



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

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

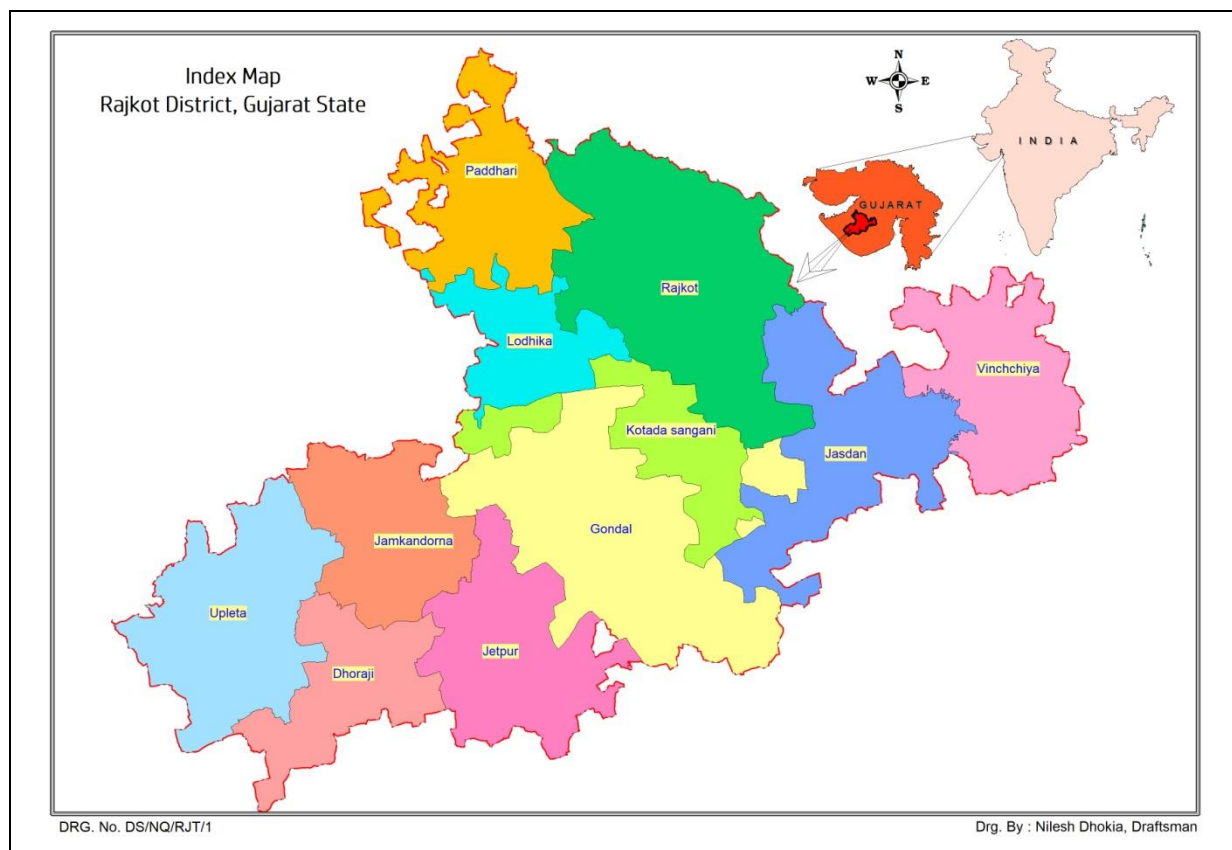
**Rajkot District
Gujarat**

पश्चिम मध्य क्षेत्र, अहमदाबाद
West Central Region, Ahmedabad

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Technical Report Series

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES RAJKOT DISTRICT, GUJARAT STATE



Government of India
Ministry of JalShakti
Department of Water Resources, RD and GR Central Ground Water Board
West Central Region Ahmedabad

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**AQUIFER MAP&MANAGEMENT PLAN OF
RAJKOT DISTRICT GUJARAT
(7753.65 sq. km)**

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RAJKOT DISTRICT AT GLANCE

Sl.No	Items	Statistics
1	General Information	
	i) Geographical area (Sq. Km)	7750
	ii) Total Reporting Area(Sq. Km)	7750
	iii) Administrative Divisions (As on 3/2011) Number of Talukas Number of Villages	11 598
	iv) Populations (As per Census 2011)	3,804,558
	v) Average Annual Rainfall (mm)	645
2.	GEOMORPHOLOGY	
	Major Physiographic Units: Pediments & Dissected Hills	
	Major Drainages: Bhadar, Aji, Machhu and Demai	
3.	LAND USE (Sq. Km) (Source: Directorate of agriculture Season & Crops record 2018-19)	
	a) Forest area	257
	b) Area under waste Land	473
	c) Gross Cropped Area	5658
	d) Net area sown	5297
	e) Area Sown more than once	362
	f) Cropping Intensity	106.81%
4.	MAJOR SOIL TYPES: Mostly of Inceptisol and Entisol order and of Othids, Ochrepts, Orthents, Fluvents, Psammments and Aquepts suborder. The soils are sandy, loamy sand, clayey and siltytype.	
5.	AREA UNDER FOOD CROPS (sq.km) (2018-19) Rice 4, Bajra-9, Jowar-6, Wheat-52, Maize-7,Total cereals-725,Total pulses-74.Total Pulses-77,Total Foodgrains-152,Total Oil seed-2548,Total Fiber Crops-2602. (Source: Directorate of agriculture Season & Crops record 2018-19)	
6.	IRRIGATION BY DIFFERENT SOURCES (Area in Hectares/ no of structures) (Source: Directorate of agriculture Season & Crops record 2018-19 & MI Census data from NWRWS & KD)	
	Dug wells	195500/83053
	Tube wells/Bore wells	135800/7155
	Tanks/Ponds/Water conservation structures	9300/104
	Canals	17200/50
	Net Irrigated area(sq. km.) (2018-19)	279,200
	Gross Irrigated area (sq. km.) (2018-19)	337,800
7.	NUMBERS OF GROUND WATER MONITORING WELLS.	
	a) CGWB-Dug Wells	34
	b) CGWB-Piezometers	05
8.	PREDOMINANT GEOLOGICAL FORMATIONS: Deccan Trap basalt with Deccan traps the predominant geological formation.	
9.	Major Water Bearing Formations: Weathered & Fractured Basalts.	
	Depth to water Level during 2019-20	

	Period	Phreatic Aquifer (DTW)		Semi-confined /Confined Aquifer (PZ head)	
		Min	Max	Min	Max
	Pre Monsoon	3.85 (Ukarda)	30.21 (Vajdi)	NA	NA
	Post Monsoon	0.10 (Ravki)	26.40 (Mandalikpur)	NA	NA
	Long Term (10 Years) Water Level Trend (2011 to 2020)				
	Trend	Pre-Monsoon		Post- Monsoon	
	Rise (m/Yr)	0.0184 (Dadvi) to 1.875 (Ambardi)		0.00018 (Kalithad1) to 1.4060(Juna Rajpipla)	
	Fall (m/Yr)	0.00403 (Roghel) to 1.94702 (Dadar)		0.00060 (Jivapar) to 2.7018(Mandalikpur)	
	10.	GROUND WATER EXPLORATION BY CGWB (As on 31-03-2020)			
	No of wells drilled (EW, OW, Pz, SH, Total) EW 79, OW 34, PZ 8, Total: 121				
	Depth Range(m)			29.8 to 500	
	Discharge (Litres per minute)			0.2 to 1980	
	Transmissivity (m2/day)			0.09 to 1100	
11	GROUND WATER QUALITY				
	Presence of chemical constituents more than permissible limit)			High Fluoride & Nitrate at isolated pockets	
	Type of water			Potable in general	
12.	DYNAMIC GROUND WATER RESOURCES (As on 2017)				
	Annual Replenishable Ground Water Resources (MCM)			1565.53	
	Net Ground water Availability (MCM)			1487.26	
	Projected Demand for Domestic and industrial Uses up to 2025 (MCM)			34.44	
	Stage of Ground Water Development (%)			64.52	
13	GROUND WATER CONTROL AND REGULATION (3/2017)				
	Number of OE Blocks			Nil	
	Number of Critical Blocks			Nil	
	Number of Semi Critical Blocks			Nil	
	Number of Safe Blocks			11	
	Number of Saline Blocks			Nil	
	No. Of Blocks Notified by CGWA			Nil	
14	MAJOR GROUND WATER PROBLEMS AND ISSUES				
	i) Low Groundwater Development ii) Pollution Geogenic and Anthropogenic (Flouride & Nitrate in localised pockets) iii) Limited Yield Potential in Hard Rock. iv) Demand supply management.				

AQUIFER MAP AND MANAGEMENT PLAN RAJKOT DISTRICT

INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. There has been a paradigm shift from “groundwater development” to “groundwater management”. An accurate and comprehensive micro-level picture of groundwater in India through aquifer mapping indifferent hydrogeological settings will enable robust groundwater management plans at the appropriate scale to be devised and implemented for this common-pool resource. This will help achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural India, and many parts of urban India as well. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of NAQUIM is not merely mapping, but reaching the goal – that of ground water management through community participation.

Objective:

The primary objective of the Aquifer Mapping Exercise can be summed up as “Know your Aquifer, Manage your Aquifer”. Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project. As per the Report of the Working Group on Sustainable Ground Water Management, “It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help integrate ground water availability with ground water accessibility and quality aspects.

Methodology:

Methodology involves creation of database for each of the principal aquifer. Delineation of aquifer extent (vertical and lateral). Standard output for effective presentation of scientific integration of Hydrogeological, geophysical, geological, hydro chemical data facts and 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.

Data Compilation & Data Gap Analysis:

One of the important aspect 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 assembled from the available sources, analyzed, examined, synthesized and interpreted. These sources were predominantly non-computerized data, which was converted into computer based GIS data sets and on the basis of available data, data gaps were identified.

Data Generation:

There 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 to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.

Aquifer Map Preparation:

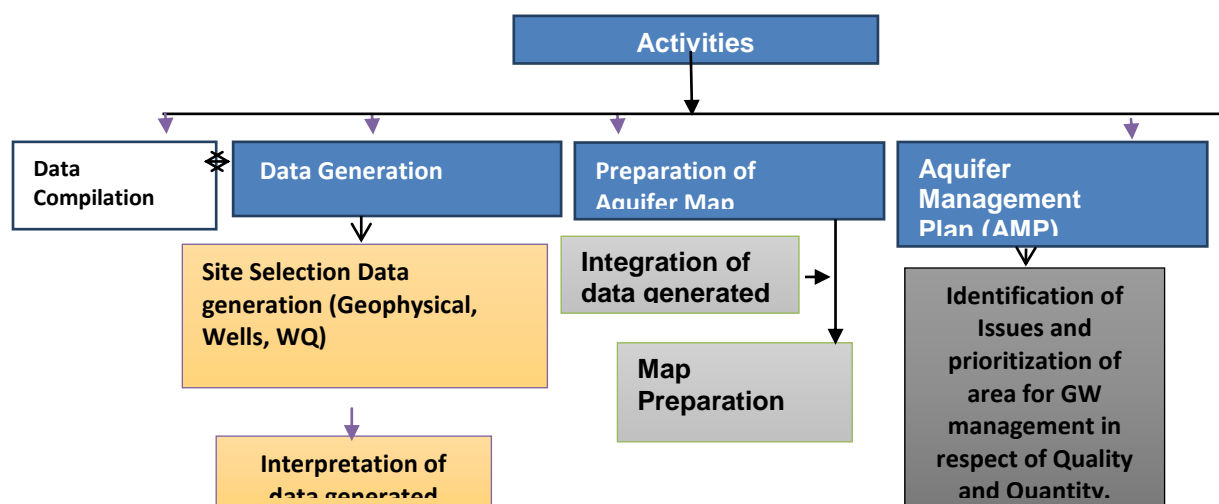
On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out details of Aquifers, these are termed as Aquifer maps providing spatial variation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

Aquifer Management Plan Formulation:

Aquifer response Model has been utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

All the above activities under the ground National Aquifer Mapping programme is depicted/elaborated in Annexure –I and presented in figure 1.

Figure – 1 Activities under National Aquifer Mapping Programme



Locations, Extent and Accessibility

The district is situated in the Saurashtra region of Gujarat state and lies between 23°08' North latitude and 20°58' North latitude and 71°40' East longitude and 70°20' East longitude. Rajkot is the largest city in the Saurashtra region. This district is surrounded by Morbi district in north, Surendranagar and Rajkot districts in east, Amreli and Junagadh districts in south and Porbandar, Jamnagar district in west. Rajkot as an independent district came into existence on 1st May, 1960, consequent upon its reincorporation into the state of Gujarat. The district derives its name from its headquarters, Rajkot City. Rajkot district has 11 Developmental Blocks / Talukas, 575 Gram Panchayats and 577 inhabited villages. The economy of Rajkot district mainly depends on agriculture. The city also contributes to the economy of the state with heavy and small scale industries. For administrative purpose, the district is divided into 11 Development Blocks or Talukas with their headquarters at Paddhari, Rajkot, Lodhika, Kotda Sangani, Jasdan, Gondal, Jamkandorna, Upleta, Dhoraji, Jetpur and Vicchiya for developmental purposes. Fig. 2 Location Map of Rajkot District.

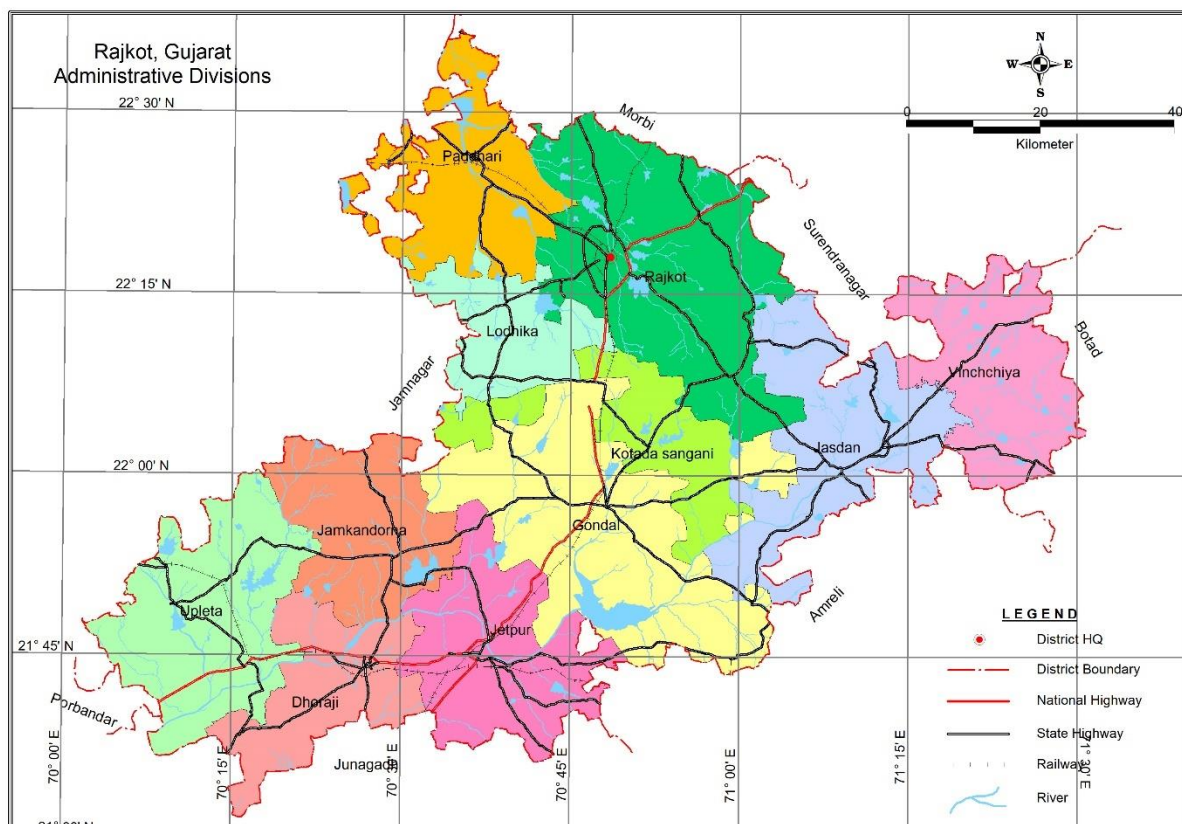


Figure 2. Administrative map of Rajkot district

Rajkot district is divided 11 talukas. Details of the Talukas and numbers of revenue villages are given in Table no: 1

Table: 1 Details of Taluka area & Villages of Rajkot District.

Sr No	Name of Taluka	Area (Sq.Km)	No of Villages
1	Dhoraji	484.94	30
2	Gondal	1193.62	81
3	Jamkandorna	560.29	50
4	Jasdan	833.42	53
5	Jetpur	627.58	47
6	Kotada sangani	447	42
7	Lodhika	373.23	38
8	Paddhari	599.33	58
9	Rajkot	1004.88	96
10	Upleta	839.24	51
11	Vinchchiya	510.3	52
	Total	7473.83	598

Demographic Particulars

As per 2011 census, the total population of the district was 3,804,558 out of which population of female and male are 1,830,113 and 1,974,445 respectively. Rajkot is the 4th most populated district of Gujarat. District is predominantly urban and around 58.19% of the population resides in urban area. After the creation of Morbi district from Rajkot, the population of the district is calculated to be 30,15,229 of which 15,67,811 are Male and 14,47,418 are female.

LAND USE PATTERNS, IRRIGATION & AGRICULTURE

Seasons & Crops Record, Rajkot District -year 2018-19, has been refereed for land use, irrigation & agriculture statistics of the district.

Land Use Patterns

As per *Seasons & Crops Record*, 775000 hectares of land is accounted for land use record. Brief account of land use classification for the district, in general, is given in table No.2

Table No. 2 Land Use Classification of Rajkot District (2018-19)

Sr No	Land Use Classification		Area in Sq KM
1	Total Geographical Area		7750
2	Total Reporting Area		7750
3	Total Forest		257
4	Not available for cultivation	Land put to Non-agricultural uses	795
		Barren and Unculturable Land	473
5	Other uncultivated land excluding fallow land	Pasture & other grazing	574
		Land under miscellaneous	0
		Culturable Waste	150
		Total	724

6	Fallow Land	Other Fallows	7
		Current Fallows	196
		Total	203
7	Net area sown		5297
8	Area sown more than once		362
9	Gross Cropped area		5658
10	Cropping (GCA/NAS) %		106.81

Land Use & Season -Crop Record - Rajkot District - Year 2018-19 - Agriculture Directorate, Government of Gujarat.

Irrigation

Details of area irrigated by surface & ground water resources are given in table No 3

Table No. 3 Details of Irrigated Areas

Source	Irrigated Area (Hectares)	
	Net	Gross
Tanks	9200	9300
Canals	16500	17200
Total Surface Water	25,700	26,500
Govt. Tube Wells	89200	112300
Pvt. Tube Wells	20700	23500
Dug Wells	143600	195500
Total Ground Water	253,500	331,300
Total Irrigated Area	279,200	337,800

Agriculture

The district areas have varied agriculture crops, both food crops & non food crops. Main food crops consist of food grains such as wheat, *jowar*, *bajra*, maize etc., and pulses. Other food crops are fruits & vegetables. Non food crops consist of cotton, oil ground nut, castor, tobacco, fodder etc. As per *Season & Crops Records*, there were 565,800 hectares of gross area under various crops in the district, out these 529,700 hectares were under net crops area.

Urban and Industrial area

Rajkot is the largest urban Centre, with a population of 1.33 million under the municipal corporation. Other four major centers are Gondal, Jetpur and Dhoraji. Rajkot taluka alone has more than 50 percent of the total district population, of which more than 90 % live in urban area.

Rajkot district is one of the most industrialized district in Gujarat State. It has established itself as a major manufacturing center for diesel engines, automobile components, gems and jewelries, a cluster of foundry units, a cluster of sari printing (Jetpur), and a cluster of ceramics (Morbi). Major manufacturing centers are Rajkot (Oil Engine Manufacture, Gold and Silver Ornaments),

Jetpur (Sari Printing), Gondal (Oil Extraction) and Jasdan (Cotton ginning and Pressing and Handicrafts).

Rainfall and Climate

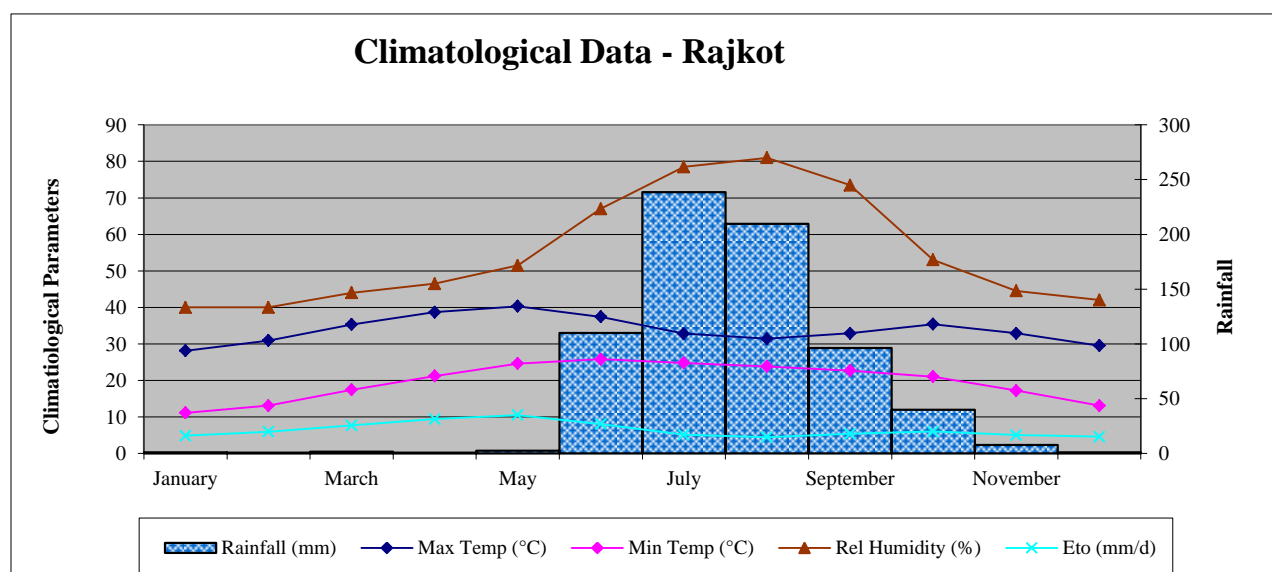
The district has semi-arid climate. Extreme temperatures, erratic rainfall and high evaporation are the characteristic features of this type of climate. Climatologically data of Rajkot IMD station (1951-1980) that is nearest is given in the table 4.

General climate of the district is sub-tropical and is characterized by three well-defined seasons, i.e. summer - from April to June, monsoon - from July to September, and winter - from October to March.

