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

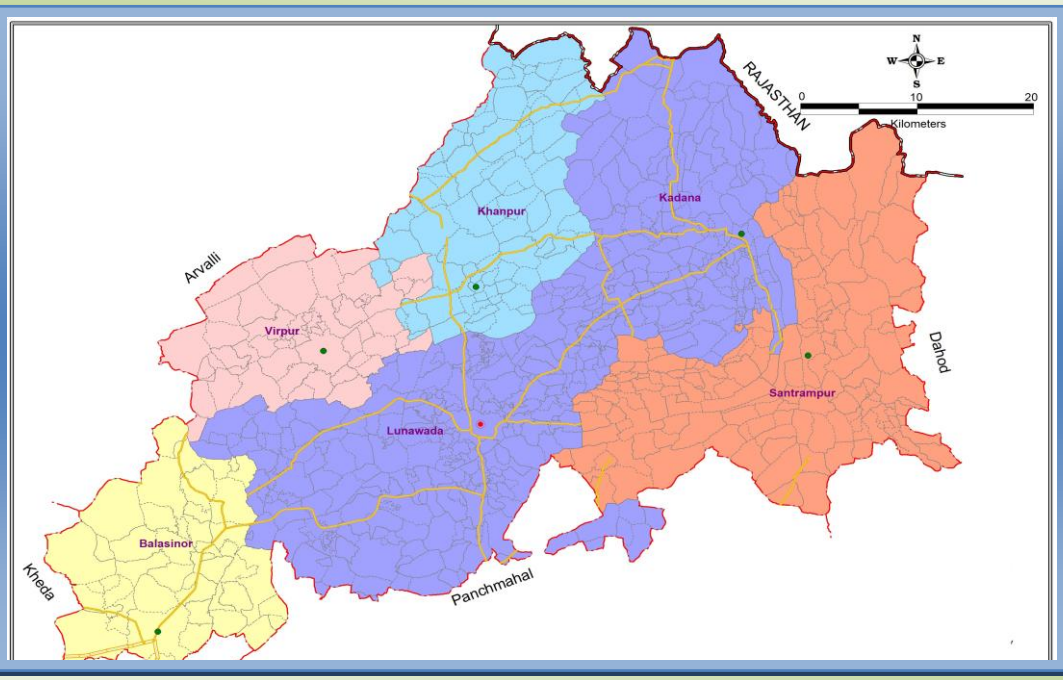
AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Mahisagar District
Gujarat

पश्चिम मध्य क्षेत्र, अहमदाबाद

West Central Region, Ahmedabad

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



Central Ground Water Board (WCR)
Department of Water Resources, RD & GR,
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DECEMBER, 2021

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES MAHISAGAR DISTRICT, GUJARATSTATE

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

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1	General Information	
	i) Geographical area /total reporting area (Sq. Km)	2512.64
	ii) Administrative Divisions (As on 3/2018) Number of Talukas Number of Villages	 06 715
	iii) Populations (As per 2011 census)	9,94,624
	iv) Average Annual Rainfall (mm)	753
2.	GEOMORPHOLOGY	
	Major Physiographic Units : Undulating plain, highly dissected plateau and hills	
	Major Drainages: Perenial river – Mahi river, Non-perenial river - Panam, Hadap, Goma, Kharod, Mesari, Chikni, Kun, Anas, Kali, Machchhan and Chibota.	
3.	LAND USE (Sq. Km) (2014-15)	
	a) Forest area b) Net area sown c) Area sown more than once d) Gross Cropped area	628 1386 524 1910
4.	MAJOR SOIL TYPES**:** Sandy soils, Yellowish brown & black soils, Black cotton soils	
5.	AREA UNDER PRINCIPAL CROPS (sq.km) (2014-15) Rice 144 , Jowar-40, Bajra-160, Wheat-242, Maize-213,Total cereals-2370, Gram -41, other pulses-330, Total pulses-72, Total food crops- 882, Ground nut-14, Seasam -9, Rapes and Mustard-4, Total oil seeds-37.	
6.	IRRIGATION BY DIFFERENT SOURCES (Area in Sq Km/ no of structures)	
	Dugwells	174/21306
	Tube wells/Borewells	32/1405
	Tanks/Ponds/Water conservation structures	232/114
	Canals	348/
	Other Sources	304/
	Net Irrigated area(sq. km.) (2014-15)	619
	Gross Irrigated area (sq. km.) (2014-15)	1090
7.	NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on 31-03-2018) No of Dug Wells No of Piezometers	19 13 06
8.	PREDOMINANT GEOLOGICAL FORMATIONS: Meta-sediments of Aravalli super group such as Phyllites, quartzites; post Delhi intrusive of Godhra granite and gneiss; Infra-trappean of lameta beds; sandstones and limestone; Deccan trap basalts and alluvium deposit along river channels and valley fills.	
9.	HYDROGEOLOGY Major Water Bearing Formation**:** Groundwater occur in unconfined to semi-confined condition in phyllite, schist & quartzite, Granite and gneiss, deccan trap formation in weathered mantle and factures zones and under unconfined condition in alluvium along river courses, valley fills, flood plain & abandoned Palaeochannel deposits.	

	Depth to water Level during 2019-20				
	Period	Phreatic Aquifer (DTW)		Semi-confined /Confined Aquifer (PZ head)	
		Min	Max	Min	Max
	Pre Monsoon	3.67 (Kothamba)	32.03 (Bavaliya Pz)	**NA**	**NA**
	Post Monsoon	1.45 (Malekpur)	8.68 (Ucharpi Pz)	**NA**	**NA**
	Long Term (10 Years) Water Level Trend (2008 to 2017)				
	Trend	Pre-Monsoon		Post- Monsoon	
	Rise (m/Yr)	0.052 (Balasinor) to 0.5307 (Virpur Pz)		0.0386 (Kothamba) to 0.5974 (Pandarvada)	
	Fall (m/Yr)	0.0113 (Bavaliya) to 2.9373 (Bavaliya Pz)		0.0022 (Limbadia peti) to 0.1188 (Santrampur)	
10.	GROUND WATER EXPLORATION BY CGWB (As on 31-03-2018)				
	No of wells drilled (EW, OW, Pz, SH, Total) EW: 13,OW: 02, PZ :03, SH:0, Total: 18			18	
	Depth Range(m)			25.70 m to 202.60	
	Discharge (Litres per minute)			2.5 to 1100	
11	GROUND WATER QUALITY				
	Presence of chemical constituents more than permissible limit)			Fluoride and Nitrate at few locations	
	Type of water			Potable in general	
12.	DYNAMIC GROUND WATER RESOURCES (As on March, 2017)				
	Annual Replenishable Ground Water Resources (MCM)			370.4384	
	Net Ground water Availability (MCM)			351.9165	
	Projected Demand for Domestic and industrial Uses upto 2025 (MCM)			18.79	
	Stage of Ground Water Development (%)			38.73	
13	GROUND WATER CONTROL AND REGULATION (2017)				
	Number of OE Blocks			Nil	
	Number of Critical Blocks			Nil	
	Number of Semi Critical Blocks			Nil	
	Number of Safe Blocks			06	
	Number of Saline Blocks			Nil	
	No. Of Blocks Notified by CGWA			Nil	
14	MAJOR GROUND WATER PROBLEMS AND ISSUES				
	i) Low Groundwater Development ii) Limited Yield Potential in Hard Rock iii) Pollution Geogenic and Anthropogenic (Fluoride & Nitrate in localised pockets) iv) Awareness amongst villagers on water conservation techniques v) Demand supply management				

AQUIFER MAP AND MANAGEMENT PLAN
MAHISAGAR DISTRICT

1. Introduction

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

1.1 Objective:

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

1.2 Methodology:

Methodology involves creation of database for each of the principal aquifer and 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.

1.3 Data Compilation & Data Gap Analysis:

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

1.4 Data Generation:

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

1.5 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).

1.6 Aquifer Management Plan Formulation:

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

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

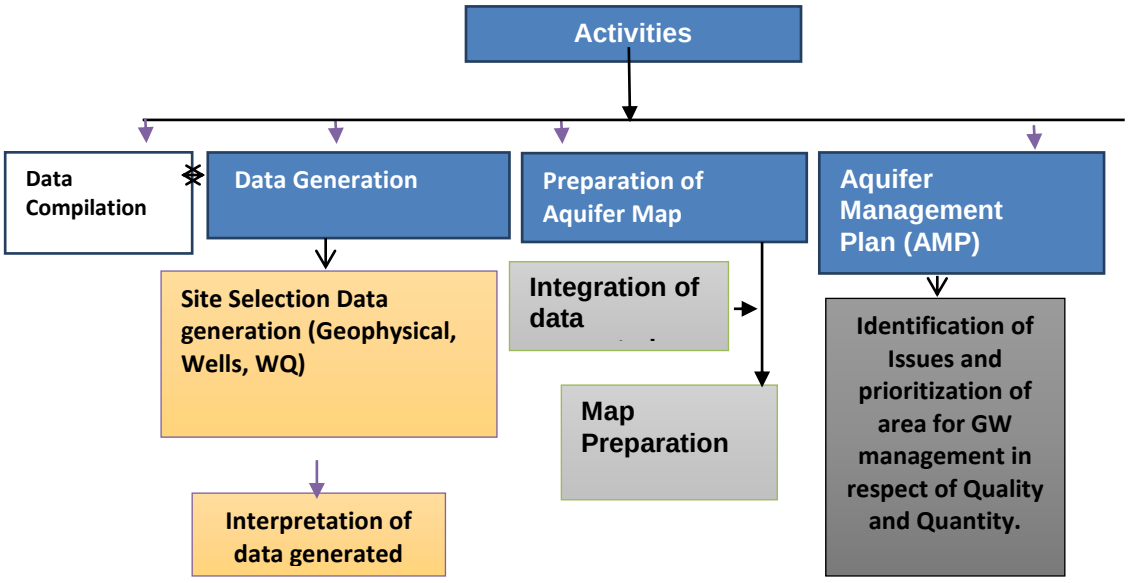


Figure 1- Activity under National Aquifer Mapping Programme

1.7 ABOUT THE AREA

Mahisagar is a district in the state of Gujarat in India that came into being on 26 January 2013, becoming the 28th district of the state. The district has been carved out of the Panchmahal district and Kheda district. Lunawada is the district headquarters of Mahisagar. It started its operation in full-fledged from 15 August 2013. It is situated in the eastern part of the State adjoining Rajsthan state and lies between north latitudes 22°55' and 23°27' and east longitudes 73°14' and 74°01'. The total area of the district is 2512.64 KM^2 falls in parts of Survey of India degree sheets 46 E, 46 F and 46I. The district is bounded on the north by Rajsthan State, on the east by Dahod district, on the west by Aravalli district and on the south and south west by Panchmahal and Kheda district.Table No-1 District bounds Latitudes and Longitudes.

TABLE 1- MAHISAGAR DISTRICT BOUNDARY LOCATION

District Name	Latitude	Longitude
Mahisagar	22°55' to23°27'	73°14' to74°01'

The district headquarters is located at Lunavada Town. For administrative convenience, the district is divided into 6 blocks viz., Balasinor, Lunavada,Santrampur, Virpur, Khanpur and Kadana. It has a total population of 9,94,624as per 2011 census.The district has 3 towns and 709 villages. The major part of the district comes under Mahi River basin. The major river flowing through this district is Mahi, from which the district derive its name.

Mahisagar district has been taken up under NAQUIM study during the year 2019-20.The total area of the district is about 2512.64 sq km. The district is categorized as safe as per Ground Water Resources Estimation as on March 2017. The Administrative and Index map of the study area is presented in **Fig 2**.

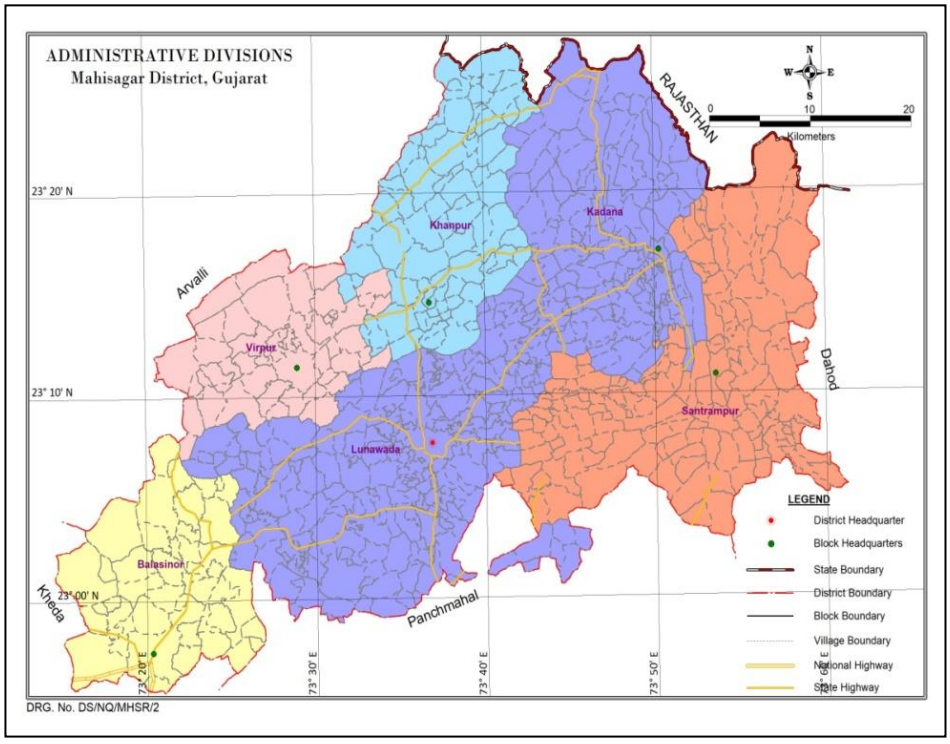


FIGURE 2- ADMINISTRATIVE MAP OF MAHISAGAR DISTRICT

1.8 DEMOGRAPHY:

As per the 2011 census, the population of the district was 9,94,624 out of which number of males and females were 4,90,662 and 4,64,632, respectively. The population density per square kilometer has increased by approximately 17% from 2001 to 2011. The percentage rural population has reduced from 92.07% in 2001 to 90.19% in 2011, due to migration from rural areas. The sex ration has increased from 942 (2001) to 946.3 (2011). The current literacy rate is around 68%. The demographic profile of the district (block wise) is indicated in below **table no. 2**.

TABLE 2- DISTRICT POPULATION FIGURE (AS PER 2011)

Sr. No	Taluka	Male	Female	Total	Sex Ratio
1	Balasinor	75480	70343	1,45,823	932
2	Kadana	66399	63146	1,29,545	951
3	Khanpur	49023	47018	96,041	959
4	Lunawada	132444	124784	2,57,228	942
5	Santrampur	135856	129838	2,65,694	956
6	Virpur	51742	48551	1,00,293	938
	Total	510,944	483,680	9,94,624	946

1.9 PHYSIOGRAPHY:

The district has high variation in topography which represents the diverse geological condition. The western part of the district constitute Pediplain, composed of weathered, unconsolidated medium to coarse grained material having gentle to moderate slope. There are scattered alluvial deposits such as flood plain, valley fills etc formed along major river courses composed of clay, silt, sand, gravel and kankar deposits with gentle slope. There are small scattered sedimentary and volcanic dissected hills. The northern, eastern and southern part of the district have undulated topography ranging the elevation more than 400m, constitute moderately to highly dissected hills of Aravallis range. They have high relief and steep slopes. The area occupies by the quartzite has an undulating topography where as phyllite and mica schist occupy broad intermountain valley. The southern border of the district is marked by a hill range with roughly east – west and forms a surface water divide particularly between Narmada and Mahi basin.

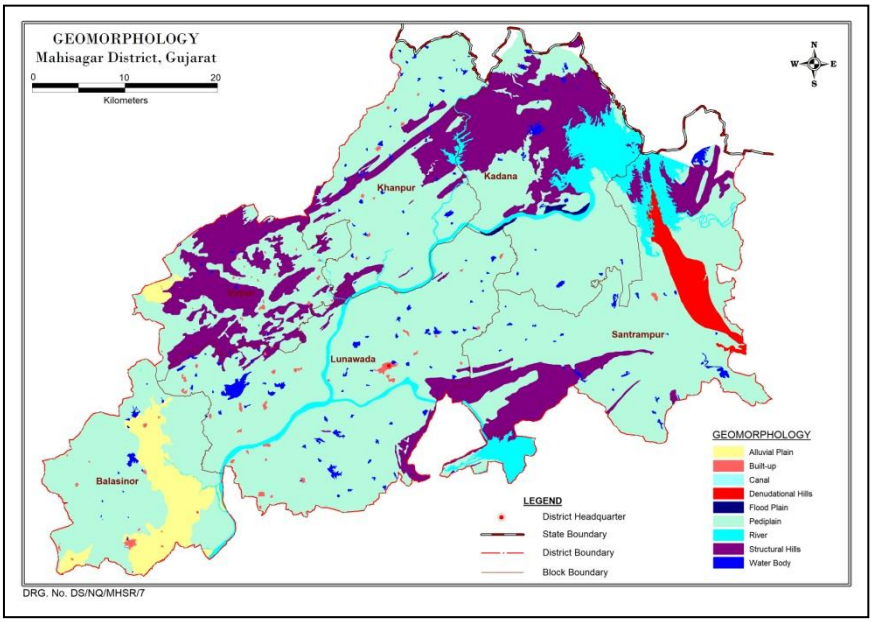


FIGURE 3- GEOMORPHOLOGIC MAP OF MAHISAGAR DISTRICT

1.10 DRAINAGE PATTERN:

The entire district forms a part of the **Mahi river basin**. The Mahi is a perennial river, enters the district from North West near Khedapa and departs near Timba in the western part. It has a length of about 126km in the district. Almost other rivers are namely Panam, Hadap, Goma, Kharad, Mesari, Chikni, Kun, Anas, Kali, Machchhan Chibata and Suki River are tributary of the Mahi river. Out of these, only **Panam and Hadaf**is only perennial. All the rivers originate in the eastern highland and flow towards west direction to the Arabian Sea. The flow of the water in the rivers is more during the rainy season. The drainage is dendrite to sub-dendrite type.

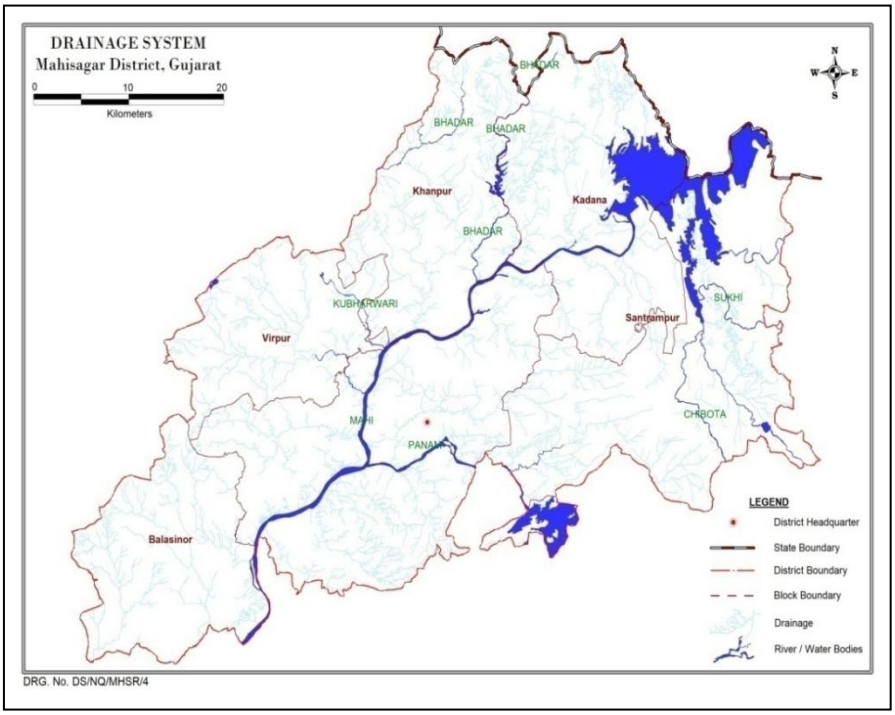


FIGURE 4- DRAINAGE MAP OF MAHISAGAR DISTRICT

1.11 SOIL TYPE:

The soil of the district can be divided broadly into three categories depending upon the source rock, namely the phyllite, granites and basalts. The granite normally gives rise to sandy soil but where weathering is intense, sandy loam is produced. The phyllite produced yellowish brown light soils but where weathering is deep, black soil produced. The basaltic rock gives rise to variegated soil depending upon the degree of weathering. The first stage of weathering produce light soil with splinters of morum where as in the second stage medium soil of light brown to brownish black color are produced. These medium soils are more than a meter depth. The black cotton soils produced by intense weathering of basalts are however deep, heavy and become sticky when saturated. They have high fertility value which is indicated in below **table no. 3**.

Table 3- Major Soil Features

Balasinor	Clay loam, light hilly soil, black soil with medium rainfall
Kadana	Sandy loam with high rainfall, Shallow to medium in depth, Low to medium N & P content.
Khanpur	
Lunavada	
Santrampur	Sandy loam with high rainfall, Shallow to medium in depth, Low to medium N & P content. Part of Santrampur, however, have Medium black soil with high rainfall, Moderate to severe erosive, Poor soil fertility, Poor permeability.

Virpur	Clay loam, light hilly soil, black soil with light/ medium rainfall.

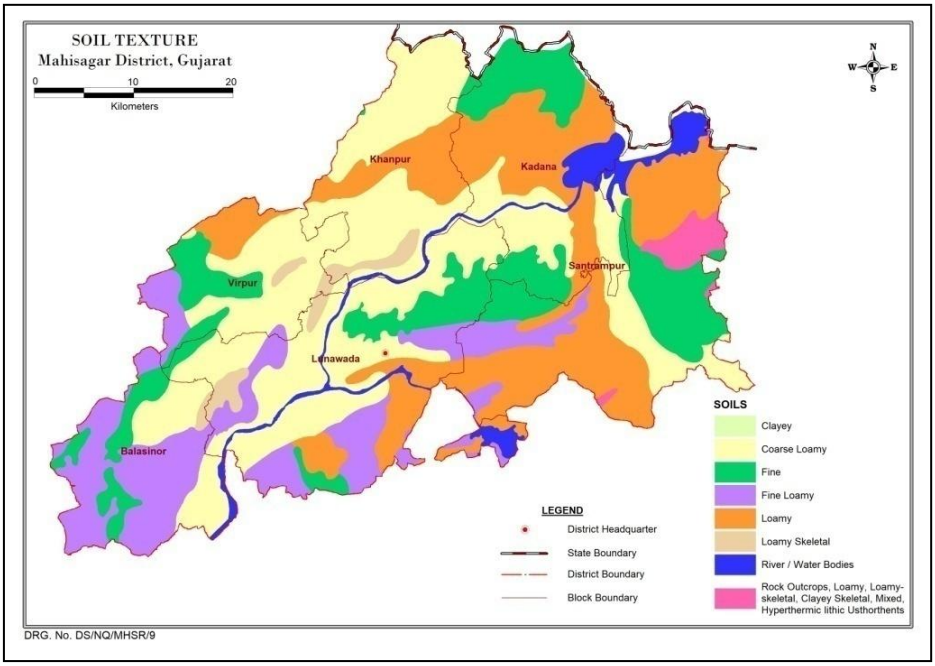


FIGURE 5- SOIL MAP OF MAHISAGAR DISTRICT

1.12 LANDUSE PATTERN:

The data on land utilization and irrigated are shows that, the land brought under cultivation and sowing in the Mahisagar district covers 1910 sq km, where area sown more than once covers 524 sq km. The details Geographical area covers 2508 sq km where forest areas cover 628 sq km. The Fallow land covers 113 sq km.

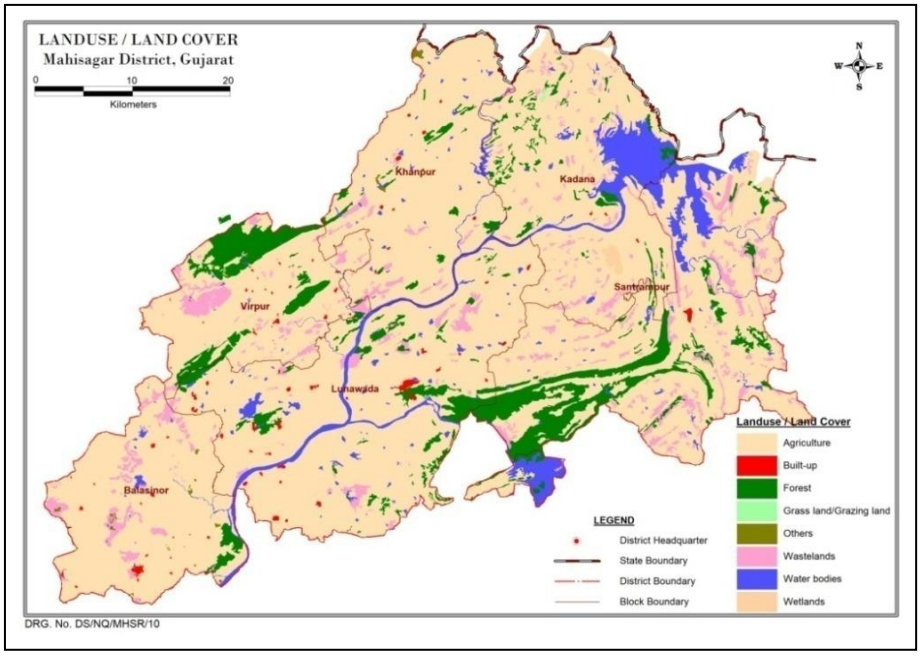


FIGURE 6- LAND USE MAP OF MAHISAGAR DISTRICT

1.13 CLIMATIC CONDITION:

Mahisagar district is located in east of *Gujarat,* comes under heavy rainfall areas in Gujarat, having sub-tropical climate with moderately low humidity. There is no meteorological station

in Mahisagar district so that nearby station is Godhra. The main seasons prevailing in the district are (a) monsoon - mid of June to October, (b) winter - November to February, and (c) summer – March to June.

The maximum daily temperature during the year ranges from 27.7 °C in January to 39.7 °C in May while minimum temperature ranges from 11.9 °C in January to 25.6°C in May. Maximum humidity ranges from 98.2 % to 79.6 % while minimum range is from 28 to 83.5 %. The wind speed ranges from 105.2 to 479.6 km/day, whereas evapotranspiration ranges from 3.4 to 11.1 mm/day.

TABLE 4- CLIMATIC DATA

Station:	Godhra				District:	Panchmahal		
Latitude:	N 22°45'57"				Longitude:	E 73°36'29"		
Month	**Max Temp (Deg.C)**	**Min Temp (Deg.C)**	**Humidity (%)**	**Wind Spd. (Kmpd)**	**Sunshine (Hours)**	**Solar Rad. (MJ/m2/d)**	**Eto (mm/d)**	**Rainfall (mm)**
January	27.7	11.7	41	138	9.6	17.7	3.8	0
February	30.6	14.1	33.5	169.1	10.2	20.6	5.2	0
March	35	19.1	27.5	220.8	9.3	21.8	7.1	0
April	38.6	23.7	28	293.3	10	24.5	9.3	0
May	39.7	25.6	38	438.2	10.6	25.9	11.1	0
June	35.8	24.8	60.5	479.6	8.8	23.2	8.4	0
July	30.8	23.6	79	405.4	4.6	16.8	4.7	168
August	28.9	22.7	83.5	351.9	4.3	16	3.9	637
September	30.6	22.2	75	265.7	6.7	18.5	4.7	136
October	33.7	20	50.5	132.8	9.5	20.4	4.9	0
November	31.6	16.2	42.5	105.2	9.7	18.3	3.9	0
December	28.7	12.9	44	112.1	9.5	16.8	3.4	0
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**941**
Average	**32.6**	**19.7**	**50.3**	**259.3**	**8.6**	**20.1**	**5.9**	**78.4**

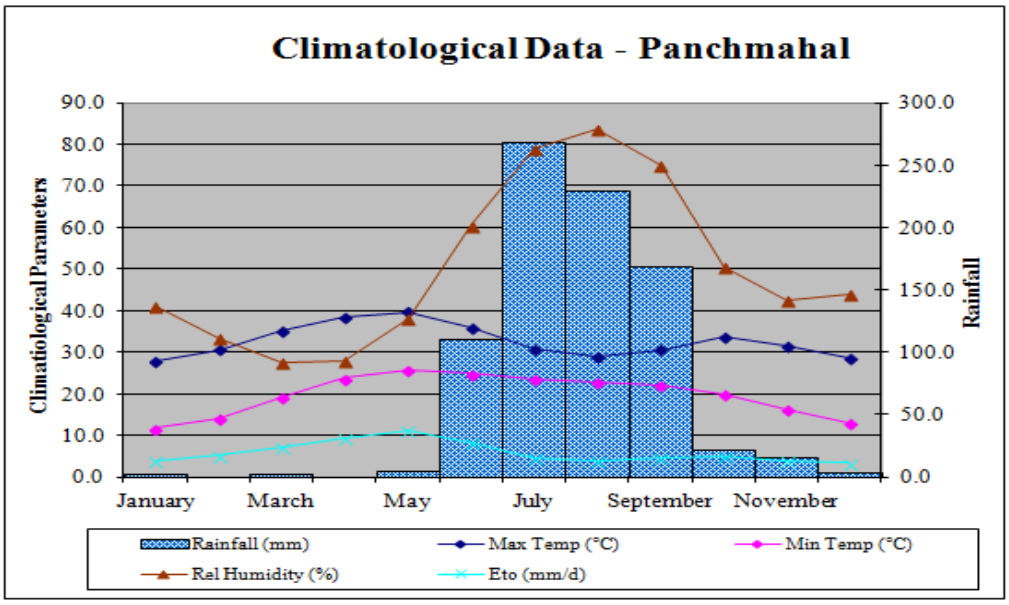


FIGURE 7- CLIMATIC DATA ANALYSIS OF MAHISAGAR DISTRICT

1.14 RAINFALL:

Mahisagar district receives much of its rainfall from the south-west monsoon during the period between June & October; its maximum intensity being in the month of July & August.

Total rainy days ranges from 30 to 40 days/year. Long term annual rainfall data of 6 rain-gauge stations of the district from year 1967-2017 are statistically analyzed and presented below in table No 5.

TABLE 5- STATISTICAL ANALYSIS OF RAINFALL DATA

Stations Name	Year	Average Annual Rainfall RF (mm)	Highest RF (mm)		Lowest RF(mm)	
			Year	Rainfall	Year	Rainfall
Lunavada	1967- 2017	754.6	2006	1942	1985	209
Khanpur	1967- 2017	706.9	1973	1393	1985	209
Santrampur	1967- 2017	783.0	1973	2068	2000	269
Kadana	1967- 2017	834.8	1973	2068	2000	269
Balasinor	1967- 2017	775.4	2006	1594	1987	276
Virpur	1967- 2017	706.3	1976	1465	1987	276

1.15
1.16 STUDIES / ACTIVITY BY CGWB

Systematic hydrogeological surveys were carried out by different officers of CGWB between 1975–76 to 1980–81.

