केंद्रीय भूमि जल बोर्ड

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भारत सरकार

Central Ground Water Board

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

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

DEOGARH DISTRICT, ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

FOREWORD

Deogarh is a new district carved out of Sambalpur in January 1994 during a major district reorganisation process in the State. Sambalpur was divided into Sambalpur, Bargarh, Jharsuguda and Deogarh. As a part of erstwhile Sambalpur district Deogarh enjoyed the taste of ancient cultural heritage of Sambalpur. It is bounded by Sundargarh district in north, Sambalpur in West and south, Anugul in east and south. The district has a geographical area of about 2940 sq. km constituting about 1.89 % of the total geographical area of Orissa and is divided into 1 subdivisions and 3 administrative blocks. Major portion of the district is covered with hilly terrain and high land dense forest.

The district is endowed with vast natural resources and is one of the agriculturally developed districts of Odisha. The district is underlain mostly by hard crystalline formations of Eastern Ghat Supergroup. The river Brahmani and its tributaries are the main surface water sources which provide water to the district. However, large part of the district still lacks surface water irrigation facility. The agrarian development of the district can be boosted by tapping the ground water resources through dug wells and medium-deep bore wells.

Due to wide variation in hydrogeological set up in the district, the occurrence and distribution of aquifers are non-uniform and so also their yielding properties. Proper site selection holds the key to the success of sustainable ground water development, which requires a thorough knowledge of hydrogeology and pattern of water usage in the terrain.

The hard crystalline rocks of the district form two distinct aquifer systems. The shallow aquifer formed by the weathered mantle where water is stored under phreatic condition. The deeper aquifer is formed by fracture zones, joints etc where water occur in semi-confined condition. Granitic hardrock aquifers have water yielding fracture zones and have average success rate with 2-5 lps of discharge. Borewells in charnockites, quartzites and khondalites have very poor yield. The places where weathering thickness is more and condition is favourable, the phreatic aquifer attains good yield potential and large diameter dug wells are suitable structures to extract water from them.

The present stage of ground water development is only 53.75 %, leaving further scope for future ground water development in the district. Ground water irrigation practices can insure increased agricultural production by enhancing the area irrigated and scope of irrigation. Apart from irrigation, drinking water scarcity can also be mitigated through judicious utilization of ground water.

Based on the available data and the earlier hydrogeological studies taken up in 3 blocks of the district viz. Barkote, Reamal and Tileibani covering 2940 Sq. Km. area, an attempt has been made in this report to compile all relevant information, such as hydrogeological, agriculture, irrigation, land use, rain fall, chemical quality of water and other collateral data. **Smt. Mausumi sahoo, Scientist-'C'**, has compiled and prepared the present report on **"Aquifer Mapping and Management Plan in Deogarh District, Odisha".** Her sincere efforts in preparation of the report will no doubt be very useful and benefit the state. It is hoped that it will help different ground water user agencies, administrators and planners in preparation of ground water development plans and will be a handy tool in effective management of ground water resources in the district.

Place: Bhubaneswar

Date: 30th March 2023

(P K Mohapatra)

Regional Director

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District at a glance

I.	General Particulars		
	(a) Location	:	21^0 11' and 21^0 43' North latitude 84^0 27' and 85^0 15' East longitude
	(b) Area	:	2940 Km^2
	(c) District Head quarters	:	Deogarh
	(d) Subdivision	:	1
	(e) Blocks	:	3 1.Barkote 2. Reamal 3.Tileibani
	(f) Population	:	312520 (as per 2011 census) 1. Rural: 290130 2. Urban: 22390
	(g) Work force	:	1. Cultivators : 42660 2. Agricultural labourers : 82490 3. Total workers : 165435
	(h) Literacy	:	72.9 %
II	Climatology	:	
	(a) Normal annual rainfall	:	1500 mm
	(b) Maximum temperature	:	41.5°C
	(c) Minimum temperature	:	13.7°C

III	Land use	:		
	(a) Total forest area	:	79263 Ha	
	(b) Net area sown	:	45473 Ha	
	(c) Irrigation potential created (2017-18) Kharif	:	26273 Ha	
	Rabi	:	11757 Ha	
IV	Irrigation potential created (source wise)		Kharif	Rabi
	(upto 2017-18)			
	(a) Major/ Medium Irrigation Projects	:	8164 Ha	0 Ha
	(b) Minor irrigation Projects (flow)	:	3583 Ha	1026 Ha
	(c) Minor Irrigation Projects (lift)	:	3036 Ha	4785 Ha
	(d) Ground water Structures	:	11490 Ha	5946 Ha
V	Exploratory wells	:		
	Bore wells drilled by CGWB under Normal Exploration Programme	:	15 Nos. (Including observation wells)	
	Bore wells drilled by CGWB under Accelerated Exploratory drilling Programme	:	5 Nos.	
VI	Ground Water Resources			
	a) Annual Extractable Ground Water Resource	:	30689.22 Ham	
	b) Annual ground water draft (for all uses)	:	16494.11 Ham	
	c) Net Ground Water Availability for Future Use	:	14117.77 Ham	
VII	Stage of ground water development	:	53.75 %	

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1. Introduction

1.1 INTRODUCTION

Deogarh was awarded the status of a district in January 1994 being carved out from the erstwhile Sumbalpur district. The district has a geographical area of about 2940 sq. km constituting about 1.89 % of the total geographical area of Orissa and is divided into 1 subdivisions and 3 administrative blocks. Mappable area of the district is 1864 aq. Km. excluding the hilly areas.

1.2 Scope of the Study:

Agriculture is the main source of income of the people and the district has a subsistence-oriented agricultural economy. The available surface water sources are not sufficient to meet the requirement of irrigation round the year. Thus the agriculture remains mostly rain fed and unstable. The exploitation of groundwater resources in the district is 53.75%. Hence there is a further scope for ground water development in the district which can cater to the need of irrigation, drinking water and industries and thus the overall development of the district. In this perspective, this report presents in a nut shell the hydrogeological framework and the ground water development prospects in the district as revealed from hydrogeological, hydromorphological, hydrochemical studies and ground water exploration so far carried out in the district to delineate potential aquifer systems and to assess their yield potentials.

1.3 Methodology

1.3.1 Approach and Methodology

Multi-disciplinary approach involving geological, geophysical, hydrological, hydrogeological and hydro-geochemical survey would be carried out to meet the aim and objectives listed above. GIS would be used to prepare the maps.

1.3.2 Compilation of Existing Data and Identification of Data Gaps

Preliminary work included the collection and review of all existing data which relate to the area. This usually included the results of any previous hydrogeological studies and exploratory drilling carried out by CGWB and State agencies and compiled to identify the data gaps in the study area. After the data compilation all the data were integrated and analysed.

1.3.3 Hydrogeological Investigations

Review of background information will help to carry out further studies in the field, where various techniques can be applied to determine the three-dimensional extent and aquifer characteristics of the significant water-bearing formations. For this purpose key wells, which are distributed throughout the study area have to be established to know the behaviour of the phreatic water table during pre and post monsoon period. Well inventory and collection of relevant data is to be carried out to strengthen the data base. The analysis of the data has to be carried out for preparation of thematic maps.

1.3.4 Geo -hydrochemical Investigations

Water Samples to be collected, analyzed and interpreted to bring out ground water quality scenario of the study area.

1.3.5 Generation of Thematic Layers Using GIS

- Drainage
- Soil
- Land use and land cover
- Geomorphology
- Geology
- Hydrogeological map
- Aquifer disposition
- Ground water quality

1.3.6 Development of Aquifer-Wise Management Plan

The dimension and disposition of the aquifer is figured out on the basis of integrated study of the geologic, hydrogeological, hydrological, geochemical and geophysical information. Determining aquifer potential and characteristics are essential for their effective management and sustainable development. Local ground water related issues should be identified and studied in detail to make plans to address them.

1.2. Location, Extent and Accessibility

Geographically, Deogarh district is located in the west-central part of Orissa state with the Deogarh town, as its headquarters. The district is situated between 21^0 11' and 21^0 43' North latitude and 84^0 27' and 85^0 15' East longitude covered under survey of India degree sheets nos. 73C, 73G. It is bounded on the north by Sundergarh district, on the east by Angul district, on the south by Angul and Sambalpur Districts, and on the west by Sambalpur district of Orissa.

The district is well connected by roads. Deogarh, the district headquarter is connected to the state capital by state high way. The Block headquarters are well connected by road. Interior villages are also connected with the nearby towns by all weather, fair weather and other roads.

1.3. Administrative Divisions, Demographic particulars, Population

The district is divided into 1 subdivision and 3 administrative blocks. The administrative divisions of the district are shown in Fig-1. There is 1 town (one Municipality) and 70 Gram Panchayats in the district. A total of 878 numbers of villages are there in the districts out of which 718 villages are inhabited and rest 160 are uninhabited.

As per 2011 census, the total population of the district is 312520 constituting about 0.74 percent of the total population of Orissa. The rural and urban populations are 290130 and 22390 respectively. The rural population constitutes about 92.83% of the total population. Out of total population 1,58,230 are male and 1,54,290 female as per the provisional data of the General Census of 2011.The density of population of the district is 106 against the state figure of 270 persons per sq. km. According to the earlier decennial Census of 2001, Deogarh district had a population of 2,74,108. There has been an increase of 14.01% in the population during the decade between 2001 and 2011. The literacy rate in the district recorded in 2011 is 72.57% as against 60.36 % in 2001, a marked increase of 12.21%. The rate of literacy among male is 81.92 % and that of the female is 63.05 %. The details regarding the administrative divisions of the study area are given in **Table 1.1**. The block-wise demographic details are shown in **Table-1.2**.

Table 1.1 Administrative divisions of Deogarh District

Sl No	Block Name	Area	GPs	Villages
1	Barkote	1004	24	297
2	Reamal	962	26	335
3	Tileibani	995	20	246
Total		2961	70	878

Table-1.2.Block-wise demographic details of Deogarh District

Sl No	Block	Population (2011)		
		Male	Female	Total
1	Barkote	54843	53327	108170
2	Reamal	54495	52981	107476
3	Tileibani	37328	37156	74484
4	Urban(Deogarh)	11564	10826	22390

Figure 1.1 Administrative map of Deogarh District

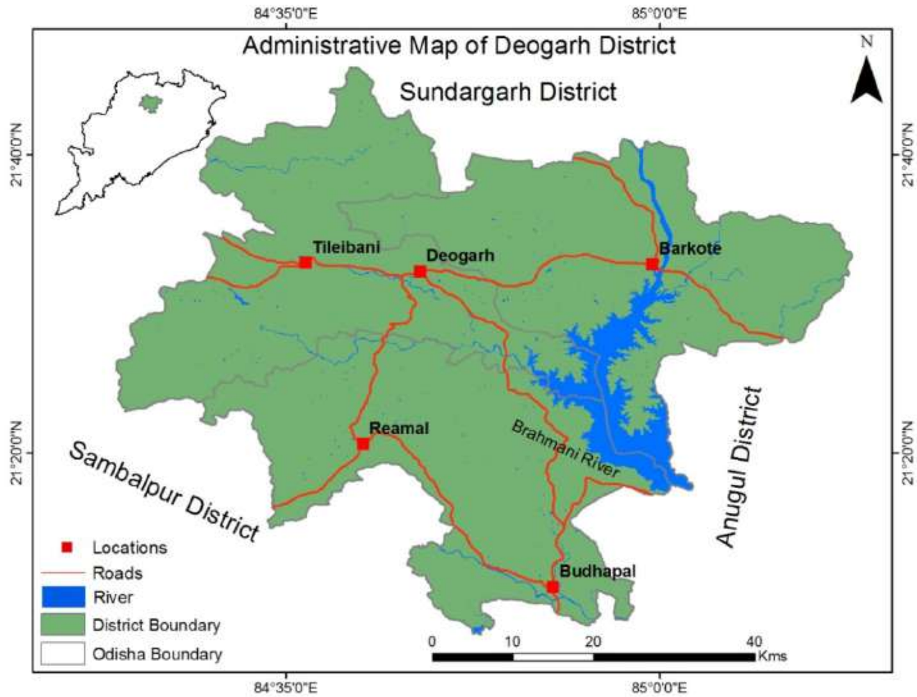
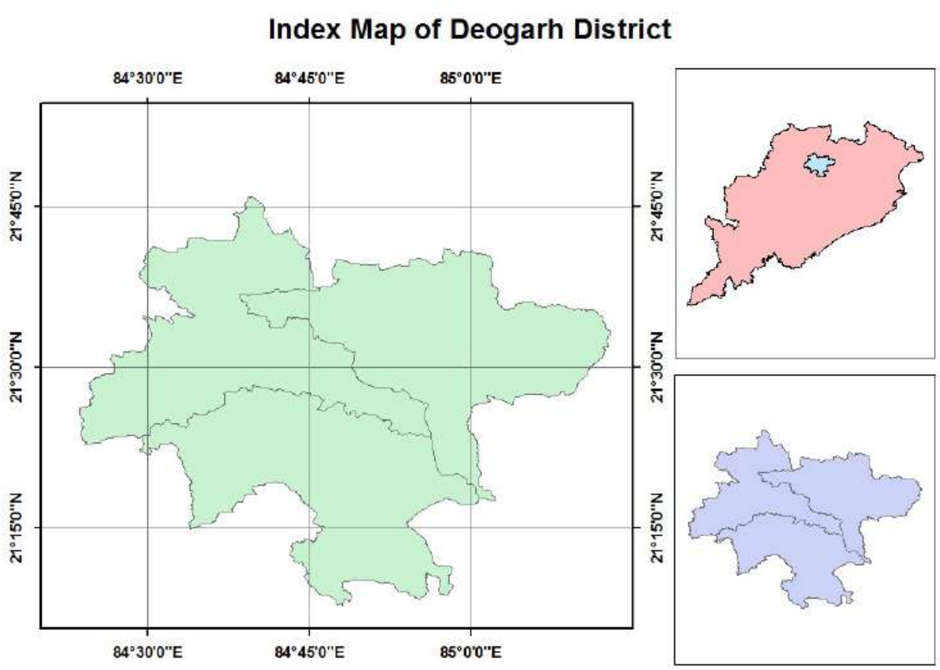


Figure 1.2 Index map of Deogarh District



2. Rainfall and Climate

1.0 Rainfall

Southwest monsoon is the principal source of precipitation in the district. The normal annual rainfall of the district is 1500 mm, out of which about 85% to 90% is received during monsoon season (mid June to mid October).

Monthly rainfall data of the district for the period from 2012 to 2021 is presented in table 2.1 and the block wise data is presented in table 2.2. Based on the rainfall data of rain gauge stations at the block head quarters the isohyetal map has been prepared. The district received the maximum precipitation in the year 2015 being 4744.8 mm. The rainfall is highly erratic both in space and time. There is a large spatial variation as observed from the rainfall data of the various blocks. The rainfall pattern over the years also shows large variations. However, it is observed that the number of surplus rainfall years and deficit rainfall years almost balance each other and there is frequent failure of the monsoon. Average rainfall of the district is presented in Fig. 2.1.

Table 2.1 Monthly Rainfall in Deogarh District

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	5.8	4.8	12.5	0.0	214.7	495.0	792.1	972.0	437.9	109.7	0.8	70.8
2013	0.0	17.8	4.4	132.7	201.3	421.4	837.5	971.5	1638.4	114.6	0.0	0.0
2014	401.5	8.2	0.0	46.8	13.6	382.8	838.8	1489.0	775.2	272.6	80.9	3.4
2015	22.2	25.5	1.1	65.1	35.9	684.1	1341.5	1188.2	467.1	914.1	0.0	0.0
2016	0.0	141.6	80.2	0.0	166.8	320.7	1499.0	1255.9	1043.9	182.5	0.0	0.0
2017	0.0	13.5	21.8	161.0	176.1	862.2	1517.5	804.0	571.9	32.0	0.0	85.4
2018	6.6	32.3	5.5	4.1	68.3	213.4	759.6	788.7	773.9	116.7	0.0	0.0
2019	1.0	0.0	119.4	1.0	172.3	856.0	1278.4	1104.5	595.9	177.4	53.0	0.0
2020	0.0	0.0	3.0	167.6	356.0	451.9	1233.9	1148.3	679.4	113.4	22.9	251.4
2021	1.5	122.8	185.9	108.1	138.9	504.1	661.4	1031.6	885.7	384.3	0.0	7.4
Average	43.9	36.6	43.4	68.6	154.4	519.2	1076.0	1075.4	786.9	241.7	15.8	41.8

Table 2.2 Block wise Rainfall in Deogarh District

Block Year	Barkote	Tileibani	Reamal
2002	797.3	1185.3	914
2003	1248	1882.1	1709
2004	549.2	1235.78	821.1
2005	952.2	1574.7	1082
2006	808	1759.9	859
2007	1096.3	1932.6	1297
2008	903.1	1591.7	1545
2009	782	1276.4	919
2010	547.5	1214.5	1085.2
2011	945.2	1616.5	1500.3
2012	1084.2	1705.1	1377
2013	1024.6	1656.2	1717.5
2014	1651.7	1567.3	1531.6
2015	1476.8	1351.5	1437
2016	1114	869.1	895.3
2017	1710.6	1449.1	1369.6
2018	1536.6	1369.3	1526.7
2019	1601.8	1435.4	1196.8
2020	383.7	317.8	325.4
2021	288.5	286.2	219.1

Table 2.3 Long-term Rainfall Analysis of Deogarh District

Year	Normal Rainfall	Actual Rainfall	Departure from Normal	Percentage Departure from Normal (in %)	Remark
2002	1300	965.53	334.47	25.73	Normal
2003	1300	1613.03	-313.03	-24.08	Moderate Drought
2004	1300	868.69	431.31	33.18	Normal
2005	1300	1202.97	97.03	7.46	Mild Drought
2006	1300	1142.30	157.70	12.13	Normal
2007	1300	1441.97	-141.97	-10.92	Moderate Drought
2008	1300	1346.60	-46.60	-3.58	Normal
2009	1300	992.47	307.53	23.66	Deficit-Normal
2010	1300	949.07	350.93	26.99	Deficit-Normal
2011	1300	1354.00	-54.00	-4.15	Deficit-Normal
2012	1300	1388.77	-88.77	-6.83	Normal
2013	1300	1466.10	-166.10	-12.78	Normal
2014	1300	1583.53	-283.53	-21.81	Moderate Drought
2015	1300	1421.77	-121.77	-9.37	Moderate Drought
2016	1300	959.47	340.53	26.19	Deficit-Normal
2017	1300	1509.77	-209.77	-16.14	Normal
2018	1300	1477.53	-177.53	-13.66	Normal
2019	1300	1411.33	-111.33	-8.56	Normal
2020	1300	1027.00	273.00	21.00	Deficit-Normal
2021	1300	793.80	506.20	38.94	Moderate Drought

2.0 Climate

The climate of Deogarh district is characterised by hot and dry summer, moist winter and rainfall during the South-West monsoon season. Winter season commences from late November and lasts until the end of February. Summer season lasts from mid-March to mid-June. The South West monsoon hits Deogarh district during mid-June and rains continue up to late September. The months of October and November constitute the post monsoon season followed by the harvesting period. Average annual rainfall in the district is 1400 millimetres of which about 86% is received during the SouthWest monsoon season and the rest rains are sporadic in nature occurring during pre-monsoon and postmonsoon period. July and August remain the wettest months. During monsoon, the sky remains overcast. In the concluding half of summer and post monsoon months clouding becomes moderate. In the rest of the year, sky remains generally clear or very thinly clouded. The relative humidity is high during the South-West monsoon season being generally over 75 percent. After the monsoon season, humidity decreases and during the winter season, the air is salubrious. The driest part of the year is the summer season when the relative humidity is rather low, the afternoon humidity being generally about 25 to 30 percent.

2.1. Temperature

Summer temperature begins to rise steadily from early March and remains at the peak until end of May or early June. The maximum temperature on an average remains about 41° Celsius and the average minimum temperature remains at about 26° Celsius during summer. On hottest days prior to the advent of the South-West monsoon during May the maximum temperatures veers between 45° to 47° Celsius. With the onset of South-West monsoon around the second week of June, day temperature appreciably drops. December and January are the coldest months of the year with the minimum temperature remaining between 7° and 12° Celsius. Due to the passing of western disturbances across North India during the winter months, short spells of extreme cold conditions prevail in the district and on certain occasions, the minimum temperature drops to about 4° Celsius.

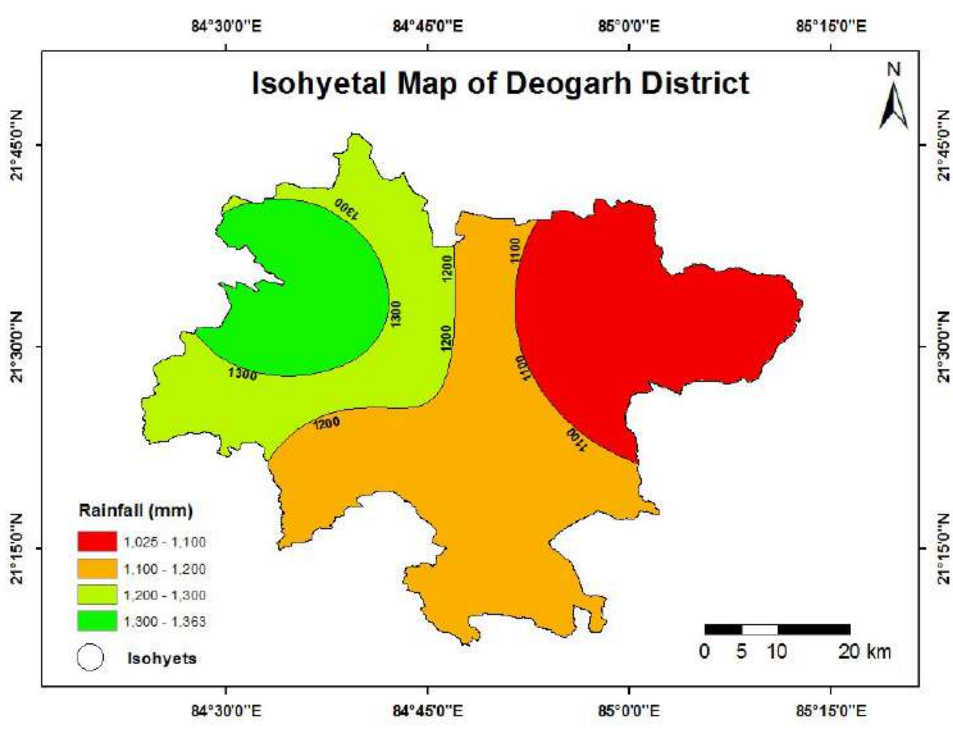
2.3. Humidity

The relative humidity is high during the South-West monsoon season being generally over 75 percent. After the monsoon season, humidity decreases and during the winter season, the air is salubrious. The driest part of the year is the summer season when the relative humidity is rather low, the afternoon humidity being generally about 25 to 30 percent. The relative humidity varies from 41% to 89% during different periods of the year.

2.4. Wind

Wind speed all across the district remains light to moderate throughout the year, with certain exceptions during summer when occasional of whirlwind is observed. In the post monsoon and winter season the wind direction is mainly from North and North-East towards South and South-West. On the onset of summer in early April, wind from the South-West and South become more common and this trend continues during the entire period from May to September. During the monsoon season, depressions form in the Bay of Bengal across the East Coast of India including the coastline of Odisha move in Westerly direction causing widespread and heavy rain accompanied by strong wind and occasional cyclonic storms. The district experiences thunderstorms accompanied by lightening mostly in the afternoon in late summer and towards early October. The South-West monsoon rain is often associated with thundershowers and thunderbolts. Fog of moderate density occurs during the winter season.

Figure 2.1 Iso-hyetal Map of Deogarh District



3. Geomorphology

3.1. Physiography and Landform

The natural bearing of the district is very beautiful and enchanting with vast ranges of deciduous forest and tree-clad hills ranges. This landscape alternates with valleys and plateaus gleaming bright in the sun, with green waving crops of paddy in monsoon and winter seasons with brilliant yellow mature crops of Surguja, an indigenous variety of paddy contrasting brilliantly with the deep green foliage of the forest. The district forms a series of hill ranges with elevation of nearly 610 metres or about 2000 feet on an average rising to a height of 797 metres at some places above the mean sea level rolling backwards towards the headquarters. Land formation of the district is mainly of two types – valleys of hill tract and the open plain land close to the various rivers and rivulets. The district forms watersheds from west to east, with fine valleys in between with discharge of water to Brahmani, Tikira and Gohira, three major rivers of the district with their rivulets of the inner tablelands. The eastern side of the district is the valley of Brahmani spreading out into fertile plains watershed by Kaidanta, Pradhanpat and Paudi Hill streams. From the eastern bank of Brahmani, the Paudi Hill ranges 678 metres high from the sea level. It slopes down upon the southern side of the Barkote Block of the district. Many waterfalls drops over the sheer southern face of the PradhanpatKaidanta hill ranges. The district has plateau land comprising small valleys bounded from all sides by hills. The tops of these ranges in the three blocks of Barkote, Reamal and Tileibani form fine plateau lands.

The topography is largely undulating with ridges and valleys as the prominent features. The uplands are located at the crest of the ridges and the upper slopes constitute the unbounded and bounded lands. These are locally called Aat and Mal land respectively, which constitute the highland. The valley bottomlands which are called Bahal constitute the low lands and the lower valley land constituting medium lands is called Berna.

Residual Hills

Physiographically the district comprises undulating plains dotted with residual hills and mounds except for a few patches of scattered hills and high relief areas in the eastern parts. A gently undulating terrain with a vast stretch of cultivable land characterizes the major parts of the district, the average elevation being 93 m to 797 m above mean sea level with a general topographic slope towards east.

Figure-3.1 Geomorphology Map of Deogarh District

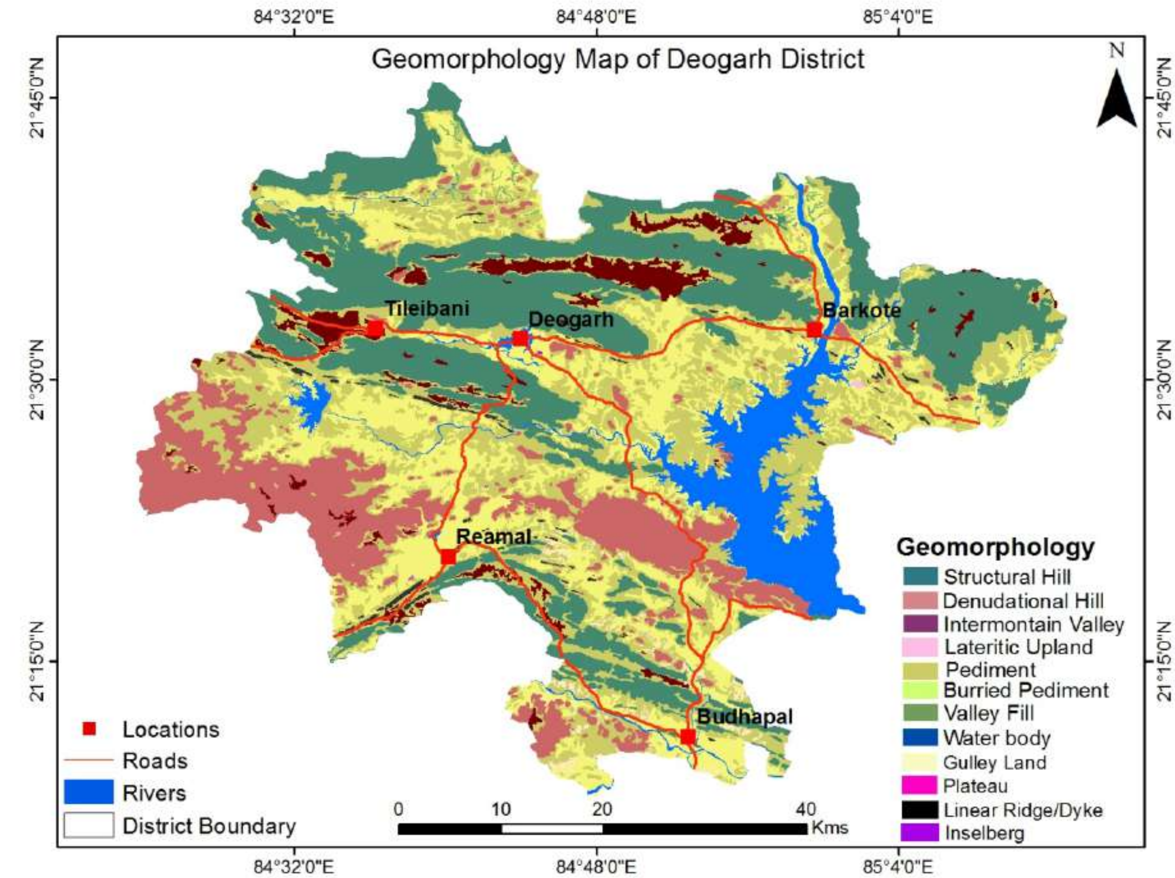


Figure-3.2 Drainage Map of Deogarh District

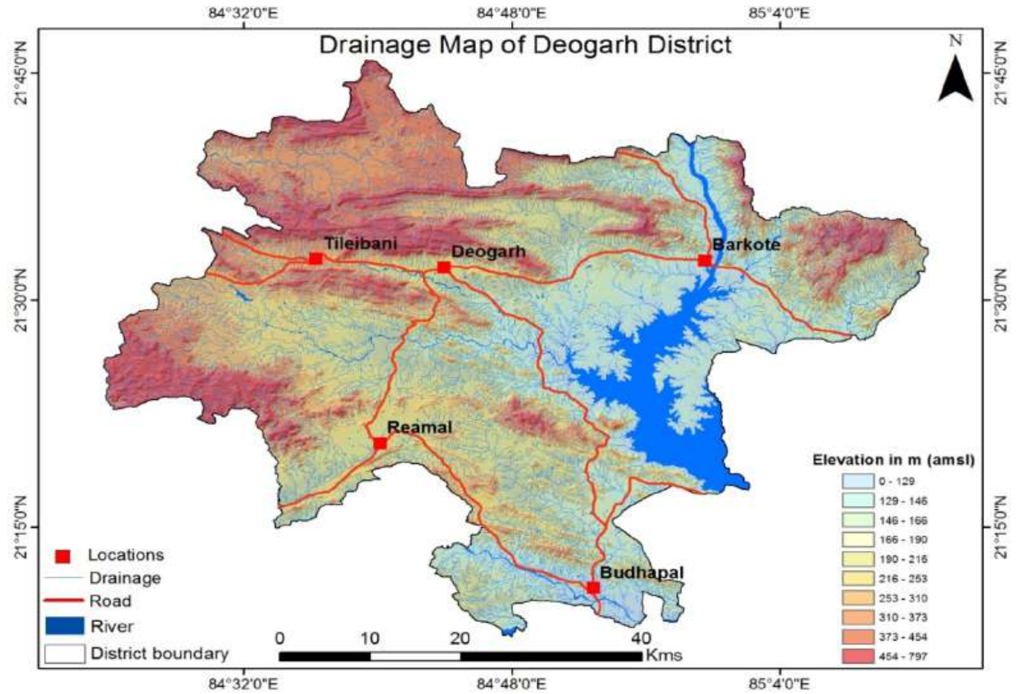


Figure-3.3 Land Elevation Map of Deogarh District

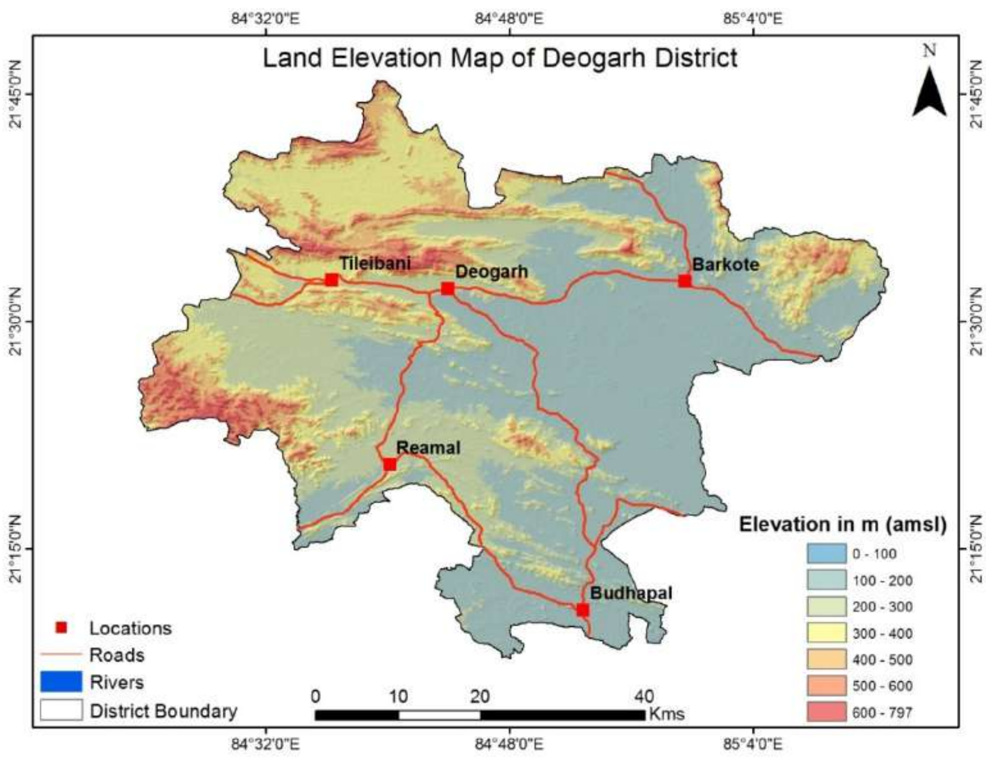
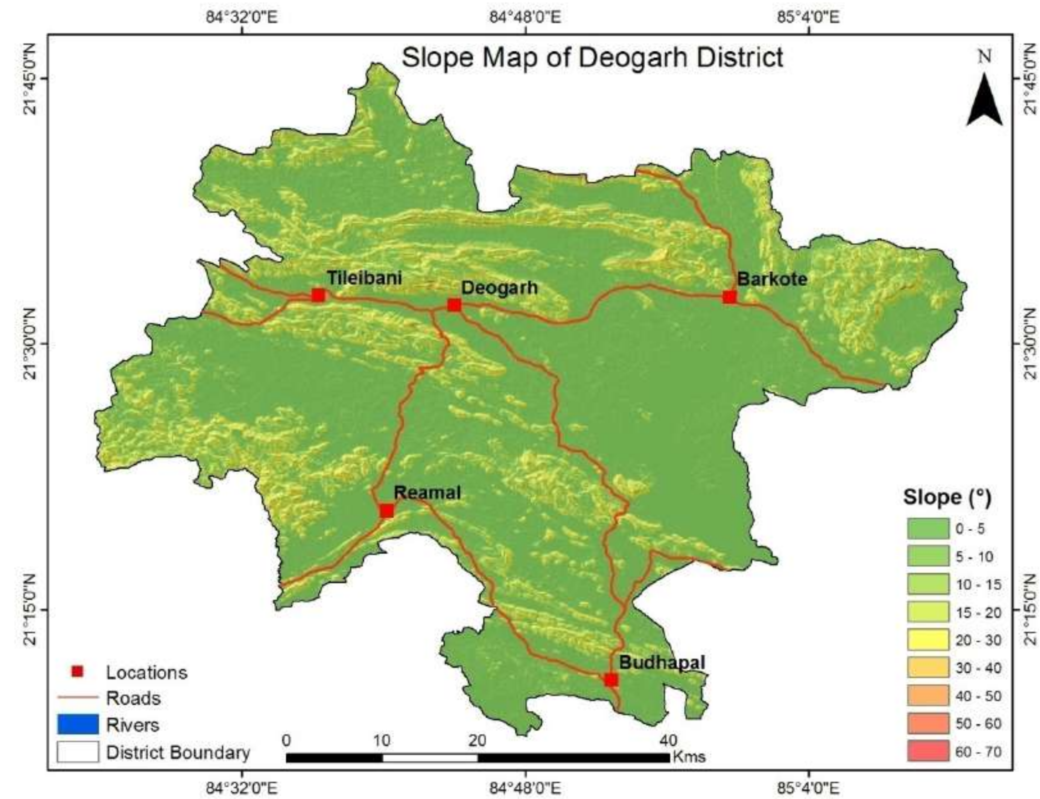


Figure-3.4 Slope Map of Deogarh District



The hill system of Deogarh district can be grouped mainly under six ranges: (i) The Khajuria range on the north side of the district running from westeast in Loimura of Deogarh Police Station, Tileibani Block with a maximum height of 745 meters from the sea level. (ii) The Pradhanpat and Kaidanta ranges 743 meters and 797 meters respectively are on the north side of the Deogarh town and just below the Khajuria range, weaving a vast (iii) Plateau in between running from west-east up to the bank of the river Brahmani covering Tileibani and Barkote Block. (iv) On the eastern side of the river Brahmani runs a range of hills called Paudi having 678 meters height from sea level. Probably the hills named after the Paudi Bhuyan, those live in the Paudi reserved forest in Barkote Block. (v) The Ushakothi range at Hillanga hills in Kansar covering Tileibani and Reamal Block extending up to Malichua-Latakhandi towards east. It is in south side of Tileibani Block. The elevation of this hill range is from 610 to 672 meters from the sea level. (vi) RambhaDebi-Sindura Hill ranges nearest to

Deogarh town in south of Tileibani Block having 580 meters to 430 meters height from the sea level. (vii) Sulia Hill range of Reamal Block having 430 meters height from the sea level. All the above hill ranges are covered by dense forest. Among them, Pradhanpat, Kansar, Pravasuni, Rambha Debi, Panguli, Thianal, Mandasila, Pauri, Badataila, Khilei, New Pauari, Khajuria, Sulia Reserve forest are the recorded forest areas of the district. The district is noted for Kendu leaf, Mahul flower and Sal trees. The forests produce a considerable quantity of Lakha, silk, cocoons, resin, bees-wax and honey. The district has thick and inaccessible forest and a large variety of wild life from elephants to rabbits is found especially in Kansar forest, close to Ushakothi Sanctuary.