Table 4

Month	Max Temp (Deg.C)	Mini Temp (Deg.C)	Humidity (%)	Wind Speed Kmpd	Sunshine (Hours)	Solar Rad. (MJ/m2/d)	ET (mm/d)	Rainfall (mm)
January	28.1	11.1	40.0	224.5	8.8	16.9	4.8	0.9
February	30.9	13.1	40.0	248.2	9.2	19.4	5.9	0.6
March	35.3	17.4	44.0	297.5	9.8	22.6	7.7	1.7
April	38.7	21.2	46.5	363.1	10.3	25.0	9.4	0.6
May	40.3	24.6	51.5	485.4	9.3	24.0	10.5	2.6
June	37.4	25.8	67.0	518.3	7.1	20.6	8.0	110.1
July	32.8	24.8	78.5	487.2	3.7	15.5	5.1	238.5
August	31.4	23.8	81.0	416.1	3.8	15.3	4.5	209.8
September	32.9	22.7	73.5	313.9	7.0	19.0	5.4	96.3
October	35.4	21.0	53.0	215.3	9.3	20.2	6.0	39.8
November	32.9	17.2	44.5	188.0	9.2	17.8	5.0	7.8
December	29.5	13.1	42.0	204.4	8.7	16.0	4.6	1.1
Total	-	-	-	-	-	-	-	709.8
Average	33.8	19.7	55.1	330.2	8.0	19.4	6.4	-

Figure No-3 Climatological Data



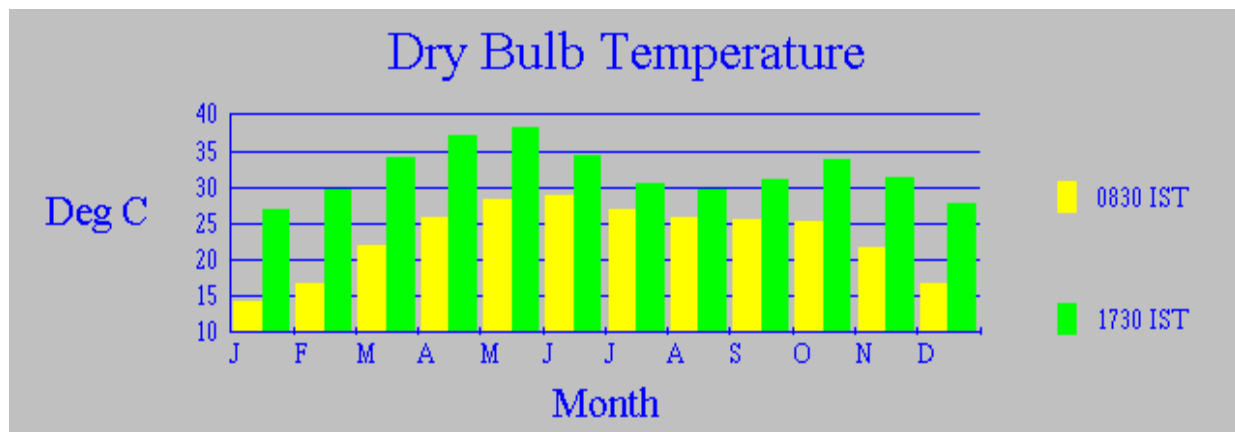


Figure No-4 Dry Bulb Temperature

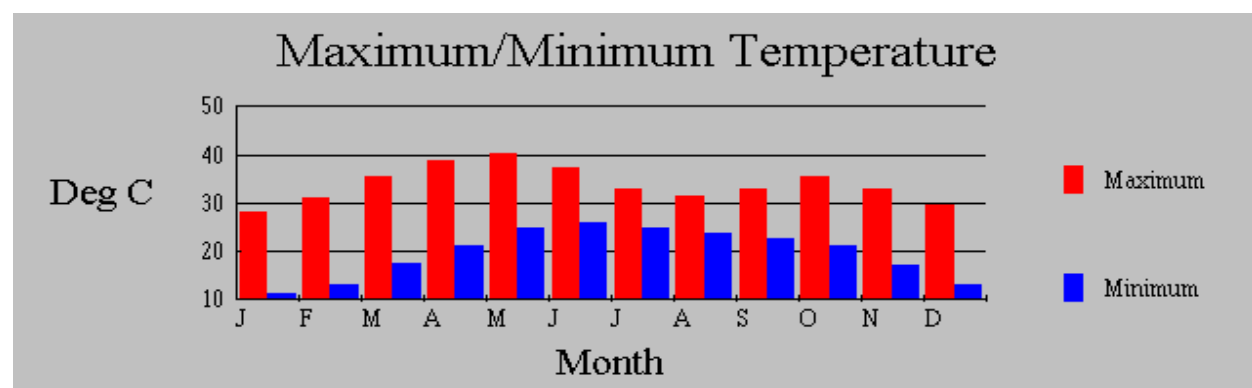


Figure No-5 Maximum/Minimum Temperature

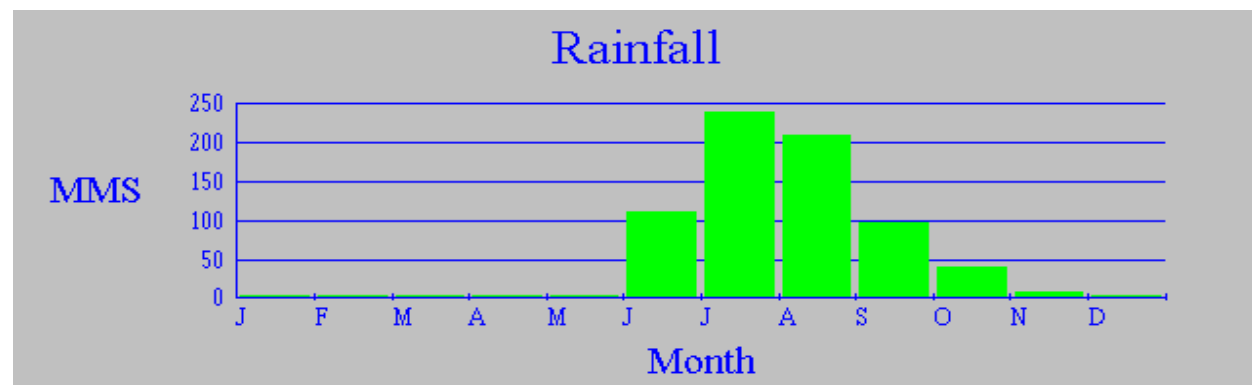


Figure No-6 Rainfall

GEOMORPHOLOGY AND SOIL TYPE

Rajkot district is situated in the central part of Saurashtra peninsula. The northern part of the district bordering the Rann of Kachchh and the main underlying rock type is Deccan Trap basalt giving rise to rugged and rolling topography intersected by ridges formed by the dykes. Some of these ridges are as high as 300m AMSL. The most prominent ridge is situated along the northern boundary of the Bhadar River and runs along the basaltic dyke locally known as Sardhar Dyke. The elevations range from almost sea level to more than 300 m AMSL. The highest point is 304 m located near Bhadala in the east-central part of the district.

In the central part of the district comprising Paddhari, Lodhika, Jasdan, Rajkot, Jam Kandorna and Kotada Sanghani talukas, the soils are of clayey loam to clay type. They are moderately deep to deep and vary in colour from very dark brown to very dark greyish brown and reddish brown. The EC of the soils is generally less than 1.0 mmhos/cm and cation exchange capacity is between 40 and 60 me/100 gm of soil.

The soils in the southern part of the district comprising Jetpur, Dhoraji, Upleta and Gondal talukas are similar to the soils of the central part. They are clayey loam to clayey type, very dark grey to dark greyish and dark brown in colour and moderately deep (25 to 75 cm). The EC of the soils is generally less than 1.0 mmhos/cm and cation exchange capacity is between 30 and 35 me/100 gm of soil.

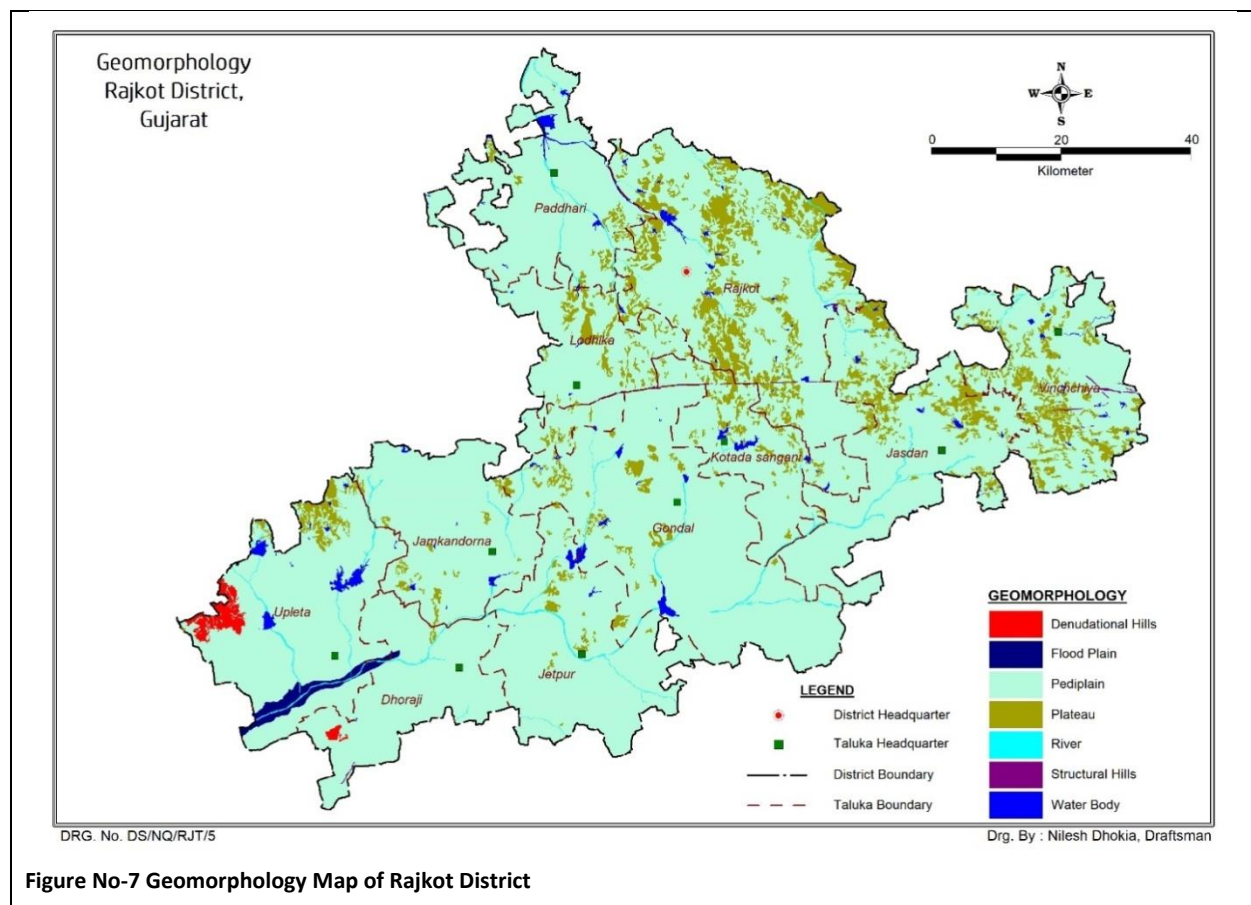


Figure No-7 Geomorphology Map of Rajkot District

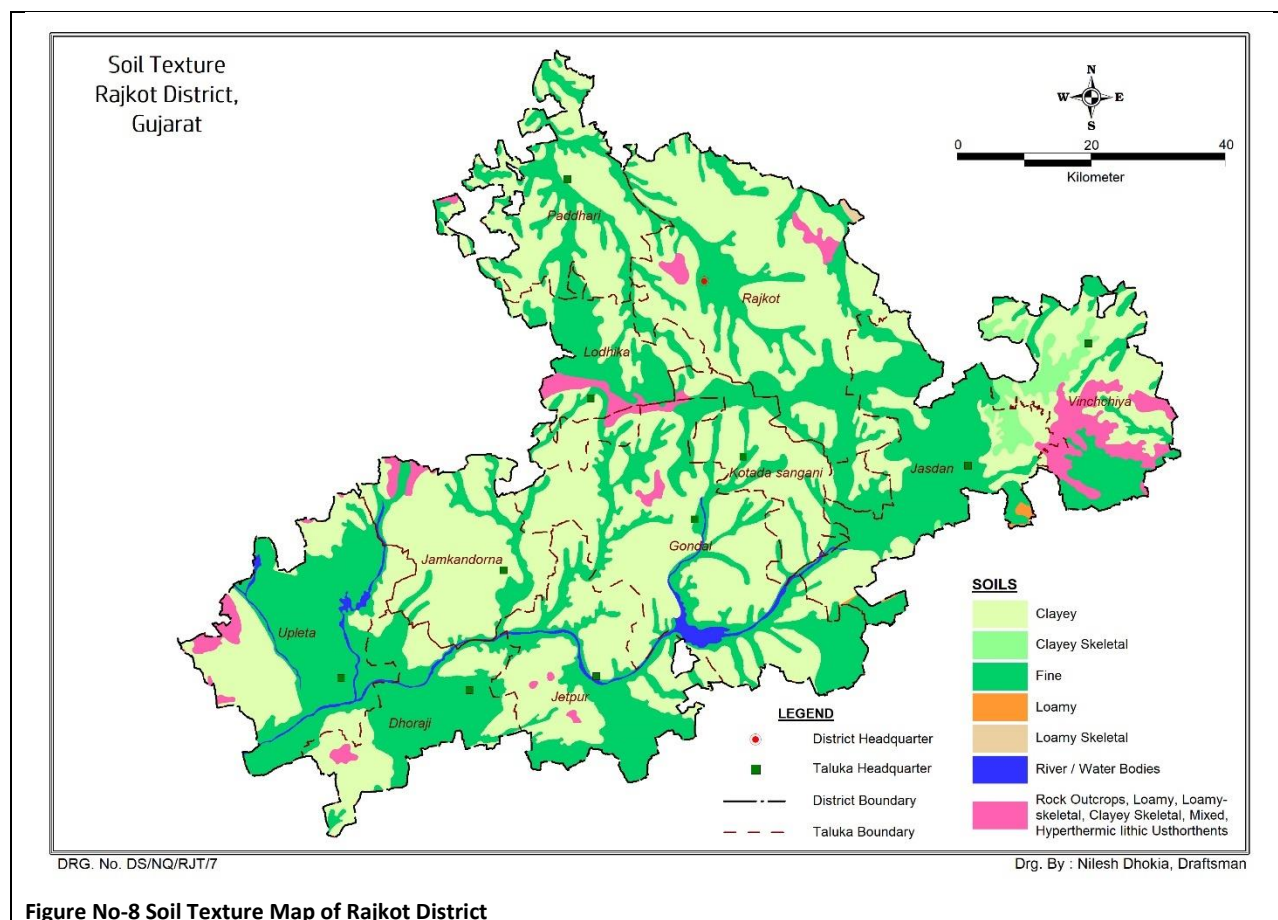
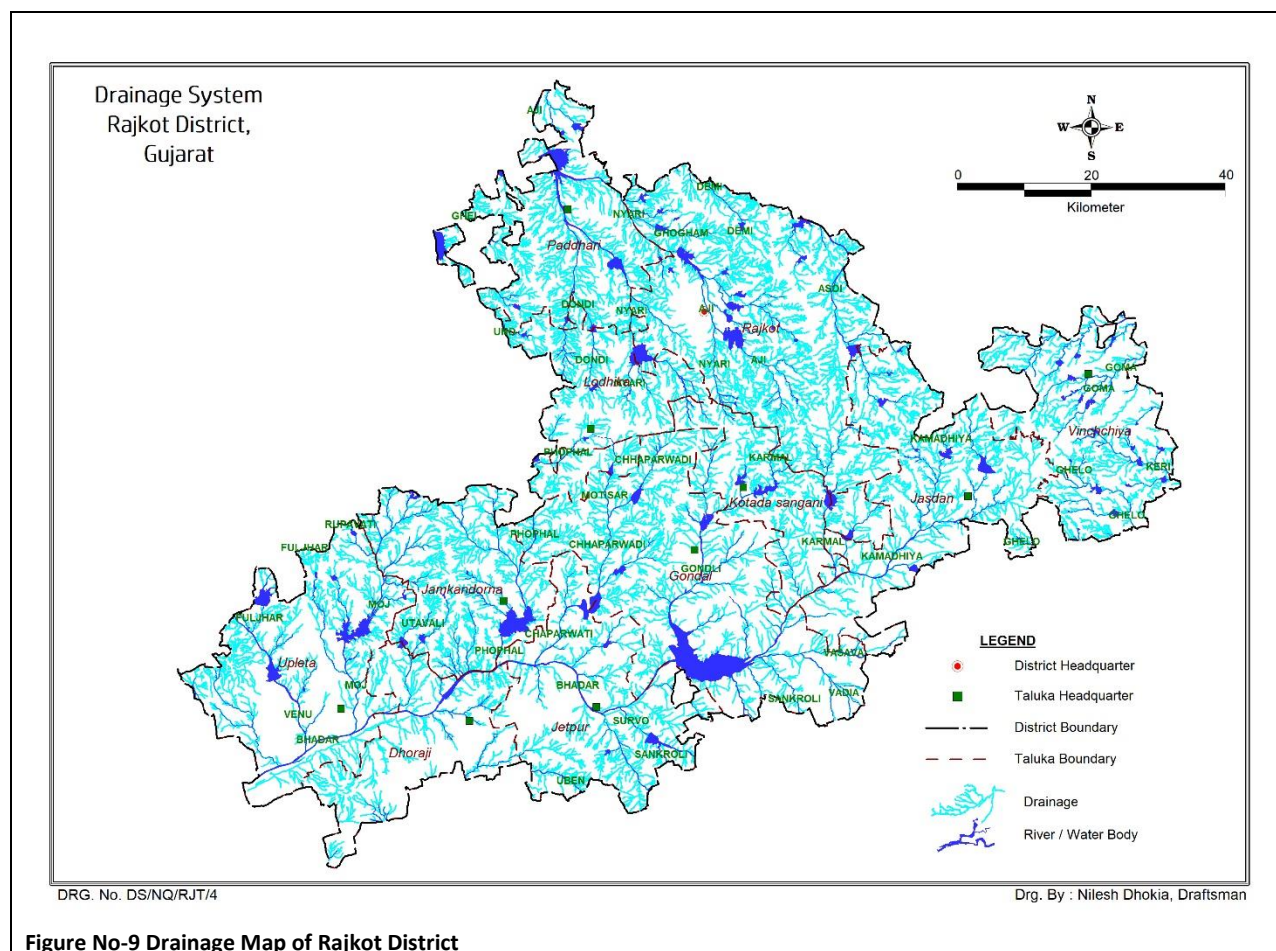


Figure No-8 Soil Texture Map of Rajkot District

Drainage

There are three major rivers in the district. The river Bhadar, which emerges from Jasdan taluka and flows across the southern part of the district is the biggest of all. Other two major rivers Machhu and Aji, flow toward north. In addition to these, there are 14 rivulets which have swift and short run to the sea.

Water of the river is mainly used for agriculture and drinking purposes. Machhu River rises in the hills of Jasdan near village Khokhara in Chotila taluka of Surendranagar district. This is one of the North flowing rivers of Saurashtra in Gujarat state. It flows from district boundary of Surendranagar and Rajkot up to village Beti then flows towards North in Rajkot and finally meets in the little Ran of Kuchchh near Malia. Bhadar River originates from, near Jasdan and meets in Arabian Sea.



HYDROLOGY

Surface Water Resources

Rajkot district has no perennial river. Narmada canal network is also important resource. It is primarily used as a supplement for drinking water supply. If and when water is available above household needs, it may be used for agriculture. However, as of now, its contribution to agriculture needs is nil. The majority of the surface water in the district is created through canals from Aji and Bhadar dams. Dhoraji has maximum command area under canal irrigation while Rajkot has the maximum number of sources of canal irrigation. Jasdan block has the majority of the community ponds in the district.

STUDIES / ACTIVITY BY CGWB

Systematic hydrogeological survey was first taken up by M. S. Jethra in 1984-85 when he covered about 2018 sq. km area in northern parts of district comprising Central part of of the district. Subsequently different workers of GSI and CGWB took up hydrogeological surveys in the district.

Table 5: Areas covered by hydrogeological surveys by different officers

Area Covered	Geographical Area (sq. km)	Year	Officer
A. Systematic Hydrogeological Surveys			
Central parts	2018	1984-85	M. S. Jethra
Parts of district falling in Bhadar River Basin		1979-80	M. R. Kulkarni
Parts of Jasdan taluka	1693	1988-89	Ahmad
B. Reappraisal Hydrogeological Surveys			
Entire Rajkot District		1988-89	P. K. Jain P.C.Panchbhaya A.B.Kawade K.Balakrishna

2. GEOLOGY AND HYDROGEOLOGY

GEOLOGY

The general geological succession of the rock formations occurring in the Rajkot district is as given below.

Age	Formation	Lithology
Quaternary	Surface Soil/ Alluvium	Wind blown sand and Black cotton soil
Lower Eocene to Upper Cretaceous	Deccan Trap	Plutonic Basalt stratified lava flows comprising amygdoloidal basalt, fine grained porphyritic basalt and basaltic/doleritic dykes.

Deccan trap occupies a major part in Rajkot District and it covers most of the Saurashtra peninsula except along its fringes where Tertiary and Quaternary sediments and portion in North West where Mesozoic rock are exposed. The total thickness of Deccan Trap rocks, revealed through DSS of ONGC (Chowdhary LR, 2004; Kaila KL, 1988) in Saurashtra ranges from 300 m to more than 900 m. The CGWB deep exploration has encountered more than 25 flows in explored depth of 500 m (Gupte PR, 2004). Most of the individual flows are 3 to 9 m thick, but some have thickness more than 25 m also. In North West part of exposure, older Jurassic sandstone is encountered at various depths of 200 to 450 mbgl. With average thickness of 300 m basaltic lava flows below ground level and except few volcanic plugs forming prominent hills & distinct high land and associated dykes swarms forming extensive & linear low lying ridges, mostly in southern part of Saurashtra, the Deccan Trap terrain exhibits overall relatively flat and low lying topography.

