भारत सरकार

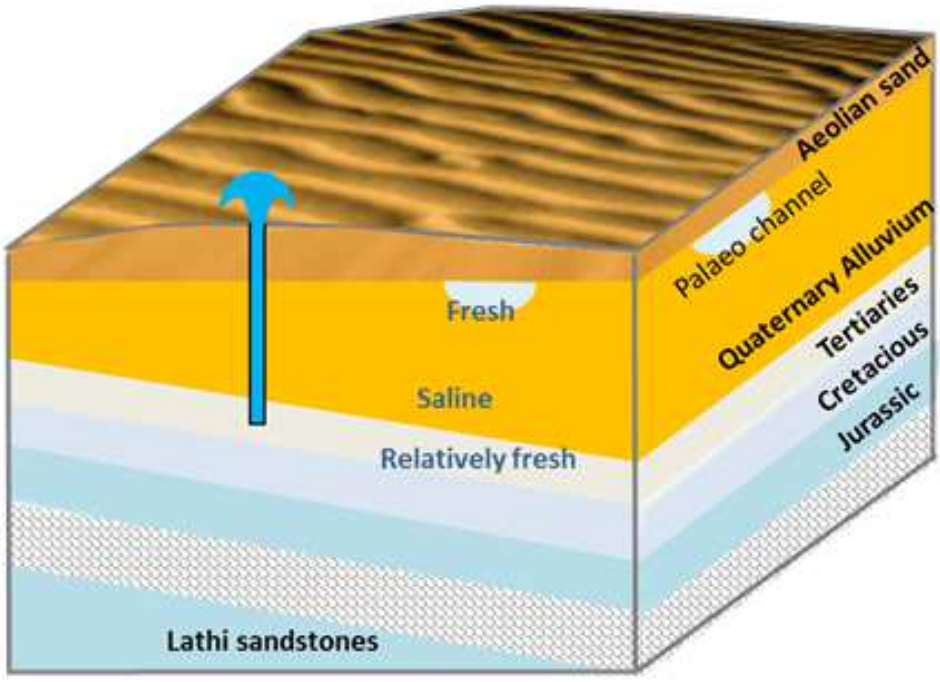
जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

केंद्रीय भूमि जल बोर्ड

GOVERNMENT OF INDIA

MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVINATION

CENTRAL GROUND WATER BOARD



प्रायोगिक जलभृत मानचित्रण परियोजना का प्रतिवेदन

थार रेगिस्तान क्षेत्र, जैसलमेर जिला राजस्थान

REPORT ON PILOT PROJECT ON AQUIFER MAPPING IN THAR DESERT, JAISALMER DISTRICT, RAJASTHAN

पश्चिमी क्षेत्र, जयपुर WESTERN REGION, JAIPUR

दिसम्बर -2015 December-2015

K. B. Biswas
Chairman

सत्यमेव जयते

केन्द्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास
एवं गंगा संरक्षण मंत्रालय
भारत सरकार
नई दिल्ली

Central Ground Water Board
Ministry of Water Resources,
River Development and Ganga Rejuvenation
Government of India
New Delhi

FOREWORD

Increasing development of ground water to meet the requirements of various segments has resulted in the over-exploitation of this vital natural resource in parts of the country and consequent adverse environmental impacts include, deepening water levels and drying up of shallow wells, reduction in sustainability of wells and seawater ingress in coastal freshwater aquifers. Contamination of ground water due to natural and anthropogenic causes has also increased substantially in the recent decades. The anticipated impact of global warming and climate change are also considered to add to further complicate the issues plaguing the water resources sector in India in the not so distant future. Sustainable development of ground water through judicious management interventions becomes very important to ensure the water security of the future generations.

It is in this context that the Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India decided to take up the National Aquifer Mapping and Management (NAQUIM) Programme, aimed at detailed and systematic study of the major aquifer systems in the country and formulation of management plans for sustainable development of their ground water resources. The Programme envisaged various activities such as compilation of all available data, analysis of data gaps and generation of additional data to fill them, preparation of detailed aquifer maps and formulation of management plans. Various conventional and modern techniques of field data generation, data processing and analysis including integration of data on a GIS platform and numerical groundwater modelling were expected to be used for the programme.

With a view to understand the applicability and efficacy of the above-mentioned techniques in different hydrogeological settings, pilot projects on aquifer mapping were taken up in Six different Hydrogeological terrains in the states of Bihar, Rajasthan, Maharashtra, Karnataka and Tamil Nadu.CSIR-NGRI was engaged as a consultant by CGWB to facilitate use of advanced geophysical techniques in the programme. During the course of the study, groundwater issues have been identified by CGWB specific to the area. With inputs from aquifer mapping studies, aquifer response models have been formulated and various strategies have been tested to arrive at optimal aquifer management plan for sustainable management of precious resources.

This is one among the six reports being brought out based on the studies taken up in the pilot projects. The findings are brought out in the report very coherently and I would like to place on record my appreciation for the excellent work done by the team. I fondly hope that this report will serve as a valuable guide for sustainable development of ground water in the area.

K.B.Biswas
Chairman

18/11, Jamnagar House, Mansingh Road, New Delhi-110011
Phone : (011) 23383561 Fax : 23382051, 23386743
E-mail : chmn-cgwb@nic.in Website: www.cgwb.gov.in, www.mowr.gov.in

Preface

The Central Ground Water Board carried out the Pilot Project on Aquifer Mapping in 6 different hydrogeological environs of the country during 2011-12 to 2014-15 with active support and funding from the World Bank. The Ramgarh Area in Jaisalmer district of Rajasthan was selected as the type area for study of aquifers in "Desert Environment"

During the project period, available data was compiled, data gap analysis was carried out and data generated to fill these gaps. Extensive hydrogeological surveys were carried out including village wise well inventory, water level and water quality monitoring, collecting hydrogeological information through well drilling, pumping tests, slug test, infiltration tests, etc. Geophysical studies were done both by CGWB and CSIR-NGRI. The geophysical studies included, Vertical Electrical Soundings, ERT, Ground TEM and SkyTem. Advance geophysical techniques of heli-borne sky-TEM surveys were carried out by CSRI-NGRI, Hyderabad in association with Aarhus University, Denmark and SkyTEM (STS), Denmark.

All the data collected using various techniques was studied and synthesized in the form of 3 dimensional aquifer maps incorporating the various attributes of the aquifer system. Based on the 3D aquifer maps and analysis of data, Aquifer Management Plans were prepared.

Apart from the efforts made by the officers and staff members of CGWB, there was significant contribution from the scientists of CSIR-NGRI and Ground Water Department, Rajasthan. Sincere efforts of Shri Rana Chatterjee, Scientist D and nodal officer of the project and the entire project team in bringing this project to a fruitful end and compilation of this report are thankfully acknowledge.

I am sure that this report would form a good basis for any aquifer management studies, including the National Aquifer Mapping and Management Programme (NAQUIM), in similar terrains.

(P.K. Parchure)

Regional Director

ACKNOWLEDGEMENT

Er. K. B. Biswas, Chairman, CGWB, Faridabad is sincerely thanked for spearheading this flagship project of MoWR, RD & GR, Govt. of India.

Sincere thanks is also expressed to Dr. S. C. Dhiman, Sh. Sushil Gupta and Dr. R. C. Jain former Chairmans, CGWB, Faridabad under whose tenure the project was conceptualized and initiated. The guidance of Sh. K. C. Naik, Member (SAM), and of former Members of CGWB, Dr. S. Kunar, Dr. Varadaraj and Dr. R. C. Jain, Asish Chakrabarty, is gratefully acknowledged.

The time to time support and scientific guidance during the project work extended by the expert team of officers from CGWB, CHQ, Faridabad especially Dr. Sunil Kumar, Regional Director & then Director (admin), Sh. Sanjay Marwah, Regional Director, Dr. S. Suresh, Scientist D , Sh. S. K. Sinha, Scientist D, Er. K.R. Biswas, S.E., Er. Nidhish Verma, Ex.En. , Sh. K. V. Kumar, Superintending Geophysicist (Retd.), Sh. Madhukar, Superintending geophysicist, Sh. Pankaj Kumar, Assistant Hydrogeologist, is gratefully acknowledged. Thanks are also due to the team of officers Dr. Subhash Chandra, Dr. Sahebrao Sonkamble, N.C.Mondal, Dr. Murlidharan from NGRI, Hyderabad under the competent leadership of Dr. Sakeel Ahmad, Chief Scientist, NGRI for providing useful geophysical input for compilation of this report.

The authors express sincere thanks to World Bank and its representatives, especially Dr. Anju Gaur and Sh. B. Jayakumar and Dr. P.C. Chandra, the Consultants, World Bank for valuable guidance. Thanks are also due to the senior officers of MoWR, RD& GR including Sh. Avnish Kant, Scientist for coordinating the project from the beginning to the end.

The expert and consultants from Aarhus University, Denmark and SkyTEM team members are also acknowledged for their valuable cooperation to this project.
The support and technical input from the colleagues of Central Ground Water Board, Western Region, Jaipur and State Unit Office, Jodhpur is gratefully acknowledgement.

The authors sincerely thanks to all nodal officers of the other four pilot projects and officers concerned for the technical discussions and inputs during the meetings.

Thanks are also due to various State and Central Govt. agencies viz., GWD, Water Resources Department, Jodhpur, GSI, Jaipur, Irrigation Department, Jaipur, Agriculture Department, Jaipur and SRSAC, Jodhpur for providing valuable data and suggestions. Special thanks are due to Sh. N.K. Vaishnav and Dr. N.D. Inakhiya, GWD, Jodhpur and Jaisalmer district, respectively. Sh. Sh. Chattar Singh Jam, Sambhav organization, Jaisalmer district have been instrumental in demonstrating the traditional water management practices in desert terrain. The input from Sh. Chattar Singh is gratefully acknowledged.

Last but not the least, sincere thanks is expressed to every person involved in this project and the villagers from project area

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ABBREVIATIONS

CGWB	Central Ground Water Board
cm	Centimetre
DES	Department of Economics & Statistics
Ham	Hectare metre
Heli-TEM	Heliborne Transient Electro Magnetic Method
IMD	India Meteorological Department
LCI	Laterally constrained inversion
Lps	Litres per second
M	Meter
m bgl	Meter below ground level
m ham	Million hectare metre
M.I.	Minor Irrigation
mcm	Million cubic metre
mm	Millimetre
MOWR	Ministry of Water Resources, Govt. of India
NGRI	National Geophysical Research Institute
SCI	Spatially constrained inversion
sq.m.	Square meter

EXECUTIVE SUMMARY

The aquifer mapping project in Ramgarh area, Jaisalmer district, Rajasthan, India was taken up with the objective to evolve an aquifer management plan in an arid desert terrain in the western India. The project study involves establishing the aquifer disposition and its characterization at 1:50,000 scale using latest state of art technology in the field of hydrogeology and geophysics and recommending aquifer management plan.

The total study area of the pilot aquifer mapping project is about 675 sq.km. The area is around Ramgarh town, located in Sam Panchayat Samiti (block), Jaisalmer district, in Western Rajasthan. The aquifers in the project area are mainly sedimentary rocks of calcareous-argillaceous-arenaceous nature of Tertiary and Mesozoic era. Aquifers are encountered at the depths of 45 to 70 m and 125 to 160 m. These are unconfined to semi-confined in nature. Water quality is around EC 3500-4000 micromhos/cm. Ground water level around Ramgarh area is about 30 to 40 m bgl. However, in the area lying south of Ramgarh, water level is comparatively deeper and goes even beyond 100 m bgl at places. The other major source of water is IGNP canal.

The aquifer disposition and characteristics prevailing in the area has been studied based on exploratory drilling tapping individual aquifers. Infiltration tests were carried out to estimate the recharge rate of the aquifers. Monthly monitoring is carried out to decipher the ground water flow pattern. Geophysical studies were carried out using ground TEM and Sky TEM techniques. Studies were also carried out on the participatory water management being practiced in the area by the stakeholders at grass root level. Ground water is stored in perched aquifers and being utilized through shallow well called *beri.* The system provides effective water management option in the desert terrain.

The study recommended development of holistic water management programme which involves - replication of traditional water management practices and controlled use of available fresh water resources.

1. INTRODUCTION

Government of India has launched National Aquifer Mapping programme for aquifer based Sustainable Groundwater Management Plan of India. It requires a comprehensive country-wide aquifer map at village or micro-watershed level. It is a holistic multi-disciplinary scientific approach for aquifer characterization.

Towards this, pilot projects on Aquifer Mapping were taken up in different hydrogeological set-up across the country (Figure 1). The main objective of the pilot project on aquifer mapping study is to establish the methodology and technology and the scope of up scaling for the forthcoming countrywide National Aquifer Mapping Programme.

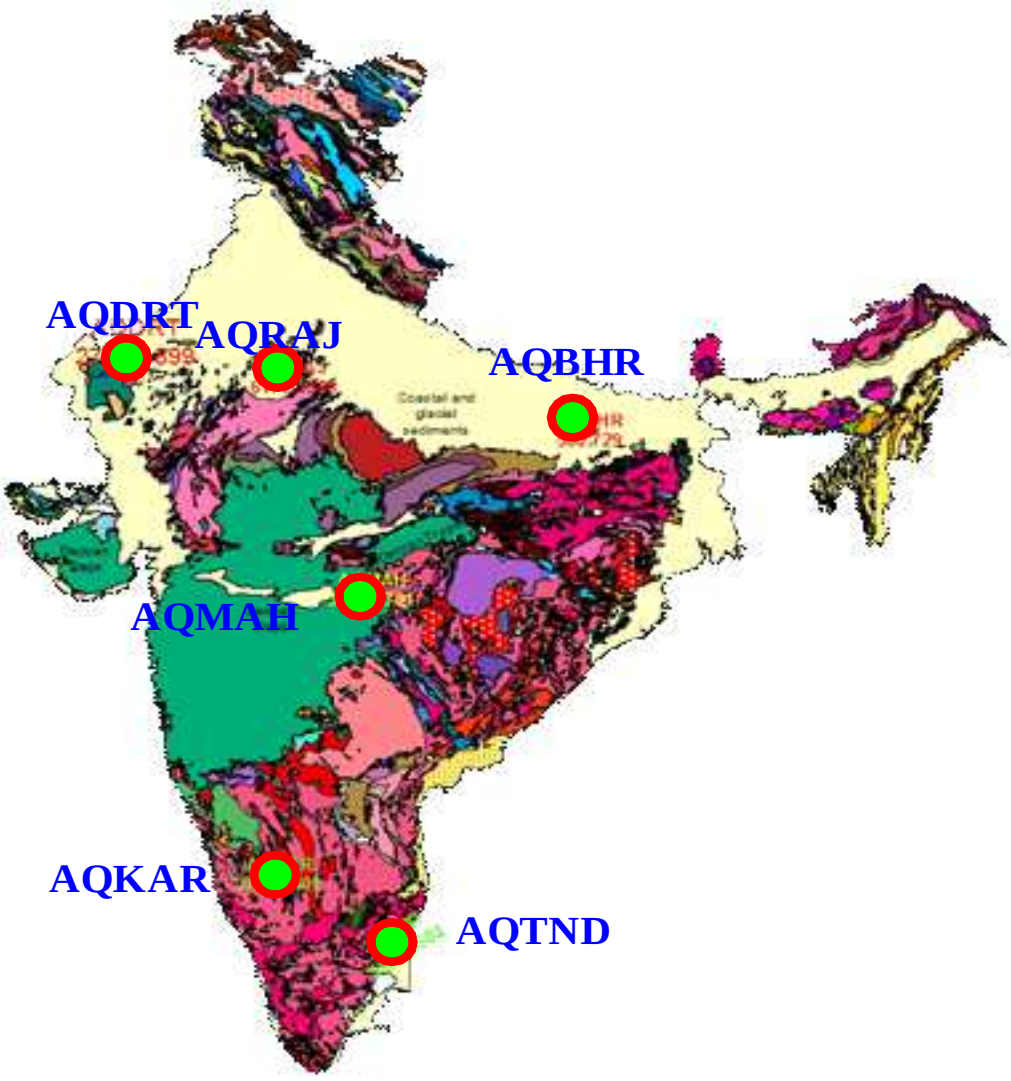


Figure 1. Locations of Pilot Aquifer Mapping project areas: Rajasthan, Desert Area, Maharashtra, Karnataka, Bihar, and Tamil Nadu

1.1 OBJECTIVES & SCOPE:

The objectives of the pilot project are -

i. To define the aquifer geometry, type of aquifers, ground water regime behaviours, hydraulic characteristics and geochemistry of Multi-layered aquifer systems on 1:50,000 scale

ii. Intervention of new geophysical techniques and establishing the utility, efficacy and suitability of these techniques in different hydrogeological setup.

iii. Finalizing the approach and methodology on which National Aquifer mapping programme of the entire country can be implemented.

iv. The experiences gained can be utilized to upscale the activities to prepare micro level aquifer mapping.

The activities of the Pilot Project on Aquifer Mapping can be envisaged as follows

1. **Data Compilation & Data Gap Analysis:** One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analysed, examined, synthesized and interpreted from available sources. These sources were predominantly non-computerized data, which was converted into computer based GIS data sets. On the basis of available data, Data Gaps were identified.
2. **Data Generation:** There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys. CSIR-NGRI has been hired as consultant to carry out geophysical studies including advance Heliborne Transient Electro Magnetic Method (Heli-TEM) to delineate multi aquifer system; to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.
3. **Aquifer Map Preparation:** On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference aquifer extremities, quality, water level, potential and vulnerability (quality & quantity).

4. **Aquifer Management Plan Formulation:** A suitable strategy for sustainable development of the aquifer in the area has been evolved based on the acquired data.

1.2. APPROACH

The overall implementation of the project has been carried out by Central Ground Water Board (CGWB), Western Region, Ministry of Water Resources, Govt. of India under Hydrology Project II funded by World Bank.

The project work involves collection of existing data from various sources including CGWB records, State Government agencies, literature available in the libraries and internet, NGO and other sources relevant for the purpose of aquifer mapping and management. Some of the baseline reports on the project area include Status report on search of palaeochannels in Western Rajasthan, CGWB (2002) and District Ground water Brochure (2011).

The data are assembled, analysed, examined, synthesized and interpreted from available sources. These sources are predominantly non-computerized data, which is converted into computer based GIS data sets. Data gap analysis was carried out and additional data are generated through hydrogeological surveys, exploratory drilling, advanced geophysical techniques, hydro-geochemical analysis, remote sensing etc. that broadly describe the aquifer system prevailing in the area.

The project component related to advanced geophysical investigation was outsourced to National Geophysical Research Institute (NGRI), Hyderabad. The Heliborne Geophysical studies would be undertaken by Aarhus University and SkyTEM (STS), Denmark. Rest of the project work was undertaken through departmental workforce.

The integrated database is transformed into aquifer maps in GIS platforms. The understanding on the disposition of aquifers are refined based on the GIS outputs and a conceptual model is developed. The conceptual model is applied to a numerical flow model to determine the overall water budget and generate predictive scenarios based on the proposed aquifer management strategies. Finally, an aquifer management plan is formulated. The following flow chart highlights the broad steps adopted in the pilot aquifer mapping project in Ramgarh area, Jaisalmer district, Rajasthan.

1.3 LOCATION

The original area identified for pilot aquifer mapping project in desert area is around Jaluwala area in Jaisalmer district. However, since Jaluwala area is close to international border, heli-borne geophysical survey would not be possible in the area. Hence, in the meeting taken by Secretary on 01.11.12 at MOWR, New Delhi to review the progress in respect of Pilot Aquifer Mapping Project, it was decided that an alternate area near Ramgarh, Jaisalmer district, Rajasthan would be taken up for Pilot Aquifer Mapping in desert area. Based on study of the literatures, various GIS layers and field traverses undertaken jointly by CGWB and NGRI consultant scientists, the area around Ramgarh, Jaisalmer district was found suitable for study under Desert Area as well as Heliborn Survey.

LOCATION DETAILS

The area lies within Latitude: 27°16'N and 27°30'N and Longitude: 70°20'00"E and 70°36'20"E, falling in topo sheets 40I/7 and 40I/11 located in Sam Panchayat Samiti (block), Jaisalmer district, in Western Rajasthan. It forms a part of Western Arid Plain (Figure 2). The total study area of the pilot aquifer mapping project is about 675 sq.km. The area is around Ramgarh town, approximately 25 km in North-South stretch and 25 km in East-West stretch with Ramgarh almost at its centre.

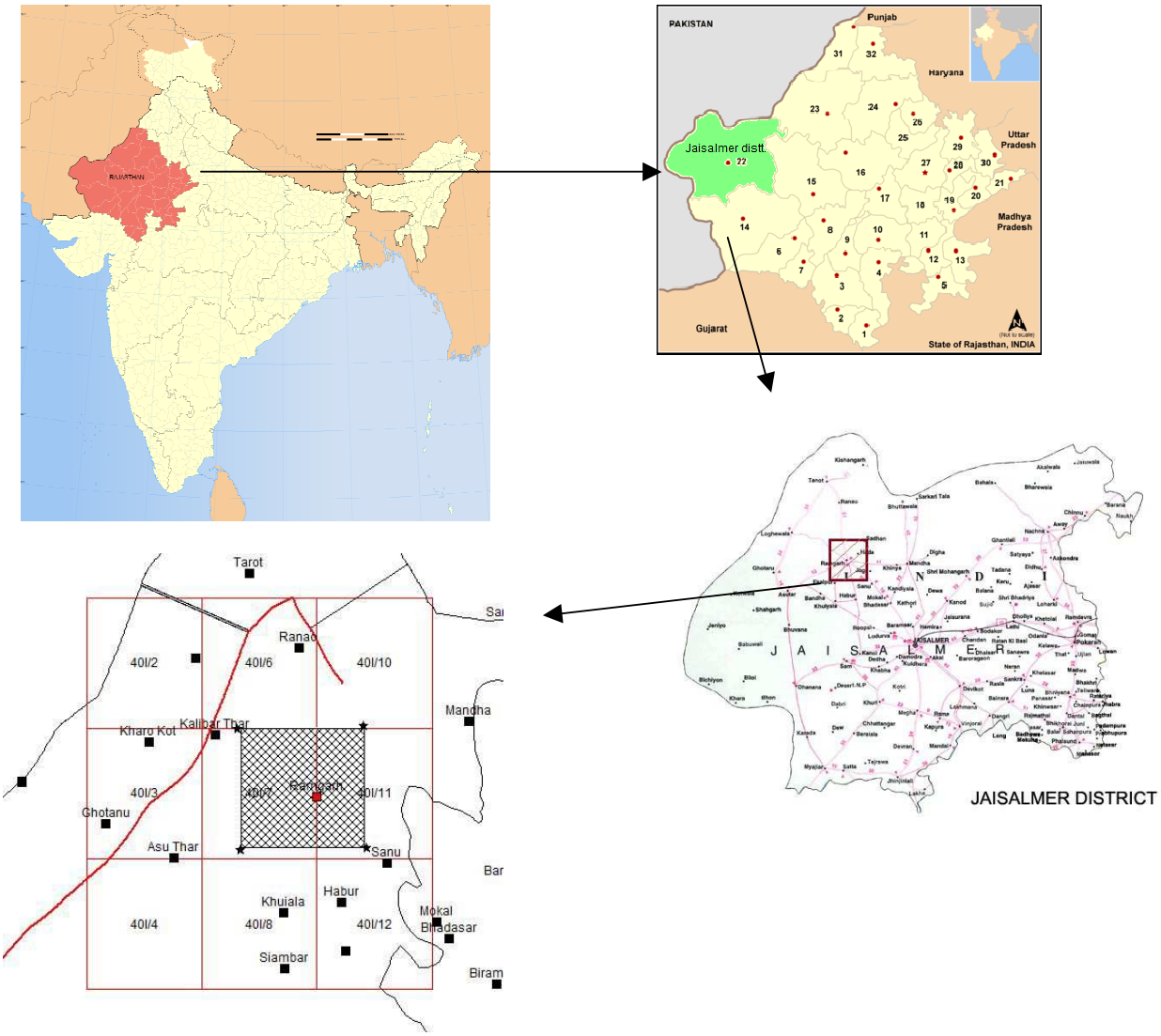


Figure 2 Location map of Ramgarh area, Jaisalmer district, Rajasthan

2 DATA AVAILABILITY & DATA GAP ANALYSIS

The data on various attributes of the study are collected from the available literatures of Central Ground Water Board, State Ground Water Department of Rajasthan and various Central and State Government agencies. The summerized table presenting the Data Requirement, Data Availability and Data Gap Analysis is presented in table 1.

Table 1. Data Availability and Data Gap Analysis in Ramgarh Pilot Aquifer Mapping Studies

Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Climate	Season-wise Rainfall pattern	Annual Rainfall of 1 Metereological Station	Time-series data on Rainfall
2	Soil	Soil map and Soil Infiltration Rate	Soil map	Soil Infiltration Rate across study area
3	Land use	Latest Land Use pattern	No Data	Latest data required
4	Geomorphology	Detailed Information on Geomorphology of the area	District level information	Study area level information
5	Geophysics	Geophyiscal data of the Study area	No Data of the Study area	Entire area unexplored
6	Exploration Data	As per requirement of Advanced Geophysical Studies for Integration of data and Validation of Techniques	No Data of the Study area	Entire area unexplored
7	Monitoring Regime	Representative Monitoring Wells well distributed over the Study Area	1 Monitoring Well	Entire area unexplored
8	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters given in Ground Water Resources Estimation	Entire study area

2.1 CLIMATE

Data Availability

The area lies in arid tract of Thar desert characterised by extremes of hot and cold weather. Rainfall is erratic and normal annual rainfall in Jaisalmer district is less than 200 mm. Droughts are frequent. Almost 90% of the total annual rainfall is received during the southwest monsoon, during July to mid of September. As the area lies in the desert area, extreme of heat in summer and cold in winter is the characteristic of the desert. Both day and night temperature increases gradually and reaches their maximum values in May and June. The temperature varies from 48 degree in summer to 2 degree in winter. Atmosphere is generally dry except during the monsoon period. The humidity is highest in August with

mean daily relative humidity in Jaislamer district is 43%. The annual maximum potential evapotranspiration in the district is 1850 mm and it is highest in the month of June and lowest in the month of December.

Data Gap Analysis

Season-wise rainfall data of the area is required.

2.2 SOIL

Date Availability

Predominant soil types area

a. Desert soil: Desert soil area is occupied by alluvium and wind blown sand, yellowish brown, sandy to sandy loam, loose, structure less, well drained with high permeability and lies in major part of the district.

b. Sand dunes: These are non-calcareous soil, sandy to loamy sand, loose, structure less and well drained. It lies in northern, western, southwestern, northeastern part of the district.

Data Gap Analysis

Data on soil infiltration rate for various types of soils existing in the project area needs to generated in order to analyses the impact of the soil cover on the ground water regime of the area.

2.3 LAND USE

Data Availability

No data

Data Gap Analysis

Updated land use statistics needs to be collected.

2.4 GEOMORPHOLOGY

Data Availability

The study area is a part of Great Thar Desert. Sand dunes are observed about 10 km north of Ramgarh town. Major part of the study is predominantly covered with flat, limestone terrain. There is little or no soil cover and thin vegetation. North of Ramgarh and along canal, agricultural activities were observed. Vegetation is more predominant along the canal. Several quarries were observed on both sides of the road between Ramgarh and Sanu. The quarries were mostly of limestone and other building materials.
There is no rivers worth the name in the area nor are there any perennial stream in the area. IGNP branch canal flows north of Ramgarh town.

Data Gap Analysis

Additional information need to be collected, so that the same can be used in hydrogeological interpretations and formulation of ground water management plan.

2.5 GEOLOGY

Geologically, the area is underlain by Mesozoic and Tertiary formations consisting of sandstone, shale, conglomerate. Mesozoic consists of Parewar and Abur formations. Sanu sandstone and limestone of Tertiary period are present in the area (figure 3). These formations are overlain at places by Pleistocene to recent alluvium consisting mainly clay, sand and silt.