1. Doshi S.K. & Bhatnagar G.C. 1974 – 75
2. Bhatnagar G.C. 1975 – 76
3. Venkatraman S. 1976 – 77
4. Sharma V. 1977 – 78
5. Venkatraman S. 1978 – 79
6. *Arun Kumar* 1980 – 81
7. *P.K.Jain,A.Kawade,P.R.Gupte* *1987 – 88*

The findings of the report during these investigations are summarised as follows:

a. Major part of the district is underlain by hard rocks.
b. Mainly the groundwater is developed by dug wells
c. The hard rock formation forms most extensive aquifers in the district.
d. The yield of the wells in the hard rock depends mainly on the thickness of weathered mantle and degree of fracturing.
e. In isolated patches, particularly in the vicinity of the rivers, valley fill, Palaeo-Channel deposits form potentials aquifers.

Later on groundwater exploration work also carried out as part of the AAP during 1985 – 86, 1987 – 88 (1-EW), 1988 – 89(1-OW), 2002 – 03(4-EW), 2003 – 04 (2-EW), 2007–08 (3-PZ), 2008–09(2-EW, 1-OW), 2009 –10 (1-EW) and 2010 – 11(2-EW, 1-OW).

1.17 SURFACE WATER RESOURCES:

There is one major irrigation project on Mahi river, namely Kadana reservoir project (Santrampur – Lunawada talukas) and medium projects such as (i) Bhadar Dam project (Lunawada) on Bhadar river, (ii) Panam dam project on Panam river (Lunawada).

2. GEOLOGY

Geologically, Mahisagar district is the manifestation of diverse geological extension from Lower Proterozoic to Holocene with different rock types such as granitic to basalt and limestone to alluvium. The stratigraphy of Mahisagar district is presented in table 4. The oldest formation in the area is

Aravallis Supergroup comprises of various meta-sediments belongs to Lower Proterozoic. The post-Delhi intrusive, Godhra granite and gneisses were intruded into older Aravalli. Both Aravallis and granite-gneiss have undergone many orogenic movements. They are overlain at places by Lower cretaceous fluvial and marine sequences, namely Bagh beds and Lametas. Lower Cretaceous rocks are overlain by Deccan basalts, extrusive rock formation; occur as sporadic exposure in the form of capping over older rocks. The youngest formation found in the district is the alluvium; occur as pediments, sand dunes, valley fills and flood plain as isolated patches.

TABLE 6- STRATIGRAPHY OF MAHISAGAR DISTRICT.

Stratigraphy of Mahisagar District.				
Geological Age	Supergroup	Group	Formation	Lithology
Holocene			Katpur Formation	Alluvium - Sand, Kankar and Clay
Pliocene			Pandu Mewasa Formation	Mottled clay & sandstone
Cretaceous to Eocene		Deccan Traps		Basalts & Rhyolite
Upper Cretaceous		Bagh/Lameta Group		Infra - Trappeans - Lameta Beds, Limestone, Nodular marls and Sand stones
Upper Proterozoic		Godhra Granites		Granite & Granodiorite
Lower Proterozoic	Aravalliies Super Group	Champaner Group	Rajgarh Formatiom	Phyllite, Slate and Mica schist with inter calations of Limestone, Subgraywacke & quartzite
			Shivrajpur Formation	Phyllite & manganiferous phyllite, quartzite & dolomitic limestone
			Jaban Formation	Phyllite, metasubgraywacke, quartzite and metaconglomerate
			Narukot Formation	Quartzite, phyllite & metaconglomerate
			Khandia Formation	Quartzite, quartz-biotite schist, dolomitic limestone, phyllite, metasubgraywacke & meta conglomerate
			Lambia Formation	Quartzite, mica schist, metasubgraywacke, conglomerate and migmatite
		Lunawada Group		Phyllites, mica schist, metasubgraywacke and chlorite schist, quartzite & Phylitic quartzite, quartz - mica schist, protoquartzite, dolomite.
		Udaipur Group	Balicha Formation	Phyllite, mica schist, quartzite

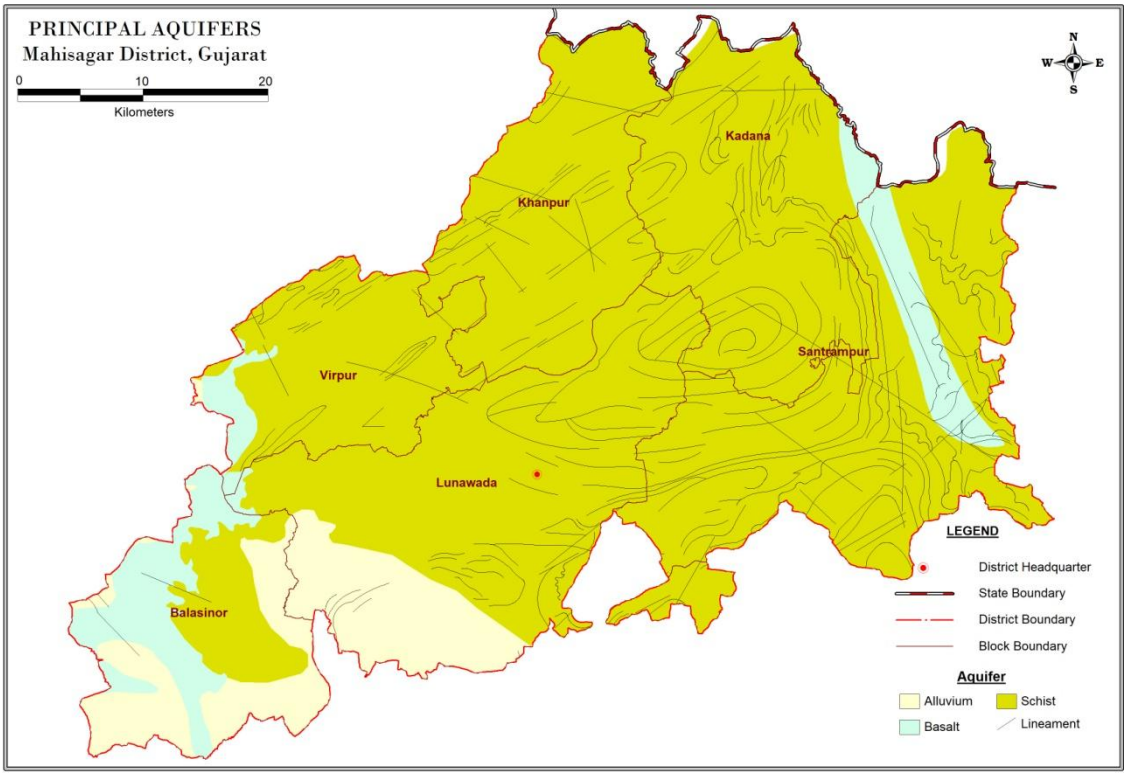


FIGURE 8- PRINCIPAL AQUIFER OF MAHISAGAR DISTRICT

Aravalli Super group: It comprises of Meta-sediments, divided in to three major groups such as: Udaipur group, Lunawada group and Champaner group.

The Udaipur group of rocks (Balicha formation) is exposed in the east of the Santrampur as a narrow belt and comprises of Phyllite, mica schist and quartzite. It is overlain by Lunawada group of rocks, which comprises of Phyllite, mica schist, meta-subgraywacke, chlorite schist, Phyllite quartzite, proto-quartzite and minor bands of dolomite.

The Champaner group of rocks overlain Lunavada group occur in the southern part of the district, has been subdivided in to six formations, mainly due to interformational conglomerate horizon. These formations are the Lambia, the Khandia, the Narukot, The Jaban, the Shivrajpur and the Rajgarh. The main litho units of this group are quartz-mica schist, metasubgraywacke, meta-conglomerate, dolomitic limestone, manganiferous phyllite, slate, migmatite etc. These meta-sediments have been intruded by the Godhra Granites. Infratrappean Bagh and Lameta group of rocks consisting of Limestone, shale, sandstone and conglomerate, exhibit presence of marine and freshwater fossils. Dinosaurian egg and bone fossils are found in the Lameta group.

Basalts and rhyolite comprises the Deccan volcanic exposed around Pavagadh as hills. A small patch of mottled clay and sandstone, belonging to the Pandu Mewasa formation is exposed in the western part of the district. Flood plain and channel fill deposit of the Katpur formation are found in the south western part of the district.

3. HYDROGEOLOGY- OCCURRENCE & DISTRIBUTION OF GROUND WATER

The groundwater in Mahisagar district occurs under confined and unconfined condition. Unconsolidated shallow alluvium and weathered, jointed and fractured rock support unconfined aquifers whereas interflow zones of basalts, inter trappeans beds, encountered at depth, deep seated fractures and shear zones give rise to confined conditions.

Generally, water level follows topographic configuration. The hot springs at Tuwa is associated with deep seated shear zones in the granitic rock with several pegmatites intrusive. The shearing of pegmatiteindicates post pegmatite tectonic activity.

As part of the hard rock, Phyllite, quartzite, schist, basalts, sandstone and limestone are forming aquifers. Alluvium and valley fills materials form potential aquifers in the vicinity of rivers and piedmont zone but their distribution is patchy with limited extension, rarely exceeding a few square kilometre in area. The groundwater condition in different formation is as follows:

a) **Phyllite, schist and quartzite as aquifers:** Groundwater occurs under unconfined conditions. The ground water is restricted to weathered mantle and fractured/sheared zones. Quartz veins act as good barriers and prevent ground water subsurface outflow. The depth to weathering normally does not extend below 10m. The fractures and joints are wide near surface or just below the weathered mantle and are effective as groundwater conduits only for 0 to 20m below which they tend to be only like hair cracks unable to allow passage for groundwater movement. Intense weathering of phyllites and schist results in production of impervious clayey matrix whereas quartzite produces sandy material. However, weathering in quartzite is very rare on account of their uniform and resistant nature. The depth to water level varies from 3 to 20m. The yield of this Aquifer in-between 0.65 to 8 lps.

b) Granites & Gneisses as aquifer: Groundwater occurs underunconfined to confined condition.The aquifer materials are weathered/fractured granite. The thickness weathered zone varies from 0 to 20m. The weathering of granite produces porous granular materials as quartz and feldspar being major constituents. The depth of dugwell varies from 6 to 20m. Dug cum borewell in the area have up to 46m depth. In exploratory well at Vejalpur, a fracture struck below 50m, indicates that the possibility of occurrence of ground water occurrence. The depth to water level varies from 3 to 15m. The yield of this Aquifer in-between 0.2 to 2 lps.

c) **Infratrappean:** Infratrappean beds form aquifer in isolated patches with limited extensions, as their occurrence is sporadic. Groundwater occurs under confined to unconfined condition restricted to solution cavities in calcareous formation and in the weathered mantle. The cavernous nature of the formation is more pronounced at the contact of formation. The confined conditions are observed wherever the formations are overlain by basalts. Maximum thickness of this formation is 42m (EW Tarkhanda

&Pavagadh) and maximum dugwell depth is around 25m. In general, they are poor aquifers on account of low permeability and limited horizontal extensions. The depth to water level varies from 5 to 15m. Yield of this aquifer is 4.5 lps.

d) **Basalts:** The basalts form aquifer in western and southern part of the district around Halol. Ground water occurs under unconfined to confined condition in the weathered mantle, joints, fractures and interflow zones. Intertrappean sediments often carry granular sediments which form good aquifer locally. Vesicular basalts are porous but not permeable as the vesicles are not interconnected. The joints and fractures help in connecting the vesicles and thus give rise to more permeable aquifer. The depth to water level varies with in 4 to 12m. Yield of this aquifer in between 1 to 4.38 lps.

e) Alluvium: The alluvium form aquifer in discontinuous isolated patches. The major river like Panam and Mahi have alluvium deposits of shallow depth on either bank almost all along the river courses but extended to limited area of 1 to 2m from the banks. The maximum thickness of alluvium is 35m in the vicinity of Mahi River near Lunavada (Chariya EW). The depth of dug well in alluvium ranges from 15 to 25m. The alluvium often comprises pebbly materials at the bottom, which support wells with very high yields. The dept to water level is vary from 1 to 22m while it less than a meter in the canal command area of Santrampur taluka. Yield of this aquifer in between 4 to 10 lps.

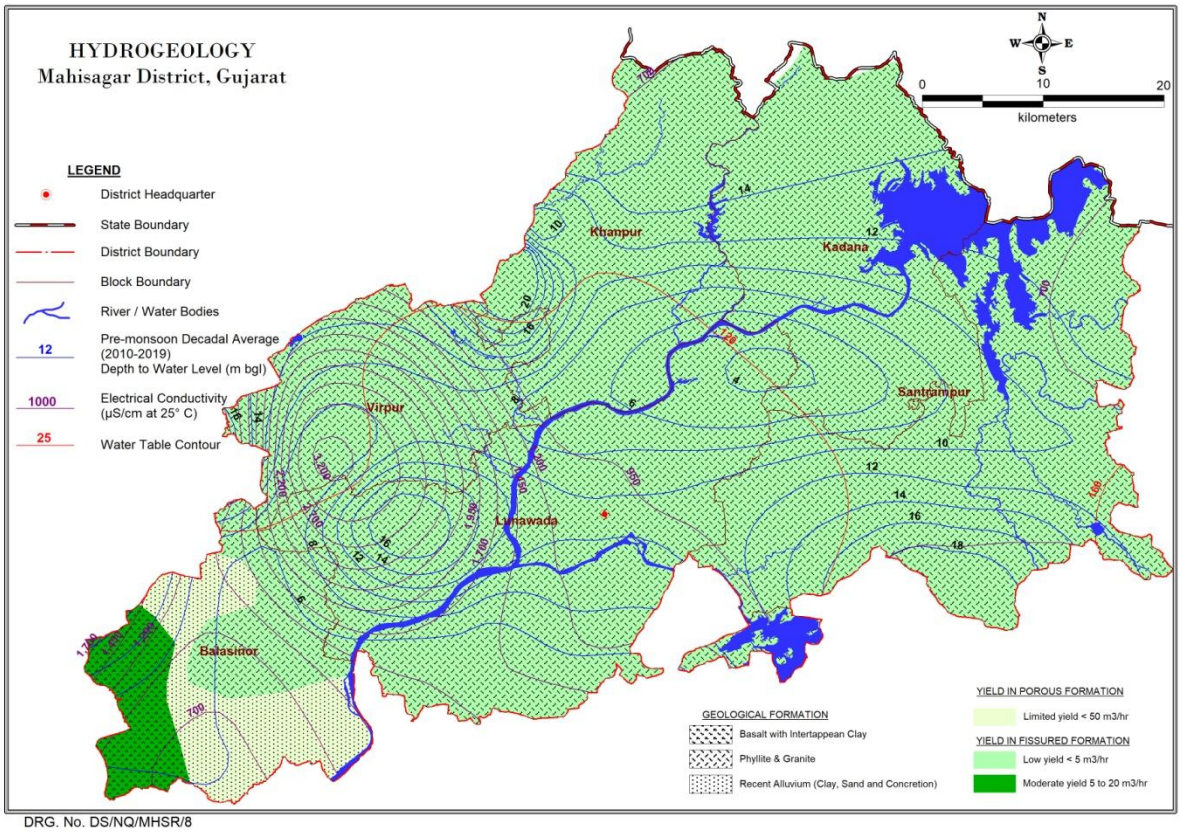


Figure 9- HYDRO-GEOLOGICAL MAP OF MAHISAGAR DISTRICT

3.1 AQUIFER PARAMETERS:

Aquifer parameters are available from ground water exploration carried out in the hard rock area of the district as well as from the pumping tests carried out on exploratory wells in Meta-sedimentary,Basaltic and Alluvial terrain.

TABLE 7- AQUIFER CHARACTERISTICS

Table 07: Aquifer Characteristics and Disposition									
Stratigraphy	Aquifer	Lithological character	Depth of occurrence	Thickness	Water Level	TDS	Discharge	Nature of Aquifer	Quality
			Aquifer (mbgl)	Range (m)	Range (m)	Mg/l	lps		
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 20	0 to 20	2 to 20	700 to 800	1 to 3	Phreatic	Good
Cretaceous	Weathered Basalt	Basalts	0 to 10	0 to 10	5 to 8	500 to 600	0.5 to 5.0	Phreatic	Good
	Fractured Basalt	Basalts	10 to 15	2 to 5	5 to 15	500 to 600	1 to 4	Fractured	Good
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic	Good
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Micaschsit	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured	Good

3.2 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING:

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs and Electrical logs of Exploratory wells studies carried out by CGWB and state Ground water Departments (GWRDC & GWSSB) were used to prepare a hydro geological cross section, Fence diagram and 3D Model. The data has been analyzed using Rockworks 16 software and is presented below in the Hydro-geological cross sections A-A' to D-D' and Solid Model of the district showing the depiction of weathered aquifers and fractured aquifers up to 200m. Map showing section lines are presented in Fig. 10. The stratigraphic sections depicting weathered aquifer, fractured aquiferfor Hard rock formations and unconfined aquifer for alluvium formation are placed at Figs 11-14. 3D Solid Model and Fence Diagram of Mahisagar district is depicted in Fig. 15 and 16, respectively.

TABLE 8- DATA INTEGRATION FOR MAHISAGAR DISTRICT

S.No.	Data	Aquifer	Total Data Points	Source	
				CGWB	GWRDC
1	3D Aquifer Disposition Map	1 no	35	Expl:16	-
2	Hydrogeological Cross Sections	4 no	35	Expl:16	-
3	Fence Diagrams	1 no	35	Expl:16	-
4	Depth of weathering	1 no	7	Expl:16	-
5	Depth of fracturing	1 no	7	Expl:16	-
7	Depth to Water Level Maps (2019)	Combine	65	15	39
8	Long term water	Combine	34	16	45
9	Water quality pre-2019 & post-2019	Combine	52	7	45

3.3 CONCEPTUALIZATION OF AQUIFER SYSTEM IN 2D AND 3D MAP:

Based on litho logical formation, electrical Log and local ground water survey,fourhydro-geological sections have been prepared along section lines shown in below figure to understand the subsurface disposition of aquifer system. Also 3-D Aquifer disposition map and Fence diagram is prepared to know the aquifer geometry in the district.

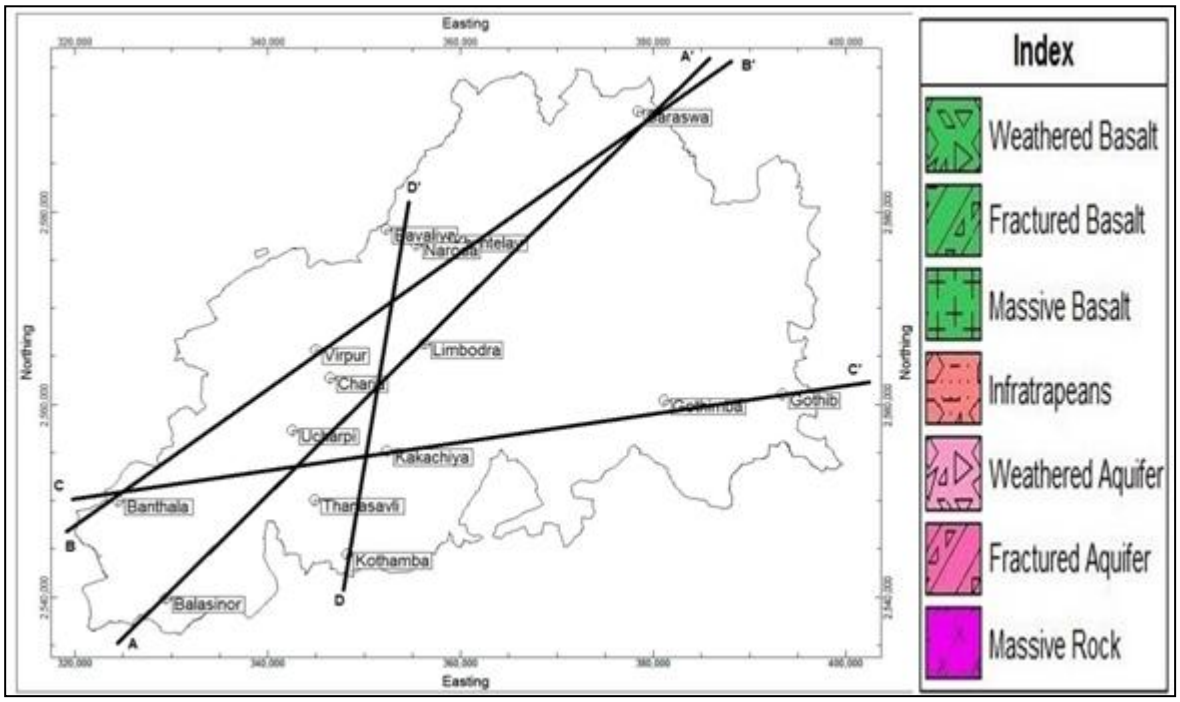


FIGURE 10- CROSS-SECTION LINE MAP OF MAHISAGAR DISTRICT & INDEX

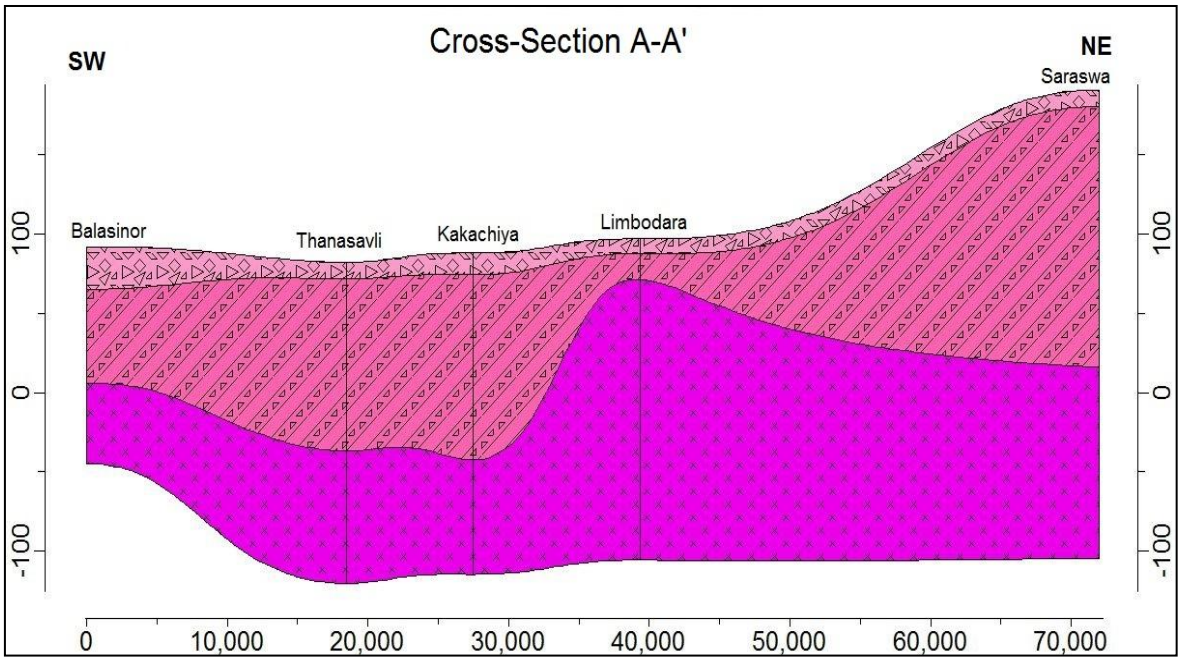


FIGURE 11- 2D AQUIFER CROSS-SECTION (A-A') MAP OF MAHISAGAR DISTRICT

Cross-Section is drawn roughly SW-NE direction and start from Balasinor to Saraswa passing through Thansavali, Kakahiya and Limbodara. Section is represented geologically;Geological formation encountered more or less same as except variation of thickness and position of out crops.

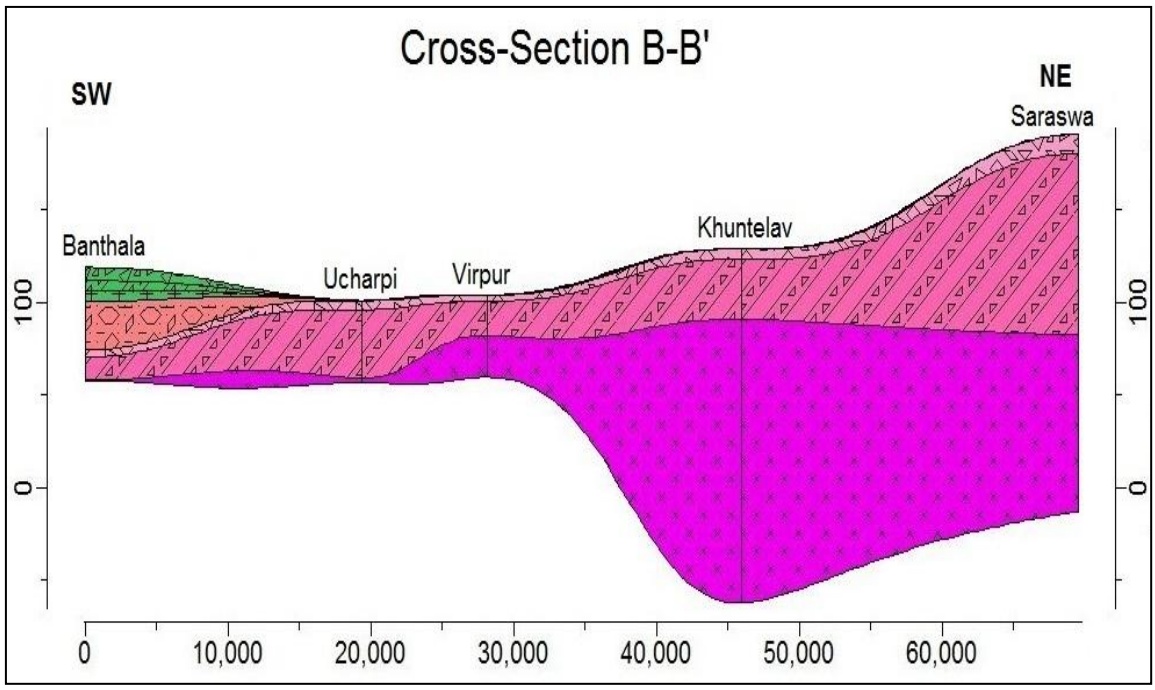


FIGURE 12- 2D AQUIFER CROSS-SECTION (B-B') MAP OF MAHISAGAR DISTRICT

Cross-Section is drawn roughly SW-NE direction and start from Banthala to Saraswa passing through Ucharpi, Virpur and Khuntelav. Section is represented geologically; in south western side near village Banthala Basalt, Infratrappean and Meta sediments encountered however in rest part of the section ismore or less same as except variation of thickness and position of out crops.

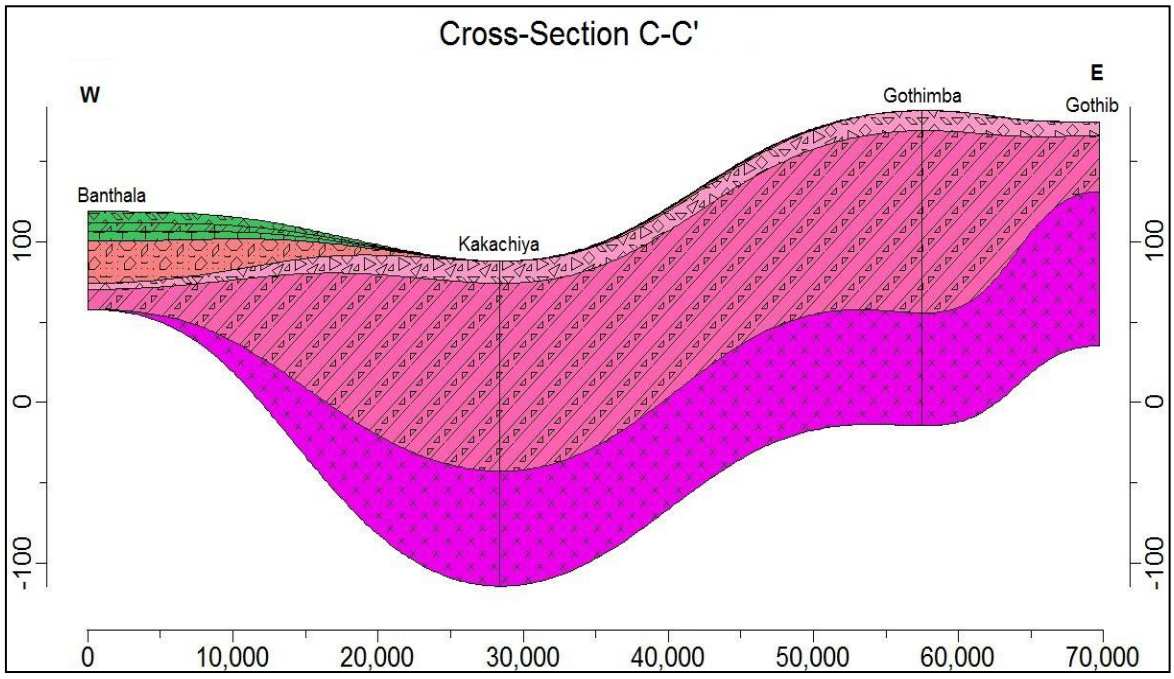


FIGURE 13- 2D AQUIFER CROSS-SECTION (C-C') MAP OF MAHISAGAR DISTRICT

Section is drawn roughly SW-NE direction and start from Banathala to Gothib passing through Kakachiya and Gothimba. Geological formation encountered more or less same as except SW part where Basalt and Infratrappean are encounter in Banathala.

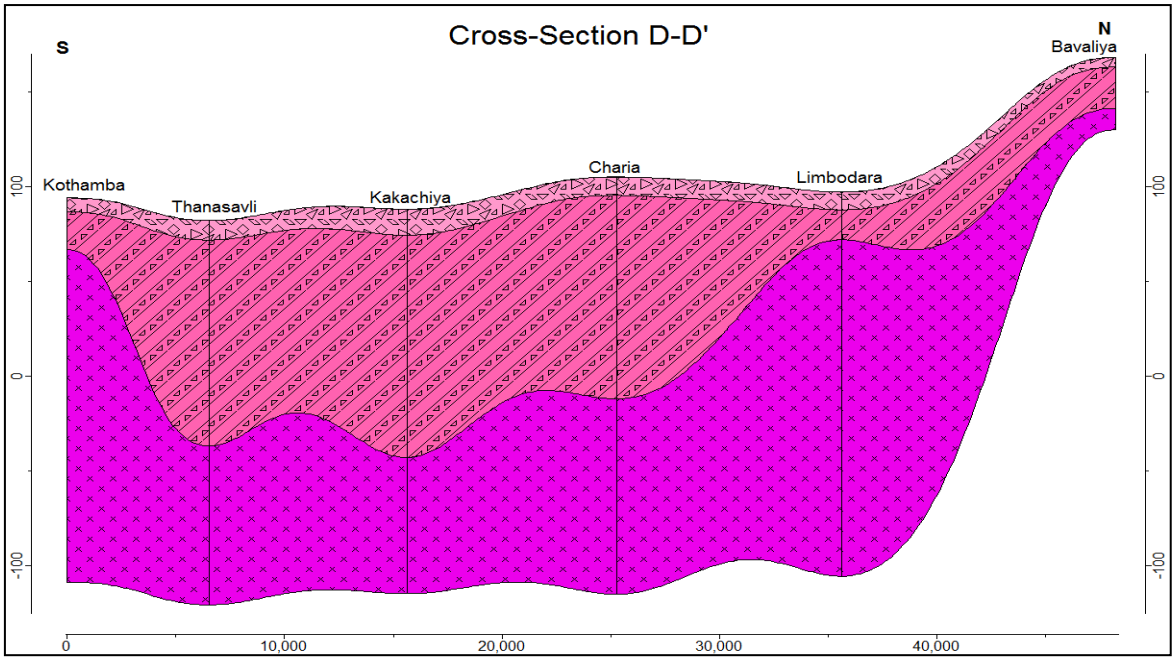


FIGURE 14- 2D AQUIFER CROSS-SECTION (D-D') MAP OF MAHISAGAR DISTRICT

Section is drawn roughly S-N direction and start from Kothamba to Bavaliya passing through Thansavali, Kakachiya, Charia and Limbodara. Geological formation encountered more or less same as except variation of thickness and position of out crops.