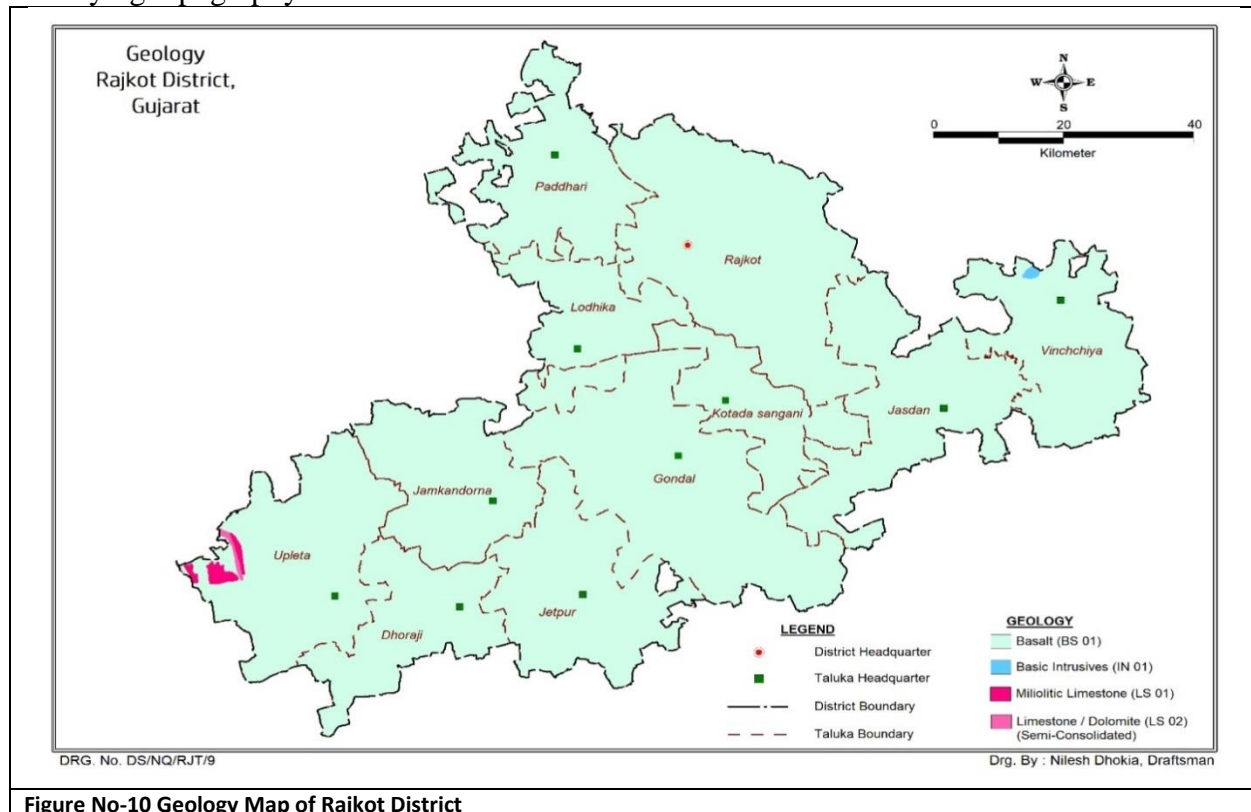


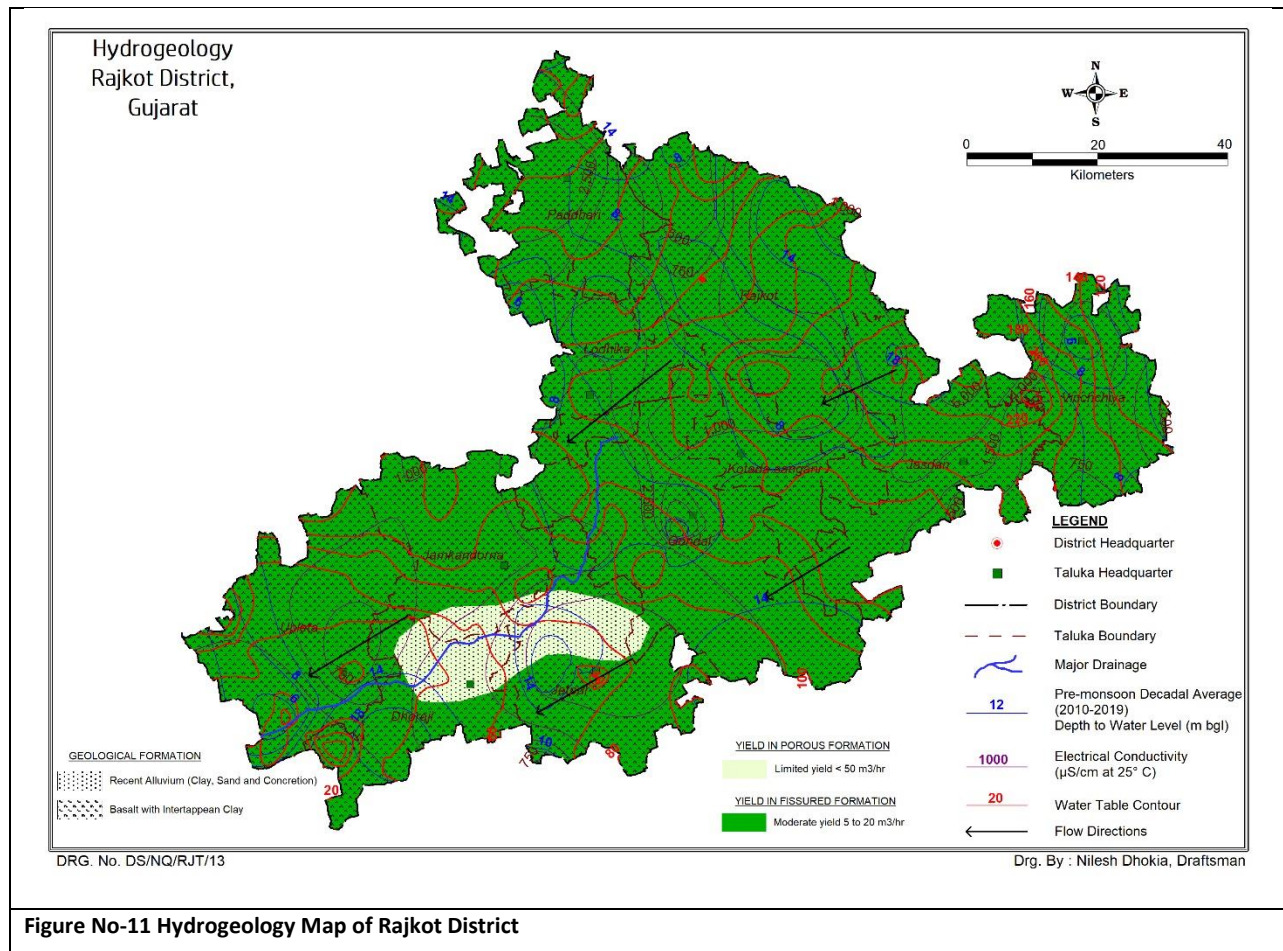
Figure No-10 Geology Map of Rajkot District

HYDROGEOLOGY

Deccan Trap

Deccan trap occupies a major part of the district and forms the most important 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. The dykes, particularly in the southern part of the district, 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 yield good yields.

The groundwater in Deccan trap occurs under phreatic to confined conditions. The groundwater is generally tapped through dug wells varying in depth from 10 to 50 m. At places, dug-cum-bored wells are also constructing bores below the bottom of dug wells. The yield of dug wells and dug-cum-bored wells generally range from 20 to 100 m³/day.



Exploration Details

The groundwater exploration in the district has been carried from 1969-72 and continued AAP 2017-18. The maximum depth of the borewells drilled is 598m at Lodika village. Details of the wells drilled up to March 2018 are given in table below.

Table 6: - Ground Water Exploration

Salient Features	Exploratory Wells	Observation Wells	Piezometers
Total Nos.	68	31	8
Drill Depth range (mbgl)	49.1 to 598	52.5 to 202.6	29.8 to 56.2
Depth Constructed range (mbgl)	49.1 to 598	36.9 to 201.6	29.8 to 56.2
Static Water Level (mbgl)	5 to 196.2	-	6 to 8.8
Discharge (LPM)	12 to 1320	-	22 to 1500

GROUNDWATER REGIME MONITORING

Ground water regime monitoring is the basic component of groundwater management and it is carried out in parts of Rajkot district through National Hydrograph Network Stations (NHNS or NHS). NHSs are observation wells, comprising of dug wells and purpose built bore wells – known as piezometers. There are 34 Dug wells and 05 piezometers as part of the NHS from CGWB and 228 no of monitoring wells from GWRDC Ltd. The following maps have been generated to understand the behaviour of ground water regime.

Depth to Water Level Pre monsoon (May 2019)

The figure 12 shows depth to water level map of Rajkot district, prepared on the basis of NHS data of May 2019. In major part of the district, the water level ranged in between 5 to 10 & 10 to 20 m bgl while some isolated patches of district showing shallow water of <2m and deep water level ranges 20 to 40 m. (Figure 12: DTW May 2019 map of Rajkot district.)

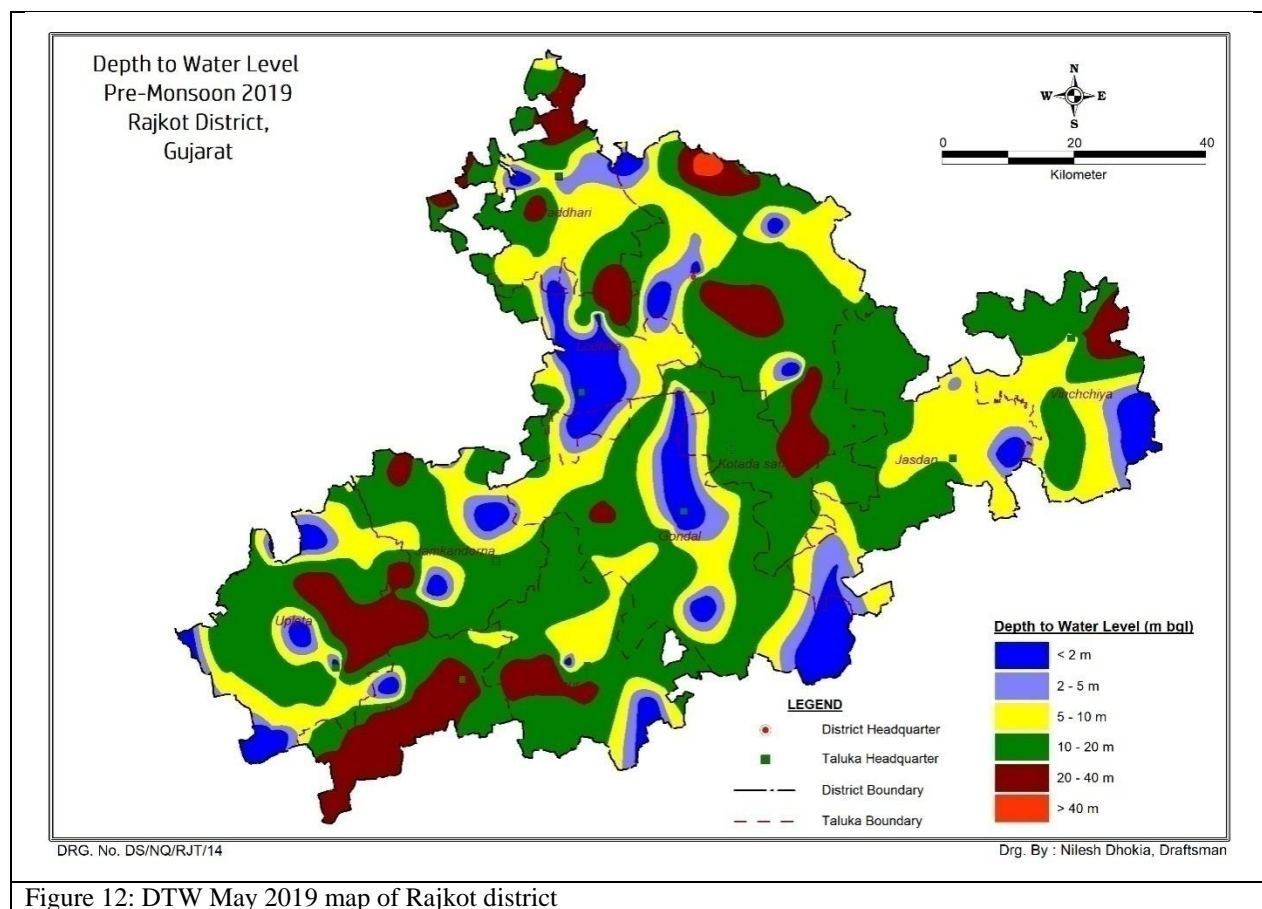


Figure 12: DTW May 2019 map of Rajkot district

DEPTH to Water Level Post monsoon (Nov 2019)

The figure 13 shows depth to water level map of Rajkot district, prepared on the basis of NHS data of November 2019. In major part of the district, the water level ranged in between 2 to 05 & 5 to 10 m bgl while some isolated patches of district showing shallow water of <2m and deep water level ranges 20 to 40 m. (Figure 13: DTW November 2019 map of Rajkot district.)

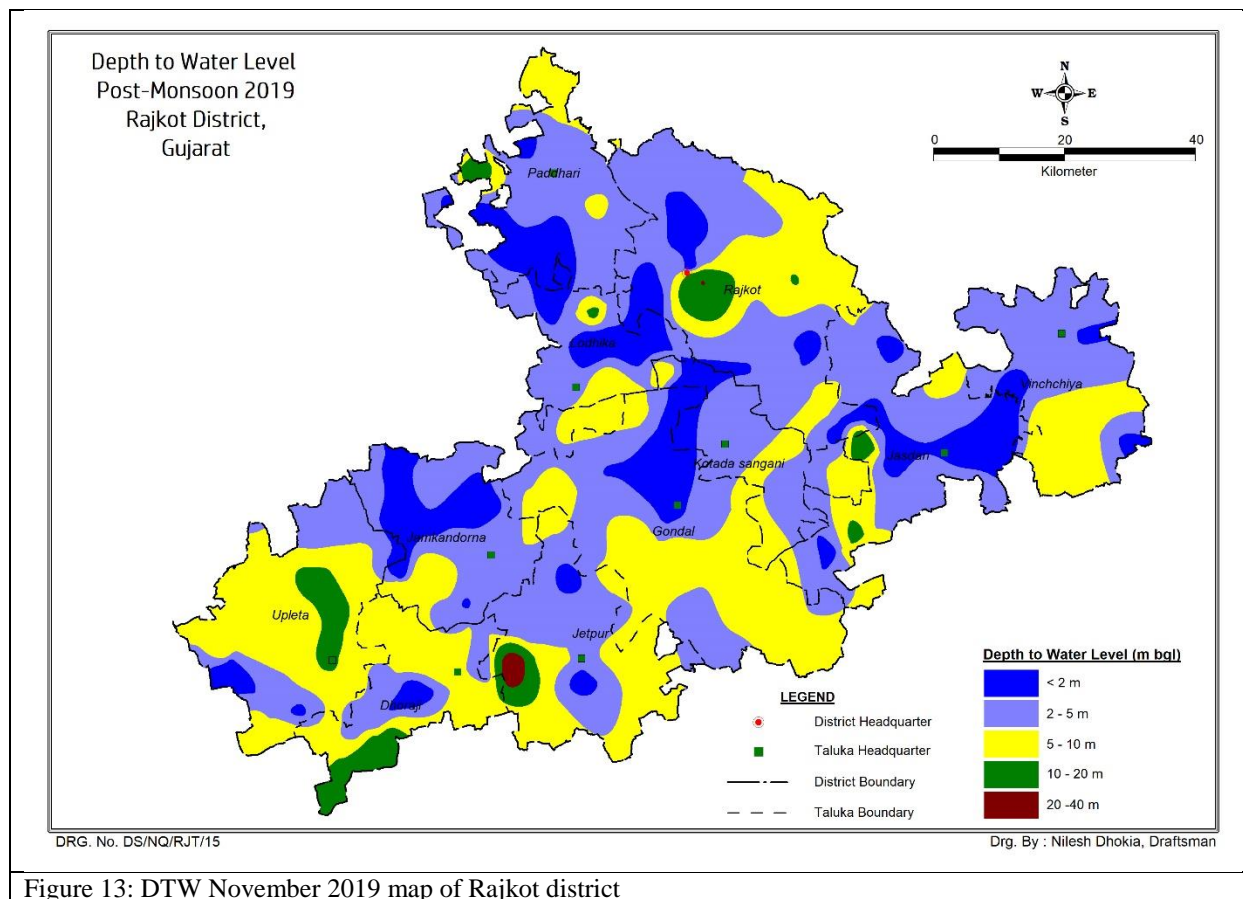


Figure 13: DTW November 2019 map of Rajkot district

Pre vs Post Monsoon Fluctuation Map.

Map showing Pre vs Post Monsoon Fluctuation water level map of May 2019 with November 2019 (Fig.14) shows rise in water level in the district from 4 mbgl to more than 6m bgl.

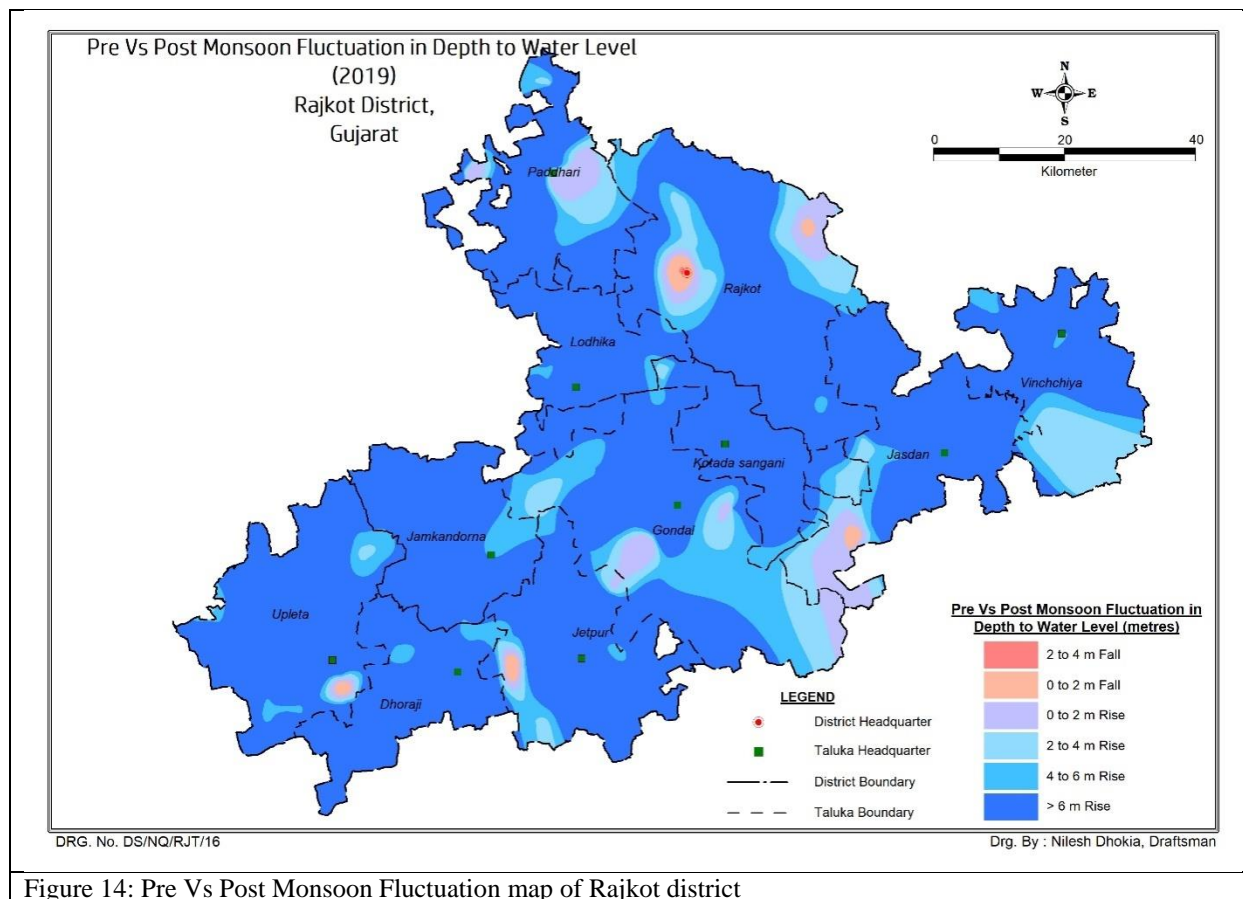


Figure 14: Pre Vs Post Monsoon Fluctuation map of Rajkot district

Depth to Water Level (Decadal Mean Pre-Monsoon (2010-2019))

Map showing Depth to Water Level (Decadal Mean Pre Monsoon (2010-2019)) (Fig 15) observed that major part of district were showing depth to water level ranges between 10 to 20m bgl.

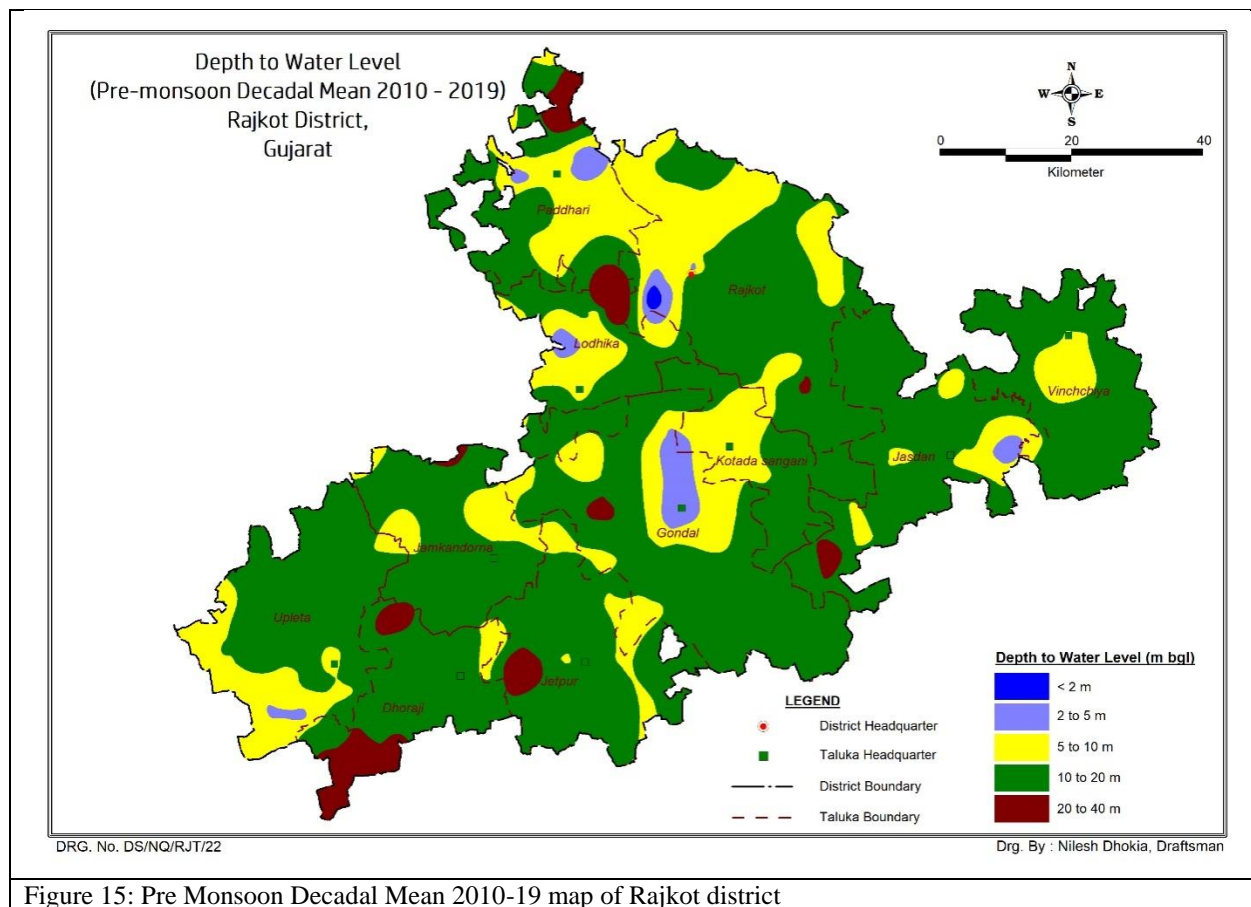


Figure 15: Pre Monsoon Decadal Mean 2010-19 map of Rajkot district

Depth to Water Level (Decadal Mean Post-Monsoon (2010-2019))

MapshowingDepth to Water Level (Decadal Mean Post Monsoon (2010-2019)) (Fig 4) observed that major part of district were showing depth to water level ranges between 2 to 5 m & 10 to 20m bgl.

