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

Report On

AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN MORBI DISTRICT, GUJARAT STATE

Central Ground Water Board West Central Region Ahmedabad

AQUIFER MAP AND MANAGEMENT PLAN MORBI DISTRICT
GUJARAT STATE

Contributors' page

Ankit Vishwakarma (Sc-B)	Report Compilation	CGWB, WCR
Dr. A K Jain Sc-D (retired, Consultant) Shri Ankit Vishwakarma (Sc-B) Shri Satyendra Kumar (Sc-B)	Hydrogeology	CGWB, WCR
Shri Biswaroop Mohapatra (Sc-D)	GWRE	CGWB, WCR
Smt. Puja Mehrotra (Sc-D) Dr. H B Meena (ACh) Smt. Adiba Khan (STA Chem)	Chemical Analysis	CGWB, WCR
Nilesh Dhokia, Draftsman	Drawing	CGWB, WCR
Dr. A K Jain (Sc-D Retired, Consultant)	Scrutiny	CGWB, WCR

Under the guidance of

Shri G Krishnamurthy,
Regional Director,
Central Ground Water Board,
West Central Region, Ahmedabad,
Gujarat

ACKNOWLEDGEMENT

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

Ankit Vishwakarma
Scientist C
Central Ground Water Board
West Central Region, Ahmedabad

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SL No.	Items	Statistics
1	**General Information**	
	i) Geographical Area/Mappable area (Sq Km)	**4872 / 3,797.71**
	ii) Administrative Divisions **Number of Taluka** **Number of Village**	**3** **5** **349**
	iii) Populations	**960329**
	iv) Average Annual Rainfall (mm)(1987-2020)	**601**
2.	**GEOMORPHOLOGY**	
	Major Physiographic Units	**Hilly areas, Piedmont slopes, Undulating, Alluvial plains.**
	Major Drainages	**No major river (only small tributaries)**
3.	**LAND USE (hec '00) (Directorate of Agriculture, Gujarat, Season and Crops 2014-15)**	
	a) **Forest area** b) **Net area sown** c) **Fallow land** d) **Uncultivable land area** e) **Area sown more than once**	**425** **3212** **12** **374** **548**
4.	**MAJOR SOIL TYPES**	**Sandy, loamy sand, clayey and silty, Medium black soils,Red Sandy soils and Silty soils.**
5.	**AREA UNDER PRINCIPAL FOODGRAIN CROPS (00'hec) (Directorate of Agriculture, Gujarat, Season and Crops 2014-15)**	**Area in Sq Km** **Total Food grains 258** **Total Food Crops 560** **Cotton 1110**
6.	**IRRIGATION BY DIFFERENT SOURCES (Directorate of Agriculture, Gujarat, Season and Crops 2014-15)**	**Area ('00 ha)**
	Other wells	**1041**
	Tubewells	**798**
	Canals	**67**
	Tank	**38**
	Other Sources	**33**
	Net Area Irrigated	**1411**
	Gross Area Irrigated	**1976**

7.	**NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on 31-03-2018)** **No of Dug Wells** **No of Piezometers**	 **18** **17** **1**
8.	**PREDOMINANT GEOLOGICAL FORMATIONS**	
	Geological formations ranges in age from Cretaceous to Recent, i.e alluvium, Basalt and Sandstones / Limestones of Dharangandra - Wadhwan formation.	

AQUIFER MAP AND GROUNDWATER MANAGEMENT PLAN, MORBI DISTRICT, GUJARAT STATE

Chapter 1: INTRODUCTION

Morbi district is located in the north eastern part of Saurashtra Peninsula of Gujarat State. The Gulf of Kachchh and Little Rann towards north, the vast low lying alluvial tract plains of North Gujarat towards east and uplands of the central Saurashtra towards and south and west encircle the district. The district covers an area of around 4872 Sq. Km. A major portion of the district is drought prone. This report deals with the salient features of hydrogeological conditions, ground water potential, Aquifer mapping, and management plan of Morbi district. This district is essentially an underdeveloped district, having diverse terrain conditions and varied but limited endowments of nature (Figure 1 &2).

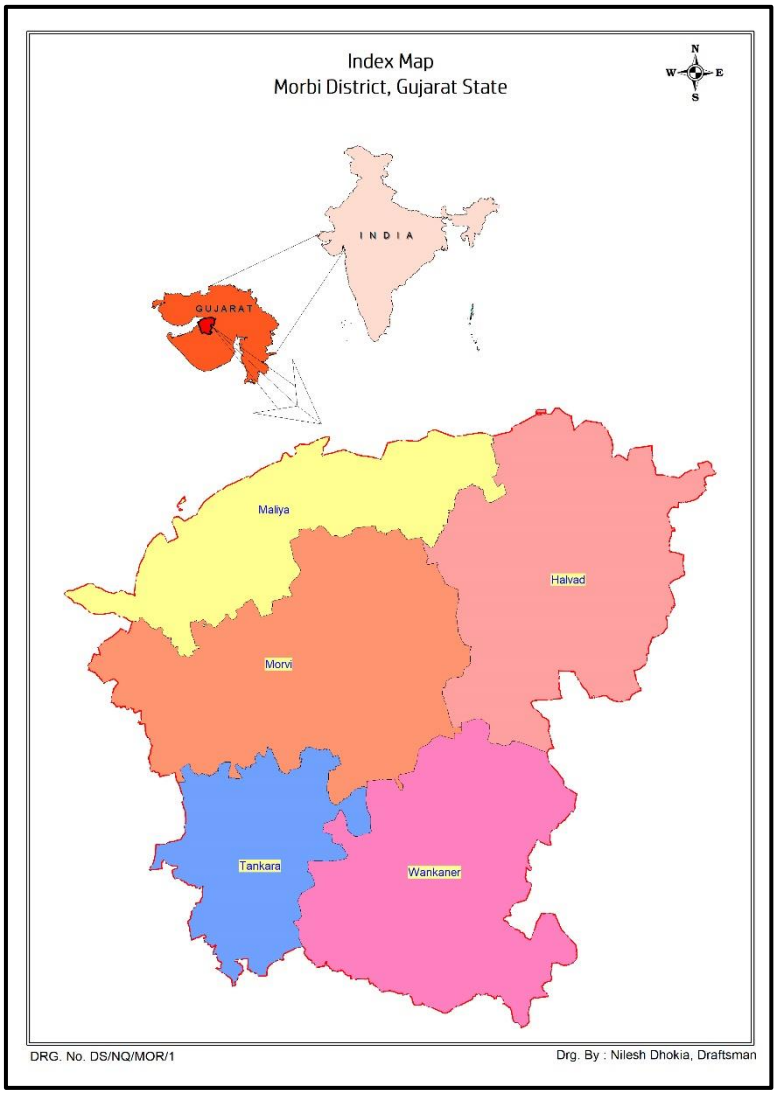

Figure 1: Index map showing the Morbi district, Gujarat, India

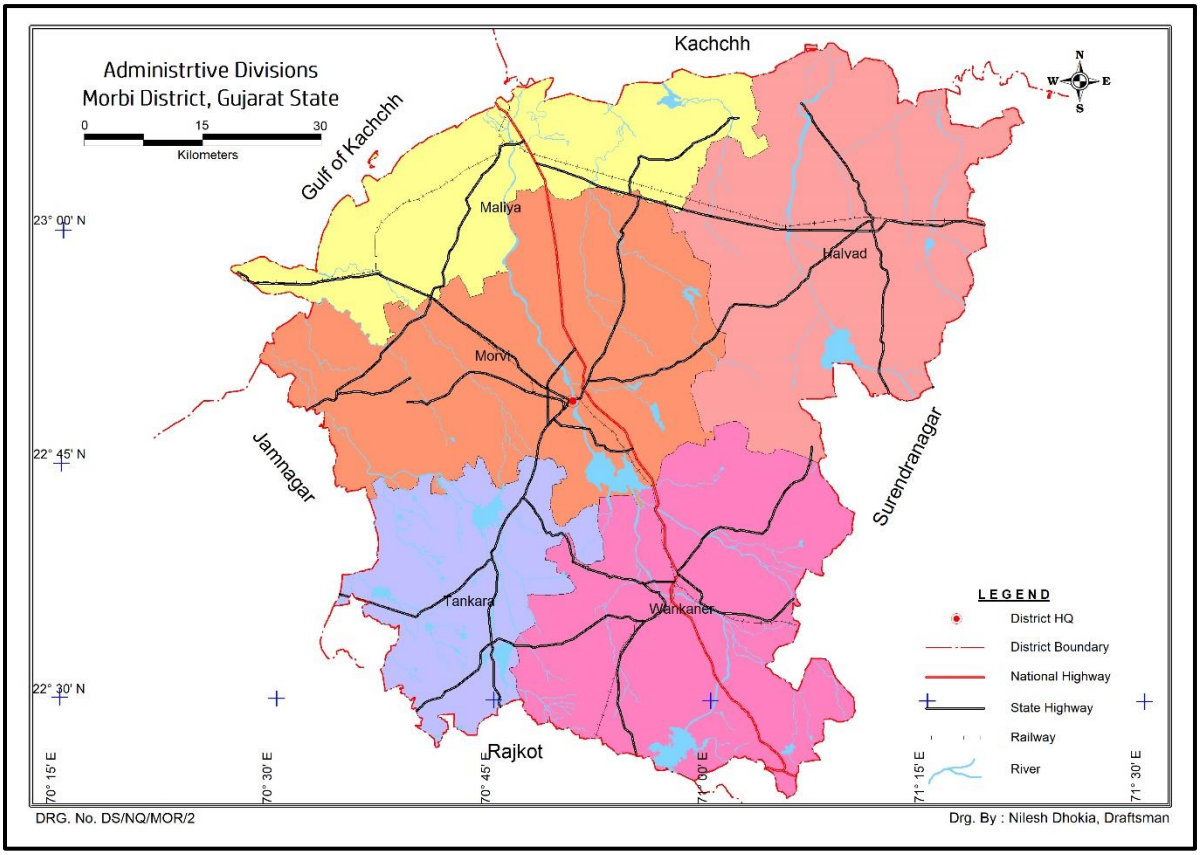

Figure 2: Administrative map of Morbi district.

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. Delineation of aquifer extent (vertical and lateral). Standard output for effective presentation of scientific integration of Hydrogeological, geophysical, geological, hydro chemical data facts and on GIS platform, identification of issues, manifestation of issues and formulation of strategies to address the issues by possible interventions at local and regional level. The activities of the Aquifer Mapping can be grouped as follows.

1.2.1 Data Compilation & Data Gap Analysis:

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

1.2.2 Data Generation

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

1.2.3 Aquifer Map Preparation

On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out details of Aquifers, these are

termed as Aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities (i.e., quality & quantity).

1.2.4 Aquifer Management Plan Formulation

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

All the above activities under the ground National Aquifer Mapping programme are presented in (Figure 3)

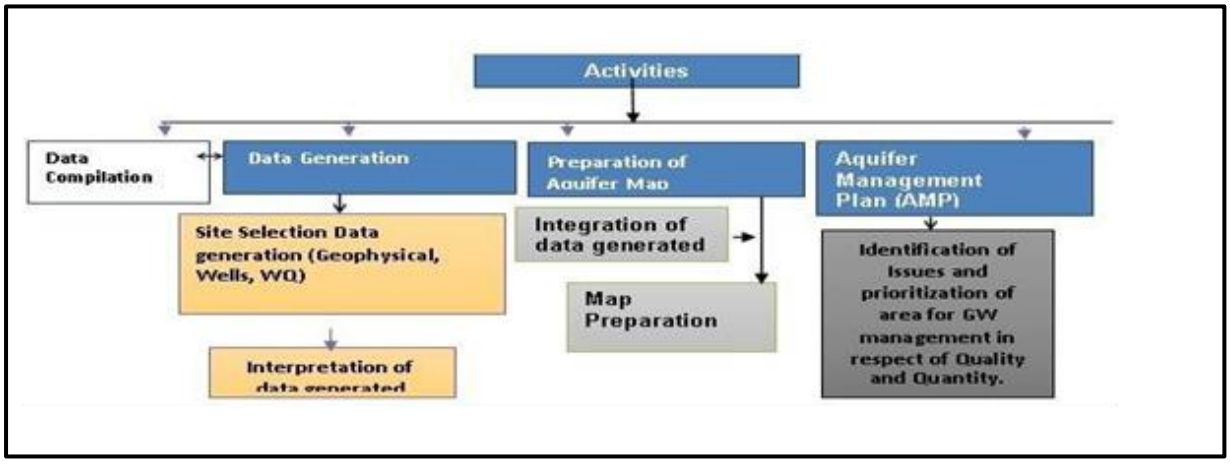

Figure 3 :Activities under National Aquifer Mapping Programme

1.3 Demography

The total population of the district is 960329 of which male population constitutes about 494726(51.51%) and female population is 465603(48.49%). Morbi taluka comprises maximum population 425000 of the district whereas Maliya taluka has minimum population 79000 in the district. The district consists of 349 villages and 5 talukas (table 1 and Figure 4).

Table 1 Demographic details of the Morbi district. (Source- District Statistical report 2019-20)

Taluka	Population('000)		Growth rate (%)	Female ratio(per 1000)	Population density(per Sq Km)	Urban population (%)	Literacy (%)
	2001	2011					
Maliya	82	79	-3.49	947.00	102.00	20.29	71.71
Morbi	350	425	21.47	926.00	328.00	60.56	80.76
Tankara	77	80	4.00	968.00	139.00	0.00	75.69
Wankaner	186	219	17.77	961.00	198.00	24.10	74.24
Halvad	142	167	18.15	942.00	141.00	19.13	73.42
Total	836	971	16.05	942.00	196.00	36.93	76.94

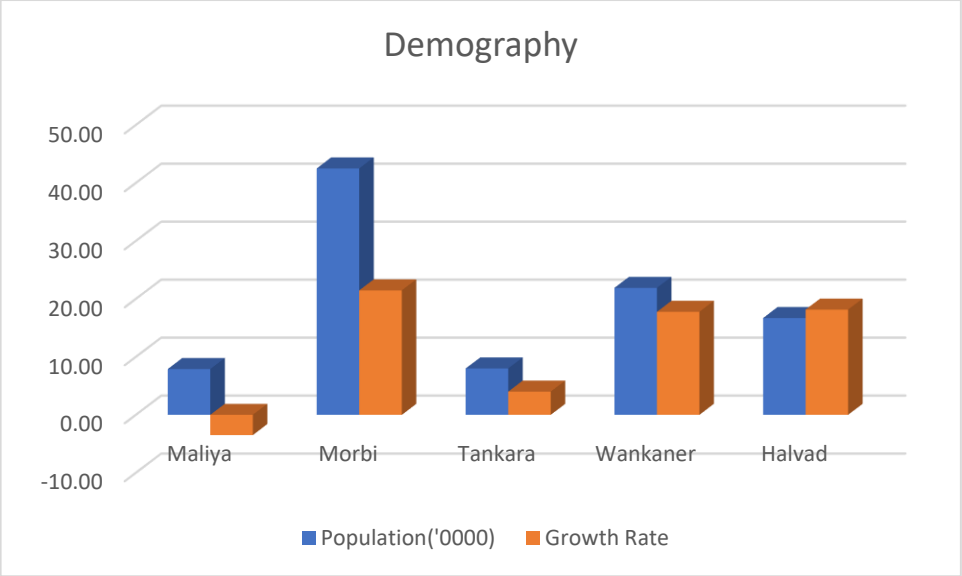

Figure 4: Histographic representation of demography of Morbi district

1.4 Studies/Activities by CGWB

Hydrogeological investigation to Exploratory drilling, at least one bore well in almost every taluka has been done. Systematic survey in Morbi town(1961) for Ground water Quality, Discharge and availability in different aquifer has been done. Subsequently different workers of CGWB took up hydrogeological surveys in the district.

Table 2: Previous studies and activities by CGWB

Area Covered	Geographical Area (sq. km)	Year	Officer
A. Systematic Hydrogeological Surveys			
Wankaner Taluka along with adjoining parts of Surendranagar district.		1971-1972	S. Romani
Northern parts comprising Malia, Morvi & parts of Wankaner Taluka	6000	1972-1973	S. K. Sharma
Central parts	2018	1984-1985	M. S. Jethra
Parts of district falling in Bhadar River Basin		1979-1980	M. R. Kulkarni

1.5 Hydrometeorology

Climatologically data of Rajkot IMD station (1951-1980) that is nearest is given in the table. General climate of the district is sub-tropical and is characterised by three well-defined seasons, i.e. summer - from April to June, monsoon - from July to September, and winter - from October to March.

Table 3: Climatological data of Rajkot IMD station

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

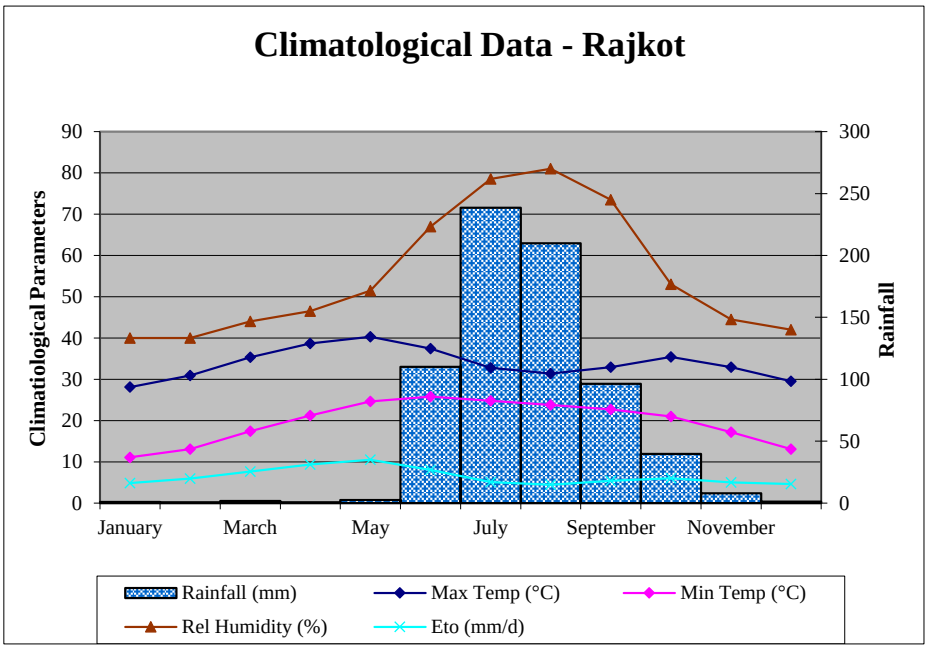

Figure 5: Graph showing climatological data of Rajkot IMD station

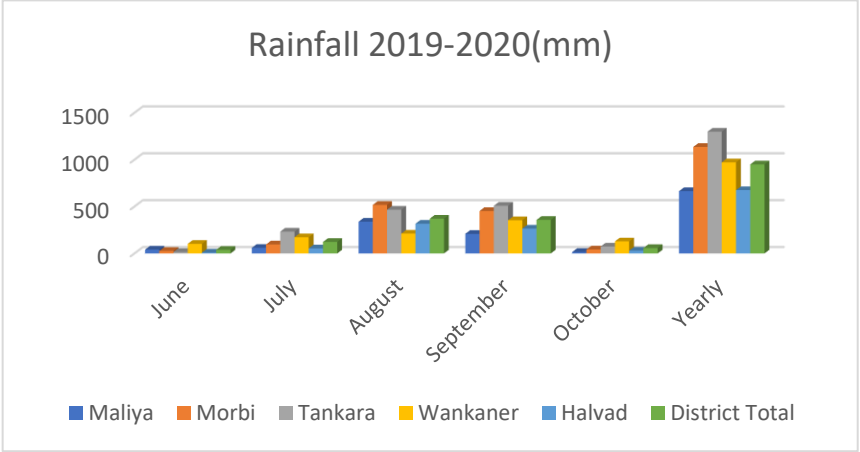

Figure 6: Rainfall distribution in Morbi during Monsoon

Rainfall 2019-2020						
Talukas	June	July	August	September	October	Yearly
Maliya	41	60	339	209	16	665
Morbi	27	96	518	453	43	1137
Tankara	16	233	467	509	74	1299
Wankaner	103	173	212	355	129	972
Halvad	9	54	318	265	30	676
Total	39	123	371	358	58	950
Source: Disaster Management department, GOG						

Table 4 Rain fall data, Morbi district, Gujarat

1.6 Geomorphology

The physiography aspect of the district varies in different talukas. The northen part of the district mainly the Malia taluka bodering the Rann of Kachchh is monotonous alluvial plain country. Towards south, i.e., in Morbi and Wankaner talukas of Morbi district, the topography is mainly rugged and undulating because of the underlying sandstone formations. The topography in these parts in intersected by ridges form by sandstone and intrusive dykes. (Figure 5).

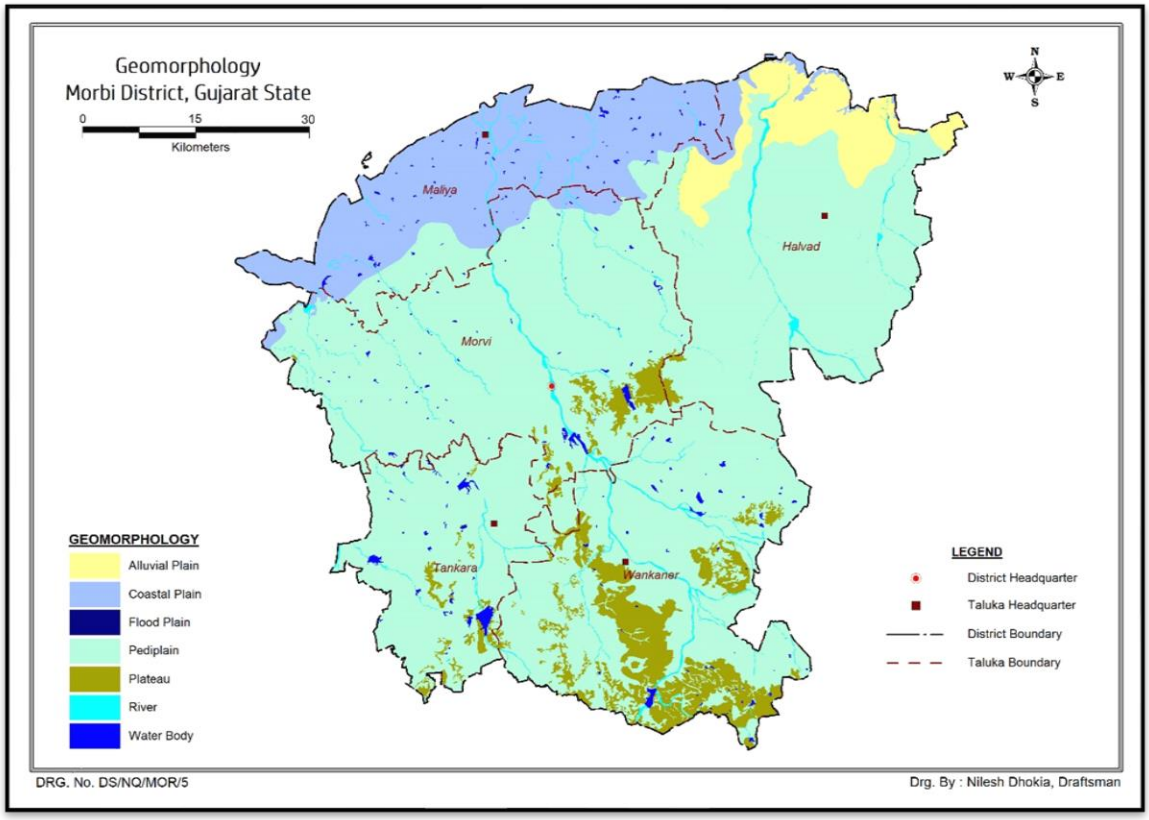

Figure 7: Geomorphological map of Morbi district, Gujarat state

1.6.1 Drainage

The drainage in the northern most and eastern parts comprises mostly short streams which disappear into the Little Rann of Kachchh towards north in the low-lying saline/partly marshy land and towards east in the sandy tracts (figure no.6).