The desert formation of Holocene age consists of Aeolian sand, silt, and occasional kankars. The beds are horizontally to sub horizontally disposed showing rolling dips of 10 to 30 towards North West.

The Shumar formation of Pleistocene unconformably overlies the Bundah formation and consists of ironstone, gritty calcareous quartzite, calcareous sand stone, sandy limestone, clay, pseudo conglomerate and pebble spread. The pebble spread is of Fluvio-glacial origin and includes clasts of quartzite, quartz, Limestone and iron stone .It indicates that glaciation took place during the Pleistocene time. Different beds of Shumar formation have been recorded in the well sections at around Ranau tar, Girdhuwala , Jogawala tar , Gaje singh ka tar and Sachchuwala tar at depths varying from 3m to 15 m.

The Bundah formation is Eocene age. It comprises foraminiferal Limestone, yellow marl, sandy limestone with gypseous bentonitic shale, calcareous and ferruginous sandstone and quartzite. Bundah formation is underlain by Khuiala formation.

The Khuiala formation and the Bundah formation represent the Tertiary rocks. The Khuiala formation consist of massive nummulitic Limestone and chalky limestone. Both the Khuiala and Bundah formations are fossiliferous .The Khuiala formation consists nummulites, assilina, alveolina and orbitolites. The Bundah formation contains Lamellibranch, echenoids and Foraminifers.

The Khuiala formation unconformably rest over the Sanu formation. The Sanu formation comprises variegated shale, sandstone and white clays with ironstone capping.

The Sanu formation is underlain by Abur formation comprising of fossiliferous calcareous sandstone, ferrugenous grit.

The oldest outcrop formation in the area is Parewar formation represented by feldspathic and quartzitic sandstone which is unconformably overlain by Abur formation.

Table2. Geological sequence in Ramgarh area, Desert Area, Jaisalmer district

Lithology	Formation	Age
Fine aeolian sand & silt with occasional kankar	Thar desrt	Holocene
A- shale , lime stone ,& psedo conglomerate B- pebble spread / conglomerate	Shumar	Pleistocene
a- Lime stone , foraminiferal lime stone , marl c- Sandy lime stone ,with gypseous bentonitic shale d-calcareous and ferrugenous sand stone & quartzite	Bundah	Eocene
Massive lime stone , nummulitic Lime stone with minor shale , chert and Quartzite	Khuiala	Paleocene
Variegated , micaceous sand stone , shale , clay with iron stone cappings	Sanu	Paleocene
Fossiliferous calcareous sand stones , ferrugenous grit , concoidal lime stone	Abur	Lower cretaceous
Feldspathic and quartzitic sand stone	Pariwar	Lower Jurassic to Lower Cretaceous

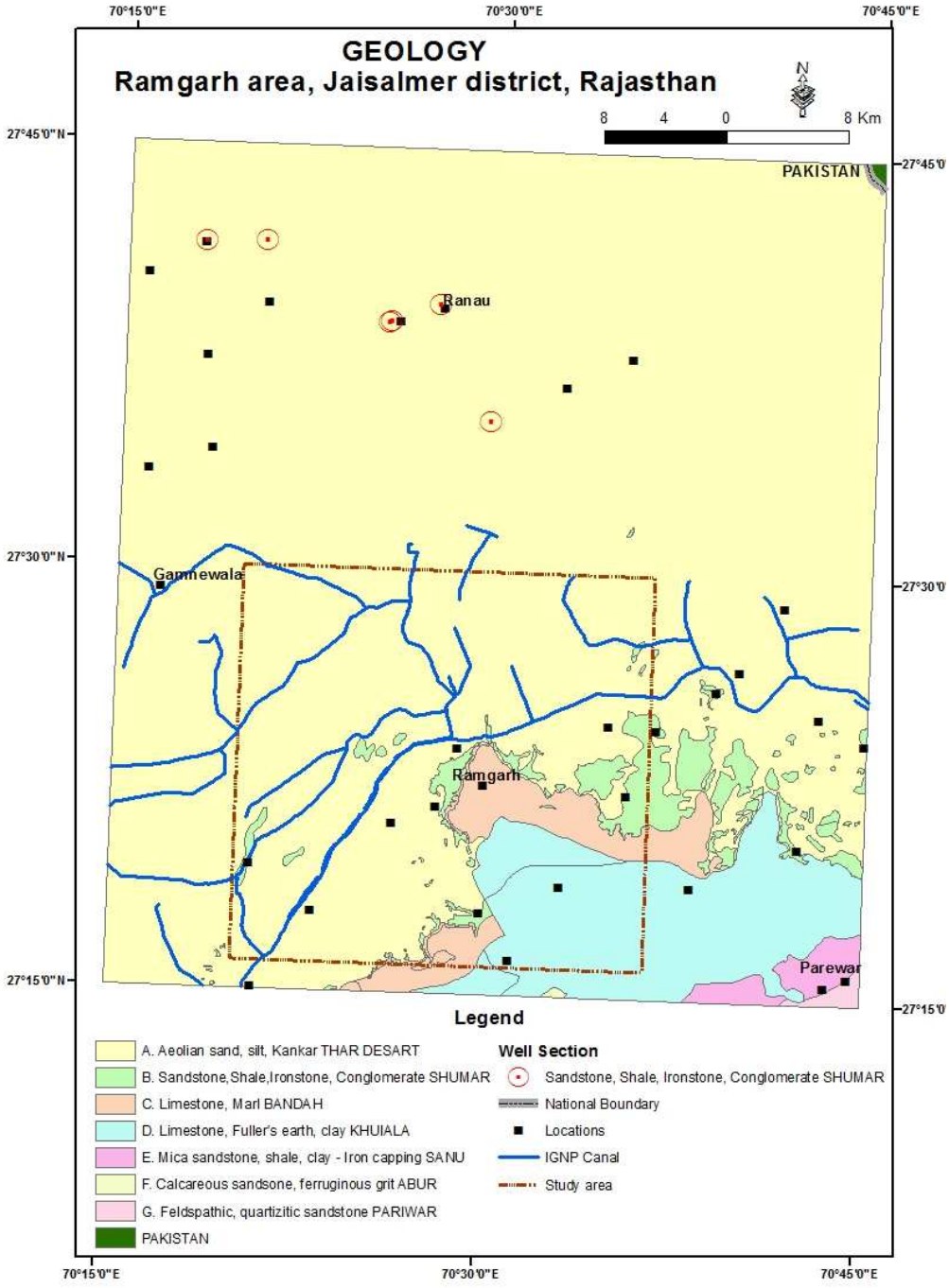


Figure 3. Geological map of Ramgarh area, Jaisalmer district, Rajasthan

2.6 GEOPHYSICS

Data Availability

No geophysical study were carried out within project area.Ground geophysical investigations are carried out in the paleo-channels north of Ramgarh area. The location map of VES study carried out in Saraswati river paleo-channels is depicted in figure 4.

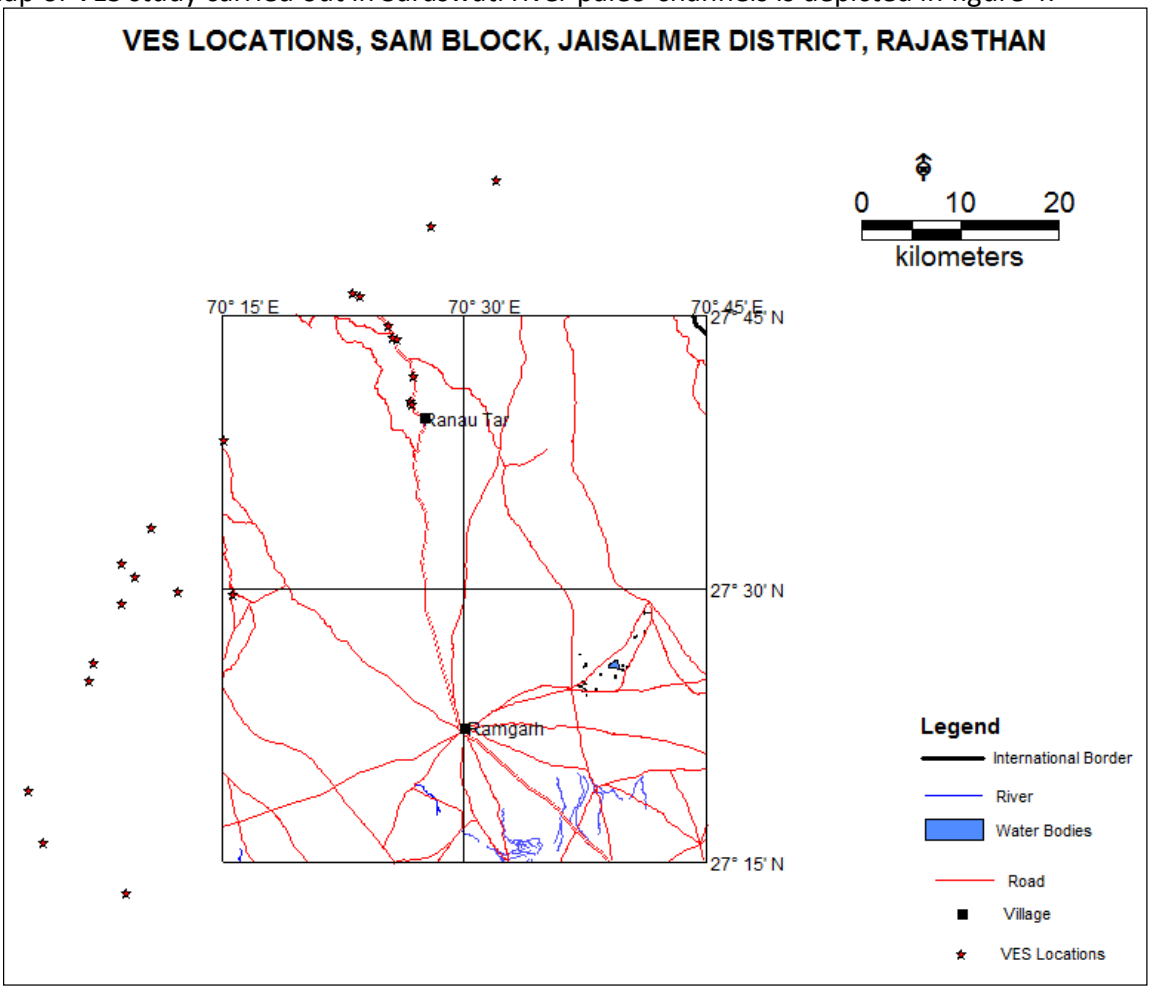


Figure 4. Location map of VES study in Swaraswati Paleo Channel

Data Gap Analysis

The entire area is un-explored as far as geophysical investigations are concerned.

2.7 SUB-SURFACE LITHOLOGICAL INFORMATION

Data Availability

Sub-surface lithological information are obtained from the Status report on search of palaeochannels in Western Rajasthan, CGWB (2002). However, all the VES studies and exploratory wells are located outside project area. The interpreted hydro-geophysical layers are given in table 3. The details of exploratory borewells drilled in Saraswati paleo-channels is given in the annexure I.

Table 3. Interpreted Layer Parameters Obtained from Vertical Electrical Soundings in Sam Block, Jaisalmer district

VES No.	Location	Lat.& Long.	Resistivity (ohm m)							Thickness (m)						Depth of fresh Saline Interface (m)
			ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	h_1	h_2	h_3	h_4	h_5	h_6	
C-1	Tanot–21.5 km Kishangarh -45 km (Ranau EBH site)	27.831, 70.4649	866	156	179	76	21	9	4	1.25	4.4	13.3	27.7	39.	191	85.75
C-2	Tanot-11.485 km Ranau-9.515 km	27.7285, 70.4306	304	976	78	10.4	7.9	-	-	5.22	3.2	47.6	72.5	-	-	128.6
C-3	Tanot-6.5 km (Ghantiyali)	27.5551, 70.1755	354.7	203.3	87.9	14.2	-	-	-	1.84	15	20.6	-	-	-	
C-4	Tanot 7.8 km Ranau – 14.2 km	27.76710, 70.39215	583	115	369	91	16.3	1()	-	5.54	17	13.4	19.8	19.	-	75.31
C-5	Between 16 × 17 km Tanot	27.69416, 70.4477	296	732	167	69	13.3	4.6	-	2.51	9.1	12.3	28.1	145.	-	197.4
C-6	Tanot 14 km Ranau – 7km	27.6716, 70.4446	133	238.5	84	16	60.6	-	-	3.8	19	46	99	-	-	-
C-7	Tanot 11.8 km	27.7397,70.4209	103	270	107	71.7	11.6	5.8	-	2.9	3.4	19.5	14.5	85.0	-	125.3
C-8	Tanot 3.1 km Ranau 17.9 km	27.7701 70.3849	389	42	160	14	7.4	-	-	0.69	2.7	32.7	103	-	-	139.7
C-9	Ranau 3.1 km	27.667718, 70.446396	291	66.8	347	139	13.6	10	-	9.0	3.6	17.5	20.5	36.8	-	87.43
C-10	Tanot 9.84 km Ranau 11.16 km	27.72973, 70.4264	7167	2343	292.4	6.27	-	-	-	1.06	1.0	82.0	-	-	-	84.12
C-11	Gamnewala 1 km Longewala 14 km	27.6360 70.2507	461	163.4	283.6	48	22.4	5.2	-	0.973	4.5	17.9	21.2	222.	-	267.0
C-12	Gumnewala 7 km Longewala – 8 km Ramgarh 35 km	27.51070, 70.1586	336.3	163.4	127.3	50	15.98	-	-	1.45	2.4	22.6	25	-	-	-
C-13	Ghotaru 17 km Longewala 9 km	27.4315 70.1161	444.6	527.6	447.6	54.4	21	60.9	-	1.85	11	13.3	9.28	-	-	-
C-14	Ghotaru 10 km Longewala 16 km	27.4156 70.112	87.31	23.06	8.42	58.96	196	-	4.57	1.09	2	7.13	8.06	50.9	359.	428.3
C-15	Ghotaru 0 km Angtala 40 km Bachia 97 km	27.3156 70.0488	111	258	132	27.1	12	28	4.6	3.2	4.0	9.0	23.0	48.3	48.8	-

VES No.	Location	Lat.& Long.	Resistivity (ohm m)							Thickness (m)						Depth of fresh Saline Interface (m)
C-16	Ghotaru 3.4 km Ramgarh 54.6 km Asataur 12.6 km	27.2680 70.0639	2052	164	186	17.1	44.4	3.8	-	2.69	7.1	22.5	23.9	72.0	-	128.4
C-17	Asataur 0.869 km Ramgarh 41.131 km	27.2216, 70.1504	307.3	28.13	13	20	7.72	-	-	2.0	7.0	22.0	50.0	-	-	81
C-18	Ghotaru- Longewala Road 1 km East of C14	27.4863,70.1449	64.36	188	162	6.3	16.6	3.4	-	0.939	3.4	14.1	63.0	100.	-	181.6
C-19	Ghotaru- Longewala Road 400 m SE of C14	27.522887, 70.162811	84.3	23.4	50.9	240	-	-	-	1.76	23.	21.3	-	-	-	
C-20	Gamnewala 9.3 km Longewala 5.7 km Ramgarh 37.3 km	27.4948, 70.2603	239	1425	220	15.6	-	-	-	3.36	4.0	27.1	-	-	-	
C-21	Longewala 2.5 km	27.4973, 70.2040	212	1336	195	2.93	-	-	-	6.36	3.4	14.6	-	-	-	
C-22	Kishangarh 0 km Kuriaberi 9 km	27.8730, 70.5336	109	2193	157	132	89.1	10.2	-	1.75	5.2	8.0	18.0	13.6	-	

Data Gap Analysis

The entire project area is unexplored.

2.8 HYDROGEOLOGY

Data Availability

Information on hydrogeology of the project area is obtained from the district brochure of Jaisalmer district. The aquifers are mainly sedimentary rocks of calcareous-argillaceous-arenaceous nature of Tertiary and Mesozoic era (figure 5). Aquifers are encountered at the depths of 45 to 70 m and 125 to 160 m. These are unconfined to semi-confined in nature. Water quality is around EC 3500-4000 micromhos/cm. Ground water level around Ramgarh area is about 30 to 40 m bgl. However, in the area lying south of Ramgarh, water level is comparatively deeper and goes even beyond 100 m bgl at places.

The area falls within Sam block, Jaisalmer district. The annual replenishable ground water resources in Sam block is around 28 million cubic metre (mcm). The net annual ground water available for utilization after keeping an allocation for unavoidable ground water discharge, is around 26 mcm. The annual ground water draft is 16 mcm. Thus the stage of ground water development in the block is around 60%. The Sam block has been categorized as Safe block.

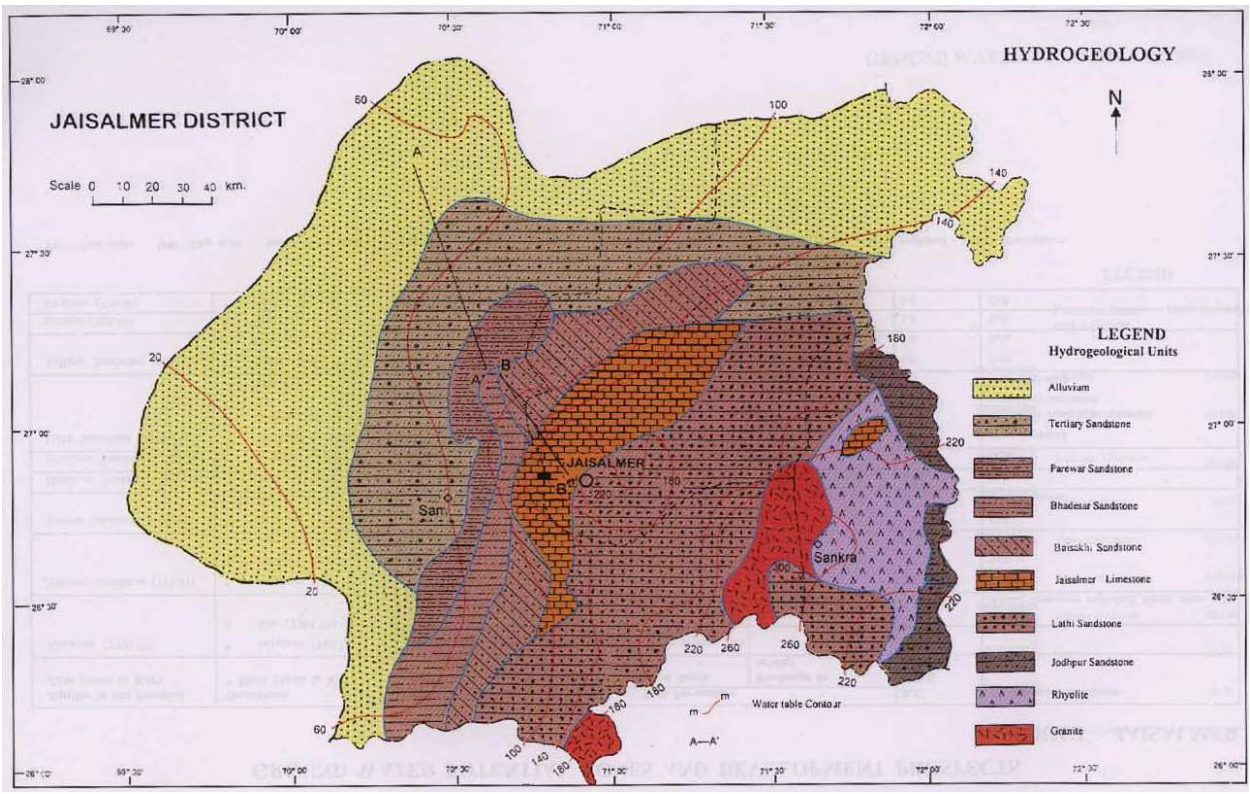


Figure 5. Hydrogeological map of Jaisalmer District including Ramgarh area, Rajasthan

Data Gap Analysis

Hydrogeological scenario is based on regional level information. This is to be substantiated with ground water exploration in the study area.

2.9 AQUIFER DISPOSITION

Data Availability

No data was available regarding aquifer disposition in Ramgarh area.

Data Gap Analysis

Sub-surface information is required for information on aquifer disposition.

2.10 WATER LEVEL

Data Availability

There is only one National Hydrograph Monitoring station existing in the project area. Two more monitoring stations are located outside the north-western boundary of the project area. The details of the wells are given in table 4.

Table 4. National Hydrograph Monitoring Stations in and around Ramgarh area, Jaisalmer district, Rajasthan

SITE_NAME	SITE_ID	SITE_VILLAGE	BLOCK_NAME	DISTRICT_NAME	xLong	yLat
GAMNEWALI	W272910070160501	GAMNEWALI	SAM	JAISALMER	70.27	27.49
GAMANEWALA	W272910070160502	GAMANEWALA	SAM	JAISALMER	70.27	27.49
RAMGARH	W272130070300001	RAMGARH	SAM	JAISALMER	70.50	27.36

The long term water level data is given in annexure II. The location of the monitoring stations are plotted in figure 6.

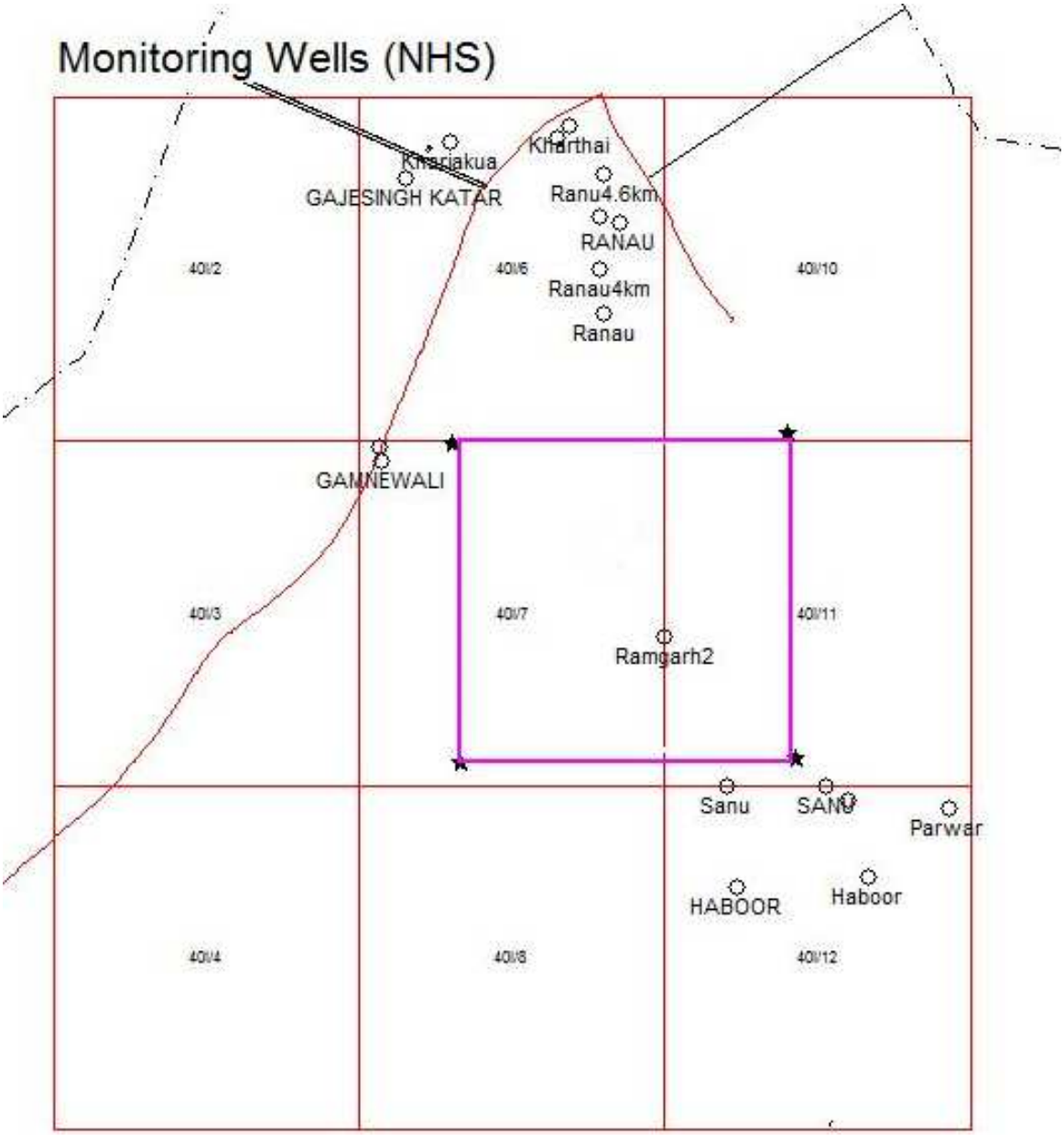


Figure 6. National Hydrograph Monitoring Stations, Ramgarh area, Sam block, Jaisalmer district, Rajasthan

Data Gap Analysis

Monitoring stations need to be established across the entire project area, since presently it is represented by only one well.

2.11 WATER QUALITY

Data Availability

Ground water quality data of two exploratory borewells are available, out of which one i.e. Khinyan is located within project area and the other one i.e. Gamnewala is located outside the north-west boundary of the project area (figure 7).

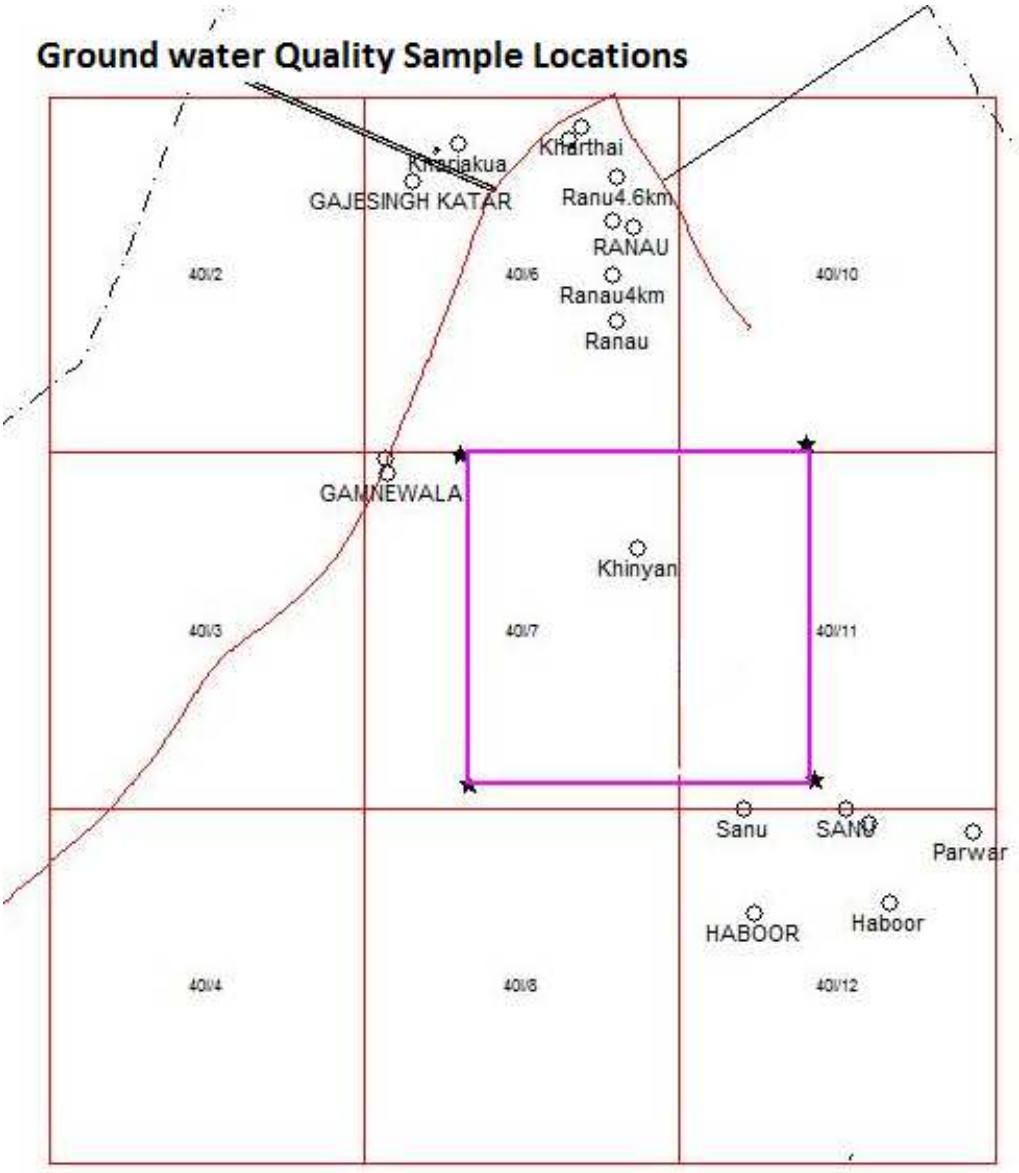


Figure 7. Locations of ground water quality samples in and around Ramgarh area

Data Gap Analysis

Ground water Quality monitoring Stations needs to be established across the entire study area.