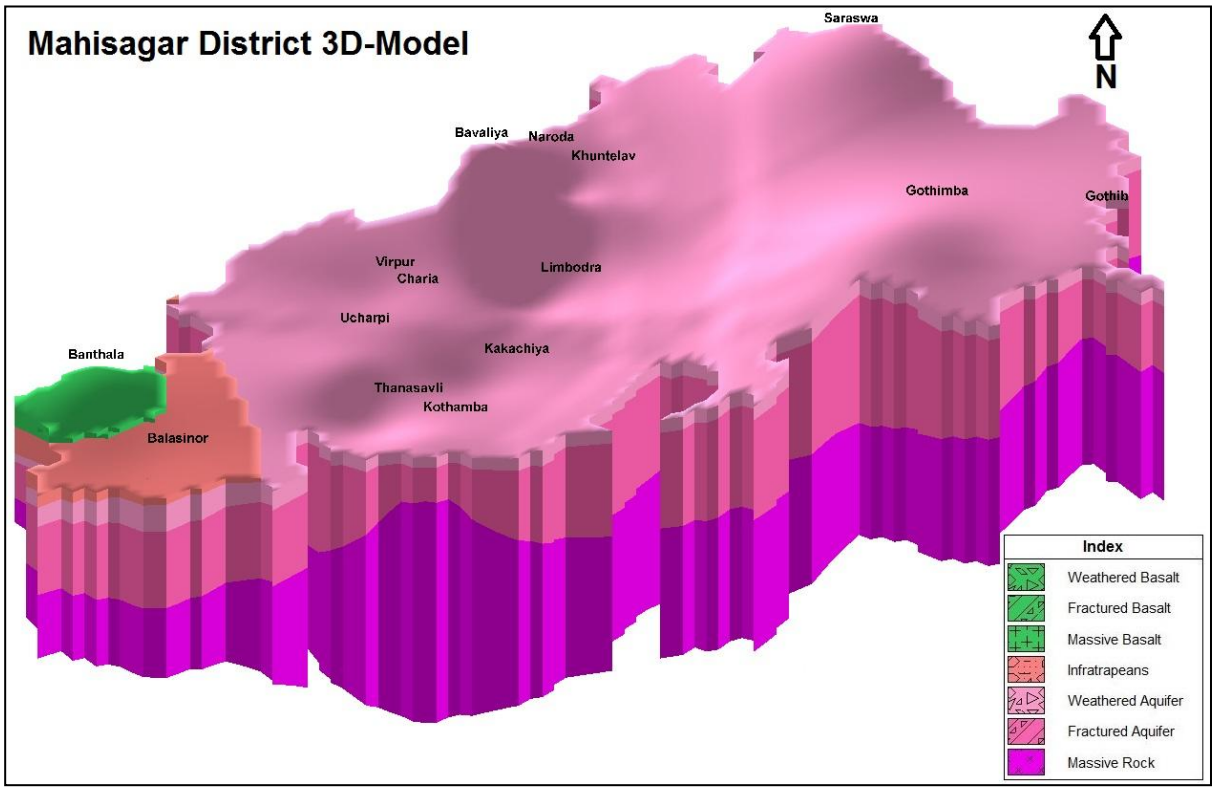


FIGURE 15- 3D AQUIFER DISPOSITION DIAGRAMOF MAHISAGAR DISTRICT

This 3D model is prepared in Rockwork-16 Software. This diagram is prepared to know the aquifer geometry in the district.

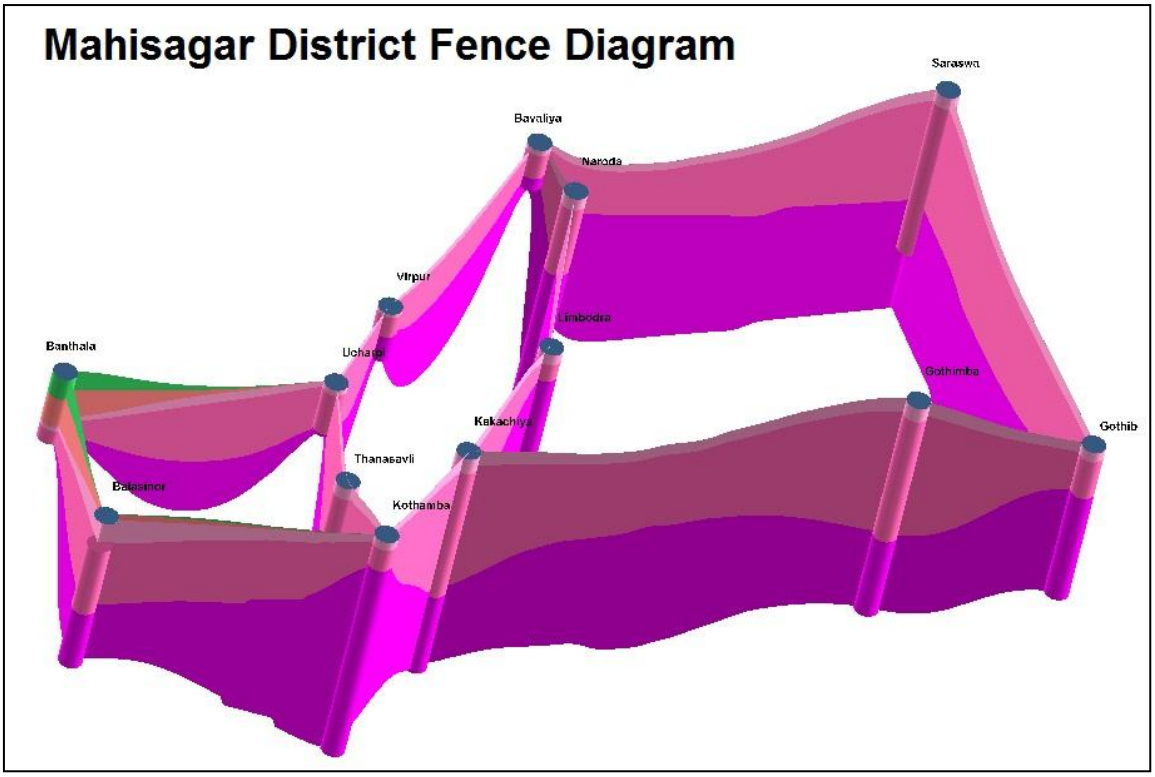


FIGURE 16- 3D FENCE/PANEL DIAGRAM OF MAHISAGAR DISTRICT

4. GROUNDWATER REGIME MONITORING:

Central Ground Water Board periodically monitors 21 Ground Water monitoring wells in the Mahisagar district, four times a year i.e. in January, May (Pre-monsoon), August and November (Post-monsoon). Ground water regime monitoring is the basic component of groundwater management and it is carried out in parts of Mahisagar district through National Hydrograph Network Stations (NHNS). These hydrograph stations comprised of dug wells and Piezometers and Observation wells. There are 15 Dug wells and 6 Piezometers as part of the NHS from CGWB and there are 18 Dug wells and 27Piezometers from GWRDC Ltd. These water level data have been used for preparation of depth to water level maps of the district to understand the behavior of ground water regime.

4.1 Depth to Water Level Pre monsoon (May 2019)

The depth to water levels in Mahisagar district during May 2019 rangesbetween 1.90 (Kothamba, Lunavada block) and 23.95 mbgl (Hadod, Lunavada block). The depth to water levels less than 5 mbgl are observed near Major/medium irrigation projects/canal command areas. In general, the depth to Water levels between 2-15 mbgl is observed in the district. The Deeper water levels between 20 and 25 mbgl are observed in isolated patches in Lunavada and Kadana block.The pre-monsoon depth to water level map is depicted in **Fig. 17**

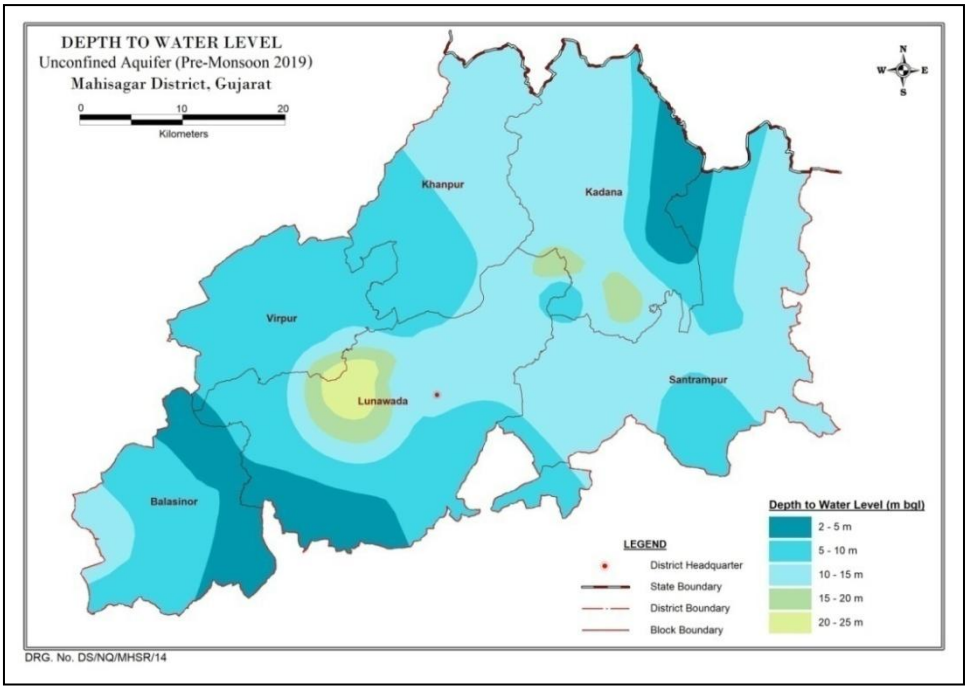


FIGURE 17- DEPTH TO WATER LEVEL MAP PRE MONSOON (MAY 2019)

4.2 Depth to Water Level Post monsoon (November 2019)

The depth to water levels in Mahisagar district during November 2019 ranges between 0.40 (Kothamba, Lunavada block) and 20.00 mbgl (Hadod, Lunavada block). The depth to water levels less than 5 mbgl are observed near Major/medium irrigation projects/canal command areas. In general, the depth to Water levels between 0-15 mbgl is observed in the district. The Deeper water levels between 15 and 20 mbgl are observed in isolated patches in Balasinor, Lunawada and Kadana block. The post-monsoon depth to water level map is depicted in **Fig. 18**

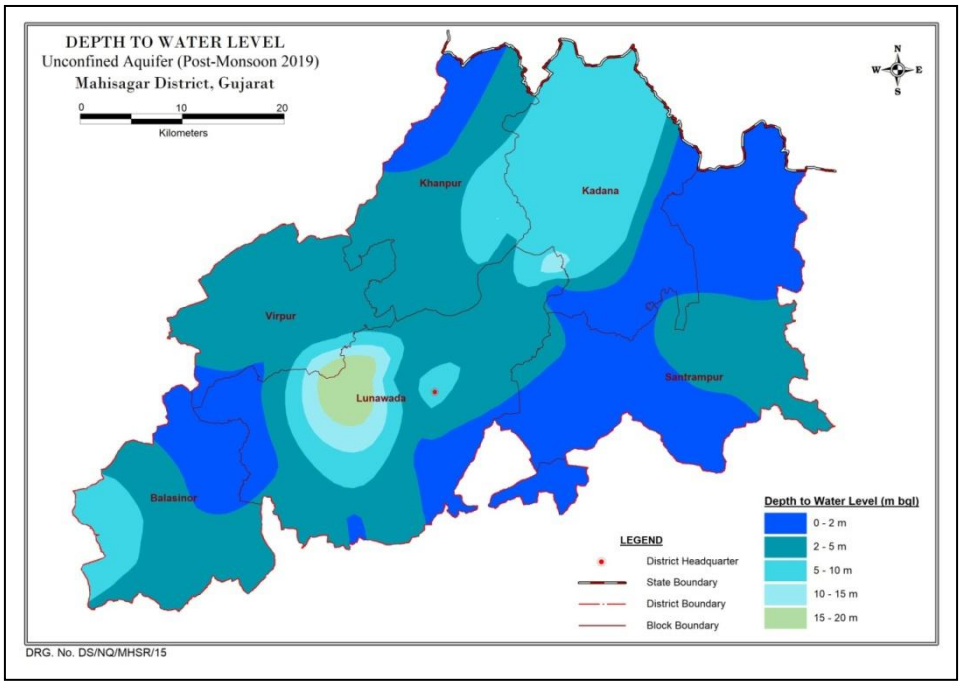


FIGURE 18- DEPTH TO WATER LEVEL MAP POST MONSOON (NOV 2019)

4.3 WATER LEVEL TREND (2009 – 2018):

During pre-monsoon, rise in water level trend has been recorded at 13 stations and ranges from 0.00252(Santrampur, Santrampur block) to 0.51350 m/year (Khadodi, Khanpur block) while falling trend was observed in 10 stations varying from 0.00780 m/year (Kothamba, Lunawada block) to 0.52738 m/year (Kadachhala, Lunawada block). Rise in water level trend has been observed in central and east central part of the district covering major part of Santrampur blocks and in part of Lunawada and Kadanablocks.

During post monsoon, rise in water level trend has been recorded at 7 stations and it ranges between 0.00991 m/year (Kothamba, Lunawada block) to 0.28 (Hadod, Lunawada block) while falling trend was observed in 16 stations varying from 0.00273 (Balasinor, Balasinor block) to 0.855 m/year (Kadachhala, Lunawada block). More than 0.10 m/year rising water level trend has been observed in western part of district covering major part of the Balasinor, Virpur blocks and part of Lunawadablock whereas 0.0 to 0.10 m/year rising water level trends has been observed in Khanpur, Kadana block and parts of Lunawada and Santrampur Blocks. Fall in water level trend has been observed in the eastern portion of the block covering almost entire area of Santrampur block and parts of Kadana and Lunawada blocks. Significant decline, more than 0.10 m/year has been observed in isolated patches in Lunawada and Santrampur Blocks. Hydrographs are attached in taluka management plan.

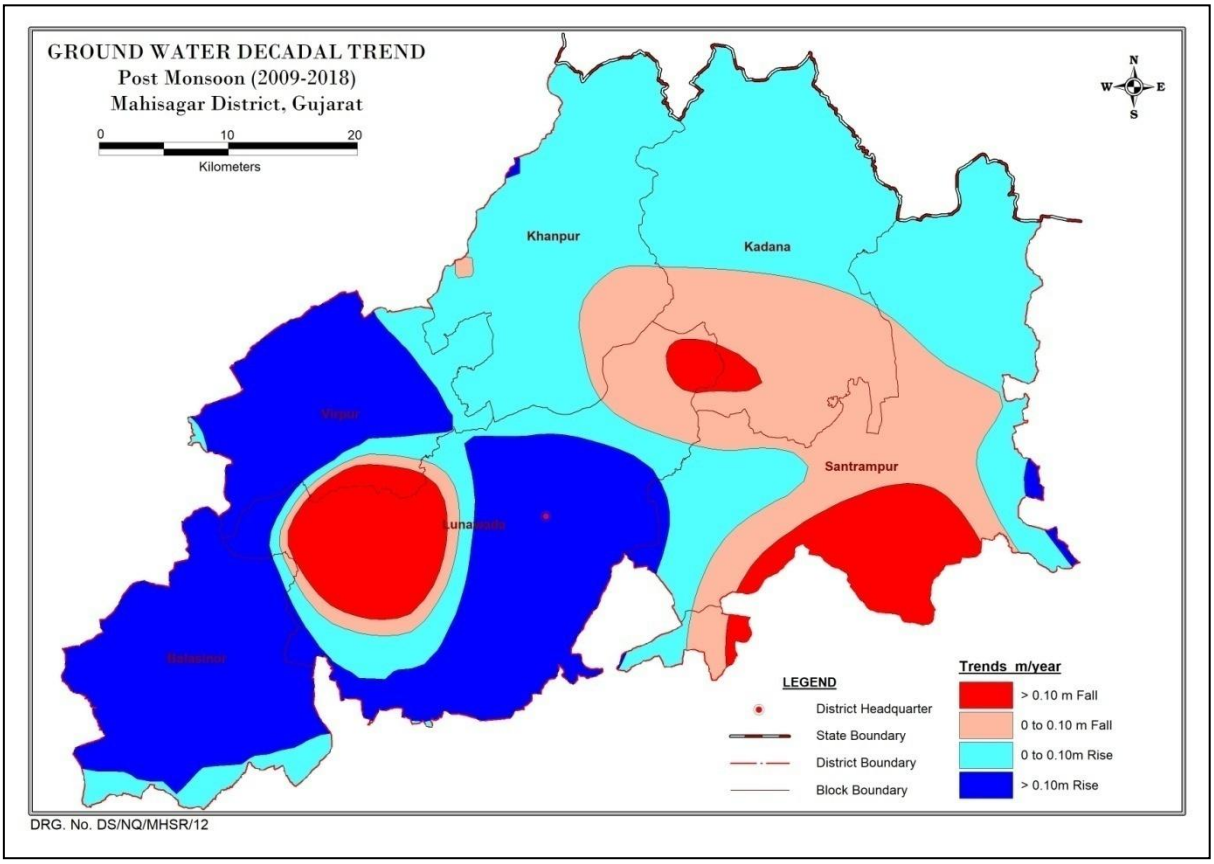


FIGURE 19- POST-MONSOON GROUND WATER DECADAL TRENDS

5. GROUND WATER QUALITY:

Water sampling is being done every year from Ground Water Monitoring wells during pre-monsoon period (May). The data gap analysis has been carried out to find out the adequacy of information on water quality and identified 36additional locationsfor unconfined aquifers. Ground water quality data of 31 monitoring wells of CGWB and GWRDC representing unconfined aquifer have been utilised to decipher the quality scenario of shallow aquifer.

TABLE 9- RANGES OF BASIC CHEMICAL ANALYSIS

Parameter	Unit	Minimum	Maximum	Average
EC	µS/cm	390.00	6270.00	1181.13
TH	mg/l	88.00	2120.00	359.72
TDS	mg/l	250.00	4201.00	776.14
CO3	mg/l	0.00	36.00	7.18
HCO3	mg/l	61.00	683.00	300.33
Cl	mg/l	35.00	1035.00	154.01
SO4	mg/l	0.00	660.00	77.54
NO3	mg/l	0.81	864.00	38.76
Ca	mg/l	15.00	184.00	57.79
Mg	mg/l	9.00	404.00	52.22
Na	mg/l	17.39	500.00	103.66
K	mg/l	0.31	80.00	7.94
F	mg/l	0.15	5.50	1.04
SAR		0.53	11.15	2.16
Alk'y	mg/l	155.00	560.00	306.53

TABLE 10- RANGES OF HEAVY METAL CHEMICAL ANALYSIS

Parameter	Unit	Minimum	Maximum	Average
Cr	ppm	0.00	0.02	0.01
Fe	ppm	0.03	0.34	0.09
Mn	ppm	0.00	0.37	0.04
Zn	ppm	0.00	0.18	0.02
Cu	ppm	0.00	0.02	0.01

5.1 ELECTRICAL CONDUCTIVITY (EC)

The concentration of EC in shallow aquifer varies between 390 (Kadana, Kadana block) and 6270 (Saliyavadi, Balasinor block). Out of 67 samples collected from dug wells and shallow tube wells, one samples are having EC in range of 3000µS/cm. Concentration of EC >3000 µS/cm has been observed in single well in village Saliyavadi, Balasinor block . In general the ground water is potable in entire part of district.The distribution of electrical conductivity in shallow aquifers is shown in **Fig. 20**.

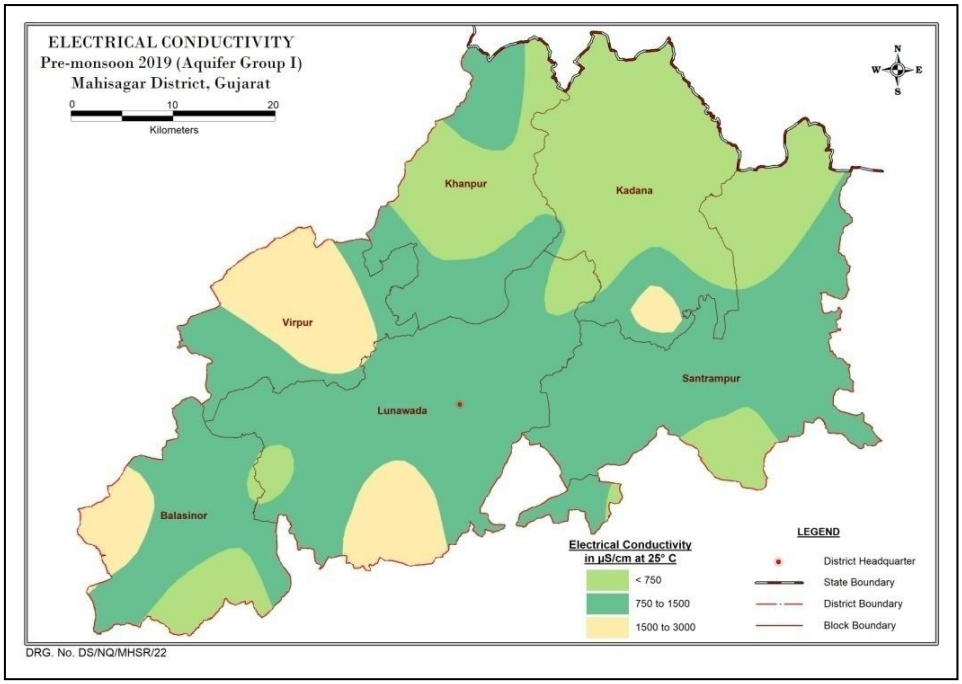


FIGURE 20- ELECTRICAL CONDUCTIVITY MAP OF MAHISAGAR DISTRICT.

5.2 NITRATE:

Nitrogen in the form of dissolved nitrate nutrient for vegetation, and the element is essential to all life. The major contribution in ground water is from sewage, waste disposal, nitrate fertilizer and decaying of organic matter. The concentration of nitrate concentration in shallow aquifer varies between 0.81 (Khanpur, Khanpur block) and 864 (Saliyavadi, Balasinor block). In shallow aquifer, 67 samples wereanalyzed;out of this onlyfew water samples show the nitrate concentrations exceeding the desirable limit of 45 mg/l. The distribution of nitrate in shallow aquifers is shown in **Fig. 21**.

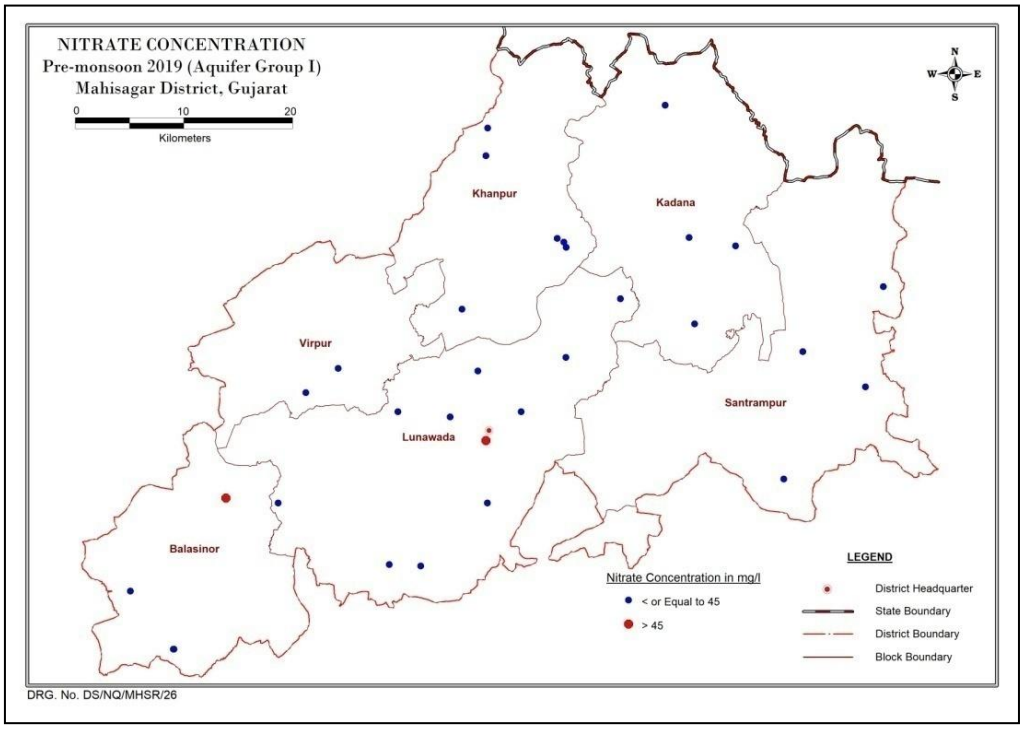


FIGURE 21- NITRATE CONCENTRATION MAP OF MAHISAGAR DISTRICT

5.3 FLUORIDE:

The major contribution in ground water is from geogenic sources by weathering of meta-sediments in Hard rock terrain. The concentration of fluoride concentration in shallow aquifer varies between 0.15 (Khanpur, Khanpur block) and 5.50 (kanesar, Khanpur block). In shallow aquifer, 67 samples were analyzed; out of this only at few places water samples show the fluoride concentrations exceeding the permissible limit of 1.5 mg/l. The distribution of fluoride in shallow aquifers is shown in **Fig. 22**.

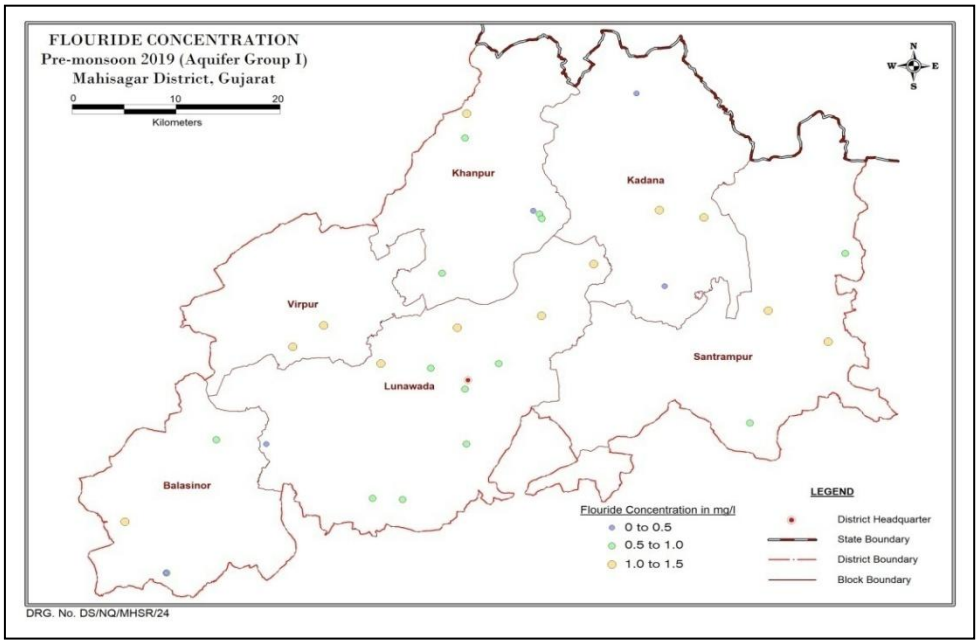


FIGURE 22- FLUORIDE CONCENTRATION MAP OF MAHISAGAR DISTRICT

5.4 SUITABILITY OF GROUND WATER FOR DRINKING PURPOSE:

In shallow aquifer, 23 % samples are having TDS more than maximum permissible limit (MPL) and 51 % of samples have TDS concentration above the Desirable limit (DL) but below the MPL. The water from such area is not fit for drinking purpose if directly consumed without treatment. It is also seen that about 14 to 50 % samples are beyond the maximum permissible limit for the parameters like TH, Ca, Mg, Cl, So_4 and No_3 indicating that the water is not suitable for drinking purpose. Concentration of Chemical constituents in shallow Aquifer is given in Table 11.

TABLE 11- CONCENTRATION OF CHEMICAL CONSTITUENTS IN SHALLOW AQUIFER

Parameter	Drinking water Standards (IS-10500-2012)		Total no of ground water samples	Shallow aquifer					
				Samples (<DL)		Samples (DL-MPL)		Samples (>MPL)	
	DL	MPL		No	%	No	%	No	%
pH	6.5-8.5	-	67	67	100	-	-	-	-
TDS	500	2000	67	19	28	47	70	1	2.0
TH	300	600	67	28	42	35	52	4	6.0
Ca (mg/L)	75	200	67	53	79	14	21	-	
Mg (mg/L)	30	100	67	27	40	36	54	4	6.0
Cl (mg/L)	250	1000	67	58	87	8	12	1	1.0
SO_4 (mg/L)	200	400	67	60	90	6	9	1	1.0
NO_3 (mg/L)	45	No relaxation	67	58	87	-		9	13.0
F (mg/L)	1	1.5	67	45	67	14	21	8	12.0

5.5 SUITABILITY OF GROUND WATER FOR IRRIGATION:

The quality of Irrigation water affects the productivity, yield and quality of the crops. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. The Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are the most important quality criteria, which asses the water quality and its suitability for irrigation.

5.5.1 Electrical Conductivity (EC)

The amount of dissolved ions in the water is represented by the electrical conductivity. The classification of water for irrigation based on the EC values is given in Table 7.6and discussed as follows: -

Low Salinity Water (EC: <1500 µS/cm): This water can be used for irrigation with most crops on most soils with little likelihood that salinity will develop.

Medium Salinity Water (EC: 1500 – 3000 µS/cm): This water can be used if moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High Salinity Water (EC: 3000 – 6000 µS/cm): This water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very High Salinity Water (EC: >6000 µS/cm): This water is not suitable for irrigation under ordinary condition. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and very salt tolerant crops should be selected.

TABLE 12- CLASSIFICATION OF GROUND WATER FOR IRRIGATION BASED ON EC VALUES

S. No	Water Quality Type	EC in µS/cm	Nos. of Samples	% of samples
1	Low Salinity Water	< 1500	52	78
2	Medium Salinity Water	>1500-3000	14	21
3	High Salinity Water	>3000-6000	1	1
4	Very High Salinity Water	>6000	-	-
Total			**67**	**100**

5.5.2 Sodium Absorption Ratio (SAR)

Excess of sodium in water render it unsuitable for irrigation on soil containing exchangeable Calcium and Magnesium ions. Soil containing exchangeable Calcium and Magnesium takes up sodium of irrigation water in exchange for Calcium and Magnesium, the ratio reflects the Sodium hazard. The SAR indicates the relative activity of the Sodium ions in exchange reactions with the soil. The main problem with high sodium concentration is its effect on soil permeability; hardening of soil & water irrigation system. Sodium also

contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. The higher value of SAR indicates soil structure damage.

Out of 36 samples analyzed for SAR, 35 samples are having SAR less than 10 and only one sample having SAR in the range of 10-18 in entire part of the district.

