केंद्रीय भूमि जल बोर्ड

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

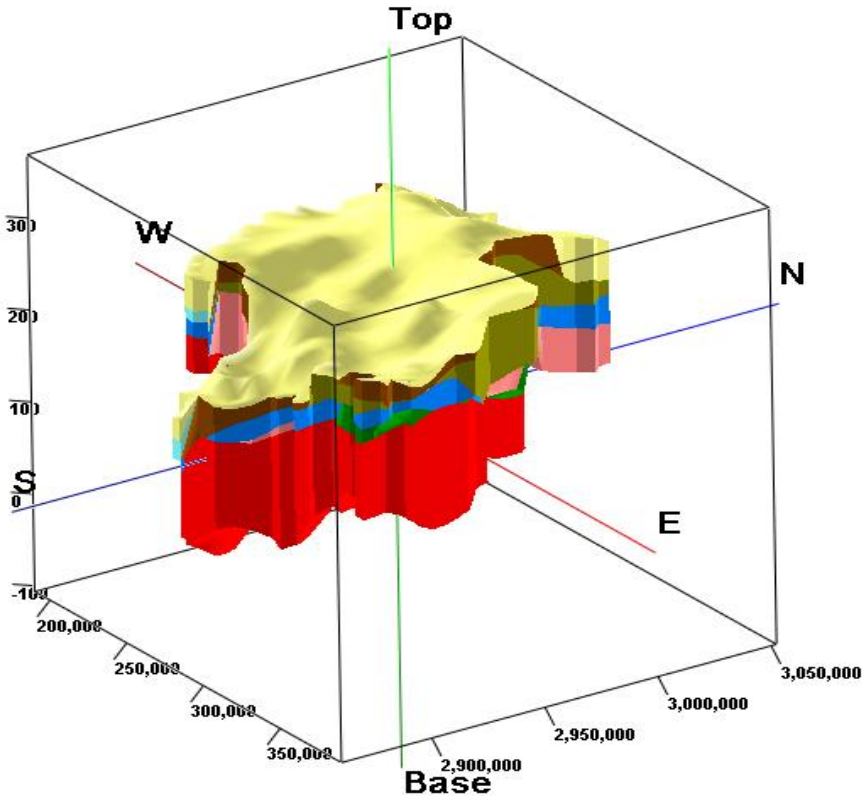
AQUIFER MAPPING AND GROUND WATER MANAGEMENT

Jodhpur District, Rajasthan

पश्चिमी क्षेत्र जयपुर

Western Region, Jaipur

Report on
AQUIFER MAPPING AND GROUND WATER MANAGEMENT
DISTRICT JODHPUR, 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 Jodhpur, Rajasthan

1.0 Introduction

Jodhpur district is situated between $25^0$51'08" & $27^0$37'09" North Latitude and $71^0$48'09" & $73^0$52'06" East Longitude covering geographical area of 22,250 sq. km. and occupies 6.68 % of total part of state. The district comes under arid zone of the Rajasthan State. Jodhpur district is part of Jodhpur Division. The district is divided into 7 Sub- division namely Jodhpur, Bhopalgarh, Luni, Osian, Phalodi, Piparcity and Shergarh and comprises of 7 tehsils & 10 blocks. The total number of villages in the district is 1838. The Jodhpur district is bounded by Nagaur in the East, Jaisalmer in the West, Bikaner in the North and Barmer as well as Pali in the South. Total population of the district is 3687165 which include 2422551 rural and 1264614 urban populations and sex ratio is 916 out of 1000 male. Decadal population growth rate of the district is 27.74% since 2011.

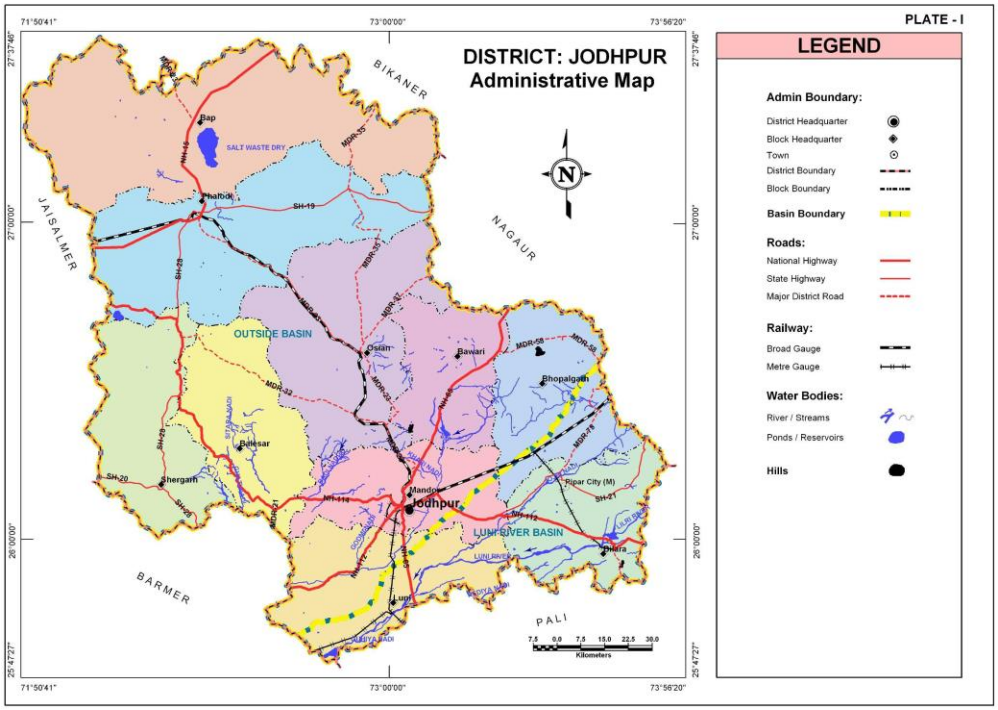

Figure 1 Administrative Map of Jodhpur District

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 Availability and Adequacy

Groundwater availability, monitoring (water level and chemical quality), exploration had been carried out by CGWB and state Ground Water Department. 68 NHS have been monitored by CGWB and 417 observation wells have been monitored by State GWD Govt. of Rajasthan, 104 bore holes have been constructed by CGWB.

The data collected from State GWD and CGWB WR Jaipur have been compiled and analyzed. It has been observed that validation and georeferncing of the location coordinates, lithologs and hydrogeological data is needed and State GWD data is lacking 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 water level behavior, there is need to generate more data by Groundwater Exploration, VES 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 map have been prepared regarding groundwater monitoring, exploration, surface water and agriculture data. Based on these maps and hydrogeological conditions in the area Jodhpur District needs further data to be generated in the gaps.

1.6 Rainfall and Climate

Jodhpur district has arid type of climate. It is characterized by large diurnal as well as seasonal variations of temperature and low rainfall.
Normal rainfall of Jodhpur as per IMD is 314mm, while as per 44 year (1970-2014) annual rainfall data, average annual rainfall of the district is 373.7 mm. The main rainfall months are July and August in which about 68% of rainfall occurs. On an average, the number of intensified rainy days in a year is about 15. The variations of annual rainfall in Jodhpur during the year 1970 to 2014 are shown in Figure 2 and rainfall data for the above period is given in Table 1. The area faces frequent droughts. The district has suffered moderate droughts during 1974, 1984 – 1987, 1991, 1993 and 2009. Severe type of drought was witnessed during 2002.