2.12 Recharge Parameters

Data Availability

Recharge parameters are obtained from State Ground Water Department which were used in the ground water resources estimation of 2009 for the state of Rajasthan. Table 5 presents the various recharge parameters used for computation of dynamic ground water resources of Sam block, Jaisalmer district for the base-year, 2009.

Table 5. Recharge parameters used for computation of ground water resources in Sam block, Jaisalmer district, Rajasthan

Ground water Potential Zones	Specific Yield	Rainfall Recharge Factor	Return flow from Irrigation	Seepage factor - Tanks & Ponds (mm/day)
Alluvium (A2/1)	0.10	0.025	0.00	0.00
Teritiary Sandstone (T1/4)	0.04	0.025		
Pariwar Sandstone (P1/1)	0.04	0.025		

Data Gap Analysis

The recharge parameters mentioned above needs to be updated by compilation of additional information on the field studies undertaken in the area and also through carrying out additional field experiments through pumping tests for specific yield determination and soil infiltration tests for rainfall recharge factor determination.

2.13 DISCHARGE PARAMETERS

Data Availability

There was no irrigation draft in ground water potential zones - A2/1 (Alluvium), Tertiary sandstone (T1/4), Pariwar sandstone (P1/1). The details of ground water draft in the above mentioned three potential zones is given in table 6.

Table 6. Discharge parameters used for estimation of ground water resources estimation of part of Sam block in 2009 assessment

S. No.	Potential zone	Aquifer	Annual Irrigation withdrawal in mcm	Annual W.S.S. withdrawal in MCM					Total Pumpage (Irr. + W.S.) in MCM
				No. of wells in use		No. of operational days	Average yield in LPD	Withdrawal in MCM	Total withdrawal in MCM	
1	2	3	4	5		6	7	8	9	10
1	A2/1 (Longewala)	Alluvium Formation	-	TW	6	300	135000	0.2430	0.2430	0.2430
2	T1/4 (Pochina area)	Tertiary Sandstone	-	TW	4	300	150000	0.1800	0.1800	0.1800
3	P1/1 (Parewar)	Parewar Sandstone	-	TW	14	300	230000	0.9660	0.9660	0.9660

Data Gap Analysis

The discharge parameters mentioned above needs to be updated by compilation of minor irrigation census for obtaining the numbers of ground water structures and carrying out draft sample survey for updating the unit draft norms of wells.

3. DATA GENERATION

Data on various attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis discussed in Chapter 2. The summary of the data generated during pilot aquifer mapping project is given in table 7.

Table 7. Data Generated on various attributes of Aquifer Mapping in Ramgarh area, Jaisalmer district, Rajasthan

Sl. No.	Items	Data Generated
1	Climate	Time series data on rainfall from 1970 to 2014
2	Soil	Estimation of Soil Infiltration Rate
3	Land use	Latest Land Use pattern
4	Geomorphology	Detailed Information on Geomorphology of the area
5	Geophysics	TEM – 70 no., Borehole logging – 2 no., SkyTEM – 3412 sq.km.
6	Exploration Data	Exploratory Wells – 2 nos.
7	Monitoring Regime	Established 14 monitoring wells, Monthly monitoring of Water Level
8	Recharge Parameters	Estimation of Recharge parameters

3.1 Climate

RAINFALL

Rainfall data were collected from State Agencies through websites of Government of Rajasthan. The details of the rainfall data in Ramgarh is given in Annexure III. The salient statistical information pertaining to the rainfall pattern in the watershed is given in the following table.

Table-8. Statistical Analysis of Annual Rainfall of the Rain Gauge Station located in Ramgarh area, Jaisalmer district, Rajasthan

Rain Gauge Station	Period	Mean annual rainfall (mm)	Standard deviation (mm)	Highest annual rainfall with year (mm)	Lowest annual rainfall with year (mm)
Ramgarh	1970-2014	146	86	386 (2010)	9 (2002)

The statistical information presented in table 6 amply reflects the arid condition of the project area with meager rainfall.

Time-series analysis

Time series analysis of rainfall data was carried out for the 1970 to 2014 and long-term trend in rainfall are established. The rainfall pattern shows a rising trend of 0.38 over the years. The trend analysis is presented in figure 8.

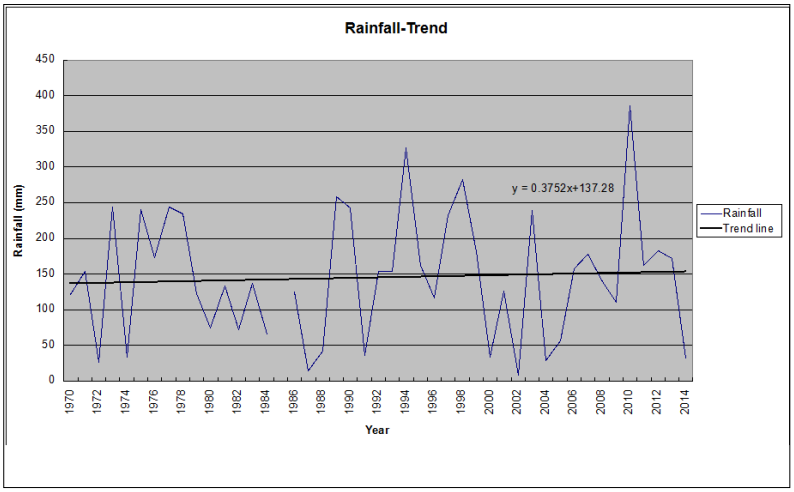


Figure 8. Long term trend analysis of annual rainfall in Ramgarh area, Jaisalmer district, Rajasthan

The percentage departure of annual rainfall is presented in figure 9.

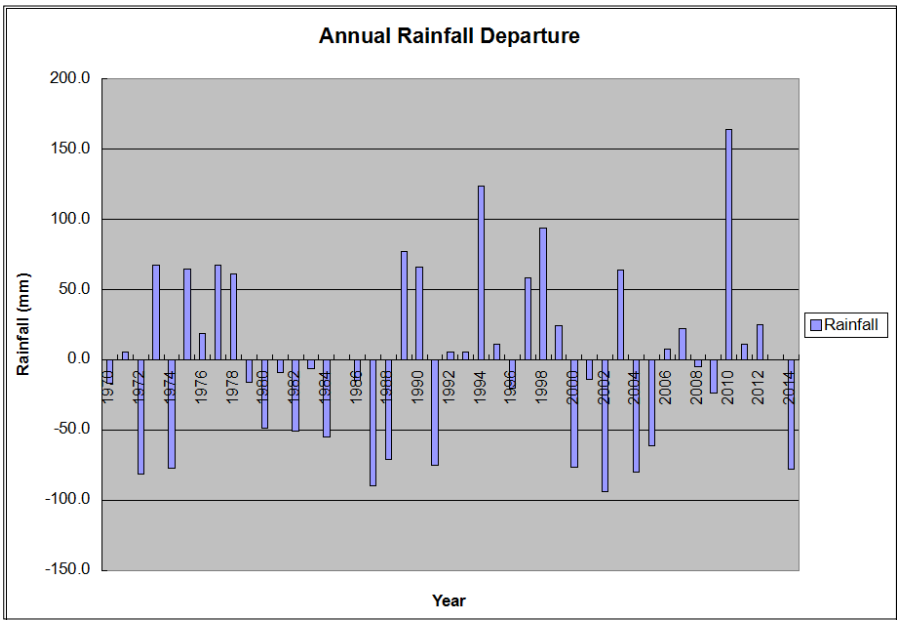


Figure 9. Percentage departure of Annual Rainfall in Ramgarh area, Jaisalmer district, Rajasthan

Almost 90% of the total annual rainfall is received during the southwest monsoon, which enters the area in the First week of July and withdraws in the mid of September. As the study area lies in the desert terrain, extreme of heat in summer and cold in winter is experienced. Both day and night temperature increases gradually and reaches their maximum values in May and June. The temperature varies from 48 degree in summer to 2 degree in winter. Atmosphere is generally dry except during the monsoon period. The humidity is highest in August with mean daily relative humidity is 43%.

3.2 SOIL

Soil cover plays an important role in the ground water recharge. Hence, data are generated on the attribute of the soil which characterizes the infiltration capacity of the soil. Soil infiltration tests have been conducted using double ring infiltrometer in different types of soils across the project area to determine the infiltration rate of the soil.

Infiltration is the process by which water on the ground surface enters the soil. Infiltration is governed by two forces, gravity and capillary action. The process of entry of water into the ground is called infiltration, while the downward movement of water after entry into the ground is called percolation.

Infiltration rate is a measure of the rate at which a particular soil is able to absorb water either from rainfall or applied irrigation water. It is measured in centimeter per minute. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier.

The soil infiltration rates are useful in determination of recharge parameters and demarcation of areas feasible for artificial recharge. The experiments are conducted at 6 sites in Desert Area project area during post-monsoon season of 2013 and pre-monsoon season of 2014

Procedure

Soil Infiltration Test was conducted using Double Ring Infiltrometer (plate - 1). A Double-ring Infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils. The final infiltration rate at which the rate of infiltration becomes constant in time scale is taken as the infiltration rate.

Plate 1. Soil Infiltration Test conducted in Ramgarh area, Jaisalmer district, Rajasthan

The infiltration rate varies from 0.04 cm/min to 0.70 cm/min in the project area. The details of the infiltration test results are given in table 7.

Table 9. Soil Infiltration test results, Ramgarh area, Jaisalmer district, Rajasthan

Sl. No.	Location	Soil Type	Season	Infiltration Rate (cm/min)
1	Ramgarh	Desert soil	Post-Monsoon'13	0.07
2	Gamnewala	Desert soil	Post-Monsoon'13	0.02
3	Navalgaon	Desert soil	Post-Monsoon'13	0.04
4	Khirar Beri	Desert soil	Pre-Monsoon'14	0.39
5	Ali Ki Dhani	Desert soil	Pre-Monsoon'14	0.10
6	Biprasar Netsi	Desert soil	Pre-Monsoon'14	0.04

A perusal of the above table would indicate that the Desert soils have wide range of Infiltration rate from 0.02 cm/min to 0.39 cm/min depending on whether the top soil is compact because of hard pans or carbonate deposits like in the case of Gamnewala. In case, the soil is loose, the infiltration rate is high as in Khirar Beri.

3.3 LAND USE

Land use map is prepared based on remote sensing studies carried out by State Remote Sensing Application Centre located at Jodhpur (figure 10).

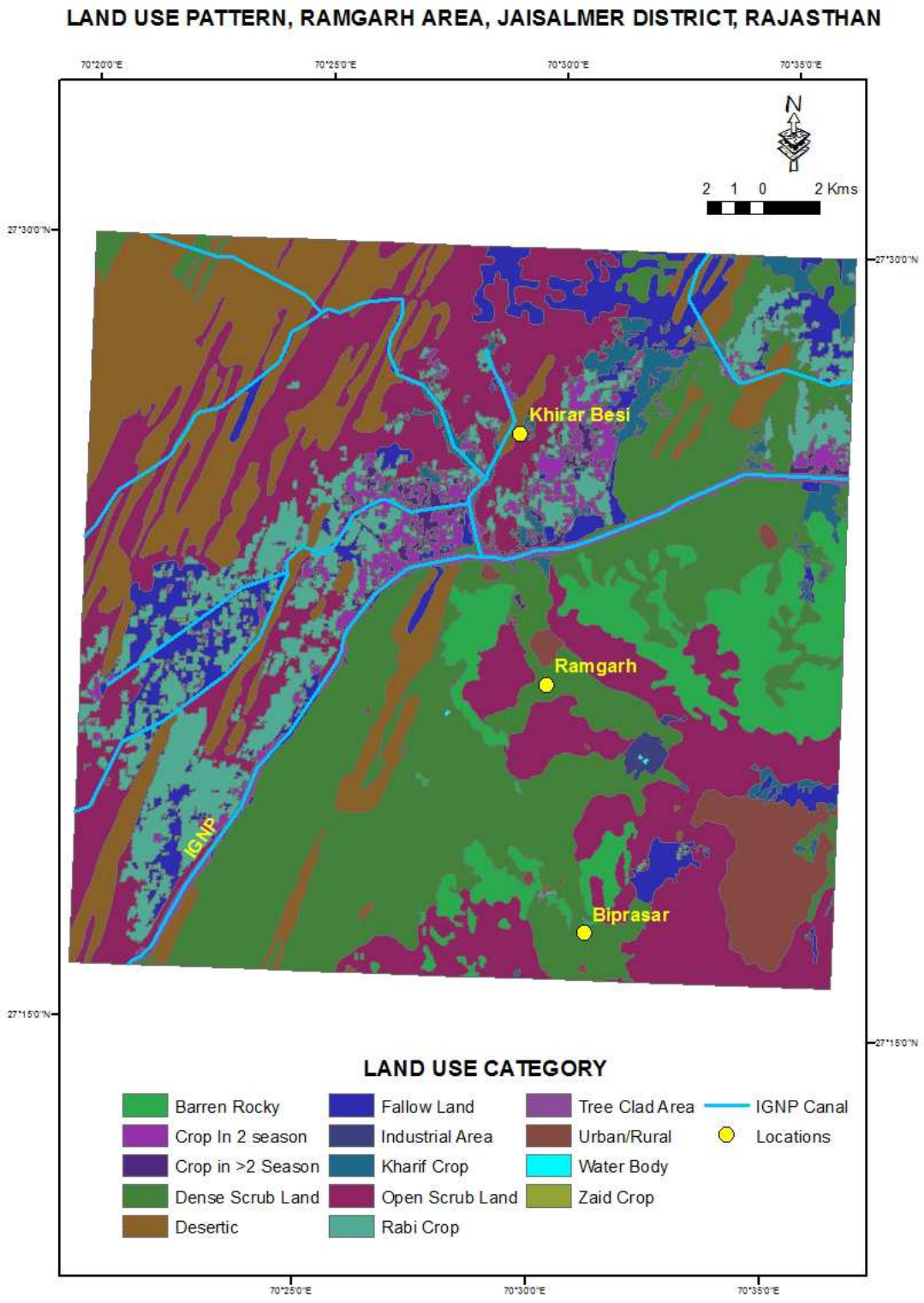


Figure10. Land use pattern in Ramgarh area, Jaisalmer district (source: SRSAC, Jodhpur)

The descriptions of various land uses are as follows.
Urban/ Rural – Areas covered by urban and rural habitations
Kharif crop - Crops which are sown in the rainy season (monsoon) and harvested in the autumn.
Rabi crop - Crops which are sown in the winters and harvested in the spring season.
Zaid crop - Crops that are grown in the season between the growing seasons of kharif and Rabi crops means from March to June.

Fallow Land- A piece of land that is normally used for farming but that is left with no crops on it for a season in order to let it recover its fertility.
Desertic land - Rainfall is sporadic and in some years no measurable precipitation falls at all. The terribly dry conditions of the deserts is due to the year-round influence of subtropical high pressure and continentality.
Scrubland - diverse assortment of vegetation types sharing the common physical characteristic of dominance by shrubs. A shrub is defined as a woody plant not exceeding 5 metres (16.4 feet) in height if it has a single main stem, or 8 metres if it is multistemmed.
Barren rocky – area covered with rock outcrops.
Water Body- area of impounded water, areal in extent and often with a regulated flow of water. It includes man-made reservoirs/lakes/tank/canals, besides natural lakes, rivers/streams and creeks.

The area for different land use pattern are computed from the digitized data of the GIS layers. The main purpose of the table for land Use is to indicate broadly the ways in which the land in the area is utilised. The distribution of land use pattern in Ramgarh Project area is given in Table 10.

Table 10. Land Use Pattern in Ramgarh area, Jaisalmer district, Rajasthan

Sl. No.	Land Use Pattern	Area (sq.Km.)
1	Desertic land	110
2	Total Scrubland	336
3	Barren Rocky Terrain	45
4	Rabi Crop	80
5	Kharif Crop	16
6	Zaid Crop	0.14
7	Crop in 2 Seasons	17
8	Crop in >2 Seasons	5
9	Fallow Land	45
10	Water Body	0.08
11	Urban/ Rural	20
	Total Area	**675**

3.4 GEOMORPHOLOGY

Major part of the area is covered by blown sand sheets and dunes. NNE-SSW trending barchans and longitudinal dunes are important dunal landforms present in the area. Drainage is poorly developed in the area and is represented by the northerly flowing Ramgarh nadi, an ephemeral stream which disappear in sandy terrain to the north. Sand dunes of Holocene represent the Quaternary stratigraphy of the area.

The Quaternary (Holocene) sand and sand dunes (mainly longitudinal and barchans) cover major part of the area Longitudinal dunes represents more evolved dunal forms than the parabolic or comb dunes from which these have been evolved .

Study of the geomorphic units indicates that the onset of aridity in the area started during early quaternary period when the last cycle of sedimentation in geologic history of Jaisalmer basin was over in the form of rocks of the Shumar formation.

Plate 2. Flat rocky terrain

Plate 3. Desert terrain

DRAINAGE

There is no rivers worth the name in the area nor are there any perennial stream in the area. IGNP branch canal flows north of Ramgarh town (figure 11).

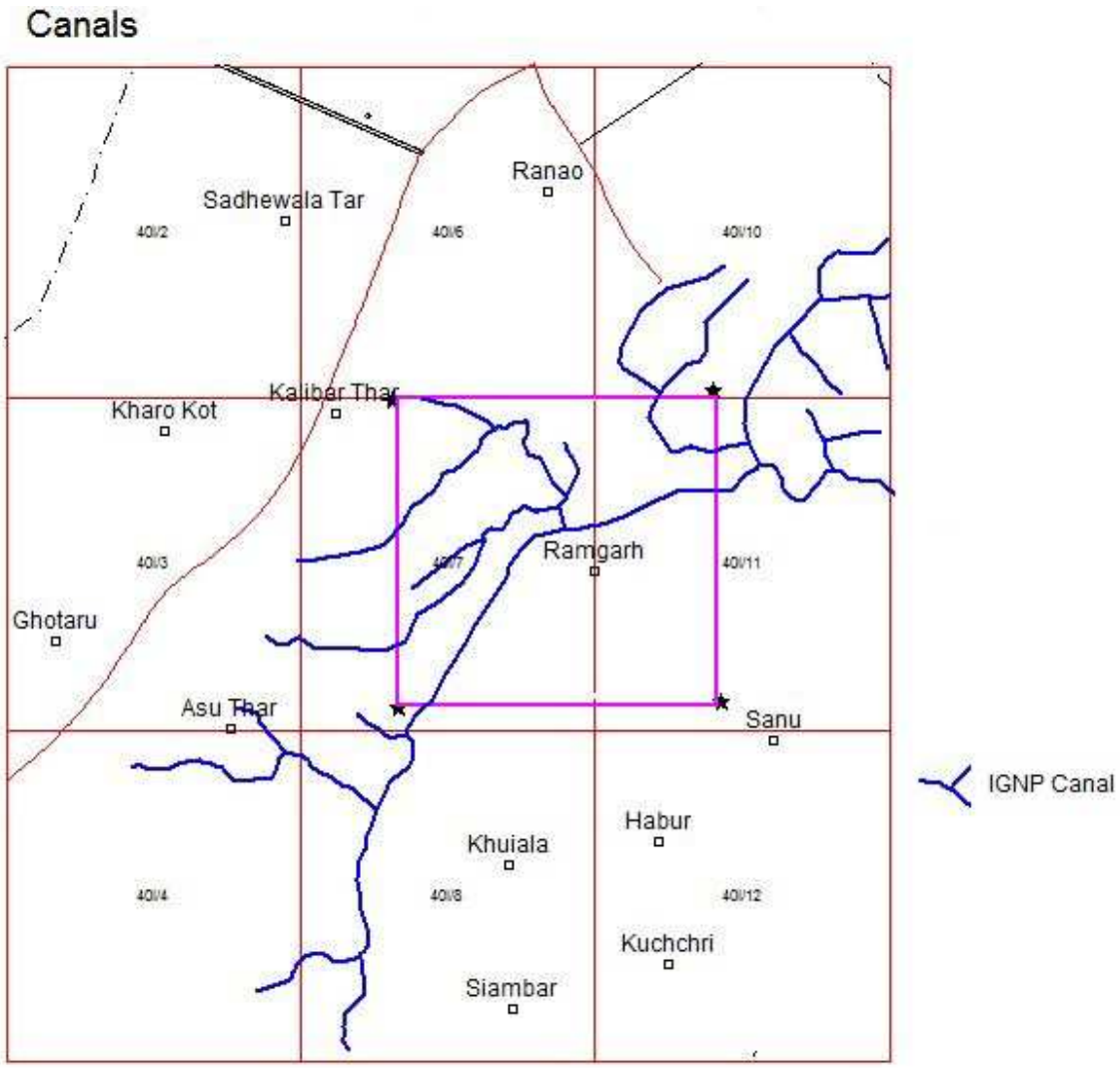


Figure 11. Canal system around Ramgarh area, Jaisalmer district, Rajasthan

Plate 4 IGNP canal near Ramgarh area, Jaisalmer district, Rajasthan

3.5 GEOPHYSICS

Modern state of art Heliborne Geophysics, the major component of the AQUIM project, has been done in collaboration with Aarhus University, Denmark using dual moment SkyTEM system developed at Aarhus University and operated and owned by SkyTEM Survey Aps, Denmark. Dual moment ensures high-resolution information from top to deeper level by means of low and high moments. The collected SkyTEM data were processed and subsequently inverted with a smooth model using the laterally constrained inversion (LCI) and spatially constrained inversion (SCI) approaches.

Details of geophysical measurement are given below:

Data summary at AQDRT, Jaisalmer (Rajasthan)							
Name of Activity		Target	pre SkyTEM	SkyTEM	Post SkyTEM	Total	Remarks
1-D GEOPHYSICS	VES (no.)	0	0		0	0	
	TEM (no.)	0	8		62	70	TEMfast48HPC system with 50m x 50m loop size, and Zonge system
2-D GEOPHYSICS	ERT (LKM)	0	0		0	0	
Borehole Logging	Wells (No.)	-	0		2	2	Out of 20 only two were drilled, where first well was loged by CGWB and other by CSIR-NGRI

HeliTEM	SkyTEM (LKM)	3412		3412	TEM data using Line/Tie line spacing : 200/2000 ms and 22 m/s flight speed
HeliMAG	Geometrics Cesium Vapour type 822A (LKM)	3412	-	3412	Magnetic data using Line/Tie line spacing : 200/2000 ms and 22 m/s flight speed

RESISTIVITY SECTIONS OF HELITEM

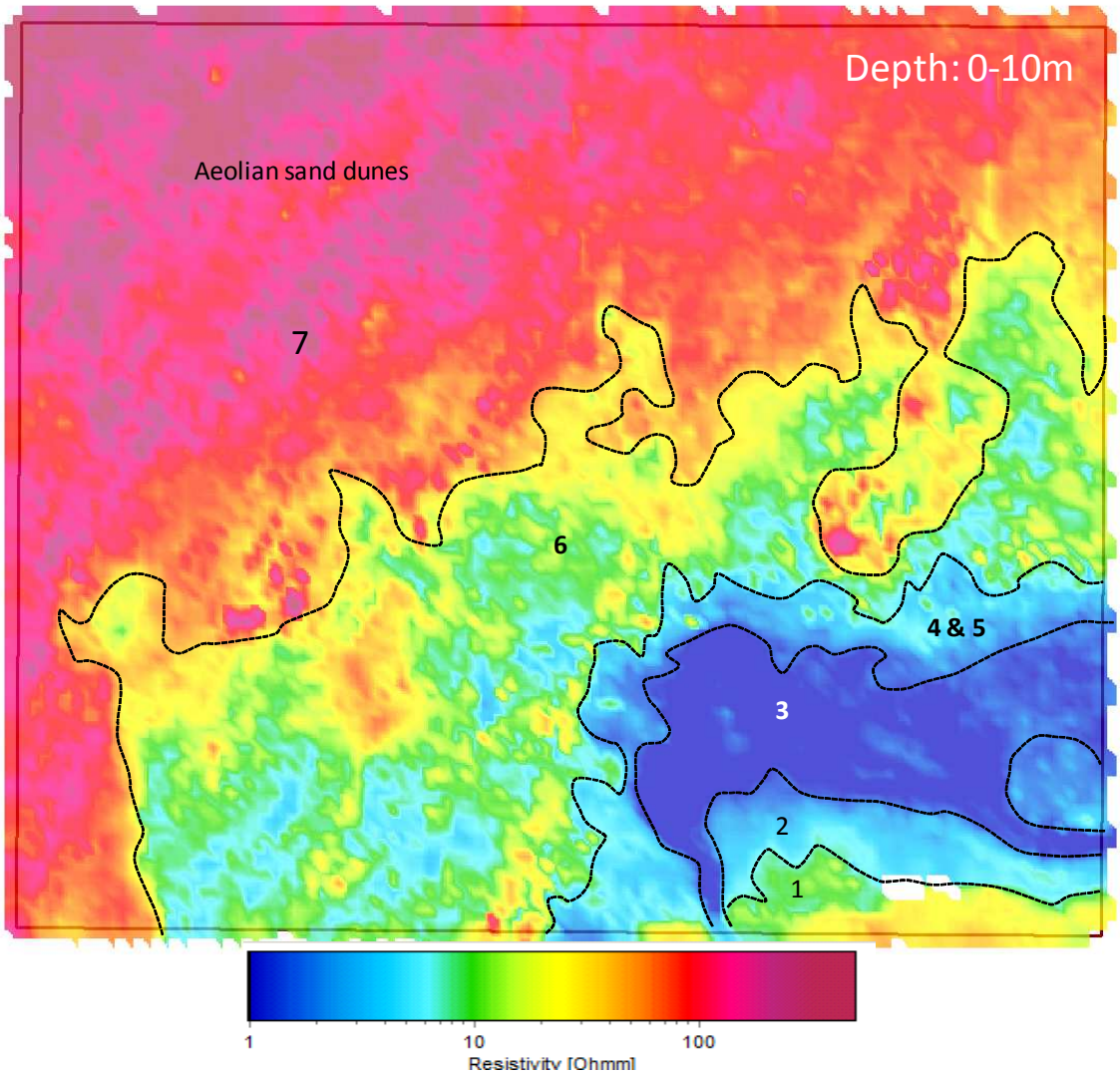
HORIZONTAL PLANAR SECTION

The mean resistivity maps have been generated at 5 m depth intervals down to a depth of 300 m. The maps are prepared by gridding the data using the Kriging method with a node spacing of 25 m and a search radius of 500 m. The nodes have further been subdivided by a factor of 4 to obtain the interpolated resistivity pixels for the bitmaps that make up the maps.