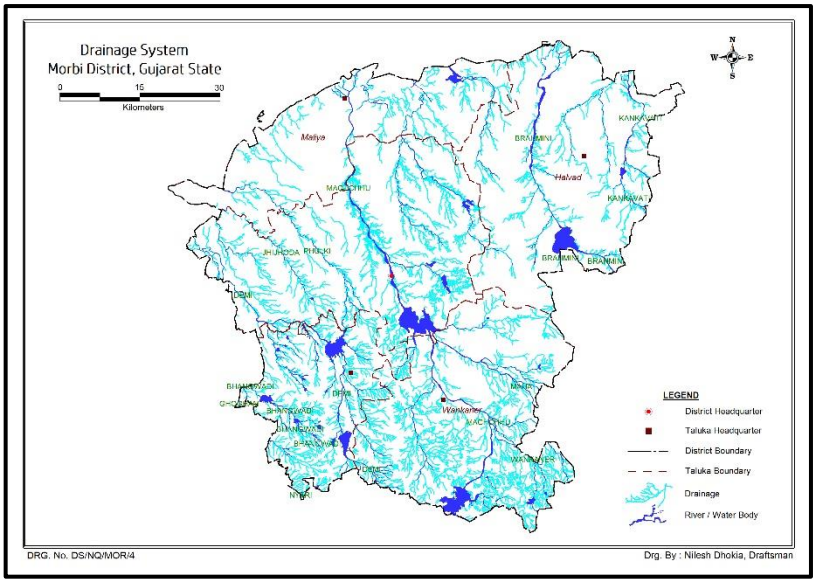

Figure 8: Drainage system of Morbi district , Gujarat

Brahmini, Kankvati, Machchhu, Maha, Jhijhoda, Phulki, Demi, and Bangwadi are some drainages all originate from the southern hilly range of Chotilla about 64 km. These rivers have almost no tributaries in the alluvial tracts. There are many small northerly flowing streams out of which the Brahmanani or Bhambani and Kankavati are the only major streams and are ephemeral.

1.8 Soil Types

The soils of Morbi district may be classified into three main categories:

a. Medium black soils

b. Red Sandy soils

c. Silty soils

Medium black soils generally occur at shallow depths (less than 5m) where basalts/shale forms the main rock unit and is exposed on the surface in the south, southwest and central part of the area. These soils are good in fertility but not suitable for heavy irrigation. The red sandy soils occur in north east, east and south east part of the area. The silty soils are found along a narrow strip close to the little Ran of Kachchh in the north east and along shallow alluvial tracts and hard rock areas in central uplands has appreciable content of sand (Figure 7).

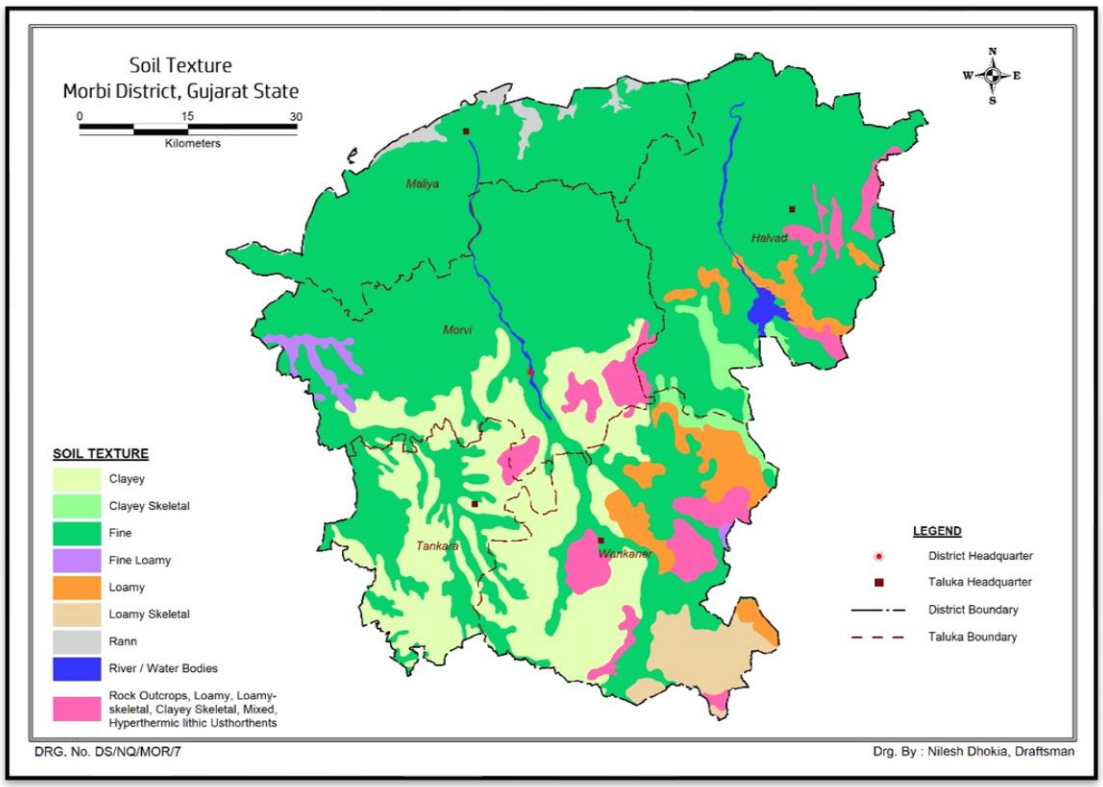

Figure 9: Map showing the soil texture in Morbi district of Gujarat district

1.9 Land Use Pattern

The total geographical area of the district is 379771 Ha, out of which nearly 208874 Ha (55%) is under agriculture, 18989 Ha (5%) under Forests cover, barren & fallow land cover is 56966 Ha (15%) and Built up is 3798 Ha (1%) of the total geographical area of the district. The land use pattern in Morbi district is shown in the map below, Figure 8.

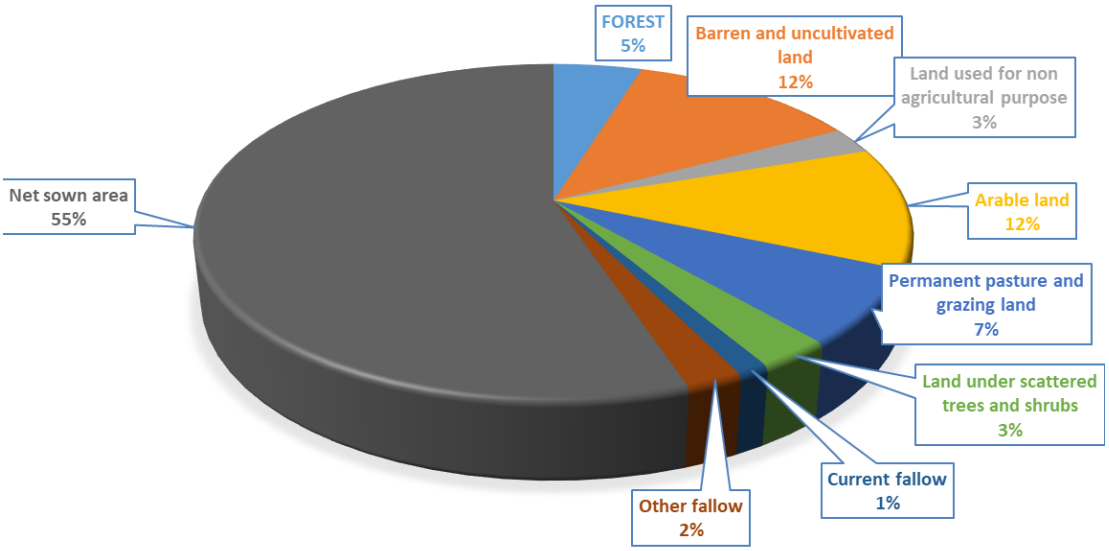

Figure 10: Pie Chart showing Land use distribution in Morbi District

Out of 378113 Ha, is 55% of total area in the district, gross cropped area 90% area is rain feed and only 10% is being irrigated, and nearly 82 % of the area is sown only once, and 18 % area is sown more than once using varous irrigation sources.

Considering Irrigation by source ground water contributes to only 20 % of the source, whereas surface water contributes to the major 80% of the irrigation in the district.

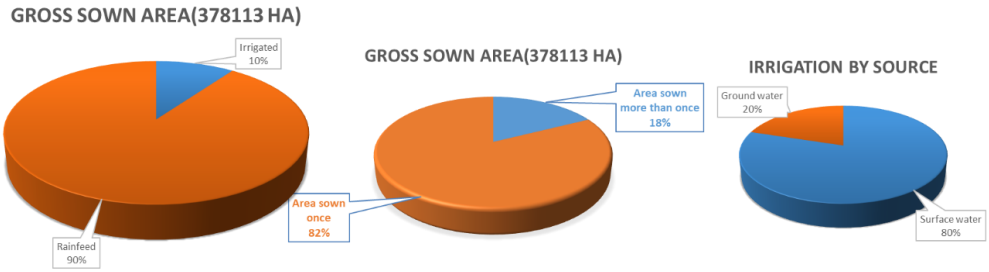

Figure 11: Pie Charts showing gross sown and irrigated areas proportion in Morbi district

Out of the 378113 Ha of gross sown area, area under non food crops covers around 83% of the cropped area, whereas the area under food crop is only 17%.

Under the food crops Cereals contributes to 41% of the total food crops followed by spices contributing to 31%, and 16% in Horticulture and 13% pulses.

Under non food crops, cotton contributes to 58%, other oilseeds 19%, fodder 16% and castor 7%.

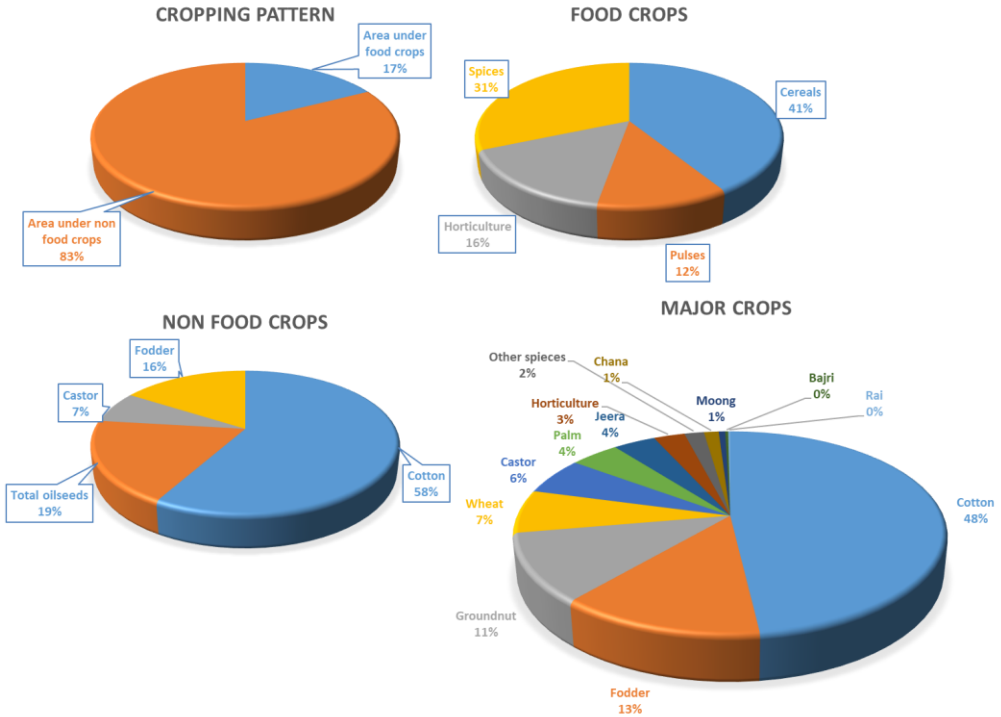

Figure 12: Pie Chart showing Cropping pattern in Morbi district

Cotton is the major crop in the district with 48% area of gross cropped area, followed by fodder (13%) Groundnut (7%), Wheat (7%), castor (6%), Palm(4%), Jeera (4%) and other crops.

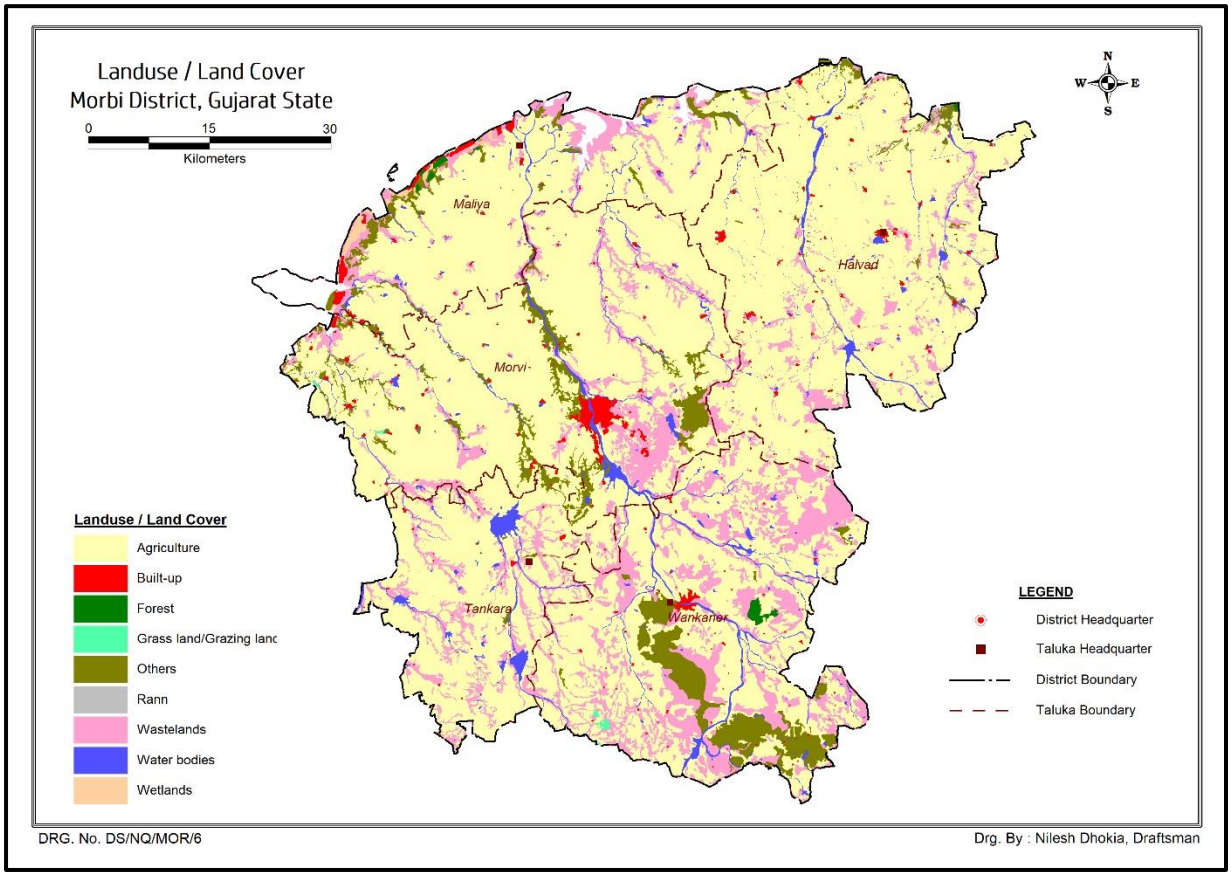

Figure 13: Map showing the land use/ land cover in Morbi district of Gujarat district

1.7 Geology

The general geological succession of the rock formations occurring in the Morbi district is as given below (Table 3). The geology of the district is depicted in Figure 9.

Table 5 Geological succession of Morbi district

Age	Formation	Lithology
Pleistocene to Recent	Soil/ Alluvium	Black cotton soil and. Clay, sandy soil, clay, silt, brown sand and gravel.
--Unconformity--		
Upper Cretaceous to Lower Miocene	Deccan Traps and related intrusive	Basalts, volcanic tuff, porcellanitic, Dolerite dykes, & related volcanic rocks
Middle Cretaceous	Wadhwan Formations	Reddish brown to brick red colored sandstone, fossiliferous cherty limestone and pebbly grit.
Upper Jurassic to Cretaceous	Dhrangadhra Formations	Medium to coarse grained sandstone, ferruginous, current bedded, intercalated with red, grey and black shales and carbonaceous matter.

1.7.1 Description of the rock units:

Dhrangadhra Formations:

This is the oldest water bearing formations in the district. It occupies parts of Wankaner and Morvi talukas in continuity with the sandstone exposures in the adjoining Surendranagar district, covering an area of about 3000 Sq. Km and 400 m in thickness. Few sandstone inliers are also seen within the overlying basalt. The sandstone is poorly permeable in general but moderate to high permeability may be observed along the bedding planes and fractures. Exploratory drilling in this formation has revealed that persistent carbonaceous shale; inter-bedded with medium to coarse-grained sandstone, occur at depths varying between 83 and 220 m. This shale horizon forms an important marker from the groundwater point of view as the groundwater is generally potable to brackish above it whereas as it is saline below. The groundwater in this formation occurs under phreatic to confined conditions. Exploitation of groundwater in areas underlain by Dhrangadhra Sandstone is through dug well, dug-cum-bored wells and tubewells. The depth of dug wells generally range from 10 to 40 m. The tubewells and bores in the dug-cum-bored wells are generally

drilled down to 80 to 200 m bgl depending on the occurrence of shale horizon as discussed above. The yields of dug wells range between 30 and 120 m^3/day.

Deccan Traps: Deccan trap occupies a major part of in the district. The basaltic lava flows unconformably overlying the Wadhwan and the Dhrangadhra formations, and are exposed in South western part of the district. The basalts are compact, fine grained to porphyritic and sparsely joint**.** The major fracture pattern in the Deccan traps is in NE—SW and NW-SE directions with high angle dips. Columnar jointing is also seen in the massive basalts. The joints are mainly cooling joints and seldom interrupt more than flow. However, a few major shear zones intersecting several flows are also encountered.

It generally forms a poor aquifer due to compactness and poor primary porosity. However, the upper weathered parts, which at places are up to 20 m thick, form good aquifer in the district. At deeper levels, the secondary porosity developed as a result of tectonic activities, in the form of joints, and fractures, shear zones, form repository of groundwater at many places.

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

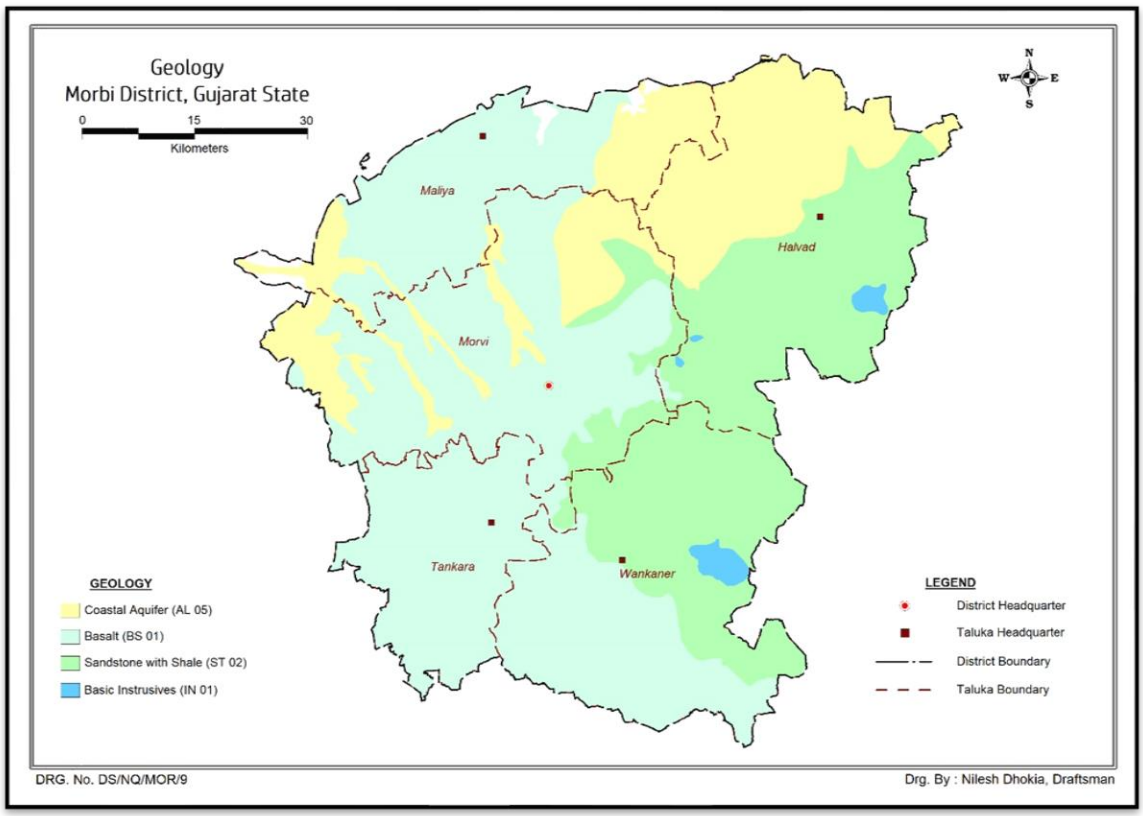

Figure 14: Map showing the geological units in Morbi district of Gujarat district

Basic Intrusive: The basic intrusive are mainly Dolerite dykes. These dykes are mostly manifested in the Dhrangadhra formation at many places. The dykes are generally compact but highly jointed/fractured dykes are also observed.