Drainage

The drainage of Deogarh district is controlled by River Brahmani along with its numerous tributaries. Gohira, Tikra, Jaraikela, and Mankra rivers are important tributaries of Brahmani having a general easternly course. The Brahmani is perennial in nature where as the tributaries are ephemeral. Few other small nalas contributing to the drainage system of the districts are Arkhai Nala, Lamodar Nala, Minjali Jor, Chilanti Jor, Borjor Jor, Gainta Nala etc. the drainage is mainly dendritic to sub dendritic in nature.

Waterfalls

The finest of waterfalls drops over the southern face of the Pradhanpat-Kaidanta hill ranges. The Pradhanpat and the Korodkot waterfalls are of aesthetic, ecological and historical importance and much visited by tourists for their beauty. The district has plateau land comprising small valleys shut in on all sides by high hills. Tops of these ranges in all the three blocks of Barkote, Reamal and Tileibani form fine plateaus of level lands but generally run up to a small elevation of some 5 metres at one end above the plateau which averages about 100 metres. These ranges are covered with tall grass and form the feeding ground of both domestic and wild animals. The largest and finest of these ranges are the Khajuria and the Rambhadebi ranges near Suguda and Laimura plateau in Tileibani Block of the district. From the eastern bank of Brahmani, the Paudi Hill ranges 678 metres high from the sea level.

4. Soil and Land Use

4.1 Soil Characteristics

The most predominant soil types of the district are sandy-loam and red soil. There are a few tracts where black soil is also present. The agricultural land of the district is marked to have five landforms such as hill, ridges, valley, plain and stream terraces. These can be further subdivided into different land types and sub-land types. Broadly these can be classified as high land, medium land and low land. The climate, vegetation and other biotic factors, rock types and topography indicating different land types have considerably influenced genesis of the soil in different parts of Deogarh district.

Nature and Type of Soil and Fertility

As regards type of soil, there exists less variation between Barkote and Tileibani blocks except that a larger portion of alluvial soil occur in Barkote block on the embankment areas of Brahmani river which covers the backwater area of Rengali Dam. However, the soil of Reamal block contain much variation as compared to the other two blocks with the presence of about 02 percent typical black soil.

Details of type of soils pre-dominant in the District

Black Soil:

This soil is found in Budido, Dharampur, Dhauragoth, Reamal, Nauliapada area of Reamal block which contains liberal amount of organic matter. On this type of soil during Kharif season paddy is cultivated. Onion and other vegetables are grown during the Rabi season under irrigated condition. Cereals like mung and gram are grown as non-irrigated Rabi crops.

Red Soil:

This soil is found extensively in all the three blocks of the district. Mostly paddy and crops other than paddy are grown in this type of soil. Sandy Soil: This soil is prevalent in high lying “Att” and “Mal” land and is dependent on rainfall. The soil is coarse and contains low organic matter. Sand is found to a considerable part in such soil and ground nut along with minor pulses are grown. Att lands are used for crops which are less dependent on moisture. This type of soil is predominant in all the three blocks of the district

Sandy Loam Soil:

This type of soil is available in all three blocks of the district and is found in most of the Berna and Bahal land of the cultivated track. Soil test results reveal that soils of Barkote and Tileibani block are mainly acidic.

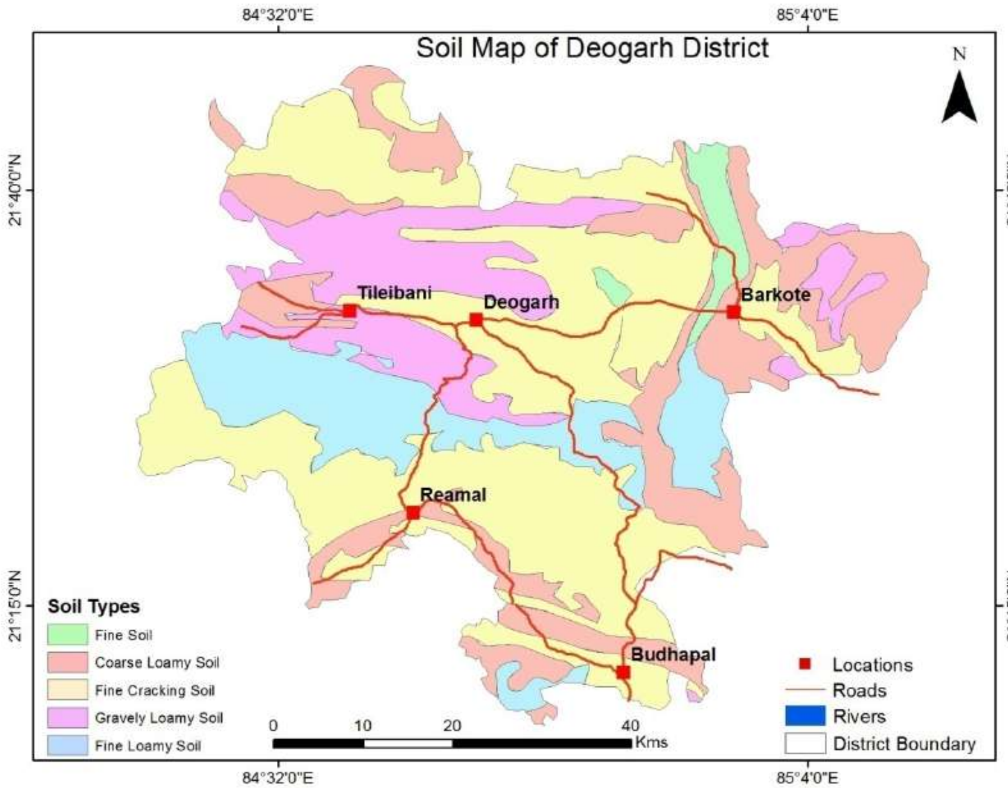
Based on the physical and chemical characteristics, mode of origin and occurrence, soils of the district can are found to be Alfisols types.

Alfisols :

The Alfisols include red sandy soils, red loamy soils mixed red and black soils. These soils occur in major parts of the district. These soils are neutral to slightly alkaline in nature. The characteristic features of red soils are (i) light texture, porous and friable structure, (ii) absence of lime kankar and free carbonates and (iii) soluble salts in small quantity usually not exceeding 0.05%. These are usually deficient in nitrogen, phosphate, organic matter and lime. These soils are suitable for cultivation of paddy and other crops. Red loamy soils are scattered in pockets throughout the districts. Mixed red & black soils are found in small patch in the southern part of the district where as the majority of the district is being covered by red sandy soil.

Soils of the district are generally having average to good fertility status. All common types of crops can be grown in the district. The distribution of different soil types in the district is presented in soil map.

Figure 4.1 Soil Map of Deogarh District



4.3 Land Utilisation:

The land use pattern is closely related to the geomorphological and climatic condition of the area. The land use pattern of the district is summarized in Table –4.1.

Table – 4.1 Land use pattern of Deogarh district

1.	Forest area	:	79263 Ha
2.	Misc. tree crops & groves	:	811 Ha
3.	Permanent pasture and other grazing lands	:	6347 Ha

4.	Culturable waste	:	10168 Ha
5.	Land put to non-agricultural uses	:	14363 Ha
6.	Barren and uncultivable land	:	3449 Ha
7.	Current fallows	:	4664 Ha
8.	Old fallows	:	6806 Ha
9.	Net area sown	:	45473 Ha

Agriculture

Deogarh district has varied agro-climatic conditions. Rainfall in the district is moderately high but the irrigation facilities are inadequate. The total cultivable land in the district is 79,267 Ha out of which the net shown area is only 66,950 Ha.

There are mainly two crop seasons, Kharif and Rabi. Paddy is the major Kharif crop. The Rabi crops are Paddy, Pulses, Oilseed, and Vegetables etc. Paddy is the principal crop of the district and the season wise area of paddy cultivation in different blocks is presented in Table- 4.2

Table- 4.2 Season wise area of paddy cultivation in different blocks

Blocks	Area in Autumn (Ha)	Area in Winter (Ha)	Area in Summer (Ha)	Total Area (Ha)
Barkote	9380	125	0	9505
Reamal	12650	1156	0	13806
Tileibani	12470	1200	0	13670
District total	34500	2481	0	36981

Figure 4.1 Land Use Map of Deogarh District

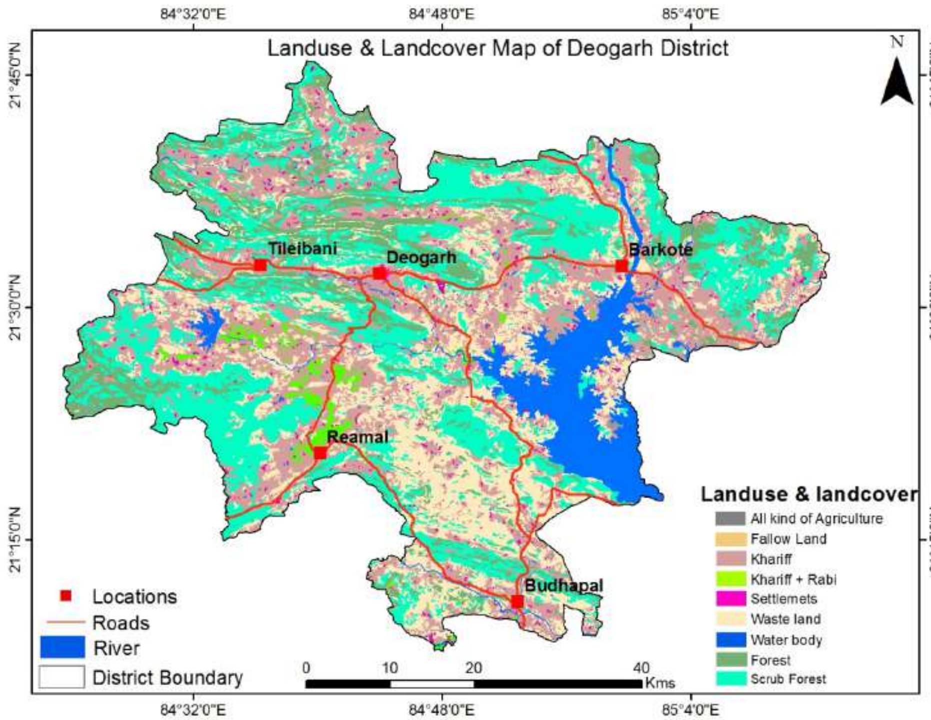


Table: 4.3 Block wise Land Utilisation Pattern (Ha)

Sl No	Block	Forest	Land under non Agricultural use	Barren and Non Cultivable land	Permanent Pastures and other grazing land	Land under misc. trees and crops not included in net sown area	Cultivable waste	Old fallows	Current fallows	Net Area Sown
1	Barkote	15321	6691	1277	1462	312	2538	1653	1459	18221
2	Reamal	39224	3633	1525	1941	269	1886	2030	1000	16894
3	Tileibani	24398	3711	629	2911	213	5627	2963	1991	9877

Table: 4.4 Crop Wise Irrigation Statuses

Crop Type	Kharif (Area in Ha)			Rabi(Area in Ha)			Summer(Area in Ha)		Total Area in Ha		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Total	Irrigated	Rainfed	Total
Cereals	19583	14917	34500	2481	0	2481	0	0	22064	14917	36981
Coarse Cereals	107	1109	1216	190	0	190	5	5	302	1109	1411
Pulses	69	15376	15445	2182	8838	11020	250	250	2501	24214	26715
Oil Seeds	50	9082	9132	2455	8163	10618	670	670	3175	17245	20420
Fibre	0	258	258	0	0	0	0	0	0	258	258
Any other crops	3330	3069	6399	6871	647	7518	760	760	10961	3716	14677
Total	23139	43811	66950	14179	17648	31827	1685	1685	39003	61459	100462

Table: 4.5 Block Wise Irrigation Status

Block	Net Area Sown	Irrigated (area in Ha)			Rainfed Area (in Ha)		% of Net sown area to Irrigated area	% of Gross cropped area toIrrigated Area
		Net Irrigated Area	Gross Cropped Area	Gross Irrigated Area	Partially irrigated/Protective Irrigation	Un-irrigated or Totally Rainfed		
Barkote	20925	6566	30649	9667	2228	18913	31	32
Reamal	24200	11056	37038	17904	1202	13463	46	48
Tileibani	21825	7621	32775	11432	3011	12044	35	35
District Total	66950	25243	100462	39003	6441	44420	38	39

Diversification, Cropping Pattern and Crop Rotation

Crop diversification is governed mostly by price fluctuations in market, change in food habit, availability of high value, efficient cropping technology and above all weather conditions.

In rain-fed area of high, medium and low land area farmers grow single crop except in residual moisture situation in some of the medium and low land area where farmers usually grow short duration non- paddy crops like pulses, oilseeds (mustard) and pyra crop like field peas, birhi, etc. In irrigation-potential areas farmers grow multiple crops during both the season of the year. Principal crops during Kharif season is paddy, followed by pulses, oil seeds, vegetables during Rabi season.

When irrigation is assured with organised extension work, farmers are usually taking up multiple cropping. Introduction of improved agricultural practices and short duration high yielding varieties have provided opportunities for multiple cropping. Farmers are growing even three crops in irrigated area.

During Kharif, hybrid Paddy is mostly grown along with other varieties of paddy. Other crops like Maize, Millets, Pulses, Oilseeds and some fibres are also gown. Besides these,wheat, pulses, vegetables and condiments are also grown. The following crop rotations are usually adopted by the farmers in Deogarh district.

1) Att Land:- Ground nut- Potato- Vegetable; Mung- Hybrid MaizePumpkin; Mung- Cauliflower- Pumpkin

2) Mal Land- Paddy- Potato, Summer Til; Paddy- Pulses- Ground Nut, Summer Vegetable; Early Paddy- Wheat

3) Berna Land- Early Paddy- Wheat; Paddy-Pulses, Field pea/ Mung, Gram; Paddy- Dalua paddy

4) Bahal Land- Paddy- Field Pea; Paddy- Dalua paddy

5. Drainage and Irrigation

Drainage System:

The drainage of Deogarh district is controlled by River Brahmani along with its numerous tributaries. Gohira, Tikra, Jaraikela, and Mankra rivers are important tributaries of Brahmani having a general easternly course. The Brahmani is perennial in nature where as the tributaries are ephemeral. Few other small nalas contributing to the drainage system of the districts are Arkhai Nala, Lamodar Nala, Minjali Jor, Chilanti Jor, Borjor Jor, Gainta Nala etc. the drainage is mainly dendritic to sub dendritic in nature.

The eastern side of the district is the valley of Brahmani spreading out into fertile plains by Kaidanta, Pradhanpat and Paudi Hill streams. It slopes down upon the southern side of the Barkote Block of the district. This watershed in turn slopes down into the Rengali Dam Reservoir. The southernmost of the district is the valley of Tikira, Gohira and the rivulet Hinjuli, spreading out into fertile plains of Reamal Block of the district by Sulia, Hillong hill tract streams.

Waterfalls, Springs, Lakes and Tanks

There are natural springs (jharana) in Deogarh district namely Pradhanpat, Kurodkot, Kai Jharan, Bairikatajharan, Nagti Jharan, Lia Jharan which cascade down the Pradhanpat reserve forest of Kaidanta hills creating pools of water at the foot of the hills. The Pradhanpat and Kurodkot are veritable waterfalls. Emanating from hill tops of considerable height, they fall down the slope of hills creating several perennial waterfalls. The Pradhanpat waterfall nearest to Deogarh town supplies drinking water to the town throughout the year. Water flowing down from Kurodkot is used for irrigation purposes. Kai Jharan, Nagti Jharan, Bairikata Jharan and Lia Jharan also come down from Pradhanpat reserve forest of Kaidanta hill range. To the west of Deogarh is the Kai Jjharan near village Kurod in Tileibani block, Nagti Jjharan near Tainsar village and Liajharan near village Dhiramunda. All these jharans are situated in Tileibani Block. There are three springs in Barkote Block. They are Kaunsibahal Jharan, Panchamahala Jharan and Chakadihi Jharan flowing down from Pradhanpat reserve forest of Kaidanta hill region. Kaunsibahal Jharan is in the east of Deogarh on near Kaunsibahal village, Panchamahala Jharan is near village

Panchamahala, Chakadihi Jharan near Chakadihi village in Barkote Block whereas Katasar and Chingudi Jharan are in Reamal Block.

There is no natural lake in the district. The Rengali Dam Reservoir covers a large area in the south eastern part of the district. 147 villages of Deogarh district were submerged in the reservoir. It is considered to be the largest artificial lake in the district. The Gohira Dam Reservoir in Tileibani block is in south-west 28 Kms from Deogarh used for irrigation of farmland in Tileibani and Reamal block. Apart from these two reservoirs, there are many tanks in the district, which serve the purpose domestic and irrigation needs of the villagers in the vicinity. Among them the important ones are Mohinipur tank at Mohinipur village, Magar kata at Santarapali village, Basudebpur kata at Basudebpur village, Kalamati kata at Kalamati villageall are in Tileibani block.

Gohira Medium Irrigation Project

Construction of the Gohira Medium Irrigation Project was started in 1976 and completed in 1981 as a part of the Rengali Dam Project before the formation of Deogarh district. It is constructed across Gohira Nalla, a tributary of the river Brahmani. The command area is irrigated by two main canals to the left and right of the dam.I t has a catchment area of 236 sq. Km with discharge capacity of 1840 Cusecs. The project has a gross command area of 10325 Ha and a certified command area of 8165 Ha covering 88 villages of Tileibani and Reamal blocks. This project irrigates 8165 Ha In Kharif and 3429 Ha during Rabi. The intensity of irrigation is 100 per cent in Kharif and 42 per cent in Rabi seasons. The water from the dam flows through two canals - the left canal and the right canals which run 22.35 km runs 25.84 km respectively.

Minor Irrigation Projects

A total no. of 31 M. I. Ps including the category of Reservoir and Diversion Weir, designed to provide 4660 hect in Kharif and 209 hect in Rabi cropping seasons. The certified ayacut are 3113 ha in Kharif and 167.41 ha in Rabi.

Lift Irrigation

In Deogarh District majority of the population depends on agriculture. The irrigation facilities are inadequate to meet growing demand of agriculture production. The monsoon rainfall is erratic, irregular and unpredictable for growing crops in both Kharif and Rabi, which is the only livelihood for the people of this area. Hence the Lift Irrigation can be treated as immediate measure to increase in irrigation facilities. This will help the farmers to save their Kharif Crops in drought like situation and to raise cash crops like Ground Nut, Potatoes, Vegetables, Water Melon and Sun Flower etc in Rabi Season. There are 122 nos existing River Lift Projects in different village under three Blocks of Deogarh District. Details are given below.

Table 5.1 Details of L.I. Projects in Deogarh District

Sl No	Block	Nos. of existing L.I. Project	Area in hect.
1	Barkote	43	960
2	Reamal	26	548
3	Tileibani	53	1180
	District Total	122	2688

Table 5.2 Source wise Irrigation Structures in Deogarh District

Block	Medium Irrigation		Minor Irrigation		Lift Irrigation		Dugwell		Borewell		Other sources	Total Ayacut in Ha
	Nos.	Ayacu t in ha.	Nos.	Ayacu t in ha.	Nos.	Ayacu t in ha.	Nos.	Ayacu t in ha.	Nos.	Ayacu t in ha.		
Barkote	0	0	11	2132	51	1099	1083	437	508	628	2270	6566
Reamal	1	6192	4	268	60	1158	2035	824	554	684	1930	11056
Tileibani	1	2246	9	886	45	1152	1285	792	192	336	2209	7621
District Total	2	8438	24	3286	156	3409	4403	2053	1254	1648	6409	25243

6. Geology

Geology

The district is underlain by Precambrian crystallines, metamorphics intrusives, sedimentaries of Permocarboniferous ages and recent laterites and alluvium. The generalized geological successions of the district is as follows:

Table 6.1 Stratigraphic sequence in Deogarh District

Quarternary	Recent to sub-recent	Alluvium and Laterites
	Unconformity	
Permian to Upper Carboniferous	Lower Gondwana	sandstone, shale Conglomerate etc.
	Unconformity	
Precambrian	Easternghats Super Group	Quartzites, slates, phyllites, schist and gneisses. Granite and granite gneisses, charnockites, khondalite

Easternghat Super group:

The granites and granite gneisses are the predominant rock type in the district forming undulating plains. These are light gray to gray in colour, fine to coarse grained and composed of quartz, felspar, biotite, garnet etc. are represented by Biotite Gneiss, Porphyritic Granite Gneiss. The granitic rocks exhibit well-developed foliation but at places are compact and massive.

The khondalite suite of rocks are exposed in small parts in the southern part of the district forming hills. The Khondalitic suit of rocks consist of mainly quartz-garnet-sillimanite-schist and gneiss and garnetiferous sillimanite-quartzite and calc silicate granulites. These rocks are medium to coarse grained in texture, well foliated and brownish to reddish in colour. These rocks usually form steep hills in the southern part of the district.

The charnockite suite of rocks occur as isolated hills and are not extensively developed in the district. Weathering is not pronounced and foliations and joints are not well developed.

Iron Ore group of rocks:

These occupy northern part of the district. The quartzites form east-west trending hills while the schists occupy the valleys. Quartzites are well bedded, jointed and having fissile bedding planes.

Gondwana Sedimentary:

These rocks occur in the southern part of the district covering a small part of the district. Gondwana sedimentary comprises sandstones, siltstones, shales and conglomerates etc. The sandstones are fine to coarse grained, gray to brown in colour and show ripple marks and current bedding. The shales are compact, greenish to brownish in colour. The conglomerates are intra-formational and contain subrounded pebbles of granite gneiss in a ferruginous and clayey matrix. The Gondwana formations have faulted contact with Precambrians. The group is represented by Talcher, Barakar, Barren measures and Kamthis.

Alluvium and Laterites :

The Quarternaries include laterite and alluvium. Laterites occur both as capping over the older formations as also in the valleys. Alluvium consisting mainly of sand, gravel, silt and clay occurs in the close vicinity of the major drainage channels like Brahmani River.

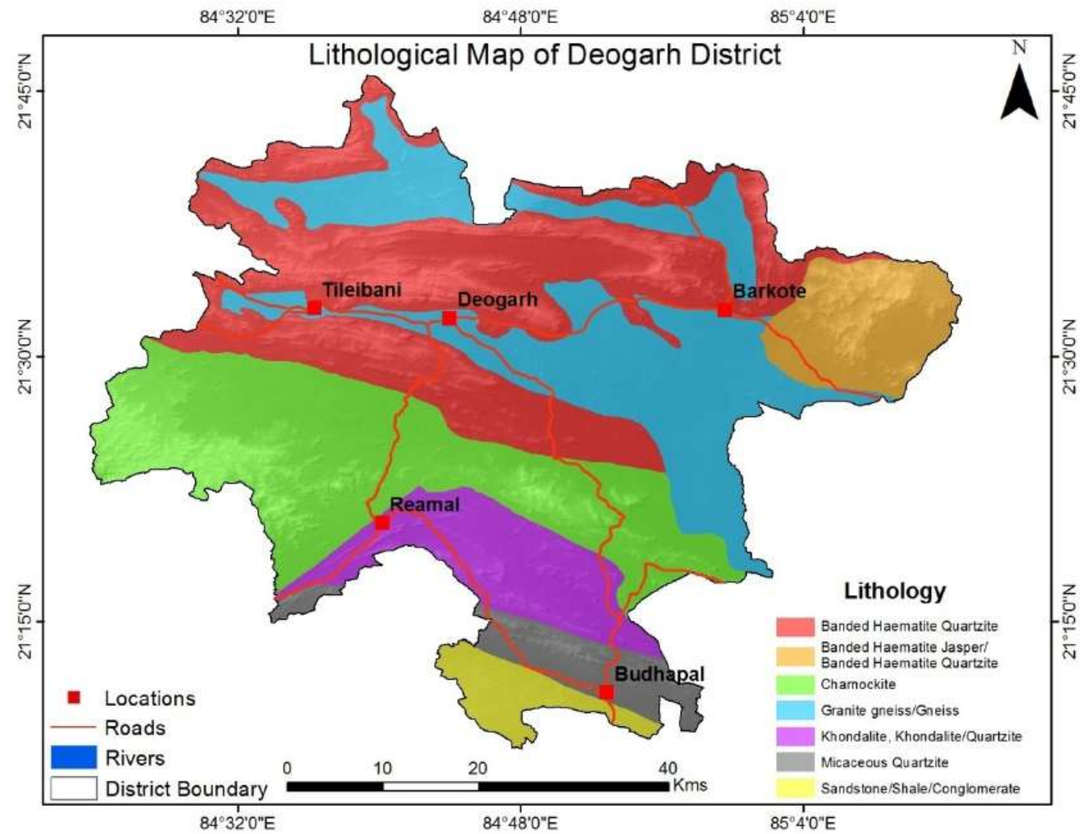
Structure: -

The regional trend of foliation and schistosity of the rocks of the Easternghat group is NE-SW, NNE-SSW and E-W. Foliation dips are steep (60^{o} to 80^{o} to almost vertical) towards north and northwest. The Precambrian rocks are well jointed. The most common sets of joints are

(i) N – S (ii) E – W (iii) NE – SW and (iv) NNW – SSE with steep dips.

Boundary fault and intrabasin faults are found in gondwana group of formations with gently dipping (4-9 degree) in various direction. Rocks are free from igneous intrusion. The Iron ore group is having E-W trend.

Figure: 6.1 Lithological map of Deogarh District



7. Hydrogeology

Hydrogeology:

The geological set up of the district primarily controls the Hydrogeological condition of the area. The geological formations of the district have diverse lithological composition and structure. Hence the hydrogeological condition too shows wide variations. Depending upon geology, water bearing and water yielding properties, three major Hydrogeological units have been identified in the district. These are:

- Consolidated formations
- Semi consolidated formations and
- Unconsolidated formations.

Rainfall and climate, topography, soil conditions and land use are the other factors controlling ground water potentials of the area. The hydrogeological map of the district is presented in figure 7.1.

Water Bearing Properties of Major Litho Units:

Granite and Granite Gneisses.

These are most predominant rock types in the district occupying undulating terrain and low-lying areas. On weathering these rocks yield sandy residuum. In general these rocks can sustain yield from 2 to 25 lps depending on topographic setting, thickness of weathered residuum, number of saturated fracture zones encountered and their interconnection. The specific capacity of the dug wells tapping weathered zone ranges from 6 to 286 lpm/m drawdown. The thickness of weathered zone in granitic rocks usually ranges from 10 to 15 m and occasionally extends up to 30m. The weathered residuum and fracture zones form principal aquifers and developed through open wells and bore wells.

Khondalites:

The khondalities, in general occupy the hills and have limited ground water development potentials. Due to well-foliated nature of the rock, weathering is quite deep. The thickness of the weathered zone ranges from 10 to 25 m. The specific capacity of the dug wells ranges from 2.3 to 13.3 lpm/m drawdown. Ground water development is possible through open wells and borewells.

Charnockite:

There is very limited occurrence of Charnockite in the district. Weathering is not pronounced and foliations and joints are not well developed. Thickness of weathered residuum varies from 5-10m. Due to hard and compact nature of the rocks ground water development prospects in the Charnockite is not good.

Quartzites:

Quartzites of iron ore group are generally well bedded, jointed and having comparatively better ground water development prospects.

Consolidated Formations:

Except for a small patch in the southern part underlain by Gondwana formations and small strips along major rivers, almost the entire district is occupied by the consolidated formations comprising granites, gneiss, Khondalites, Quartizites, These rocks are very hard and compact, and lack primary porosity. Ground water is stored mainly in the secondary porosity resulting from weathering and fracturing of the rocks. The aquifer materials are highly heterogeneous in character showing both vertical and lateral variations. The weathered residuum forms the main repository of ground water, in which ground water occurs under water table condition and circulates through deeper fractures and fissures. Ground water occurs under confined to semi-confined condition in the deeper fractured zones. The water yielding capacity of fractured rocks largely depends on the extent of fracturing, openness and size of fractures and extent of their interconnections to the near surface weathered zone. Usually two to four water bearing fracture zones occur down to a depth of 100 mbgl.

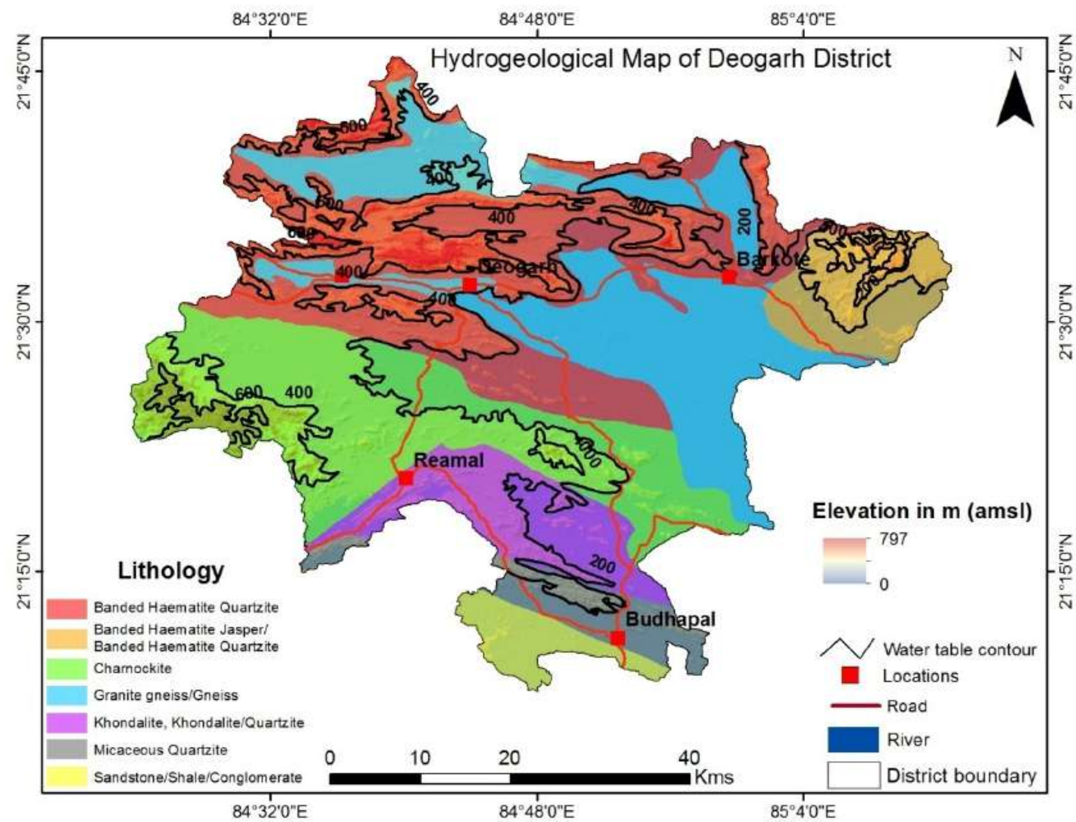
Semi-Consolidated Formations:

These are represented by the rocks of Lower Gondwana formations. These rocks occur in a small patch in the southern part of the district. These rocks have faulted contact with Pre-cambrians. The friable and loosely connected sandstones form the aquifers. Ground water occurs under water table conditions in the weathered zone and under semi-confined to confined condition in the deeper fractured and friable sandstone beds. The depth of the open wells ranges from 5 to 12 mbgl and depth to water level ranges from 3 to 10 mbgl. The yield of the wells in these formations in the district is generally limited.

Unconsolidated Formation:

Laterites and alluvium of Sub-recent to Recent age constitute the unconsolidated formations. Laterites occurring as capping over older formations are highly porous in nature and form good aquifers to be tapped through dug wells. The alluvial deposits of recent origin occur as thin discontinuous patches along the prominent drainage channels. The alluvium varies in thickness from 6 to 12 m. These mainly consist of silt, sand with gravel & pebble, which form potential shallow aquifers tapped through dug wells.

Figure: 7.1 Hydrogeological map of Deogarh District



8. Ground Water Exploration

Ground Water Exploration:

The Deogarh sub-division was carved out from erstwhile Sambalpur district and was conferred the status of separate district during 1993. The district is underlain by hard rocks of Pre-cambrian age which includes granitic rocks, quartzites and also minor meta volcanic. The quartzites mainly forms ridges and the valley areas are mostly occupied by granitic rocks. Exploratory drilling has been taken up by the Central Ground Water Board in Deogarh district with the objective to delineate deeper water bearing fractures in the consolidated formation and the Gondwanas and their yield potentiality within a maximum depth of 193m. A total of 20 exploratory and 15 observation wells were drilled in the granitic rocks more or less alog the central part in Barkote-Deogarh-Tileibani section. The depth of the wells varies from 50.9 to 193m and yield varies from negligible to 20lps. Majority of the wells yielded more than 5lps. High discharge are recorded from Deogarh (15 lps) and Purnagarh (20 lps). Other high discharge wells are located at Barkote (7 lps) and Tileibani (6 lps). The granitic rocks along Barkote-Deogarh-Tileibani section are found to be very high yielding. Apart from the normal Exploratory drilling, to mitigate the drinking water scarcity in the drought affected areas 13 Nos. of exploratory wells were drilled under Accelerated Exploratory Drilling Programme (AEDP) on contractual basis. The details of exploratory wells are given in Figure 8.1.

Aquifer Characteristics:

Phreatic Aquifer

The pumping tests were conducted on selected dugwells representing different hydrogeological units and the aquifer characteristics was evaluated in terms of Specific Capacity Index i.e. flow of ground water per metre depression of head over unit cross sectional area of inflow offered by the aquifer. The wide range of yield and specific capacity is due to very much heterogeneous nature of the weathered zone in lateral extension as well as variation of thickness of this zone.

