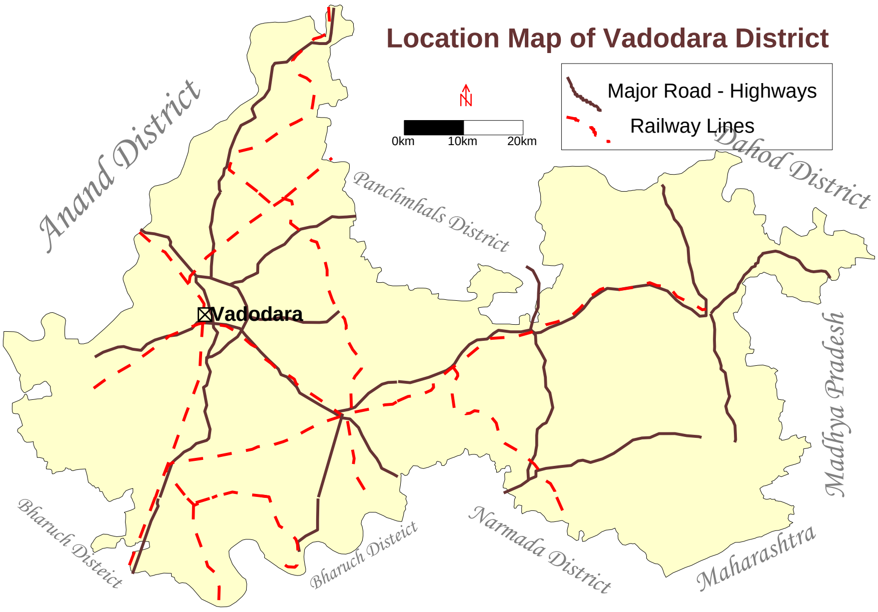
DISTRICT GROUND WATER BROCHURE : VADODARA

1. INTRODUCTION

Vadodara district with 7548.50 Sq km area, is located central part of mainland Gujarat, lies between 21°49’19” and 22°48’37” north latitude and 72°51’05”and 74°16’55” east longitude. It falls in the Survey of India, degree sheets numbered 46B, 46F, 46J & 46G. The district is bounded in north & northeast by Anand, Panchmahals & Dahod districts, in east & in south east by Madhya Pardesh & Maharashtra State, in south east by Narmada district & in south & in west by Bharuch district. Vadodara city, the district headquarter is about 100 km south of Ahmedabad, is well connected to other parts of the State & Country by network of highways and railway network. (Location Map, Fig No. 1).



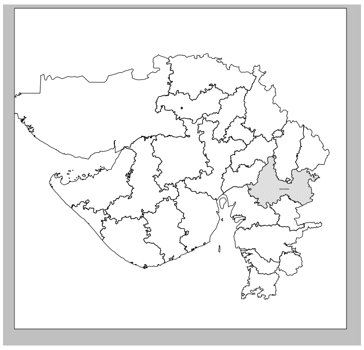


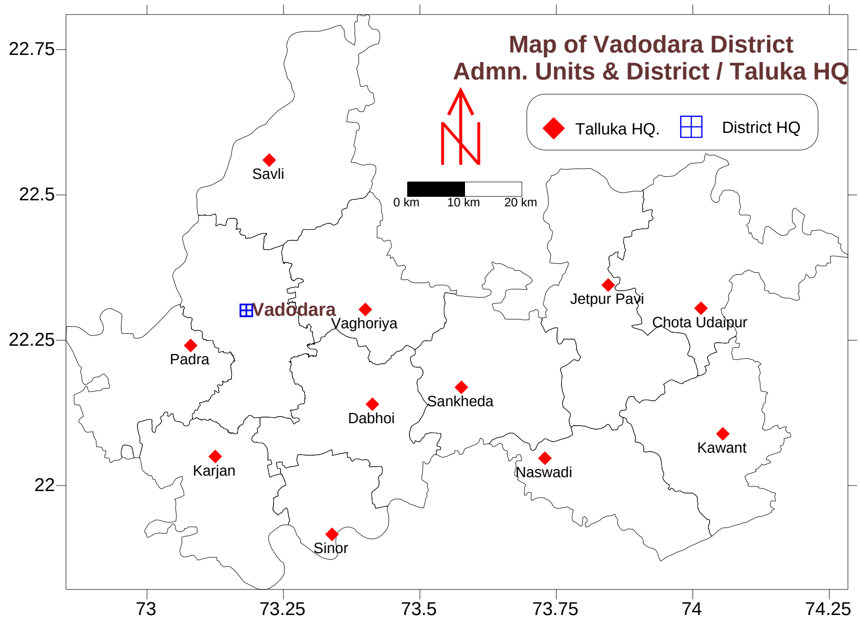
Figure 1. Location map of Vadodara district

Vadodara district is divided 12 taluaks. Details of the Talukas, their urban & rural areas and numbers of revenue villages & towns etc., are given in Table – 1 Map showing its administrative units as Taluka & their headquarter is given as Fig –2.

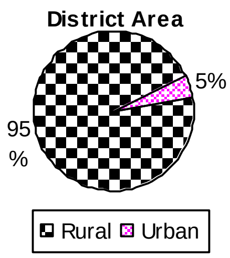
Table : 1 Details of Taluka area & Nos. of Towns & Villages

Sr. No	Taluka	Area (Sq.km)	Urban (Sq.km)	Rural (Sq.km)	No. Town	No. Villages
1	Chhota Udaipur	765.4563	4.0099	761.4464	1	144
2	Dabhoi	632.1895	23.82	608.3695	1	118
3	Jetpur	805.64	4.4098	801.2302	1	212
4	Karjan	601.8724	15.7094	586.163	1	93
5	Kawant	607.762	2.0399	605.7221	1	132
6	Naswadi	535.1656	0	535.1656	0	219
7	Padra	534.7288	12.8331	521.8957	1	82
8	Sankheda	722.6128	31.8354	690.7774	3	182
9	Savli	791.9973	0	791.9973	0	137
10	Shinor	292.5048	16.1894	276.3154	1	40
11	Vadodara	693.4307	213.8801	479.5506	9	91
12	Vaghodiya	565.1405	15.0595	550.081	1	95
	Total	**7548.5007**	**339.7865**	**7208.7142**	**20**	**1545**

Figure No. 2 Administrative Unit Map – Vadodara District



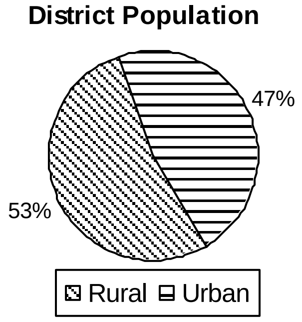
1.1. DEMOGRAPHIC PERTICULARS



According to the 2001 census, total population of Vadodara District is 3,639,775 persons. Out of these nearly 53.47 % of *Rural Population* is spread in 1545 villages having total areas of 7208.71 sq.km while 46.53 % of urban population spread is in 20 towns & 11 urban agglomerate, having total areas of 339.78 sq,km. The density of population in rural area is 268 persons per sq.km while in urban area it is around 5,029 persons per sq.km while as a whole district it is 489 persons per sq.km. (Table 2). As per 2001 census report, Vadodara taluka area is one of the most urbanized talukas of the State, have 87.49 % urban population with average population density of 6,978 persons per Sq.km.

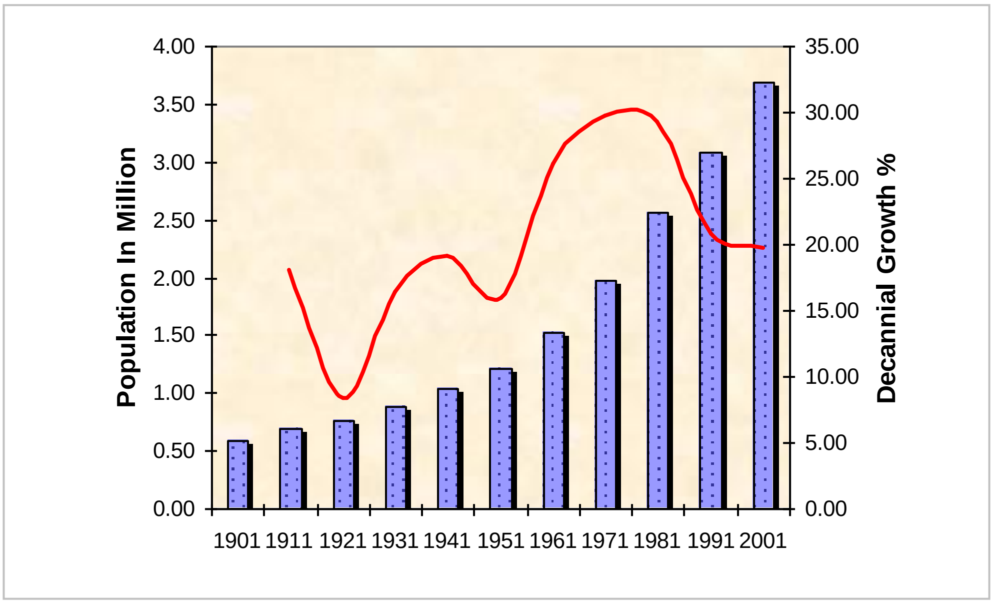
Table No.2 Area & Population

Area in Hectares (2001 Census)	
Urban	720871.42
Rural	33978.65
Total District	754850.07
Population Nos. (2001 Census)	
Urban	1932976
Rural	1708826
Total District	3641802
Population Density (Nos / hectares)	
Urban	268
Rural	5029
Total District	482

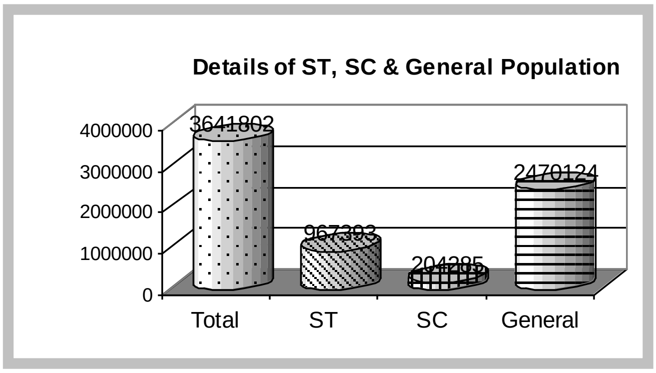


The district had decadal growth of population of around 28 % during 1961 to 1981, which declined to around 20 % during last two decades. (Figure 3)

Figure : 3 Decannial Growth of Population



The tribal population of Vadodara district is mostly located in eastern hilly terrain of the districts, which is a continuous part of tribal belt of Gujarat State covering all boarder areas along neighboring States of Madhya Pradesh & Maharashtra. As per 2001 census, percentage of tribal population to total population is 26.56 % while percentage of scheduled caste population to total population is 5.61 % while rest, 67.83 % is general population.