Table 1: Rainfall data analysis of Jodhpur (1970-2014)

Year	Rainfall	Dep (%) From Normal	Remarks	Drought
1970	631.8	101.2	Normal	
1971	268.5	-14.5	Normal	
1972	237.0	-24.5	Defict	
1973	651.8	107.6	Excess	
1974	194.4	-38.1	Defict	Moderate
1975	708.9	125.8	Excess	
1976	645.1	105.4	Excess	
1977	389.0	23.9	Excess	
1978	386.0	22.9	Excess	
1979	537.2	71.1	Excess	
1980	250.2	-20.3	Defict	
1981	279.4	-11.0	Normal	
1982	454.2	44.6	Excess	
1983	517.0	64.6	Excess	
1984	220.5	-29.8	Defict	Moderate
1985	186.6	-4.6	Defict	Moderate
1986	175.0	-44.3	Defict	Moderate
1987	165.0	-47.5	Defict	Moderate
1988	318.7	1.5	Normal	
1989	304.0	-3.2	Normal	
1990	821.0	161.5	Excess	
1991	232.5	-26.0	Defict	Moderate
1992	526.0	67.5	Excess	
1993	232.0	-26.1	Defict	Moderate
1994	396.0	26.1	Excess	
1995	344.0	9.6	Normal	
1996	521.1	66.0	Excess	

Year	Rainfall	Dep (%) From Normal	Remarks	Drought
1997	572.1	82.2	Excess	
1998	577.0	83.8	Excess	
1999	357.0	13.7	Normal	
2000	273.0	-13.1	Normal	
2001	527.0	67.8	Excess	
2002	91.0	-71.0	Excess	Severe
2003	359.0	14.3	Excess	
2004	182.0	-42.0	Defict	
2005	283.0	-9.9	Normal	
2006	210.0	-33.1	Defict	
2007	205.0	-34.7	Defict	
2008	476.0	51.6	Excess	
2009	156.0	-50.3	Defict	Moderate
2010	511.0	62.7	Excess	
2011	314.0	0.0	Normal	
2012	480.0	52.9	Excess	
2013	522.0	75.9	Excess	
2014	304.8	2.7	Normal	

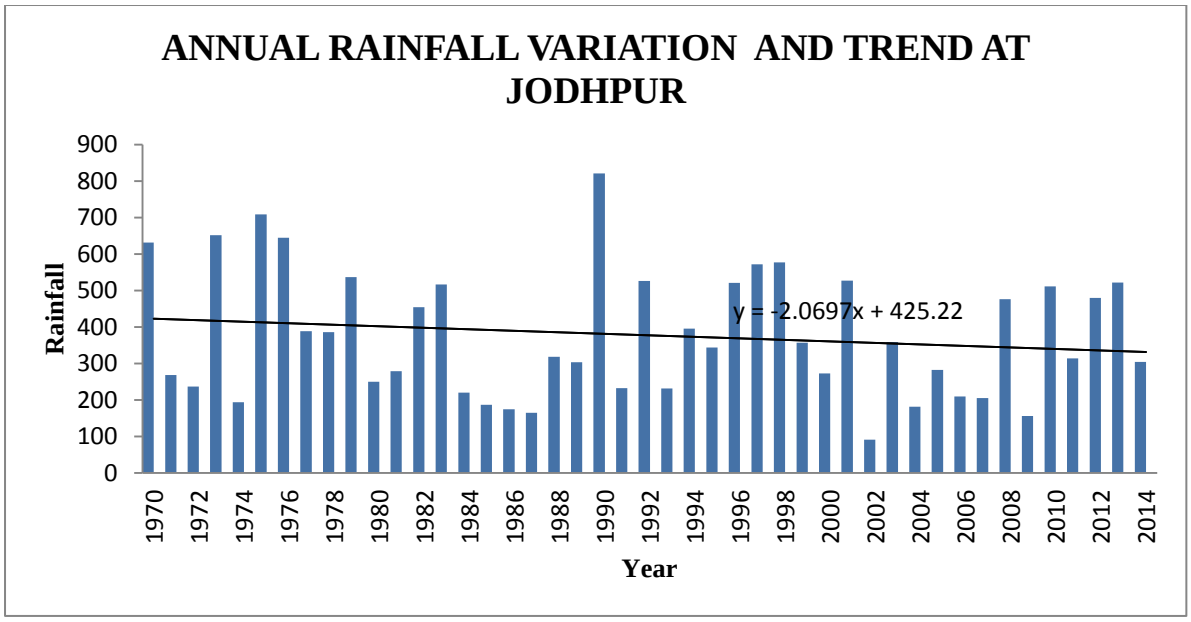

Figure 2: Bar Diagram of annual rainfall variation & Trend of Jodhpur

The average maximum temperature and the average minimum temperature during summer are reported to be 42.2°C, and 27.3°C respectively, and during winter the average maximum temperature is 27.5° and the average minimum temperature is 9.5°C.

1.7 Geomorphology and Drainage

Jodhpur district forms part of Great Thar Desert of Rajasthan. In this arid region, there are sand dunes, alluvial areas dotted with few hillocks and hill chains scattered in the area. In the eastern

part of the district, the area between Bilara and Jodhpur is covered by alluvium deposited due to the fluvial action of Luni river system. The eastern part of the district exhibits gentle undulating topography interrupted by small ridges of hard rocks. The general elevation of plains varies from 300 m amsl in north to 150 m amsl in south. Regional slope is from north-east towards south-west direction. Orientation of alluvial plain area follows the Luni River and its tributaries. Sand dunes occupy a major part of the district north of Vindhyan escarpment in northern and northwestern part of the district. The sand dunes are transverse and longitudinal type formed due to aeolian action and overlies the denuded consolidated formations. Ridges composed of comparatively resistive rocks like granite, rhyolite and Jodhpur sandstone are found extending from Shergarh in the west to Bilara in the east. The alluvial and sand filled valleys are separated by the ridges whose crest elevation ranges from 325 to 460 m amsl. In the northern part of the district, highest peak of the hill is 284 m amsl. Presence of boulder bed exhibit striking plain topography around Bap and low lying outcrops of limestone, shale and sandstone layers are observed part of the district near Phalodi. Distribution of various geomorphic units in the district is shown in Table 2.

Table 2: Distribution of various geomorphic units in Jodhpur District

Origin	Landform Unit	Occurrence
Aeolian	Sand Dunes	North and Northwestern part of the District.
	Sandy Plains	North and Northwestern part of the District.
Fluvial	Alluvial Plains	Eastern part of the district along rivers- Luni, Mithri etc.
	Interdunal Plains	Scattered in entire district, mainly in north and western part of the district.
Denudational	Pediments	Scattered in the district, mainly in east & west.
Hills	Linear Ridges	Occur in Bilara and Osian Blocks. Extended from Shergarh in the west to Bilara in the east.
	Structural Hills	In northwastern and eastern parts of the district and Jodhpur town.

Jodhpur district falls in the Luni and Barmer basins. Major River of the district is Luni, which flows in ENE – WSW direction. It enters Jodhpur district near village Jakh in Bilara tehsil and leaves the district near village Dhundhara. Total length of the Luni River in Jodhpur district is 125 Km. Channel pattern of Luni is dendritic to sub- parallel. However, major part of the district, the drainage is essentially ephemeral and internal. Important tributaries of the Luni River are Mithri and Bandi. Other streams in the district are Jojri, Golasmi, Guniamata and Bastua, which are all ephemeral.

1.8 Soils

Soils of the Jodhpur district have been classified as follows:

Red desertic soils: This type of soil is predominant in central, eastern and southern parts of the district. These are pale brown to reddish brown soils, loose and drained and texture varies from sandy loam to sandy clay loam.

Desert soil: Desert soils occupy a considerable area covering northern and western part of the district, These are mainly windblown sand and soils of interdunal depressions.

Sand dunes: Sand dunes occupy a small part in northern and north- western margin of the district, These are sandy to loamy sand, loose, structure less and well drained.

Lithosoils and regosols of hills: These type of soils are found in hills and hill slopes of central and western parts of the district. These are shallow, light textured, fairly drained and reddish brown to grayish in colour.

1.9 Land Use

Total reported area for land utilization statistics is 22, 56,405 hectares and about 70.03% of the total areas are being cultivated. The district is very poor in forest covering only 6996 hectares, which forms only 0.31% of the total area of the district. Agriculture is the main occupation of the rural population. Net cultivable area of the district is 12, 84,645 hectares whereas non agriculture land area including fallow land is 617105 hectares. Maximum cultivated area lies in Osian tehsil followed by Bhopalgarh tehsil. The Land use pattern of Jodhpur district is given in table 3. (Census 2011)

Table 3: Land use pattern of Jodhpur district

Classification	Area (Hectares)	Percentage
Total Geographical Area	22,56,405	100.00
Area under forest	6,996	0.31
Area not available for cultivation	2,25,623	9.99
Permanent Pastures and other Grazing lands	1,21,928	5.40
Miscellaneous trees crops and groves not included in the net area sown	108	0.004
Non Agriculture Land including Fallows	6,17,105	27.34
Net Area Sown	12,84,645	56.93
Area sown more than once	1,35,058	5.98
Total Area Sown	14,19,703	62.91

The district comes under arid zone of the State and on account non- availability of adequate water, cropping is by and large, single only. Only 15% of the net cultivated area is being utilized for double/ multiple cropping. The total area under Kharif and Rabi crop is 1221430 and 416413 hectare (As on 2013-14, Agriculture Statistics). During Kharif millet, Jawar, pulses, groundnut and guar are the main crops cultivated and during Rabi wheat, barley, isabgol, and mustard are the main crops cultivated in the district.

