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

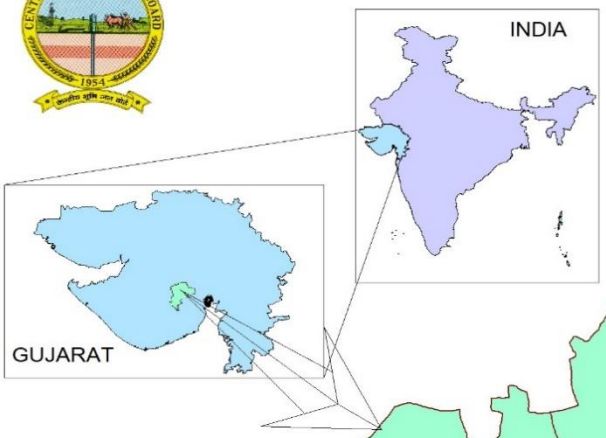
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Botad District
Gujarat

पश्चिम मध्य क्षेत्र, अहमदाबाद

West Central Region, Ahmedabad



Government of India Ministry of Jal Shakti

Department of Water Resources, River Development and Ganga Rejuvenation.

Report On

AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN, BOTAD DISTRICT, GUJARAT STATE

Central Ground Water Board

West Central Region Ahmedabad

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AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

BOTAD DISTRICT GUJARAT STATE

Contributors' page

Sh. Saddam Husain (Assistant Hydrogeologist)	Report Compilation	CGWB, WCR Ahmedabad
Sh. Sanjeev Mehrotra, Scientist-D, Dr A K Jain, Sc-D (Retired), Sh Ramesh Jena, Scientist-B, Sh Ankit Vishwakarma, Scientist-B, Sh Kamar Ujjam Khan, Scientist-B Sh Avinash Chandra, STA (HG)	Hydrogeology	CGWB, WCR Ahmedabad
Smt Puja Mehrotra, Scientist-D, Sh H.B. Meena (ACH), Smt Adiba Khan (STA Chem)	Chemical Analysis	CGWB, WCR Ahmedabad
Nilesh Dhokia, Draftsman	Drawings	CGWB, WCR Ahmedabad
Dr A K Jain (Sc-D) Retired & Consultant	Scrutiny	CGWB, WCR Ahmedabad

Under the guidance of

Shri G. Krishnamurthy

Regional Director, CGWB, WCR, Ahmedabad

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(Saddam Husain)
Assistant Hydrogeologist
Central Ground Water Board
West Central Region, Ahmedabad

AQUIFER MAPPING AND MANAGEMENT PLAN OF BOTAD DISTRICT

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1. Chapter

INTRODUCTION

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.

1.2 Aquifer Mapping:

Aquifer mapping can be defined as a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality andsustainability of ground water in aquifers. Systematic aquifer mapping is expected to improve ourunderstanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants thataffect the potability of ground water

1.2.1 Need for Aquifer Mapping:

Various development activities over the years have adversely affected the ground water regime in many parts of the country. There is a need for scientific planning in development of ground water under differenthydrogeological situations and to evolve effective management practices with involvement of communityfor better ground water governance.

1.2.2 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 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.

1.2.3 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.

1.2.4 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 assembled from the available sources, analysed, 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.

1.2.5 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 data gap analysis, site selection, exploratory drilling, PYT, pumping test, 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 environments.

1.2.6 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).

1.2.7 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 are depicted/elaborated in figure 1.

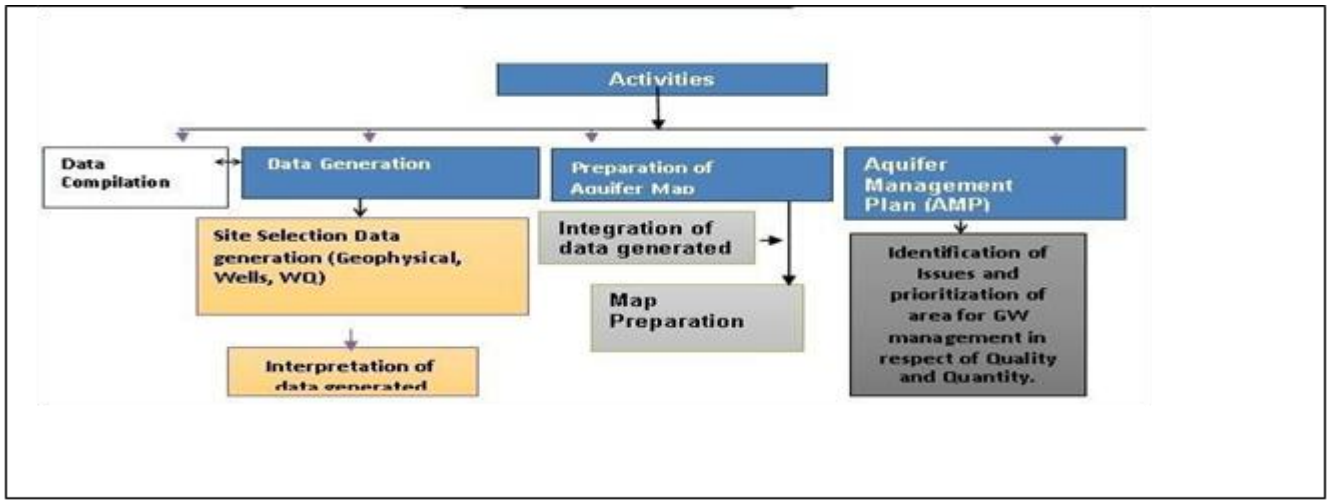

Figure 1: Activities under National Aquifer Mapping Programme

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 Location And Areal Extent

Botad was created on 15 August 2013 from the southwestern part of Ahmedabad District (Barwala and Ranpur blocks) and the north-western part of Bhavnagar District (Botad and Gadhada blocks). Botad city is the administrative headquarters of the district situated between 20°59’ and 22°16’ north latitudes and 71°23’ and 72°18’ east longitudes in the Gujarat state. The district is surrounded by Bhavnagar District to the southeast, Surendranagar District to the north and northwest, Amreli District to the southwest, Ahmedabad District to the northeast and Rajkot District to the west. Botad district has an area of 2,564 Sq. Km. It falls in the Survey of India (SOI) degree sheets 41O and 46 C.

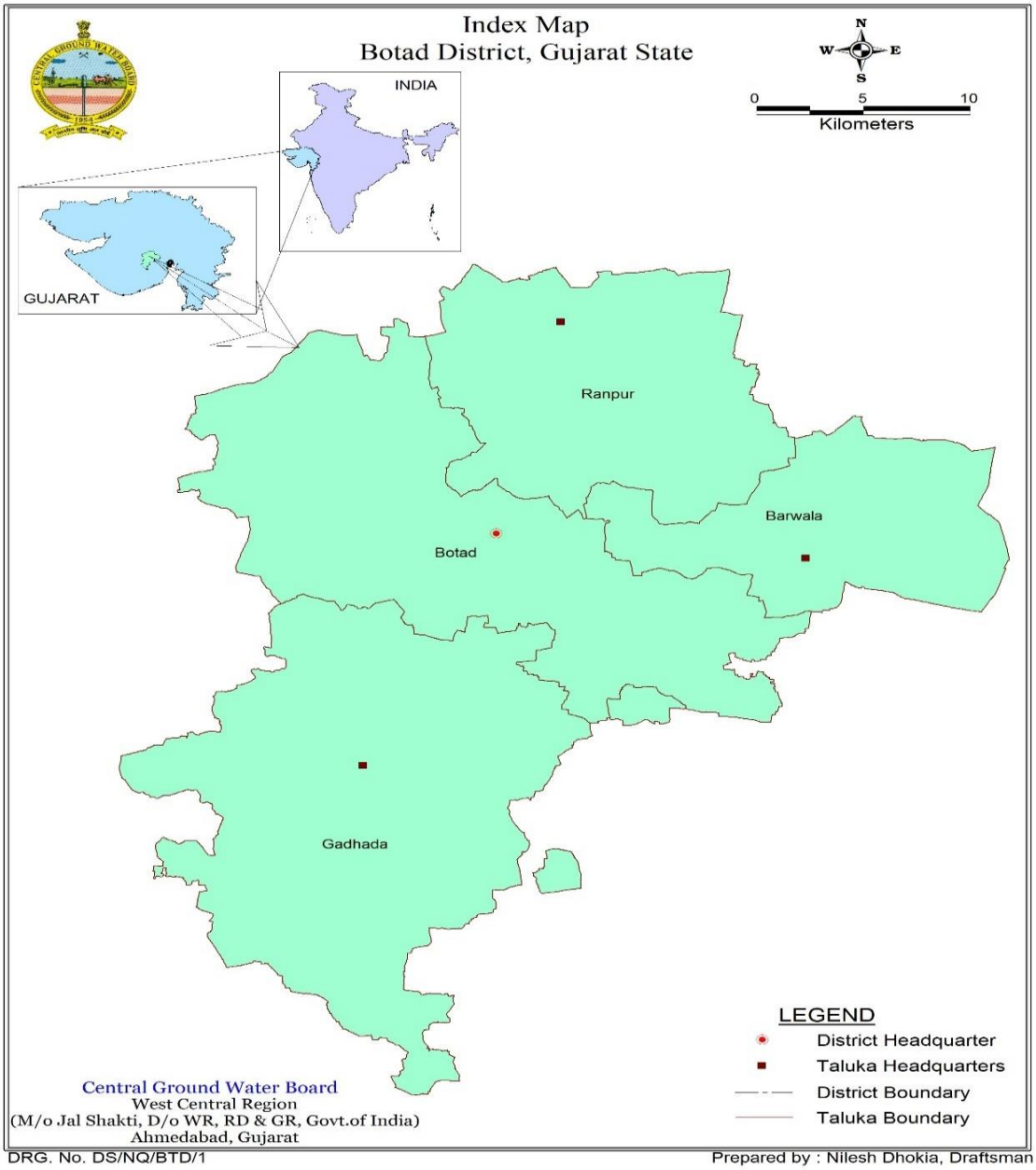

Figure 2: Index Map Botad District

1.5 Administrative Units, Accessibility, And Population

The district comprises of four talukas namely, Gadhada, Barwala, Botad, Ranpur. It has 180 numbers of Panchayat and 190 numbers of villages. Total area of the district is 2564 sq. km. According to the 2011 census Botad district has a population of 656005.

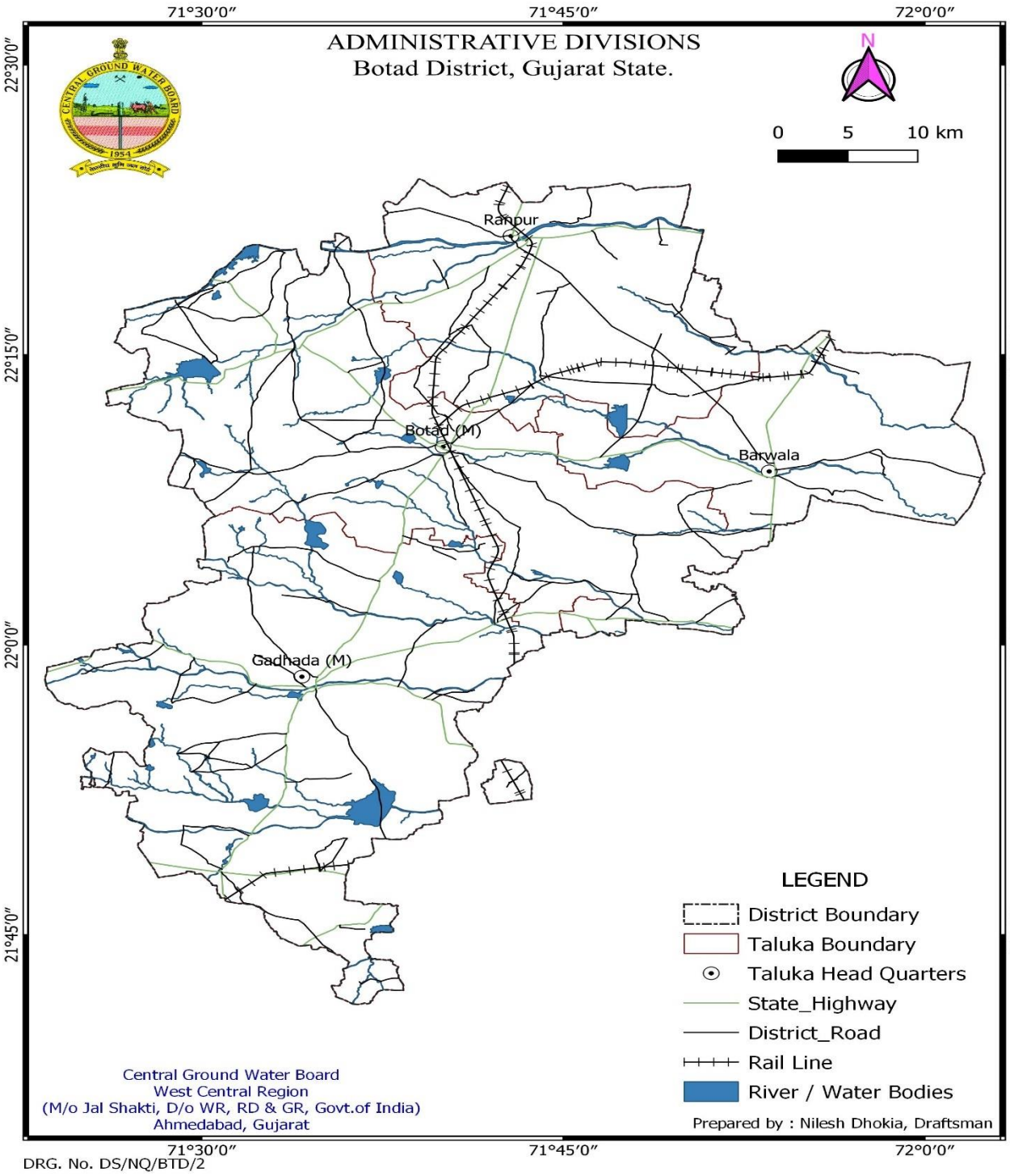

Figure 3: Administrative division Botad district, Gujarat.

The administrative Map of the district is given in **Fig.-3**. The Botad taluka from the Bhavnagar district is now become the district itself in 15 August 2013. Gadhada taluka which was in Bhavnagar district previously, is now in Botad district.

1.5.1 Botad Taluka

Botad Taluka has total population of 286,618 as per the Census 2011. Out of which 147,749 are males while 138,869 are females. In 2011 there were total 53,495 families residing in Botad Taluka. The Average Sex Ratio of Botad Taluka is 940.

1.5.2 Gadhada Taluka

Gadhada Taluka has total population of 200,475 as per the Census 2011. Out of which 102,328 are males while 98,147 are females. In 2011 there were total 36,992 families residing in Gadhada Taluka. The Average Sex Ratio of Gadhada Taluka is 959.

1.5.3 Barwala Taluka

Barwala Taluka has total population of 75,986 as per the Census 2011. Out of which 39,440 are males while 36,546 are females. In 2011 there were total 13,615 families residing in Barwala Taluka. The Average Sex Ratio of Barwala Taluka is 927.

1.5.4 Ranpur Taluka

Ranpur Taluka has total population of 92,926 as per the Census 2011. Out of which 47,717 are males while 45,209 are females. In 2011 there were total 17,277 families residing in Ranpur Taluka. The Average Sex Ratio of Ranpur Taluka is 947.

Table 1 Area and Population details of parted talukas

Taluka Name	Geographical location and administrative structure									
	Taluka wise Area and Population, Census-2011									
	Area (Sq. Km.)	Total population			Rural population			Urban population		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
Barwala	484.72	39440	36546	75986	30103	27932	58035	9337	8614	17951
Botad	749.4	147749	138869	286618	80074	76217	156291	67675	62652	130327
Gadhada	897.9	102328	98147	200475	79430	76725	156155	22898	21422	44320
Ranpur	429.1	47717	45209	92926	39000	36982	75982	8717	8227	16944
District	**2561.12**	**337234**	**318771**	**656005**	**228607**	**217856**	**446463**	**108627**	**100915**	**209542**

Source: Office of Registrar General & Census Commissioner, India (2011)

1.6 Studies / Activity by CGWB

Central Ground Water Board Has Carried Out Number of Studies in The District. Central Ground Water Board (P. Natarajan, 2000) carried out detailed hydrogeological investigation in Ahmedabad (Barwala & Ranpur Taluka which was the Part of Ahmedabad). Hydrogeological Survey work in Parts of Bhavnagar district was carried out by Sandeep Vidyarthi (2013). The first systematic hydrogeological investigation was carried out by researchers such as S.G. Rajput, K.B. Polara, Brijesh Yadav And Som Raj (2013), Hardi Joshi , Ravirajsinh Jadeja, Meet Shah, Vivek Bhadiyadra, Nirali Padhiyar(2018), Smruti Vijaykumar Patel, Paresh Chavda & Sanjiv Tyagi(2019). CGWB, compiled “Hydrogeology of Gujarat State” And Discussed Groundwater

Resource Potential of the District based on Earlier Studies. Groundwater Exploration by test drilling in the district conducted In 2015-16, 2016-17 And is continued till 2020-21. Apart from the exploratory wells Piezometer have also been constructed in the district. Representative dug wells and Piezometers are monitored periodically for the ground water level and quality changes in the district and is continued till date.

1.7 Hydrometeorology:

Botad district having sub-tropical climate with a tropical wet-and-dry climate. The main seasons prevailing in the district are

(a) monsoon - mid-June to October,
(b) winter- November to February, and
(c) dry summer– March to June.

District receives much of its rainfall from the south-west monsoon during the period between June & October; its maximum intensity being in the month of July & August. Average Annual Rainfall of the district is 615 mm for the 34 years (1987-2021).

1.7.1 Climate

The district is an agro-climatic zone VI (South Saurashtra) and VII (North Saurashtra). The climate of the district varies from hot to moderately hot throughout the year except in winter. The climate is humid along with the belt. The maximum temperature of the district is 44.0 degree centigrade while the minimum temperature is 9.0 degree centigrade.

1.8 Rainfall

District receives much of its rainfall from the south-west monsoon during the period between June & October; its maximum intensity being in the month of July & August. Average Annual Rainfall of the district is 615 mm for the 34 years (1987-2021).

Table 2 Rainfall trend of Botad District (in mm) from 1987-2021

Year	Taluka			
	Barwala	**Botad**	**Gadhada**	**Ranpur**
1987	181	292	142	181
1988	934	744	891	934
1989	695	743	667	695
1990	709	445	469	709
1991	340	192	273	340
1992	789	676	429	789
1993	547	329	281	547
1994	705	545	750	705
1995	471	442	393	471
1996	533	349	281	533

1997	1010	523	467	1010
1998	663	655	391	470
1999	451	388	370	410
2000	263	335	233	356
2001	691	666	609	552
2002	431	495	571	391
2003	550	477	696	711
2004	717	458	415	678
2005	1002	773	695	1194
2006	735	685	489	743
2007	957	1173	901	1078
2008	1106	698	735	997
2009	382	335	294	340
2010	831	667	800	1117
2011	546	575	683	653
2012	446	437	354	463
2013	1266	939	842	925
2014	749	486	597	530
2015	427	576	391	362
2016	465	529	650	485
2017	662	572	832	949
2018	405	362	386	363
2019	925	1158	1091	752
2020	837	1037	1396	568
2021	723	673	565	531
Average	**661**	**584**	**572**	**644**
Minimum	**263**	**192**	**233**	**340**
Maximum	**1266**	**1173**	**1396**	**1194**
Average Botad Dist.	**615**			

From above Table, it is observed that the minimum rainfall for the Botad dist. is 192 mm (Botad Taluka) and maximum rainfall is 1396 mm (Gadhada Taluka). The average rainfall for Botad dist. is 615 mm for the period of 34 years (1987-2021).

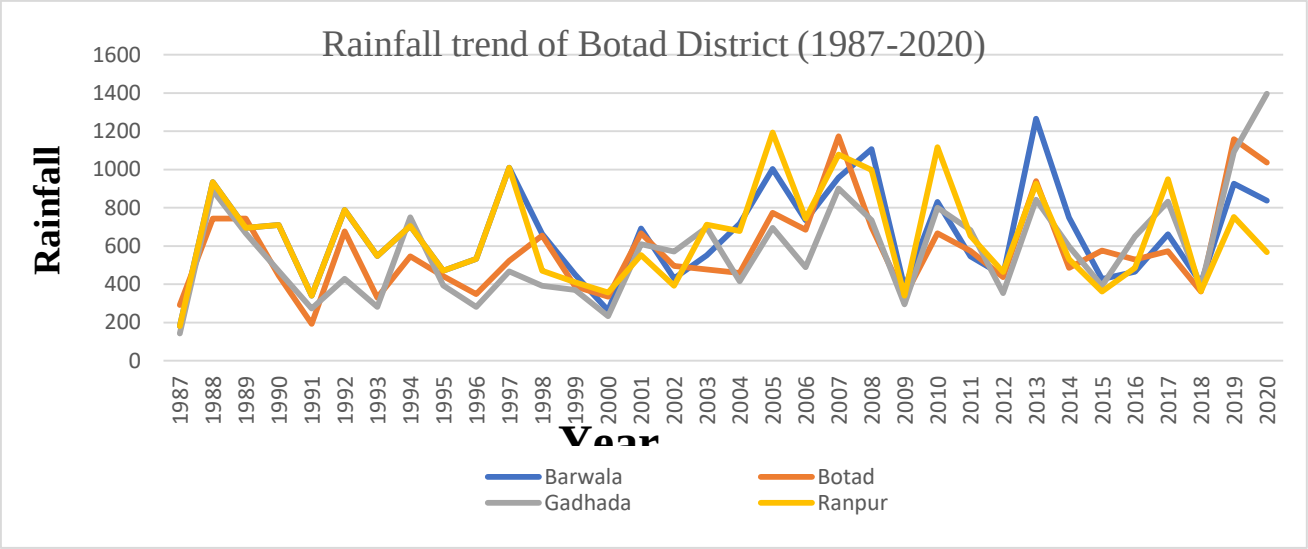

Figure 4: Rainfall trend of Botad District (1987-2021)

From above Fig-4, it is observed that the minimum rainfall 192 mm (Botad Taluka) for the year 1991. Year 1991 received the lowest rainfall in all district Talukas. While the maximum rainfall is received in year 2020.Gadhada Taluka has maximum rainfall 1396 mm for the year 2020.

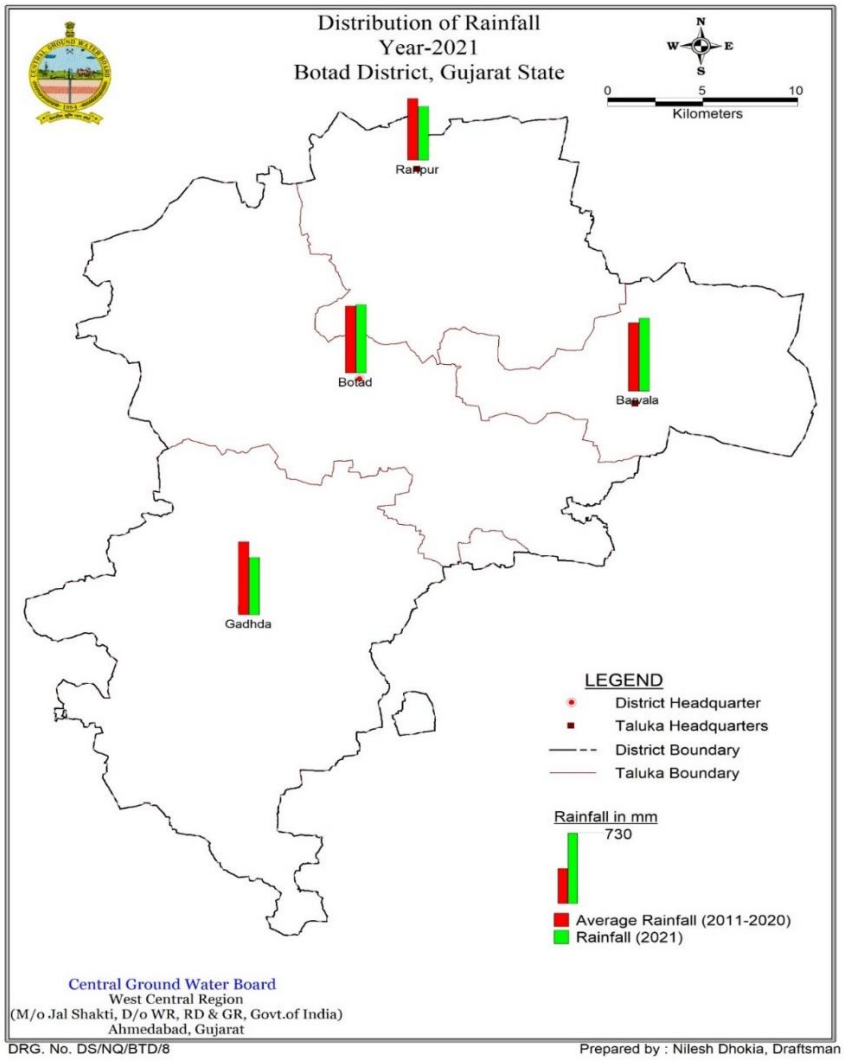

Figure 5: Rainfall Trend Botad District (2021)

From fig 5, it is concluded that Barwala and Botad taluka, Rainfall for the year 2021 is more than the average rainfall (2011-2020). While in Gadhada and Ranpur taluka rainfall for the year 2021 is less than the average rainfall (2011-2020).

1.9 Geomorphology And Soil Type

1.9.1 Physiography Division

A series of low hills are present few kilometers west of Ranpur, in the western Dhandhuka, Botad and Gadhada in the northwest. The hills around Ninana in the most westerly part of Dhandhuka are covered with fragments of quartz and limestone. The western part of the district mainly Barwala and Gadhada taluka is monotonous alluvial plain areas.