TABLE 13- CLASSIFICATION OF GROUND WATER FOR IRRIGATION BASED ON SAR VALUES

Characteristics	Quality	SAR value							
		< 10		10-18		18-26		> 26	
		Good		Good to Permissible		Doubtful		Bad (Unsuitable)	
	Total Number of GW samples	No	%	No	%	No	%	No	%
Unconfined Aquifer	36	35	99	1	1	-	-	-	-

It is observed that 99% samples shows SAR values less than 10 and only 1% samples having SAR value in the range of 10-18, indicating that the ground water of the area is suitable for irrigation.

5.5.3 Residual Sodium Carbonate (RSC):

Residual Sodium Carbonate (RSC) is considered to be superior to SAR as a measure of sodacity particularly at low salinity levels. Calcium reacts with bi-carbonate and precipitate as $CaCO_3$. Magnesium salt is more soluble and so there are fewer tendencies for it to precipitate. When calcium and magnesium are lost from the water, the proportion of sodium is increased resulting in the increase in sodium hazard. This hazard is evaluated in terms of RSC.The classification of ground water samples based on RSC values for its suitability for irrigation purpose is shown in below Table no 14.

TABLE 14- CLASSIFICATION OF GROUND WATER FOR IRRIGATION BASED ON RSC VALUES.

Characteristics	Quality	RSC values (meq/L)					
		< 1.25		1.25-2.50		> 2.50	
		Good		Doubtful		Bad (Unsuitable)	
	Total Number of GW samples	No	%	No	%	No	%
Unconfined Aquifer	67	67	100	-	-	-	-

It is observed that all the samples shows RSC values less than 1.25 meq/L indicating that the ground water of the area is suitable for irrigation.

1. GROUND WATER RESOURCES FOR MAHISAGAR DISTRICT

Central Ground Water Board and Gujarat water Resources Development Corporation Limited (GWRDC) have jointly estimated the ground water resources of Mahisagar district based on GEC-15 methodology in GWRE-2017. Block wise ground water resources are given in Table 15, and graphical representations of the resources on the map are shown in Figure-23.

As per the Ground Water Resources estimation 2017, the annual replenishable ground water is 370.44 MCM and the net annual ground water availability comes to be 351.92 MCM. The gross draft for all uses is estimated at 136.31 MCM with irrigation sector being the major consumer having a draft of 119.80 MCM. The domestic and industrial water requirements are worked at 16.52 MCM. The net ground water availability for future irrigation is estimated at 213.33 MCM. Stage of ground water development varies from 21.87 % (Kadana) to 56.27% (Balasinor). The overall stage of ground water development for the district is 38.73%. Block wise assessments indicate that all the blocks in the district fall under "Safe" category.

TABLE 15- GROUND WATER RESOURCES ESTIMATION AS PER GWRE 2017

District :Mahisagar															
Sr. No.	Taluka	ANNUAL REPLENISHABLE GROUND WATER RESOURCE (mcm)					Natural Discharge during non-monsoon season (mcm)	Net Annual Ground Water Availability (mcm)	ANNUAL GROUND WATER DRAFT (mcm)			Projected Demand for Domestic and Industrial uses upto 2025 (mcm)	Ground Water Availability for future irrigation (mcm)	Stage of Ground Water Development (%)	Category
		Monsoon		Non Monsoon		Total Annual Ground Water Recharge			Irrigation	Domestic And Industrial uses	Total				
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
1	Balasinor	29.62	4.48	0.00	1.07	35.17	1.76	33.41	16.42	2.38	18.80	2.64	14.35	56.27	Safe
2	Kadana	33.13	17.24	0.00	30.84	81.21	4.06	77.14	14.71	2.16	16.87	2.48	59.96	21.87	Safe
3	Khanpur	31.50	7.90	0.00	7.77	47.18	2.36	44.82	15.68	1.60	17.29	1.84	27.30	38.57	Safe
4	Lunawada	39.76	24.22	0.00	27.61	91.58	4.58	87.00	30.52	4.30	34.81	4.93	51.56	40.01	Safe
5	Santrampur	60.09	7.00	0.00	12.89	79.98	4.00	75.98	26.55	4.44	30.99	5.09	44.34	40.79	Safe
6	Virpur	29.85	4.42	0.00	1.05	35.32	1.77	33.55	15.91	1.64	17.55	1.81	15.83	52.29	Safe
District Total		223.95	65.26	0.00	81.23	370.44	18.52	351.92	119.80	16.52	136.31	18.79	213.33	38.73	Safe

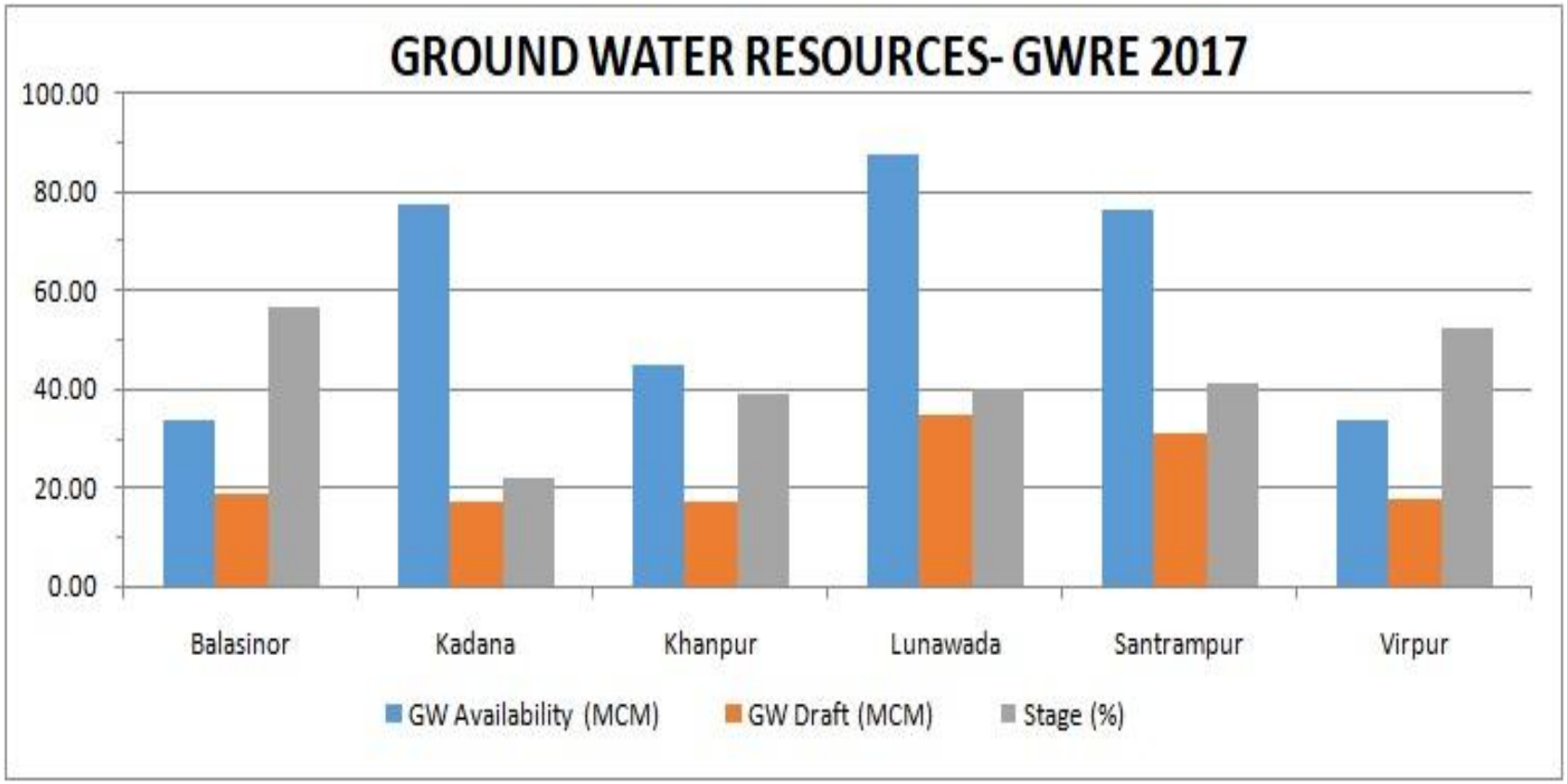


FIGURE 23- GROUND WATER RESOURCES AVAILBILITY, DRAFT & STAGE

2. GROUND WATER MANAGEMENT PLAN AND SUSTAINABLE DEVELOPMENT:

The management plan has been proposed to manage the ground water resources and to arrest further decline in water levels. The management plan comprises two components namelysupply-side management and demand side management. The supply side managements proposed based on surplus surface water availability and the unsaturated thickness of aquifer whereas the demand side management is proposed by use of micro irrigation techniques and change in cropping pattern.

2.1 GROUND WATER RELATED ISSUES:

1. **Low Ground water development:**The stage of ground water development all over the district is low (38.73%) and there is good scope for further ground water development.
2. **Low Yield and Sustainability of the Wells:**Low yield and Sustainability of hard rock Aquifers and Non Availability of sufficient Surface Water for Irrigation.
3. **Ground water Quality:**Ground water in both Phreatic and confined Aquifers is Potable and fit for domestic, drinking, irrigation and other industrial purposes but higher concentration of Fluoride and Nitrate is observed in shallow aquifer at localised pockets.
4. **Groundwater management plan:**Ground water management plan (Both supply side and Management side) needs to be prepared with an aim to enhance the groundwater usage for creation of additional irrigation potential for the district for uplifting the economic condition of the farmers.

2.2 SUPPLY SIDE MANAGEMENT

The supply side management of ground water resources can be done through the artificial recharge of surplus runoff available within river sub basins and micro watersheds. Also, it is necessary to understand the unsaturated aquifer volume available for recharge. The unsaturated volume of aquifer was computed based on the area feasible for recharge, unsaturated depth below 5mbgl and the specific yield of the aquifer. The Table no16gives the block wise volume available for the recharge.

TABLE 16- AREA FEASIBLE AND VOLUME AVAILABLE FOR ARTIFICIAL RECHARGE

Block	Area (KM^2)	Surplus water available for AR	No Recharge Shaft (From Artificial Recharge Plan)	Defunct Well (From Artificial Recharge Plan
Balasinor	304.70	2.4	79	1.0
Kadana	424.31	3.4	113	0.0
Khanpur	331.22	2.6	87	0.0
Lunawada	624.37	5.0	166	1.0
Santrampur	569.76	4.5	149	1.0
Virpur	258.28	2.1	69	1.0
Total	**2512.64**	**20**	**663.0**	**4.0**

2.3 GROUND WATER DEVELOPMENT PLAN

As per GWRE 2017 all the 06 no blocks of Mahisagar district are under safe category Ground water stage of development ranges from 21.87 % (Kadana) to 56.27 % (Balasinor). To elevate the stage of ground water development to 70% in five blocks (Balasinor, Khanpur, Lunawada, Santrampur, Virpur) and 40% in Kadana block, 22690 nos. of Dug wells (20m depth) and 810 no Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 10782hams which will create 21564 ha additional irrigation potential for the district.

TABLE 17- PROPOSED GROUND WATER DEVELOPMENT PLAN INTERVENTIONS

Block	Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)	
	DW	TW
Balasinor	665	200
Kadana	4815	190
Khanpur	3365	50
Lunawada	6000	240
Santrampur	6725	30
Virpur	1120	100
Total	**22690**	**810**

2.4 DEMAND SIDE MANAGEMENT

Even though the stage of ground water development in the district is low, however to manage the resources perceiving the future demand, following water use efficiency interventions are proposed.

- 3930 Ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 660 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water.
- Ground water recharge of 5012.12 ham (through on farm activities and GW return flow) is expected for the district.
- 484.49 hams saving of ground water through WUE measures & farm ponds activities are expected for the district.

TABLE 18- PROPOSED WUE INTERVENTIONS IN MAHISAGAR DISTRICT

Block	On farm Activities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
Balasinor	55	55	10
Kadana	2450	0	175
Khanpur	200	150	100
Lunawada	600	200	175
Santrampur	515	115	150
Virpur	110	50	50
Total	**3930**	**570**	**660**

2.5 EXPECTED BENEFITS:

The impact of groundwater management plans on the groundwater system in the district after its implementation is evaluated and the outcome shows significant improvement in groundwater scenario in all blocks as given in the Table 19.

TABLE 19- PROJECTED STATUS OF GROUNDWATER RESOURCE AFTER IMPLEMENTATION OF GW MANAGEMENT PLAN

Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Balasinor	3341.21	241.5	49.25	3631.96	1880.3	12.10	492.5	2360.7	56.3	70.0	65.0	985
Kadana	7714.49	584	525.46	8823.95	1687.2	176.72	2021	3531.5	21.9	45.0	40.0	4042
Khanpur	4481.92	281	447.85	5210.77	1728.7	63.48	1722.5	3387.7	38.6	70.0	65.0	3445
Lunawada	8700.5	561	829.92	10091.42	3481.3	114.22	3192	6559.1	40.0	70.0	65.0	6384
Santrampur	7598.11	501.5	705.64	8805.25	3099.0	89.47	2714	5723.5	40.8	70.0	65.0	5428
Virpur	3355.41	221	64	3640.41	1754.7	28.49	640	2366.2	52.3	70.0	65.0	1280
Total	35191.64	2390	2622.12	40203.76	13631.1	484.49	10782	23928.6	38.7	65.8	60.8	21564.0

- By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 70 % for 05 no blocks (Balasinor, Khanpur, Lunawada, Santrampur, Virpur) and 40% in Kadana block in Mahisagar district.
- Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 65 % for 05 no blocks (Balasinor, Khanpur, Lunawada, Santrampur, Virpur) and 40% in Kadana block in Mahisagar district.

3. Sum Up:

A thorough study was carried out based on data gap analysis, data generated in-house; data acquired from State Government departments and GIS maps prepared for various themes. All the available data was brought on GIS platform and an integrated approach was adopted for preparation of block wise aquifer maps and aquifer management plans of Mahisagar district.

Mahisagar district covering an area of 2512.64 sq km, out of this 40.96 $KM^2$is hilly area. Geologically, the area is occupied by Granite, Schist, Basalt and Alluvium formations. The stage of ground water development is 38.73%. The district has witnessed low stage of Ground Water Development and low yield potential aquifers, which are the major issues.

The management plan has been proposed to manage the ground water resources and to arrest further decline in water levels. The management plan comprises two components namely supply-side management and demand side management.

As a part of Supply side Management, a total 663 recharge shaft and 4 defunct tube wells are proposed, which will augment ground water resources to the tune of 20.00 MCM. Even though the stage of ground water development in the district is low, however to manage the resources perceiving the future demand, 3930 Ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 660 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water.

The ground water development plan has been proposed in view of the developing additional ground water resources available after supply side interventions to bring the stage of ground water development up to 70%. The 107.82 MCM volume of ground water generated can bring 215.64 sq km additional area under assured ground water irrigation by constructing 22690 Dug wells and 810 Borewells.

Present supply side interventions are suggested based on availability 20 MCM non committed source of water is referred by State Government (Reference Master Plan of Artificial recharge 2020). Proposed enhancements of present Groundwater development stage is 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.

BLOCK WISE AQUIFER MAPS AND MANAGEMENT PLAN

1. BALASINOR BLOCK
2. KADANA BLOCK
3. KHANPUR BLOCK
4. LUNAWADA BLOCK
5. SANTRAMPUR BLOCK
6. VIRPUR BLOCK

4. AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,BALSINOR BLOCK, MAHISAGAR DISTRICT, GUJARAT

4.1 INTRODUCTION:

Balasinor taluka is located in the Mahisagar district of Gujarat, India. Balasinor is located at 22.95°N 73.33°E, on the National Highway Number 47 and the Gujarat State Highway Number 2. The total population of Balasinor Taluka is 145,823 out of which urban population is 39,330 while rural is 106,493. As per Census 2011, total families in Balasinor were 7,591. Previously Balasinor Block was the part of Kheda District of Gujarat. Total area of Balasinor is 305 km² including 283.32 km² rural area and 21.64 km² urban area. There are 28,821 houses in the sub-district. There are about 45 villages in Balasinor block.

TABLE 20- LAND USE & CROPPING PATTERN FOR BALASINOR TALUKA

Area (Km^2):		304.70
No. of Villages:		45
Population (As per Census 2011)		145823
Density of Population/Km^2:		478.6
Net Sown Area (Hectare) :		18865
Gross Sown Area (Hectare):		24577
Gross Irrigated Area(Hectare):		10608
Area Irrigated by GW (%):		100
Cropping Intensity:		130.28
Irrigation Intensity:		43.2
Principal crops	Kharif:	Maize, Paddy, Castor, Cotton
	Rabi:	Wheat, Maize, Gram
	Summer:	Ground Nut, Bajra, Mung

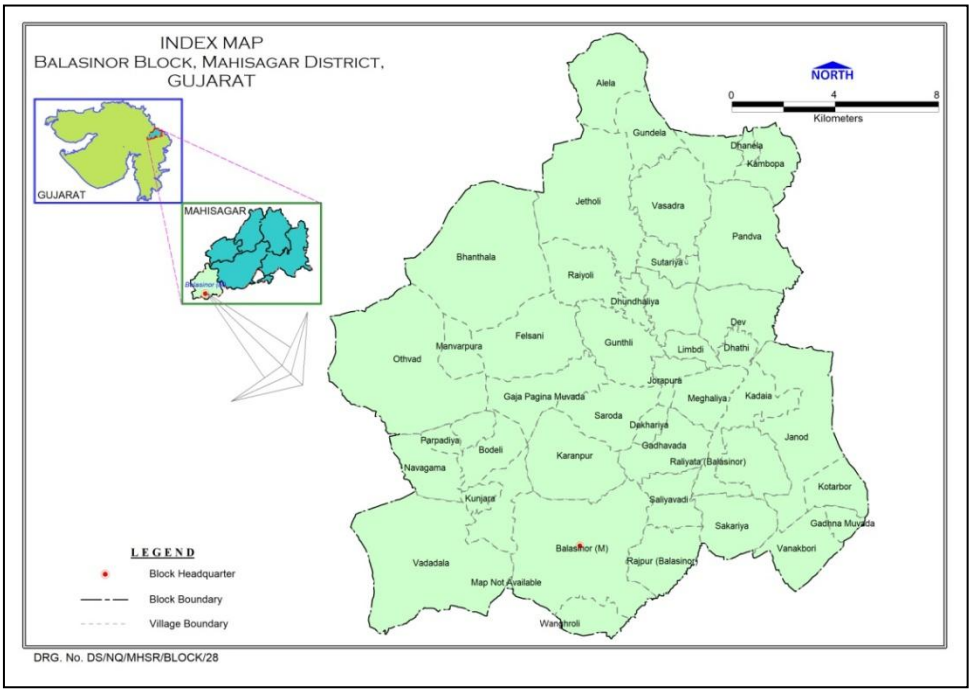
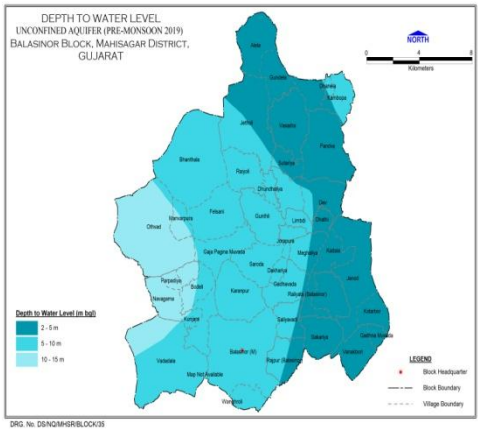
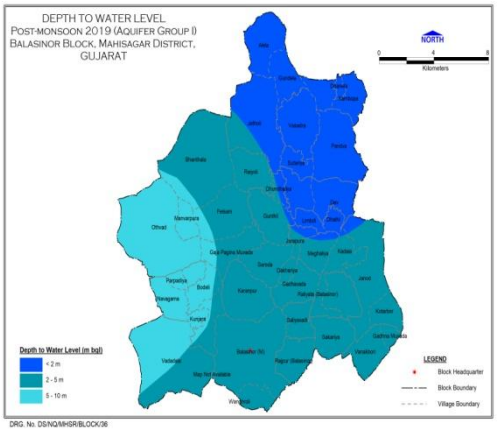


FIGURE 24- ADMINISTRATIVE MAP OF BALASINOR BLOCK

TABLE 21-BALASINOR BLOCK GEOMORPHOLOGY, DRAINAGE, GEOLOGY AND RAINFALL

Geomorphic Unit	Plateau (Un-dissected to highly Dissected) with weathered thickness ranging from 0 to 30 m and Alluvial Plains of Mahi River (younger alluvium).
Basin/Sub-basin	Major Drainages: Perennial river – Mahi river, Non-perennial river – No any. But tributary channels and streamlets are there.
Principal Aquifer System	Alluvium, Basalt, Granite, Schist and Quartzite.
Major Aquifer System	Meta-sediments of Aravalli super group such as Phyllite, quartzite; post Delhi intrusive of Godhara granite and gneiss; Infra-trappeans of lameta beds; sandstones and limestone; Deccan trap basalts and alluvium deposit along river channels and valley fills.
Normal Annual Rainfall	853.8 mm

TABLE 22- BALASINOR BLOCK WATER LEVEL BEHAVIOUR

Phreatic Aquifer	**Pre-Monsoon (May-2019)**	**Post-Monsoon (November-2019)**
Water Level	Water level ranges from4.80 mbgl (Juna Vasadara village) to 11.00 mbgl (Parabiya Village). It is observed that depth to water level is shallower in eastern part in compare to western part of the block.	The post-monsoon Water Level in the taluka is less than 10 mbgl. Water level ranges from1.25 mbgl (Velsani village) to 6.35 mbgl (Parabiya Village). It is observed that depth to water level decreases from west to east direction.
Water Level Map	 **FIGURE 25- BALASINOR WATER LEVEL PRE-MONSOON**	 **Figure 26- Balasinor Water Level Post-Monsoon**

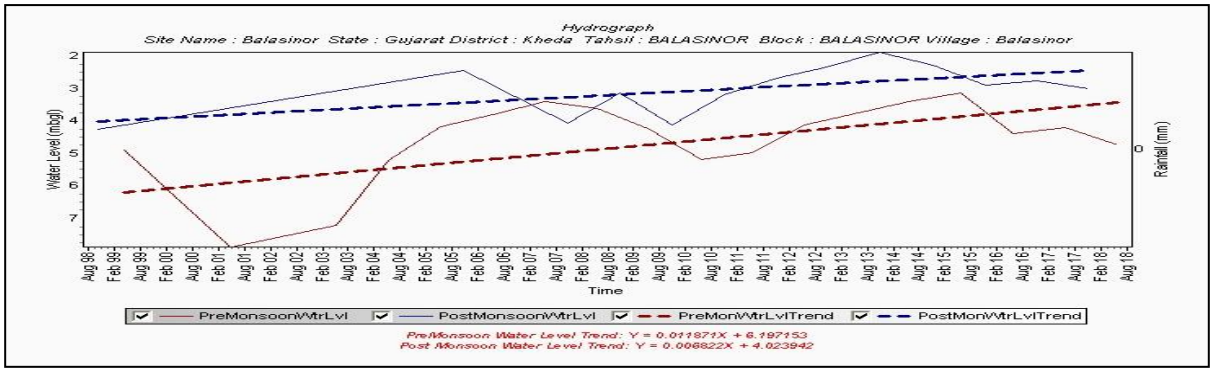


FIGURE 27- BALASINOR HYDROGRAPH

It shows both Pre-Monsoon and Post-Monsoon rising water Level Trends @ 0.0118 m/year and 0.0068 m/year respectively.

4.2 AQUIFER DISPOSITION

Number of Aquifers

- Schist/Phyllite- Weathered Aquifer, Fractured Aquifer
- Basalt – Weathered Aquifer, Fractured Aquifer
- Alluvium- Unconfined Aquifer

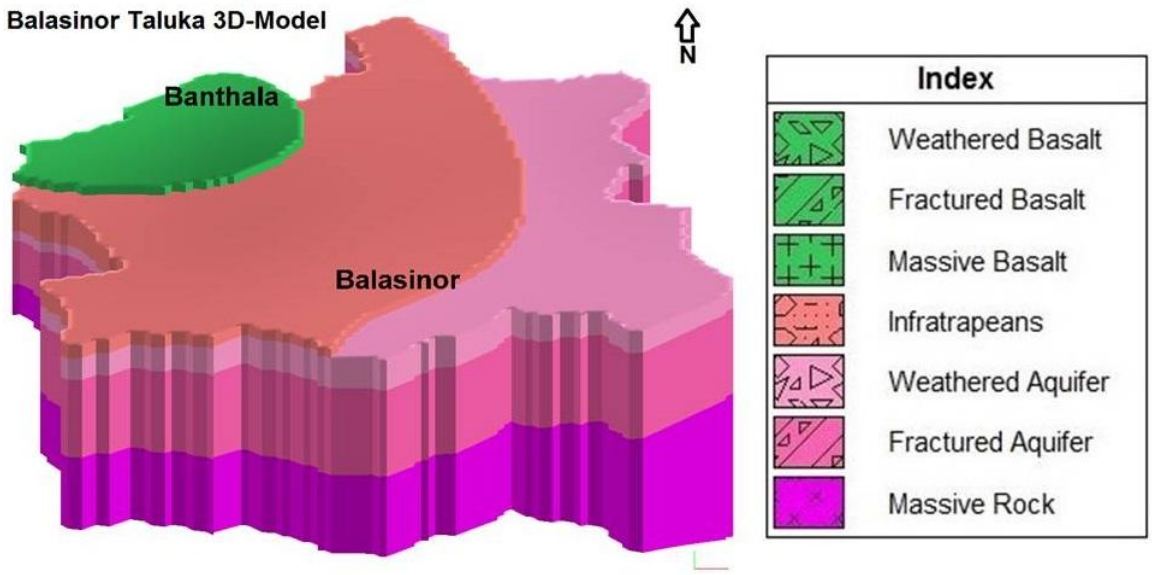


FIGURE 28- 3D- AQUIFER MODEL OF BALASINOR BLOCK

TABLE 23- AQUIFER CHARACTERISTICS AND DISPOSITION

Stratigraphy	Aquifer	Lithological character	Depth of occurrence	Thickness	Water Level	TDS	Discharge	Nature of Aquifer
			Aquifer (mbgl)	Range (m)	Range (m)	Mg/l	lps	
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 20	0 to 20	2 to 20	700 to 800	1 to 3	Phreatic
Cretaceous	Weathered Basalt	Basalts	0 to 10	0 to 8	5 to 8	500 to 600	0.5 to 5	Phreatic
	Fractured Basalt	Basalts	10 to 15	2 to 5	5 to 15	500 to 600	1 to 4	Fractured
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Schist	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured

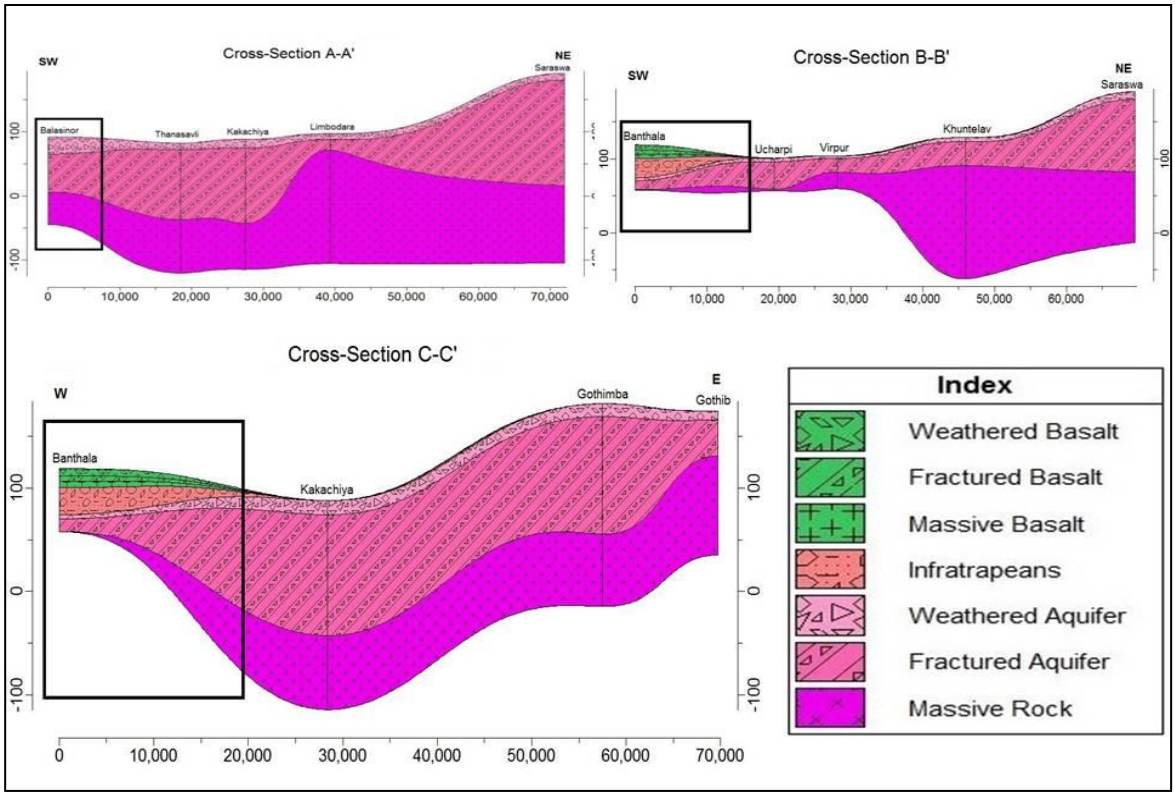
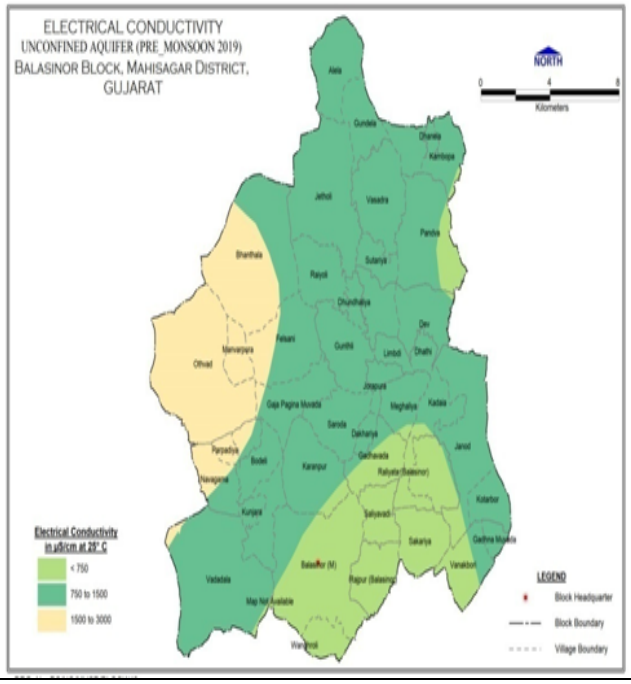


FIGURE 29- 2D AQUIFER CROSS-SECTIONS FOR BALASINOR BLOCK

4.3 CHEMICAL QUALITY OF GROUND WATER



Quality	Minimum	Maximum	Average
EC	550	1690	1155.5
TH	163	610.488	331.46
TDS	350	1070	748.75
CO3	0	36	19.5
HCO3	122	305	207.40875
Cl	85	291	182
SO4	0	154	81.25
NO3	0.53	65	17.525
Ca	35	116.232	65.67
Mg	18	77.824	40.285
Na	46	181	104
K	0.31	80	18.83
F	0.24	1.26	0.78

4.4 Ground Water Resources for Balasinor Block as Per GWRE-2017

TABLE 24- GROUND WATER RESOURCES FOR BALASINOR BLOCK

GWRE-2017 GROUND WATER RESOURCES	
Phreatic Aquifer (Granite, Schist, Phyllite, Basalt & Alluvium)	
Total Annual Ground Water Recharge (MCM)	35.17
Natural Discharge (MCM)	1.76
Net Annual Ground Water Availability (MCM)	33.41
Existing Gross Ground Water Draft for irrigation (MCM)	16.42
Existing Gross Ground Water Draft for domestic and industrial water supply(MCM)	2.38
Existing Gross Ground Water Draft for All uses(MCM)	18.80
Provision for domestic and industrial requirement supply to 2025(MCM)	2.64
Net Ground Water Availability for future irrigation development(MCM)	14.35
Stage of Ground Water Development (%)	56.27
Category	**SAFE**

4.5 GROUND WATER MANAGEMENT PLAN:

4.5.1 Ground Water Development Plan

The stage of ground water extraction of Balasinor taluka is 56.27 %.To elevate the stage of ground water development to 70% in 665 nos. of Dug wells (20m depth) and 200 no Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 492.5ham which will create 985 Ha additional irrigation potential for the taluka.