Alluvium: The fluvio-marine alluvium of Upper Tertiary to Quaternary age occupy about 1200 sq. km area in the northern parts of district in Malia and Morvi talukas It mainly consists of clay, clayey sand, silt and gravel. The alluvium in the district generally forms a poor aquifer due to predominance of argillaceous material. The groundwater development in this formation is limited due to poor quality.

Groundwater in this formation occurs under phreatic and confined conditions. It is exploited through dug wells ranging in depth from 3 to 20 m. The yields of wells range between 20 and 80 m3/day.

One spring is observed at Avaliya Thakar temple, north of Chotila, in sandstone formation. It has a discharge of 8 lps in peak summer.

Chapter 2: HYDROGEOLOGY

The groundwater in the area occurs phreatic, semi-confined and confined conditions. The ground water occurrence is controlled by topography, drainage, lithology and disposition of fractures and joints. The medium to coarse grained sandstone act as good repository of ground water. The main water bearing formations identified with in the area as follows (Figure 10).

2.1 Ground Water in alluvium

Most of the northern parts of the district, comprise semi and unconsolidated formations. The ground water occurs under unconfined to confined conditions. The depth of the wells in this formation ranges between 2.00 and 30.00 m bgl. The depth of water levels ranges from 0.20 to 20.0 m bgl. The yield of shallow dug wells varies from 40 to 60 m3/day. The depth of the tube wells ranges from 60 to 300 m. The free flow discharge of these well ranges from 5 to 60 m3/day.

2.2 Ground Water in Dhrangadhra Sandstone

The Dhrangadhra sandstone are the most important water bearing formations in the district, and situated in the central and eastern parts of the district. The shallow dug wells in the depth range between 5 and 28m, tapping Upper Dhrangadhra sandstone have water yielding capacity of 20 to 60 m3/day. The general range of water level in this aquifer is around 4 to 22 m. A number of tube wells sited, in Middle Dhrangadhra formations, down to depths ranging between 90 and 157 m are in operation. The yield of tube wells varies from 25 to 80 m3/day. The piezometric head in this aquifer vary from 10 to 30 mbgl.

2.3 Ground Water in Deccan Traps

The Deccan basalts, unconformably overlying the Dhrangadhra formation form aquifers in southern part of the district. The movement of ground water is controlled by weathered zone, joints and fissures. The groundwater occurs under both water table and semi-confined conditions. The depth of the dug wells in the traps range from 6.0 to 28.0 m and depth to water level rests between 1.0 and 20 m bgl. The yield of shallow dug wells ranges from 20.0 to 50.0 m3/day. The depth of the boreholes tapping interflow zones range from 80 to 110 m, where in the piezometric head rests between 18 and 25 m bgl. As such the yield of the shallow/deep boreholes in the traps are ranging from 35 to 70 m3/day.

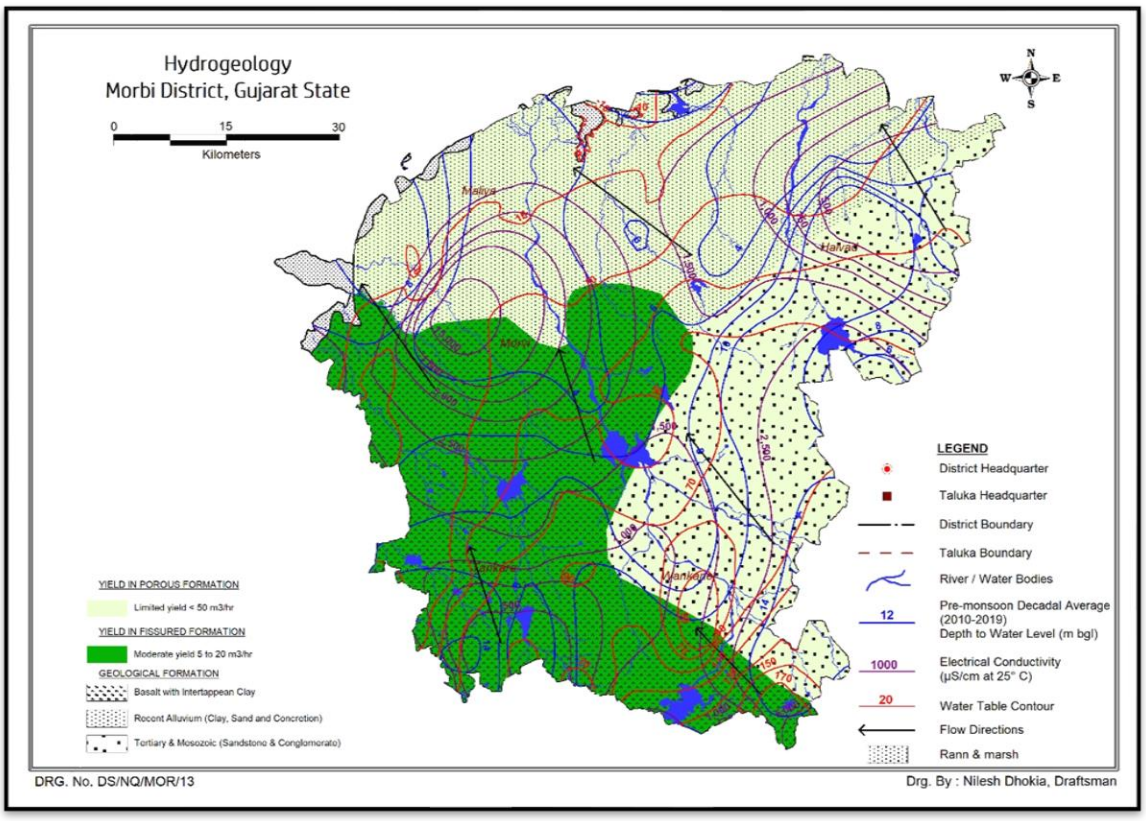

Figure 15: Hydrogeological map of Morbi district.

Chapter 3: DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities (Table-4).

Table 6: Brief activities showing data compilation and generations

S.No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.

S.No.	Activity	Sub-activity	Task
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological Parameters On groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional Water quality parameters	Analysis of groundwater for general parameters Including fluoride.
3	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.

S.No.	Activity	Sub-activity	Task
4	Aquifer Managem ent Plan	Preparation of aquifer management plan	Information on aquifer through training to Administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

3.1 Data Generation

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of lithological logs and Electrical logs of Exploratory wells studies carried out and used in prepare a hydro geological cross section, Fence diagram and 3D Model. The data has been analyzed using Rockworks 16 software and is presented below in the Hydrogeological cross sections A-A' to D-D' and Solid Model of the district showing the depiction of Aquifer Groups and Aquitard up to 200 m. The stratigraphic sections depicting unconfined aquifer, Confined Aquifer for alluvium and weathered aquifer & fractured aquifer for Basaltic rock are placed at Figs (12 to 15). Fence Diagram and 3D Solid Model of district is depicted in Fig. 16A and 16B, respectively.

Table 7: Data integration in respect to Morbi district

Type of Data & source	No of Wells
Aquifer Disposition	
CGWB	**18**
Long term Fluctuation	
CGWB+GWRDC	**18+23**
Decadal Analysis water Level	
CGWB+GWRDC	**18+23**
Analysis of water Quality	
CGWB	**17**

3.2 Conceptualization of Aquifer system in 2D

A total of 18 exploratory wells and piezometers lithologs are utilized to decipher the subsurface geometry of the aquifer by using Rockworks 16 software prepared hydro geological cross sections, Fence diagram and 3D Model up to the depth of 200 mbgl.

And four hydrogeological cross sections (2D) are drawn in different direction to cover entire area as per the availability of data point in the district and represented in figure 12 (A-A') to figure 15 (D-D').

1. Section A-A' (Fig. 12)- Section is drawn roughly NE-SW direction and in between Malia and Meghpur Zala, passing through Hajnali and Morbi . Stratigraphicaly from Section, it is deciphered that coastal alluvium form the major alluvium in the northern part of the district and sandstone, intercalation of Shale and sandstone in the southern part of the district, both being underlain by Deccan basalt.

2. Section B-B' (Fig. 13)- Section is drawn roughly W-E direction and in between Bangawadi and Lunsar passing through Tajpur, and Tithwa. Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & fractured), Deccan Basalt and (weathered & fractured), sandstone, intercalation of Shale and sandstone the major aquifer system in the district along drawn section line.

3. Section C-C' (Fig. 14)- Section is drawn roughly NW-SE direction and in between Malia and Rupawati, passing through Rangpur, Matel and Lunsar. Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & fractured) sandstone forms the major aquifer system in the south eastern part of district and coastal alluvium in the north westeren part of the district along drawn section line.
4. Section D-D' (Fig. 15)- Section is drawn roughly SW-NE direction and in between Meghpur Zala and Matel, passing through Sajanpur and Dhuva. Section is represented Stratigraphicaly, from section it is deciphered that that Hard rock formation (weathered & fractured) Deccan Basalt in the south western part, (weathered & fractured) sandstone and intercalation of shale and sandstone in central part and coastal alluvium in the north eastern part forms the major aquifer system in the district along drawn section line.

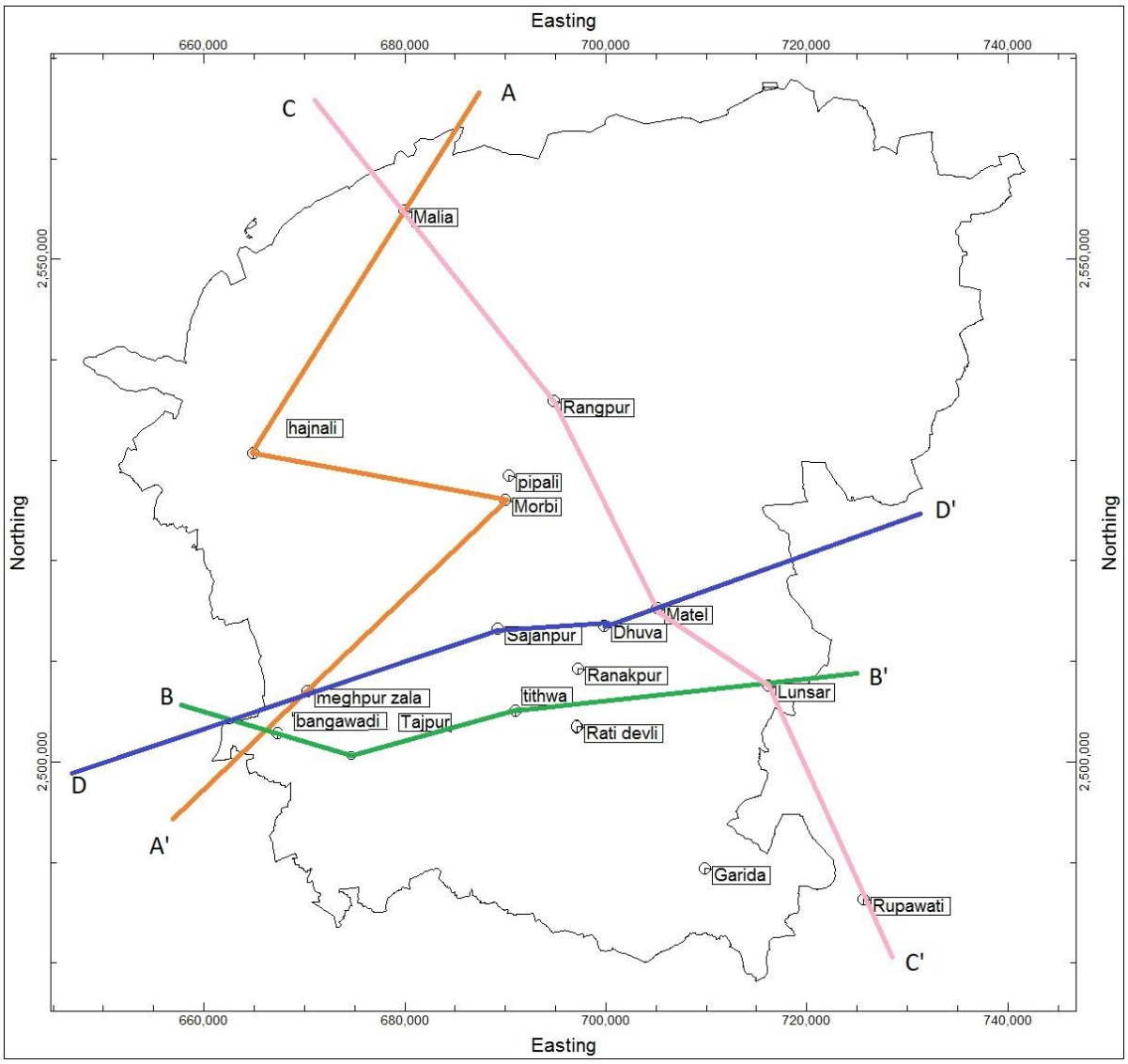

Figure 16: Map showing drawn section lines

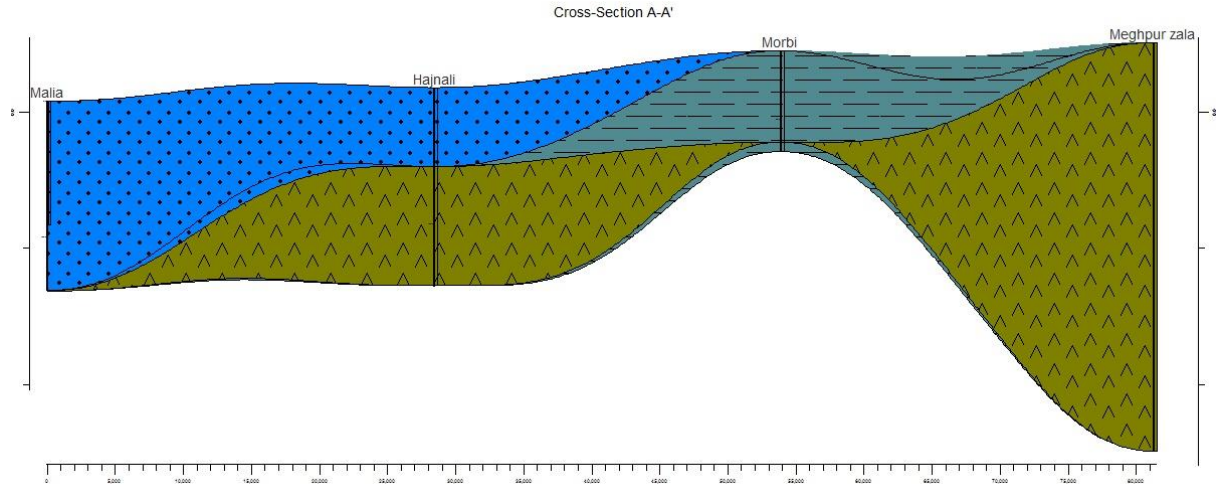

Figure 17: Hydrogeological cross section between Dhrangadhra and Limdi(A-A')

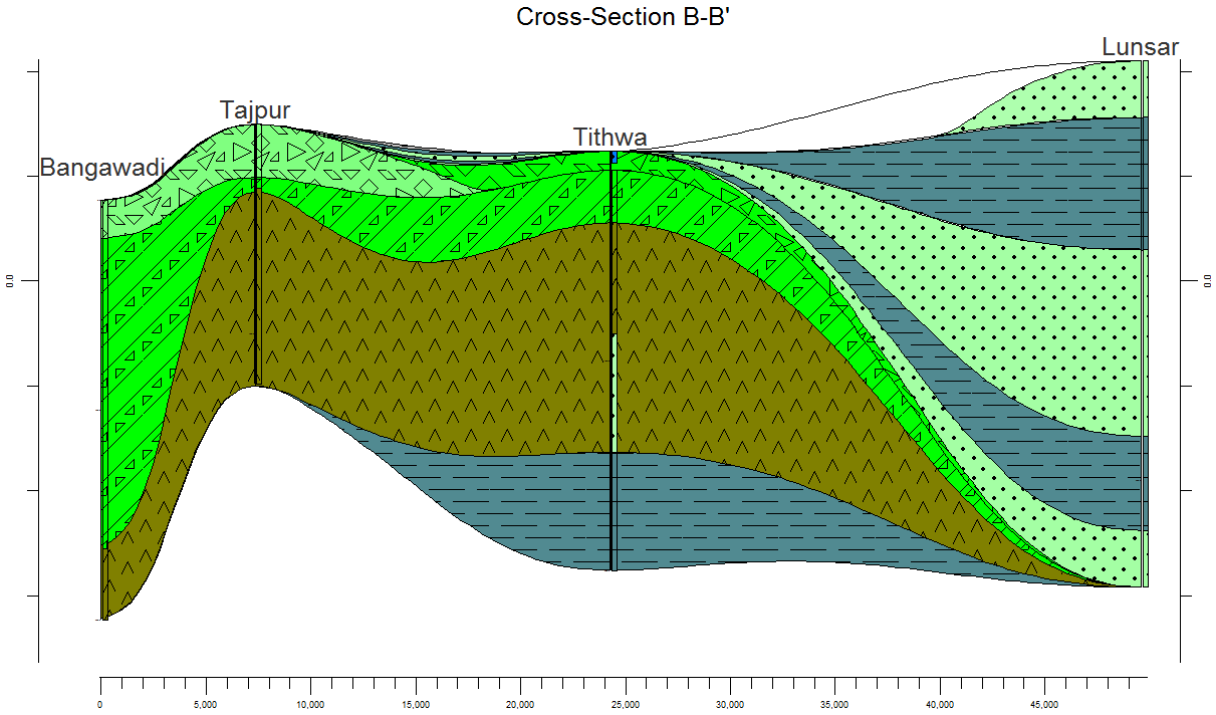

Figure 18: Hydogeological cross section between Parali and pipaliya Dhokalva(B-B')

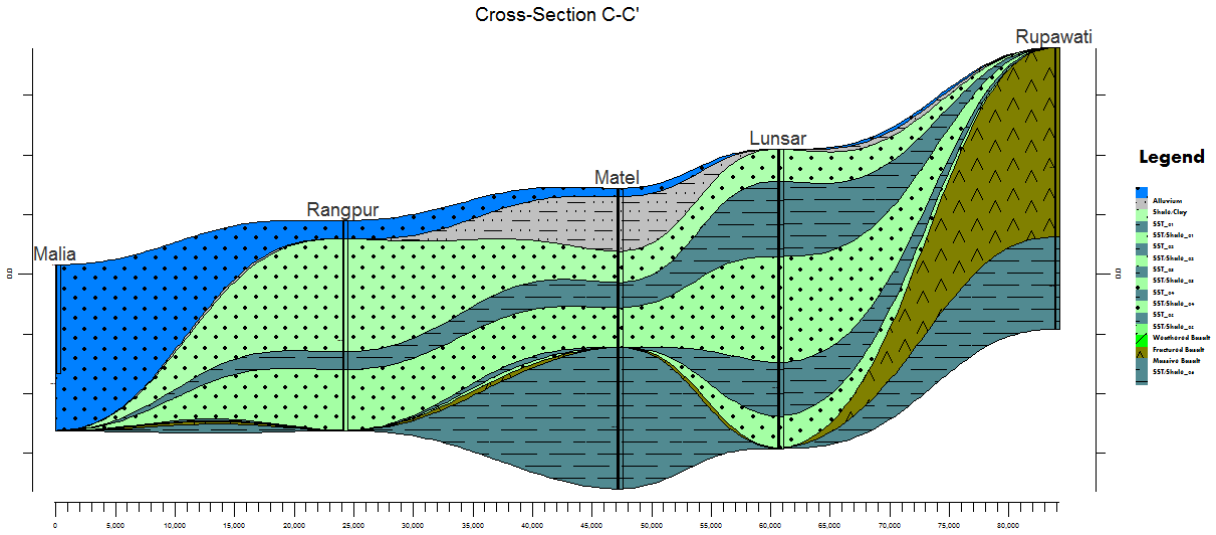

Figure 19: Hydogeological cross section between Moti Moladi and Parali(C-C')

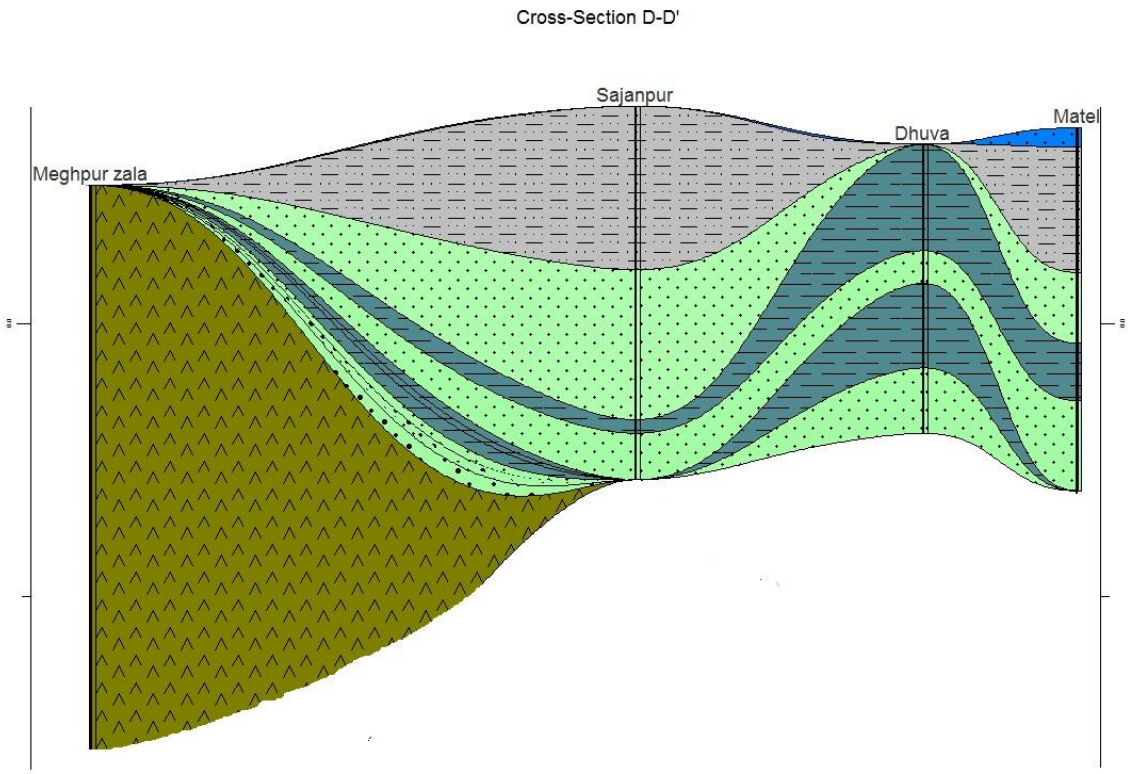

Figure 20: Hydogeological cross section between Moti Moladi and Parali(C-C')