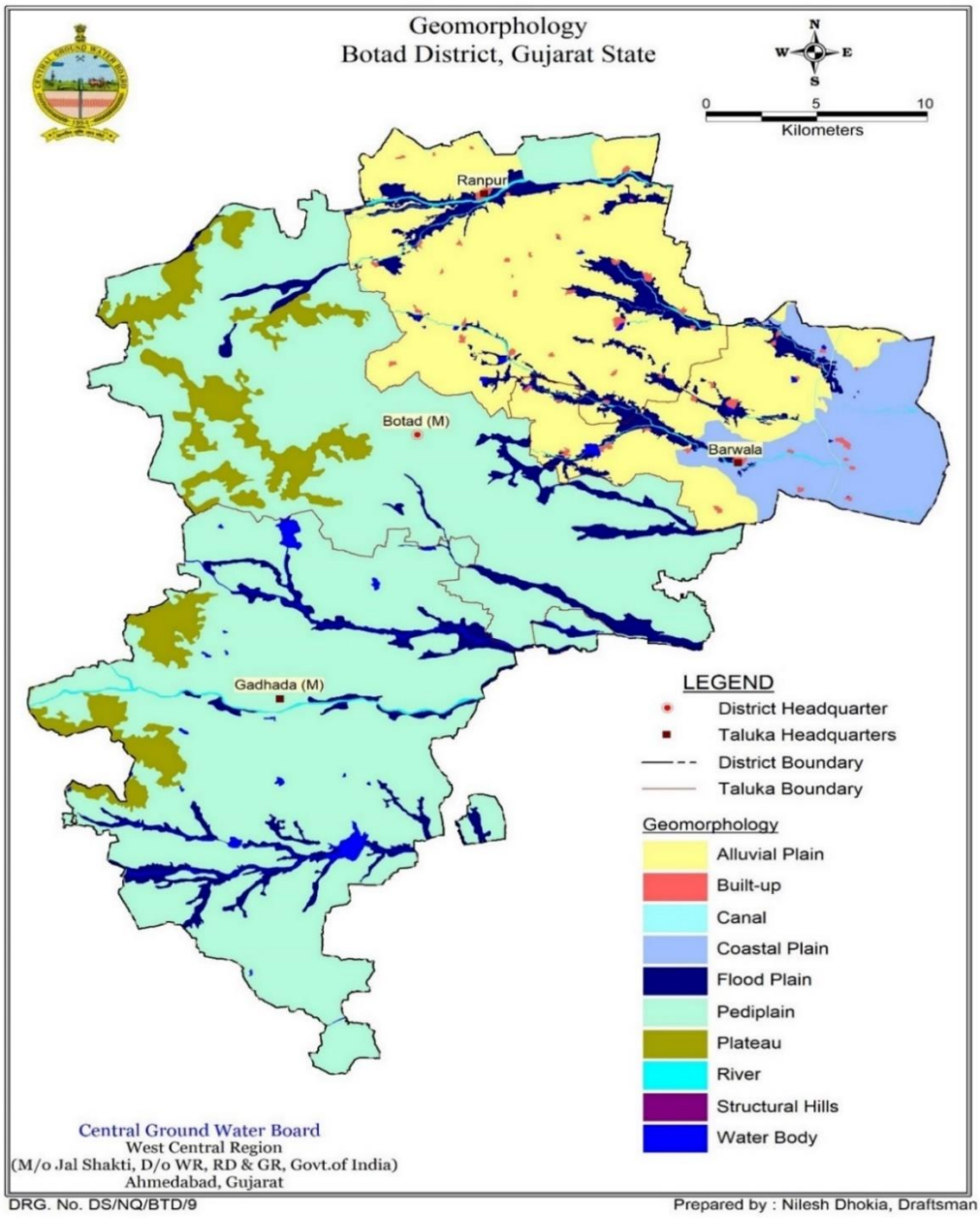

Figure 6: Geomorphology map of Botad district.

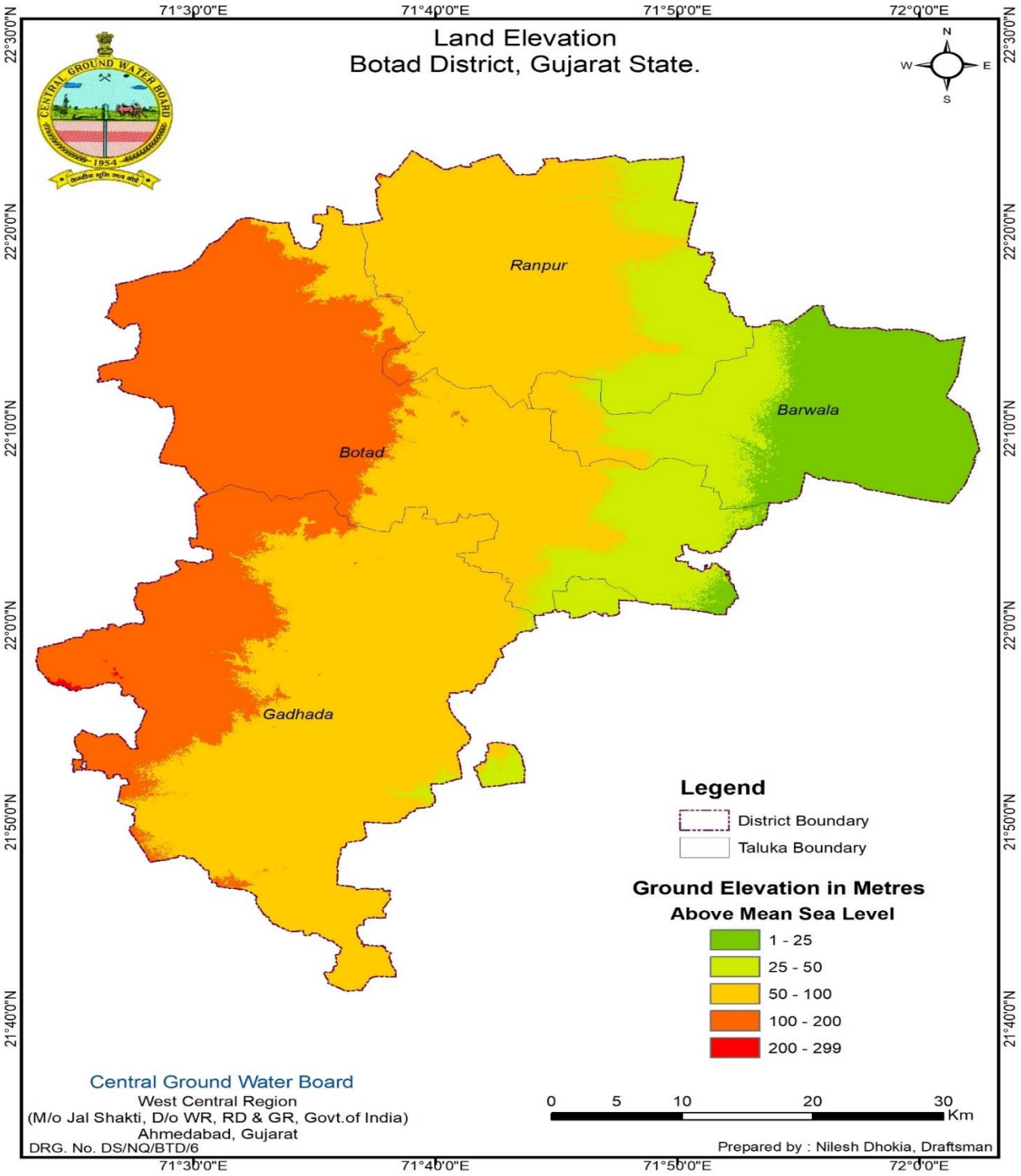

Figure 7: Land Elevation Botad District

From above fig-7 it is concluded that the Ground Elevation at Barwala Taluka is lowest. While SW part of Ranpur, NW and SW of Botad, NW part of Gadhada Talukas have highest Ground Elevation.

1.9.2 Drainage

Botad district is drained by a number of rivers, namely Kalubhar, Ghelo, Vagad. 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.

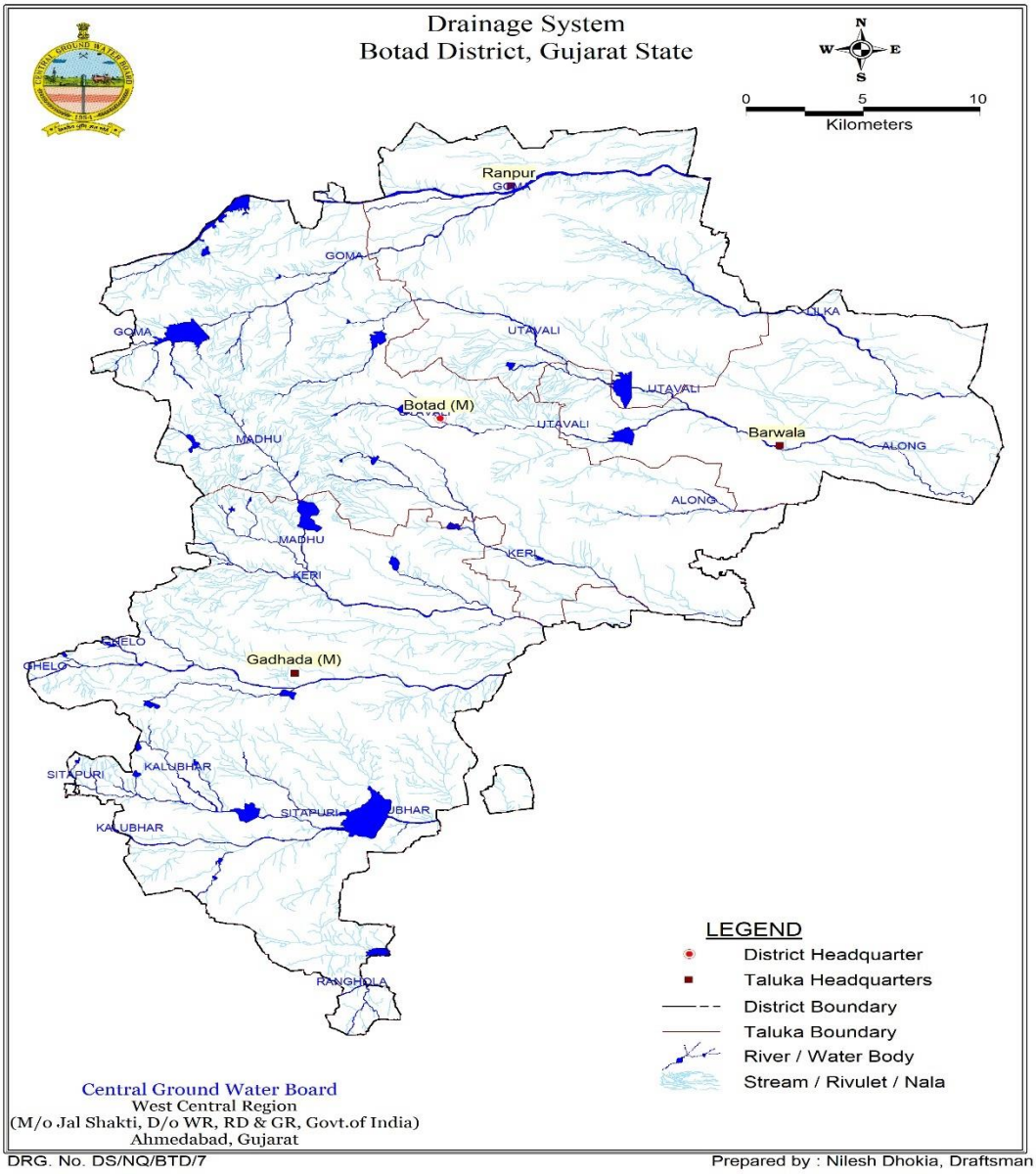

Figure 8: Drainage System Botad District

1.10 Soil

The geographical formation of Saurashtra is of volcanic origin; hence the soil of Botad and Gadhada taluka with the exception of a few strips, are derived from basalt rock known as deccan trap. However, the volcanic effusions and spread of lava, followed by denudation have resulted in the creation of a basaltic topography. The black cotton soils which are not very deep are susceptible to erosion in the undulating areas in the interior of the district due to rains. Medium black soil is the most predominant type of soil in the district and covers a major part of its area.

In most parts in the eastern side of the district, especially in Barwala and Ranpur the soil is of plain, fine texture and shallow to medium in depth and levelled. The permeability in the soil is poor thereby leading to problems of water logging and poor, soil physical condition. The soil has low to medium N & P content. The soil of this part has been developed from granite and gneiss parent material. The soil is Shallow black and are light grey in colour and mainly sandy clay loam in texture. The soil is poor in fertility.

The types of soil in Botad district are generally alkaline, organic carbon and nitrogen content of soil is medium, phosphorous content is low and potash is high. The overall fertility is satisfactory which is suitable for early monsoon crops like Cotton, Bajra and Jowar and also wheat, groundnuts cumin pulses, etc.

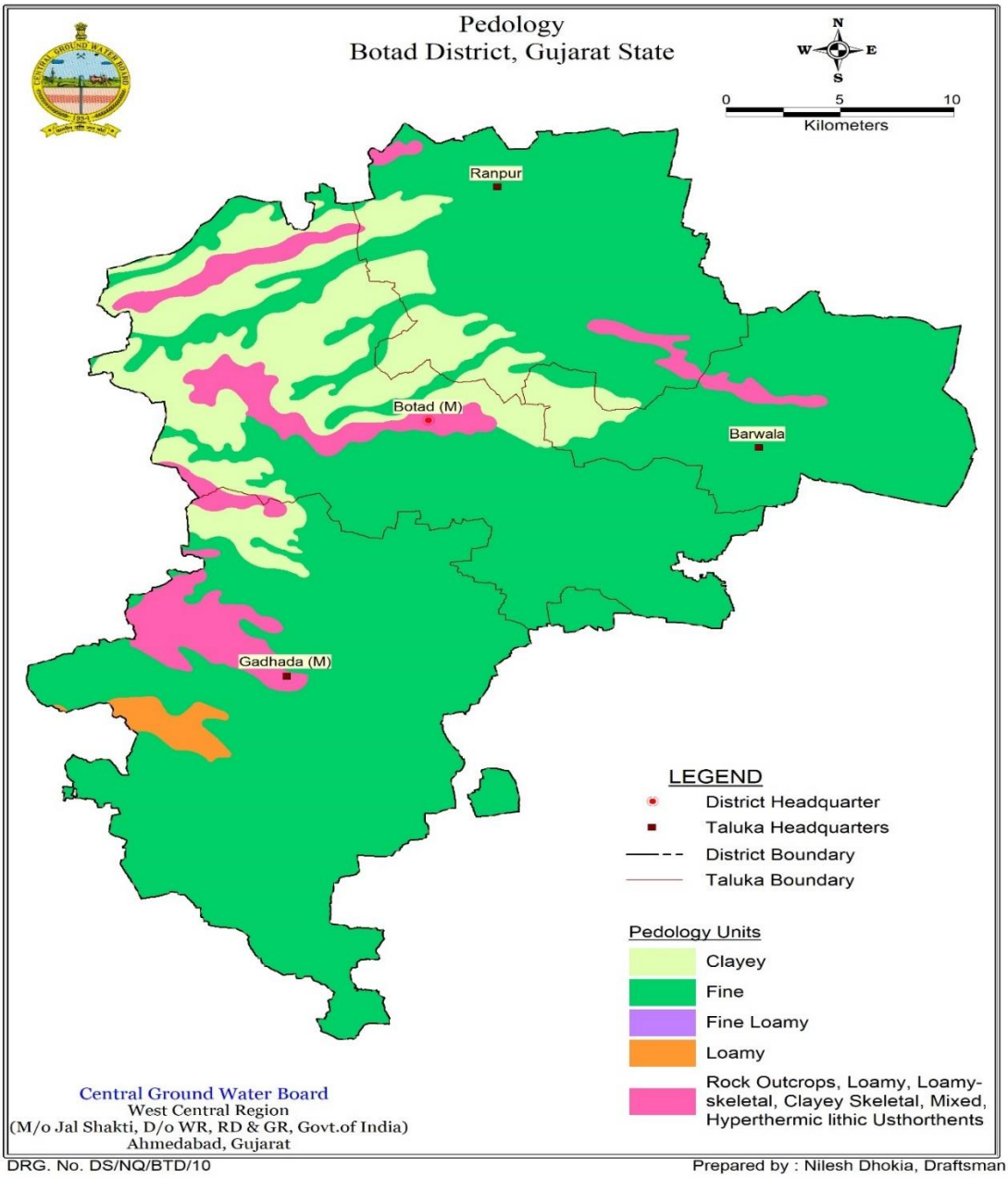

Figure 9: Soil of Botad District

1.11 Land Utilization:

The total geographical area (TGA) of Botad is **256112** hectares. The largest block of the district is Gadhada which comprises TGA of 89790 hectares i.e., about 35% of the TGA of the district. The Gross Cropped Area of the district is 213,397 hectares out of which 74,629 hectares i.e., 35% of the area falls in Botad Block, followed by Gadhada block having GCA of 62,714 ha i.e., 29% of the district. Botad Block also has the maximum Net Sown area of 67548 hectare i.e., 34% of the Net Sown area of the district.

Table 3 Area under Agriculture (Cropping Pattern) Botad District

Area Under Agriculture(ha)					
Block	**TGA**	**GCA**	**NSA**	**AST**	**Cropping Intensity%**
Barwala	48472	38027	28066	1545	104
Botad	74940	**74629**	58022	24640.1	110
Gadhada	**89790**	62714	**66079**	**29423.4**	108
Ranpur	42910	38027	38649	1545	104
Total	**256112**	**213397**	**190816**	**57153.5**	**106.5**

Source: C-DAP, Ahmedabad, 2011, SCN Bhavnagar, Dept. of Agriculture

TGA: Total Geographical area NSA: Net Sown area

GCA: Gross Cropped area AST: Area sown more than once

Table 4 Land Use pattern of Botad District

Taluka	Area as received for the year under report for the purpose of land use	forest	barren and uncultivated land	land used for non-agricultural purpose	arable land	permanent pasture and grazing land	land under scattered trees and shrubs	current fallow	other fallow	net sown area	area sown more than once	gross sown area
Barwala	33938	721	2151	750	350	850	0	1050	0	28066	4545	32611
Botad	76521	903	12	4346	2674	5672	0	4892	0	58022	3689	61711
Gadhada	89677	2700	3545	261	400	4092	0	2005	409	66079	1538	67617
Ranpur	48272	0	1830	2470	229	1657	0	3008	429	38649	2467	41116
Total	**248408**	**4324**	**7538**	**7827**	**3653**	**12271**	**0**	**10955**	**838**	**190816**	**12239**	**203055**

Source: Ankadiya Rooprekha Botad District (2017-2018)

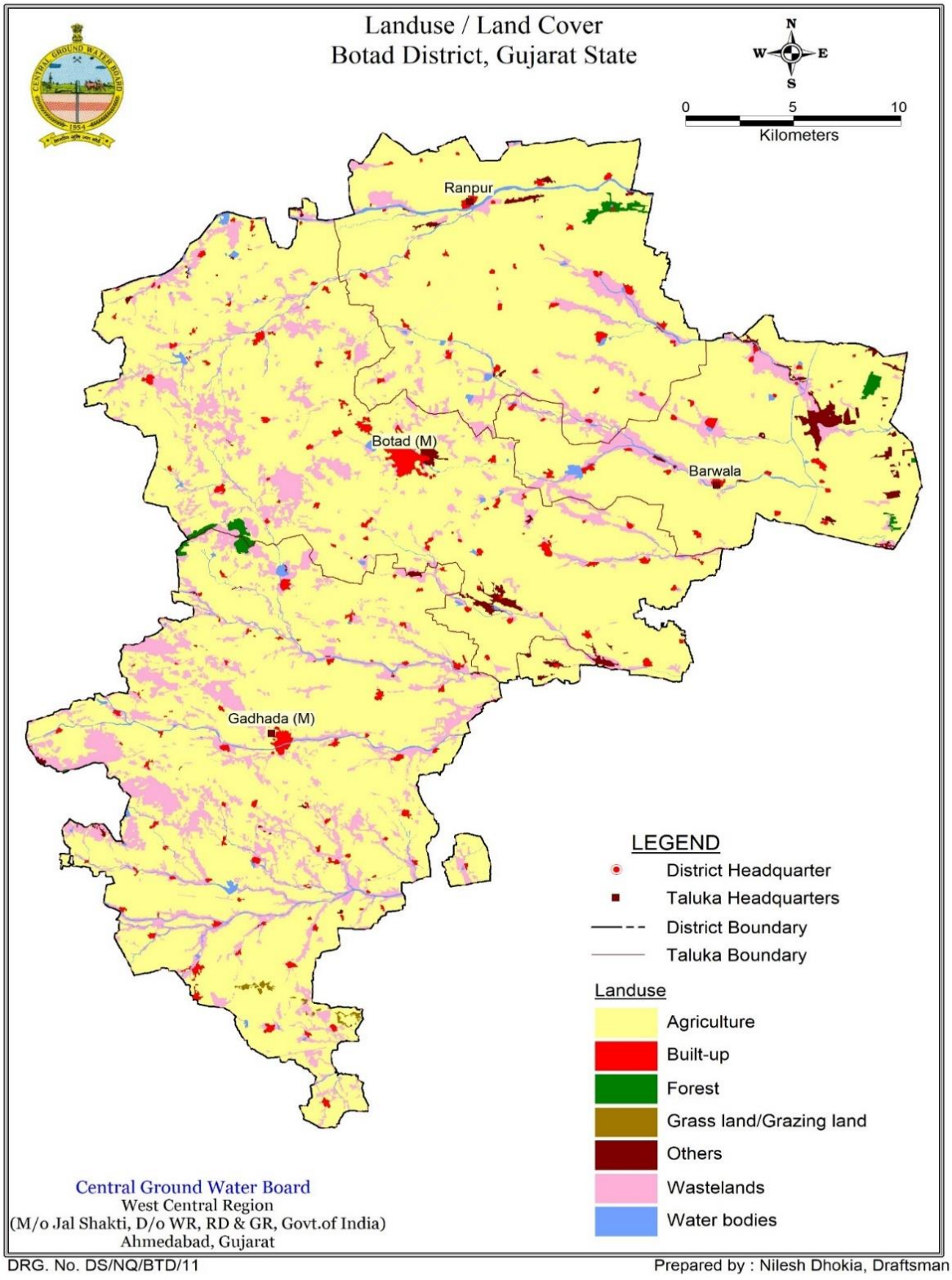

Figure 10: Land Use of Botad District

1.12 Agriculture

Agriculture and horticulture play an important role in rural economy in Botad district. The Gross Irrigated Area of Botad district is 90278 hectares, which is around 42.3% of the 213397 hectares of gross cropped area.

1.12.1 Existing type of Irrigation

Gadhada block has the maximum number of canal and reservoir structures (45%) while covering a command area of 29095 Ha (25%). Barwala block has the maximum number of canal and reservoir structure (2%) but has the maximum command area of 34197 Ha (30%) under surface irrigation. Botad block has the least command area covered by surface irrigation.

1.12.2 Crop Calendar

Botad 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. The area under different crops for the year 2017-18 is given in Table 5

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

Table 5 Month of sowing and harvesting of various crops in the Botad district

S. No.	Crop	Season	Month of sowing	Time of Harvesting
1	Cotton	Kharif	15 May to 15 June	From October to January
2	Paddy	Kharif	15 June to 15 July	October-November
3	Corn	Kharif & Rabi	All Season	All Season
4	Bajra	Kharif	15 June to 15 July	September-October
5	Sorghum	Kharif	15 June to 15 July	September-October
6	Peanuts	Kharif	15 May to 15 July	October-November
7	Beans	Kharif	15 June to 15 July	September
8	wheat	Rabi	15 November to 30 November	Feb-March
9	Sugarcane	Rabi	Oct-Nov	Feb-March
10	Gram	Rabi	Oct-Nov	Jan-Feb

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

Cropping pattern in Botad is mostly cotton-sorghum, cotton-wheat, sorghum-wheat and horticulture based under irrigated conditions. The system is mostly uniform in all the blocks. Under irrigated conditions, oilseed crops are cultivated in most blocks. During kharif season,

cotton is sown in more than 93 percent area, while sesame and sorghum occupies two percent each of the remaining area. While in Rabi 74% of the area cultivated is occupied by sorghum and wheat is cultivated in remaining 25%.

Table 6 Irrigation based area of Botad District

Irrigation Based classification			
Block	Irrigated area(ha)	Rainfed area(ha)	Total area(ha)
Botad	44937	16674	61611
Gadhada	6314	67548	73862
Ranpur	16135	31830	47965
Barwala	22892	22008	44900
Total	**90278**	**138060**	**228338**

Source: Ankadiya Rooprekha Botad District (2017-2018)

The Gross Irrigated Area of Botad district is 90278 hectare which is around 42.3% of the 213397 hectares of gross cropped area. The percentage of Gross Irrigated Land to Gross Cropped Area is maximum in Botad and Ranpur (60% each) followed by Barwala (42.43%) and the percentage of Gross Irrigated Land to Gross Cropped Area is minimum in Gadhada (10%).

1.13 Irrigation

1.13.1 Status of Command Area

Total area developed through canal command is 65727 Ha in the district. Barwala block has the maximum area with 25812 hectares of land which is irrigated through canal command. An area of 24465 hectares is undeveloped in the district. Of the total area 73°o of the area has been developed with canal command as specified in the table below.

Table 7 Status of Command Area (ha) in Botad District

Name of information of Canal Command Block	Total Area	Developed area	Undeveloped area
Botad	23048.1	15714.1	7334
Gadhada	17480.2	16462.2	1018

Ranpur	18126	7739	10387
Barwala	31538	25812	5726
Total	**90192.3**	**65727.3**	**24465**

Source: SSNL and State irrigation department

Table 8 Irrigated Area in Botad District

Irrigated Area(ha) in Botad District

Taluka	Surface water irrigated area (ha)		Total surface water irrigated area in (ha)	Total surface water irrigated area in %	Groundwater irrigated area (ha)		Total Ground water irrigated area in (ha)	Total Ground water irrigated area in %	Area irrigated more than once (ha)	Total Irrigated area (ha)	Total Land area(ha)	Total irrigated area in %
	Canal	Pond			Well	Tube well						
Barwala	5770	350	6120	**45.43**	780	450	1230	**14.34**	0	7350	28066	26.19
Botad	4416	0	4416	**9.23**	3532	0	35312	**44.85**	3689	43417	58022	74.83
Gadhada	2800	3	2803	**6.66**	3392	0	33952	**46.38**	2500	39255	66079	57.91
Ranpur	3500	0	3500	**19.44**	1050	0	10500	**42.00**	500	14500	38649	37.5
Total	**16486**	**353**	**16839**	**20.19**	**80544**	**450**	**80994**	**43.66**	**6689**	**104522**	**190816**	**49.10**

Source: Ankadiya Rooprekha Botad District (2017-2018)

2. Chapter GEOLOGY

2.1 Geology

Geologically, major part of the area is covered by Basalts and the remaining by alluvial formation (Fig-). The generalized geological succession is given in the following table no 9.