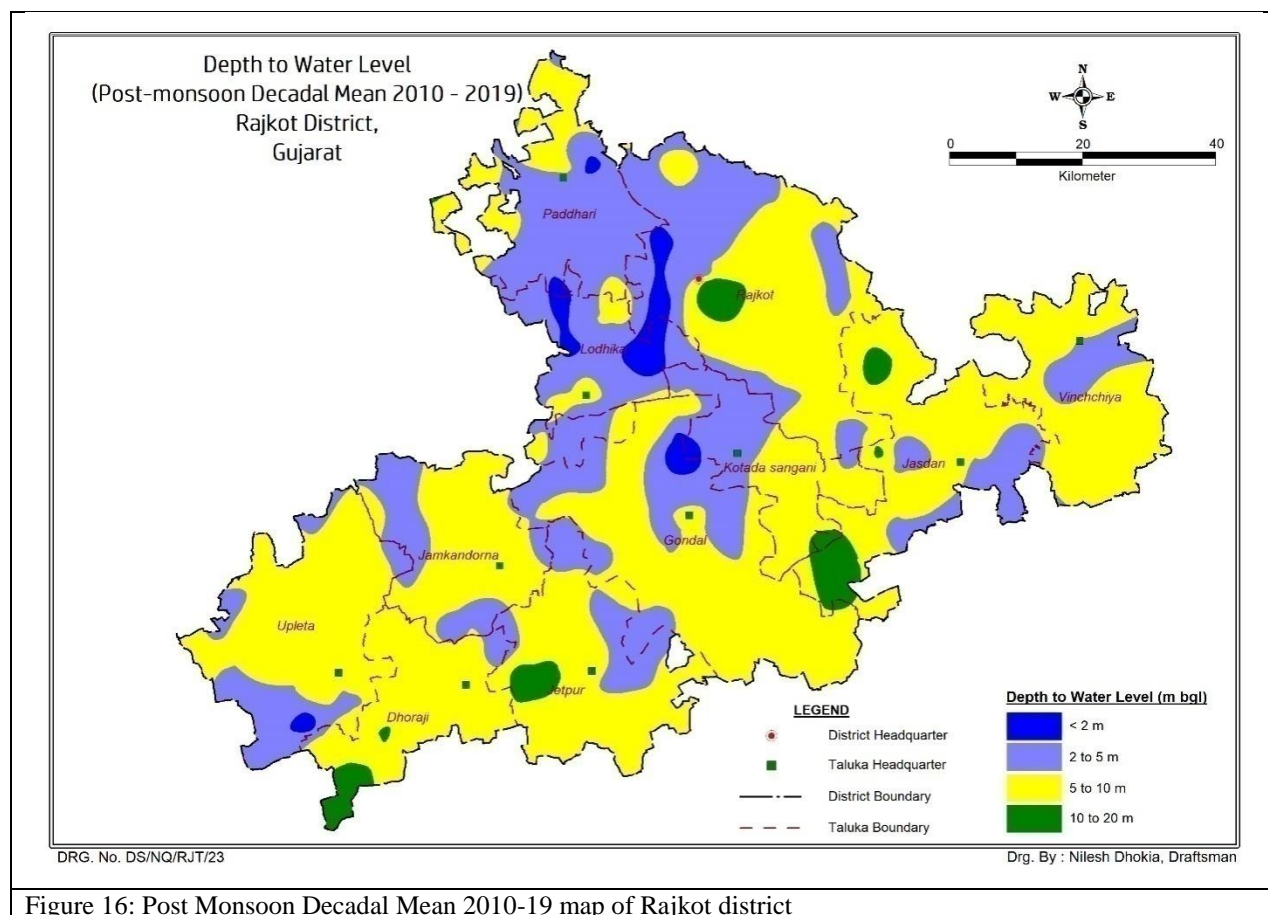


Figure 16: Post Monsoon Decadal Mean 2010-19 map of Rajkot district

Water Level Trend (2011 – 2022)

From the analysis of the water level trend of the Rajkot district from 2011 to 2022, it is observed that, during year, the water level has a rise of 0.13 m/yr (Gogavadar) to 0.74 m/yr (Movaiya) and also has a fall of 0.0213 m/yr (Morbi) to 0.326 m/yr (Macchukunda). Details of rise and fall during the year 2011 and 2022 is given in the Table no 7 and selected hydrographs are shown in Fig No 17 (A to G).

Table No Ground water trends in m/year for the period of 2011 to 2022 in the district of Rajkot										
Sr no	Location	Pre-Monsoon			Post-Monsoon			Annual		
		Data Points	Rise	Fall	Data Points	Rise	Fall	Data Points	Rise	Fall
1	Patanvav	10	-	0.3839	11	0.5356	-	42	0.2184	-
2	Bhada jodiya	9	0.0905	-	11	0.4393	-	38	0.3355	-
3	Ganod	11	-	0.2289	11	0.0124	-	40	-	0.0345
4	Motagundala	10	0.0683	-	11	0.2518	-	43	0.3978	-
5	Dhoraji	11	0.0165	-	10	0.638	-	41	0.3395	-

6	Upleta1	8	0.0143	-	8	-	0.7153	32	-	0.2029
7	Pedhla	8	-	0.5014	8	0.6732	-	33	0.1537	-
8	Jetpur	9	-	0.1564	10	0.0765	-	34	-	0.0578
9	Jetpur pithad.	9	0.0137	-	6	-	-	29	0.3315	-
10	Virpur1	12	-	0.3094	11	-	0.2805	44	-	0.1934
11	Jasapur	12	0.0519	-	9	0.2023	-	38	0.1231	-
12	Jamkandorna	11	0.1827	-	11	0.2039	-	40	0.1185	-
13	Chordi	11	-	0.0677	10	0.3626	-	41	0.1076	-
14	Umrli	10	-	0.1618	9	-	0.0206	36	-	0.0816
15	Jamwali	9	0.0177	-	8	-	0.244	31	-	0.0759
16	Gogavadar	12	-	0.2528	10	0.1592	-	41	0.013	-
17	Mota Dadwa	10	0.1851	-	11	0.4231	-	41	0.3305	-
18	Viranagar	11	-	0.0303	9	0.8267	-	36	0.1114	-
19	Jasdan	12	0.0602	-	11	0.2172	-	43	0.1868	-
20	Jasdan2	12	0.4531	-	10	0.4299	-	41	0.4817	-
21	Dadia	12	-	0.0038	10	0.3783	-	42	0.2145	-
22	Halenda	12	0.4275	-	11	0.2158	-	45	0.3104	-
23	Ribda	12	0.0926	-	11	0.5404	-	45	0.4013	-
24	Lodhika	12	0.0854	-	11	0.2891	-	42	0.2613	-
25	Lalavadar	12	0.9944	-	11	0.3877	-	45	0.5207	-
26	Lodhika1	10	0.1612	-	9	0.1486	-	38	0.2011	-
27	Kamlapur	7	-	-	6	-	-	31	0.6051	-
28	Bhadla	10	0.2942	-	11	0.8219	-	42	0.4943	-
29	Vinchhia	12	0.1912	-	10	0.1279	-	41	0.143	-
30	Rajkot1	9	0.4663	-	9	-	0.44	34	0.0216	-
31	Ranpur1	9	0.1164	-	10	0.7696	-	40	0.6054	-
32	Targhari	10	0.4417	-	9	0.9246	-	38	0.4638	-
33	Bhalgam	11	0.3913	-	11	0.2113	-	42	0.3181	-
34	Padadhari1	7	-	-	9	0.2114	-	35	0.2234	-
35	Movaiya	12	0.1969	-	9	0.5136	-	40	0.7397	-
36	Khamta	10	0.3953	-	10	0.6508	-	38	0.5722	-
37	Neknam	8	0.36	-	7	-	-	30	0.0798	-
38	Chhatar	12	0.0035	-	10	0.1566	-	40	0.0289	-
39	Sindhavadar	9	-	0.0496	11	0.5757	-	41	0.2922	-
40	Kalyanpur2	9	-	0.2959	9	0.2082	-	37	0.1253	-
41	Hadmatia	11	-	0.1884	11	-	0.0905	39	-	0.1877
42	Lajai	9	0.1518	-	9	0.2191	-	35	0.1299	-
43	Morvi	12	0.005	-	10	-	0.3843	43	-	0.118
44	Morbi	12	-	0.1209	10	0.0084	-	41	-	0.0213
45	Nichi mandal	10	-	0.0637	11	0.0144	-	43	0.0501	-
46	Modpar1	12	0.117	-	10	0.1879	-	41	0.1613	-
47	Amar nagar	10	0.0872	-	11	0.193	-	41	0.1697	-
48	Mota dhansura	12	0.0397	-	11	0.2812	-	44	0.0908	-
49	Macchukunda	8	-	0.5612	9	-	0.2859	33	-	0.3258
50	Sarvad	10	0.0287	-	9	0.0808	-	40	0.0413	-
51	Malia	9	-	0.4083	11	0.115	-	39	-	0.1997
	Minimum		0.0035	0.0038		0.0084	0.0206		0.0130	0.0213
	Maximum		0.9944	0.561		0.925	0.715		0.74	0.326

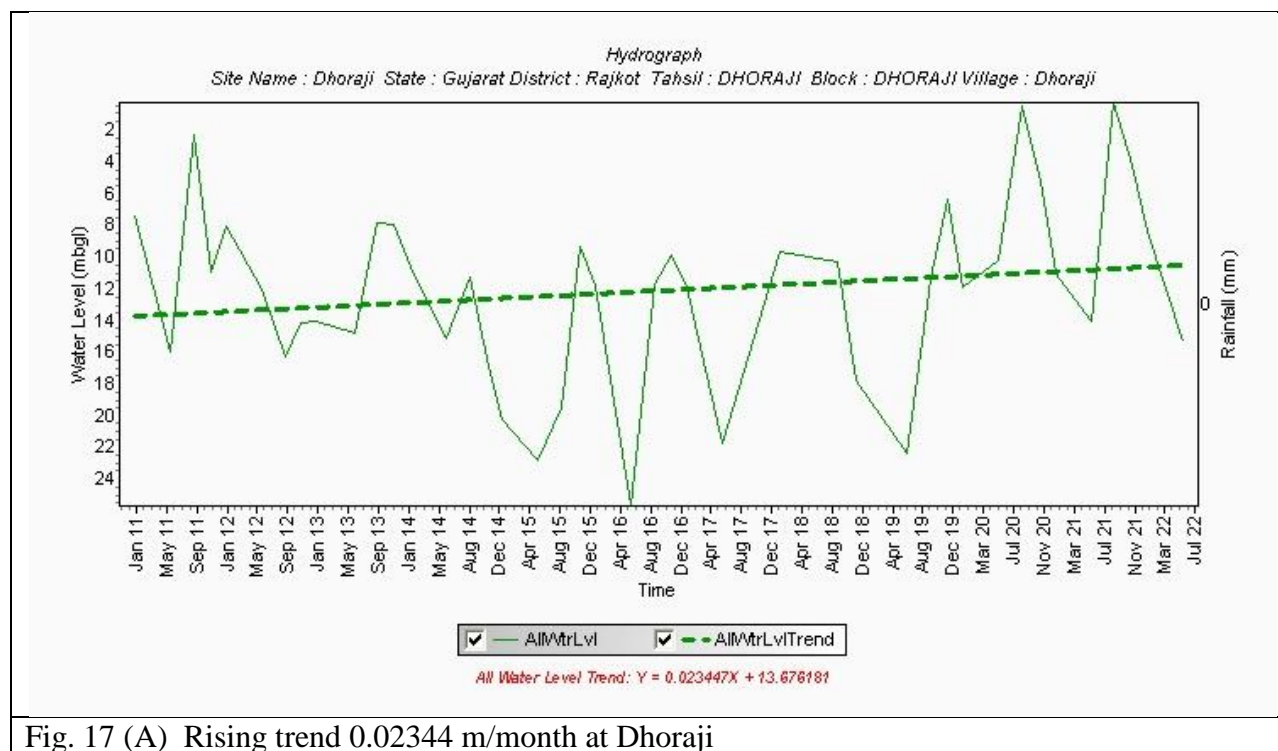


Fig. 17 (A) Rising trend 0.02344 m/month at Dhoraji

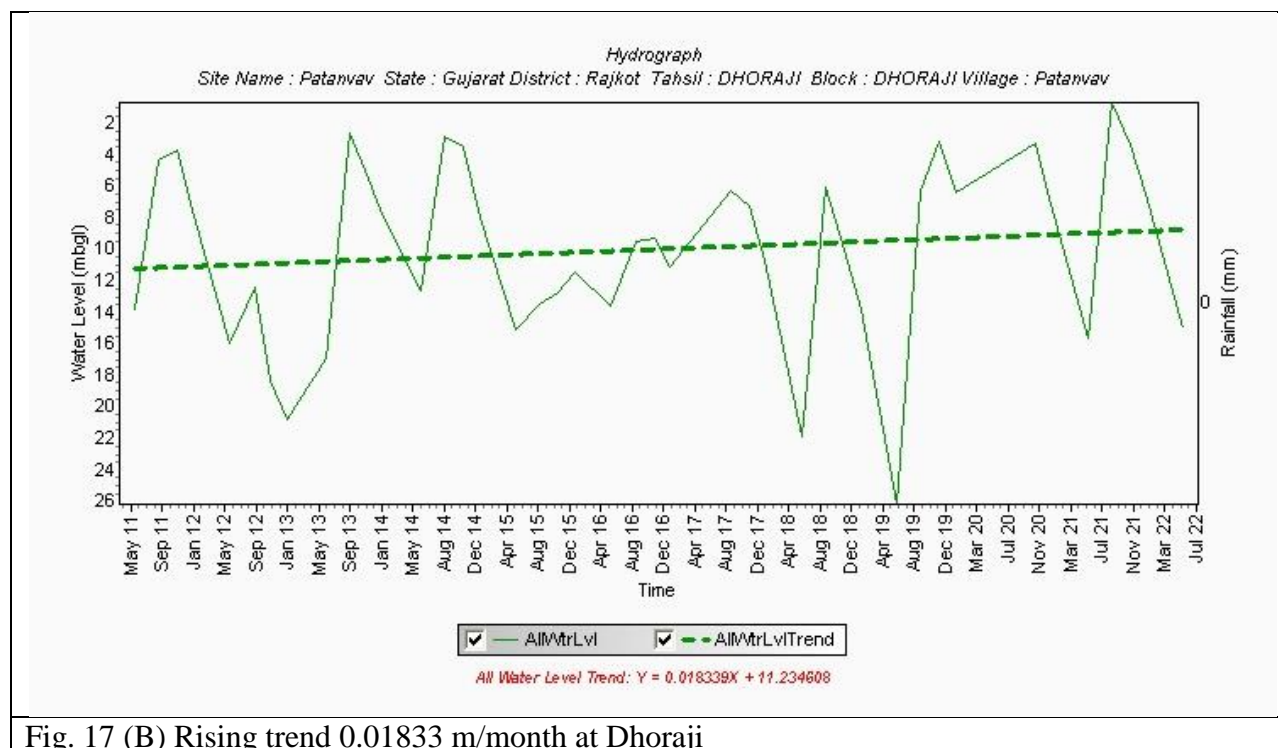


Fig. 17 (B) Rising trend 0.01833 m/month at Dhoraji

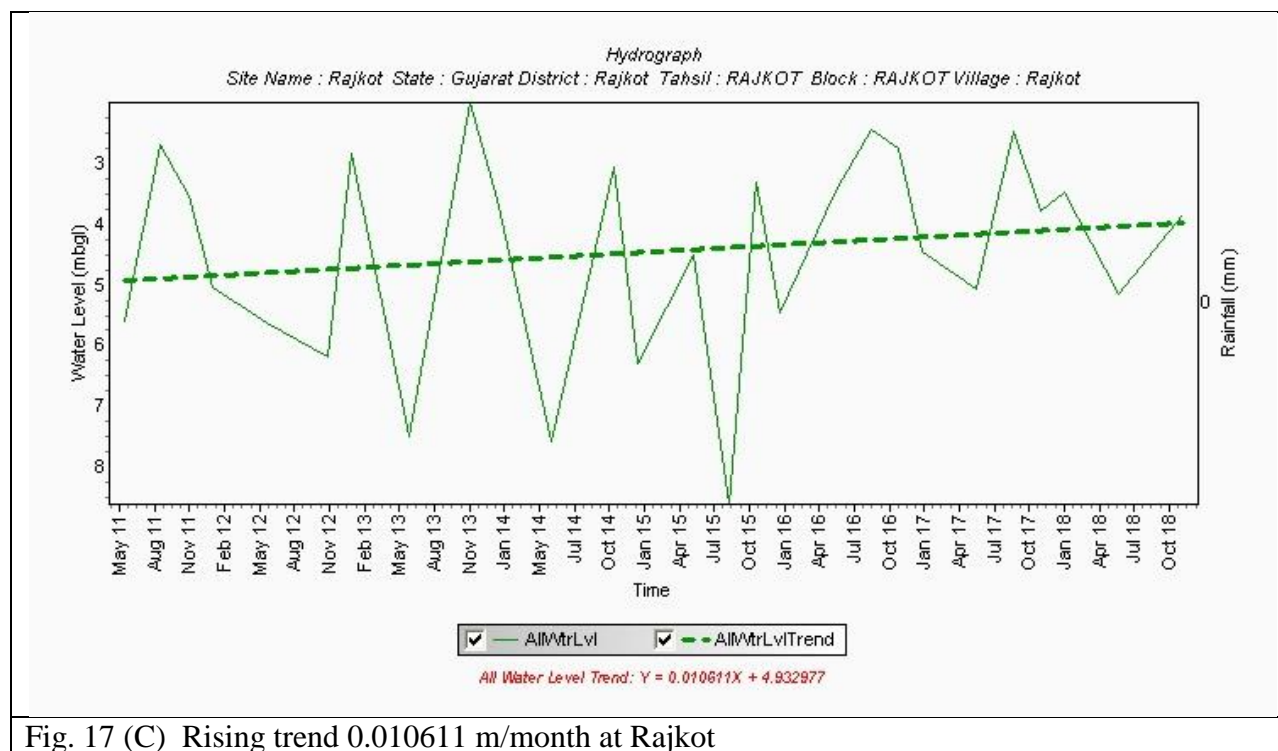


Fig. 17 (C) Rising trend 0.010611 m/month at Rajkot

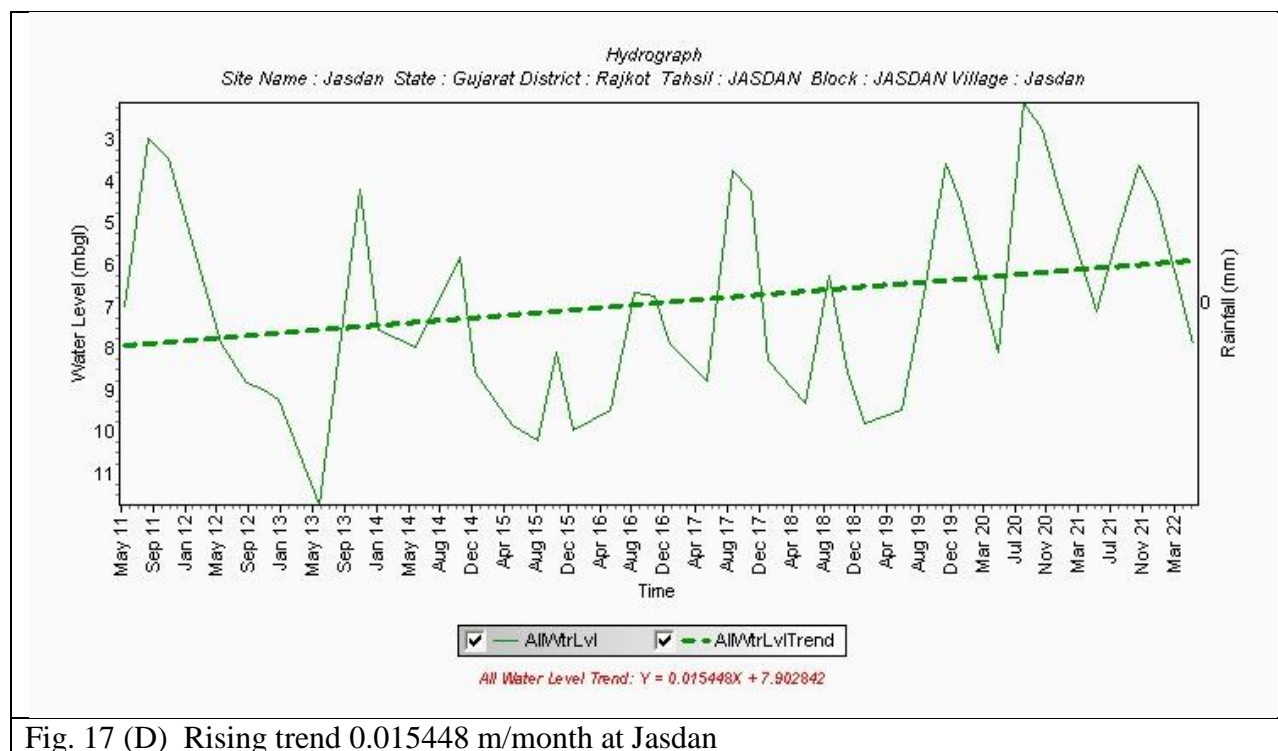


Fig. 17 (D) Rising trend 0.015448 m/month at Jasdan

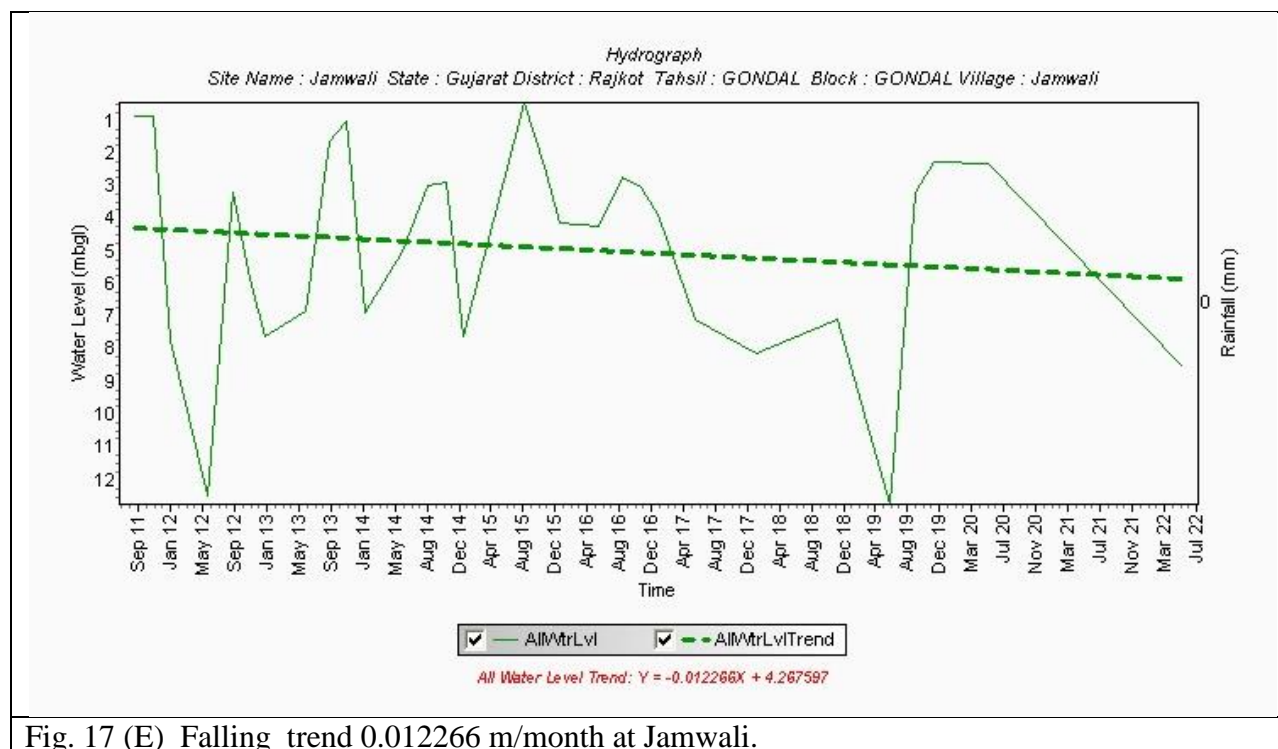


Fig. 17 (E) Falling trend 0.012266 m/month at Jamwali.

