	Piparla	21.64	71.92	DW	8.05	720	482	0	256	78	29	40	0.33	210	48	36	270	52	0.88	82	1.39
Gujarat	Bhavnagar	Devaliya	21.06	71.72	DW	7.74	16000	10720	0	305	5213	43	434	0.93	250	640	547.2	3850	1944.2	1	27.84	13.62
Gujarat	Bhavnagar	Trapaj	21.42	72.10	DW	7.19	1475	988	0	281	163	175	160	0.34	230	132	83	670	58	1.11	74	0.97
Gujar	Bhavna	Dudadhar	21.94	71.77	DW	7.56	3715	2489	0	366	851	190.6	221	0.49	300	180	243.2	1450	197.	1.6	74.92	2.25

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Gujarat	Bhavnagar	Jalia	21.80	71.61	DW	7.30	2910	1950	0	293	689	83	210	0.50	240	224	119	1050	226	1.70	82	3.03
Gujarat	Bhavnagar	Timbi2	20.89	71.20	DW	8.59	815	546	48	73	156	30	56	0.39	140	32	44	260	86	1.75	45	2.33
Gujarat	Bhavnagar	Bora	21.16	71.87	DW	8.64	1470	985	120	488	78	55	50	2.75	600	12	12	80	325	1.88	23	15.80
Gujarat	Bhavnagar	Mahuva	21.10	71.75	DW	8.52	5070	3397	132	451	1115	72	310	0.94	590	24	39	220	1025	2.16	42	30.05
Gujarat	Bhavnagar	Sajnasar	21.43	71.91	DW	8.18	790	529	0	244	92	35	52	0.49	200	44	34	250	78	3.14	50	2.14
Gujarat	Bhavnagar	Sandhida	21.69	71.76	DW	7.97	890	596	0	342	99	10	48	0.39	280	56	49	340	68	3.35	48	1.61
Gujarat	Bhavnagar	senjadiya	21.89	71.81	DW	7.95	3500	2345	0	85	887	268.2	202	0.52	70	200	145.92	1100	292	3.7	50.8	3.83
Gujarat	Bhavnagar	Bhavnagar 1	21.77	72.15	DW	7.18	1315	881	0	305	241	30	65	0.49	250	80	39	360	150	3.71	40	3.44
Gujarat	Bhavnagar	Dudhala	21.14	71.65	DW	7.94	2540	1702	0	305	540	167	154	0.46	250	88	151	840	214	4.00	101	3.21
Gujarat	Bhavnagar	Palitana	21.54	71.81	DW	8.03	4471	2996	0	366	1206	89.4	151	0.88	300	200	133.76	1050	550	4.02	57.22	7.38
Gujarat	Bhavnagar	Vallbhipur	21.90	71.88	DW	8.88	4835	3239	108	342	959	58	557	0.52	460	20	58	290	1030	5.65	43	26.30
Gujarat	Bhavnagar	Motivadal	21.19	71.55	DW	8.26	1230	824	0	403	185	25	65	0.35	330	64	68	440	99	6.86	74	2.06
Gujarat	Bhavnagar	Timbi2	20.90	71.20	DW	8.39	2660	1782	96	244	462	224	146	0.88	360	32	75	390	412	7.94	44	9.06
Gujarat	Bhavnagar	Datha	21.21	71.95	DW	8.45	1435	961	84	122	312	7.53	50	1.09	240	44	27	220	224	9.25	19	6.57
Gujarat	Bhavnagar	Longadi	21.21	71.89	DW	8.20	760	509	0	293	78	6.38	40	0.60	240	40	10	140	96	28.70	68	3.51
Gujarat	Bhavnagar	Ghogha	21.68	72.28	DW	8.42	2780	1863	120	403	391	182	199	0.29	530	92	46	420	420	63	51	8.91
Gujarat	Bhavnagar	Umrala	21.84	71.80	T/W	8.64	3450	2312	132	1257	248	37.6	95	1.78	1250	16	7.296	70	759.2	0.02	76.38	39.45
Gujarat	Bhavnagar	Paravadi	21.57	71.62	T/W	7.97	1610	1079	0	427	135	243.4	63	0.51	350	88	60.8	470	161	0.06	57.14	3.23
Gujarat	Bhavnagar	Ratanpur	21.35	71.82	T/W	8.28	855	573	36	305	57	20.2	24	0.48	310	40	48.64	300	57.4	0.1	41.38	1.44
Gujarat	Bhavnagar	Sadodara	21.56	72.13	T/W	8.3	1295	868	48	476	57	95	23	0.52	470	64	29.184	280	165	0.1	67.52	4.29
Gujarat	Bhavnagar	Kardez	21.75	71.05	T/W	8.31	1280	858	42	451	113	33.8	9	0.56	440	44	41.344	280	167	0.1	43.94	4.34
Gujarat	Bhavnagar	Varal	21.52	71.99	T/W	8.27	1190	797	0	220	177	31.4	133	0.25	180	60	0	150	202.4	0.1	30.66	7.19
Gujarat	Bhavnagar	Zadakala	21.37	71.62	T/W	8.28	1841	1233	54	622	128	137.4	21	0.32	600	28	81.472	405	230	0.1	61.32	4.97

Gujarat	Bhavnagar	Sarvedi	21.68	71.72	T/W	7.89	1286	862	0	317	149	108.4	82	0.42	260	96	41.344	410	100	0.13	46.58	2.15
Gujarat	Bhavnagar	Malavav	21.15	71.89	T/W	9	1570	1052	90	439	121	68.2	38	1.2	510	16	21.888	130	295.4	0.2	24.3	11.26
Gujarat	Bhavnagar	Bapada	21.40	71.10	T/W	8.29	1635	1095	48	451	163	86.4	78	0.3	450	108	80.256	600	100	0.3	44.28	1.77
Gujarat	Bhavnagar	Okteria	21.05	71.71	T/W	8.1	1911	1280	0	390	355	25.8	108	0.81	320	84	58.368	450	230	0.3	15.04	4.71
Gujarat	Bhavnagar	Nawasobavat	21.34	71.02	T/W	8.91	2890	1936	240	769	213	63.6	64	0.76	1030	16	14.592	100	615.4	0.3	89.66	26.76
Gujarat	Bhavnagar	Otha	21.18	71.84	T/W	8.07	4420	2961	0	98	1383	14.8	160	0.58	80	80	97.28	600	750	0.3	78.22	13.31
Gujarat	Bhavnagar	Amargadh	21.71	71.88	T/W	7.81	4050	2714	0	1037	546	44	357	0.34	850	200	72.96	800	587.2	0.5	39.34	9.03
Gujarat	Bhavnagar	Panvi1	23.13	72.78	T/W	8.71	2850	1910	90	854	298	59.8	107	1.24	850	28	31.616	200	554.2	0.8	54.94	17.04
Gujarat	Bhavnagar	Dharai	21.30	71.85	T/W	8.31	1902	1274	36	329	298	121	93	0.21	330	136	87.552	700	104	1.16	58.84	1.71
Gujarat	Bhavnagar	Manvar	21.55	71.80	T/W	8.47	2680	1796	78	842	248	64.8	110	1.23	820	32	29.184	200	523.4	1.2	43.3	16.09

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