Table 9 Stratigraphic succession

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

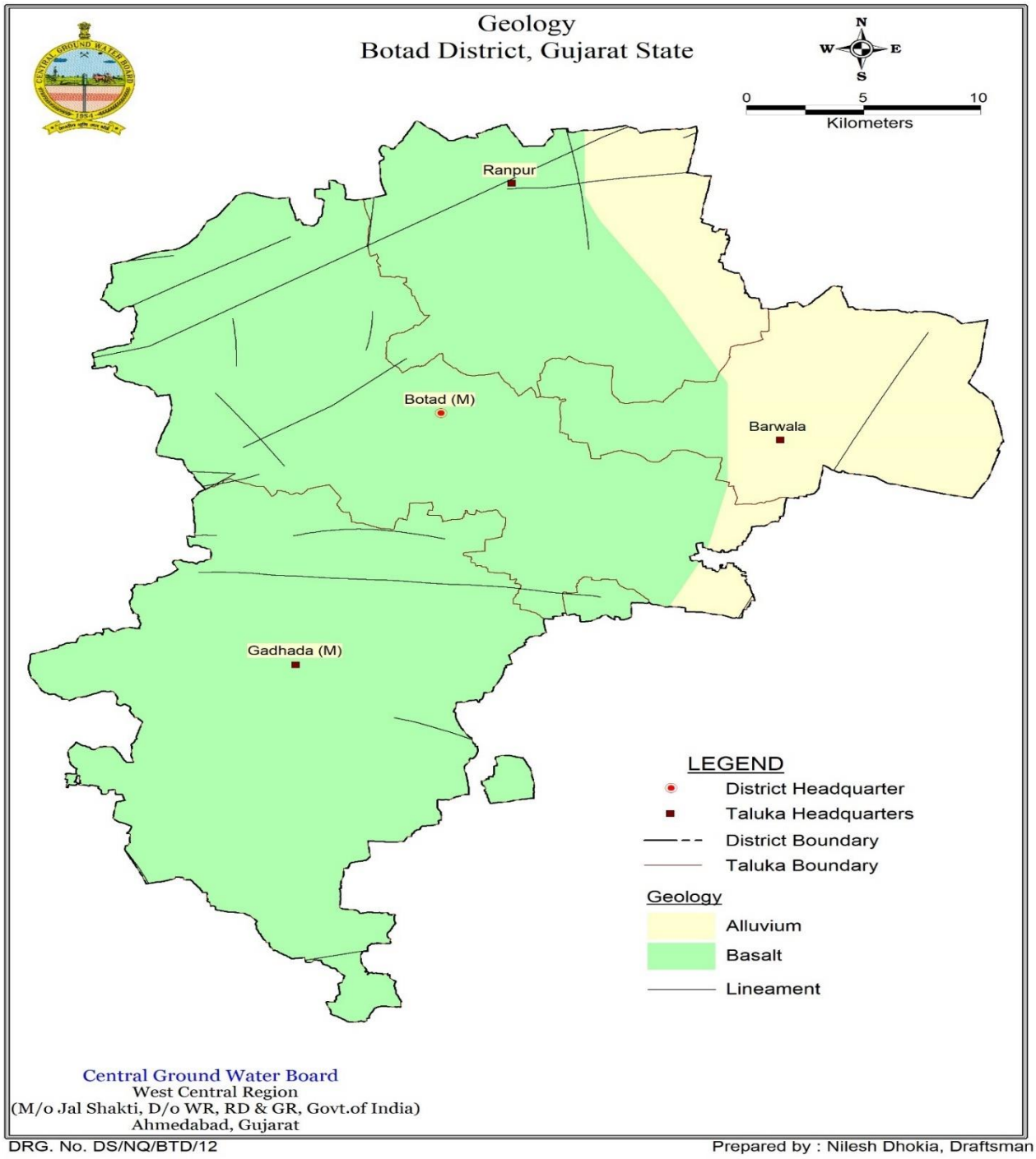

Figure 11: Geology of Botad Dist.

From above Fig-11 it is infer that Botad dist. mainly have Basaltic formation. However, some parts of Barwala and Ranpur Taluka have Alluvium formation.

2.1.1 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. In the plain terrain, 1 – 2 m of soils and weathered part cover these formations. Deccan traps in this area are represented by basalts, both massive and amygdoidal or vesicular type, dolerite flows, ash beds, basaltic and dolerite dykes. Massive basalt is dark grey or steel grey in color, very fine grained and compact.

Major part of the district covered by Deccan Trap lava flows. The trap rock is mostly basalt and dolerite, though, trachyte is also found. The Deccan Trap occurs in the form of lava flows with thickness of individual flows ranging from few meters to more than 26 m. Each individual lava flow can be sub divided into three distinct units - (1) grayish red clay and reddish clayey vesicular basalt, (2) vesicular and amygdaloidal basalt and (3) jointed and massive basalt.

2.1.2 Dykes

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

2.1.3 Alluvium

The eastern part of the district comprises unconsolidated to semi consolidated sediments of Recent to Pleistocene age. The alluvium which primarily rests on the basalt mainly comprise of the sand and clays along with the carbonate nodules (kankar).

2.2 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.

2.2.1 Alluvium:

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 dug wells ranges from 170 m3/day to 800 m3/day. Drilling of horizontal bores in the wells to increase the yields is quite common practice. Such horizontal bores generally have diameter of 2.5 to 5 cm and extend laterally to 10 to 15 m. The yield of wells ranged between 10 and 820 m^3/day.

2.2.2 Dykes/ lineament:

The presence of many dykes and lineaments in the district 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.

2.2.3 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 groundwater in basalt occurs under phreatic to confined conditions. The groundwater is generally tapped through dug wells varying in depth from 5 to 26 m. At places, dug-cum-bored wells are also constructed by drilling bores below the bottom of dug wells.

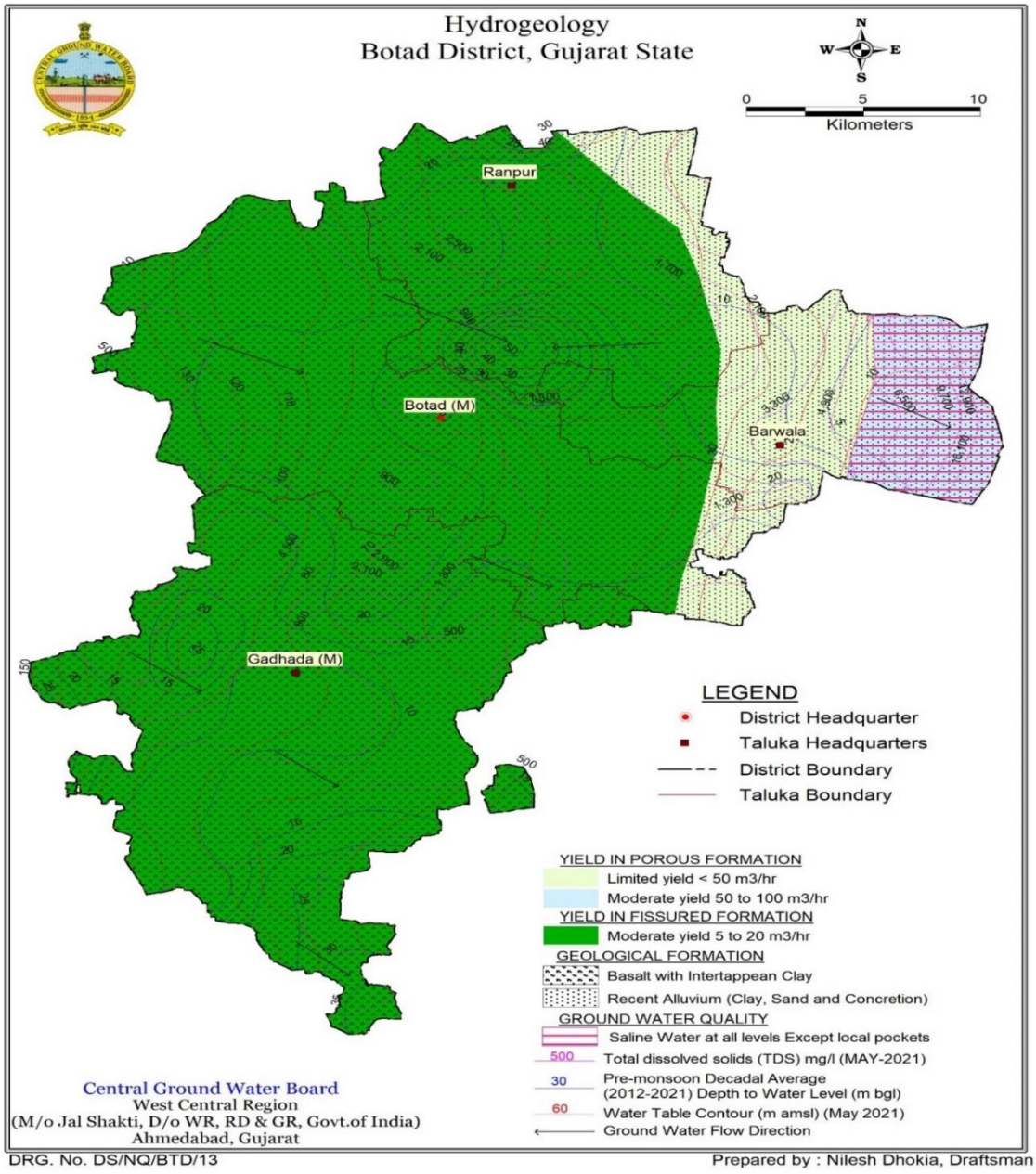

Figure 12: Hydrogeology of Botad district

Fig: 12 Shows the Hydrogeological units of Botad district. Some parts of Ranpur and Barwala Taluka have low yield capacity. While rest parts of the district have moderate to high yield capacity. Barwala Taluka has Saline water condition at its eastern side.

3. Chapter DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 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-).

Table 10: Brief activities showing data compilation and generations

S.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.

3.2 Data Generation:

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of lithological 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 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 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 Figs (14 to 18). 3D Solid Model and Fence Diagram of district is depicted in Fig. 18 and 19, respectively.

Table 11: Data integration in respect to Botad district

Type of Data & source	No of Wells
Aquifer Disposition	
CGWB	**9**
Long term Fluctuation	
CGWB+GWRDC	**39+29**
Decadal Analysis water Level	
CGWB+GWRDC	**12+29**
Analysis of water Quality	
CGWB+GWRDC	**61+0**

3.3 Conceptualization of Aquifer system in 2D

A total of 9 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. Four 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 14 (A-A') to figure 17 (D-D'). Fence Diagram and 3D Solid Model of district is depicted in Fig. 19 and 18, respectively.

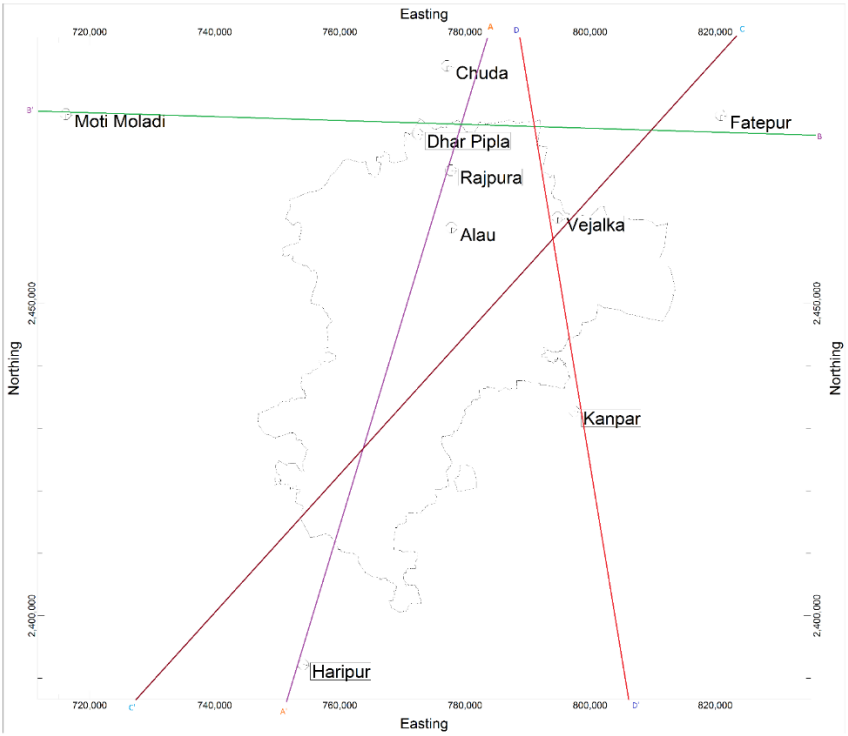

Figure 13: Map showing drawn section lines

1. Section A-A' (Fig. 14)- Section is drawn roughly N-S direction in between Chuda and Haripur and passing through Dharpipla, Rajpura Alau. 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.

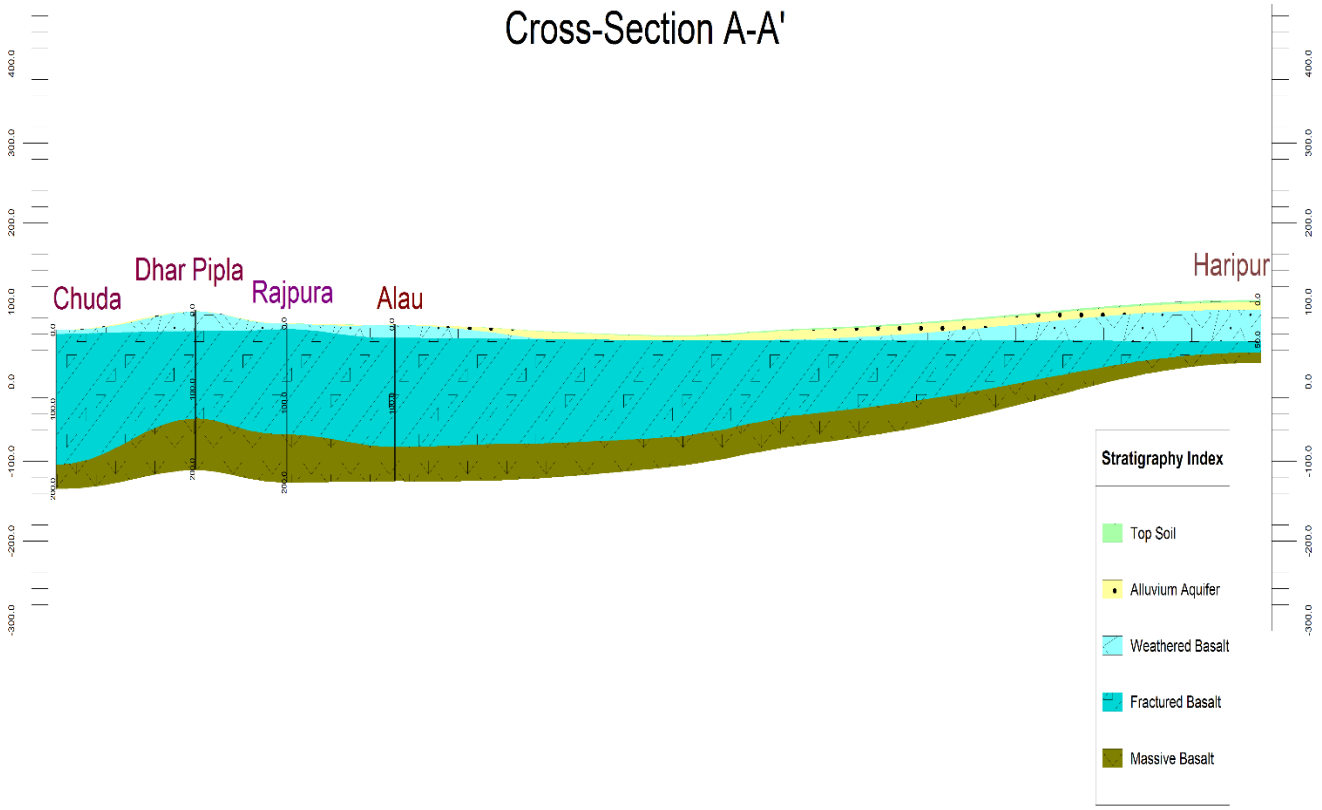

Figure 14: Hydrogeological cross section between Chuda and Haripur

2. Section B-B' (Fig. 15)- Section is drawn roughly N-S direction in between Fatepur, and Moti Moladi passing through Rajpura, Dharpipla. Section is represented Stratigraphically. From section it is deciphered that that Hard rock formation (Weathered & Fractured) forms the major aquifer system in the district and rested on Massive rock along drawn section line.

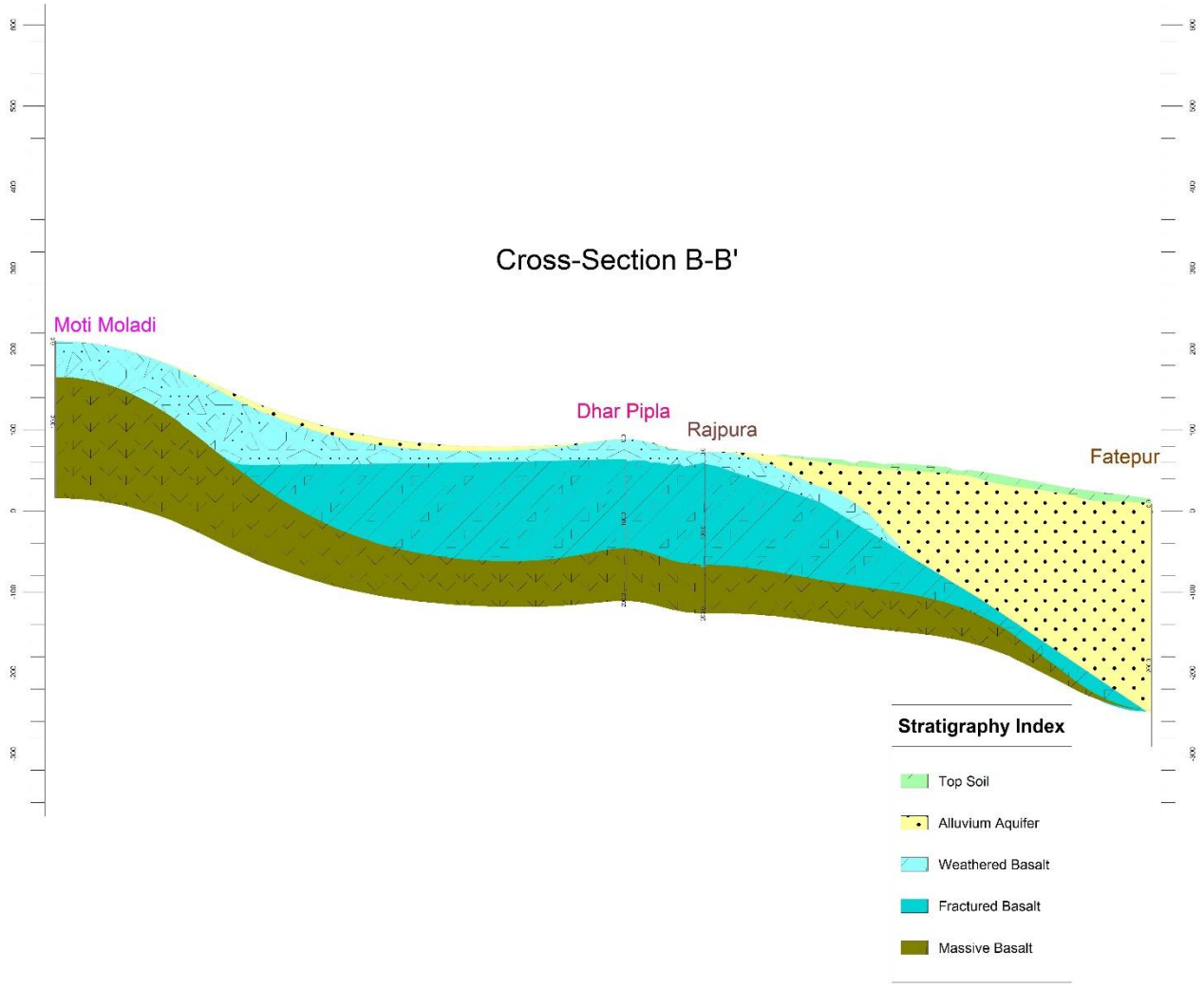

Figure 15: Hydrogeological cross section between Fatepur and Moti Moladi

1. Section C-C' (Fig. 16)- Section is drawn roughly N-S direction and in between Fatepur and Haripur, passing through Vejalka. Section is represented Stratigraphically; from section it is deciphered that that Hard rock formation (Weathered & Fractured) forms the major aquifer system in the district and rested on Massive rock along drawn section line.

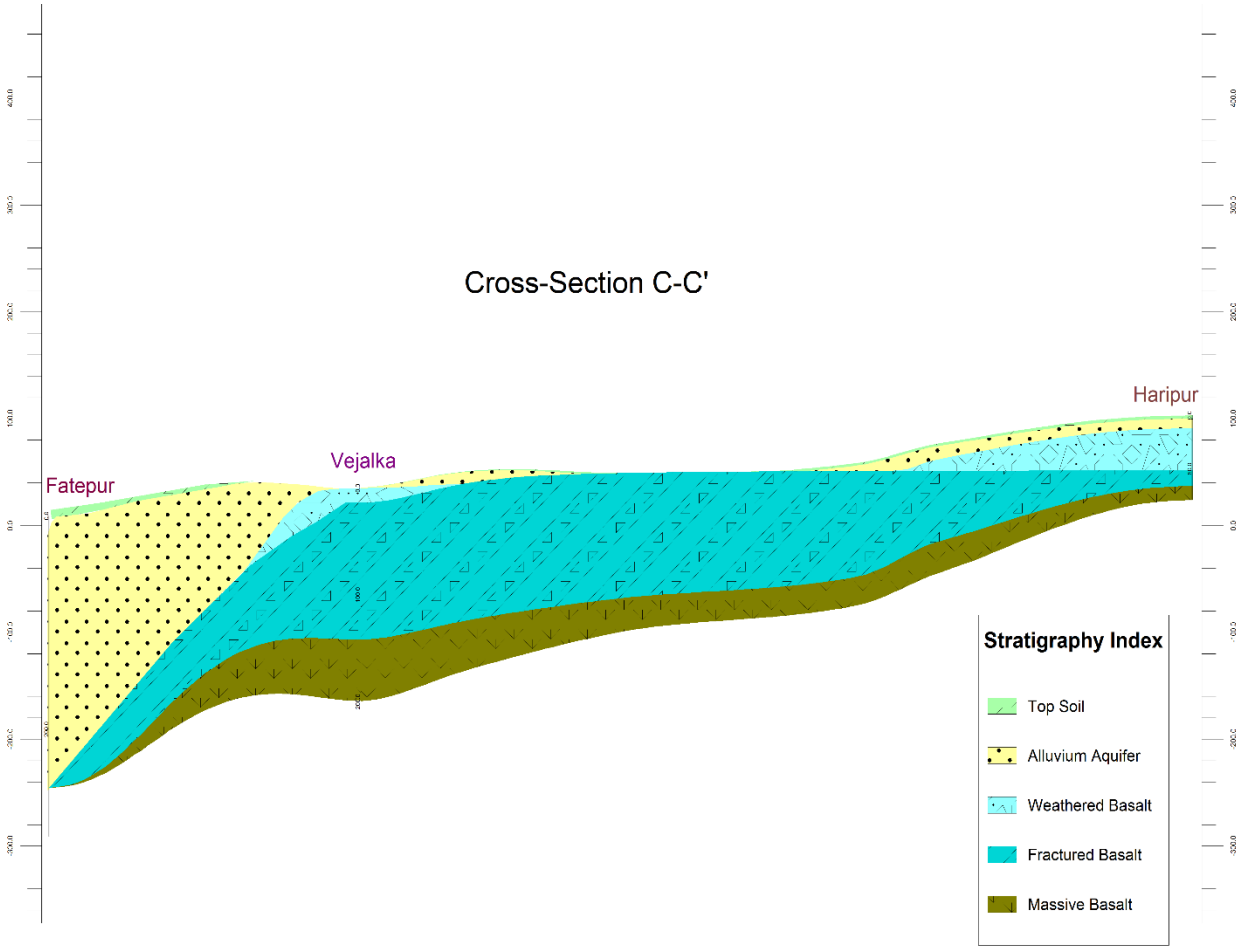

Figure 16: Hydrogeological cross section between Fatepur and Haripur

2. Section D-D' (Fig. 17)- Section is drawn roughly N-S direction and in between Kanpur and Chuda, passing through Vejalka. Section is represented Stratigraphically, from section it is deciphered that that Hard rock formation (Weathered & Fractured) forms the major aquifer system in the district and rested on Massive rock along drawn section line.

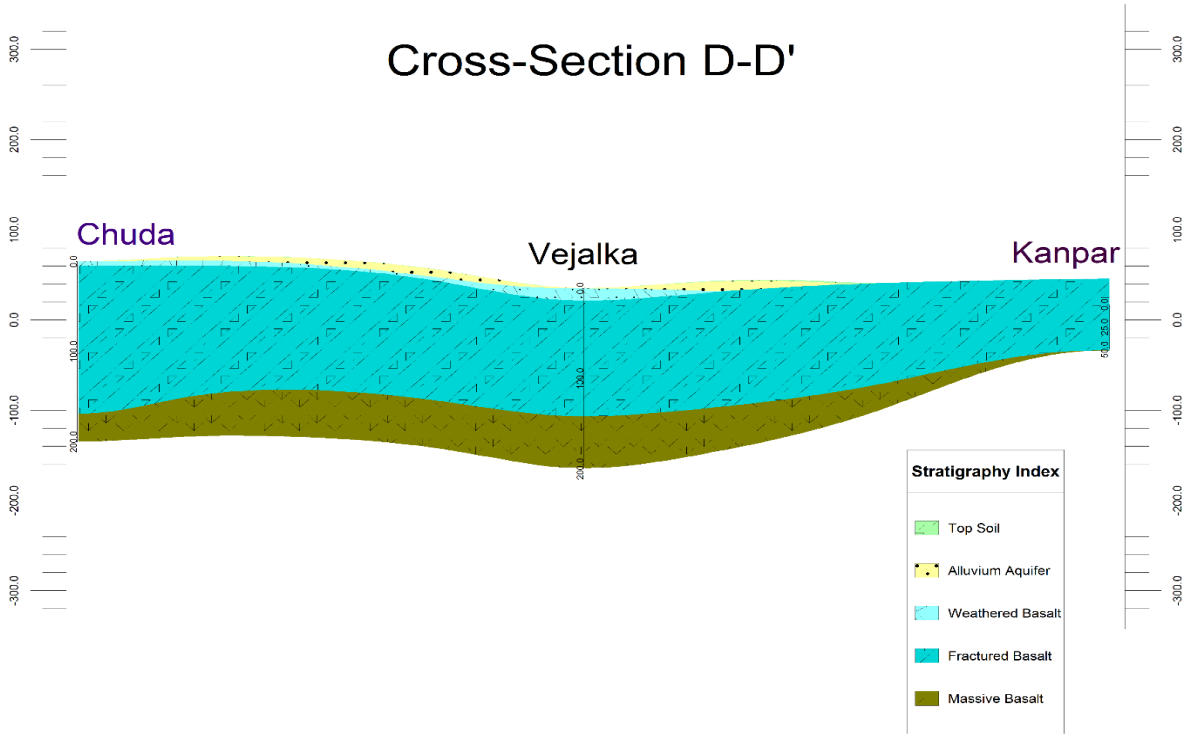

Figure 17: Hydrogeological cross section between Chuda and Kanpar.