1.2. LAND USE PATTERNS, IRRIGATION & AGRICULTURE

Seasons & Crops Record[1] , Vadodara District -year 2001-02, has been refereed for land use, irrigation & agriculture statistics of the district.

1.4.1. Land Use Patterns

As per *Seasons & Crops Record,* 7,52,776 hectares of land is accounted for land use record. Brief account of land use classification for the district, in general, is given in table No.3

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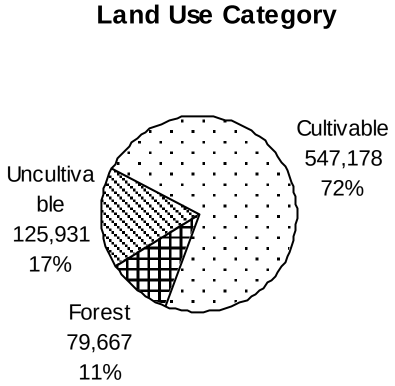
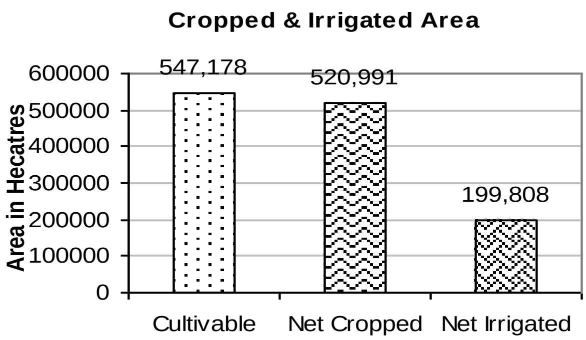
Table No. 3 Land Use Classification of Vadodara District (2001-02)

Sr No	Land Use Classification	Area in Hectare
1	Area Reported for Land Use	7,52,776
2	Forest	79,667
3	Total Uncultivable area	1,25,931
4	Culturable Waste	6,724
5	Cultivated Area (1 - 2 – 3 – 4)	5,40,454
6	Cultivable Area (5 + 4)	5,47,178
7	Current Fallow	20,188
8	Net Area Sown (5 -7)	5,20,266
9	Area Shown More Than Once	43,777
10	Total Cropped Area (8 + 9)	5,64,043
11	Net Area Irrigated	1,99,808
12	Area Irrigated More Than Once	36,052
13	Gross Area Irrigated (11 + 12)	2,35,860





1.4.2. Irrigation

Details of water supply sources and irrigation structures etc., and area irrigated by various sources are in table No. 4 while details of area irrigated by surface & ground water resources are given in table No 5

Table No. 4 Structure for Irrigation & Other Uses[1]

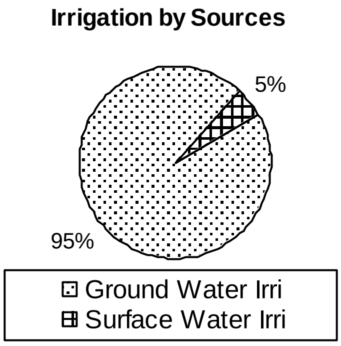
Sr.No	Structure	Nos.
1	Tank for Irrigation	24
2	Non Irrigation Tank	1,569
3	Canal No. / Length km	7 / 65
4	Lift Irrigation Sources	4
5	Tube Wells for Irrigation	1,676
6	Dug Wells for Irrigation	18,015
7	Domestic Wells	9,773
8	Abandoned Wells	3,056
9	No. of Oil Engines	7,564
10	No. of Electric Pump	12,933

[1] Land Use & Season –Crop Record – Vadodara District – Year 2001-02 – Agriculture Directorate, Government of Gujarat.

Table No. 5 Details of Irrigated Areas[1]

Source	Irrigated Area (Hectares)		
	Net	MTO *	Gross
Tanks	3,642	523	4,165
Canals	4,073	745	4,818
Lift & Flow Irrigation	2,283	238	2,521
Total Surface Water	**9,998**	**1,506**	**11,504**
Govt. Tube Wells	19,029	3,086	22,115
Pvt. Tube Wells	71,705	6,867	78,572
Dug Wells	99,076	24,593	123,669
Total Ground Water	**189,810**	**34,545**	**224,355**
Total Irrigated Area	**199,808**	**36,052**	**235,860**

* MTO – more than once



1.4.3. Agriculture

The district areas have varied agriculture crops, both food crops & non food crops. Main food crops consist of food grains such as paddy, wheat, *jowar*, *bajra*, maize etc., and pulses. Other food crops are sugarcane, fruits & vegetables. Non food crops consists of cotton, oil ground nut, castor, tobacco, fodder etc. As per *Season & Crops Records,*[1] there were 5,64,043 hectares of gross area under various crops in the district, out these 2,35,860 hectares were under irrigated crops. Figure shows further subgroups under *Kharif, Rabi* & *Hot* seasons. Details of areas under various food crop & non food crop of the district are given in table No 6

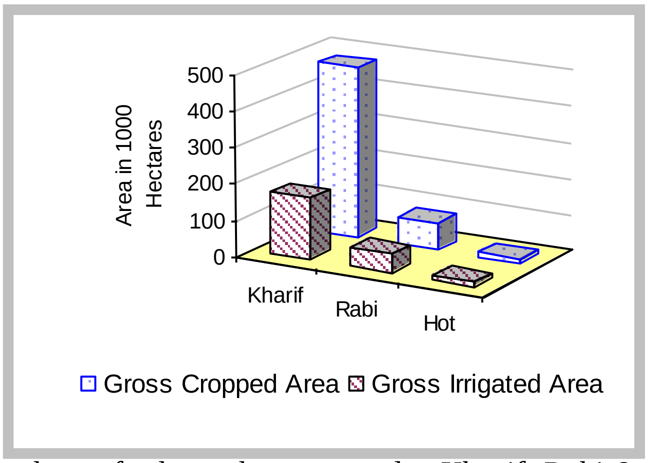


Table No .6 Details of Areas under Food & Non-food Crops & Irrigation

		Kharif	Rabi	Hot	Total
Food Crop : Paddy, Wheat & other cereals, pulses, vegetables, fruits etc.	Irrigated Area *	70413	47604	5448	123465
	Non Irrigated Area*	179389	20153	0	199542
	Total Cropped Area *	249802	67757	5448	323007
Non Food Crop : Cotton, Oil seeds, tobacco, fodder etc.	Irrigated Area *	99409	5593	7393	112395
	Non Irrigated Area*	126309	2332	0	128641

	Total Cropped Area*	225718	7925	7393	241036
Gross Cropped Area *		475520	75682	12841	**564043**
Gross Irrigated Area *		169822	53197	12841	**235860**

* Area in Hectares

1.14.4. Urban and Industrial area

Vadodara district is one of the most industrially developed areas the state. It has many *Strategic Industries*, such as oil refinery, petrochemical complex, fertilizers, and heavy water project etc., located around areas of Vadodara Taluka. Other important industries are of metal product, rubber& plastic, non- metallic mineral product, pharmaceuticals, engineering & machinery parts etc. Besides these, there are many industrial notified area in various Taluka areas of the district of which 8 are established and managed by Gujarat Industrial Development Corporation Ltd. (GIDC Ltd).

2. HYDROMETEOROLOGY

2.1. CLIMATE

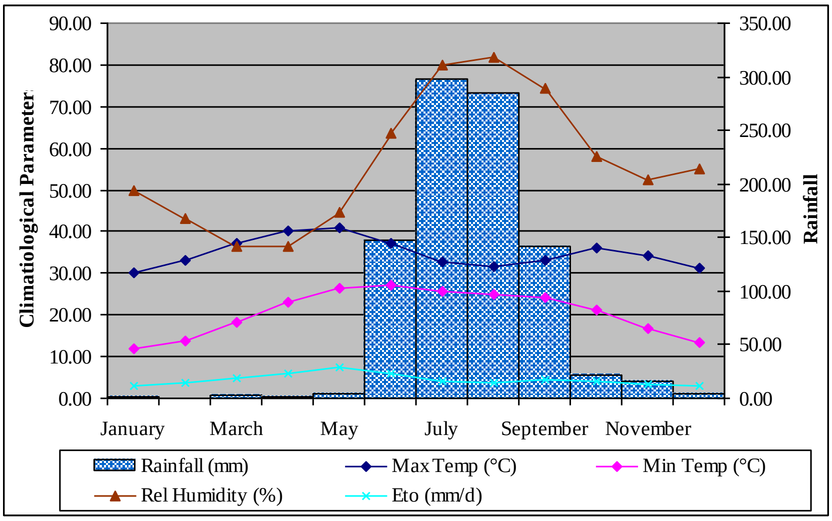
Vadodara district area, in general, being located south of *Tropic of Cancer* and in transition zone of heavy rainfall areas of South Gujarat and arid areas of North Gujarat plains, have sub-tropical climate with moderate humidity. The various season of the year are (a) monsoon - middle of June to October, (b) winter - November to February, and (c) summer – March to June. From March onward the temperature starts rising till it reaches maximum, as high as 41° C in some parts of the district. January is the coldest month of the year.