Deeper Aquifer

Unlike phreatic aquifer, ground water occurs under confined to semi-confined condition in the deeper aquifer. The deeper aquifer comprises of the jointed and fractured consolidated or crystalline formations. In general it is confined on top by weathered formations and bottom by massive rocks. Generally 1 to 4 potential fracture zones are encountered within the depth range of 200 m. The first promising zone occurs in the depth range of 15 to 35 m., which is just below the zone of weathering. The depth range of prime importance is from 40 to 100 m. Normallythe fracture zones in this depth range have high water yielding capacities and majority of successful bore wells in the study area tapped zones within this depth range. The other potential fracture zones are found at the depth ranges of 40-65, 70-80, 95-120 and 135-160 mbgl. Granite suites rocks have more promising aquifers in comparison to other rocks like Charnockites Khondalites and Quartzites. However the success of bore wells is site specific and depends on topographic and hydro geological conditions. The details of the exploratory wells are given in Table 8.1 and exploratory wells drilled under Accelerated Exploratory Drilling Programme (AEDP) are given in Table 8.2**.**

Figure: 8.1 Locations of Exploratory Wells drilled by CGWB in Deogarh District

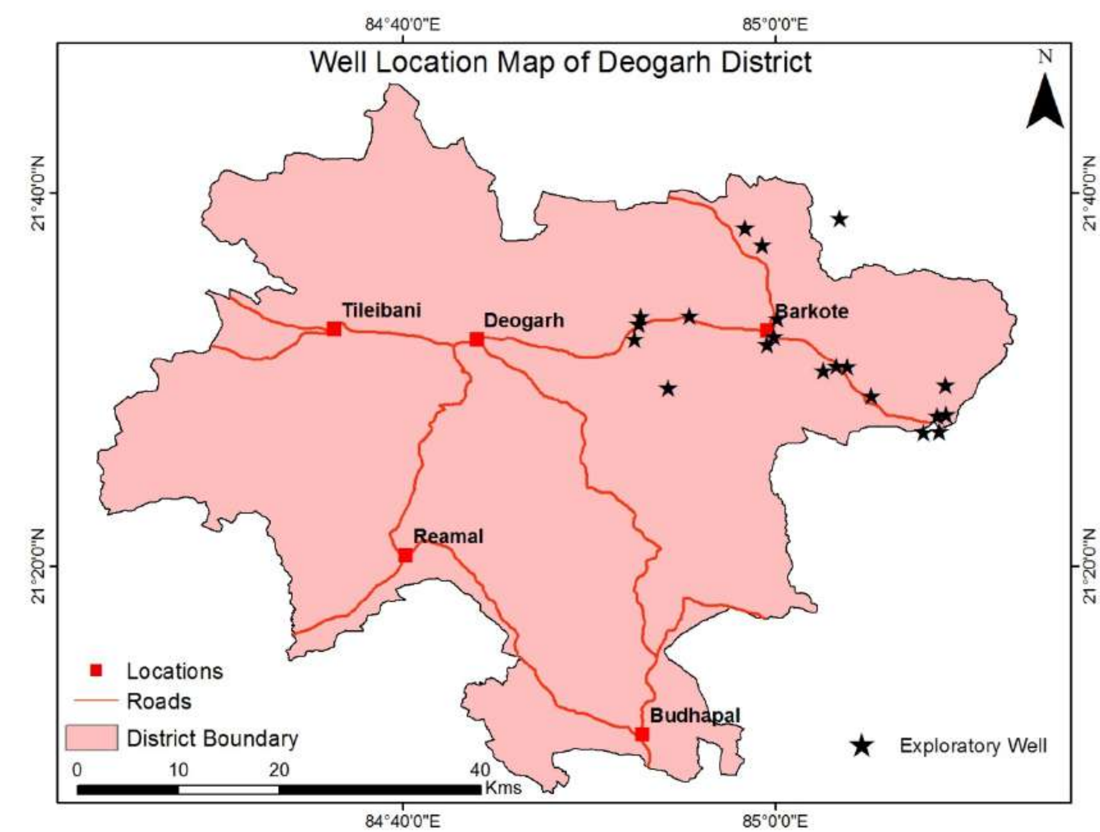


Table 8.1 Basic Data of Exploratory Wells Drilled by CGWB in Deogarh District

District	Block	Location	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Depth to Bed rock (mbgl) Casing Pipe Lowered	Granular zones/ deciphered (mbgl)	Weathered zone	Discharge (lps)	SWL (mbgl)	Drawdown (m)	T (m^2 / day)
Deogarh	Barkote	Phafand	21.4528	85.1469	175	Granite gneiss	6.3		6.3	2	5.35		
Deogarh	Barkote	Badakudur	21.4944	85.1522	141.4	Granite Gneiss	19	25.5-26.5, 52.9-53.9, 77.3-78.3, 132.2-133.2	19	6	3.05		
Deogarh	Barkote	Mandasila	21.4672	85.1450	171.9	Biotite granite gneiss	10	72.3-73.3	10	1	3.75		
Deogarh	Barkote	Thakurpally	21.6350	84.9733	171.9	Garnetiferous Granite Gneiss	12.7	72.3-73.3	12.7	2.5	4.50		
Deogarh	Barkote	Thianal	21.4522	85.1328	50.9	Gneiss Hard	25	30.6-31.6	25	5 .5	4.95		
Deogarh	Barkote	Singuri	21.6200	84.9883	166.8	Biotite granite gneiss	13.5	31-32	13.5	1.5	6.30		
Deogarh	Barkote	Badakudur	21.4944	85.1522	104.8	Granite gneiss	17.9	26.5-27.5,54.9-55.9,73.3-74.3,92-93	17.9	8	3.30		
Deogarh	Barkote	Badianali	21.0231	84.0681	172.2	Garnetiferous Granite Gneiss	11.9	15.3-16.3	11.9	0.5	3.1		
Deogarh	Barkote	Saida	21.0242	84.0564	110.9	Garnetiferous Granite Gneiss	23	36.6-37.7	23	5	5.1		
Deogarh	Barkote	Saida	21.0242	84.0564	110.9	Garnetiferous Granite Gneiss	28.5	27.5-28.5	28.5	7	2.8		
Deogarh	Barkote	Golmara	21.5111	85.0644	165.8	Garnetiferous Granite Gneiss	25.8	27.5-28.5	25.8	3.5	6.35		
Deogarh	Barkote	Manoharpur	21.5075	85.0431	141.5	Granite gneiss	7.5	18.3-19.3	7.5	3	6.5		
Deogarh	Barkote	Mandasila	21.4681	85.1528	62.1	Granite gneiss	30.9	31.9-32.9,45.8-46.8	30.9	4			
Deogarh	Barkote	Mandasila	21.4681	85.1528	142	Granite gneiss	25.3	27.5-28.5,45.8-46.8	25.3	2			

District	Block	Location	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Depth to Bed rock (mbgl) Casing Pipe Lowered	Granular zones/ deciphered (mbgl)	Weathered zone	Discharge (lps)	SWL (mbgl)	Drawdown (m)	T (m² / day)
Deogarh	Barkote	Jharabahal	22.4847	85.0861	123.1	Quartzite	37.5	39.70 - 106.80	37.5	5	5.70		-
Deogarh	Barkote	Jharabahal	21.5383	84.9992	147.5	Quartzite	44.5	41.7	44.5	0.5	5.2		-
Deogarh	Barkote	Nuasahi	21.5383	84.9992	135.3	Quartzite	20.3	26.5,45.8,73.2,124.1	20.3	8	5.50		13.47
Deogarh	Barkote	Nuasahi	21.5381	84.9992	92.6	Quartzite	19.9	22.4,50.9,63.1,71.2	19.9	8	3.00		16.65
Deogarh	Barkote	Barkote	21.5542	85.0022	86.5	Quartzite	12.7	34.6,62.1,71.2	12.7	7	1.85		26.04
Deogarh	Barkote	Jhunpura	21.6436	85.0578	159.7	Basic intrusive	19.8	22.4-23.4,123.1-124.1	19.8	1	1.20		
Deogarh	Barkote	Kaliapal	21.5356	84.8742	123.1	Granite gneiss	9.5	10-11,22.4-23.4,31.6-32.6,58-59	9.5	5	5.10		-
Deogarh	Barkote	Belam	21.5356	84.8742	78.3	Granite gneiss	19.8	24.8	19.8	7	5.20		45.21
Deogarh	Barkote	Belam	21.4919	84.9044	111.2	Garnetiferous Granite Gneiss	19.3	14.6	19.3	5	3.05		
Deogarh	Barkote	Majhichakundapal	21.5494	84.8783	111.2	Garnetiferous Granite Gneiss	23.5	32.-33.7	23.5	6	2.80		
Deogarh	Barkote	Khandal	21.5564	84.9233	123.4	Garnetiferous Granite Gneiss	15.7	43.8-44.8,56-58,62.63,72.3-73.3	15.7	1.9	0.25		
Deogarh	Barkote	Kansibahal	21.5558	84.8797	153.9	Garnetiferous Granite Gneiss	8.2	30.6-31.6,74.4-75.4	8.2	2	2.8		
Deogarh	Barkote	Bisi Baliposi	21.5311	84.9925	153.6	Granite gneiss	19.2	40.7-41.7,52.9-53.9	19.2	1	6.3		7.76
Deogarh	Barkote	Donra	21.5117	85.0550	190.4	Granite gneiss	31.4	71.4-72.4,127.1-128.1	31.4	0.5	9.79		
Deogarh	Barkote	Markandapur	21.5117	85.0550	190.4	Granite gneiss	25.3	36.6-37.6,115.5-116.5	25.3	1	2.1		
Deogarh	Barkote	Barkote	21.5299	85.0177	166.3	Granite gneiss	10	31.5,42.8,77.2,123.1	10	7	6.64	8.66	-
Deogarh	Barkote	Barkote	21.5299	85.0177	162.00	Granite gneiss	16	25.4,56.9,69.1,75.2	16	5	7.31	28.50	2784

District	Block	Location	Latitude	Longitude	Depth drilled (mbgl)	Lithology	Depth to Bed rock (mbgl) Casing Pipe Lowered	Granular zones/ deciphered (mbgl)	Weathered zone	Discharge (lps)	SWL (mbgl)	Drawdown (m)	T (m^2 / day)
Deogarh	Barkote	Barkote	21.5299	85.0177	162.20	Granite gneiss	14	36.6,67.1,78.2	14	5	6.65		-
Deogarh	Barkote	Bamparda	21.4717	85.0619	193	Granite gneiss	16.2	93-94	16.2	3.5			1030.724
Deogarh	Barkote	Bamparda	21.4717	85.0619	191.00	Granite gneiss	16.2	95.00	16.2	2			2263.47
Deogarh	Barkote	Teleibani	21.5212	84.5902	136.90	Granite gneiss	9.4	115.30, 123.30, 137.70	9.4	6	6.87		8254.77
Deogarh	Barkote	Teleibani	21.5212	84.5902	166.30	Granite gneiss	9.4		9.4	0.5			3497.41
Deogarh	Barkote	Khondol	21.5437	84.8879	180.6	Granite gneiss	12.3		12.3	2	5.3	29.5	3691.71
Deogarh	Tileibani	Purnagarh	21.5144	84.7143	139.90	Granite gneiss	11	31.10, 44.30, 55.50, 53.50	11	20	6.6	10.36	-
Deogarh	Tileibani	Deogarh	21.5156	84.7586	105.80	Granite gneiss	17.2	21.90, 29.00, 104.20	17.2	15	2.33	10.54	
Deogarh	Tileibani	Deogarh	21.5156	84.7586	154.10	Granite gneiss	17.2	43.10	17.2	4		14.52	
Deogarh	Tileibani	Kalla	21.4297	84.9635	190.70	Basic Rock	30.2	27.10, 55.50, 137.90, 159.20	30.2	5	7.16	26.79	28.760
Deogarh	Tileibani	Kalla	21.4297	84.9635	145.00	Basic Rock	30.3	29.10, 58.50, 136.90, 158.20	30.3	4.5			-

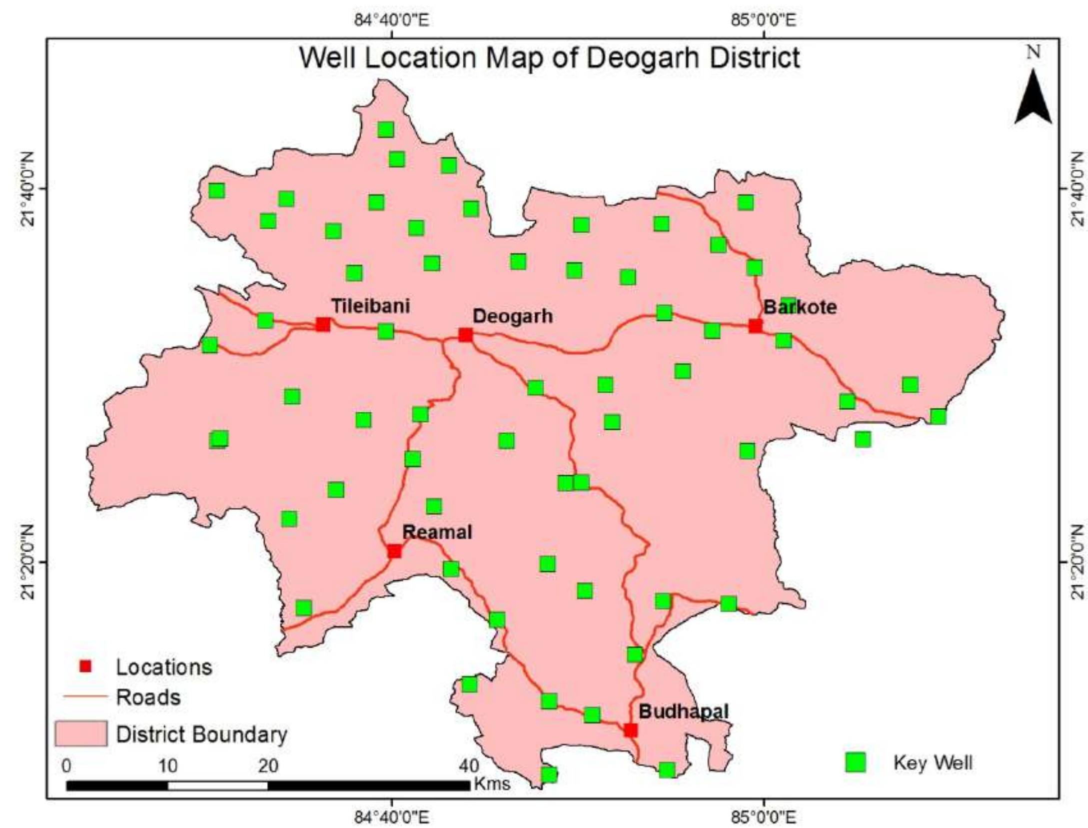
Table 8.2 Exploratory wells drilled under Accelerated Exploratory Drilling Programme (AEDP)

No	District	Block	Location	Depth	Discharge
1	DEOGARH	BARKOTE	BASALOI	121	7
2	DEOGARH	DEOGARH MNC	DEOGARH(MAHULDHIPA)	150	1.0
3	DEOGARH	REAMAL	TINKBIR	153	2.5
4	DEOGARH	TILEIBANI	KANSAR	152	Negligible
5	DEOGARH	TILEIBANI	LOIMURA	116.8	5.0
6	DEOGARH	BARKOTE	BOLANDA	150	1
7	DEOGARH	BARKOTE	GURSANGA	150	6
8	DEOGARH	BARKOTE	KANTAPALI	93	14
9	DEOGARH	BARKOTE	KHAJURIKHAMAN	150	2
10	DEOGARH	BARKOTE	KUNDAPITHA	150	0.5
11	DEOGARH	REAMAL	CHATABAR	150	3.5
12	DEOGARH	REAMAL	RENGALBEDA	150	1
13	DEOGARH	TELEIBANI	SUGUDA	150	Negligible

9. Ground Water Monitoring

The nature of occurrence and movement of ground water were studied through ground water monitoring wells during pre-monsoon and post-monsoon period. Under NAQUIM, the ground water regime of the phreatic aquifer was monitored during pre- and post-monsoon periods in 2021-22 in 11 National Hydrograph Network Stations (NHNS) and 62 Key Observation wells (dug wells). The details of the monitoring wells are shown in **Table 9.2** and the locations of the monitoring stations are shown in **Fig. 9.1**. The chemical quality of ground water in the district is monitored annually on a routine basis by CGWB through its National Hydrograph Network Stations. During the NAQUIM programme, 96 water samples were collected and results of their chemical analysis is given in **Table 11.2 and 11.3.**

Figure: 9.1 Locations of Ground Water Monitoring Stations in Deogarh District



9.1 Shallow Aquifer

Ground water occurs in phreatic condition in shallow aquifers and is utilized by means of dug wells or shallow tube wells. The depth of the dug wells used as observation points vary from 7.5to 15.5 mbgl and their diameter ranges from 1.2 m to 4.00 m. The wells are generally lined to the total depth.

9.1.1 Pre monsoon depth to Water level

Depth to water level in pre-monsoon period (May 2021) varies from 2.0 mbgl to 10.6mbgl the average being 6.17 m bgl. In general, the study area has the depth to water level in between 3 to 7 mbgl during the pre-monsoon. Water logging conditionis found nowhere during the pre-monsoon. Shallower water level of 0-4mbgl is observed in some parts of Tileibani and Reamal block and in some isolated patches of Barkote blocks. Deeper water levels (>7mbgl) are found in all blocks in patches. The locations where the depth to water level is more than 8 mbgl are Ambagaon (8.2), Balanda(8.1), Gothanali (10.6), Laxmipur (8.7) Mankadamunda (8.6), Ranja (8.75), Suringipal (8.2).The pre-monsoon depth to water level map is shown in **Fig. 9.2(A)** and water table contour map is shown in **Fig. 9.2(B).**

Figure: 9.2(A) Depth to Water Level in Phreatic Aquifer during Pre monsoon

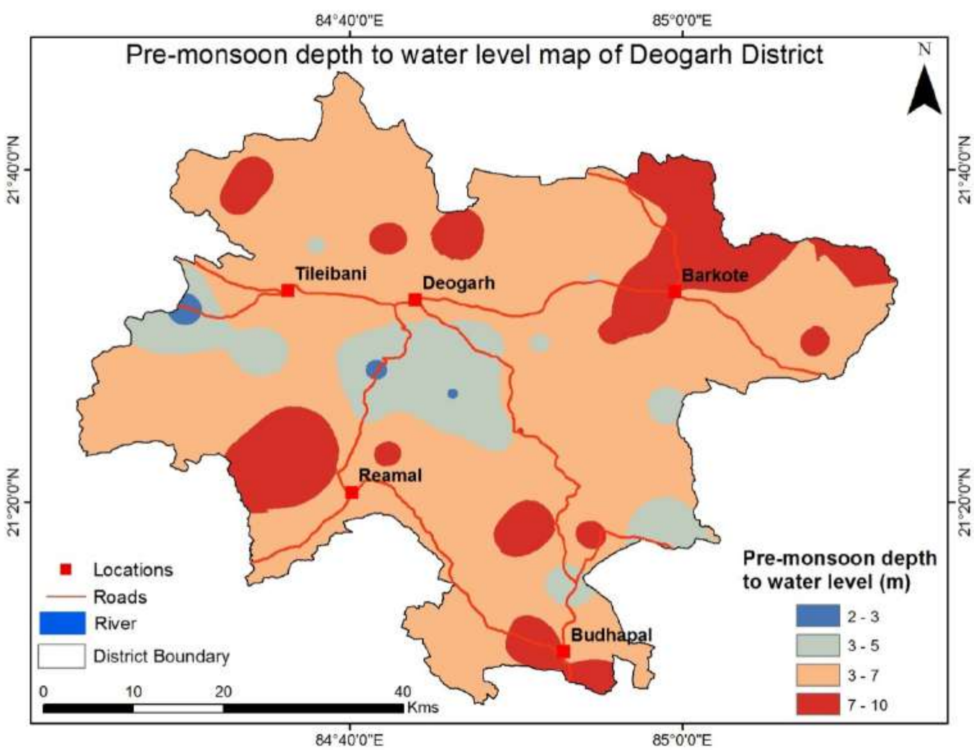
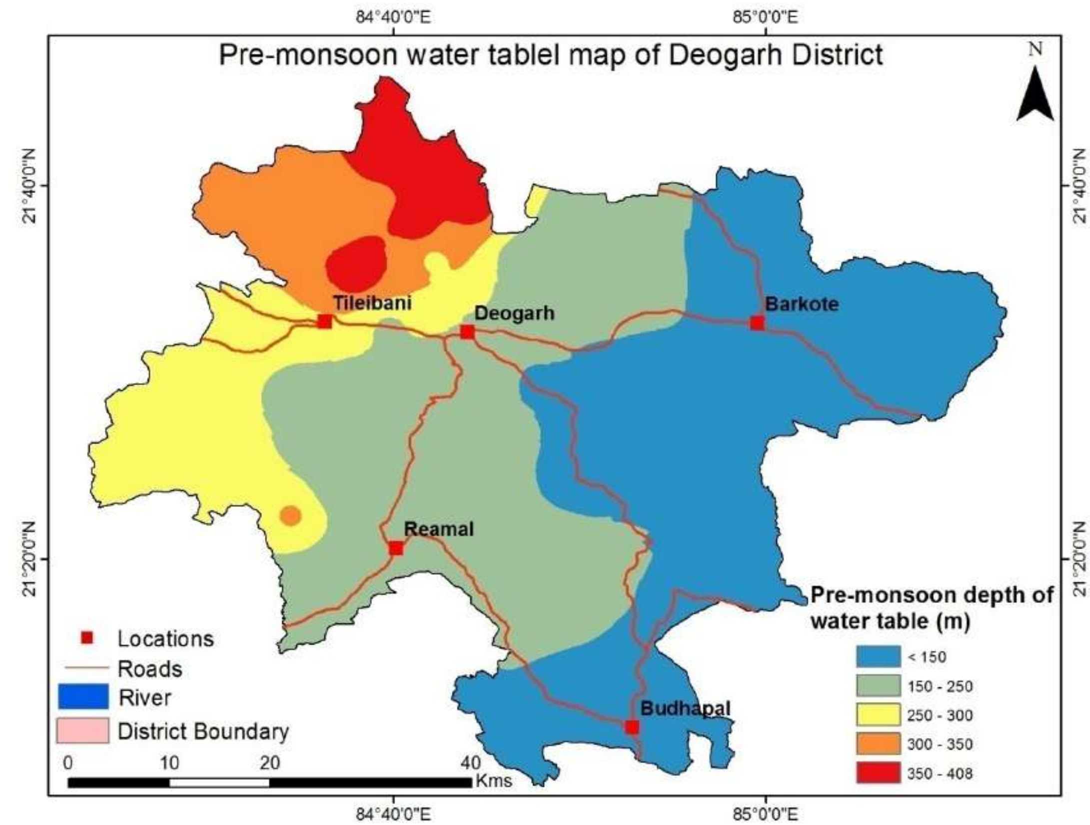


Figure: 9.2(B) Water Table Contour map of Phreatic Aquifer during Pre monsoon



9.1.2 Post monsoon depth to Water level

Depth to water level in post-monsoon period (Nov 2021) varies from 0.7 mbgl (Danardanpalli) to 7.37 (Gothanali) mbgl, the average being 3.09 m bgl. The depth to water level of the study area during Nov 2021 is in general within 2 to 4 mbgl. The areas where water level is less than mbgl are found in almost all the blocks covering central part of the district. Almost the entire district shows a shallow water level (<5 mbgl) during post monsoon except few isolated patches in Reamal block. The locations where the depth to water level is more than 5 mbgl are Gothanali (7.37), Laxmipur (5.6), Suringipal (5.6) and Tuhilamal (5.45). The post-monsoon depth to water level map is shown in **Fig. 9.3(A)** and water table contour map is shown in **Fig. 9.3(B).**

Figure: 9.3(A) Depth to Water Level in Phreatic Aquifer during Post monsoon

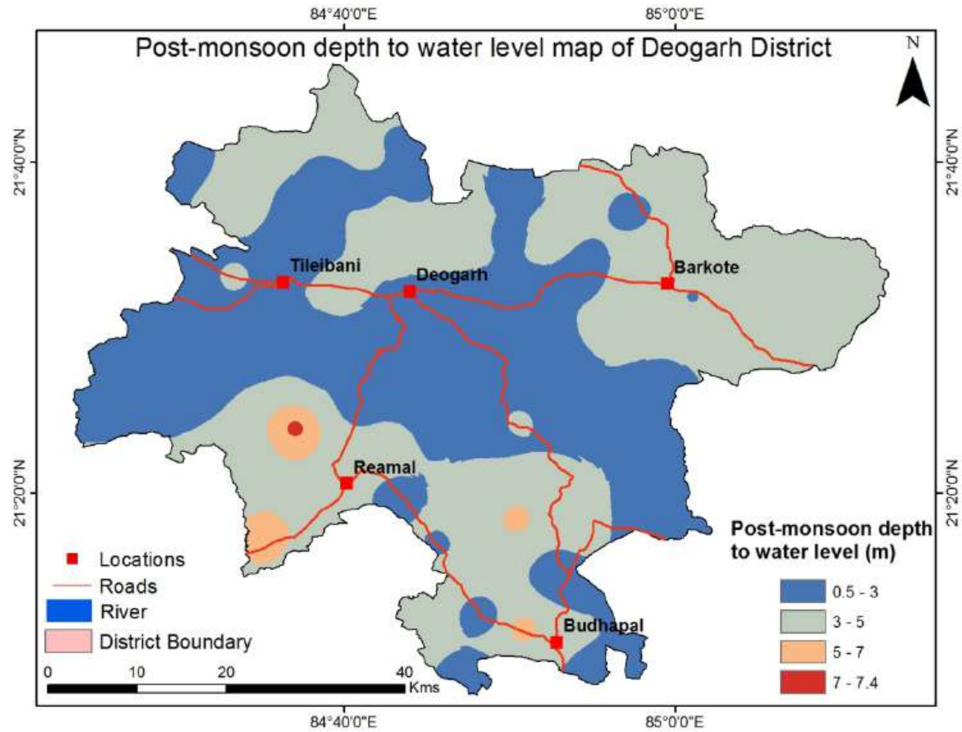
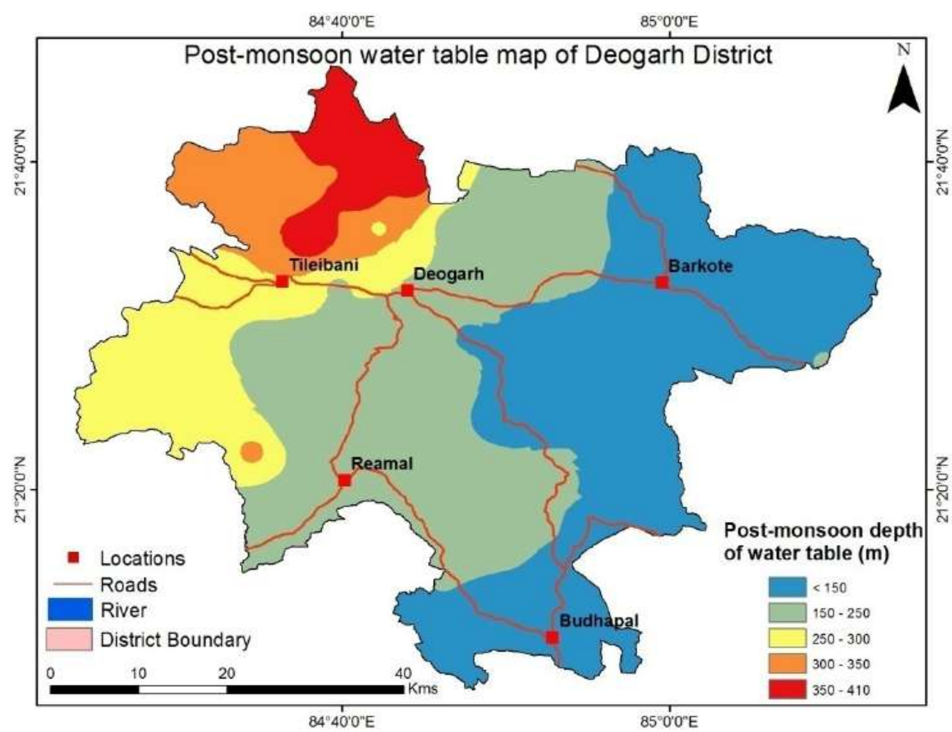


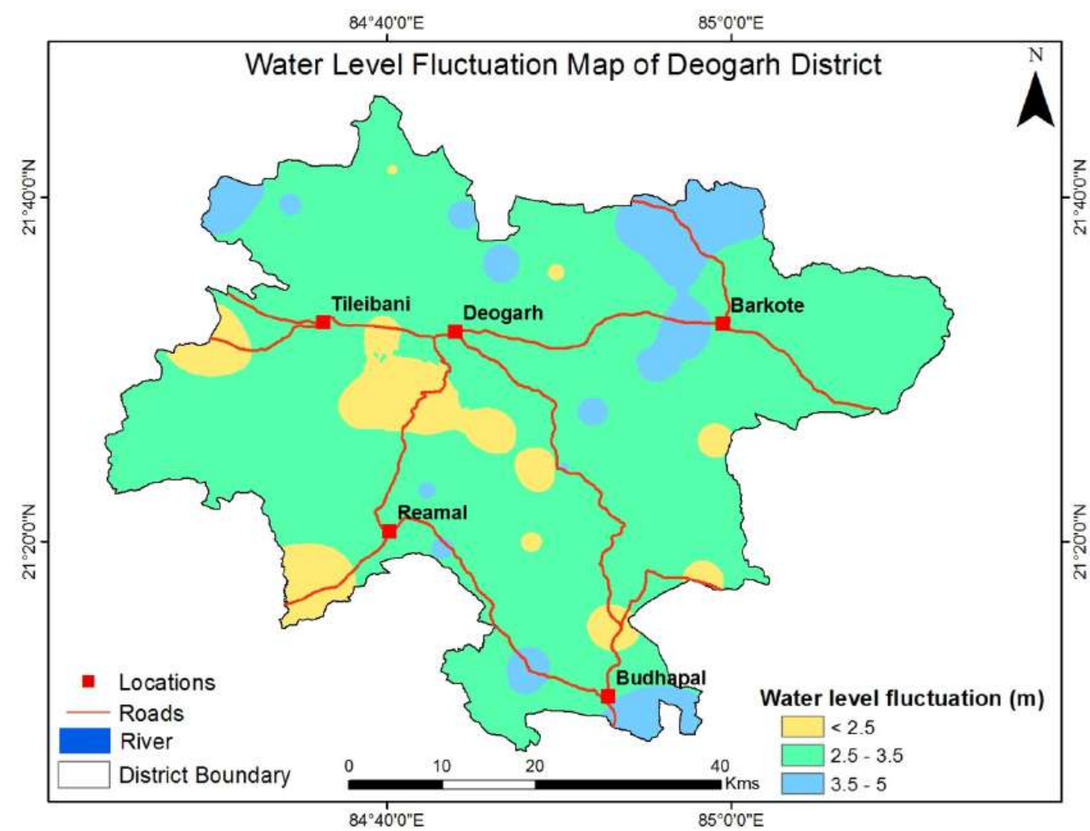
Figure: 9.3(B) Water Table Contour map of Phreatic Aquifer during Post monsoon



9.1.3 Seasonal Fluctuation of Water Level

Fluctuation of ground water table between pre and post monsoon period in the study area varies from 1.28 to 4.93 m, the average being 3.08 m. The general range of fluctuation in water level in the study area is between 1-3m. The locations where the fluctuation of water level is more than 4 m bgl are Kadopada (4.05), Kirtanpalli (4.58),Luhurakote (4.93) and Sahajbahal (4.2). The shallow post-monsoon water level along with fluctuation pattern indicates that the annual replenishment of phreatic aquifer due to monsoon rainfall is adequate in the district but deeper summer level is due to rapid dewatering of the phreatic aquifer due to steep gradient towards the Brahmani river which occupies the eastern part of the district. The seasonal fluctuation of water level of Aquifer-I is shown in **Fig. 9.4**. Some hydrographs of different locations in the district showing water level trend are given below.

Figure: 9.4 Seasonal Fluctuation of Water Level in Phreatic Aquifer



9.1.4 Decadal Water Level Trend

There are 11 National Hydrograph Station (NHS) in the district, the data from which are considered for analysis of long-term decadal trend for the period 2011-2021. The decadal trend of water level for both pre-monsoon and post-monsoon periods were analyzed. The results of trend analysis have been shown in **Table-9.1 (A) & (B)**. The long term trend analysis indicates that out of 11 stations, only two stations are showing rising trend and the rest 9 stations are showing no change during pre monsoon period. Similarly during post monsoon period 4 stations are showing rising trend and rest7 stations are showing no change. There is no significant falling trend in the district.