Mean resistivity map is found well corresponding to the geological map of the area. Mean resistivity map looks to be proxy of geological map giving distinct resistivity response of different lithology. There are five litho units existing in the surveyed boundary. The litho unit 1 and 2 lie at southern fringe. SkyTEM mean resistivity revealed all seven litho units starting from sandstone in SE to Aeolian sand in NW of the area. This is important note that the mean resistivity represent 10 m thick vertical column. Hence if the ground is covered by thin layer, it may or may not be reflected in the mean resistivity. Mapping depends on layer thickness and resistivity contrast. Following resistivity range are taken to interpret the geophysical image to lithological model.

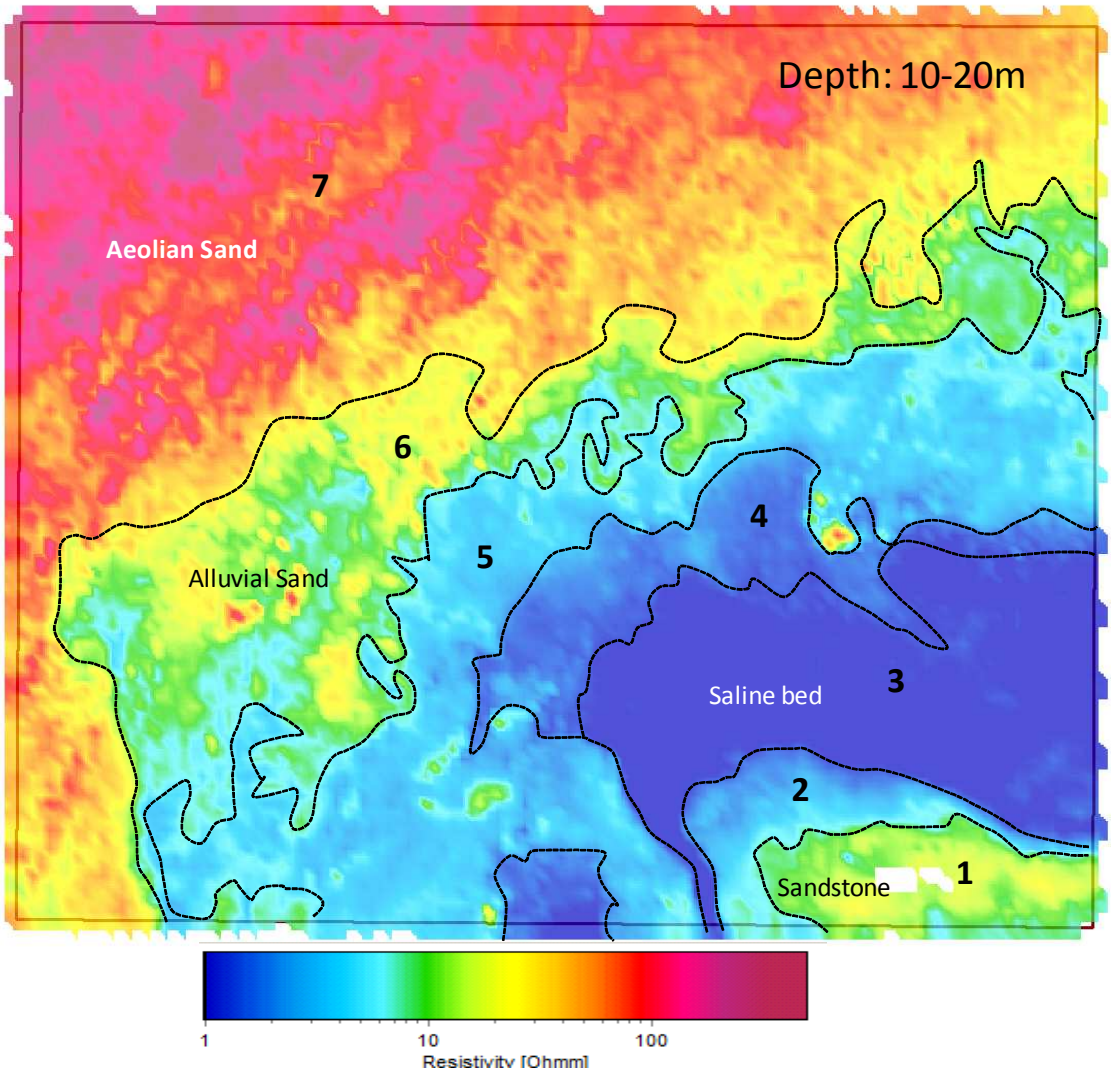
Table 11. Resistivity scale used for litho characterization

S.No.	Lithology	Resistivity (Ωm)
1	Sandstone, sandy limestone, ironstone shale	8-40
2	Sandstone	6-15
3	Limestone, marly Limestone, bentonitic, gypseous clay	1-3
4	Crystalline Limestone, chalky limestone	2-6
5	Gepseous limestone	2-8
6	Conglomerate, ferruginous sandstone	10-100
7	Aeolian sand and kankar	70-1000 or more



1. Sandstone, sandy limestone, ironstone shale
2. Sandstone
3. Limestone, marly Limestone, bentonitic, gypseous clay
4. Crystaline Limestone, chalky limestone
5. Gepseous limestone
6. Conglomerate, ferugenous sandstone
7. Aeolian sand and kankar

FIGURE 12. MEAN RESISTIVITY MAPS OF 0-10 M THICKNESS.



1. Sandstone, sandy limestone, ironstone shale
2. Sandstone
3. Limestone, marly Limestone, bentonitic, gypseous clay
4. Crystaline Limestone, chalky limestone
5. Gepseous limestone
6. Conglomerate, ferugenous sandstone
7. Aeolian sand and kankar

FIGURE 13. MEAN RESISTIVITY MAPS OF 10-20 M THICKNESS.

Figure 13 shows that the inferred litho boundaries are increasing and extending towards north and north-west. This reveals that the beds are dipping towards north and north-west. The saline bed which primarily dominated by limestone and gypseous clay acts as marker

bed separating unconfined and confined aquifer in north and north-west (see appendix-II; mean resistivity)

Mean resistivity map revealed a NW-SE running fault in the east of Ramgarh town (hereafter called Ramgarh fault). This looks to be a text book example of a fault with distinct shift of beds on either side of the fault. The Ramgar fault continued even in the south ward almost maintaining the same strike which divides Khara Runn and Meetha Runn villages located roughly 12 km in NW of Jaisalmer city.

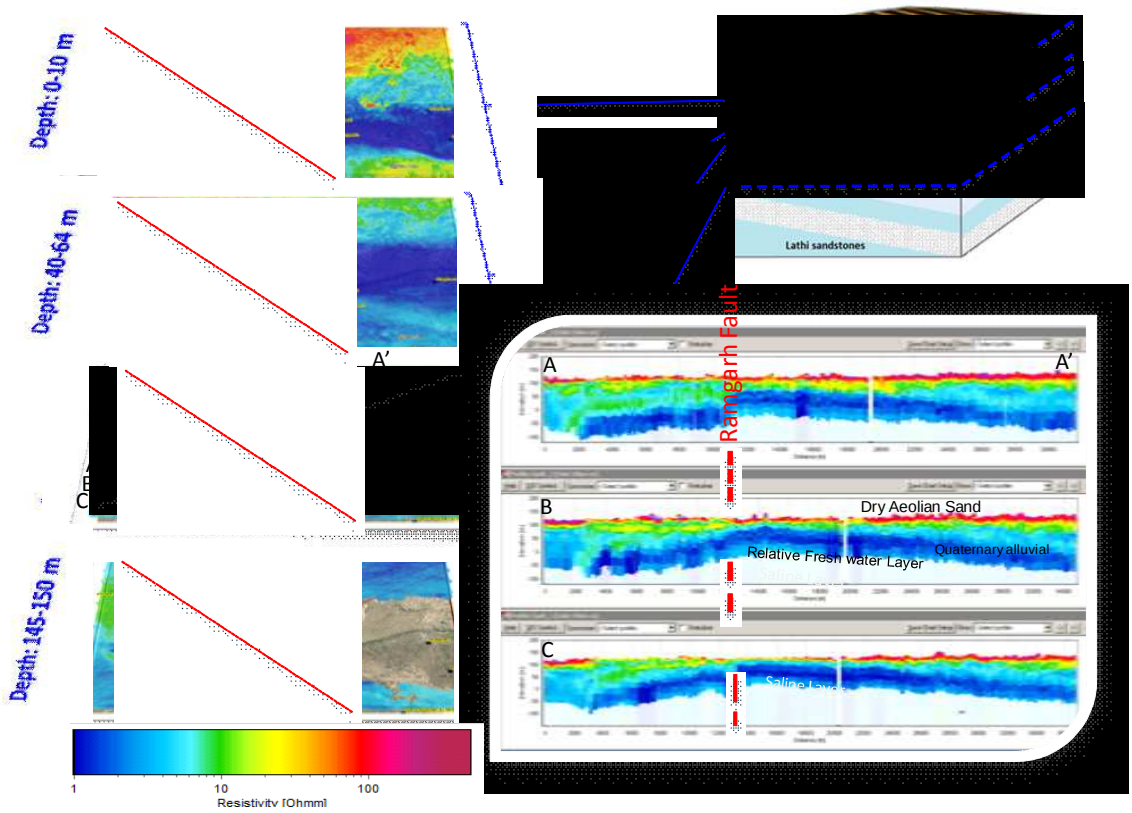


Figure 14.Mean Resistivity Map And Vertical Cross Section Showing Inferred Ramgarh Fault And Disposition Of Saline Bed That Separates Upper Unconfined And Below Confined Aquifers

HELIMAG RESULTS

HeliMag survey was carried out along with the HeliTEM using Geometrix Caesium vapour type having sensitivity 0.1 nT. Magnetic sensor was synchronized with TEM measurements. The position of the magnetometer sensor is located at the front panel as shown in Figure 16.

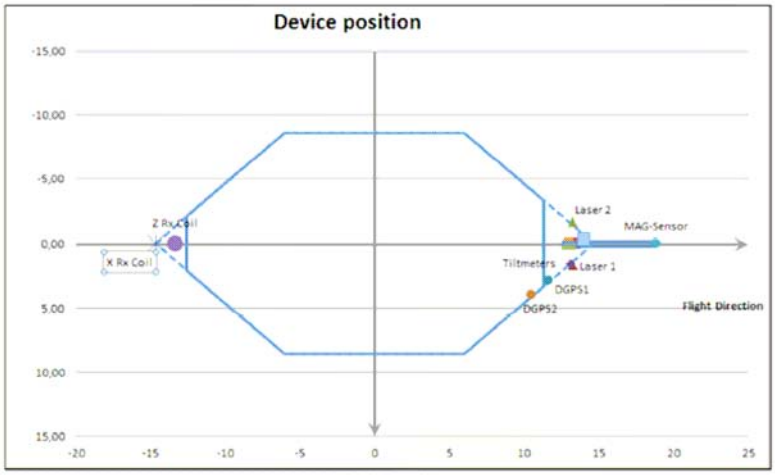


FIGURE 15. Sketch showing the frame and the position of the basic instruments including the GPS position

A base station was used for continuous magnetic measurement to record the temporal changes, which is applied for correcting the magnetic data recorded by the by main magnetometer attached with HeliTEM transmitter. Final processing of the magnetic data involved the application of traditional corrections to compensate for diurnal variation and heading effects prior to gridding. Advanced full processing of magnetic data was implemented in Geosoft's Oasis Montaj softwareas follows:

- Processing of static magnetic data acquired on magnetic base station
- Pre-processing of airborne magnetic data
- Stacking of data to 10 Hz in SkyLab (SkyTEM in-house software).
- Moving positions to the center of the sensor in SkyLab.
- Processing and filtering of airborne magnetic data
- Standard corrections to compensate the diurnal variation and heading effect
- IGRF correction
- Statistical and full leveling
- Micro leveling
- Gridding

Finally total magnetic field intensity map has been prepared after all correction and data leveling (figure 16). Magnetic data is found varying from 46632 nT to 46897 nT. Magnetic being potential field that cumulative magnetic field response of thick layer, looks to be not of much useful for 300 m depth of investigation.

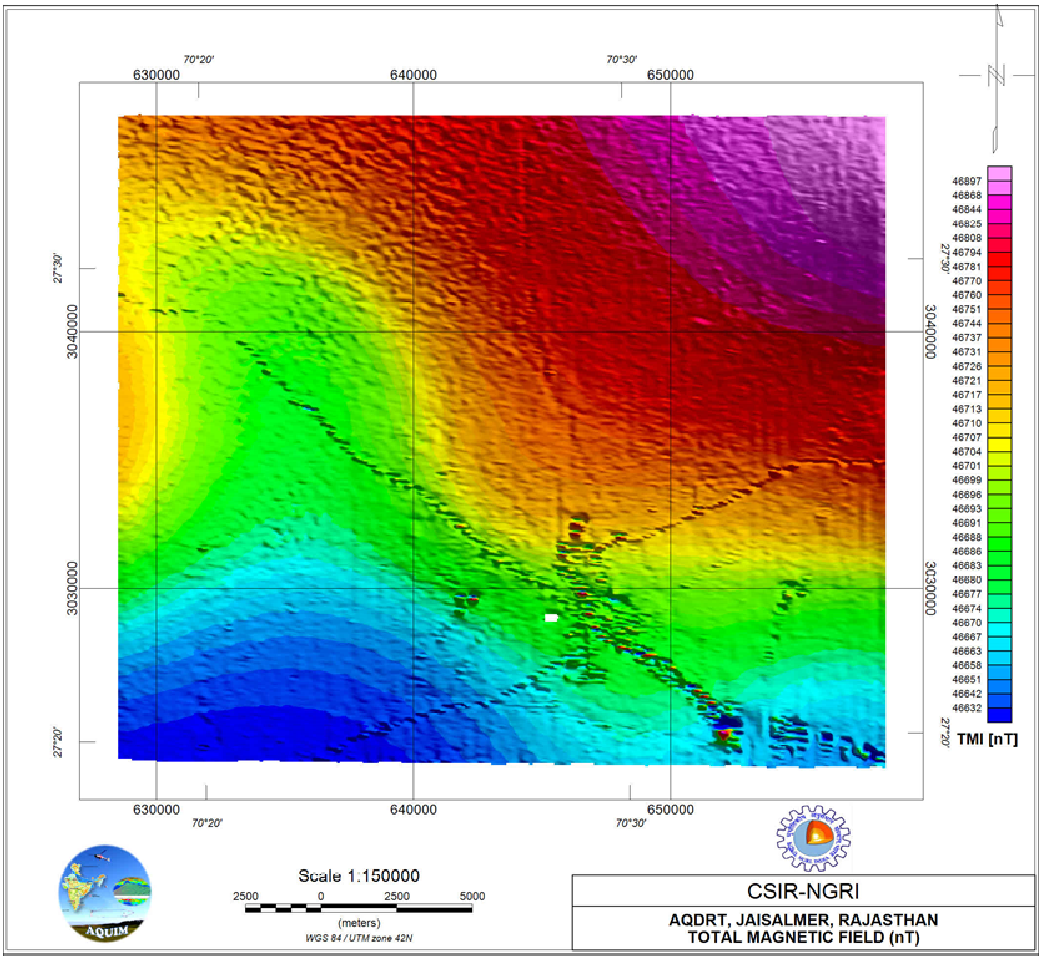


FIGURE 16.Total Magnetic Field Intensity Map (NT) of DESERT AREA.

3.6 SUB-SURFACE INFORMATION

Data on sub-surface information is partly generated through ground water exploration carried out in the Desert Area project area and partly though SkyTEM study carried out by NGRI. The objective of the construction of exploratory tubewells is to validate the geophysical findings arrived through surface and airborne geophysical studies particularly SkyTEM carried out by NGRI. The objective of the study is to configure the Aquifer Geometry and its characterization. So far, 2 wells have been constructed in the area and another well is under construction. The location of exploratory well sites constructed during the project is given in figure 17.

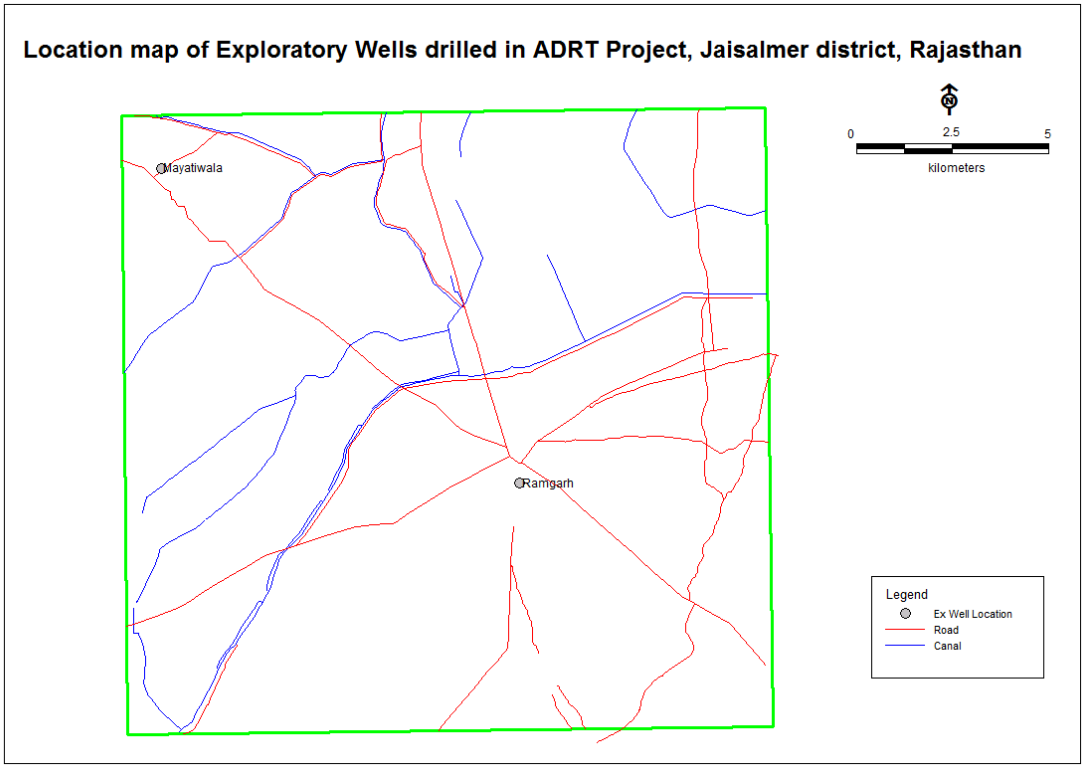


Figure 17. Location of exploratory wells drilled in Desert Area project

Two wells are drilled in Desert project area. The salient features of the exploratory wells are given in table 12.

Table 12. Salient features of exploratory wells constructed in Desert Area project, Ramgarh area, Jaisalmer district, Rajasthan

S. No.	Location	Coordinates		Drill depth	constructed depth	Zones Tapped		Formation	Disc	DD
		Long.	Lat.	(m)	(m)	From	To		(lpm)	(m)
EW1	Ramgarh	70.48	27.38	300	235	221	233	Tertiary Sedimentary rocks	180	60
EW2	Mayatiwala	70.35	27.48	300	91	84	90	Alluvial formation	-	-

Selection of Drilling Sites

Sites for construction of Exploratory Well were selected based on the recommendation of NGRI for validation of SkyTEM results. All the sites are located in the Government land.

Construction of Exploratory Borewells

The conventional direct Rotary Method of drilling was adopted since the formations are soft rocks. Drag bits are used for drilling the hole. The pilot holes are drilled of 215 mm diameter. During drilling, drill time log and lithological log are maintained. Geophysical loggings are carried out in the pilot hole to identify the potential fresh water zones. Geophysical loggings include Spontaneous Potential and Resistivity logging as well as Gamma logging. Well assembly are recommended based on the combined interpretation of drill time log, lithological log and geophysical logs. The detailed lithological logs, drill time logs and borehole geophysical logs are given in Annexure IV.

Once, well assembly is recommended, reaming of pilot hole is carried out to accommodate well assembly and pea gravel pack. The water wells are developed with the aim to remove mud cake and also finer material from the aquifer, thereby cleaning out, opening up and/ or enlarging passages in the formations so that water can enter the well more freely.

Plate 5 Exploratory drilling operation in Desert Area project, Ramgarh area, Jaisalmer district, Rajasthan

3.7 WATER LEVEL

In all 14 monitoring wells are established in the project area which include 9 tubewells and 5 open wells taping perched aquifer. The perched aquifer is not connected with the principal aquifer system of the area. It collects rain water and therefore the quality if good as compared with the principle aquifer system. The locations of the wells are shown in the figure 18. The basic attributes of the monitoring wells are given in table 130.

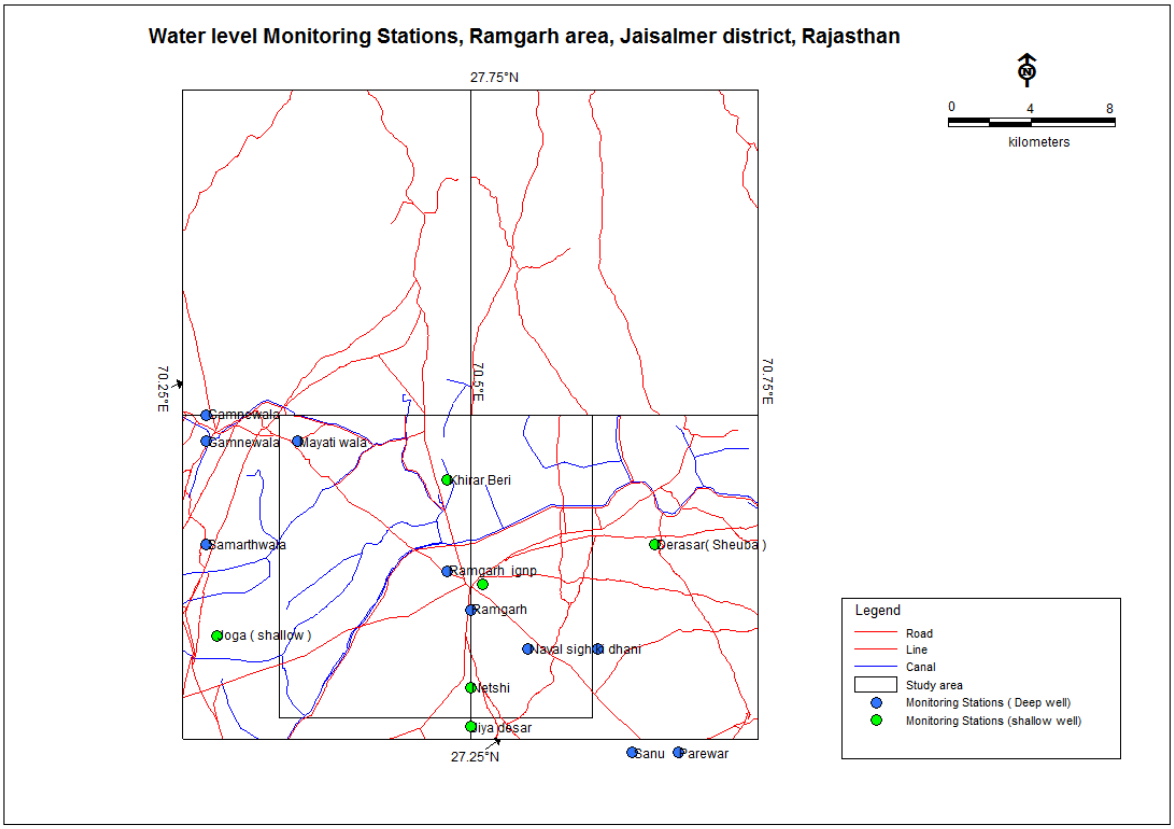


Figure 18. Location Map of monitoring wells

Table 13. Monitoring Wells established in the Desert Area project, Jaisalmer district, Rajasthan

Sno.	Location	LongD	LongM	LongS	LatD	LatM	LatS	Elevation (m)	Block	Type	Others
MW1	Naval sigh ki dhani	27	19	7	70	33	1	177	Sam	Pz.	DTW
MW2	Gamnewala	27	29	33	70	16	47	110	Sam	Pz.	DTW
MW3	Gamnewala	27	29	13	70	16	47	111	Sam	Pz.	DTW
MW4	Joga (shallow)	27	19	49	70	37	18		Sam	DW	Perched
MW5	Joga (Deep)	27	19	49	70	37		207	Sam	DW	DTW
MW6	Netshi	27	17	43	70	30	20	168	Sam	DW	Perched
MW7	Jiya desar	27	15	45	70	31	5	183	Sam	DW	Perched
MW8	Raypal	27	22	20	70	30	50		Sam	DW	Perched
MW9	Derasar (Sheuba)	27	24	7	70	39	35		Sam	DW	Perched
MW10	Mayati wala	27	29	1	70	21	24	117	Sam	DW	DTW
MW11	Samarthwala	27	24	14	70	16	26	117	Sam	DW	DTW
MW12	Sanu	27	14	55	70	38	59	214	Sam	Pz.	DTW
MW13	Ramgarh	27	21	49	70	30	21	148	Sam	Pz.	DTW
MW14	Ramgarh IGNP	27	22	39	70	29	12	150	Sam	Pz.	DTW

Monthly water level data of all the 14 monitoring wells of the area is given in the Annexure - V. It is observed that the depth to water level of the principle aquifer is generally in the range of 50 to 70 m below ground level and that of perched aquifer is mostly within 5 m bgl. The hydrographs of representative monitoring stations were prepared and are shown in figures 19.

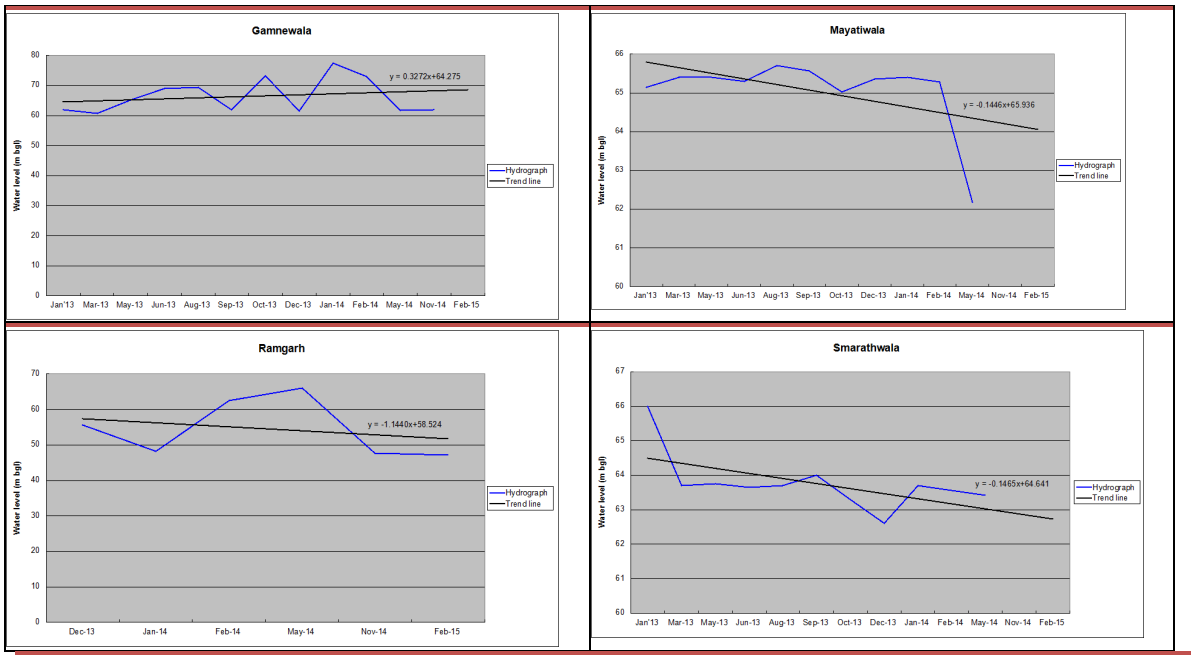


FIGURE 19. HYDROGRAPHS SHOWING MONTHLY WATER LEVEL OF REPRESENTATIVE MONITORING STATIONS IN DESERT AREA, JAISALMER DISTRICT, RAJASTHAN

A description of the pre-monsoon and post-monsoon water level scenario of the project area during the study period is given in the following paragraphs.