There is a Indian Meteorological Department (IMD) station located at Baroda (Vadodara), where observation of climatic data is recorded since 1900. Details of this climatological data is given in table No. 2.1 and same is depicted graphically in figure No. 2.1

Table No. 2.1 - Climatological Data of IMD Station –(Baroda) - Vadodara

Month	Max Temp (Deg.C)	Mini Temp (Deg.C)	Humidity (%)	Wind Spd. Kmpd	Sun shine (Hours)	Solar Rad. (MJ/m2/d)	Eto (mm/d)	Rainfall (mm)
January	30.30	12.00	50.00	65.80	9.10	17.23	3.02	1.20
February	33.00	13.80	43.00	67.50	9.70	20.07	3.81	0.60
March	37.10	18.40	36.50	69.10	10.20	23.16	4.88	2.20
April	40.20	22.90	36.50	79.00	10.80	25.75	6.03	0.90
May	40.90	26.50	44.50	143.20	10.90	26.38	7.46	4.40
June	37.10	27.00	63.50	169.50	7.10	20.62	5.97	146.80
July	32.70	25.70	80.00	138.20	4.40	16.51	4.11	297.60
August	31.50	25.00	82.00	116.80	4.50	16.32	3.82	284.70
September	33.20	24.30	74.50	83.90	6.90	18.87	4.28	141.70
October	36.00	21.30	58.00	49.40	9.30	20.24	4.12	22.00
November	34.30	16.70	52.50	49.40	9.40	18.02	3.24	16.20
December	31.20	13.40	55.00	59.20	9.10	16.50	2.83	4.40
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**922.70**
Average	**34.79**	**20.58**	**56.33**	**90.92**	**8.45**	**19.97**	**4.46**	**-**

Figure No 2.1 - Plot of Climatological Data – (Baroda) –Vadodara IMD Station



3. GEOMORPHOLOGY

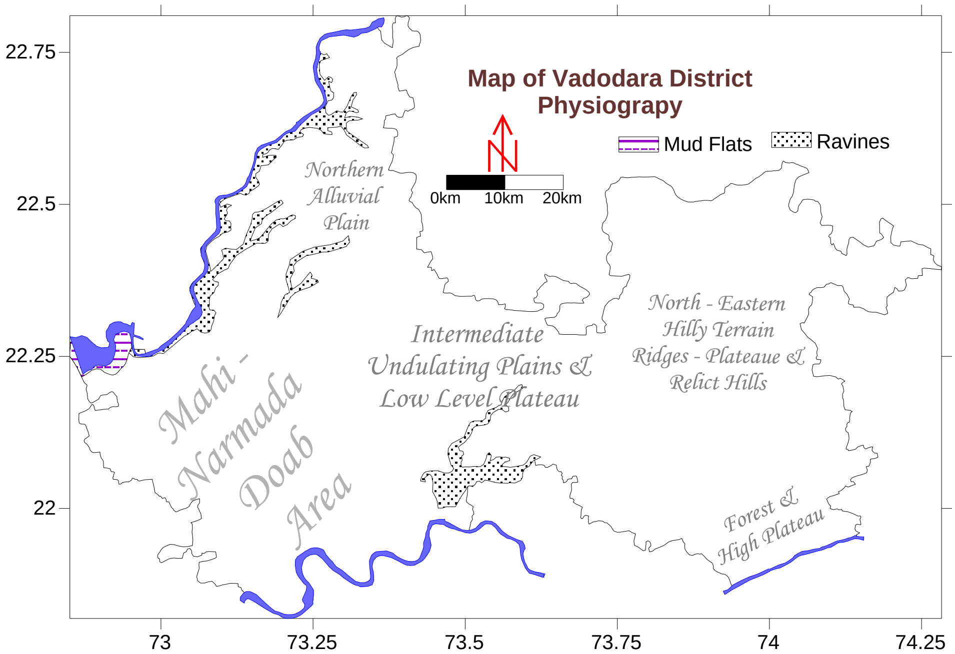
3.1. PHYSIOGRAPHY

Vadodara district forms a part of the great Gujarat plain. The eastern portion of the district comprising the Chhota Udepur, the Kavant, the Jambughoda and the Naswadi taluka is hilly terrain with several ridges, plateaus and isolated relict hills have elevation in range of 150 to 481 m amsl. The south eastern plateau have the highest peaks of the district – Amba Dungar & Mandai Dongar 637 m amsl. The rest of the district, the western & southern part, comprising of Mahi & Narmada *Doab*, is a level plain with gentle undulating terrain have elevation in range of 120 to 20 m amsl . The overall elevation ranges from 610m in east to 20 m amsl in south-west

The most of the western part, comprising of Mahi – Narmada *Doab* and northern alluvial plain is more or less level terrain, have elevation in range from 20 to 80 m amsl. There are some linear tracts, along Mahi, Viswamitre, Dhadahar and Orsang rivers, have *ravine landforms*, with typical head ward erosional featured gully formation in soft alluvium. The banks of the Mahi has high vertical cliff , 10 to 25 m height, generally on left bank; same way left bank of the Narmada also has high cliff of 10 to 20 m high on right bank. All such features of *Mahi-Narmada Doab*, like ravine features, high cliff along banks and entrenched meandering courses with dry and wide sandy river bed of intermediate independent river systems of the Dhadhar & its tributaries indicate mature river stage and also tectonic uplift of *Doab* portion in *Recent* geological past.

The central part of the district is low level undulating plain with low level plateau and few relict hills. The area between the Unch and the Orsang river have aeolian low level stabilized dune with rolling topography. The hilly terrains of north - eastern part have residual hill features with more or less flat topped plateau. Except few volcanic peaks – Phenai Mata Hills and Amba Dungar, all have plateau or ridge type features and are few tens of meter height than surrounding rocky dissected plain. The highest plateaus are in south eastern part of the district, marked with rift valley of the Narmada River towards south.

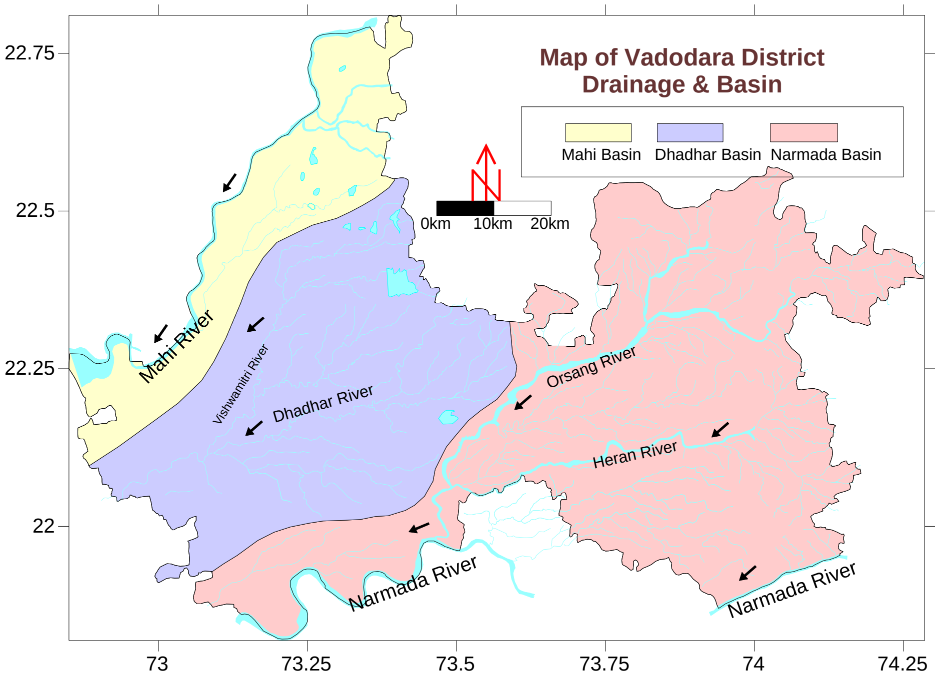
Figure No. 3.1 The physiographic map of the district



3.2. DRAINAGE

The Narmada and the Mahi are the chief rivers of the district, flow along the northwestern and southern boundary respectively while independent small river system of the Dhadhar with its numerous tributaries flow in south central part of the district. Broadly, the entire district, as a *River Basin* is divided into these three basin, namely the Narmada, the Mahi Basin and the Dhadhar. The Mesari, the Goma and the Karad are the small rivers flowing northwest part of the district, are tributaries of Mahi River, and are part of the Mahi Basin. The Jambuva, the Surya, the Viswamitre and the Dhadhar, which flow through central part of the district and empty into the Gulf of Khambat, are part of the Dhadhar Basin. The eastern and the southern part of the district, drained by the Narmada River and its tributaries, like the Unch, the Heran, the Dev, the Orsang, the Karjan, the Aswan and the Bhukhi, constitutes the Narmada basin. (Drainage & Basin Map in figure No. 3.2)

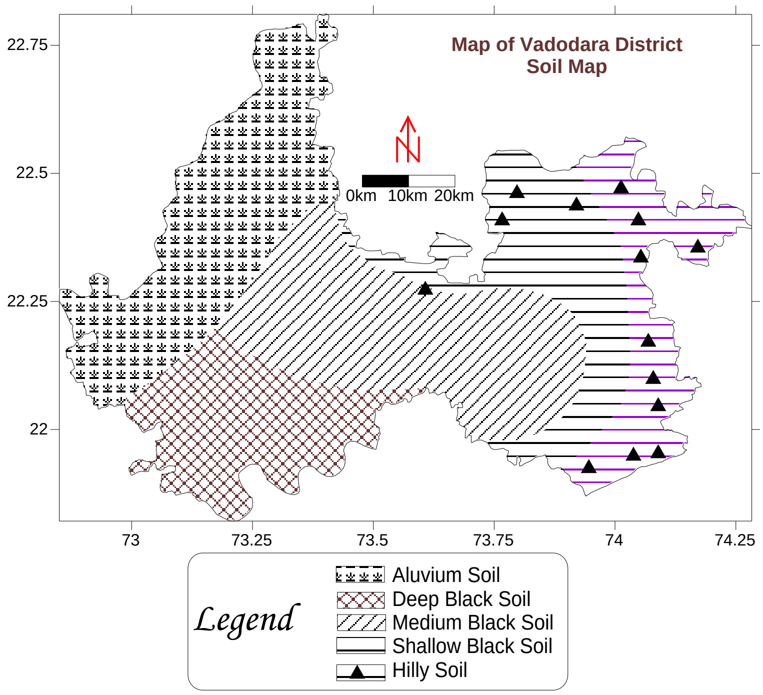
Figure No. 3.2 Drainage & Basin Map of Vadodara District



3.3. SOILS

The soils[2] of Vadodara district can be broadly classified into three groups. They are black soils, alluvial soils and hilly soils. Soil map of the district is given as figure no 3.3.