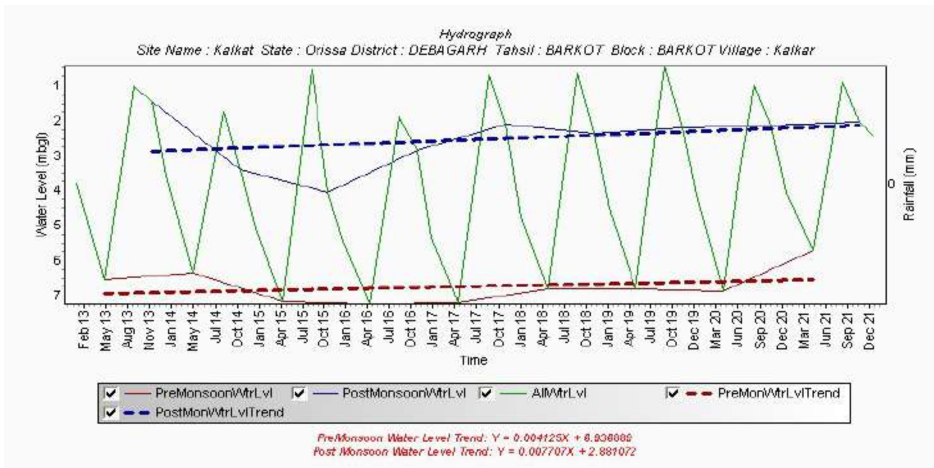
Table 9.1 (A) Water level trend during Pre Monsoon Period in Deogarh District

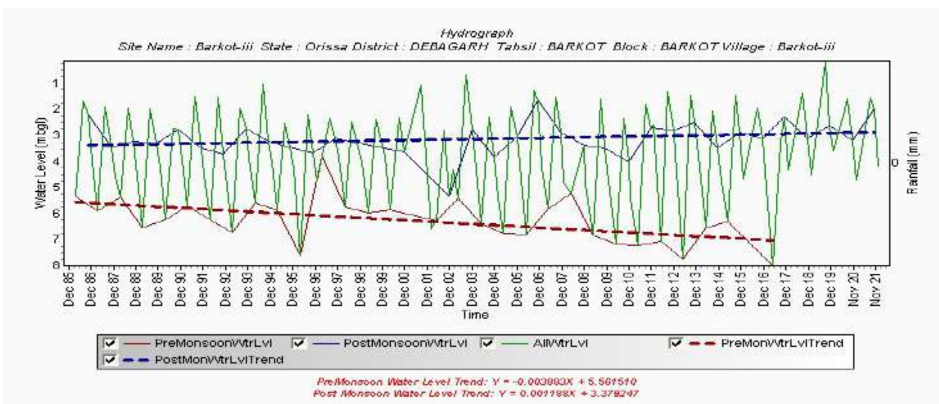
Water Level Trend during Pre Monsoon					
Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept
1	Barkot	16			0.0951
2	Deogarh	19	0.1509		
3	Kalamati	8			
4	Kalkat	9			
5	Kondal	0			
6	Purumunda	6			
7	Rengalbeda	22	0.1733		
8	Riamal	1			
9	Tarang	4			
10	Telimunda	8			
11	Tileibani	16			0.0391

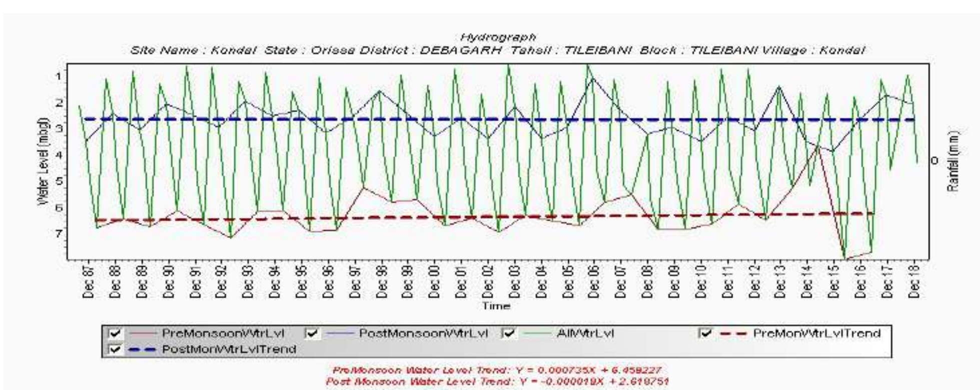
Table 9.1 (B) Water level trend during Post Monsoon Period in Deogarh District

Water Level Trend during Post Monsoon					
Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept
1	Barkot	21	0.0536		
2	Deogarh	17	0.0925		
3	Kalamati	7			
4	Kalkat	9			
5	Kondal	1			
6	Purumunda	6			
7	Rengalbeda	21	0.0583		

Water Level Trend during Post Monsoon					
Sl No	Location	Data points	Rise(m/year)	Fall(m/year)	Intercept
8	Riamal	2			
9	Tarang	9			
10	Telimunda	8			
11	Tileibani	17	0.0252		







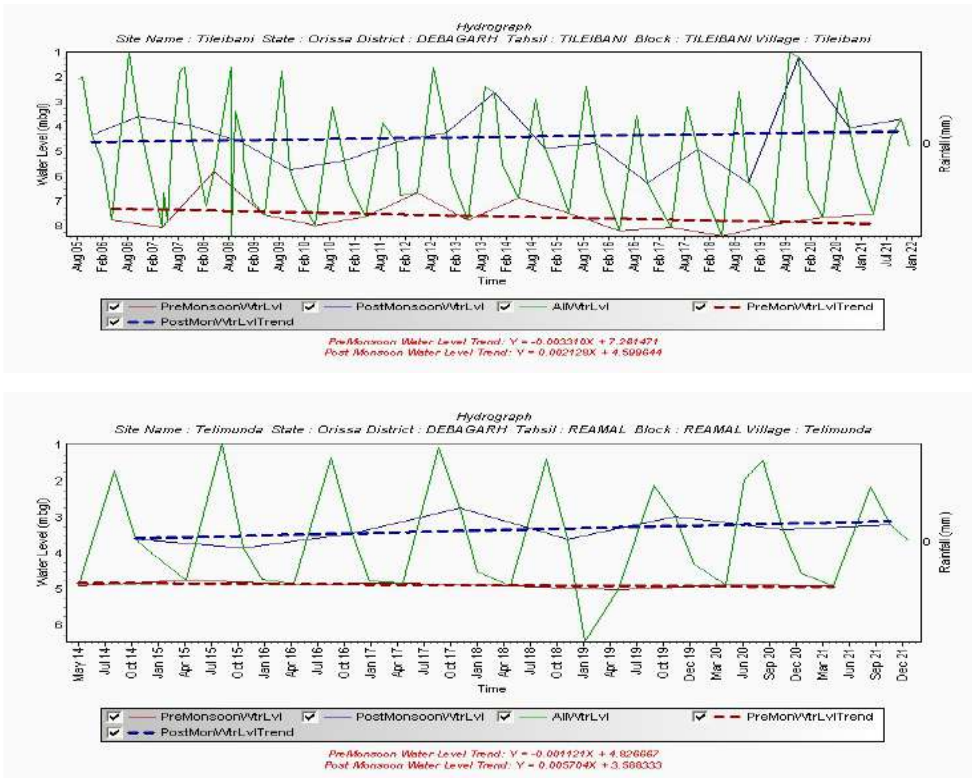


Figure: 9.5(A) Decadal Trend of Water Level in Phreatic Aquifer during Pre monsoon

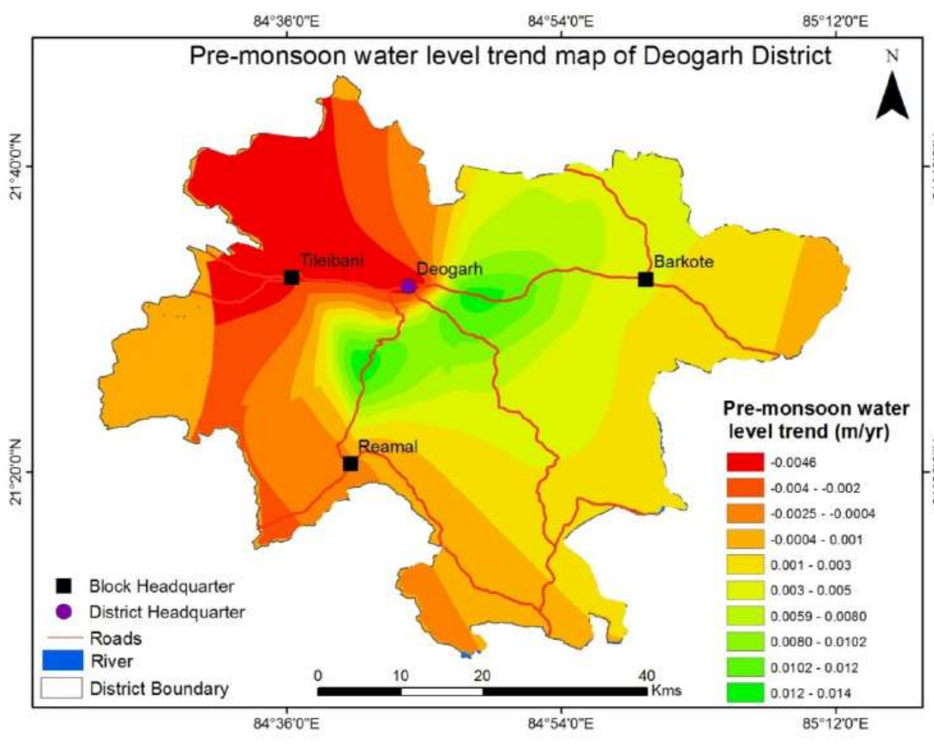


Figure: 9.5(B)Decadal Trend of Water Level in Phreatic Aquiferduring Post monsoon

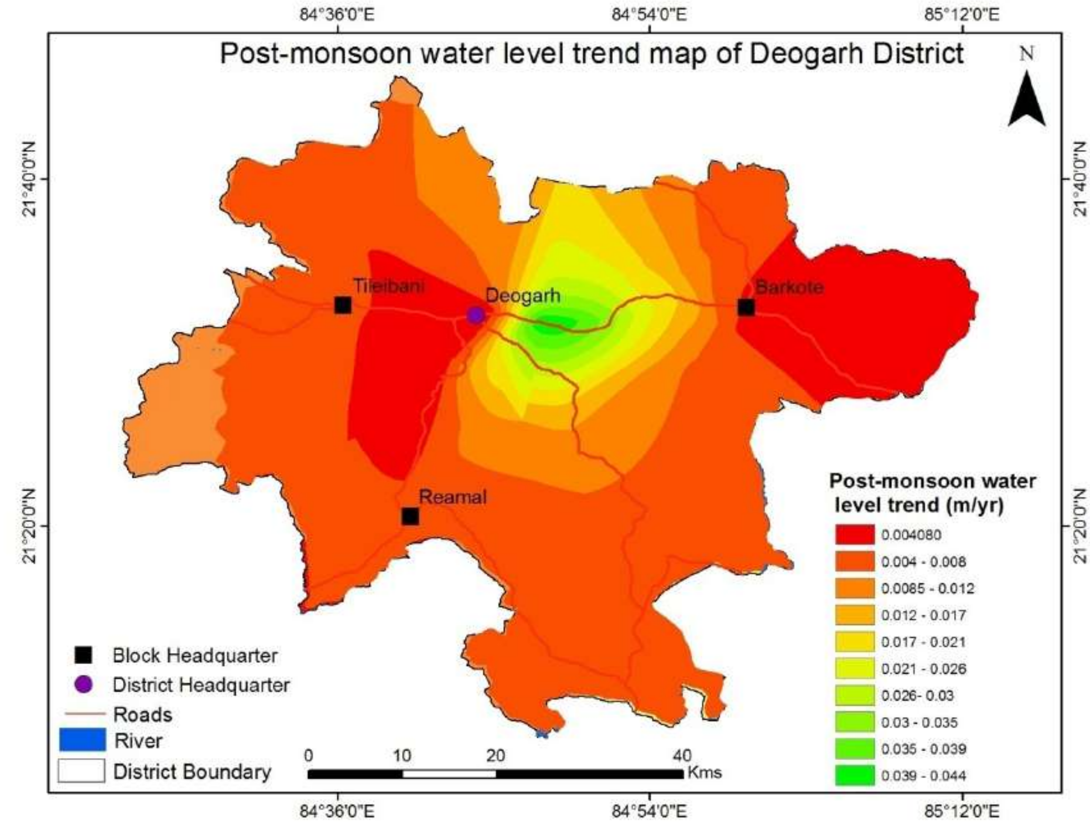


Table 9.2 Details of Monitoring wells in Deogarh District

DIST_NAME	BLOCK_NAME	Location	Latitude	Longitude	pre(mbgl)	post(mbgl)	Fluctuation(mbgl)	RL(m)
DEOGARH	BARKOTE	Ambagaon	21.654451	84.984158	8.2	4.42	3.78	134.4
DEOGARH	BARKOTE	Asananali	21.491602	84.858441	4.8	1.37	3.43	137.4
DEOGARH	BARKOTE	Balanda	21.56272	85.02202	8.1	4.68	3.42	146.9
DEOGARH	BARKOTE	Bamparda	21.476677	85.074928	6.5	3.8	2.7	137.1
DEOGARH	REAMAL	Barkul	21.372079	84.575684	7.9	4.7	3.2	315.4
DEOGARH	BARKOTE	Budhabahal	21.587829	84.878424	6.7	3.62	3.08	180.6
DEOGARH	BARKOTE	Chapabahal	21.634666	84.837173	5.5	2.57	2.93	205.8
DEOGARH	BARKOTE	Chasagurujang	21.442846	85.088845	6.4	3.06	3.34	141.8
DEOGARH	TILEIBANI	Danardanpalli	21.441772	84.770328	2.9	0.7	2.2	153.5
DEOGARH	BARKOTE	Dandasingha	21.503556	84.927509	7.2	3.6	3.6	125.6
DEOGARH	REAMAL	Dhauragotha	21.425321	84.686396	4.6	2	2.6	188.4
DEOGARH	REAMAL	Dhiramunda	21.295665	84.96877	3.2	0.85	2.35	142
DEOGARH	TILEIBANI	Dimirikuda	21.638015	84.556471	7.45	4.25	3.2	328.3
DEOGARH	BARKOTE	Dontaribahal	21.593939	84.830886	5.1	2.72	2.38	196.3
DEOGARH	TILEIBANI	Gailo	21.591341	84.634161	4.8	1.4	3.4	413
DEOGARH	TILEIBANI	Gambhariposi	21.649316	84.73832	5.9	2.2	3.7	389.8
DEOGARH	BARKOTE	Gopapur	21.531236	85.017968	6.1	2.93	3.17	128.2
DEOGARH	REAMAL	Gothanali	21.397998	84.617647	10.6	7.37	3.23	240.4
DEOGARH	TILEIBANI	Gundeimara	21.527076	84.504292	2	0.72	1.28	279.9
DEOGARH	BARKOTE	Gurusang	21.491474	85.131112	7.1	3.86	3.24	150
DEOGARH	TILEIBANI	Jjhargogua	21.629142	84.614761	5.7	2.65	3.05	341.1
DEOGARH	BARKOTE	Kadopada	21.616662	84.95979	6.3	2.25	4.05	145.1
DEOGARH	TILEIBANI	Kansar	21.441771	84.511238	5.6	2.25	3.35	272.9
DEOGARH	REAMAL	Kantabahal	21.331744	84.807205	6.3	3.9	2.4	192.1
DEOGARH	REAMAL	karlaga	21.250718	84.884617	3.5	1.57	1.93	145.8
DEOGARH	BARKOTE	Kaunsibahal	21.556124	84.911222	4.8	1.56	3.24	165
DEOGARH	REAMAL	Kirtanpali	21.327081	84.720641	7.1	2.52	4.58	212.8
DEOGARH	REAMAL	Kirtanpali	21.327081	84.720641	5.1	2.52	2.58	212.8
DEOGARH	REAMAL	Kundheigola	21.208672	84.808194	6.5	2.52	3.98	124.8
DEOGARH	REAMAL	Kuradkhol	21.282108	84.761334	6.4	2.9	3.5	231.7
DEOGARH	REAMAL	Kushakhalia	21.298593	84.910237	7.5	4.3	3.2	150.4
DEOGARH	TILEIBANI	Laimura	21.69322	84.672068	6.9	4.45	2.45	376.2
DEOGARH	TILEIBANI	Lambadora	21.688019	84.718344	6.2	2.87	3.33	379.1
DEOGARH	REAMAL	Laxmipur	21.307306	84.839974	8.7	5.6	3.1	179.9
DEOGARH	TILEIBANI	Luchar	21.657472	84.573416	7.6	4	3.6	321
DEOGARH	REAMAL	Luhurakote	21.147343	84.91341	7.5	2.57	4.93	117.2
DEOGARH	BARKOTE	Madang	21.596498	84.992013	7.33	4.1	3.23	143.1
DEOGARH	REAMAL	Madhyapur	21.460165	84.642062	5.1	2.78	2.32	191
DEOGARH	BARKOTE	Mankadmunda	21.602187	84.7803	8.6	4.8	3.8	225.4
DEOGARH	BARKOTE	Nuabanakhal	21.463375	85.156411	6.8	3.49	3.31	155
DEOGARH	TILEIBANI	Nuansahi	21.481412	84.578472	4.2	1.7	2.5	230.4
DEOGARH	REAMAL	Nuapada	21.143485	84.808029	5.5	2.15	3.35	134.7

DIST_NAME	BLOCK_NAME	Location	Latitude	Longitude	pre(mbgl)	post(mbgl)	Fluctuation(mbgl)	RL(m)
DEOGARH	TILEIBANI	Palunipada	21.443553	84.513876	5.7	2.25	3.45	268
DEOGARH	TILEIBANI	Panibhandar	21.719956	84.662288	6.35	3.27	3.08	399.4
DEOGARH	TILEIBANI	Pendarakhol	21.465288	84.693168	2.5	0.77	1.73	167.6
DEOGARH	TILEIBANI	Pravasuvi	21.549034	84.554433	6.6	3.21	3.39	293
DEOGARH	BARKOTE	Raitabahal	21.432408	84.98513	4.5	2.2	2.3	147.1
DEOGARH	BARKOTE	Ranja	21.539729	84.954235	8.75	4.93	3.82	138.8
DEOGARH	REAMAL	Rohinigadia	21.224213	84.737009	6.4	3.51	2.89	137.8
DEOGARH	TILEIBANI	Sahajbahal	21.665218	84.510705	6.3	2.1	4.2	309.1
DEOGARH	BARKOTE	Saloi	21.635512	84.909021	6.9	3.2	3.7	158.1
DEOGARH	TILEIBANI	Samasingha	21.631923	84.689343	5.1	2.57	2.53	376.8
DEOGARH	REAMAL	Siarimalia	21.404356	84.83729	7.2	3.5	3.7	137.8
DEOGARH	TILEIBANI	Subarnapali	21.458261	84.864687	6.5	2.82	3.68	140.6
DEOGARH	TILEIBANI	Suguda	21.488948	84.795721	4.6	1.53	3.07	149.4
DEOGARH	REAMAL	Suringipal	21.196567	84.846605	8.2	5.6	2.6	128.7
DEOGARH	TILEIBANI	Tanisar	21.539301	84.662081	6.2	3.85	2.35	246.7
DEOGARH	REAMAL	Tinkbir	21.383217	84.705303	7.44	3.85	3.59	233.6
DEOGARH	TILEIBANI	Tipirisingha	21.654894	84.653711	5.5	2.43	3.07	349.6
DEOGARH	REAMAL	Tuhilamal	21.292527	84.588743	6.8	5.45	1.35	184
DEOGARH	BARKOTE	Tusula	21.600251	84.703215	7.9	4.6	3.3	297.5
DEOGARH	REAMAL	Valchabha	21.403774	84.823062	3.3	1.81	1.49	142

Table 9.2 Details of Monitoring wells in Deogarh District

District	Block	Location	Latitude	Longitude	Type of Well	Pre monsoon DTWL(mbgl)	Post monsoon DTWL(mbgl)
DEBAGARH	REAMAL	Purumunda	21.307222	84.6375	NHS	7	4.25
DEBAGARH	BARKOT	Barkot	21.541667	84.998333	NHS	7.98	4.72
DEBAGARH	BARKOT	Kondal	21.557222	84.885	NHS	4.25	
DEBAGARH	BARKOT	Kalkat	21.485833	84.951667	NHS	5.7	4.05
DEBAGARH	REAMAL	Riamal	21.364444	84.660278	NHS	4.45	2.85
DEBAGARH	REAMAL	Tarang	21.273889	84.579722	NHS	8.2	5.7
DEBAGARH	REAMAL	Telimunda	21.3425	84.668889	NHS	4.9	4.55
DEBAGARH	TILEIBANI	Rengalbeda	21.445278	84.683333	NHS	3.14	2.54
DEBAGARH	TILEIBANI	Tileibani	21.545833	84.602222	NHS	7.48	5.8
DEBAGARH	TILEIBANI	Deogarh	21.536667	84.743333	NHS	5.35	2.55
DEBAGARH	TILEIBANI	Kalamati	21.525556	84.8025	NHS	4.95	2.8

10. Ground Water Resource

Estimation of Ground Water Resources has been carried out based on the methodology recommended by the Groundwater Estimation Committee (GEC'2015). A ground water resource of the entire state has been computed by CGWB (CGWB, SER, 2020) for the year 2019-2020. Salient features of the estimation of ground water resources are described below. The present computations pertain to the ground water year 2019-20. The resources have been computed block wise. Areas having slope more than 20 % were excluded from recharge computations. Ground water recharge and draft were computed separately for command and non-command areas.

Ground Water Recharge in various Seasons

Recharge from monsoon rainfall has been estimated separately for command and non-command areas. Recharge has been computed using both water level fluctuation method as well as rainfall infiltration factor method. For comparison of figures obtained from the above two methods, percent deviation has been computed and the recharge has been calculated according to the recommended methodology. Recharge from rainfall during non-monsoon period has been computed by Rainfall Infiltration Factor Method only.

Table 10.1: Specific yield and rainfall infiltration factors of different rock types in the study area

Sl. No.	Rock type	Specific Yield	Rainfall Infiltration Factor
1	Granite	0.02	0.01
2	Charnockite	0.02	0.05
3	Khondalite	0.02	0.02
4	Quartzite	0.02	0.01

Besides rainfall, the other sources which contribute towards recharge of ground water resources are seepage from canal, return flow from irrigation (both surface as well as ground water), recharge from tanks and ponds, recharge from water conservation structures etc. The recharge from such sources has been computed based on the data supplied by the state agencies. As per the recommended methodology the recharge has been computed separately for monsoon and non-monsoon periods. The factors for computation of return flow from irrigation, seepage from canals, recharge from tanks and ponds and water conservation structures have been taken as those recommended by GEC'2015 (Table 10.2).

Table 10.2: Norms used for Recharge from Other Sources

1	**Recharge Due to Seepage From Canals**	
	Formation	**Canal Seepage factor ham/day/ million square meters of wetted area**
	Unlined canals in normal soils with some clay content along with sand	17.5
	Lined canals in normal soils with some clay content along with sand	5
	All canals in hard rock area	3.5
2	**Recharge Due to Irrigation by Surface Water**	
	Crop type	**Recharge as a percentage of applied water**
	Paddy	50%
	Non-paddy	30%
3	**Recharge Due to Irrigation by Ground Water**	
	Crop type	**Recharge as a percentage of applied water**
	Paddy	45%
	Non-paddy	25%
4	**Recharge due to Tanks & Ponds**	
	Seepage from Tanks & Ponds	1.4 mm / day
5	**Recharge due to Water Conservation Structures**	
	Season	**Recharge as a percentage of gross storage**
	Monsoon	20%
	Non-monsoon	20%

Table 10.3: Block wise groundwater recharge in different seasons

(Figures are in Ham)

Sl. No.	Block	Monsoon		Non Monsoon		Total Recharge
		Rainfall	Other Sources	Rainfall	Other Sources	
1	BARKOTE	7090.08	2086.25	265.07	2072.57	11513.97
2	REAMAL	6781.12	2100.37	352.27	2569.12	11802.88
3	TILEIBANI	6857.02	1298.04	606.35	1562.15	10323.56

Ground Water Draft for Various Purposes

Ground water draft for domestic use has been estimated based on block-wise population. The annual average per capita consumption has been taken as 22.5 m^3 (60 litres per day) assuming 100% dependence on ground water. Drafts during monsoon and non-monsoon periods have been estimated separately. Ground water draft for irrigation was estimated based on the number of structures and the unit draft(Table 10.4) of different types of structures. Ground water draft for industrial use is negligible and has not been included while assessing the ground water draft.

Table 10.4:Unit Draft of different types of structures

Sl. No.	Type of structure	Average annual draft (ha m/structure)	
		Monsoon	Non-monsoon
1	Dug well with Pump	0.075	0.675
2	Shallow bore well	0.200	1.800
3	Dug well	0.040	0.360

Table 10.5: Block wise ground water draft for various uses

(Figures are in Ham)

Sl. No.	Block	Draft for domestic use	Draft for industrial Use	Draft for irrigation Use	Draft for all uses
1	BARKOTE	5193.80	113.83	309.45	5617.08
2	REAMAL	5028.05	18.60	285.94	5332.59
3	TILEIBANI	5131.70	75.52	337.23	5544.44

Level of Development and Categorisation

Net annual ground water availability has been computed by deducting the unaccounted natural discharge from the total annual recharge. Unaccounted natural discharge has been taken as 5% of the total annual recharge as per the criteria recommended by GEC'2015.

Stage of ground water development has been computed using the relation:

$$Stage of groundwater development = \frac{Gross groundwater draft for all uses}{Annual available groundwater resource} \times 100$$

The block-wise resource of the aquifer mapping blocks as on 2020 is given below in Table 10.6.

Table 10.6 Dynamic Ground Water Resources of Aquifer-I in Deogarh District. (2020)

Sl No	District	Block	Annual Extractable GW (Ham)	Gross Draft (Ham)	GW Available for Future Use (Ham)	Stage of Extraction
1	DEOGARH	BARKOTE	10362.57	5617.08	4720.89	54.21
2	DEOGARH	REAMAL	10622.59	5332.59	5264.61	50.20
3	DEOGARH	TILEIBANI	9704.06	5544.44	4132.27	57.14
	Total		30689.22	16494.11	14117.77	53.75

The combined net ground water available is 30689.22 ham and gross annual draft is 16494.11 ham. The stage of ground water development is minimum for Reamal block which is 50.20 %. The highest ground water development is in Tileibani block that is 53.75 % and all the blocks are in safe category.

The ground water resource can be aquifer wise divided into Dynamic and Static resource. The dynamic resource is the part of resource within the water level fluctuation zone which is also the annual replenishable resource. The resource below the water level fluctuation zone is termed as the In-storage (Static) resource. Mainly the water level fluctuation method was adopted for calculation of recharge. The in-storage resources are calculated separately for aquifer-I and II. However the semi-confined to confined deeper aquifers have linkage to the unconfined aquifer through the fractures and receive continuous recharge. The in-storage ground water resources of aquifer-I are given in table 10.7 and the total resources of aquifer-I in table 10.8 below.

Table 10.7 In-storage Ground Water Resources of Aquifer-I in Deogarh District

Sl No	Block	Assessment Area	Bottom Depth of Aquifer	Average Pre-monsoon Water Level	Total Effective Saturated Thickness	Average Specific Yield	In Storage Ground Water Resources
					5% of (2-3)		[(1)*(4)*(5)]
		(Ha)	(mbgl)	(mbgl)	(m)		(Ham)
		1	2	3	4	5	6
1	BARKOTE	100448	19.7	6.67	13.03	0.02	26176.749
2	REAMAL	96268	15.2	6.42	8.78	0.02	16904.661
3	TILEIBANI	99548	12.84	5.45	7.39	0.02	14713.194

Table 10.8 Total Ground Water Resources in Aquifer-I in Deogarh District (2020)

Sl No	Block	Dynamic Resource (Ham)	In Storage Resource (Ham)	Total Ground Water Resource (Ham)
1	BARKOTE	10362.57	26176.75	36539.3188
2	REAMAL	10622.59	16904.66	27527.2508
3	TILEIBANI	9704.06	14713.19	24417.2544
	TOTAL	30689.22	57794.6	88483.824

The in-storage ground water resource in Aquifer- II i.e. the semi-confined to confined aquifer is shown in Table 10.9.

Table 10.9 In-storage Ground Water Resources of Aquifer-II in Deogarh District

Sl No	Block	Assessment Area	Top Depth of Aquifer	Bottom Depth of Aquifer	Total Satu-rated Thickness	Productive Zone	Avg. Sp. Yield	In Storage Ground Water Resources
		(Ha)	(mbgl)	(mbgl)	(m)	(5% of Total Thickness) (m)		(Ham)
		1	2	3	(4)=(3-2)	5	6	(7)=(1*5*6)
1	BARKOTE	100448	19.7	200	180.3	9.015	0.015	13583.081
2	REAMAL	96268	15.2	200	184.8	9.24	0.015	13342.745
3	TILEIBANI	99548	12.84	200	187.16	9.358	0.015	13973.553

Irrigation Potential that can be created:

Irrigation potential of ground water resources is the area that can be irrigated from available ground water resources. In this report block-wise irrigation potentials have been computed considering both 70% and 90% of the available resources as exploitable within safe limits. Since the principal irrigated crop in the district is paddy, the irrigation potential has been computed considering the crop water requirement of paddy for Odisha i.e. 0.125 m.

The computational procedure followed is given below.

1. Considering 70% stage of development: $P_i = ((0.7 \text{ X } R_a) - D_G^{\ i} - D^d_{2025}) / \Delta$
2. Considering 90% stage of development: $P_i = ((0.9 \text{ X } R_a) - D_G^{\ i} - D^d_{2025}) / \Delta$
3. Ultimate irrigation potential: $P_i = R_a - D^d_{2025} / \Delta$

Where,

P_i = Irrigation potential in ha

R_a = Available ground water resources (Total Resources – Natural losses) in ha m

$D_G^{\ i}$ = Gross ground water draft for irrigation in ha m

D^d_{2025} = Allocation for domestic and industrial use in the year 2025 in ha m

Δ = Crop water requirement in m (here it is 0.125 m)

Present ground water development:

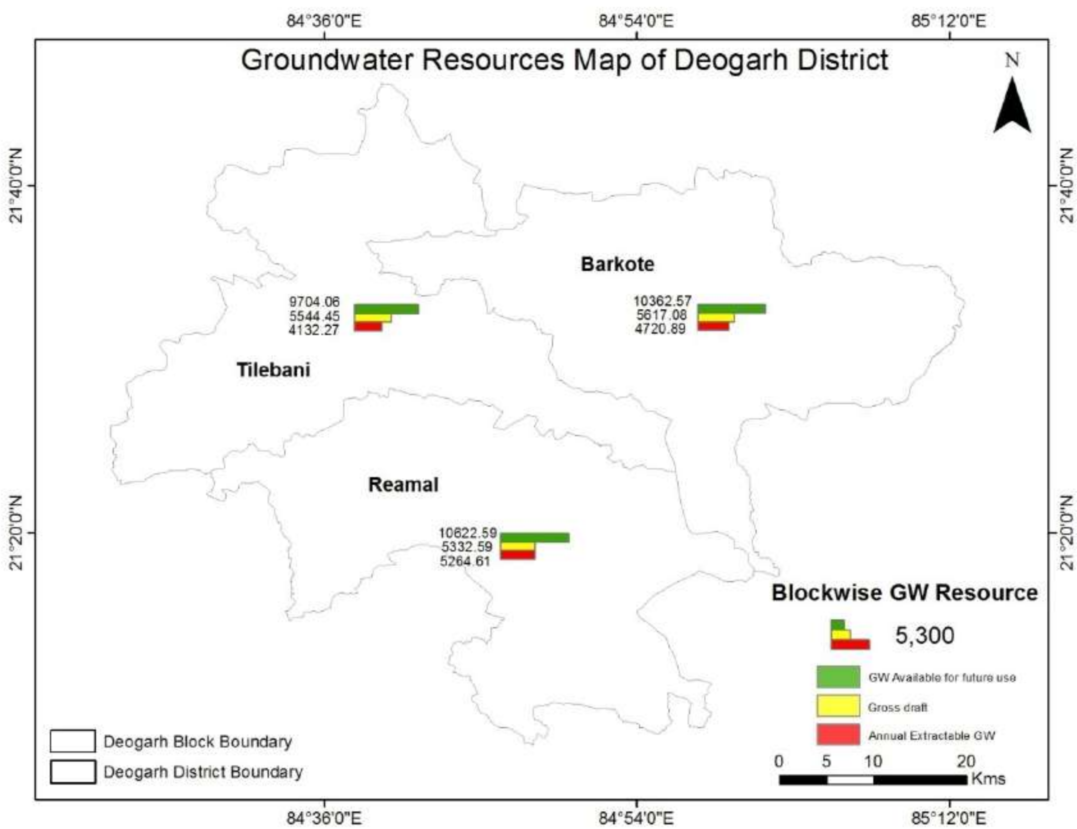
The present Ground Water Development in the district has been calculated for each block. All the blocks in the study area have been categorized as safe from ground water abstraction point of view.

The overall ground water development in the study area is moderate with Tileibani having the maximum stage of extraction. This may be attributed to the high stage of development in the Deogarh urban area. The ground water development in the entire study area is 53.75 %. The study area as a whole and each individual blocks are safe from ground water development point of view.

Table 10.10:Block wise irrigation potentials

Sl. No.	Block	Net Annual Extractable Ground Water (ha m)	Natural losses (ha m)	Allocation for domestic and industrial use in the year 2025 (ha m)	Gross draft for irrigation (ha m)	Irrigation potential (assuming 70% development) (ha)	Irrigation potential (assuming 90% development) (ha)
1	BARKOTE	10362.57	1151.40	334.04	309.45	46434.64	61172.51
2	REAMAL	10622.59	1180.29	311.35	285.94	48098.6	63206.28
3	TILEIBANI	9704.06	619.50	364.58	337.23	45259.07	59794.37
	TOTAL	30689.22	2951.19	1009.97	932.61	139792.3	184173.2

Fig 10.1 Dynamic Ground Water Resources of Deogarh District (2020)



11. Hydrochemistry

11.1 INTRODUCTION

Evaluation of ground water quality is as important as its quantity for assessment of ground water resources. Ground water is never pure and contains varying amount of dissolved solids, the type and concentration of which depends on its source, surface and sub-surface environment and rate of ground water movement. The chemical quality of ground water is a function of the quality of the recharge water and the reaction occur along its flow path, particularly between the moving fluids and the geologic materials. The concentration of various chemical constituents in ground water depends on the solubility of mineral present, the resident time and the amount of dissolved carbon dioxide. In addition to the natural changes, anthropogenic activities such as sewage disposal, agricultural practices, industrial pollution, etc. also contribute significantly to changes in ground water quality.

To study the ground water quality of Deogarh district, water samples were collected from dug well as well as bore wells representing the phreatic and deeper aquifers respectively. A total of 59 samples from dug wells and 37 samples from bore wells are collected to study the hydrochemistry of ground water in the district. The location of sampling points is given in fig. 11.1. The samples were analysed for concentration of major cations and anions. The analyses of the samples have been carried out in the laboratory of CGWB, SER, Bhubaneswar.

Different descriptive statistical parameters like minimum, maximum and mean of the water quality parameters of both phreatic and deeper aquifers of the district are computed. The statistics of concentration of all chemical parameters are presented in table 11.1**.** Perusal of the table 11.1 show that almost all the parameters in both phreatic and deeper aquifers are same or have very little difference indicating that the water in both the aquifer are of the same quality. The comparison of mean concentration of water quality parameters is presented in fig. 11.2. Value and concentration of different water quality parameters found in the samples collected from the district are discussed in the subsequent paragraphs.

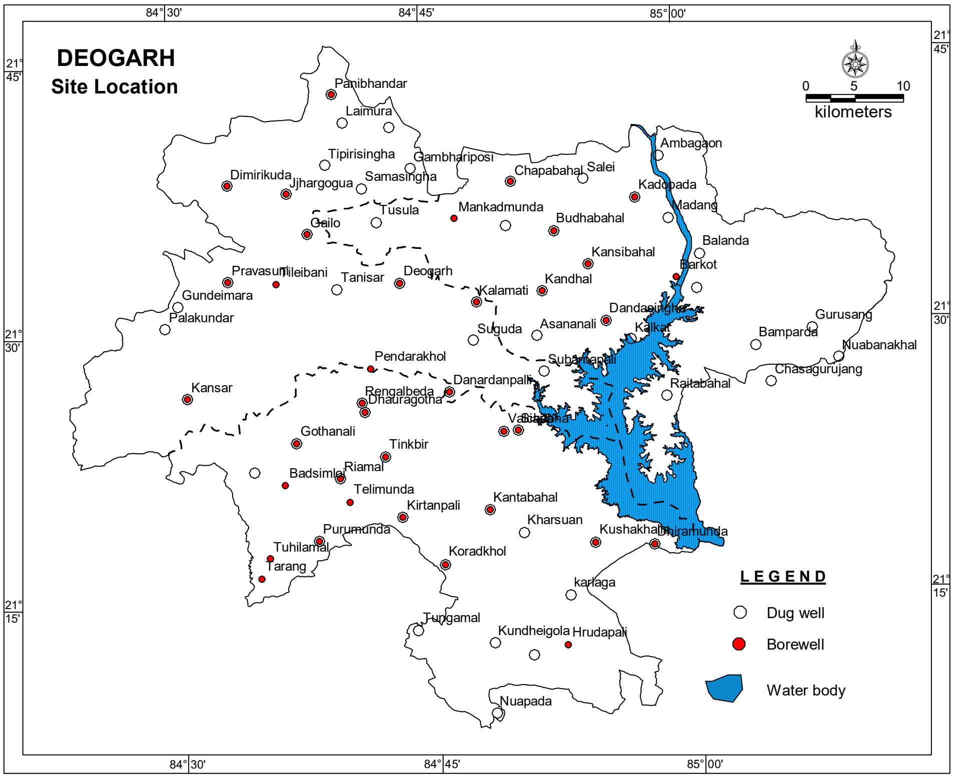


Fig. 11.1: Location of sampling points

Table 11.1: Comparison of concentration of chemical parameters in ground water in phreatic and deeper aquifers

Sl. No.	Parameter		Minimum		Maximum		Mean	
			Phreatic	Deeper	Phreatic	Deeper	Phreatic	Deeper
1	pH		6.86	7.4	8.28	8.25	7.76	7.88
2	EC in µS/cm		80	122	1420	1350	573.76	599.51
3	TDS	in mg/L	64	88	744	681	318.58	320.22
4	TH		20	50	560	610	213.90	232.84
5	Ca		4	12	114	100	41.49	45.46
6	Mg		2	5	100	87	26.81	28.95
7	Na		5	12	186	96	34.34	32.14
8	K		0.5	0.9	57.4	44.5	10.00	5.44
9	CO_3		0	0	0	0	0.00	0.00
10	HCO_3		31	61	421	354	209.86	220.03
11	Cl		12	10	297	265	72.39	71.27
12	SO_4		0	0	134	54	19.79	16.56
13	NO_3		0	0	49	82	10.93	12.51
14	F		0.03	0.05	1.62	0.82	0.25	0.26

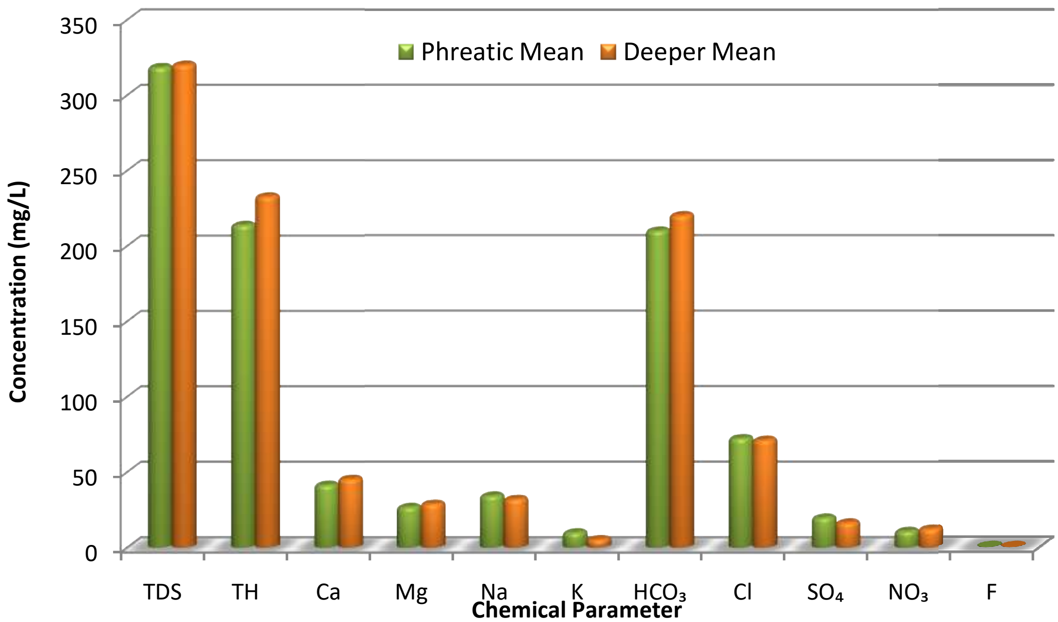


Fig. 11.2: Comparison of mean concentration of chemical parameters in ground water in phreatic and deeper aquifers.