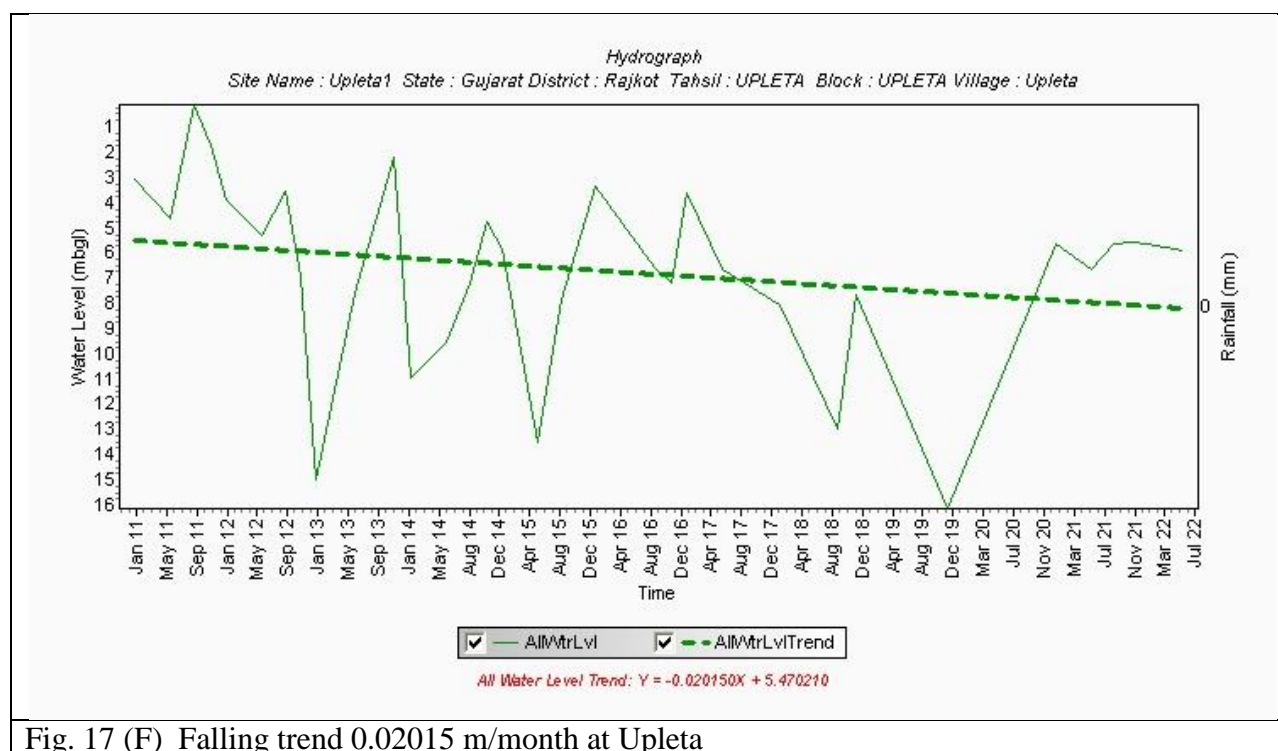


Fig. 17 (F) Falling trend 0.02015 m/month at Upleta

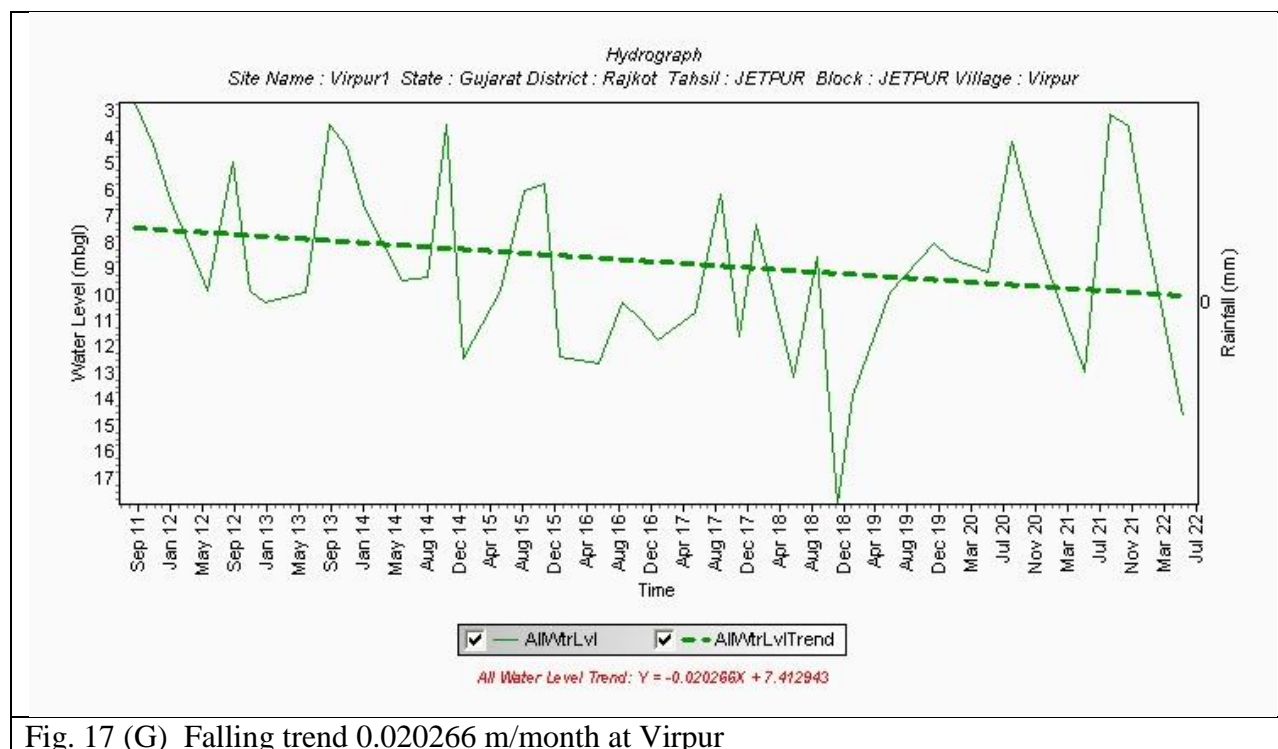


Fig. 17 (G) Falling trend 0.020266 m/month at Virpur

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs of Exploratory wells studies carried out by CGWB and state Ground water Departments (GWRDC & GWSSB) were used to prepare a hydro geological cross section, Fence diagram and 3D Model. The data has been analyzed 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 up to 200m. Map showing section lines are presented in Fig. 18. The stratigraphic sections depicting Hard area weathered Aquifer depth of occurrence is from 0 to 15m and fractured aquifer depth of occurrence is from 10 to 180m.unconfined aquifer are placed at Figs 19 (A to E). Fence Diagram and 3D Solid Model of Rajkot district is depicted in Fig. 19 and 20, respectively.

A total of 46 exploratory wells and piezometers constructed by CGWB. And 46 litho logs 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.

Table No: - 08 Data integration

S.No.	Data	Aquifer	Total Data Points	Source	
				CGWB	GWRDC
1	Panel Diagram (3-D)	1 no	46	Expl:46	-
2	Hydrogeological Cross Sections	05 no	46	Expl:46	-
3	Fence/panel Diagrams	1 no	46	Expl:46	-
4	Depth of weathering	1 no	46	Expl:46	-
5	Depth of fracturing	1 no	46	Expl:46	-
7	Depth to Water Level Maps (2019)	Combine	197	37	156
8	Long term water	Combine	197	37	156
9	Water quality pre-2019 & post-2019	Combine	108	26	82

Conceptualization of Aquifer system in 2D

Ten hydrogeological cross sections are drawn from North-East to South-West and North-West to South-East directions across the area represented in Figs 19 (A to E)

Litho logical logs of subsurface are correlated based on the position and depth of the geological formations and prepared ten cross sections one fence diagram and one 3D solid model of Rajkot district.

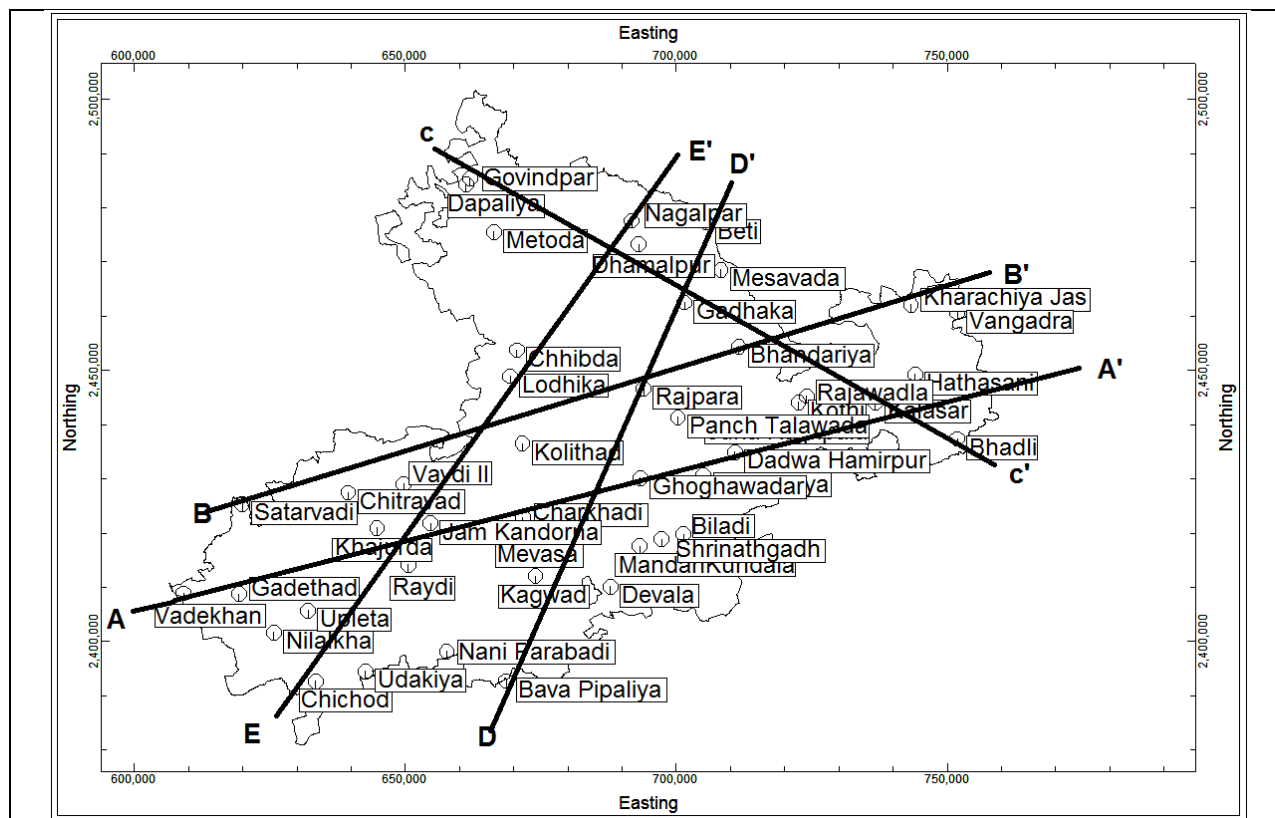


Fig No :18 Map Showing Section Lines of Rajkot District

Stratigraphic Legend



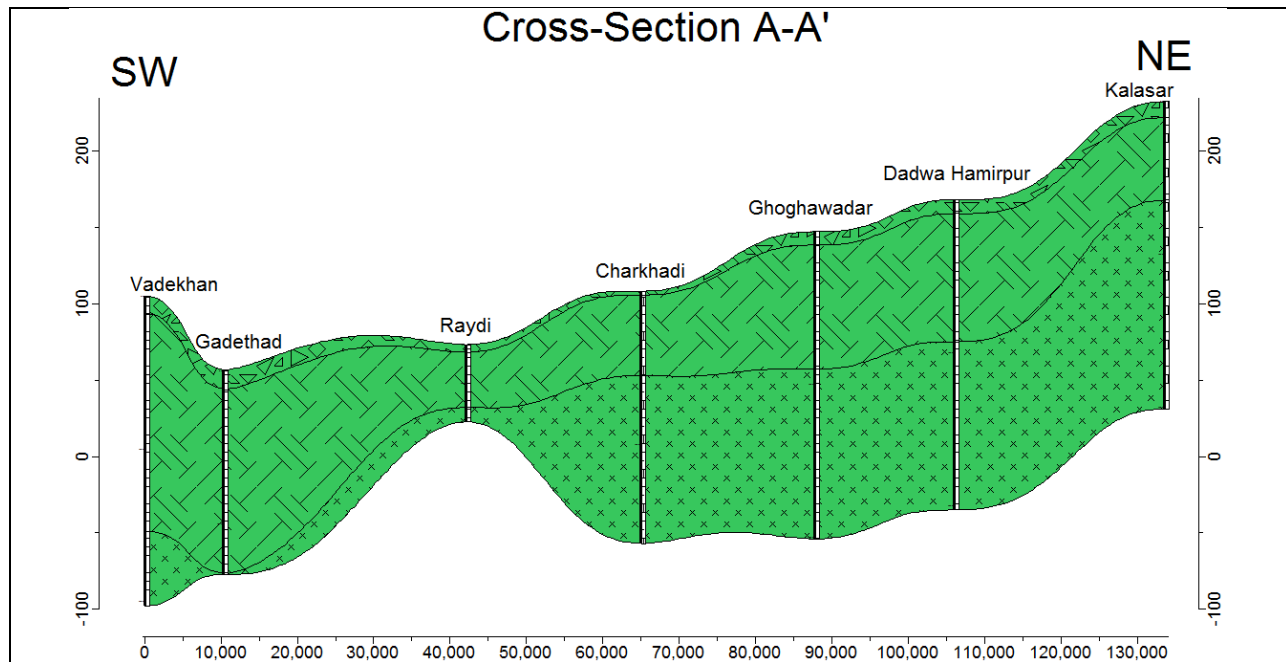
Weathered Basalt



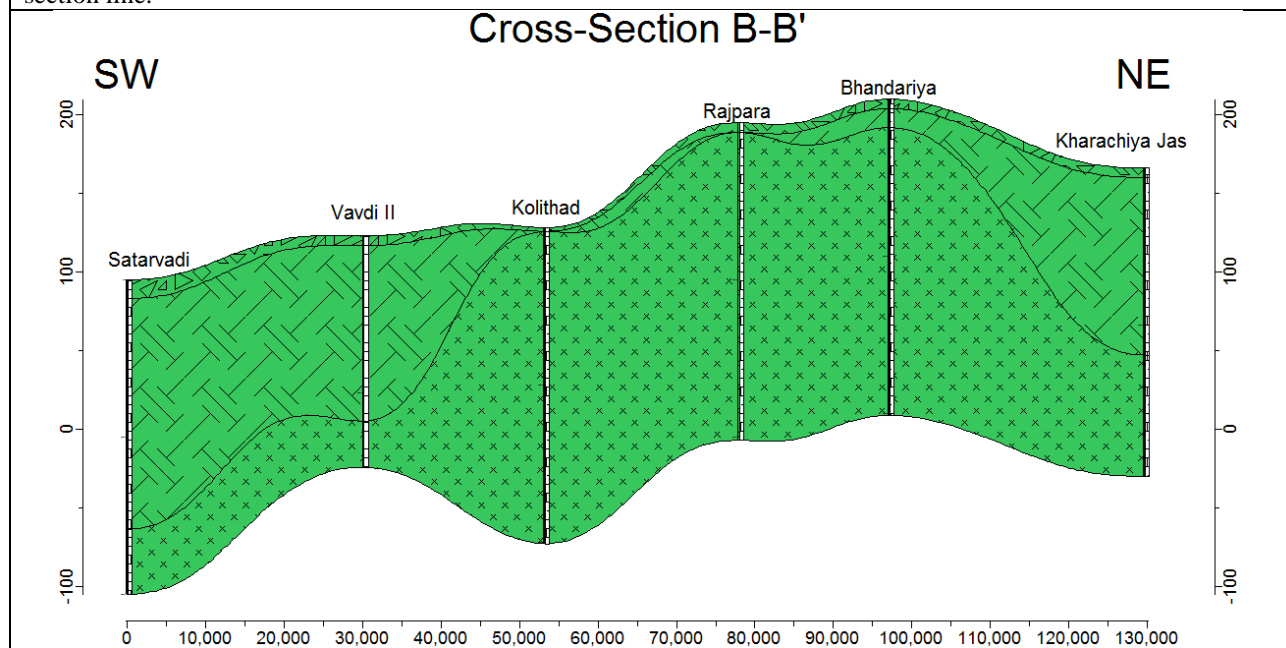
Fractured Basalt



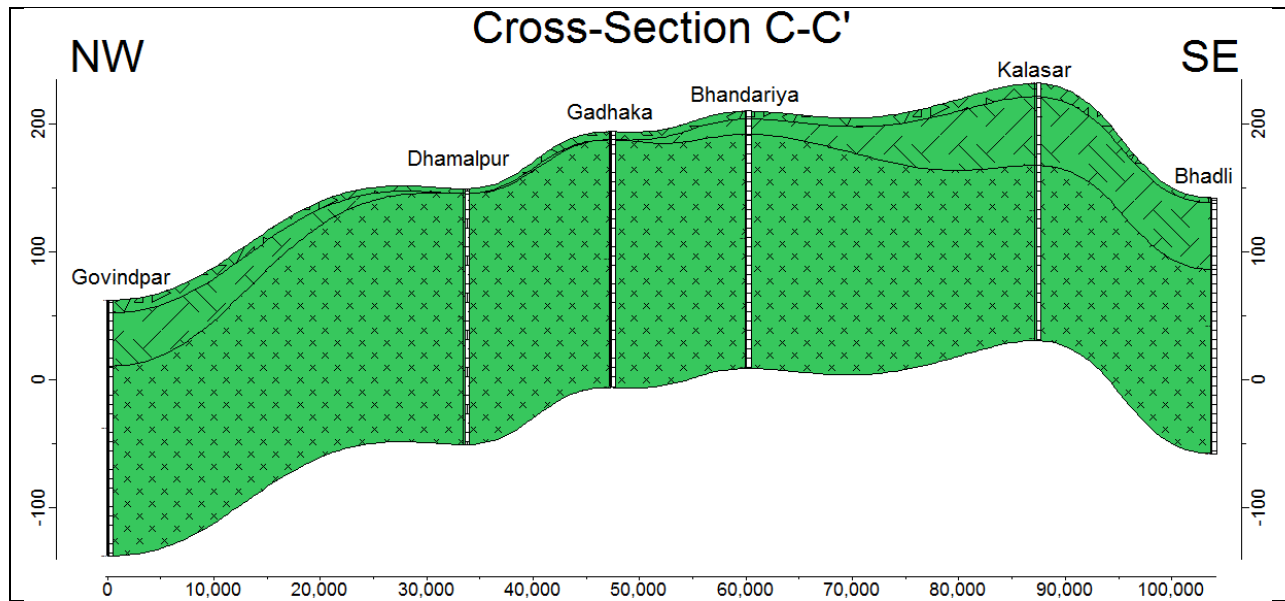
Massive Basalt



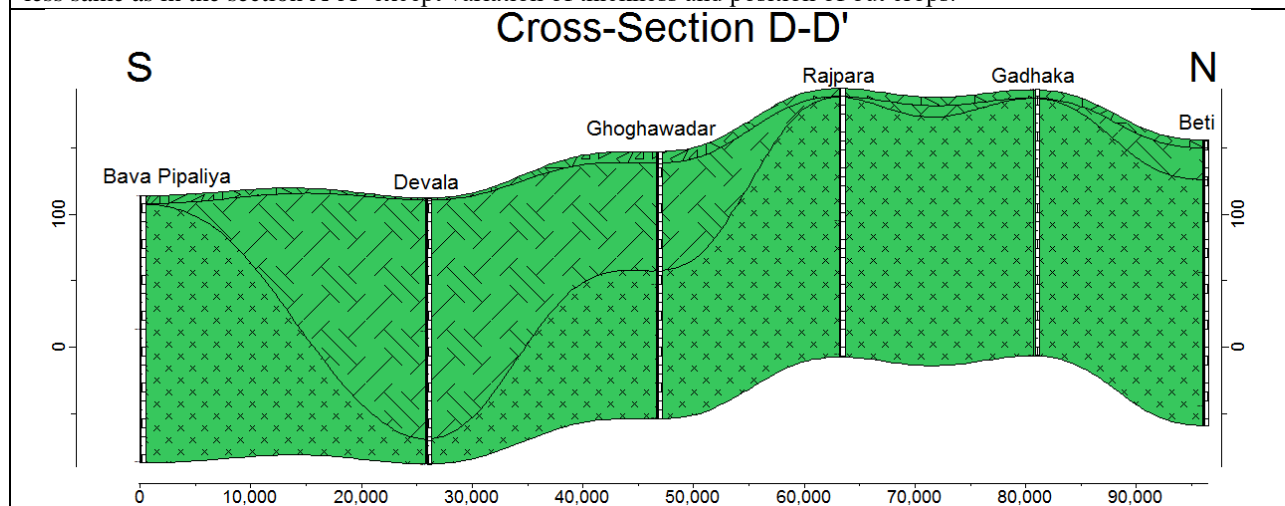
Section A-A' (Fig. 19)- Section is drawn roughly NE-SW direction and in between Vadekhan and Kalasar, passing through Gadethad, Raydi, Charkhadi, Ghoghawadar and Dadwa Hamirpur. Section is represented geologically, from which it is deciphered that basalt (weathered & Fractured Basalt) forms the major aquifer system in the district along the section line.



