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जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

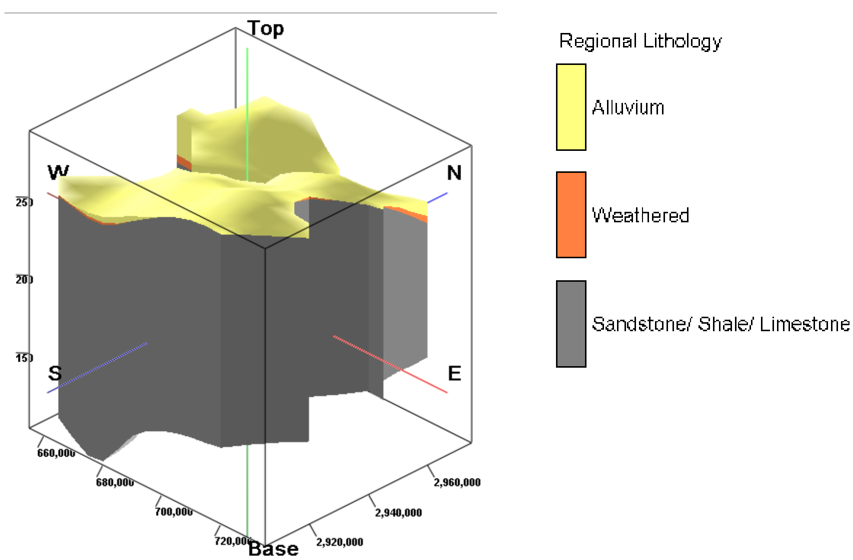
AQUIFER MAPPING AND GROUND WATER MANAGEMENT

Karuali District, Rajasthan

पश्चिमी क्षेत्र जयपुर

Western Region, Jaipur

Report on
AQUIFER MAPPING AND GROUND WATER MANAGEMENT
DISTRICT KARAULI, RAJASTHAN
(UNDER XII PLAN)



CENTRAL GROUND WATER BOARD
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVANATION
GOVERNMENT OF INDIA
WESTERN REGION, JAIPUR

JULY, 2017

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(Based on Available Data)

District Karauli, Rajasthan

1. Introduction

1.1 Objectives

Various developmental activities over the years have adversely affected the groundwater regime in the state. There is a need for scientific planning in development of groundwater under different hydrogeological situation and to evolve effective management practices with involvement of community for better ground water governance. In view of emergent challenges in the ground water sector in the state there is an urgent need for comprehensive and realistic information pertaining to various aspects of groundwater resource available in different hydrogeological setting through a process of systematic data collection, compilation, data generation, analysis and synthesis. Hence, aquifer mapping of the study area is the need of the hour.

1.2 Scope of the study

Aquifer mapping can be understood as a scientific process wherein a combination of geological, Geophysical, hydrological and chemical fields and laboratory analyses are applied to characterized the quantity, quality, and sustainability of ground water in aquifers. Aquifer mapping is expected to improve our understanding of the geological framework of aquifer, their hydrologic characteristics, water level in aquifer and how they changes over time and space and the occurrence of natural and anthropogenic contaminants that affect the portability of groundwater. Results of these studies will contribute significantly to resource management tools such as long term aquifer monitoring network and conceptual and quantitative regional groundwater flow models to be used by planners, policy makers and other stake holders. Aquifer mapping at appropriate scale can help to prepare, implement, and monitor the efficacy of various management interventions aimed at long term sustainability of our precious groundwater recourses, which in turn will help to achieve drinking water scarcity, improved irrigation facilities and sustainability of water resource in the state.

1.3 Approach & Methodology

As mentioned above, aquifer mapping is an attempt to integrate the geological, Geophysical, hydrological and chemical field and laboratory analyses are applied to characterize the quality, quantity and sustainability of groundwater in aquifer. Under the National aquifer Prograrmme, it is proposed to generate Aquifer maps on 1:50000 scale, which basically aims at characterizing the aquifer geometry, behavior of groundwater levels and status of groundwater development in various aquifer system to facilitate planning of their suitable management. The major activities involved in this process include compilation of existing data, identification of data gaps, generation of data for feeling data gaps and preparation of different aquifer layers.

1.4 Data Adequacy

The data collected from State GWD and CGWB WR Jaipur have been compiled and analysed. It has been observed that validation and georeferncing of the location coordinates, lithologs and hydrogeological data is needed and State GWD data is lacks in aquifer parameters. Geophysical data collected needs georeferncing of the hydrogeological interpretations. It has been observed that available data are limited largely to State highways and main roads only. Hence, to get a clear 3D hydrogeological geometry of the aquifer system and its behaviour, we need to generate data by Groundwater Exploration and to establish more numbers of monitoring stations for better understanding of the groundwater regime behavior in terms of both quantity and quality.

1.5 Data Gap Analysis

Data collected from State GW agencies and CGWB has been brought to a standard format and integrated location maps has been prepared regarding groundwater monitoring, exploration, surface water and agriculture data. Based on these maps and hydrogeological conditions in the area. Karauli district further needs generation of data in the gap areas.

1.6 Area details

Karauli district is located in the eastern part of the Rajasthan State and lies between 26°02’00” and 27°00’00” North Latitudes and between 76°28’30” and 77°23’30” East Longitudes covering geographical area of 5038.60 sq.km (Figure 1). Administratively the Karauli district is divided into two sub-divisions viz. Hindaun and Karauli. It has five blocks viz. Hindaun, Todabhim, Nadauti, Karauli and Sapotra. The total population of the district is 1,458,248 (Census 2011). Out of this, 14.96% of total population lives in towns and 85.04% in rural areas. The population density is 264 persons per sq. km of area.

Systematic hydrogeological surveys were carried out by the officers of Geological Survey of India during 1965-66 and by Central Ground Water Board during1976-77, 1977-78, 1978-80, 1979-80, 1981-82 and 1979-80. Geophysical surveys (Resistivity survey) were carried out by Central Ground Water Board during 1979 and 1980. Reappraisal ground water survey was carried during 1995-96 and 1994-95. On the basis of hydrogeological studies, exploratory drilling programme was undertaken by Central Ground Water Board in parts of Banganga river basin during 1976-79 (drilled one exploratory well); in Morel river basin during 1979-82 (drilled 5 EW and 2 slim holes); in Gambhir river basin during 1983-85 (drilled 2 exploratory well, one slim hole and one piezometer). Later piezometers were constructed during 1993-94 (two), 1994-95 (three) and during 1997-98 (two). During 2012-13, 4 Exploratory well and 4 piezometers were constructed in hard formation.

1.7 Rainfall and Climate

The climate of the district can be classified as semi-arid. It is characterized by very hot summers and very cold winters with poor rainfall during south-west monsoon period. In May and June, the maximum temperature may sometimes goes up to 48oC. The potential evapotranspiration rates are quite high, especially during May and June. The total annual potential evapotranspiration is 1502.6mm. The normal rainfall of district is 559 mm with 67.12% of humidity. The height of mean sea level for the district varies from 400 to 600 m amsl.

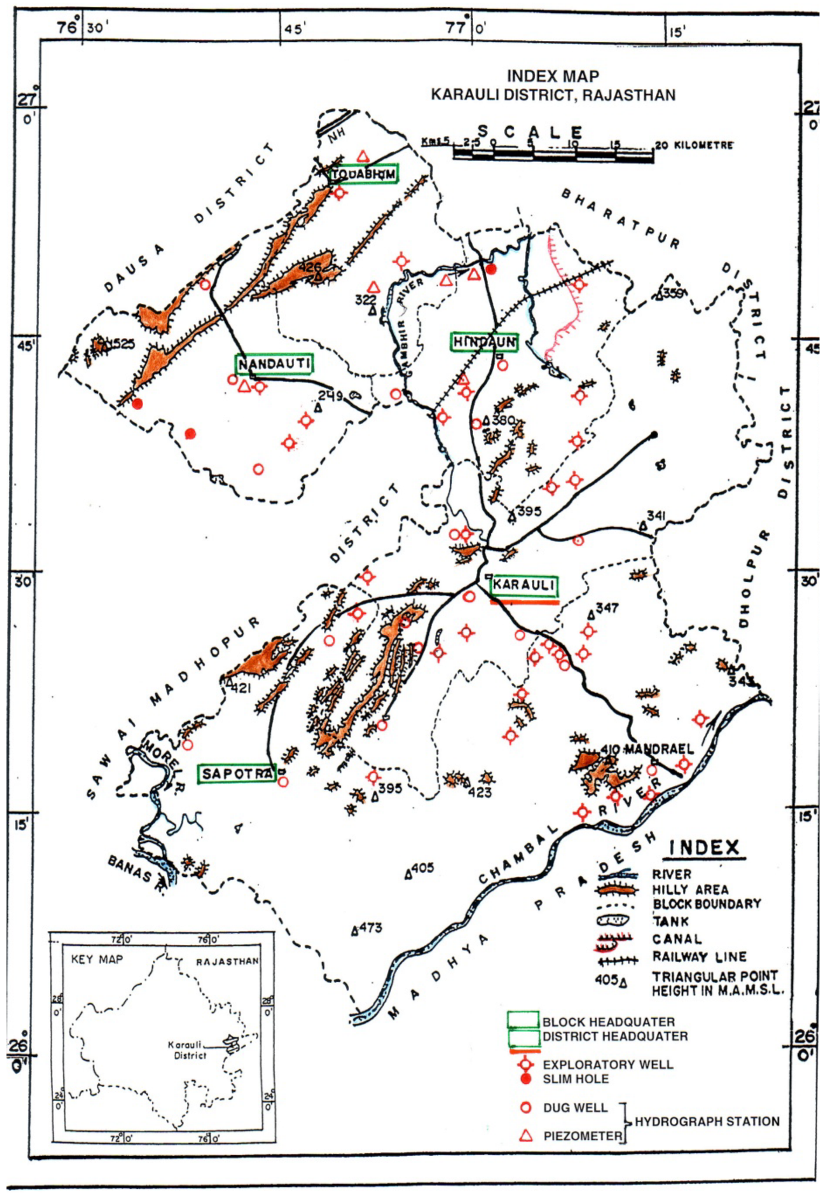


Figure1: Index map of Karauli District

1.8 Physiography, Drainage and Soils

Physiography:

The surface elevation of the district ranges from 223 to 525 m above mean sea level. The south and south eastern part of the district comprises hilly terrain. Hills have generally NE-SW trend. Along the north-western border of the district between Todabhim and Raisana, a series of hill ranges belonging to Pre-Aravalli and Delhi Super Groups of rocks exist. These are also trending in NE-SW direction. Physiographically, the district is divided into three main parts as given below. The general elevation of these hill lie between 384 and 525 m above mean sea level. The geomorphological divisions of Karauli district are shown in Table 1.