Ground water is the only source of irrigation in the district. Gross area od irrigated land by wells and tube wells works out to 478676 hectares (As on 2012-13Agriculture Statistics). Maximum irrigated area is in Osian tehsil followed by Bhopalgarh and Bilara tehsils respectively. Minimum area under irrigation is in Luni tehsil due to poor ground water potential. Source wise details of irrigated area in the district are given in table 4. (As in 2012-13Agriculture Statistics)

Table 4: Source wise details of irrigated area in Jodhpur district

Source	Net Irrigated Area (Hectares)	Gross Irrigated Area (Hectares)
Tube Wells	312349	475097
Other Wells	2541	3579
Other Sources	166	621
Total	315056	479297

1.10 Data collection and Generation

On the basis of available data of exploratory tube wells drilled by CGWB/GWD/PHED, the status of data were assessed and based on that gaps were identified for data to be generated in respect of quality, quantity and lithology (through exploration as well as VES). Data pertaining to available statistics on cropping pattern and land under agriculture use was collected from statistic directorate for recommending the management plan of the available resource keeping in view of the prevailing cropping pattern.

2.0 Ground Water Scenario

2.1 Geological Framework

Geological set-up of the district is represented by various igneous, metamorphic and sedimentary rocks. Delhi Super Group litho units are very limited and occur in the form of isolated pockets. Erinpura granite and Malani igneous rocks cover large area in the southern part of the district. Marwar Super group of rocks occupy maximum geographical area covering the central, western and eastern part of the district. The rock units of various formations belonging to Cenozoic era occupy very small area and lie in the north-western part of the district. In the entire district, hard rocks are overlain by thin blanket of alluvium and wind blown sand. The district is traversed by major lineaments: Jaisalmer- Barwani lineaments trending NW-SE, Luni- Sukri lineament trending NE-SW. Following is the regional geological succession of rock types encountered in and around Jodhpur district. The geological succession of Jodhpur district is given in Table 5.

Table 5: Geological Succession of Jodhpur district

Super Group	Group/ Series	Formation
Quaternary	Recent to Sub-Recent	Alluvium and blown sand
Permo-Carboniferous	Bhadaura Series (Bap boulder bed)	Boulders, sand and clays
Marwar	Nagaur Group	Sandstone, Gypsum, siltstone and limestone
	Bilara Group	Limestone, cherty and dolomitic with
	Jodhpur Group	Sandstone and shale
Post Delhi	Malani suites	Rhyolite with tuffs and granite
	Jalore granite	Granite and Gneiss
Delhi		Schist and Phyllite

2.2 Hydrogeology

Ground water occurs under unconfined to semi-confined conditions in rocks of Delhi Super Group, Jodhpur Sandstone, Bilara Limestone Nagaur Sandstone, Lathi Sandstone and unconsolidated sediments (valley fills and alluvium). These form the chief source of ground water in the district. Confined conditions are also met sometimes at deeper levels in the northwestern part of the district. The principal aquifer map of Jodhpur district is depicted in figure 3.

Sandstone aquifer covers 12602 sq km (56.63%) and found in Osian, Bawri, Balesar, Shergarh, Phalodi and Bap blocks of Jodhpur district.

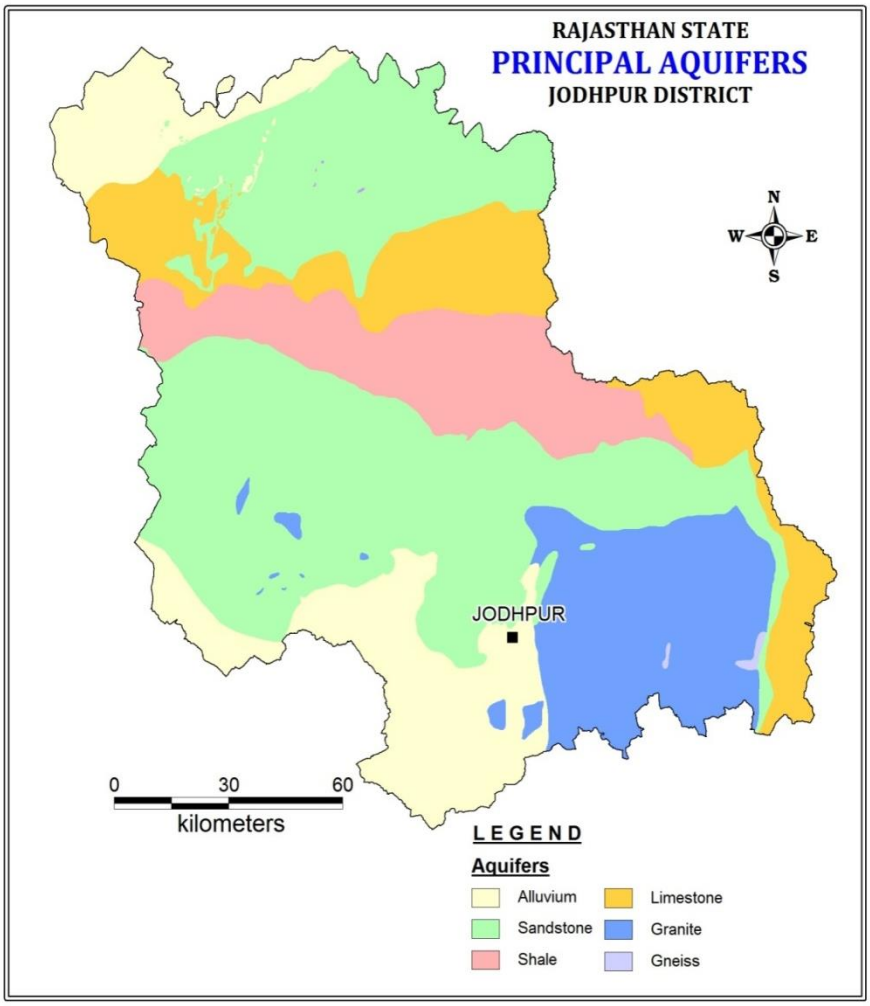

Figure 3 Principal Aquifer map of Jodhpur district

Ground water occurs under unconfined to semi-confined conditions in rocks of Delhi Super Group, Jodhpur sandstone, Bilara limestone, Nagaur sandstone, Lathi sandstone and unconsolidated sediments (valley fills and alluvium). These form the chief source of ground water in the district. Confined condition is also met sometimes at deeper levels in the northwestern part of the district. Hydrogeological map of the district is presented in Figure 4.

Delhi Super Group: Rocks comprising of schists, phyllites, slates and quartzites form aquifer in isolated patches in small area in south-eastern part of the district. These patches occur within the granitic terrain. These generally form poor aquifer. Ground water occurs under unconfined condition in weathered mantle and fractured zone. Yield of existing open wells generally varies from 30 to 90 m^3/day and discharge of bore wells is also very poor (below 160 lpm).

Granites and Rhyolites: Granites and rhyolites covering a vast area in the southern part of the district, form poor aquifers. Ground water occurs under unconfined conditions in secondary spaces in weathered and fractured zones. The fractures tend to die out with depth. Yield of open wells in these formations varies from 10 to 50 m^3/day. Yield of wells tapping good weathered

zone in granites is up to 80 m^3/day. Dug-cum bore wells and bore wells in favourable selective locations can yield up to 120 m^3/day.