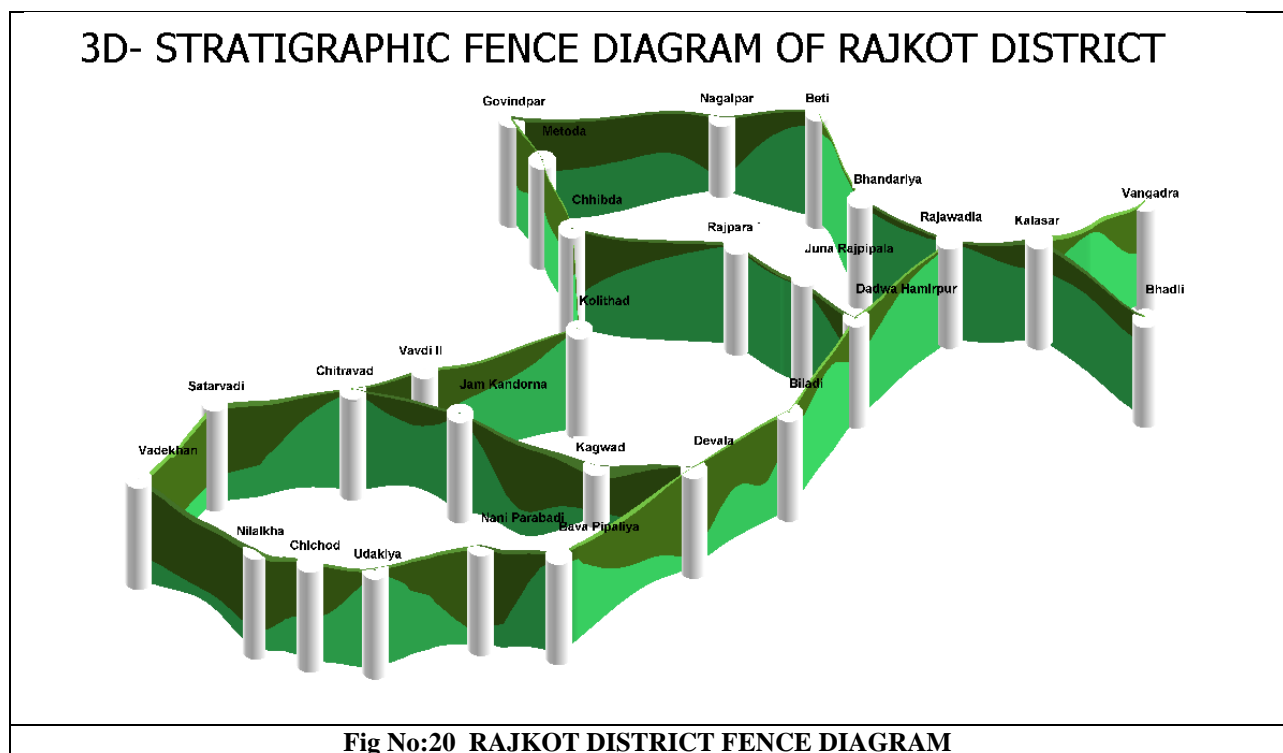
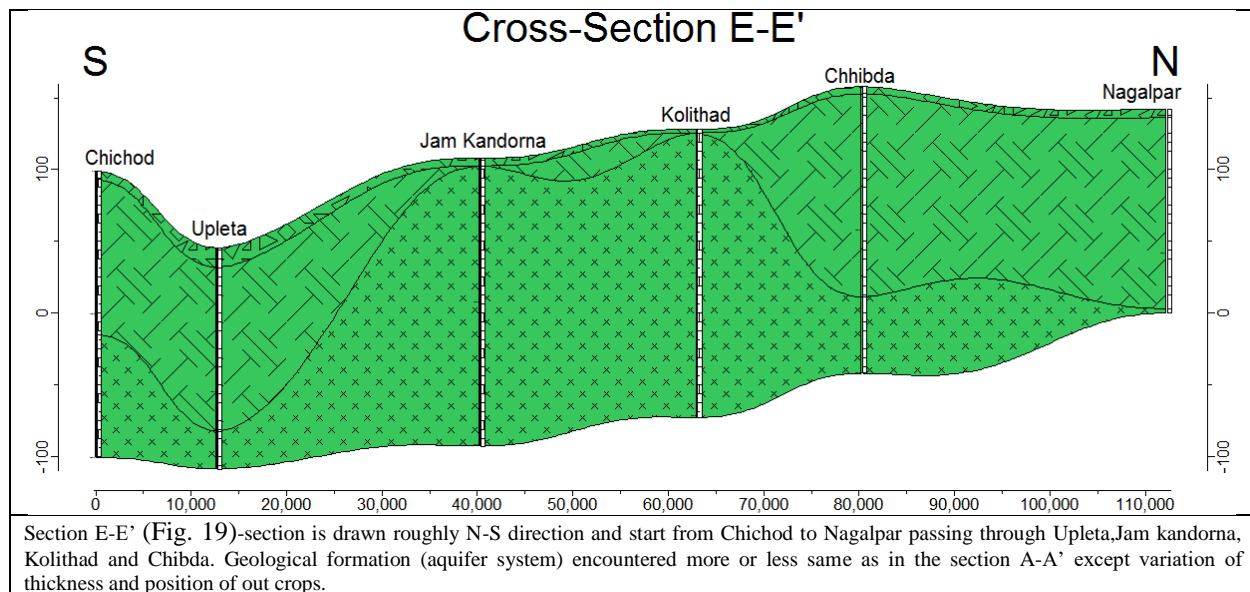
Section B-B' (Fig. 19)- Section is drawn roughly NE-SW direction and starts from Satarvadi to Kharachiya Jas passing through Vavdi, Kolithad, Rajpara and Bhandariya. Geological formation (aquifer system) encountered more or less same as in the section A-A' except variation of thickness and position of outcrops.

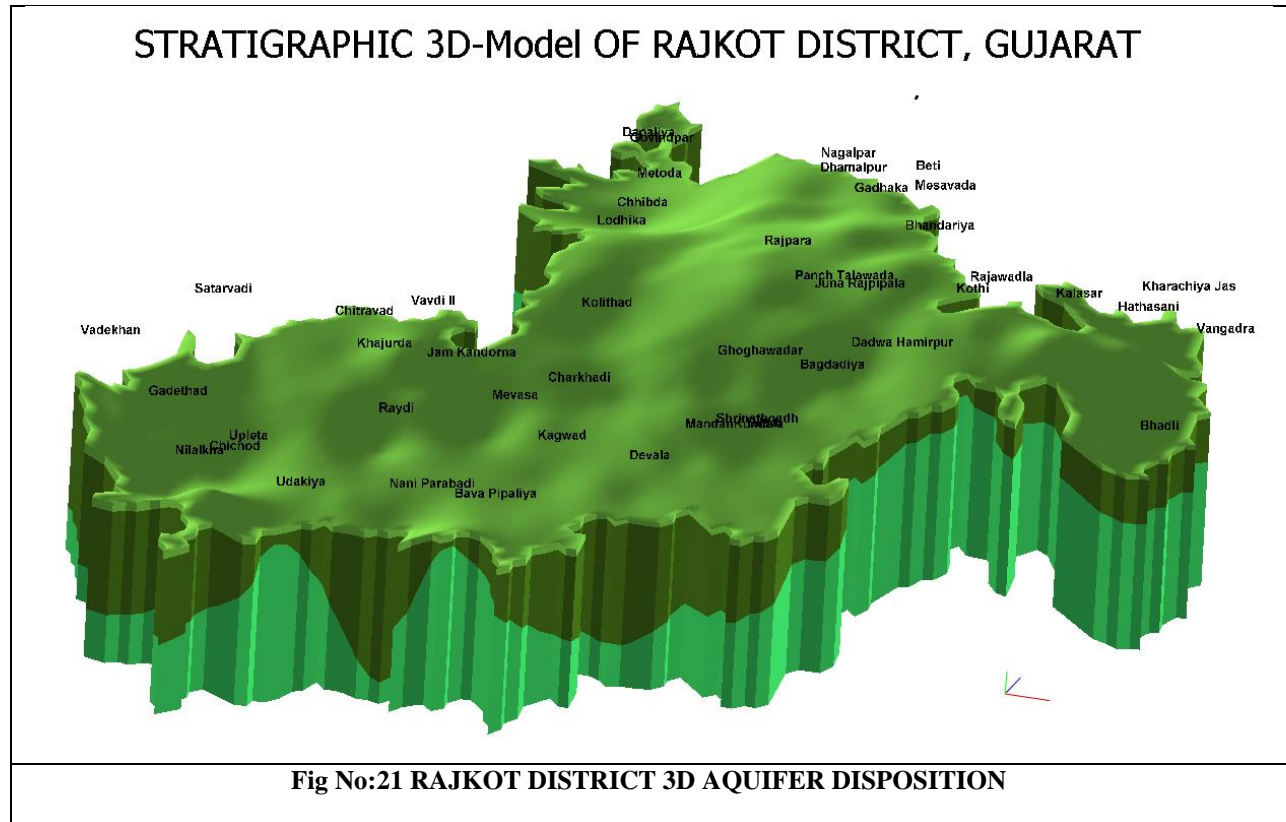


Section C-C' (Fig. 19)- Section is drawn roughly NW-SE direction and start from Govindpar to Bhadli passing through Dhamalpur, Gadhaka, Bhandariya and Kalasar). Geological formation (aquifer system) encountered more or less same as in the section A-A' except variation of thickness and position of out crops.



Section D-D' (Fig. 19)- section is drawn roughly N-S direction and start from Bava Pipaliya to Berti passing through Devala, Ghoghawadar, Rajpara and Gadhaka. Geological formation (aquifer system) encountered more or less same as in the section A-A' except variation of thickness and position of out crops.





Finally, the study of these sections reveals that the identification and delineating the Aquifers vertically and laterally. The study of these 2D sections, Fence and 3D solid model reveals that there is a basaltic formation with weathered rocks followed by fracture basalts and lower most formation is Massive basalts in all the talukas. The weathered basalts varies in thickness from 4.2 to 15m. And the fractured/ jointed basalts encountered in between 10m to 180m.

Aquifer Characterization and Disposition.

On the basis of Hydrogeological cross sections the following salient features of aquifer system in the area is summarised below Table No :-09

Aquifer Characteristics and Disposition										
Stratigraphy	Aquifer	Lithological character	Depth of occurrence	Thickness	Water Level	TDS	Discharge	Transmissivity	Nature of Aquifer	Quality
			Aquifer (mbgl)	Range (m)	Range (m)	Mg/l	lps	m2/day		
Cretaceous	Weathered Basalt	Basalts	0 to 15	0 to 15	5 to 8	500 to 600	1 to 3	0.5 to 20	Phreatic	Good
	Fractured Basalt	Basalts	10 to 180	10 to 180	8 to 90	500 to 6000	1 to 10	0.5 to 100	Fractured	Good

4. HYDROCHEMISTRY

The ground water in major part of the district is suitable for domestic, irrigation and industrial purposes for both in phreatic and confined aquifers within 200 m depth. Deccan trap occupies a major part of the district and forms the most important aquifer system.

The chemical quality of groundwater in shallow aquifer of the district has been analyzed based on the water samples collected during National Hydrographs Monitoring Stations (NHS) and NAQUIM studies in May 2019 and the range of major constituents and parameters are given below in table 10. The ground water is in general alkaline in nature. Distribution of Electrical Conductivity and Nitrate & Fluoride concentrations has been shown in figure (22) and (23) respectively.

Table No: 10

Summarised Chemical Data of Rajkot District.							
Chemical Parameters	pH	EC	TH	TDS	Cl	NO3	F
Min	7.25	507	150	339.69	35.5	0.1	0
Max	8.7	6690	1520	4030	2112	235.7	4.8
Average	8.22	1896.79	316.92	1224.75	402.53	14.25	0.78
* All values are in mg/l except pH and EC in $\mu\text{S/cm}$ at 25°C							

Rajkot district is one of the most industrialized district in Gujarat State. It has established itself as a major manufacturing center for diesel engines, automobile components, gems and jewelries, a cluster of foundry units, a cluster of sari printing (Jetpur), and a cluster of ceramics (Morbi). Major manufacturing centers are Rajkot (Oil Engine Manufacture, Gold and Silver Ornaments), Jetpur (Sari Printing), Gondal (Oil Extraction) and Jasdan (Cotton ginning and Pressing and Handicrafts).

No major chemical quality problem reported so far, but looking at the quality problems in other parts of the Gujarat due industrial set up, enforcing regulatory measures mandatory before releasing of industrial effluents only after due treatment in ETPs and solid waste disposal at designated sites.

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 7.25 & 8.7 in the district.

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 (Fig.22), Due to Basaltic Nature of the district has EC value within Permissible limit i.e. almost all talukas except extreme western region of Upleta taluka show EC value more than permissible limit.

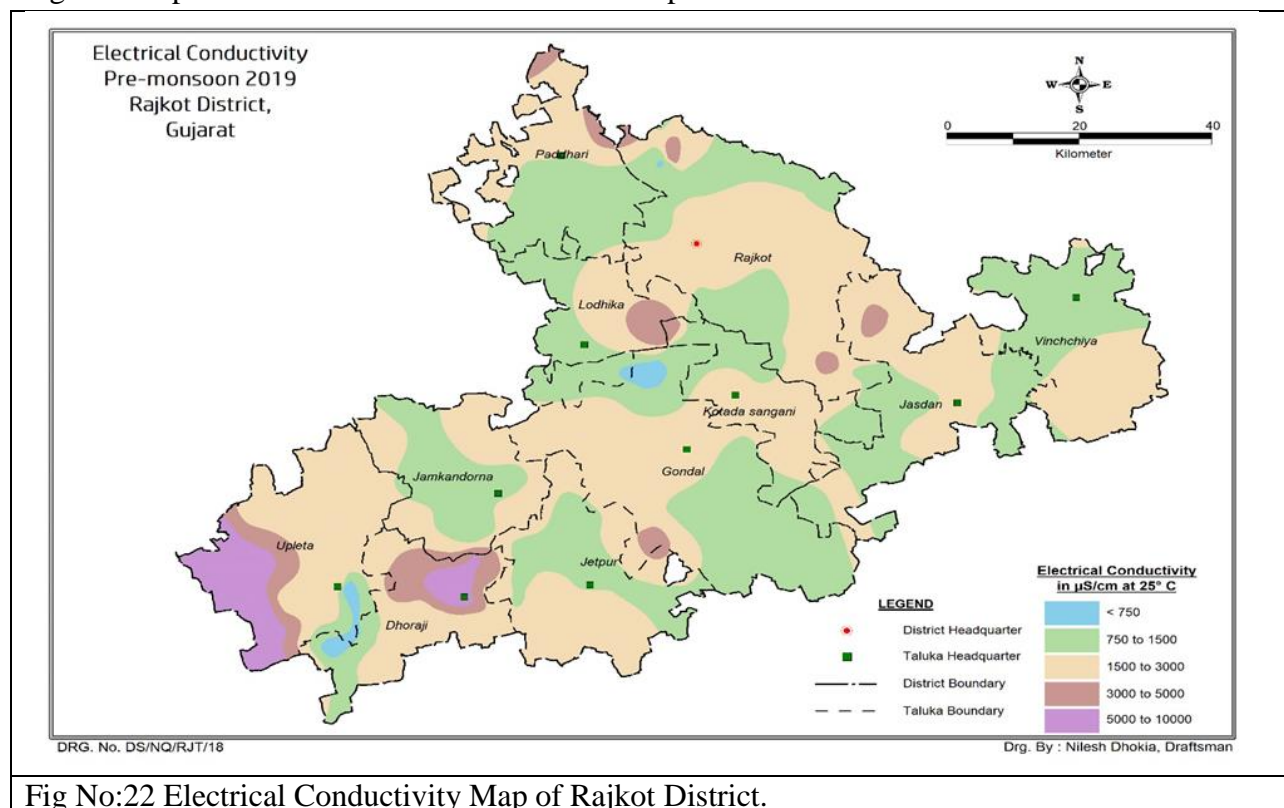


Fig No:22 Electrical Conductivity Map of Rajkot District.

Total Dissolved Solid (TDS)

Total Dissolved Solid is an overall parameter indicating salinity of ground water. The Total Dissolved Solid of ground water varies from 340 mg/l to about 4030 mg/l.

Nitrate (NO₃)

Nitrate concentration in the ground water in district varies between 0.1 mg/l and 235.7 mg/l. There are Nine stations where these values are more than the limits as per BIS drinking water standards (45 mg/l).

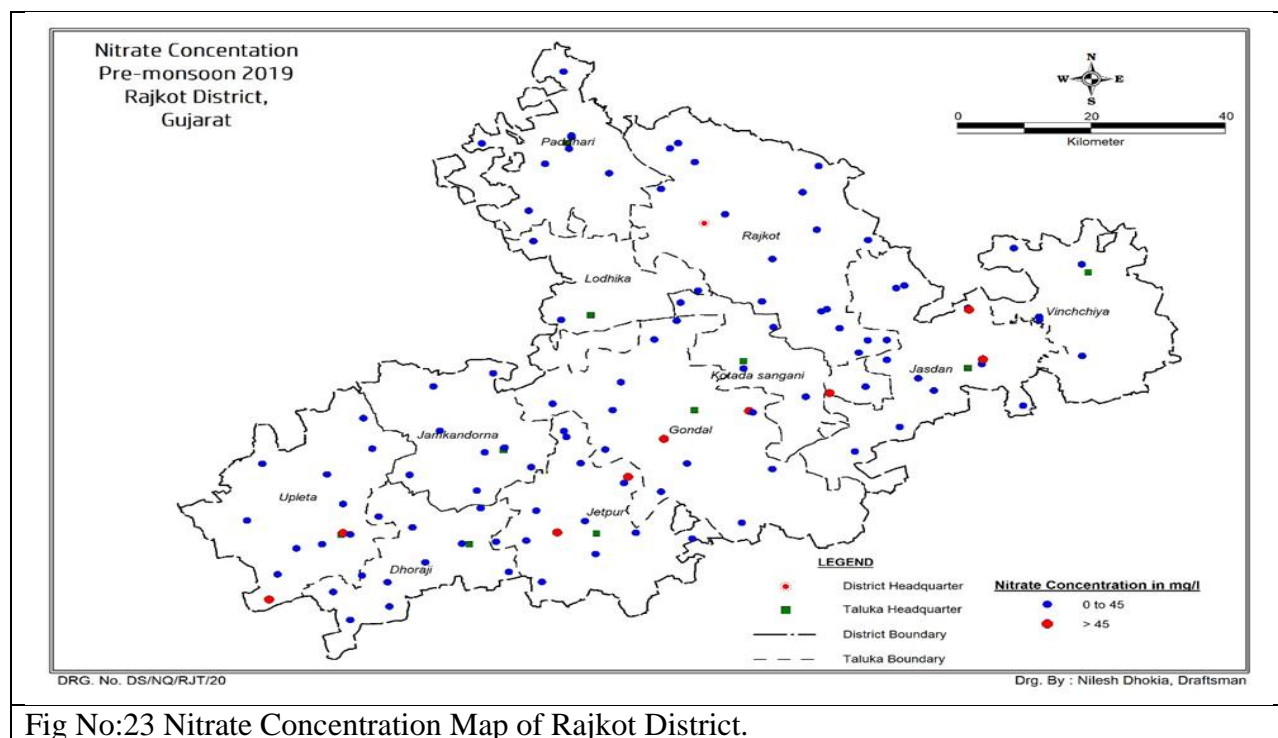


Fig No:23 Nitrate Concentration Map of Rajkot District.

Fluoride (F)

Fluoride concentration in ground water varies between almost 0.1 mg/l and 4.8 mg/l. Concentration of fluoride more than the permissible limit i.e. 1.5mg/l is observed at only in 3 stations.

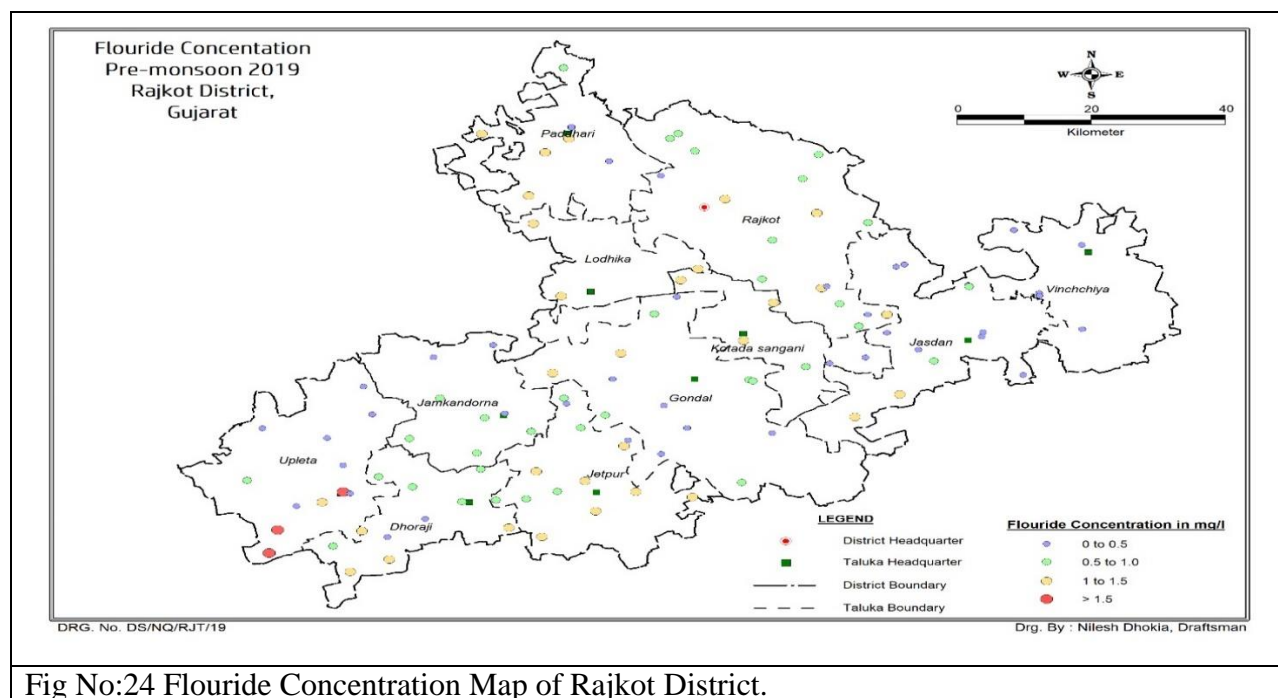


Fig No:24 Fluoride Concentration Map of Rajkot District.

5. GROUND WATER RESOURCES

The ground water resources of the district were calculated as on March 2017 in collaboration with the Government of Gujarat using the methodology suggested by Ground Water Resource Estimation Committee (GEC-15). These resources were computed after reorganization of the districts.

Ground Water Recharge

The Annual Ground Water Recharge varies from 7197.63ha.m (Vinchchiya taluka) to 27968.37ha.m (Gondal Taluka). The Gross Annual Ground Water Recharge in the district is 156553.76ha.m. The net available recharge after leaving natural discharge from monsoon period varies from 6837.74ha.m (Vinchchiya taluka) to 26569.96ha.m (Gondal Taluka). The net available recharge in the district is 148726.07ha.m.

Ground Water Draft

The ground water draft from irrigation and Domestic /Industrial sources is presented in Table: 10. The Existing Gross Ground Water Draft for all uses varies from 4313.90ha.m (Vinchchiya taluka) to 16670.50ha.m (Gondal Taluka). The Gross Ground Water Draft for All uses in the district is 95955.75ha.m.

Level of Ground Water Development & Stage

The stage of ground water development at year 2017, for all the talukas of the Rajkot district computed range from 62.06 % to 67.94 % and 11 units of assessment (talukas) have been categorized as *Safe*, based on the stages of ground water development and the long-term trend of pre and post monsoon ground water levels. The average stage of groundwater development for district is 64.52%. Taluka wise ground water resources and categorization for each assessment unit is presented in table 11.

Table No-11 Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2017)																
Sl. No	Assessment Unit Name	Ground Water Recharge(Ham)				Total Annual Ground Water (Ham) Recharge (10=6+7+8+9)	Total Natural Discharges (Ham)	Annual Extractable Ground Water Recharge (Ham) (12=10-11)	Current Annual Ground Water Extraction(Ham)				Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use (18=12-13-14-17)	Stage of Ground Water Extraction (%) (19=(16/12)*100))	Categorization (OE/Critical/Semcritical/Safe)
		Monsoon Season		Non-monsoon season					Irrigation Use	Industrial Use	Domestic Use	Total Extraction (16=13+14+15)				
		Recharge from Rainfall	Recharge from Other Sources	Recharge from Rainfall	Recharge from Other Sources											
1	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Dhoraji	10195.43	1835.87	0.00	2096.82	14128.13	706.41	13421.72	8588.50	39.16	221.92	8849.58	304.00	4490.06	65.93	Safe
2	Gondal	21764.09	3003.15	0.00	3201.13	27968.37	1398.42	26569.96	16189.20	72.20	409.11	16670.50	560.00	9748.56	62.74	Safe
3	Jamkandorna	9679.13	2025.03	0.00	1443.88	13148.04	657.40	12490.64	7959.30	19.75	111.94	8090.99	153.00	4358.59	64.78	Safe
4	Jasdan	9239.77	2919.05	0.00	1553.68	13712.51	685.63	13026.88	8263.70	79.42	450.05	8793.17	616.00	4067.76	67.50	Safe
5	Jetpur	12425.83	1962.42	0.00	1539.18	15927.43	796.37	15131.06	8973.60	62.48	354.08	9390.16	484.00	5610.98	62.06	Safe
6	Kotadasangani	6030.14	1485.84	0.00	1042.10	8558.08	427.90	8130.17	4939.40	22.87	129.60	5091.87	177.00	2990.90	62.63	Safe
7	Lodhika	5882.23	1432.01	0.00	855.95	8170.19	408.51	7761.68	4791.10	14.52	82.26	4887.87	177.00	2779.06	62.97	Safe
8	Paddhari	8978.78	2378.88	0.00	1830.77	13188.43	659.42	12529.01	8360.50	18.91	107.14	8486.55	147.00	4002.60	67.74	Safe
9	Rajkot	16346.52	2983.14	0.00	1042.81	20372.46	1018.62	19353.84	12220.80	31.57	178.92	12431.29	269.00	6832.46	64.23	Safe
10	Upleta	10879.82	1913.64	0.00	1389.04	14182.50	709.13	13473.38	8648.30	45.23	256.33	8949.86	351.00	4428.84	66.43	Safe
11	Vinchchaya	4323.93	1960.63	0.00	913.07	7197.63	359.88	6837.74	4136.90	27.00	150.00	4313.90	206.00	2467.84	63.09	Safe
		115745.68	23899.65	0.00	16908.43	156553.76	7827.69	148726.07	93071.30	433.12	2451.34	95955.75	3444.00	51777.66	64.52	

6. GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

Issues

Deep water levels

Deep water levels (> 20 m bgl) are observed during pre as well as post-monsoon season in 04 no and 02 no of the wells respectively.