Pre-monsoon 2014

In the month of May, 2014, the depth to water level in the principle aquifer system of the area varies from 65 m bgl at Gamnewala outside the north-west border of the study area to 81 m bgl at Naval Singh Ki Dhani in the south-east corner of the study area. The thematic water level map for the month (figure 20) shows that the depth to water level gradually increases from north-west to south-east.

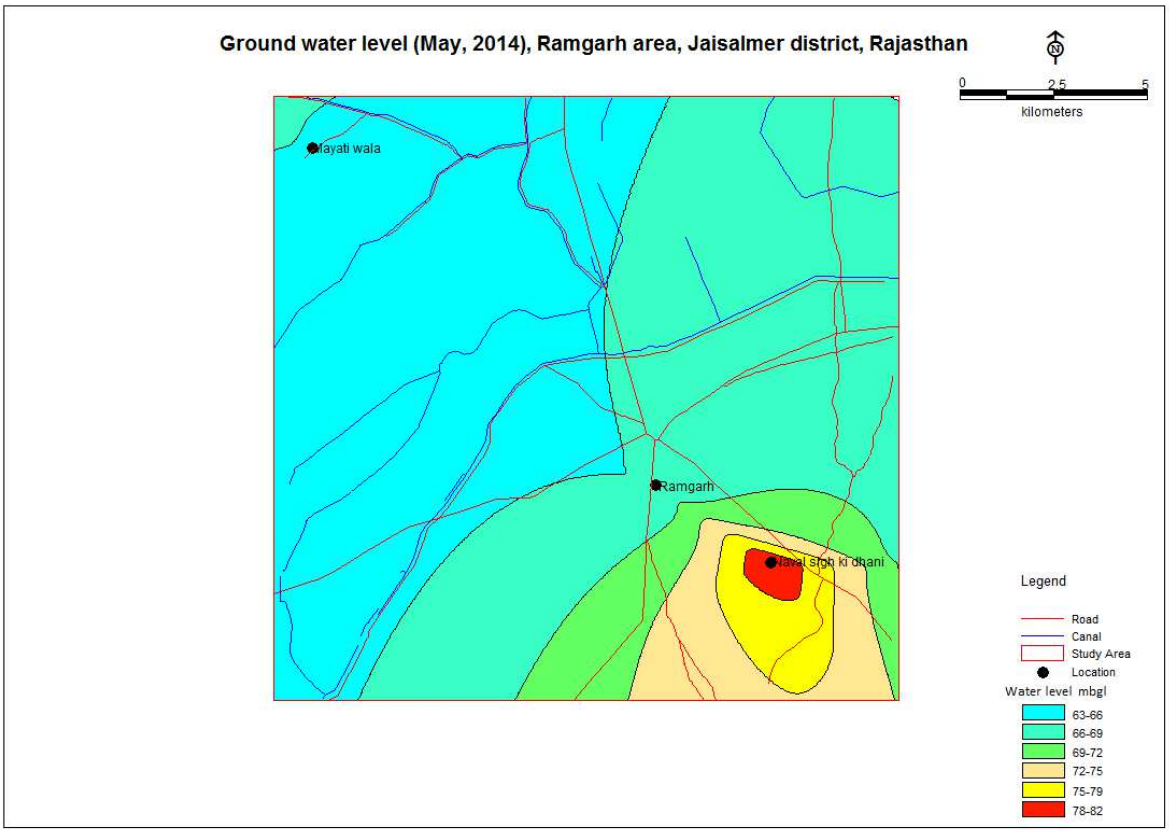


Figure 20. Depth to water level map of pre-monsoon (May), 2014, Desert Area, Jaisalmer district, Rajasthan

Post-monsoon, 2014

The depth to water level scenario during November, 2014 has changed due to the seepage from IGNP canal system which has resulted in shallower ground water level in the central portion of the project area through which the canal is following. The depth to water level in the area varies from 43 m bgl at Ramgarh to 67 m bgl at Joga, on the south-east boundary, just outside the project area. As described above, the shallower ground water level in the range of 43 m bgl to 45 m bgl have been recorded in the central portion of the project area and deeper water level of more than 63 m bgl have been recorded at Mayatiwala, Gamnewala sites in the north-west corner and Joga in south-east corner.

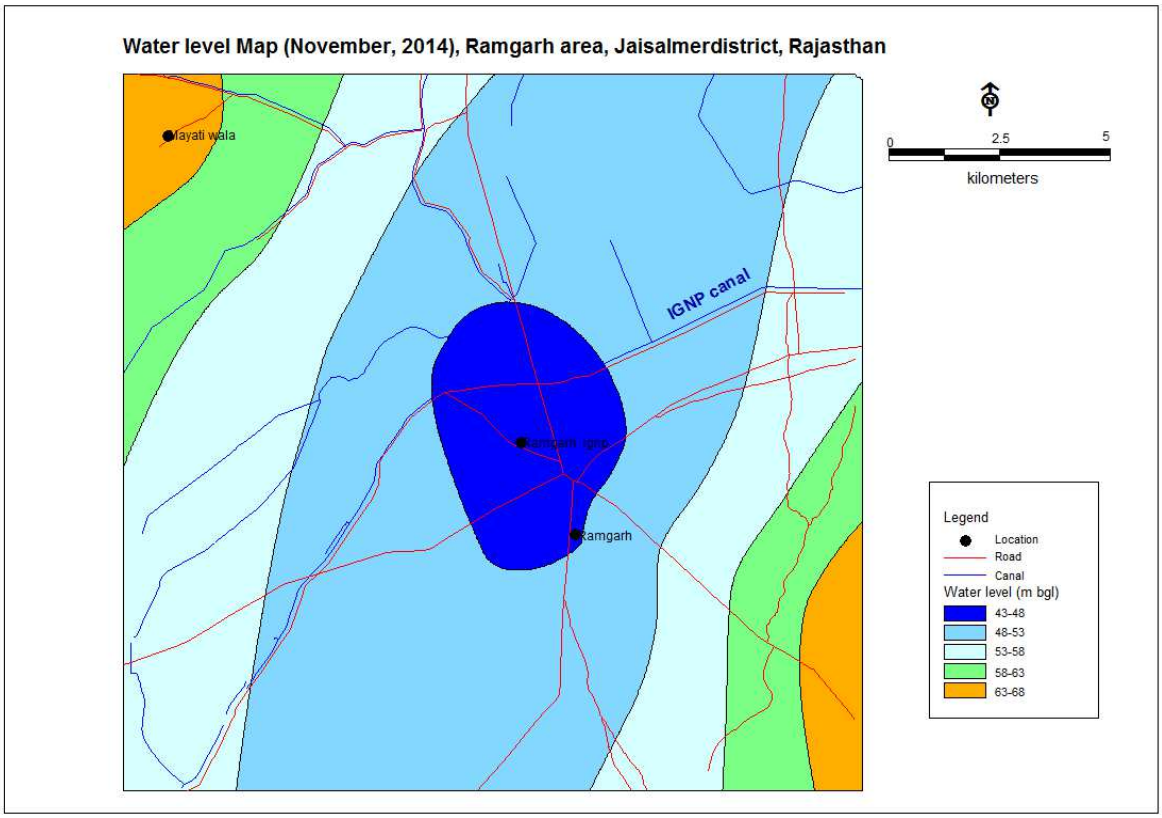


Figure 21. Depth to water level map of post-monsoon (November, 2014), Desert Area, Jaisalmer district, Rajasthan

Long term ground water level trend

The long-term water level trend was computed for two national hydrograph monitoring stations of CGWB exiting within the project area. These are Ramgarh, in the central part of the project area and Gamnewala outside the north-western boundary of the project area. The information on long term water level trend is given in table 14 and presented in figure 23. No significant trend in water level has been observed in monitoring wells in Ramgarh area.

Table 14. Long term water level trend of National Hydrograph Monitoring Stations, CGWB

Sl. No.	Location	Longitude	Latitude	Data Availability	long Trend (m/yr.)
1	Ramgarh	70.28	27.49	2003-2014	0.0008
2	Gamnewala	76.64	27.07	2004-2014	(-)0.0002

The Hydrographs of the Long-term water level trend stations are shown in Figure 22.

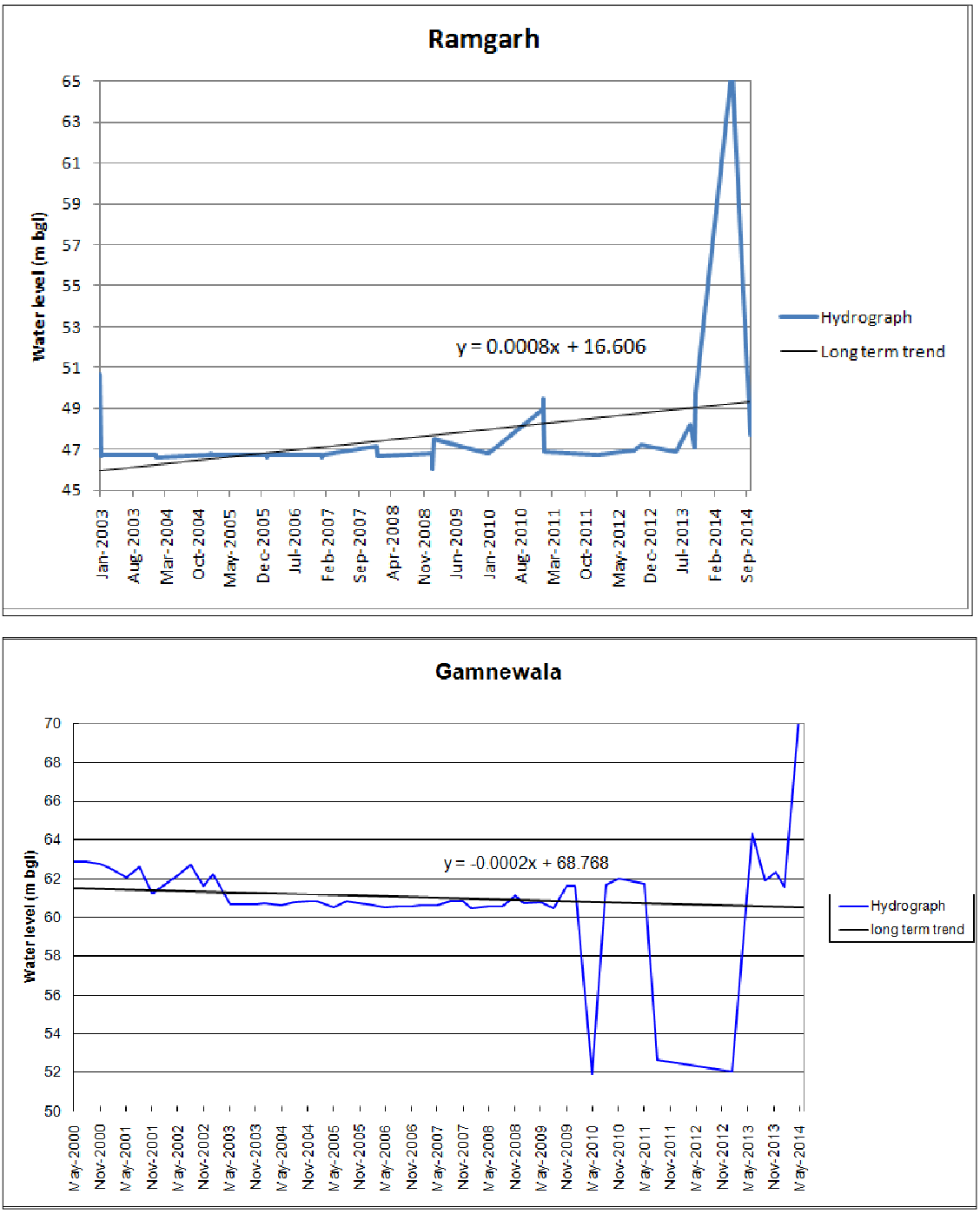


Figure 22. Time series data of the National Hydrograph Stations of CGWB in Ramgarh area, Jaisalmer district, Rajasthan

The average water level long term trends of the different ground water potential zones as computed in the ground water resources assessment, 2011 jointly assessed by State Ground

Water Department and CGWB is given in table 15. A perusal of the data indicates that as such there is no significant long term trend in the study area.

Table 15. Average long term water level trend computed in Ground water resources assessment, 2011

Sl. No.	Ground Water Potential Zone	Pre-monsoon trend (m/year)	Post-monsoon trend (m/year)	Pre-monsoon (whether significant change?)	Post-monsoon (whether significant change?)
1	Alluvium (A2/1)	0.20	0.17	Yes	No
2	Pariwar sandstone (P1/1)	-0.02	-0.17	No	No

3.8 WATER QUALITY

The basic chemical parameters were determined for evaluating the groundwater quality of Ramgarh area, Jaisalmer district, Rajasthan are pH, EC, TDS, CO_3, HCO_3, Cl, NO_3, $S0_4$, PO_4, F, Ca, Mg, TH, Alkalinity, Na, K, and Fe. These elements are determined using instruments such as pH meter, EC Meter, Flame Photometer, UV/Visible spectrophotometer and titrimetric methods. Water samples are collected from both dug wells and tubewells. The chemical analysis results are given in Annexure VI. The major quality findings are described as under.

1. Electrical conductivity

Electrical conductivity represents total number of cations and anions present in ground water indicating ionic mobility of different ions, total dissolved solids and saline nature of water. Salinity can be caused due to the intrinsic property of the aquifer. Over exploitation of fresh ground water, lack of recharge, average rainfall and strong evaporation in area with shallow water tables may also lead to salinization. Excessive pumping and irrigation practices may stimulate precipitation of dissolved solids and salts on agricultural lands leading to salinity of ground water. In Jaisalmer district, the potable groundwater was considered upto 3000µS/cm.

The electrical conductivity in the study area varies distinctly between water samples collected from shallow perched aquifer and deep principle aquifer system. The perched aquifer has EC ranges from 440 µmhos/cm to 3710 µmhos/cm, indicating potable nature of the water. In contrast, the deeper principle aquifer system has EC range between 4660 µmhos/cm and 7010 µmhos/cm. The high salinity content of the aquifer is attributed to the intrinsic chemical composition of the sediments which are marine deposits. Table 16 gives the EC of the water samples collected from both the perched aquifer and deep principle aquifer system.

Table 16. Electrical conductivity in Ramgarh area, Jaisalmer district, Rajasthan

Perched aquifer

SITE	Long	Lat	EC in µmhos/cm
Biprasar netsi pond	70.50	27.29	440
Jiyadesar dw	70.52	27.34	580
Derasar seasonal pond	70.65	27.40	620
Joga shallow dw	70.62	27.32	1090
Raypal Kharin dw	70.51	27.37	3710

Principle Aquifer System

SITE	Long	Lat	EC in µmhos/cm
Maayatiwala dw	70.35	27.48	7010
Samrathwala dw	70.27	27.40	6400
Gamnewala tw	70.27	27.48	4660

3. Fluoride

Fluoride is one of the most important ion to human health. Fluoride in drinking water has both positive and negative effects on human health. In small amount of Fluoride (<1.0 mg/l) have proven to be beneficial in reducing tooth decay. Community water supplies commonly treated with sodium fluoride and fluorosilicates to maintain fluoride level ranging between 0.8 to 1.2 mg/l to reduce the incidences of dental carries. But excess fluoride concentration in drinking water has detrirous effects on human health. It causes a dreadful disease known as Fluorosis.

The fluoride content in ground water of Ramgarh area, Jaisalmer district is given in table 174. A perusal of the table reveals that at all places, the fluoride content is within the permissible limit of 1 mg/l.

Table 17. Flouride content in ground water in Ramgarh area, Jaisalmer district, Rajasthan

SITE	F (mg/l)
Perched aquifer	
Biprasar netsi pond	0.05
Derasar seasonal pond	0.05
Joga shallow dw	0.20
Raypal Kharin dw	0.60

SITE	F (mg/l)
Jiyadesar dw	0.05
Principle aquifer	
Maayatiwala dw	0.88
Samrathwala dw	0.20
Gamnewala tw	0.95

4. Nitrate

As per the BIS standard for drinking water the desirable limit of nitrate concentration in ground water is 45 mg/l with relaxation up to 100 mg/l. Though nitrate is considered relatively no toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of methoemoglobinomial particularly in infants.

The table 18 showing distribution of nitrate in the Ramgarh area reveals that all the samples have nitrate concentration within the permissible limit of 100 mg/l.

Table 18. Nitrate content in ground water in Ramgarh area, Jaisalmer district, Rajasthan

SITE	NO3 (mg/l)
Perched aquifer	
Biprasar netsi pond	4.00
Jiyadesar dw	1.00
Derasar seasonal pond	3.00
Joga shallow dw	22.00
Raypal Kharin dw	11.00
Principal aquifer	
Maayatiwala dw	80.00
Samrathwala dw	15.00
Gamnewala tw	18.00

3.9 RECHARGE PARAMETERS

Rainfall recharge factor or Infiltration factor is a recharge parameter which can be estimated using various techniques including soil infiltration tests. Infiltration factor can be defined as a ratio of quantum of infiltration to quantum of water applied, in other words, it indicate a quantum of water recharged to the ground water system in relation to the rainfall. It is a function of rate of infiltration and ability of the system to accept the infiltrated water. The Infiltration factor can be expressed as –

IF = (Qi/Qa) X SY,

Where,
IF = Infiltration Factor
Qi = Quantum of water infiltrated over the test period in m
Qa = Quantum of water applied in m
SY = Specific Yield
Qi and Qa are derived from the soil infiltration test as discussed in section 3.2. The specific yield values are obtained from dynamic ground water resources assessment report of 2011 for Sam block, Jaisalmer district. Infiltration factors computed for various test sites are given in table 19. The average Infiltration / Recharge factor of various ground water potential zones as deducted from the above mentioned study are as follows –
Alluvium – 0.01; Tertiary sandstone –0.01 and Pariwar sandstone – 0.01

Table 19. Infiltration Test results carried out in Ramgarh area, Jaisalmer district

S. No.	Site	Ground water Potential Zone	Season	Total Quantum of water added (m)	Total Quantum of Water infiltrated (m)	Sp. Yld	Total quantum of water recharged (m) [6*7]	IF (Recharged water/added water)	IF (GEC Norms)	Moderated IF value
1	2	3	4	5	6	7	8	9	10	11
1	Ramgarh	Tertiary Sandstone	Post-Monsoon'13	20.9	4.6	0.04	0.184	0.01	0.025	0.01
2	Gamnewala	Alluvium	Post-Monsoon'13	21	1.3	0.04	0.052	0.002	0.025	0.01
3	Navalgaon	Pariwar Sandstone	Post-Monsoon'13	19.7	1.6	0.04	0.064	0.003	0.025	0.01
4	Khirar Beri	Saline Tertiary	Pre-Monsoon'14	38.7	26.6	0.04	1.0640	0.03	0.025	0.03
5	Ali Ki Dhani	Saline Tertiary	Pre-Monsoon'14	21.4	4.5	0.04	0.180	0.01	0.025	0.02

3.10 DISCHARGE PARAMETERS

There are no irrigation wells as per the dynamic ground water resources of Rajasthan, 2011 in Ramgarh area. Therefore, estimation of discharge parameter has not been carried out in Desert Area project.

4. DATA INTEGRATION

4.1 Introduction

Validation of the heiloborne and surface geophysical data with the drilling log results has been done on the WellCAD platform using the evaluation version. This provides excellent platform for data validation and integration. Finally we have integrated all sorts of available information from heliborne, surface, borehole geophysics and drilling logs and prepared composite and integrated litholog upto 300 m depth. There are total two well drilled where first drill well is located at Ramgarh village and other drilled recently at Maithywala well site. Ramgarh well is logged only for SP and short and long normal. The Maithywala well logged last week is found successful. The logged resistivity is found almost of the same order as achieved by SkyTEM smooth model. It is yet to be received the full log and CGWB consolidated report. In this report the Ramgarh log has been presented in figure 23. Based on the borehole resistivity log entire lithology could broadly be divided into three major section. The first top 15 m is resistive which corroborate well with the SkyTEM resistivity. Followed by low resistive zone till 33 m which is attributed as clay stone and found as low resistivity by SkyTEM as well. Further there is distinct high resistivity shown by N-16 and little by N-64 till 75 m that also correspond well by SkyTEM. Integrated litho units are given in table 20.

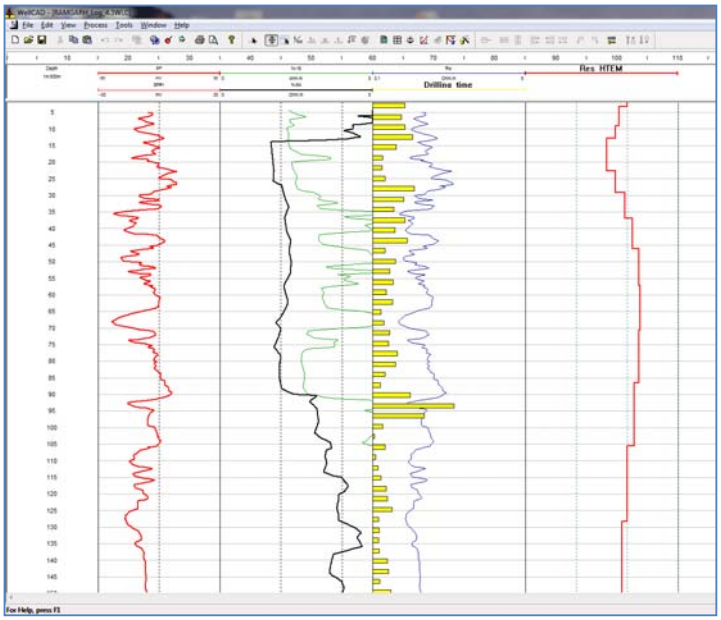


Figure 23. Borehole geophysical logs i.e. Self potential (sp), resistivity (short normal, long normal and lateral), drill time, penetration rate (pr), SkyTEM smooth resistivity model of ramgarh village

Table 20. Consolidated Litholog of Exploratory Borewell at I G N P Colony, Ramgarh, District Jaisalmer

From	To	Lithology
5	14	Aeolian soil (sandy and silty)
14	33	Clay stone
33	56	Siltstone with calcareous intercalation
56	62	Limestone
62	90	Claystone
90	136	Siltstone with calcareous intercalation
136	190	Shaly limestone
190	205	Shale
205	230	Shaly limestone (slotted zone)
230	247	Shale
247	262	Shaly limestone
262	295	Shale

4.2 TRANSLATION INTO HYDROGEOLOGICAL MODEL

In order to achieve one of the main objectives of mapping the principal aquifers, we established an approach for translating the geophysical results into the hydrogeological models through the steps as follows:

a. SkyTEM results are calibrated against the drilling lithologs, ground and borehole geophysical results and then integrated lithological log at each borehole are prepared.
b. Equivalent litho-units of the integrated logs are converted into principal litho-units as proxy of principal aquifer and aquitard.
c. The principal lithologs are imported to the Arhus Workbench and incorporated with the individual sections prepared at each 2 km x 2 km grid line as shown in Figure 20.
d. The principal litho-facies are interpolated and extrapolated along the SkyTEM sections using the calibrated resistivity values.
e. Based on the hydro-stratigraphy, the principle lithological units are finally attributed into principal aquifers, exploited aquifers , confining layers and bedrocks

Lithological layer boundaries are prepared for all possible SCI model separated ~25 m from each other along the grid lines. This is followed by gridding using the kriging interpolation scheme. Of course, the interpolation has averaged out some of the sharp anomalies indicating smooth variation. In order to retain the small-scale variation, it is desired to do the digitization and demarcation of lithological boundaries for all the flight lines. Elevation of all the inferred lithological layers at each grid intersection have been handed over to the CGWB to form 3-D Aquifer Geometry.

One typical profile is shown below

North **South**

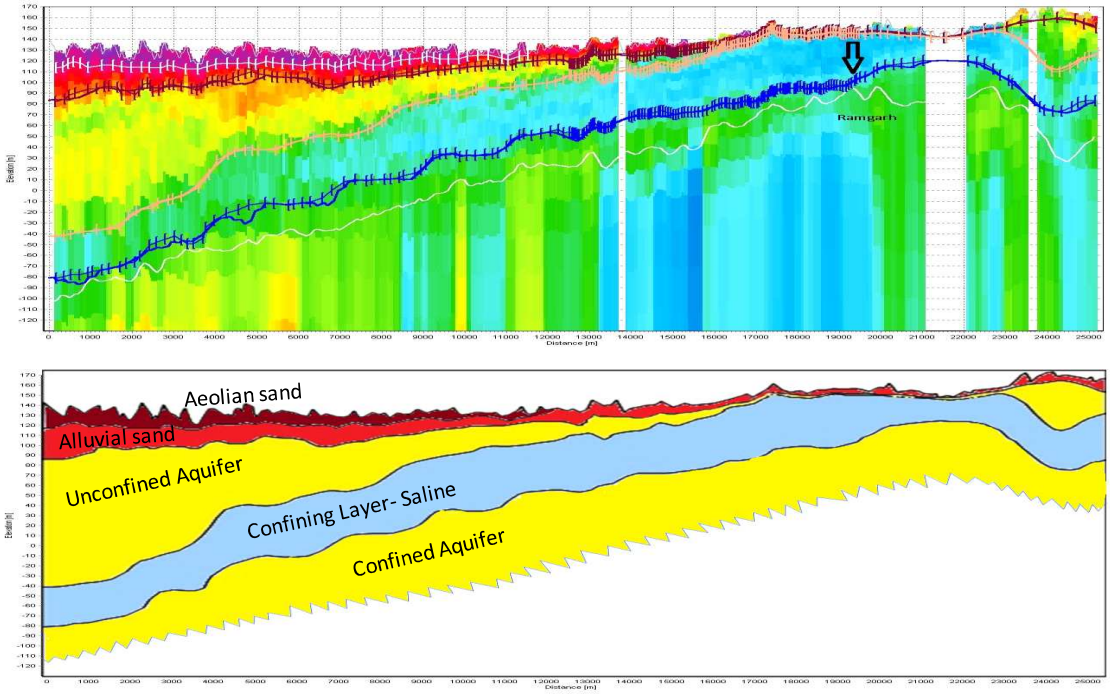


Figure 24. Skytem Resistivity Section and Translated Litho/Aquifer Model Along The Nine Passing Through Ramgarh Village Running In N-S Direction

AQUIFER MAPS

Using the above logic and methodology of translating the geophysical data into hydrogeological model, aquifer maps are prepared in the entire area by digitizing the SCI resistivity model with reference to the integrated lithologs. The upper surface of the hydrogeological layers forming aquifer maps are prepared showing the following: i) DEM (Fig. 25), (ii) elevation map of sand dunes (Fig. 26), (iii) *Elevation map of top of unconfined aquifer and* or *water table* surface (Fig. 27), (iv) *Elevation map of top of* saline layer which marly limestone and gypseous clay (Fig. 28) and (v) *Elevation map of top of* confined aquifer containing relatively fresh groundwater (Figure 29).