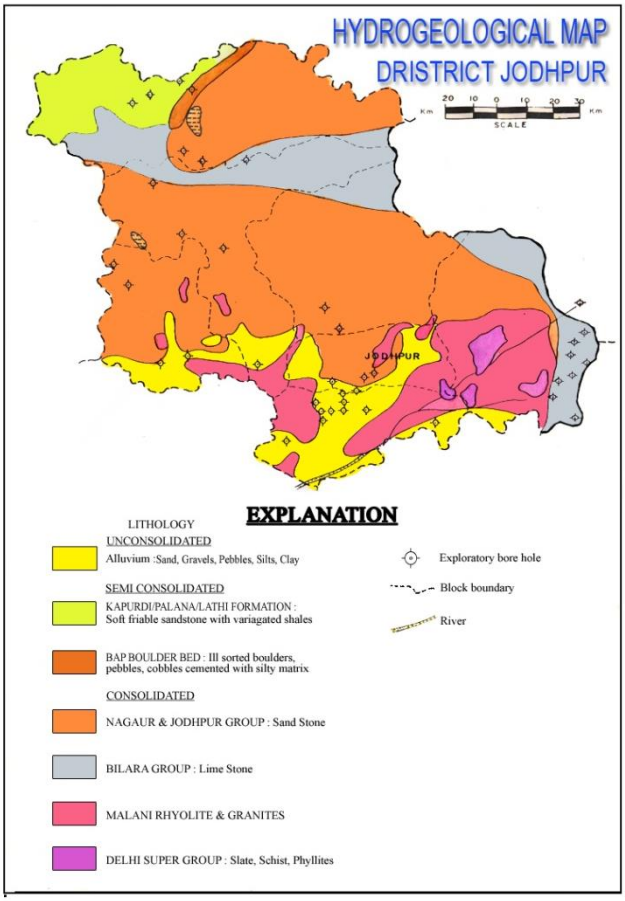

Figure 4: Hydrogeological map of Jodhpur district

Jodhpur and Nagaur Sandstone: Jodhpur and Nagaur sandstones form aquifer over a large area in central and northern parts of the district. These cover maximum area among all aquifers. These are generally hard and compact layered rocks with intermittent shale and clay layers. Softer and friable sandstone layers and patches do occur in these formations making it a good yielding aquifer tapped by open wells and bore wells. Sandstone is fine to medium grained, sometimes coarse to gritty and friable. In such formations, friable and soft nature often leads to formation of small cavities in saturated zones. This makes it a very good aquifer forming chief source of ground water in the area. A large number of light to medium duty bore wells have been constructed in such areas for irrigation and water supply purposes. In the central part of the district, ground water occurring in this formation is generally free from salinity problem. Ground water in sandstone occurs under unconfined to semi-confined conditions. Open wells tapping sandstone generally yield low to moderate quantity of water with yield varying from 30 to 180 m^3/day. Bore wells tapping saturated zones down to depth of 200 m yield 7 to 55 m^3/hr water with 5m to 8m drawdown.

Bilara limestone: Bilara limestone is the most potential aquifer in the district. The limestone exposures are found between Khawaspura & Bilara in eastern part of the district and between Phalodi & Chadi in northern part. Siliceous and cherty limestone and dolomites with association of shale beds are quite common. In Borunda - Bilara area, limestone is mostly dolomitic, grey to dark grey at places, inter bedded with thin cherty layers. In Chadi - Phalodi area, limestones are predominantly cherty or siliceous. Further north-west of Phalodi, limestone is overlain by thick cover of shale. In Borunda - Ransigaon - Bilara area, limestone shows steep dips and pitching folds. These beds are highly crumpled and show development of caverns formed due to solution activities. In Phalodi - Chadi area, limestone are not so much disturbed having low angle of dip towards north and show development of caverns to lesser extent. Thickness of limestone varies from a few meters to more than 100 m. The yield of wells in both the areas varies largely because of considerable variation in limestone characters. In Phalodi area, yield of wells generally lies between 10 & 40 m^3/hr for 2 to 9 m drawdown. In Borunda - Bilara area, discharge of wells varies from 12 to 272 m^3/hr with a drawdown in the range of 3 to 16 m.

Bap boulder bed: Bap boulder bed occurs in narrow stretch in northern part of the district having NE-SW extension. It consists of ill-sorted boulders, pebbles, cobbles embedded in silty matrix. Ground water occurs under unconfined condition. Wells in this formation yield meager quantity of water, which is saline.

Paleocene and associated formation: Semi-consolidated formations comprising of soft, friable sandstone, grit and conglomerate ranging from Permian to Paleocene age form aquifer in extreme north- western part of the district. There is association of varying amount of shales and clays with the above sediments, which causes great variation in the yield of wells. Among semi-consolidated formations, Lathi sandstone does not form prominent aquifer in the district. Yield of wells varies largely but generally lies in the range of 15 to 60 m^3/hr. There is also quality zonation due to intermittent shale/clay layers.

Unconsolidated sediments: The unconsolidated Quaternary sediments comprising of alluvium, valley fills and aeolian sands form important aquifers in some parts of the district mainly in Shergarh, Luni and Bilara blocks. In major part of the area, these sediments occur as thin blanket over the older sediments but in certain areas, they are upto 70 m thick and as such form aquifers. In a narrow strip extending east-west wards between Shergarh- Balesar- Agolai-Doli- Jodhpur, alluvium forms aquifer. Thickness of alluvium varies from 47 to 69 m in this area. Yield of open wells varies from 20 to 100 m^3/day in alluvium. Yield of exploratory tube wells constructed in alluvium ranges from 22 to 55 m^3/hr. In Shergarh and Balesar, yield of tube wells tapping valley fills varies from 20 to 36 m^3/hr. Thickness of alluvium in southern part of the district along the course of Luni river and its tributaries is comparatively less and water is generally brackish.

The Aquifer Disposition Based on Surface Geophysical Investigation and Lithology of Bore Wells is given in Figure 5.

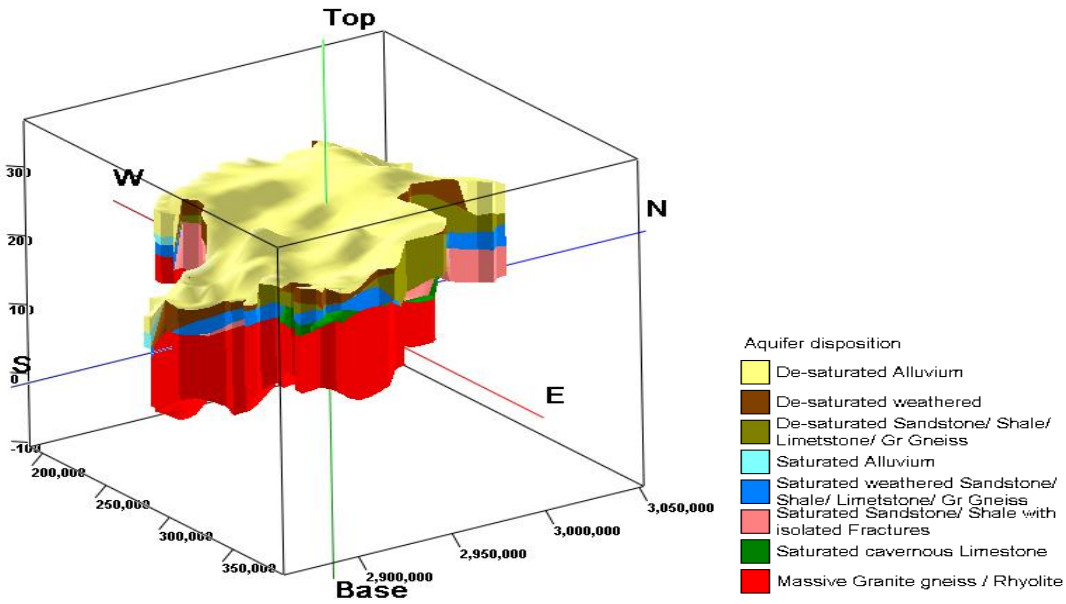

Figure 5: Aquifer disposition (Based on surface geophysical investigations & lithology of bore wells)

A total of 159 no. of bore holes have been drilled in different parts of the district. The depth of bore holes varies from 50 to 270 m. Discharge of tube wells varies from meager to 4542 lpm. Based on the selected available data from exploratory wells various cross sections depicting the aquifer disposition along with aquifer saturation and quality maps using Rockworks software have been prepared which are shown below in figures 6 to 8.

