5. GROUNDWATER POTENTIAL

The local geology plays a very important role in the calculation of groundwater potential of any area.

5.1 GEOLOGY OF AREA

The Kutch region is represented by an interesting and unique tectonic and litho-stratigraphic set up and has attracted many earth scientists of international as well as national repute. Tectonically the Kutch region forms a part of one of the most active domains in India. The litho-stratigraphically this region is known for its well developed strato-type Jurassic (Mesozoic) and Tertiary sequences. Although the geology of the Kutch region has been subsequently studied by number of researchers there has been not much change in an overall litho-stratigraphic set up from that of proposed by Biswas and Deshpande (1970). Table 5.1 shows the Geological Sequence for Kutch.

Table 5.1 Geological Sequence for Kutch

Period	Stratigraphic Sequence	Depositional Environment	Lithology	Water Draining Nature
Pliestocene To Recent	Alluvium Miliolite	Fluviatile	Sands, Dark Clays, Miliolite Limestone	Moderate to Good
Pliocene	Manchar	Fluviatile and Estuarine	Sands, Clays, Conglomerates, Motiled Sandstone	Moderate to Good
Miocene	Gaj	Marine	Argillaceous Beds	Poor with Brakish Saline Water
Oligocene	Lower Nari to Lower Gaj	Marine	Arenaceous Beds	Poor Saline
Eocene to Oligocene	Kirthat to Lower Nari	Marine	Nummulitic Limestones	Poor Saline
Palaeocene	Ranikot	Marine and Fluviatile	Supra Trppean Clays Laterite and Bauxite	Poor
Cretaceous to Eocene	Deccan Trap	Volcanic	Basalts and Dolerite	Poor to Moderate
Port Aptian	Bhuj	Lacustrine and Fluviatile	Sandstones, Shales, Silt, Stones and Clays	Prolific to Good
Aptain	Ukra	Marine	Calcareous Shales and Sandstone	Poor
Upper Tithonian to Neocomain	Umia	Marine	Fossilferous and Shales	Poor
Upper Argovian to Portlandian	Katrol	Marine	Sandstone, Shales, Fossilferous	Poor to Moderate
Upper Bathonain to Lower Argovian	Chari	Marine	Yellowish, Olive green Ostite and Calcareous Sandstones	Very Poor
Lower Bathonian	Patcham	Marine	Limestones, Conglomerates and Golite	Very Poor

(Source : Biswas S K (1980))

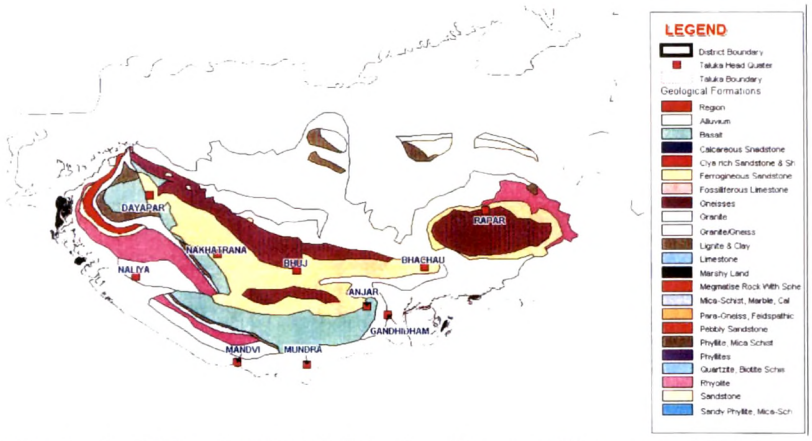

Figure 5.1 Geological Map for Kutch District *(Source: Biswas and Deshpande (1970))*

Taking into consideration the factors of altitude, slope and ruggedness of relief, Kutch can be divided into four main physiographic units from north to south, viz., 1.The Ranns, 2.The low lying Banni Plain, 3.The Hilly Region and 4.The Southern Coastal Plains as shown in Figure 5.2. The above four units show considerable diversity within each of them, depending on the rock types, their mode of occurrences and fault patterns.

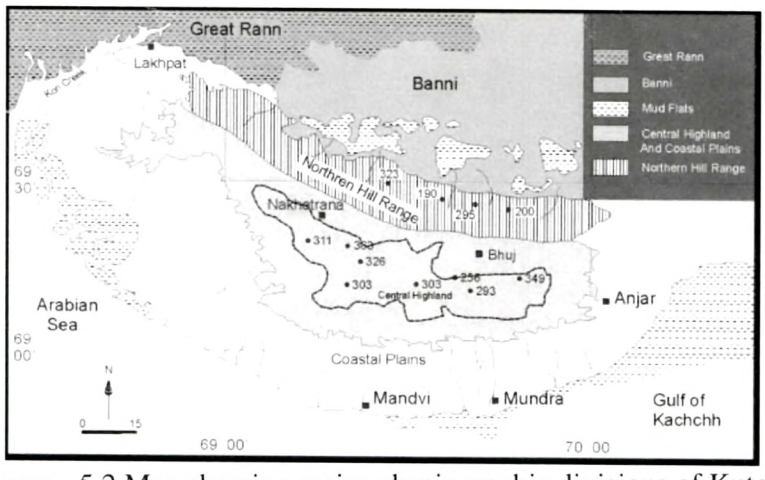

Figure - 5.2 Map showing major physiographic divisions of Kutch
(Source: Biswas and Deshpande (1970))

5.2 SOILS OF KUTCH

The soils of Kutch can be mainly classified into:
(1) Clayey
(2) Sandy clay
(3) Clayey medium black
(4) Sandy clayey and medium black

Though other types such as loamy, silty and clayey are also found at certain places, the northern part of the district is dominated by desert and sandy soils which are mostly salt

affected soils. Proceeding southwards, the interior area is composed of either sandy or medium black soils. The southern part of the district comprising the coastal area around Mandvi and Mundra has saline soils suitable for cultivation. The eastern part is mostly plain with some rocky patches where the soil is sandy with clay and alluvial loam in some parts. The central portion is hilly and rocky with strips of cultivable lands along the lower slopes. The soil is poor but due to better underground water currents in this part the irrigation facilities are adequate. In the western part, the soils are mostly sandy with patches of fine sandy loams having no scope for well irrigation. The soils in Kutch are generally poor in plant nutrients and lime content in most of them is quite high. Table 5.2 shows the talukawise distribution of the type of soils. The distribution of the type of soil for all the talukas has been shown in Figure 5.7.

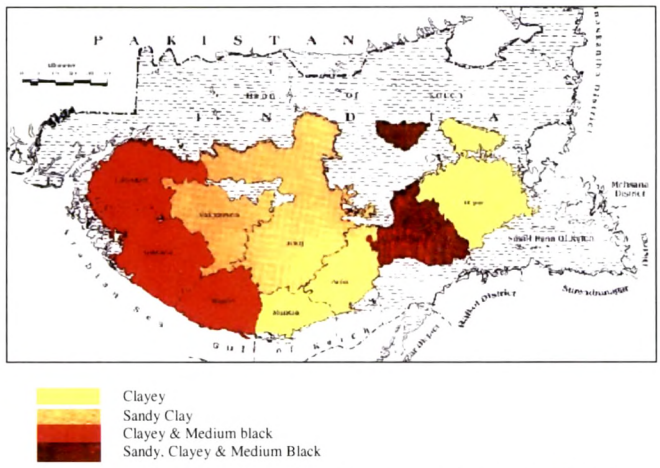

Figure 5.3 Map showing types of Soils in Kutch
(Source: GWRDC)

Table 5.2 Types of Soils

Type of Soil	Taluka
Clayey	Mundra
Sandy Clay	Bhuj, Anjar Rapar Nakhatrana
Clayey & Medium black	Lakhpat Mandvi Abdasa
Sandy, Clayey & Medium Black	Bhachau

5.3 LITHOLOGY OF AREA

The lithology of any area plays an important role in calculating the groundwater potential at any spot.

5.3.1 Sub-surface Geological Cross-sections

Two subsurface geological cross sections for have been taken to study the variation in the ground water table. The same have been shown here. It shows that although the top soil of the region may vary, most of the area consists of sand-stone which is being intercepted by shale at few locations. Figure 5.9 shows the location of the section lines in

the study area, Figure 5.10 shows the details at section AA and Figure 5.11 shows the details at section BB.

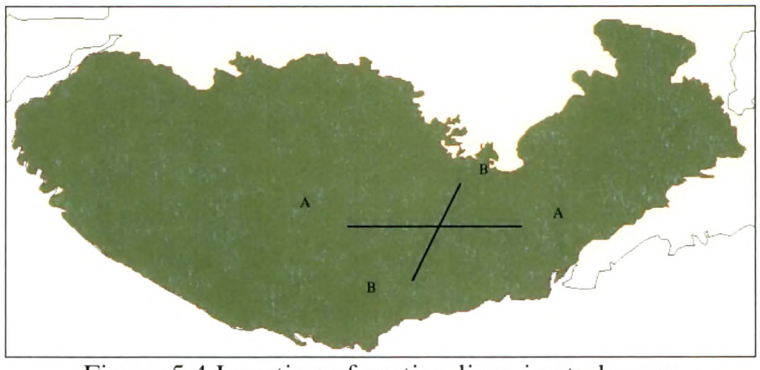

Figure 5.4 Location of section lines in study area

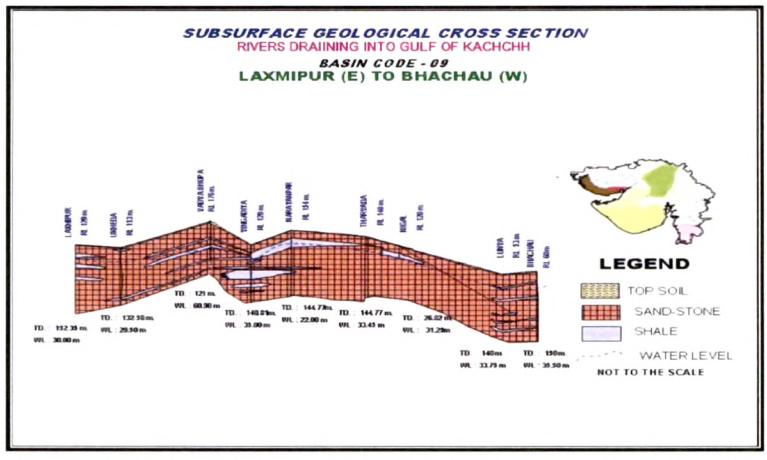

Figure 5.5 Subsurface geological cross-section at Section AA for Kutch District (Source: GWRDC)