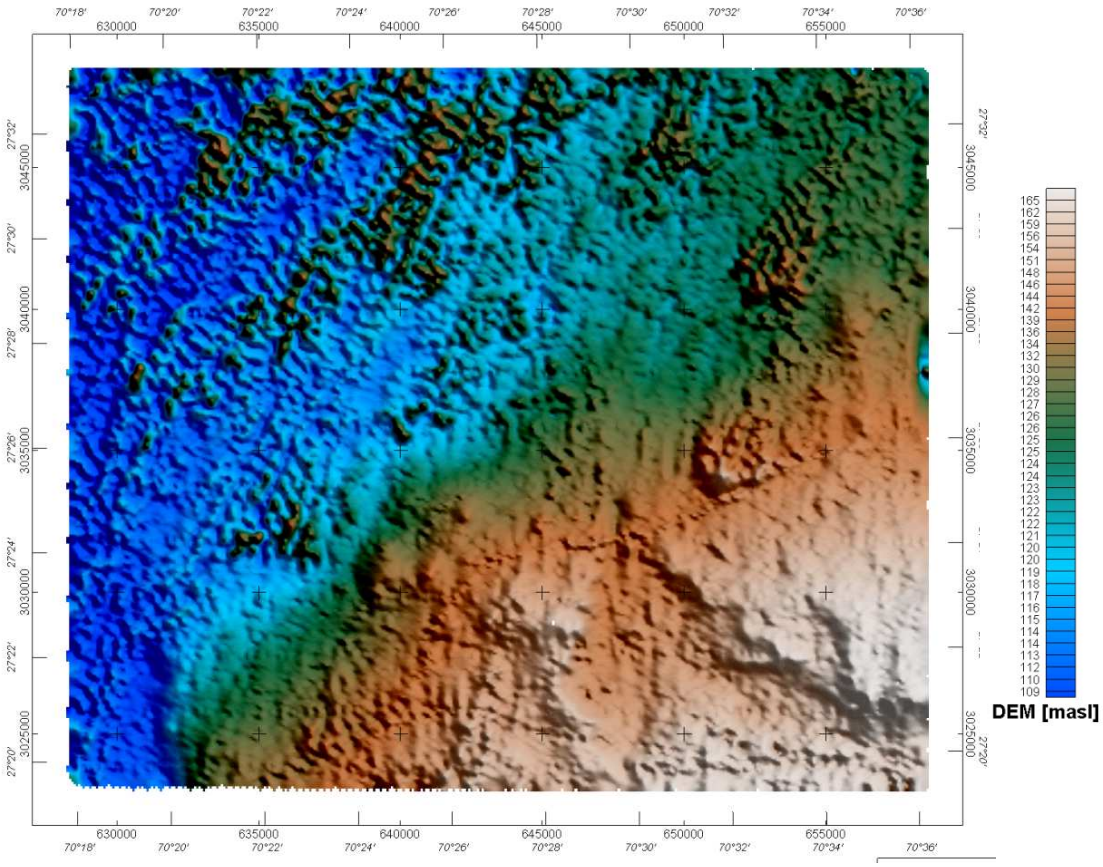


FIGURE 25. Dem Map Prepared From DGPS Data Collected While Skytem Survey.

Elevation map of sand dunes bottom

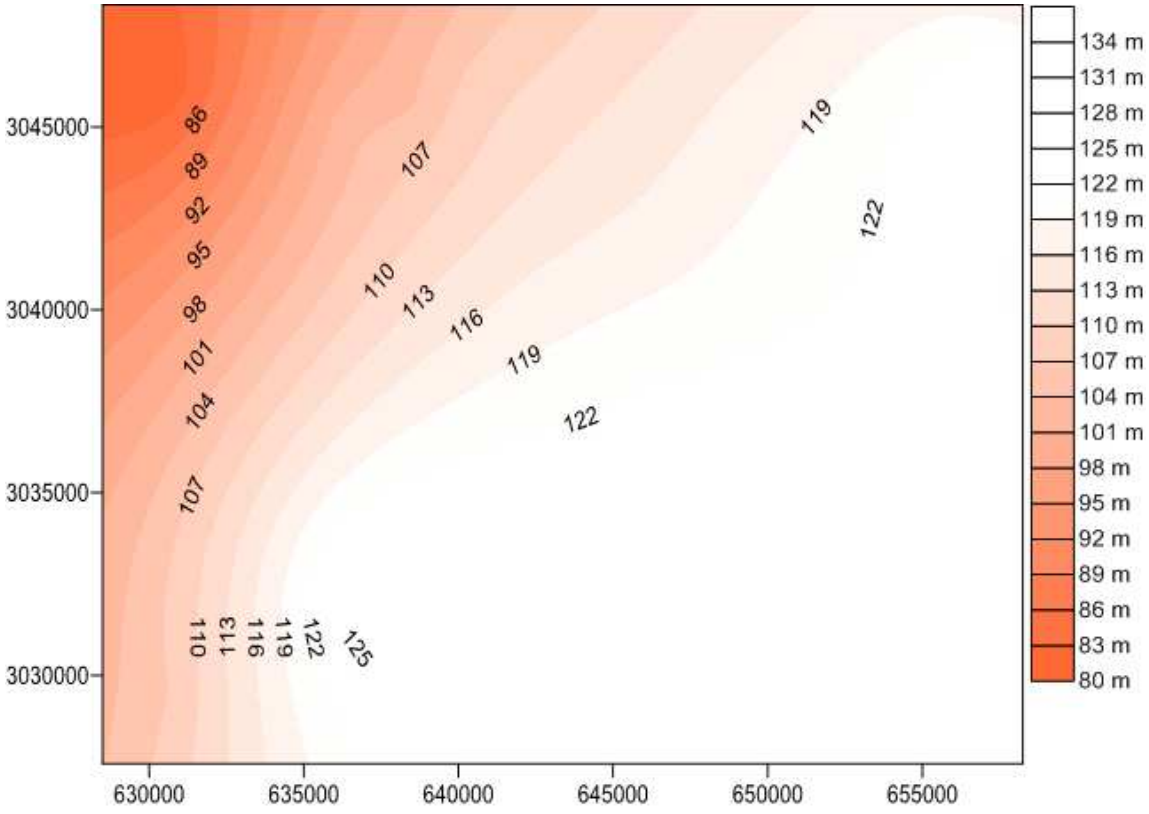


FIGURE 26. Elevation Map of Sand Dune Bottom

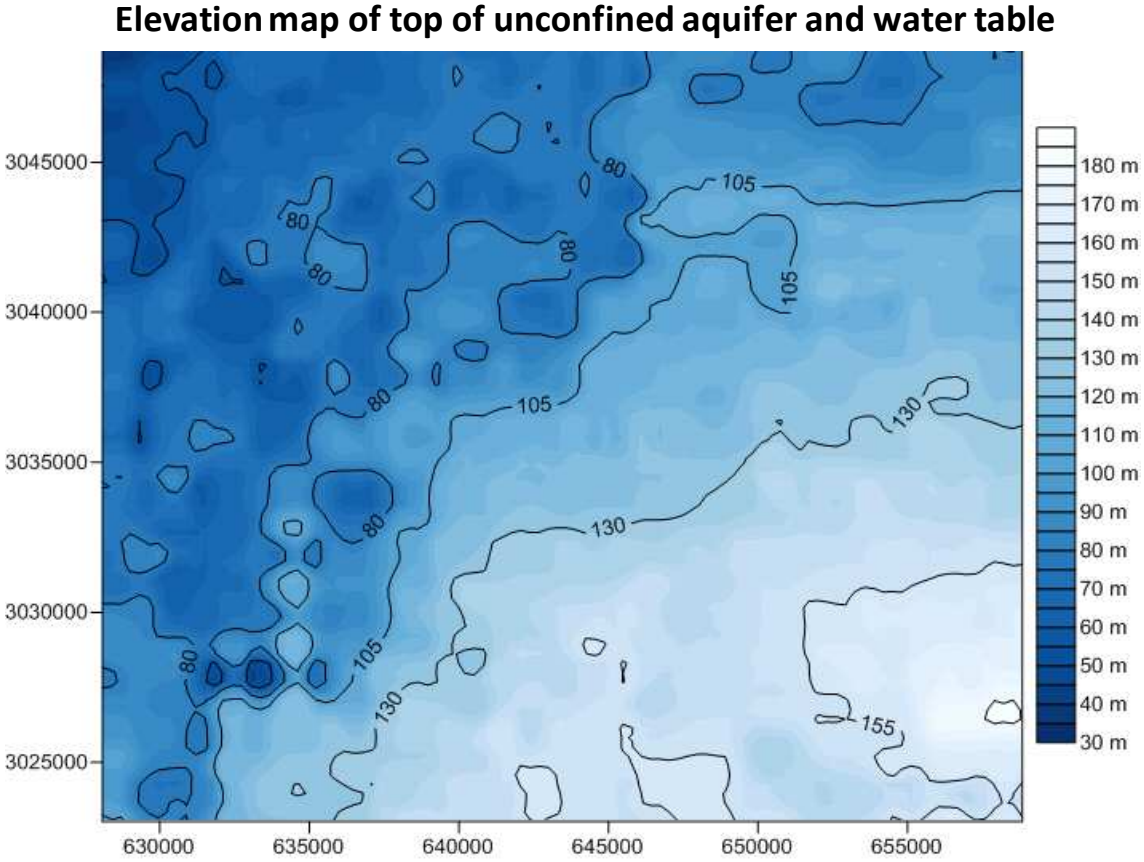


FIGURE 27. Elevation Map of Top of Unconfined Aquifer and Water Table Surface

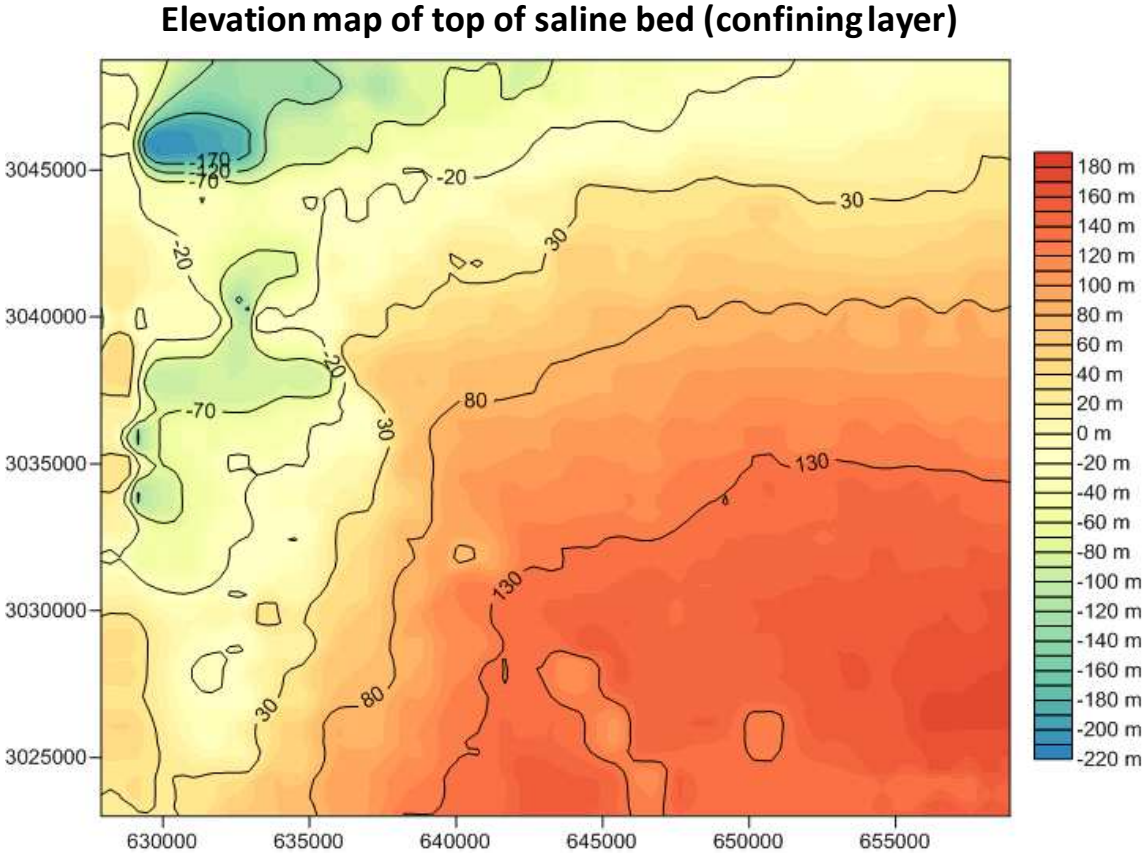


FIGURE 28. Elevation Map of Top Of Saline Layer which Marly Limestone and Gypseous Clay

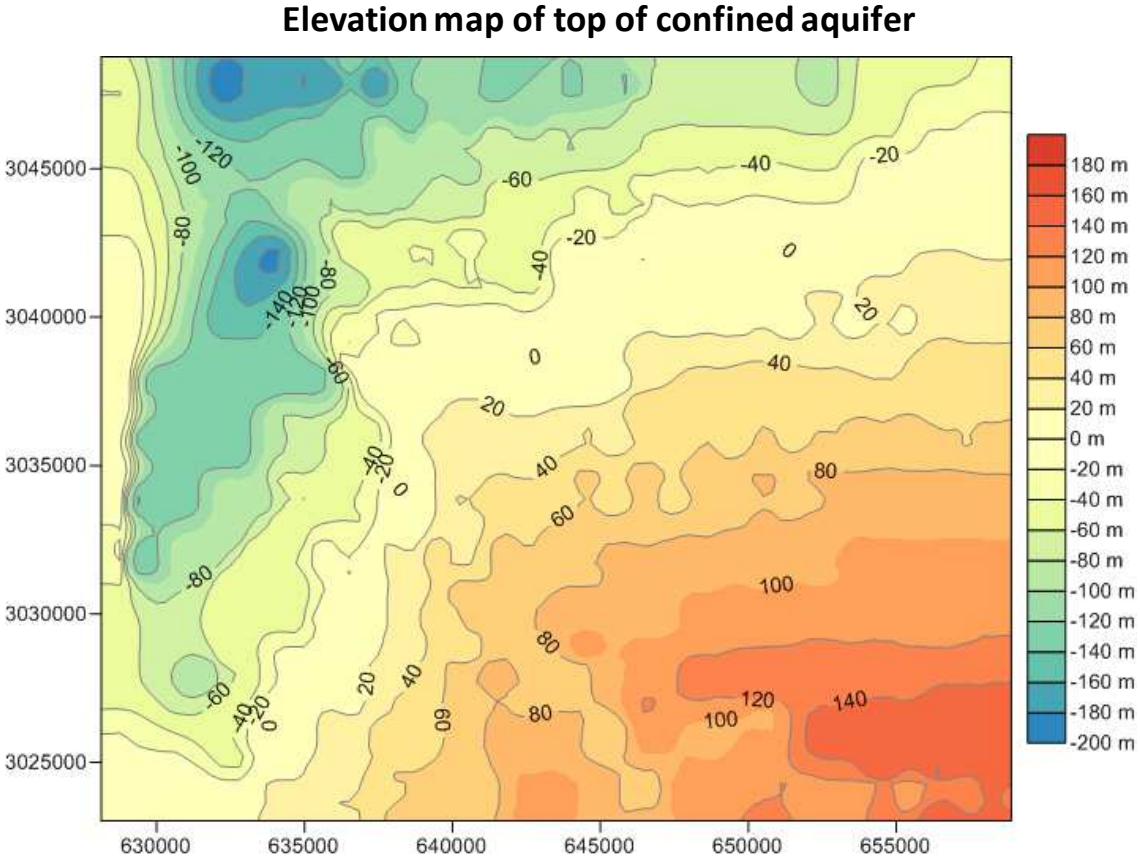


Figure 29. Elevation map of top of Confined Aquifer containing relatively fresh groundwater

THREE-DIMENSIONAL RESISTIVITY SECTION

Figure 30 shows 3-D map of the aquifer system by slicing the two vertical sections in the EW and NE-SW direction keeping 250 m thickness. This shows clearly Aeolian sand, quaternary alluvial, disposition of saline bed separating unconfined and confined aquifer. Once precise drilling is done and groundwater quality is analyzed, more precise interpretation would be possible.

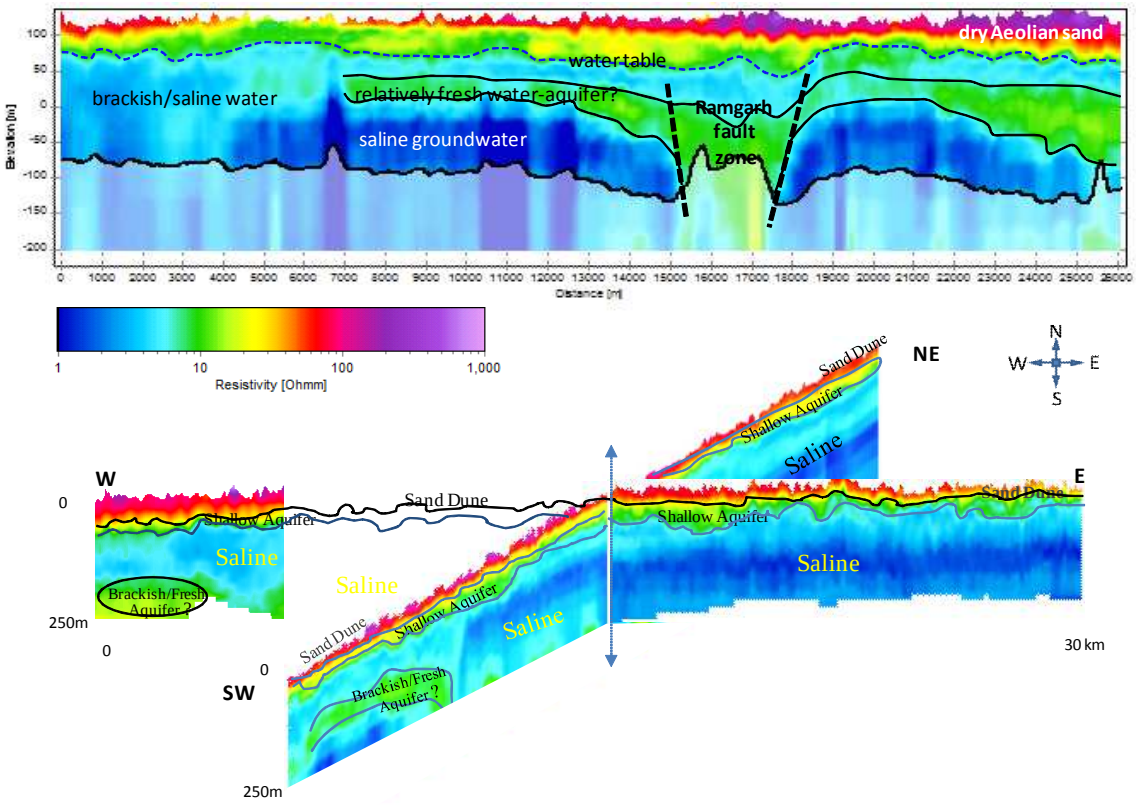


FIGURE 30. Three- dimensional aquifer section represented by EW and NE-SW profiles of 250 m thickness.

4.3 MAJOR FINDINGS

The field campaign was performed and good quality data were obtained. The collected data were afterwards carefully processed to remove couplings and noise before the inversion. The inversion was done with a smooth model using the spatially constrained inversion (SCI) approach.

The SkyTEM data gave a new and comprehensive three-dimensional picture of the subsurface. The low moment data ensured the high resolution mapping of near surface and high moment data to the deeper level. Thus the dual moment provided high resolution mapping of subsurface from top to ~ 300 m depths. The results revealed a clear contrast between the ranges of resistivity of different layers as shown in table 10. The data quality was so good that it gives water table surface as well clearly.

The area is found quite favourable for heliborne TEM because of the presence of top dry Aeolian sand that acts as a transparent window for electromagnetic induction. In such areas the conventional DC resistivity method normally fails in injecting current into the ground due to the presence of Aeolian resistive sand. The dimensions of Aeolian sand have been mapped over the entire area. Its thickness increases towards north and north-west. The relevant findings are the identification of:

- Saline groundwater zone that dips and thickens towards north,
- The regional extents of relatively fresh water aquifer underlying the saline water zone,
- SE-NW trending Ramgarh fault that passes through the area,
- The lateral and vertical movement along the fault,
- The role of Ramgarh fault in controlling the groundwater condition. The fault separates the Khara-Rann (i.e. brackish water) and Meetha-Rann (sweet water) and

  Thick sediments deposited in a linear alignment (could be structurally controlled) forming isolated pockets of fresh water aquifer within the saline water zone.

4.4 PERFORMANCE MATRIX

The result and outcome of various geophysical methods employed in the project area are summarized in the following tables.

Table 21. Performance of SkyTEM in Aquifer Mapping in Ramgarh area, Jaisalmer district, Rajasthan

Hydrogeology	**Objective/Target**	**Status / Achievements**				**Remarks & Additional Achievements**
		Delineated	**Partially Delineated**	**Not Delineated**	**Reason for non-Delination**	
Aeolian sand and alluvium overlying the Tertiaries associated with groundwater salinity	Aeolian sand	Yes	-	-	-	*In a few pockets, the thick saline zone shields the underlying zones with fresh water zone
	Relatively Fresh-water aquifer below saline zone	-	Yes*	-	-	
						The Ramgarh Fault has also been identified. The fault is supposed to have significant role in separating the Meetha Rann and Khara Rann

Table 22. Performance of various Geophysical methods in Aquifer Mapping in Ramgah area, Jaisalmer district, Rajasthan

Hydrogeological Objective	Geophysical Objective	Performance of Geophysical Methods Used					Borehole Logging
		Surface			Heliborne		
		VES	GRP	TEM	TEM	MAG	
Aquifers in alluvium clay beds	Moderately Resistive and low Resistivity Layers	1	NA	2	1	NA	-
Aquifers in deeper formations	Resistive layers at depth	3	2	NA	1	-	-
Fresh-Saline Interface	Very low Resistivity	3	1	NA	1	-	1
	Geological Structures	5	5	5	2	-	NA
(Maximum depth – 300 m)							

Index on Five point Scale : 1- Excellent, 2 – Very Good, 3 - Good, 4 - Fair, 5 – Poor, NA – Not Applicable

4.5 PROTOCOL FOR UP-SCALING THE FINDINGS OF GEOPHYICAL METHODS IN SIMILAR HYDROGEOLOGICAL TERRAIN CONDITIONS

The advanced Geophysical techniques can be applied in an area of ~3,03,780 sq.km. in North-western India based on the parameters mentioned in table 23.

Table 23. Parameters for up-scaling the advanced Geophysical techniques in National Aquifer Mapping

Upscaling Parameters	Quantity/ Nos.
Heli TEM	Dual Moment
Flight/ Tie Line Spacing	1/10 km
Frequency	12.5 – 25 Hz
Additional Ground based measurements	G-TEM, Drilling, logging, Water Quality
Deliverables	High Resolution 3-D Aquifer maps with Characterization

Following supplementary survey needs to be carried out in this region –

1. A few G-TEM to cover the non-flown area as well as to supplement the HTEM survey
2. A few traverses of CSMT will be useful for bed rock
3. Selected drilling for validation and calibration of Heliborne survey
4. Water quality measurement to apply suitable correction.

5.0 GENARATION OF AQUFIER MAP

5.1 Aquifer Disposition

The integrated lithological layers are generated using borehole data and advanced geophysical techniques. The layers are broadly classified into – sand dunes, unsaturated sand, un-confined aquifer, saline bed and confined aquifer. Isopach maps of sand dunes, unsaturated sand, un-confined aquifer and saline bed are generated (figure 31-a to d).

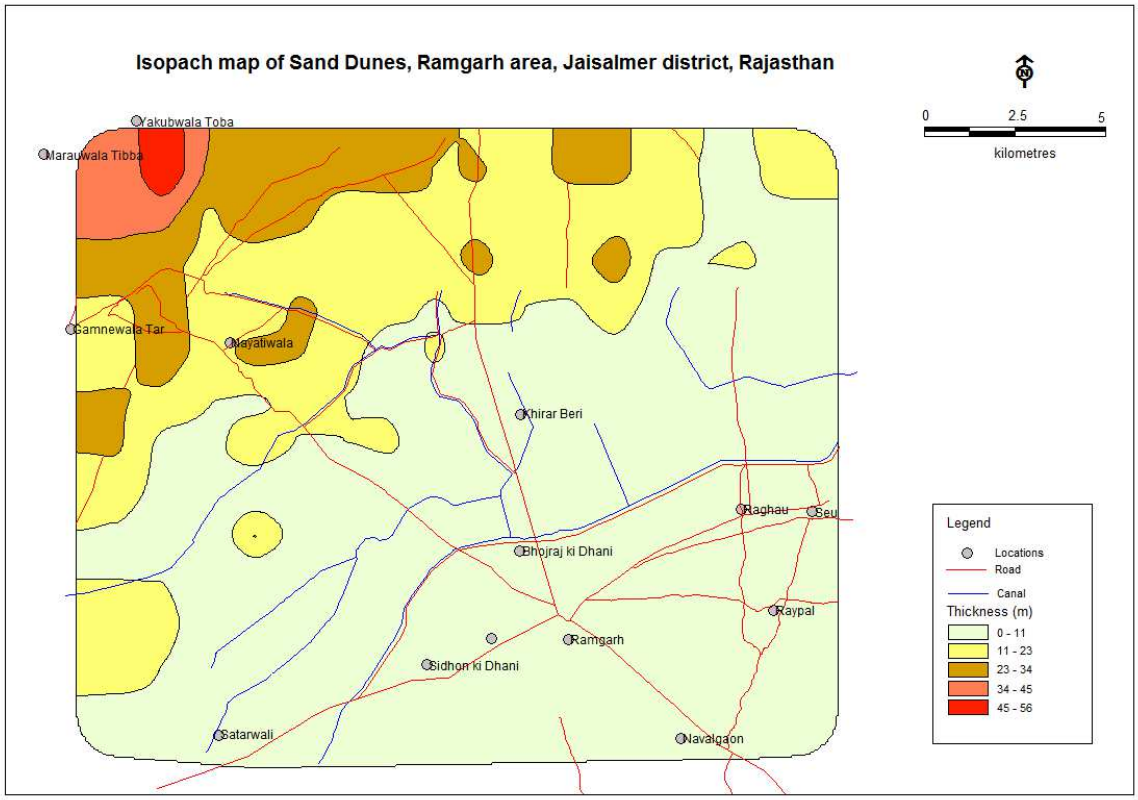


Figure 31a Isopach map of Sand dunes in Ramgarh area, Jaisalmer district, Rajasthan