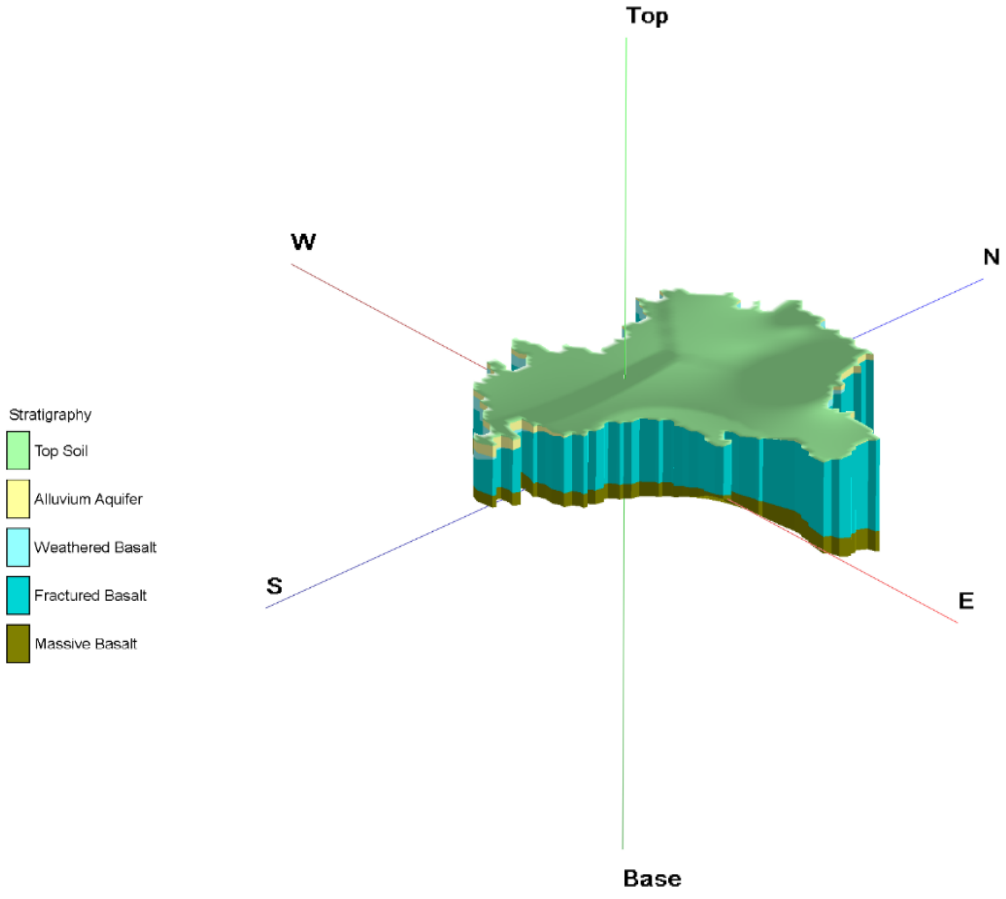

Figure 18: 3D Model/ Aquifer disposition of Botad District.

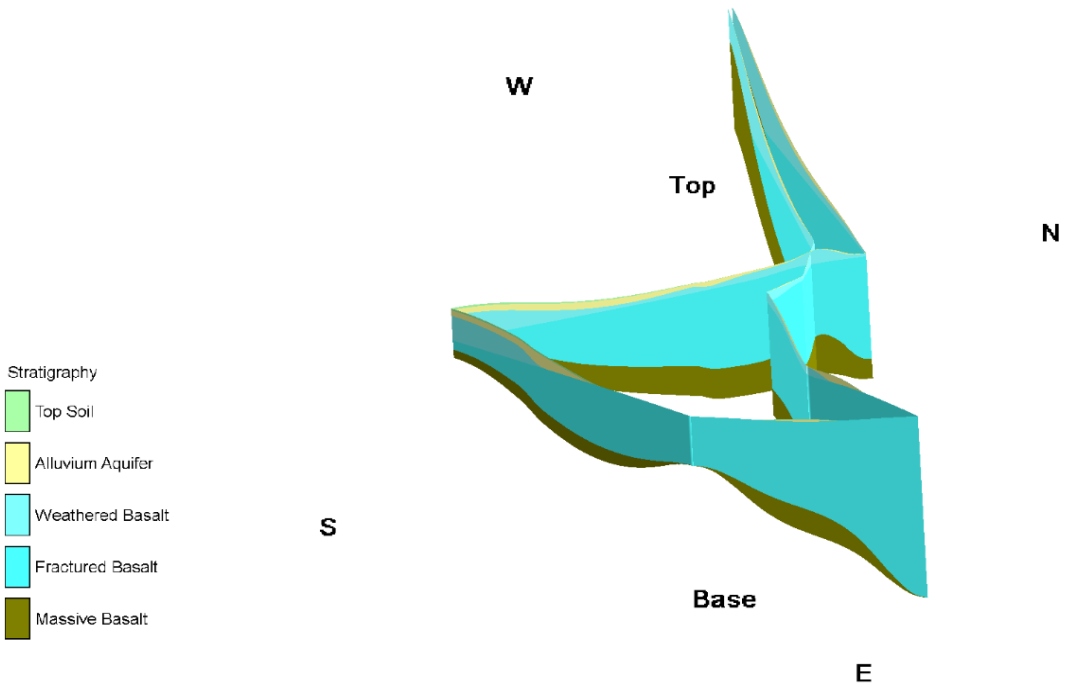

Figure 19: Fence diagram Botad District

Table 12 Aquifer Characterisation and Disposition (Botad)

Aquifer Characterisation and Disposition (Botad)										
Stratigraphy	**Aquifer Nomenclature**	**Lithological**	**Depth of occurrence**	**Thickness**	**Water Level (mbgl)**	**Quality**	**Discharge**	**Transmissivity**	**Nature of Aquifer**	**Remarks**
		Characteristics	**Aquifer**	**Range**	**Range**	**(EC)**	**Range**	**Range**		
			(mbgl)	**(m)**	**(mbgl)**	**µs/cm at 25°C**	**lps**	**m2/day**		
Quatenary	**Alluvium**	**Younger Alluvium with sand, silt, clay, cobble and Pebble dominated [AL03]**	0 to 20	2 to 20	1.0 to 21.86	710 to 7385			Phreatic	Good Quality (only few places in Barwala Taluka), Alluvium only occurs in Barwala taluka
Cretaceous/ Tertiary	**Weathered Basalt**	Basalt as stratified lava flows comprising amygdaloidal basalt, fine grained porphyritic basalt and basaltic/dolerite dykes.	**0 to 26.3**	**6 to 26**	**1.10 to 27.80**	330 to 8873			Phreatic	Good Quality
	Fractured Basalt		17 to 187	107 to 137	17 to 142.2	600 to 12000	0.5 to 12	2.89 to 6.83	Semi-confined	Good Quality, At few places. quality is not good
	Massive Basalt		134 to 200	42 to 66						

4. Chapter GROUND WATER SCENARIO

Groundwater occurs both in alluvium and hard rock. Major area of the district is covered by hard rock aquifer, covering a large area in the northern, eastern and southern-western part. Though ground water occurs in all types of formation, but the most productive aquifer are Deccan traps. Since 1969, Central Ground Water Board, as a part of its national programme, has established a network of observation wells in the state of Gujarat and UT of Daman and Diu for periodic monitoring of water levels and the variation in quality of groundwater.

4.1 GROUNDWATER REGIME MONITORING:

Ground water regime monitoring is the basic component of groundwater management, and it is carried out in Botad district four times a year, during January, May, August and November through 12 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.

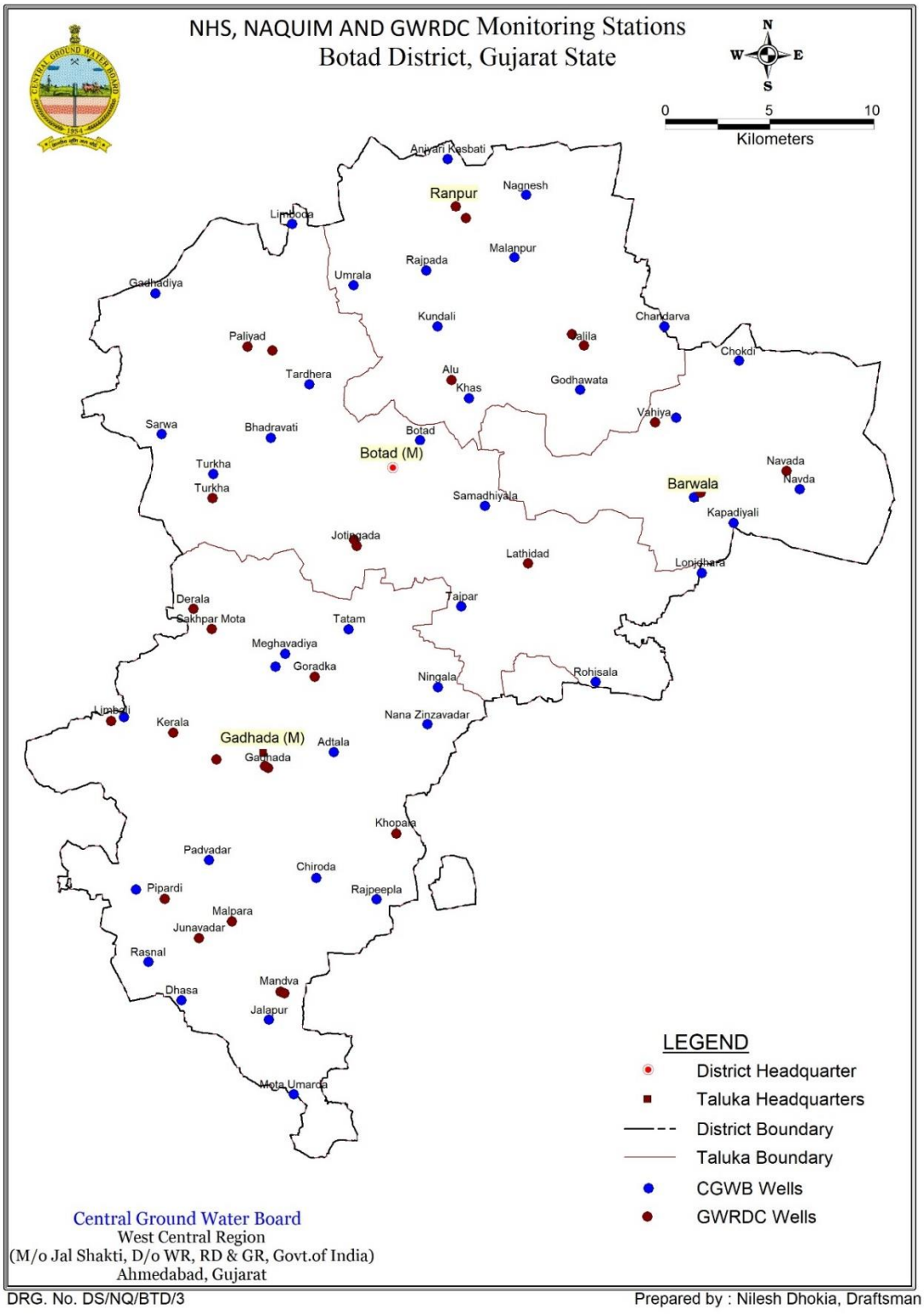

Figure 20: NHS , NAQUIM and GWRDC well monitoring stations

4.2 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 68 nos. of monitoring stations including 29 nos. monitoring station of Gujarat Water Resources Development Corporation (GWRDC) were taken during preparation of maps.

4.2.1 Depth to water level (Pre-monsoon 2021)

Pre monsoon depth to water levels of Botad district are shown in the (Fig. 21), which depict that water levels in most part of the district ranges in between 2 mbgl to 10 mbgl. Small stretches in adjoin boundary region Ranpur and Botad taluka shows deeper water level of more than 20 m bgl. Shallow water level is observed in patches in all talukas of the district.

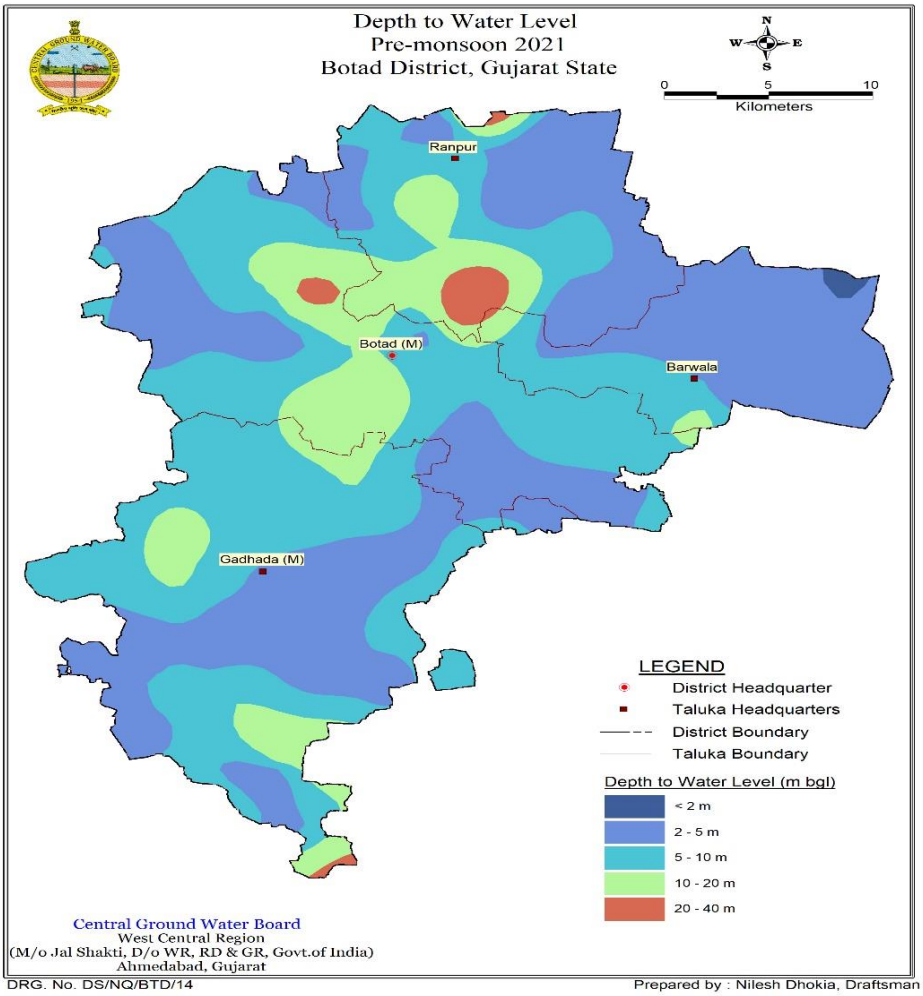

Figure 21: Depth to Water Level Pre-monsoon 2021 of Botad District

4.2.2 Depth to water level (Post-monsoon 2021)

Post-monsoon water level as shown below in map for the period of November, 2021(Fig. 22) shows that shallow water level upto 10 m bgl are observed in most part of the district which reflect good recharge were taken place due to rainfall. Deeper water level is concentrated only in SW part of Ranpur Taluka and few small patches in Gadhadha Taluka.

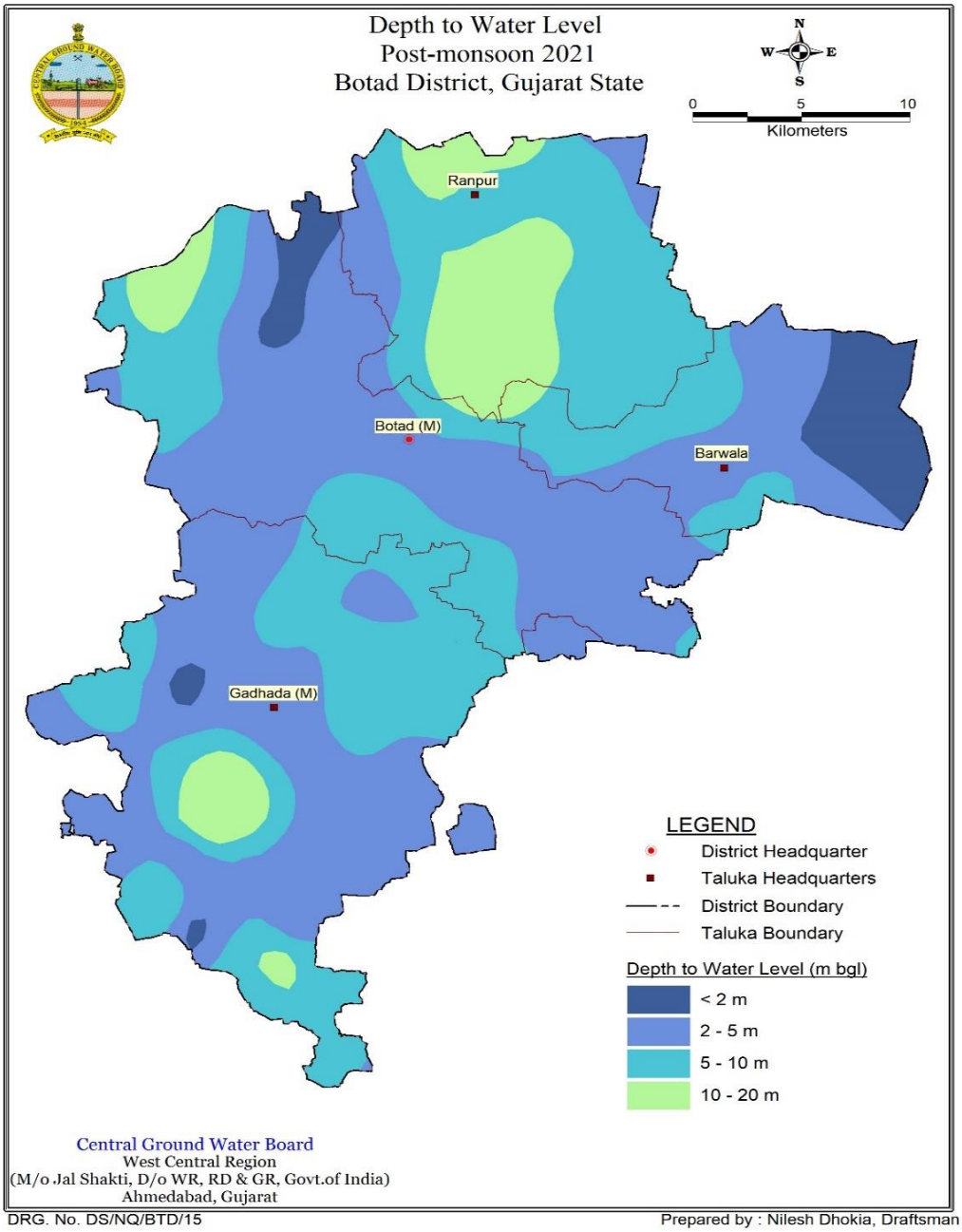

Figure 22: Depth to Water Level Post-monsoon 2021 of Botad District

4.2.3 Water table and groundwater movement

The elevation of water table in Pre monsoon 2021 is observed higher along NW adjoining district boundary with Surendranagar district where water table contour ranges in between 15 m amsl to 135m amsl which shows water flowing towards SE direction (Fig 23). South eastern part of Barwala Taluka has water table at the low elevation of 10 m amsl in Premonsoon.

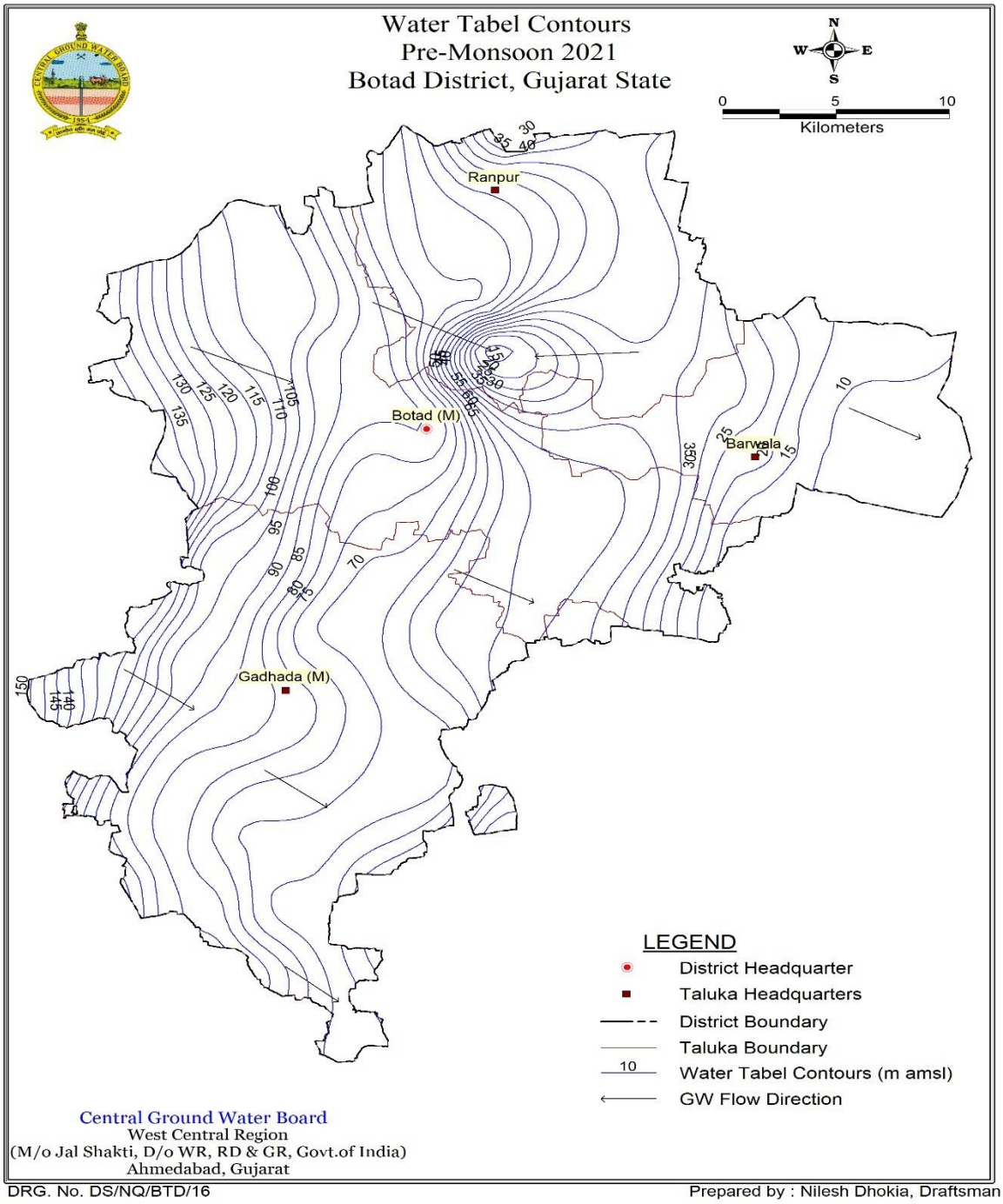

Figure 23: Water Table Contour Map of Botad District

4.2.4 Water Level Fluctuation:

The fluctuation of water levels between Pre-monsoon (May, 2021) and Post Monsoon (November, 2021) shows in fig 24. Most parts of the district have registered rise in water levels. A few localized pockets in North, Northeast parts of District have small rise in water level (Barwala & Ranpur Taluka) and major part of Northwest and Southwest districts have registered large rise in water level (Botad & Gadhada Taluka).

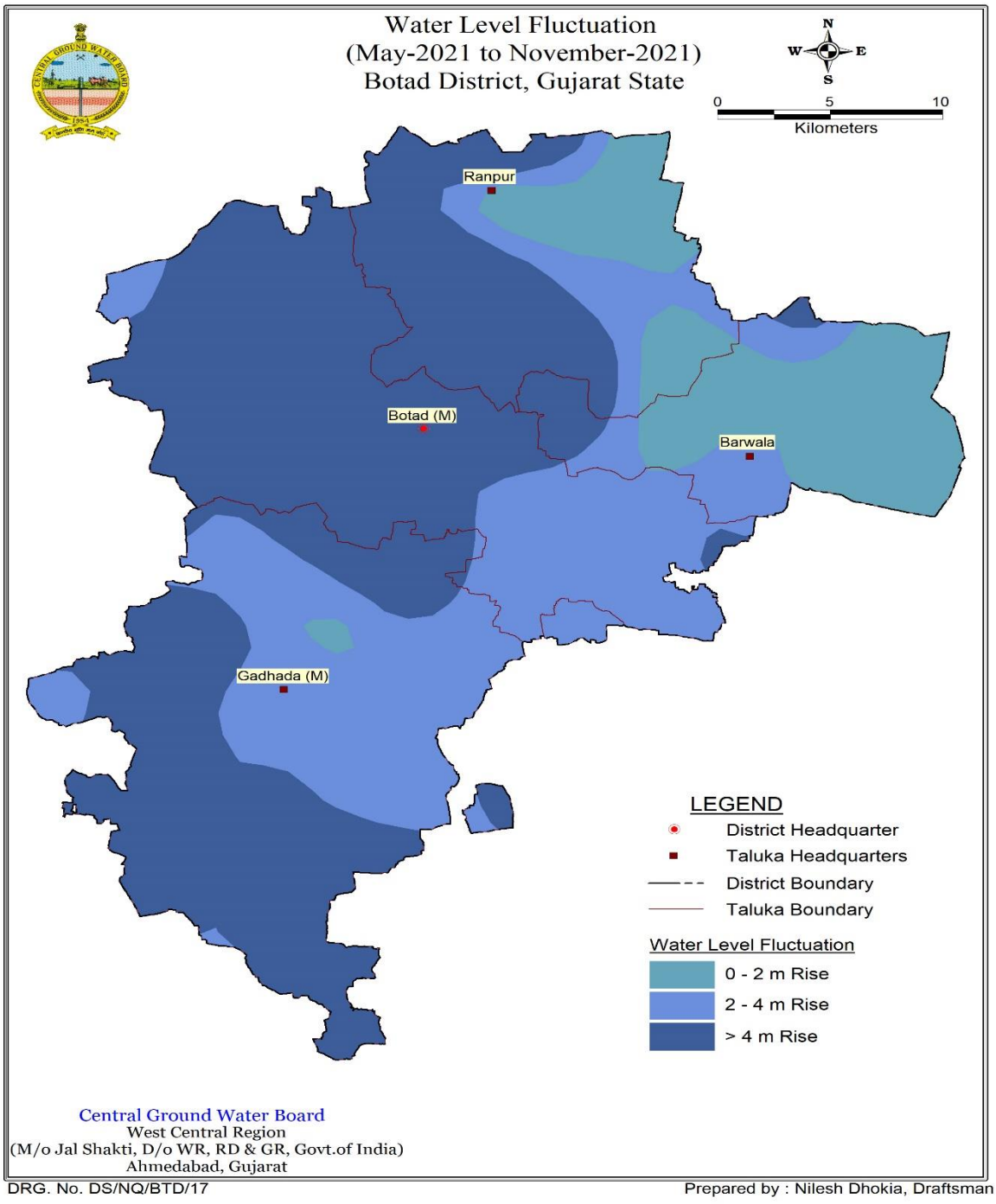

Figure 24: Water Level Fluctuation Botad District

4.2.5 Decadal average depth to water level Pre-monsoon

Pre monsoon average depth to water level of Botad district are shown in the (Fig. 25), which depict that water levels in most part of the district ranges in between 8m bgl to 20m bgl. Small stretches in adjoin boundary region Ranpur and Botad taluka shows deeper water level of more than 30 m bgl. Shallow water level is observed in patches in all talukas of the district.