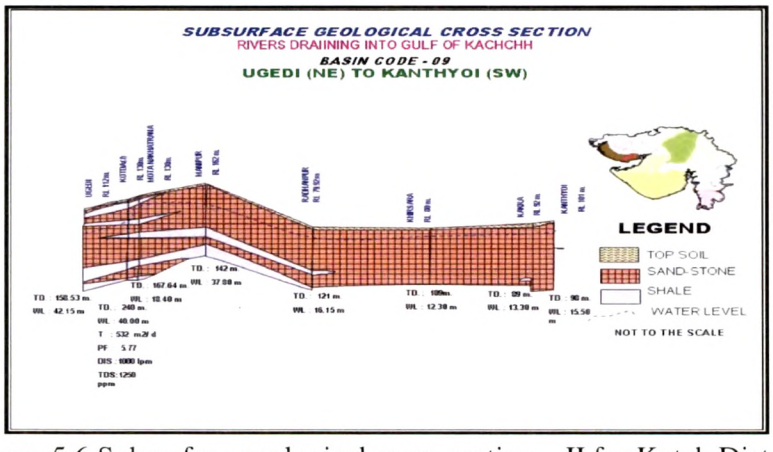

Figure 5.6 Subsurface geological cross-section – II for Kutch District (Source: GWRDC)

5.4 OPEN WELLS IN KUTCH

Gujarat Water Resources Development Corporation (GWRDC) has set up several observation wells, tubewells and piezometers in Kutch. Observations for the pre-

monsoon and post-monsoon for ground water table have been considered for the purpose of the study for the period 1989 to 2007. Figure 5.12 shows the location of the observation wells for Kutch district. The details of the locations of the wells for each taluka have been given in the alphabetical order of the names of the talukas.

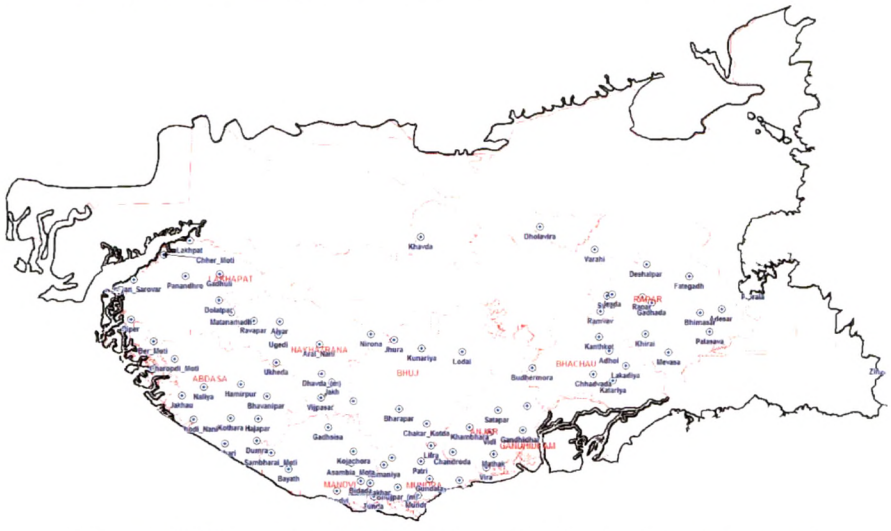

Figure 5.7 Map showing locations of Observation Open wells
(Source: GWRDC)

5.4.1 Anjar Taluka

The general details of the open wells for Anjar taluka are as follows.
Basin: West Coast Minor
Rainfall Station: Anjar

Table 5.3 Details of Open wells for Anjar Taluka

Village	Sub Basin	Minor Basaltin	Geology	Latitude	Longitude	Height of Measuring Point in m	R.L. in m	stratigraphy
Gandhi-dham	Sang	Sang	Alluvial	23°05'22"	70°08'50"	0.60	8.40	Recent to Sub recent
Vidi	Sang	Sang	Sandstone	23°04'58"	70°00'43"	0.60	70.50	Cretaceous
Mathak		Local Basaltin	Limestone	22°59'45"	70°01'32"	0.40	37.11	Pliestocene
Vira	Lerakh	Lerakh	Limestone	22°56'36"	69°59'45"	0.70	16.55	Pliestocene

(Source: GWRDC)

5.4.2 Bhachau Taluka

The general details of the open wells for Bhachau taluka are as follows.
Basin: West Coast Minor
Geology: Alluvial
Rainfall Station: Bhachau
Stratigraphy: Recent to Sub Recent

Table 5.4 Details of Open wells for Bhachau Taluka

Village	Sub Basin	Minor Basaltin	Latitude	Longitude	Height of Measuring Point in m	R.L. in m
Lakadiya	Khari	Khari	23°20'24"	70°34'21"	0.20	45.99
Katariya	Khari	Khari	23°17'01"	70°36'09"	0.30	23.64

(Source: GWRDC)

5.4.3 Bhuj Taluka

The general details of the open wells for Bhuj taluka are as follows.
Basin: West Coast Minor
Geology: Sandstone
Rainfall Station: Bhuj
Stratigraphy: Cretaceous

Table 5.5 Details of Open wells for Bhuj Taluka

Village	Sub Basin	Minor Basaltin	Latitude	Longitude	Height of Measuring Point in m	R.L. in m
Jhura	Kaila	Kaila	23°26'22"	69°37'04"	0.20	6.92
Bharapar	Nagwati	Nagwati	23°10'03"	69°38'19"	1.20	160.87

(Source: GWRDC)

5.4.4 Lakhpat Taluka

The general details of the open wells for Lakhpat taluka are as follows.
Basin: West Coast Minor
Geology: Alluvial
Rainfall Station: Lakhpat
Stratigraphy: Recent to Sub Recent

Table 5.6 Details of Open wells for Lakhpat Taluka

Village	Sub Basin	Minor Basaltin	Geology	Latitude	Longitude	Height of Measuring Point in m	R.L. in m	Stratigraphy
Narayan sarovar	Kori creek	Local Basaltin	Limestone	23°40'35"	68°32'32"	1.35	9.03	Pliestocene
Panandhro	Kali	Kali	Limestone	23°41'17"	60°45'05"	0.40	38.90	Pliestocene
Chher Moti	Kapurasi	Kapurasi	Limestone	23°45'59"	68°38'40"	1.20	10.91	Pliestocene
Lakhpat	Naira	Naira	Limestone	23°50'31"	68°46'51"	1.30	13.12	Pliestocene
Gadhuli	Kali	Kankavati	Sandstone	23°41'51"	68°53'16"	0.00	103.61	Cretaceous
Dolatpar	Kali	Chock	Sandstone	23°35'51"	68°53'16"	0.60	117.05	Cretaceous

(Source: GWRDC)

5.4.5 Mandvi Taluka

The general details of the open wells for Mandvi taluka are as follows.
Basin: West Coast Minor
Geology: Alluvial
Rainfall Station: Mandvi
Stratigraphy: Recent to Sub Recent

Table 5.7 Details of Open wells for Mandvi Taluka

Village	Sub Basin	Minor Basaltin	Geology	Latitude	Longitude	Height of Measuring Point in m	R.L. in m	stratigraphy
Kojachora	Rukmavati	Rukmavati	Basalt	23°00'34"	69°28'52"	0.45	66.75	Cretaceous to Lower Eocene
Asambia Mota	Rukmavati	Rukmavati	Sandstone	22°57'53"	69°26'16"	0.80	61.77	Cretaceous
Mandvi	Rukmavati	Rukmavati	Alluvial	22°05'09"	69°22'46"	1.00	19.60	Recent to Sub recent
Bidada	Khari	Khari	Alluvial	22°53'33"	69°28'31"	0.40	25.49	Recent to Sub recent
Bayath	Vengodi	Vengodi	Alluvial	22°56'24"	69°10'43"	0.70	29.26	Recent to Sub recent
Gadsisa	Kharod	Kharod	Sandstone	23°05'54"	69°20'34"	0.90	134.64	Cretaceous

(Source: GWRDC)

5.4.6 Mundra Taluka

The general details of the open wells for Mundra taluka are as follows.
Type of well: Dug Well
Basin: West Coast Minor
Rainfall Station: Mundra

Table 5.8 Details of Open wells for MundraTaluka

Village	Sub Basin	Minor Basaltin	Geology	Latitude	Longitude	Height of Measuring Point in m	R.L. in m	stratigraphy
Patri	Bhukhi	Bhukhi	Basalt	22°57'38"	69°43'38"	0.85	65.25	Cretaceous to Lower Eocene
Gundala	Bhukhi	Bhuki	Alluvial	22°54'06"	69°45'42"	0.75	34.36	Recent to Sub recent
Mundra	Bhukhi	Bhuki	Alluvial	22°50'18"	69°42'57"	1.00	12.93	Recent to Sub recent
Bhjpar	Nagwati	Nagwati	Alluvial	22°52'11"	69°37'49"	0.60	24.23	Recent to Sub recent
Beraja	Nagwati	Nagwati	Basalt	22°58'51"	69°36'30"	1.50	64.50	Cretaceous to Lower Eocene