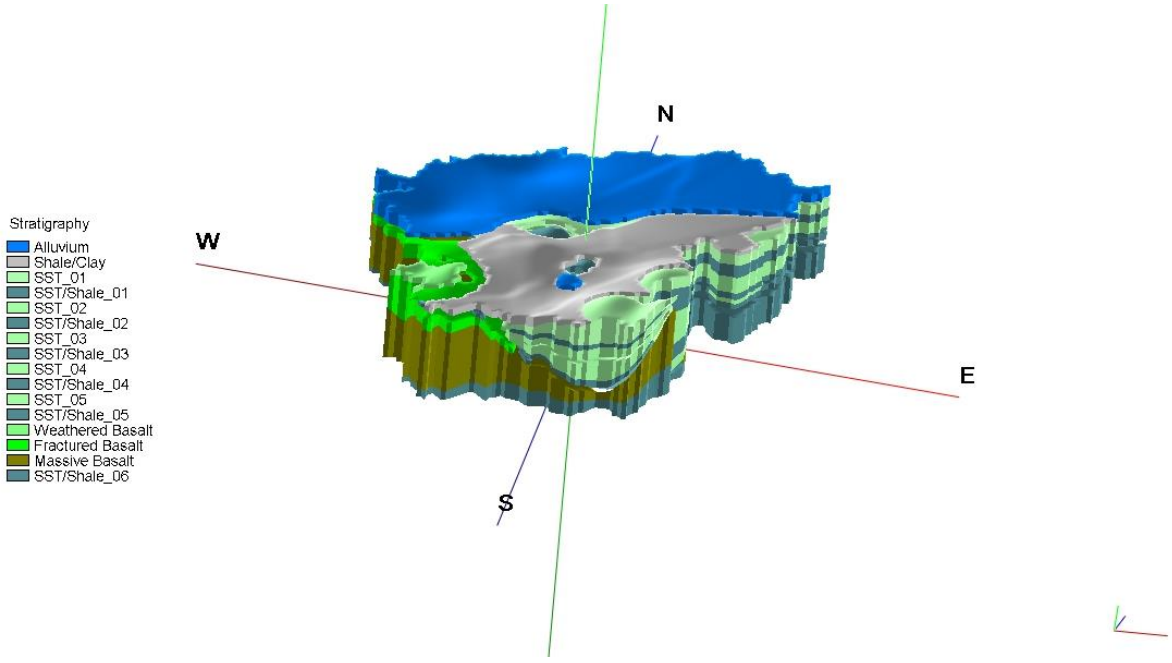

Figure 21A: 3D- Aquifer disposition/ model of Morbi district

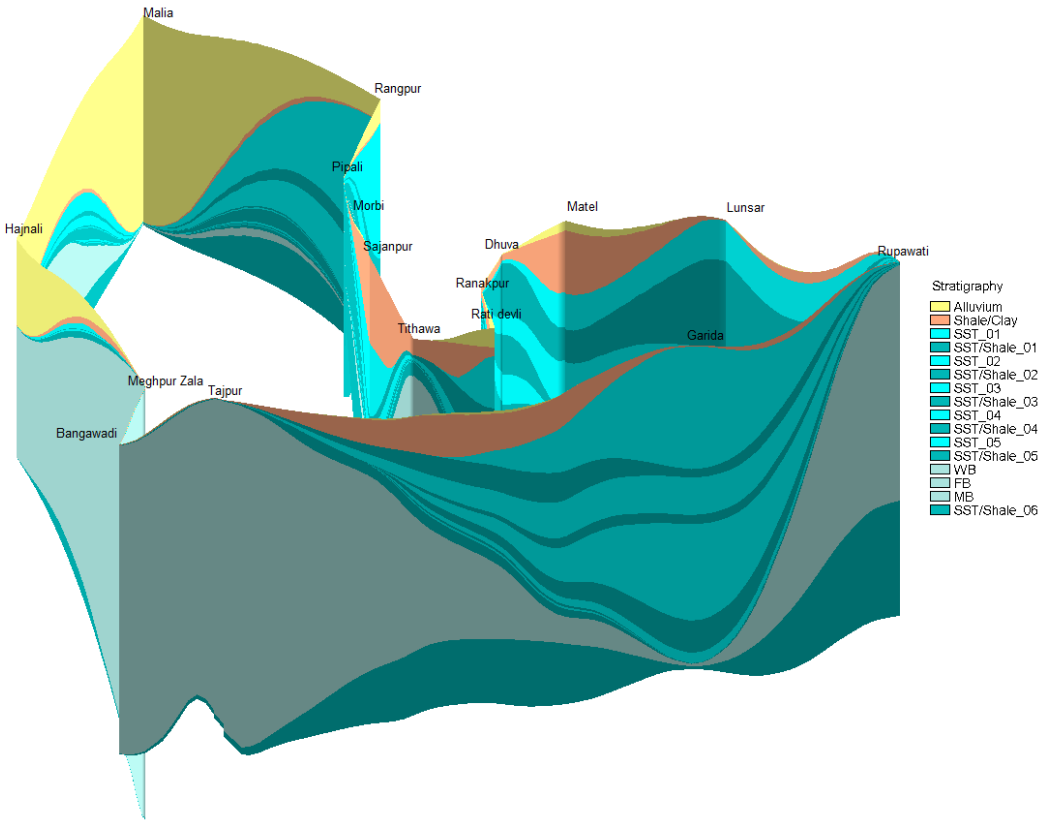

Figure 22B: Fence diagram of Morbi district

Table 8Aquifer characterization and disposition of Morbi district.

Aquifer Characterisation and Disposition										
Stratigraphy	Aquifer Nomenclature	Lithological Characteristics	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level (mbgl) Range (mbgl)	Quality TDS Range Mg/l	Discharge Range lps	Transmissivity Range m2/day	Nature of Aquifer	Remarks
Quaternary	Alluvium	Sand Silt Dominant	0-139	1-138	0.7-16.0	1785-9174	1.4-12	-	Phreatic	Saline
Cretaceous-Eocene	Weathered Basalt	Deccan Trap Basalts	0-60	40-60	0.7-31.15	510-9060	0.15-20	-	Phreatic	Brakish Locally
	Fractured Basalt	Deccan Trap Basalts	60-541	100-400	3.6-87.80	550-7526	0.4-15	1.34-1.99	Semi-confined	Brakish Locally
Lower Cretaceous	Sandstone	Sandstone Shale Intercalations	0-317	More than 400	1.10-36.05	499-5273	0.41-15	0.67-136.18	Phreatic	Brackish with depth

Chapter 4: GROUND WATER SCENARIO

4.1 Behaviour of Water levels

The behaviour of water levels was studied based on the water level data collected from the National Network of Hydrograph Stations (NNHS). The water level data of May 2020 and November 2020 was used for preparing the depth to water level maps. The seasonal fluctuation in water levels was calculated between May and November 2020. Total 41 nos. of monitoring stations including 23 nos. monitoring station of Gujarat Water Resources Development Corporation (GWRDC) were taken during preparation of maps (figure 17).

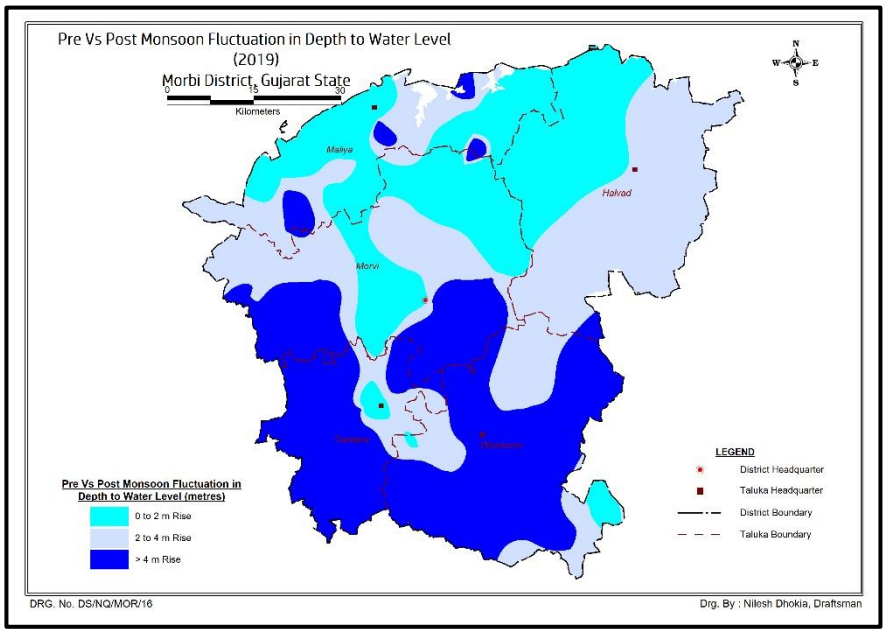

Figure 23: Map showing groundwater fluctuation of pre to post monsoon season 2019

4.2 Depth to water level (Pre monsoon)

Pre monsoon depth to water levels of Morbi district is shown in the (Fig. 18), which depict that depth to water levels in the district ranges in between 1.45 m bgl (Maliya) to 36.05 m bgl (Wankaner), with an average depth to water level 9.26 mbgl. It is also observed that depth to water level is deeper in the hard rock terrain in the southern and south western part of the district. Major part of the district has depth to water level above 10 mbgl.

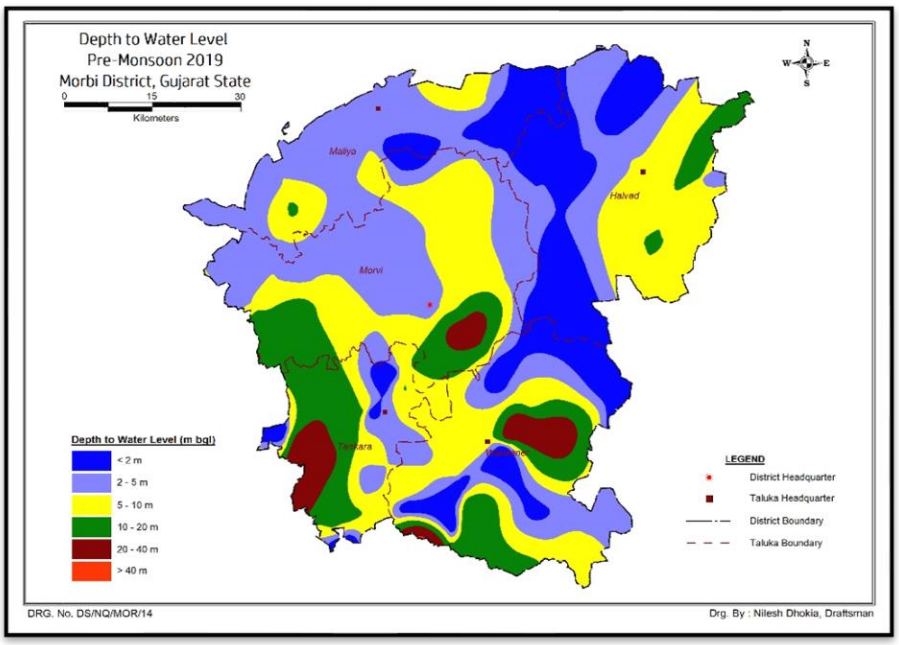

Figure 24: Map showing Pre-monsoon (May 2019) depth to water level of Morbi District

4.3 Dept of Water level (Post monsoon)

Post monsoon depth to water levels of Morbi district is shown in the (Fig. 19), which depict that depth to water levels in the district ranges in between 0.14 m bgl (Morbi) to 30.01 m bgl (Wankaner), with an average depth to water level 4.7 mbgl. It is also observed that depth to water level in the major part of the district is above 10 mbgl except in the central part of the district where a patch of depth to water level deeper than 10 mbgl is observed.

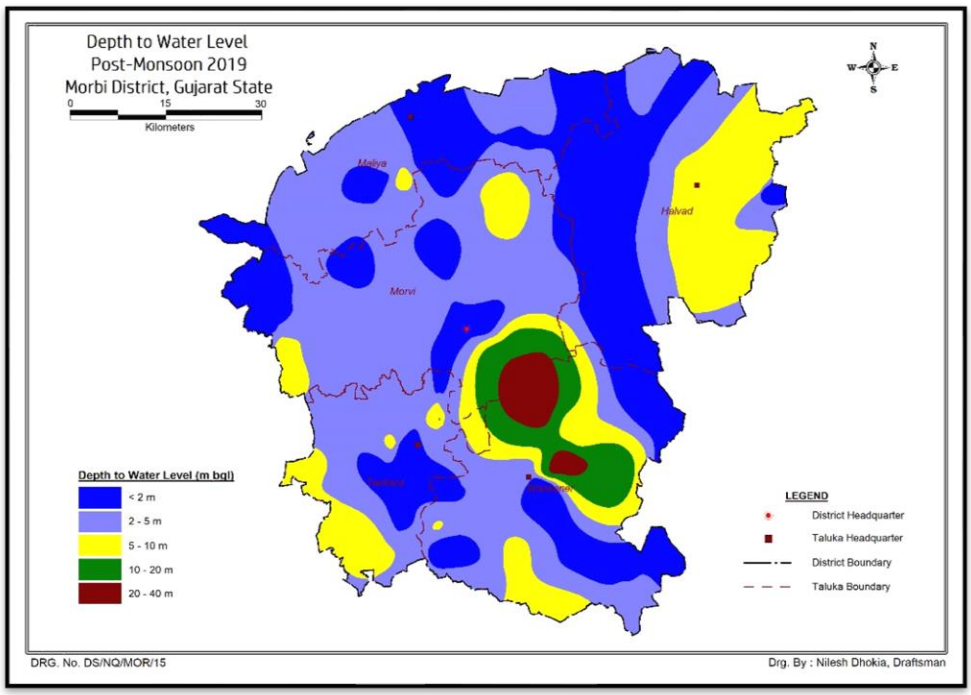

Figure 25: Post-monsoon (Nov. 2019) depth to water level of Morbi District

4.5 Water table and Groundwater movement

The elevation of water table in Pre-monsoon 2019 is observed higher along SE (Wankaner taluka) adjoining district boundary with Bhavnagar district where water table contour starts at 180m amsl which flowing towards NE direction, with many local domes shaped contour showing radial flow (Figure 20).

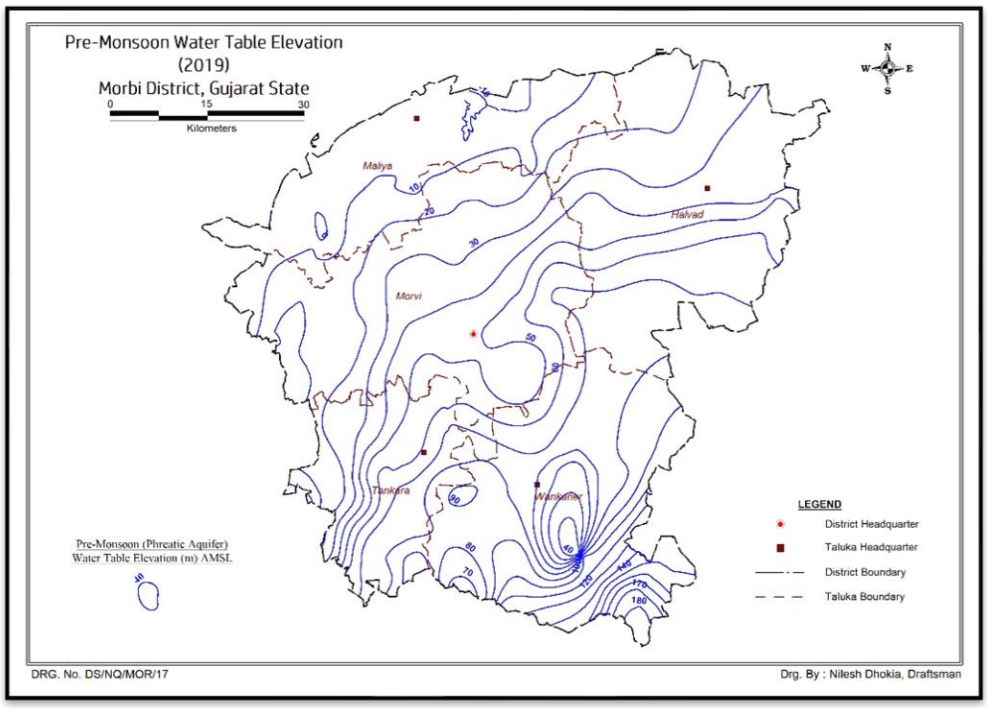

Figure 26: Water level contour map (Pre-Monsoon_2019) of Morbi district

4.6 Ground water decadal average depth to water level (2009-2018) Map

Decadal trend of ground water level for the period of 2009 to 2018 has been prepared and presented in figure 21 and 22.

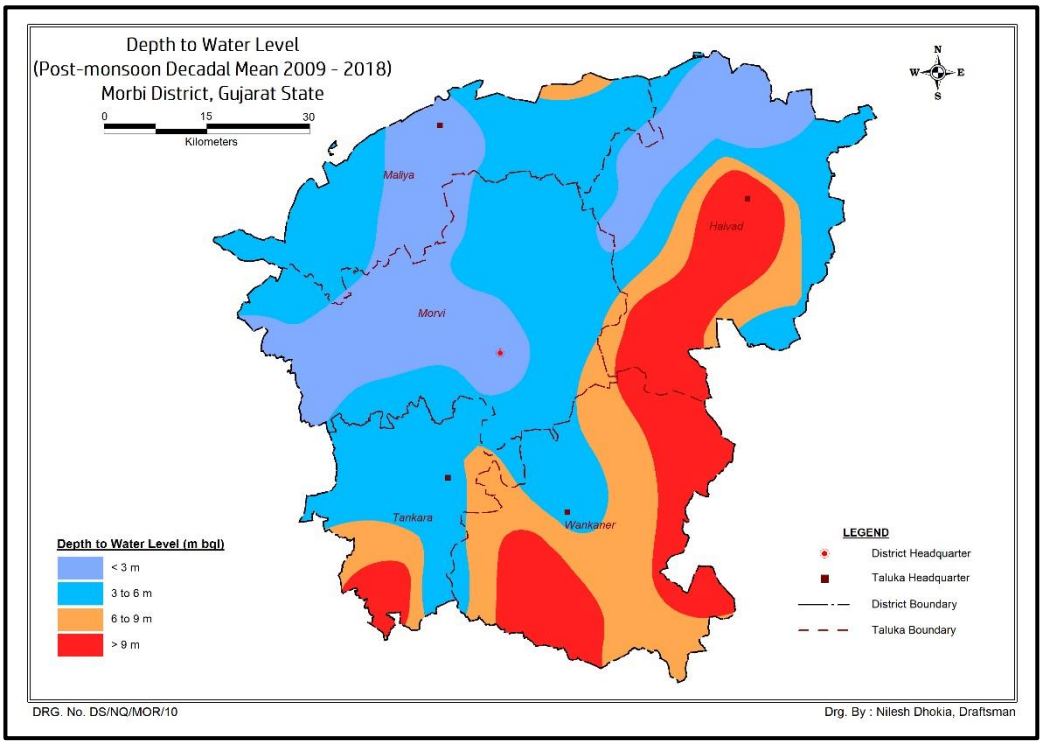

Figure 27: Ground water decadal trend Pre-Monsoon (2009-2018)

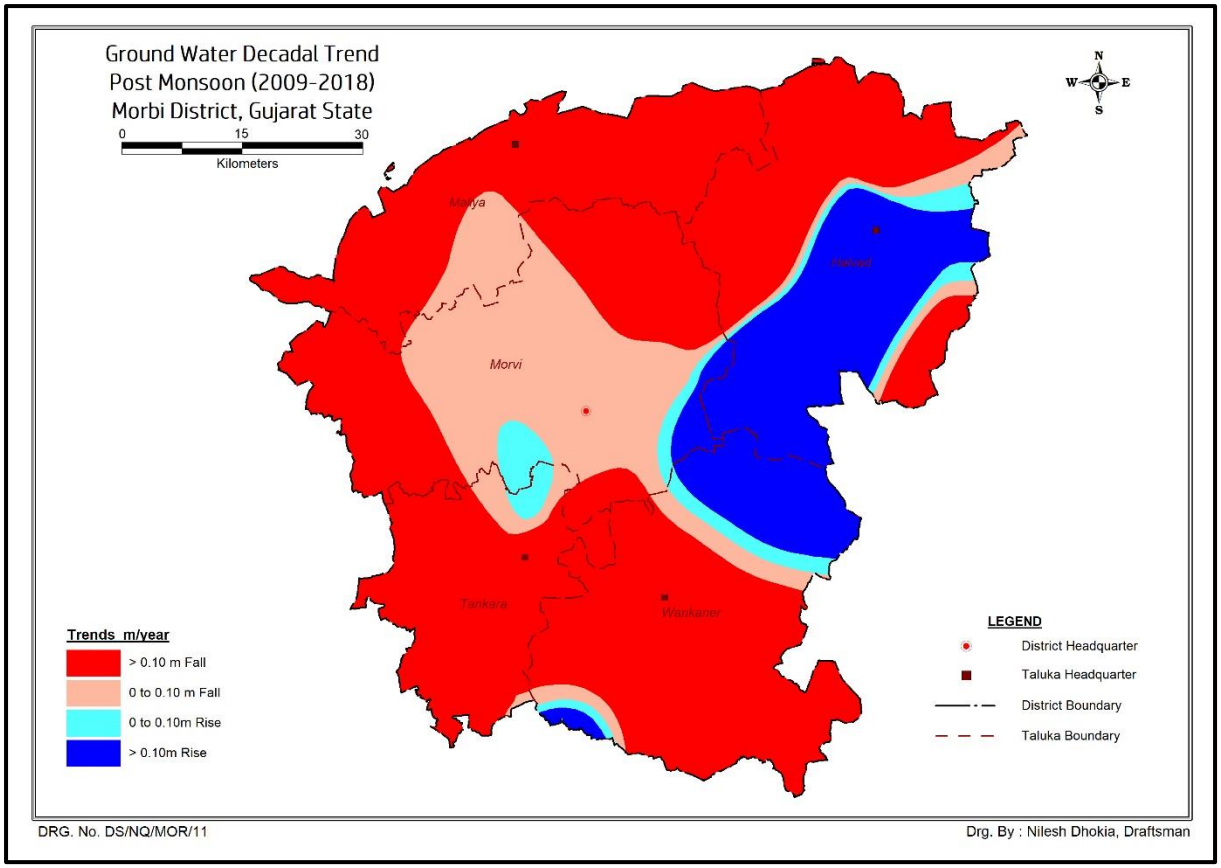

Figure 28: Ground water decadal trend post-Monsoon (2009-2018)

4.7 Hydrograph and water level trend (2012-2019)

Pre monsoon and Post monsoon long-term rising and decline trend of water level of various hydrograph stations established by CGWB are also studied in graphic form.

Historical data of water level were used for preparing the hydrographs as well as for computing long term trend. Few of the hydrographs representing the falling trends of water level of Morbi district are presented below.