TABLE 25- PROPOSED GROUND WATER DEVELOPMENT STRUCTURES FOR BALASINOR BLOCK

Block	**Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)**	
	DW (Nos.)	**TW (Nos.)**
Balasinor	665	200

4.5.2 Supply Side Management

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 2.4 MCM of surplus surface water is provisioned for artificial recharge through 79 no of recharge shafts and 01 no of existing defunct tube wells in Balasinor Taluka, which may result into 240 ham Ground Water recharge.

TABLE 26- PROPOSED VOLUME OF WATER FOR ARTIFICIAL RECHARGE AND RECHARGE STRUCTURES

Block	**Area in Sq.Km**	2.4 MCM Surplus water available	No Recharge Shaft (From Artifical Recharge Plan)	Defunct Well (From Artifical Recharge Plan
Balasinor	**304.70**	**2.4**	**79**	**1.0**

4.5.3 Demand Side Management Plan:

15 ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 10 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water.Ground water recharge of 290.75 ham (through on farm activities and GW return flow) is expected for the district.12.10 ham saving of ground water through WUE measures & farm ponds activities is expected for the block.

TABLE 27- DEMAND SIDE MANAGEMENT PLAN FOR BALASINOR BLOCK

Block	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
Balasinor	55	55	10

4.5.4 Expected Benefits

By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 70 % for Balasinor block. Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 65 % for Balasinor block

TABLE 28- EXPECTED BENEFITS AFTER IMPLEMENTATION OF MANAGEMENT PLAN

Projected Status of Groundwater Resource after implementation of GW Management Plan, Mahisagar District (Gujarat)													
Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Balasinor	3341.21	241.5	49.25	3631.96	1880.3	12.10	492.5	2360.7	56.3	70.0	69.6	65.0	985

5. AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,KADANA BLOCK, MAHISAGAR DISTRICT, GUJARAT

5.1 INTRODUCTION:

Kadana taluka is located in the Mahisagar district of Gujarat, India. Previously Kadana Block was the part ofPanchmahal District of Gujarat. Total area of Kadana block is 424.31 km². Kadana talukalies between north latitudes 23.175088 and 23.456106 and east longitudes 73.683163 and 73.890336. The total population of Kadana Taluka is 129,545 out of which of which 66,399 are male and 63,146 are female. Literacy rate in the taluka is 56.93 percent, out of these male and female literacy rate is 34.41% and 22.52% respectively.There are about 135 villages in Kadana block.

TABLE 29- LAND USE & CROPPING PATTERN FOR KADANA BLOCK

Area (Km^2):		424.31
No. of Villages:		135
Population (As per Census 2011)		129545
Density of Population/Km^2:		305.3
Net Sown Area (Hectare) :		16148
Gross Sown Area (Hectare):		18154
Gross Irrigated Area(Hectare):		10669
Area Irrigated by GW (%):		44.89
Cropping Intensity:		112.42
Irrigation Intensity:		58.8
Principal crops	Kharif:	Maize, Paddy, Castor, Cotton
	Rabi:	Wheat, Maize, Gram
	Summer:	Ground Nut, Bajra, Mung

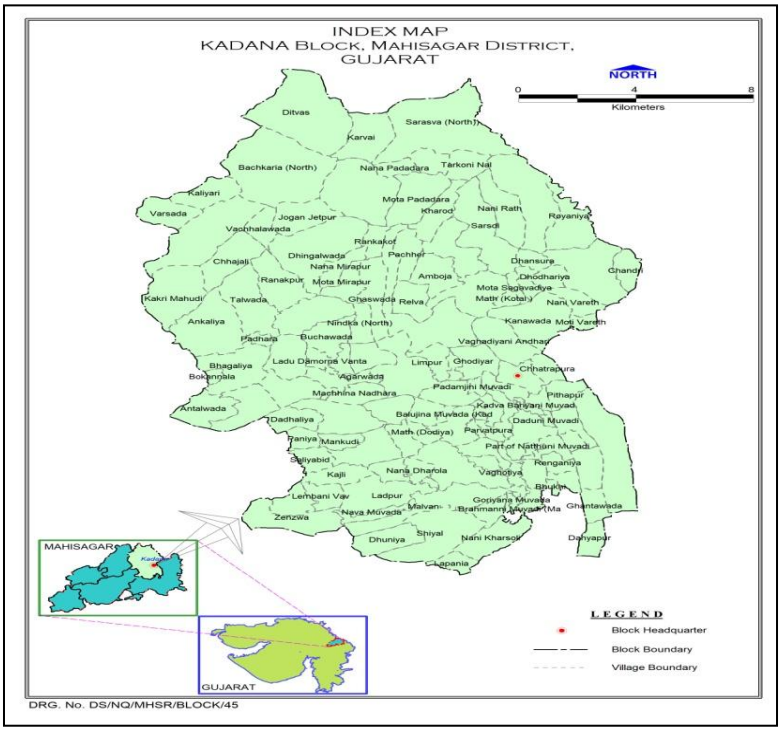
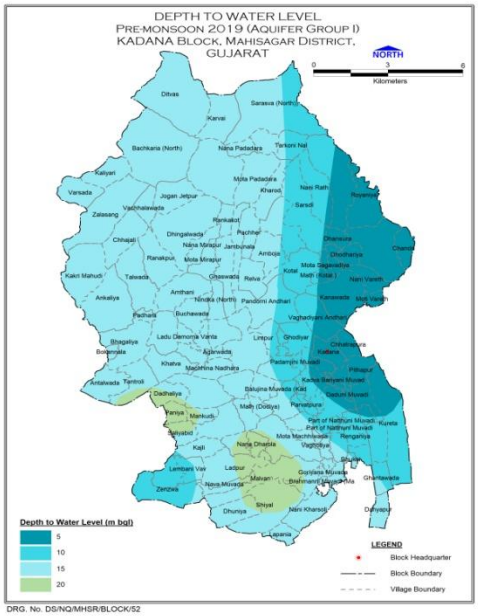
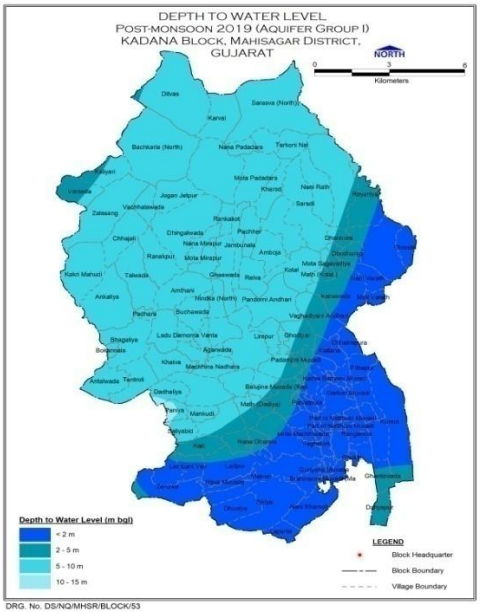


FIGURE 30- ADMINISTRATIVE MAP OF KADANA BLOCK

FIGURE 31- GEOMORPHOLOGY, DRAINAGE, GEOLOGY AND RAINFALL FOR KADANA BLOCK

Table 19- Geomorphology, Drainage, Geology and Rainfall	
Geomorphic Unit	Plateau (Undissected to highly Dissected) with weathered thickness ranging from 0 to 30 m
Basin/Sub-basin	Major Drainages: Perennial river – Bhadar river,
	Non-perennial river – No any. But tributary channels and streamlets are there.
Principal Aquifer System	Phyllite, Schist and Quartzite.
Major Aquifer System	Meta-sediments of Aravalli super group such as Phyllites, quartzite; post Delhi intrusive of Godhra granite and gneiss.Alluvium deposit along valley fills.
Normal Annual Rainfall	842.3 mm

TABLE 30- WATER LEVEL BEHAVIOUR FOR KADANA BLOCK

Water Level Behaviour		
Phreatic Aquifer	**Pre-Monsoon (May-2019)**	**Post-Monsoon (November-2019)**
Water Level Map		
Water Level	Water level ranges from3.30 mbgl (Kadana) to 16.30 mbgl (Malvan Village). It is observed that depth to water level is shallower in eastern part in compare to western part of the block.	The post-monsoon Water Level in the taluka is less than 10 mbgl. Water level ranges from1.00 mbgl (Kadana village) to 5.60 mbgl (Malvan Village). It is observed that depth to water level shallower in southern and south eastern part or block.

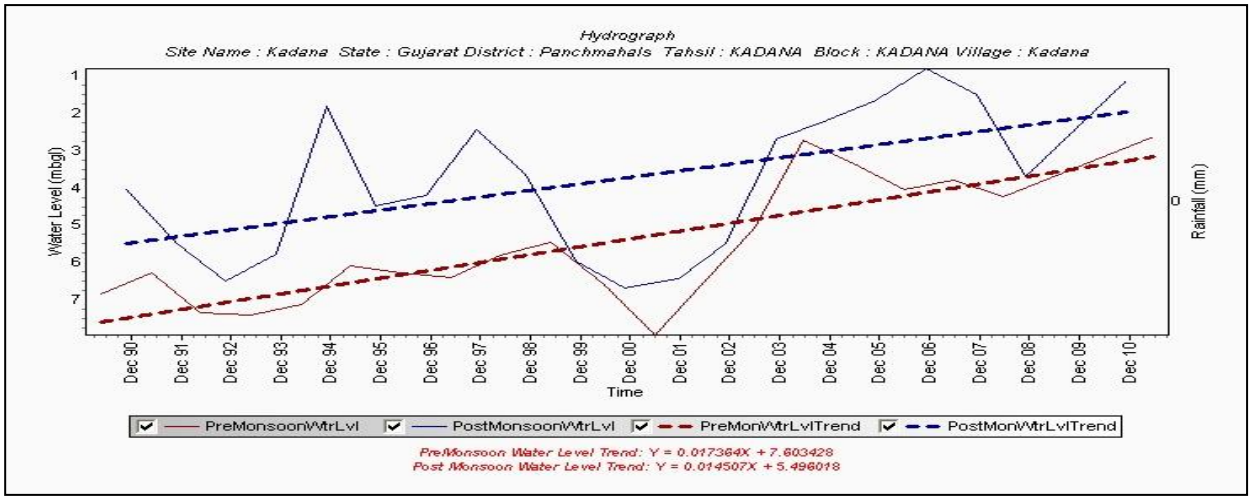


FIGURE 32- KADANA HYDROGRAPH

It shows both Pre-Monsoon and Post-Monsoon rising water Level Trends @ 0.0174 m/year and 0.0145 m/year respectively.

5.2 AQUIFER DISPOSITION

Number of Aquifers

- Schist/Phyllite- Weathered Aquifer, Fractured Aquifer

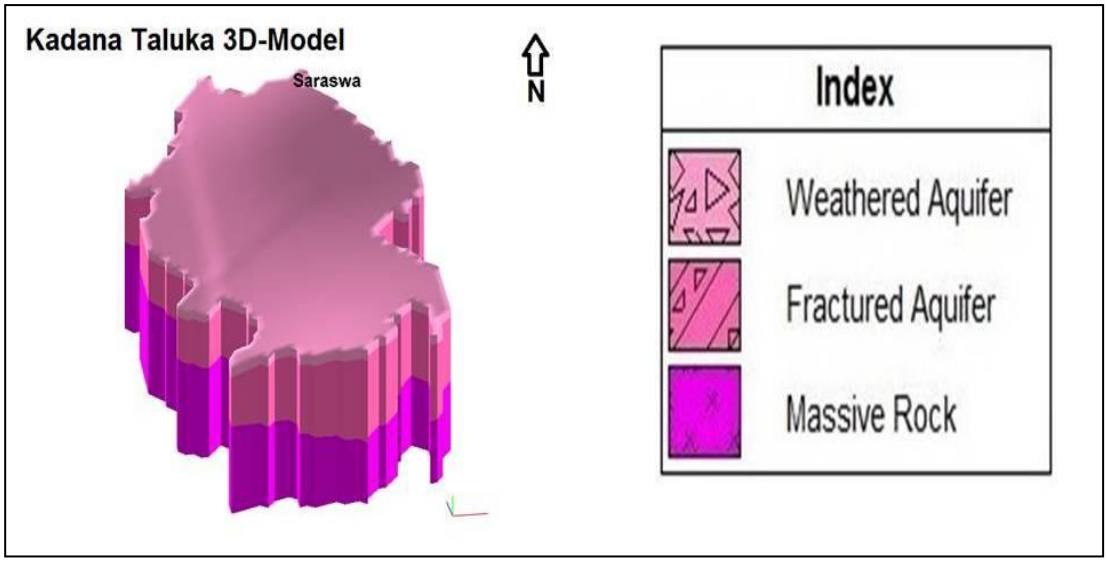


FIGURE 33- 3D- AQUIFER MODEL FOR KADANA BLOCK

TABLE 31- AQUIFER CHARACTERISTICS AND DISPOSITION FOR KADANA BLOCK

Aquifer Characteristics and Disposition								
Stratigraphy	Aquifer	Lithological character	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level Range (m)	TDS Mg/l	Discharge lps	Nature of Aquifer
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 20	0 to 20	2 to 20	700 to 800	1 to 3	Phreatic
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Schist	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured

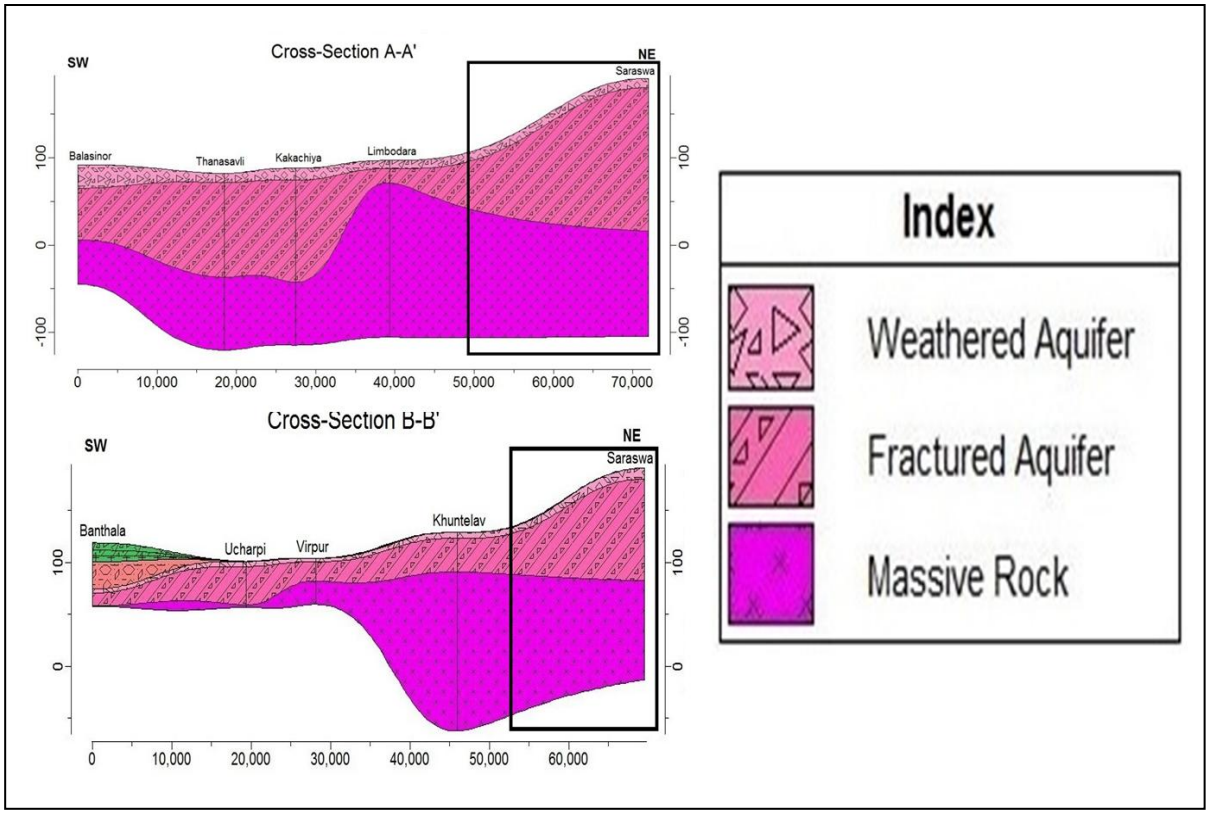
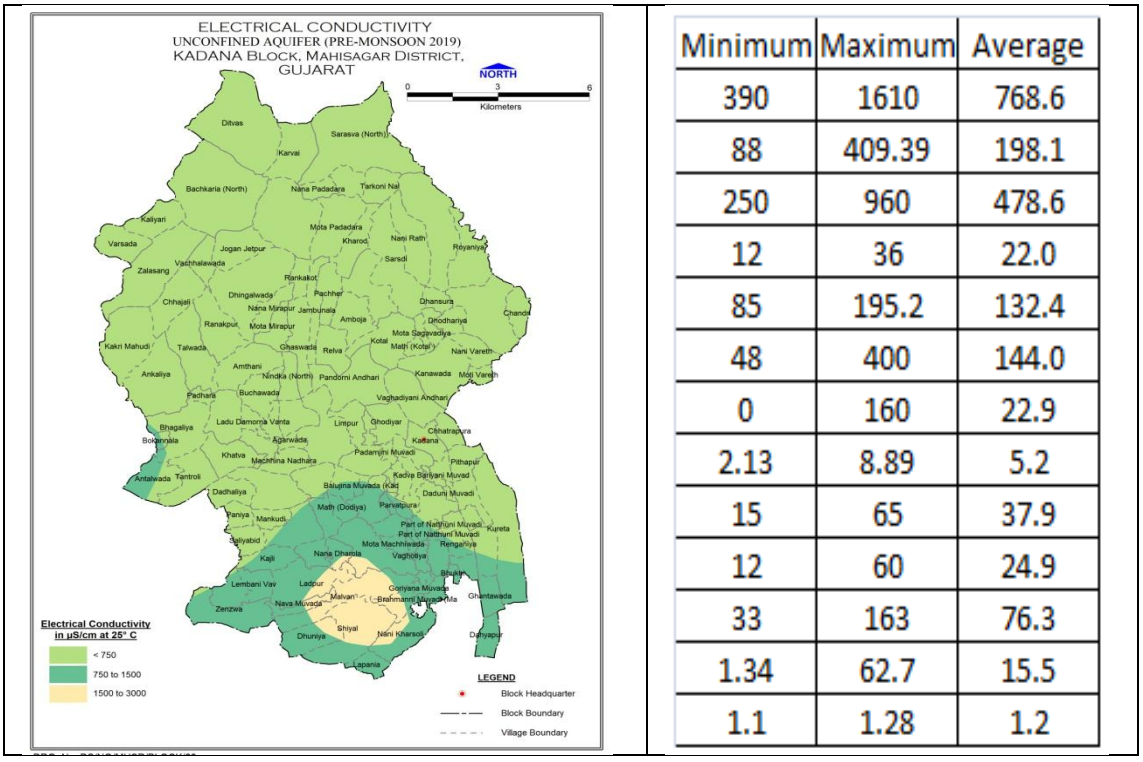


FIGURE 34- 2D AQUIFER CROSS-SECTIONS FOR KADANA BLOCK

5.3 CHEMICAL QUALITY OF GROUND WATER



Minimum	Maximum	Average
390	1610	768.6
88	409.39	198.1
250	960	478.6
12	36	22.0
85	195.2	132.4
48	400	144.0
0	160	22.9
2.13	8.89	5.2
15	65	37.9
12	60	24.9
33	163	76.3
1.34	62.7	15.5
1.1	1.28	1.2

5.4 GROUND WATER RESOURCES FOR KADANA BLOCK AS PER GWRE-2017

TABLE 32- GWRE-2017 GROUND WATER RESOURCES

GWRE-2017 GROUND WATER RESOURCES	
Phreatic Aquifer (Granite, Schist, Phyllite)	
Total Annual Ground Water Recharge (MCM)	81.21
Natural Discharge (MCM)	4.06
Net Annual Ground Water Availability (MCM)	77.14
Existing Gross Ground Water Draft for irrigation (MCM)	14.71
Existing Gross Ground Water Draft for domestic and industrial water supply(MCM)	2.16
Existing Gross Ground Water Draft for All uses(MCM)	16.87
Provision for domestic and industrial requirement supply to 2025(MCM)	2.48
Net Ground Water Availability for future irrigation development(MCM)	59.96
Stage of Ground Water Development (%)	21.87
Category	**SAFE**

5.5 GROUND WATER MANAGEMENT PLAN:

5.5.1 GROUND WATER DEVELOPMENT PLAN

The stage of ground water extraction of Kadana taluka is 21.87 %.To elevate the stage of ground water development to 45% in 4815 nos. of Dug wells (20m depth) and 190 no Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 2021.0ham which will create 4042.0 Ha additional irrigation potential for the taluka.

TABLE 33- PROPOSED GROUND WATER DEVELOPMENT STRUCTURES FOR KADANA BLOCK

Block	**Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)**	
	DW (Nos.)	**TW (Nos.)**
Kadana	4815	190

5.5.2 . SUPPLY SIDE MANAGEMENT

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 3.4 MCM of surplus surface water is provisioned for artificial recharge through 113 no of recharge shafts in Kadana Taluka, which may result into 340 ham Ground Water recharge.

TABLE 34- PROPOSED WATER AVAILABLE FOR ARTIFICIAL RECHARGE AND RECHARGE STRUCTURES

Block	**Area in KM^2**	3.4 MCM Surplus water available	Nos. of Recharge Shaft (From Artificial Recharge Plan)	Defunct Well (From Artificial Recharge Plan
Kadana	**424.31**	**2.4**	**113**	**-**

5.5.3 DEMAND SIDE MANAGEMENT:

2450 ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 175 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Ground water recharge of 1109.46 ham (through on farm activities and GW return flow) is expected for the block. 176.82ham saving of ground water through farm ponds activities is expected for the block.

TABLE 35- DEMAND SIDE MANAGEMENT FOR KADANA BLOCK

Block	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
Kadana	2450	0	175

5.5.4 . EXPECTED BENEFITS

By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 45 % for Kadana block. Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 40 % for Kadana block.

TABLE 36- EXPECTED BENEFITS AFTER IMPLEMENTATION OF MANAGEMENT PLAN

Projected Status of Groundwater Resource after implementation of GW Management Plan, Kadana Taluka, Mahisagar District (Gujarat)

Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Kadana	7714.49	584	525.46	8823.95	1687.2	176.72	2021	3531.5	21.9	45.0	41.6	40.0	4042

6. AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,KHANPURBLOCK, MAHISAGAR DISTRICT, GUJARAT

6.1 INTRODUCTION:

Khanpur taluka is located in the Mahisagar district of Gujarat, India. Previously KhanpurBlock was the part ofPanchmahal District of Gujarat. Total area of Khanpur block is 331.22 km². Khanpur talukalies between north latitudes 23.195521 and 23.454623 and east longitudes 73.521142 and 73.725430. The total population of KhanpurTaluka is 96041 out of which of which 49,023 are male and 47,018 are female. Literacy rate in the taluka is 57.76 percent, out of these male and female literacy rate is 34.87% and 22.89% respectively.There are about 85 villages in Khanpurblock.

TABLE 37- LAND USE & CROPPING PATTERN FOR KHANPUR BLOCK

Area (Km^2):		331.22
No. of Villages:		85
Population (As per Census 2011)		96041
Density of Population/Km^2:		290
Net Sown Area (Hectare) :		13392
Gross Sown Area (Hectare):		20526
Gross Irrigated Area(Hectare):		6185
Area Irrigated by GW (%):		29.76
Cropping Intensity:		153.27
Irrigation Intensity:		30.1
Principal crops	Kharif:	Maize, Paddy, Castor, Cotton
	Rabi:	Wheat, Maize, Gram
	Summer:	Ground Nut, Bajra, Mung

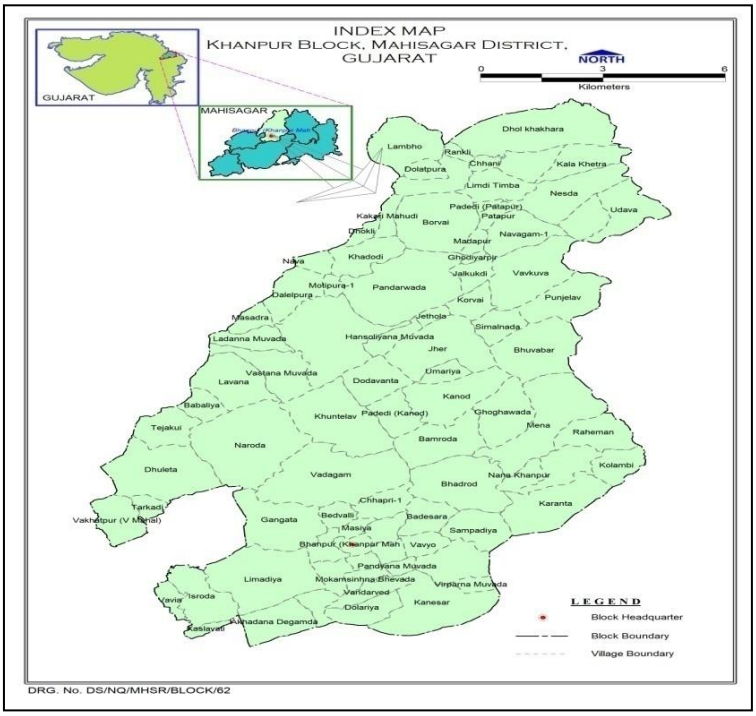
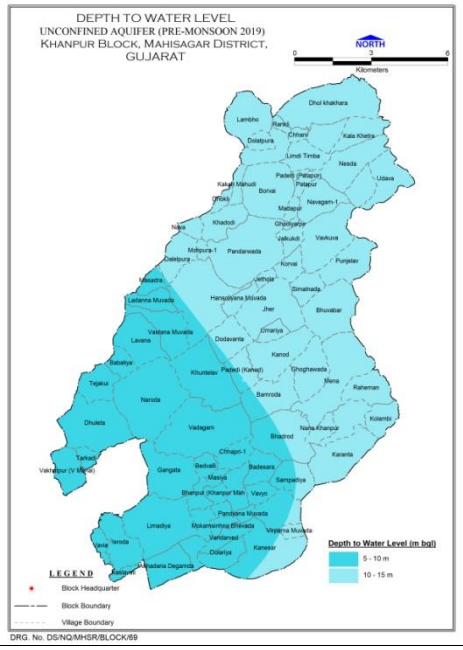
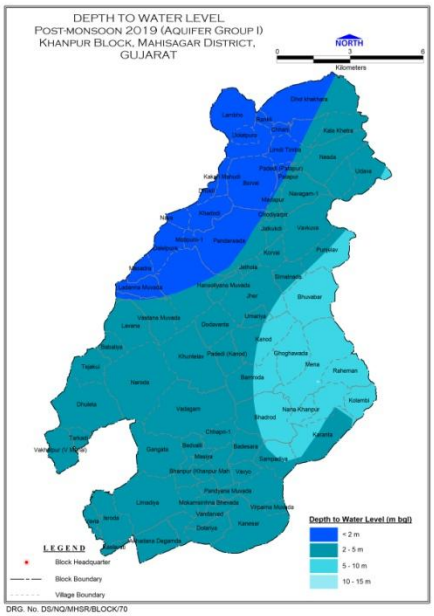


FIGURE 35- ADMINISTRATIVE MAP OF KHANPUR BLOCK

TABLE 38- GEOMORPHOLOGY, DRAINAGE, GEOLOGY AND RAINFALL FOR KHANPUR BLOCK

Geomorphology, Drainage, Geology and Rainfall	
Geomorphic Unit	Plateau (Undissected to highly Dissected) with weathered thickness ranging from 0 to 30 m
Basin/Sub-basin	Major Drainages: Perennial river – Mahi River,
	Non-perennial river – Bhadar River. But tributary channels and streamlets are there
Principal Aquifer System	Phyllite, Schist and Quartzite.
Major Aquifer System	Meta-sediments of Aravalli super group such as Phyllites, quartzite; post Delhi intrusive of Godhra granite and gneiss.Aeolian alluvium deposit valley fills.
Normal Annual Rainfall	558.8 mm

TABLE 39- WATER LEVEL BEHAVIOUR FOR KHANPUR BLOCK

Water Level Behaviour		
Phreatic Aquifer	**Pre-Monsoon (May-2019)**	**Post-Monsoon (November-2019)**
Water Level Map		
Water Level	Water level ranges from5.45 mbgl (Pandarvada village) to 11.60 mbgl (Khanpur mota Village). It is observed that depth to water level is shallower in southeren part in compare to northern part of the block.	The post-monsoon Water Level in the taluka is less than 10 mbgl. Water level ranges from1.69 mbgl (Pandarvada village) to 10.20 mbgl (Khanpur mota Village).

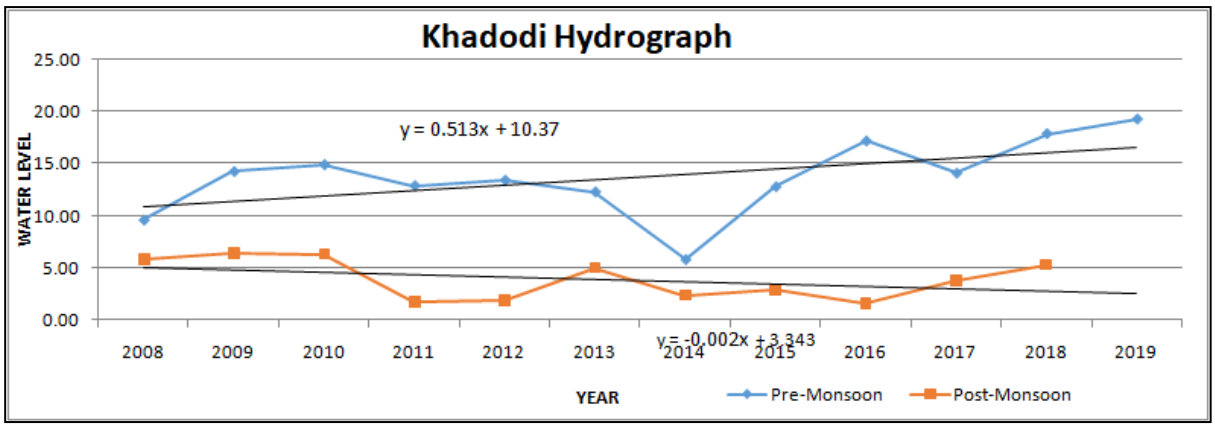


FIGURE 36- KHADODI HYDROGRAPH

This Hydrograph of Khadodi Village shows Pre-Monsoon 0.513 m/year rising water level trends whereas Post-Monsoon shows falling water Level Trends @ 0.002 m/year.