(Source: GWRDC)

5.4.7 Nakhatrana Taluka

The general details of the open wells for Nakhatrana taluka are as follows.
Basin: West Coast Minor
Geology: Sandstone
Rainfall Station: Nakhatrana
Stratigraphy: Recent to Sub Recent

Table 5.9 Details of Open wells for Nakhatrana Taluka

Village	Sub Basin	Minor Basaltin	Latitude	Longitude	Height of Measuring Point in m	R.L. in m	stratigraphy
Vijpasar	Kankavati	Kankavati	23°13'01"	69°18'40"	0.30	179.30	Cretaceous
Dhavda	Bhukhi	Bhukhi	23°18'41"	69°19'5 "	0.00	134.27	Cretaceous
Aralnani	Kadral	Kadral	23°25'33"	69°18'21"	0.35	61.06	Cretaceous
Nirona	Nirona	Nirona	23°27'49"	69°31'16"	0.20	19.50	Cretaceous
Ukheda	Mithi	Mithi	23°21'14"	69°07'36"	0.00	128.47	Cretaceous

(Source: GWRDC)

5.4.8 Naliya Taluka

The general details of the open wells for Naliya taluka are as follows.
Basin: West Coast Minor
Geology: Alluvial
Rainfall Station: Naliya
Stratigraphy: Recent to Sub Recent

Table 5.10 Details of Open wells for Naliya Taluka

Village	Sub Basin	Minor Basaltin	Geology	Latitude	Longitude	Height of Measuring Point in m	R.L. in m	Stratigraphy
Bhavanipur	Naira	Naira	Limestone	23°13'31"	69°05'6 "	0.00	65.54	Pliestocene
Hajapar	Kankavati	Kankavati	Limestone	23°07'55"	69°03'01"	0.60	82.05	Pliestocene
Dumra	Chock	Chock	Limestone	23°02'31"	69°02'58"	0.00	33.89	Pliestocene
Suthari	Naira	Vegadoi	Alluvial	23°02'20"	68°54'46"	0.20	9.96	Recent to Sub recent
Kotharia	Naira	Naira	Alluvial	23°08'10"	68°56'09"	0.60	29.90	Recent to Sub recent
Hamirpur	Khari	Mithi	Limestone	23°16'02"	68°58'40"	0.90	70.70	Pliestocene
Naliya	Khari	Local Basaltin	Limestone	23°15'35"	68°49'26"	1.35	24.40	Pliestocene
Ber Moti	Bhurud	Bhurud	Sandstone	23°26'08"	68°36'14"	1.20	35.32	Recent to Sub recent

(Source: GWRDC)

5.4.9 Rapar Taluka

The general details of the open wells for Rapar taluka are as follows.
Basin: West Coast Minor
Geology: Sandstone
Rainfall Station: Rapar
Stratigraphy: Cretaceous

Table 5.11 Details of Open wells for Rapar Taluka

Village	Sub Basin	Minor Basaltin	Latitude	Longitude	Height of Measuring Point in m	R.L. in m
Adesar		Local Basaltin	23°33'12"	70°58'37"	0.00	33.30
Palasava		Local Basaltin	23°28'04"	70°55'31"	0.40	20.73
Bhimasar	Dabhodan wali	Dabhodanwali	23°32'42"	70°52'55"	0.20	60.40
Mevasa	Khari	Khari	23°23'99"	70°45'00"	0.00	77.22
Khirai	Ranothar	Ranothar	23°27'53"	70°39'11"	0.30	139.50
Rapar	Narelawali	Narelawali	23°26'20"	70°38'28"	0.00	60.74
Ramvav	Bhimguda	Bhimguda	23°33'03"	70°28'06"	0.00	76.97
Suvai	Bhimguda	Bhimguda	23°36'35"	70°29'36"	0.60	44.97
Jesda	Bhimguda	Bhimguda	23°37'03"	70°30'57"	0.00	56.23
Fategadh	Banalyo	Banalyo	23°41'12"	70°50'09"	0.00	19.99

(Source: GWRDC)

5.5 TUBE WELLS IN KUTCH

The groundwater level for pre-monsoon and post-monsoon for the tubewells has been obtained from 1989 to 2008. Figure 5.13 and Figure 5.14 shows the location of the observation tubewells and observation piezometers for Kutch district. The details of the locations of the wells for each taluka have been given in the alphabetical order of the names of the talukas.

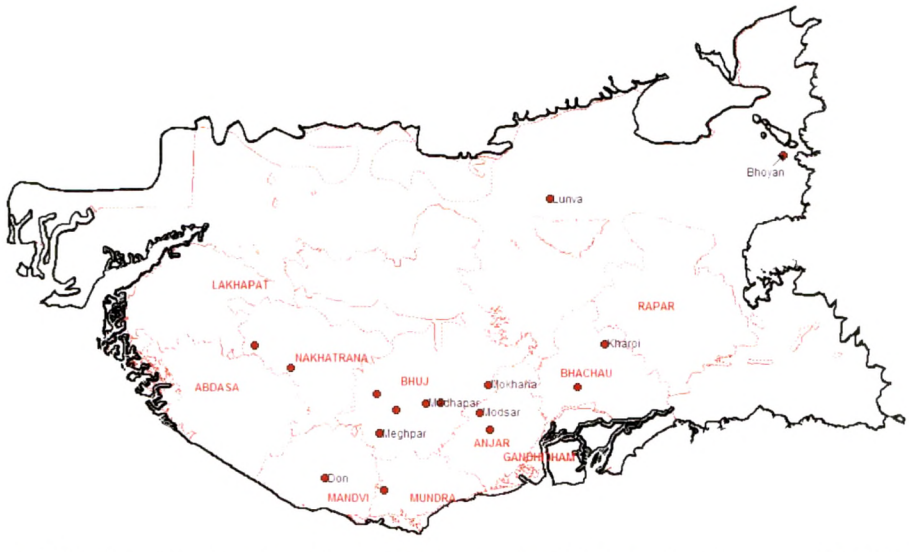

Figure 5.8 Map showing locations of Observation Tubewells (Source: GWRDC)

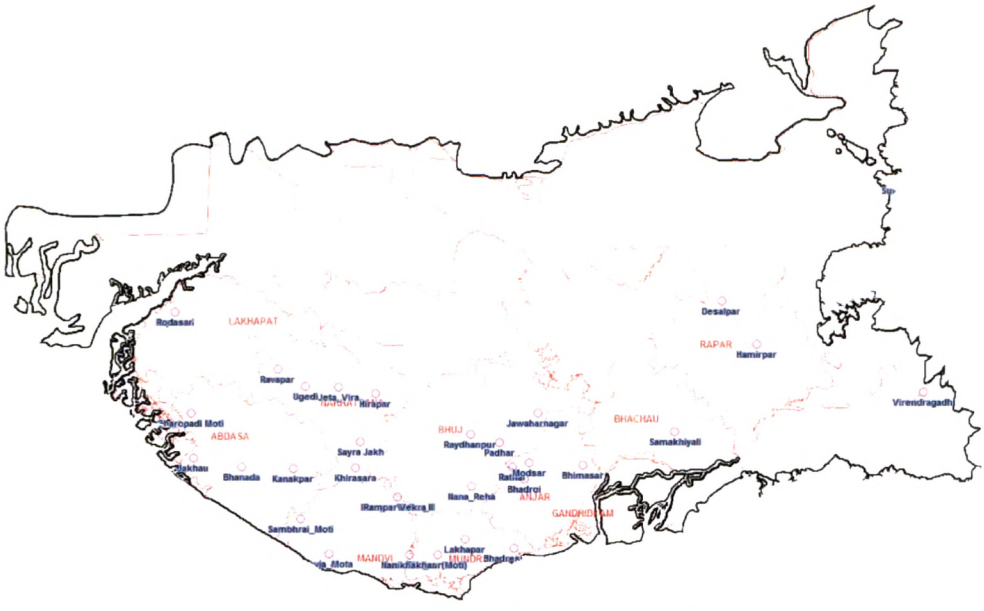

Figure 5.9 Map showing locations of Observation Peizometers (Source: GWRDC)

5.5.1 Anjar Taluka

The general details of the Tube wells & Piezometers for Anjar taluka are as follows.

Table 5.12 Details of Tubewells & Piezometers for Anjar taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Chandroda	Basalt	23°00'15"	69°51'29"	15.70	61.00
Khambhra	Sandstone	23°06'07"	69°55'46"	28.40	95.38
Satapar	Alluvium	23°10'05"	70°02'39"	18.40	61.30
Anjar	Sandstone	23°07'57"	69°59'49"	152.40	65.70
Modsar	Sandstone	23°11'54"	69°57'28"	152.40	88.60
Bhimasar	Alluvium	23°11'28"	70°10'05"	60.00	31.66
Ratnal	Sandstone	23°11'13"	69°54'09"	60.00	115.51
Modsar	Sandstone	23°12'02"	69°58'02"	152.44	83.36
Bhadroi	Sandstone	23°08'43"	69°56'59"	109.76	103.50

(Source: GWRDC)

5.5.2 Bhachau Taluka

The general details of the Tube wells & Peizometers for Bhachau taluka are as follows.

Table 5.13 Details of Tubewells & Piezometers for Bhachau taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Kanthkot	Sandstone	23°27'09"	70°27'47"	18.80	73.52
Adhoi	Sandstone	23°23'51"	70°30'16"	28.00	57.20
Bhachau	Sandstone	23°17'45"	70°21'25"	152.00	52.03
Lunva	Sandstone	23°16'02"	70°15'23"	155.00	64.17
Kharoi	Sandstone	23°17'37"	70°22'18"	143.30	49.90
Samikhiyali	Alluvium	23°18'18"	70°30'41"	60.00	41.54

(Source: GWRDC)

5.5.3 Bhuj Taluka

The general details of the Tube wells & Peizometers for Bhachau taluka are as follows.