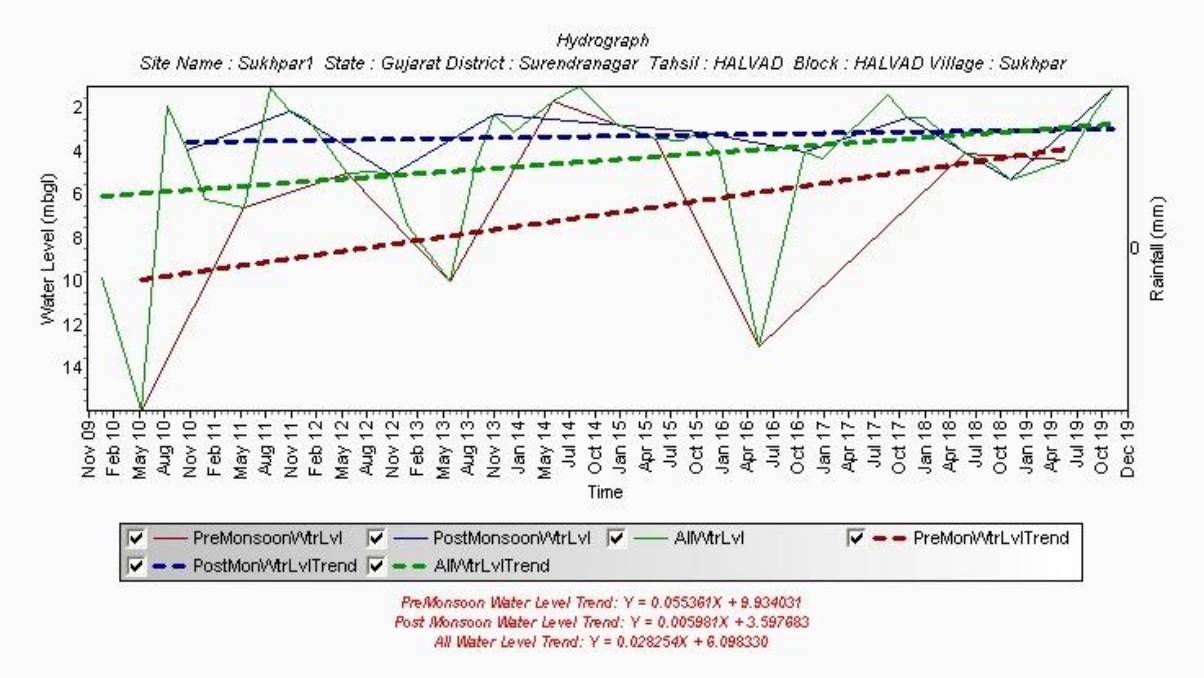

Figure 29: Hygrograph and WL trend at Sukhpar1, Halvad, Morbi

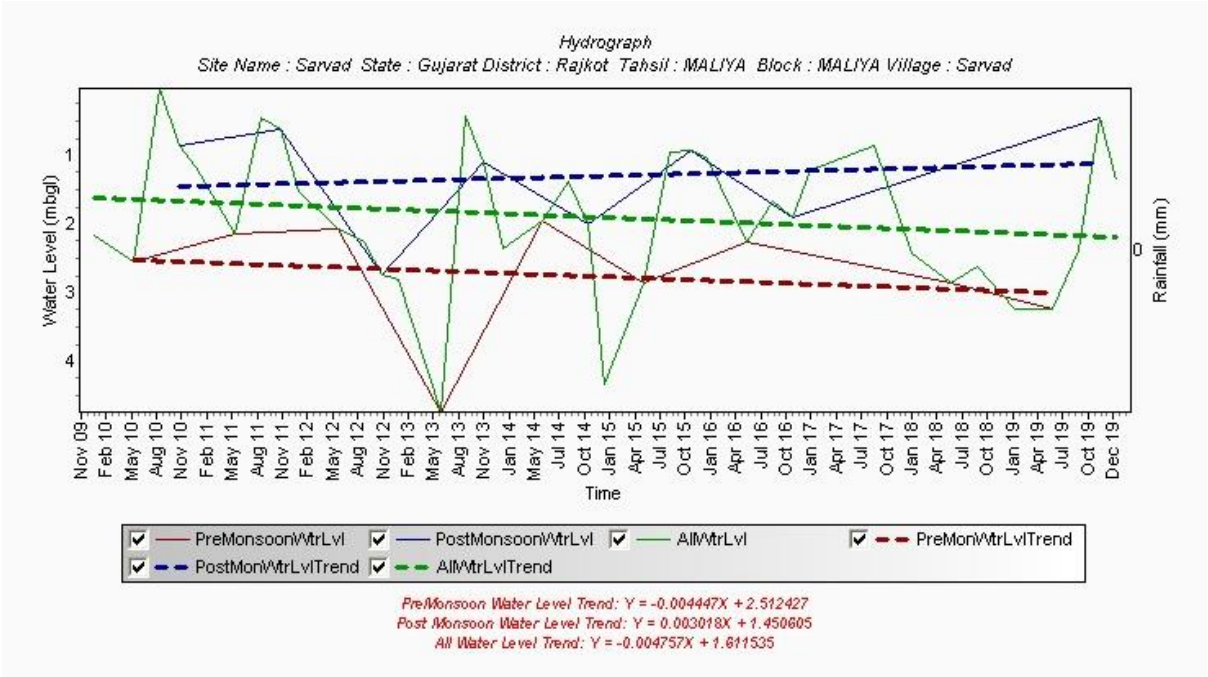

Figure 30: Hygrograph and WL trend at Sarvad, Malia, Morbi

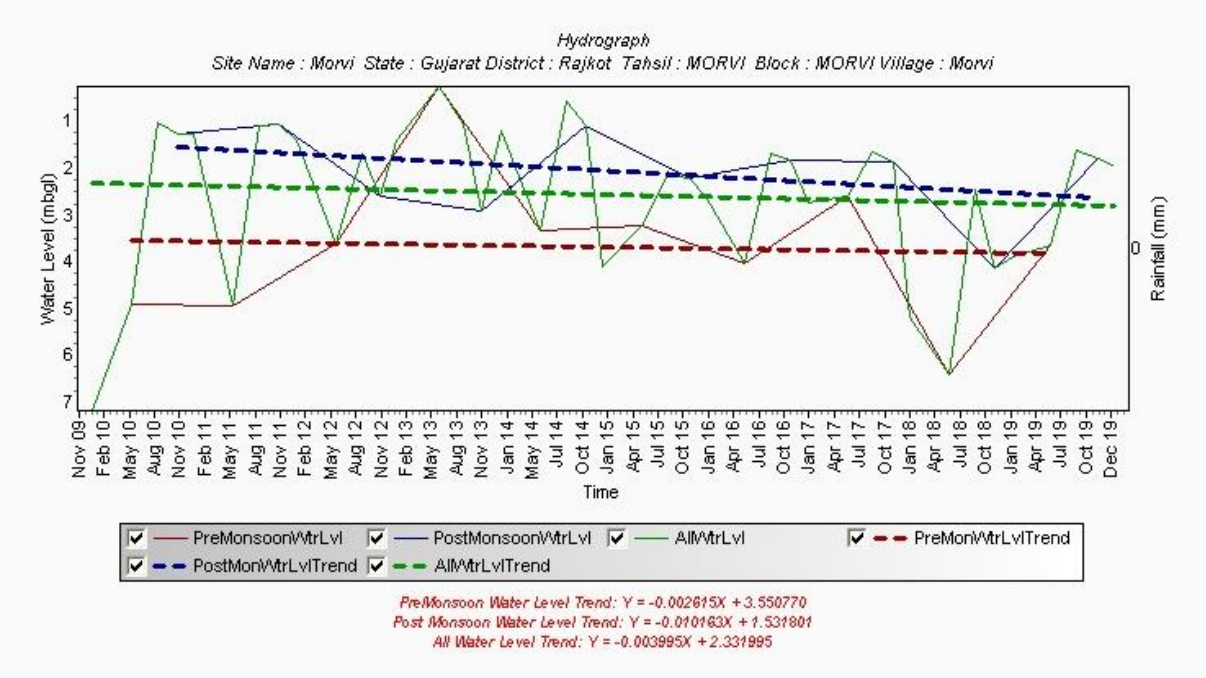

Figure 31: Hygrograph and WL trend at Morbi, Morbi .

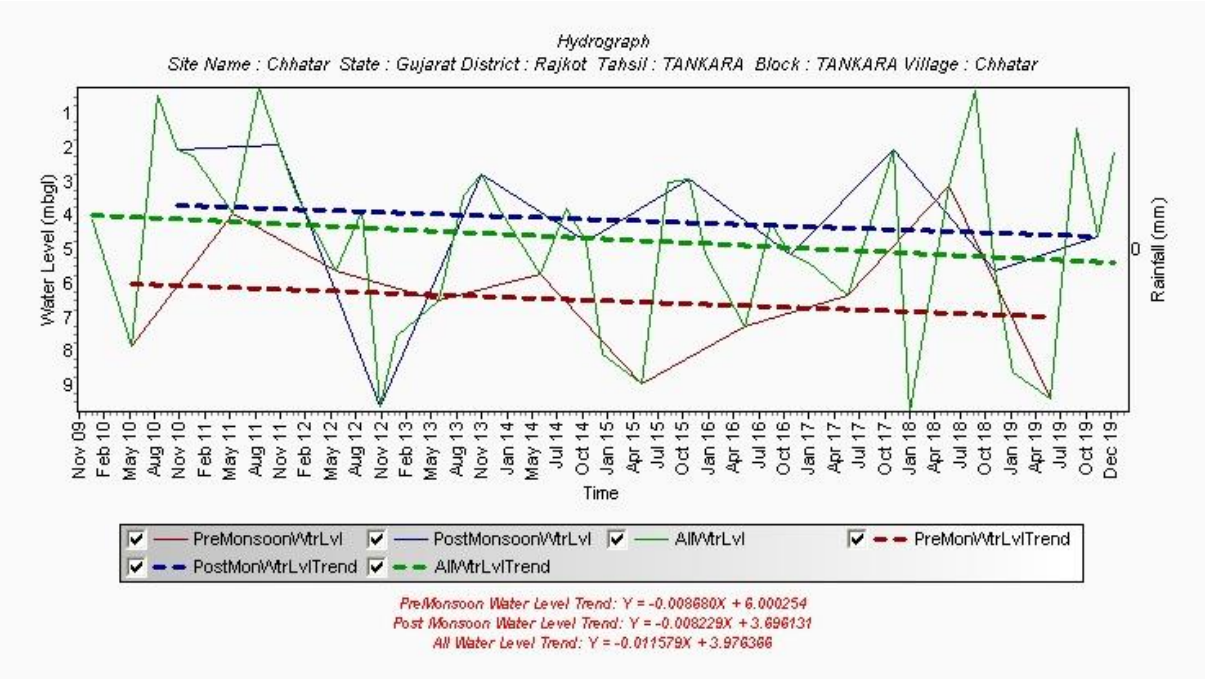

Figure 32: Hygrograph and WL trend at Chhatar, Tankara, Morbi.

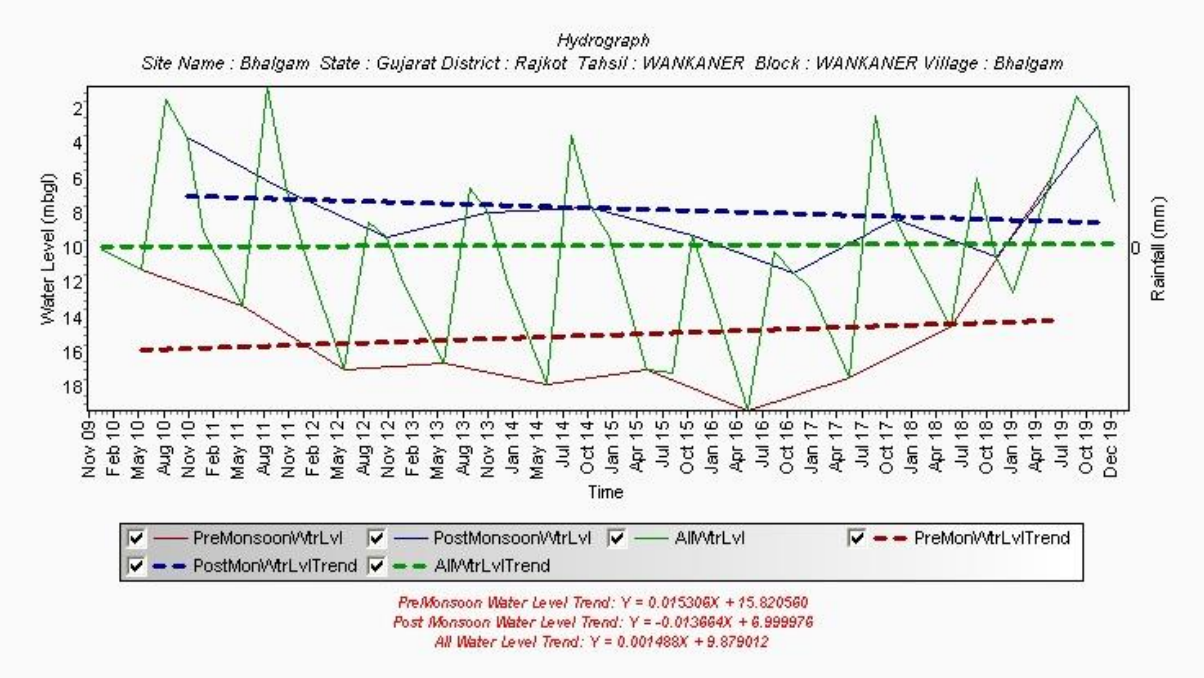

Figure 33: Hygrograph and WL trend at Bhalgam, Wankaner, Morbi.

Chapter 5: GROUND WATER RESOURCE POTENTIAL

The ground water resources of the district were calculated as on March 2022 in collaboration with the Government of Gujarat using the GEC-2015 methodology suggested by Ground Water Resource Estimation Committee (GWRE-2022). These resources were computed after reorganization of the districts, talukas of the district are considered as Assessment Unit (AU) and total area of 4992.70 sq. km area taken as area of assessment of the district including 5 talukas. Computed resource is presented in tabulated (table-8) and graphically represented as below (figure 35).

Table 9 Taluka wise Ground Water resources, Availability, Utilization and Stage of Ground Water Development.

District	MORBI				
Taluka	HALVAD	MALIYA	MORBI	TANKARA	WANKANER
Total Geog Area (Ha)	126148.88	75610.37	130609.78	56376.10	110524.60
Recharge worthy Area					
Command (Ha)	83355.64	0.00	102599.08	51572.76	110524.60
Poor Quality (Ha)	42793.24	75610.37	28010.69	4803.35	0.00
Recharge (ham)					
Rainfall Recharge	1434.29	0.00	10263.05	11749.51	16058.45
Canals	0.21	0.00	0.73	3.43	0.07
Surface Water Irrigation	17005.61	0.00	1051.72	6.94	961.03
Ground Water Irrigation	2211.92	0.00	1092.98	2148.78	2427.73
Tanks and Ponds	77.14	0.00	66.50	105.36	85.32
Water Conservation Structure	81.23	0.00	288.42	1339.57	786.61
Annual Ground water Recharge (ham)	20810.41	0.00	12763.40	15353.60	20319.22
Environmental Flows (ham)	2081.04	0.00	638.17	767.68	1015.97
Annual Extractable Ground water Resource (ham)	18729.37	0.00	12125.23	14585.92	19303.25
Draft (ham)					
Domestic	224.12	0.00	776.37	228.24	191.58
Industrial	39.43	0.00	52.16	13.20	21.65
Irrigation	7627.30	0.00	3768.90	7409.60	11239.50
Total Draft	7890.84	0.00	4597.44	7651.04	11452.74
Stage of Ground Water Extraction (%)	42.13	0.00	37.92	52.45	59.33
Categorization of Assessment Unit	safe	Saline	safe	safe	safe
Allocation of Ground Water Resource for Domestic Utilisation for projected year 2025 (ham)	238.99	0.00	843.11	247.86	208.05
Net Annual Ground Water Availability for Future Use (ham)	10823.66	141.39	7461.05	6915.26	7834.04

5.1 Ground Water Recharge

Total Annual Ground Water Recharge from Rainfall and other sources for both monsoon and non-monsoon season for the district is 692.47 mcm. And ground water recharge in talukas varies from 127.63 mcm (Morbi taluka) to 208.10 mcm (Halvad Taluka).

5.2 Net Ground Water Availability

Annual Extractable Ground Water Resource/ Net Ground Water Availability of the district varies from 121.25 mcm (Morbi taluka) to 193.03 mcm (Tankara Taluka) with a total of 647.44 mcm, which is computed after deducting total natural discharge of 45.03 mcm from total annual ground water recharge.

5.3 Annual Ground Water Draft

The gross ground water draft for all uses (i.e., Irrigation, Domestic and Industrial uses) in the district is 300.45 mcm. The existing gross ground water extraction for all uses varies from 45.97 mcm (Morbi taluka) to 114.52 mcm (WankanerTaluka). Approximately 98 % of ground water extraction are used for Irrigational purposes, remaining 2% are being extracted mainly for Domestic and Industrial purposes (very less).

5.4 Allocation of Ground Water Resource for Domestic Utilisation for projected year 2025

The Allocation of Ground Water Resource for Domestic Utilisation for projected year 2025 in the district is 15.38 mcm and varies from 2.08 mcm (Wankaner taluka) to 8.43 mcm (Morbi taluka).

5.5 Ground water Availability for future Irrigation

Net ground water availability for future use in the district is 331.75 mcm. Taluka wise it varies from 1.41 mcm (Maliya taluka) to 108.23 mcm (Halvad taluka).

5.6 Stage of Ground Water Extraction

As per the Ground Water Resource Estimation (GWRE-2022), the stage of Ground Water extraction of the district is 47.96 % which categorized as Safe. Whereas in taluka it varies varies from 37.92% (Morbi Taluka) to 59.33% (Wankaner Taluka) 04 talukas of the district are categorized as Safe. Maliya Taluka is Categorized as Saline block with no fresh ground water.

Chapter 6: HYDROCHEMISTRY

The chemical quality of groundwater in shallow aquifer of the district has been analyzed based on the water samples collected during National Hydrographs Monitoring Stations (NHS) and NAQUIM(Pre-monsoon) in May 2019 from CGWB, and presented in Table-9. The ground water is in general alkaline in nature.

Table 10 Statistical Analysis of Chemical Constituents of Ground Water in Morbi District, May 2019.

Constituents	Minimum	Maximum	Average
pH	7.53	8.98	8.11
EC (uS/cm)	470	14430	3194
Alkalinity (mg/l)	95	760	265.55
TDS (mg/l)	310	9668	2112.59
HCO_3 (mg/l)	110	805	300
Cl (mg/l)	28	4544	791
SO_4 (mg/l)	7.6	818	237.47
NO_3 (mg/l)	0	392	45.78
Ca (mg/l)	12	844	112
Mg (mg/l)	5	435	120.67
Na (mg/l)	31	1750	438
K (mg/l)	0.2	350	11.61
F (mg/l)	0.21	6	1.37
Sio_2(mg/l)	7	85.56	39.74
U(ppb)	0	22	3.92

6.1 Hydrogen Ion Concentration (pH)

The pH is an indicator of acidity of the water. The ground water in the district is generally alkaline with pH more than 7. The value of pH ranges between 7.53 (Lajai) & 8.98 (Manekvada) in the district. 6.5 -8.5

6.2 Electrical conductivity

The value of EC for the district lies between 470 uS/cm (Bhalgamda) and 14430 uS/cm (Amarnagar). Average EC value of the district is 3194 uS/cm which is greater than the permissible limit. Out of the 98 Locations 52 locations have greater value of EC than 2500 uS/cm.

6.3 Total Dissolved Solid (TDS)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit and permissible limit of Total Dissolve Solid (TDS) are 500 mg/l and 2000 mg/l respectively. Total Dissolved Solid (TDS) is an overall parameter indicating salinity of ground water. The Total Dissolved Solid of ground water in the district varies from 310 mg/l (Bhalgamda) to about 9668 mg/l (Amarnagar) (Figure 36). Out of the 98 Locations 39 locations have greater value of EC than 2000 uS/cm.

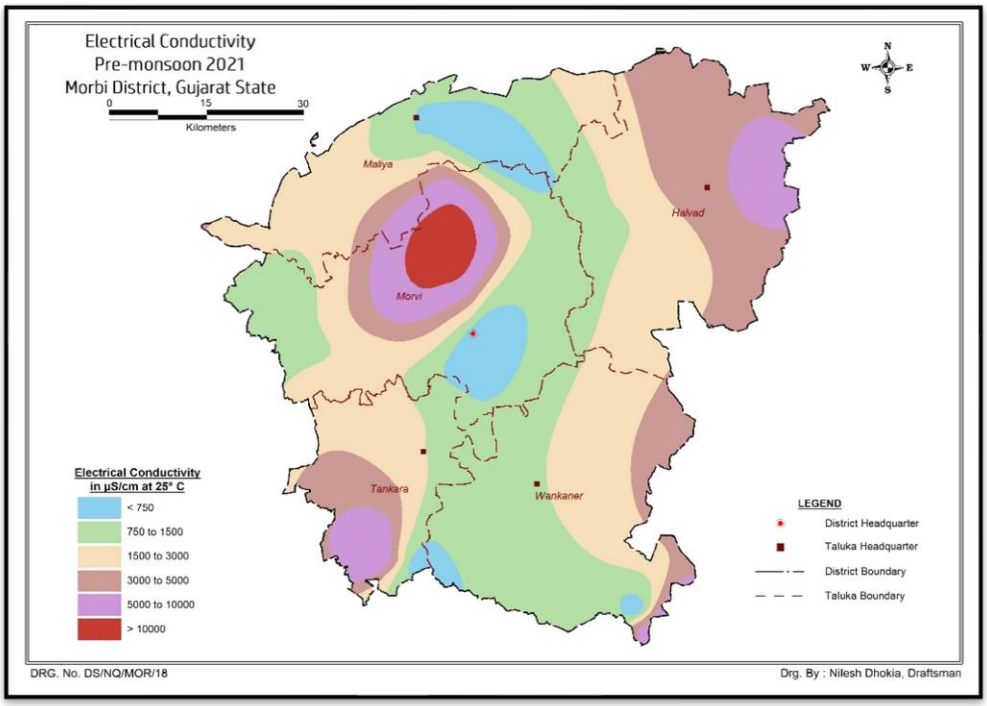

Figure 34: Map showing Taluka wise Total Dissolved Solid (TDS) values of Morbi District

6.4 Chloride (Cl)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Chloride are 250 mg/l and 1000 mg/l respectively. It is depicted from the map shown in figure-37, that except few patches Cl concentration is within permissible limit. The values of Cl concentrations are varying from 28 mg/l(Malia) to 4544 mg/l (Amarnagar) in the district. 26 locations out of 98 locations have the Cl concentration greater than permissible limit.