Table 1: Geomorphological Divisions of Karauli District

Type	Description
Hilly terrain in south, south eastern part and extreme north-western part.	Hilly terrains are mainly confined to Karauli and Sapotra blocks. The highest elevation is 525 m amsl about 2.5 km. west of Chirawanda (in Nadauti block
Isolated hills in alluvium plain in central part	Major portion of district lying in northern, central and north-western part, comprises alluvial plains with isolated hills. Development of ravines is seen in area along Chambal river and its tributaries
Alluvial plain in the northern part.	Hindaun, Nadauti, and Todabhim form mainly plain terrain. The general elevation lies between 226 and 262 m amsl.

Drainage:

The drainage system of the district is well developed. Main rivers in the district are Chambal, Gambhir & Morel and their tributaries. Chambal is the only perennial river and flows in north-easterly direction along interstate border of the district with Madhya Pradesh. Banas river making short boundary touches the Sawai Madhopur district boundary at Hadoti and joins. Morel river enters district 3 km south of Khera (in Sapotra block) and flows for a short distance in south direction and joins Banas river at Hadoti. Gambhir river originates from the hills near Karauli and follows a northernly course till Lapavali from where it takes turn and flows in the easterly direction. Near village Pali, it leaves the district and enters Bharatpur district.

Drainage in the rocky terrain is sub-parallel type, while in plain area, it is dendritic type. The drainage density in the district increases gradually towards south. Between Todabhim and Nadauti, it is less than 0.30 km/sq.km. The drainage density around Nayagaon, Begrama and west of Nadauti, is between 0.30 and 0.50 km/sq.km. Around Karauli, north of Sapotra , Hindaun and entire norht-eastern part of district, it ranges from 0.5 to 0.70 km/sq.km. In the southern part of district, the drainage density is more than 0.70 km/sq.km.

Soils:

The soil types in Karauli district have been presented in table 2 given below.

Table 2: Soil Types

Soil	Area (sq. km)	%	Distribution
Older alluvium	145	2.88	Lies in parts of Todabhim and Nadauti blocks. These are derived from alluvium. They are non-calcareous, semi consolidated to unconsolidated brown soils, loamy sand to sandy loam in texture. They are well drained and occupy gently sloping terrains.
Lithosols and Regosols of Hills	2359	46.82	Occupies the parts of Nadauti, Karauli, Sapotra and Todabhim blocks. These are formed on the Bhilwara hills, and hill slopes. These soils are shallow with gravels very near the surface, light textured, fairly drained, reddish brown in colour. Cultivation is restricted because of a limited root zone.

Soil	Area (sq. km)	%	Distribution
Recent Alluvium	2535	50.30	Rests in parts of Nadauti, Hindaun, Todabhim, Sapotra and Karauli blocks. These are found along the flood plains of Chambal and Gambhir rivers and are developed on alluvium and covers about 2535 sq. km of district. The soil are deep, well drained, sandy loam to loam in texture and non-calcareous.

2. Aquifer System

2.1 Geology

Quaternary alluvium occupies a large area of about 2453 sq. km. It is composed of silt, sand, clay, kankar and gravel and is deposited by major rivers and streams. It occupies the major part of Todabhim, Nadauti, Hindaun blocks underlained by Bhilwara Super Group of rocks (comprising of interbedded sequence of shale slate schist quartzite phyllite and limestone) separated with Vindhyan Super Group of formations (represented by Semri, Rewa, Bhander Groups consisting mainly of various types of Shales, Sandstones and Limestones) in entire east, south eastern part by the Great Boundary Fault. The extreme north-western stretch in small area is underlain by Delhi Super Group of rocks. The Delhi Super Group of rocks are found unconformably overlying the mica schist and gneisses of Bhilwara Super Group. The Alwar Group of rocks are folded forming the strike ridges. Conglomerates and conglomeratic quartzites are exposed as narrow outcrop to the south of Todabhim.Talus and Scree are found in local patches near hilly catchments having width from a few tens of metres to 500 metres and thickness from 40 to 55 m. Exploratory drilling has indicated a wide variation in thickness of alluvium ranging from 10 m in west to 65 m in eastern part.

2.2 Hydrogeology

The ground water occurs both in unconsolidated and consolidated formations of the district (Figure 2).

A) Consolidated Formation

Consolidated formation covers about 2495 sq. km (49.52%) of district and forms the principal aquifer in the district. It covers the southern, eastern and extreme north western strip of the district. The consolidated formations include sandstone and shale of Vindhyan Super Group and quartzites and schists of Delhi Super Group. The ground water occurs under unconfined condition in weathered and fractures portion of consolidated formations. These form generally poorer aquifer than alluvium and are tapped by open wells, dug cum borewells and bore wells.The ground water condition in various formations is described as below:

i. Vindhyan Sandstone and Shale

It encompasses about 2280 sq. km area and lies in southern and entire eastern part of the district. It forms the most prominent aquifer after alluvium in areal extent. The quartzitic sandstone occurring around Sapotra, Ramsar Bad and Khiskar in southern part of district are fine grained,

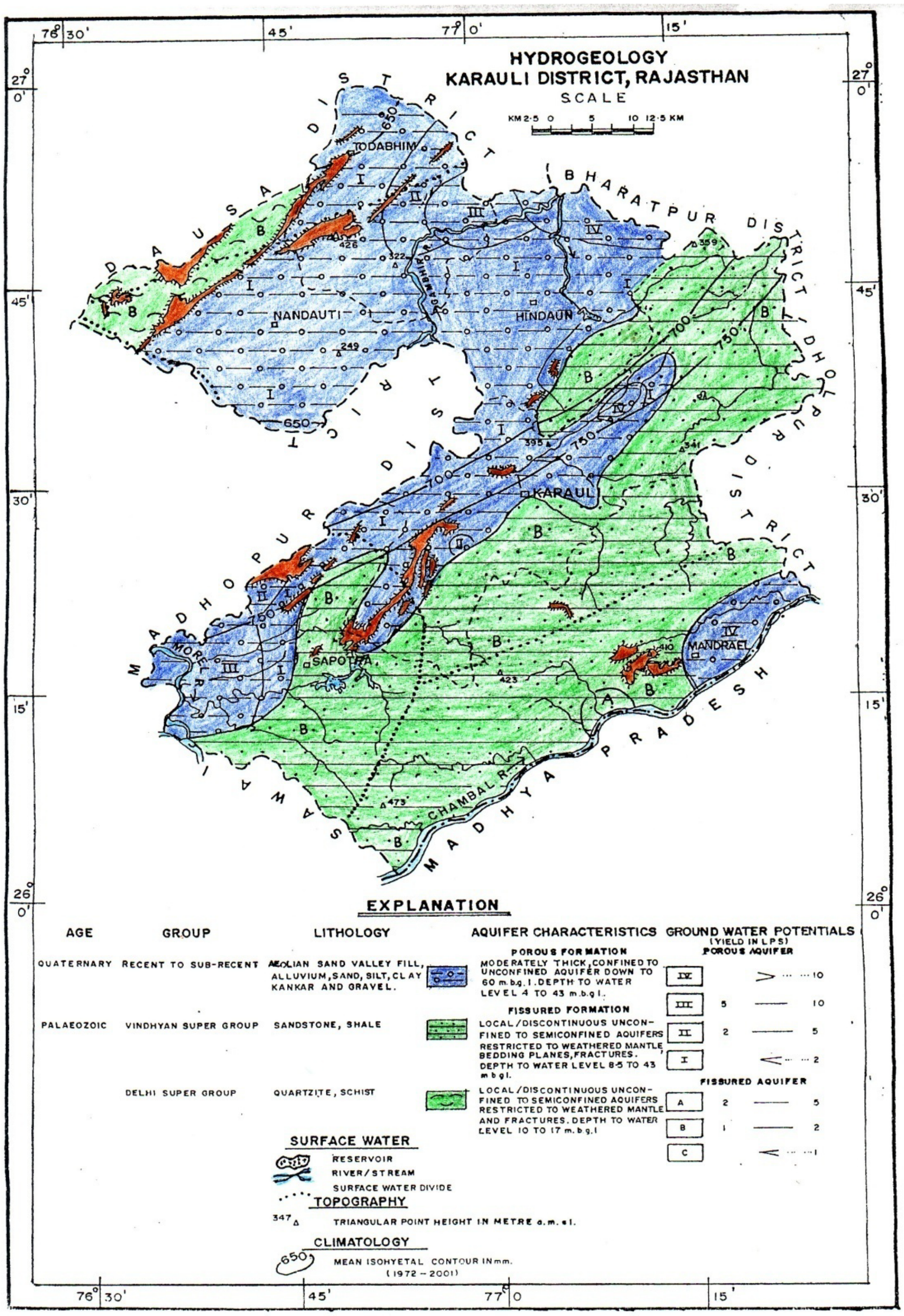


Figure 2: Hydrogeological map of Karauli district

compact and massive. These are highly resistant to weathering. Ground water occurs under unconfined conditions in fractures and jointed space. This forms poor aquifer and many wells in these got dry during summers. These Sandstones are horizontal to sub-horizontal and more or less tectonically undisturbed, as a result, vertical joints are very rare.