Table 5.14 Details of Tubewells & Piezometers for Bhuj taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Jhura	Sandstone	23°26'31"	69°37'02"	21.00	6.72
Deshalpar	Sandstone	23°12'10"	69°26'48"	35.50	172.20
Chakar Kotda	Sandstone	23°06'58"	69°45'00"	21.00	122.30
Paddhar	Sandstone	23°14'14"	69°47'27"	164.60	110.00
Madhapar	Sandstone	23°14'03"	69°44'02"	98.50	120.00
Makhna	Sandstone	23°16'5 "	69°31'47"	126.28	153.80
Sukhpar	Sandstone	23°12'12"	69°36'40"	150.98	130.00
Meghpar	Sandstone	23°07'23"	69°33'45"	160.98	162.00
Jawahar Nagar	Sandstone	23°22'07"	70°00'00"	90.00	41.14
Paddhar	Sandstone	23°16'06"	69°51'21"	90.00	116.51
Nana reha	Sandstone	23°07'11"	69°45'05"	90.00	141.71
Raydhanpur	Sandstone	23°17'49"	69°44'51"	121.95	79.92

(Source: GWRDC)

5.5.4 Lakhpat Taluka

The general details of the Tube wells & Peizometers for Lakhpat taluka are as follows.

Table 5.15 Details of Tubewells & Piezometers for Lakhpat taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Kapurasi	Limestone	23°42'31"	68°38'53"	30.00	17.50
Rodasar	Limestone	23°34'20"	68°32'12"	30.00	21.24

(Source: GWRDC)

5.5.5 Mandvi Taluka

The general details of the Tube wells & Peizometers for Mandvi taluka are as follows.

Table 5.16 Details of Tubewells & Piezometers for Mandvi taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Nani Khakhar	Alluvium	22°53'02"	69°31'05"	22.00	24.70
Mandvi	Alluvium	22°51'12"	69°22'48"	21.75	19.60
Bidada	Alluvium	22°53'33"	69°28'36"	24.40	31.59
Gadhsisa	Sandstone	23°06'02"	69°20'33"	33.40	132.72
Don	Alluvium	22°57'02"	69°18'59"	120.00	46.29
Rampar Vekra III	Sandstone	23°05'11"	69°28'33"	60.00	120.50
Rampar Vekra II	Sandstone	23°05'11"	69°28'33"	90.00	120.50
Rampur vekra I	Sandstone	23°05'11"	69°28'33"	60.00	120.31
Layja Mota	Alluvium	22°53'31"	69°13'09"	60.00	16.84
Sambhrai moti	Alluvium	23°00'42"	69°06'59"	60.00	35.40
Nanikhakhar	Alluvium	22°53'28"	69°31'07"	141.46	24.70

(Source: GWRDC)

5.5.6 Mundra Taluka

The general details of the Tube wells & Peizometers for Mundra taluka are as follows.

Table 5.17 Details of Tubewells & Piezometers for Mundra taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Bhujpar (m)	Alluvium	22°52'09"	69°37'48"	24.80	23.63
Tunda	Alluvium	22°50'00"	69°31'59"	13.40	11.04
Deshalpar	Alluvium	22°54'05"	69°35'46"	172.30	38.00
Bhadreshwar	Alluvium	22°54'47"	69°54'31"	60.00	12.69
Lakhapar	Alluvium	22°56'27"	69°43'37"	60.00	55.13
Bhujpur(Moti)	Alluvium	22°53'26"	69°37'25"	106.68	23.29

(Source: GWRDC)

5.5.7 Nakhatrana Taluka

The general details of the Tube wells & Peizometers for Nakhatrana taluka are as follows.

Table 5.18 Details of Tubewells & Piezometers for Nakhatrana taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Dhavda	Sandstone	23°18'41"	69°19'03"	28.80	134.27
Nirona	Sandstone	23°27'48"	69°31'12"	18.30	19.50
Kotda (j)	Sandstone	23°22'08"	69°11'43"	150.45	130.00
Laxmipar	Sandstone	23°27'01"	69°01'33"	136.60	130.20
Hirapar	Sandstone	23°25'58"	69°23'33"	60.00	90.62
Jeta Vira	Sandstone	23°27'18"	69°15'27"	60.00	54.03
Ravapar	Sandstone	23°31'00"	69°01'55"	60.00	112.91
Sayra (jakh)	Sandstone	23°16'21"	69°20'14"	109.76	163.53
Khirasara	Sandstone	23°11'07"	69°19'09"	152.44	203.87
Ugedi	Sandstone	23°27'32"	69°08'02"	152.44	87.06

(Source: GWRDC)

5.5.8 Naliya Taluka

The general details of the Tube wells & Peizometers for Naliya taluka are as follows.

Table 5.19 Details of Tubewells & Piezometers for Naliya taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Bhanada	Alluvium	23°11'12"	68°53'50"	60.00	28.80
Charopadi Moti	Alluvium	23°22'00"	68°42'21"	30.00	14.16
Jakhau	Alluvium	23°12'59"	68°42'57"	30.00	8.29
Kanakpar	Alluvium	23°10'50"	69°05'18"	60.00	104.07

(Source: GWRDC)

5.5.9 Rapar Taluka

The general details of the Tube wells & Peizometers for Rapar taluka are as follows.

Table 5.20 Details of Tubewells & Piezometers for Rapar taluka

Village	Geology	Latitude	Longitude	Total Depth in m	Elevation of Ground Level in m
Ramvav	Sandstone	23°33'03"	70°28'07"	11.00	76.97
Deshalpar	Sandstone	23°44'42"	70°41'11"	60.00	22.00
Hamirpar	Sandstone	23°35'52"	70°48'57"	60.00	45.44

(Source: GWRDC)

5.6 GROUNDWATER LEVELS

The ground water levels for the wells of all the talukas were plotted using software Surfer. The grid files thus obtained were then plotted using Arcview GIS software to obtain the weighted average ground water levels for pre-monsoon and post-monsoon for all the talukas. Figures 5.10 to 5.47 show the water levels for May (pre-monsoon) and October (post-monsoon) for the study period of 1989 to 2007. Table 5.21 shows the legends for the plots of groundwater levels. Table 5.22 and 5.23 show the average groundwater levels in m for all the talukas