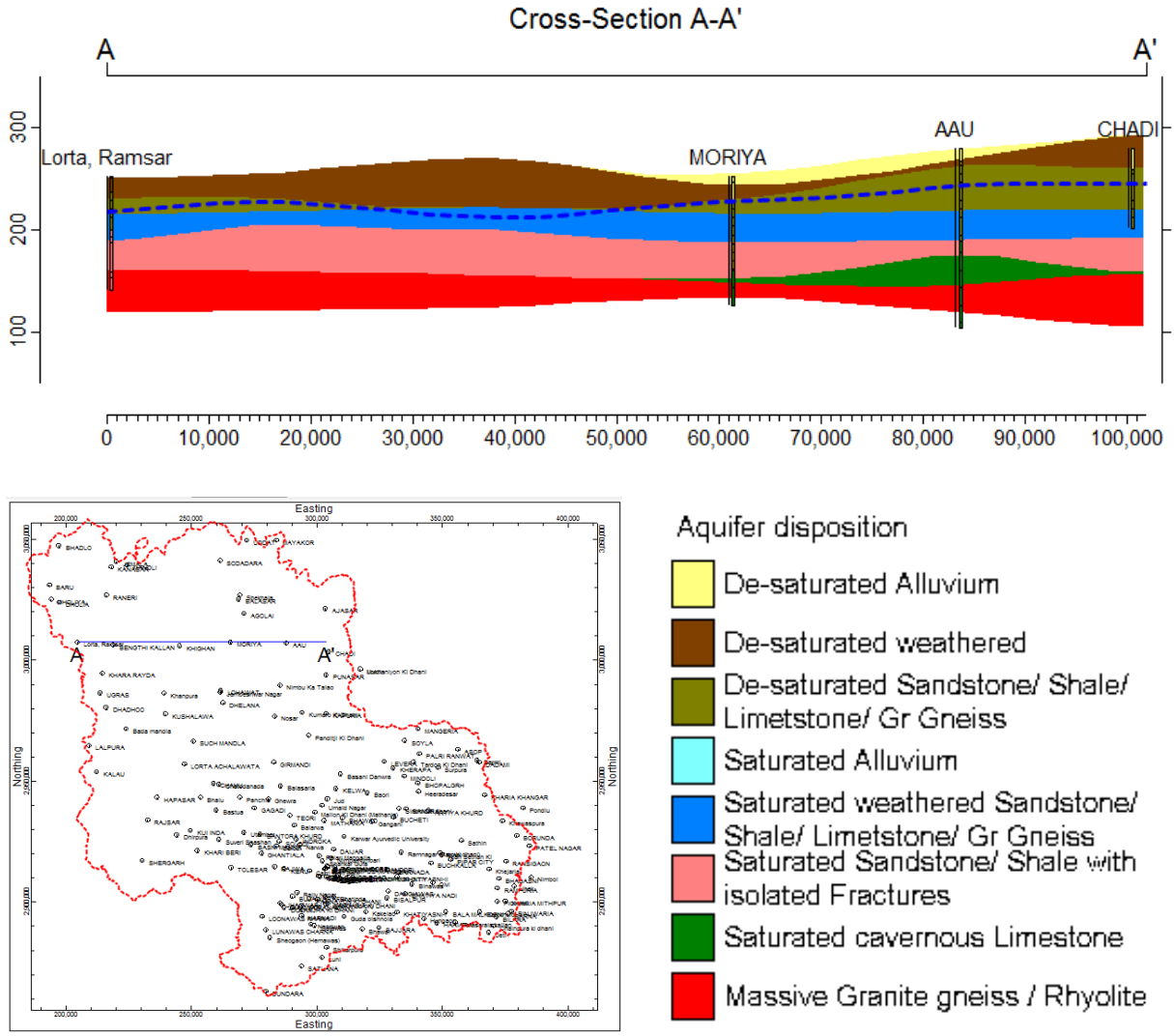

Figure 6: Cross Section along A-A'

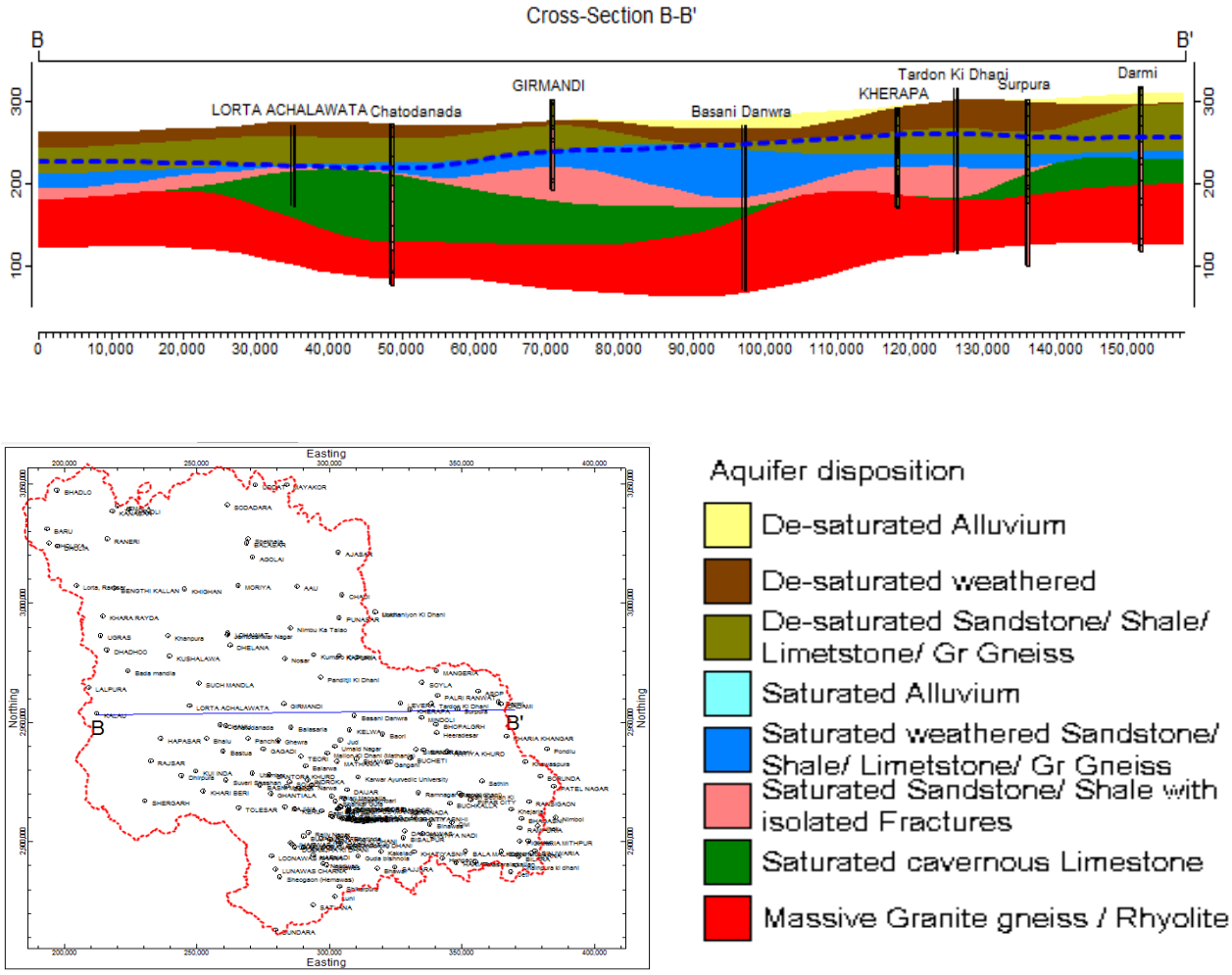

Figure 7: Cross Section along B-B'