Figure No. 3.3 Soil Map of Vadodara District



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[2] Technical Bulletin- Revised (No. 11) – May 1992 ; Agriculture Information, Directorate of Agriculture, Government of Gujarat, Ahmedabad.

4. HYDROLOGY

4.1. SURFACE WATER RESOURCES

Vadodara district has huge potential of Surface Water Resources, but the irrigation potential created through various sources was only 11,504 hectare according to Season & Crops Report (2001-02)[1]. Till 2003, scope of canal irrigation was limited in spite of the fact that the district has the advantage of having two major river, the Narmada and the Mahi on its borders, besides smaller rives like the Viswamitri, the Orsang, the Heran, the Dadhar etc. Recently, water of the Narmada river have been harnessed by Sardar Sarovar Dam and consequently large part of the district now forms a part of *Narmada Canal Command*. The dam constructed on Mahi at Kadana and Weir at Wanakbori did not produced any direct surface water resources benefit for irrigation in parts of Vadodara district as such Mahi Project command areas falls in neighboring Anand & Kheda district. However, surface water release, from Kadana Dam through Wanakbori weir during lean season, satisfy huge demands of Vadodara City and surrounding many Strategic Industrial Units for their domestic and industrial requirement.

Besides these two major rivers, other rivers of the district such as the Orsang and the Heran do sustain some base flow upto February / March which is being utilized for supplement irrigation at places along their course at suitable places.

5. GEOLOGY

5.1. STRATIGRAPHIC SET UP

The rocks of the Vadodara district shows an age from Proterozoic to Recent but a striking features of the district stratigraphy is the total absence of Paleozoic, and the development of only the uppermost Mesozoic rocks. The south westerly extended Precambrian basement of Peninsular India, the oldest rocks of Proterozoic age, are exposed in eastern and north eastern part of the district. Post Cretaceous sediments & major volcanic rocks rest over this south westerly extended Precambrian basement. Post Cretaceous sediments, Infratrappean and Intratrappean are exposed as scattered inliers while younger volcanic rocks unit as Deccan trap is well represented and so are the Tertiary and Quaternary, though the Tertiary records are not complete and fully exposed. The stratigraphic outline of the district is given in table no. 5.1.

Table No. 5.1 Stratigraphic outline of the Vadodara District

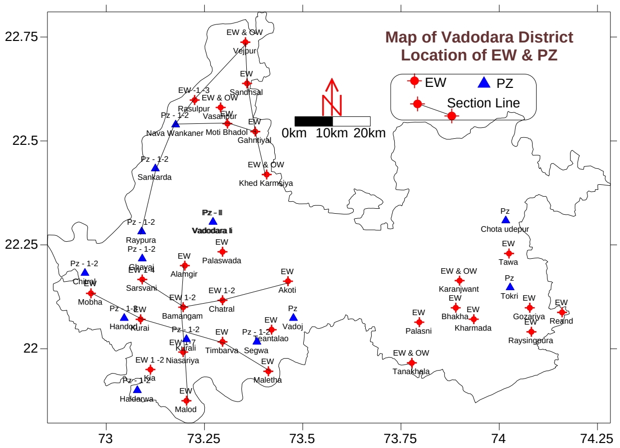
Continental sediments – fluvio-marine, fluvial and aeolian	Quaternary
Marine and fluvio-marine sediments	Tertiary
……………………………………Unconformity……………………………………………….	
Basalts of the Deccan Trap with associated differentiates and intrusive bodies	Upper Cretaceous to Lower Eocene
……………………………………Unconformity……………………………………………….	
Marine, fluvio-marine and fluvial sediments	Cretaceous
……………………………………Unconformity……………………………………………….	
Crystalline rocks -Metasediments associated with granite, gneiss and other mafic rocks	Precambrian (Aravalli)

5.2. SUBSURFACE GEOLOGY

5.2.1. Exploration Details

The boreholes drilled by CGWB and erstwhile ETO, as a part of Ground Water Exploration work, in various parts of Vadodara district have revealed the sub surface geological formation in the district. ETO have drilled few boreholes in parts of the district and adjoining Bharuch & Kheda during under various program. Then CGWB have drilled 14 Boreholes in 'Outfall Area of Narmada Project' (1972-1978) in parts of Vadodara district & Bharuch district. Then under piezometer construction program, few bore holes were drilled in parts of Padara, Karjan, Dabhoi, Vadodara & Savli Taluka areas during 1988 -90. Recently exploration in hard rock areas of northern & eastern parts of the district has been under progress since 2002-04. Map showing locations of all such sites is given as figure No. 5.1

Figure No. 5.1 Location of Exploratory Wells & Piezometers



6. HYDROGEOLOGY

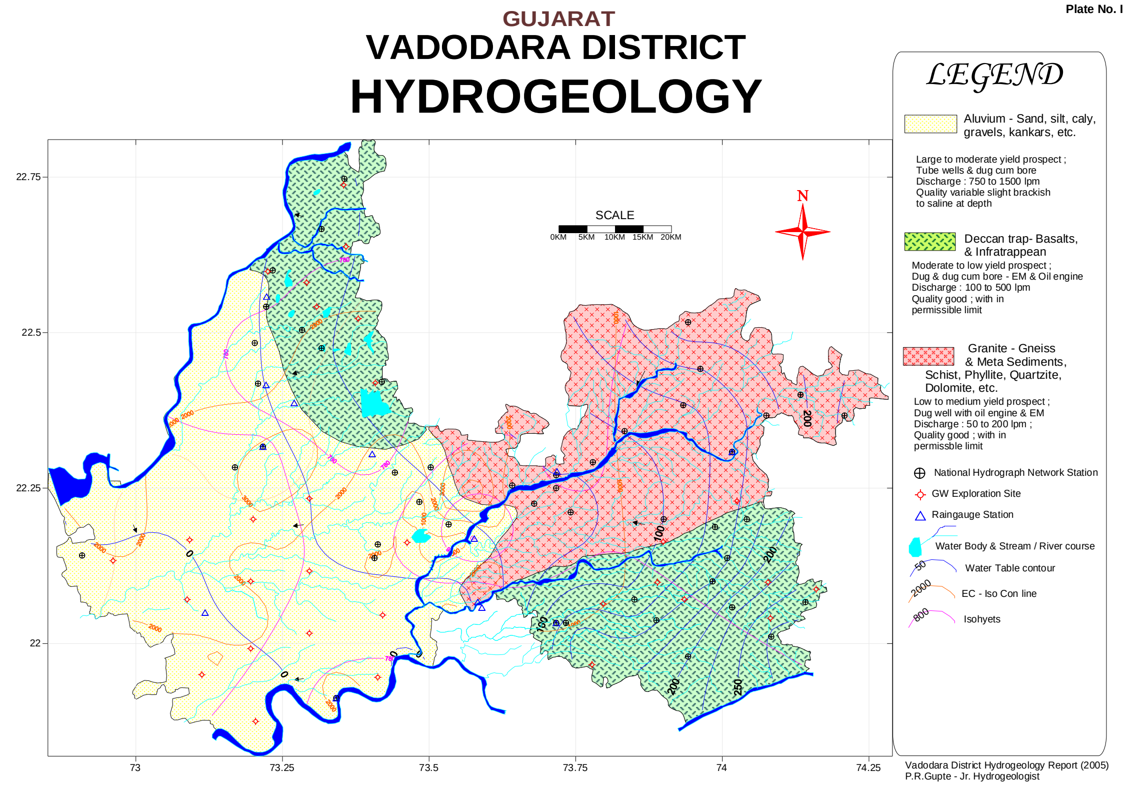
6.1. OCCURRENCE & DISTRIBUTION OF GROUNDWATER

In Vadodara district area, groundwater occurs both as unconfined and confined conditions. Saturated zones of unconsolidated shallow alluvium and weathered zones, shallow depth jointed and fractured rocks forms unconfined aquifers, whereas multilayered aquifer below impervious clay horizons in alluvium formation and interflow zones of basalts, inter-trappean beds, deep seated fracture zones, shear zones in basalts, granites and gneisses give rise to semi confined to confined conditions.

Generally the water table follows topographic configuration. The depth to water is greater in upland areas whereas in valley portion and shallow grounds, the levels are very close to surface. In hilly terrain of eastern, north- east and south-east part of the district, spring zones are seen in stream river section; also along the section of the Mahi, the Narmada and the Orsang rivers. The piezometric surface, mainly in alluvium areas of western half the district also follows the gentle gradient corresponding to subsurface configuration of deep aquifer zones.

In major part of the district, in north and almost in eastern half of the district, the hard rocks, such as phyllite, schist, granite, gneiss, basalt and other sediments such as sandstone, limestone etc., form aquifers, whereas multilayered alluvium deposits form aquifer system in remaining central, south-central and western half of the district. The weathered basalts, granite, gneiss etc., covered by soil / *muram* and the valley fill & piedmont deposits forms potential aquifer in the vicinity of rivers and on vast undulating plains adjacent to hilly terrain but their regional continuity and extent are limited due to heterogeneous nature of deposits with limited thickness and as such rarely exceed a few square kilometers. Map showing general hydrogeology of the district is given as figure no. 6.1.

Figure 6.1 Hydrogeological Map of Vadodara District.