6.2 AQUIFER DISPOSITION

Number of Aquifers

- Schist/Phyllite- Weathered Aquifer, Fractured Aquifer

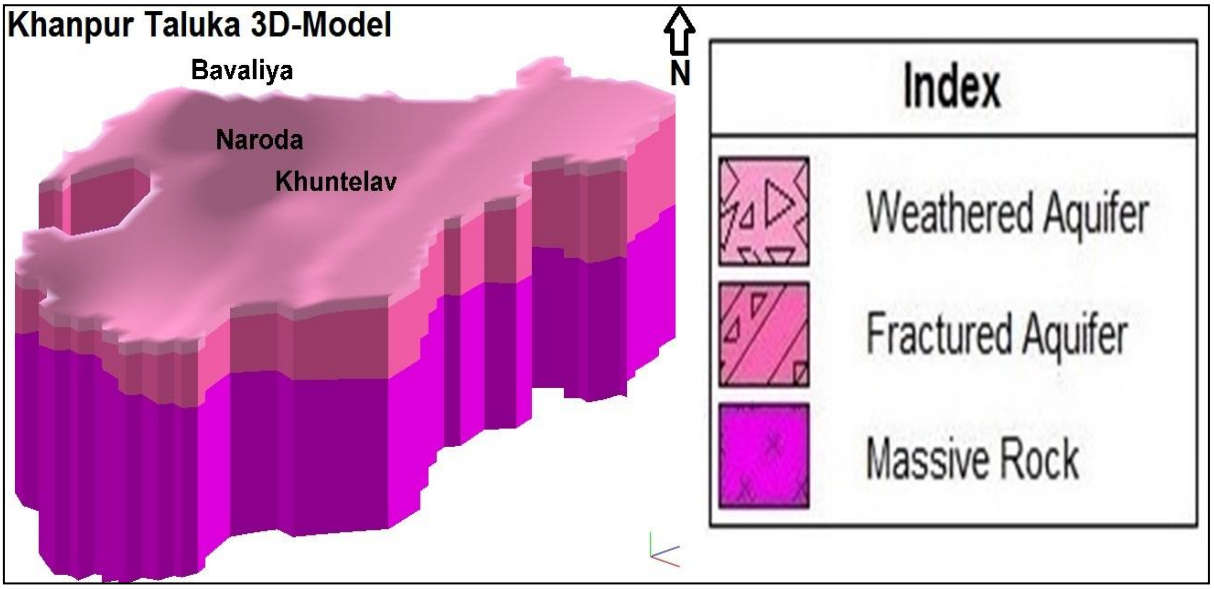


FIGURE 37- 3D- AQUIFER MODEL FOR KHANPUR BLOCK

TABLE 40- AQUIFER CHARACTERISTICS AND DISPOSITION

Aquifer Characteristics and Disposition								
Stratigraphy	Aquifer	Lithological character	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level Range (m)	TDS Mg/l	Discharge lps	Nature of Aquifer
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 10	5 to 15	2 to 20	700 to 800	1 to 3	Phreatic
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Schist	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured

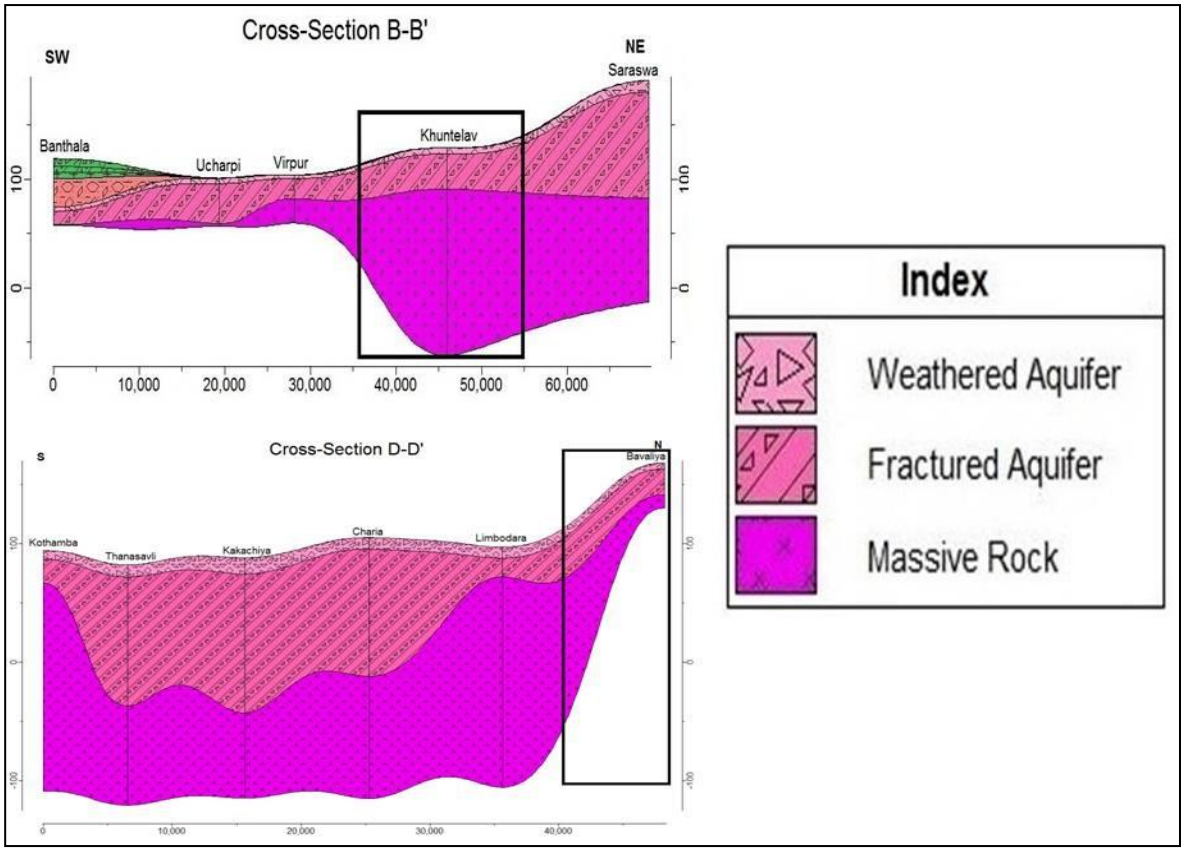
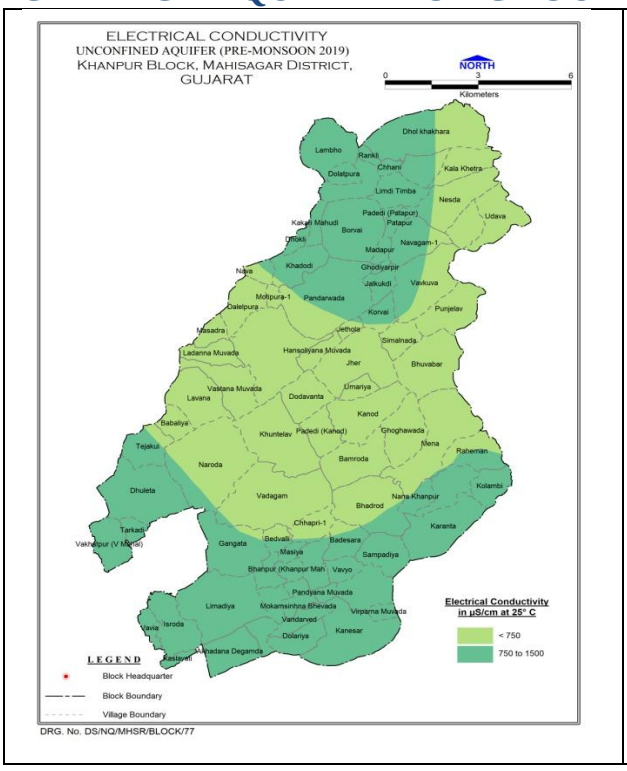


FIGURE 38- 2D AQUIFER CROSS-SECTIONS MAPS OF KHANPUR BLOCK

6.3 CHEMICAL QUALITY OF GROUND WATER



Khanpur		
Minimum	Maximum	Average
550	1600	874.9
138	313	232.5
370	1030	564.7
0	24	12.0
134.2	268.444	198.6
43	304	130.6
0	182	50.4
0.81	32	10.9
25	90	54.3
9	45	23.2
48	172	86.7
0.55	88.43	18.5
0.15	1.19	0.8

6.4 Ground Water Resources for Khanpur Block as Per GWRE-2017

TABLE 41- GROUND WATER RESOURCES FOR KHANPUR BLOCK

GWRE-2017 GROUND WATER RESOURCES	
Phreatic Aquifer (Granite, Schist, Phyllite)	
Total Annual Ground Water Recharge (MCM)	47.18
Natural Discharge (MCM)	2.36
Net Annual Ground Water Availability (MCM)	44.82
Existing Gross Ground Water Draft for irrigation (MCM)	15.68
Existing Gross Ground Water Draft for domestic and industrial water supply(MCM)	1.60
Existing Gross Ground Water Draft for All uses(MCM)	17.29
Provision for domestic and industrial requirement supply to 2025(MCM)	1.84
Net Ground Water Availability for future irrigation development(MCM)	27.30
Stage of Ground Water Development (%)	38.57
Category	**SAFE**

6.5 GROUND WATER MANAGEMENT PLAN:

6.5.1 . GROUND WATER DEVELOPMENT PLAN

The stage of ground water extraction of Khanpurtaluka is 38.57 %.To elevate the stage of ground water development to 70% in 3365 nos. of Dug wells (20m depth) and 50 no Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 1722.5ham which will create 3445.0 Ha additional irrigation potential for the taluka.

TABLE 42- PROPOSED GROUND WATER DEVELOPMENT STRUCTURES FOR KHANPUR BLOCK

Block	**Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)**	
	DW (Nos.)	**TW (Nos.)**
Khanpur	3365	50

6.5.2 SUPPLY SIDE MANAGEMENT

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 2.6 MCM of surplus surface water is provisioned for artificial recharge through 87 no of recharge shafts in KhanpurTaluka, which may result into 260 ham Ground Water recharge.

TABLE 43- PROPOSED WATER AVAILABLE FOR ARTIFICIAL RECHARGE AND RECHARGE STRUCTURES

Block	**Area in KM^2**	3.4 MCM Surplus water available	Nos. of Recharge Shaft (From Artificial Recharge Plan)	Defunct Well (From Artificial Recharge Plan
Khanpur	**331.22**	**2.6**	**87**	**-**

6.5.3 DEMAND SIDE MANAGEMENT:

200 ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 100 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Ground water recharge of 728.85 ham (through on farm activities and GW return flow) is expected for the block. 63.48ham saving of ground water through Water Use Efficiency measures and farm ponds activities is expected for the block.

TABLE 44- DEMAND SIDE MANAGEMENT FOR KHANPUR BLOCK

Block	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
Khanpur	200	150	100

6.5.4 EXPECTED BENEFITS

By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 70 % for Khanpurblock. Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 65 % for Khanpurblock.

TABLE 45- EXPECTED BENEFITS AFTER IMPLEMENTATION OF MANAGEMENT PLAN

Projected Status of Groundwater Resource after implementation of GW Management Plan, Khanpur Taluka, Mahisagar District (Gujarat)													
Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Khanpur	4481.92	281	447.85	5210.77	1728.7	63.48	1722.5	3387.7	38.6	70.0	68.4	65.0	3445

7. AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,LUNAWADA BLOCK, MAHISAGAR DISTRICT, GUJARAT

7.1 INTRODUCTION:

Lunawada taluka is located in the Mahisagar district of Gujarat, India. Previously Lunawada Block was the part of Panchmahal District of Gujarat. Total area of Lunawada block is 624.37 km². Lunawada taluka lies between north latitudes 22.982313 and 23.263148 and east longitudes 73.365749 and 73.703040. The total population of Lunawada Taluka is 257228 out of which of which 113,278 are male and 106,996 are female. Literacy rate in the taluka is 63.30 percent, out of these male and female literacy rate is 37.58% and 25.71% respectively. There are about 240 villages in Lunawada block.

TABLE 46- LAND USE & CROPPING PATTERN FOR LUNAWADA BLOCK

Area (Km^2):		624.37
No. of Villages:		240
Population (As per Census 2011)		257228
Density of Population/Km^2:		412
Net Sown Area (Hectare) :		37015
Gross Sown Area (Hectare):		45304
Gross Irrigated Area(Hectare):		29111
Area Irrigated by GW (%):		27.22
Cropping Intensity:		122.39
Irrigation Intensity:		64.3
Principal crops	Kharif:	Maize, Paddy, Castor, Cotton
	Rabi:	Wheat, Maize, Gram
	Summer:	Ground Nut, Bajra, Mung

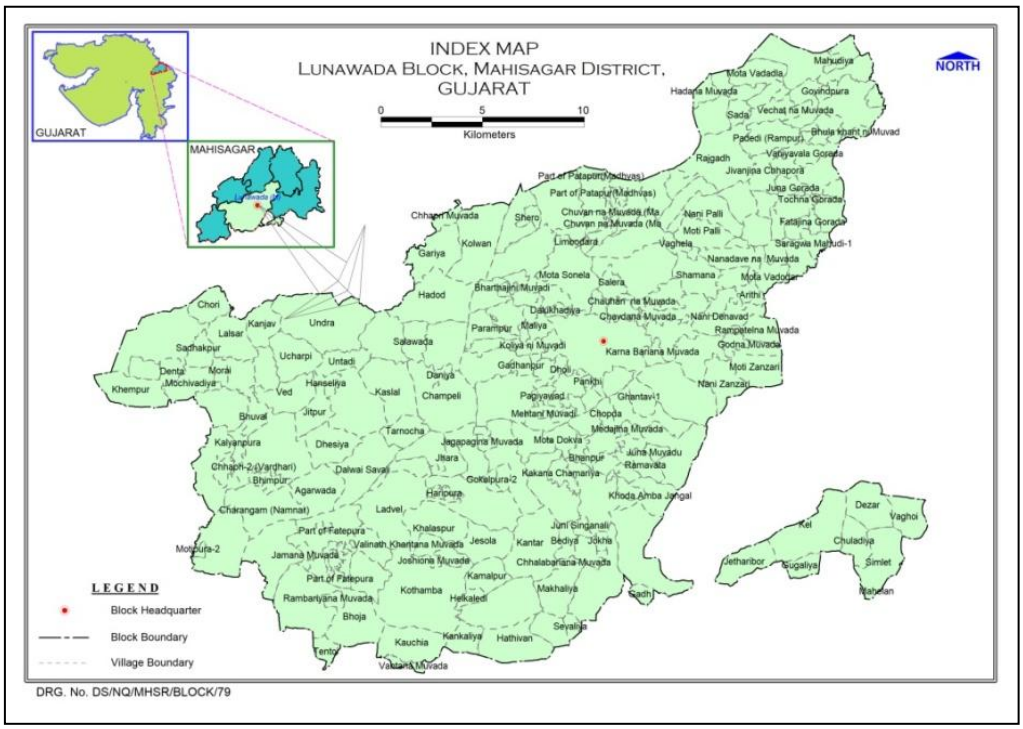
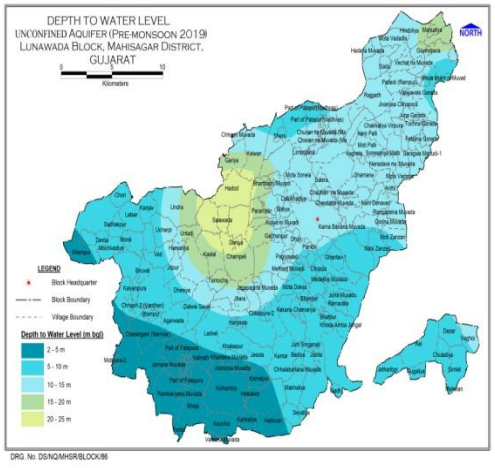
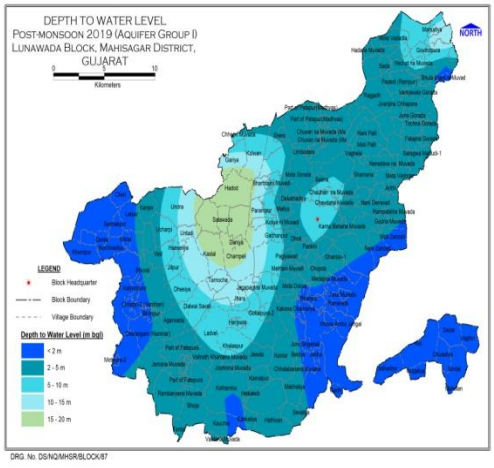


FIGURE 39- ADMINISTRATIVE MAP OF LUNAWADA BLOCK

TABLE 47- GEOMORPHOLOGY, GEOLOGY AND RAINFALL FOR LUNAWADA BLOCK

Geomorphology, Drainage, Geology and Rainfall	
Geomorphic Unit	Plateau (Undissected to highly Dissected) with weathered thickness ranging from 0 to 30 m
Basin/Sub-basin	Major Drainages: Perennial river – MahiRiver,
	Non-perennial river – Panam River and tributary channels and streamlets are there.
Principal Aquifer System	Phyllite, Schist and Quartzite.
Major Aquifer System	Meta-sediments of Aravalli super group such as Phyllites, quartzite; post Delhi intrusive of Godhra granite and gneiss. Alluvium deposit along valley fills.
Normal Annual Rainfall	674.2 mm

TABLE 48- WATER LEVEL BEHAVIOR FOR LUNAWADA BLOCK

Water Level Behaviour		
Phreatic Aquifer	**Pre-Monsoon (May-2019)**	**Post-Monsoon (November-2019)**
Water Level Map		
Water Level	The depth to water levels in rangesbetween 1.90 (Kothamba, Lunavada block) and 23.95 mbgl (Hadod, Lunavada block). The depth to water levels less than 5 mbgl are observed near Major/medium irrigation projects/canal command areas. In general, the depth to Water levels between 2-15 mbgl is observed.	The depth to water levels less than 5 mbgl are observed near Major/medium irrigation projects/canal command areas. In general, the depth to Water levels between 0 to 15 mbgl is observed. The Deeper water levels between 15 and 20 mbgl are observed in isolated patche.

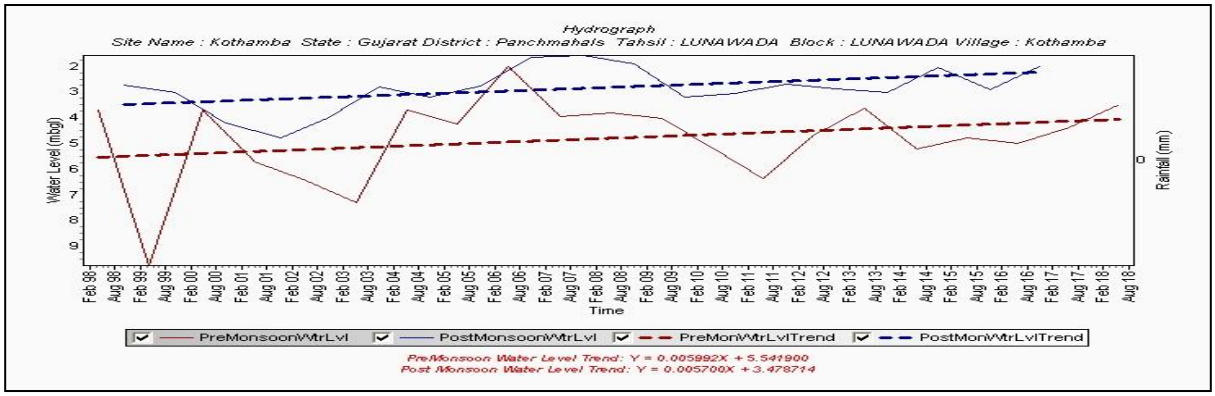


FIGURE 40- HYDROGRAPH OF KOTHAMBA VILLAGE,

Taluka Lunawadashows both Pre-Monsoon and Post-Monsoon rising water Level Trends @ 0.0059 m/year and 0.0057 m/year respectively.

7.2 AQUIFER DISPOSITION

Number of Aquifers

- Schist/Phyllite- Weathered Aquifer, Fractured Aquifer

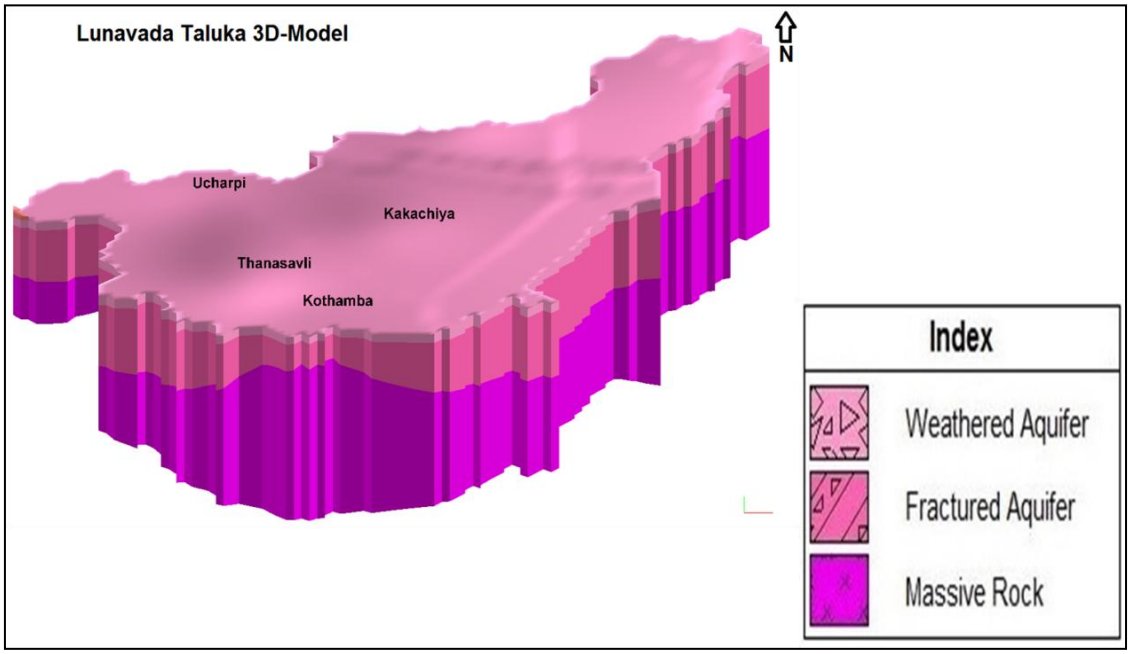


FIGURE 41- 3D- AQUIFER MODEL FOR LUNAWADA BLOCK

TABLE 49- AQUIFER CHARACTERISTICS AND DISPOSITION

Aquifer Characteristics and Disposition								
Stratigraphy	Aquifer	Lithological character	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level Range (m)	TDS Mg/l	Discharge lps	Nature of Aquifer
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 20	0 to 20	2 to 20	700 to 800	1 to 3	Phreatic
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Schist	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured

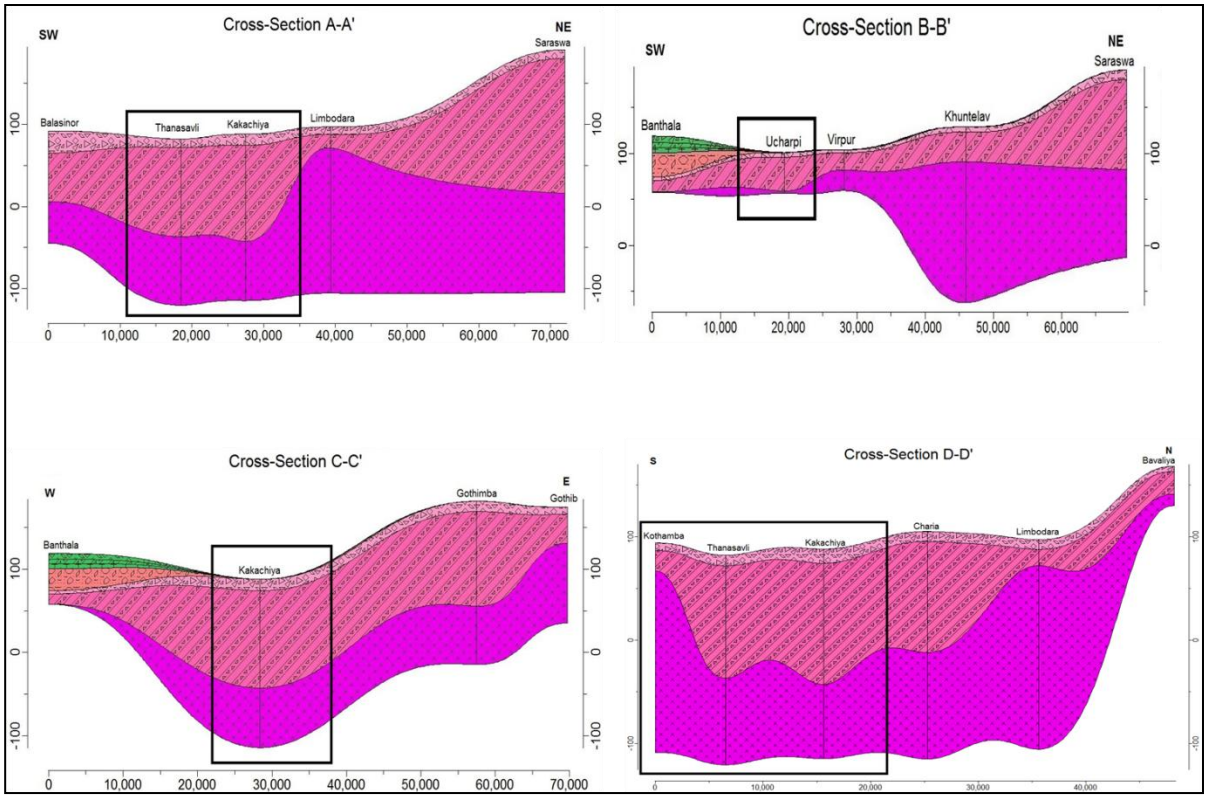
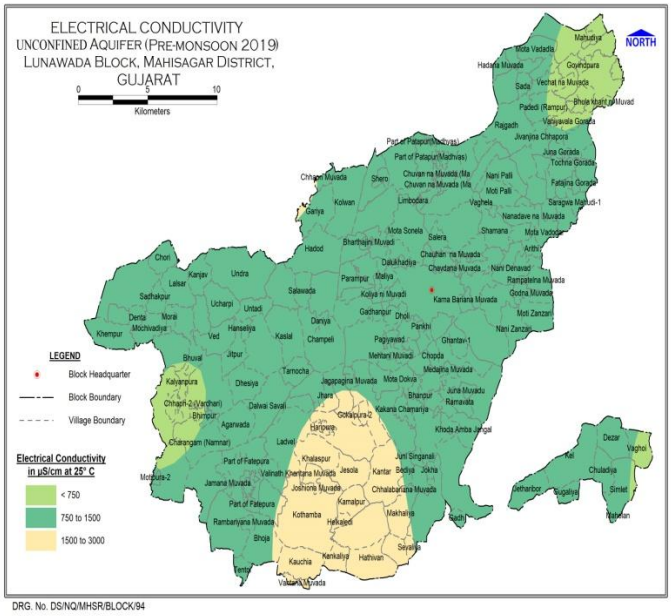


FIGURE 42- 2D AQUIFER CROSS-SECTIONS MAPS OF LUNAWADA BLOCK

7.3 CHEMICAL QUALITY OF GROUND WATER

CHEMICAL QUALITY OF GROUND WATER



Lunawada		
Minimum	Maximum	Average
420	2620	1088.7
113	600	299.4
270	1610	688.4
0	36	13.6
61	488	251.3
71	480	166.7
0	100	32.8
2.74	57	26.8
25	116.232	61.1
12	84	35.2
42	325	112.9
1.07	20	5.1
0.68	1.31	1.0

7.4 GROUND WATER RESOURCES FOR LUNAWADA BLOCK (GWRE-2017)

TABLE 50- GWRE-2017 GROUND WATER RESOURCES

GWRE-2017 GROUND WATER RESOURCES	
Total Annual Ground Water Recharge (MCM)	91.58
Natural Discharge (MCM)	4.58
Net Annual Ground Water Availability (MCM)	87.00
Existing Gross Ground Water Draft for irrigation (MCM)	30.52
Existing Gross Ground Water Draft for domestic and industrial water supply(MCM)	4.30
Existing Gross Ground Water Draft for All uses(MCM)	34.81
Provision for domestic and industrial requirement supply to 2025(MCM)	4.93
Net Ground Water Availability for future irrigation development(MCM)	51.56
Stage of Ground Water Development (%)	40.01
Category	**SAFE**

7.5 GROUND WATER MANAGEMENT PLAN:

7.5.1 GROUND WATER DEVELOPMENT PLAN

The stage of ground water extraction of Lunawada taluka is 40.01 %.To elevate the stage of ground water development to 70% in 6000 nos. of Dug wells (20m depth) and 240 nos. Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 3192.0ham which will create 6384.0 Ha additional irrigation potential for the taluka.

TABLE 51- PROPOSED GROUND WATER DEVELOPMENT STRUCTURES FOR LUNAWADA BLOCK

Block	Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)	
	DW (Nos.)	TW (Nos.)
LUNAWADA	6000	240

7.5.2 SUPPLY SIDE MANAGEMENT

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 5.0 MCM of surplus surface water is provisioned for artificial recharge through 166 no of recharge shafts and 01 number of defunct wellin Lunawada Taluka, which may result into 500 ham Ground Water recharge.

TABLE 52- PROPOSED WATER AVAILABLE FOR ARTIFICIAL RECHARGE AND RECHARGE STRUCTURES

Proposed volume of water available for Artificial Recharge and Recharge Structures				
Block	**Area in KM^2**	3.4 MCM Surplus water available	Nos. of Recharge Shaft (From Artificial Recharge Plan)	Defunct Well (From Artificial Recharge Plan
Lunawada	**624.37**	**5.0**	**166**	**1**

7.5.3 DEMAND SIDE MANAGEMENT:

600 ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 175 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Ground water recharge of 1390.92 ham (through on farm activities and GW return flow) is expected for the block. 114.22ham saving of ground water through Water Use Efficiency Measures and farm ponds activities is expected for the block.

TABLE 53- DEMAND SIDE MANAGEMENT FOR LUNAWADA BLOCK

Block	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
LUNAWADA	600	200	175

7.5.4 EXPECTED BENEFITS

By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 70 % for Kadana block. Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 65 % for Lunawada block.