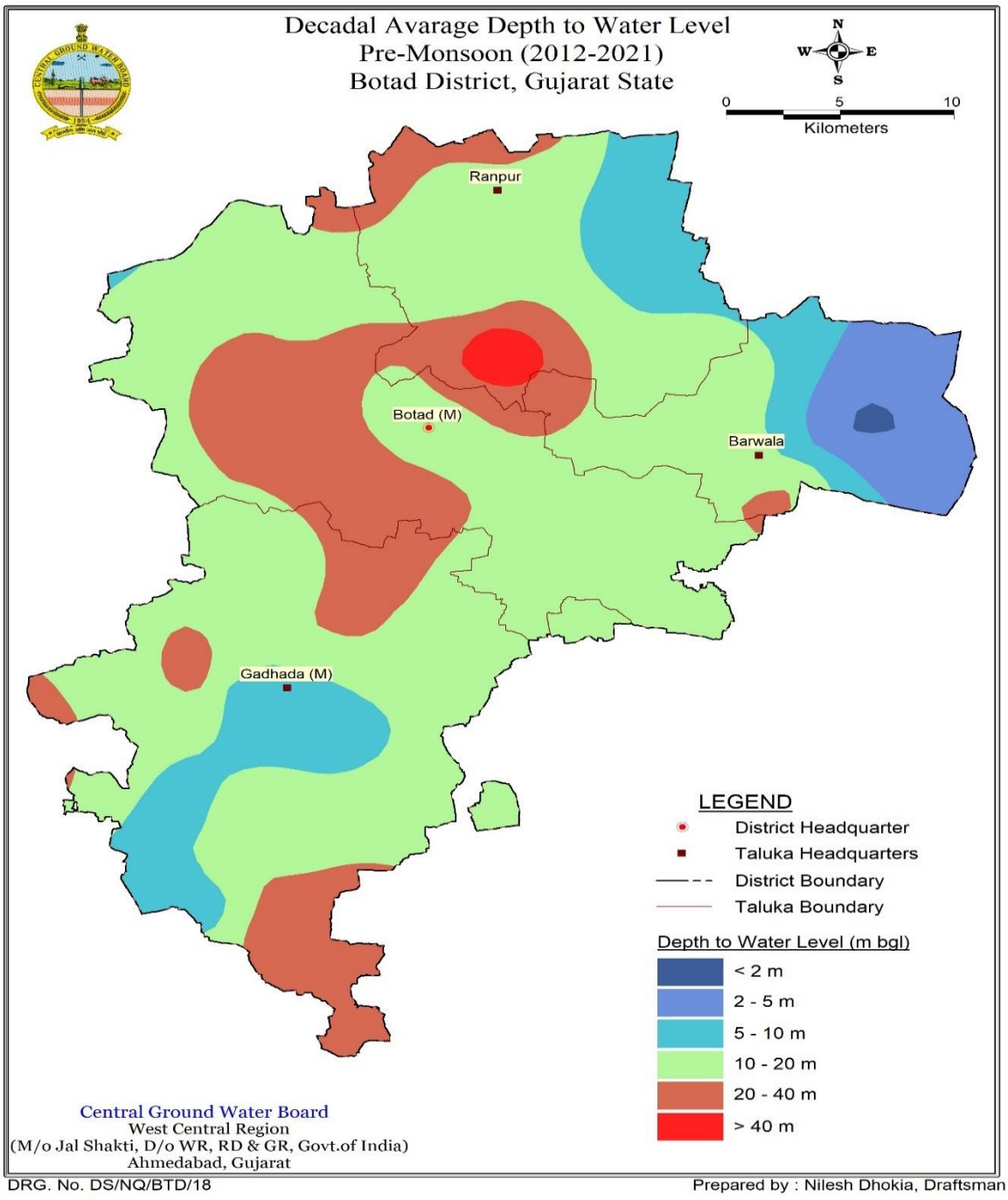

Figure 25: Decadal DTW Pre-monsoon 2012-21 Botad District.

4.2.6 Decadal average depth to water level Post-monsoon

Post-monsoon average depth to water level as shown below in map for the period of November, 2021. Fig 26 shows that shallow water level up to 10 mbgl are observed in most part of the district which reflect good recharge were taken place due to rainfall. Deeper water level is concentrated only in Southern part of Ranpur.

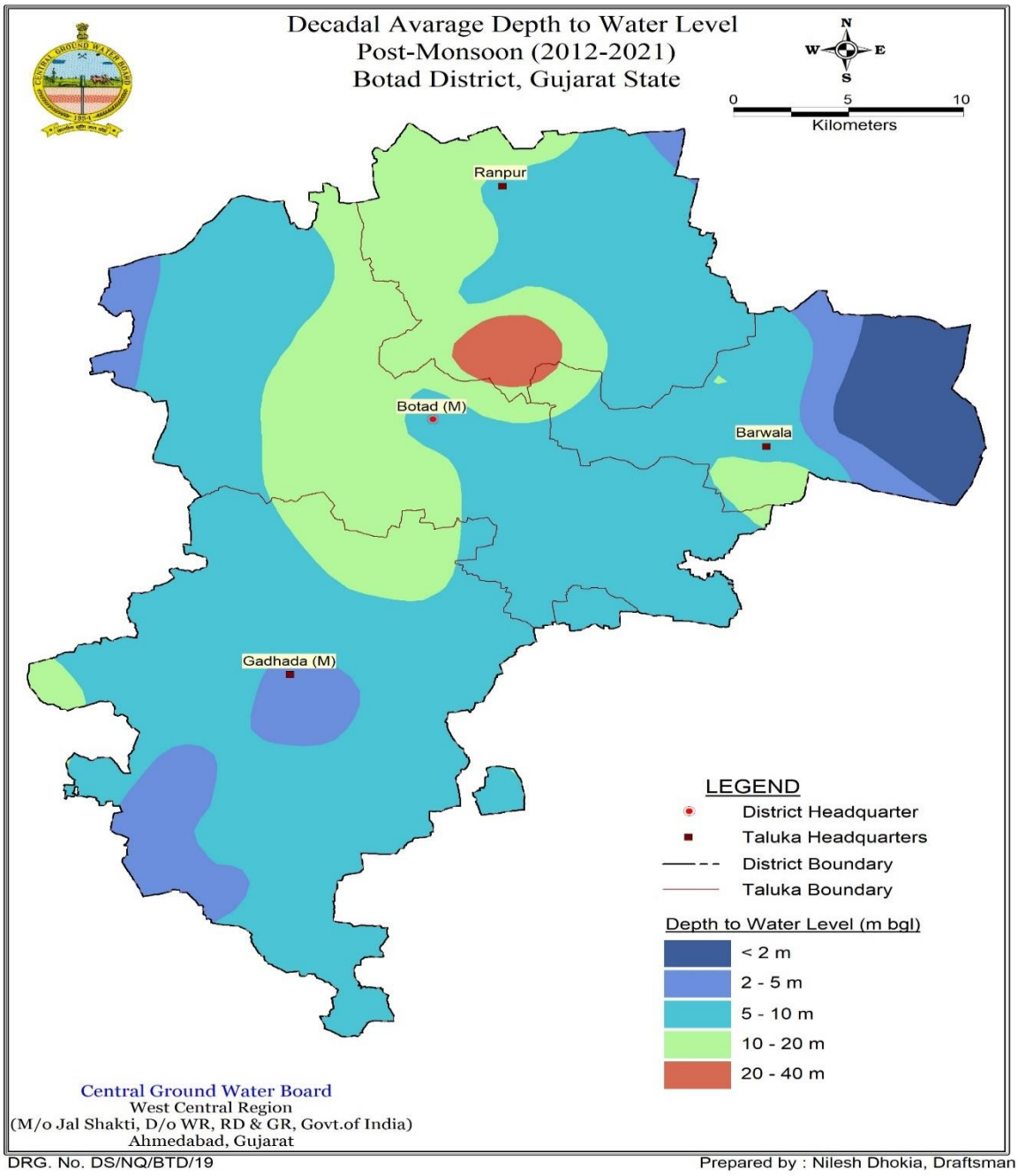

Figure 26: Decadal DTW Post-monsoon 2012-21 Botad District

4.3 Decadal water level trend

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 0.0288 m/yr (Gadhada) to 2.0976 m/yr (Salangpur) and also has a fall of 0.04836 m/yr (Dhasa) to 0.2712 m/yr (Tardhera). Similarly, from the analysis of the post-monsoon data of 2012 to 2021, the water level has a rise of 0.0384 m/yr (Gadhada) to 0.7081 m/yr. (Barwala) and also has a fall of 1.203 m/yr (Tardhera). 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 and post monsoon period. However, falling trend in few hydrographs is also observed.

Table 13: Decadal Water level trend (2012-2021) Botad District

Long Term Trend of Water Level (2012-2021)								
Sr. No	Taluka	Location	**Pre-Monsoon**			**Post-Monsoon**		
			Data Point	**Rise (m/year)**	**Fall (m/year)**	**Data Point**	**Rise (m/year)**	**Fall (m/year)**
1	**Barwala**	Barwala	10	0.36528		10	0.7081	
		Salangpur	10	2.0976		10	0.6648	
2	**Botad**	Tardhera	10		0.2712	10		1.203
3	**Gadhada**	Dhasa	10		0.04836	10	0.2136	
		Gadhada	10	0.0288		10	0.0384	
4	**Ranpur**	Kundali	10	1.02384		10	0.6447	
		Rajpada	10	0.78132		10	0.4086	
			Min	**0.0288**	**0.04836**		**0.0384**	**1.203**
			Max	**2.0976**	**0.2712**		**0.7081**	**1.203**

4.4 Hydrographs

Historical data of water levels were used for preparing the hydrographs as well as for computing long term trends. Few of the hydrographs representing the rising and falling trends of water level in Botad district is presented below.