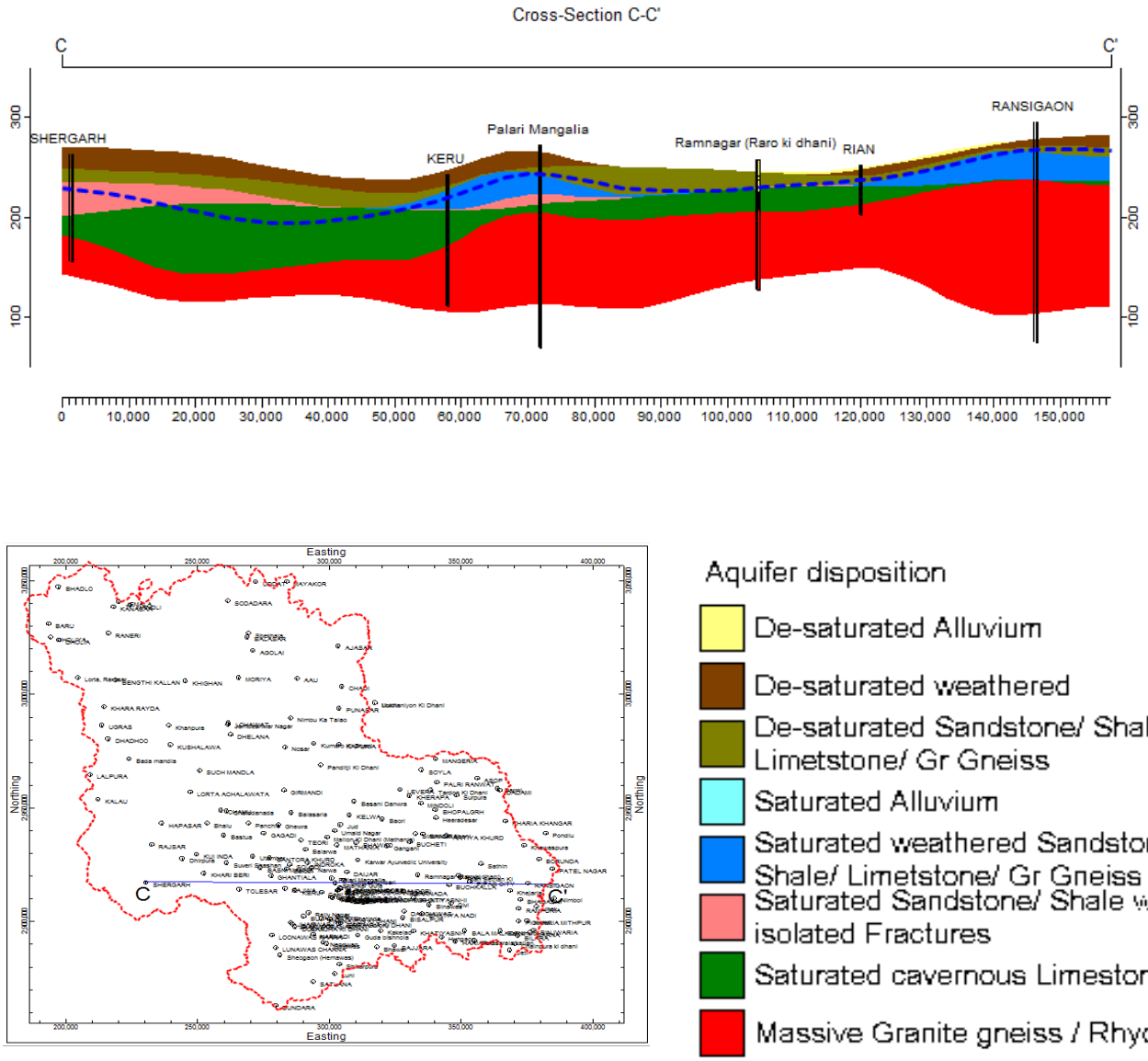

Figure 8: Cross Section along C-C'

2.3 Water table Elevation

Based on the available data the water table elevation map has been generated with the help of Rockworks software and shown in figure 9. As per the map the elevation of water table in the area ranges between 140 to 280 m amsl. Highest elevations of water table of nearly 280 m amsl in the north west part of the district while the lowest 140 m amsl in south east part of Jodhpur district.

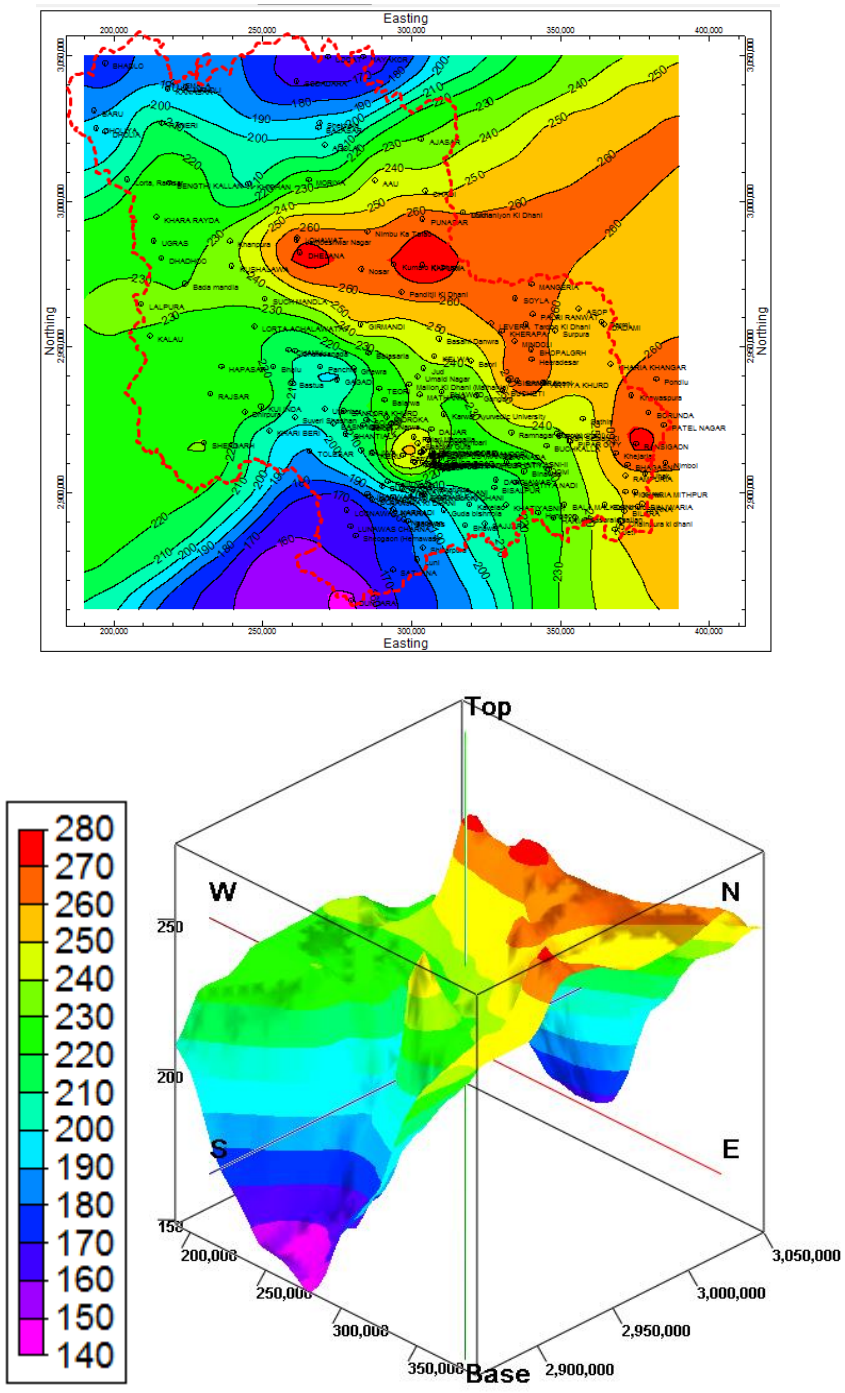

Figure 9: Water Table Elevation

2.4 Depth to Water Level

The depth to water level in the district generally ranges from less than 1m to more than 100 m below ground level (mbgl). It varied from and 0.01 to 82.51 m during pre-monsoon (May, 2015). Depth to water level in major part of the district varied from 20 m to more than 40 m bgl except for parts of Luni, Mandore, Bilara, Osian, Bhopalgarh and Bap blocks where shallower water levels upto 20 m bgl were observed (Figure 10).