TABLE 54- EXPECTED BENEFITS AFTER MANAGEMENT IMPLEMENTATION IN LUNAWADA BLOCK

Projected Status of Groundwater Resource after implementation of GW Management Plan, LunavadaTaluka, Mahisagar District (Gujarat)													
Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Lunawada	8700.5	561	829.92	10091.42	3481.3	114.22	3192	6559.1	40.0	70.0	68.4	65.0	6384

8. AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,SANTRAMPUR BLOCK, MAHISAGAR DISTRICT, GUJARAT

8.1 INTRODUCTION:

Santrampur taluka is located in the Mahisagar district of Gujarat, India. Previously Santrampur Block was the part ofPanchmahal District of Gujarat. Total area of Santrampurblock is 569.76 km². Santrampurtalukalies between north latitudes 23.050506 and 23.377222 and east longitudes 73.672472 and 74.025922. The total population of SantrampurTaluka is 265694 out of which of which145,292 are male and 120,439are female. Literacy rate in the taluka is 57.45percent, out of these male and female literacy rate is 34.15% and 23.29% respectively.There are about 151 villages in Santrampur block.

TABLE 55- LAND USE & CROPPING PATTERN FOR SANTRAMPUR BLOCK

Area (Km^2):		569.76
No. of Villages:		151
Population (As per Census 2011)		265694
Density of Population/Km^2:		466.3
Net Sown Area (Hectare) :		29033
Gross Sown Area (Hectare):		32077
Gross Irrigated Area(Hectare):		12030
Area Irrigated by GW (%):		100
Cropping Intensity:		110.48
Irrigation Intensity:		37.5
Principal crops	Kharif:	Maize, Paddy, Castor, Cotton
	Rabi:	Wheat, Maize, Gram
	Summer:	Ground Nut, Bajra, Mung

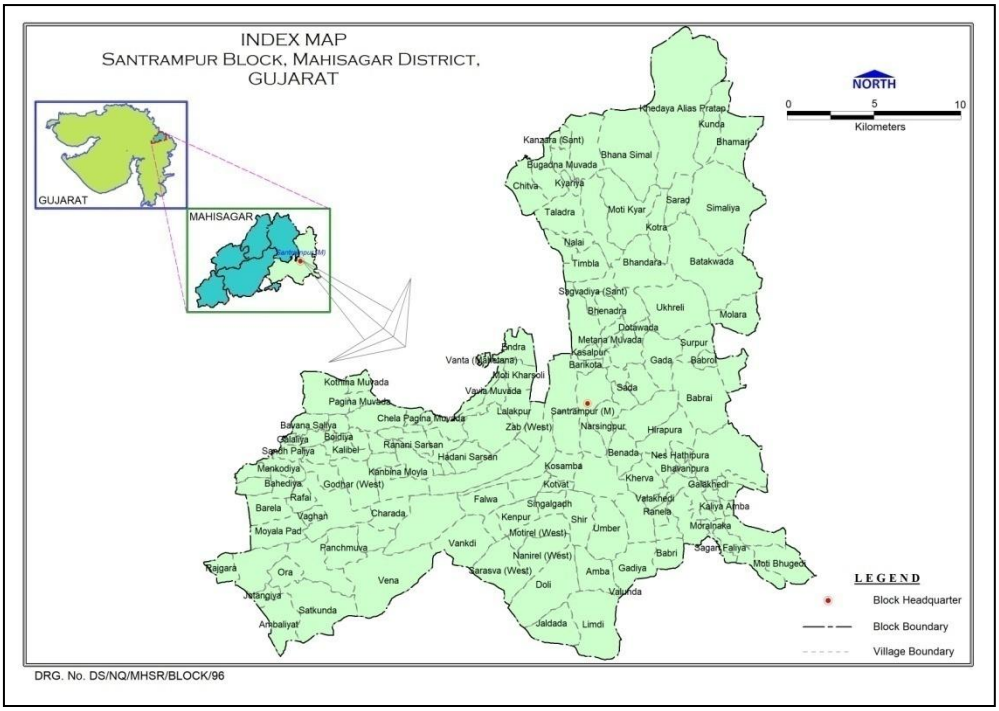


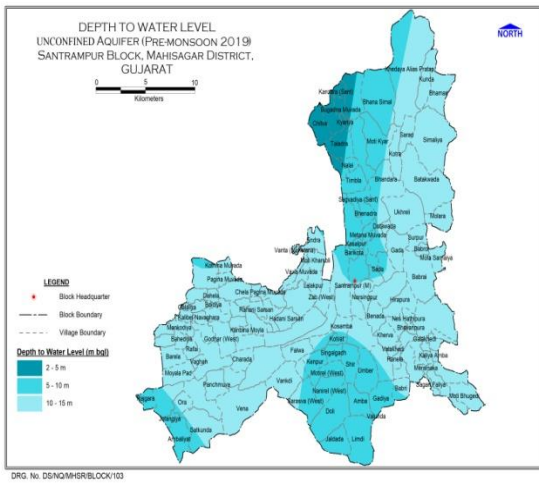
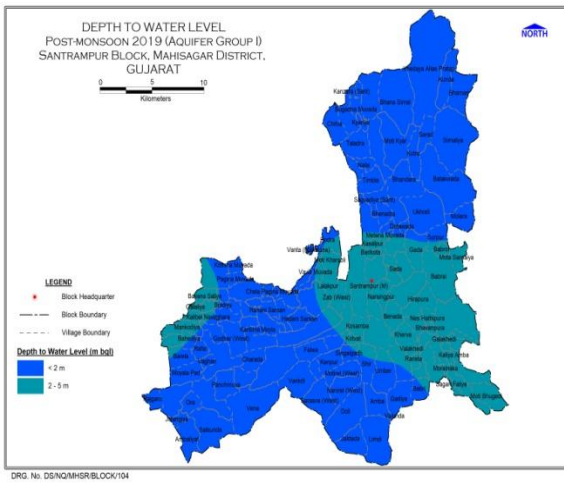
FIGURE 43- ADMINISTRATIVE MAP OF SANTRAMPUR BLOCK

TABLE 56- GEOMORPHOLOGY, GEOLOGY AND RAINFALL FOR SANTRAMPUR BLOCK

Geomorphology, Drainage, Geology and Rainfall	
Geomorphic Unit	Plateau (Undissected to highly Dissected) with weathered thickness ranging from 0 to 30 m
Basin/Sub-basin	Major Drainages: Perennial river – No Major Drainage,
	Non-perennial river – Chibota river. Other tributary channels and streamlets are ther.
Principal Aquifer System	Phyllite, Schist and Quartzite.
Major Aquifer System	Meta-sediments of Aravalli super group such as Phyllites, quartzite; post Delhi intrusive of Godhra granite and gneiss. Aeolian alluvium deposit along valley fills.
Normal Annual Rainfall	647.7 mm

TABLE 57- WATER LEVEL BEHAVIOR IN SANTRAMPUR BLOCK

Water Level Behaviour		
Phreatic Aquifer	**Pre-Monsoon (May-2019)**	**Post-Monsoon (November-2019)**

Water Level Map		
Water Level	Water level ranges from7.60mbgl (Santrampur) to 13.60 mbgl (Batakwada Village). It is observed that depth to water level vary from 5 to 15 mbgl in majority of area.	The post-monsoon Water Level in the taluka is less than 5 mbgl. Water level ranges from0.60mbgl (Doli village) to 7.30 mbgl (Amba Village). It is observed that depth to water level comparatively deeper in central part pf the taluka.

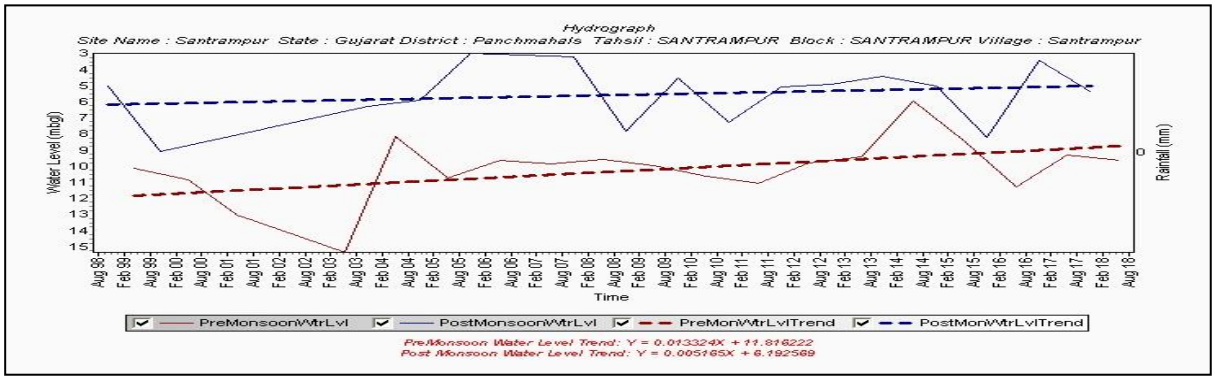


FIGURE 44- HYDROGRAPH OF SANTRAMPUR

This Hydrograph shows both Pre-Monsoon and Post-Monsoon rising water Level Trends @ 0.0133 m/year and 0.0051 m/year respectively.

8.2 AQUIFER DISPOSITION

Number of Aquifers

- Schist/Phyllite- Weathered Aquifer, Fractured Aquifer

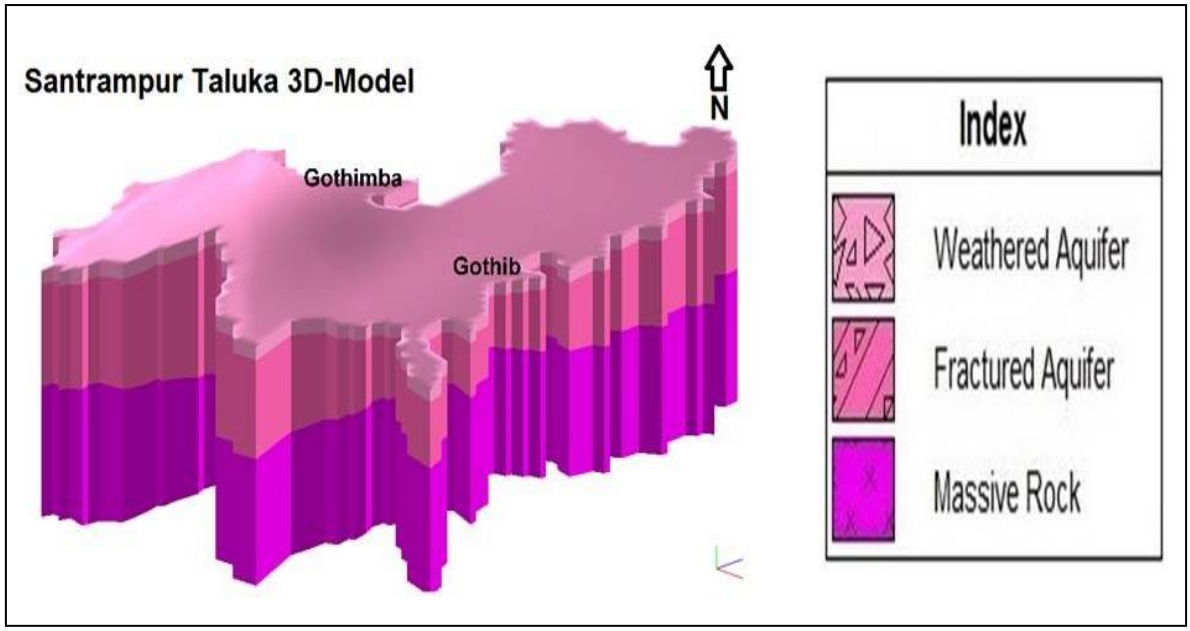


FIGURE 45- 3D- AQUIFER MODEL FOR SANTRAMPUR BLOCK

TABLE 58- AQUIFER CHARACTERISTICS AND DISPOSITION FOR SANTRAMPUR BLOCK

Aquifer Characteristics and Disposition								
Stratigraphy	Aquifer	Lithological character	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level Range (m)	TDS Mg/l	Discharge lps	Nature of Aquifer
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 20	0 to 20	2 to 20	700 to 800	1 to 3	Phreatic
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Schist	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured

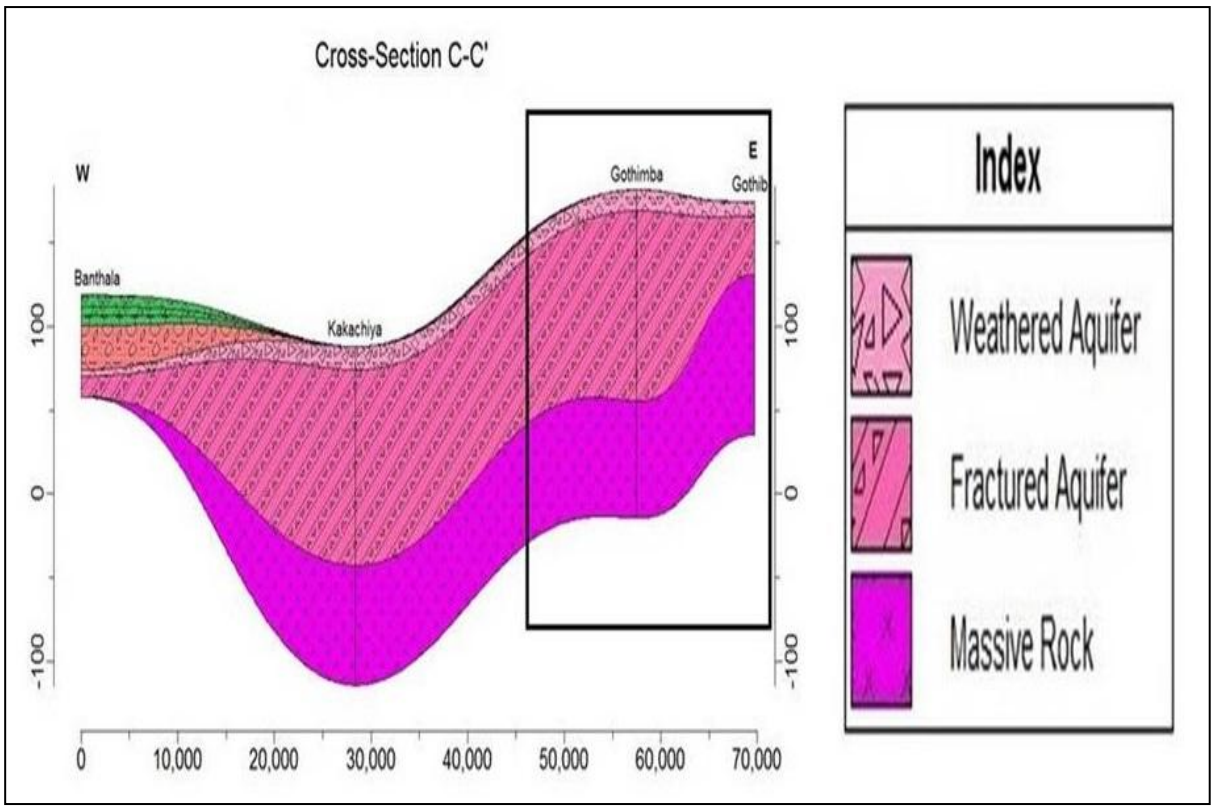
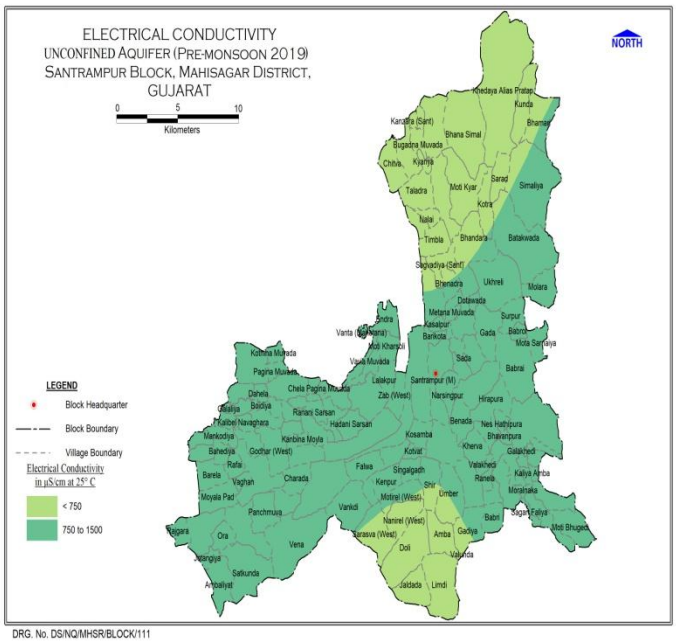


FIGURE 46- 2D AQUIFER CROSS-SECTIONS MAPS OF SANTRAMPUR BLOCK

8.3 CHEMICAL QUALITY OF GROUND WATER

CHEMICAL QUALITY OF GROUND WATER



Santrampur		
Minimum	Maximum	Average
340	1860	853.3
75	538	229.3
200	1140	535.6
0	36	16.0
36.6	219.6	141.0
64	336	153.8
0	348	38.7
4.85	30.09	16.3
15	125	47.8
9	54	26.3
43	178	87.0
1.32	15.7	6.3
0.62	1.52	1.1

8.4 GROUND WATER RESOURCES FOR SANTRAMPUR BLOCK (GWRE-2017)

TABLE 59- GWRE-2017 GROUND WATER RESOURCES

GWRE-2017 GROUND WATER RESOURCES	
Total Annual Ground Water Recharge (MCM)	79.98
Natural Discharge (MCM)	4.0
Net Annual Ground Water Availability (MCM)	75.98
Existing Gross Ground Water Draft for irrigation (MCM)	26.55
Existing Gross Ground Water Draft for domestic and industrial water supply(MCM)	4.44
Existing Gross Ground Water Draft for All uses(MCM)	30.99
Provision for domestic and industrial requirement supply to 2025(MCM)	5.09
Net Ground Water Availability for future irrigation development(MCM)	44.34
Stage of Ground Water Development (%)	40.79
Category	**SAFE**

8.5 GROUND WATER MANAGEMENT PLAN:

8.5.1 GROUND WATER DEVELOPMENT PLAN

The stage of ground water extraction of Santrampurtaluka is 40.79 %.To elevate the stage of ground water development to 70% in 6725 nos. of Dug wells (20m depth) and 30 no Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 2714.0ham which will create 5428.0 Ha additional irrigation potential for the taluka.

TABLE 60- PROPOSED GROUND WATER DEVELOPMENT STRUCTURES FOR SANTRAMPUR BLOCK

Block	Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)	
	DW (Nos.)	TW (Nos.)
SANTRAMPUR	6725	300

8.5.2 SUPPLY SIDE MANAGEMENT

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 4.5 MCM of surplus surface water is provisioned for artificial recharge through 149 no of recharge shafts and 01 number of defunct well in Santrampur Taluka, which may result into 450 ham Ground Water recharge.

TABLE 61- PROPOSED WATER AVAILABLE FOR ARTIFICIAL RECHARGE AND RECHARGE STRUCTURES

Proposed volume of water available for Artificial Recharge and Recharge Structures				
Block	**Area in KM^2**	3.4 MCM Surplus water available	Nos. of Recharge Shaft (From Artificial Recharge Plan)	Defunct Well (From Artificial Recharge Plan
Santrampur	**569.76**	**4.5**	**149**	**1**

8.5.3 DEMAND SIDE MANAGEMENT:

515 ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 150 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Ground water recharge of 1207.14 ham (through on farm activities and GW return flow) is expected for the block. 89.47ham saving of ground water through Water Use Efficiency Measures and farm ponds activities is expected for theSantrampurblock.

TABLE 62- DEMAND SIDE MANAGEMENT FOR SANTRAMPUR BLOCK

Block	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
SANTRAMPUR	515	115	150

8.5.4 EXPECTED BENEFITS

By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 70 % for Santrampurblock. Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 65 % for Santrampurblock.

TABLE 63- EXPECTED BENEFITS AFTER MANAGEMENT IMPLEMENTATION IN SANTRAMPUR BLOCK

Projected Status of Groundwater Resource after implementation of GW Management Plan, Santrampur Taluka, Mahisagar District (Gujarat)													
Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Santrampur	7598.11	501.5	705.64	8805.25	3099.0	89.47	2714	5723.5	40.8	70.0	68.5	65.0	5428

9. AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,VIRPUR BLOCK, MAHISAGAR DISTRICT, GUJARAT

9.1 INTRODUCTION:

Virpur taluka is located in the Mahisagar district of Gujarat, India. Previously Virpur Block was the part ofKheda District of Gujarat. Total area of Virpurblock is 258.28 km². Virpurtalukalies between north latitudes 23.116003 and 23.287580 and east longitudes 73.340966 and 73.576547. The total population of VirpurTaluka is 100293 out of which of which 51742 are male and 48551are female. Literacy rate in the taluka is 66.43percent, out of these male and female literacy rate is 39.24% and 27.19% respectively.There are about 53 villages in Virpur block.

TABLE 64- LAND USE & CROPPING PATTERN FOR VIRPUR BLOCK

Land Use, Agriculture, Irrigation & Cropping Pattern		
Area (Km^2):		258.28
No. of Villages:		53
Population (As per Census 2011)		100293
Density of Population/Km^2:		388.3
Net Sown Area (Hectare) :		14235
Gross Sown Area (Hectare):		18535
Gross Irrigated Area(Hectare):		7139
Area Irrigated by GW (%):		100
Cropping Intensity:		130.21
Irrigation Intensity:		38.5
Principal crops	Kharif:	Maize, Paddy, Castor, Cotton
	Rabi:	Wheat, Maize, Gram
	Summer:	Ground Nut, Bajra, Mung

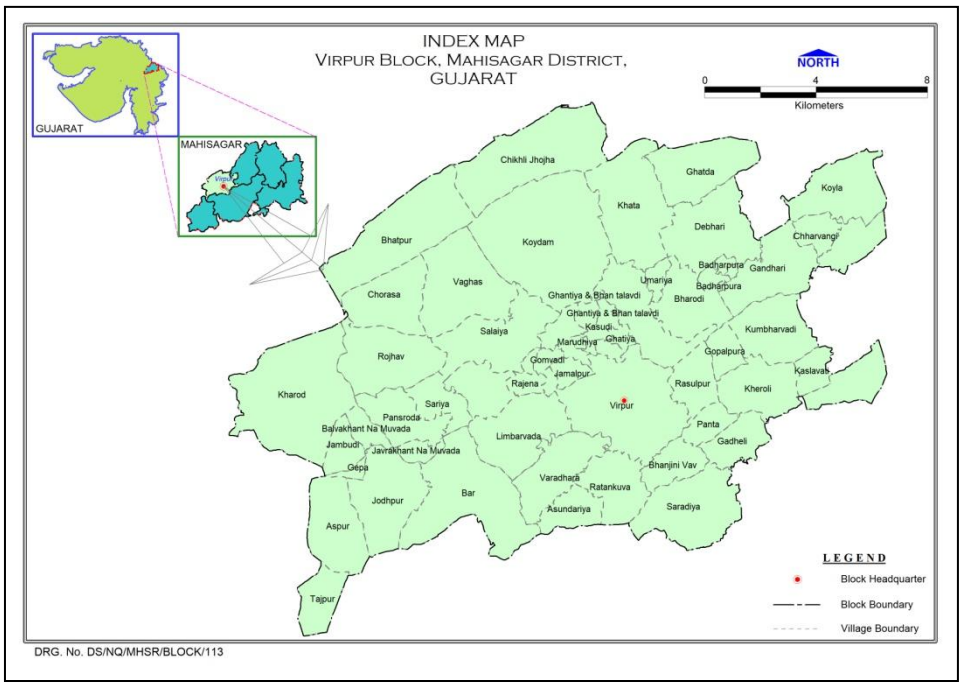
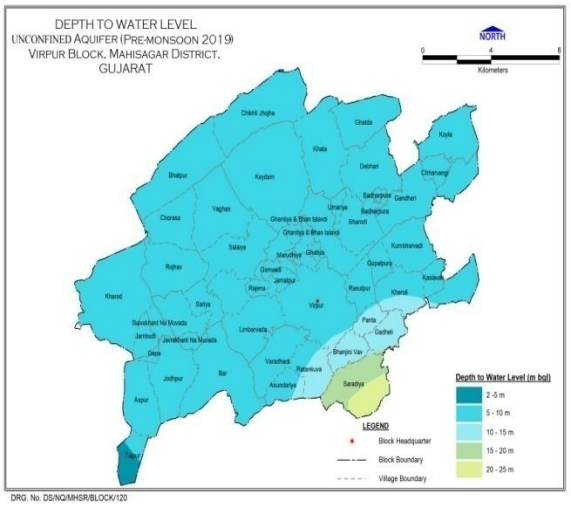
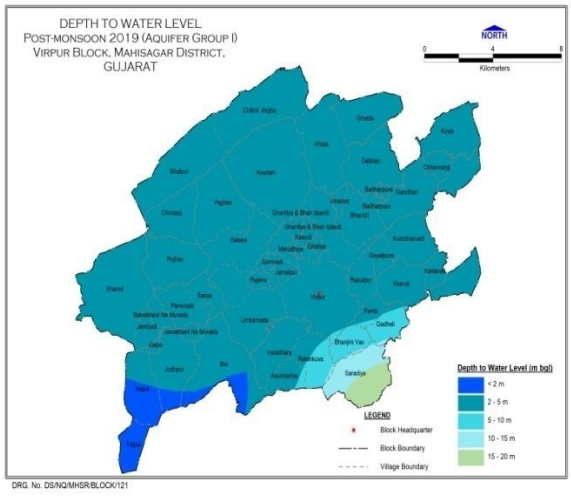


FIGURE 47- ADMINISTRATIVE MAP OF VIRPUR BLOCK

TABLE 65- GEOMORPHOLOGY, GEOLOGY AND RAINFALL FOR VIRPUR BLOCK

Geomorphology, Drainage, Geology and Rainfall	
Geomorphic Unit	Plateau (Undissected to highly Dissected) with weathered thickness ranging from 0 to 30 m
Basin/Sub-basin	Major Drainages: Perennial river – MahiRiver,
	Non-perennial river – Kubharwar River and tributary channels and streamlets are there.
Principal Aquifer System	Phyllite, Schist and Quartzite.
Major Aquifer System	Meta-sediments of Aravalli super group such as Phyllites, quartzite; post Delhi intrusive of Godhra granite and gneiss. Alluvium deposit along valley fills.
Normal Annual Rainfall	527.7 mm

TABLE 66- WATER LEVEL BEHAVIOR IN VIRPUR BLOCK

Water Level Behaviour		
Phreatic Aquifer	**Pre-Monsoon (May-2019)**	**Post-Monsoon (November-2019)**
Water Level Map		
Water Level	Water level ranges from5.29mbgl (Bar) to 15.90 mbgl (Koydam Village). It is observed that depth to water level in majority of the area is less than 10 mbgl. Only at isolated place water is having deeper than 10.0 mbgl.	The post-monsoon Water Level in the taluka is less than 10 mbgl. Water level ranges from2.02mbgl (Vardhara village) to 9.84 mbgl (Gandhari Village). It is observed that depth to water level in majority of the area is less than 5 mbgl. Only at isolated place water is having deeper than 5.0 mbgl.

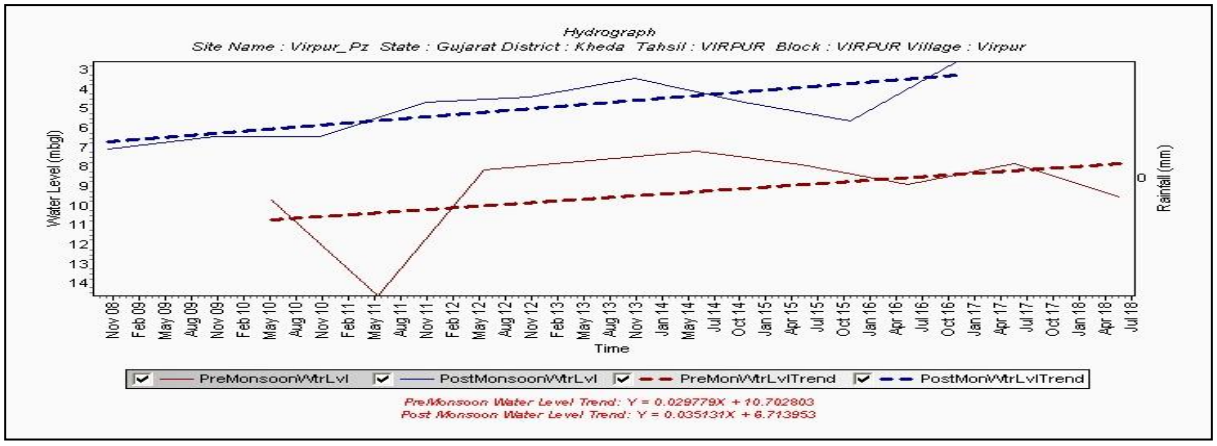


Figure 48- Hydrograph of Virpur

This Hydrograph shows both Pre-Monsoon and Post-Monsoon rising water Level Trends @ 0.0297 m/year and 0.0351 m/year respectively.