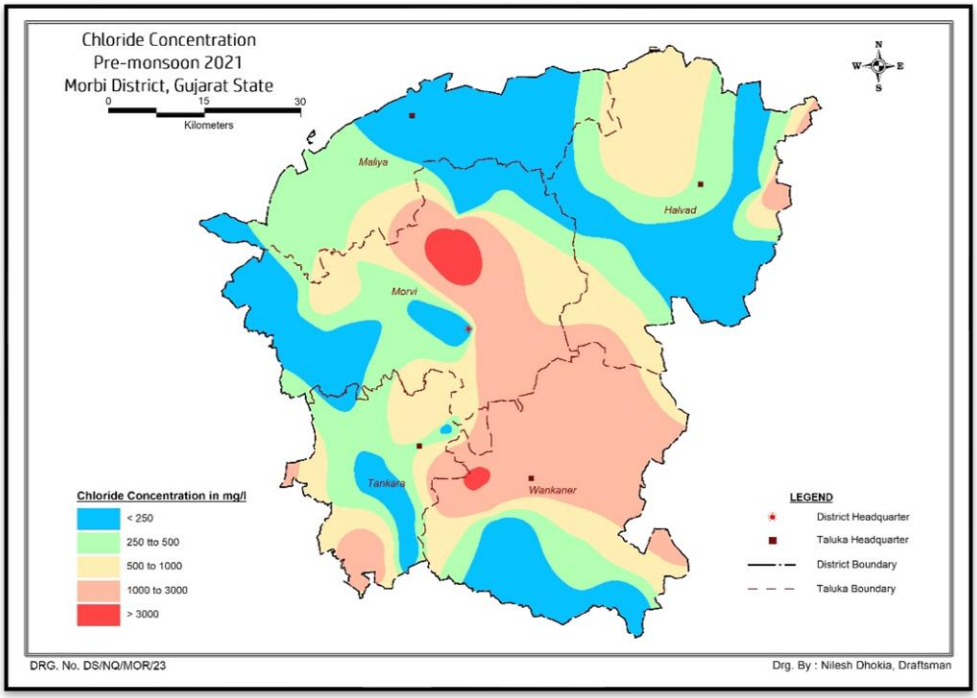

Figure 35 : Map showing Taluka wise Chloride (Cl) concentration in Morbi District.

6.5 Nitrate (NO_3)

As per the BIS standards [IS 10500: 2012] for drinking water, acceptable limit is 45 mg/l (maximum) and there is no relaxation in permissible limit. Nitrate concentration in the ground water in district varies between 0.10 mg/l (Hadala) and 392 mg/l (Pipaliyaraj). There are 33 isolated locations out of 98 locations, where these values are more than the permissible limit as per BIS drinking water standards (45 mg/l) as shown in figure 38.

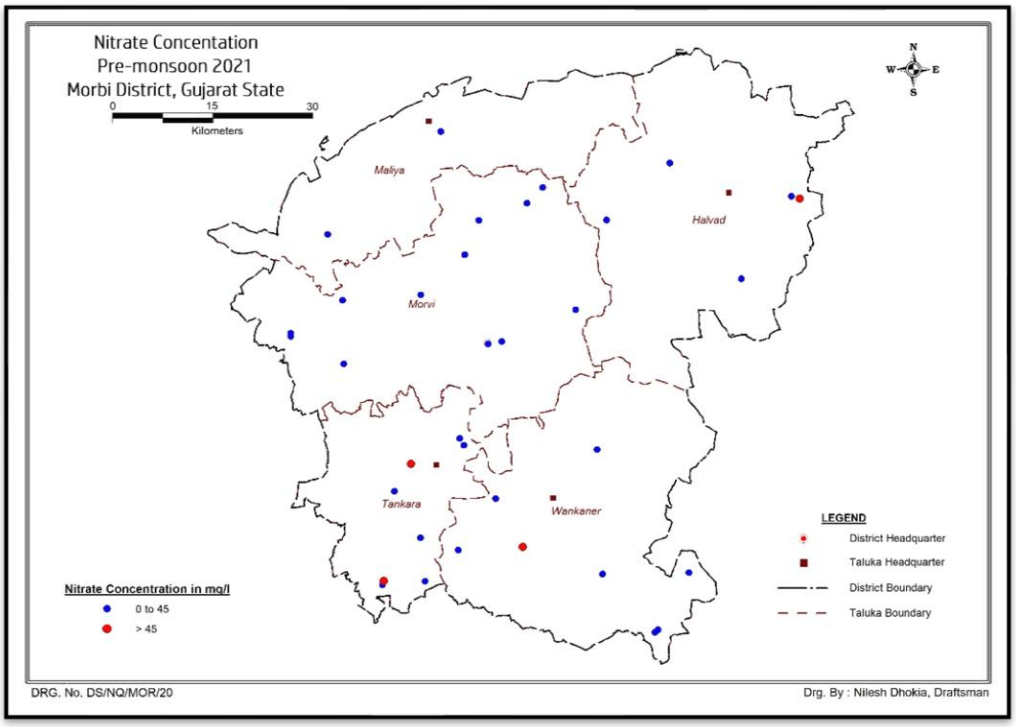

Figure 36: Map showing Taluka wise Nitrate (NO3) concentration in Morbi District

6.6 Carbonate (CO3) and Bicarbonate (HCO3)

The ground water in Morbi district contain Carbonate only at few places in 20 out of 63 samples show carbonate concentration. Its values vary from 9 mg/l (Mota Dahisara) to 228 mg/l (Nani Vavdi). The Bicarbonate concentration in district are varies in between 109.8 mg/l (Manaba) to 805 mg/l (Madhapar).

6.7 Sulphate (SO4)

As per the BIS standards [IS 10500: 2012] for drinking water, Permissible limit of Phosphate is 400 mg/l. In the district, Sulphate concentration varies from 7.6 mg/l (Malia) to 818 mg/l (Jivapar) with the average concentration of 237.47 mg/l in 64 locations. There are 10 isolated locations out of 90 locations, where these values are more than the permissible limit as per BIS drinking water standards (400mg/l).

6.8 Calcium (Ca)

Calcium concentration in district varies between 12 mg/l (Nani Vavdi) and 844 mg/l (Nava Sadulka). There are 7 isolated locations where calcium concentration is more than permissible limit (permissible limit as per BIS norms is 200 mg/l).

6.9 Magnesium (Mg)

The Concentration of Magnesium in the district ranges from 5 mg/l (Amran) to 435.33 mg/l (Nava Sadulka).). There are 26 isolated locations out of 43 locations where Magnesium concentration is more than permissible limit (Permissible limit as per BIS norms is 100 mg/l).

6.10 Sodium (Na)

Sodium concentration in the district varies between 31 mg/l (Hajnali) and 1750 mg/l (Malia).

6.11 Potassium (K)

The concentration of Potassium in shallow ground water ranges from 0.2 mg/l (Juna Dhuva) to 350 mg/l (Mota Dahisara).

6.12 Fluoride (F)

As per the BIS standards [IS 10500: 2012] for drinking water, Acceptable limit and Permissible limit of Fluoride (mg/l) are 1 mg/l and 1.5 mg/l respectively. Fluoride concentration in the district varies in between 0.21 mg/l (Modpar) and 6.00 mg/l (Nani Vavdi). There are 31 out of 71 locations have where Fluoride concentration is more than permissible limit as presented in figure 39.

6.13 Total Hardness

The concentration of Total Hardness as $CaCO_3$ in shallow ground water ranges from 70 mg/l (Nani Vavadi) to 3900 mg/l (Nava Sadulka).

6.14 Total Alkalinity

The concentration of Potassium in shallow ground water ranges from 95 mg/l (Valasan) to 760 mg/l (Nani Vavadi).

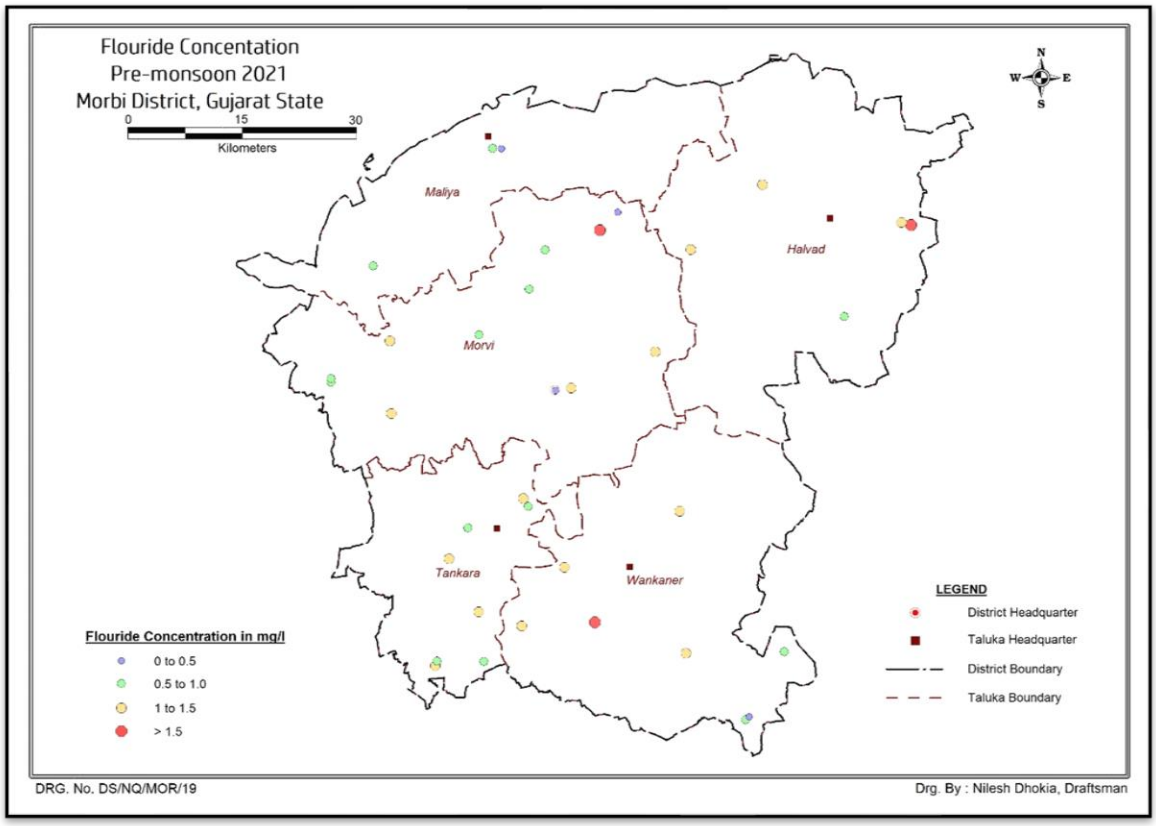

Figure 37: Map showing Taluka wise Fluoride (F) concentration in Morbi District.

6.13 Uranium (U)

As per the BIS standards [IS 10500: 2012] for drinking water, Permissible limit of U ranium is 30 ppb. Uranium concentration in the district varies between 0.16 ppb (Sindhavadar) and 22 ppb (Nani vavdi). Uranium concentration in Morbi district is within the permissible limit at all sites.

Chapter 7: SUSTAINABLE GROUNDWATER DEVELOPMENT AND MANAGEMENT

7.1 Groundwater related issue:

7.1.1 Low Ground water development

As per GWRE 2022 the total ground water resources of the district are in order of 692.47 mcm/year and utilizable resources are 647.44 mcm/year. The net annual drafts of 315.92 mcm/year leaves a balance of 331.52 mcm/year of ground water available for future development. Low Ground water Development: Stage of Ground water development of the

district is 47.96 %, however talukas wise it ranges from 37.92% (Morbi taluka) to 59.33% (Wankaner taluka).

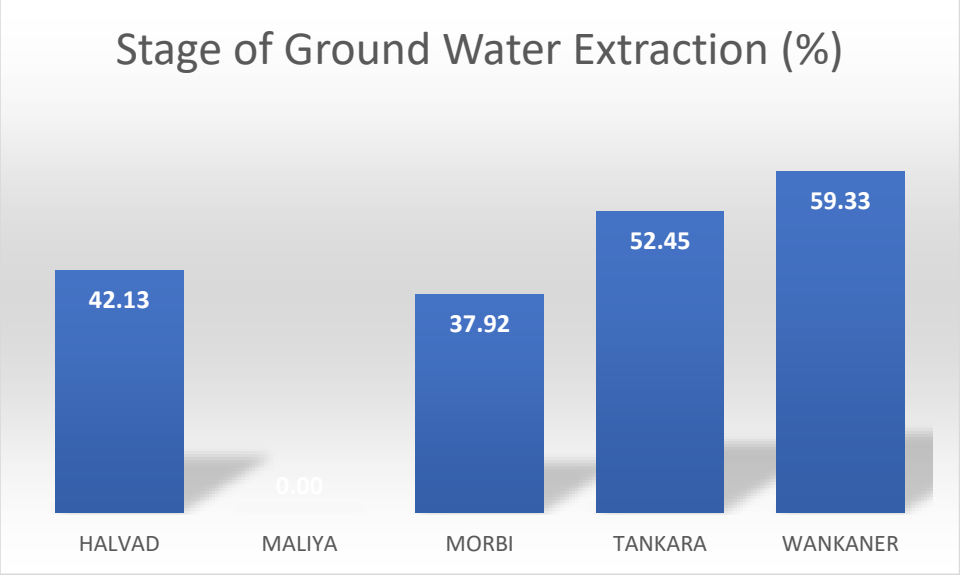

Figure 38: Taluka wise stage of Ground water extraction in Morbi district

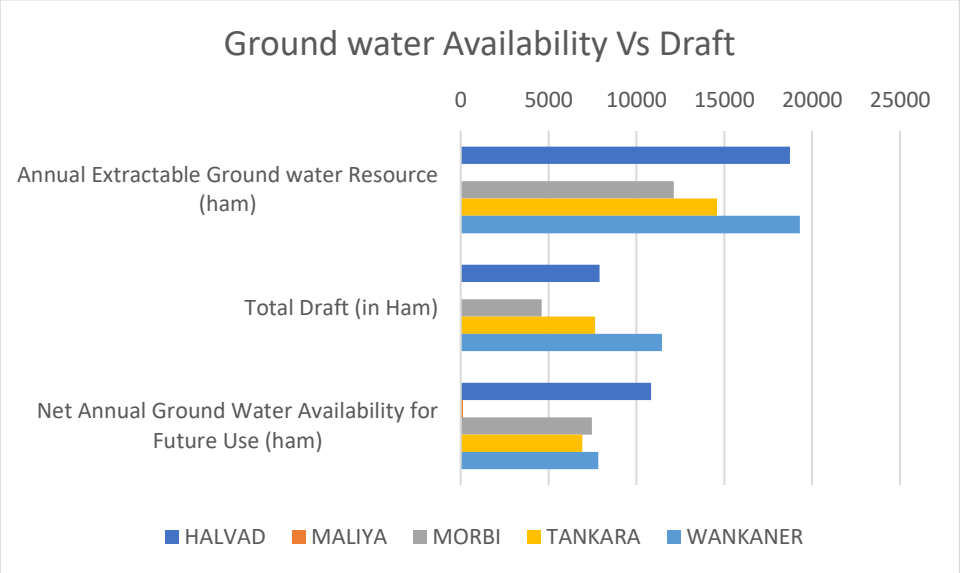

Figure 39: Taluka wise Ground water Availability and Ground water Draft in Morbi District

7.1.2 Pollution (Geogenic and Anthropogenic)

We have collected 68 pre-monsoon ground water samples from shallow aquifer for this study. Chemical analysis of these samples is showing that 47 samples are potable and fit for domestic,

drinking, irrigation and other industrial purposes and remaining 21 sample are not fit for drinking purpose but may be used for irrigation and other industrial purposes. We also collected 22 samples from deeper aquifer, 15 samples are potable and fit for domestic, drinking, irrigation and other industrial purposes and remaining 7 sample are not fit for drinking purpose but may be used for irrigation and other industrial purposes. Occurrence of Fluoride (31 Locations) and Nitrate (18 Locations) beyond acceptable limit (As per the BIS standards [IS 10500: 2012] for drinking water) in Shallow and deep aquifers identified in localized isolated villages.

7.2 Management Strategies

As per the estimate of ground water resources and irrigation potential, there exists a scope for further development of ground water resources in major parts of the district. As per GWRE 2020 Eight (08) talukas out Ten (10) talukas of the district are under safe category with one saline (Lakhtar) and another is semi critical (Chuda). Stage of Ground water development of the district is 38.62 %, however talukas wise it ranges from 11.80% (Limdi taluka) to 75.8% (Chuda taluka). Thus, further ground water development could be augmented in a judicious way.

7.3 Management plan

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy (table 12). The study suggests notable measures for sustainable groundwater management, which involves a combination of various measures given below.

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

7.3.1Identification of Areas Feasible for Managing Aquifer Recharge

District is having total mappable area of 3797.71 km2. The geological formations in the basin are alluvium, Basalt, Intusives and Sandstone formations . The Alluvium consisting of sand, silt, kankar and clay. The average post monsoon water level (2012-2021) ranges from less than 6.00 to 30 m below ground level (Fig. :). The trend of post monsoon water level show both rising and decline trend in the entire district (Fig. :). The quality of ground water in the major part of the district is having TDS less than 2500 mg/l (Fig. :). All along the Gulf of khambhad, in major pockets, TDS concentration is found between . 2500 mg/l. The areas feasible for artificial recharge is the area where groundwater level is below 6 m bgl and quality of water is fresh (TDS< 2500 mg/l) as shown in Fig. .

It is estimated that an area of 1886.15 km^2 having depth to water table more than 6 m below ground level is feasible in which total volume of vadose zoneof this area is 8151.05 mcm (Table -). Further in an area of 1318.20 km^2 the area is under decaling trends and volume of vadose zone in this area is 704.34 mcm (Table -). Thus the total volume of de-saturated zone feasible for recharge in the basin is 8855.39 mcm. Considering the co-efficient of replenishment of different formations, it isestimated that around 179.59 mcm of water is required to recharge to bring the water level up to 6.00 m and it is estimated that around 17.65 mcm of water is required to control annual depletion..Taluka wise in different formations, the requirement of water is computed and shown in table . Thus total volume of water requirement is 198.03 mcm in district. (Table –).

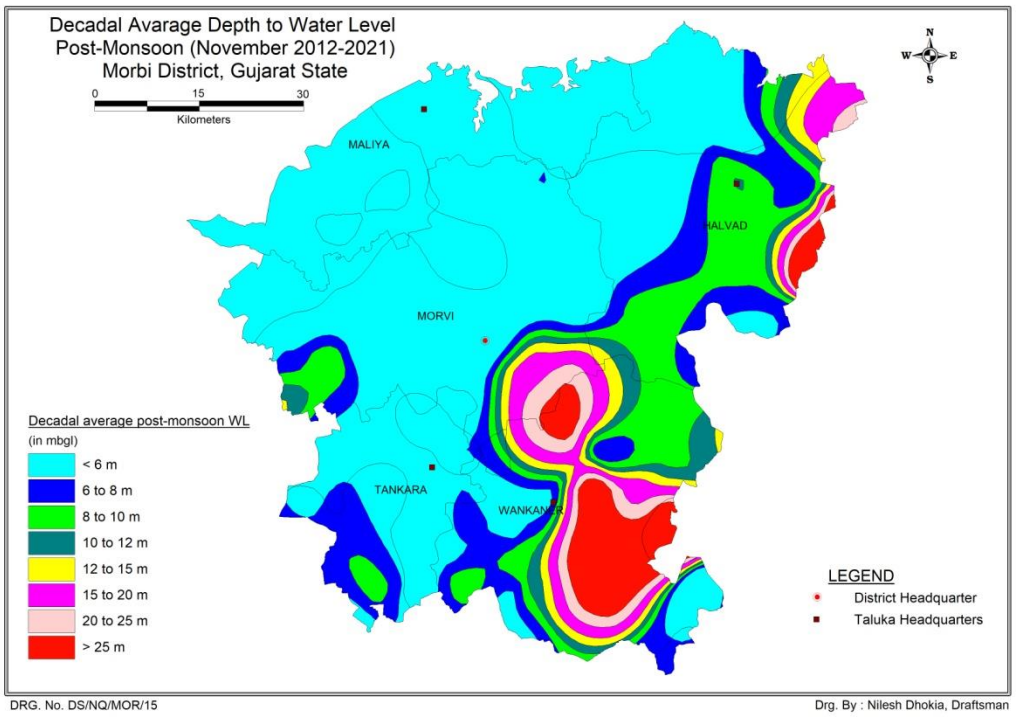

Figure 40: Decadal average post-monsoon depth to water level from the period of Nov 2012 to 2021.