0-20 m	21-40 m	41-60 m	61-80 m	81-100 m	101-120 m	121-140 m	141-160 m	161-180 m

Table 5.21 Legends for Groundwater Levels

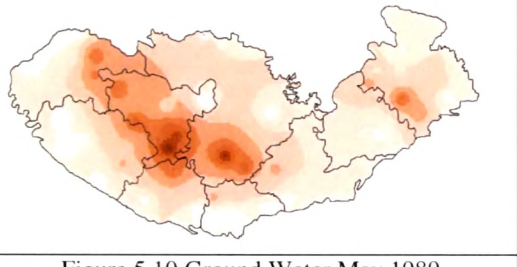

Figure 5.10 Ground Water May 1989

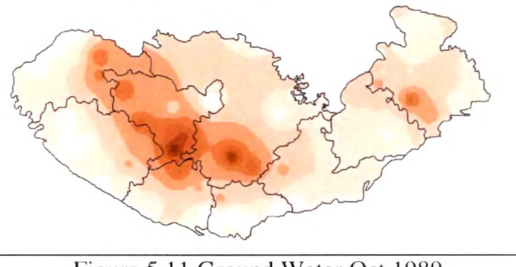

Figure 5.11 Ground Water Oct 1989

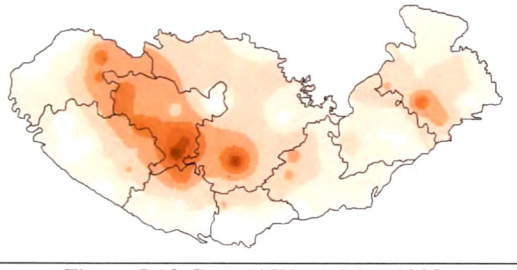

Figure 5.12 Ground Water May 1990

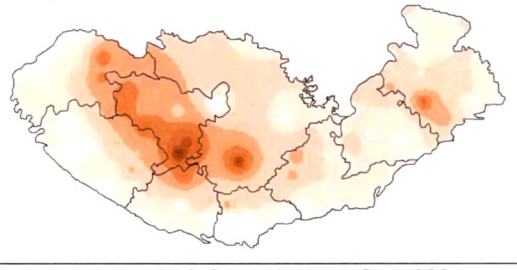

Figure 5.13 Ground Water Oct 1990

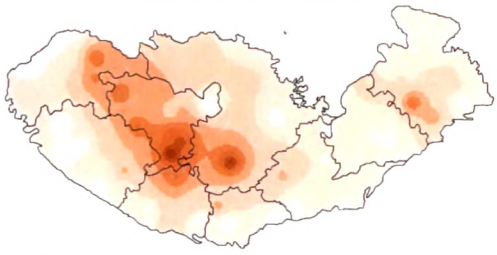

Figure 5.14 Ground Water May 1991

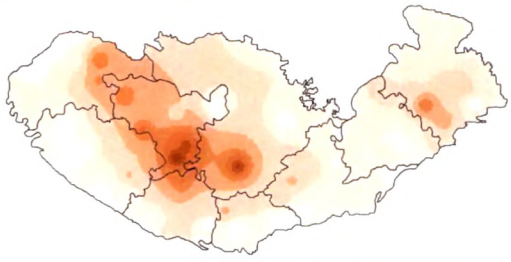

Figure 5.15 Ground Water Oct 1991

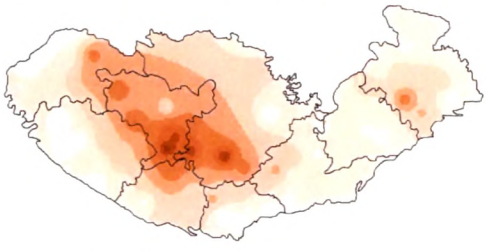

Figure 5.16 Ground Water May 1992

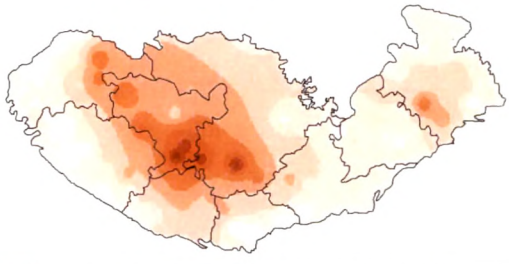

Figure 5.17 Ground Water Oct 1992

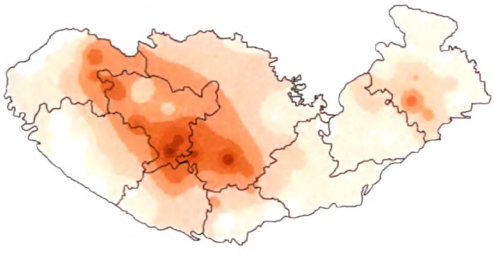

Figure5.18 Ground Water May 1993

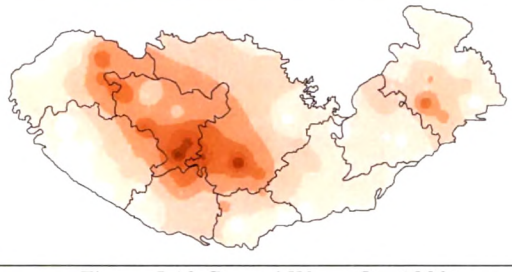

Figure 5.19 Ground Water Oct 1993

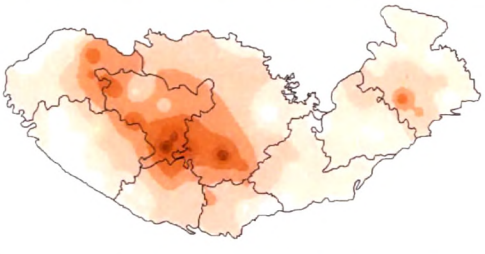

Figure 5.20 Ground Water May 1994

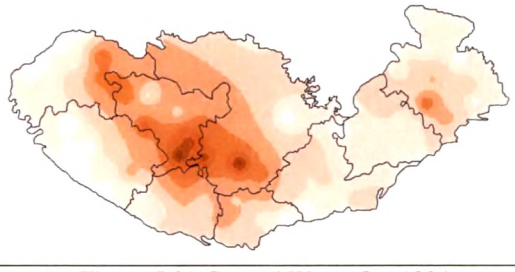

Figure 5.21 Ground Water Oct 1994

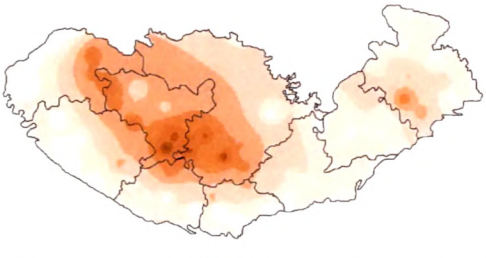

Figure 5.22 Ground Water May 1995

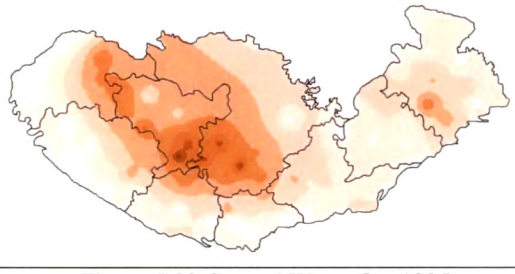

Figure 5.23 Ground Water Oct 1995

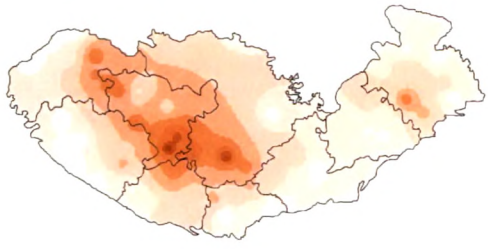

Figure 5.24Ground Water May 1996

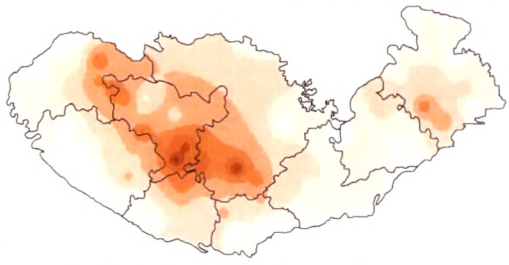

Figure 5.25 Ground Water Oct 1996

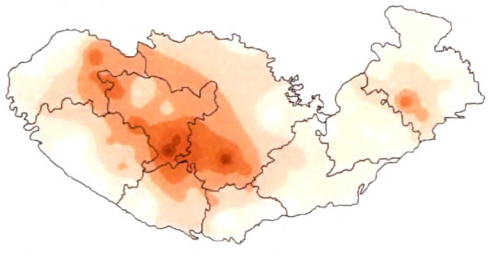

Figure 5.26 Ground Water May 1997

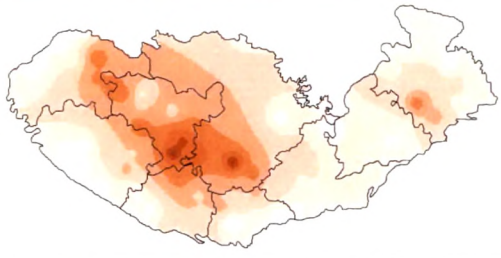

Figure 5.27 Ground Water Oct 1997

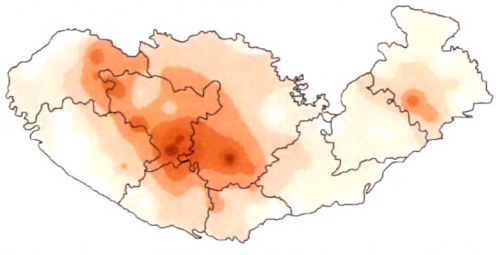

Figure 5.28 Ground Water May 1998

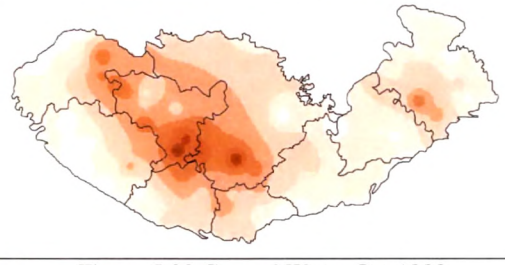

Figure 5.29 Ground Water Oct 1998

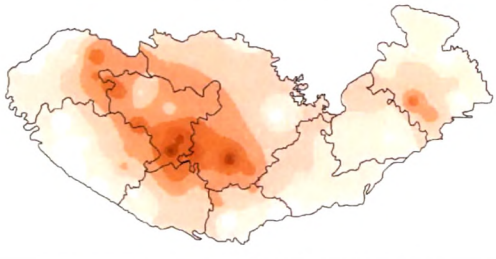

Figure 5.30 Ground Water May 1999

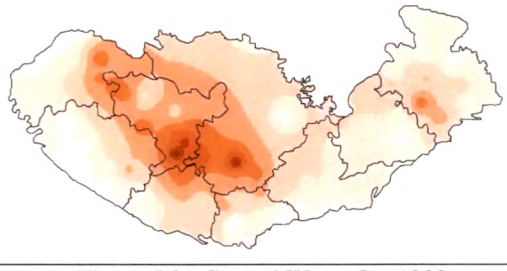

Figure 5.31 Ground Water Oct 1999

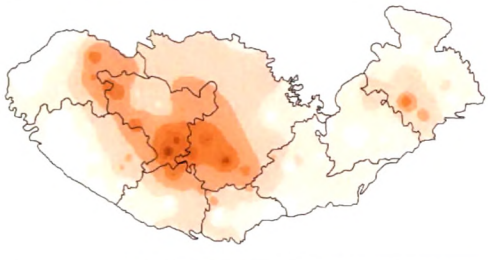

Figure 5.32 Ground Water May 2000

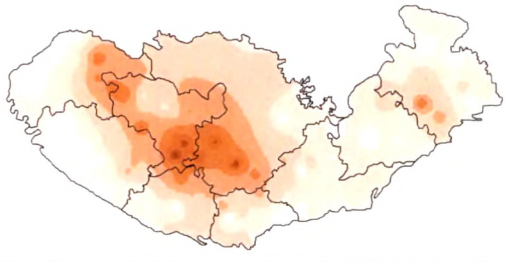

Figure 5.33 Ground Water Oct 2000

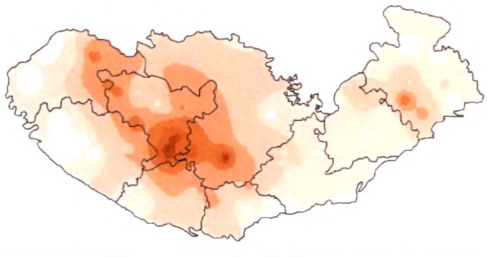

Figure 5.34 Ground Water May 2001

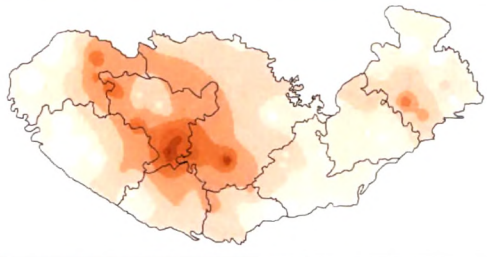

Figure 5.35 Ground Water Oct 2001

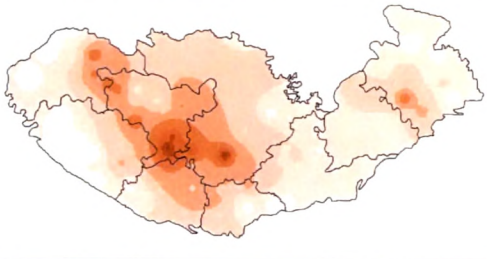

Figure 5.36 Ground Water May 2002

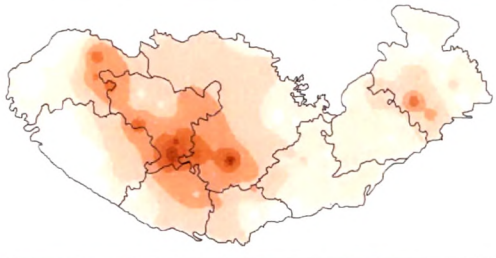

Figure 5.37 Ground Water Oct 2002

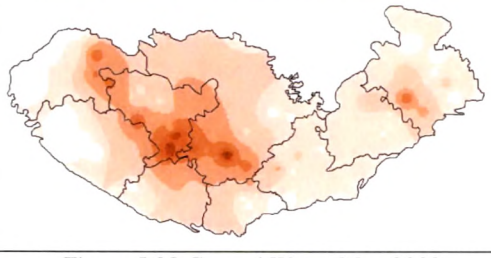

Figure 5.38 Ground Water May 2003

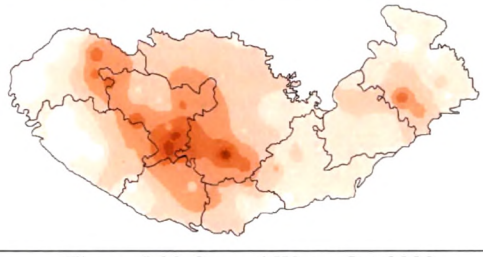

Figure 5.39 Ground Water Oct 2003

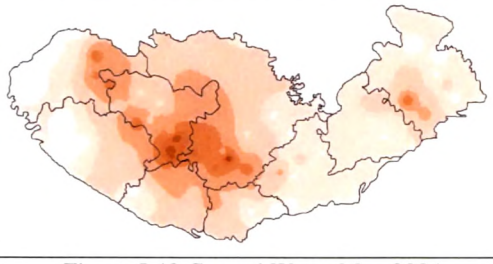

Figure 5.40 Ground Water May 2004

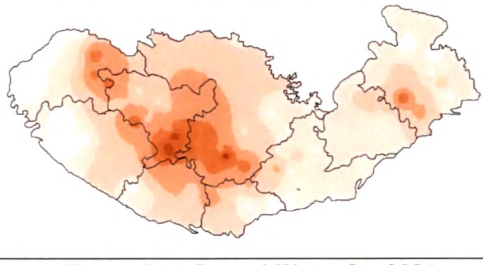

Figure 5.41 Ground Water Oct 2004

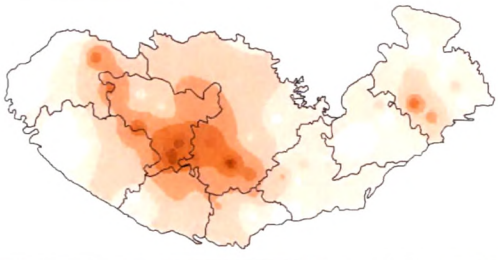

Figure 5.42 Ground Water May 2005

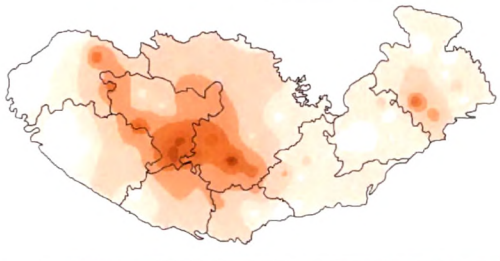

Figure 5.43 Ground Water Oct 2005

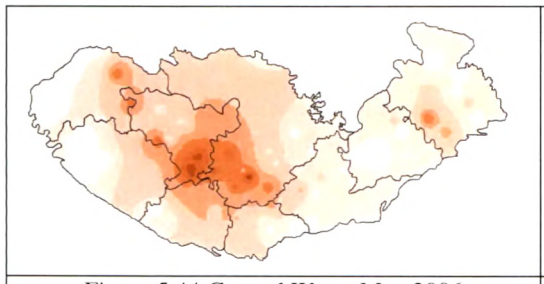

Figure 5.44 Ground Water May 2006

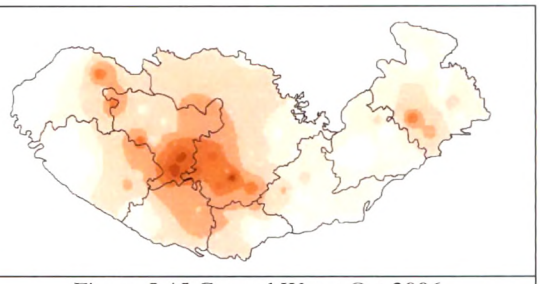

Figure 5.45 Ground Water Oct 2006

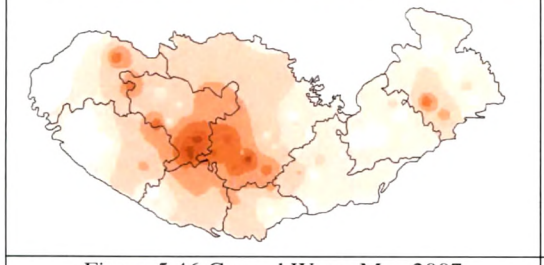

Figure 5.46 Ground Water May 2007

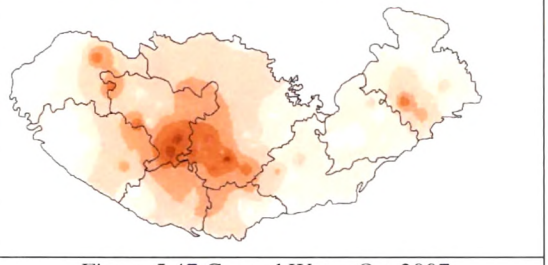

Figure 5.47 Ground Water Oct 2007

Table 5.22 Average Pre-Monsoon Water Levels for All Talukas (in mm)

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