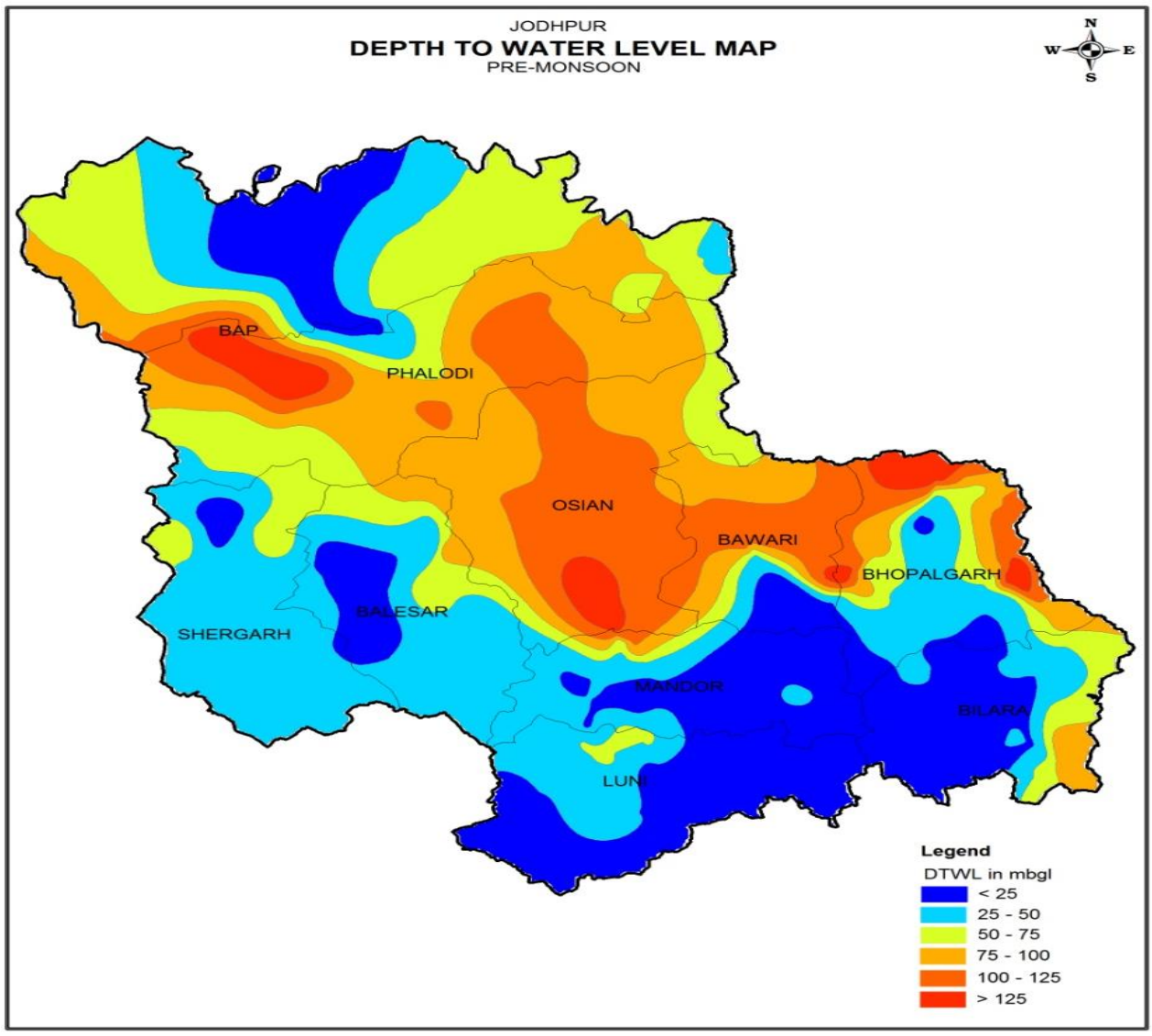

Figure10: Pre monsoon water level map of Jodhpur district

During post monsoon (November, 2012), depth to water level varied from 0.01 to 114.9 m bgl. Shallow water level upto 20 m bgl has been observed in western half of Bap, central part of Osian, southern part of Balesar, southern and eastern parts of Mandore and major parts of Luni and Bilara blocks. Water levels in the remaining areas have been found to be 20 to more than 40 m bgl.

2.5 Ground Water Quality

There is a large variation in chemical quality of ground water in the district depending on the characteristics of water bearing formation, movement of ground water, depth to water levels etc. It is seen that in shallow ground water zone, the electrical conductance varies generally from 570 ms/cm at 25^0C. Highly mineralized ground water occurs in Rann area. The ground water in southern, southeastern, and southwestern parts of the district is saline. In Bap block, northern and western parts have brackish ground water. The electrical conductance is less than 3000ms/cm at 25^0 C in major part of the district. In the central part of the district where sandstone forms the aquifer, electrical conductance generally varied from less than 1000 to 2000 ms/cm at 25^0 C.

Fluoride concentration in ground water was found to vary between 0.124 mg/l at Rohila Kalan, Osian to 2.552 mg/l at Nandwan, Mandore. Fluoride content in excess maximum permissible limit of 1.5 mg/l has been reported from major parts of the district covering western halves of Bap, Balesar and Phalodi blocks, major part of Shergarh block, eastern and southcentral parts of Osian block, southwestern part of Mandore block, northwestern, southwestern and southeastern part of Luni block, northern part of Bhopalgarh and eastern and western part of Bilara block. Nitrate concentration in ground water varied from 8 mg/l at Balesar to 199 mg/l at Baori, Osian. Exceptionally high concentration of 536 mg/l was observed at Mandore. Nitrate in excess of maximum permissible limit of 45 mg/l has been reported from parts of Osian, Bhopalgarh, Mandore and Luni blocks.

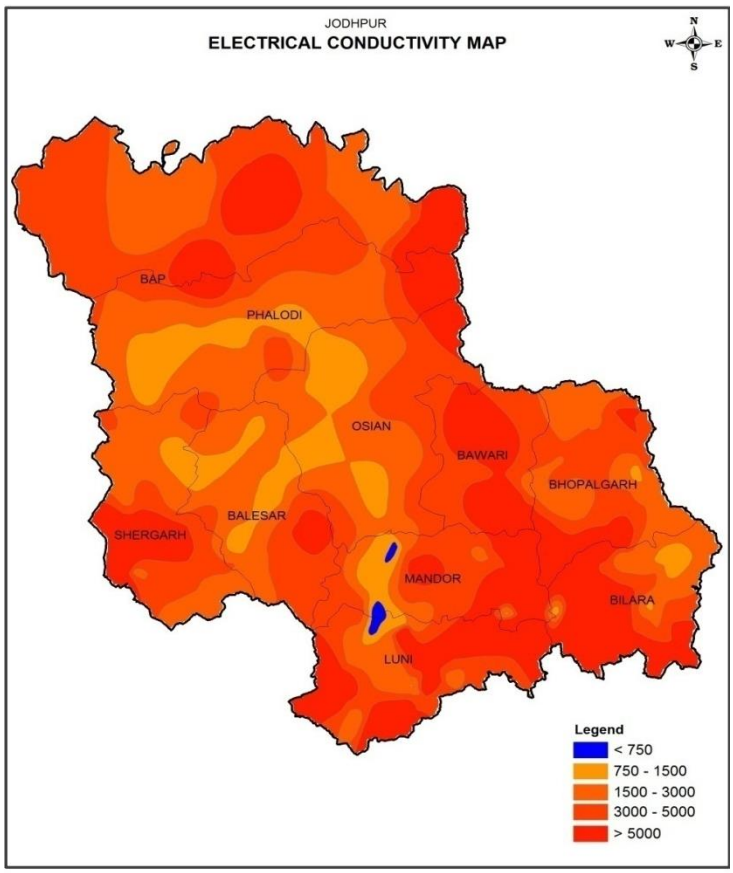

Figure 11: Iso Electrical Conductivity Map

3.0 Ground Water Resources

Groundwater resources have been reassessed as on 31.3.2013 based on Groundwater Estimation Committee (1997) and are given in Table 6.