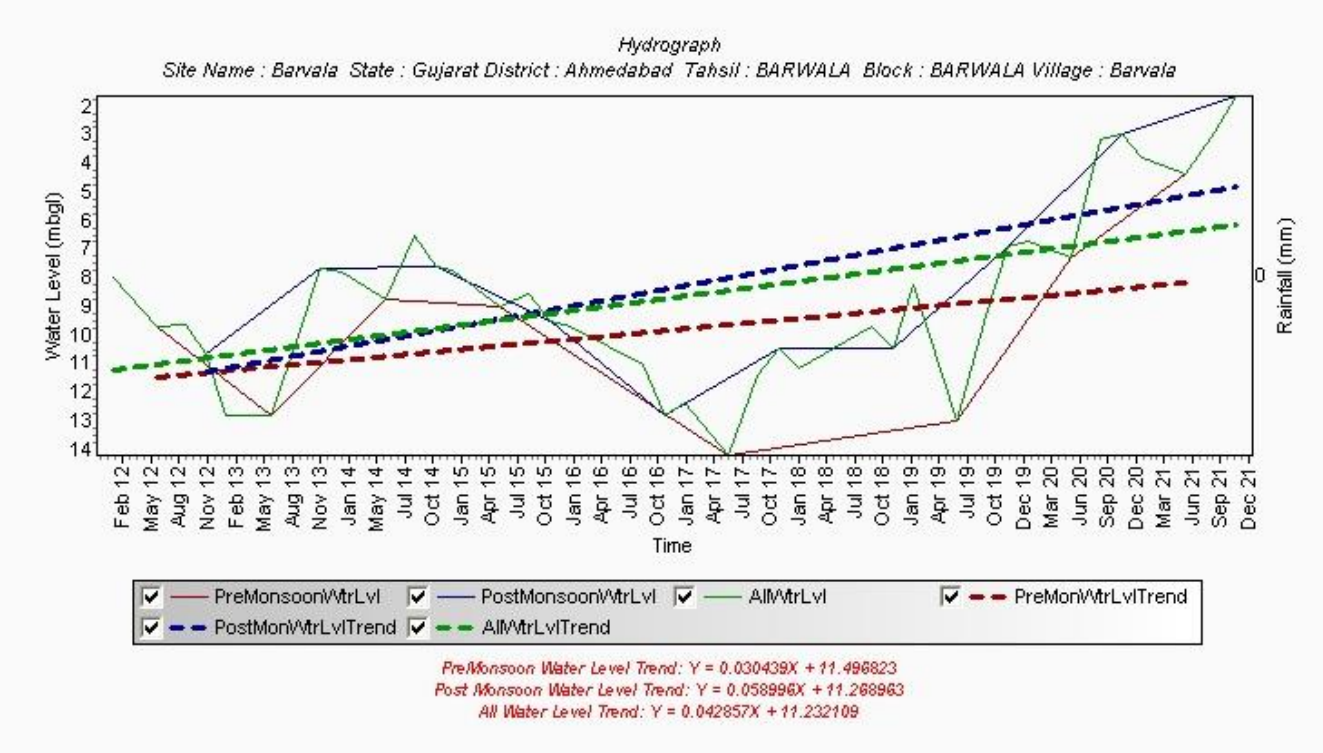

Figure 27: Hydrograph of Barwala NHS well in Botad District

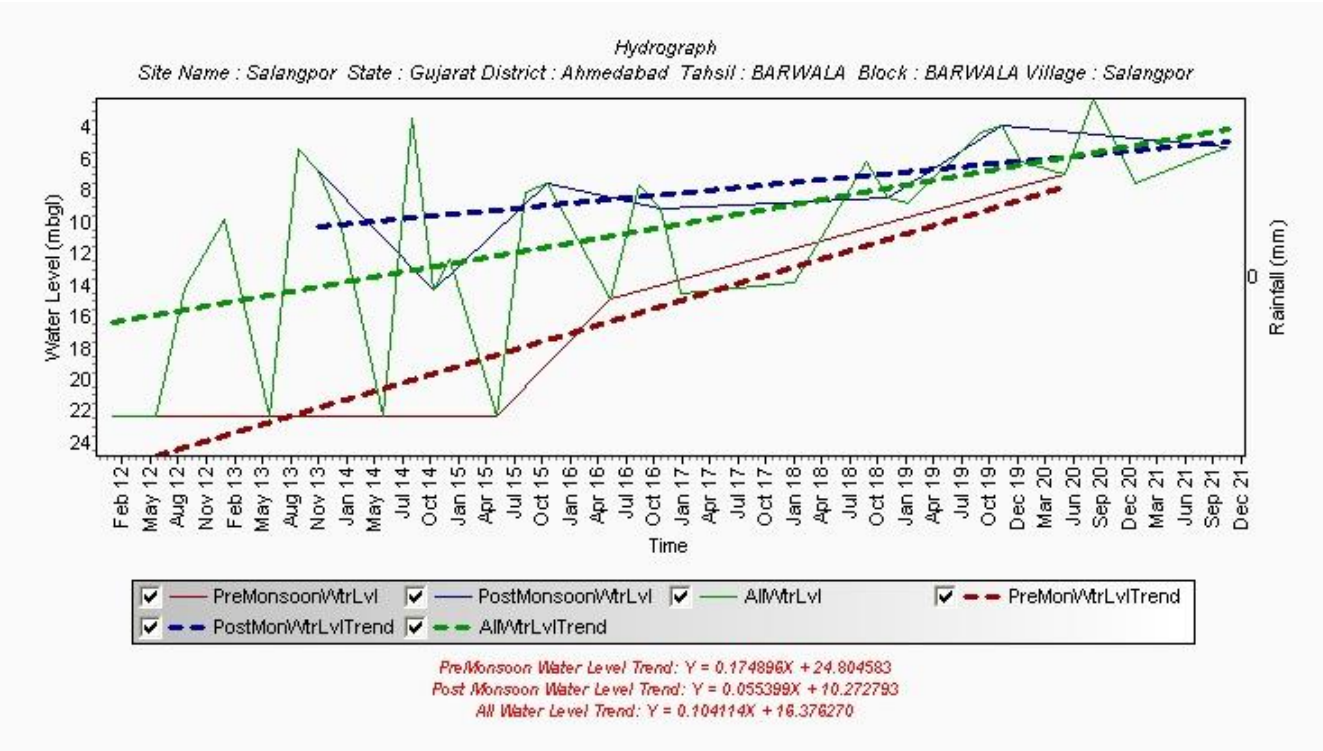

Figure 28:Hydrograph of Salangpur NHS well in Botad District

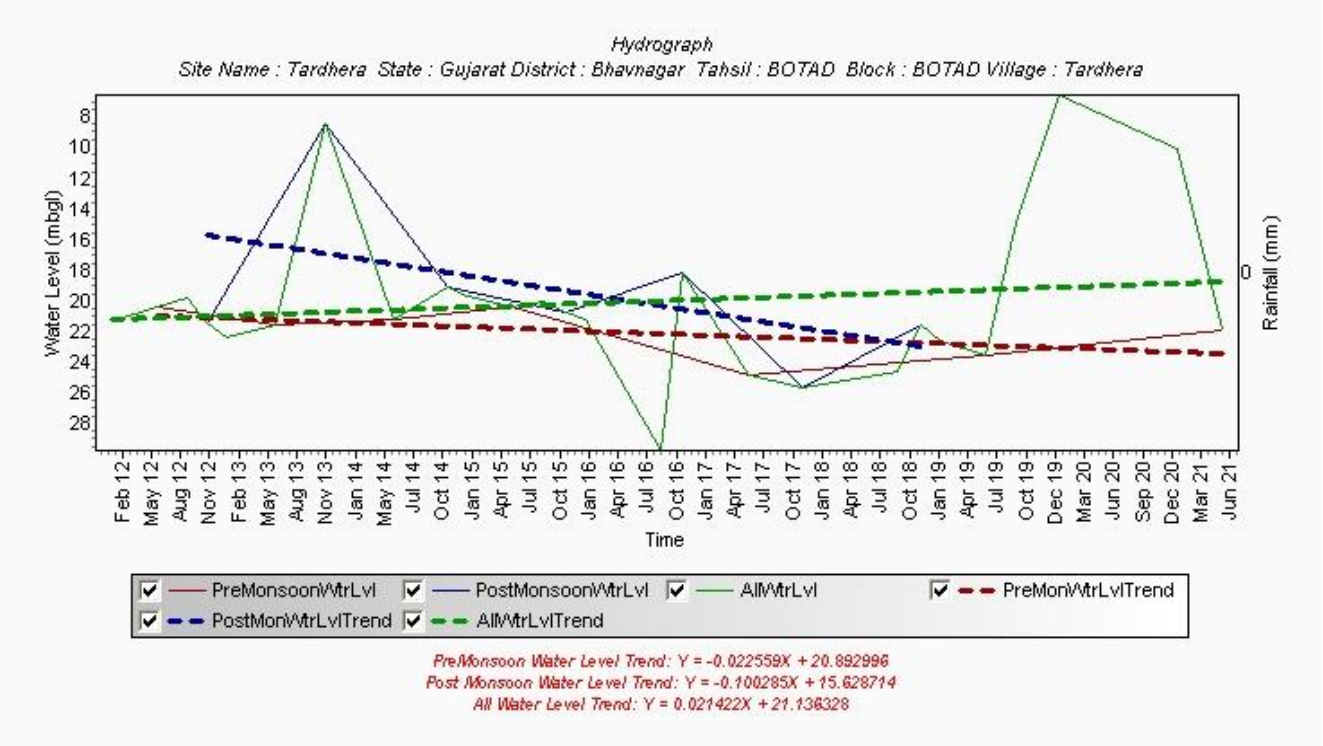

Figure 29: Hydrograph of Tardhera NHS well in Botad District

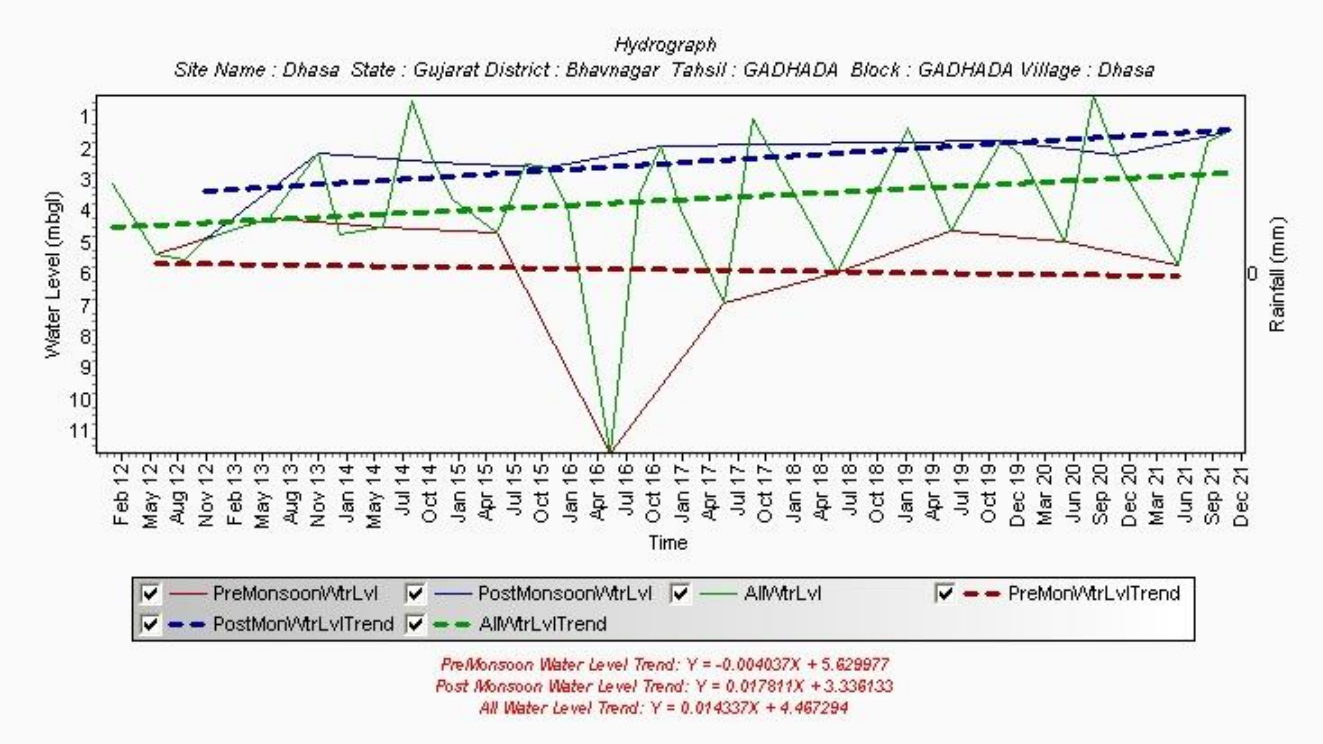

Figure 30: Hydrograph of Dhasa NHS well in Botad District

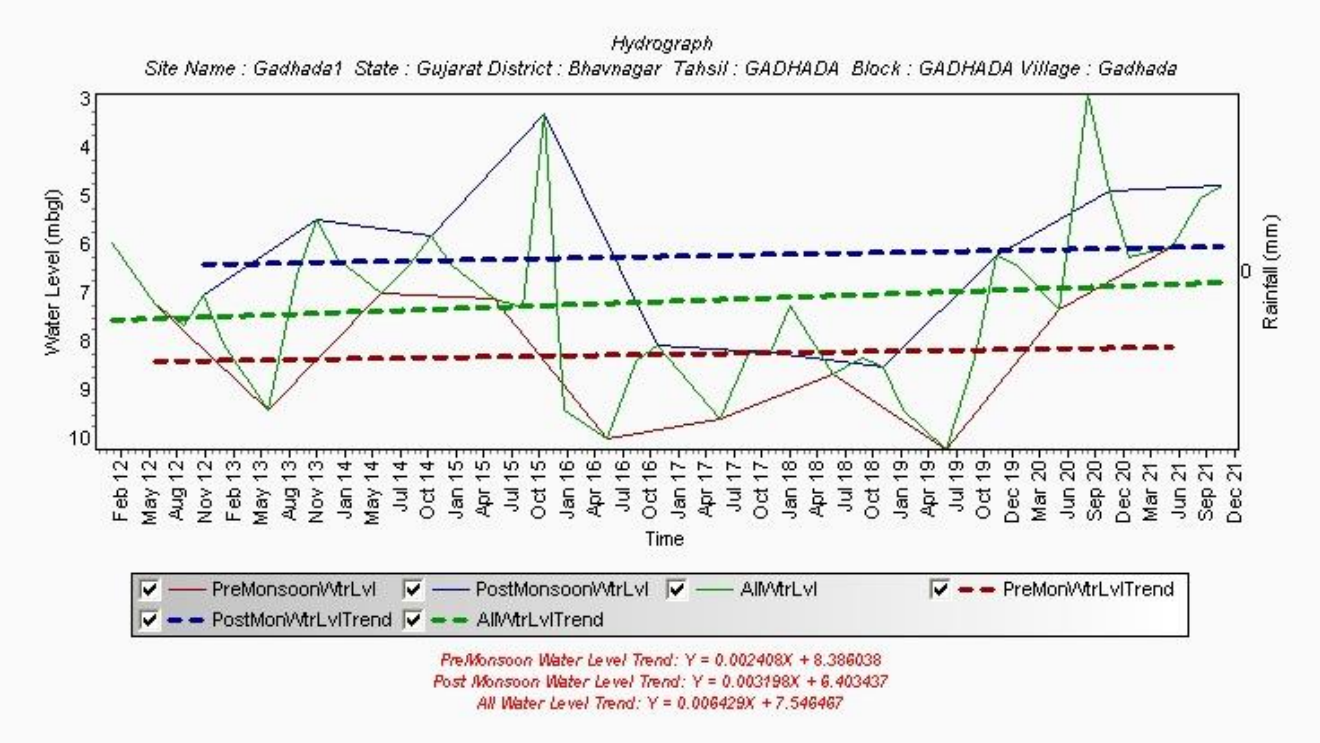

Figure 31: Hydrograph of Gadhada NHS well in Botad District

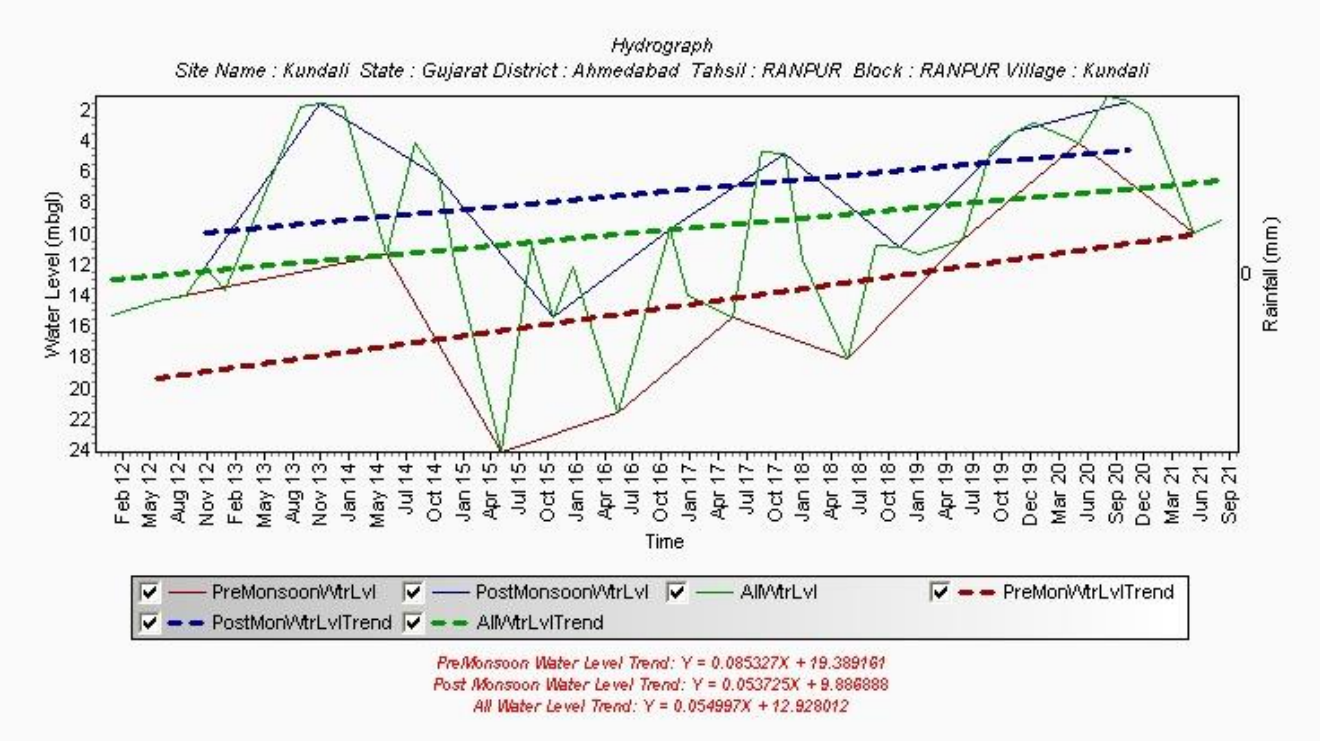

Figure 32: Hydrograph of Kundali NHS well in Botad District

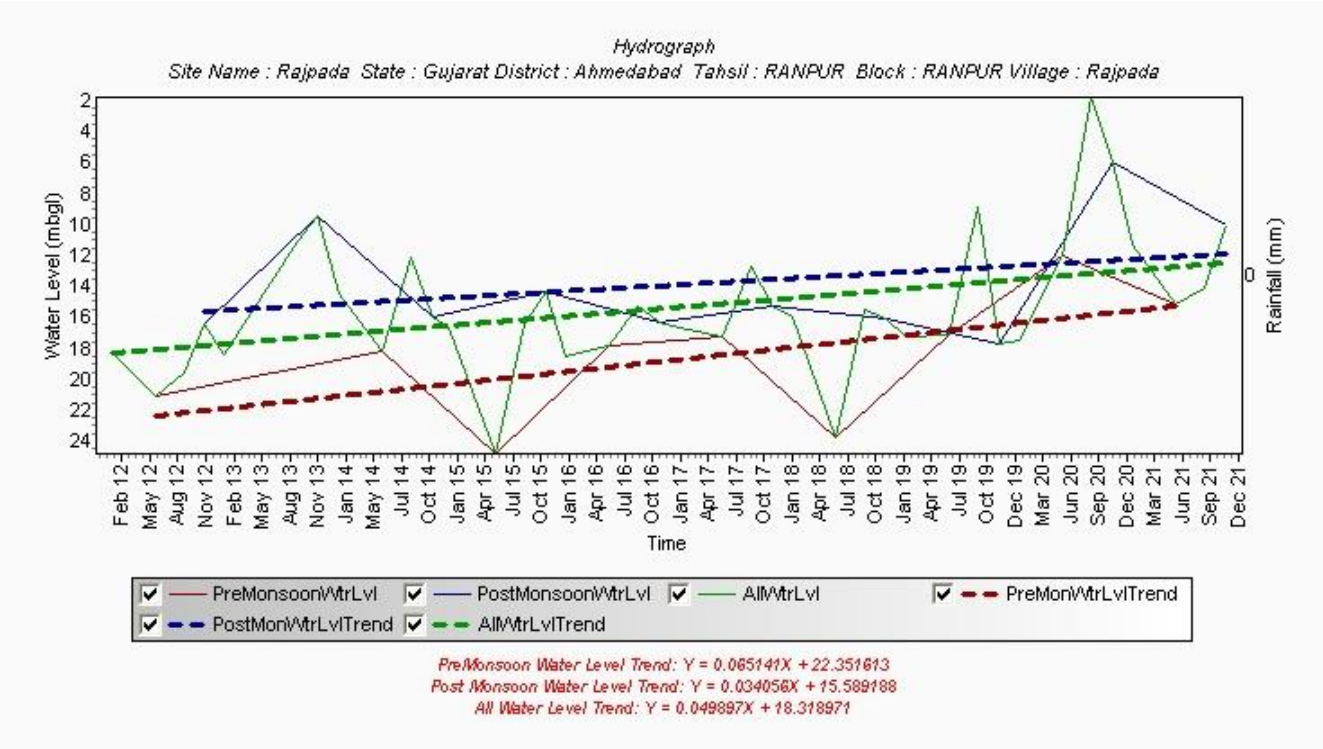

Figure 33: Hydrograph of Rajpada NHS well in Botad District

5. Chapter GROUND WATER RESOURCE POTENTIAL

5.1 Ground Water Resource Potential

The ground water resources of the district were calculated as on May 2020 in collaboration with the Government of Gujarat usingthe GEC-2015 methodology suggested by Ground Water Resource Estimation Committee (GWRE-2020). These resources were computed after reorganization of the districts, talukas of the district are considered as Assessment Unit (AU) and total area of 2561.12 sq km are taken as area of assessment of the district including 04 talukas. Computed resource are presented in tabulated (table-6) and graphically representedas below.

Table 14: 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 (GWRE-2020)																
Taluka	Total Area of Assessment Unit (Sq. Km.)	ANNUAL REPLENISHABLE GROUND WATER RESOURCE (Ham)				Total Annual Ground Water Recharge	Natural Discharge during non-monsoon season (Ham)	Net Annual Ground Water Availability (Ham)	ANNUAL GROUND WATER DRAFT (Ham)				Projected Demand for Domestic uses upto 2025 (Ham)	Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Category
		Monsoon		Non-monsoon					Irrigation	Domestic use	Industrial use	Total				
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources											
Barwala	48472	1287.39	66.5	0	167.22	1521.11	76.04	1445.06	793.6	0	0	793.6	0	651.46	54.92	safe
Botad	74940	13622.1	883.23	0	1213.71	15719.04	785.96	14933.08	8396.3	0	0	8396.3	0	6536.78	56.23	safe
Gadhada	89790	11085.11	1221.78	0	2025.18	14332.07	716.6	13615.47	9439.7	0	0	9439.7	0	4175.77	69.33	safe
Ranpur	42910	17271.72	269.77	0	414.04	17955.53	897.77	17057.76	4420.1	0	0	4420.1	0	12637.66	25.91	safe
Total	**256112**	**43266.32**	**2441.28**	**0**	**3820.15**	**49527.75**	**2476.37**	**47051.37**	**23049.7**	**0**	**0**	**23049.7**	**0**	**24001.67**	**48.99**	**Safe**

Note: **Data for Annual Groundwater draft for domestic and irrigation use for the year 2020 is not available**

As per GWRE 2020 the total ground water resources of Botad district is order of **49527.75** Ham/year and utilisable resources are **47051.37** Ham/year. The net annual drafts of **23049.7** Ham/year leaves a balance of **24001.67**Ham/year of ground water available for future development.

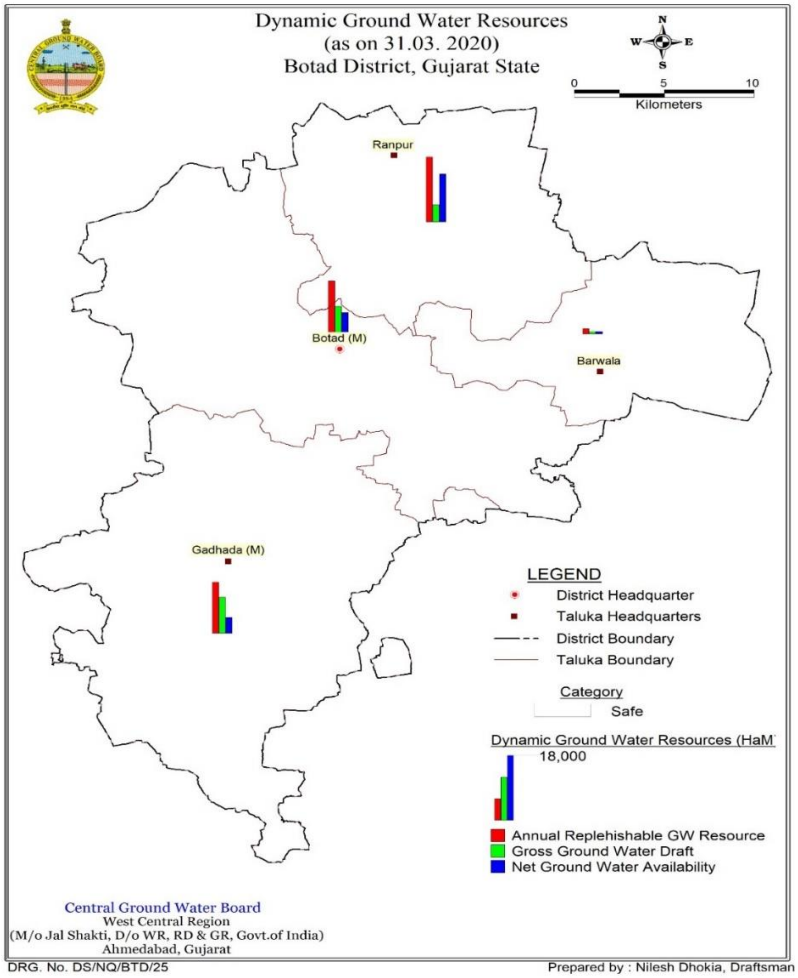

Figure 34: Dynamic Groundwater Resources Botad District.

5.2 Ground Water Recharge:

Total Annual Ground Water Recharge from Rainfall and other sources for both monsoon and non-monsoon season for the district is 49527.75 Ham. And ground water recharge in talukas varies from 14332.07 Ham (Gadhada taluka) to 17955.53 Ham (Ranpur Taluka).

5.3 Net Ground Water Availability:

Annual extractable ground water resource/ net ground water availability of the district is 47051.37 ham which computed after deducting total natural discharge of 2476.37 ham from total annual ground water recharge.

5.4 Annual Ground Water Draft

The gross ground water draft for all uses (i.e. Irrigation, Domestic and Industrial uses) in the district is 23049.7. The existing gross ground water extraction for all uses varies from 793.6 Ham (Barwala taluka) to 9439.7 (Gadhada Taluka). Approximately 96 % of ground water extraction are used for Irrigational purposes, remaining 5% are being extracted mainly for Domestic and Industrial purposes (very less) (as per GWRE 2017).

5.5 Projected demand for Domestic and Industrial use up to 2025

The total Projected demand of ground water for Domestic and Industrial uses in the district is very less or negligible.

5.6 Ground water Availability for future Irrigation

Net ground water availability for future use in the district is 24001.67 Ham. Taluka wise it varies from 651.46 Ham (Barwala taluka) to 12637.66 (Ranpur taluka).

5.7 Stage of Ground Water Extraction

As per the Ground Water Resource Estimation (GWRE-2020), the stage of Ground Water extraction of the district is 51.60 % which categorized as Safe. Whereas in taluka it varies from 25.91% (Ranpur Taluka) to 69.33 % (Gadhada Taluka) and all the 04 talukas of the district are categorized as SAFE.

6. Chapter HYDROCHEMISTRY

Variation in chemical quality of ground water is due to hydrogeological factors controlled by rock types, depicting aerial distribution of various water quality features.

Groundwater in the district is in general potable and fresh, both in phreatic and confined aquifers within 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) in May 2021 from CGWB and Chemical data from Gujarat Water Resources Development Corporation (GWRDC) were also incorporated, and presented in Table-16. The ground water is in general alkaline in nature

Table 15: Statistical Analysis of Chemical Constituents of Ground Water in Botad District, May 2021

Constituents	Minimum	Maximum	Average
pH	7.2	8.8	7.87
EC (uS/cm)	330	8873	2526.98
Alkalinity (mg/l)	120	1200.9	329.8
TDS (mg/l)	221.1	5944.91	1693.1
HCO_3 (mg/l)	146.4	1464.24	376.66
Cl (mg/l)	28.36	2683.8	495.8
SO_4 (mg/l)	17.75	975	155.74
NO_3 (mg/l)	1.1	522	100.28
Ca (mg/l)	12	372.74	107.61
Mg (mg/l)	4.86	433	80.66
Na (mg/l)	28	1600	304.15
K (mg/l)	0	30.5	2.93
F (mg/l)	.22	4.8	0.91

6.1 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 7.2 (Botad) & 8.8 (Rohisala) in the district

6.2 Total Dissolved Solid (TDS)

Total Dissolved Solid is an overall parameter indicating salinity of ground water. 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. The Total Dissolved Solid of ground water varies from 221.10 mg/l to about 5944.91 mg/l (Meghavadiya). From fig 36, it is concluded that the TDS values are higher in and around areas of Ranpur, Barwala and Gadhda Taluka. About 23% Groundwater sample have TDS values more than the permissible limits.

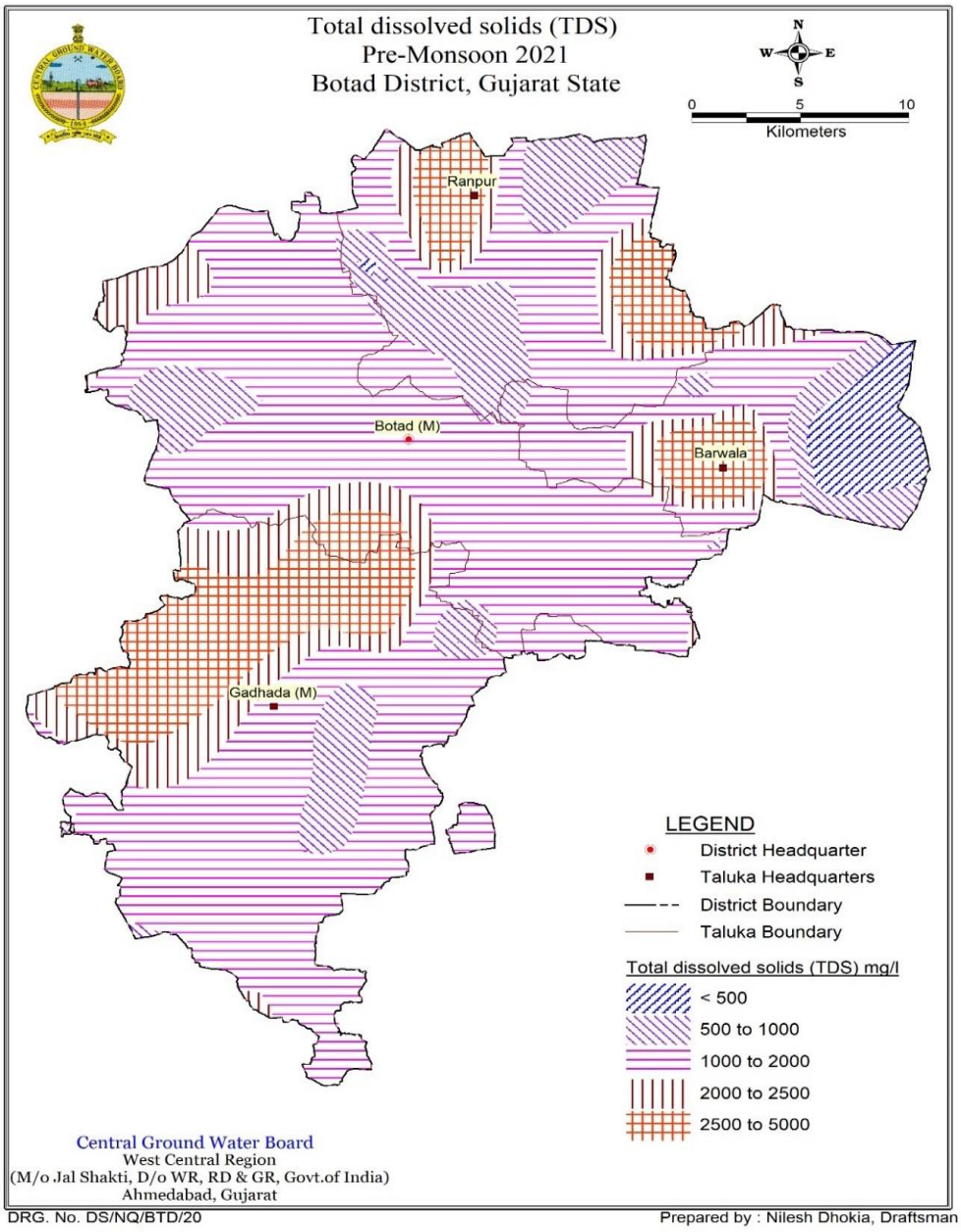

Figure 35: Map showing Taluka wise Total dissolve solids (TDS) values of Botad District

6.3 Carbonate (CO_3) and Bicarbonate (HCO_3)

The shallow ground water in Botad district contain small amount of Carbonate at few places. The Bicarbonate concentration in district are varies in between 146.40 mg/l (Navda) to 1464.24 mg/l (Barwala).

6.4 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-36, a very small patches in Gadhada taluka (Meghavadiya, Tatam, Limbali) and Ranpur Taluka (Chandarva) shows Cl concentration is more than permissible limit.

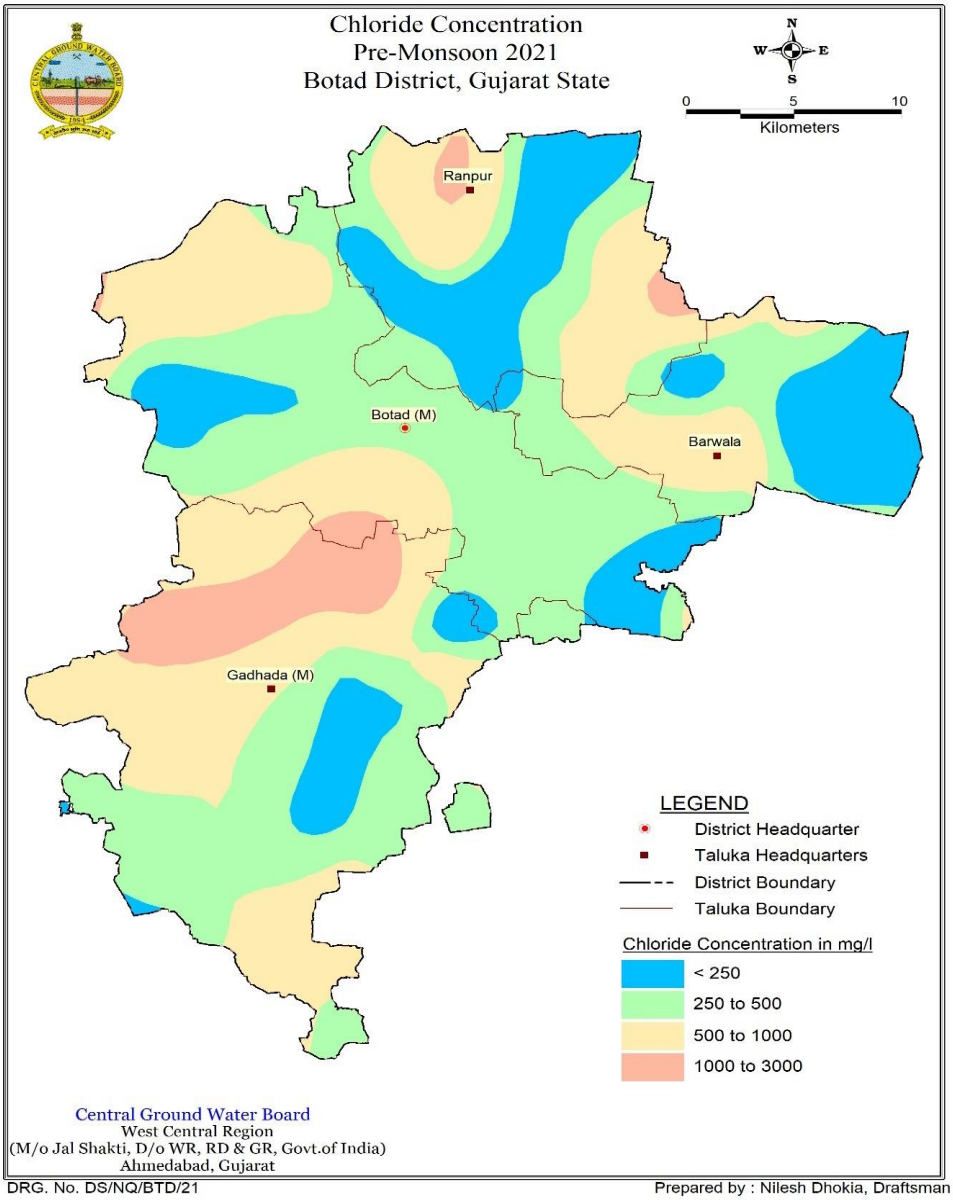

Figure 36: Map showing Taluka wise Chloride(CL) values of Botad District

6.5 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 1.10 mg/l (Navda) and 522 mg/l (Limbali). There are 33 isolated monitoring stations where these values are more than the limits as per BIS drinking water standards (45 mg/l) as shown in figure 37.

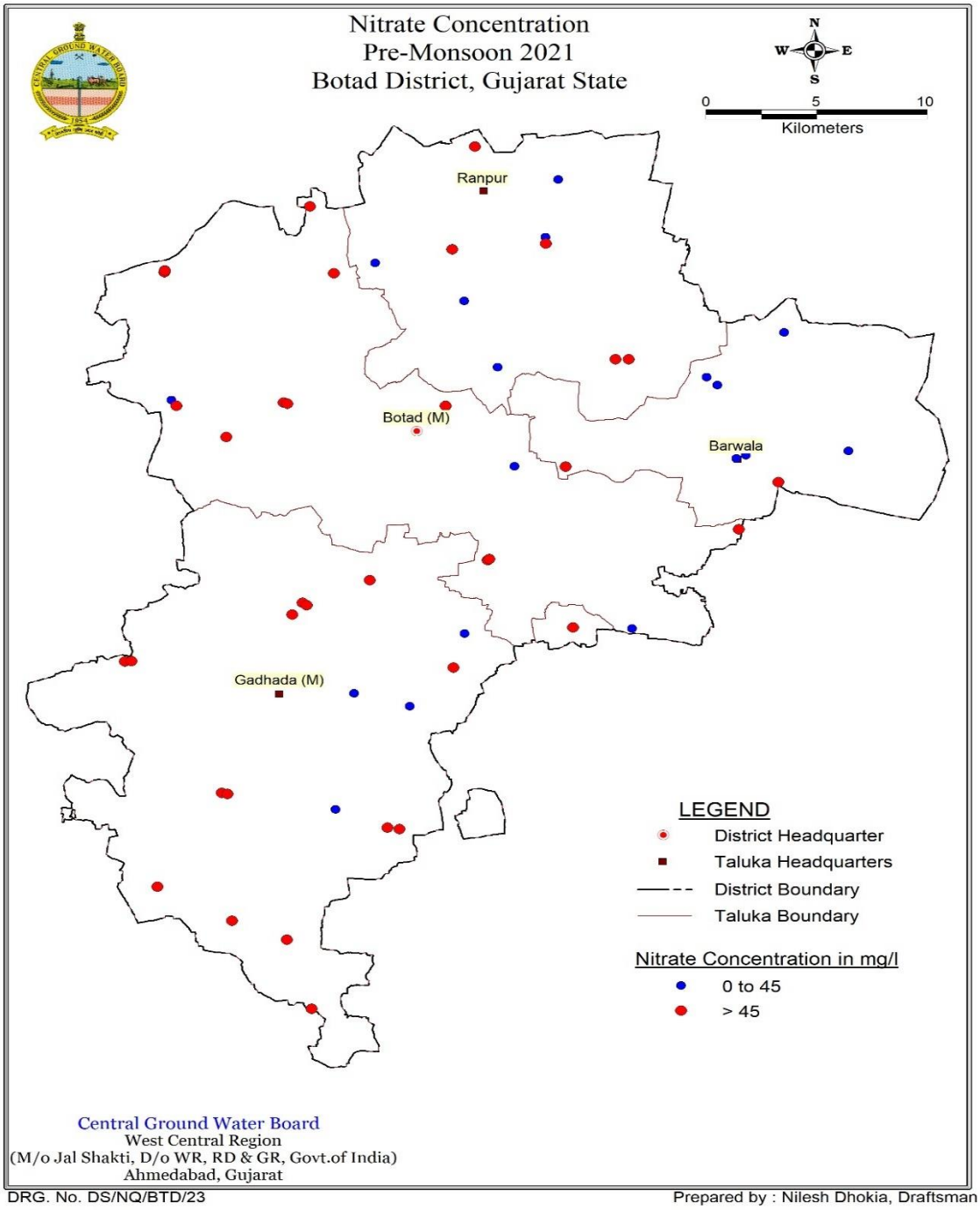

Figure 37: Map showing Taluka wise Nitrate values of Botad District

6.6 Sulphate (SO_4)

In the district, Sulphate concentration varies from 17.75 mg/l (12 locations) to 975 mg/l (Barwala).