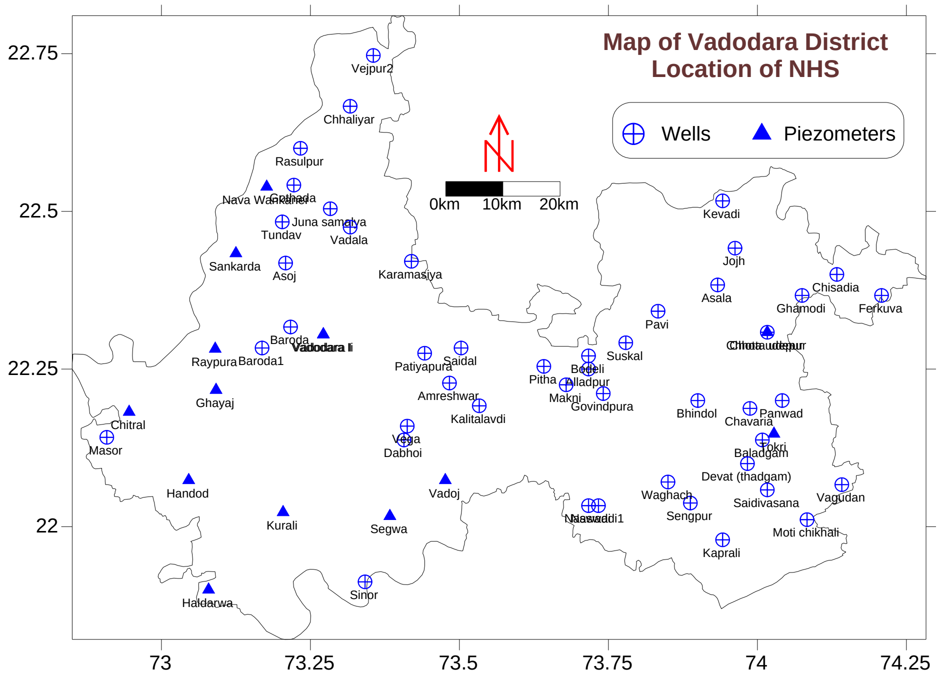
6.2. GROUND WATER STRUCTURES

Vadodara district area has varied ground water extraction structures, appropriate to different hydrogeological units and necessity. Various types of dug wells (DW) are common to both alluvial / soft rock areas and also in hard rock areas. In unconsolidated formation the depth of dug well is few meter to more than 25 m; while in hard rock areas, generally their depth depends upon weathering zone, through which they have curbing and below it have naked zone. With declining water levels along with rapid development, bore well of 30 to 90 m depth are drilled at bottom of dried up dug well section and such well are termed as *dug cum bore well (DCB well),* are common in both unconsolidated & consolidated formation of the district. In consolidated rock units, especially in Deccan Trap areas, horizontal bores at the bottom of the well, with gentle gradient towards well are common. Large dia, collector type wells, generally for regional water supply or for industrial uses are common in sandy beds of Mahi and Orsang rivers. To meet large demands bore well / tube wells are common structures. There are shallow bore wells up to 60 to 80 m depth both in consolidated and unconsolidated areas. Such bore well, in hard rock areas are drilled for hand pump and also for irrigation purposes. In unconsolidated arrears, in areas of Quaternary alluvial deposits having deep aquifer, deep tube wells up to 200 m depth are common.

6.3. GROUNDWATER REGIME MONITORING

Ground water regime monitoring is the basic component of groundwater management, and it is carried out in parts of Vadodara district through National Hydrograph Network Stations (NHNS or NHS). NHSs are observation wells, consisting of dug wells and purpose built bore wells – known as piezometers. There are 36 NHS as shown in Map of NHS in figure no 6.1. Through these observation wells ground water levels are monitored four times of each year. Water samples are collected during pre-monsoon period i.e., during May monitoring and is subjected to complete chemical analysis to know its chemical constituents

Figure No. 6.1 Map showing location of NHS



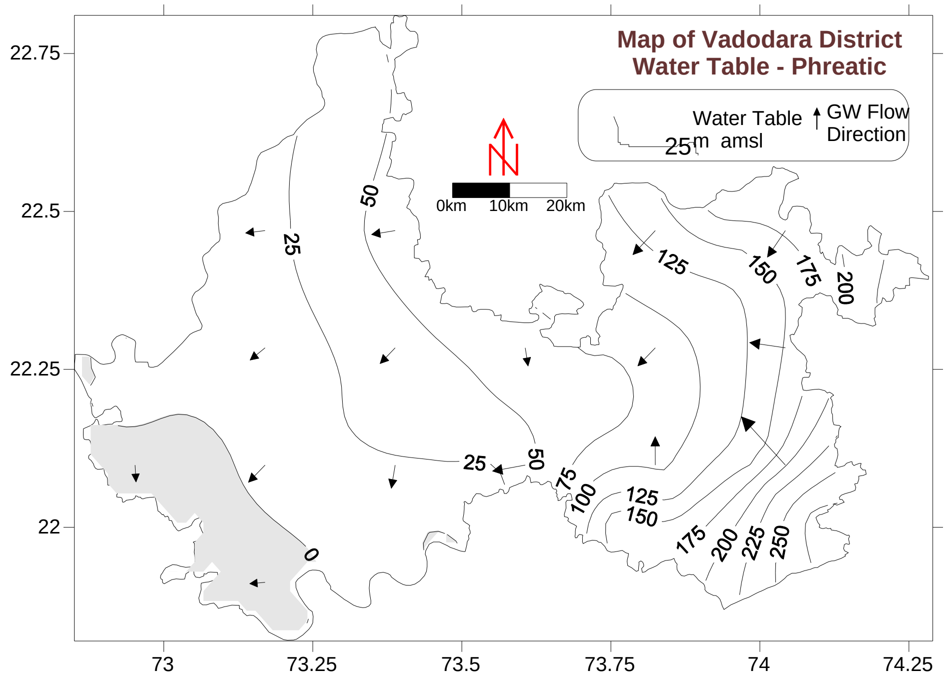
6.3.1. Water Level Map

Various maps prepared on the basis of available data of NHS monitoring and other data, incorporated from the systematic and reappraisal hydrogeological surveys carried out in the district areas, are described as follows.

6.3.1.1.Water Table Map

The figure 6.2 shows the water table map in the district. The movement of ground water in general, from north-east highland to south-west and western low lying Mahi Rive estuary zone. In north – east areas and also along area along Mahi & Narmada River in west and south, the counters show effluent nature of all streams, rivulets and rivers. The gradient is steep in eastern hilly terrain, a hard rock terrain. It becomes gentler towards central and western part of semi-consolidated to un-consolidated formation areas.

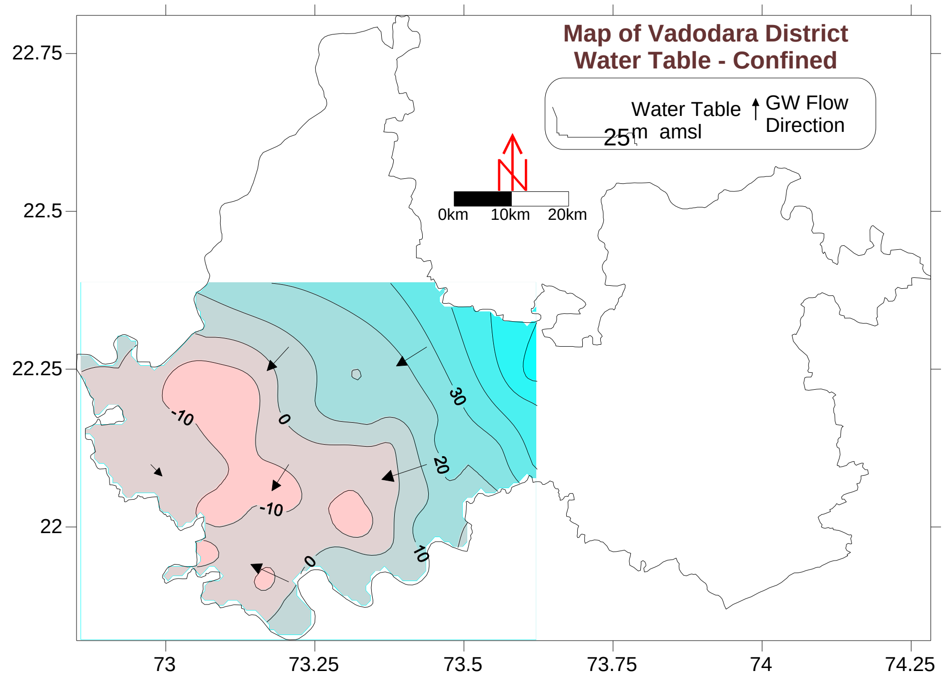
Figure No. 6.2 Water Table Map



6.3.1.2.Piezometric Surface Map

The figure 6.3 shows the piezometric surface map, in the areas having deep aquifer system, on the basis of data collected during the systematic and reappraisal surveys. The piezometric surface range from 40 m amsl in north central to 0 m amsl in southwest corner of the district. Groundwater through (below -10 m amsl) observed in southwestern part of the district where ground water development through deep aquifer is high.

Figure No. 6.3 Piezometric Surface Map



7. GROUND WATER RESOURCES ESTIMATION

Estimation of Ground Water Resources for Gujarat State (GWRE-2002)[3] has been carried out by the Government of Gujarat as per the 'Ground Water Resources Estimation Methodology GEC –1997'[4] set up by Ministry of Water resources, Government of India. The ground water resources of Vadodara district are as follows.

As per GWRE 2002, ground water recharge during monsoon season has been computed using water level fluctuation method and compared with recharge by the infiltration factors. Depending upon percent deviation value, Gross Recharge has been calculated as per the recommended methodology. Besides rainfall, the recharge due to seepage from canal, return flow from irrigation, recharge from tanks, ponds & water conservation structures, etc. were also considered. The total annual recharge was obtained as the sum of the monsoon and non-monsoon periods comes out to be 1053.03 MCM per year. It has been decided to keep a provision at rate 5 % of the annual ground water recharge, when water table fluctuation method is followed for the computation. Making provision of 52.65 MCM (@ 5 %) for environmental /runoff purposes, net annual ground water availability is worked out to be of 1000.37 MCM per year.

The level of ground water development in an area is taken as the ratio of existing gross ground water draft for all uses to available ground water recharge and it is expressed as %. Thus the level of ground water development at year 2002, in all the taluka of the Vadodara district computed range from 23.00 % to 103.11 %. The average for district is 53.50 %. As per *GWRE* [3] norm, the units of assessment (talukas) can be categorized for ground water development in different categories such as *Safe, Semi-critical, Critical* and *Over Exploited*, based on the stages of ground water development and the long-term trend of pre and post monsoon ground water levels. Level of Ground Water Development and Categorization for all talukas of Vadodara district and as a whole district is given in table no. 7.1.