Bhander sandstone occur as aquifer in southern and eastern part of the district around Bhankri, Machilpur and Langra. This is also resistant to weathering and has two sets of joints. Ground water in these occurs under phreatic conditions.

The aquifer is tapped by open wells, dug cum borewells and tubewells/ borewells. In general, the diameter and depth of open wells varies from 2.5 to 3.5 m and 12 m to 30 m, respectively whereas depth of bore wells lies between 50 m and 210 m. The yield of open wells/ dug cum bore wells in majority of cases ranges from 20 to 70 m3/day, whereas discharge of borewells from 4.5 m3/hr to 22.50 m3/hr.

ii. Quartzites and schists

Quartzites and Schists of Delhi Super Group constitute poor aquifer and occur in a limited area in extreme north western strip of district (forming western part of Nadauti block) and covers an area of about 215 sq.km. Ground water occurs under unconfined conditions in weathered portion of rock units and in joints, fractures and other structural weaker zones. The extent of weathering is low and varies from 2 to 10 m in thickness. Yield of open wells depends on extent of weathering and the diameter of wells. Generally the yield of dug wells tapping these formation ranges from 30 to 70 m3/day

B) Unconsolidated Formation

The ground water occurs under unconfined to confined conditions in the unconsolidated formation (alluvium of Quaternary age) which is tapped through various ground water abstraction structures viz. dug well, dug cum borewell and tubewell.

i. Alluvium

Quaternary alluvium occupying an area of about 2453 sq. km., forms aquifer in large part. It lies in central, northern, western parts of the district and in extreme south-eastern patch along Chambal river. It consists of silt, sand, clay, kankar and gravel. Out of these sandy clay and silty clay with kankar forms the most dominating constituent which generally occur in upper zone and is being tapped by dug wells. Gravel generally occurs at depth near the basement and these too generally do not form continuous layer. Quaternary alluvium forms most important aquifer which is being tapped by dug wells, dug cm borewells and tubewells.

The ground water occurs under unconfined, semi-confined and confined conditions in these formation. Eleven exploratory wells, five slim holes and eight piezometers have been drilled as on March, 2014. The boreholes data revealed that the thickness of alluvium in major part of alluvial area varies from 10 m in western part to 65 m in eastern part. However, at Soroth thickness of alluvium reaches up to 91 m.

The yield of dug wells in majority of cases varies from 40 to 150 m3/day. Higher yield is found where gravel bed is encountered. A few pumping tests have been conducted on open wells tapping alluvium. The data revealed that discharge of open wells lies between 9.06 m3/hr and 31.6 m3/hr. The draw down varies from 0.88 m to 3.76 m on 45 to 180 minutes of pumping. The time required for complete recuperation ranges from 150 to 240 minutes. The specific capacity ranges from 0.030 to 0.255 m3/min/m of draw down and optimum yield from 0.050 to 0.64 m3/min.

The yield of open wells and dug cum borewells tapping alluvial formation varies from 175 to 900 lpm having drawdown from 0.609 to 12.17 m depending upon the locations. The specific capacity of wells ranges from 0.0383 to 0.1131 m3/m/m. The optimum yield (Karanjack's method) of wells varies from 106 to 374 lpm. The permeability of wells tapping quartzite ranges from 0.016 to 0.045 m/hr and maximum water inflow capacity from 8.61 to 32.99 m3/hr.

ii. Talus and Scree

The Talus and Scree forms important aquifer in the district. These generally occur along fault zone in foot hill regions. These occur in flanks of high hills mainly Delhi Quartzites ranges lying in north-western part of district in Nadauti and Todabhim blocks and in central western part of district in Sapotra and Karauli blocks. The width of the talus and scree zone varies from a few tens of metres to 500 metres. These are composed to fine to coarse sand with angular fragments of rocks together with loess. Exploratory drilling at Todabhim and Patoli indicated that the thickness of talus and scree deposit varies from 40 to 55 m. Yield of dug wells tapping this formation ranges from 100 to 1000 m3/day.

The talus and scree forms aquifer around Gidani, Chirawada, Chainpura, Timawa and Pal in Nadauti Block; around Todabhim, Patoli, Bhandari and Parli in Todabhim Block and also to south west of Sapotra in Sapotra Block.

2.3 Aquifer Parameters

The specific capacity of wells ranges from 0.11 m3/min/m (at Katkar in Hindaun block) to 0.916 m3/min/m (at Mahu in Hindaun block). Wells tapping talus and scree gave specific capacity values varying from 0.028 m3/min/m (at Khora in Todabhim block) to 0.33 m3/min/m (at Mohanpur in Karauli block). In Vindhyan sandstone it was 0.0715 m3/min/m at Karauli.

The aquifer characteristics of deeper aquifers have been revealed by the pumping test done on exploratory well drilled by Central Ground Water Board in Banganga, Morel and Gambhir river basins. In part of Banganga basin falling in Karauli district, the confined aquifer occurs at Todabhim and has transmissivity of 413 m2/day value and stortivity is of order of 2.40 × 10-2. In Morel river basin slug test was conducted on a few exploratory wells where yield was very poor. The value of transmissivity ranges from 0.104 to 0.1053 m2/day. The low transmissivity values indicate clayey and silty nature of formation. In the Gambhir river basin, the values of transmissivity computed were 28.12, 75.22, 220 and 288 m2/day in exploratory wells at Hindaun, Sanet, Sri Mahaveerji and Suroth, respectively. The storage coefficient of formation was found varying between 1.50×10-3 to 0.355x10-3.

The 3-D Fence diagram has been prepared using the said software given in Figure 3.

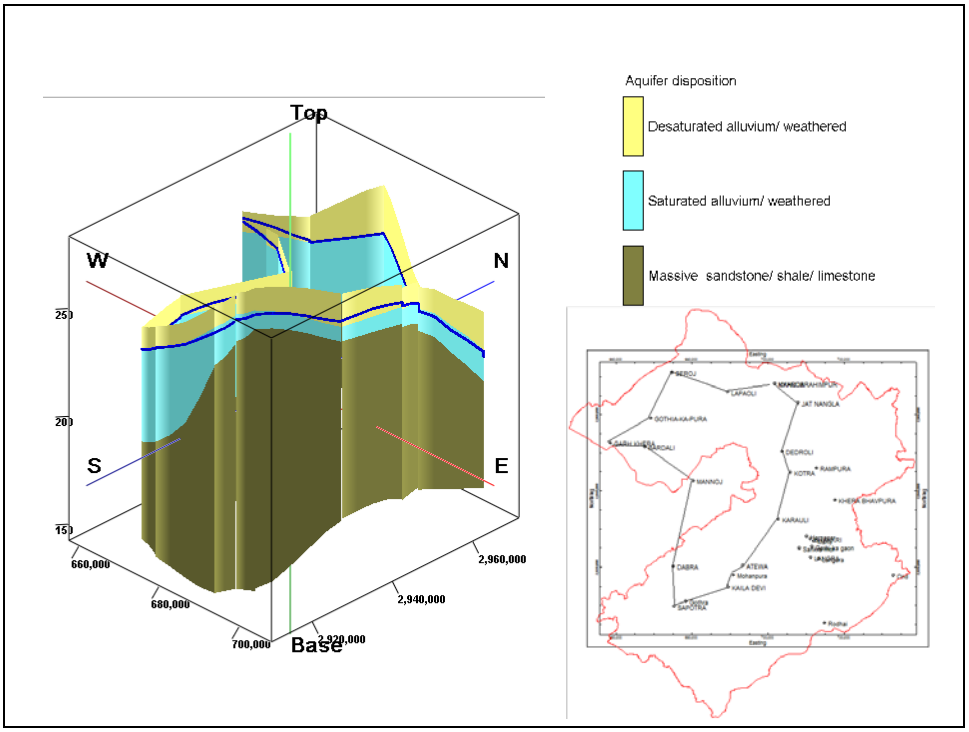


Figure 3: 3-D Fence Diagram of Aquifer Disposition

Three dimension regional lithology model has been prepared using Rock Works Software which is given in Figure 4.

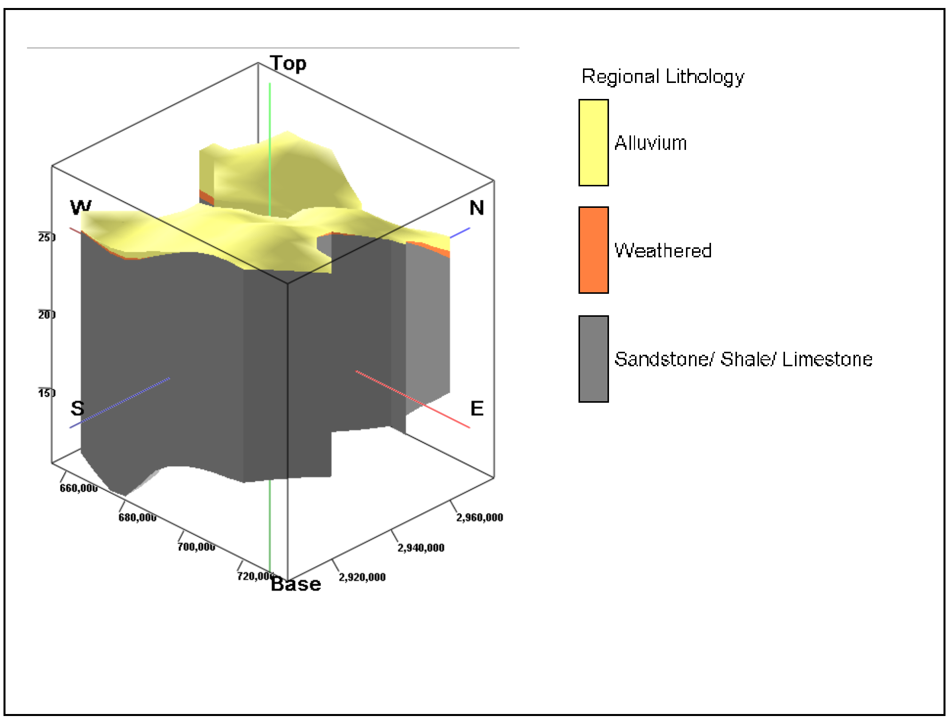


Figure 4: Regional Lithology Model

Three dimension aquifer disposition model has been prepared using Rock Works Software which is given in Figure5.