Table 6 Groundwater resource, Draft and stage of development (as on 31.03.2013)

BLOCK	AREA IN Sq.Kms.	POTENTIAL ZONE AREA IN Sq.Km.	TOTAL ANNUAL G.W RECH. IN MCM	NATURAL DISCH. DURING NON MONSOON IN MCM	NET ANNUAL G.W AVAIL ABILITY IN MCM	Existing Gross Ground Water Draft for Irrigation	Existing Gross G.W. Draft for Dom. & Ind. Use	Existing Gross Ground Water Draft for all uses	Allocation for Dom. & Ind. Requirement	Net G.W. availability for future irrigation Dev.	Stage of G.W. Development	CATEGORY
BALESAR	1888.25	1503.03	25.6388	2.5639	22.0445	50.8594	10.4	61.0694	10.4000	0	277.03	OVER EXPLO.
BAORI	1387.33	1387.33	32.8707	3.2871	28.4425	118.54875	22.464	85.39815	22.464	0	300.25	OVER EXPLO.
BAP	4393.31	3586.92	63.0015	6.3002	64.8397	29.0664	10.5920	39.6584	10.5062	25.2671	61.16	SAFE
BHOPALGARH	1757.69	1718.69	56.9810	5.6980	50.6564	105.9445	10.4124	116.3569	10.3074	6.7607	229.70	OVER EXPLO.
BILARA	1504.33	1234.20	47.4325	4.7432	40.3010	100.8409	8.0174	108.8583	8.7488	3.8101	270.11	OVER EXPLO.
LUNI	1978.95	758.78	23.3537	2.0600	22.4102	12.3400	1.0980	13.4380	5.6160	4.4542	59.96	SAFE
MANDORE	1260.96	1165.19	29.2687	2.9268	26.6456	39.8272	3.0136	42.8408	3.1812	1.6477	160.78	OVER EXPLO.
OSIAN	2861.07	2861.07	59.0402	5.9040	54.1478	174.2298	59.7840	234.0138	59.7840	0.0000	432.18	OVER EXPLO.
PHALODI	3118.13	3118.13	51.2995	5.1300	54.2680	93.8160	32.2800	126.0960	32.2800	0.0000	232.36	OVER EXPLO.
SHERGARH	2099.98	1534.58	40.6384	3.7779	32.5675	50.6190	17.4500	68.0690	15.8618	9.1518	209.01	OVER EXPLO.
G. TOTAL	22250	18867.92	429.5249	42.3911	396.3234	776.0920	175.5114	895.7988	179.1494	51.0916	226.03	OVER EXPLO.

Groundwater resources estimation data of Jodhpur district shows that net ground water availability is 776.0920 (MCM) whereas ground water draft for all purposes is 179.1494 (MCM). In Jodhpur district 08 blocks are fall under overexploited category and 02 blocks are safe. The stage of groundwater development in the district is 226.03%.

4.0 Ground Water Related Issues & Problems

Major part of the district is covered by hard rock formations such as Jodhpur sandstone, Malani rhyolites, granites, and Delhi Super Group metamorphics. These formations have poor water yielding capacity. Also such areas suffer from water quality problems and in some of the areas ground water is highly saline. Villages located in such areas have the basic problem of drinking water scarcity and the situation becomes very critical in summers and in drought years.

Another problem of concern in the district is that most of the potential zones have registered heavy ground water development causing lowering of water table and drying up of a large number of shallow wells or reduction in their yields. Heavy decline of more than 15 m observed in Tinwari- Mathania, Bilara, Ransigaon- Borunda area, part of Bhopalgarh area during last 10 years.

Jodhpur is the second largest urban agglomerate of the State and has a developed industrial center. The textile processing and stainless steel re-rolling industries generate industrial waste effluent, which contains toxic elements. These industries are located in Basni industrial area of Jodhpur city. The combined industrial effluents are carried through drainage and discharged in the river Jojri having its course south of city. Industrial effluents have caused ground water pollution in downstream of the river in villages viz. Salawas, Nandwan, Bhandu Kallan etc. which is harmful for irrigation also. Suitable measures are also required to be adopted to tackle the rising water level problem observed in the Jodhpur city during last few years.

5.0 Management Strategies

Due to over development, further exploitation of precious resource must be checked. For sustainable development of ground water, artificial recharge measures to be employed to augment ground water and surface water resources. Exploratory drilling results show potential zone having inferior quality water, which can be blended with fresh water for irrigation use.

Table 7: Supply Side Management

Block	Potential Zone Area (Sq. Km)	Surplus Available in Zone (mcm)	Surplus Available as per the Water Level (mcm)	No of Rs 0.03 mcm/ Shaft	No of Shafts possible in block (as per water bodies)
Balesar	1823.84	0.6181	0.6181	21	18
Baori	1357.17	0.4599	0.4599	15	15
Bhopalgarh	1662.83	0.4888	0.4888	16	16
Bilara	1623.81	0.3614	0.3614	12	12
Mandor	1607.91	0.5143	0.5143	17	17
Osian	1823.52	0.6180	0.6180	21	18

Shergarh	1816.75	0.6157	0.6157	20	1
Total	11715.83	3.6762	3.6762	122	97

The area has undergone polyphase deformation in geological past, which has resulted in a complex structure (folded, faulted and jointed) that may not be conducive for such structures. Therefore, site of these structures should be selected carefully. The groundwater can also be recharged by use of sprinklers. The description of sprinkler and estimated cost are mentioned in the table 8.

Table 8: Demand Side Management

Block	**Irrigated Area (ha)**	**Water Saving by Sprinkler in mcm @ 0.08 m**	**Water Saving by Change in Cropping Pattern in mcm @ 0.1m**	**Total Water Saving (mcm)**
Balesar	25613	10.25	1.39	11.64
Baori	24836	9.93	2.27	12.20
Bap	33039	13.22	2.52	15.74
Bhopalgarh	16355	6.54	4.04	10.58
Bilara	12579	5.03	6.75	11.78
Luni	3868	1.55	1.21	2.76
Mandore	3876	1.55	2.25	3.80
Osian	54489	21.80	9.08	30.88
Phalodi	120205	48.08	1.87	49.95
Shergarh	23048	9.22	1.66	10.88
Total	317908	127.16	33.05	160.21

The above study have shown that surplus water available for the ground water recharge is 3.67 mcm and recharge shaft 97 nos are required for the percolation of surface water to underground. The surplus water can be used for recharge through this net groundwater saving would be 160 mcm and total cost of proposed intervention is nearly 05 crore.

The water saving of the Jodhpur district can be done by change in cropping pattern and advance irrigation practices. Irrigated area to be brought under irrigation by sprinkler – 1589 sq km and net Water saving - 127 MCM (20% of crop water requirement). The expected cost for sprinklers – Rs 795 crore @Rs 50,000 per hectare. Similary if cropping pattern changes from wheat to gram in 330 sq km irrigated area than net water saving would be 33 mcm and total water saving will be nearly 160 mcm. And expected cost of the project is 795 crores.

The expected outcomes after implementation of the above suggested various methods are shown in table 9.

Table 9: Expected Outcome of project

Block	Existing G.W. draft for all purposes	Ground water savings through RWH & AR projects (mcm)	Net G.W. draft after intervention	Percentage stage of G.W. Development	Projected stage of G.W. development
Balesar	61.06	11.64	49.42	277.03	218.07
Baori	85.39	12.20	73.19	300.25	253.23
Bap	39.66	15.74	23.92	61.16	36.89
Bhopalgarh	116.35	10.58	105.77	229.70	161.90
Bilara	108.85	11.78	97.07	270.11	190.27
Luni	13.43	2.76	10.68	59.96	47.65
Mandore	42.84	3.80	39.04	160.78	95.65
Osian	234.01	30.88	203.13	432.18	370.91
Phalodi	126.10	49.95	76.15	232.36	140.31
Shergarh	68.06	10.88	57.18	209.01	209.75
Total	895.75	160.21	735.55	223	121

If we use the above suggested method for the ground water conservation and recharge then the stage of ground water development decrease successively from 223 % to 121 %. Similarly if cropping pattern changes from wheat to gram will not affect farmers economy and sustainable ground water supply will be maintained and the details of change in cropping pattern is mention in the table 10.

Table 10: Water saving by Change in cropping pattern (Wheat to Gram)

Irrigated Area (ha)	Irrigated Area (ha) under wheat proposed for Gram cultivation	Production of wheat (ton)/ha	Production of gram (ton)/ha	Unit cost (Rs) of wheat /ton	Unit cost (Rs) of gram /ton	Market value (Rs) of wheat (ton)/ha	Market value (Rs) of gram (ton)/ha
317908	67555	5	1.5	16000	53000	80000	79500