Table No. 7.1 Level of Groundwater development - Vadodara district

Name of Taluka	Available Ground Water Recharge in MCM / Year	Existing Gross Ground Water Draft for all uses in MCM / Year	Level of Ground Water Development (%)	Category
Chhota Udepur	55.61	26.93	48.42	Safe
Dabhoi	123.52	84.91	68.74	Safe
Karjan	161.31	137.71	85.37	Semi Critical
Kavant	29.36	19.14	65.20	Safe
Naswadi	34.19	12.17	35.59	Safe
Padra	113.01	77.73	68.78	Safe
Pavi Jetpur	99.96	60.45	60.47	Safe
Sankheda	66.26	35.96	54.27	Safe
Savli	71.35	37.56	52.65	Safe
Sinor	80.99	64.76	79.96	Semi Critical

[3] Report on Estimation of Ground Water Resources and Irrigation Potential in Gujarat State, GWRE-2002, (June – 2004) by NWR, WS & K Department, Government of Gujarat, Gandhinagar

[4] Report of the Ground Water Resources Estimation Committee (June 1997), Ministry of Water Resources, Government of India.

Vadodara	100.99	104.12	103.10	Over Exploited
Vaghoriya	63.84	14.69	23.01	Safe
Total	1000.38	676.13	67.59	Safe

8. HYDROCHEMISTRY

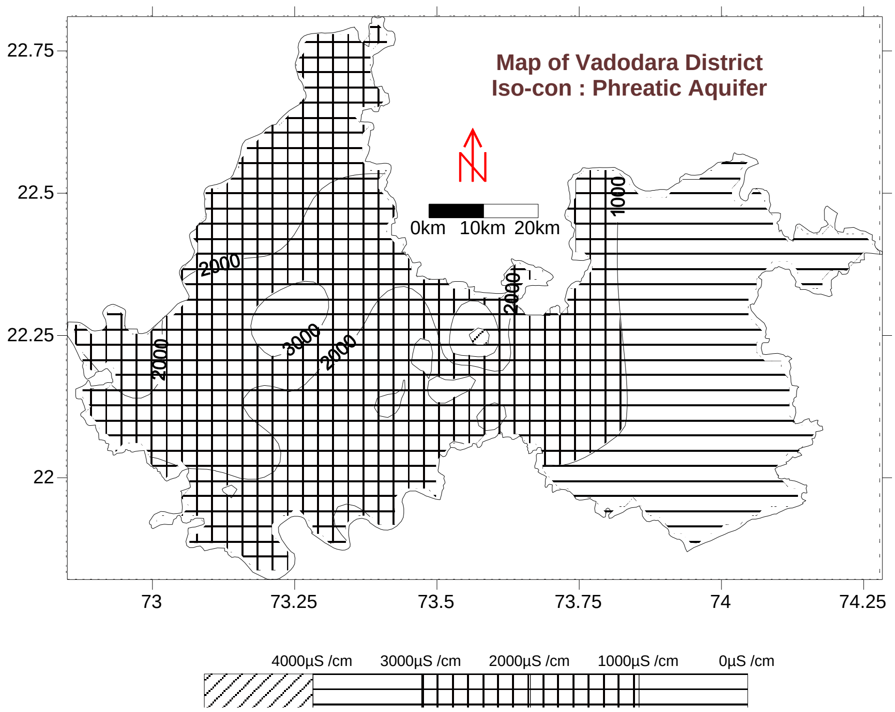
The Vadodara district has main three hydrogeological provinces, Aravalli terrains, Deccan trap & associated Cretaceous sediments terrains and Alluvium areas. Each terrain also have varied hydrological regime, as shown in basin map. During the course of systematic and reappraisal hydrogeological surveys water sample were collected from the wells inventoried in all these ares. Further water samples are also collected periodically from National Hydrograph Stations in the district. On the basis of chemical analysis of such water samples hydrochemistry of shallow and deeper aquifers are describe as follows.

8.1. QUALITY OF SHALLOW GROUND WATER

It is observed that the quality of ground water in shallow aquifer varies as per the nature of underlying formation. Generally in hard rock areas of eastern part overall quality is uniform, good in nature, whereas in western part, in alluvium area quality varies widely, have high concentration of dissolved ions (TDS).

Based on the analytical results of about 100 samples distributed throughout the district, collected during various surveys (1994-95), map depicting areal distribution of electrical conductance (Iso-con map), measures of dissolved ions, in phreatic aquifer is prepared and given as figure No.8.1

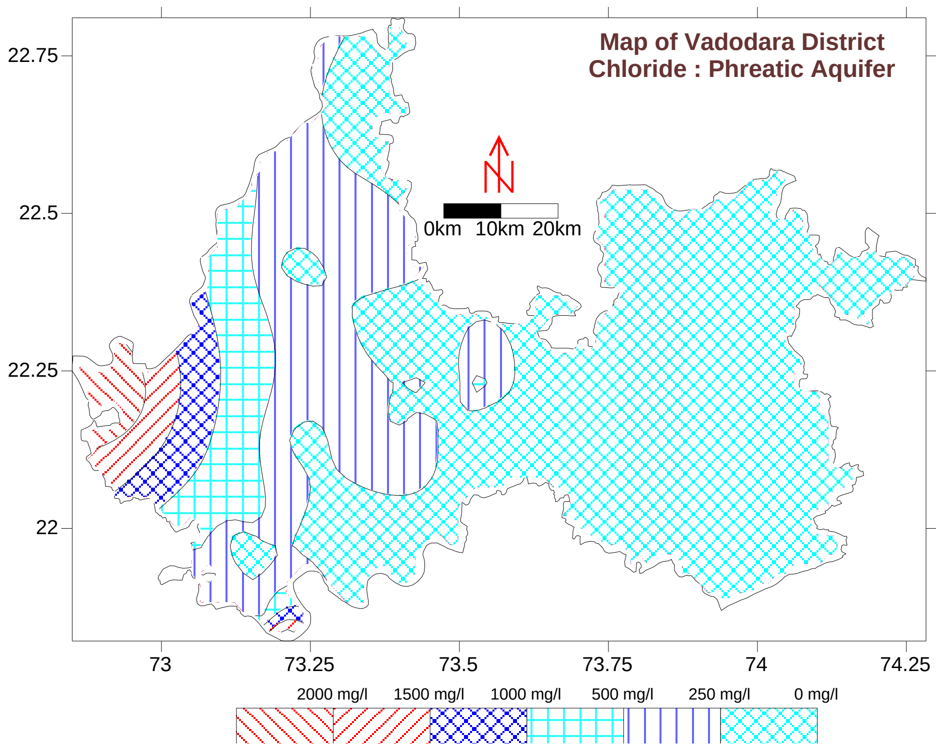
Fig. No. 8.1 Iso-con map of Vadodara district



The Iso-con map (Fig. 8.1) reveals that E.C. of ground water varies from less than 380 µS /cm to more than 4000 µS/cm in the district In central part of *Mahi-Narmada Doab* where thickness of alluvium is limited (14-40m) and is underlain by Tertiary sediments, have ground water quality with relatively high electrical conductance (more than 3000 µS /cm). Similarly in some localized pockets of alluvium area, overlying Deccan trap rocks, in parts of Vaghoriya, Vadodar & Dabhoi Taluka areas also have high EC groundwater. In in areas of consolidated formations – hard rock areas and also along Mahi river alluvium zone, ground water with EC less than 2000 µS /cm are observed. The high EC areas in south central part have formation having inherent salinity.

An iso-chloride (Iso- chloride) map for the phreatic aquifer is also prepared and presented in fig no. 8.2, shows gradual variation in chloride content from east to west. However , in major part of the district chloride content is less than 250 ppm, which gradually increase westward and towards Mahi Estuary zone reaches to highest of 2800 ppm.

Figure No. 8.2 Iso-chlor map of Vadodara district



8.2. QUALITY OF DEEP GROUND WATER

The quality of ground water in the confined a1quifer has been determined by analysis of water samples collected during various surveys. Study of exploratory boreholes geophysical logs also reveals the nature of formation water quality at various depths. Plot of electrical conductance of deep aquifer water samples shows that in major part of confined aquifer zones, ground water is within range of 2000 µS / cm range. More than 2000 µs / cm are observed in areas where Tertiary formation is at depth. Towards east, in Padra Taluka area and southeast of Vadodara city also have high mineralized ground water at depth. Deterioration of ground water quality is observed from central part of the district to the eastern fringe at Mahi Estuary zone.

8.3. HYDROCHEMICAL REGIME

Based on the study of hydrochemical nature of ground water, the district can be divided into following distinct areas, such as

i) Areas with fresh ground water at all levels : In this category are included area where ground water is fresh with in 200 m explored depth, both in phreatic as well as confined aquifer, which can be used for irrigation and domestic consumption.

ii) Areas with fresh ground water overlain by saline ground water: In this category phreatic ground water quality with high mineral content is underlain by relatively low mineralized ground water.

iii) Area with fresh ground water is underlain by saline ground water: In this category phreatic ground water quality with low mineral content is underlain by relatively highly mineralized ground water.

iv) Areas with saline ground water at all levels :

Map showing all such spatial variation of ground water quality regime is given below as figure no. 8.3 & 8.4.