11.2 CHEMICAL PARAMETERS AND THEIR CONCENTRATION IN GROUND WATER

Hydrogen Ion Concentration (pH): Most ground waters have a pH range of 6.5 to 8 (Karanth, 1989) and mostly it is slightly basic because of the presence of bicarbonates and carbonates of alkali and alkaline earth metals. The acceptable limits (IS: 10500, 1991) set for pH of ground water is 6.5 to 8.5. The pH of ground water in the district varies between 6.86 and 8.28 in phreatic and between 7.40 and 8.25 in deeper aquifers. The values of pH of ground water in both the aquifer system are well within the permissible range. From the pH values it is evident that the ground water in the study area is slightly alkaline in nature.

Electrical Conductivity (EC) and Total Dissolved Solids (TDS): Electrical conductivity is related to the concentration of ionized substances in the water.The Electrical conductivity is a measure of the dissolved solids in water and hence is an indicator of degree of mineralisation of the water. The value of EC of ground water in the district varies between 80 and 1420 µS/cm in phreatic and between 122 and 1350 in deeper aquifers.

In ground water chemistry the total dissolved solids refers to the sum total of different cations and anions present in the ground water. Total dissolved solids give an overall idea about the quality of the ground water. The TDS concentration of fresh water varies between

192 mg/L and 1280 mg/L.The value of TDS of ground water in the district varies between 64 and 744 mg/L in phreatic and between 88 and 681 mg/L in deeper aquifers.

The values of EC and in turn the values of TDS in ground water in both the aquifers in the district are well within the permissible limits. These values suggest that the ground water in the area is very fresh in nature. The concentration of EC and TDS values in ground water of the district in both the aquifers are presented in fig. 11.3, 11.4, 11.5 and 11.6.

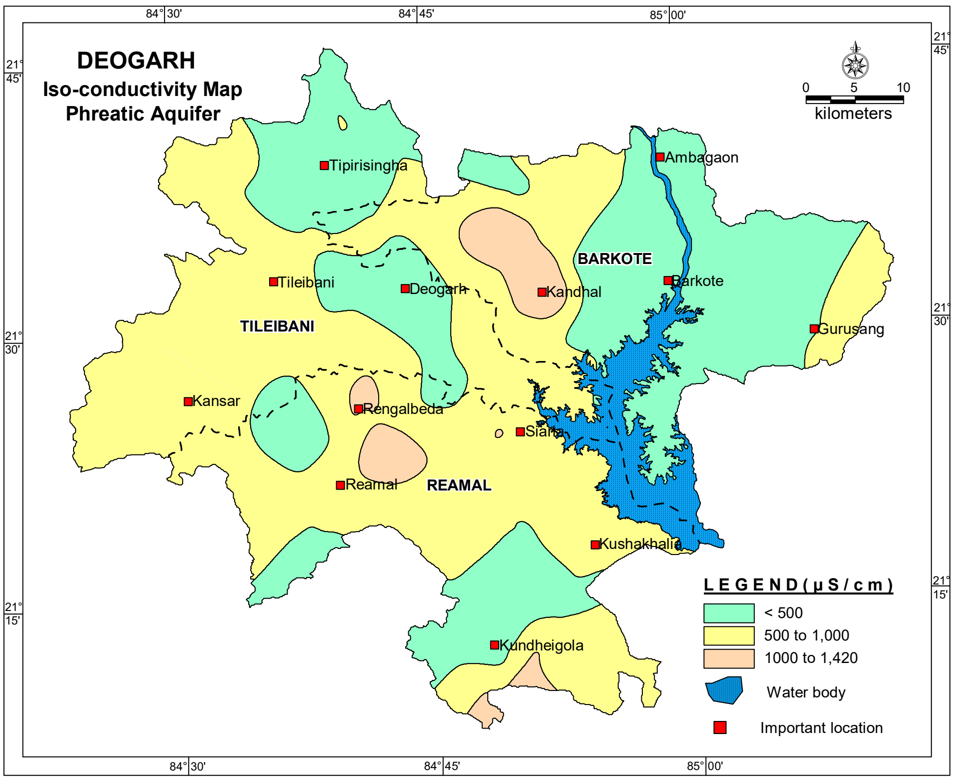


Fig. 11.3: Map showing electrical conductivity of ground water in phreatic aquifer

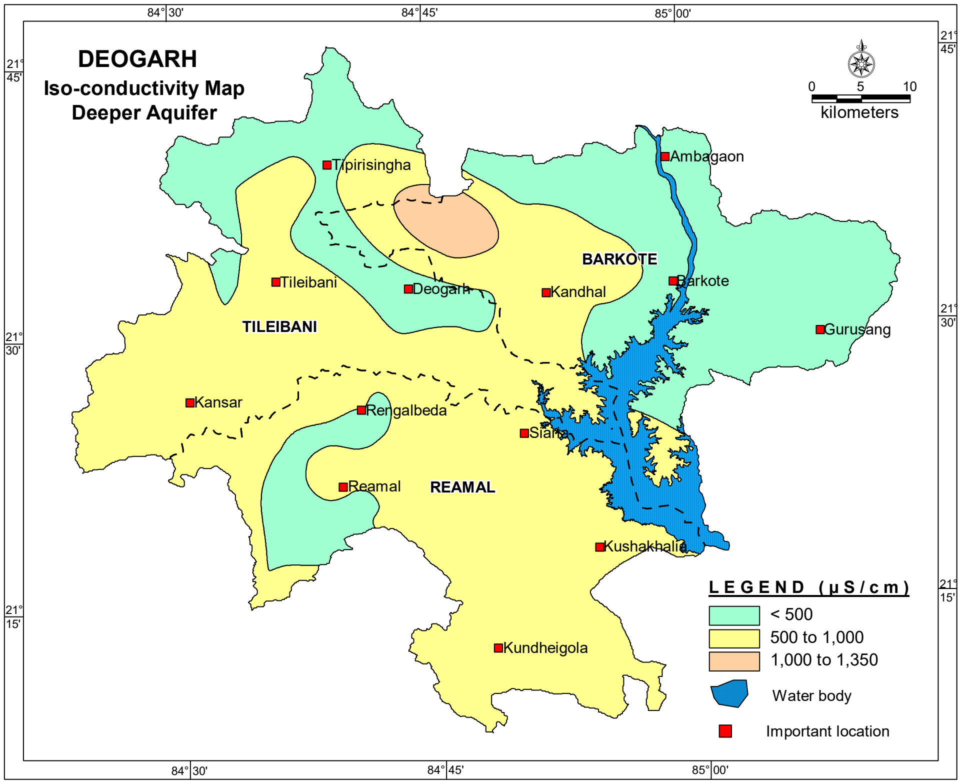


Fig. 11.4: Map showing electrical conductivity of ground water in deeper aquifer

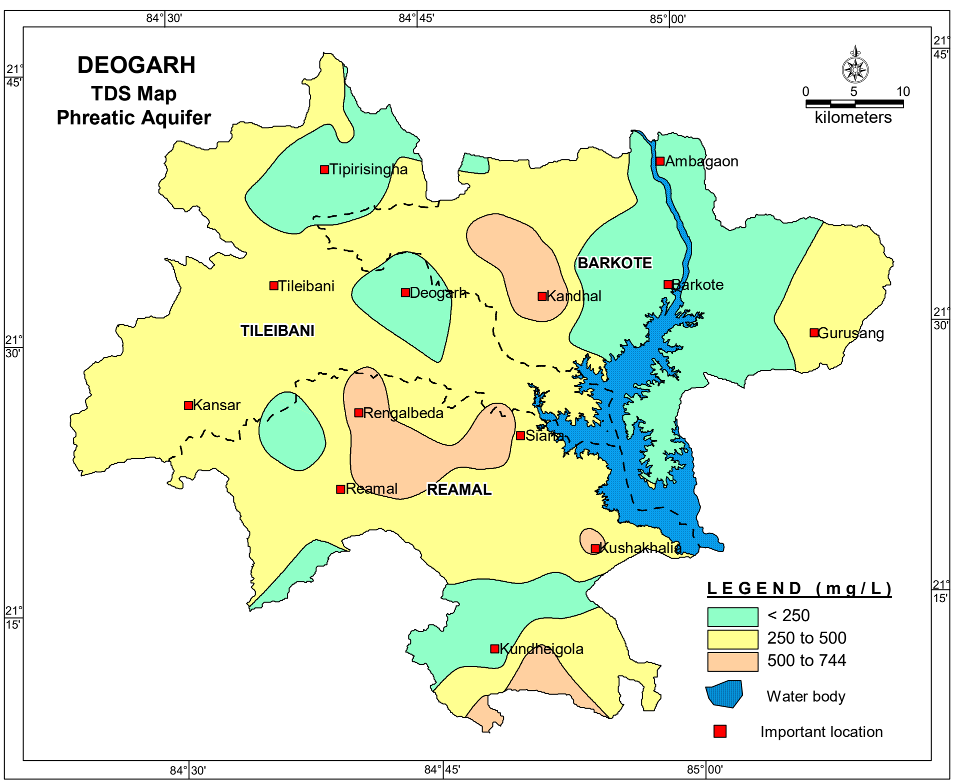


Fig. 11.5: Map showing distribution of TDS of ground water in phreatic aquifer

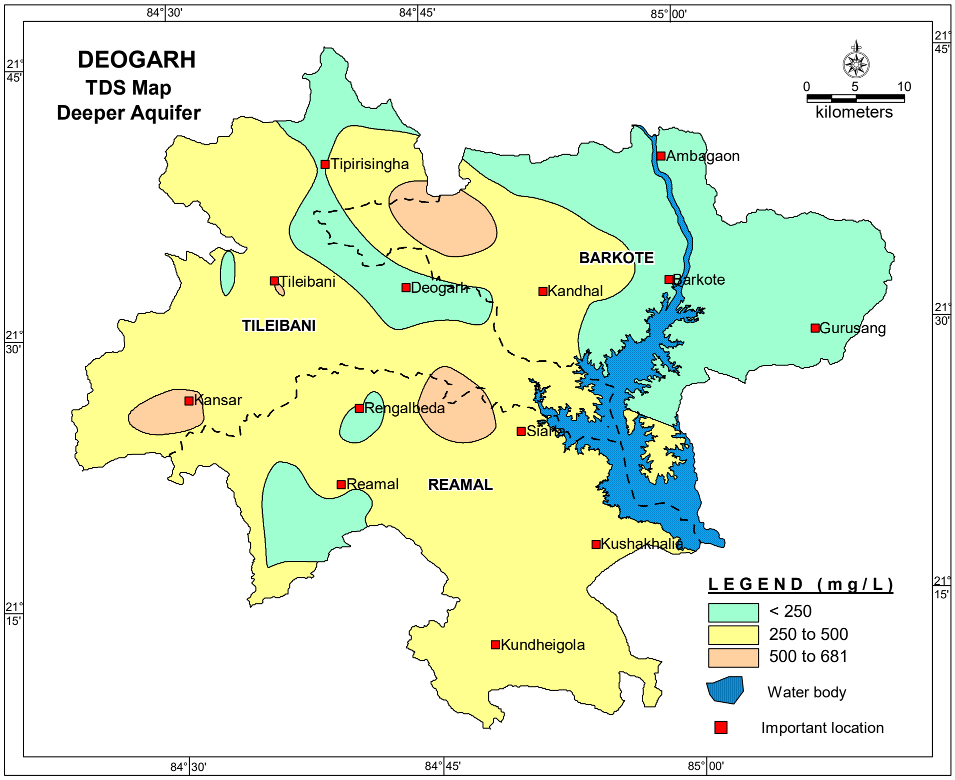


Fig. 11.6: Map showing distribution of TDS of ground water in deeper aquifer

Total Hardness (TH): Water hardness is a traditional measure of the capacity of water to precipitate soap. In fresh water, the principal hardness causing ions are calcium and magnesium which precipitate soap. Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as $CaCO_3$, in mg/L. Based on hardness measurements, water can be hard or soft.

Desirable and maximum permissible limits (IS: 10500:2012) in drinking water are 200 and 600 mg/l respectively. Higher hardness of water leads to precipitation with soap, scaling etc. There are suggestive evidences that drinking extremely hard water might lead to an increased incidence of urolithiasis (Kidney Stones).

The degree of hardness of drinking water has been classified by Sawyer and Mecartyin terms of the equivalent $CaCO_3$ concentration as follows.

Table 11.2: Classification of ground water based on hardness values
(Sawyer and Mecarty)

Sl. No.	Hardness as $CaCO_3$ (mg/L)	Water class	Percentage of samples	
			Phreatic	Deeper
1	0-75	Soft	11.86	5.41
2	75-150	Moderately hard	20.34	16.22
3	150-300	Hard	45.76	64.86
4	>300	Very hard	22.03	13.51

The TH values in the district vary between 20 mg/L and 560 mg/L in phreatic and between 50 mg/L and 610 mg/L in deeper aquifers. The TH value of all the samples are well within the permissible limits for drinking water except in one sample from bore well of Mankadmunda village in Barkote block of the district.

Calcium (Ca^{2+}): The concentration of calcium in water depends on the residence time of the water in calcium-rich geological formations. Calcium is the most predominant cation present in the natural waters.The desirable and permissible limits of Ca (IS: 10500:2012) are 100 and 300 mg/L respectively.The Ca^{2+} values in the district vary between 4 mg/L and 114 mg/L in phreatic and between 12 mg/L and 100 mg/L in deeper aquifers. The Ca^{2+} values of all the samples are well within the permissible limits for drinking water.

Magnesium (Mg^{2+}): Major sources of Mg in ground water are carbonate minerals (Dolomite). Normal concentration of magnesium in ground water is 1 to 40 mg/L. Desirable and maximum permissible limits (IS: 10500, 2012) in drinking water are 30 and 100 mg/l respectively. As the district is mainly underlain by granitic suite of rocks, the Mg^{2+} values of all the samples are well within the permissible limits for drinking water. The Mg^{2+} values in the district vary between 2 mg/L and 100 mg/L in phreatic and between 5 mg/L and 87 mg/L in deeper aquifers.

Sodium (Na^{+}): Most common sources of Na in a geological environment are plagioclase feldspars. Weatherining of sodium bearing minerals like albite, nepheline, sodalite and glaucophane release primary soluble products of sodium which are present in soil; and therefore, soil is the most significant source of sodium in ground water. All groundwater contains some sodium because most rocks and soils contain sodium compounds from which sodium is easily dissolved.No guidelines have been prescribed for Na concentration in drinking water.The Na^+ values in the district vary between 5 mg/L and 186 mg/L in phreatic and between 12 mg/L and 96 mg/L in deeper aquifers.

Potassium (K^+): Sources of potassium includeweathering and erosion of potassium bearing minerals, such as feldspar, leaching of fertilizer. No guidelines have been prescribed for K concentration in drinking water.The K^+ values in the district vary between 0.5 mg/L and 57.4 mg/L in phreatic and between 9 mg/L and 44.5 mg/L in deeper aquifers.

Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-): The pH of water indicates the form in which carbon dioxide is present in water. Presence of carbonic acid is indicated when pH is less than 4.5, bicarbonate in pH between 4.5 to 8.3 and carbonate in pH over 8.2. Under usual condition bicarbonate may range from 100 to 800 ppm in ground water. The pH value of ground water in the district refers to very negligible concentration of CO_3^{2-} in it. The HCO_3^- values in the district vary between 31 mg/L and 421 mg/L in phreatic and between 61 mg/L and 354 mg/L in deeper aquifers.

Chloride (Cl^-): Chloride is one of the major anions in ground water. The high mobility and high solubility of chloride salts make the chloride ions present in water. Ground water containing less than 250 mg/L chloride can be used safely for drinking, agricultural andindustrial purpose. Abnormally high concentration of chloride in ground water may result from sewage wastes and leaching of saline residues in soil.

The Cl^- values in the district vary between 12 mg/L and 297 mg/L in phreatic and between 10 mg/L and 265 mg/L in deeper aquifers. The Cl^- values of all the samples in the district are well within the permissible limits for drinking water. The distribution of Cl^-in ground water is presented in fig. 11.7 and 11.8.

Sulphate (SO_4^{2-}): The primary source of sulphur is the sulphide minerals present in igneous and metamorphic rocks and gypsum & anhydrides present in sedimentary rocks. Apart from that application of fertilizer and soil conditioner also plays great role in its abundance in ground water. The desirable and permissible concentrations of SO_4^{2-} in ground water are 200 and 400 mg/L respectively.

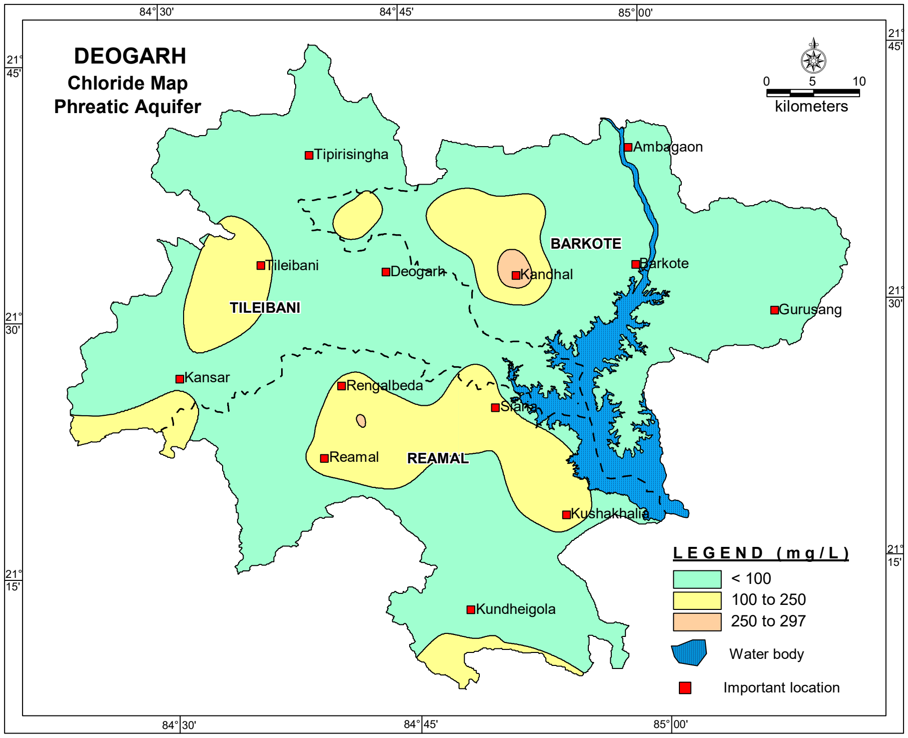


Fig. 11.7: Map showing distribution of chloride in ground water in deeper aquifer

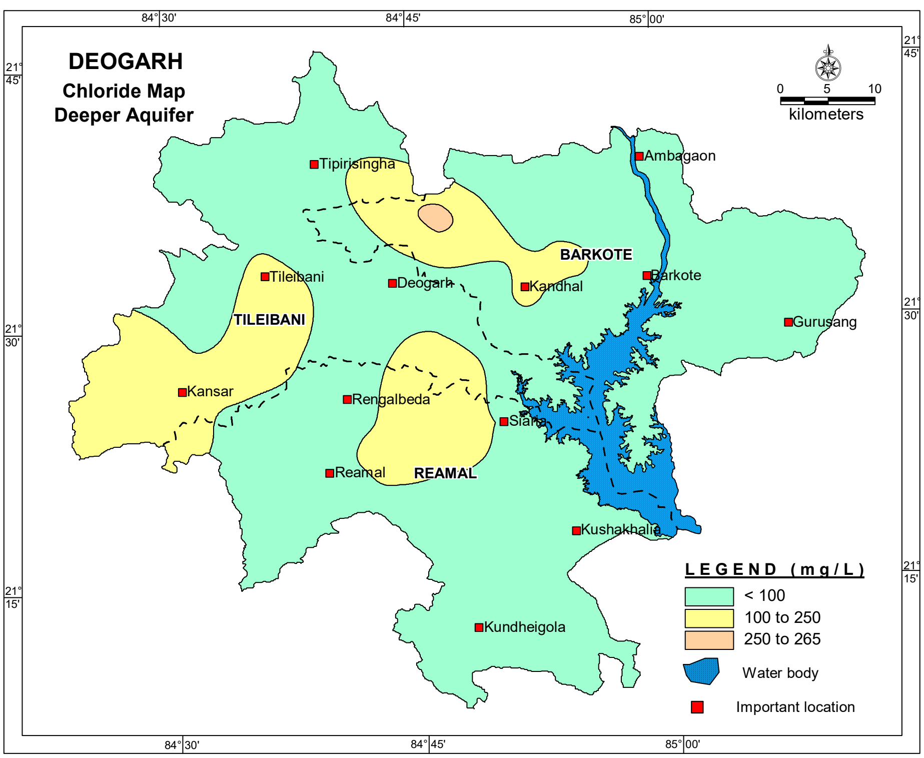


Fig. 11.8: Map showing distribution of chloride in ground water in deeper aquifer

The SO_4^{2-} values in the district vary between 0 mg/L and 134 mg/L in phreatic and between 0 mg/L and 54 mg/L in deeper aquifers. The SO_4^{2-} values of all the samples in the district are well within the permissible limits for drinking water.

Nitrate (NO_3^-): Significant sources of nitrate are chemical fertilizers, decayed vegetable and animal matter, domestic effluents, sewage sludge disposal to land, industrial discharge, leachates from refuse dumps and atmospheric washout. Depending on the situation, these sources can contaminate streams, rivers, lakes and ground water. Unpolluted natural water contains minute amounts of nitrate. Ground water containing nitrates more than 45 mg/L is harmful for infants (Hem, 1985). Excessive concentration in drinking water is considered hazardous for infants because of its reduction to nitrite in intestinal track causing methemoglobinemia.

All the samples have NO_3^- concentration well within the permissible limits for drinking water except in dug well at Tusula in Barkote block and in bore well at Kansar in Tileibani block. The occurrence of higher concentrations of Nitrate (> 45 mg/L) in these locations is due to anthropogenic activities and is propagated in the ground water through point sources.

Fluoride (F^-): Fluoride occurs naturally within many types of rock as a constituent of the common accessory minerals like Hornblende, Biotite and Muscovite. Chemical weathering leads to the breakdown of these minerals and add fluoride to ground water. Fluoride ions have dual significant in water supplies. High concentration of F causes dental fluorosis (disfigurement of the teeth). At the same time, a concentration less than 0.5 mg/L results in 'dental caries'. Hence, it is essential to maintain the F concentration between 0.5 to 1.0 mg/L in drinking water.

The F^- values in the district vary between 0.03 mg/L and 1.62 mg/L in phreatic and between 0.05 mg/L and 0.82 mg/L in deeper aquifers. The F^- values of all the samples in the district are well within the permissible limits for drinking water except at Rengalbeda dug well in Reamal block.

Uranium (U): Uranium is a naturally occurring radioactive chemical element that occurs in low concentrations in nature. It is present in certain types of soils and rocks, especially granites. Studies have revealed that presence of Uranium in drinking water causes Nephritis (kidney damage) due to its radiological property being radioactive in nature. The WHO has set 30 µg/L (ppb) as the upper limit of U concentration in ground water for drinking purpose.

None of the ground water samples of bore well has U concentration more than the prescribed limit. However, four samples from dug well have U concentration more than the prescribed limit of 30 µg/L. They are Rengalbeda (74 µg/L, Reamal block), Dhauragotha (86.8 µg/L, Reamal block), Palakundar (127 µg/L, Tileibani block) and Tinkbir (68.3 µg/L, Reamal block).

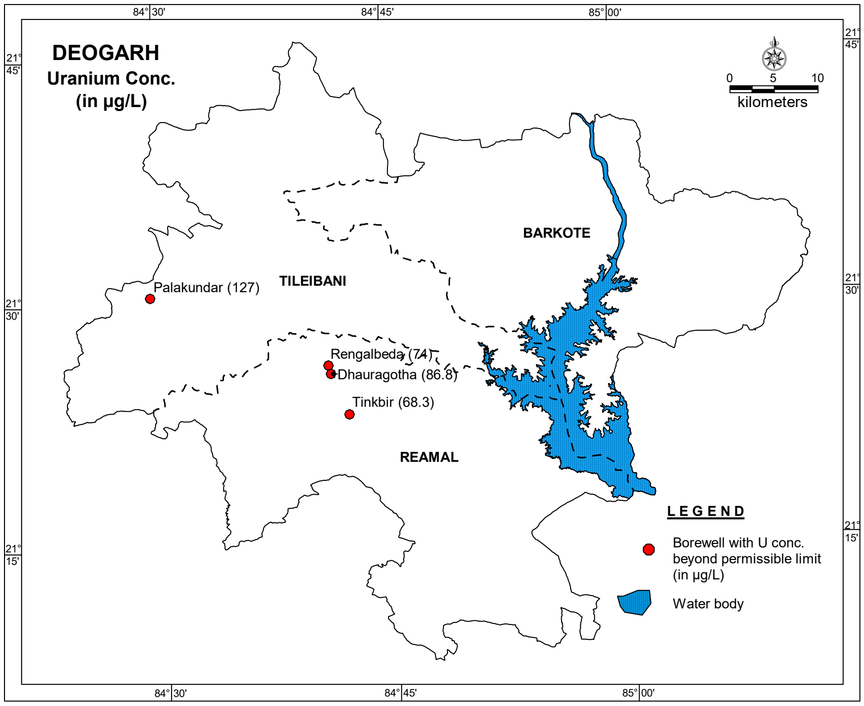


Fig. 11.9: Map showing locations with U concentration beyond permissible limit

11.3 SUITABILITY OF WATER FOR VARIOUS USES

Drinking Purpose:

The quality of ground water in both phreatic as well as deeper aquifers in Deogarh district is studied for its suitability for various uses. The ground water is slightly alkaline in nature. Major chemical constituents of water in both the aquifers are well within the permissible limit of the standard prescribed by BIS for drinking purpose. There are certain places where the concentration of NO_3^- is higher than the permissible limits. Overall, the water is commonly potable. Tables 11.3 and table 11.4 show the suitability of the ground water for drinking purposes.

Table 11.3: Chemical quality of water (Phreatic) for drinking purposes

S. No.	Parameters	Conc.		Range	No of samples	Percentage of samples	Indian standard (BIS)	
		Min	Max				Desirable	Permissible
1	TDS in mg/l	64	744	<500	50	84.75	500	2000
				500-2000	9	15.25		
				>2000	0	0		
2	Total Hardness as $CaCO_3$ in mg/l	20	560	<200	31	52.54	200	600
				200-600	28	47.46		
				>600	0	0		
3	Chloride in mg/l	12	297	<250	58	98.31	250	1000
				250-1000	1	1.69		
				>1000	0	0		
4	Sulphate in mg/l	0	134	<200	59	100	200	400
				200-400	0	0		
				>400	0	0		
5	Nitrate in mg/l	0	49	<45	58	98.31	45	No. Relaxation
				>45	1	1.69		
6	Fluoride in mg/l	0.03	1.62	<1.0	58	98.31	1	1.5
				1.1-1.5	0	0.00		
				>1.5	1	1.69		
7	Calcium in mg/l	4	114	<75	56	94.92	75	200
				75-200	3	5.08		
				>200	0	0.00		
8	Magnesium in mg/l	2	100	<30	41	69.49	30	100
				30-100	18	30.51		
				>100	0	0.00		
9	Sodium in mg/l	5	186	<100	56	94.92	No Guideline	No Guideline
				>100	3	5.08		
10	Potassium in mg/l	0.5	57.4	<10	43	72.88	No Guideline	No Guideline
				>10	16	27.12		
11	Uranium in µg/L	BDL	127	<30	55	93.22	30	No. Relaxation
				>30	4	6.78		

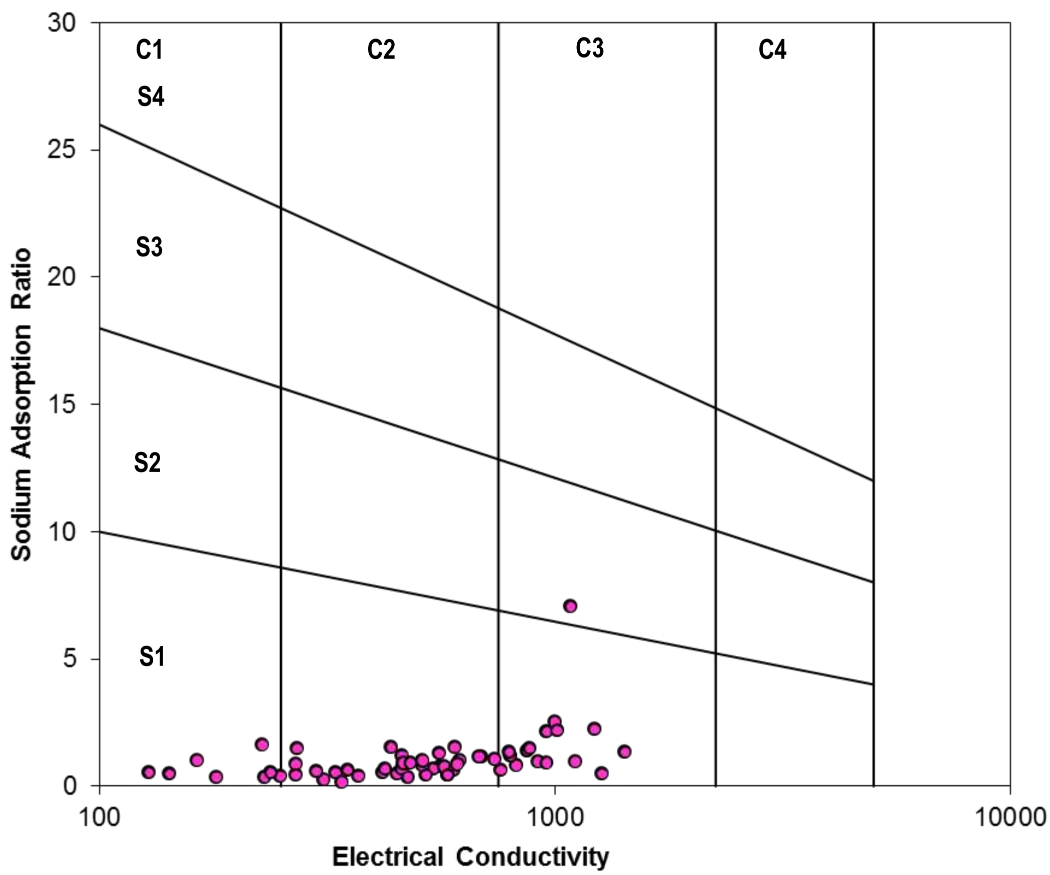
Table 11.4: Chemical quality of water (Deeper) for drinking purposes

S. No.	Parameters	Conc.		Range	No of samples	Percentage of samples	Indian standard (BIS)	
		Min	Max				Desirable	Permissible
1	TDS in mg/l	88	681	<500	33	89.19	500	2000
				500-2000	4	10.81		
				>2000	0	0.00		
2	Total Hardness as $CaCO_3$ in mg/l	50	610	<200	17	45.95	200	600
				200-600	19	51.35		
				>600	1	2.70		
3	Chloride in mg/l	10	265	<250	36	97.30	250	1000
				250-1000	1	2.70		
				>1000	0	0.00		
4	Sulphate in mg/l	0	54	<200	37	100.00	200	400
				200-400	0	0.00		
				>400	0	0.00		
5	Nitrate in mg/l	0	82	<45	36	97.30	45	No. Relaxation
				>45	1	2.70		
6	Fluoride in mg/l	0.05	0.82	<1.0	37	100.00	1	1.5
				1.1-1.5	0	0.00		
				>1.5	0	0.00		
7	Calcium in mg/l	12	100	<75	35	94.59	75	200
				75-200	2	5.41		
				>200	0	0.00		
8	Magnesium in mg/l	5	87	<30	22	59.46	30	100
				30-100	15	40.54		
				>100	0	0.00		
9	Sodium in mg/l	12	96	<100	37	100.00	No Guideline	No Guideline
				>100	0	0.00		
10	Potassium in mg/l	09	44.5	<10	33	89.19	No Guideline	No Guideline
				>10	4	10.81		
11	Uranium in µg/L	BDL	14.2	<30	37	100	30	No. Relaxation
				>30	0	0		

Irrigation Purpose:

The suitability of ground water for irrigation purpose in the district has also been studied. The sodium absorption ratio (SAR) is calculated and is plotted against EC value for both phreatic and deeper aquifers and are presented in **fig. 11.10**and**fig. 11.11**as US salinity diagram. The SAR values indicate the degree to which irrigation water tends to enter into cation exchange reaction with soil. High value of SAR indicates a hazard of sodium replacing already absorbed Ca and Mg in the soil, which in turn leads to damaging soil structure.