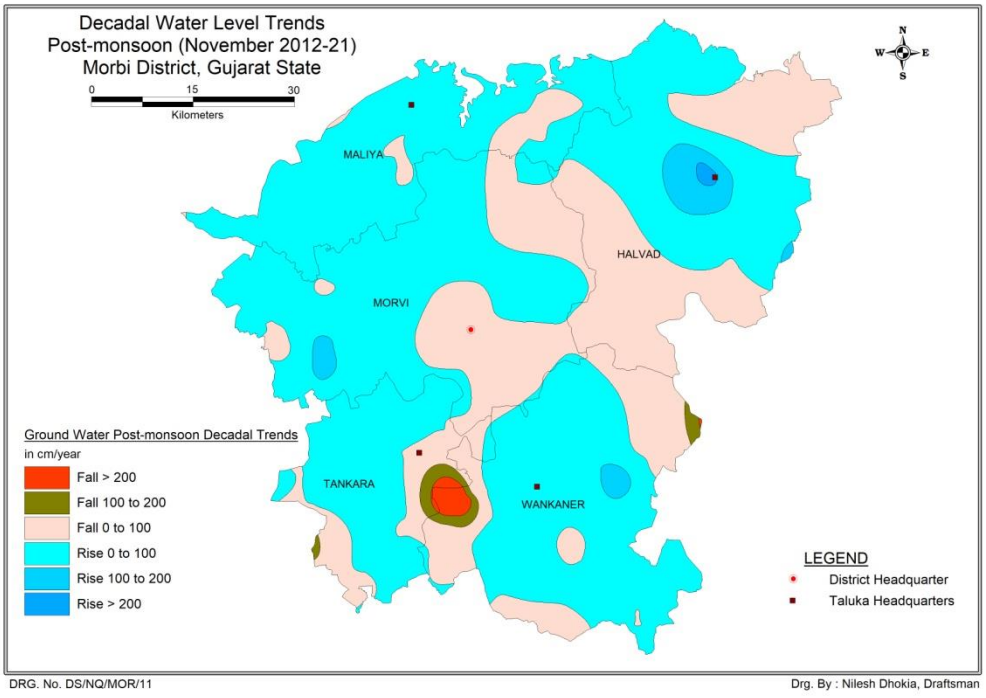

Figure 41: Post monsoon groundwater trends in year 2012 to 2021

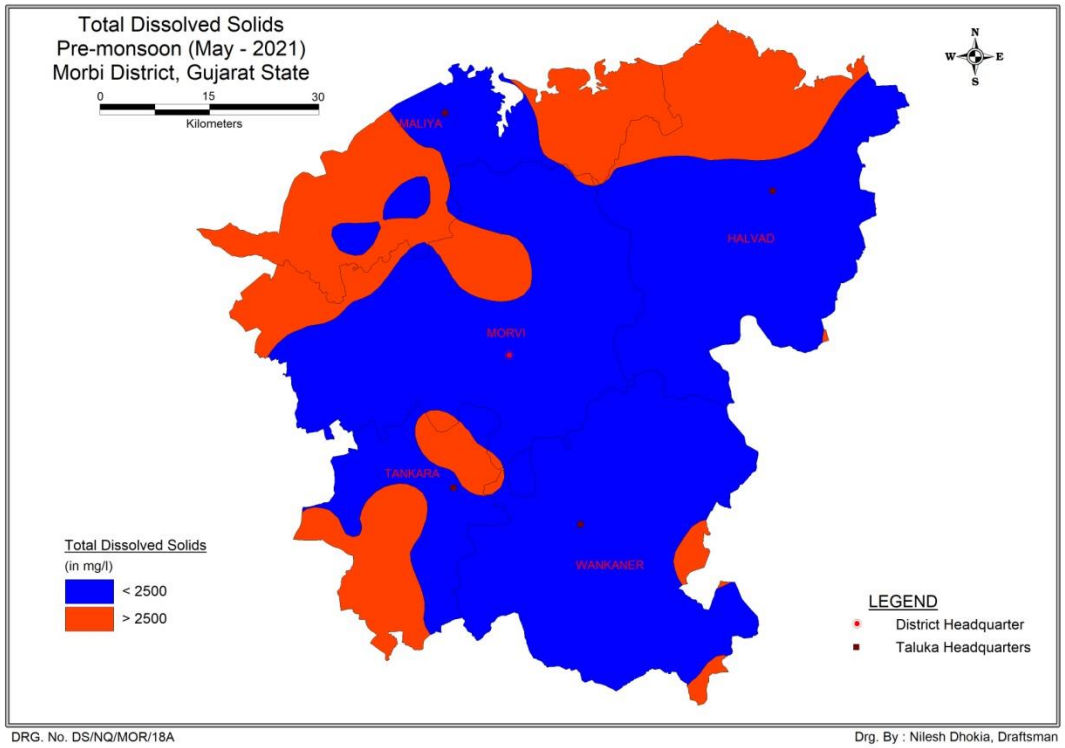

Figure 42: Distribution of Total dissolved solids in groundwater in year May 2021.

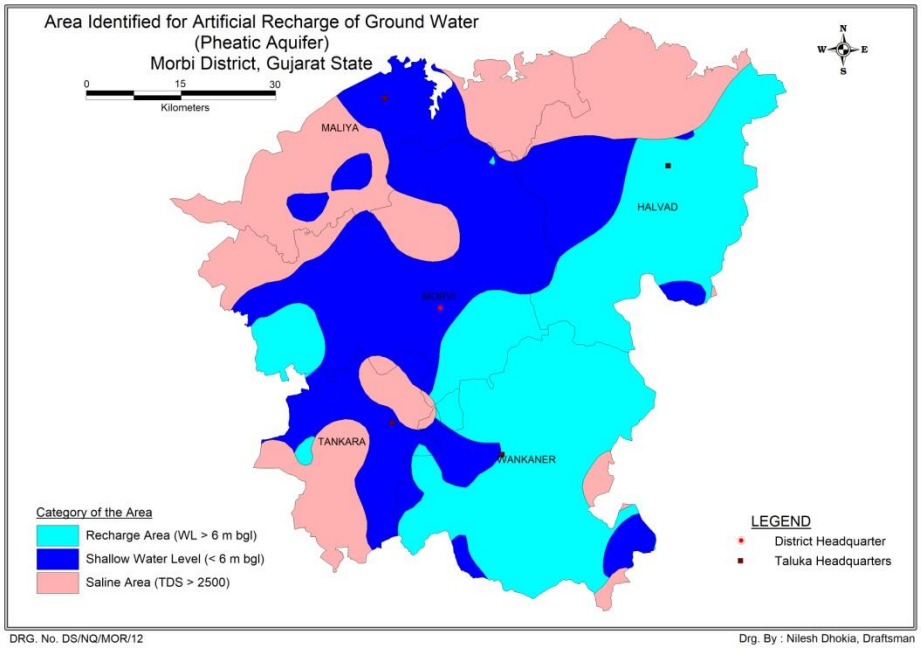

Figure 43: Area suitable for recharge

Table 11: Volume of water in MCM required to recharge vadose zone in Morbi district

Taluka	Volume of water is required to recharge to bring the water level up to 6.00 m	Volume of water is required to control annual depletion	Total
HALVAD	58.6	7.84	66.44
MALIYA	Saline & shallow water level		
MORVI	19.21	5.91	25.91
TANKARA	0.71	0.73	1.44
WANKANER	101.07	3.17	104.24
Total	179.59	17.65	198.03

7.3.2 Ground water Development Plan

To elevate the stage of ground water development in all blocks, 2143 nos. of Dug wells (30 m depth) and 1303 nos. of Tube well (100m depth) are proposed as feasible extraction structures (table 10). The extraction structures will result as expected annual ground water draft of 3026.00 ham which will create 6724.44 Ha additional irrigation potential in the district.

7.3.2 Supply side interventions

As per Master Plan 2019, surplus surface water of 17.85 mcm non committed is allocated to suggest artificial recharge in district of Morbi. To harvest the surface water the different artificial recharge structures are proposed as check dam, Percolation tank and use existing defunct tube well to recharge the aquifer which is presented in table 13. Expected annual Groundwater recharge is 601.73 ham (6 mcm) through check dams of total 202 nos. of 17000 m^3capacity, 36 nos. of percolation tank of 90000m^3 capacity and 90 nos. of defunct tube wells, are recommended for harvesting the part of available runoff and to recharge the Groundwater as in table 11.

7.3.4 Demand side intervention

Feasible extraction structures are proposed to elevate the stage of ground water development to 42.14%, to avoid further exploitation demand side management is also recommended to restrict the stage of ground water development to 40.93 %. An area of 13692 Ha is proposed for on farm activities (Laser leveling/Bench terracing/Contour banding), 1035 no of farm ponds are recommended to recharge the ground water. And expected conservation of ground water through efficiency enhancement measures is 1369.20 ham is expected for the district.

- **Farm pond**

A farm pond is a large hole dug out in the earth, usually square or rectangular in shape (Fig. 41), which harvests rainwater and stores it for future use. It has an inlet to regulate inflow and an outlet to discharge excess water. The pond is surrounded by a small bund, which prevents erosion on the banks of the pond. The size and depth depend on the amount of land available, the type of soil, the farmer's water requirements, the cost of excavation, and the possible uses of the excavated earth. Water from the farm pond is conveyed to the fields manually, by pumping, or by both methods.

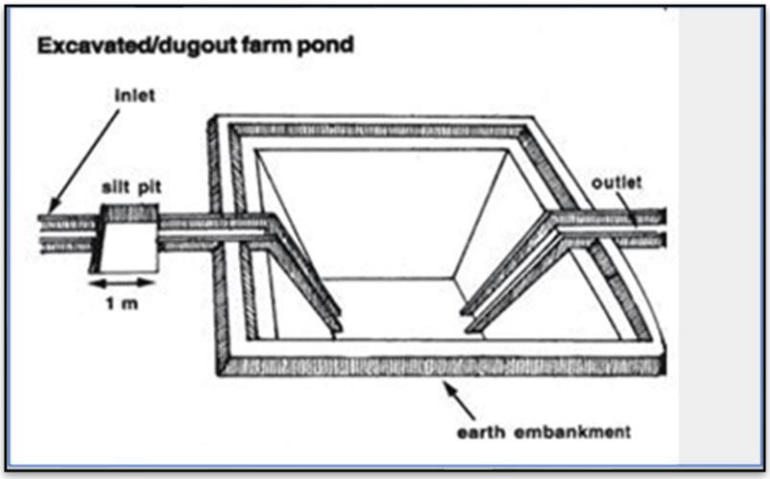

Figure 44: Schematic diagram of Farm Pond.

Advantages of Farm Ponds

- They provide water to start growing crops, without waiting for rain to fall.

- They provide irrigation water during dry spells between rainfalls. This increases the yield, the number of crops in one year, and the diversity of crops that can be grown.
- Bunds can be used to raise vegetables and fruit trees, thus supplying the farm household with an additional source of income and of nutritious food.
- Farmers are able to apply adequate farm inputs and perform farming operations at the appropriate time, thus increasing their productivity and their confidence in farming.
- They check soil erosion and minimize siltation of waterways and reservoirs.
- They supply water for domestic purposes and livestock
- They promote fish rearing.
- They recharge the ground water.
- The excavated earth has a very high value and can be used to enrich soil in the fields, leveling land, and constructing farm ponds.

Table 12: Summary of Interventions recommended and expected benefits

Interventions Recommended	
Check Dam (17000 m3 Capacity)Nos.	160
Percolation Tank (~ 90000 m3 capacity)	42
Recharge through defunct tube wells @3Ham Nos.	20
On-farm Activities (in ha)	6825.00
Water Use Efficiency (WUE) Measures (in ha)	13880.00
Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock) DW	1460
Feasible Extraction structures to elevate the Stage of GW development to 70% (Hard Rock) TW	3785
Expected Benefits	
Expected Annual Recharge ham	2744.02
Conservation from supplemental irrigation ham	220.32
Conservation from On-farm Activities, WUE Measures & Farm Ponds ham	2180.93
Total Recharge/ Saving ham	**5145.27**
Additional Irrigation Potential Created (Ha)	14238.89

Table 13 Projected Status of Groundwater Resource after implementation of GW Management Plan, Morbi District (Gujarat)

	Projected Status of Groundwater Resource after implementation of GW Management Plan, Morbi District (Gujrat)														
Taluka	**Net G.W. Availability (Ham)**	**Additional Recharge from Recharge interventions (ham)**	**Additional Recharge from RTRWH (ham)**	**Additional Recharge from Return flow of GW Irrigation**	**Total Net G.W. Availability after intervention (Ham)**	**Existing G.W Draft for all purpose (ham)**	**Conservation of Ground water through Supplemental irrigation (ham)**	**Conservation of Ground water through WUE, on farm activity & farm ponds (ham)**	**G.W Draft from Extraction structures (ham)**	**Net GW draft after interventions (ham)**	**Present stage of G.W. Development (%)**	**Projected stage of G.W. Development after construction of extraction structures (%)**	**Projected stage of GW development after construction of extraction structures & implementation of conservation measures(in %)**	**Projected stage of GW development after construction of extraction structures & implementation of conservation measures & Recharge measures (in %)**	**Additional Irrigation Potential Created (Ha)**
Morbi	8345.81	35.35	0.00	79.30	8460.46	5591.91	55.08	390.69	305.00	5451.14	67.00	69.99	65.35	64	678
Halvad	20746.79	426.45	0.00	840.45	22013.69	11879.01	55.08	724.77	3232.50	14331.66	57.26	70.00	66.64	65	7183
Wankaner	15738.00	387.59	0.00	616.20	16741.79	9077.12	55.08	657.23	2370.00	10734.81	57.68	69.99	65.98	64	5267
Tankara	10835.04	96.19	0.00	130.00	11061.23	7176.41	55.08	408.24	500.00	7213.09	66.23	70.01	66.28	65	1111
Total	55665.64	1078.07	0.00	1665.95	58409.66	33724.46	220.32	2180.93	6407.50	37730.71	60.58	70.00	65.42	65	14239

Table 14: Proposed artificial Recharge and WUE Interventions in Morbi District

Table-: Proposed Artificial Recharge and WUE Interventions in Morbi District															
Block	**Check Dams of 17000 cum Capa-city (Nos)**	**Tentative cost Check Dams of 17000 cum Capa-city (Nos)**	**Percolation Tank (~ 90000 m3 capacity)**	**Tentative cost Percolation Tank (~ 90000 m3 capacity)**	**Recharge through defunct tube wells @3Ham**	**Tentative cost Recharge through defunct tube wells @3Ham**	**On farm activities (proposed in 20% of total catchment area) (in ha)**	**Tentative cost for On farm activities(in crores)**	**Water Use Efficiency Measures , Srinklers/Drip Irrigation**	**Tentative cost for Water Use Efficiency Measures , Srinklers/Drip Irrigation (in crores)**	**Feasible Extraction structures to elevate the Stage of GW development to 70% Dugwell (5TCM/YR)**	**Tentative cost for Extraction structures to elevate the Stage of GW development to 70% (in crores) Dugwell (5TCM/YR)**	**Feasible Extraction structures to elevate the Stage of GW developme nt to 70% Tubewell (15TCM/YR)**	**Tentative cost for Extraction structures to elevate the Stage of GW developme nt to 70% (in crores) Tubewell (15TCM/YR)**	**Project Cost (Crore)**
Morbi	40	320	12	120	5	10	0	0	2894	2894	70	245	180	540.00	41.29
Halvad	40	320	10	100	5	10	3911	547.54	4065	4065	750	2625	1905	5715.00	133.83
Wankaner	40	320	10	100	5	10	2914	407.96	3897	3897	540	1890	1400	4200.00	108.25
Tankara	40	320	10	100	5	10	0	0	3024	3024	100	350	300	900.00	47.04
Total	160	1280	42	420	20	40	6825.00	955.5	13880.00	13880	1460	5110	3785	11355.00	330.41
Note:	**Maliya being a completely saline block rain water harvesting needs to be practised vigorously.**														

Chapter 8: CONCLUSION AND RECOMMENDATIONS

- Artificial recharge structures like recharge shaft and through defunct tube well are proposed in the district to encounter needed surface runoff.
- To elevate the stage of ground water development 42.14 to in district, 4143 no of Dug wells (20 m depth) in Hard rock and 1303 no. of Tube wells (100m depth) are proposed as feasible extraction structures.
- The extraction structures will result as expected annual ground water draft of 3026.00 ham which will create 6724.44 Ha additional irrigation potential in the district.
- To prevent Over Exploitation, water conservation activities like on farm activities, farm ponds and check dams are recommended.
- 13692 Ha area is proposed for on farm activities (Laser leveling/Bench terracing/Contour banding) and 1040 nos. of farm ponds are recommended which will serve dual purpose of irrigation and recharge to ground water.
- Ground water return flow of 786.76 ham is expected from irrigation of fields in the district.
- 936.81 ham conservation of ground water through WUE measures, on activities & farm ponds is expected for the district.
- As a conservation measure, farmers should be encouraged and educated to adopt modern irrigation techniques like drip, sprinkler irrigation etc. to effect minimum withdrawal and maximum utilization of groundwater.
- The water quality of the district is very inconsistent, with 62 locations having potable water and 28 locations having non potable water out of 90 locations. Almost every taluka in the district has the patches of both potable and non-potable water. In GWRE-2020, Lakhtar taluka of the district is saline but in the Water quality map it is fresh, this is because of samples are collected from very shallow aquifer. In addition to this higher Nitrate, fluoride and Fe concentration is observed in isolated pockets. Ground water in such areas may be used after blending with surface water. In areas where ground water has higher concentration of Nitrate is observed, necessary sanitation measures should be adopted.
- Taking into consideration drought prone area, the ‘Mass Awareness Programme’ and 'Water Management Training Programme‟ should be organized in regular basis in the district for awareness on the depletion of groundwater resources and quality problems.
- Present supply side interventions are suggested based on availability17.85 MCM non committed source of water is referred by State Government (Reference Master Plan of Artificial recharge 2020). Proposed enhancements of present Groundwater development stage are subjected to implementation of recharge interventions, availability of cultivable land and yield of Groundwater structures.
- These interventions also need to be supported by regulation, so that the ground water resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought. IEC activities and capacity building activities needs to be aggressively propagated to establish the institutional framework for participatory ground water management.

References

- Census of India 2011, District Census Handbook, Morbi District.
- Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) District Irrigation Plan (2016-2020), Morbi, Gujarat
- And several other unpublished and published reports of CGWB and Govt. websites.

ANNEXURE I: Well Inventory in NAQUIM Area district Morbi 2020-21

WELL INVENTORY FOR NAQUIM AREA DISTRICT - MORBI 2020-21																	
SR.NO	SAMPLE NO.	DATE OF SAMPLE COLLECTION	LATITUDE	LONGITUDE	SOURCE/TYPE OF WELL	TOPOSHEET NO.	MEASURING POINT (MP)	DEPTH	DEPTH TO METER (SWL)	DIAMETER	DISCHARGE (lpm)	TYPE OF MOTOR/H.P.	USE	OWNER NAME	VILLAGE NAME	TEHSIL NAME	DISTRICT
1	1	05-02-2021	23.007718 N	71.282669 E	BW	41N/05	NIL	198	137.16	NIL	66	Electric - 20	Irrigation	Khodabhai Lalubhai Parmar	Kavadiya	Halvad	Morbi
2	2	15-12-2020	23.021593 N	71.183976 E	BW	41M/04	NIL	91	45.72	NIL		Electric - 20	Irrigation	Ramjibhai Sivabhai Patel	Halvad	Halvad	Morbi
3	3	16-12-2020	23.011955 N	71.175319 E	DW	41M/04	1.24	21.33	4.67	2.87			Domestic	Gram Panchayat	Halvad	Halvad	Morbi
4	4	16-12-2020	22.99821 N	71.082499 E	BW	41N/01	NIL	152	68.58	NIL		Electric - 20	Irrigation	Vibabhai Gangaram Dalvadi	Susva	Halvad	Morbi
5	5	16-12-2020	23.011465 N	70.990781 E	DW	41J/13	0.46	15.24	2.75	2.34		Electric - 2	Domestic	Sankar Mandir Trust	Juna Devaliya	Halvad	Morbi
6	6	16-12-2020	22.710598 N	70.930605 E	BW	41J/13	NIL	70.1	42.67	NIL		Electric - 10	Domestic	Dhuva Gram Panchayat	Juna Dhuva	Wankaner	Morbi
7	7	16-12-2020	22.617086 N	70.93292 E	BW	41J/14	NIL	152.4	18.28	NIL		Electric - 05	Domestic	Nirmala Convent High School	Wankaner	Wankaner	Morbi
8	8	16-12-2020	22.583331 N	70.92061 E	DW	41J/14	NILL	12.19	6	3		Electric - 05	Irrigation	Khoradiya Hasanbhai Amibbhai	Wankaner	Wankaner	Morbi
9	9	16-12-2020	22.54992 N	70.894117 E	DW	41J/14	0.65	10.64	3.68	5.5			Irrigation	Sirasiya Noor Mohammed	Sindhavadar	Wankaner	Morbi
10	10	16-12-2020	22.549958 N	70.996656 E	DW	41J/14	Ground Level	9.14	2.43			Electric - 7.5	Irrigation	Vinubhai Samjibhai Dadrecha	Jodhpar	Wankaner	Morbi
11	11	16-12-2020	22.51602 N	71.021618 E	DW	41N/02	1.88	24.38	20	4.36			Irrigation	Hussain Ahmad nura	Mahika	Wankaner	Morbi
12	12	16-12-2020	22.585437 N	70.906117 E	DW	41J/14	0.9	24.38	8.6	6.2			Domestic	Gram Panchayat	Amarsar	Wankaner	Morbi
13	13	16-12-2020	22.561082 N	70.825879 E	DW	41J/14	0.1	13.71	6.68	4.7		Electric - 5	Irrigation	Ibrahim Mohammed Kadiyar	Pipaliyaraj	Wankaner	Morbi
14	14	17-12-2020	22.558527 N	70.807797 E	BW	41J/14	NIL	402.3	198.1	NIL	80	Electric - 20	Irrigation	Sultanbhai Kadiyar Amibhai	Valasan	Wankaner	Morbi
15	15	17-12-2020	22.590171 N	70.743198 E	DW	41J/10	0.64	24.38	4.42	5.1		Electric - 5	Irrigation	Dharmendrabhai Jadavbhai Tedhi	Hirapar	Tankara	Morbi
16	16	17-12-2020	22.812703 N	70.839852 E	DW	41J/13	1		11.66	1.5			Domestic	Molae raja Masjid	Morbi	Morbi	Morbi
17	17	17-12-2020	22.806547 N	70.774139 E	DW	41J/13	0.61	6.09	3.28	5.5			Irrigation	Dharamsingh Moti Satvara	Madhapar	Morbi	Morbi
18	18	17-12-2020	22.847799 N	70.722124 E	DW	41J/09	0.6	6.09	2.76	6			Irrigation	Vasantlal Kodi	Bagathala	Morbi	Morbi
19	19	17-12-2020	22.818828 N	70.624841 E	BW	41J/09	NIL	36.57	4.57	NIL		Electric - 1	Domestic	Hemad Santilal Adiyel	Jivapar	Morbi	Morbi
20	20	17-12-2020	22.82117 N	70.562588 E	DW	41J/09	0.6		4.15	3.27			Domestic	Mandir Trust	Amran	Morbi	Morbi
21	21	17-12-2020	22.774053 N	70.604596 E	DW	41j/09	0.8	3.65	8	3.65		Electric - 7.5	Irrigation	Mansukhbhai Tulsibhai Sapariya	Dhulkot	Halvad	Morbi
22	22	08-12-2020	22.765794 N	70.616659 E	BW	41J/09	NIL	38	16.7	NIL		Electric - 7.5	Irrigation	Kaileshbhai Arjanbhai Kodasara	Khanpar	Morbi	Morbi
23	23	08-12-2020	22.756434 N	70.626379 E	DW	41J/09	0.6		9	3.6			Irrigation	Vijaybhai Patel	Khanpar	Morbi	Morbi
24	24	08-12-2020	22.770037 N	70.774223 E	DW	41J/09		12	3.38				Irrigation	Kantibhai Pabatbhai Marvaniya	Rajpar	Morbi	Morbi
25	25	08-12-2020	22.629037 N	70.751767 E	DW	41J/10	0.15		4.14				Irrigation		Tankara	Tankara	Morbi
26	26	08-12-2020	22.5166 N	70.707909 E	DW	41J/10	Ground Level	18.2	4.87	5			Irrigation	Govindbhai Monasbhai Rabari	Neknam	Tankara	Morbi
27	27	08-12-2020	22.863724 N	70.794572 E	DW	41J/13	0.15	13.7	7.3	3.3		Electrict - 5	Irrigation	Karsan Kadva Chavda	Gor Khijadia	Morbi	Morbi
28	28	08-12-2020	22.866818 N	70.63755 E	DW	41J/13	0.32	10.6	5	3.65		Electrict - 2.5	Irrigation	Dharamsinghbhai Sivasbhai Sankani	Hajnali	Morbi	Morbi
29	29	08-12-2020	22.959036 N	70.616784 E	DW	41J/09	0.8	15.2	2.25	3.65		Electrict - 3	Irrigation	Nizambhai Alambhai Ajmeri	Mota Dahisara	Maliya	Morbi
30	30	08-12-2020	22.962098 N	70.614209 E	BW	41J/09	NIL	60.96	6	NIL			Irrigation	Dhirubhai Malyal Aahir	Mota Dahisara	Maliya	Morbi
31	31	08-12-2020	23.006342 N	70.707117 E	DW	41J/09	1.5	6	2.65	2			Domestic	Gram Panchayat	Sarvad	Malia	Morbi
32	32	08-12-2020	23.088694 N	70.756946 E	DW	41I/06	1.6	7.6	3.85	8.8			Domestic	Gram Panchayat	Malia	Malia	Morbi
33	33	08-12-2020	23.065635 N	70.857769 E	DW	41I/16	0.86		1.25	4.8			Domestic		Manaba	Malia	Morbi
34	34	09-12-2020	22.844265 N	70.758338 E	DW	41J/03	0.45	5.85	2.62	5.2			Irrigation	Babubhai Jinabhai Rupala	Nani Vavdi	Morbi	Morbi
35	35	09-12-2020	22.829226 N	70.696399 E	DW	41J/09	0.45	15	3.67	3.9		Electric - 5	Irrigation	Megjibhai Mohanbhai Chaniyara	Manekvada	Morbi	Morbi
36	36	09-12-2020	22.829407 N	70.697368 E	BW	41J/09	NILL	105	3	NIL		No Motor Installed	Irrigation	Keshavjibhai Revasbhai Chaniyara	Manekvada	Morbi	Morbi
37	37	09-12-2020	22.929556 N	70.824638 E	DW	41J/13	Ground Level	7.64	2.6	4.5		Electric - 2.5	Irrigation	Vasram Purusottam Kasundar	Nava Sadulka	Morbi	Morbi
38	38	09-12-2020	22.940691 N	70.816189 E	DW	41J/13	0.15	9	7.6	3.65			Irrigation	Dhanuba Darbar	Ravapar Nadi	Maliya	Morbi
39	39	09-12-2020	23.003111 N	70.894096 E	BW	41I/16	NIL	55	5	NIL		Electric - 15	Domestic	Gram Panchayat	Jetpar	Morbi	Morbi
40	40	09-12-2020	23.031736 N	70.913486 E	DW	41I/16	1	4.57	1.24	3			Domestic	Gram Panchayat	Aniyari	Morbi	Morbi
41	41	09-12-2020	23.005229 N	71.144721 E	BW	41M/04	NIL	183	106	NIL		Electric - 20	Irrigation	Amarsinghbhai Popatbhai Patel	Ranjitgadh	Halvad	Morbi
42	42	09-12-2020	23.027607 N	71.200892 E	BW	41M/04	NIL	198	122	NIL		Electric - 30	Irrigation	Najirbhai Umarbhai Lokadia	Vegadvav	Halvad	Morbi
43	43	09-12-2020	23.046315 N	71.225877 E	DW	41M/04	0.53	6.4	3.5	3.2			Domestic	Gram Panchayat	Vegadvav	Halvad	Morbi
44	44	09-12-2020	23.100752 N	71.256427 E	BW	41M/04	NIL	122	12	NIL		Electric - 15	Irrigation	Ranchhodbhai Sura Bharvad	Malaniyad	Halvad	Morbi
45	45	10-02-2021	22.651813 N	70.933897 E	BW	41J/14	NIL	91	91	NIL		Electric - 7.5	Irrigation	Bhorabha Bahadursingh Zala	Vaghasiya	Wankaner	Morbi
46	46	10-02-2021	22.655345 N	70.93064 E	DW	41J/14	0.24	15	4.22	4.5			Irrigation	Miraji Alibhai Mathaki	Vaghasiya	Wankaner	Morbi
47	47	10-02-2021	22.504143 N	71.048672 E	BW	41N/03	NIL	259	76 - 91	NIL		Electric - 10	Irrigation	Kareemben Alibhai Serasiya	Garida	Wankaner	Morbi
48	48	10-02-2021	22.435814 N	71.082808 E	DW	41N/03	0.9	21	10.45	5.6			Irrigation	Gram Panchayat	Bhalgam	Wankaner	Morbi
49	49	10-02-2021	22.424309 N	71.086827 E	DW	41N/03	0.9	14.2	4.8	3.65			Irrigation	Menandbhai Aahir	Thikariyala	Wankaner	Morbi