May-89	25.76	25.18	56.13	41.82	44.18	24.87	81.12	34.50	34.93
May-90	31.03	32.79	46.54	40.43	41.19	24.85	76.52	35.00	40.78
May-91	26.63	25.18	54.42	40.97	42.21	24.50	79.04	34.77	34.53
May-92	26.33	23.87	54.45	40.31	47.13	35.55	78.75	33.82	33.76
May-93	28.81	28.90	56.42	41.44	45.95	25.94	79.54	34.58	34.96
May-94	24.93	27.52	51.61	38.38	42.70	30.18	78.42	31.37	31.79
May-95	28.37	28.17	53.76	39.59	36.75	23.97	80.86	35.56	35.55
May-96	22.90	23.49	48.62	38.17	41.52	32.15	71.68	32.95	31.95
May-97	24.22	21.79	49.59	33.89	41.51	30.22	71.86	27.75	32.65
May-98	23.49	20.96	47.92	32.86	40.79	30.23	69.95	32.57	31.79
May-99	26.68	25.14	55.07	41.39	45.79	25.89	79.34	35.02	34.42
May-00	25.03	25.96	53.36	39.38	37.90	21.10	80.05	33.09	32.70
May-01	24.93	27.52	51.61	38.38	42.70	30.18	78.42	31.37	31.79
May-02	24.85	27.21	50.67	39.38	43.45	29.38	77.47	32.78	32.01
May-03	23.26	27.51	49.28	37.16	37.33	26.61	73.75	30.05	30.94
May-04	22.90	23.49	48.61	38.32	41.51	32.15	71.67	33.15	31.95
May-05	24.01	21.08	50.30	34.03	40.58	29.82	74.67	33.44	31.74
May-06	22.87	20.09	48.24	33.22	38.10	28.09	70.21	31.77	31.21
May-07	23.49	20.96	47.91	33.06	40.79	30.22	69.94	32.81	31.79

Table 5.23 Average Post-Monsoon Water Levels for All Talukas (in mm)

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Oct-88	27.90	27.56	45.14	39.98	42.58	24.05	73.11	35.58	35.46
Oct-89	24.80	24.66	53.09	39.96	44.66	31.45	79.12	32.97	34.10
Oct-90	31.85	33.07	46.16	41.41	41.13	25.16	77.10	35.53	41.31
Oct-91	26.03	23.23	54.35	39.14	42.61	24.18	78.76	36.05	33.47

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Oct-92	27.36	25.20	55.44	41.15	45.65	26.16	79.37	34.45	34.09
Oct-93	24.97	25.94	53.51	39.29	38.62	22.25	80.05	32.97	32.70
Oct-94	25.01	24.14	51.37	39.52	44.93	32.86	78.87	32.99	32.64
Oct-95	30.49	28.62	54.75	40.17	37.84	25.11	81.76	36.39	36.30
Oct-96	24.81	27.51	48.86	38.40	41.65	31.65	71.66	32.91	32.65
Oct-97	22.87	20.09	48.25	33.08	38.11	28.09	70.22	31.59	31.21
Oct-98	19.84	20.61	49.51	33.88	42.49	33.73	70.90	31.46	33.48
Oct-99	28.81	28.90	56.42	41.44	45.95	25.94	79.54	34.58	34.96
Oct-00	25.91	24.38	54.27	40.25	37.59	22.31	79.72	33.58	26.00
Oct-01	25.01	24.14	51.37	39.56	44.92	32.86	78.87	33.07	32.64
Oct-02	23.95	25.94	48.95	37.80	43.43	28.93	74.21	31.51	32.06
Oct-03	25.69	27.24	53.04	39.51	43.21	34.34	75.49	30.08	33.27
Oct-04	24.81	27.51	48.86	38.49	41.65	31.64	71.66	33.02	32.65
Oct-05	24.22	21.79	49.59	34.04	41.51	30.22	71.85	27.95	32.65
Oct-06	24.57	21.83	49.65	34.54	42.12	31.63	71.23	31.53	33.55
Oct-07	19.84	20.61	49.50	34.01	42.49	33.73	70.89	31.66	33.48

5.7 GROUNDWATER WITHDRAWAL

5.7.1 Formations of the Area

There are three main types of formations for groundwater recharge in Kutch district i.e. hard rock, alluvium and sandstone. The distribution of these three formations for all the district along with the net suitable area for recharge and the specific yield of these formations was obtained from GWRDC. Table 5.24 shows the values for specific yield for all the formations for all the talukas. Table 5.25 shows the areas for alluvium, hard rock and sandstone as well as the average specific yield and the net suitable area for recharge for all the talukas.