Figure No. 8.3 Iso-Con map – Confine Aquifer – Vadodara District

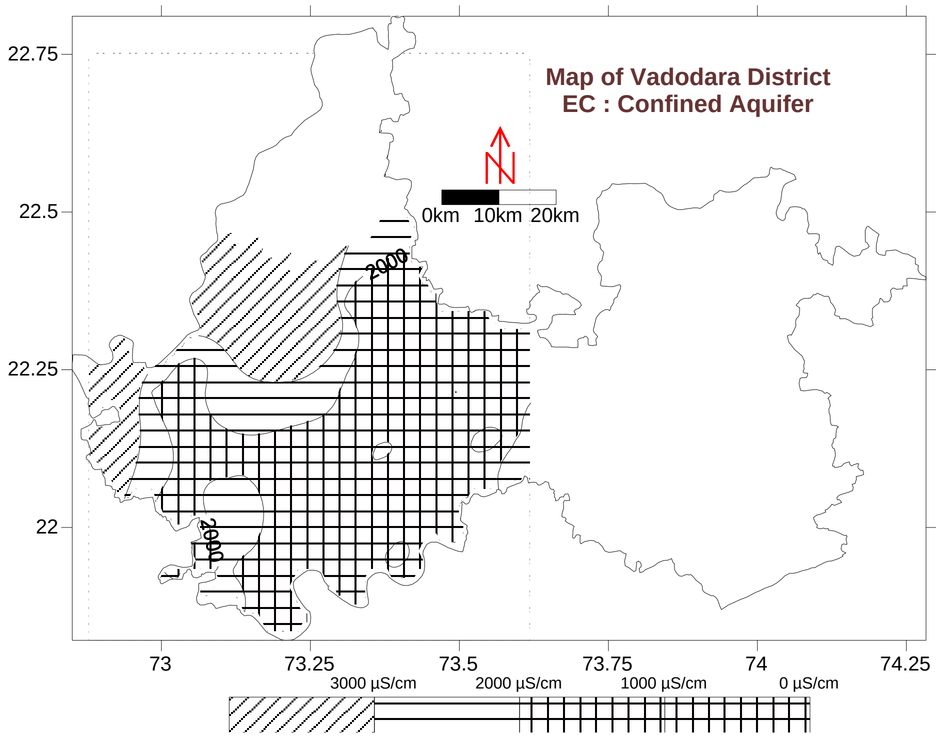
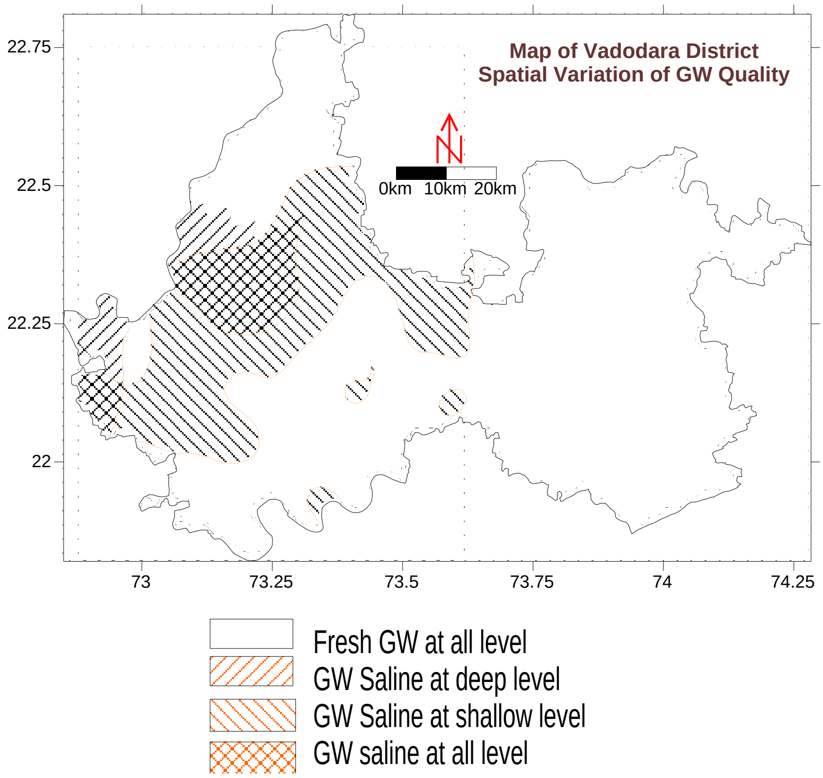


Figure No. 8.4 Spatial variation of ground water quality – Vadodara district



8.4. WATER POLLUTION

Vadodara district is one of the highest industrialized districts in the state. The noteworthy notified industrial areas are IPCL Complex (Petrochemicals & Oil Refinery), GSFC Complex, Nandesari Complex and other industrial estates. Gujarat Pollution Control Board (GPCB)[5], in their survey found that rapid industrialization and concurrent urbanization have had adverse impact on vital environment parameters like water and air of these areas. It was observed that different analytical values, in terms of pH, TDS, DO, BOD, COD, NH_3N and NO_2 + NO_3 , for rivers of the district, namely Mahi, Mini, Vishwamitri and Dhadhar have crossed the critical levels to become harmful for living flora and fauna.

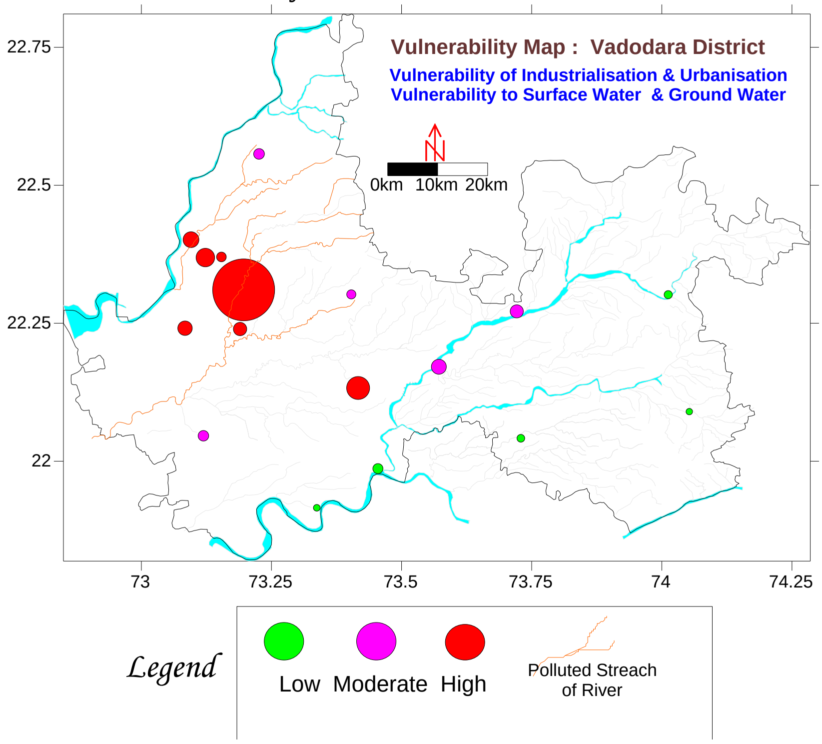
8.5. VULNERABAL AREA

8.5.1. Vulnerability of shallow aquifer to pollution

Large part of the Vadodara district is urbanized and also have industrial activities. In event of uncontrolled development and lack of adequate infrastructure for effective treatment and safe disposal of effluents and solid waste, these areas would be prone to ground water pollution. These may ultimately result in deterioration of ground water quality, mostly in phreatic zones in down gradient areas. A map showing vulnerability to ground water & surface water bodies, as consequence of pollution in urban & industrial zones, in the basic three groups (high, moderate and low) is given as figure no. 8.5.1. The area of circle is proportional to sources of pollution (size of urban & industrial areas).

[5] A report on the status of air and water of Gujarat (May 1988), GPCB, Gandhinagar.

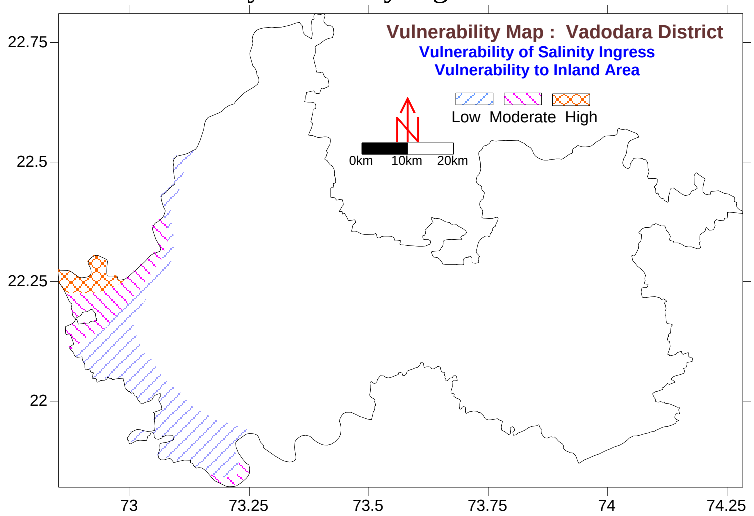
Figure No. 8.5.1 Vulnerability of Industrialization & Urbanization



8.5.2. Vulnerability of ground water to saline ingress

Under natural system, two main rivers of the district, the Mahi & the Narmada has tidal ingress up to few kilometers inland from their estuarine zone. With construction of major dam on Mahi (1970), there has been drastic reduction in flow of river in down stream area of dam. Coupled with ever increasing high ground water development, the base flow is reducing drastically since last two decades and ultimately tidal water ingress came several kilometers inland. Same situation is likely to be envisaged in areas of Narmada River after completion SS Dam in next few years. With basis attributes of base flow data of rivers, rate of ground water development, aquifer disposition & water level & quality data etc., a map showing vulnerability to ground water source of saline ingress in the basic three groups (high, intermediate and low) is given as figure no. 8.5.2

Figure No. 8.5.2 Vulnerability of salinity ingress



8.6. SCOPE OF CONJUNCTIVE USE

The conjunctive use of surface and ground water resources is one of the indispensable aspects of sustainable water resource management strategy. In the Vadodara district the main source for irrigation (2002-03) is ground water, which has already high rate of development. Further development of ground water resources for agriculture or for any other sector, in few highly developed Taluka of western half is likely to cause environment imbalance. With commencement of Narmada Project Irrigation, the stress on ground water resources is likely to lessen and there is a great scope to use conjunctively both surface and ground water resources for sustainable development of the district area.

8.7. SCOPE OF ARTFICIAL RECHARGE

The Vadodara district area has moderated to high rate of ground water development, mainly in areas of western part where multilayer aquifer system exists. This area has come under Narmada Irrigation Command since last two years. There is likely to have surplus surface water resources in various stretches of canal command which can be diverted to numerous tanks & dray rivulets of the areas which will help to recharge subsurface dry aquifers. With efficient water management practice, seepage losses and any other surplus water can be diverted to amiable or purposes build structure for artificial recharge.

9. GROUND WATER DEVELOPMENT & MANAGEMENT

9.1. PRESENT GROUND WATER DEVELOPMENT

The estimation of ground water resources of the Vadodara district (2002) show that present ground water development in the district is about 676 MCM, out of which nearly 70 MCM accounted for domestic and industrial purposes while remaining 606 is for irrigation. Taken as a whole district, level of ground water development is about 67 %.