Out of 189 wells analyzed, 76 wells during pre-monsoon 105 wells during post monsoon shown falling trend in the last 10 years (@-0.004 to -3.34 m/yr and -0.006 to -2.70 m/yr) respectively.

Pollution (Geogenic and Anthropogenic)

Ground water in both Phreatic and confined Aquifers is Potable and fit for domestic, drinking, irrigation and other industrial purposes but higher concentration of Fluoride and Nitrate is observed in shallow aquifer at localised pockets.

Sustainability

In Rajkot district, the main aquifers being hard rock the yield depends on the thickness of weathered mantle and persistence of jointing, fracturing which is not uniform in nature. The yield from bore wells have reduced over a period of time and some bore wells which used to yield sufficient quantity of water have gone dry due to low rainfall.

Reasons for Issues

Sustainability: Absence of primary porosity, negligible development of secondary porosity, low rainfall, de saturation of weathered zone and urbanization.

Geo-genic pollution (Fluoride): Higher concentration of fluoride in ground water is attributed due to source rock,

7. MANAGEMENT STRATEGIES IN RAJKOT DISTRICT

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.

- a) Supply side measures
- b) Demand side measures

SUPPLY SIDE INTERVENTIONS

ARTIFICIAL RECHARGE TO GROUND WATER AND WATER CONSERVATION PLAN

IDENTIFICATION OF RECHARGE AREA

An area of about 1951.20 sq. km has been identified in District Rajkot of Gujarat State. Deccan trap basalt/intrusive is the water bearing geological formations occurring in the district. The thickness of available unsaturated zone (below 6 m bgl) is computed on basis of Post monsoon (2011-20) decadal average depth to water level map (Fig 25). Based on the decadal average depth to water level of post monsoon period (2011-20) data and long term trend of ground water level (2011-20) four categories were identified as follows.

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

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

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

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

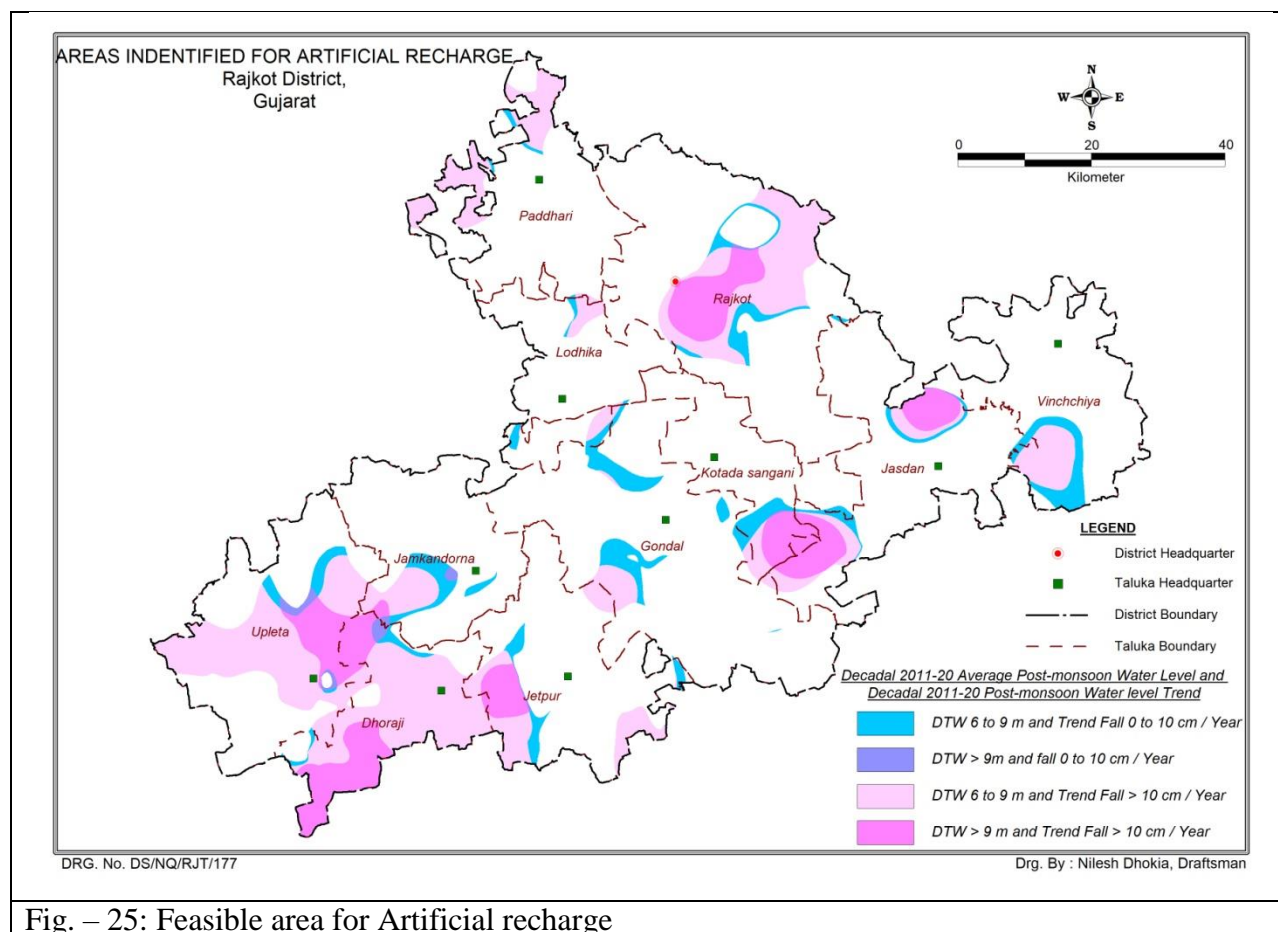


Fig. – 25: Feasible area for Artificial recharge

Table no: 12 Identification of area feasible for Artificial Recharge in Rajkot District, Gujarat								
S.No.	Taluka	Aquifer	Area (DTW > 9m; Trend 0 to 10cm / year (Sq.km.)	Area (DTW > 9m; Trend > 10cm / year (Sq.km.)	Area(DTW < 9m; Trend 0to10cm/year (Sq.km.)	Area (DTW < 9m; Trend > 10cm / year (Sq.km.)	Area feasible for artificial recharge (Sq.km.)	Geographical Area (in sq.km)
1	Dhoraji	Basalt	5.93	146.17	11.80	257.70	421.60	489.30
2	Gondal	Basalt	--	--	78.55	40.11	118.66	1207.42
3	Jamkandorna	Basalt	5.10	5.37	32.24	52.58	95.29	572.27
4	Jasdan	Basalt	--	95.15	23.57	49.18	167.90	771.76
5	Jetpur	Basalt	1.43	43.90	25.36	101.21	171.90	685.35
6	Kotada sangani	Basalt	--	40.51	29.51	26.58	96.60	449.60
7	Lodhika	Basalt	--	--	3.34	18.05	21.39	376.05
8	Paddhari	Basalt	--	--	5.57	115.01	120.58	601.20
9	Rajkot	Basalt	1.865	107.4	38.18	148.6	296.045	1172.60
10	Upleta	Basalt	11.6	--	21.9578	293.5	327.0578	805.54
11	Vinchchiya	Basalt	--	--	47.7152	66.48	114.1952	622.53
		Total	25.92	438.50	317.79	1169.00	1951.20	7753.65

A total of 1951.20 sq. km area spread over the district in the isolated patches having water level & trend as above is computed (Table 12) and same is depicted as suitable areas for artificial recharge.

Table-13 Computation of volume of unsaturated zone available for recharge							
S.No.	Taluka	Aquifer	Volume MCM : DTW > 9 m ; Trend 0 to 10 cm / year	Volume MCM DTW > 9 m ; Trend > 10 cm / year	Volume MCM DTW 6 to 9 m ; Trend 0 to 10 cm / year	Volume MCM DTW 6 to 9 m ; Trend > 10 cm / year	Volume of unsaturated zone available for artificial recharge
		Average Depth unsaturated below 6 m bgl (Excluding clay & impervious hard zones)	6 m	6 m	3 m	3 m	
1	Dhoraji	Basalt	35.58	877.02	35.41	773.10	1721.11
2	Gondal	Basalt	0.00	0.00	235.64	120.33	355.97
3	Jamkandorna	Basalt	30.60	32.20	96.72	157.74	317.26
4	Jasdan	Basalt	0.00	570.90	70.70	147.54	789.14
5	Jetpur	Basalt	8.56	263.40	76.08	303.63	651.67
6	Kotada sangani	Basalt	0.00	243.06	88.54	79.74	411.34
7	Lodhika	Basalt	0.00	0.00	10.01	54.15	64.16
8	Paddhari	Basalt	0.00	0.00	16.71	345.03	361.74
9	Rajkot	Basalt	11.19	644.40	114.54	445.80	1215.93
10	Upleta	Basalt	69.60	0.00	65.87	880.50	1015.97
11	Vinchchiya	Basalt	0.00	0.00	143.15	199.44	342.59
		Total	155.53	2630.98	953.36	3507.00	7246.87

SUB-SURFACE STORAGE SPACE AND WATER REQUIREMENT

Further, while calculating the total volume of unsaturated zone available for recharge, clay & massive non porous intervening zones have been deleted from the total thickness of potential zone for recharge. Average specific yield data of above formations, as per norm of GWRE were considered to compute volume of water required for recharge to saturate dry zones. Storage space volume available in aquifers is 7246.87 MCM. On the basis of specific yield factor of major aquifer system considered, the volume of water required for artificial recharge to fully saturate aquifer (below 6 m bgl) in each talukas areas is around 144.94 MCM (Table 13).

Table-14 Computation of volume of unsaturated zone available for recharge.

Sr No	Taluka	Aquifer	Volume of unsaturated zone available for artificial recharge MCM	Specific yield factor	Volume of water required for recharge MCM	Volume of rain water planned for Artificial recharge (MCM)
1	Dhoraji	Basalt	1721.11	0.02	34.42	
2	Gondal	Basalt	355.97	0.02	7.12	
3	Jamkandorna	Basalt	317.26	0.02	6.35	
4	Jasdan	Basalt	789.14	0.02	15.78	
5	Jetpur	Basalt	651.67	0.02	13.03	
6	Kotada sangani	Basalt	411.34	0.02	8.23	
7	Lodhika	Basalt	64.16	0.02	1.28	
8	Paddhari	Basalt	361.74	0.02	7.23	
9	Rajkot	Basalt	1215.93	0.02	24.32	
10	Upleta	Basalt	1015.97	0.02	20.32	
11	Vinchchiya	Basalt	342.59	0.02	6.85	
		Total	7246.87		144.94	

SOURCE WATER AVAILABILITY

The availability of source water, one of the prime requisites of artificial recharge. Gujarat State has been adopted concept of managed aquifer recharge in the state. While planning/finalization of Master plan for Artificial Recharge (2020) to Ground water in Gujarat state it was said that efforts shall be made for supplying surplus water from surface storage for recharging. Also it is expected that under climatic change effect due to change in hydrology more rain fall water may be available. Considering this 15 MCM of surplus surface water is provisioned for artificial recharge in Rajkot district. 15 MCM of surplus surface water was apportioned with taluka wise and for Rajkot district 15 MCM of surplus surface water is considered for artificial recharge through 499 no of recharge shafts and 01 no of existing defunct tube wells which can be used as injection wells in Rajkot district.

Table No: 15 Feasibility of Artificial Recharge in Rajkot District As per master Plan Gujarat 2020.

Sr No	District Name	Area of District in sqkm	Decadal Average (2011-20) Post Monsoon Depth to Water Level (m bgl)	Area Feasible for Artificial Recharge	Volume of unsaturated zone available for recharge (MCM)	Volume of Water required for recharge (MCM)	Surplus Runoff Available District (As per Master Plan 2020) (MCM)	Balance Volume of Surplus Local / Distant Sources available for recharge (MCM)	Additional Percolation Tank Structure Proposed Recharge Capacity @0.14 MCM	Additional Check Dam Structure Proposed Recharge Capacity @0.05 MCM	PT	CD	Total Coast (Rs Cores)
1	Rajkot	7753.65	6.44	1951.20	7246.89	144.94	15.00	0.00	As per Masterplan 2020 for Artificial Recharge to Ground Water in Gujarat state, 15 MCM of surplus surface water is provisioned for artificial recharge through 499 no of recharge shafts and 01 no of existing defunct tube wells which can be used as injection wells in Rajkot district. Ground water recharge of 1500 ham (through recharge shafts and defunct tube wells) is expected for the district Additional Artificial Recharge Structures are not recommended as Surplus Runoff is not available.				

Ground Water Development Plan

As per GWRE 2017 total 11 no blocks of Rajkot district are under safe category Ground water stage of development ranges from 62.06 % (Jetpur) to 67.94 % (Padhari). Further development to elevate the stage of ground water development is not advisable, since the district is already reached stage more than 60% in all blocks.

Demand side intervention

To prevent further ground water development, water conservation activities like on farm activities and farm ponds are recommended in the district. By these activities where groundwater extraction can be developed in between 58.18% to 64.60% i.e., under safe category.

19512 Ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 3885 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Ground water recharge of 1950.7 ham (through on farm activities) is expected for the district. 3424.33 ham saving of ground water through WUE measures & farm ponds activities is expected for the district.

Table-16 Water Conservation interventions in Rajkot District of Gujarat State				
Sr No	Block	On farm Activities (Area in ha)	Water Use Efficiency (WUE) Measures	No of Farm ponds (30 m x 30m x 1.5 m)
1	Dhoraji	4216.04	933	710
2	Gondal	1186.57	1518	1050
3	Jamkandorna	952.86	738	480
4	Jasdan	1678.953	279	155
5	Jetpur	1718.96	1126	595
6	Kotada sangani	966.02	623	70
7	Lodhika	213.863	337	295
8	Paddhari	1205.795	1394	110
9	Rajkot	2960.45	1981	75
10	Upleta	3270.578	662	55
11	Vinchchiya	1141.952	356	290
	Total	19512.041	9947	3885

Farm Ponds

A farm pond is a large hole dug out in the earth, usually square or rectangular in shape (Fig. 26), which harvests rainwater and stores it for future use. It has an inlet to regulate inflow and an outlet to discharge excess water. The pond is surrounded by a small bund, which prevents erosion on the banks of the pond. The size and depth depend on the amount of land available, the type of soil, the farmer's water requirements, the cost of excavation, and the possible uses of the excavated earth. Water from the farm pond is conveyed to the fields manually, by pumping, or by both methods.

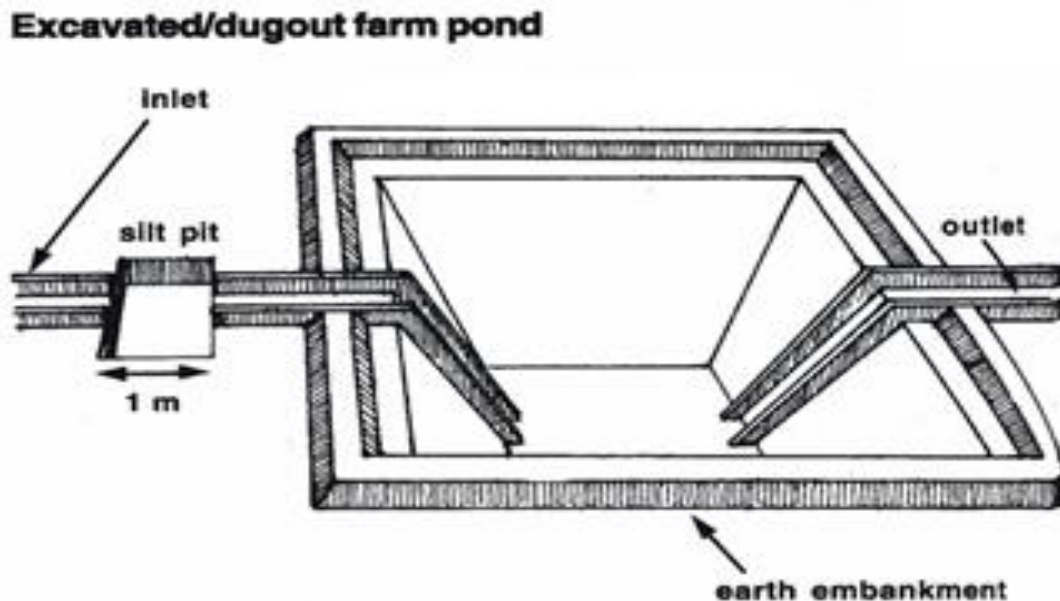


Fig. 26: Thematic diagram of Farm pond

Advantages of Farm Ponds

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

It is proposed to construct 3885 farm ponds as per the specification (30 x 30 x 1.5 m). Farm ponds can be constructed in the village at feasible location. Dimension of the farm pond depends on land holdings.

Table No-17 Projected Status of Groundwater Resource after implementation of GW Management Plan of Rajkot District of Gujarat state										
Sr No	Taluka	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of GW development after implementation of conservation measures (in %)	Projected stage of GW development after & implementation of conservation measures & Recharge measures (in %)
1	Dhoraji	13421.72	517.60	13939.32	8849.58	535.65	8313.93	65.93	60.06	59.64
2	Gondal	26569.96	361.60	26931.56	16670.50	583.62	16086.89	62.74	60.28	59.73
3	Jamkandorna	12490.64	206.3	12696.94	8090.99	291.23	7799.75973	64.78	61.97	61.43
4	Jasdan	13026.88	335.4	13362.28	8793.17	161.02	8632.14865	67.50	65.42	64.60
5	Jetpur	15131.06	297.9	15428.96	9390.16	413.71	8976.45187	62.06	58.66	58.18
6	Kotadasangani	8130.17	186.6	8316.77	5091.87	149.26	4942.61061	62.63	60.08	59.43
7	Lodhika	7761.68	96.4	7858.08	4887.87	146.52	4741.35153	62.97	60.92	60.34
8	Paddhari	12529.01	240.6	12769.61	8486.55	276.54	8210.00513	67.74	64.90	64.29
9	Rajkot	19353.84	497.00	19850.84	12431.29	423.87	12007.42	64.23	61.11	60.49
10	Upleta	13473.38	495.1	13968.48	8949.86	253.61	8696.25679	66.43	63.01	62.26
11	Vinchchiyana	6837.74	216.2	7053.94	4313.90	189.30	4124.60075	63.09	59.33	58.47
		148726.07	3450.70	152176.77	95955.75	3424.33	92531.42	64.55	61.43	60.81

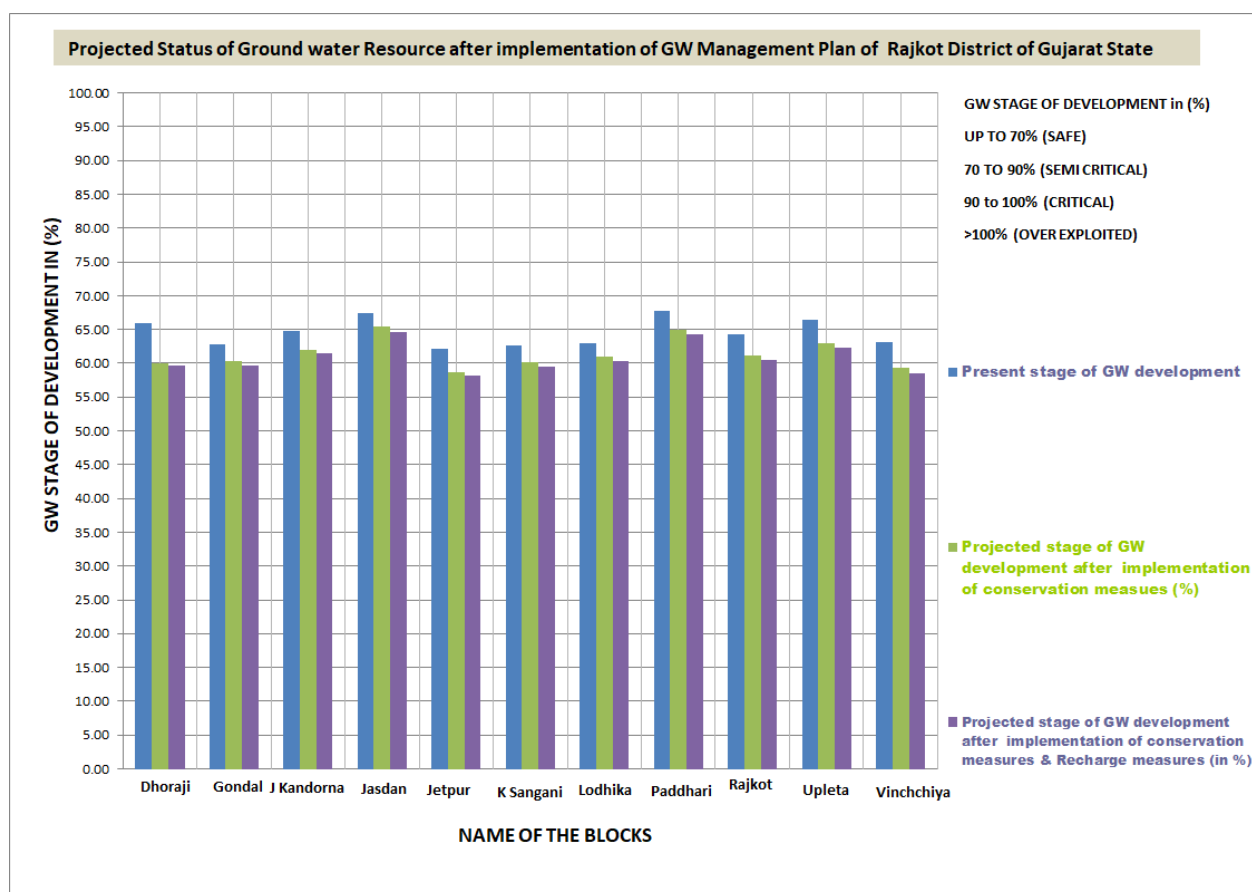


Fig. 27: Projected Status of Ground Water Resources after implementation of GW management Plan.

Table- 17 Summary of Interventions and Expected Benefits of Rajkot district of Gujarat State

Interventions Recommended	
On-farm Activities (ha)	19512.04 ha
Water Use Efficiency (WUE) Measures	9947 ha
No of Farm Ponds	3885
Expected Benefits	
Expected Annual Recharge(Through On farm activities)	1950.70 ham
Expected Annual Recharge(Recharge Shaft & Defunct Tube wells)	1500 ham
Conservation from On-farm Activities, WUE Measures & Farm Ponds	3424.33 ham
Total Recharge/ Saving	6875.03 ham

8. CONCLUSION AND RECOMMENDATIONS

- Artificial recharge structures like recharge shafts and Defunct Tube well are suggested as 15 MCM surplus surface water is provisioned as per the data provided by the State Water Resources Department.
- To prevent Over Exploitation, water conservation activities like On farm activities , farm ponds and Micro irrigation system (Sprinkler/drip) are recommended.
- 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 values 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.
- If surface water is not available in aforesaid areas with quality issues there water supply tube wells may be constructed tapping deeper aquifer after casing the Phreatic aquifer.