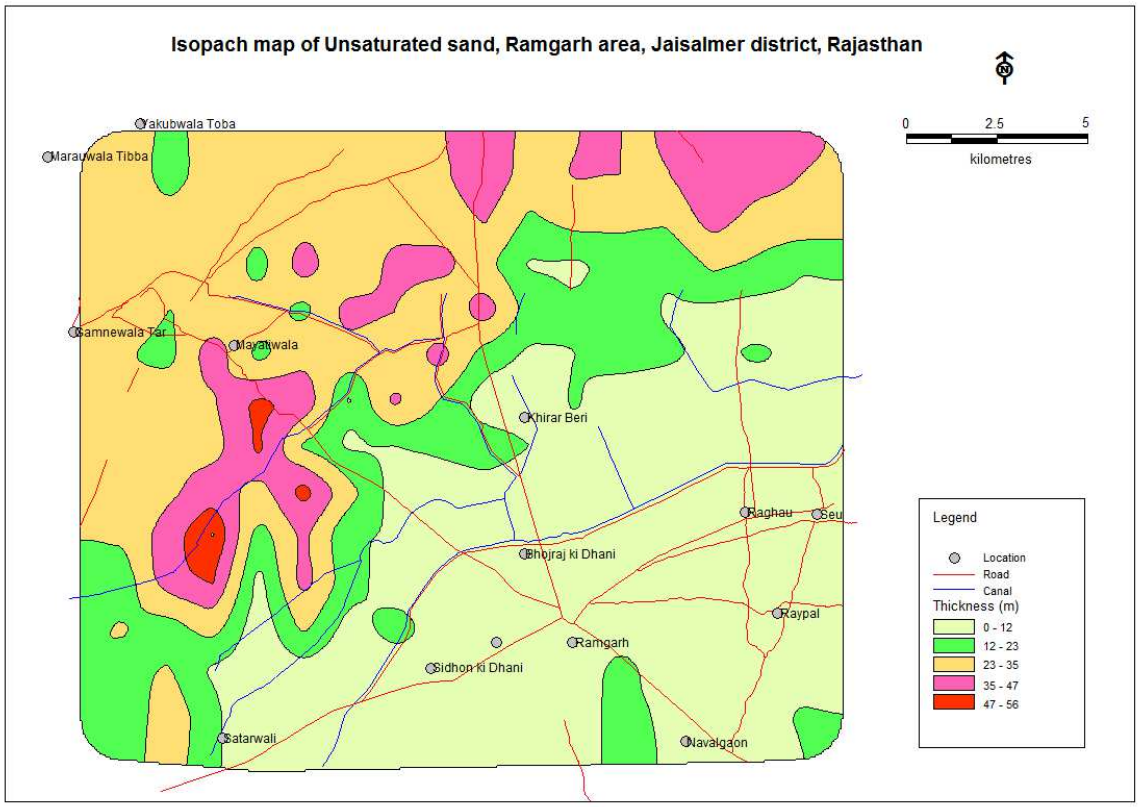


Figure 31b Isopach map of Unsaturated Aquifer in Ramgarh area, Jaisalmer district, Rajasthan

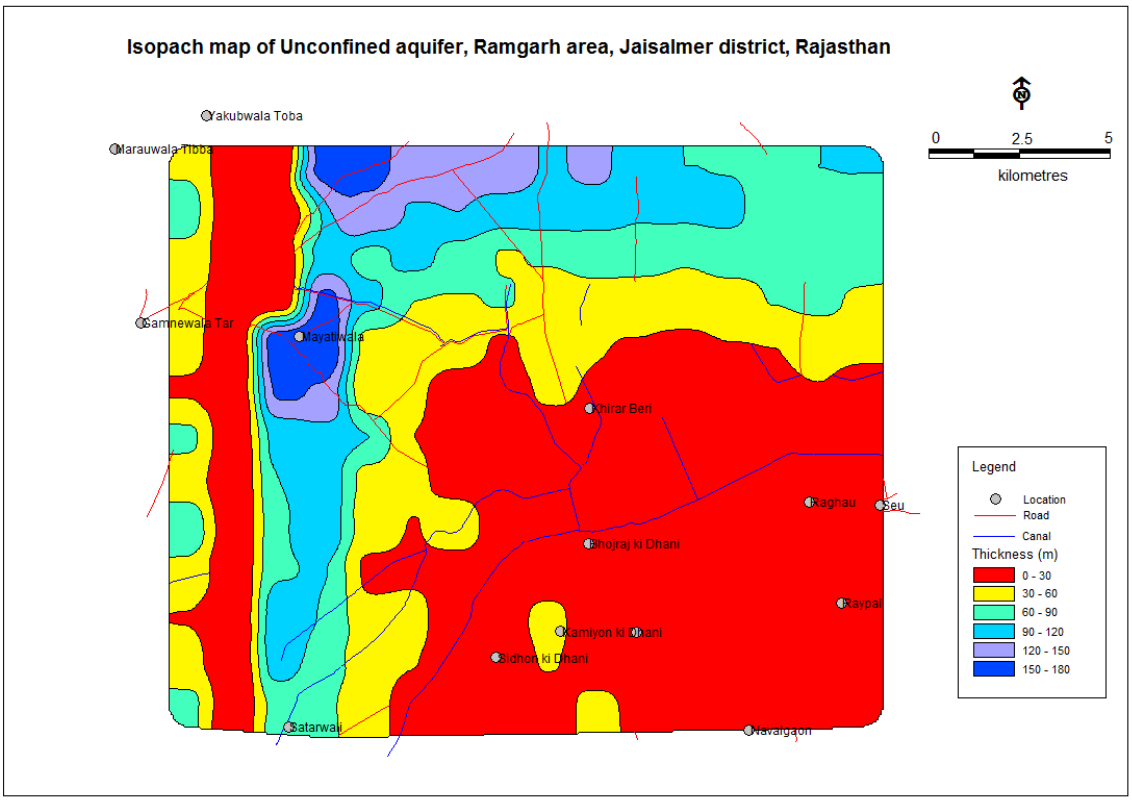


Figure 31c Isopach map of Unconfined Aquifer in Ramgarh area, Jaisalmer district, Rajasthan

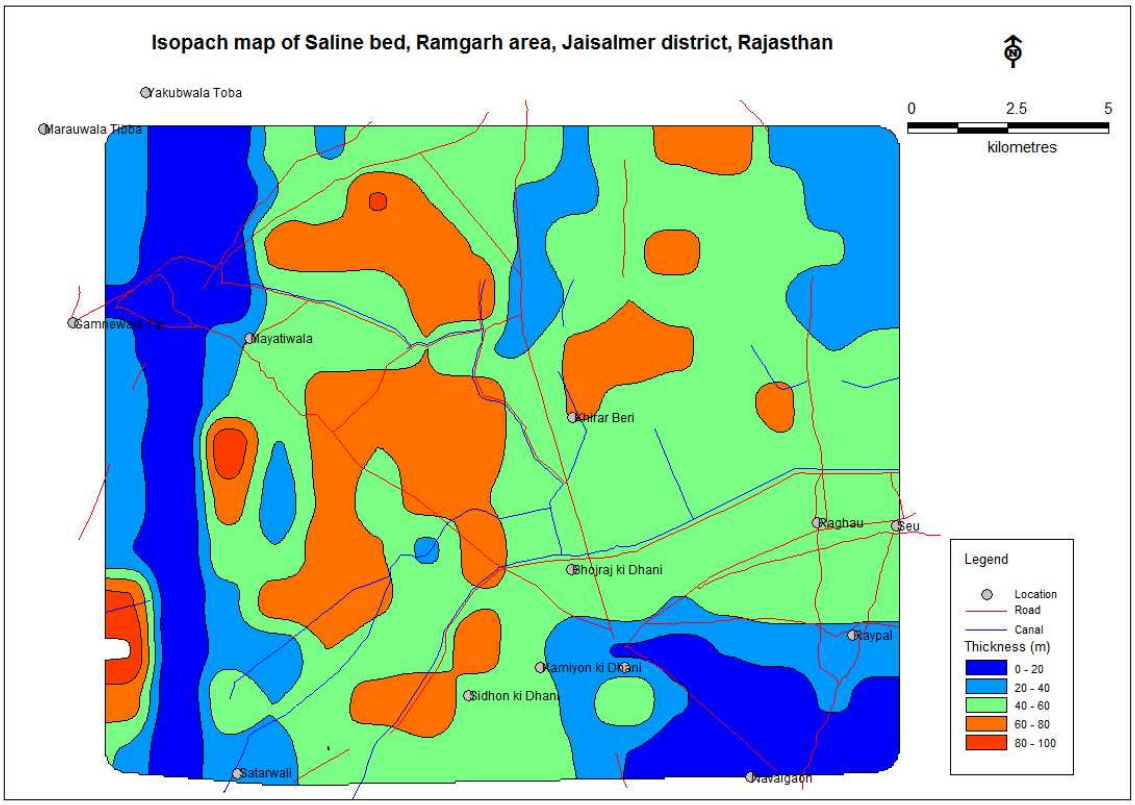


Figure 31d Isopach map of Saline Bed in Ramgarh area, Jaisalmer district, Rajasthan

Thickness of un-confined aquifer in major part of the study area is upto 30 m. However, thickness of 90 m to 180 m have also been encountered in the northern and eastern part of the project area. Saline bed of 40 m to 60 m thickness have been encountered in major part of the project area. Thickness of saline bed is within 20 m in a small linear belt along the eastern boundary of the study area.

The 3-D aquifer models are depicted in Figure 32.

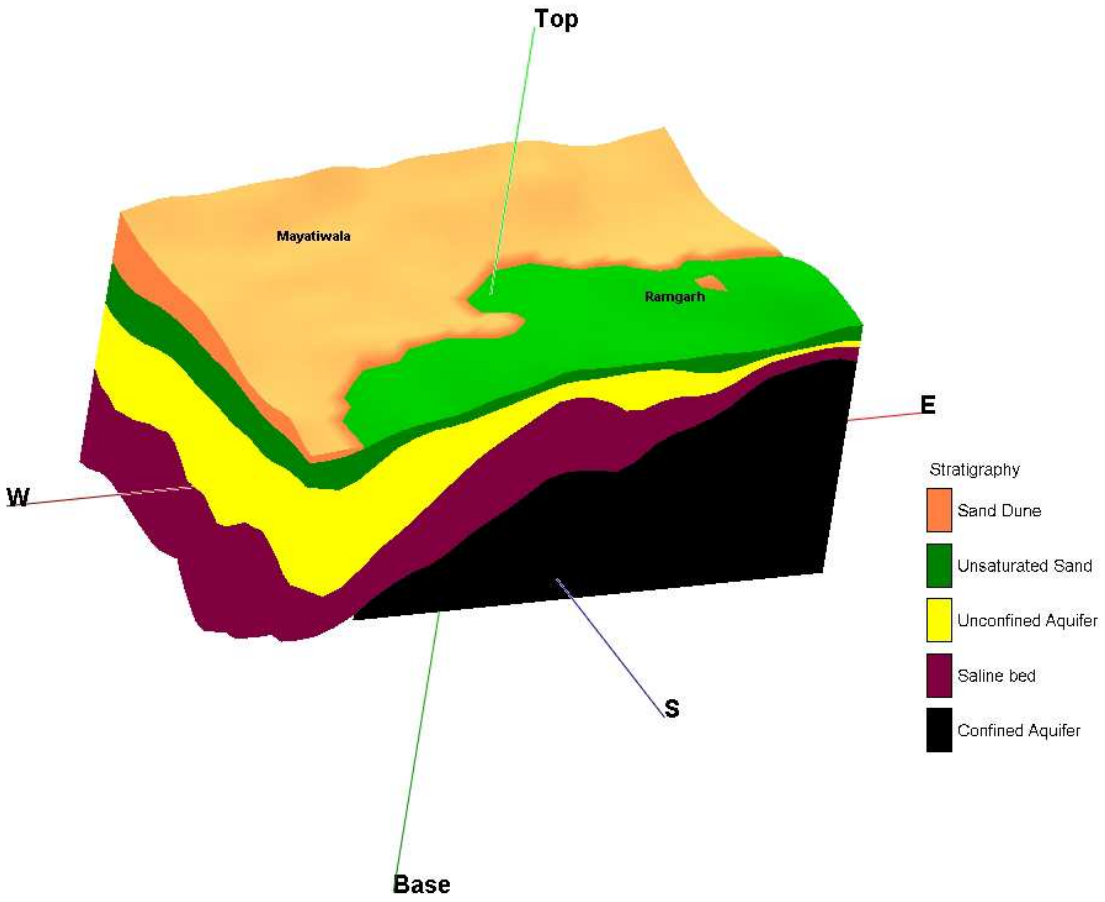


Figure 32. 3-D Aquifer Model, Ramgarh area, Jaisalmer district, Rajasthan

The volumes of each layer is given in table 24 and figure 33. The un-confined aquifer has the volume of about 39000 cubic km.

Table 24. Volumes of layers in Desert Area, Jaisalmer district, Rajasthan

Sl. No.	Lithological formation	Volume (km^3)
1	Sand Dunes	6564.74
2	Un-saturated Sand	14808.53
3	Unconfined aquifer	38665.82
4	Saline Bed	41881.63

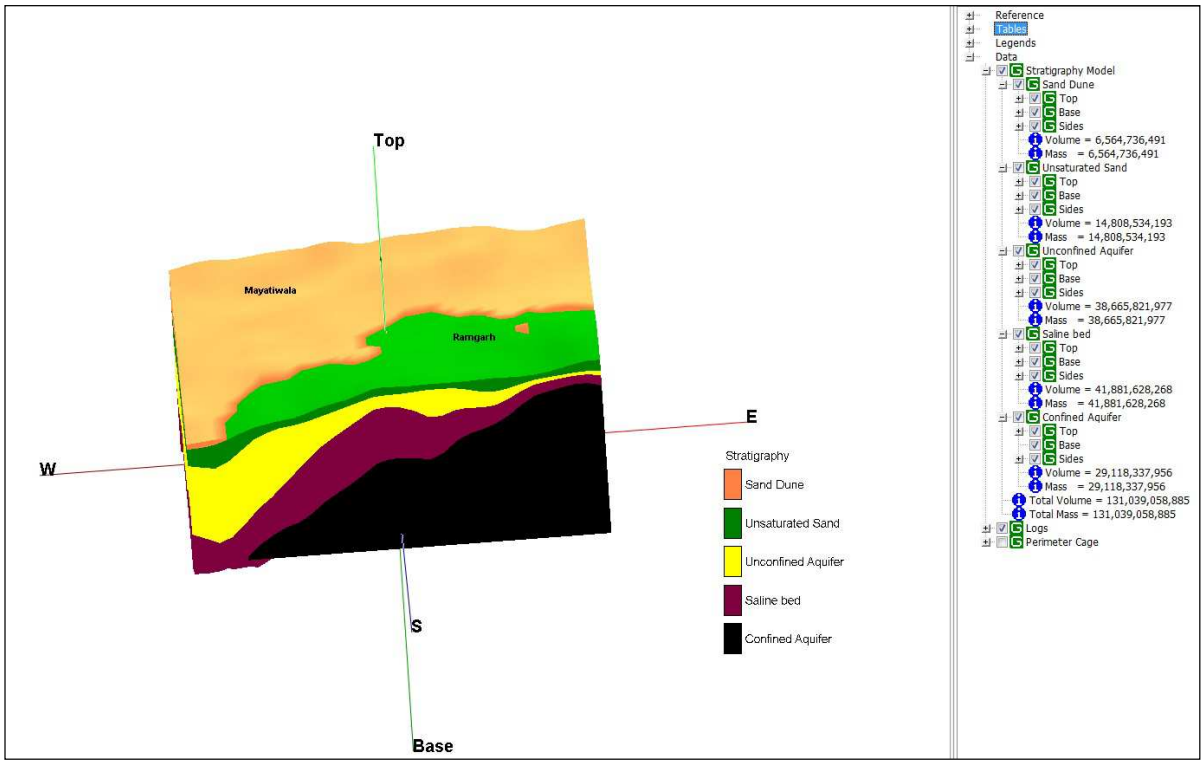


Figure 33. 3-D model depicting volumes of different layers

5.2 Aquifer Characterization

The various attributes of the Unconfined aquifer is described in the following paragraphs. The characteristics of the aquifers dealt in this section include – water level and water quality.

5.2.1 Water level

Ground water level monitoring in the unconfined aquifer was carried out 9 tubewells. A description of the pre-monsoon and post-monsoon water level scenario is given in the following paragraphs.

Pre-monsoon 2014

In the month of May, 2014, the depth to water level in the unconfined aquifer varies from 65 m bgl at Gamnewala outside the north-west border of the study area to 81 m bgl at Naval Singh Ki Dhani in the south-east corner of the study area. The thematic water level map for the month (figure 34) shows that the depth to water level gradually increases from north-west to south-east.

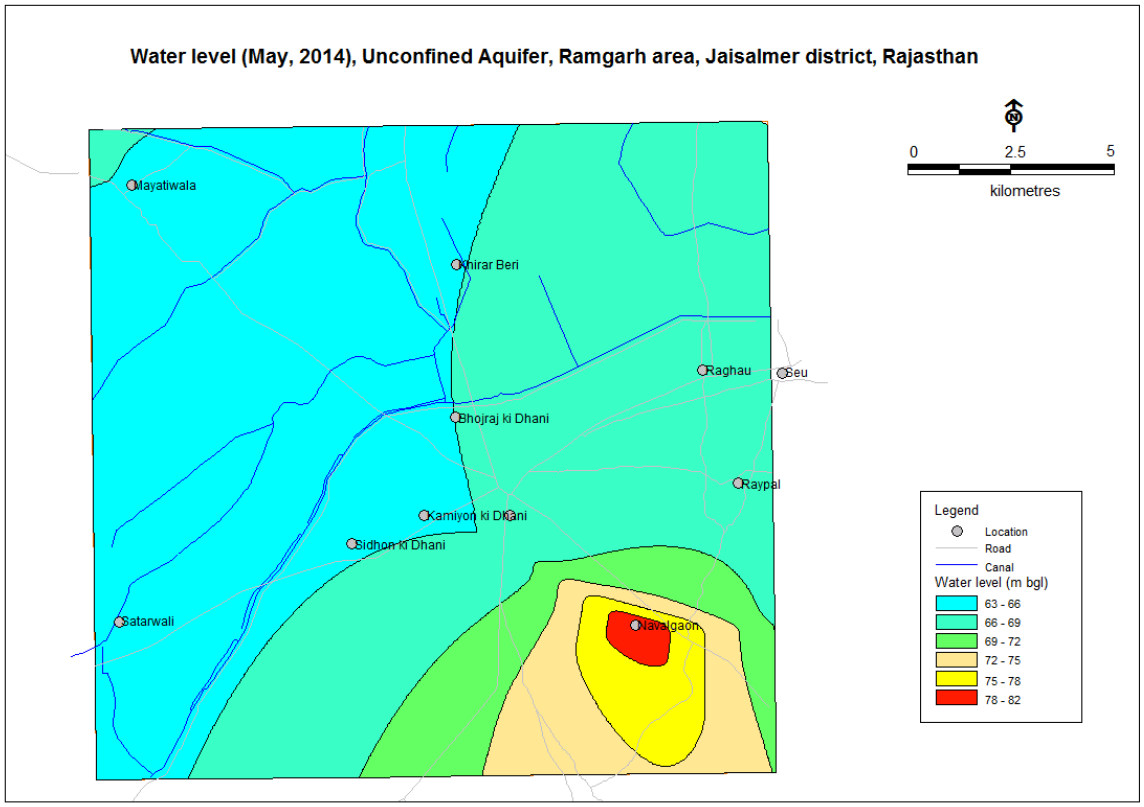


Figure 34. Depth to water level map of pre-monsoon (May), 2014, un-confined aquifer, Desert Area, Jaisalmer district, Rajasthan

Post-monsoon, 2014

The depth to water level scenario during November, 2014 has changed due to the seepage from IGNP canal system which has resulted in shallower ground water level in the central portion of the project area through which the canal is flowing (figure 35). The depth to water level in the area varies from 43 m bgl at Ramgarh to 67 m bgl at Joga, on the south-east boundary, just outside the project area. As described above, the shallower ground water level in the range of 43 m bgl to 45 m bgl have been recorded in the central portion of the project area and deeper water level of more than 63 m bgl have been recorded at Mayatiwala, Gamnewala sites in the north-west corner and Joga in south-east corner.

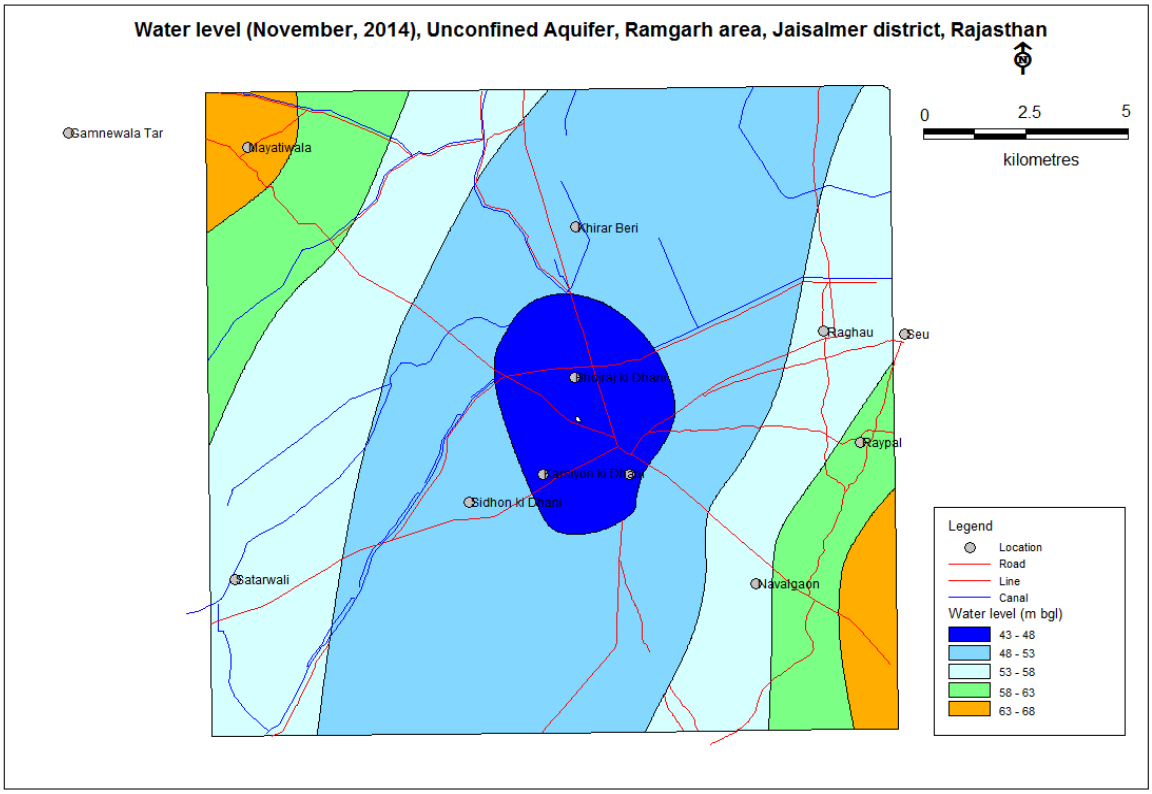


Figure 35. Depth to water level map of post-monsoon (November, 2014), un-confined aquifer, Desert Area, Jaisalmer district, Rajasthan

5.2.2 Water table

Pre-monsoon, 2014

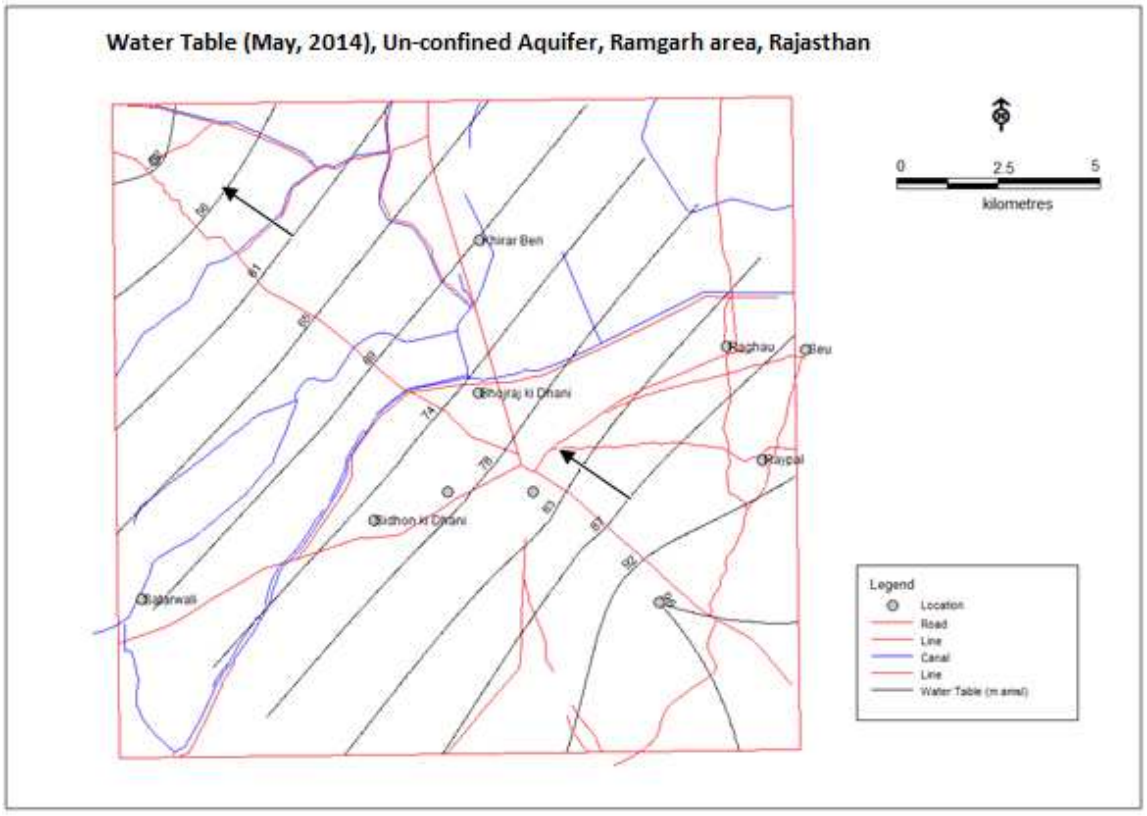


Figure 36. Water Table map of pre-monsoon (May, 2014), un-confined aquifer, Desert Area, Jaisalmer district, Rajasthan

The pre-monsoon water table map of unconfined aquifer (figure 36) shows that water table varies from 46 m above mean sea level (a msl) in the north-west to more than 107 m a msl in the south-east part of the project area. The ground water flow direction is from south-east to north-west direction.

Post-monsoon, 2014

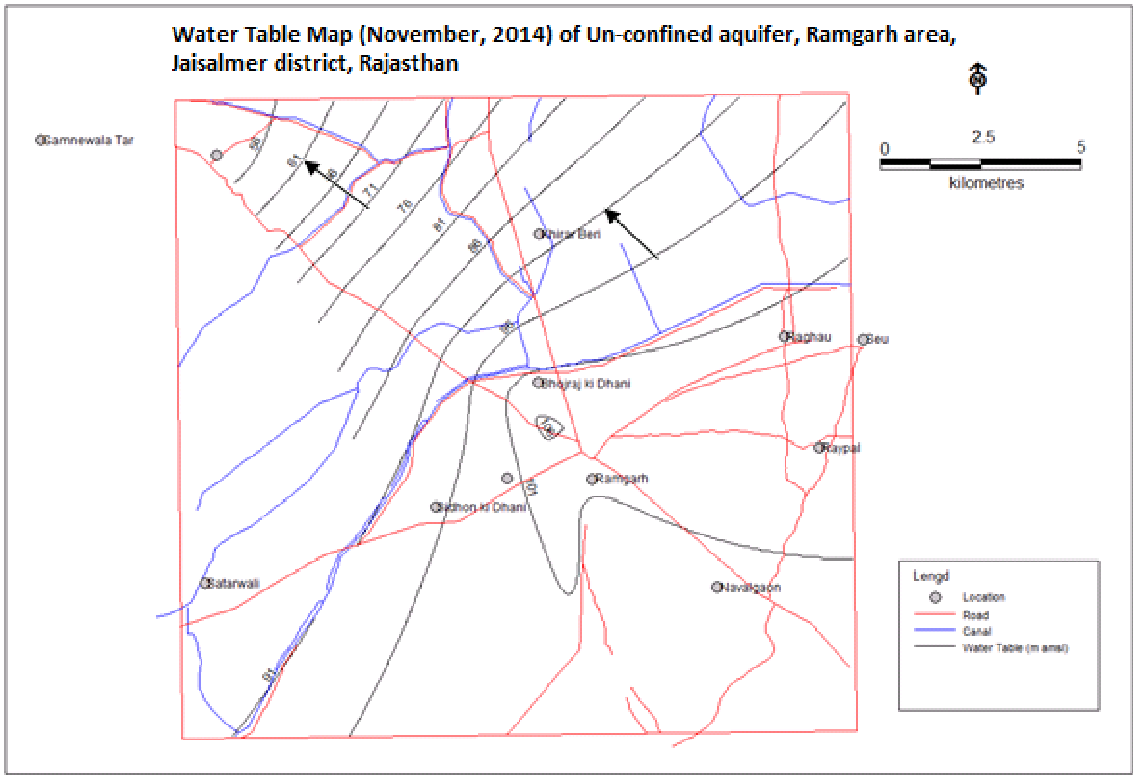


Figure 37. Water Table map of post-monsoon (November, 2014), un-confined aquifer, Desert Area, Jaisalmer district, Rajasthan

The post-monsoon water table map of unconfined aquifer (figure 37) shows that water table varies from less than 50 m a msl in the north-west to 100 m a msl in the south-east part of the project area. The ground water flow direction is from south-east to north-west direction.