Table 5.24 Specific Yield for all the talukas

Specific Yield In %	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Hard Rock	0.02	0.02	0.02	0.02	0.10	0.02	0.02	0.02	0.02
Alluvium	0.18	0.10	0.15	0.10	0.15	0.10	0.15	0.10	0.10
Sandstone	0.10	0.10	0.10	0.10	0.12	0.07	0.10	0.08	0.05

(Source: GWRDC)

Table 5.25 Distribution of Areas for Various Formations for All Talukas

Taluka	Alluvial Area In km^2	Hard Rock Area In km^2	Sandstone Area In km^2	Average Specific Yield in %	Total Suitable Area In km^2
Anjar	188.00	0.00	370.25	0.13	558.25
Bhachau	0.00	0.00	499.60	0.10	499.60
Bhuj	0.00	0.00	2532.00	0.10	2532.00
Lakhpat	0.00	75.00	224.00	0.08	299.00
Mandvi	287.49	498.75	176.03	0.12	962.27

Taluka	Alluvial Area In km^2	Hard Rock Area In km^2	Sandstone Area In km^2	Average Specific Yield in %	Total Suitable Area In km^2
Mundra	150.65	403.80	48.00	0.04	602.45
Nakhatrana	0.00	0.00	989.90	0.10	989.90
Naliya	100.00	0.00	140.00	0.09	240.00
Rapar	0.00	0.00	997.60	0.05	997.60

(Source: GWRDC)

5.7.2 Groundwater Water Extracting Mechanism

The data for the number of wells as well as the quantity of groundwater withdrawal was obtained from GWRDC. The data given by GWRDC was at every five year interval starting from the year 1984 to 2007. However, as the data regarding the number of wells for the years 1984 and 1991 was not available, the data for the years 1997, 2002 and 2007 was utilized and the number of wells for all the talukas were interpolated based on this data for the study period of 1989 to 2007. The details for the number of wells as well as the groundwater withdrawal for all the talukas as obtained from GWRDC has been shown in Annexure 7. Table 5.26 shows the number of wells obtained after interpolation of the given data for the study period.

Table 5.26 Number of Wells for All Talukas

Year	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
1989	2686	2776	5744	627	4122	2786	2653	804	4527
1990	2707	2797	5787	631	4153	2807	2673	810	4562
1991	2727	2818	5831	636	4184	2828	2693	816	4596
1992	2747	2839	5874	641	4215	2849	2713	822	4630
1993	2767	2860	5917	646	4246	2870	2733	828	4664
1994	2788	2881	5961	650	4277	2891	2753	834	4698
1995	2808	2902	6004	655	4308	2912	2773	840	4732
1996	2828	2923	6047	660	4339	2933	2793	846	4766
1997	2849	2944	6091	665	4371	2954	2814	853	4801
1998	2622	2735	5839	632	3987	2782	2533	884	4660
1999	2396	2526	5587	599	3603	2609	2252	915	4519
2000	2169	2317	5336	566	3218	2437	1972	946	4379
2001	1943	2108	5084	533	2834	2264	1691	977	4238
2002	1716	1899	4832	500	2450	2092	1410	1008	4097
2003	1929	1853	4767	419	2305	1878	1961	896	3397
2004	2141	1807	4702	338	2160	1664	2513	783	2696
2005	2354	1762	4638	258	2016	1450	3064	671	1996
2006	2566	1716	4573	177	1871	1236	3616	558	1295
2007	2779	1670	4508	96	1726	1022	4167	446	595

5.7.3 Groundwater Withdrawal Pattern

The groundwater withdrawal pattern or draft was obtained from GWRDC at every five year interval from 1984, 1991, 1997, 2002 and 2007. Based on those values a

relationship for determining the draft pattern was worked out using multiple regression with the help of the software Statistica. After number of permutations and combinations for the determining the variables giving significant impact of the draft value, the following relationship was obtained.

$$Dr = .0062*W + .0721*P_{m-2} + .0198*P_{m-1} - .0185*P_m + .00047*A_{ag} - 0.0000795*A_t$$

Where, Dr = draft in mm
W = water extracting mechanisms / wells in the taluka
m = number of year
P_{m-2} = Rainfall value two years ago in mm
P_{m-1} = Rainfall value of previous year in mm
P_m = Rainfall value of current year in mm
A_{ag} = Total agricultural area in the taluka in hectares
A_t = Total area of taluka in hectares

It was found that the rainfall pattern of the previous two years played a very significant role in the draft pattern for the current year besides the number of wells, the total agricultural area and the total area of the taluka. Table 5.27 shows the value of the draft derived for all the talukas for the study period of 1989 to 2007.

Table 5.27 Derived values for Groundwater Draft in mm

Year	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
1989	38.65	15.48	21.87	0.78	35.60	33.32	26.79	4.98	10.40
1990	64.57	53.85	77.86	30.96	101.11	80.92	75.89	88.77	30.03
1991	61.11	53.80	74.75	38.76	92.11	66.93	61.97	76.78	36.87
1992	38.51	34.12	31.96	-1.12	31.38	36.97	24.51	3.66	28.87
1993	42.89	24.66	34.19	16.76	52.63	51.49	40.91	20.03	22.75
1994	47.34	12.46	41.28	38.90	72.45	59.70	64.63	45.15	29.74
1995	54.25	30.22	39.40	14.63	54.01	48.50	45.24	10.02	38.53
1996	99.53	70.76	82.16	52.34	108.00	112.74	96.75	51.33	58.55
1997	34.33	24.66	27.99	5.88	43.64	36.06	26.28	31.67	22.17
1998	49.75	35.13	28.65	9.60	43.65	40.09	33.50	19.08	41.95
1999	81.92	52.00	52.49	28.68	72.61	78.34	52.39	19.98	61.41
2000	43.18	44.30	42.04	7.58	62.05	53.65	30.34	3.10	43.26
2001	29.65	33.85	21.36	3.20	33.33	24.50	20.90	0.51	20.12
2002	41.75	16.28	34.42	1.93	40.44	37.69	13.37	22.54	19.17
2003	30.69	0.94	12.44	-20.67	41.05	36.18	-0.15	29.47	3.03
2004	46.46	27.59	45.55	27.33	41.37	40.64	48.42	30.60	29.02
2005	89.41	49.24	114.19	99.71	59.05	87.65	106.18	67.46	71.95
2006	48.32	28.92	22.98	10.28	40.01	46.49	31.68	6.01	19.75
2007	53.74	32.06	26.34	14.64	38.97	53.08	48.44	20.32	15.89

5.8 RECHARGE CALCULATIONS

The groundwater recharge occurring due to rainfall as well as that occurring due to surface storage has been calculated. The total recharge is taken as the sum of the recharge due to rainfall as well as the recharge due to surface storage.

5.8.1 Recharge Due To Rainfall

The average groundwater levels obtained for pre-monsoon and post-monsoon have been used to work out the recharge due to the rainfall. The difference in the groundwater levels for post-monsoon and pre-monsoon has been multiplied by the average specific yield value for the taluka to find out the change in groundwater level in mm for all the talukas. The value for change in groundwater level in mm has been then multiplied by the fraction obtained by the ratio of the area suitable for recharge to the total area of the taluka i.e net suitable area fraction to obtain the recharge depth in mm due to the rainfall. The recharge depth thus calculated for all the talukas has been tabulated in Table 5.28. The values for recharge depth obtained for the years 1991, 1996 and 2002 are negative indicating fall in the groundwater level for those years. This fall may be a result of excessive withdrawal of groundwater during those years.

Table 5.28 Groundwater Recharge Depth in mm due to Rainfall

Year	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
1989	44.37	28.80	76.13	20.07	126.67	33.67	96.46	11.40	20.51
1990	32.43	13.12	32.98	7.87	17.99	18.33	29.15	4.42	11.50
1991	13.86	-0.35	2.72	0.22	8.15	0.30	5.58	0.84	-4.55
1992	90.93	67.03	189.25	46.00	213.34	73.76	165.25	27.99	29.92
1993	5.06	6.34	-21.61	4.12	-34.31	-7.92	-2.28	1.42	10.47
1994	174.19	98.61	226.62	29.89	351.92	181.65	175.48	32.58	46.38
1995	47.30	18.09	59.70	8.26	105.22	38.34	53.67	7.99	13.01
1996	61.56	-40.50	-25.26	-0.99	-85.05	-19.08	-12.22	-1.96	1.24
1997	62.86	54.30	65.12	13.75	101.41	49.39	45.62	5.96	26.81
1998	35.04	12.27	45.45	8.46	60.29	22.11	40.07	6.07	3.57
1999	18.92	4.24	18.13	-0.08	5.47	4.44	11.28	-2.77	8.23
2000	16.54	1.04	7.27	5.81	-37.44	10.06	13.75	2.91	-6.08
2001	37.61	1.93	47.67	24.10	105.56	48.09	39.05	14.95	14.79
2002	-54.88	-50.66	-124.59	-13.17	-167.02	-44.85	-139.04	-11.07	-6.70
2003	111.35	70.11	148.59	21.65	199.59	143.46	94.21	11.93	41.89
2004	15.64	29.45	4.00	1.72	-1.23	-1.18	3.58	-0.62	12.84
2005	19.12	18.33	24.24	2.03	53.86	16.87	26.47	1.29	15.69
2006	55.78	36.47	73.46	13.33	169.81	69.00	60.35	12.82	37.52
2007	42.38	28.65	68.12	10.53	140.09	75.42	51.35	8.93	28.68

5.8.2 Recharge Due To Surface Storage

The groundwater recharge occurring due to surface storage structures has been worked out for all the talukas. Sufficient data regarding the monitoring of the surface storage structures for was not available for all the structures i.e. medium irrigation schemes, minor irrigation schemes as well as check dams. Therefore, the rainfall values and the

catchment areas of the surface storage structures have been used to find out the recharge depth occurring due to the surface storage.