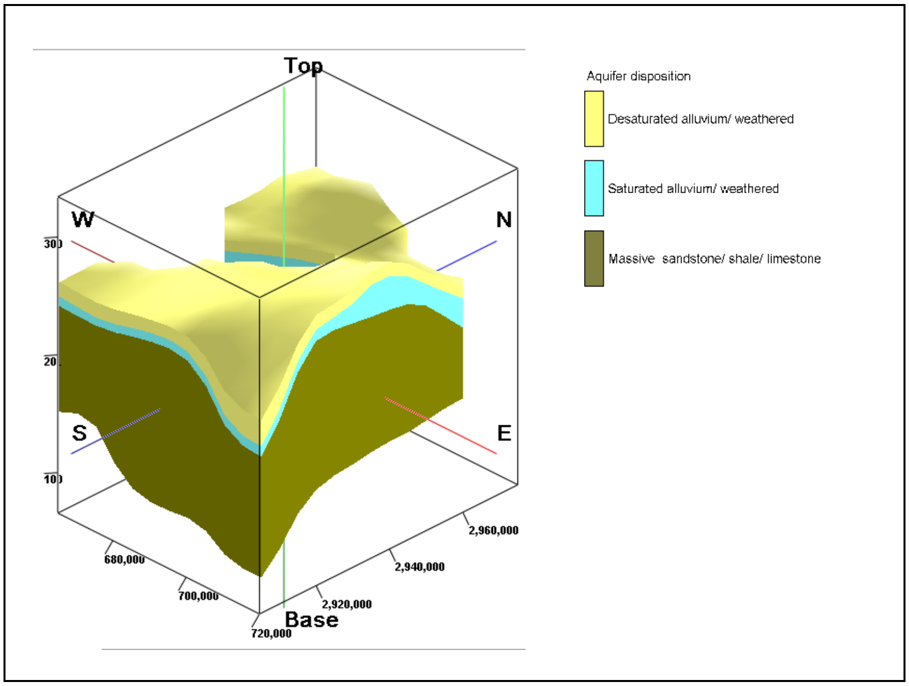


Figure 5: Aquifer Disposition Model

The hydrogeological sections showing aquifer disposition have been prepared and depicted in Figures 6A to 6D.

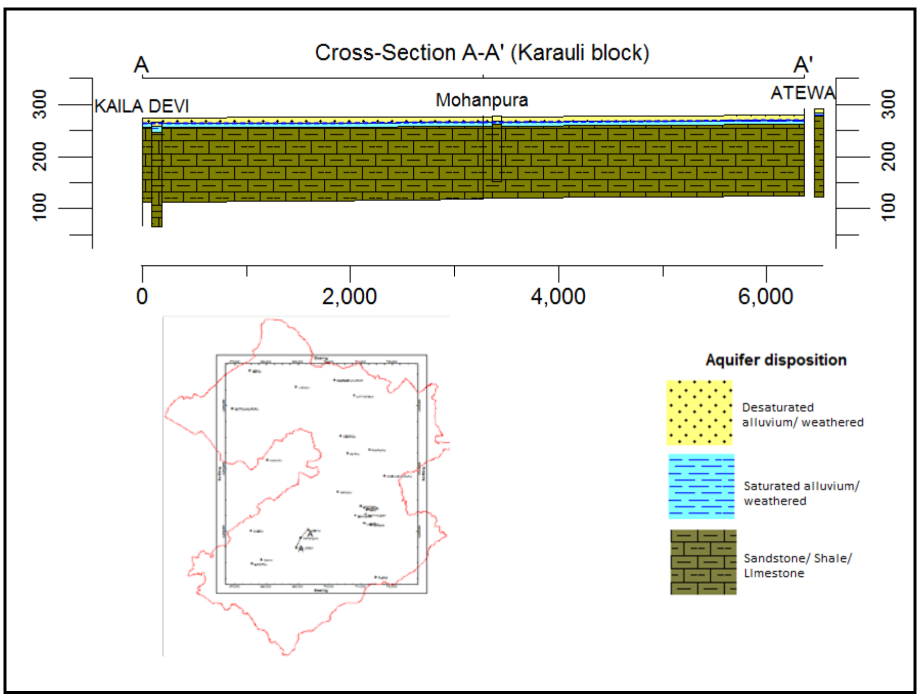


Figure 6A: Section A - A'

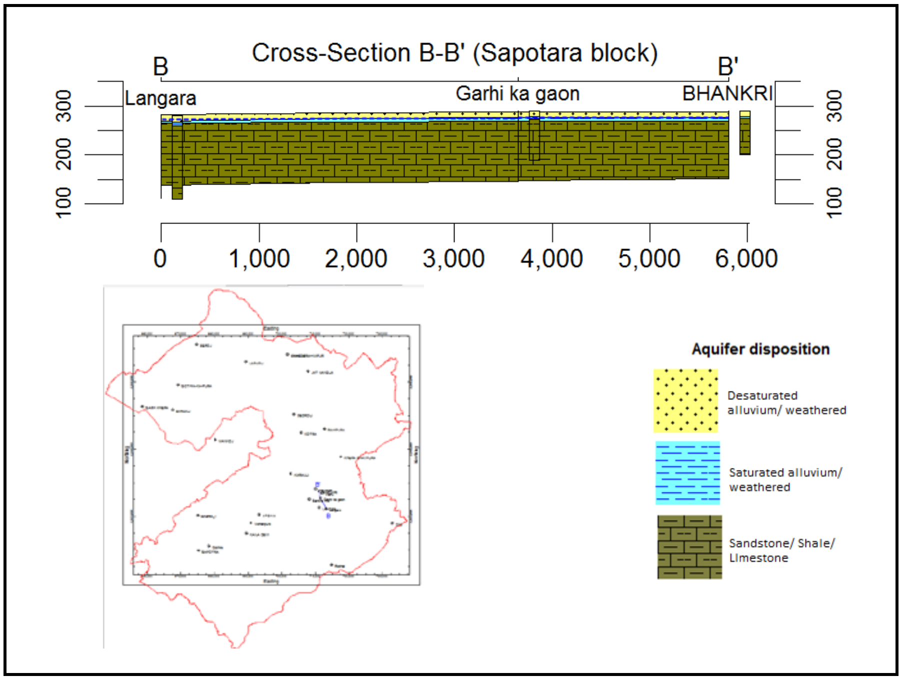


Figure 6B: Section B - B'

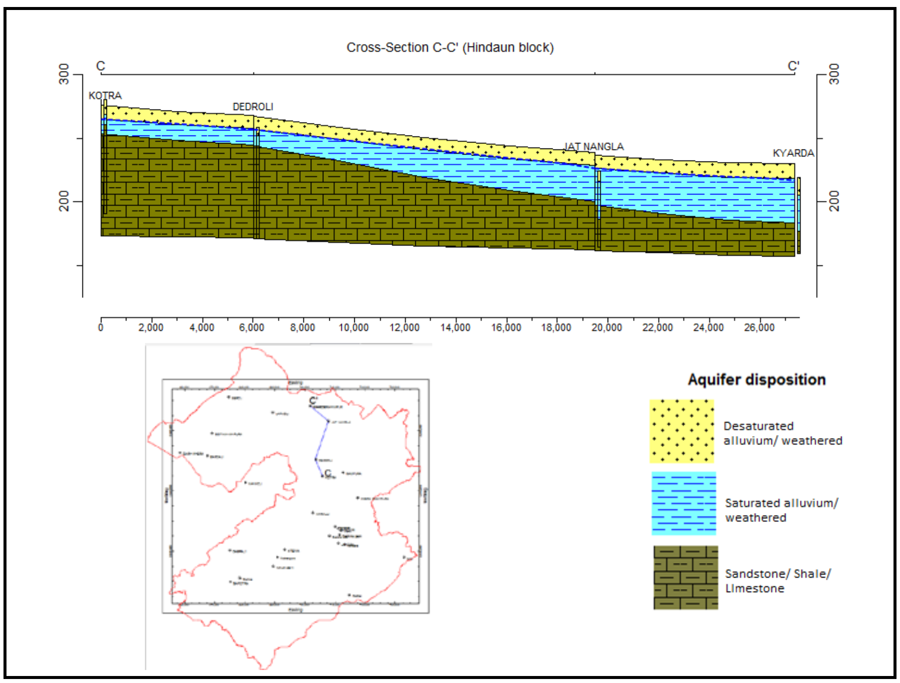


Figure 6C: Section C - C'