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Annexure 1 Rajkot Pre/Post_WL &Avg WL & Water Table & Fluctuation (Un Confined)																
Sr No	Well No	Distri ct	Taluka	Village	Geology	LAT_Y	LONG_ X	M P	RL	TOTA L DEPT H	May_20_ WL	Oct_20_ WL	PRE_AVG_20 10-19	POST_AVG_20 10-19	WTE_P RE	FLUC_PRE_P OST
1	W213840070154001	Rajko t	Dhoraji	Patanvav	Not Available	21.64444	70.26111		81.7	34.64			15.61	7.67	55.5	23
2	W213945070203001	Rajko t	Dhoraji	Bhada jodiya	Not Available	21.6625	70.34167		61	30.38			16.04	10.21	31.5	27.2
3	W214030070104501	Rajko t	Upleta	Ganod	Not Available	21.675	70.17917		31	13.8	6.74		4.64	3.39	22	5.9
4	W214405070300501	Rajko t	Jetpur	Motagund ala	Basalt	21.73472	70.50139		81.4	18.44			9.24	6.04	63.75	15.2
5	W214445070170901	Rajko t	Upleta	Dhoraji	Not Available	21.74583	70.28583		44	27	10.2		15.05	9.83	21.6	16.1
6	W214455070163001	Rajko t	Upleta	Upleta1	Not Available	21.74861	70.275		45.7	28.4			5.26	4.95	45.7	-16.16
7	W214505070353001	Rajko t	Jetpur	Pedhla	Not Available	21.75139	70.59167		97.7	30.01			19.61	11.27	72.25	18.1
8	W214522070371001	Rajko t	Jetpur	Jetpur	Basalt	21.75611	70.61944		89.6	56.2	4.98		8.22	5.36	89.6	-7.2
9	W214630070380001	Rajko t	Jetpur	Jetpur pithad.	Basalt	21.775	70.63333		84	21.1			12.1	4.91	84	0
10	W215100070414501	Rajko t	Jetpur	Virpur1	Basalt	21.85	70.69583		114	18.65	9.13		10.49	7.98	104.07	1.9
11	W215330070290001	Rajko t	Jamkandor na	Jasapur	Not Available	21.89167	70.48333		99	15	9.8		12.92	7.92	87.5	8.1
12	W215500070445501	Rajko t	Gondal	Chordi	Basalt	21.91667	70.74861		127.3	12.01	9.15		10.33	6.67	117.9	0
13	W215510070361501	Rajko t	Jetpur	Umrli	Not Available	21.91944	70.60417		101.3	14.05			8.75	4.33	89.2	7.8
14	W215600070460001	Rajko t	Gondal	Jamwali	Basalt	21.93333	70.76667		131	14.81	2.33		6.05	3.24	118.25	10.5
15	W215800070523001	Rajko t	Gondal	Gogavadar	Basalt	21.96667	70.875		155	12.55	8.35		10.6	5.33	149	0.2
16	W215954070593801	Rajko t	Gondal	Mota Dadwa	Basalt	21.99833	70.99389		164.3	16.8			11.26	5.64	155.07	6.6
17	W220110070393701	Rajko t	Gondal	Kalithad1	Not Available	22.01944	70.66028		126.8	16	3.5		5.91	3.3	119.3	4.1
18	W220130071073001	Rajko t	Jasdan	Viranagar	Basalt	22.025	71.125		181	25.01	5.2		10.84	6.43	172.42	7.55
19	W220330071131501	Rajko t	Jasdan	Jasdan2	Not Available	22.05833	71.22083		205	24.5	5.55		11.4	6.25	195.2	8.2
20	W220530070440	Rajko	Gondal	Dadia	Not	22.091	70.733		153	25.01	10.27		12.76	6.91	140.23	7.4

	001	t			Available	67	33									
21	W220530071030001	Rajkot	Rajkot	Halenda	Not Available	22.09167	71.05		212	17	1.7		9	3.02	205.67	5.8
22	W220730070460001	Rajkot	Gondal	Ribda	Not Available	22.125	70.76667		173	25.01	8.82		11.57	6.62	163	5.4
23	W220800071181501	Rajkot	Vinchchiya	Lalavadar	Basalt	22.13333	71.30417		255	22.01	5.06		12.11	5.99	248.87	4.3
24	W220830070383001	Rajkot	Lodhika	Lodhika1	Basalt	22.14167	70.64167		159	12.7	7.57		8	5.49	159	-2.4
25	W220845071120001	Rajkot	Jasdan	Kamlapur	Not Available	22.14583	71.2		243	21	10.65		7.21	6.47	243	0
26	W220907071115901	Rajkot	Jasdan	Kamlapur1	Not Available	22.15194	71.19972		245	20	6.05		6.2	4.4	230.4	11.8
27	W221100071053001	Rajkot	Jasdan	Bhadla	Basalt	22.18333	71.09167		230	20.94	12.7		14.52	11.56	211.4	13.9
28	W221230071224501	Rajkot	Vinchchiya	Vinchhia	Basalt	22.20833	71.37917		171	12.83	2.18		5.41	2.8	164.35	4
29	W221430070384501	Rajkot	Lodhika	Khirsara1	Basalt	22.24167	70.64583		125	20.1	11.8		10.5	4.27	110.8	8.9
30	W221800070480001	Rajkot	Rajkot	Rajkot1	Basalt	22.3	70.8		133	19			8.1	4.54	125.93	-2.1
31	W221820070483001	Rajkot	Rajkot	Rajkot	Basalt	22.30556	70.80833		118.3	29.8			4.44	2.85	118.3	0
32	W222200070554501	Rajkot	Rajkot	Ranpur1	Basalt	22.36667	70.92917		164	26	17.81		12.19	9.62	164	-2.4
33	W222300070400001	Rajkot	Paddhari	Targhari	Basalt	22.38333	70.66667		84	16.45	5.62		6.38	4.85	76.4	4.3
34	W222400070474501	Rajkot	Rajkot	Gavridad	Basalt	22.4	70.79583		108	29			5.59	3.41	101.09	3.4
35	W222650070363002	Rajkot	Paddhari	Padadhari1	Basalt	22.44722	70.60833		70	17.5	5.6		4.65	3.89	59.8	7.2
36	W222700070363001	Rajkot	Paddhari	Movaiya	Basalt	22.45	70.60833		70	21	2.06		11.93	6.94	58.7	6.8
37	W222830070330001	Rajkot	Paddhari	Khamta	Basalt	22.475	70.55		73	17.5	8.1		11.15	6.73	56.85	15.2

Annexure 2 Rajkot Pre Monsoon Water Quality_2019 (Un Confined)													
Sr Np	Well No	District	Taluka	Village	LAT_Y	LONG_X	pH	EC	TH	TDS	Cl	NO3	F
1	CGW B	Rajkot	Upleta	Kutiya	21.6305 6	70.1666 7	7.2 5	583 0	129 1	3906	1439	148	1.7
2	CGW B	Rajkot	Upleta	Ganod	21.675	70.1791 7	7.8 6	566 0	800	3792.2	1242. 5	36.26	3.5
3	CGW B	Rajkot	Dhoraji	Patan Vav	21.6444 4	70.2611 1	8.1 8	607	190	406.69	35.5	3.6	0.6 8
4	CGW B	Rajkot	Upleta	Upleta	21.7486 1	70.275	8.3 6	271 5	200	1819.0 5	284	89	4.8
5	CGW B	Rajkot	Upleta	Dhorajee	21.7458 3	70.2858 3	7.9 7	541	200	362.47	85.2	2.83	0.3 7
6	CGW B	Rajkot	Dhoraji	Bhada Jodiya	21.6625	70.3416 7	7.6 7	169 8	390	1137.6 6	461.5	5.81	0.4 2
7	CGW B	Rajkot	Jamkandor na	Jasapar	21.8916 7	70.4833 3	7.8 2	126 5	580	847.55	184.6	33.88	0.6 5
8	CGW B	Rajkot	Jetpur	Mota Gundala	21.7347 2	70.5013 9	8.1 4	570	150	381.9	56.8	8	0.8 6
9	CGW B	Rajkot	Jetpur	Pedhla	21.7513 9	70.5916 7	7.7 7	255 0	102 0	1708.5	639	48.03	0.5 5
10	CGW B	Rajkot	Jetpur	Umrli	21.9194 4	70.6041 7	7.9 7	182 1	490	1220.0 7	369.2	44.62	0.4 7
11	CGW B	Rajkot	Paddhari	Targhari	22.4472 2	70.6083 3	7.9 8	170 0	610	1139	355	28.52	0.4 9
12	CGW B	Rajkot	Paddhari	Movaiya	22.45	70.6083 3	8.1 4	199 1	560	1333.9 7	390.5	36.94	0
13	CGW B	Rajkot	Jetpur	Virpur	21.85	70.6958 3	8.1 2	170 6	540	1143.0 2	262.7	148.2 5	0.2 5
14	CGW B	Rajkot	Gondal	Dadiya	22.0916 7	70.7333 3	8.0 3	507	190	339.69	42.6	37.9	0.5 2
15	CGW B	Rajkot	Gondal	Chordi	21.9166 7	70.7486 1	7.8 6	249 0	840	1668.3	653.2	53.73	0.2 5
16	CGW B	Rajkot	Gondal	Ribda	22.125	70.7666 7	7.8 3	961	410	643.87	149.1	38.6	0.2 5
17	CGW B	Rajkot	Gondal	Gogavadar	21.9666 7	70.875	8.1 9	969	320	649.23	113.6	46.07	0.5 1
18	CGW B	Rajkot	Rajkot	Sardhar	22.1458 3	70.9888 9	8.1 8	186 8	410	1251.5 6	269.8	31.99	0.1 9
19	CGW B	Rajkot	Gondal	Motadadva	21.9983 3	70.9938 9	8.1 5	145 4	570	974.18	248.5	86	0.3 7
20	CGW B	Rajkot	Rajkot	Halenda	22.0916 7	71.05	8.2 1	132 3	510	886.41	234.3	14.95	0.4 9
21	CGW B	Rajkot	Jasdan	Bhadla	22.1833 3	71.0916 7	7.8 2	340 7	900	2282.6 9	923	27.54	0.4 2
22	CGW B	Rajkot	Jasdan	Virnagar	22.025	71.125	8.2 9	100 8	360	675.36	156.2	16.94	0.3 5
23	CGW B	Rajkot	Jasdan	kamlapur	22.1458 3	71.2	7.7 6	419 6	152 0	2811.3 2	1050. 8	235.7	0.5 5
24	CGW B	Rajkot	Jasdan	Jasdan	22.0583 3	71.2208 3	8.0 3	164 9	600	1104.8 3	319.5	53.5	0.3 4
25	CGW B	Rajkot	Vinchchiya	Lalavadar	22.1333 3	71.3041 7	7.9 6	710	290	475.7	42.6	7.63	0.1 3
26	CGW B	Rajkot	Jetpur	Mota Gundala	21.7347 2	70.5013 9	8	425 7	980	2852.1 9	1136	39.64	0.4 5

Annexure-3 Rajkot Distrcit Exploration Data																					
SI N o.	Location	Block	Distr ict	EW/ OW	Lat	Long	Dep th drill ed (m bgl)	Depth of Constru ction (m bgl)	Major Litholog y Encount ered	Casi ng (m)	Zone Encountered (m bgl)						SWL (m bgl)	Discha rge (lps)	RDD	T (m2/ day	EC (μs/ cm at 25°)
											0-50	50-100	100- 150	150- 200	200- 250	250- 300					
1	Hathasani	Vichhiya	Rajkot	EW	22.1316	71.3661	252.6	252.6	Basalt	10			128.90-130	162.50-163.50	205.20-209.30		196.2	0.3	NA	NA	1000
2	Rajawadla	Jasdan	Rajkot	EW	22.0979	71.1715	197.6	197.6	Basalt	4.35		69-70	117.8	120.8	197.10-200.10	233.70-236.70	57.95	Negligible	NA	NA	NA
3	Rajpara	Kotda Sangani	Rajkot	EW	22.1146	70.8805	202	202	Basalt	6.1							148.36	Negligible	NA	NA	NA
4	Nagalpar	Rajkot	Rajkot	EW	22.3939	70.8626	142.1	142.1	Basalt	5.8			136-139				5	10.6	2.7 (7th min)	46.95	404
5	Dadwa Hamirpur	Gondal	Rajkot	EW	22.0064	71.0422	203	203	Basalt	9.17	8.35-11.35	90.20-93.00		190-193			4.33	3.3	22.09(5th min)	1.56	120
6	Panch Talawada	Kotda Sangani	Rajkot	EW	22.0658	70.9409	203	203	Basalt	7.9							31.5	Negligible	NA	NA	NA
7	Mesavada	Rajkot	Rajkot	EW	22.3103	71.0211	200	200	Basalt	6							7.4	0.36	NA	NA	3180
8	Beti	Rajkot	Rajkot	EW	22.3894	70.9958	215.4	215	Basalt	6							18.92	3.68	40.73(2nd min)	1.75	906
9	Juna Rajpipala	Kotda Sangani	Rajkot	EW	22.0161	71.0122	203	203	Basalt	8.4							39.11	Negligible	NA	NA	1000
10	Bagdadiya	Kotda Sangani	Rajkot	EW	21.968	70.9854	203	203	Basalt	8.9							11.5	Negligible	NA	NA	1800
11	Ghoghawadar	Gondal	Rajkot	EW	21.965	70.8726	201	201	Basalt	8.7	14.65 to 15.50	87 to 89.90					12.5	1.5	62.73(10th min)	0.14	1447
12	Dapaliya	Paddhari	Rajkot	EW	22.4577	70.5664	205	205	Basalt	6.12	3-148		150.5-182.5				28.9	0.1			5780
13	Metoda	Paddhari	Rajkot	EW	22.3776	70.6156	201	201	Basalt	3	Mar-89						2.58	Negligible			1120
14	Udakiya	Dhoraji	Rajkot	EW	21.6482	70.3786	200	200	Basalt	6	03-Sep						28.86	0.48			750
15	Khajurda	Jamkandorna	Rajkot	EW	21.8871	70.4013	201	201	Basalt	6							58.68	0.88			1040

16	Mevasa	Jetpur	Rajkot	EW	21.876	70.5949	200	200	Basalt	9.5		80-94, 94-135, 144-163, 163-171					16.81	Negligible			1340
17	Bava Pipaliya	Jetpur	Rajkot	EW	21.6298	70.6295	201	201	Basalt	6.1							10.5	Negligible			
18	MandanKundala	Gondal	Rajkot	EW	21.8515	70.8701	193	193	Basalt	6		28-64					17.18	Negligible			910
19	Lodhika	Lodhika	Rajkot	EW	22.1372	70.6418	194	194	Basalt	6							10.01	Negligible			
20	Bhandariya	Jasdan	Rajkot	EW	22.1823	71.0514	201	201	Basalt	6	Mar-18						54.33	Negligible			2530
21	Kharachiya Jas	Jasdan	Rajkot	EW	22.2477	71.3607	196	196	Basalt		3-16, 16-31, 31-52,	52-60, 60-87, 87-119		119-196			9.42	Negligible			
22	Dhamalpur	Rajkot	Rajkot	EW	22.3542	70.875	200	200	Basalt	3.6							62.24	1.04			1930
23	Gadhaka	Rajkot	Rajkot	EW	22.2565	70.9555	300.8	300.8	Basalt	6.3							-	Negligible	-	-	-
24	Devala	Gondal	Rajkot	EW	21.785	70.8167	200	200	Basalt	1.5	9.25-13.35, 16.35-22.45		102.0-119.0	161.0-165.0, 175-182.0			8.4	7		1100	3000
25	Charkhadi	Gondal	Rajkot	EW	21.9667	70.65	165	165	Basalt	2.5	25.0, 37.0	55					4.05	18		253	2300
26	Kalasar	Jasdan	Rajkot	EW	22.0861	71.2944	201	201	Basalt	10.35	10.40-22.60	52.10-64.30					3.37	16.6		517	560
27	Kothi	Jasdan	Rajkot	EW	22.0875	71.1569	201	201	Basalt	5	8.40-11.40						2.9	5		4	3175
28	Kolithad	GONDAL	Rajkot	OW	22.025	70.6625	201	201	Basalt	2.3	Negligible						6.14	0.75		0.3	5986
29	Shrinathga dh	Kotda Sangani	Rajkot	EW	21.8833	70.9167	201	201	Basalt	4	7.40-12.50, 40.43	68.40-70.40		165-167			9.96	3		15.82	710
30	Raydi	Jamkandorna	Rajkot	EW	21.8247	70.4567	50	50	Basalt	5	4.30-12.50, 28.70-30.80, 38.90-						8	25		326	816

										40.90											
31	Vavdi II	Jamkand orna	Rajkot	EW	21.9594	70.4494	147	147	Basalt	6.4		81.0-82.0,90.70-91.70	117.20-118.20				23.1	18		129.3	4800
32	Jam Kandorna	Upleta	Rajkot	EW	21.8892	70.3347	201	201	Basalt	5.3	Negligible						14.22	0.25		0.7	1000
33	Gadethal	Upleta	Rajkot	EW	21.7778	70.1797	133	133	Basalt	12.6			105.0,133.0				20.5	10		75.2	1900
34	Vadekhan	Upleta	Rajkot	EW	21.7806	70.0553	203	203	Basalt	11.3	30.70-32.80	82.60-83.60	146.60-147.70	151.70-153.80			9.72	2.5		15.8	850
35	Upleta	Upleta	Rajkot	EW	21.75	70.2769	154	154	Basalt	13.5	17.5	73.5	128	153.5			12.48	18		55.83	8400
36	Nilalkha	Upleta	Rajkot	EW	21.7139	70.2158	200	200	Basalt	13.2		50	92	165			6.78	10		22.6	40000
37	Chitravad	Jamkand orna	Rajkot	EW	21.9461	70.3503	203	203	Basalt	3.5	Negligible						2.64	0.05		0	4000
38	Kagwad	Jetpur	Rajkot	EW	21.8042	70.6833	104	104	Basalt	28.9			86.70,94.80				68.9	4.4			
39	Chichod	Dhoraji	Rajkot	EW	21.6319	70.2894	500	500	Basalt		10.5		114				90	1.5			700
40	Nani Parabadi	Dhoraji	Rajkot	EW	21.68	70.5236	311	311	Basalt		15			183		293.0,308.0	93.6	18			2830
41	Bildi	Gondal	Rajkot	EW	21.8981	70.9817	500	500	Basalt		27					358	21.6	0.25			6700
42	Amrapur	Kotda Sangani	Rajkot	EW	22.2114	71.3131	376	376	Basalt							374	8.02	12			5840
43	Bhadli	Jasdan	Rajkot	EW	22.0736	71.4533	299	299	Basalt		5.0,13.50	56					8.56	10.5			1336
44	Vangadra	Jasdan	Rajkot	EW	22.2433	71.4706	334	334	Basalt				100			283	84.2	12			3910
45	Chhibda	Lodhika	Rajkot	EW	22.1806	70.6542	215	215	Basalt		6.5,20.0		147.5				44.2	20			2890
46	Govindpar	Paddhari	Rajkot	EW	22.3947	70.57	500	500	Basalt		16.5	51.5					13.62	0.8			1800

4 7	Satarvadi	Upleta	Rajkot	EW	21.9 283	70.1 611	247	247	Basalt		19.5			158. 5	204. 0, 234. 0		51	25			130 8
4 8	Vadali	Upleta	Rajkot	EW	21.9 486	70.2 703	500	500	Basalt							484	-	0.2			120 0

Annexure-4 Rajkot District_Rockworks_Lat_Long								
Sr No	Bore	Long	Lat	Elevation	CollarElevation	TotalDepth	Easting	Northing
1	Hathasani	71.3661	22.1316	206	206	200	744055	2449293
2	Rajawadla	71.1715	22.0979	220	220	198	724029	2445261
3	Rajpara	70.8805	22.1146	195	195	202	693976	2446710
4	Nagalpar	70.8626	22.3939	142	142	142	691748	2477615
5	Dadwa Hamirpur	71.0422	22.0064	168	168	203	710821	2434944
6	Panch Talawada	70.9409	22.0658	193	193	203	700277	2441385
7	Mesavada	71.0211	22.3103	181	181	200	708194	2468568
8	Beti	70.9958	22.3894	156	156	215	705471	2477293
9	Juna Rajpipala	70.9722	22.055	196	196	203	703523	2440230
10	Bagdadiya	70.9854	21.968	152	152	203	705011	2430614
11	Ghoghawadar	70.8726	21.965	147	147	201	693364	2430135
12	Dapaliya	70.5664	22.4577	72	72	205	661176	2484331
13	Metoda	70.6156	22.3776	78	78	201	666334	2475516
14	Udakiya	70.3786	21.6482	67	67	200	6,42,659	23,94,522
15	Khajurda	70.4013	21.8871	103	103	201	644768	2420991
16	Mevasa	70.5949	21.876	88	88	200	664785	2419957
17	Bava Pipaliya	70.6295	21.6298	114	114	201	668648	2392736
18	MandanKundala	70.8701	21.8515	123	123	193	693259	2417564
19	Lodhika	70.6418	22.1372	158	158	194	669321	2448928
20	Bhandariya	71.0514	22.1823	210	210	201	711508	2454435
21	Kharachiya Jas	71.3607	22.2477	166	166	196	743298	2462143
22	Dhamalpur	70.875	22.3542	149	149	200	693080	2473235
23	Gadhaka	70.9555	22.2565	194	194	200	701512	2462521
24	Devala	70.8167	21.785	112	112	200	687826	2410135
25	Charkhadi	70.6621	21.9018	108	108	165	671699	2422887
26	Kalasar	71.2944	22.0861	232	232	201	736733	2444140
27	Kothi	71.1569	22.0875	209	209	201	722538	2444088
28	Kolithad	70.6625	22.025	128	128	201	671592	2436528
29	Shrinathgadh	70.909	21.8627	131	131	201	697264	2418854
30	Raydi	70.4567	21.8247	73	73	50	650558	2414136
31	Vavdi II	70.4494	21.959	123	123	147	649663	2429041

			4					
32	Jam Kandorna	70.497	21.893 6	108	108	201	654650	2421804
33	Gadethad	70.154	21.778 8	56	56	133	619307	2408789
34	Vadekhan	70.0553	21.780 6	105	105	203	609100	2408916
35	Upleta	70.2769	21.75	45	45	154	632041	2405701
36	Nilalkha	70.2158	21.713 9	35	35	200	625753	2401654
37	Chitravad	70.3503	21.946 1	98	98	203	639441	2427475
38	Kagwad	70.6833	21.804 2	98	98	104	674008	2412105
39	Chichod	70.2894	21.631 9	99	99	200	633442	2392638
40	Nani Parabadi	70.5236	21.68	77	77	200	657631	2398183
41	Biladi	70.9482	21.870 7	130	130	200	701305	2419791
42	Bhadli	71.4396	22.023	142	142	200	751832. 2	2437384
43	Vangadra	71.4433	22.233 4	141	141	200	751839. 7	2460694
44	Chhibda	70.6542	22.180 6	158	158	200	670548. 1	2453747
45	Govindpar	70.5742	22.468	62	62	200	661966. 4	2485480
46	Satarvadi	70.1611	21.928 3	95	95	200	619916	2425345