9.1.1. Urban & Rural Water Supply Scheme

Urban and rural water supply of the district is partly based on the ground water as well as surface water sources. Most of the urban areas and also rural area water supply schemes in western half of the district, where unconsolidated formation (alluvium) constitutes main aquifer, are based on surface water sources. The Mahi River is the main source of surface water supply. Major water requirements of many regional water supply schemes of rural areas, Vadodara city and many industrial unit of western part of the district are meet through series of in-take wells (Collector Wells) constructed in river beds. Part of the remaining requirement is augments through local ground water sources. Contrary to this scenario, main source for domestic need in central and remaining eastern half of the district is meet through local ground water resources and augmented partially by surface water sources. In unconsolidated formation area tube wells are the main sources while in hard rock area, dug wells & DCB wells used as ground water sources for domestic need. All the rural areas, mostly the tribal area scattered helmets, have hand- pump (shallow depth (40-80 m) as main local source of drinking & domestic need.

9.1.2. Groundwater for Irrigation

Ground water is most reliable source of irrigation in the district & constitutes nearly 95 % of irrigation sources (2002-03). Moreover, groundwater constitutes more than 70% to 100 % of total cropped areas of the district during *Rabi* & *Summer* season. During *Kharif* season (monsoon) it is mainly used as supplementary but as a reliable source of irrigation in events of failures of required rainfall spell during vital stage of crop development. During remaining two seasons of *Rabi* & *Summer*, it is difficult to satisfy full demand of irrigation in want of other source (rainfall), ground water is sparsely used for less water intensive food crops & for vegetable, fruits or mainly cash crops or essential fodder for livestock. Tube wells are the main sources in the unconsolidated formation in western half of the district while dug wells and DCB wells are the main sources in remaining hard rock areas of the district.

9.2. FEASIBLE GROUND WATER STRUCTURES

9.2.1. Hard Rock Area – Consolidated Formations

Development prospects in this area are more complicated because of the heterogeneity of the formations, non uniformity in the degree and nature of weathered zone and variations in degree and nature of fracturing. Favorable hydrogeological situations in such areas are in the form of valley fill materials, pediplain with weathered residuum and low lying hilly terrain crisscrossed by the lineaments. Almost eastern half of the district have such terrain, in which two mode of development are feasible namely i) the traditional *Dug cum Bore well (DCB well)* and ii) moderate depth Bore Well (BW).

The dimension of DCB well varies in Deccan Trap & Granite /Gneiss areas. In former it have medium diameter of 2 to 4 m with suitable depth (8 to 12 m) tapping the weathered residuum and with additional 50 to 100 mm dia bore well at the bottom, either vertical or two-three sets of slightly horizontal bores with gentle gradient toward well. In granite – gneiss areas, dug well section in general, have large diameter (4 to 8 m) with one or two vertical bores at the bottom the dug well.

The bore wells having diameter of 200 to 150 mm and depth in range of 120 m 200 m appears feasible in hard core areas. There appear to be fairly good prospects for moderate depth bore wells in Deccan Trap areas. Ground Water exploration carried out by CGWB (2004-05) have indicated possibility of tapping potential deep fracture system as a sustained source of water supply. As a point source for drinking water in such difficult areas, about 100 numbers may be attempted. Considering the resource potential of the hard rock terrain about 7,000 irrigation wells (dug & DCB type) are recommended in first phase such that, properly located, designed , constructed and energized bore well may be able to command an area of 2.5 hectare. Construction of remaining 7000 structures may be taken after accessing development of first phase program.

9.2.2. Alluvium – Soft Rock Area – Unconsolidated Formation

Level of ground water development in unconsolidated formation areas, mainly in Vadodara, Padra, Sinor & Karjan Taluka is highest (80 to 100 %). Ground water, in general occurs in semi confined to confine condition in deep 40 to 300 m) depth multilayered aquifer system. The phreatic zone, at most palace is dry or unsaturated to sustain pumping. Main ground water strictures are in form of medium depth (80 to 250 m) tube wells. The depth and yield of tube wells varies as per aquifer disposition. Considering the resource potential of the unconsolidated formation, about 800 irrigation tube wells of 150-200 m depth are recommended in first phase such that, properly located, designed , constructed and energized bore well may be able to command an area of 10 to 15 hectare.

9.3. GROUND WATER MANAGEMENT

Management ground water resources in Vadodara district has to be viewed against the backdrop of varied & complementary economy scenario, i.e., agrarian economy of rural areas and industrial economy of urban and semi –urban areas. Both scenarios are marked by stifled growth due to non availability of vital water resources at critical juncture; i.e. for raising *rabi* & hot season crops in agrarian economy and for crucial need & sustenance, during lean season, of industrial and urban economy. Although, it may be prudent to mention that the present status of ground water development for the whole district is about 67.6 % of the net utilizable recharge, more attention has to be focused for conserving the groundwater endowed with dependability, less cost, better quality, possibility for time bound development and as a 'Safe Point Source' for drinking and related purposes. Various aspects of emerging issues of Water Resources Management, with emphasis on ground water and related environment issues, for both agrarian economy of rural areas and industrial economy of urban and semi –urban areas in context of water resources of the Vadodara district are discusses as follows

9.3.1. Agrarian Economy of Rural Areas

A critical examination of source wise Net irrigated Area of the Vadodara district , during both *Kharif* & *Rabi* seasons, clearly bring out the severe limitations of surface water irrigation as contrast to near reliable nature of ground water irrigation. Before commencement of Narmada Irrigation Project, total canal irrigation in Vadodara district, year 2001-02 accounted for 5 % of the gross irrigated area. These figures are likely to be increased substantially after reliable supply of surface water supply by Narmada Irrigation Project. It will drastically improve ground water resource scenario, which is facing severe stress due to ever increasing demand since decades. During year 2001-02, contribution of ground water resources during *Kharif, Rabi and Summer* season were 36 %, 70 % and 100 % respectively. With input of additional surface water of Narmada Irrigation Project, stress on ground water resources will be lessening considerably.

9.3.2. Industrial Economy of Urban and Semi –Urban Areas

One of the most significant urban changes in Vadodara district areas has been the growth of cities to unprecedented sizes. Although rapid urban change during last few decades is often viewed as an uncontrolled flood of people, but there is an economic logic underpinning global urban trends The great migrations of people from rural to urban areas all over the district, during last few decades are proof of their power to attract and dazzle with their promise of a better life. Meeting the water needs of fast-growing cities with competing demands from commercial, domestic and industrial users have put great pressures on freshwater resources. The scenario of such degradation and depletion of freshwater resources would threaten the very livelihood of cities and the sustainability of economic and social development

It is observed that, in general, many urban water systems are poorly maintained, and often large quantity is lost in distribution. Many urban residents and especially the poor get irregular or no water supplies, and no sanitation. For the urban poor, this lack of access to safe water and basic sanitation may cause widespread ill-health that would further limit their productive capabilities. At the same time, revenue collection for much of the urban institutes with poor infrastructures is poor which further restrict operation, maintenance and investment funds for expansion. The scenarios of such are threatening the very livelihood of cities and the sustainability of economic and social development. New ways of responding to rapid change and making the urban environment sustainable should be explored, especially through better management and service pricing, greater participation of community groups and women, and creative partnerships between public and private sector enterprises. Better management of resources in and around urban centers is therefore a major challenge to the administrators all over such areas.

9.3.3. Aspect of Urban Hydrogeolgy

Vadodara district has 5 % of area termed as Urban Area with 47 % population of the district. Amongst various *talukas* (blocks) of the district, Vadodara Taluka with 21,388 hectares area (31 % of *Taluka*) and with 14,92,398 persons (87 % of the *Taluka*) with population density of 6,978 persons per sq.km., is most *Urbanised area* of the district. Most of the urbanized areas lies in western half of the district, relies both, almost equally on surface water supply and ground water supply. The scope of further ground water development in Vadodara, Padra & Karjan Taluka area is limited as these areas is underlain by inferior quality ground water at depth their existing level of development has reached to a critical stage. Besides this natural constraint of limited & poor aquifer potential, other aspects of anthropogenic activities of urban and industrial development, as described follows, demand careful ground water management strategy.

- As a consequent to urbanization & concurrent industrialization, overall demands of water are increasing and cause decline of agriculture in such area. There is extreme disproportionate ratio of agriculture area vs. urban areas in western part of the district.
- Problems relating to inadequate sewerage disposal and industrial waste are posing great environmental hazards in small urban areas, resulting into degradation and depletion of freshwater resources. Natural stream courses of Mini, Vishwamitri & Dhadhar, down to urban & industrial areas have been converted into effluent disposal channels. Many fresh water bodies, tanks in low-lying areas, have become puddles of sewerage water in many towns of the district. Quality of such fresh water bodies are degraded to such an extent, in terms of BOD, COD requirement[5], too support aquatic flora & fauna.
- In addition to pollution problem, an urban & industrial activity greatly increases the consumptive use of water and precludes water recycling, thereby contributing disproportionately to water scarcity. Huge

withdrawal of surface water (base flow) of Mahi River in northwest border of the district for urban and industrial requirement, which ultimately disposed as effluent to the sea, ultimately result dry river bed in downstream portion. This has been explanation to more ingress of tidal water inland & deterioration of already dwindling scare groundwater resources of the area.

- The competitive demands of all three, agriculture, urban and industrial sector encroach upon vital demand of *environment*, which is degraded in most of the urban & industrial areas of Vadodara district.

9.4. STRATEGY FOR GROUND WATER DEVELOPMENT

Based on the scenario of present ground water development and its management aspects and feasible structures, as discussed above, a comprehensive strategy for stepping for optimum utilization of available resource potential may be undertaken. With the concept of “Conjunctive Use for Sustainable Water Resource Management”, large irrigation requirement as well as domestic & industrial need would be satisfied through ‘Narmada Canal’ water. With more focus on other complementary aspect of development, i.e. conservation of water resources, mainly ground water resources, both in space and time such that it can be used efficiently with surface water resources, concept of conjunctive use can be effectively implemented with optimum development strategy. In canal command, conjunctive use management should be such that cumulative draft of ground water should never exceed annual replenisher recharge as per guideline of National Water Policy. Moreover, unilateral development of surface water, without adequate planning for utilization of available ground water, which often leads to undesirable situations like water logging and related soil salinity problems, should be avoided. There are many such areas, prone to water logging, are identified during ‘Pre Irrigation Study’ by the State Government. As per the guideline of NWP every effort has to be made for proper integration and dovetailing of any surface water development especially in canal command areas such so that environment hazards like water logging can be eliminated. At the same time, through adequate back up from the ground water reservoir, duration of canal operation can be extended.