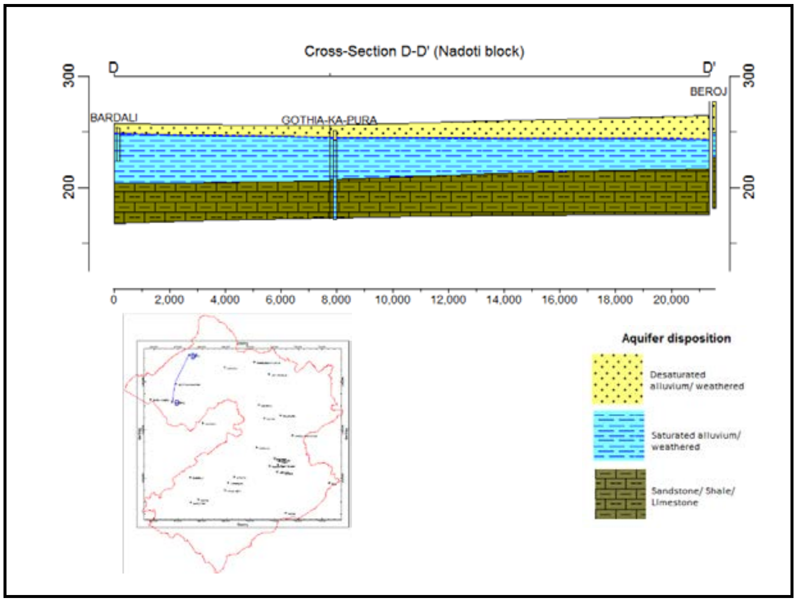


Figure 6D: Section D- D'

2.4 Ground Water Scenario

The total number of hydrograph stations in the district is 26 including 17 dug wells and 9 piezometers. The depth to water level varies from 0.18 to 34.06 m during pre-monsoon 2014 and 1.33 to 34.06 m during post-monsoon 2014. According to the depth to water level map of pre monsoon 2014, water level ranges between 5 to 20 mbgl in the major part of block except some north western & central parts where it ranges between 20 to 40 mbgl and some south central parts where it is shallower upto 2 mbgl and even less (Figure 7).

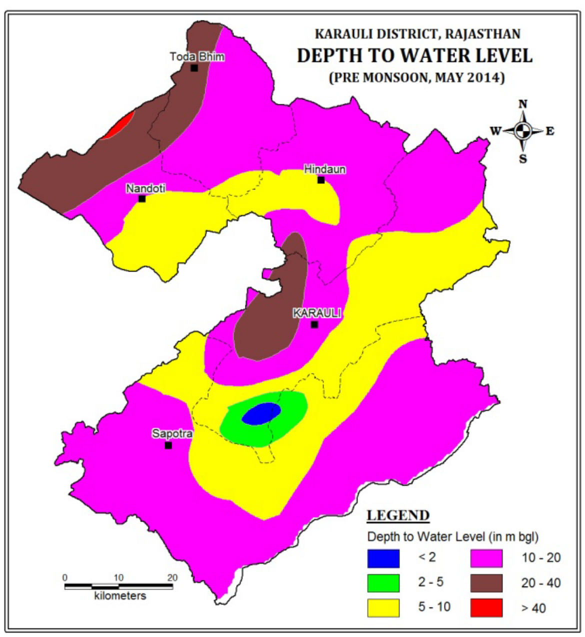


Figure 7: Depth to Water Level Map (May 2014)

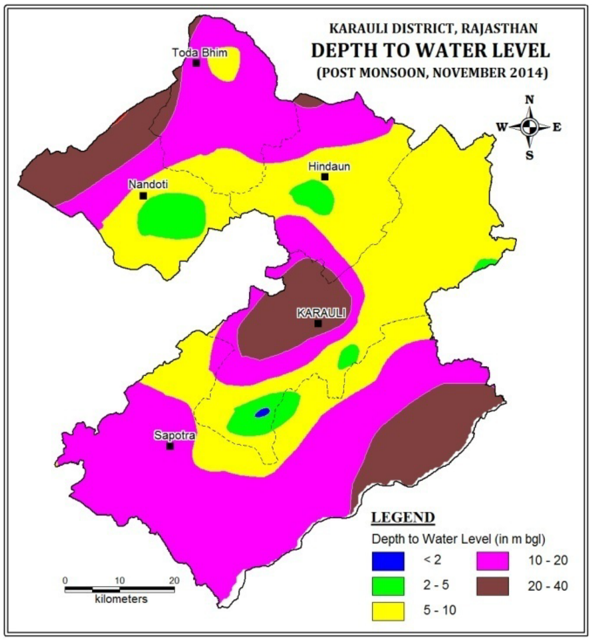


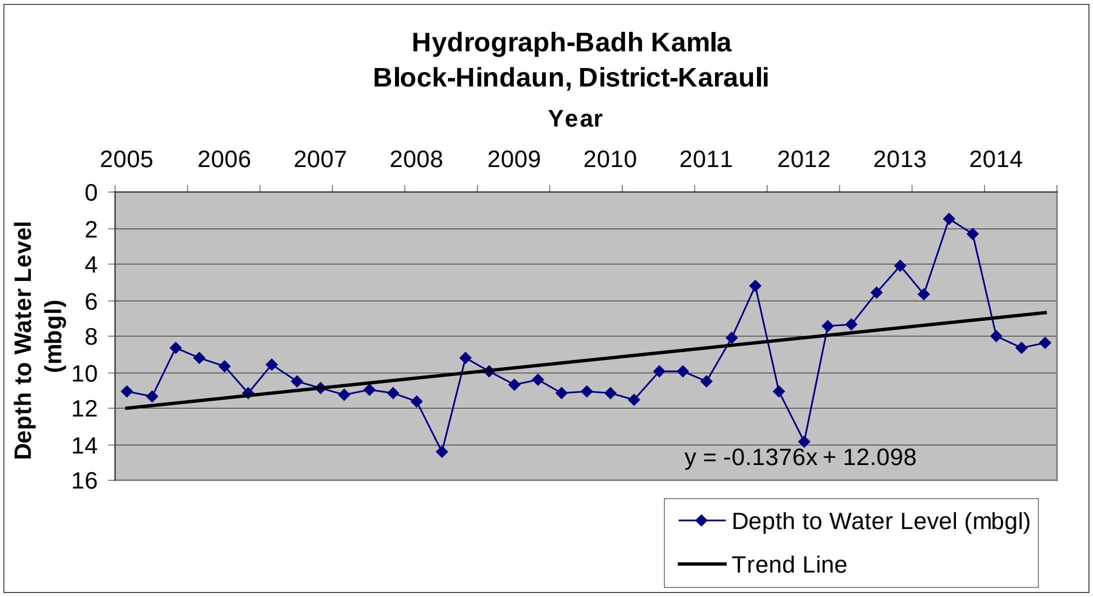
Figure 8: Depth to Water Level Map (November 2014)

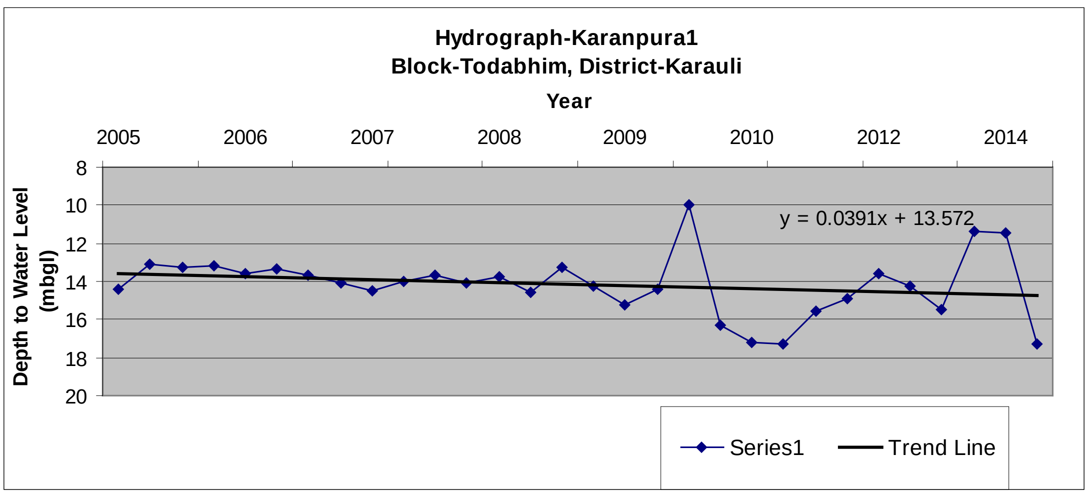
The water levels during post monsoon are almost similar to pre monsoon except the areas under 5 to 10 mbgl and 2 to 5 mbgl has increased (Figure 8).

Analysis of long term water level data of selected hydrograph stations for the last ten years (2005-2014) indicates that most of the selected representative wells from each block have shown rising water levels. The Badh Kamla station of Hindaun Block, Keladevi station of Karauli Block and Langra station of Sapotra Block have shown water level rises of 0.14, 0.06, 0.07 m/year, respectively. A very small water level falls have been seen at Karanpura station of Todabhim Block and Nadauti station of Nadauti Block during this period. The long term trends of selected stations are given below in Table 3 and hydrographs for these are given in Figure 9.