6.7 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 Botad district are varies in between almost 0.22 mg/l (Rajpeepla village) and 4.80 mg/l (Kapadiyali village of Barwala taluka). There are 7 isolated locations where Fluoride concentration is more than permissible limit as presented in figure 38.

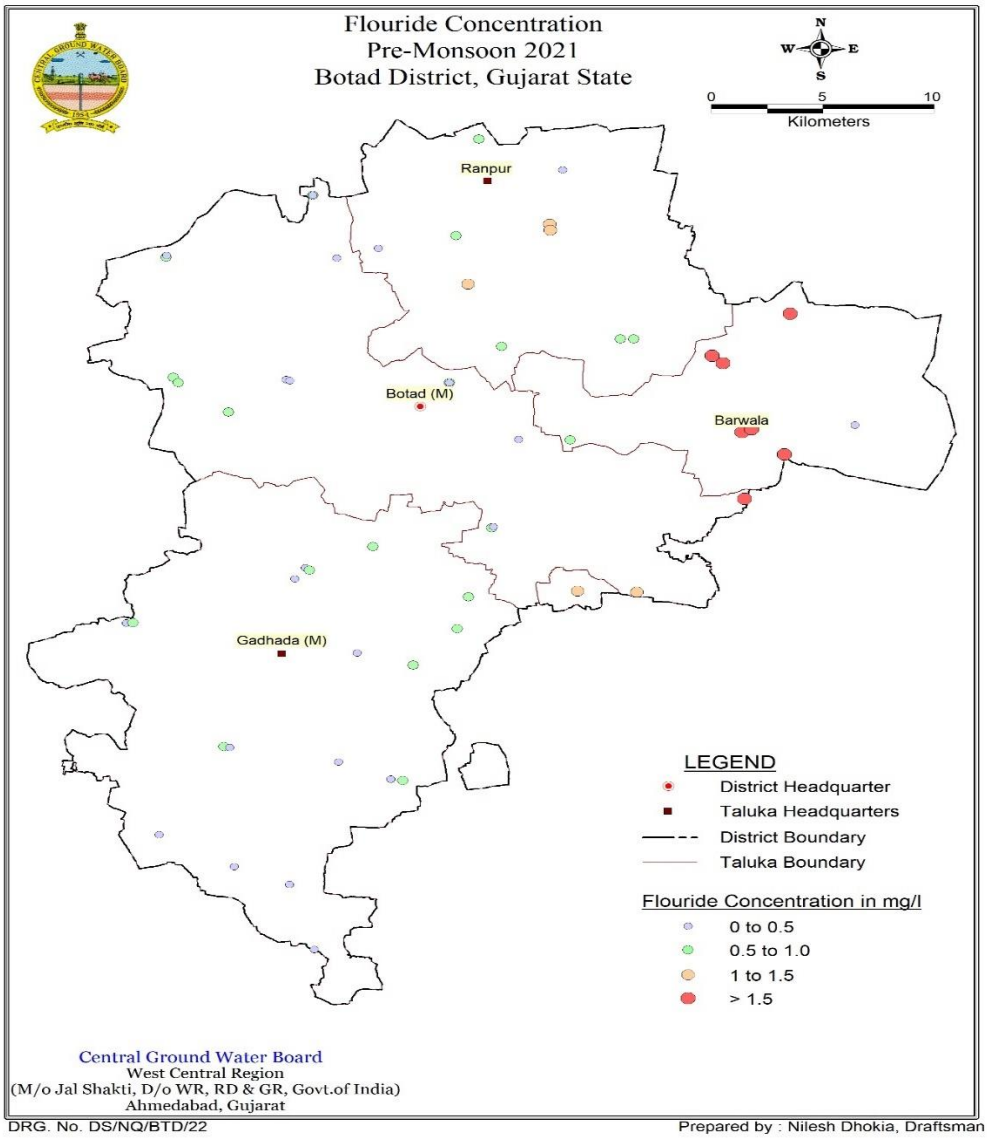

Figure 38: Map showing Taluka wise Fluoride values of Botad District.

6.8 Iron (Fe):

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Iron(Fe) are 0.3 mg/l. Iron concentration in Botad district are varies in between almost 0.009 mg/l (Kapadiya village) and 0.653 mg/l (Nagnesh village of Ranpur taluka). There are 2

isolated location where Iron concentration is more than permissible limit as presented in figure 39.

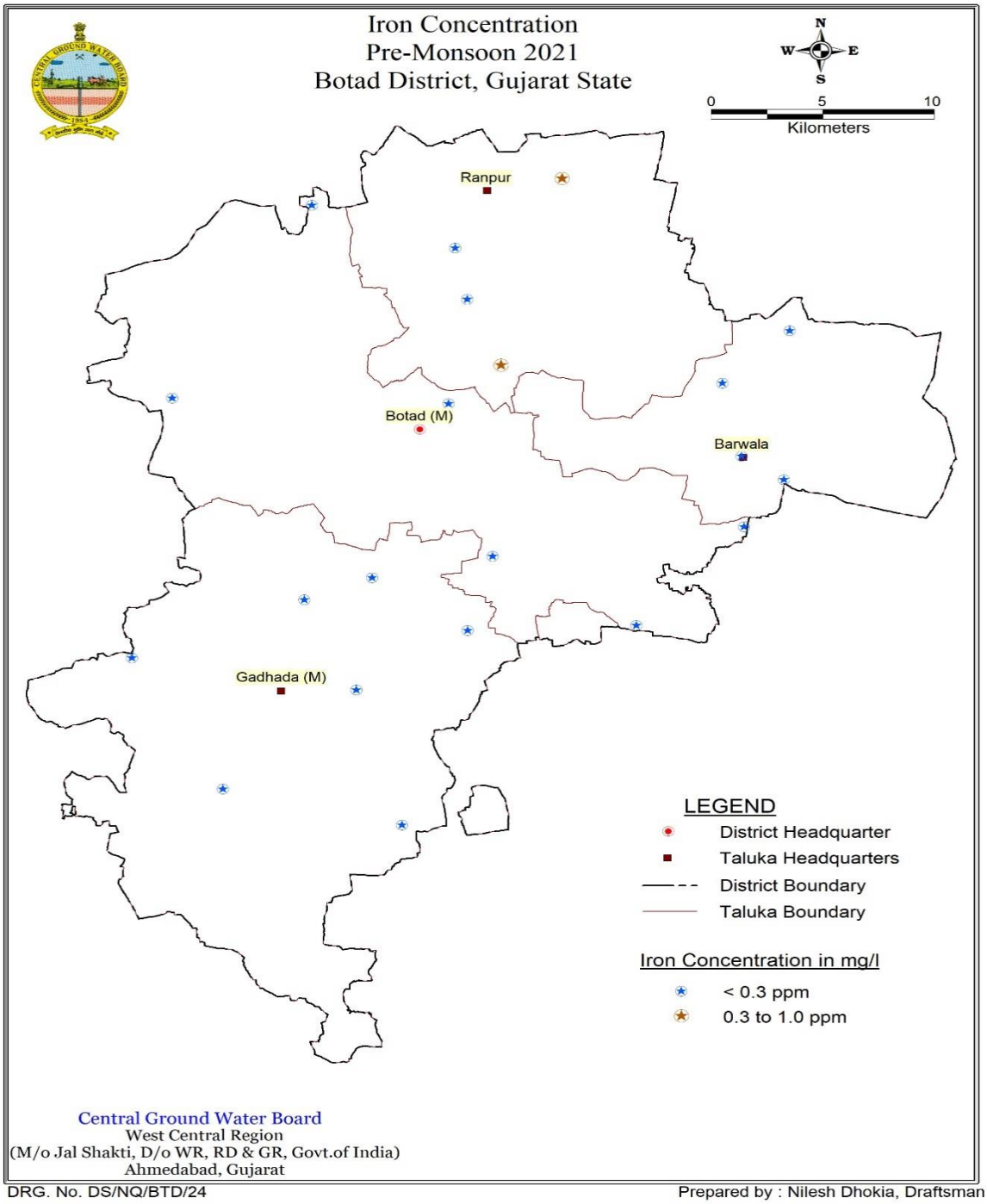

Figure 39: Map showing Taluka wise Iron values of Botad District

6.9 Calcium (Ca)

Calcium concentration in district varies between 12 mg/l (Rohisala village) and 372.74 mg/l (Gadhadiya)). The concentration of calcium is found within permissible limits in the district (permissible limit as per BIS norms is 200 mg/l) except ten location i.e. AniyariKasbati,

Gadhadiya, Meghavadiya, Ingorala, Dhasa, Mota Umarda, Jalapur, Rajpeepla, Padvadar, Rajpada village.

6.10 Magnesium (Mg)

The Concentration of Magnesium in areas ranges from 4.86 mg/l (Nagnesh) to 433 mg/l (Limbali). In isolate villages namely Bodi (107.008 mg/l), Godhawata (150.784 mg/l), Botad(182 mg/l), Bhadravati (122 mg/l), Meghavadiya (348 mg/l), Sitapar (151 mg/l), Jalapur (105 mg/l), Limbali (433 mg/l), Samadhiyala (126 mg/l) Saranpur (136 mg/l), Rajpada (141 mg/l), Tatam (348 mg/l) the concentration of Magnesium is more than maximum permissible limits of 100 mg/l (as per BIS norms).

6.11 Sodium (Na)

Sodium concentration in the district varies between 28 mg/l (Navda) and 1600 mg/l (Barvala).

6.12 Potassium (K)

The concentration of Potassium in shallow ground water ranges from 0.00 mg/l (Umrala) to 30.50 mg/l (Meghavadiya).

7. Chapter
SUSTAINABLE GROUNDWATER DEVELOPMENT AND MANAGEMENT

7.1 Groundwater related issue

7.1.1 Low Ground water development

As per GWRE 2020 the total ground water resources of the district are in order of 49527.75 Ham/year and utilizable resources are 47051.37 Ham/year. The net annual drafts of 23049.7 Ham/year leaves a balance of 24001.67 Ham/year of ground water available for future development. Ground water Development: Stage of Ground water development of the district is 51.60%, however talukas wise it ranges from 25.91% (Ranpur taluka) to 69.33% (Gadhada taluka).

7.1.2 Sustainability

Most part of the district has secondary porosity in the form of weathered & fractured rock which forms the good repository or major aquifer of groundwater. Yield in this formation varies from 100 to 500 m^3/day. The yield from bore wells have reduced in a lean period, recoupment time in some phreatic aquifer is very low that's the reason people residing there constructed large diameter of well for maximum storage.

7.1.3 Reasons for Issues

Sustainability: Absence of primary porosity and very low development of secondary porosity, de-saturation of weathered zone and permeability.

- Ground water contamination due to unscientific well construction.
- Uniformity in pumping pattern is required.
- Demand vis-a-vis supply management.

Awareness among the people regarding rainwater harvesting and artificial recharge

7.2 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 2020 all the four (04) talukas of the district are under **safe** category. Stage of Ground water development of the district is 51.60%, however talukas wise it ranges from 25.91% (Ranpur taluka) to 69.33% (Gadhada taluka).

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

7.3 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

7.3.1 Ground water Development Plan

To elevate the stage of ground water development 52% in district, **1632** nos. of Dug wells (around 15m depth) are proposed as feasible extraction structures (table 18). The extraction structures will result as expected annual ground water draft of **856** ham which will create **1901** Ha additional irrigation potential in the district.

Table 16: Feasible Extraction structures to elevate the Stage of GW development to 52% (Hard Rock)

Extraction / Talukas	Feasible Extraction structures to elevate the Stage of GW development to 52% (Hard Rock)	G.W Draft from Extraction structures (ham)	Additional Irrigation Potential Created (Ha)
	DW		
Barwala	78	39	87
Botad	1056	528	1173
Gadhada	0	39	87
Ranpur	499	250	554
Total	1632	856	1901

7.3.2 Supply side interventions

As per Master Plan 2020, surplus surface water of 15 mcm non committed is allocated to suggest artificial recharge in district of Botad. To harvest the surface water the different artificial recharge structures are proposed as Recharge shaft, Percolation tank and use existing defunct tube well to recharge the aquifer which is presented in table 19. Expected annual Groundwater recharge is **1246.2** ham through Recharge Shaft of total **317** nos. of 3 ham/ shaft capacity. And 2 nos. of existing defunct tube well are recommended for harvesting the part of available runoff and to recharge the Groundwater.

❖ Recharge shaft

This is the most efficient and cost-effective technique to recharge unconfined aquifer overlain by poorly permeable strata. Recharge shaft may be dug manually if the strata are of non-caving nature. The diameter of shaft is normally more than 2 m. The shaft should end in more permeable strata below the top impermeable strata. It may not touch water table. The unlined shaft should be backfilled, initially with boulders/ cobbles followed by gravel and coarse sand.

In case of lined shaft, the recharge water may be fed through a smaller conductor pipe reaching up to the filter pack. These recharge structures are very useful for village ponds where shallow clay layer impedes the infiltration of water to the aquifer.

It is seen that in rainy season village tanks are fully filled up but water from these tanks does not percolate down due to siltation and tube well and dug wells located nearby remains dried up. The water from village tanks gets evaporated and is not available for the beneficial use. By constructing recharge shaft in tanks, surplus water can be recharged to ground water. Recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed depending upon availability of quantum of water. The top of shaft is kept above the tank bed level preferably at half of full supply level. These are back filled with boulders, gravels and coarse sand. In upper portion of 1 or 2 m depth, the brick masonry work is carried out for the stability of the structure.

Through this technique all the accumulated water in village tank above 50% full supply level would be recharged to ground water. Sufficient water will continue to remain in tank for domestic use after recharge.

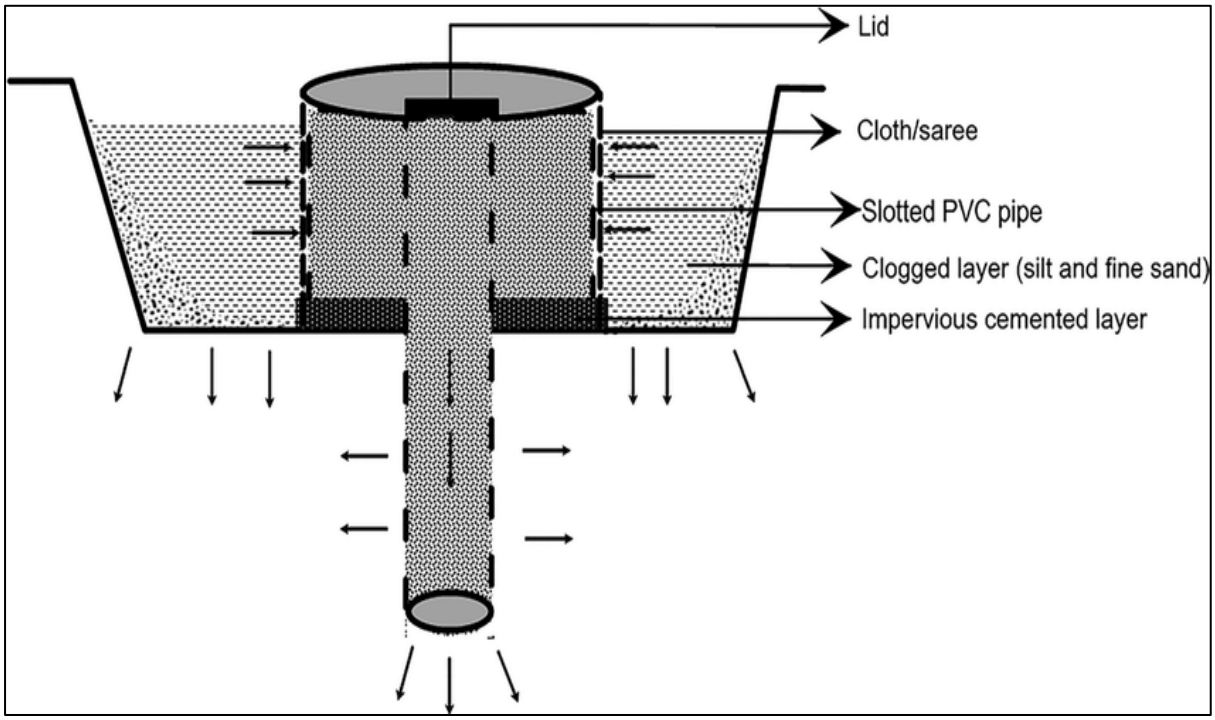

Figure 40 Schematic diagram of Recharge Shaft.

Advantages of Recharge Shaft

It does not require acquisition of large piece of land as in case of percolation tanks. There are practically no losses of water in the form of soil moisture and evaporation, which normally occur when the source water has to traverse the vadose zone.

7.3.3 Demand side intervention

Feasible extraction structures are proposed to elevate the stage of ground water development to 52%, to avoid further exploitation demand side management is also recommended to restrict the stage of ground water development to 45%. An area of 115 Ha is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding), and 91 no. of farm ponds are recommended. which will serve dual purpose of irrigation and recharge to ground water. And expected conservation of ground water through efficiency enhancement measures is 33.37 ham is expected for the district.

- **Farm Ponds**

A farm pond is a large hole dug out in the earth, usually square or rectangular in shape (Fig. 32), 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 thebanks 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.

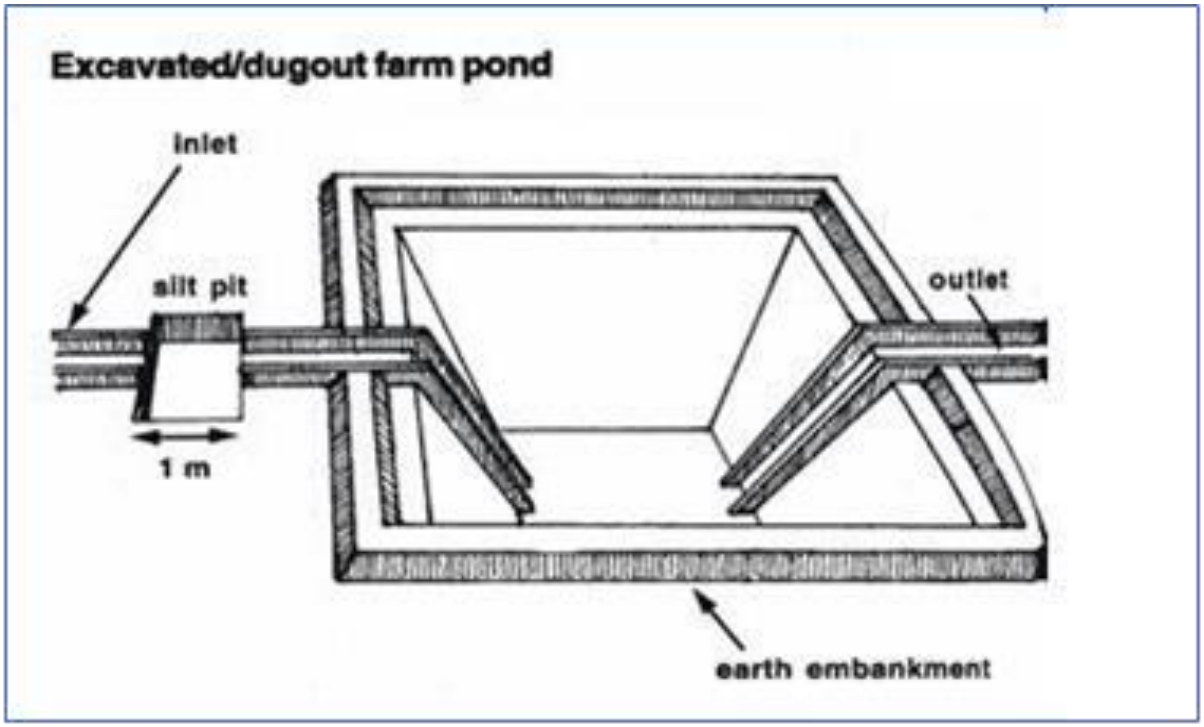

Figure 41: Schematic diagram of Farm Pond

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, thenumber 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 withan 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 17: Proposed Artificial Recharge and WUE Interventions in Botad District

Recharge / Talukas	Artificial Recharge through Recharge Shaft	Defunct Wells with capacity to recharge @ 3Ham	On farm Activities (Area in ha)	Farm Pond (Per Farm Pond Storage 0.576 m3 considered as per DIP.)	Additional Recharge from Recharge interventions (ham)
Barwala	88	0	4	15	282.4
Botad	146	0	42	24	442.2
Gadhada	0	0	47	33	264.4
Ranpur	83	2	22	19	257.2
District	317	2	115	91	1246.2

Table 18: Projected Status of Groundwater Resource after implementation of GW Management Plan, Botad District (Gujarat)

Projected Status of Groundwater Resource after implementation of GW Management Plan, Botad 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 %)	Additional Irrigation Potential Created (Ha)
Barwala	1445.06	282.4	0.00	10.14	1737.60	793.6	0.00	4.83	39	827.77	54.92	57	57	48	87
Botad	14933	442.2	0	132	15507	8396	0	9	528	8915	56.23	59	59	57	1173
Gadhada	1445.06	264.4	0.00	10.14	1719.60	793.6	0.00	4.83	39	827.77	54.92	57	57	48	87
Ranpur	17058	257.2	0	65	17380	4420	0	7	250	4663	25.91	27	27	27	554
Total	34881	1246.2	0	217	36344	14404	0	26	856	15233	48	50	50	45	1901

8. CONCLUSION AND RECOMMENDATIONS

- Artificial recharge structures like recharge shaft are proposed in the district to encounter needed surface runoff.
- To elevate the stage of ground water development 52% in district, **1632** nos. of Dug wells (around 15m depth) are proposed as feasible extraction structures
- The extraction structures will result as expected annual ground water draft of **856** ham which will create **1901** Ha additional irrigation potential in the district.
- To prevent Over Exploitation, water conservation activities like on farm activities, farm ponds are recommended.
- Expected annualGroundwater recharge is **1246.2** ham through Recharge Shaft of total **317** nos. of 3 ham/ shaft capacity. And 2 nos. of existing defunct tube well are recommended for harvesting the part of available runoff and to recharge the Groundwater.
- An area of 115 Ha is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding), and 91 no. of farm ponds are recommended. which will serve dual purpose of irrigation and recharge to ground water.
- 25.86 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 15 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 and Post monsoon_2021 water level data of Botad District.

AGENCY	DNAME	TNAME	SITE_NAME	LOCAL_GEOL	AQUIFER_TY	X	Y	DEPTH	PRE_2021	POST_2021
CGWB	BOTAD	BARWALA	Barvala	Alluvium	Unconfined	71.89	22.15	21.00	4.39	1.64
CGWB	BOTAD	RANPUR	Kundali	Basalt	Unconfined	71.70	22.27	16.00	9.97	0.00
CGWB	BOTAD	RANPUR	Rajpada	Basalt	Unconfined	71.69	22.31	23.00	15.09	10.05
CGWB	BOTAD	BARWALA	Salangpor	Basalt	Unconfined	71.77	22.16	22.75	0.00	5.23
CGWB	BOTAD	GADHADA	Dhasa	Basalt	Unconfined	71.51	21.80	9.82	5.71	1.45
CGWB	BOTAD	GADHADA	Gadhada2	Basalt	Unconfined	71.58	21.97	7.08	0.00	2.50
CGWB	BOTAD	BOTAD	Lonjdhara	Basalt	Unconfined	71.90	22.10	31.38	13.22	7.76
CGWB	BOTAD	GADHADA	Ningala	Basalt	Unconfined	71.70	22.02	19.00	4.40	4.99
CGWB	BOTAD	BOTAD	Paliyad	Basalt	Unconfined	71.56	22.26	40.00	0.00	0.00
CGWB	BOTAD	BOTAD	Paliyad2	Basalt	Unconfined	71.56	22.26	25.00	0.00	0.30
CGWB	BOTAD	BOTAD	Tardhera	Basalt	Unconfined	71.60	22.23	30.01	21.86	0.00
CGWB	BOTAD	GADHADA	Tatam	Basalt	Unconfined	71.63	22.06	36.38	10.30	4.82
NAQUIM	Botad	Barwala	Chokdi	Basalt	Unconfined	71.93	22.25	15.24	3.26	3.35
NAQUIM	Botad	Barwala	Barwala	Basalt	Unconfined	71.90	22.15	18.28	2.99	2.79
NAQUIM	Botad	Barwala	Navda	Basalt	Unconfined	71.97	22.16	13.72	2.99	2.79
NAQUIM	Botad	Barwala	Kapadiyali	Basalt	Unconfined	71.92	22.13	16.76	3.65	7.40
NAQUIM	Botad	Ranpur	Chandarva	Basalt	Unconfined	71.87	22.27	21.34	2.10	6.60
NAQUIM	Botad	Ranpur	Malanpur	Basalt	Unconfined	71.76	22.32	18.29	2.70	12.19
NAQUIM	Botad	Ranpur	Nagnesh	Basalt	Unconfined	71.77	22.36	30.48	2.70	7.20
NAQUIM	Botad	Ranpur	Aniyari Kasbati	Basalt	Unconfined	71.71	22.39	18.29	4.00	14.52
NAQUIM	Botad	Botad	Limboda	Basalt	Unconfined	71.59	22.34	21.34	3.50	1.20
NAQUIM	Botad	Ranpur	Umrala	Basalt	Unconfined	71.64	22.30	21.34	3.66	3.10
NAQUIM	Botad	Botad	Gadhadiya	Basalt	Unconfined	71.49	22.29	18.29	5.00	12.10
NAQUIM	Botad	Barwala	Rojid	Basalt	Unconfined	71.88	22.21	30.48	2.00	10.45