The Sodium Adsorption Ratio (SAR) is an irrigation water quality parameter used in the



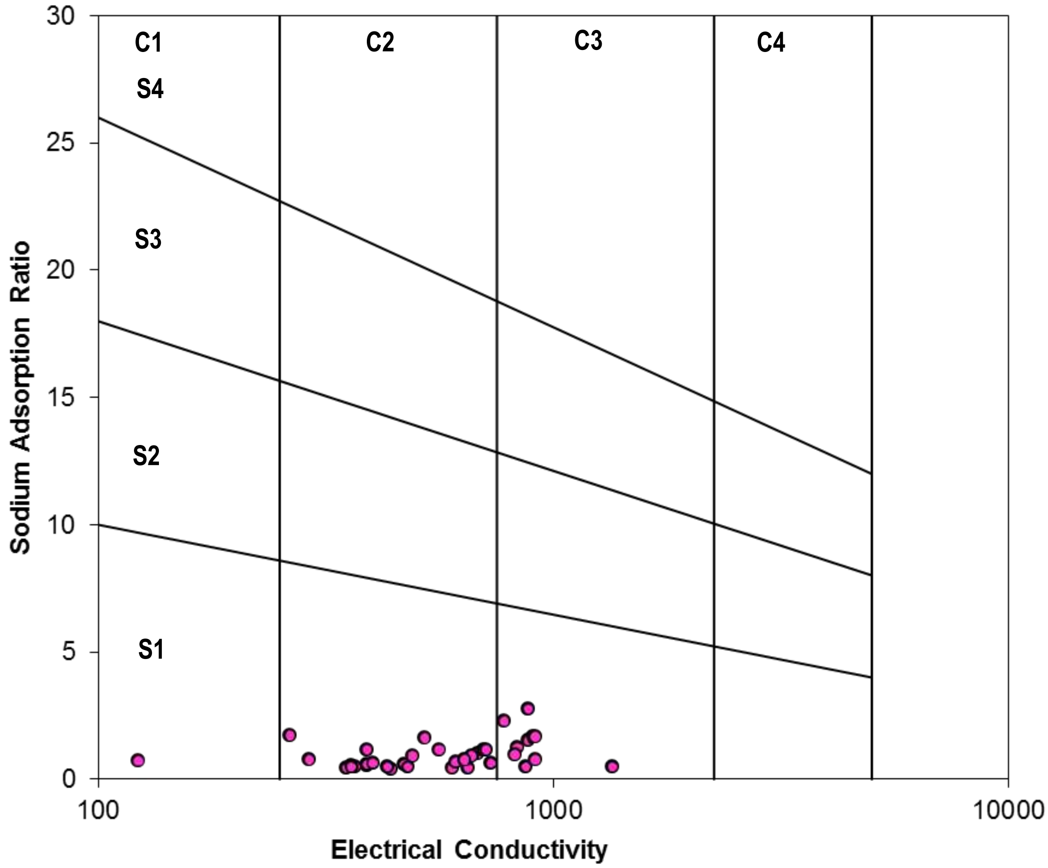
S1, S2, S3 and **S4** are Low, Medium, High and Very High Sodium Hazards respectively.
C1, C2, C3 and **C4** are Low, Medium, High and Very High Salinity Hazards respectively.

Fig. 11.10: Suitability of water for irrigation use (Phreatic aquifer)
Adapted from U.S. Salinity Laboratory Staff (1954).

management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation. The formula for calculating the sodium adsorption ratio (SAR) is:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Where sodium, calcium and magnesium concentrations are expressed in milliequivalents/litre.



S1, S2, S3 and **S4** are Low, Medium, High and Very High Sodium Hazards respectively.
C1, C2, C3 and **C4** are Low, Medium, High and Very High Salinity Hazards respectively.

Fig.11.11: Suitability of water for irrigation use (Deeper aquifer)
Adapted from U.S. Salinity Laboratory Staff (1954).

From the figures it may be seen the ground water is falling under medium to high salinity hazard zone and low sodium hazard zone. The suitability of water for irrigation purpose is given in **table 11.5 and table 11.6**for phreatic and deeper aquifers respectively. As the SAR value is less than 10 for all the samples, the water is suitable for irrigation on almost all types of soils.

Table 11.5:Chemical Quality of water (Phreatic) for Irrigation

S. No.	Parameter	Values obtained		Range	No. of samples	Percentage of samples	Recommended value
		Min.	Max				
1	Salinity (in terms of Electrical conductivity)	80	1420	<500	27	45.76	250-2250
				501-1000	26	44.07	
				1001-2250	6	10.17	
				> 2250	0	0	
2	Sodium Adsorption Ratio	0.17	7.05	< 10	59	100.00	10-26
				10-26	0	0.00	

Table 11.6:Chemical Quality of water (Deeper) for Irrigation

S. No.	Parameter	Values obtained		Range	No. of samples	Percentage of samples	Recommended value
		Min.	Max				
1	Salinity (in terms of Electrical conductivity)	122	1350	<500	16	43.24	250-2250
				501-1000	20	54.05	
				1001-2250	1	2.70	
				> 2250	0	0	
2	Sodium Adsorption Ratio	0.38	2.77	< 10	37	100.00	10-26
				10-26	0	0.00	

11.4: HYDROCHEMICAL EVOLUTION OF GROUND WATER

The groundwater gets enriched in dissolved minerals as it percolates through different lithologies. As it moves underground, it tends to develop a chemical equilibrium with its environment. Mapping of hydrochemicalfacies in an area gives an idea about the evolution of ground water in that area.The trilinear diagram independently developed by Hill (1940) and Piper (1944), forms the basis for classification of groundwater. Trilinear diagrams can be used to delineate hydrochemicalfacies, because they graphically demonstrate relationships between the most important dissolved constituents in a set of ground-water samples. A simple but useful scheme for describing hydrochemicalfacies with trilinear diagrams (**fig.11.12**) is presented by Walton (1970) and is based on methods used by Piper (1944).

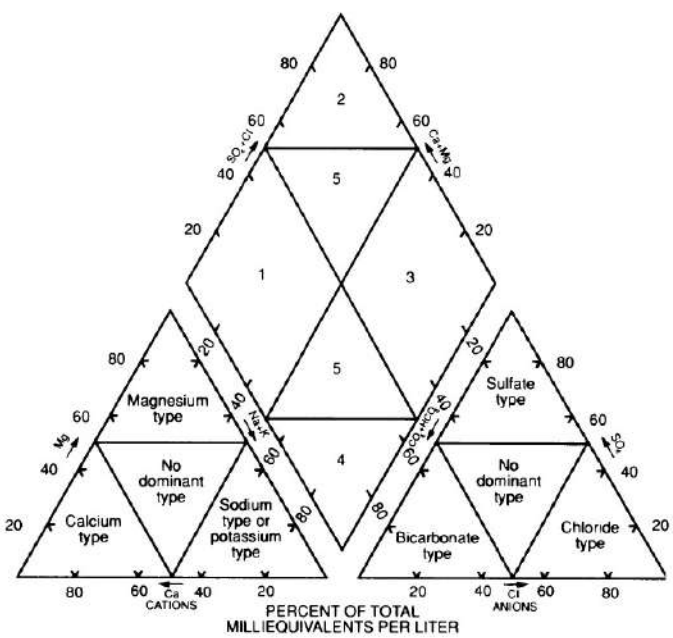


Fig. 11.12: Classification of water based on Piper trilinear diagram

Walton (1970) described a simple but useful classification scheme that divides the central part of the diagram into five subdivisions. In the first four of these subdivisions, the concentration of a specific cation-anion combination exceeds 50 percent of the total milliequivalents per liter (meq/L). Five basic hydrochemicalfacies can be defined with these criteria:

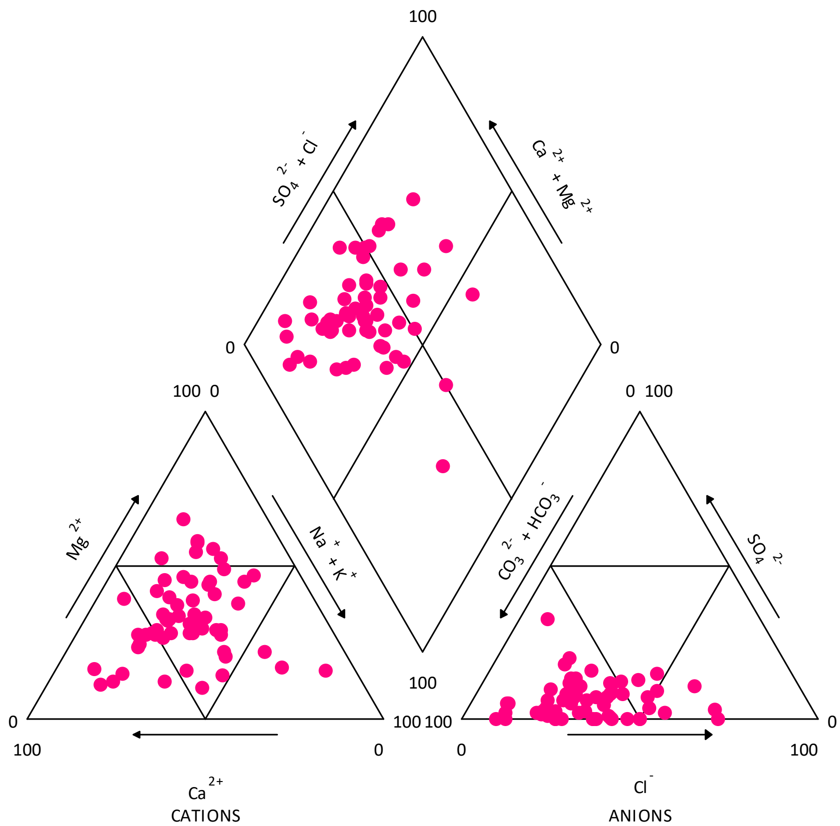


Fig. 11.13: Trilinear plot of water samples collected from phreatic aquifer

1. Primary Hardness; Combined concentrations of calcium, magnesium and bicarbonate exceed 50 percent of the total dissolved constituent load in meq/L. Such waters are generally considered hard and are often found in limestone aquifers or unconsolidated deposits containing abundant carbonate minerals.
2. Secondary Hardness; Combined concentrations of sulphate, chloride, magnesium and calcium exceed 50 percent of total meq/L.
3. Primary Salinity; Combined concentrations of alkali metals, sulphate and chloride are greater than 50 percent of the total meq/L. Very concentrated waters of this hydrochemicalfacies are considered brackish or (in extreme cases) saline.
4. Primary Alkalinity; Combined sodium, potassium and bicarbonate concentrations exceed 50 percent of the total meq/L. These waters generally have low hardness in proportion to their dissolved solids concentration (Walton, 1970).

5. No specific cation-anion pair exceeds 50 percent of the total dissolved constituent load. Such waters could result from multiple mineral dissolution or mixing of two chemically distinct ground-water bodies.

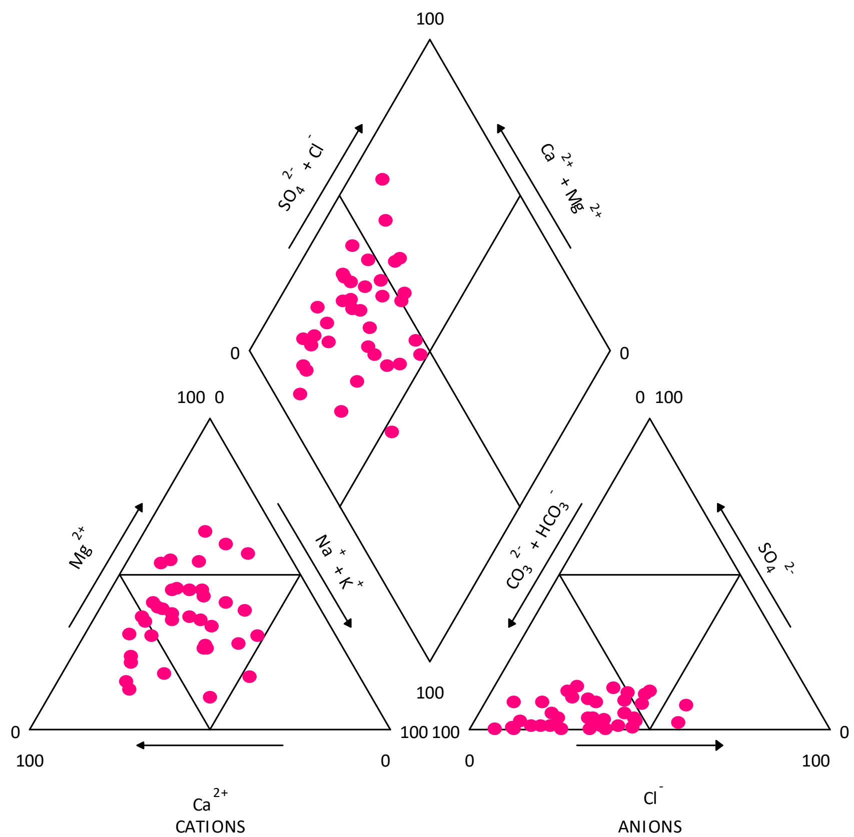


Fig. 11.14: Trilinear plot of water samples collected from deeper aquifer

The plotting of samples of phreatic and deeper aquifers on the Hill-Piper diagrams (**fig. 11.13** and**fig. 11.14**) show that almost all the samples fall in the 1st and 5th fields of the central diamond shape. From the plots it is evident that the water in the district has very low residence time and has not evolved much.

The details of the chemical analysis of water samples collected during study is presented in Table 11.7 and 11.8.

Table 11.7 Ground Water Quality Data of Phreatic Aquifer in Deogarh District

Sl No	Dist.	Block	Village	Lat Decimal	Long Decimal	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3-	F -	U
							µS/cm	mg/l	as $CaCO_3$ mg/l		mg/l										
1	DEOGARH	BARKOTE	Ambagaon	21.654451	84.984158	6.96	370	184	155	135	54	5	12	1.5	0	165	27	2.6	1	0.09	BDL
2	DEOGARH	BARKOTE	Asananali	21.491602	84.858441	8.1	690	334	240	250	54	26	41	12	0	305	45	6.2	1	0.36	BDL
3	DEOGARH	BARKOTE	Bamparda	21.476677	85.074928	7.11	330	165	120	100	26	13	14	8.3	0	122	42	0	1	0.08	BDL
4	DEOGARH	BARKOTE	Budhabahal	21.587829	84.878424	7.63	870	475	295	195	70	29	55	13	0	238	135	54	3	0.15	BDL
5	DEOGARH	BARKOTE	Dandasingha	21.503556	84.927509	6.86	270	139	90	100	30	4	19	1.5	0	122	22	1	2	0.17	BDL
6	DEOGARH	TILEIBANI	Deogarh	21.54361111	84.7244444	7.41	310	152	135	130	44	6	7	0.9	0	159	12	3	1	0.07	BDL
7	DEOGARH	REAMAL	Dhiramunda	21.295665	84.96877	8.18	560	276	220	235	50	23	26	1.4	0	287	20	14	1	0.27	BDL
8	DEOGARH	TILEIBANI	Dimirikuda	21.638015	84.556471	7.08	540	279	185	150	40	21	21	28.8	0	183	55	14	10	0.12	BDL
9	DEOGARH	BARKOTE	Dantaribahal	21.593939	84.830886	7.5	1270	581	560	335	60	100	28	10	0	409	157	25	1	0.27	0.012
10	DEOGARH	TILEIBANI	Gailo	21.591341	84.634161	8.28	510	263	185	145	46	17	25	9.98	0	177	60	17	1	0.16	BDL
11	DEOGARH	TILEIBANI	Gambhariposi	21.649316	84.73832	7.69	570	333	160	175	52	7	23	57.4	0	214	47	31	10	0.14	BDL
12	DEOGARH	BARKOTE	Gopapur	21.531236	85.017968	7.88	230	117	90	85	30	4	8	3.4	0	104	17	3	1	0.09	BDL
13	DEOGARH	TILEIBANI	Jjhargogua	21.629142	84.614761	7.79	270	140	110	65	38	4	11	0.5	0	79	37	10	1	0.07	BDL
14	DEOGARH	TILEIBANI	Kalamati	21.524346	84.799792	8.03	580	297	230	210	60	19	16	16.6	0	256	42	17	1	0.19	BDL
15	DEOGARH	BARKOTE	Kalkat	21.48583333	84.9516667	8.12	450	221	185	195	50	15	16	2.9	0	238	20	0	1	0.16	BDL
16	DEOGARH	BARKOTE	Kandhal	21.532713	84.865299	7.76	1420	744	540	205	90	77	72	10	0	250	297	73	3	0.2	0.0098

Sl No	Dist.	Block	Village	Lat Decimal	Long Decimal	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3-	F -	U
							µS/cm	mg/l	as $CaCO_3$ mg/l		mg/l										
17	DEOGARH	REAMAL	Kantabahal	21.331744	84.807205	7.91	680	337	245	225	46	32	41	2.9	0	275	60	20	1	0.18	BDL
18	DEOGARH	REAMAL	karlaga	21.250718	84.884617	7.81	340	172	155	140	36	16	5	1.7	0	171	12	8	10	0.15	BDL
19	DEOGARH	BARKOTE	Kansibahal	21.556124	84.911222	7.75	350	178	130	95	30	13	16	4.2	0	116	45	12	1	0.12	BDL
20	DEOGARH	REAMAL	Kundheigola	21.208672	84.808194	7.9	300	152	115	100	30	10	14	1.8	0	122	20	13	4	0.15	BDL
21	DEOGARH	REAMAL	Koradkhol	21.282108	84.761334	7.94	520	265	205	135	26	34	14	16.7	0	165	40	28	25	0.14	BDL
22	DEOGARH	REAMAL	Kushakhalia	21.298593	84.910237	7.83	960	514	295	160	32	52	84	1.3	0	195	145	61	43	0.29	BDL
23	DEOGARH	TILEIBANI	Laimura	21.69322	84.672068	7.97	510	276	180	135	28	27	32	4	0	165	65	29	10	0.15	BDL
24	DEOGARH	TILEIBANI	Lambadora	21.688019	84.718344	7.58	250	137	100	65	28	7	9	3.1	0	79	32	13	6	0.11	BDL
25	DEOGARH	REAMAL	Nuapada	21.143485	84.808029	7.68	1110	561	445	240	52	77	46	4.4	0	293	187	37	14	0.55	0.0157
26	DEOGARH	TILEIBANI	Pravasuni	21.549034	84.554433	8.05	920	479	360	180	60	51	43	1.3	0	220	160	40	16	0.18	BDL
27	DEOGARH	REAMAL	Purumunda	21.30722222	84.6375	7.63	460	243	135	115	28	16	32	16	0	140	37	19	27	0.11	BDL
28	DEOGARH	REAMAL	Rengalbeda	21.433704	84.683888	7.78	1080	585	130	345	18	21	186	3.8	0	421	107	41	2	1.62	0.074
29	DEOGARH	REAMAL	Riamal	21.36444444	84.6602778	7.65	880	464	305	250	36	52	60	2.2	0	305	122	35	7	0.51	BDL
30	DEOGARH	BARKOTE	Salei	21.635512	84.909021	8.06	760	420	270	220	40	41	24	43.4	0	268	60	45	35	0.19	BDL
31	DEOGARH	TILEIBANI	Samasingha	21.631923	84.689343	7.32	180	91	70	55	18	6	7	2.7	0	67	17	6	1	0.08	BDL
32	DEOGARH	REAMAL	Siaria	21.404356	84.83729	8.14	820	437	330	190	38	57	34	2.7	0	232	105	46	41	0.36	BDL
33	DEOGARH	TILEIBANI	Suguda	21.488948	84.795721	8.13	600	320	225	165	24	40	21	22	0	201	60	44	10	0.25	BDL
34	DEOGARH	TILEIBANI	Tanisar	21.539301	84.662081	7.71	460	262	175	150	40	18	21	6.7	0	183	40	18	28	0.14	BDL

Sl No	Dist.	Block	Village	Lat Decimal	Long Decimal	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3-	F -	U
							µS/cm	mg/l	as $CaCO_3$ mg/l		mg/l										
35	DEOGARH	REAMAL	Valchabha	21.403774	84.823062	7.66	997	641	360	340	54	55	110	3.4	0	415	213	0	3	0.99	0.0135
36	DEOGARH	REAMAL	Dhauragotha	21.425321	84.686396	7.91	955	558	410	205	114	30	43	4.2	0	250	195	10	39	0.16	0.0868
37	DEOGARH	REAMAL	Barkul	21.372079	84.575684	7.82	736	434	300	280	78	26	42	7	0	342	96	9	9	0.1	BDL
38	DEOGARH	TILEIBANI	Kansar	21.441771	84.511238	7.64	799	474	310	265	50	45	48	34	0	323	99	11	28	0.2	BDL
39	DEOGARH	TILEIBANI	Subarnapali	21.458261	84.864687	7.5	604	367	235	260	52	26	55	3.3	0	317	64	8	4	0.76	0.0115
40	DEOGARH	TILEIBANI	Gundeimara	21.527076	84.504292	8.01	580	349	305	270	50	44	17	3	0	330	57	12	5	0.17	BDL
41	DEOGARH	TILEIBANI	Palakundar	21.50713	84.491009	8.14	618	376	290	245	60	34	40	2.4	0	299	74	18	1	0.43	0.127
42	DEOGARH	REAMAL	Kirtanpali	21.327081	84.720641	8.09	610	373	230	200	54	23	31	35	0	244	99	4	7	0.25	BDL
43	DEOGARH	REAMAL	Tinkbir	21.383217	84.705303	7.43	1220	735	410	315	36	78	104	38	0	384	248	24	19	0.71	0.0683
44	DEOGARH	TILEIBANI	Danardanpalli	21.441772	84.770328	7.9	419	257	215	250	40	28	18	1.4	0	305	18	0	2	0.23	BDL
45	DEOGARH	REAMAL	Kharsuan	21.309458	84.840047	8.2	465	330	180	175	54	11	28	35	0	214	89	0	8	0.3	BDL
46	DEOGARH	REAMAL	Tungamal	21.22199	84.732898	7.75	128	81	50	50	10	6	9	4	0	61	21	0	1	0.06	BDL
47	DEOGARH	REAMAL	Suringipal	21.196567	84.846605	7.68	1012	571	340	320	72	39	94	6.8	0	391	74	89	4	0.74	0.0164
48	DEOGARH	BARKOTE	Tusula	21.600251	84.703215	7.76	557	355	170	75	36	19	38	25	0	92	135	8	49	0.32	BDL
49	DEOGARH	BARKOTE	Gurusang	21.491474	85.131112	7.88	480	307	195	175	40	23	29	16	0	214	74	0	20	0.15	BDL
50	DEOGARH	TILEIBANI	Panibhandar	21.719956	84.662288	7.62	476	263	215	120	44	26	12	11	0	146	60	18	20	0.17	BDL
51	DEOGARH	Chapabahal	Chapabahal	21.634666	84.837173	8.12	423	258	200	195	40	24	22	1.4	0	238	53	0	0	0.14	BDL
52	DEOGARH	BARKOTE	Madang	21.596498	84.992013	7.55	80	64	20	25	4	2	11	6	0	31	18	0	8	0.03	BDL

Sl No	Dist.	Block	Village	Lat Decimal	Long Decimal	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3-	F -	U
							µS/cm	mg/l	as $CaCO_3$ mg/l		mg/l										
53	DEOGARH	BARKOTE	Kadopada	21.616662	84.95979	7.98	436	252	115	115	28	11	38	7	0	140	28	36	35	0.06	BDL
54	DEOGARH	BARKOTE	Balanda	21.56272	85.02202	7.44	142	94	70	70	16	7	9	0.5	0	85	18	0	2	0.05	BDL
55	DEOGARH	BARKOTE	Nuabanakhal	21.463375	85.156411	7.83	794	470	330	255	36	58	56	5	0	311	25	134	4	0.23	0.003
56	DEOGARH	BARKOTE	Raitabahal	21.432408	84.98513	7.91	272	167	75	85	22	5	30	3	0	104	43	1	12	0.18	BDL
57	DEOGARH	REAMAL	Gothanali	21.397998	84.617647	7.94	237	138	110	100	28	10	13	2.4	0	122	25	0	0	0.12	BDL
58	DEOGARH	TILEIBANI	Tipirisingha	21.654894	84.653711	7.63	164	123	55	45	14	5	17	7	0	55	32	0	21	0.04	BDL
59	DEOGARH	BARKOTE	Chasagurujang	21.442846	85.088845	7.14	228	166	60	35	12	7	29	8.9	0	43	64	0	24	0.03	BDL

Table 11.8 Ground Water Quality Data of Deeper Aquifer in Deogarh District

Sl No	Dist.	Block	Village	Lat Decimal	Long Decimal	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3-	F -	U
							µS/cm	mg/l	as $CaCO_3$ mg/l		mg/l										
1	DEOGARH	REAMAL	Badsimloi	21.359761	84.605567	8.15	440	213	190	175	44	19	12	2	0	214	12	17.3	1	0.24	BDL
2	DEOGARH	BARKOTE	Barkot	21.5416667	84.9983333	8.17	390	194	155	170	50	7	16	1.2	0	207	17	0	1	0.18	BDL
3	DEOGARH	BARKOTE	Budhabahal	21.587829	84.878424	8.09	730	358	300	215	64	34	26	4.7	0	262	90	10	1	0.23	BDL
4	DEOGARH	BARKOTE	Dandasingha	21.503556	84.927509	7.77	390	193	150	125	26	21	17	3.9	0	153	42	7	1	0.09	BDL
5	DEOGARH	TILEIBANI	Deogarh	21.5436111	84.7244444	7.93	400	197	155	180	52	6	18	2	0	220	10	0	1	0.27	BDL
6	DEOGARH	REAMAL	Dhiramunda	21.295665	84.96877	7.69	560	283	180	200	42	18	35	15.7	0	244	30	22	1	0.24	BDL
7	DEOGARH	TILEIBANI	Dimirikuda	21.638015	84.556471	7.4	490	276	135	115	44	6	24	44.5	0	140	60	19	10	0.11	BDL
8	DEOGARH	TILEIBANI	Gailo	21.591341	84.634161	7.97	350	173	145	140	42	10	12	1.8	0	171	20	1.5	2	0.17	BDL
9	DEOGARH	TILEIBANI	Jjhargogua	21.629142	84.614761	7.91	650	318	285	235	74	24	17	1	0	287	45	15	1	0.12	BDL
10	DEOGARH	TILEIBANI	Kalamati	21.524346	84.799792	8.17	430	211	175	185	52	11	15	3	0	226	17	1	1	0.14	BDL
11	DEOGARH	BARKOTE	Kandhal	21.532713	84.865299	7.79	880	456	290	205	58	35	60	14.8	0	250	110	45	10	0.16	BDL
12	DEOGARH	REAMAL	Kantabahal	21.331744	84.807205	7.55	780	410	215	230	44	26	77	3.3	0	281	82	32	8	0.43	0.00931
13	DEOGARH	BARKOTE	Kansibahal	21.556124	84.911222	7.86	870	402	380	215	58	57	21	4.1	0	262	112	19	2	0.11	BDL
14	DEOGARH	REAMAL	Koradkhol	21.282108	84.761334	8.09	600	302	255	155	54	29	17	2.6	0	189	50	23	34	0.2	BDL
15	DEOGARH	REAMAL	Kushakhalia	21.298593	84.910237	7.74	880	491	225	225	38	32	96	3.9	0	275	100	54	33	0.43	0.006
16	DEOGARH	BARKOTE	Mankadmunda	21.602187	84.7803	7.62	1350	681	610	240	100	87	28	2.1	0	293	265	48	7	0.07	BDL
17	DEOGARH	TILEIBANI	Pendarakhol	21.465288	84.693168	8.12	610	302	245	180	44	33	24	2.4	0	220	45	27	19	0.51	0.0111
18	DEOGARH	TILEIBANI	Pravasuni	21.549034	84.554433	7.6	470	240	190	120	48	17	18	3.7	0	146	72	6	4	0.13	BDL
19	DEOGARH	REAMAL	Purumunda	21.3072222	84.6375	7.5	290	149	100	75	20	12	18	1.8	0	92	30	1	21	0.11	0.0037
20	DEOGARH	REAMAL	Rengalbeda	21.433704	84.683888	7.55	520	252	155	155	22	24	47	2	0	189	55	8	1	0.18	BDL
21	DEOGARH	REAMAL	Riamal	21.3644444	84.6602778	8.06	680	344	255	205	22	49	37	1.2	0	250	52	43	18	0.43	BDL
22	DEOGARH	REAMAL	Siaria	21.404356	84.83729	7.88	900	458	300	290	20	61	66	2	0	354	65	51	20	0.46	BDL
23	DEOGARH	REAMAL	Tarang	21.2738889	84.5797222	8.02	700	365	255	125	42	36	42	1.5	0	153	90	34	44	0.31	0.0128

Sl No	Dist.	Block	Village	Lat Decimal	Long Decimal	pH	EC	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4=	NO3-	F -	U
							µS/cm	mg/l	as $CaCO_3$ mg/l		mg/l										
24	DEOGARH	REAMAL	Telimunda	21.3425	84.6688889	8.23	360	182	140	135	30	16	15	3.2	0	165	27	2	8	0.24	BDL
25	DEOGARH	TILEIBANI	Tileibani	21.5458333	84.6022222	7.87	910	501	300	210	46	45	67	6.4	0	256	135	35	41	0.15	BDL
26	DEOGARH	REAMAL	Tuhilamal	21.292527	84.588743	8.25	390	197	125	160	30	12	29	3.9	0	195	17	5	4	0.26	0.0039
27	DEOGARH	REAMAL	Valchabha	21.403774	84.823062	7.89	830	493	315	245	94	19	51	9	0	299	142	2	29	0.82	BDL
28	DEOGARH	REAMAL	Dhauragotha	21.425321	84.686396	8.09	264	160	70	115	18	6	33	4	0	140	25	5	0	0.34	BDL
29	DEOGARH	REAMAL	Hrudapali	21.204656	84.880221	7.42	662	373	290	200	64	32	36	4	0	244	99	4	14	0.76	0.011
30	DEOGARH	TILEIBANI	Kansar	21.441771	84.511238	8.11	821	505	340	165	70	40	40	25	0	201	110	39	82	0.2	BDL
31	DEOGARH	REAMAL	Kirtanpali	21.327081	84.720641	8.1	637	370	290	245	38	47	30	4.8	0	299	89	11	3	0.43	0.0142
32	DEOGARH	REAMAL	Tinkbir	21.383217	84.705303	7.66	711	417	300	210	48	44	46	2.8	0	256	124	14	13	0.62	BDL
33	DEOGARH	TILEIBANI	Danardanpalli	21.441772	84.770328	7.59	912	557	445	235	42	83	38	5.7	0	287	227	10	12	0.1	BDL
34	DEOGARH	TILEIBANI	Panibhandar	21.719956	84.662288	8.1	365	230	185	175	34	24	16	3	0	214	43	0	5	0.14	BDL
35	DEOGARH	BARKOTE	Kadopada	21.616662	84.95979	7.66	122	88	50	50	12	5	12	1.7	0	61	18	0	10	0.05	BDL
36	DEOGARH	REAMAL	Gothanali	21.397998	84.617647	8.09	478	284	235	180	56	23	18	0.9	0	220	78	0	0	0.08	BDL
37	DEOGARH	BARKOTE	Chapabahal	21.634666	84.837173	7.88	360	223	185	185	40	21	15	1.8	0	226	32	2	1	0.21	BDL

12. Geophysical Study

1.1 INTRODUCTION

Geo-electrical resistivity survey is a widely used geophysical method for subsurface studies; including groundwater exploration, environmental application and other engineering applications. The main benefit of this method is that it allows for performing the survey quite fast and in a cost effective manner. Detection of different types of subsurface geology, water table, variation of resistivity with depths (distinguishing layered earth), detection of bedrocks depth, overburden thickness, etc. are the objectives of this survey.

Geophysical survey incorporates the Vertical Electrical Sounding (VES) and Horizontal Profiling activities. The Vertical Electrical Sounding (VES) is currently being very popular with groundwater investigations due to its simplicity. The interpretation of electrical resistivity data is the process of deriving the values of true resistivity's (ρ) and thicknesses (t) of various subsurface strata from the values of recorded resistance (R) or apparent resistivity (ρa) at electrode separations (a). There are a number of interpretation techniques for evaluating (ρ) and (t) of each of the stratum as proposed by many investigators. These can be grouped as analytical, numerical, empirical, and graphical; with several procedures within each category. The computer software, IP2WIN was used to analyze the filtered and processed field data. The software inverts the field data, calculates the appropriate model in term of resistivity, and provides output in the form of resistivity layers.

This inversion data is used to draw up the lithological and geological information. The resistivity of any given layer depends upon rock type, grain size, degree of void spaces and amount of water present, degree of weathering, mineral constituents etc.

1.2 ELECTRICAL RESISTIVITY SURVEY LOCATION

A total no. of 77 VES were carried out in and around Tileibani, Reamal and Barkote Blocks of Deogarh District**,** Orissa State to study about Ground water availability in this area during

Annual Action Plan 2021– 2022 using Signal Stacking Resistivity Meter CRM 20 (Aqua meter) of Anvic Systems**,** Pune**.** The VES locations are shown in Figure 12. 1.

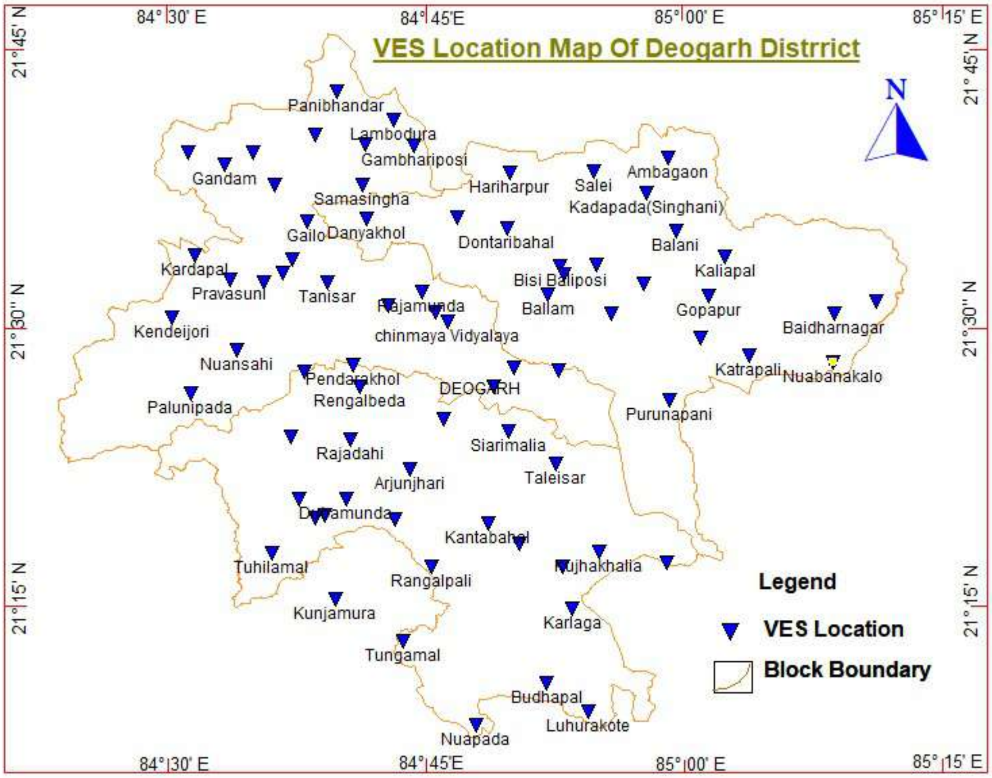


Figure 12.1 VES Location Map of Deogarh District

1.3 METHODOLOGY

During the surface resistivity survey, CRM 20 resistivity meter (manufactured by Anvic System, Pune) was used. The instrument measures resistance i.e. ratio of potential differences and current in between two potential electrodes when current is sent through two current electrodes and there by apparent resistivity is calculated by multiplying the geometrical factor. Vertical Electrical Soundings (VES) using Schlumberger array were carried out at Seventy seven (77) stations.

The apparent resistivities are plotted in the double log graph paper and the types of the field curves are obtained as H, K, A, AH and AK. All the curves are interpreted with the help of partial curve matching technique and also by the resistivity sounding interpretation software programme IPI2WIN.