Table 3: Long Term Trends of Selected Stations

Name of Station	Block	Trend (m/year)
Badh Kamla	Hindaun	-0.14
Karanpura1	Todabhim	0.04
Keladevi	Karauli	-0.06
Langra	Sapotra	-0.07
Nadauti	Nadauti	0.01





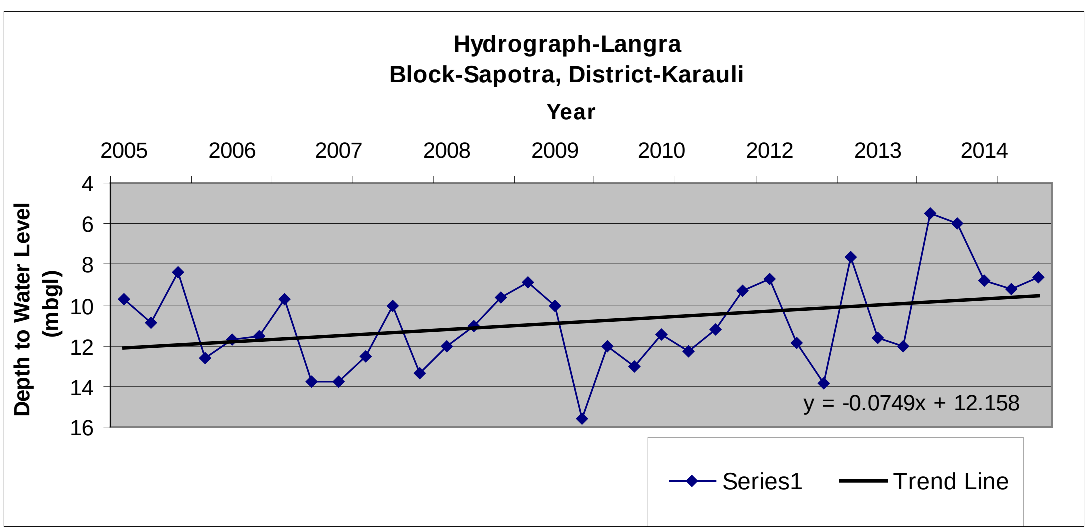


Figure 9: Hydrographs of Karauli district

3. Ground Water Quality

The ground water is alkaline type having pH value more than 7. According to ground water chemical quality data for Premonsoon 2014, the electrical conductivity value ranges from 550 µmhos/cm at 25°C (at Mamachari in Karauli Block) to a maximum of 6999 µmhos/cm at 25°C (at Sahar in Nadauti Block). However, in general it varies from 500 to 5000 µmhos/cm at 25°C (Figure 10). In major part of all the blocks, the electrical conductivity between 750 and 1500 µmhos/cm at 25°C is found. And in another larger part, it varies between 1500 to 3000 µmhos/cm at 25°C except few western areas the block. EC value ranging between 2000 and 3000 is constituted by 11% of the samples and 20% of stations rest beyond 3000 µmhos/cm at 25°C occupying the south western part of Hindaun Block, southern part of Nandauti Block, some western part of Karauli Block and northern part of Sapotra Block.

Fluoride content ranges from 0.36 (at Hindaun station in Hindaun Block) to a maximum of 2.2 mg/I (at Islampur station in Hindaun Block). Out of total stations, 11% of stations have Fluoride concentration more than permissible limit of 1.5 mg/I (Figure 11). Nitrate concentration falls within permissible limit of 45 mg/l at 50% of stations (Figure 12). The minimum value of Nitrate is observed at Mamachari in Karauli Block (4 mg/l) and maximum at Sahar in Nadauti Block (600 mg/l).

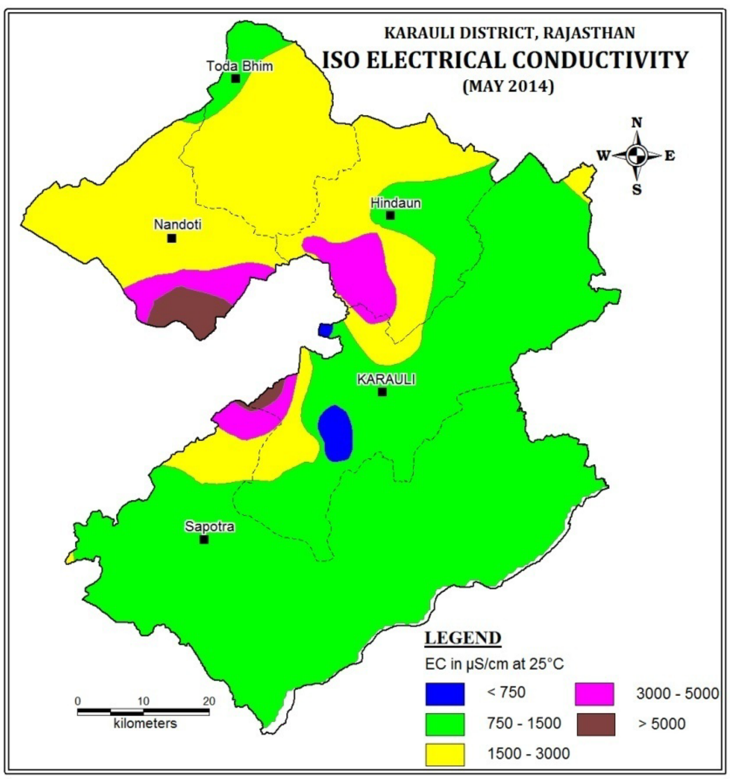


Figure 10: Iso Electrical Conductivity Map (May 2014)

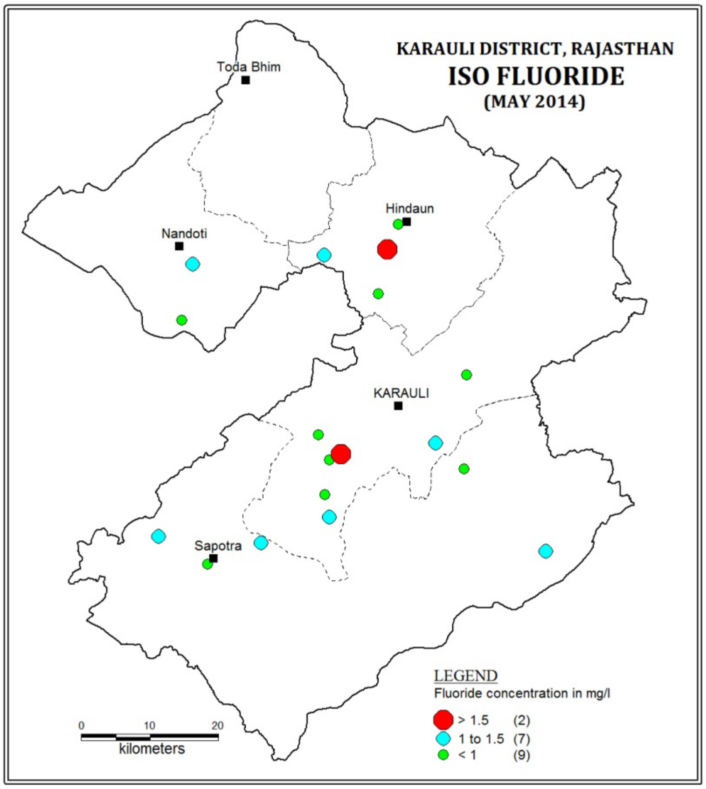


Figure 11: Fluoride Distribution Map (May 2014)

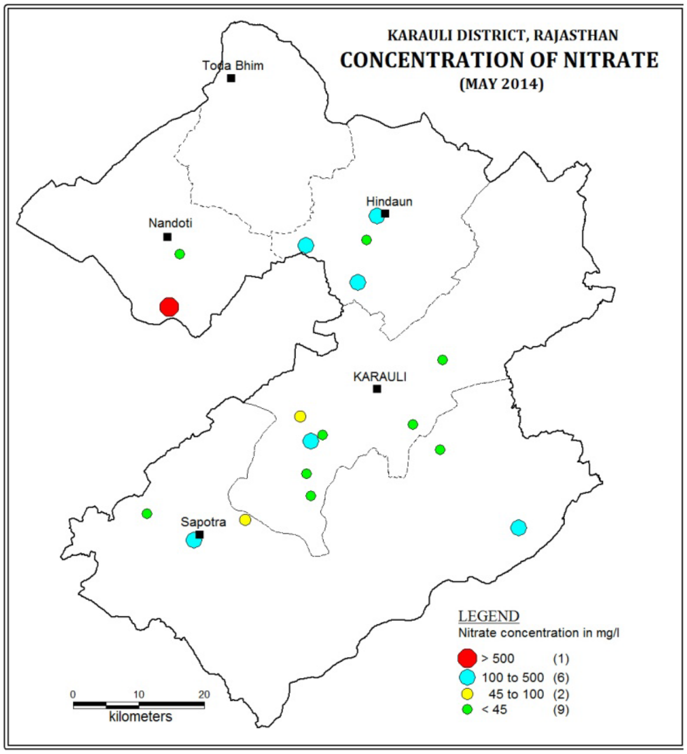


Figure 12: Nitrate Distribution Map (May 2014)

3.1 Ground water quality in shallow aquifers (Exploration Data)

The ground water in shallow aquifers is alkaline type having pH value more than 7. The electrical conductivity value ranges from 280 µmhos/cm at 25°C (at Atewa in Karauli Block) to a maximum of 8400 µmhos/cm at 25°C (Bardala in Nadauti Block). However, in general it varies from 500 to 5000 µmhos/cm at 25°C. In major part of all the blocks, the electrical conductivity between 750 and 3000 µmhos/ cm at 25°C is found. Electrical conductivity less than 750 µmhos/ cm at 25°C is found in major part of Nadauti block and locally in Todabhim, Hindaun, Karauli and Sapotra blocks.The isolated patches falling in Nadauti, Todabhim and Hindaun blocks, have been noticed between 3000 and 5000 µmhos/ cm at 25°C electrical conductivity values. Electrical conductivity more than 5000 µmhos/ cm at 25°C is observed in isolated pockets lying in southern part of Nadauti block (Figure 13). EC more than 3000 µmhos/cm at 25°C is constituted by 12% of ground water samples analyzed.