ANNEXURE II Computation of fesssible zones for artificial recharge in different Geological formations

			Area of Vadose zone in sq. km					Volume of vadose zone MCM				
Taluka	WL Range in m	Average thickness m	Alluvium	Basalt	Intusive	Sandstone	Grand Total	Alluvium	Basalt	Intusive	Sandstone	Grand Total
HALVAD	6 to 8	1	19.76	0.59	2.16	186.37	208.88	19.76	0.59	2.16	186.37	208.88
HALVAD	8 to 10	2	10.75	0.63		279.10	290.49	21.50	1.27	0.00	558.20	580.97
HALVAD	10 to 12	3	2.27	2.04	1.79	29.86	35.96	6.81	6.12	5.37	89.59	107.89
HALVAD	12 to 15	4.5	15.20	1.89	2.65	19.27	39.02	68.42	8.52	11.94	86.71	175.60
HALVAD	15 to 20	7	25.95		3.09	26.45	55.50	181.67	0.00	21.66	185.18	388.51
HALVAD	20 to 25	9.5	5.67		2.42	10.82	18.90	53.83	0.00	22.97	102.75	179.54
HALVAD	25 to 30	12			3.88	21.79	25.68	0.00	0.00	46.59	261.51	308.10

Total			**79.61**	**5.16**	**16.00**	**573.67**	**674.43**	**351.99**	**16.50**	**110.69**	**1470.32**	**1949.50**
MORVI	6 to 8	1	12.41	58.46		1.26	72.13	12.41	58.46	0.00	1.26	72.13
MORVI	8 to 10	2	2.18	60.72			62.91	4.37	121.45	0.00	0.00	125.81
MORVI	10 to 12	3		27.53		0.78	28.31	0.00	82.59	0.00	2.34	84.93
MORVI	12 to 15	4.5		18.49		6.28	24.77	0.00	83.19	0.00	28.27	111.45
MORVI	15 to 20	7		17.48		27.46	44.93	0.00	122.33	0.00	192.20	314.53
MORVI	20 to 25	9.5		0.46		25.52	25.98	0.00	4.34	0.00	242.43	246.77
MORVI	25 to 30	12				4.66	4.66	0.00	0.00	0.00	55.95	55.95
Total			**14.59**	**183.13**	**0.00**	**65.96**	**263.68**	**16.77**	**472.35**	**0.00**	**522.45**	**1011.57**
TANKARA	6 to 8	1		18.35		4.67	23.01	0.00	18.35	0.00	4.67	23.01

TANKARA	8 to 10	2		2.16		3.04	5.20	0.00	4.32	0.00	6.08	10.40
TANKARA	10 to 12	3		0.82		1.49	2.31	0.00	2.45	0.00	4.48	6.93
TANKARA	12 to 15	4.5				0.43	0.43	0.00	0.00	0.00	1.95	1.95
Total			**0.00**	**21.32**	**0.00**	**9.63**	**30.96**	**0.00**	**25.12**	**0.00**	**17.18**	**42.30**
WANKANER	6 to 8	1		113.40		29.74	143.15	0.00	113.40	0.00	29.74	143.15
WANKANER	8 to 10	2		64.24		120.07	184.30	0.00	128.47	0.00	240.13	368.61
WANKANER	10 to 12	3		33.83		74.31	108.14	0.00	101.50	0.00	222.93	324.43
WANKANER	12 to 15	4.5		30.88		57.81	88.69	0.00	138.96	0.00	260.14	399.10
WANKANER	15 to 20	7		36.86	7.82	67.95	112.62	0.00	258.01	54.73	475.62	788.36
WANKANER	20 to 25	9.5		31.22	11.62	52.41	95.25	0.00	296.54	110.43	497.85	904.83

WANKANER	25 to 30	12		62.00	1.64	121.30	184.93	0.00	743.94	19.66	1455.61	2219.22
Total			**0.00**	**372.42**	**21.08**	**523.58**	**917.08**	**0.00**	**1780.83**	**184.82**	**3182.03**	**5147.68**
Grand Total			**94.20**	**582.03**	**37.08**	**1172.85**	**1886.15**	**368.77**	**2294.79**	**295.51**	**5191.98**	**8151.05**

ANNEXURE III: Area with declining trends -Fessible for Recharge in Alluvium

Taluka	WL trends cm/year	Average thickness of desaturation in m	Area in sq. km					Volume of vadose zone in (MCM)				
			Alluvium	Basalt	Intusive	Sandstone	Total	Alluvium	Basalt	Intusive	Sandstone	Total
HALVAD	0 to 100	0.5	120.75	4.96	2.33	347.39	475.44	60.38	2.48	1.17	173.70	237.72
MALIYA	0 to 100	0.5	0.95	6.30			7.25	0.48	3.15	0.00	0.00	3.63
MORVI	0 to 100	0.5	114.08	217.38	0.01	98.22	429.69	57.04	108.69	0.00	49.11	214.84
TANKARA	0 to 100	0.5		56.81		3.89	60.70	0.00	28.40	0.00	1.95	30.35

TANK ARA	100 to 200	1		19.02			19.02	0.00	19.02	0.00	0.00	19.02
TANK ARA	200 to 300	1.5		6.08			6.08	0.00	9.12	0.00	0.00	9.12
			0.00	**81.91**	**0.00**	**3.89**	**85.80**	**0.00**	**56.55**	**0.00**	**1.95**	**58.50**
WANK ANER	0 to 100	0.5		147.49		132.29	279.78	0.00	73.74	0.00	66.15	139.89
WANK ANER	100 to 200	1		13.02		8.17	21.20	0.00	13.02	0.00	8.17	21.20
WANK ANER	200 to 300	1.5		18.66		0.38	19.04	0.00	28.00	0.00	0.57	28.56
			0.00	**179.17**	**0.00**	**140.85**	**320.02**	**0.00**	**114.76**	**0.00**	**74.89**	**189.65**
Grand Total			**235.79**	**489.73**	**2.34**	**590.35**	**1318.20**	**117.89**	**285.63**	**1.17**	**299.64**	**704.34**

ANNEXURE IV: Taluka wise Ground Water Storage Potential in De-saturated Zone to be used for storage upto 6 m bgl

Ground Water Storage Potential in De-saturated Zone to be used for storage upto 6 m bgl in HALVAD Taluka

Sr. No	Description	Alluvium	Basalt	Intusive	Sandstone	Total
1	Volume of the vadose zone (mcm)	351.99	16.50	110.69	1470.32	1949.50
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the vadose zone (mcm)	176.00	-	-	-	176.00
4	Net Volume of formation in de-saturated zone (mcm)	176.00	16.50	110.69	1470.32	1773.50
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge in de-saturated zone (mcm) (4 x 6)	21.12	0.20	1.99	35.29	58.60
Ground water storage potential in the annually declining zone						
1	Volume of annually declining zone (mcm)	60.38	2.48	1.17	173.70	237.72
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the annually declining zone (mcm)	30.19	-	-	-	-

4	Net Volume of formation to arrest declining trend (mcm)	30.19	2.48	1.17	173.70	207.53
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge to control annual Depletion (mcm) (4 x 6)	3.62	0.03	0.02	4.17	7.84
Total Volume of water required for recharge (mcm)		24.74	0.23	2.01	6.16	66.44

Ground Water Storage Potential in De-saturated Zone to be used for storage upto 6 m bgl in MORBI Taluka

Sr. No	Description	Alluvium	Basalt	Intusive	Sandstone	Total
1	Volume of the vadose zone (mcm)	16.77	472.35	0.00	522.45	1011.57
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the vadose zone (mcm)	8.39	-	-	-	8.39
4	Net Volume of formation in de-saturated zone (mcm)	8.39	472.35	0.00	522.45	1003.19
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-

7	Volume of water required for recharge in de-saturated zone (mcm) (4 x 6)	1.01	5.67	0.00	12.54	19.21
Ground water storage potential in the annually declining zone						
1	Volume of annually declining zone (mcm)	57.04	108.69	0.00	49.11	214.84
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the annually declining zone (mcm)	28.52	-	-	-	-
4	Net Volume of formation to arrest declining trend (mcm)	28.52	108.69	0.00	49.11	186.32
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge to control annual Depletion (mcm) (4 x 6)	3.42	1.30	0.00	1.18	5.91
Total Volume of water required for recharge (mcm)		4.43	6.97	0.00	1.18	25.91

Ground Water Storage Potential in De-saturated Zone to be used for storage upto 6 m bgl in TANKARA Taluka

Sr. No	Description	Alluvium	Basalt	Intusive	Sandstone	Total

1	Volume of the vadose zone (mcm)	0.00	25.12	0.00	17.18	42.30
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the vadose zone (mcm)	0.00	-	-	-	0.00
4	Net Volume of formation in de-saturated zone (mcm)	0.00	25.12	0.00	17.18	42.30
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge in de-saturated zone (mcm) (4 x 6)	0.00	0.30	0.00	0.41	0.71
Ground water storage potential in the annually declining zone						
1	Volume of annually declining zone (mcm)	0.00	56.55	0.00	1.95	58.50
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the annually	0.00	-	-	-	-

	declining zone (mcm)					
4	Net Volume of formation to arrest declining trend (mcm)	0.00	56.55	0.00	1.95	58.50
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge to control annual Depletion (mcm) (4 x 6)	0.00	0.68	0.00	0.05	0.73
Total Volume of water required for recharge (mcm)		0.00	0.98	0.00	0.05	1.44

Ground Water Storage Potential in De-saturated Zone to be used for storage upto 6 m bgl in WANKANER Taluka

Sr. No	Description	Alluvium	Basalt	Intusive	Sandstone	Total
1	Volume of the vadose zone (mcm)	0.00	1780.83	184.82	3182.03	5147.68
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the vadose zone (mcm)	0.00	-	-	-	0.00

4	Net Volume of formation in de-saturated zone (mcm)	0.00	1780.83	184.82	3182.03	5147.68
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-
6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge in de-saturated zone (mcm) (4 x 6)	0.00	21.37	3.33	76.37	101.07
Ground water storage potential in the annually declining zone						
1	Volume of annually declining zone (mcm)	0.00	114.76	0.00	74.89	189.65
2	Clay Content (%)	50	-	-	-	-
3	Volume of Clay in the annually declining zone (mcm)	0.00	-	-	-	-
4	Net Volume of formation to arrest declining trend (mcm)	0.00	114.76	0.00	74.89	189.65
5	Average Sp. Yield of the formations	0.1	0.01	0.015	0.02	-

6	Average co-efficient of Replenishment of the formations	0.12	0.012	0.018	0.024	-
7	Volume of water required for recharge to control annual Depletion (mcm) (4 x 6)	0.00	1.38	0.00	1.80	3.17
Total Volume of water required for recharge (mcm)		0.00	22.75	3.33	5.12	104.24

ANNEXURE V: Heavy Metal Analysis results NHS 2021-22

S.No.	District	Taluka	Site_Name	Source	Date of Collection	Latitude	Longitude	Cr [mg/l]	Cu [mg/l]	Fe [mg/l]	Mn [mg/l]	Zn [mg/l]
329	Morbi	Halvad	Halvad 2	DW	20-05-2021	23.01917	71.18500	0.016	0.004	0.010	0.000	0.003
330	Morbi	Halvad	Juna Devaliya 1	DW	20-05-2021	23.01111	70.99083	0.000	0.001	0.098	0.033	0.004
331	Morbi	Halvad	Mathak	DW	20-05-2021	22.84278	71.06139	0.000	0.005	0.073	0.005	0.015
332	Morbi	Maliya	Malia	DW	19-05-2021	23.08861	70.75694	0.000	0.002	0.076	0.016	0.006
333	Morbi	Maliya	Mota Dahisara	DW	19-05-2021	22.96194	70.61361	0.000	0.002	0.058	0.077	0.007
334	Morbi	Maliya	Sarvad	DW	19-05-2021	23.00639	70.70694	0.000	0.003	0.043	0.108	0.007

335	Morbi	Morvi	Amarnagar	DW	19-05-2021	22.93444	70.82417	0.000	0.010	0.108	0.175	0.019
336	Morbi	Morvi	Jetpur	DW	20-05-2021	23.00278	70.89472	0.000	0.002	0.084	0.028	0.004
337	Morbi	Morvi	Modpar1	DW	19-05-2021	22.90167	70.66278	0.000	0.003	0.066	0.225	0.010
338	Morbi	Morvi	Morvi	DW	19-05-2021	22.83139	70.85278	0.001	0.002	0.115	0.055	0.005
339	Morbi	Morvi	Nichimandal	DW	20-05-2021	22.86111	70.96333	0.000	0.006	0.058	0.021	0.055
340	Morbi	Tankara	Chhatar	DW	19-05-2021	22.50528	70.75306	0.000	0.004	0.183	0.010	0.009
341	Morbi	Tankara	Lajai	DW	19-05-2021	22.71583	70.78028	0.027	0.010	0.185	0.034	0.028
342	Morbi	Wankaner	Sindhavadar	DW	19-05-2021	22.55167	70.89722	0.000	0.002	0.088	0.004	0.007

ANNEXURE VI: Uranium Analysis in Ground water results NHS 2021-22

S.N	District	Taluka	Site Name	Source	Date Of Collection	Uranium(ppb)	Lat	Long
14	Morbi	Wankaner	Bhalgam	DW	16-05-2021	1.68	22.4356	71.0825
45	Morbi	Tankara	Chhatar	DW	19-05-2021	1.17	22.5053	70.7531
46	Morbi	Tankara	Lajai	DW	19-05-2021	1.6	22.7158	70.7803

48	Morbi	Wankaner	Sindhavadar	DW	19-05-2021	1.02	22.5517	70.8972
49	Morbi	Morvi	Modpar1	DW	19-05-2021	2.84	22.9017	70.6628
50	Morbi	Maliya	Mota Dahisara	DW	19-05-2021	1.85	22.9619	70.6136
51	Morbi	Maliya	Sarvad	DW	19-05-2021	0.54	23.0064	70.7069
52	Morbi	Maliya	Malia	DW	19-05-2021	0.5	23.0886	70.7569
53	Morbi	Morvi	Amarnagar	DW	19-05-2021	3	22.9344	70.8242
54	Morbi	Morvi	Morvi	DW	19-05-2021	1.28	22.8314	70.8528
55	Morbi	Morvi	Nichimandal	DW	20-05-2021	2.71	22.8611	70.9633
56	Morbi	Halvad	Mathak	DW	20-05-2021	4.85	22.8428	71.0614
57	Morbi	Halvad	Juna Devaliya 1	DW	20-05-2021	1.34	23.0111	70.9908
58	Morbi	Morvi	Jetpur	DW	20-05-2021	4.8	23.0028	70.8947
59	Morbi	Halvad	Halvad 2	DW	20-05-2021	11.1	23.0192	71.1850

ANNEXURE VII: Basic Analysis of Ground water Quality result

District	Taluka	Location	Latitude	Longitude	Source	Date of	pH	EC	TDS	CO3	HCO3	Cl	SO4	NO3	F	Alkalinity	Ca	Mg	TH	Na	K	SiO2	SAR

						Collection		µs/cm at 25 °C	mg/l													
Morbi	Wankaner	Bhalgam	22.43556	71.08250	DW	16.5.21	7.57	2095	1404	0	232	532	102	63	0.31	190	196	90	861	84	0.6	56	1.25
Morbi	Tankara	Chhatar	22.50528	70.75306	DW	19.5.21	8.02	1426	955	0	232	277	114	52	0.66	190	96	54	460	140	0.45	66	2.84
Morbi	Tankara	Lajai	22.71583	70.78028	DW	19.5.21	7.53	5723	3834	0	220	1631	249	286	0.66	180	481	285	2372	329	2.1	71	2.94
Morbi	Wankaner	Sindhavadar	22.55167	70.89722	DW	19.5.21	8.18	1497	1003	0	317	255	87	74	0.7	260	44	44	290	208	0.51	58	5.31
Morbi	Morvi	Modpar	22.90167	70.66278	DW	19.5.21	8.16	4229	2833	0	317	1205	184	7.5	0.21	260	124	80	641	669	8.6	9.2	11.5
Morbi	Maliya	Mota Dahisara	22.96194	70.61361	DW	19.5.21	8.09	1808	1211	0	317	404	113	4.6	0.34	260	96	51	450	228	10	30	4.67
Morbi	Maliya	Sarvad	23.00639	70.70694	DW	19.5.21	7.88	1834	1229	0	366	411	56	2.7	0.54	300	56	49	340	295	5.8	29	6.96
Morbi	Maliya	Molia	23.08861	70.75694	DW	19.5.21	8.02	472	316	0	244	28	7.6	2.8	0.36	200	48	15	180	31	10	29	1
Morbi	Morvi	Amarnagar	22.93444	70.82417	DW	19.5.21	7.81	7557	5063	0	329	2425	162	2.2	3.5	270	204	297	1731	1062	8.4	16	11.1

Morbi	**Morvi**	**Morvi**	**22.8313**	**70.85278**	**DW**	**19.5.21**	**8.2**	**1350**	**905**	**0**	**390**	**170**	**85**	**27**	**2.4**	**320**	**76**	**24**	**290**	**190**	**3.1**	**35**	**4.85**
Morbi	**Morvi**	**Nichimandal**	**22.8611**	**70.96333**	**DW**	**20.5.21**	**7.88**	**3296**	**2208**	**0**	**415**	**766**	**125**	**100**	**0.82**	**340**	**72**	**58**	**420**	**563**	**11**	**32**	**11.94**
Morbi	**Halvad**	**Mathak**	**22.8427**	**71.06139**	**DW**	**20.5.21**	**7.85**	**3435**	**2301**	**0**	**232**	**858**	**170**	**32**	**0.9**	**190**	**100**	**71**	**540**	**520**	**4.8**	**17**	**9.73**
Morbi	**Halvad**	**Juna Devaliya 1**	**23.0111**	**70.99083**	**DW**	**20.5.21**	**8.12**	**835**	**559**	**0**	**317**	**92**	**21**	**6.4**	**0.81**	**260**	**40**	**27**	**210**	**100**	**6.2**	**22**	**3**
Morbi	**Morvi**	**Jitpur**	**23.0278**	**70.89472**	**DW**	**20.5.21**	**8.16**	**1452**	**973**	**0**	**329**	**269**	**67**	**19**	**2.3**	**270**	**40**	**44**	**280**	**222**	**7.8**	**20**	**5.77**
Morbi	**Halvad**	**Halvad 2**	**23.0191**	**71.185**	**DW**	**20.5.21**	**7.79**	**5435**	**3641**	**0**	**378**	**1290**	**683**	**31**	**3.4**	**310**	**148**	**117**	**851**	**975**	**21**	**40**	**14.54**