9.2 AQUIFER DISPOSITION

Number of Aquifers

- Schist/Phyllite- Weathered Aquifer, Fractured Aquifer

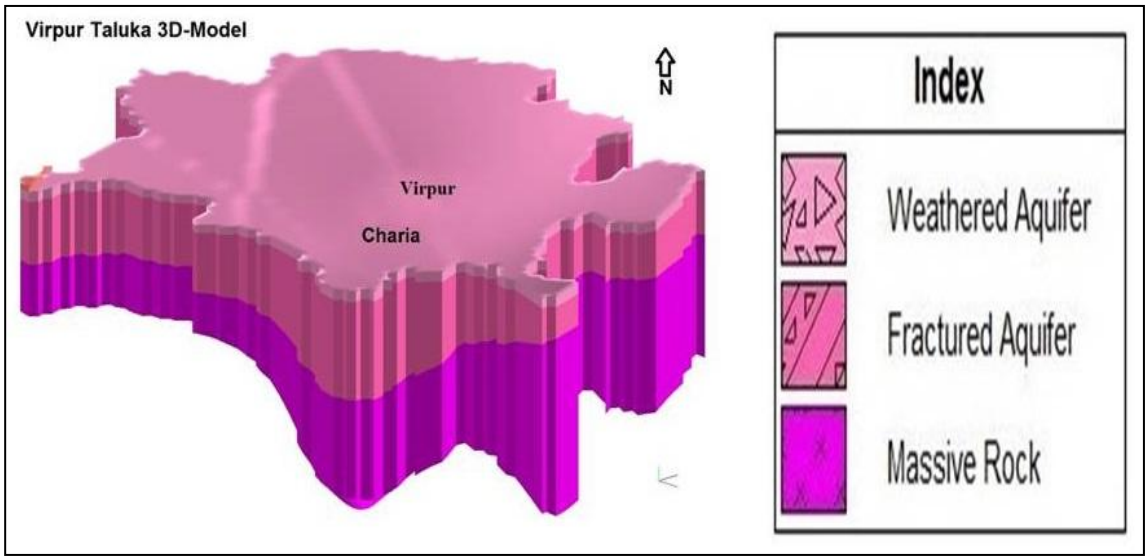


FIGURE 49- 3D- AQUIFER MODEL FOR VIRPUR BLOCK

TABLE 67- AQUIFER CHARACTERISTICS AND DISPOSITION FOR VIRPUR BLOCK

Aquifer Characteristics and Disposition								
Stratigraphy	Aquifer	Lithological character	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level Range (m)	TDS Mg/l	Discharge lps	Nature of Aquifer
Holocene	Alluvium	Pediments, Sand dunes, Flood Plain	0 to 20	0 to 20	2 to 20	700 to 800	1 to 3	Phreatic
Proterozoic	Weathered Granite	Granite & Granodiorite	0 to 26	3 to 26	3 to 16	200 to 1600	0.1 to 1.25	Phreatic
	Fractured Granite, Meta Sediment	Granite, Granodiorite, Phyllite, Schist	5 to 149	12 to 135	3 to 20	300 to 1100	0.5 to 4.0	Fractured

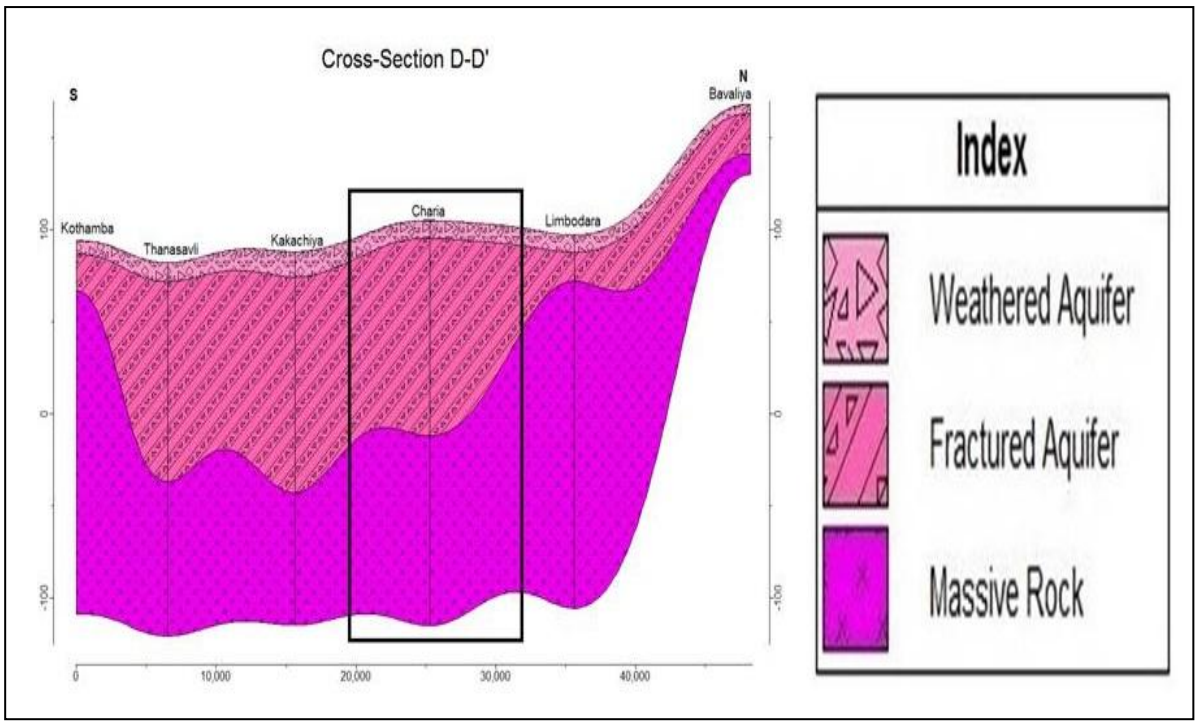
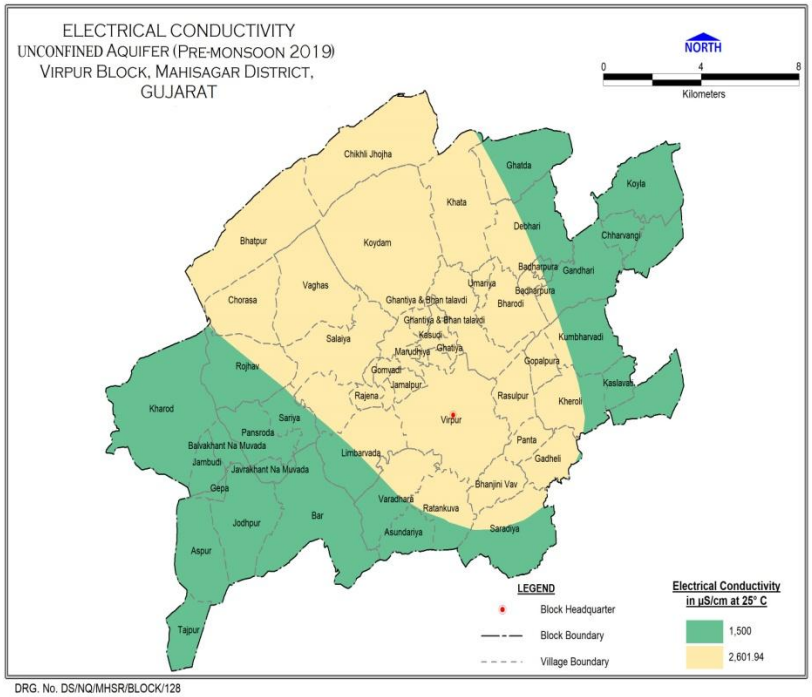


FIGURE 50- 2D AQUIFER CROSS-SECTIONS MAPS OF VIRPUR BLOCK

9.3 CHEMICAL QUALITY OF GROUND WATER OF VIRPUR BLOCK

CHEMICAL QUALITY OF GROUND WATER



Virpur		
Minimum	Maximum	Average
600	3090	1633.3
188	750	429.3
390	2000	1051.7
12	36	22.0
134.2	366	262.3
72	480	246.7
0	514	190.5
2.99	8.76	5.0
30	115	71.7
27	111	60.0
42	315	158.7
12.05	86.49	33.4
0.57	1.5	1.3

9.4 GROUND WATER RESOURCES FOR VIRPUR BLOCK (GWRE-2017)

TABLE 68- GWRE-2017 GROUND WATER RESOURCES

GWRE-2017 GROUND WATER RESOURCES	
Phreatic Aquifer (Granite, Schist, Phyllite)	
Total Annual Ground Water Recharge (MCM)	35.32
Natural Discharge (MCM)	1.77
Net Annual Ground Water Availability (MCM)	33.55
Existing Gross Ground Water Draft for irrigation (MCM)	15.91
Existing Gross Ground Water Draft for domestic and industrial water supply(MCM)	1.64
Existing Gross Ground Water Draft for All uses(MCM)	17.55
Provision for domestic and industrial requirement supply to 2025(MCM)	1.81
Net Ground Water Availability for future irrigation development(MCM)	15.83
Stage of Ground Water Development (%)	52.29
Category	**SAFE**

9.5 GROUND WATER MANAGEMENT PLAN:

9.5.1 GROUND WATER DEVELOPMENT PLAN

The stage of ground water extraction of Virpur taluka is 52.29 %.To elevate the stage of ground water development to 70% in 1120 nos. of Dug wells (20m depth) and 100 no Bore wells (100m depth) are proposed as feasible extraction structures.The extraction structures will result in additional ground water draft of 640.0ham which will create 1280.0 Ha additional irrigation potential for theVirpur taluka.

TABLE 69- PROPOSED GROUND WATER DEVELOPMENT STRUCTURES FOR VIRPUR BLOCK

Block	**Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock)**	
	DW (Nos.)	**TW (Nos.)**
VIRPUR	1120	100

9.5.2 SUPPLY SIDE MANAGEMENT

As per Master plan 2020 for Artificial Recharge to Ground Water in Gujarat state, 2.1 MCM of surplus surface water is provisioned for artificial recharge through 69 no of recharge shafts and 01 number of defunct well in VirpurTaluka, which may result into 210 ham Ground Water recharge.

TABLE 70- PROPOSED WATER AVAILABLE FOR ARTIFICIAL RECHARGE AND RECHARGE STRUCTURES

Block	**Area in KM^2**	3.4 MCM Surplus water available	Nos. of Recharge Shaft (From Artificial Recharge Plan)	Defunct Well (From Artificial Recharge Plan
Virpur	**258.28**	**5.0**	**69**	**1**

9.5.3 DEMAND SIDE MANAGEMENT:

For Virpurblock, 110 ha area is proposed for on farm activities (Laser levelling/Bench terracing/Contour banding) and 50 no of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water. Ground water recharge of 285.0 ham (through on farm activities and GW return flow) is expected for the block. 28.49ham saving of ground water through Water Use Efficiency Measures and farm ponds activities is expected for theVirpurblock.

TABLE 71- DEMAND SIDE MANAGEMENT FOR VIRPUR BLOCK

Block	On farm Acti-vities (Area in ha)	Water Use Efficiency Measures (Area in ha)	Farm Pond (Nos.)
VIRPUR	110	50	50

9.5.4 EXPECTED BENEFITS

By adopting above management strategies, projected stage of Ground water extraction after creating additional abstraction structures is 70 % for Virpurblock. Projected stage of Ground Water extraction after adopting Artificial Recharge and additional conservation activities is 65 % for Virpurblock.

TABLE 72- EXPECTED BENEFITS AFTER MANAGEMENT IMPLEMENTATION IN VIRPUR BLOCK

Projected Status of Groundwater Resource after implementation of GW Management Plan, Taluka, Mahisagar District (Gujarat)													
Block	Net G.W. Availability (Ham)	Additional Recharge from Recharge interventions (ham)	Additional Recharge from Return flow of GW Irrigation	Total Net G.W. Availability after intervention (Ham)	Existing G.W Draft for all purpose (ham)	Conservation of Ground water through WUE, on farm activity & farm ponds (ham)	G.W Draft from Extraction structures (ham)	Net GW draft after interventions (ham)	Present stage of G.W. Development (%)	Projected stage of G.W. Development after construction of extraction structures (%)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)	Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)	Additional Irrigation Potential Created (Ha)
Virpur	3355.41	221	64	3640.41	1754.7	28.49	640	2366.2	52.3	70.0	69.0	65.0	1280

LIST OF ANNEXURE

Annexure 1- NHS 2019 WATER LEVEL DATA

Sr No	District	Tahsil / Taluk	Village	Latitude	Longitude	Pre-Monsoon-Water Level (m)	Pre-Monsoon-Water Level (m)
1	Mahisagar	Balasinor	Balasinor	22.948	73.326	6.65	6.04
2	Mahisagar	Balasinor	Parabiya	22.997	73.287	11.00	6.35
3	Mahisagar	Virpur	Virpur	23.182	73.478	8.40	2.99
4	Mahisagar	Lunawada	Virania	23.067	73.612	7.60	1.50
5	Mahisagar	Lunawada	Helakledi	23.015	73.550	4.40	3.60
6	Mahisagar	Lunawada	Kadachhala	23.069	73.422	5.00	1.20
7	Mahisagar	Lunawada	Hadod	23.145	73.532	23.95	20.00
8	Mahisagar	Lunawada	Pavapur	23.140	73.579	11.50	3.30
9	Mahisagar	Lunawada	Dalji na chaklia	23.188	73.685	14.60	4.30
10	Mahisagar	Lunawada	Sajjanpur	23.178	73.605	12.60	2.25
11	Mahisagar	Khanpur	Khanpur mota	23.285	73.684	11.60	10.20
12	Mahisagar	Santrampur	Santrampur	23.190	73.899	9.40	2.50
13	Mahisagar	Kadana	Malvan	23.214	73.802	16.20	1.70
14	Mahisagar	Santrampur	Doli	23.083	73.880	7.60	0.60
15	Mahisagar	Santrampur	Gothib	23.159	73.956	13.50	3.05
16	Mahisagar	Santrampur	Batakwada	23.243	73.974	13.60	1.50
17	Mahisagar	Kadana	Munpur	23.287	73.798	10.70	7.70
18	Mahisagar	Virpur	Vardhara(alu.vav)	23.162	73.448	7.40	2.02
19	Mahisagar	Santrampur	Santrampur	23.185	73.887	7.60	5.80
20	Mahisagar	Santrampur	Amba	23.084	73.892	13.30	7.30
21	Mahisagar	Santrampur	Barela	23.129	73.717	8.70	2.70
22	Mahisagar	Kadana	Kadana	23.279	73.840	3.30	1.00
23	Mahisagar	Khanpur	Khanpur	23.280	73.686	10.40	3.70
24	Mahisagar	Lunawada	Navi Singnali	23.035	73.605	14.40	9.50
25	Mahisagar	Lunawada	Kolwan	23.172	73.554	15.60	6.50
26	Mahisagar	Lunawada	Mal Talawadi	23.023	73.485	7.75	0.45
27	Mahisagar	Balasinor	Limbdi	23.029	73.379	8.92	6.24
28	Mahisagar	Balasinor	Felsani	23.022	73.320	7.91	1.25
29	Mahisagar	Virpur	Gandhari	23.234	73.537	12.71	9.84
30	Mahisagar	Virpur	Koydam	23.244	73.458	15.90	7.43
31	Mahisagar	Virpur	Virpur	23.185	73.482	7.90	5.10
32	Mahisagar	Kadana	Malvan	23.210	73.800	18.60	5.60
33	Mahisagar	Khanpur	Bhadesara	23.254	73.637	17.30	6.90
34	Mahisagar	Balasinor	Nava Vasadra	23.090	73.378	5.90	2.67
35	Mahisagar	Lunawada	Malekpur	23.236	73.735	18.40	11.60
36	Mahisagar	Lunawada	Kothamba	23.017	73.522	1.90	0.40
37	Mahisagar	Khanpur	Vadagam	23.273	73.607	12.60	2.30
38	Mahisagar	Kadana	Sarsawa (north)	23.422	73.813	18.20	4.70
39	Mahisagar	Santrampur	Gothib	23.153	73.963	16.30	2.30

40	Mahisagar	BALASINOR	Balasinor	22.958	73.336	5.33	2.58
41	Mahisagar	BALASINOR	Balasinor1	22.950	73.325	6.89	1.70
42	Mahisagar	VIRPUR	Bar	23.168	73.411	5.29	2.19
43	Mahisagar	KHANPUR	Bavaliya	23.325	73.569		
44	Mahisagar	SANTRAMPUR	Gadhar	23.150	73.775	12.75	1.63
45	Mahisagar	BALASINOR	Juna vasadra	23.083	73.363	4.80	1.66
46	Mahisagar	LUNAWADA	Kothamba	23.019	73.519	3.67	4.20
47	Mahisagar	LUNAWADA	Limbadia peti	23.204	73.600	7.28	2.44
48	Mahisagar	LUNAWADA	Lunawada	23.129	73.608	11.19	6.21
49	Mahisagar	LUNAWADA	Malekpur1	23.231	73.736	6.30	1.45
50	Mahisagar	KHANPUR	Pandarvada	23.375	73.633	5.45	1.69
51	Mahisagar	SANTRAMPUR	Santrampur	23.171	73.908	11.22	4.60
52	Mahisagar	SANTRAMPUR	Santrampur1	23.192	73.908	9.32	2.28
53	Mahisagar	LUNAWADA	Ucharpi Pz	23.119	73.472	23.36	8.68
54	Mahisagar	VIRPUR	Virpur_Pz	23.193	73.485		3.70

ANNEXURE 2- CHEMICAL QUALITY OF NHS WELLS

Sr No	District	BLOCK	VILLAGE	EC	TDS	NO3	F
1	Mahisagar	Balasinor	Balasinor	650.00	420.00	2.96	0.59
2	Mahisagar	Balasinor	Parabiya	1530.00	1000.00	9.21	1.26
3	Mahisagar	Virpur	Virpur	2170.00	1390.00	5.42	1.18
4	Mahisagar	Lunawada	Virania	990.00	630.00	32.65	0.78
5	Mahisagar	Lunawada	Helakledi	2620.00	1610.00	30.86	0.98
6	Mahisagar	Lunawada	Kadachhala	630.00	410.00	2.74	
7	Mahisagar	Lunawada	Hadod	1250.00	790.00	38.32	1.08
8	Mahisagar	Lunawada	Pavapur	1500.00	900.00	27.65	0.92
9	Mahisagar	Lunawada	Dalji na chaklia	840.00	530.00	39.62	1.31
10	Mahisagar	Lunawada	Sajjanpur	1220.00	740.00	26.87	1.13
11	Mahisagar	Khanpur	Khanpur mota	800.00	480.00	25.36	0.67
12	Mahisagar	Santrampur	Santrampur	900.00	570.00	20.86	1.20
13	Mahisagar	Kadana	Malvan	1610.00	960.00		
14	Mahisagar	Santrampur	Doli	700.00	450.00	28.37	0.62
15	Mahisagar	Santrampur	Gothib	940.00	600.00	17.89	1.21
16	Mahisagar	Santrampur	Batakwada	860.00	560.00	6.33	0.72
17	Mahisagar	Kadana	Munpur	550.00	350.00	6.27	1.16
18	Mahisagar	Kadana	Godhar (North)	420.00	270.00	4.16	
19	Mahisagar	Virpur	Vardhara(alu.vav)	1260.00	810.00	3.55	1.50
20	Mahisagar	Kadana	Kadana	390.00	250.00	5.98	1.28
21	Mahisagar	Khanpur	Khanpur	970.00	620.00	0.81	0.99
22	Mahisagar	Khanpur	Khadodi	960.00	620.00	3.22	1.19
23	Mahisagar	Lunawada	Malekpur	420.00	270.00	25.65	1.23
24	Mahisagar	Lunawada	Kothamba	1600.00	1020.00	4.23	0.68

25	Mahisagar	LUNAWADA	Kantha	858.00	575.00	12.00	0.82
26	Mahisagar	KHANPUR	Khanpur	684.00	458.00	32.00	0.15
27	Mahisagar	BALASINOR	Balasinor1	665.00	446.00	12.00	0.24
28	Mahisagar	LUNAWADA	Lunawada	1150.00	771.00	57.00	0.76
29	Mahisagar	LUNAWADA	Limbadia peti	792.00	530.64	7.00	0.97
30	Mahisagar	KHANPUR	Pandarvada	560.00	375.20	6.30	0.76
31	Mahisagar	BALASINOR	Juna vasadra	1469.00	984.00	65.00	0.62
32	Mahisagar	Balasinor	Vadadala	1580.00	1059.00	65.00	0.58
33	Mahisagar	Balasinor	Manvarpura	1030.00	690.00	37.00	0.79
34	Mahisagar	Balasinor	Saliyavadi	6270.00	4201.00	864.00	0.47
35	Mahisagar	Balasinor	Sutariya	2660.00	1782.00	63.00	2.40
36	Mahisagar	Balasinor	Allela	2950.00	1977.00	39.00	1.50
37	Mahisagar	Virpur	Kharod	1920.00	1286.00	179.00	0.73
38	Mahisagar	Virpur	Koydam	1380.00	925.00	5.00	0.55
39	Aravali	Malpur	Butiya	1692.00	1134.00	56.00	1.60
40	Mahisagar	Lunavada	Navi Singanli	863.00	578.00	8.00	0.56
41	Mahisagar	Lunavada	Jethribor Sukha Timba	721.00	483.00	14.00	0.75
42	Mahisagar	Santrampur	Veni	780.00	523.00	17.00	0.61
43	Mahisagar	Lunavada	Rampatel Muvada	1850.00	1240.00	38.00	1.60
44	Mahisagar	Lunavada	Kothamba	840.00	563.00	24.00	0.71
45	Mahisagar	Lunavada	Kharol	1750.00	1173.00	42.00	2.00
46	Mahisagar	Lunavada	Ved	1411.00	945.00	19.00	0.91
47	Mahisagar	Lunavada	Hadod	1810.00	1213.00	26.00	1.20
48	Mahisagar	Virpur	Gandhar	1085.00	727.00	23.00	0.57
49	Mahisagar	Khanpur	Dhuleta	1390.00	931.00	16.00	0.65
50	Mahisagar	Khanpur	Chhapri	833.00	558.00	5.00	0.68
51	Mahisagar	Khanpur	Kanesar	920.00	616.00	24.00	5.50
52	Mahisagar	Lunavada	Mota Sonela	1190.00	797.00	25.00	1.30
53	Mahisagar	Lunavada	Padaidi	1130.00	757.00	23.00	0.93
54	Mahisagar	Kadana	Kajali	1090.00	730.00	18.00	0.58
55	Mahisagar	Kadana	Bhagliya	750.00	503.00	22.00	0.76
56	Mahisagar	Kadana	Chhajali	720.00	482.40	16.00	0.78
57	Mahisagar	Kadana	Motirah	870.00	583.00	49.00	0.58
58	Mahisagar	Kadana	Navi Godhar	562.00	377.00	38.00	0.41
59	Mahisagar	Kadana	Muvala	655.00	439.00	11.00	0.62
60	Mahisagar	Kadana	Renganiya	1040.00	697.00	26.00	3.00
61	Mahisagar	Santrampur	Ukhreli	650.00	436.00	6.00	1.40
62	Mahisagar	Santrampur	Simaliya	705.00	472.00	20.00	2.00
63	Mahisagar	Santrampur	Gothib	481.00	322.00	8.00	0.59
64	Mahisagar	Santrampur	Padhariya	1351.00	905.00	49.00	0.75
65	Mahisagar	Santrampur	Falwa	810.00	543.00	41.00	0.89
66	Mahisagar	Santrampur	Umber	634.00	425.00	40.00	0.75
67	Mahisagar	Santrampur	Bugad	805.00	539.00	42.00	0.79

ANNEXURE 3- NEW ESTABLISHED WELLS HEAVY METAL DATA

S.No.	District	Taluka	Village	Cr(ppm)	Fe(ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
1	Mahisagar	Balasinor	Vadadala	0.004	0.186	0.047	0.0114	0.007
2	Mahisagar	Balasinor	Manvarpura	0.004	0.197	0.053	0.0117	0.005
3	Mahisagar	Balasinor	Saliyavadi	0.019	0.112	0.083	0.0589	0.018
4	Mahisagar	Balasinor	Sutariya	0.000	0.058	0.019	0.0117	0.002
5	Mahisagar	Balasinor	Allela	0.014	0.064	0.023	0.1465	0.005
6	Mahisagar	Virpur	Kharod	0.004	0.081	0.009	0.185	0.000
7	Mahisagar	Virpur	Koydam	0.019	0.051	0.015	0.0126	0.002
8	Aravali	Malpur	Butiya	0.009	0.072	0.024	0.0135	0.003
9	Mahisagar	Lunavada	Navi Singanli	0.009	0.341	0.103	0.0098	0.001
10	Mahisagar	Lunavada	Jethribor Sukha Timba	0.004	0.200	0.191	0.017	0.003
11	Mahisagar	Santrampur	Veni	0.009	0.075	0.032	0.0104	0.002
12	Mahisagar	Lunavada	Rampatel Muvada	0.009	0.046	0.029	0.0123	0.002
13	Mahisagar	Lunavada	Kothamba	0.009	0.240	0.375	0.0104	0.000
14	Mahisagar	Lunavada	Kharol	0.004	0.049	0.011	0.0104	0.002
15	Mahisagar	Lunavada	Ved	0.000	0.106	0.068	0.0142	0.000
16	Mahisagar	Lunavada	Hadod	0.019	0.132	0.014	0.0063	0.000
17	Mahisagar	Virpur	Gandhar	0.000	0.038	0.008	0.0057	0.000
18	Mahisagar	Khanpur	Dhuleta	0.004	0.218	0.069	0.019	0.000
19	Mahisagar	Khanpur	Bakor	0.000	0.051	0.011	0.0096	0.000
20	Mahisagar	Khanpur	Chhapri	0.000	0.049	0.017	0.0063	0.000
21	Mahisagar	Khanpur	Kanesar	0.000	0.061	0.015	0.0111	0.000
22	Mahisagar	Lunavada	Mota Sonela	0.000	0.038	0.019	0.0099	0.000
23	Mahisagar	Lunavada	Padaidi	0.004	0.042	0.009	0.0044	0.000
24	Mahisagar	Kadana	Kajali	0.009	0.055	0.009	0.0169	0.000
25	Mahisagar	Kadana	Bhagliya	0.009	0.075	0.009	0.0041	0.000
26	Mahisagar	Kadana	Chhajali	0.009	0.039	0.046	0.0166	0.000
27	Mahisagar	Kadana	Motirah	0.009	0.063	0.008	0.0081	0.000
28	Mahisagar	Kadana	Navi Godhar	0.009	0.064	0.014	0.0123	0.000
29	Mahisagar	Kadana	Muvala	0.000	0.051	0.000	0.0011	0.000
30	Mahisagar	Kadana	Renganiya	0.000	0.078	0.002	0.0029	0.000
31	Mahisagar	Santrampur	Ukhreli	0.000	0.066	0.005	0.0051	0.000
32	Mahisagar	Santrampur	Simaliya	0.000	0.110	0.006	0.006	0.000
33	Mahisagar	Santrampur	Gothib	0.000	0.055	0.005	0.0038	0.000
34	Mahisagar	Santrampur	Padhariya	0.004	0.054	0.002	0.0081	0.000
35	Mahisagar	Santrampur	Falwa	0.000	0.081	0.027	0.0105	0.000
36	Mahisagar	Santrampur	Umber	0.000	0.055	0.006	0.0075	0.000
37	Mahisagar	Santrampur	Bugad	0.000	0.042	0.006	0.0498	0.002

ANNEXURE 4- DECADAL WATER LEVEL TREND (2009-18)

Village	Balasinor		Parabiya		Khanpur mota		Khadodi		Hadod		Sajjanpur		Kothamba		Santrampur		Doli		Gothib	
Year	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
2008	6.35	2.85	9.15	6.60	12.30	9.10	9.60	5.82	21.00	19.10	8.60	4.70	1.80	0.74	8.30	7.54	5.35	4.85	10.95	7.62
2009	9.10	5.05	9.45	8.00	12.22	8.75	14.26	6.40	21.85	18.80	9.60	6.00	2.26	1.06	10.22	9.10	8.64	6.35	12.60	8.80
2010	6.25	1.85	9.55	7.60	10.00	9.05	14.92	6.30	22.70	20.80	10.70	5.37	2.92	1.00	10.40	4.65	9.80	3.26	13.80	3.65
2011	5.45	2.65	9.00	6.50	10.30	7.42	12.90	1.76	22.90	20.80	12.40	5.09	2.29	0.42	11.30	3.75	8.90	1.40	14.80	2.95
2012	6.85	3.05	8.10	5.60	9.40	7.60	13.42	1.90	22.50	21.10	8.40	4.90	2.10	0.50	9.40	3.65	7.00	1.20	12.80	7.60
2013	6.35	5.05	8.70	3.60	11.10	6.40	12.30	5.00	23.70	20.00	11.20	1.65	2.35	2.00	9.40	2.60	7.20	0.80	12.40	6.70
2014	6.50	3.05	10.20	6.00	10.10	8.80	5.80	2.40	21.10	19.90	6.10	5.60	2.15	0.77	6.65	4.70	5.27	3.00	12.40	12.30
2015	7.55	3.60	9.65	5.80	11.90	9.10	12.80	2.90	21.20	20.80	8.85	6.20	3.00	0.95	10.05	8.60	8.80	8.80	12.65	11.35
2016	9.35	3.85	8.00	5.20	12.30	10.40	17.20	1.60	22.20	21.40	13.45	8.05	2.60	1.00	13.40	7.30	11.00	4.20	14.80	10.15
2017	8.65	1.75	8.80	5.30	11.40	10.80	14.10	3.80	22.00	22.60	12.25	8.65	2.20	0.80	8.70	5.50	6.90	0.80	15.00	1.85
2018	7.45	3.85	8.10	6.80	8.80	8.60	17.90	5.30	22.90	22.10	12.35	3.15	2.00	0.90	9.20	4.20	7.40	1.40	12.55	4.65
2019	6.65		11.00		11.60		19.30		23.95		12.60		1.90		9.40		7.60		13.50	
TRENDS	0.0944056	-0.0027273	0.0143357	-0.1636364	-0.0425874	0.1300909	0.5134965	-0.2210909	0.0944056	0.2800000	0.2835664	0.1255455	-0.0077972	0.0099091	0.0025175	-0.1127273	0.0253846	-0.1820909	0.1243007	-0.0150000
Average	7.21	3.33	9.14	6.09	10.95	8.73	13.71	3.93	22.33	20.67	10.54	5.40	2.30	0.92	9.70	5.60	7.82	3.28	13.19	7.06

ANNEXURE 5- EXPLORATORY DETAILS IN MAHISAGAR DISTRICT

VILLAGE	*TALUKA*	*DISTRICT*	*STATE*	WELL_TYPE	*YEAR_CONS*	*LATITUDE*	*LONGITUDE*	*GEOLOGY*	*DEPTH*	*PYT_Disch*	*PYT_SWL*	*PYT_RDD*	*EC*
Banthala	Balasinor	Mahisagar	Gujarat	EW	1970-1971	23.0583	73.1792	SR	61				
Charia	Lunawada	Mahisagar	GUJARAT	EW	1987-1988	23.1472	73.5306	HR	37	17.3			
Charia	Lunawada	Mahisagar	GUJARAT	EW	1988-1989	23.1667	73.5000	HR	220	2.08			
Thanasavli	Lunawada	Mahisagar	GUJARAT	EW	2002 - 2003	23.0519	73.4856	Granite/Schist	202.60	3.75	13.55	37.45	872
Kothamba	Lunawada	Mahisagar	GUJARAT	EW	2002 - 2003	23.0014	73.5189	Granite	202.60	1.60	1.35	47.00	Potable
Khuntelav	Lunawada	Mahisagar	GUJARAT	EW	2002 - 2003	23.3000	73.6144		111.10	Abandoned	-	-	-
Khuntelav	Lunawada	Mahisagar	GUJARAT	EW	2002 - 2003	23.3000	73.6144		191.40	1.50	24.36	3.04	570
Limbodra	Lunawada	Mahisagar	GUJARAT	EW	2003 - 04	23.1900	73.6000	Meta-sediments	25.7	2.00	16.00		2750
Limbodra	Lunawada	Mahisagar	GUJARAT	EW	2003 - 04	23.1900	73.6000	Meta-sediments	202.6	0.25	6.78	44.62	684
Virpur	VIRPUR	Mahisagar	GUJARAT	Pz	2007 - 2008	23.1931	73.4853	Meta sediments	44.1	0.1	5.81	NA	698
Uchharpi	Lunawada	Mahisagar	GUJARAT	Pz	2007 - 2008	23.7783	72.2861	Meta sediments	44.1	1.25	10	13.96 (2nd min of recovery)	415
Bavaliya	Khanpur	Mahisagar	GUJARAT	Pz	2007 - 2008	23.3067	73.5550	Meta sediments	38	0.8	10.5	7.78 4th min of rec	1319
Gothimba	Santrampur	Mahisagar	GUJARAT	EW	2008 - 2009	23.1486	73.8389	Meta sediments	135.6	8	16.05	10.7 (2)	584
Kakachiya	Lunawada	Mahisagar	GUJARAT	EW	2008 - 2009	23.0986	73.5583	Schist	202.7	-	>150	-	1572
Gothimba	Santrampur	Mahisagar	GUJARAT	OW	2008 - 2009	23.1486	73.8389	Meta-sediments Qtzt/Phyllite	196.6	2	16.62	37.04 (4)	800
Gothib	Santrampur	Mahisagar	GUJARAT	EW	2009 - 2010	23.1550	73.9583	Quartzite & Phyllites	139.5	0.4	21.17	N.A. (> 60 M)	
Naroda	Khanpur	Mahisagar	GUJARAT	EW	2010 - 2011	23.2925	73.5861	Phyllites	202.7	0.65	22.46	N.A.	1528
Saraswa	Kadana	Mahisagar	GUJARAT	EW	2010 - 2011	23.4194	73.8097	Quartzites	200.6	3.75	11.36	5.76 (5th min of Recovery)	710
Saraswa	Kadana	Mahisagar	GUJARAT	OW	2010 - 2011	23.4194	73.8097	Quartzites	202.7	2.50	11.64	13.20 (7th min of recovery)	630