The Nitrate content ranges from 2 ppm (minimum at Sai Markarpura in Karauli Block) to 571 ppm (miximum at Sahar in Nadauti Block). However, in general it lies between 10 ppm and 268 ppm. The analysis of data reveals that 66% of water samples analyzed fall within acceptable limit i.e. 45 ppm of drinking water standards and 34% beyond the limit which is not relaxable. The nitrate concentration is noticed within permissible limit of 45 ppm in major part of all the blocks. However, isolated pockets in Nadauti, Todabhim, Hindaun, Karauli and Sapotra Blocks, Nitrate concentration beyond acceptable limit of 45 ppm is observed (Figure 14).

The Fluoride content mostly fall within permissible limit of 1.5 mg/l. However, it ranges in the district from traces to 6.45 mg/l (maximum at Gudachanderji in Nadauti Block). However, in general it falls between traces and 2.60 mg/l (Figure 14).

The statistical analysis of data indicates that 82.03% of samples have Fluoride concentration within permissible limit i.e. 1.5 mg/l of drinking water standards and 18% beyond the limit. The Fluoride concentration less than 1.5 mg/l (permissible limit as per drinking water standards) is observed in major part of all the blocks in the district. However, isolated patches having Fluoride content more than 1.5 mg/l have been observed in northern part of Nadauti Block and in extreme part of Hindaun Block.

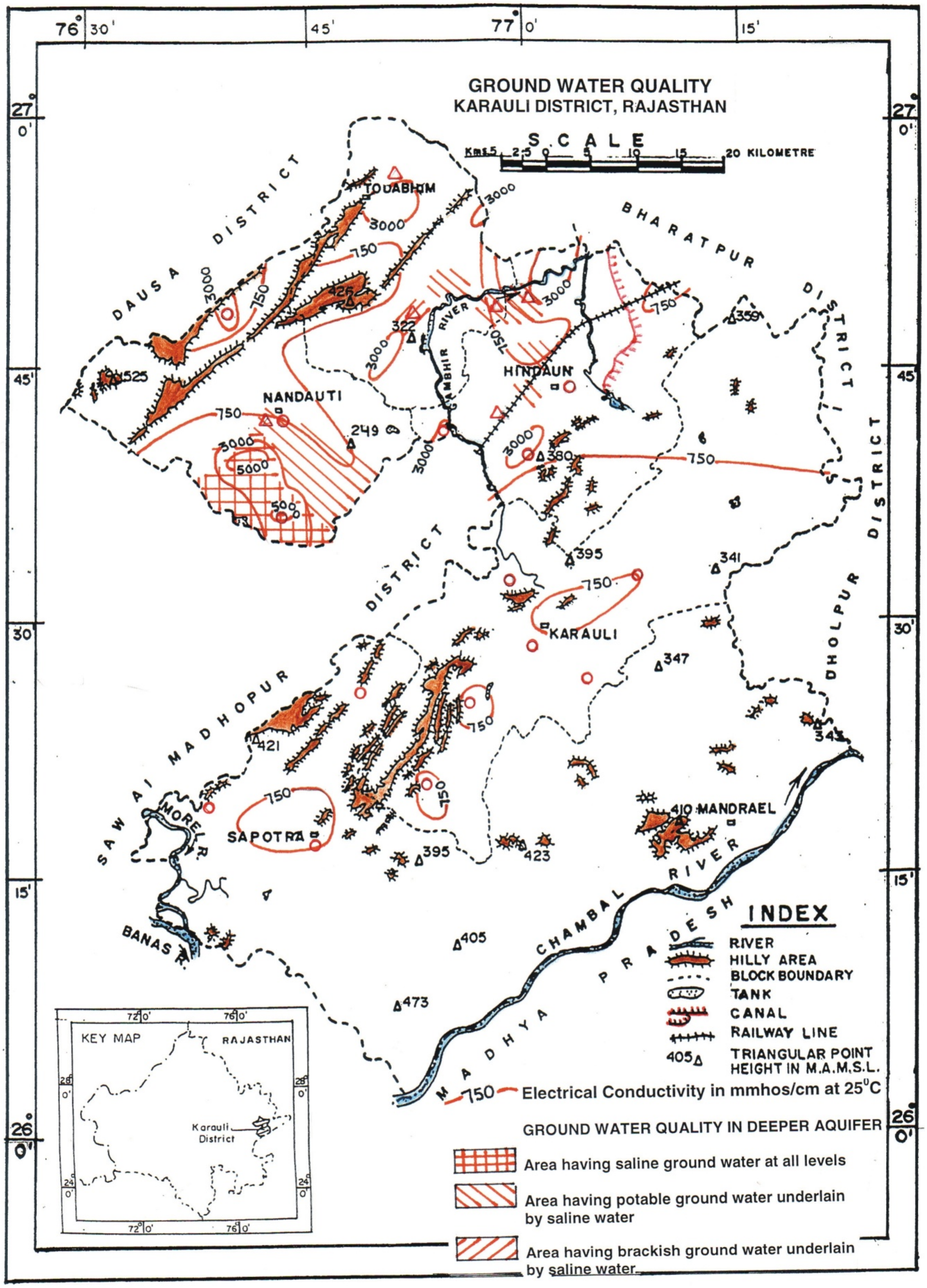


Figure 13: Electrical Conductivity Map (Exploration Data)

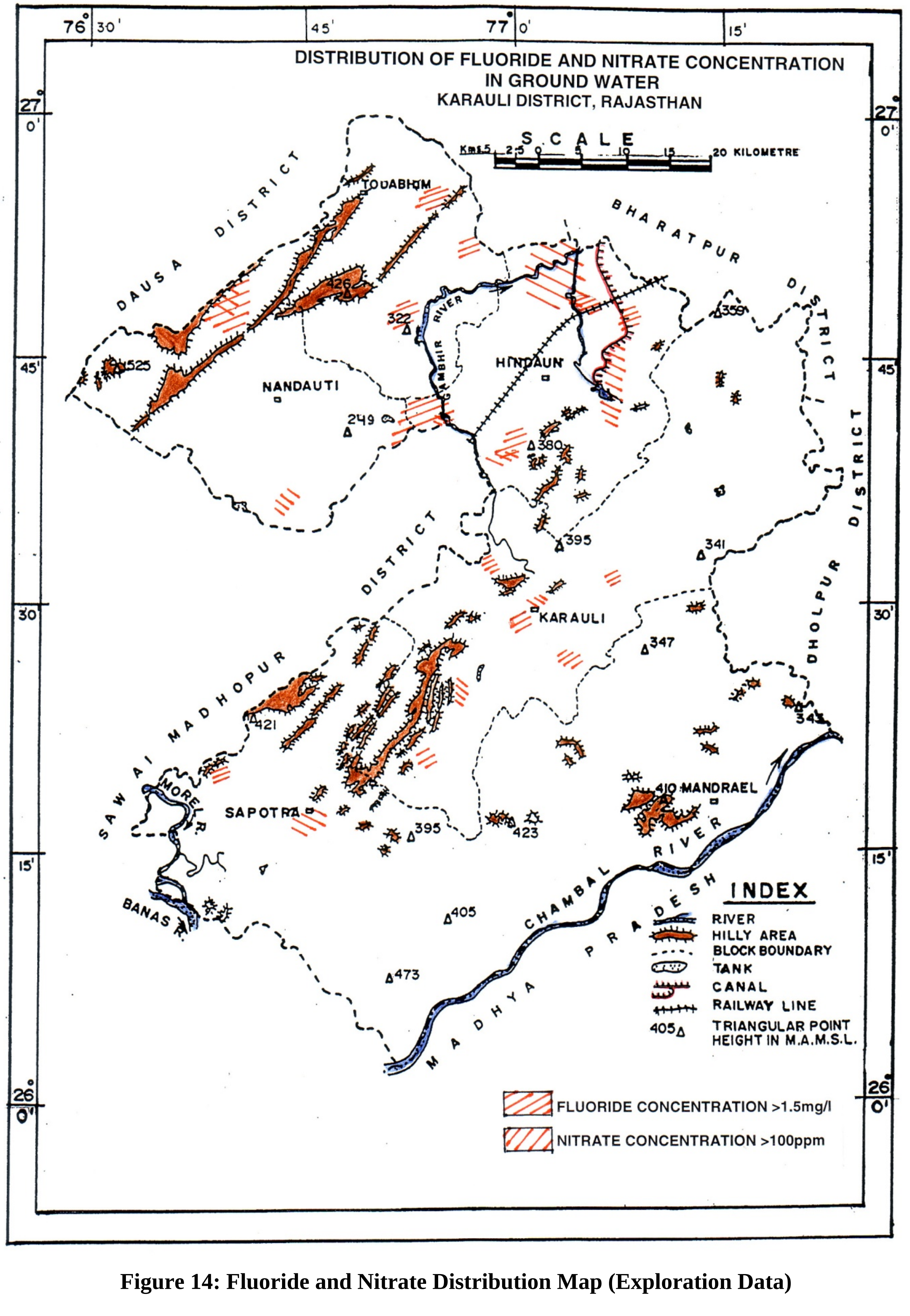


Figure 14: Fluoride and Nitrate Distribution Map (Exploration Data)

3.2 Ground water quality in deeper aquifer (Exploration Data)

The electrical conductivity value ranges from 500 (minimum at Ratanpura in Sapotra block) to 16500 (maximum at Nagal Pahari in Todabhim block) mmhos/cm at 25°C. The electrical conductivity value more than 3000 mmhos/cm at 25°C is constituted by 27.05% of stations. The minimum & maximum values of Electrical Conductivity values in deeper aquifers are on higher side. The Nitrate concentration in deeper formation ranges from 6 ppm (at Banki in Hindaun Block) to 306 ppm (at Mandryel in Sapotra Bblock). The nitrate content more than 45ppm (which is acceptable limit and no relaxation beyond this) is constituted by 67% of stations. The Fluoride concentration varies form 0.26 mg/l (at Kurgaon EW in Sapotra Block) to 4.0 mg/l (at Nadauti Pz in Nadauti Block). The Fluoride concentration more than 1.50 mg/l is constituted by 22% of stations.