Sharda et al (2006) have developed a formula for the estimation of recharge depth from surface storage structures in semi-arid climate of India. It gives the value of recharge depth due to surface storage in mm if value of rainfall in mm is known. The formula is as follows:

$$Log_{10}R_e = a(b\text{-}e^{-cP})$$

Where
R_e = recharge in mm due to the surface storage
P = rainfall in mm
a = 3.322 (constant)
b = 0.611 (constant)
c = 4.72×10^{-3} (constant)

The values for a, b and c obtained by them have been used here as the surface conditions for their study are comparable to the surface conditions of the study area at Kutch.

The recharge value in mm thus obtained was then multiplied by the fraction obtained by the ratio of the total catchment area of all the surface storage structures in a taluka to that of the total area of the taluka to obtain the recharge depth due to surface storage structures. The values for the recharge due to surface storage structures for all the talukas have been tabulated in Table 5. 29.

Table 5.29 Groundwater Recharge Depth in mm due to Surface Storage Structures

Year	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
1989	25.46	12.13	22.66	26.04	71.45	62.08	29.10	66.99	52.12
1990	5.98	3.37	5.32	0.50	1.38	1.20	0.56	1.29	1.01
1991	0.82	0.25	0.73	0.03	0.08	0.07	0.03	0.08	0.06
1992	31.51	0.66	28.04	44.00	120.76	104.92	49.18	113.22	88.08
1993	1.59	0.05	1.42	0.03	0.08	0.07	0.03	0.08	0.06
1994	65.12	21.03	57.95	43.40	119.12	103.49	48.51	111.68	86.89
1995	4.48	1.10	3.98	0.66	1.82	1.58	0.74	1.71	1.33
1996	3.15	2.75	2.80	0.03	0.09	0.08	0.04	0.09	0.07
1997	54.90	12.55	48.85	12.73	34.94	30.35	14.23	32.76	25.48
1998	10.40	8.65	9.26	0.19	0.51	0.45	0.21	0.48	0.37
1999	0.69	3.58	0.62	0.03	0.08	0.07	0.03	0.08	0.06
2000	5.69	0.57	5.06	0.03	0.08	0.07	0.03	0.08	0.06
2001	11.13	0.01	9.90	0.03	0.08	0.07	0.03	0.08	0.06
2002	1.46	0.90	1.30	0.19	0.51	0.45	0.21	0.48	0.37
2003	62.99	16.10	56.05	61.85	169.75	147.48	69.13	159.16	123.82
2004	12.46	3.32	11.08	7.18	19.70	17.11	8.02	18.47	14.37
2005	20.38	8.08	18.14	0.63	1.74	1.51	0.71	1.63	1.27
2006	30.56	7.01	27.19	44.44	121.97	105.96	49.67	114.35	88.96
2007	46.06	17.50	40.99	15.51	42.57	36.98	17.34	39.91	31.05

5.8.3 Total Recharge

The total groundwater recharge was obtained by summing the values of groundwater recharge due to rainfall and the groundwater recharge due to surface storage structures. The values for the total recharge have been tabulated in Table 5.30. Once again the values of the recharge are negative for the years 1991, 1996 and 2002 indicating fall in the groundwater level for those years. This may be due to probability of excessive withdrawal of groundwater during those years and that the values of recharge due to surface storage structures is less than the withdrawal in those years.

Table 5.30 Total Groundwater Recharge Depth in mm

Year	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
1989	69.83	40.93	98.78	46.10	198.12	95.75	125.56	78.39	72.63
1990	38.41	16.49	38.29	8.37	19.37	19.53	29.71	5.72	12.51
1991	14.69	-0.10	3.45	0.25	8.24	0.37	5.61	0.91	-4.49
1992	122.45	67.70	217.29	90.00	334.10	178.68	214.43	141.21	118.00
1993	6.66	6.39	-20.19	4.15	-34.23	-7.85	-2.24	1.50	10.53
1994	239.31	119.64	284.56	73.29	471.04	285.14	223.99	144.27	133.26
1995	51.78	19.20	63.68	8.92	107.04	39.92	54.41	9.69	14.34
1996	64.71	-37.75	-22.46	-0.96	-84.96	-19.00	-12.18	-1.87	1.31
1997	117.76	66.85	113.97	26.48	136.35	79.74	59.85	38.71	52.29
1998	45.45	20.92	54.70	8.64	60.81	22.56	40.28	6.55	3.94
1999	19.62	7.82	18.74	-0.05	5.55	4.51	11.31	-2.70	8.29
2000	22.22	1.62	12.33	5.84	-37.36	10.13	13.79	2.99	-6.02
2001	48.73	1.94	57.57	24.13	105.64	48.16	39.08	15.02	14.85
2002	-53.43	-49.76	-123.30	-12.98	-166.51	-44.41	-138.83	-10.59	-6.33
2003	174.34	86.21	204.64	83.50	369.34	290.94	163.34	171.09	165.71
2004	28.10	32.77	15.08	8.90	18.46	15.93	11.60	17.84	27.20
2005	39.50	26.41	42.38	2.67	55.60	18.39	27.18	2.92	16.96
2006	86.33	43.48	100.65	57.78	291.78	174.96	110.02	127.18	126.48
2007	88.44	46.15	109.11	26.04	182.65	112.40	68.68	48.85	59.73

5.9 SUMMARY FOR GROUNDWATER ANALYSIS

The above figures for the water level fluctuations for all the talukas show that for the study period of 1989 to 2007, the water level for post-monsoon is higher than the water level for pre-monsoon for almost all years except 1991, 1996 and 2002. During the year 2001, there was a major earthquake in Kutch which had resulted in the damage to almost all the surface storage structures. These structures were repaired subsequently with priority being given to the structures which were used for water supply. This may have resulted in excessive withdrawal of groundwater. The years 1991 and 1996 have the annual rainfall values less than 50% of the average annual rainfall for the region, which may have resulted in excessive withdrawal of groundwater. This is also reflected in the

values of total groundwater recharge as shown in Table 5.30 as the values of the total groundwater recharge for the years 1991, 1996 and 2002 show negative values.

Individual analysis of the water level fluctuation for the wells shows that levels of the wells located in the vicinity of any surface storage structure like a medium irrigation scheme, minor irrigation scheme or check dam have comparatively more rise in the water level as compared to those located away from these structures.

5.9.1 Summary for Draft Pattern

The analysis of the draft in mm for obtaining the mean values, minimum values, maximum values, variance, standard deviation and the standard error was done for the annual values for the period of 1989 to 2007 using the software Statistica. The results for the analysis have been tabulated in Table 5.31.

Table 5.31 Results for Draft Values (mm) for 1989 to 2007

Taluka	Mean	Median	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Anjar	54.85	47.83	29.65	101.00	473.90	21.77	4.87
Bhachau	37.07	32.96	0.94	101.00	503.97	22.45	5.02
Bhuj	46.65	36.91	12.44	114.19	803.56	28.35	6.34
Lakhpat	20.01	14.63	-20.67	99.71	670.03	25.88	5.94
Mandvi	55.97	43.65	31.38	108.00	539.86	23.23	5.33
Mundra	53.94	48.50	24.50	112.74	503.26	22.43	5.15
Nakhatrana	44.63	40.91	-0.15	106.18	743.73	27.27	6.26
Naliya	29.02	20.32	0.51	88.77	670.64	25.90	5.94
Rapar	31.76	29.02	3.03	71.95	316.00	17.78	4.08

5.9.2 Summary for Total Groundwater Recharge

The analysis of total annual groundwater recharge depth in mm for obtaining the mean values, minimum values, maximum values, variance, standard deviation and the standard error was done for the annual values for the period of 1989 to 2007 using the software Statistica. The results for the analysis have been tabulated in Table 5.32.

Table 5.32 Results for Annual Groundwater Recharge Values (mm) for 1989 to 2007

Taluka	Mean	Median	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Anjar	64.47	48.73	-53.43	239.31	4268.67	65.34	14.99
Bhachau	27.21	20.92	-49.76	119.64	1627.21	40.34	9.25
Bhuj	66.80	54.70	-123.30	284.56	8918.79	94.44	21.67
Lakhpat	24.27	8.90	-12.98	90.00	956.20	30.92	7.09
Mandvi	107.42	60.81	-166.51	471.04	27485.15	165.79	38.03
Mundra	69.78	22.56	-44.41	290.94	9557.90	97.76	22.43
Nakhatrana	55.03	39.08	-138.83	223.99	7172.41	84.69	19.43
Naliya	41.98	9.69	-10.59	171.09	3533.23	59.44	13.64
Rapar	43.22	14.85	-6.33	165.71	2951.52	54.33	12.46