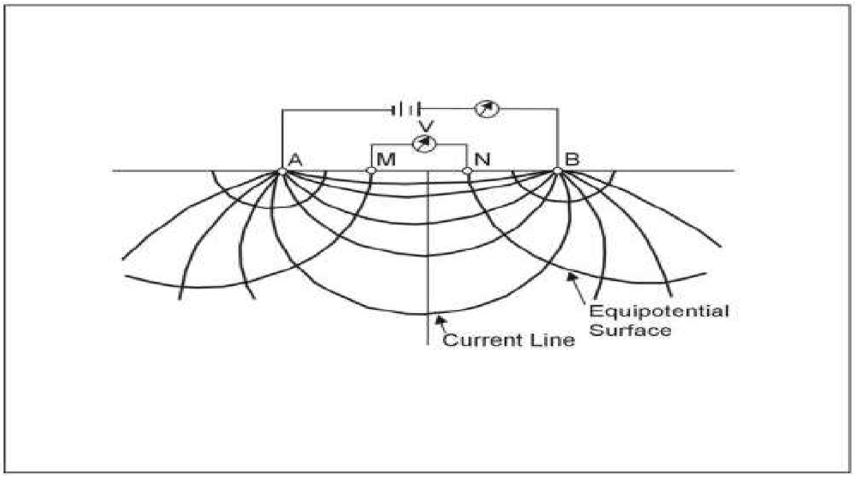


Figure 12.2 The generalized form of the electrode configuration used in resistivity measurements

1.4 INTERPRETED VES RESULT

A total no. of 77 VES were carried out in Deogarh district. The VES locations are shown in Figure 12.1. Here Seventy Seven (77) interpreted VES data results are given in Table 12.1.The VES results were correlated with the local geology & Hydrogeology and compared with the lithologs of 25 bore holes drilled by CGWB in Deogarh district. Then, geoelectrical characteristics of the near surface soil, weathered rock and that of the underlying massive /fractured formation are presented in Table 12. 1.

The VES interpreted results are nearly same in all blocks of Deogarh district. The resistivity of the top geoelectric layer with resistivities varying between from 2.75-973 Ωm inferred as Top soil depending on its nature and saturation and the thickness varies between 0.3 and 3.5 m and the depth also varies from 0-4.5m occasionally exceeds to 8.25m.

Mostly the 2nd or 3rd geoelectric layer, occasionally the 1st one with resistivities ranging from 3.39 to 100 Ohm m has been inferred as weathered layer. The layer with more than 100 Ohm m has been considered as semi weathered layer. The wide range of resistivities may be due to its nature and saturation and degree of weathering. In general, the weathered / semi weathered zone extends down to a depth of 19 m bgl m, occasionally exceeds to 47m.

Mostly the 3rd or 4th geoelectric layer, occasionally, the 2nd one with resistivities ranging from 158 to 1000 Ohm m, occasionally exceeding to 1571 Ohm m has been inferred as Less compact formation / formation with fractures. The higher order of resistivities may be due to the suppression of thin low resistive geoelectric layer in between the two high resistive layers. Wide range of the resistivities may be due to the variations in the degree of fracturing, nature of the formation, etc. The thickness of the geoelectric layer inferred as less compact / formation with fractures, in general varies between 4.21 to 80.8 m, occasionally exceeds to more than 104m.

The depth to bottom of compact layer is, in general, varying from 4.07 to 104 m. occasionally exceeds to more than 100m. The layer with resistivities more than 1000 Ohm m may be inferred as compact depending on the nature and type of the formation. On the basis of geoelectrical layer parameters and the fractured zone analysis a few sites are recommended for borehole drilling.

Table 12.1 Interpreted VES result in Deogarh District

SL NO.	LOCATION	BLOCK	VES NO.	EASTING	NORTHING	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Charectristics		
				Longitude	Latitude	Layer	Resistivity(ohm.m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
1.	Bisi Baliposi	Barkote	1	84.88035	21.55613	1	62.8	1.75	1.75	Top Soil			
						2	27.1	2.46	4.21	Top Soil			
						3	250	13.5	17.68	Less Compact Formation	Aquifer	4.21-17.68	Potable
						4	39.6	19.2	36.9	Weathered Formation	Aquifer	17.68-36.9	Potable
						5	VH			Compact Formation			
2.	Ballam	Barkote	2	84.86848	21.53021	1	99.5	0.807	0.807	Top Soil			
						2	2.75	.628	1.43	Top Soil			
						3	14	2.38	3.82	Weathered Formation	Aquifer	1-9.99	Potable
						4	3.39	6.17	9.99	Weathered Formation			
						5	4008	94.4	104	Compact Formation			
3.	Tanisar	Tileibani	3	84.65511	21.54051	1	39.1	0.972	0.972	Top Soil			
						2	9.73	1.91	2.88	Weathered Formation	Aquifer	1-31.5	Potable
						3	90.1	28.6	31.5	Weathered Formation			
						4	VH			Compact Formation			
4.	Tileibani	Tileibani	4	84.61181	21.54982	1	200	1.34	1.34	Top Soil			
						2	44.6	13.2	14.5	Weathered Formation	Aquifer	1.34-14.5	Potable
						3	VH			Compact Formation			
5.	Gailo	Tileibani	5	84.63512	21.59606	1	72.8	0.926	0.926	Top Soil			
						2	28.8	3.02	3.94	Weathered Formation	Aquifer	1-7.46	Potable
						3	11	3.52	7.46	Weathered Formation			
						4	VH			Compact Formation			
6.	Pravasuni	Tileibani	6	84.56045	21.54392	1	250	1.02	1.02	Top Soil			
						2	100	2.17	3.2	Top Soil			
						3	37.5	14.3	17.5	Weathered Formation	Aquifer	3.2-17.5	Potable
						4	895	21	38.5	Less Compact Formation	Aquifer	17.5-38.5	Potable
						5	VH						

7.	Kardapal	Tileibani	7	84.52676	21.56535	1	29.1	1.71	1.71	Top Soil			
						2	3.61	2.36	4.07	Weathered Formation	Aquifer	1.71-4.07	Potable
						3	VH			Compact Formation			
8.	Tileibani 2	Tileibani	8	84.59351	21.54135	1	29.49	1.2	1.2	Top Soil			
						2	55.29	4.044	5.244	Weathered Formation	Aquifer	1.2-10.96	Potable
						3	135	5.713	10.96	Semi Weathered Formation			
						4	894.1	37.02	47.97	Less Compact Formation	Aquifer	10.96-47.97	Potable
						5	VH			Compact Formation			
9.	Pendarakhol	Reamal	9	84.6798	21.46626	1	23.4	0.663	0.663	Top Soil			
						2	14.2	7.22	7.89	Weathered Formation	Aquifer	0.663-7.89	Potable
						3	VH			Compact Formation			
10.	Madhyapur	Reamal	10	84.63226	21.46041	1	165.3	2.159	2.159	Top Soil			
						2	78.16	4.165	6.325	Weathered Formation	Aquifer	2-6.325	Potable
						3	328.4	19.97	26.3	Less Compact Formation	Aquifer	6.3-26.3	Potable
						4	VH			Compact Formation			
11.	Nuansahi	Tileibani	11	84.56707	21.48052	1	30.92	1.2	1.2	Top Soil			
						2	50.99	5.239	6.439	Weathered Formation	Aquifer	1.2-6.5	Potable
						3	VH			Compact Formation			
12.	chhepillipali	Tileibani	12	84.83524	21.4645	1	111.5	2.884	2.884	Top Soil			
						2	48.92	5.465	8.349	Weathered Formation	Aquifer	2.9-8.35	Potable
						3	VH			Compact Formation			
13.	chinmaya Vidyalaya	Tileibani	13	84.77093	21.50594	1	104.3	9.379	9.379	Top Soil			
						2	627.4	13.41	22.78	Less Compact Formation	Aquifer	9.4-22.8	Potable
						3	VH			Compact Formation			
14.	Rajamunda	Tileibani	14	84.74612	21.5321	1	22.23	1.915	1.915	Top Soil			
						2	54.61	4.841	6.755	Weathered Formation	Aquifer	1.9-19.3	Potable
						3	24.3	12.55	19.3	Weathered Formation			
						4	2729	40.75	60.04	Less Compact Formation	Aquifer	19.3-60.04	Potable
						5	VH			Compact Formation			

15.	Rengalbeda	Reamal	15	84.68571	21.44767	1	220	1.2	1.2	Top Soil			
						2	66.1	3.86	5.06	Weathered Formation	Aquifer	1.2-10.4	Potable
						3	29.4	5.33	10.4	Weathered Formation			
						4	VH			Compact Formation			
16.	Rajadahi	Reamal	16	84.67646	21.39973	1	93.3	1.23	1.23	Top Soil			
						2	12.8	7.46	8.69	Weathered Formation	Aquifer	1.2-8.69	Potable
						3	375	34.8	43.5	Less Compact Formation	Aquifer	8.69-43.5	Potable
						4	VH			Compact Formation			
17.	Dubamunda	Reamal	17	84.67272	21.34687	1	46.4	1.91	1.91	Top Soil			
						2	279	2.6	4.51	Top Soil			
						3	9.32	6.24	10.8	Weathered Formation	Aquifer	4.51-10.8	Potable
						4	VH			Compact Formation			
18.	Kendeijori	Tileibani	18	84.50427	21.50938	1	169.7	1.2	1.2	Top Soil			
						2	365	1.308	2.508	Top Soil			
						3	74.96	2.734	5.241	Weathered Formation	Aquifer	2.5-5.24	Potable
						4	290.3	5.713	10.95	Less Compact Formation	Aquifer	5.24-10.95	Potable
						5	2144	11.94	22.89	Compact Formation			
						6	464.2	24.95	47.85	Less Compact Formation	Aquifer	22.89-47.85	Potable
						7	VH			Compact Formation			
19.	Palunipada	Tileibani	19	84.52242	21.44079	1	37.12	1.2	1.2	Top Soil			
						2	16.74	1.264	2.464	Weathered Formation	Aquifer	1.2-10.44	Potable
						3	55.16	7.979	10.44	Weathered Formation			
						4	1321	35.88	46.32	Less Compact Formation	Aquifer	10.44-46.32	Potable
						5	VH			Compact Formation			

20.	Panibhandar	Tileibani	20	84.66367	21.71323	1	93.5	47.8	47.8	Weathered Formation	Aquifer	1-47.8	Potable
						2	VH			Compact Formation			
21.	Lambodura	Tileibani	21	84.71845	21.68731	1	116	0.567	0.567	Top Soil			
						2	44.6	2.15	2.72	Top Soil			
						3	12	4.59	7.31	Weathered Formation	Aquifer	2.72-7.31	Potable
						4	1700			Compact Formation			
22.	Bhaluguha	Tileibani	22	84.64275	21.67378	1	710.8	1.221	1.221	Top Soil			
						2	255	1.98	3.201	Top Soil			
						3	55.09	9.353	12.55	Weathered Formation	Aquifer	3.2-12.55	Potable
						4	179.8	42.92	55.47	Less Compact Formation	Aquifer	12.55-55.47	Potable
						5	VH			Compact Formation			
23.	Gambharip osi	Tileibani	23	84.73918	21.66366	1	277.5	1.236	1.236	Top Soil			
						2	174.4	5.328	6.564	Semi Weathered Formation	Aquifer	1.2-12.33	Potable
						3	90.81	5.766	12.33	Weathered Formation			
						4	407.2	33.66	45.99	Less Compact Formation	Aquifer	12.33-45.99	Potable
						5	VH			Compact Formation			
24.	Salohi	Tileibani	24	84.69092	21.66584	1	187	2.09	2.09	Top Soil			
						2	49.4	8.8	10.9	Weathered Formation	Aquifer	2.09-10.9	Potable
						3	VH			Compact Formation			
25.	Samasingha	Tileibani	25	84.68867	21.62852	1	117	1.2	1.2	Top Soil			

						2	55.3	4.08	5.28	Weathered Formation	Aquifer	1.2-11	Potable
						3	24.5	5.71	11	Weathered Formation			
						4	228	37.2	48.1	Less Compact Formation	Aquifer	11-48.1	Potable
						5	VH			Compact Formation			
26.	Siarimalia	Tileibani	26	84.83044	21.40668	1	139	1.87	1.87	Top Soil			
						2	8.64	8.58	8.58	Weathered Formation	Aquifer	1.87-8.58	Potable
						3	VH			Compact Formation			
27.	Gadpal	Tileibani	27	84.81634	21.44788	1	77.5	0.907	0.907	Top Soil			
						2	12.6	8.66	9.56	Weathered Formation	Aquifer	1-9.56	Potable
						3	1974			Compact Formation			
28.	Gandam	Tileibani	28	84.55487	21.64648	1	99.6	1.65	1.65	Top Soil			
						2	406	0.915	2.57	Top Soil			
						3	10.8	9.69	12.3	Weathered Formation	Aquifer	2.57-12.3	Potable
						4	VH			Compact Formation			
29.	Puhulamara	Tileibani	29	84.51951	21.65847	1	198.8	1.261	1.261	Top Soil			
						2	49.42	7.847	9.108	Weathered Formation	Aquifer	1.2-9.1	Potable
						3	782.7	6.789	15.9	Less Compact Formation	Aquifer	9.1-15.9	Potable
						4	109.4	26.59	42.49	Semi Weathered Formation	Aquifer	15.9-42.49	Potable
						5	VH			Compact Formation			
30.	Ludar udaipur	Tileibani	30	84.58236	21.65843	1	74.7	2.51	2.51	Top Soil			
						2	95.5	2.73	5.24	Weathered Formation	Aquifer	2.51-11	Potable
						3	14.1	5.71	11	Weathered Formation			
						4	421	37	48	Less Compact Formation	Aquifer	11-48	Potable

						5	VH			Compact Formation			
31	Jhargugua	Tileibani	31	84.60432	21.62861	1	76.6	0.9165	0.9165	Top Soil			
						2	30.14	4.068	4.985	Weathered Formation	Aquifer	1-19.43	Potable
						3	21.14	14.45	19.43	Weathered Formation			
						4	427.7	22.5	41.93	Less Compact Formation	Aquifer	19.43-41.93	Potable
						5	VH						
32.	Kailash	Tileibani	32	84.62025	21.56239	1	123	1.2	1.2	Top Soil			
						2	259	1.31	2.51	Top Soil			
						3	66.6	2.73	5.24	Weathered Formation	Aquifer	2.51-5.24	Potable
						4	1409	17.9	23.2	Less Compact Formation	Aquifer	5.24-23.2	Potable
						5	134	25	48.1	Semi Weathered Formation	Aquifer	23.2-48.1	Potable
						6	VH						
33.	Samtarapali	Tileibani	33	84.76014	21.51489	1	69.2	1.2	1.2	Top Soil			
						2	40.5	5.32	6.52	Weathered Formation	Aquifer	1.2-6.52	Potable
						3	193	8.47	15	Less Compact Formation	Aquifer	6.52-15	Potable
						4	VH	19.6	34.6	Compact Formation			
						5	28.6						
34.	Sunapasi sahi	Reamal	34	84.76715	21.41838	1	45.16	1.107	1.107	Top Soil			
						2	11.96	1.571	2.678	Top Soil			
						3	158.1	58.61	61.29	Less Compact Formation	Aquifer	2.678-61.29	Potable
						4	VH			Compact Formation			
35.	Arjunjhari	Reamal	35	84.73515	21.37333	1	23.6	11.5	11.5	Weathered Formation	Aquifer	0-11.5	Potable
						2	VH			Compact Formation			

36.	Kantabahal	Reamal	36	84.81019	21.32484	1	243.8	0.899	0.899	Top Soil			
						2	96.35	12.73	13.62	Weathered Formation	Aquifer	1-13.62	Potable
						3	174.3	59.13	72.75	Less Compact Formation	Aquifer	13.62-72.75	Potable
						4	VH			Compact Formation			
37.	Kaunsibahal	Barkote	37	84.9153	21.55681	1	16.9	0.611	0.611	Top Soil			
						2	43.8	1.08	1.69	Top Soil			
						3	3.41	2.57	4.26	Weathered Formation	Aquifer	1.69-4.26	Potable
						4	4941	5.17	9.43	Compact Formation	Aquifer	4.26-9.43	Potable
						5	3.07						
38.	Kandhal	Barkote	38	84.88424	21.54788	1	29.5	1.54	1.54	Top Soil			
						2	15.1	2.27	3.81	Weathered Formation	Aquifer	1.54-3.81	Potable
						3	591	77	80.8	Less Compact Formation	Aquifer	3.81-80.8	Potable
						4	VH			Compact Formation			
39.	Karlaga	Reamal	39	84.89219	21.24747	1	39.21	1.2	1.2	Top Soil			
						2	72.9	1.308	2.508	Weathered Formation	Aquifer	1.2-11.02	Potable
						3	33.06	8.51	11.02	Weathered Formation			
						4	461.9	11.94	22.96	Less Compact Formation	Aquifer	11.02-22.96	Potable
						5	58.42	24.95	47.91	Weathered Formation	Aquifer	22.96-47.91	Potable
						6	VH			Compact Formation			
40.	Kujhakhalia	Reamal	40	84.91752	21.29923	1	65.2	0.564	0.564	Top Soil			
						2	167	1.18	1.74	Top Soil			
						3	7.34	2.31	4.05	Weathered Formation	Aquifer	1.74-4.05	Potable
						4	255	40.9	44.9	Less Compact Formation	Aquifer	4.05-44.9	Potable

						5	VH			Compact Formation			
41.	Khairapali	Reamal	41	84.98338	21.28855	1	93.8	0.601	0.601	Top Soil			
						2	304	1.14	1.14	Top Soil			
						3	24.3	10.2	11.9	Weathered Formation	Aquifer	1.14-11.99	Potable
						4	4474	22.7	34.6	Compact Formation			
						5	28.6						
42.	Taleisar	Reamal	42	84.87544	21.37755	1	43.2	1.31	1.31	Top Soil			
						2	19.2	4.74	6.05	Weathered Formation	Aquifer	1.31-6.05	Potable
						3	233	47.2	53.3	Less Compact Formation	Aquifer	6.05-53.3	Potable
						4	VH			Compact Formation			
43.	Palsama	Reamal	43	84.88228	21.28561	1	269	1.6	1.6	Top Soil			
						2	22.7	6.65	8.25	Weathered Formation	Aquifer	1.6-8.25	Potable
						3	VH			Compact Formation			
44.	Hadsanghar	Reamal	44	84.84004	21.30666	1	13.3	1.87	1.87	Top Soil			
						2	6.34	1.77	3.64	Weathered Formation	Aquifer	1.87-3.64	Potable
						3	VH						
45.	Regalbahal	Reamal	45	84.65204	21.3315	1	9.11	1.27	1.27	Top Soil			
						2	4.79	13.1	14.3	Weathered Formation	Aquifer	1.27-14.3	Potable
						3	VH			Compact Formation			
46.	Tuhilamal	Reamal	46	84.6008	21.29807	1	8.56	1.2	1.2	Top Soil			
						2	3.75	1.31	2.51	Top Soil			
						3	12.6	8.51	11	Weathered Formation	Aquifer	2.51-11	Potable
						4	VH			Compact Formation			

47.	Lakhabahal	Reamal	47	84.62678	21.34626	1	10.2	1.015	1.015	Top Soil			
						2	4.601	10.32	11.33	Weathered Formation	Aquifer	1-11.33	Potable
						3	31.01			Weathered Formation	Aquifer		
48.	Khairaramda	Reamal	48	84.61944	21.40246	1	13.7	1.65	1.65	Top Soil			
						2	4.08	1.67	3.32	Top Soil			
						3	VH			Compact Formation			
49.	Kirtonapali	Reamal	49	84.72056	21.32847	1	54.4	1.96	1.96	Top Soil			
						2	135	1.01	2.97	Top Soil			
						3	24.1	23.8	26.8	Weathered Formation	Aquifer	2.97-26.8	Potable
						4	1945			Compact Formation			
50.	Rangalpali	Reamal	50	84.75569	21.284909	1	118	0.646	0.646	Top Soil			
						2	64.8	2.93	3.58	Weathered Formation	Aquifer	1-28.1	Potable
						3	20.8	5.36	8.94	Weathered Formation			
						4	76.2	19.2	28.1	Weathered Formation			
						5	VH			Compact Formation			
51.	Kundheigda	Reamal	51	84.75569	21.28491	1	53.7	0.613	0.613	Top Soil			
						2	191	1.35	1.96	Top Soil			
						3	4.32	1.24	3.2	Weathered Formation	Aquifer	1.96-50.1	Potable
						4	43	46.9	50.1	Weathered Formation			
						5	VH			Compact Formation			
52.	Tungamal	Reamal	52	84.72816	21.21883	1	427.5	1.147	1.147	Top Soil			
						2	157.1	1.486	2.632	Top Soil			

						3	16.77	2.671	5.303	Weathered Formation	Aquifer	2.6-36.65	Potable
						4	98.29	31.5	36.65	Weathered Formation			
						5	167.5	27	63.65	Less Compact Formation	Aquifer	36.65-63.65	Potable
						6	VH						
53.	Kunjamura	Sambalpur	53	84.66245	21.25565	1	29.27	0.567	0.567	Top Soil			
						2	13.4	9.832	10.4	Weathered Formation	Aquifer	1-10.4	Potable
						3	740.4	32.25	42.65	Less Compact Formation	Aquifer	10.4-42.65	Potable
						4	VH			Compact Formation			
54.	Kakharumal	Reamal	54	84.64274	21.32891	1	14.9	1.2	1.2	Top Soil			
						2	4.05	4.11	5.31	Weathered Formation	Aquifer	1.2-23.4	Potable
						3	21.5	18.1	23.4	Weathered Formation			
						4	VH						
55.	Dontaribahal	Barkote	55	84.82833	21.58937	1	474	8.25	8.25	Top Soil			
						2	296	19.1	27.3	Less Compact Formation	Aquifer	8.25-27.3	Potable
						3	VH			Compact Formation			
56.	Mankamunda	Barkote	56	84.78007	21.59942	1	33.5	1.92	1.92	Top Soil			
						2	237	2.42	4.34	Top Soil			
						3	7.58	4.18	8.51	Weathered Formation	Aquifer	4.34-47	Potable
						4	66.5	38.5	47	Weathered Formation			
						5	VH			Compact Formation			
57.	Danyakhol	Barkote	57	84.69218	21.5978	1	21.6	1.14	1.14	Top Soil			
						2	10.1	2.63	3.78	Weathered Formation	Aquifer	1.14-14.6	Potable

						3	19.7	10.8	14.6	Weathered Formation			
						4	508	28.8	43.4	Less Compact Formation	Aquifer	14.6-43.4	Potable
58.	Nuapada	Reamal	58	84.79826	21.14334	1	12.2	1.2	1.2	Top Soil			
						2	4.86	4.06	5.26	Weathered Formation	Aquifer	1.2-101	Potable
						3	46.5	96.2	101	Weathered Formation			
						4	0.46						
59.	Luhurakote	Reamal	59	84.90748	21.15471	1	153	1.83	1.83	Top Soil			
						2	7.22	4.27	6.1	Weathered Formation	Aquifer	1.83-6.1	Potable
						3	VH			Compact Formation			
60.	Budhapal	Reamal	60	84.86721	21.1809	1	273.6	0.559	0.559	Top Soil			
						2	41.04	4.248	4.808	Weathered Formation	Aquifer	1-63.48	Potable
						3	17.83	5.554	10.36	Weathered Formation			
						4	68.08	53.12	63.48	Weathered Formation			
						5	275.4	21.5	84.98	Less Compact Formation	Aquifer	63.48-84.98	Potable
						6	VH			Compact Formation			
61.	Nuabanakalo	Barkote	61	85.14702	21.45852	1	26.07	1.2	1.2	Top Soil			
						2	11.78	1.308	2.508	Weathered Formation	Aquifer	1.2-23.06	Potable
						3	51.25	20.55	23.06	Weathered Formation			
						4	614.4	41	64.06	Less Compact Formation	Aquifer	23.06-64.06	Potable
						5	VH						
62.	Baidharnagar	Barkote	62	85.14546	21.51341	1	973	2.51	2.51	Top Soil			
						2	154	9.27	11.8	Less Compact Formation	Aquifer	2.51-11.8	Potable
						3	67.7	57.4	69.2	Weathered Formation	Aquifer	11.8-69.2	Potable

						4	VH			Compact Formation			
63.	Madalia	Barkote	63	85.18659	21.52376	1	12.1	0.651	0.651	Top Soil			
						2	70.8	1.2	1.85	Top Soil			
						3	8.26	7.63	9.48	Weathered Formation	Aquifer	1.85-9.48	Potable
						4	VH			Compact Formation			
64.	Gopapur	Barkote	64	85.02431	21.52869	1	36.48	0.5659	0.5659	Top Soil			
						2	6.487	5.472	6.038	Weathered Formation	Aquifer	1-6.038	Potable
						3	VH			Compact Formation			
65.	Ambagaon	Barkote	65	84.98424	21.65312	1	27.3	0.782	0.782	Top Soil			
						2	6.39	6.86	7.64	Weathered Formation	Aquifer	1-7.64	Potable
						3	VH			Compact Formation			
66.	Kaliapal	Barkote	66	85.04006	21.56413	1	11.6	0.692	0.692	Top Soil			
						2	4.72	1.66	2.36	Top Soil			
						3	VH			Compact Formation			
67.	Balani	Barkote	67	84.99196	21.58703	1	26.6	16.1	1.61	Top Soil			
						2	4.2	3.79	5.39	Weathered Formation	Aquifer	1.61-5.39	Potable
						3	VH			Compact Formation			
68.	Kadapada(Singhani)	Barkote	68	84.96345	21.62152	1	17.9	1.02	1.02	Top Soil			
						2	8.86	1.63	2.65	Weathered Formation	Aquifer	1-14.3	Potable
						3	147	1.98	4.63	Semi Weathered Formation			
						4	15.3	9.63	14.3	Weathered Formation			
						5	VH			Compact Formation			

69.	Salei	Barkote	69	84.91243	21.6405	1	14.5	3.97	3.97	Top Soil			
						2	57.5	28.1	32	Weathered Formation	Aquifer	3.97-32	Potable
						3	VH			Compact Formation			
70.	Hariharpur	Barkote	70	84.83187	21.6399	1	102	0.736	0.736	Top Soil			
						2	14.5	7.83	8.57	Weathered Formation	Aquifer	0.736-8.57	Potable
						3	VH			Compact Formation			
71.	Ananta pichhalu	Barkote	71	84.96085	21.53986	1	17.5	0.895	0.895	Top Soil			
						2	8.17	8.36	9.25	Weathered Formation	Aquifer	1-9.25	Potable
						3	1571	10.9	20.1	Less Compact Formation	Aquifer	9.25-20.1	Potable
						4	VH			Compact Formation			
72.	Dandasingha	Barkote	72	84.92906	21.51254	1	67.53	2.757	2.757	Top Soil			
						2	19.67	2.81	5.567	Weathered Formation	Aquifer	2.757-5.567	Potable
						3	VH			Compact Formation			
73.	Badachhapal	Tileibani	73	84.87882	21.46243	1	88.4	2.53	2.53	Top Soil			
						2	9.98	2.45	4.99	Weathered Formation	Aquifer	2.5-42.3	Potable
						3	92.7	37.3	42.3	Weathered Formation			
						4	VH			Compact Formation			
74.	Purnaghar	Tileibani	74	84.71337	21.52046	1	334	1.25	1.25	Top Soil			
						2	87.2	4.47	5.72	Weathered Formation	Aquifer	1.25-11.6	Potable
						3	12.5	5.91	11.6	Weathered Formation			
						4	VH			Compact Formation			

75.	Katrapali	Barkote	75	85.06231	21.47477	1	443.7	2.199	2.199	Top Soil			
						2	168.5	17.54	19.74	Semi Weathered Formation	Aquifer	2.19-19.74	Potable
						3	729.6	83.92	103.7	Less Compact Formation	Aquifer	19.74-103.7	Potable
						4	VH			Compact Formation			
76	Purunapani	Barkote	76	84.98544	21.435211	1	15.6	2.41	2.41	Top Soil			
						2	74	10.3	12.7	Weathered Formation	Aquifer	2.41-12.7	Potable
						3	VH			Compact Formation			
77	Badamanpur	Barkote	77	85.01622	21.49059	1	75.7	2.94	2.94	Top Soil			
						2	13.7	3.04	5.98	Weathered Formation	Aquifer	2.94-5.98	Potable
						3	VH			Compact Formation			

13. Aquifer Groups and their Disposition

Based on extensive analysis of historical data, micro level hydrogeological survey data generated and ground water exploration carried out in the area, the following two types of aquifers can be demarcated and the details are given below:

Aquifer- I (Unconfined Aquifer): Unconfined aquifer occurs in entire area except rocky outcrops, formed by the weathered mantle atop all crystalline formations and discontinuous alluvial tracts along major river channels. This aquifer generally occurs down to maximum depth of 44m bgl. Based on field observations, isopach map of Aquifer–I is generated and shown in Fig.13.9.

Aquifer-II (Semi-Confined to Confined Aquifer): Semi-confined to confined aquifer occurs as fracture zone aquifers in the entire area irrespective of rock types. However the aquifer properties, the yield of bore wells constructed in them depends on the rock type. As per the ground water exploration, carried out by CGWB. Aquifer-II in Granitic rocks has better yield in comparison to Gondwanas, Charnockites and Khondalites. In general, most of the fracture zones are encountered within 0 to 150 mbgl and seldom beyond that. Thus the maximum depth for the Aquifer-II has been taken as 200 mbgl.

Aquifer Disposition:

The ground water exploration data has been used to generate the 3D disposition of the aquifer system. It comprises of all existing litho-units and the zones tapped during the ground water exploration forming an aquifer. Based on the ground water exploration and micro-level hydrogeological survey data and aquifer delineation method,a schematic 3-D aquifer dispositionis prepared and shown in **Fig. 13.1.** Four 2D schematic sections were drawn along lines A-A’, B-B’, C-C’ and D-D’ which are shown in plain view in **Fig.13.2** and the corresponding 2D schematic sections are shown in **Fig. 13.3**, **13.4, 13.5** and **13.6.** A 3D Fence diagram is shown in **Fig. 13.7 and Fig. 13.8.**

Fig.13.1 Schematic 3D Aquifer Disposition in Deogarh District

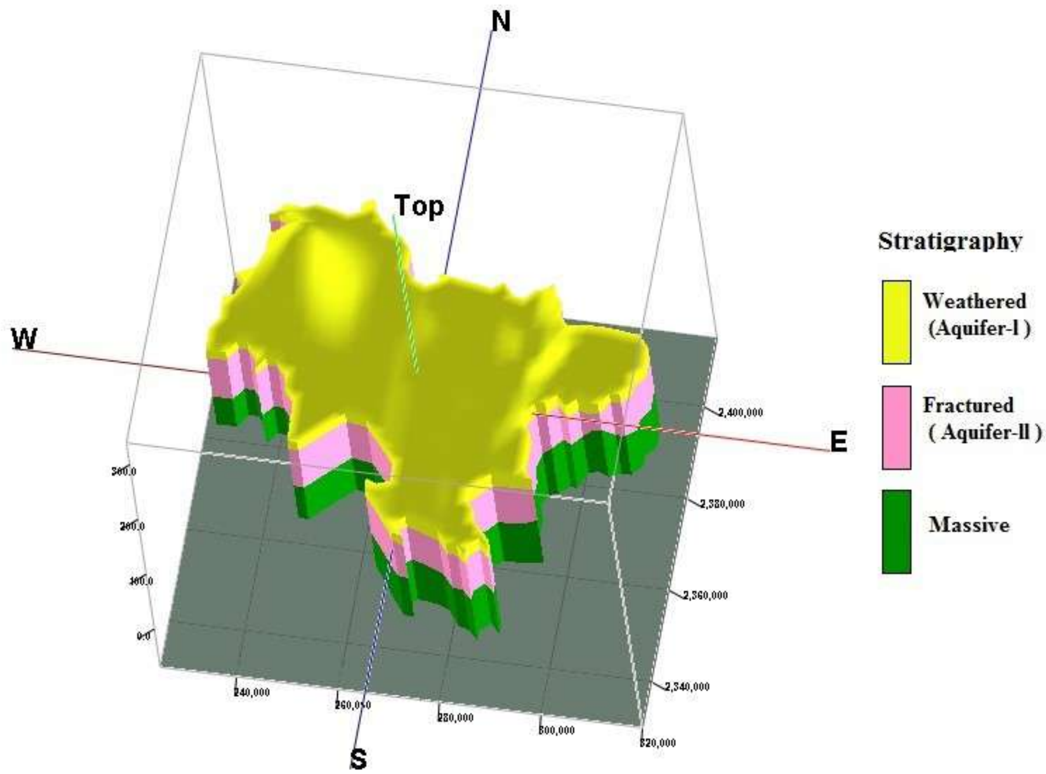


Fig.13.2 Aquifer 2D Section Lines along A-A', B-B', C-C', D-D'

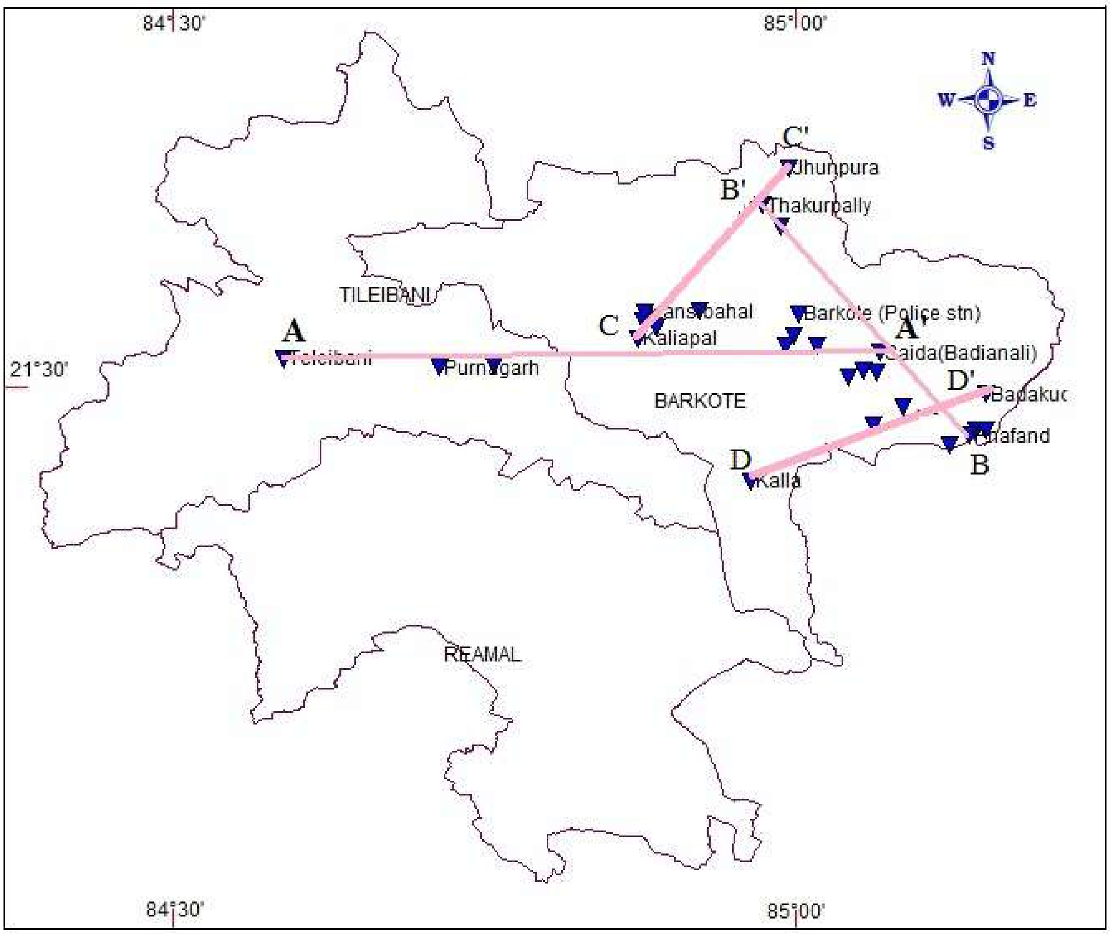


Fig. 13.3 Schematic Aquifer Cross Section along A-A'