Depth wise salinity variation:

The depth wise salinity variation of ground water is indicated by analytical results of water samples collected from exploratory wells, slim holes and piezometers falling in the study area and also from geophysical analysis/ interpretation results of these bore holes. The depth wise ground water quality variation scenario is described in the following paragraph and depicted in Fig.8.

a. Saline ground water at all level

The saline ground water at all level has been noticed around Bamori, Bardala, north of Gandal Sagar, Bagar Shahar and south of Gothra ka Pura areas falling in southern part of Nadauti Block.

b. Potable ground water underlain by saline ground water

Such areas around Nadauti and complete south-eastern part of Nadauti upto the Sawai Madhopur district (around Gothra Kapura, Sop, Khedla Khedi, Badagaon, Kalma Kemri, Lanwad) boundary in Nadauti Block; around Mundia, Karanpura (Todabhim Block), Tibara, Mandawar, Sikranda Meena in Hindaun Block) have been noticed.

c. Brackish ground water underlain by saline water

Such areas have been observed around Nangal Pahari in Todabhim block.

4. Ground Water Resources

Central Ground Water Board and Rajasthan State Ground Water Department have jointly estimated the ground water resources of Dholpur district as on 31.03.2013 based on GEC-97 methodology (Table 4). Ground Water Resource estimation was carried out for 3902.42 sq.km. area.

Table 4: Block wise ground water resources (As on 31.03.2013)

Block	Total Annual Ground Water Recharge	Natural Discharge during non-monsoon season	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross G.W. Draft for Dom. & Ind. Use	Existing Gross Ground Water Draft for all uses	Stage of G.W. Development	Category of Block
Hindaun	64.2156	6.1664	58.0492	118.2497	9.7043	127.954	220.42	Over Exploited
Karauli	94.4807	9.448	85.0327	85.8711	9.6461	95.5172	112.33	Over Exploited
Nadoti	39.1843	3.7265	35.4578	23.3357	5.576	28.9117	81.54	Safe
Sapotra	109.8146	10.1793	99.6353	97.4311	10.0735	107.5046	107.9	Over Exploited
Todabhim	51.0097	5.101	45.9087	96.9822	17.1753	114.1575	248.66	Over Exploited
Total	358.7049	34.6212	324.0837	421.8698	52.1752	474.045	146.27	Over Exploited

The total annually replenishable resource of the district has been assessed to be 358.7049 MCM and net annual ground water availability has been estimated to be 324.0837 MCM. The Gross annual ground water draft for all uses has been estimated to be 474.045 MCM. The overall stage of ground water development in the district is 146.27%. Out of total 5 Blocks, 4 fall under Overexploited category and the remaining one under Safe category.

5. Ground Water Related Issues and Problems

Declining ground water level:

Long term water level data (2005 -2014) has indicated declining water level trends at many stations of district. As a result of which, three blocks viz. Hindaun, Sapotra and Todabhim have entered into over-exploited category which is needed to be controlled through notifying the blocks and further imposing ban on the construction of ground water abstraction structures except drinking use.

Ground water salinity:

The electrical conductivity more than 3000 µmhos/cm at 25°C is represented by 20% of stations only. The isolated patches falling in Nadauti, Todabhim and Hindaun blocks, have been noticed between Electrical Cobnductivity values of 3000 and 5000 µmhos/cm at 25°C. Electrical conductivity more than 5000 µmhos/cm at 25°C is observed in isolated pockets lying in southern part of Nadauti Block and western part of Karauli Block.

Fluoride hazard:

The Fluoride content more than 1.5mg/l is constituted by 11% of stations which has been observed in isolated pockets in Hindaun and Karauli Blocks.

Nitrate hazard:

The Nitrate content more than 45 ppm is constituted by 50% of stations which has been observed in isolated pockets in Nadauti, Hindaun, Karauli and Sapotra blocks.

6. Management Strategy

Out of total 5 blocks, 4 no. of blocks of this district are over exploited, thereby, leaving limited scope of further ground water development for various consumptions and area is devoid of sustained surface water bodies. In order to manage the ground water resources and to control further decline in water levels, a management plan has been proposed. In order to manage the ground water resources and to control further decline in water levels, a management plan has been proposed. The management plan comprises two components- supply side management and demand side management. Since there is very little surplus surface water available in this district, very little intervention in the form of supply side management could be proposed.

6.1 Supply Side Management

The supply side management of ground water resources can be done through the artificial recharge of surplus runoff available within river sub basins and micro watersheds. Also it is necessary to understand the unsaturated aquifer volume available for recharge. The unsaturated volume of aquifer for the Dholpur district is computed based on following; the area feasible for recharge, unsaturated depth below 5 m bgl and the specific yield of the aquifer.

6.1.1 Artificial recharge to ground water through interventions of various structures

The following parameters are inevitable for planning of artificial recharge to ground water.

- Availability of sufficient storage space to accommodate recharged water
- Availability of surplus water to recharge
- Feasibility of sub-surface geological formations

In case of Karauli district, sufficient sub-surface storage space is available to accommodate the recharged water. Details of feasible recharge structures to recharge the surplus water in respective block are given in Table 5.

Table 5: Block-wise details of feasible recharge structures

Block	Usable Surplus Water (MCM)	Recharge Shafts proposed	Percolation Tanks Proposed	Recharge from Recharge Shaft (MCM)	Recharge from Percolation Tanks (MCM)	Total Recharge (MCM)	Effective Recharge (MCM)
Hindaun	2.32	33	6	0.99	1.20	2.19	1.75
Karauli	2.58	37	5	1.11	1.00	2.11	1.69
Nadoti	1.59	45	0	1.35	0.00	1.35	1.08
Sapotra	70.72	173	112	5.19	22.40	27.59	22.07
Todabhim	0.34	7	0	0.21	0.00	0.21	0.17

It can be observed that 26.76 MCM of effective recharge is possible through Supply side Management.

6.2 Demand Side Management

Though not much augmentation can be done through supply side management due to less availability of surplus water, applying the techniques of demand side management can save large amount of water. Demand side management has been proposed through two interventions – changing the more water intensive wheat crop to gram (chick pea) and use of sprinkler irrigation in the areas where rabi crop is being irrigated through ground water.

6.2.1 Change in cropping pattern

In view of the alarming decline of water level, drastic reduction in saturated thickness of aquifer and resulting of depletion of aquifer, there is need to bring paradigm change/shift in cropping pattern in the area. It is proposed to grow low water requirement crop like gram in the instead of wheat. Growing of gram will save the water to the tune of about 100 mcm per annum @ 0.1m (Table 6).

6.2.2 Adoption of modern practice of sprinkler irrigation/improved irrigation practices

Data indicate that flooding method of irrigation is still in practice in many parts of the district which causes wastage of ample quantity of water. In view of this, it is proposed to bring about 50% of total irrigated area under sprinkler irrigation which may save water to the tune of about 64.67mcm/annum @0.08m (Table 6).

Table 6: Block-wise water saving through change in cropping pattern and irrigation practice

Block	Irrigated Area (ha)	Irrigated Area proposed for irrigation through sprinkler (ha)	Water Saving by sprinkler in MCM (@0.08 m)	Irrigated Area (ha)	Irrigated Area under wheat proposed for Gram cultivation (ha)	Water Saving by change in cropping pattern in MCM @0.1 m	Total Water savings in MCM
Hindaun	32513	16257	13.01	32513	7713	7.71	20.72
Karauli	9335	4668	3.73	9335	4010	4.01	7.74
Nadauti	15744	7872	6.3	15744	2761	2.76	9.06
Sapotra	26060	13030	10.42	26060	4938	4.94	15.36
Todabhim	33917	16959	13.57	33917	5787	5.79	19.36

Considerable saving of ground water can be achieved if the proposed supply side and demand side management plans are implemented. With the implementation of supply side management, additional 26.76 MCM/year can be recharged. It can be seen that not much augmentation in ground water resources can be achieved through artificial recharge due to constraints of availability of surplus/non-committed surface water. However, considerable improvement in ground water situation can be achieved with implementation of demand side management plans.

With the proposed use of sprinkler irrigation in the areas where rabi crop is being irrigated through ground water it is expected that 47.03 MCM/year can be saved due to reduction in pumping. The water saving under change in cropping pattern is expected to be 25.21 MCM/year. Therefore, total water saving through demand side management is 72.24 MCM/year. Block wise details of ground water recharged and saved along with expected improvement in stage of ground water development is given in Table 7.

Table 7: Summary of expected benefit of management strategies, Karauli district

Block	Net Annual Ground Water Availability	Additional recharge from RWH & conservation (mcm)	Total net GW availability after intervention (mcm)	Existing Gross Ground Water Draft for all uses	Saving of GW through projects (mcm)	Net GW draft after interventions (mcm)	Present stage of GW development (%)	Projected stage of GW development (%)
Hindaun	58.0492	1.75	59.7992	127.954	20.72	107.234	220.42	179.32
Karauli	85.0327	1.69	86.7227	95.5172	7.74	87.7772	112.33	101.22
Nadoti	35.4578	1.08	36.5378	28.9117	9.06	19.8517	81.54	54.33
Sapotra	99.6353	22.07	121.7053	107.5046	15.36	92.1446	107.9	75.71
Todabhim	45.9087	0.17	46.0787	114.1575	19.36	94.7975	248.66	205.73
Total	324.0837	26.76	350.8437	474.045	72.24	401.805	146.27	114.53