NAQUIM	Botad	Ranpur	Godhawata	Basalt	Unconfined	71.81	22.23	35.05	2.50	7.30
NAQUIM	Botad	Ranpur	Khas	Basalt	Unconfined	71.72	22.22	36.58	2.50	3.60
NAQUIM	Botad	Botad	Botad	Basalt	Unconfined	71.69	22.19	30.48	4.10	7.80
NAQUIM	Botad	Botad	Bhadravati	Basalt	Unconfined	71.58	22.19	18.29	2.50	3.26
NAQUIM	Botad	Botad	Turkha	Basalt	Unconfined	71.53	22.17	18.29	3.50	2.42
NAQUIM	Botad	Botad	Sarwa	Basalt	Unconfined	71.49	22.19	30.48	2.90	6.75
NAQUIM	Botad	Gadhadha	Meghavadiya	Basalt	Unconfined	71.59	22.04	21.34	7.35	5.12
NAQUIM	Botad	Botad	Ratanpar	Basalt	Unconfined	71.58	22.03	15.24	4.95	5.90
NAQUIM	Botad	Gadhadha	Sitapar	Basalt	Unconfined	71.47	21.88	30.48	2.55	3.46
NAQUIM	Botad	Gadhadha	Rasnal	Basalt	Unconfined	71.48	21.83	27.43	3.60	9.10
NAQUIM	Botad	Gadhadha	Dhasa	Basalt	Unconfined	71.54	22.80	30.48	5.50	7.80
NAQUIM	Botad	Gadhadha	Mota Umarda	Basalt	Unconfined	71.59	21.73	31.70	4.46	9.14
NAQUIM	Botad	Gadhadha	Jalapur	Basalt	Unconfined	71.57	21.79	30.48	3.10	10.82
NAQUIM	Botad	Gadhadha	Rajpeepla	Basalt	Unconfined	71.65	21.87	21.34	3.35	4.70
NAQUIM	Botad	Gadhadha	Chiroda	Basalt	Unconfined	71.61	21.89	15.24	3.30	3.14
NAQUIM	Botad	Gadhadha	Padvadar	Basalt	Unconfined	71.53	21.90	22.86	3.55	18.10
NAQUIM	Botad	Gadhadha	Limbali	Basalt	Unconfined	71.47	22.00	15.24	3.80	8.48
NAQUIM	Botad	Gadhadha	Adtala	Basalt	Unconfined	71.62	21.97	21.34	3.16	6.30
NAQUIM	Botad	Gadhadha	Nana Zinzavadar	Basalt	Unconfined	71.69	21.99	15.24	4.65	6.68
NAQUIM	Botad	Botad	Tajpar	Basalt	Unconfined	71.72	22.07	21.34	2.25	5.84
NAQUIM	Botad	Botad	Samadhiyala	Basalt	Unconfined	71.74	22.14	18.29	5.25	2.34
NAQUIM	Botad	Botad	Rohisala	Basalt	Unconfined	71.82	22.02	19.81	2.95	2.35

AGENCY	DNAME	TNAME	SITE_NAME	LOCAL_GEOL	AQUIFER_TY	X	Y	DEPTH	PRE_2021	POST_2021
CGWB	BOTAD	BARWALA	Barvala	Alluvium	Unconfined	71.89	22.15	21.00	4.39	1.64
CGWB	BOTAD	RANPUR	Kundali	Basalt	Unconfined	71.70	22.27	16.00	9.97	0.00
CGWB	BOTAD	RANPUR	Rajpada	Basalt	Unconfined	71.69	22.31	23.00	15.09	10.05
CGWB	BOTAD	BARWALA	Salangpor	Basalt	Unconfined	71.77	22.16	22.75	0.00	5.23
CGWB	BOTAD	GADHADA	Dhasa	Basalt	Unconfined	71.51	21.80	9.82	5.71	1.45
CGWB	BOTAD	GADHADA	Gadhada2	Basalt	Unconfined	71.58	21.97	7.08	0.00	2.50
CGWB	BOTAD	BOTAD	Lonjdhara	Basalt	Unconfined	71.90	22.10	31.38	13.22	7.76
CGWB	BOTAD	GADHADA	Ningala	Basalt	Unconfined	71.70	22.02	19.00	4.40	4.99
CGWB	BOTAD	BOTAD	Paliyad	Basalt	Unconfined	71.56	22.26	40.00	0.00	0.00
CGWB	BOTAD	BOTAD	Paliyad2	Basalt	Unconfined	71.56	22.26	25.00	0.00	0.30
CGWB	BOTAD	BOTAD	Tardhera	Basalt	Unconfined	71.60	22.23	30.01	21.86	0.00
CGWB	BOTAD	GADHADA	Tatam	Basalt	Unconfined	71.63	22.06	36.38	10.30	4.82
NAQUIM	Botad	Barwala	Chokdi		Unconfined	71.93	22.25	15.24	3.26	3.35
NAQUIM	Botad	Barwala	Barwala		Unconfined	71.90	22.15	18.28	2.99	2.79
NAQUIM	Botad	Barwala	Navda		Unconfined	71.97	22.16	13.72	2.99	2.79
NAQUIM	Botad	Barwala	Kapadiyali		Unconfined	71.92	22.13	16.76	3.65	7.40
NAQUIM	Botad	Ranpur	Chandarva		Unconfined	71.87	22.27	21.34	2.10	6.60
NAQUIM	Botad	Ranpur	Malanpur		Unconfined	71.76	22.32	18.29	2.70	12.19
NAQUIM	Botad	Ranpur	Nagnesh		Unconfined	71.77	22.36	30.48	2.70	7.20
NAQUIM	Botad	Ranpur	Aniyari Kasbati		Unconfined	71.71	22.39	18.29	4.00	14.52
NAQUIM	Botad	Botad	Limboda		Unconfined	71.59	22.34	21.34	3.50	1.20
NAQUIM	Botad	Ranpur	Umrala		Unconfined	71.64	22.30	21.34	3.66	3.10
NAQUIM	Botad	Botad	Gadhadiya		Unconfined	71.49	22.29	18.29	5.00	12.10
NAQUIM	Botad	Barwala	Rojid		Unconfined	71.88	22.21	30.48	2.00	10.45
NAQUIM	Botad	Ranpur	Godhawata		Unconfined	71.81	22.23	35.05	2.50	7.30

NAQUIM	Botad	Ranpur	Khas		Unconfined	71.72	22.22	36.58	2.50	3.60
NAQUIM	Botad	Botad	Botad		Unconfined	71.69	22.19	30.48	4.10	7.80
NAQUIM	Botad	Botad	Bhadravati		Unconfined	71.58	22.19	18.29	2.50	3.26
NAQUIM	Botad	Botad	Turkha		Unconfined	71.53	22.17	18.29	3.50	2.42
NAQUIM	Botad	Botad	Sarwa		Unconfined	71.49	22.19	30.48	2.90	6.75
NAQUIM	Botad	Gadhadha	Meghavadiya		Unconfined	71.59	22.04	21.34	7.35	5.12
NAQUIM	Botad	Botad	Ratanpar		Unconfined	71.58	22.03	15.24	4.95	5.90
NAQUIM	Botad	Gadhadha	Sitapar		Unconfined	71.47	21.88	30.48	2.55	3.46
NAQUIM	Botad	Gadhadha	Rasnal		Unconfined	71.48	21.83	27.43	3.60	9.10
NAQUIM	Botad	Gadhadha	Dhasa		Unconfined	71.54	22.80	30.48	5.50	7.80
NAQUIM	Botad	Gadhadha	Mota Umarda		Unconfined	71.59	21.73	31.70	4.46	9.14
NAQUIM	Botad	Gadhadha	Jalapur		Unconfined	71.57	21.79	30.48	3.10	10.82
NAQUIM	Botad	Gadhadha	Rajpeepla		Unconfined	71.65	21.87	21.34	3.35	4.70
NAQUIM	Botad	Gadhadha	Chiroda		Unconfined	71.61	21.89	15.24	3.30	3.14
NAQUIM	Botad	Gadhadha	Padvadar		Unconfined	71.53	21.90	22.86	3.55	18.10
NAQUIM	Botad	Gadhadha	Limbali		Unconfined	71.47	22.00	15.24	3.80	8.48
NAQUIM	Botad	Gadhadha	Adtala		Unconfined	71.62	21.97	21.34	3.16	6.30
NAQUIM	Botad	Gadhadha	Nana Zinzavadar		Unconfined	71.69	21.99	15.24	4.65	6.68
NAQUIM	Botad	Botad	Tajpar		Unconfined	71.72	22.07	21.34	2.25	5.84
NAQUIM	Botad	Botad	Samadhiyala		Unconfined	71.74	22.14	18.29	5.25	2.34
NAQUIM	Botad	Botad	Rohisala		Unconfined	71.82	22.02	19.81	2.95	2.35

Annexure- II- Pre monsoon_2021 Water Quality Data (Basic) Well inventory (established well) of Botad District.

Taluka	Location	Source	pH	EC µs/cm at 25°C	TDS	CO3	HCO3	Cl	NO3	SO4	F	Alk	Ca	Mg	TH	Na	K	SiO2	SAR	Lat	Long
											mg/l							mg/l			
Barwala	Chokdi	DW	8.07	3057	2048	0	598	461	14	360	2.1	490.4	20.0	26.8	160.1	598.0	0.1	37.0	20.6	22.245121	71.925555
Barwala	Barwala	Pz	7.70	5229	3503	0	1464	666	2.8	490	3.3	1201.0	40.1	48.6	300.2	1040.0	0.2	80.0	26.1	22.152521	71.898333
Barwala	Navda	DW	7.59	330	221	0	146	28	1.1	18	0.32	120.1	24.0	12.2	110.1	28.0	2.2	19.0	1.2	22.155555	71.970555
Barwala	Kapadiyali	DW	8.20	3536	2369	0	781	560	124	260	4.8	640.5	12.0	17.0	100.1	755.0	0.1	55.0	32.8	22.132223	71.921111
Ranpur	Chandarva	DW	7.89	5736	3843	0	781	1021	62	650	3.0	640.5	48.1	68.1	400.3	1080.0	0.5	54.0	23.5	22.269166	71.869722
Ranpur	Chandarva	Pz	7.79	6050	4054	0	830	1149	75	670	1.5	680.5	64.1	75.4	470.4	1130.0	0.5	64.0	22.7	22.269166	71.869722
Ranpur	Malanpur	DW	7.81	1380	925	0	647	78	37	50	1.2	530.4	20.0	51.1	260.2	225.0	0.4	62.0	6.1	22.317512	71.757521
Ranpur	Malanpur	Pz	7.97	1858	1245	0	683	206	61	68	1.3	560.4	20.0	31.6	180.1	350.0	0.2	72.0	11.3	22.312777	71.757777
Ranpur	Nagnesh	DW	7.68	750	503	0	220	92	34	45	0.28	180.1	40.1	4.9	120.1	115.0	1.2	35.0	4.6	22.361111	71.766388
Ranpur	Aniyari Kasbati	DW	7.44	4500	3015	0	342	1035	302	270	1.0	280.2	240.5	90.0	970.8	550.0	2.2	84.0	7.7	22.386111	71.707777
Botad	Limboda	DW	7.89	2116	1418	0	305	468	50	143	0.38	250.2	72.1	90.0	550.4	225.0	12.3	51.0	4.2	22.341111	71.591388
Botad	Limboda	Pz	7.97	1770	1186	0	354	312	32	128	0.56	290.2	64.1	58.4	400.3	210.0	3.9	64.0	4.6	22.341111	71.591388
Botad	Bodi	Pz	8.22	2630	1762	0	329	567	160	120	0.24	270.2	184.4	107.0	900.7	160.0	11.2	49.0	2.3	22.290277	71.608055
Ranpur	Umrala	DW	7.55	565	379	0	256	35	3.9	25	0.40	210.2	40.1	21.9	190.2	51.0	0.0	45.0	1.6	22.298333	71.637222
Botad	Gadhadiya	DW	7.67	2540	1702	0	232	624	147	76	0.37	190.2	200.4	119.2	990.8	106.0	0.7	66.0	1.5	22.292521	71.488888
Botad	Gadhadiya	Pz	7.58	3844	2575	0	146	1163	132	56	0.62	120.1	372.7	48.6	1130.9	335.0	1.4	36.0	4.3	22.291111	71.488611
Barwala	Rojid	DW	8.19	1305	874	0	549	99	32	59	2.2	450.4	24.0	21.9	150.1	235.0	0.2	48.0	8.3	22.205555	71.878333
Barwala	Ranpuri	Pz	8.24	1081	724	0	488	78	12	46	3.6	400.3	24.0	21.9	150.1	186.0	0.6	69.0	6.6	22.211388	71.870833

Ranpur	Godhawata	DW	7.85	2321	1555	0	512	468	73	102	0.76	420.3	120.2	99.7	710.6	215.0	12.0	66.0	3.5	22.225277	71.806666
Ranpur	Godhawata	Pz	8.05	3358	2250	0	293	808	230	148	0.71	240.2	128.3	150.8	940.8	335.0	1.4	73.0	4.8	22.225277	71.815833
Ranpur	Khas	Pz	7.58	873	585	0	305	107	19	39	0.54	250.0	32.0	44	260	95	0.50	55	2.56	22.219444	71.723611
Ranpur	Khas	DW	7.62	1103	739	0	305	163	33	58	0.53	250.0	40.0	56	330	104	0.60	53	2.49	22.219444	71.723611
Botad	Botad	Pz	7.77	1366	915	0	293	220	111	48	0.38	240.0	72.0	95	570	60	0.70	62	1.09	22.190277	71.686944
Botad	Botad	DW	7.2	2570	1722	0	549	511	7.5	75	0.56	450.0	132.0	182	1080	92	3.30	72	1.21	22.190277	71.686944
Botad	Bhadravati	DW	7.72	1340	898	0	305	192	181	76	0.47	250.0	64.0	122	660	43	0.40	66	0.72	22.191944	71.575277
Botad	Bhadravati	Pz	7.9	1675	1122	0	329	284	80	100	0.44	270.0	68.0	122	670	92	1.60	59	1.55	22.192777	71.572777
Botad	Turkha	DW	7.68	1920	1286	0	586	284	75	86	1.00	480.0	44.0	51	320	320	0.40	66	7.78	22.166666	71.532222
Botad	Sarwa	DW	7.86	580	389	0	268	43	15	21	0.58	220.0	36.0	27	200	58	0.20	62	1.78	22.194722	71.493611
Botad	Sarwa	Pz	7.85	960	643	0	293	114	79	41	0.51	240.0	48.0	56	350	80	0.70	64	1.86	22.190277	71.496944
Gadhadha	Meghavadiya	DW	7.68	1747	1170	0	342	362	51	81	0.42	280.0	56.0	54	360	260	1.60	42	5.96	22.041388	71.585833
Gadhadha	Meghavadiya	Pz	7.3	8873	5945	0	354	2684	151	450	0.72	290.0	268.0	348	2100	1150	30.5	58	10.91	22.039444	71.588888
Botad	Ratanpar	DW	7.5	1222	819	0	378	163	73	71	0.50	310.0	84.0	58	450	100	0.70	64	2.05	22.032531	71.578611
Gadhadha	Ingorala	Pz	7.49	2497	1673	0	183	518	158	133	0.32	150.0	216.0	58	780	180	0.90	56	2.80	22.885555	71.485121
Gadhadha	Sitapar	DW	7.78	3401	2279	0	390	760	124	213	0.63	320.0	124.0	151	930	365	0.30	53	5.20	22.877222	71.474444
Gadhadha	Rasnal	DW	7.69	1983	1329	0	378	341	151	120	0.40	310.0	136.0	78	660	170	15.00	64	2.88	21.826731	71.483638
Gadhadha	Dhasa	DW	7.65	2809	1882	0	183	653	138	171	0.32	150.0	288.0	54	940	190	1.10	48	2.69	22.801388	71.536111
Gadhadha	Dhasa	Pz	7.75	2831	1897	0	171	710	136	163	0.25	140.0	304.0	51	970	200	0.70	49	2.79	22.801111	71.536112
Gadhadha	Mota Umarda	DW	7.56	2196	1471	0	159	497	142	93	0.35	130.0	208.0	75	830	105	0.40	53	1.59	21.801111	71.536112
Gadhadha	Mota Umarda	Pz	7.62	2222	1489	0	146	518	137	96	0.31	120.0	220.0	46	740	135	0.50	48	2.16	21.734444	71.592222
Gadhadha	Jalapur	DW	7.54	2671	1790	0	207	596	172	125	0.31	170.0	220.0	105	980	140	0.20	67	1.94	21.786666	71.574722
Gadhadha	Rajpeepla	DW	7.62	1452	973	0	281	220	124	84	0.63	230.0	100.0	46	440	123	0.70	64	2.55	21.870277	71.653888
Gadhadha	Rajpeepla	Pz	8.02	2352	1576	0	171	489	161	166	0.22	140.0	228.0	22	661	238	0.61	47	4.03	21.871388	71.645555
Gadhadha	Chiroda	Dw	8.28	1245	834	0	281	170	33	77	0.42	230.0	48.0	44	300	138	0.04	69	3.46	21.885277	71.608888
Gadhadha	Padvadar	DW	7.8	2716	1820	0	232	525	275	143	0.71	190.0	297.0	34	881	216	0.71	61	3.17	21.897777	71.528888
Gadhadha	Padvadar	Pz	7.8	2662	1784	0	244	489	270	158	0.46	200.0	244.0	51	821	230	1.14	55	3.49	21.896944	71.533055

Gadhadha	**Limbali**	**DW**	**7.52**	**6604**	**4425**	**0**	**268**	**1581**	**522**	**288**	**0.83**	**220.0**	**44.0**	**433**	**1892**	**644**	**2.00**	**61**	**6.44**	**21.997222**	**71.465551**
Gadhadha	**Limbali**	**Pz**	**8.06**	**2369**	**1587**	**0**	**305**	**425**	**152**	**140**	**0.48**	**250.0**	**100.0**	**80**	**580**	**268**	**0.80**	**56**	**4.84**	**21.996944**	**71.460833**
Gadhadha	**Adtala**	**DW**	**7.99**	**1250**	**838**	**0**	**305**	**227**	**13**	**43**	**0.45**	**250.0**	**72.0**	**41**	**350**	**115**	**0.54**	**50**	**2.67**	**21.973055**	**71.622222**
Gadhadha	**Lakhanka**	**Pz**	**8.28**	**1702**	**1140**	**0**	**415**	**241**	**39**	**110**	**0.92**	**340.0**	**24.0**	**15**	**120**	**338**	**0.7**	**53**	**13.4**	**21.963055**	**71.661388**
Gadhadha	**Nana Zinzavadar**	**Dw**	**7.98**	**2828**	**1895**	**0**	**281**	**617**	**74**	**183**	**0.56**	**230.0**	**144.0**	**71**	**651**	**347**	**0.59**	**64**	**5.92**	**21.992222**	**71.692222**
Botad	**Tajpar**	**Pz**	**7.86**	**1869**	**1252**	**0**	**171**	**390**	**83**	**137**	**0.85**	**140.0**	**92.0**	**32**	**360**	**262**	**1.59**	**58**	**6**	**22.073611**	**71.716388**
Botad	**Tajpar**	**Dw**	**7.9**	**1840**	**1233**	**0**	**244**	**376**	**206**	**67**	**0.41**	**200.0**	**80.0**	**88**	**560**	**185**	**1.48**	**58**	**3.4**	**22.074444**	**71.717521**
Botad	**Samadhiyala**	**Dw**	**8.02**	**1887**	**1264**	**0**	**378**	**390**	**11**	**65**	**0.36**	**310.0**	**72.0**	**126**	**701**	**117**	**7.51**	**33**	**1.92**	**22.144444**	**71.735211**
Botad	**Saranpur**	**Pz**	**8.09**	**2498**	**1674**	**0**	**415**	**468**	**122**	**104**	**0.68**	**340.0**	**60.0**	**136**	**711**	**248**	**0.85**	**62**	**4.05**	**22.144166**	**71.771388**
Gadhadha	**Shiyanagar**	**Pz**	**8.013**	**2436**	**1632**	**0**	**537**	**376**	**109**	**90**	**1.2**	**440.0**	**48.0**	**61**	**370**	**371**	**3.69**	**69**	**8.39**	**22.022512**	**71.776388**
Botad	**Rohisala**	**Dw**	**8.8**	**1694**	**1135**	**48**	**671**	**128**	**9.8**	**44**	**1.16**	**631.0**	**12.0**	**29**	**150**	**319**	**0.43**	**42**	**11.3**	**22.021666**	**71.817777**
Barwala	Barvala	**DW**	**8.53**	**7385**	**4948**	**348**	**756**	**1193**	**32**	**975**	**3.75**	**1200.0**	**24.0**	**58**	**300**	**1600**	**10**	**80**	**40.16**	**22.15112**	**71.8916667**
Ranpur	Kundali	**DW**	**8.34**	**1017**	**681**	**48**	**183**	**170**	**18**	**18**	**1.05**	**230.0**	**40.0**	**54**	**320**	**92**	**0.63**	**60**	**2.23**	**22.2694444**	**71.7121**
Ranpur	Rajpada	**DW**	**8.33**	**4060**	**2720**	**276**	**268**	**845**	**55**	**224**	**0.93**	**680.0**	**220.0**	**141**	**1130**	**420**	**28**	**74**	**5.43**	**22.3083333**	**71.6916667**
Gadhada	Ningala	**DW**	**8.48**	**710**	**476**	**48**	**159**	**78**	**11**	**40**	**0.57**	**210.0**	**20.0**	**15**	**110**	**115**	**1.39**	**41**	**4.77**	**22.0180556**	**71.7121**
Gadhada	Tatam	**DW**	**8.09**	**4775**	**3199**	**0**	**329**	**1207**	**180**	**300**	**0.56**	**270.0**	**176.0**	**348**	**1870**	**300**	**2.66**	**79**	**3.02**	**22.0583333**	**71.6333333**
		Min	7.20	330	221.10	0.0	146.4	28.4	1.1	17.8	0.22	120.0	12.0	4.86	100.1	28.0	0.0	19.0	0.72		
		Max	8.80	8873	5944.9	348.0	1464.2	2683.8	522.0	975.0	4.80	1201.0	372.7	433.0	2100.0	1600.0	30.5	84.0	40.16		
		Ave	7.87	2527	1693.1	12.59	376.7	495.8	100.3	155.7	0.91	329.8	107.6	80.66	600.7	304.15	2.93	57.8	6.57		

			pH	**EC µs/cm at 25°C**	**TDS**	**CO3**	**HCO3**	**Cl**	**NO3**	**SO4**	**F**	**Alk**	**Ca**	**Mg**	**TH**	**Na**	**K**	**SiO2**	**SAR**		
											mg/l							**mg/l**			

Annexure- III- Pre monsoon_2021 Water Quality (Heavy Metals+ Uranium) Data of Established well (well Inventory) of Botad District.

District	Taluka	Site	Latitude	Longitude	Source	Cr [mg/l]	Cu [mg/l]	Fe [mg/l]	Mn [mg/l]	Zn [mg/l]	U (ppb)
Botad	Barwala	Chokdi	22.2451	71.9256	DW	0.002	0.002	0.017	0.003	BDL	12.25
Botad	Barwala	Kapadiya	22.1322	71.9211	DW	0.002	0.001	0.009	0.000	0.001	13.63
Botad	Ranpur	Nagnesh	22.3611	71.7664	DW	0.000	0.004	0.653	0.019	0.016	1.55
Botad	Botad	Limboda	22.3411	71.5914	DW	0.038	0.003	0.146	0.003	0.006	1.48
Botad	Barwala	Rojid	22.2056	71.8783	DW	0.011	0.002	0.207	0.002	0.004	4.87
Botad	Ranpur	Khas	22.2194	71.7236	DW	0.002	0.003	0.362	0.006	0.009	2.09
Botad	Botad	Botad	22.1903	71.6869	DW	0.029	0.004	0.150	0.145	0.015	1.36
Botad	Botad	Sarwa	22.1947	71.4936	DW	0.000	0.002	0.130	0.000	0.002	0.73
Botad	Gadhada	Meghavadiya	22.0414	71.5858	DW	0.000	0.003	0.019	0.014	0.003	2.24
Botad	Gadhada	Rajpeepla	21.8703	71.6539	DW	0.002	0.004	0.128	0.005	0.007	0.94
Botad	Gadhada	Padvadar	21.8978	71.5289	DW	0.029	0.007	0.241	0.013	0.010	2.46
Botad	Gadhada	Limbali	21.9972	71.4656	DW	0.038	0.009	0.120	0.023	0.016	7.57
Botad	Gadhada	Adtala	21.9731	71.6222	DW	0.000	0.005	0.098	0.010	0.006	1.44
Botad	Botad	Tajpar	22.0744	71.7175	DW	0.000	0.003	0.102	0.008	0.007	1.34
Botad	Botad	Rohisala	22.0217	71.8178	DW	0.000	0.004	0.132	0.003	0.003	2.75
Botad	Barwala	Barvala	22.15000	71.89167	DW	0.000	0.002	0.014	0.001	0.004	
Botad	Ranpur	Kundali	22.26944	71.70000	DW	0.000	0.002	0.189	0.009	0.006	
Botad	Ranpur	Rajpada	22.30833	71.69167	DW	0.000	0.003	0.018	0.005	0.007	
Botad	Gadhada	Ningala	22.01806	71.70000	DW	0.000	0.000	0.191	0.000	0.004	
Botad	Gadhada	Tatam	22.05833	71.63333	DW	0.017	0.007	0.223	0.127	0.021	
					Min	**0.000**	**0.000**	**0.009**	**0.000**	**0.001**	**0.730**
					Max	**0.038**	**0.009**	**0.653**	**0.145**	**0.021**	**13.630**
					Ave	**0.009**	**0.003**	**0.157**	**0.020**	**0.008**	**3.780**

Annexure- IV Average Decadel WL Trend (2012-21) in Botad District

Table 19: Average Decadel WL_Trend(2012-21) in Botad District

AGENCY	DNAME	TNAME	SITE_NAME	LOCAL_GEOL	AQUIFER_TY	X	Y	PRE_AVG_12_21	POST_AVG_12_21
CGWB	BOTAD	BARWALA	Barvala	Alluvium	Unconfined	71.89	22.15	9.90	8.07
CGWB	BOTAD	GADHADA	Dhasa	Basalt	Unconfined	71.51	21.80	5.85	2.42
CGWB	BOTAD	GADHADA	Gadhada2	Basalt	Unconfined	71.58	21.97	4.55	3.81
CGWB	BOTAD	RANPUR	Kundali	Basalt	Unconfined	71.70	22.27	14.38	7.30
CGWB	BOTAD	BOTAD	Lonjdhara	Basalt	Unconfined	71.90	22.10	25.04	16.59
CGWB	BOTAD	GADHADA	Ningala	Basalt	Unconfined	71.70	22.02	12.07	7.73
CGWB	BOTAD	BOTAD	Paliyad	Basalt	Unconfined	71.56	22.26	20.69	8.25
CGWB	BOTAD	BOTAD	Paliyad2	Basalt	Unconfined	71.56	22.26	21.11	6.25
CGWB	BOTAD	RANPUR	Rajpada	Basalt	Unconfined	71.69	22.31	18.53	13.74
CGWB	BOTAD	BARWALA	Salangpor	Basalt	Unconfined	71.77	22.16	18.51	7.88
CGWB	BOTAD	BOTAD	Tardhera	Basalt	Unconfined	71.60	22.23	21.94	19.26
CGWB	BOTAD	GADHADA	Tatam	Basalt	Unconfined	71.63	22.06	24.06	15.57

References

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- Directorate of Agriculture, Seasons and Crops, Botad for (2017-18)
- District Irrigation Plan of Botad District, under Pradhan Mantri Krishi
- Sinchayee Yojana (PMKSY).
- And several other published reports of CGWB and Govt. website