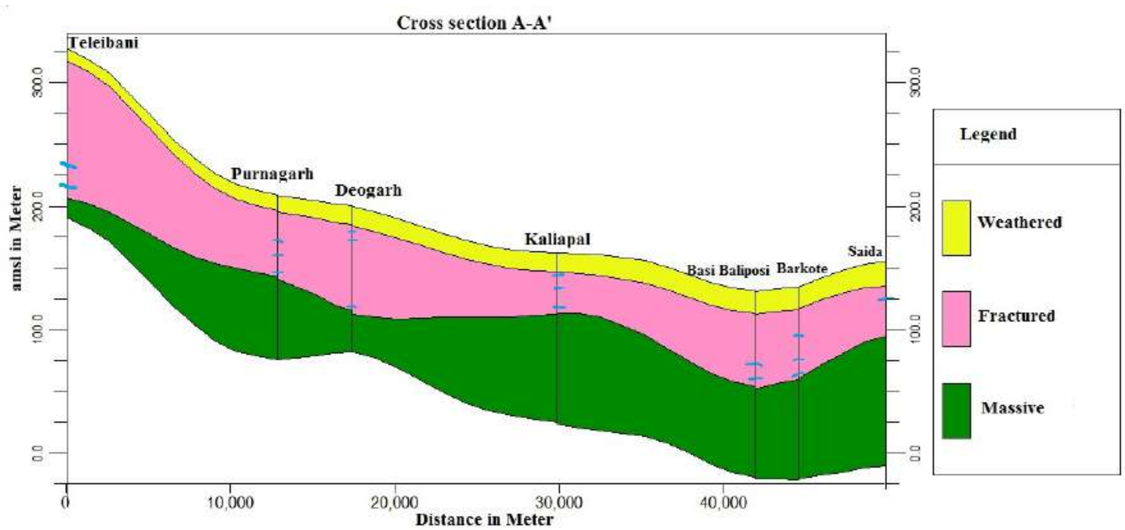


Fig. 13.4 Schematic Aquifer Cross Section along B-B'

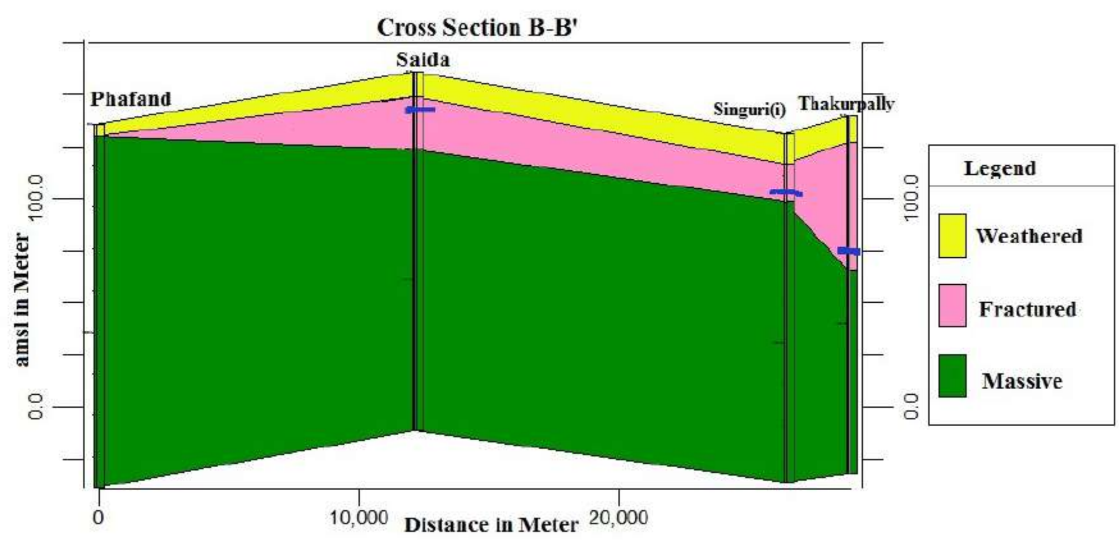


Fig. 13.5 Schematic Aquifer Cross Section along C-C'

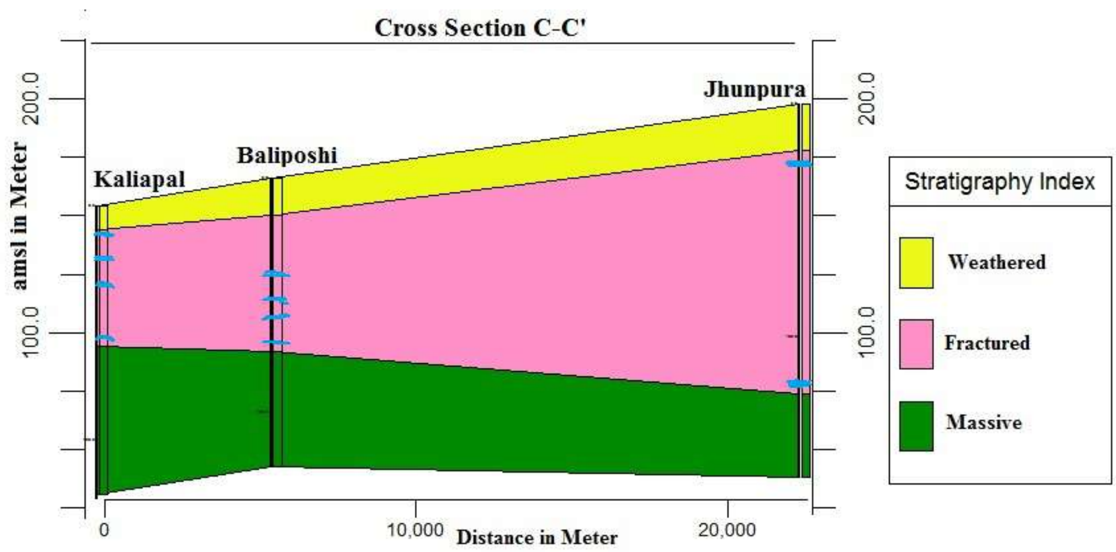


Fig. 13.6 Schematic Aquifer Cross Section along D-D'

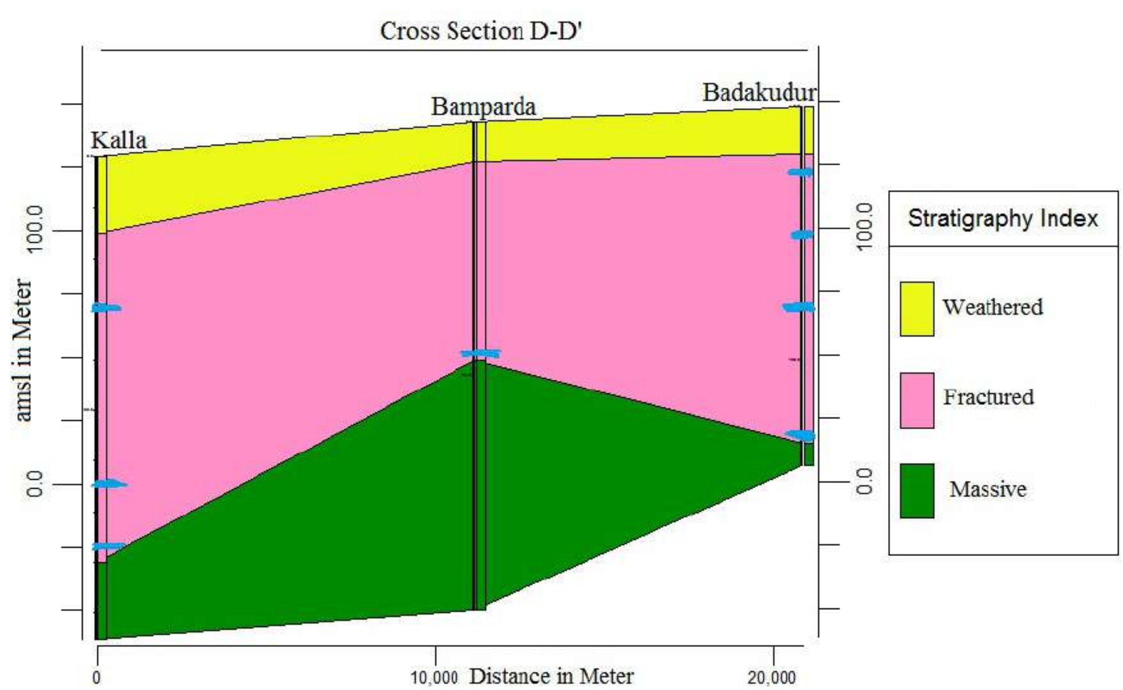


Fig. 13.7 Schematic 3D-Fence Diagram in Deogarh District

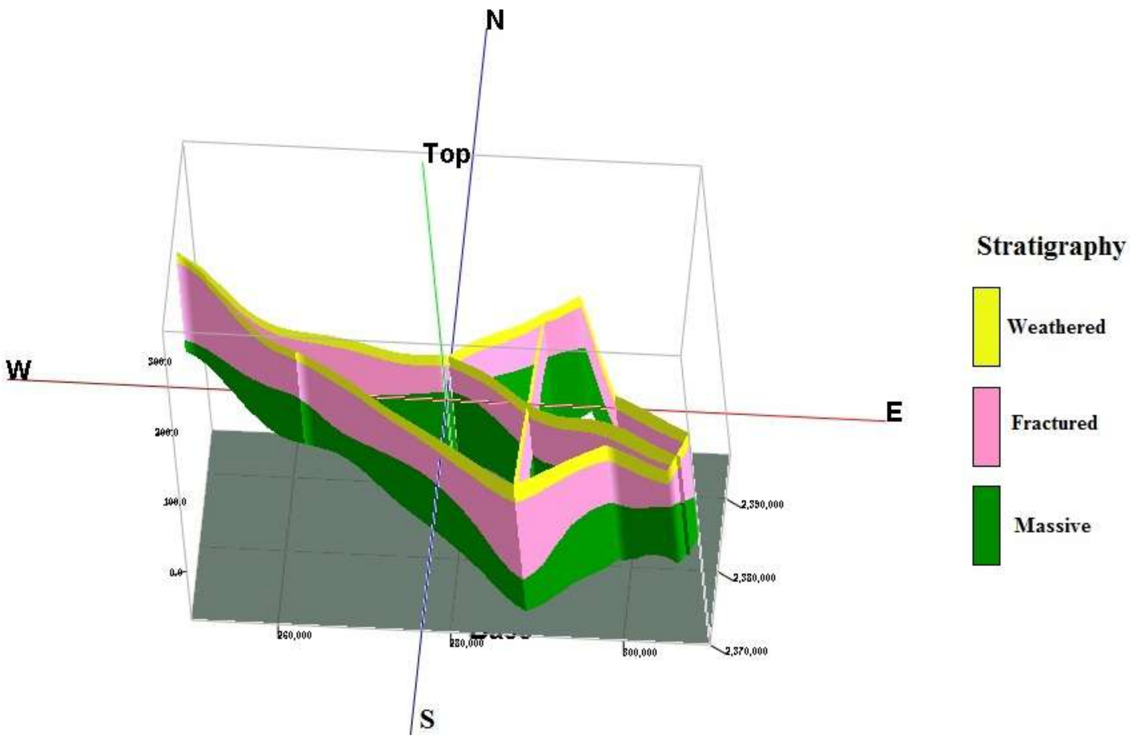


Fig. 13.8 Aquifer 2-D section lines for Fence Diagram in Deogarh District

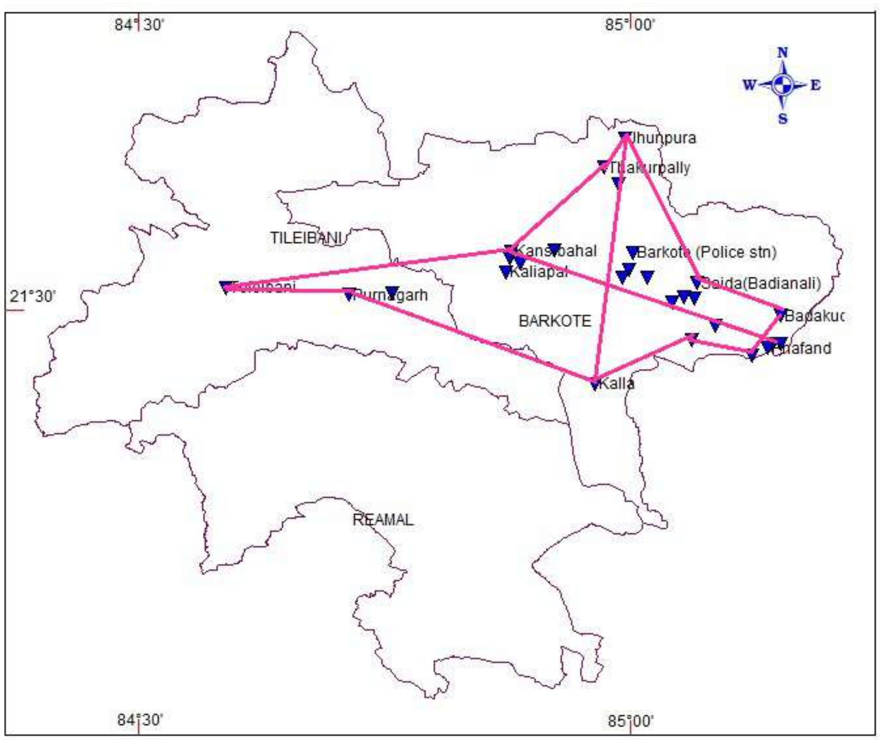
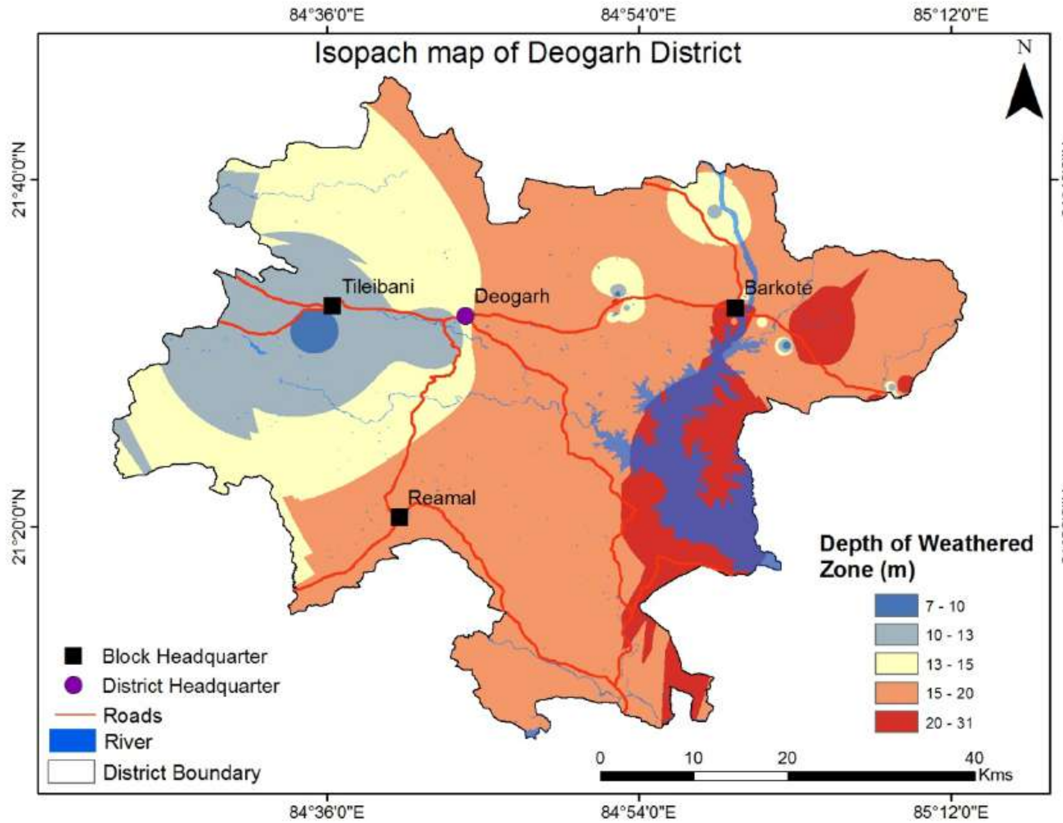


Fig. 13.9 Isopach of Weathered Zone (Aquifer-I) in Deogarh District



The characteristics of the aquifer groups are summarized in **Table 13.1.**

Table 13.1: Characteristics of Aquifer Groups in Doegarh District

Type of Aquifer Group	Formation	Depth range (mbgl)	Yield	Aquifer parameter	Suitability for drinking/ irrigation
Aquifer-I (Phreatic)	**Unconsolidated and Weathered** **Recent**: Soil, Alluvium & Laterite **Lower Gondwana**: Sandstone, Shale and conglomerate **Pre-cambrian**: Granite Gneiss, Charnockite, Khondalite, Quartzite	0-44	10-50m^3/day	Specific Capacity Index: 0.5-40 lpm/m/m^2	Yes for both
Aquifer-II (Semi-confined to Confined)	**Fractured** Granite Gneiss, Charnockite, Khondalite, Gondwanas	44-200	Negl.-20 lps	Transmissivity: 7.76-3691.71	Yes for both

14. Management Plan

The highly diversified occurrence and considerable variations in the availability and utilization of groundwater makes its management a challenging task. Scientific development and management strategy for groundwater has become imperative to avert the looming water crisis. In this context, various issues such as, prioritization of areas for development of groundwater resources vis-a-vis its availability, augmentation of groundwater through rainwater harvesting and artificial recharge, pricing and sectoral allocation of resources and participation of the stakeholders must be considered.

1.1 Ground Water Quality Issues

Fluoride in Ground Water

The F^- values in the district vary between 0.03 mg/L and 1.62 mg/L in phreatic and between 0.05 mg/L and 0.82 mg/L in deeper aquifers. The F^- values of all the samples in the district are well within the permissible limits for drinking water except at Rengalbeda dug well in Reamal block.

Nitrate in Ground Water

All the samples have NO_3^- concentration well within the permissible limits for drinking water except in dug well at Tusula in Barkote block and in bore well at Kansar in Tileibani block. The occurrence of higher concentrations of Nitrate (> 45 mg/L) in these locations is due to anthropogenic activities and is propagated in the ground water through point sources.

Uranium in Ground Water

None of the ground water samples of bore well has U concentration more than the prescribed limit. However, four samples from dug well have U concentration more than the prescribed limit of 30 µg/L. They are Rengalbeda (74 µg/L, Reamal block), Dhauragotha (86.8 µg/L, Reamal block), Palakundar (127 µg/L, Tileibani block) and Tinkbir (68.3 µg/L, Reamal block).

1.2 Under Utilisation of Ground Water Resources

As per the ground water resource estimated jointly by CGWB and State Govt. in 2020, the Net Ground Water Availability of Barkote, Reamal and Tileibani blocks are 10362.57, 10622.59 and 9704.06 ham respectively. The stages of ground water development are

54.21, 50.20 and 57.14 % respectively. Thus there is ample scope exists for further ground water development.

1.3 Ground Water Problem in Hilly Areas

Deogarh district receives adequate rainfall and the normal annual rainfall is 900 mm. The northern,southern and western parts of the district are mainly of hilly terrain and thus high run off zone. They act as recharge zones as well as good reservoir of ground water. Once they get saturated, during monsoon the excess water flows as runoff and base flow. During the post-monsoon period, the thin weathered zones soon loose the entire storage water due to base flow. So there is scarcity of water in these areas in lean and summer season.

1.4 Less Productive Deeper Aquifer

The exploratory drilling in the district reveals that the deep fractured aquifer is less productive. Many of the borewells drilled in the district have very poor discharge. The failure rate of borewells is very high in the Easternghat Group of rocks like the Charnockites, Quartzites and Khondalites. Granite gneiss is comparatively better for laying bore wells.

1.5 Depleted Water Level in Phreatic Aquifer

Ground water level in the phreatic aquifer is found to be deep in many parts of Deogarh district. Deeper water levels (>7mbgl) are found in all blocks in patches. The locations where the depth to water level is more than 8 mbgl are Ambagaon (8.2), Balanda(8.1), Gothanali (10.6), Laxmipur (8.7) Mankadamunda (8.6), Ranja (8.75), Suringipal (8.2).The seasonal fluctuation in some of the villages in this area indicates inadequate monsoon recharge which face problems of water scarcity round the year.

2. Aquifer Management Plan

Management Plan for Quality Issues

2.1 Management Plan for Higher Concentration of Fluoride

Fluoride is only detected in the phreatic sample from Rengalbeda. The occurrence of fluoride is point specific and there are alternate sources available. For example, fluoride value from deeper sample is 0.18 mg/l. Hence deeper aquifers form a better alternative source for the domestic use in this area. Other samples collected from the district are well within the range. Detail sampling may be done around Rengalbeda area to detect the regional extension.

2.2 Management Plan for Higher Concentration of Nitrate

Nitrate has been detected in dug well at Tusula in Barkote block and in bore well at Kansar in Tileibani block. The occurrence of higher concentrations of Nitrate (> 45 mg/L) in these locations is due to anthropogenic activities and is propagated in the ground water through point sources. So bore wells and dug wells should not be constructed near places where decayed vegetable and animal matter, domestic effluents and sewage sludge disposal are there.

2.3 Management Plan for Higher Concentration of Uranium

Uranium is a naturally occurring radioactive chemical element that occurs in low concentrations in nature. It is present in certain types of soils and rocks, especially granites. Studies have revealed that presence of Uranium in drinking water causes Nephritis (kidney damage) due to its radiological property being radioactive in nature. The WHO has set 30 µg/L (ppb) as the upper limit of U concentration in ground water for drinking purpose.

Only four samples from dug well have U concentration more than the prescribed limit of 30 µg/L. They are Rengalbeda (74 µg/L, Reamal block), Dhauragotha (86.8 µg/L, Reamal block), Palakundar (127 µg/L, Tileibani block) and Tinkbir (68.3 µg/L, Reamal block). So it is evident that uranium concentration more than the prescribed limit persists only in the phreatic aquifer of Reamal and Tileibani block. So intensive sampling may be carried out in these areas to detect its regional spreading.

Management Plan for Under-Utilisation of Ground Water

Demand and Supply Scenario: The water demand and supply scenario of the district is depicted in **Table 14.1** where the demand figures were projected for year 2025 and 2035 and the supply represents the existing water supply status.

Table 14.1 Water Demand and Supply Scenario in Deogarh District

Block	Existing Water Availability (MCM)			Water Demand (MCM)			Water Gap (MCM)		
	Surface Water	Ground Water	Total	Present	Projected (2025)	Projected (2035)	Present	Projected (2025)	Projected (2035)
BARKOTE	370	67.29	437.29	690.75	722.25	747.48	157.79	217.9	300.31
REAMAL	360	85.88	445.88	941.99	978.2	1006.21	345.3	416.53	516.16
TILEIBANI	370	53.12	423.12	784.9	810.52	829.12	387.01	434.8	498.81
Total	**1100**	**206.29**	**1306.29**	**2417.64**	**2510.97**	**2582.81**	**890.1**	**1069.23**	**1315.28**

Proposed Interventions: There is very little scope for the demand side interventions as the district experiences acute shortage of water during the lean seasons. However to meet the irrigation requirement in relatively water deficient areas, efficient irrigation techniques such as drip and sprinkler should be practised. No other demand side intervention is feasible.

For the supply side intervention, further development of ground water resource is possible as there is sufficient scope for this is available in the districtas the present ground water development is medium. The quantum of water available for extraction from the phreatic aquifer is thus calculated, keeping the percentage of ground water development within 60%. The same is shown in the **Table 14.2**.

Table 14.2: Ground Water Development Potential of Deogarh District

Block	Net Annual Extractable Ground Water (Ham)	Stage of Ground Water Extraction (% in 2020)	Present Ground Water Draft (Ham)	Ground Water draft at 60% Stage of extraction (Ham)	Surplus Ground Water at Present Stage of development (Ham)	Number of BW/ STW Recommended in Each block(assuming unit draft as 2.21 ham per structure per year) 50%	Number of DW Recommended in Each block(assuming unit draft as 0.26 ham per structure per year) 50%	Additional irrigation potential to be created (Hactre)1.32*no. of structures
					(4)-(3)			
				(1)*0.6				
	1	2	3	4	5	6	7	8
BARKOTE	10362.57	54.21	5617.08	6217.542	600.462	136	1155	1524.6
REAMAL	10622.59	50.20	5332.59	6373.554	1040.964	236	2002	2642.64
TILEIBANI	9704.06	57.14	5544.44	5822.436	277.986	63	535	706.2

Structures Feasible: The feasible ground water structures and probable yield in different geological units in Boudh district is given below:

Graniteand Granite Gneiss: Ground water occurs in weathered horizon in unconfined condition, yield of dug well upto 50 m3/day; Deeper fracture zones - yield of bore wells within 5.0 lps, occasionally upto 20 lps.

Charnockites: Ground water in weathered zone in unconfined condition, yield of dug wells upto 30 m^3/day; deeper fracture zones- yield of bore wells less than 1 lps

Khondalites: Ground water in weathered zone in unconfined condition, yield of dug wells upto 50 m^3/day; deeper fracture zones- yield of bore wells less than 1 lps

Quartzite: Ground water in weathered zone in unconfined condition, yield of dug wells upto 30 m^3/day; deeper fracture zones- yield of bore wells less than 1 lps

Management Plan for Scarcity of Water in Hilly Areas

Due to uneven and hilly terrain and lower ground water recharge and storage capacity, there are many areas where the phreatic aquifer quickly desaturates causing water scarcity during non-monsoon periods. To enhance the ground water availability, suitable measures for augmentation of monsoon recharge, should be taken up. In the foot hill regions, contour trenching along with gabion structures should be constructed to arrest the surface runoff and improve rainfall recharge.

Management Plan for Less Productive Deeper Aquifer

Selection of proper site for drilling of bore wells, based on the favourable hydrogeological conditions has to be done. As discussed earlier, a lot of scope exists for ground water development. Priority should be given to the phreatic aquifer for extraction of ground water through large diameter dug wells and dug cum bore wells at hydro geologically suitable locations.

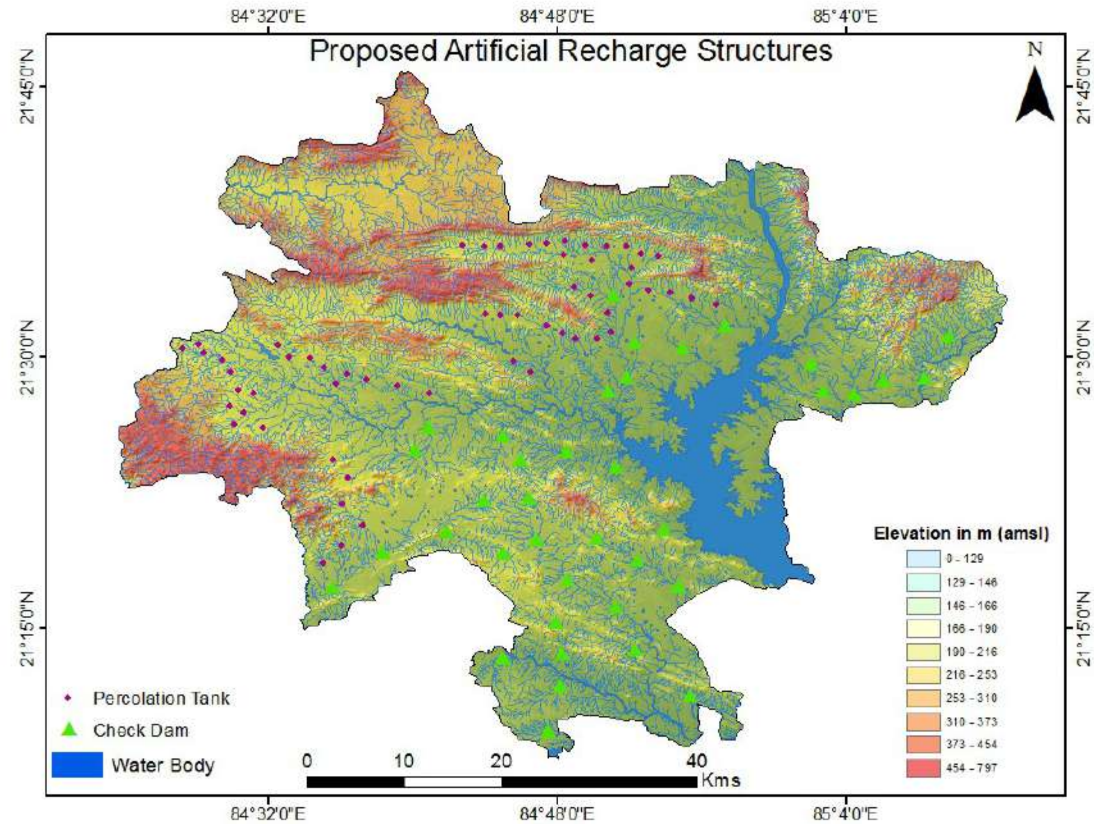
Management Plan for Depleted Water Level in Phreatic Aquifer

The problem of water level depletion in the phreatic aquifers can be addressed through artificial recharge and through various water conservation structures. As the deeper aquifer is usually less productive, injection wells are less feasible. Rather surface spreading techniques will be useful in these areas. During the canal running days the phreatic aquifer gets adequate recharge from the canal water. Thus the foot hill areas to the south of the Main Canals are suitable areas for construction of recharge structures such as percolation tanks. Similarly 2nd and 3rd order drainages are suitable for the construction of check dams. For the mitigation of deeper water level areas in the district, the following measures can be taken up:

1. Contour trenching, staggered trenching and gully plugging in foot-hill areas.
2. Construction of farm ponds and renovation of existing water bodies.
3. Construction of percolation tanks and checkdams can be done.

The proposed sites for these structures are shown in **Fig. 14.1**.

Figure 14.1 Proposed sites for Artificial Recharge Structures



15. Summary and Recommendations

Summary

1. Deogarh district has a total geographical area of 2940 sq. km with 3 administrative blocks. The total population of the district as per 2011 census is 312520. The rural population constitutes about 92.83% of the total population.
2. Physiographically the district comprises undulating plains dotted with residual hills and mounds barring few patches of scattered hills and high relief areas in the eastern parts. A gently undulating terrain with a vast stretch of cultivable land characterizes the major parts of the district, the average elevation being 93 m to 797 m above mean sea level with a general topographic slope towards east. The drainage of Deogarh district is mainly controlled by the River Brahmani along with its numerous tributaries. Gohira, Tikra, Jaraikela, and Mankra rivers are important tributaries of Brahmani having a general easternly course.
3. Southwest monsoon is the principal source of precipitation in the district and the normal annual rainfall of the district is 1500 mm. Soils of the districts can broadly be grouped into Alfisols. Soils of the district are generally having average to good fertility status and can support all common types of crops.
4. About 27% of the total geographical area constitutes forest area. The total cultivable land in the district is 79267 Ha out of which the net shown area is only 66950 Ha. Irrigation potential created in the district is 23139 Ha during Kharif and 14179 Ha during Rabi season. Paddy is the principal crop grown in the district. Other crops are Pulses, Oilseeds and Vegetables etc.
5. Major parts of the district is underlain by crystallines, metamorphics and intrusives of Precambrian age with a small patch of Gondwana sedimentaries occurring in the southern part of the district. The laterites occurr as capping over the older formations and mostly form lateritic uplands. The alluvium occurs along the major river courses. Iron ore group of rocks occupy northern part of the district. The quartzites form east-west trending hills while the schists occupy the valleys. Quartzites are well bedded, jointed and

having fissile bedding planes. The crystallines comprise varied rock types like granite / granite gneiss, khondalites, charnockites, gabbro-anorthositic rocks, quartzite, pegmatite and quartz veins. Semi-consolidated formations of permo-carboniferous age comprise sandstones, siltstones, shales and conglomerates etc.

6. Depending upon geology, water bearing and water yielding properties, three major Hydrogeological units have been identified in the district such as (i) Consolidated formations, (ii) Semi consolidated formations and (iii) Unconsolidated formations. As major parts of the district are underlain by consolidated formations, prevailing lithology and structure controls the occurrence and movement of groundwater. The weathered residuum constitutes the shallow aquifer, while fractured and fissured hard rocks constitute the deeper aquifers. Groundwater occurs under phreatic condition in weathered residuum and under semi confined to confined condition in the deeper fractured zone. In semi-consolidated formations, the friable and loosely connected sandstones form the main aquifers. Ground water occurs under water table conditions in the weathered zone and under semi-confined to confined condition in the deeper fractured and friable sandstone beds. Unconsolidated formations mostly represented by alluvium along the major river Brahmani form prolific aquifer under unconfined condition. The flood plains of Brahmani sustain luxuriant growth of sugarcane and other cash crop during Rabi season.
7. The CGWB has carried out ground water exploration under its normal exploration and AEDP to study the aquifer parameters of deeper aquifers. A total of 28 wells have been drilled in the Granitic rocks along the central part in Barkote- Deogarh-Tileibani section. The depth of the wells varied from 105 to 191m and yield varied from negligible to 20 lps. Majority of wells yielded more than 5 lps. The very high discharges were recorded from Deogarh (15 lps) and Purnagarh (20lps). Other high discharge wells are located at Barkote (7 lps), and Tileibani (6 lps). The granitic rocks along Barkote- Deogarh- Tileibani section are found to be high yielding. These high yielding wells are located along major lineaments/fractures. The quality of

ground water from the shallow as well as from deeper aquifers is generally found to be good and water is suitable for both drinking and irrigation purposes.

8. The principal source of groundwater recharge in the district is the rainfall infiltration. Other sources of recharge are seepage from minor irrigation canals, tanks, reservoirs etc and return seepage from applied irrigation.
9. The annual extractable ground water resource for all uses in the district is estimated to be 30689.22 hectare metre. The annual ground water draft through existing structures for irrigation use has been worked out to be 15353.55 hectare metre and the gross annual ground water draft for all uses including domestic and industrial is 16494.11 hectare metre leaving a balance ground water resource of 14117.77 hectare metre for further development for irrigation use. The present stage of groundwater development has been worked out to be 53.75 %.
10. Depending upon the distribution of major litho units, extent of weathering and intensity of fracturing, ground water development potential varies widely from area to area. Contemplating a safe level of ground water development at 60% of the available ground water resource for irrigation, it is estimated that tentatively 3692 numbers of energized dug wells are feasible in the district, which can create additional irrigation potential of about 4873 ha at a cropping intensity of about 170 %.

Recommendations

1) As there is further scope for development of ground water, suitable schemes may be launched for ground water development to boost agricultural production in the district. The financial institutions should generously finance such schemes.
2) In construction of ground water abstraction structures, such as dug wells, dug cum bore wells and bore wells, for irrigation minimum safe spacing should be maintained to avoid interference of the wells.

3) For optimum utilization of the groundwater potential, necessary steps should be taken for energisation of the wells.
4) The yield of existing dug wells may be enhanced by converting those into dug cum bore wells wherever feasible and the wells should be provided with brick lining which will facilitate the free flow of ground water into the well.
5) Detailed surface geophysical survey aided by photogeological & remote-sensing studies may be taken up in the district to identify the exact thickness of weathered zone and occurrence and extent of lineaments, which form potential aquifer zones.
6) The agricultural extension services should motivate and guide the farmers to adopt suitable cropping patterns to maximize the benefits of irrigation through dug wells / bore wells. The farmers should be encouraged to adopt suitable water management practices in their field through various programmes implemented by state and central agencies.
7) Runoff conservation structures like check dams, nalla bunds, gully plugging, percolation tanks in the highly slopping hilly regions may be constructed at suitable locations which will help in effecting additional recharge to the ground water reservoir. Sub-surface dams may also be constructed at hydrogeologically suitable sites to arrest sub-surface out flow of ground water in the weathered mantle of hard massive rocks. This will increase the dynamic ground water storage in the adjacent phreatic aquifer.