5.2.3 Water Quality

The electrical conductivity in the unconfined aquifer varies between 4660 µmhos/cm and 7010 µmhos/cm. The high salinity content of the aquifer is attributed to the intrinsic chemical composition of the sediments which are marine deposits. Apart from salinity problem, the unconfined aquifer does not suffer from any other contamination like fluoride and Nitrate.

5.2.4 Specific Yield

The map on specific yield of unconfined aquifer is drawn based on the figures provided by State Ground Water Department in the ground water resources assessment, 2011.

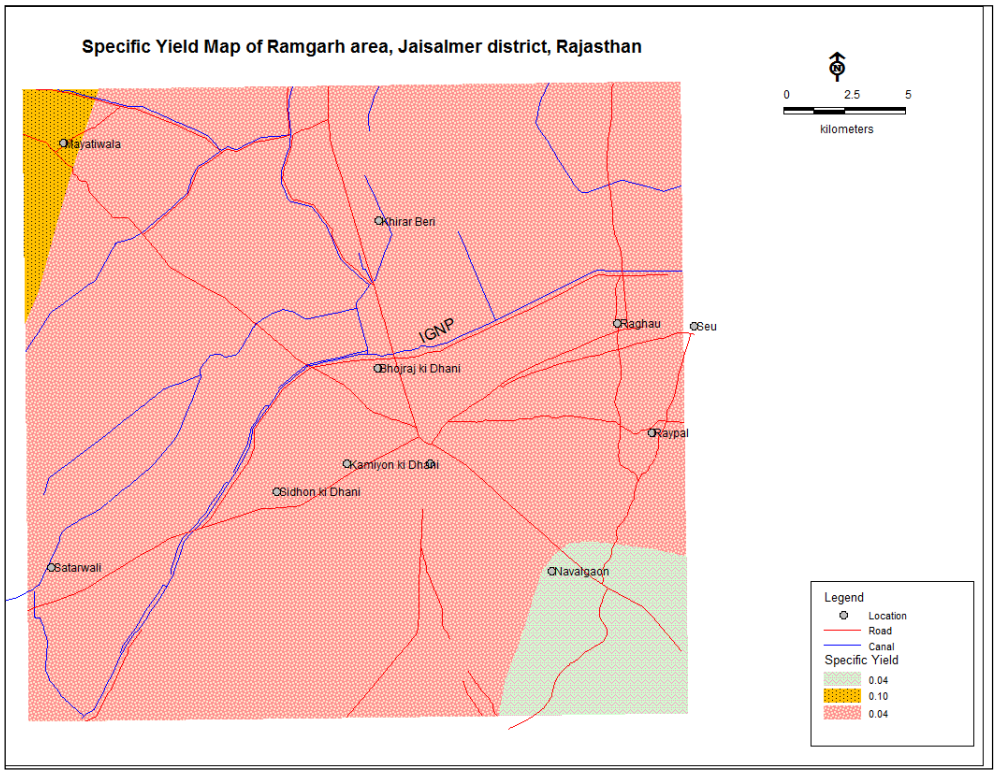


Figure 38. Specific yield map of un-confined aquifer

The specific yield of the alluvium aquifer is 0.10 whereas that of Tertiary sandstone aquifer and Parewar sandstone aquifer is 0.04.

5.2.5 Yield Potential

The map on yield potential map of unconfined aquifer is drawn based on the figures provided by State Ground Water Department in the ground water resources assessment, 2011. Maps showing yield potential of the aquifers are presented below -

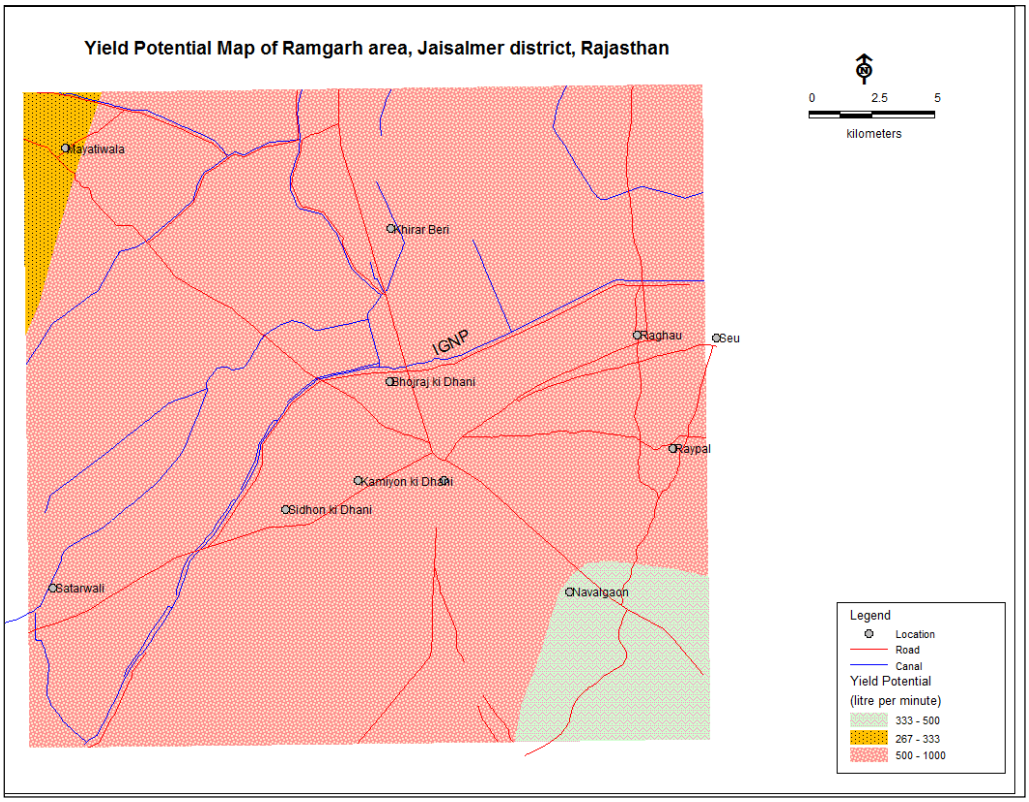


Figure 39. Yield potential map of alluvium aquifer and hard rock aquifer

The yield potential map of unconfined aquifer indicates that the yield potential of alluvium aquifer is 267 litres per minute (lpm) to 333 lpm. The Tertiary sediments are most prolific ground water potential zone in the area, the yield potential is 500 lpm to 1000 lpm. The yield potential zone of the Pariwar sandstone is 333 lpm to 500 lpm.

6. IMPLEMENTATION PLAN & RECOMMENDATIONS

The desert area around Ramgarh, Sam block, Jaisalmer district has meagre ground water resources as reflected in the ground water resources assessment of Sam block, Jaisalmer district, Rajasthan for the year 2011. Table 25 presents the ground water resources of Desert Area which falls under Sam block, Jaisalmer district.

Table 25. Dynamic Ground Water Resources of Desert Area project area, Jaisalmer district, Rajasthan

Potential zone	Potential zone area	Annual Recharge Desert Area	Natural Discharge_ Desert Area	Annual Ground Water Availability _Desert Area	Ground water draft Irrigation_ Desert Area	Ground water draft_Domestic use_Desert Area	DRAFT_all uses_Desert Area	Stage of Ground Water Development	Long term Trend (pre-monsoon)	Long term Trend (post-monsoon)	Category
	Sq.km.	Mcm	Mcm	Mcm	Mcm	Mcm	Mcm	%			
A2/1	6.40	0.025	0.002	0.022	0.000	0.006	0.006	25	NO	NO	
T1/4	125.50	0.407	0.041	0.366	0.000	0.176	0.176	48	NO	NO	
P1/1	46.00	0.179	0.018	0.161	0.000	0.131	0.131	81	NO	NO	
	177.90	0.611	0.061	0.550	0.000	0.313	0.313	57	NO	NO	SAFE

A perusal of the above table indicates that though the area falls in SAFE category of ground water resources assessment of 2011, the unit annual ground water recharge is very meagre, around 3.44 mm per year. This constitutes to be only 2% of the annual rainfall which is around 146 mm. Even this meagre resource is brackish in nature due to intrinsic property of the rock formations, thus rendering it to be unsuitable for use. The management interventions proposed in the desert project area are – a. upscaling the traditional water harvesting system in the area, b. controlled use of limited fresh ground water pockets around IGNP canal command area.

a. Upscaling of Traditional water harvesting

Traditional water harvesting structures in Desert area, Jaisalmer district, Rajasthan

In the desert area, the traditional water harvesting practices involve collection of rain water howsoever meagre and storage of it for long time use. During the monsoon, the rain collects in a catchment or khadin, which is often walled up in a semi-circular fashion by the farmers using stones and mud, just so that the water does not escape. Even when the top layer of water evaporates, the soil retains the moisture and is ideal for sowing a variety of crops including wheat, mustard, melons, and millets like jowar and bajra. These help to maintain the groundwater levels too. The outlets from one khadin let out excess water to fill up farms on the other side too, so that farmers on both sides benefit equally.

Within villages and around pasture lands, one finds kunds or tanks to store water. Every open space in the home is used to collect precious rainwater. Every terrace slopes to one side, where surakhos (openings) let rainwater in through netted filters. The water is then collected in tanks small or big and used the year round for drinking, washing and cooking. Wherever sweet water occurs, it is collected and cared for by the community.

Large kunds have a door for people to come in and collect water. Every kund or tanka (large tank) is covered and kept clean. These harvesters are cleaned regularly and maintained spotless by families or communities.

When there is a natural pond or talaab, beris are also built along its banks. Since the pond is an open body, the dry heat of the desert can dry it up in summer. This is when the beris continue to retain water for use by communities. These are shared assets.

Plate 6. Beri in Desert land of Ramgarh area, Jaisalmer district, Rajasthan

Sambhav - Success story on reviving traditional water harvesting systems in the Thar desert

Sambhav is an organization which is working for Water Conservation movement in the Thar desert in Jaisalmer district. Established in 2006 by Sh. Chattar Singh Jam, it has revived old traditions of water harvesting in dozens of hamlets across 20 km radius in Jaisalmer district, Rajasthan. Annual expenditure is about Rs. 5 lakh. Some of the case studies are described below.

1st Site - Netsi village

About 7 km west of Ramgarh, Birprasar talav – fetch domestic water supply for human and lifestock of Netsi (through the year), Hema (drinking - 3 months, lifestock – through the year), Navalsigh Ki Dhani, Ekalpar, Dabalpur (only drought periods) villages. Migratory birds even from far places like Sibraria visits during winter.

The Water Conservation Structures have been constructed following surface contour in topographical lowlands. At first, 'Toba's are build in topographical lowlands, constructing small sand mount and growing thorny bushes which held the shifting sand mound. Rain water gets collected within these structures and forms pool of water. Next 'Talai' is build, which are bigger than 'Toba' and finally it turns into 'Talav' – the large pond.

Plate 7. Beris in Biprasar talav, Jaisalmer district, Rajasthan

2nd Site – Ekalpar

About 16 km west of Ramgarh. Kui (Beri) – Dug well digged in alluvium underlain by sedimentary rocks (perched aquifer). The dimension of the structure is - 27' deep, Diameter – 2' (upper part), 5' (lower part). The water level is about 3'. Cost of construction – Rs. 7000/-.

Plate 8. Ekalpar Beri, Jaisalmer district, Rajasthan

3rd site – Derasar Khadin

East of Ramgarh. Area about 10 sq.km. Low land. Bund was constructed using local construction material i.e. limestone slabs. It was originally constructed by Paliwals (local landlords) about 500 years ago for agriculture and livestock. Revived by Sambhav. The khadin gets filled up by 30 mm rainfall in one rain spell. There are provisions for draining out the excess accumulated water through outlets so that the water saturated land can be used for cultivation. Cultivation in Derasar Khadin is done by the people from Joga, Sheova, Ragwa villages. Outside Derasar Khadin, about 12 sq.km. area is cultivated by using the excess drained out water from the outlets of Derasar Khadin. At the centre of Derasar Khaid, within the fields, a Goidhan (stone stambh/ memorial) is build by Paliwals as a symbol of water harvesting practices in desert land. Similar stambhs are build in other places also, by the ancestral kings / builders of khadins/ water conservation/ management practices. During 2013, Kharif (winter) crop within Derasar khadin was 1000 quintal Channa and outside Derasar Khadin was 1000 quintal of sarson.

4th site – Saran Khadin

Two khadins are located side by side – Saran Khadin at South and Barala Khadin at North. These two khadins are build up at geographical divide – Saran khadin at lateritic upland and Barala khadin in alluvial lowland terrain. These has resulted in the formation of catchment areas – one flowing towards South in Saran Khadin and the other flowing towards north in Barala Khadin. The Bagar Ghati Shila – water conservation memorial build at the junction of two khadins on Bikram Sambad 530 years (about 1541 years ago).

Khadin renovation work is being maintained during April to June, before the onset of monsoon. Sambhav group has tried to revive and modify the already existing traditional water conservation practices.

Recommendation

Considering the fact that the principle aquifer system of the area does not have fresh ground water resources and as enumerated above, the traditional water harvesting measures have been successful in not only fulfilling the domestic water demand but also to a large extent the agricultural requirement of water, it is recommended that the storage of meager fresh rainfall in various kinds of surface and sub-surface structures be implemented on large scale.

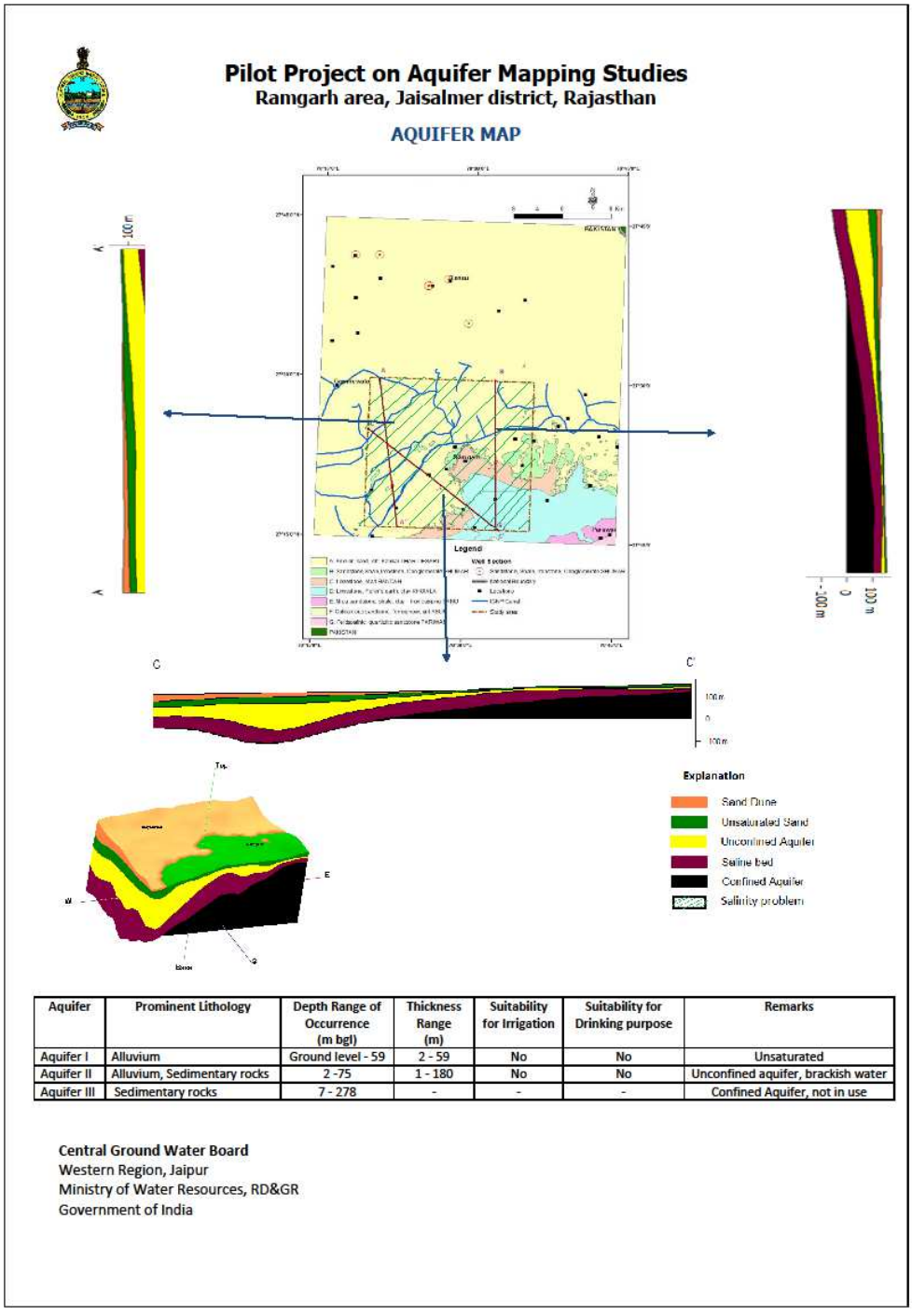
b. Controlled use of fresh ground water resources

Along the Indira Gandhi Nahar Pariyojna (IGNP) canal, fresh water pockets are formed due to seepage from the lined canal which sometimes even amount to water-logging situation as shown in the following photograph (plate - 9).

Plate 9. Water logging situation along IGNP Canal, Ramgarh area, Jaisalmer district, Rajasthan

It is recommended in these areas which are suffering from water logging problems and where ground water level is within 8 m, ground water be used in a controlled manner to mitigate the water logging situation and at the same time caution to be adopted to avoid over-pumping which may lead to salinity ingress from the brackish water of the principle aquifer system.

An overview of Aquifer map and its 3-D disposition in Ramgarh area is presented in Figure 40 and 41.



Aquifer	Prominent Lithology	Depth Range of Occurrence (m bgl)	Thickness Range (m)	Suitability for Irrigation	Suitability for Drinking purpose	Remarks
Aquifer I	Alluvium	Ground level - 59	2 - 59	No	No	Unsaturated
Aquifer II	Alluvium, Sedimentary rocks	2 -75	1 - 180	No	No	Unconfined aquifer, brackish water
Aquifer III	Sedimentary rocks	7 - 278	-	-	-	Confined Aquifer, not in use

Central Ground Water Board
Western Region, Jaipur
Ministry of Water Resources, RD&GR
Government of India

Figure 40. Aquifer Map of Ramgarh area, Jaisalmer district, Rajasthan

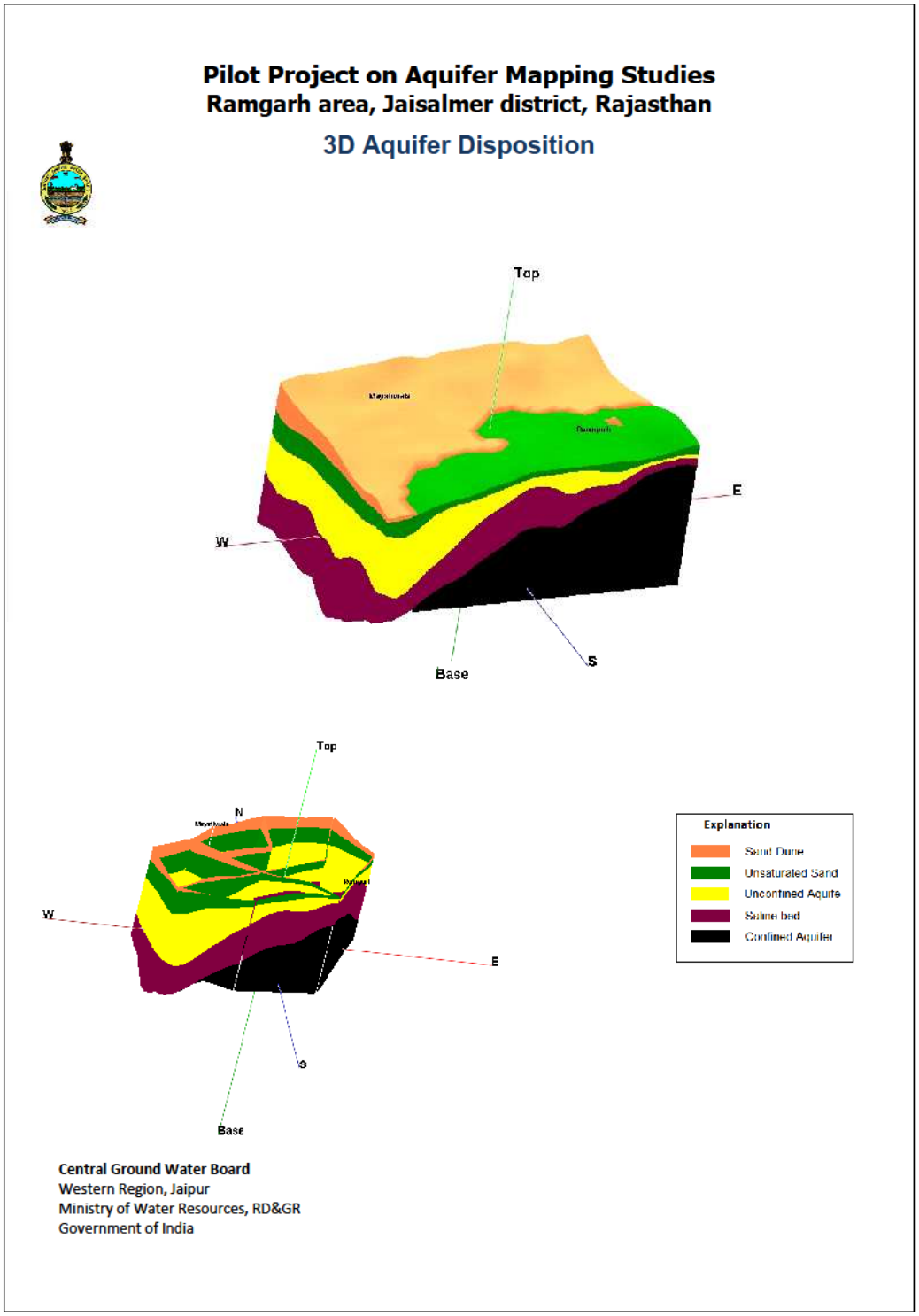


Figure 41. 3-D Aquifer Disposition of Ramgarh area, Jaisalmer district, Rajasthan

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Annexure - I

Details of Exploratory borewells drilled in Saraswati paleo-channels

S. No	Location	Coordinates		Type of well	Year of cons.	Depth drilled	Depth constr.	Zones tapped (mbgl)		Formation tapped	SWL	Disc.	DD	Trans.	Stora	Chemical quality		
		Lat.	Long.			(m)	(m)	From	To		(m)	(lpm)	(m)	m^2/day	(S)	EC mmhos/cm at 25°C	Cl mg/l	F mg/l
1	Khinyan	27°26'	70°28'	EW	1962	286.51	-	111 147	129 168	Sst	-	-	-	-	4222 938	1550 200	-	-
2	Sanu	27°15'	70°33'	EW	1962	280.11	-	-	-	Sst	106.40	1627	5.99	-	-	-	-	-
3	Khuiala	27°19'	70°49'	EW	1962	305.10	-	-	-	Lathi Sst	-	-	-	-	-	-	-	-
4	Natu Ka Bera	27°48'40"	70°24'55"	EW	99-00	120.05	75.00	43 60 71	55 69 74	Quaternary Alluvium	31.70	220	2.40	-	-	4410	996	0.6
5	Kurla Beri	27°49'00"	70°29'00"	EW	99-00	121.50	94.00	55 66 78	58 69 93	-do-	35.30	650	-	-	-	2480	625	0.6
6	Karthal	27°43'45"	70°25'20"	EW	99-00	125.30	86.00	78	84	Quaternary	42.00	220	-	-	-	3390	639	2.2
7	Ghantlyall	27°45'10"	70°24'15"	EW	99-00	130.00	88.00	62 72 82	65 78 85	Quaternary Alluvium	38.10	220	-	-	-	3060	731	1.3
8	Ranau	27°41'40"	70°27'00"	EW	99-00	125.60	87.00	71 81	74 85	-do-	38.10	48	-	-	-	1210	234	0.9
9	Gaje Singh Ka Tar	27°41'30"	70°17'15"	EW	99-00	131.00	115.00	82 106	88 112	-do-	35.33	200	-	-	-	5320	1640	0.9
10	Longewala-I	27°31'00"	70°11'00"	EW	99-00	116.40	98.00	66 72 82 92	69 75 87 95	-do-	47.15	175	-	-	-	2930	873	1.0
11	Longewala-II	27°31'00"	70°13'00"	EW	99-00	138.50	106.00	65 101	71 104	-do-	51.10	110	-	-	-	6500	2009	1.4

S. No	Location	Coordinates		Type of well	Year of cons.	Depth drilled	Depth constr.	Zones tapped (mbgl)		Formation tapped	SWL	Disc.	DD	Trans.	Stora	Chemical quality		
		Lat.	Long.								(m)	(lpm)	(m)	m^2/day	(S)	EC	Cl	F
						(m)	(m)	From	To							mmhos/cm at 25°C	mg/l	mg/l
12	Nlhal Khan Ki Dhani	27°23'30"	70°06'30"	EW	99-00	131.20	98.00	63 80 93	69 82 96	-do-	43.50	150	-	-	-	9500	2875	1.0
13	Gamnewala	27°29'45"	70°16'00"	EW	99-00	142.50	136.00	97 103 116 132	101 107 119 134	-do-	62.22	60	-	-	-	9360	2840	1.60
14	Ghotaru	27°18'45"	70°03'00"	EW	99-00	120.00	116.00	90 99 111	94 103 114	-do-	42.89	240	10.00	-	-	1330	213	0.41
15	Ghotaru	27°18'45"	70°03'00"	OW	99-00	137.50	116.00	90 99 111	94 103 114	-do-	43.15	220	-	-	-	1510	240	0.40
16	Longewala-III	26°40'	75°48'	EW	2000-2001	151.10	80.00	54 66	57 78	Alluvium	51.25	2	-	-	-	-	-	-
17	Longewala-IV	26°40'	75°48'	EW	2000-2001	137.00	110.00	96	108	-do-	55.50	140	2.34	-	-	5370	1512	0.27
18	Ranau-7 km. Tanot road	27°42'	70°26'30"	EW	2000-2001	129.00	70.00	50 62	56 68	-do-	-	-	-	-	-	7300	1597	1.48
19	Ranau (4 km) - Ramgarh road	27°37'30"	70°26'45"	EW	2000-2001	151.00	106.00	79 101	91 104	-do-	64.85	60	3	-	-	3400	1008	0.64
20	Ranau	27°37'30"	70°26'45"	OW	2000-2001	125.00	117.00	79 101 105 111	91 104 109 115	-do-	64.10	200	-	-	-	-	-	-

S. No	Location	Coordinates		Type of well	Year of cons.	Depth drilled	Depth constr.	Zones tapped		Formation tapped	SWL	Disc.	DD	Trans.	Stora	Chemical quality		
		Lat.	Long.					(mbgl)			(m)	(lpm)	(m)	m^2/day	(S)	EC	Cl	F
						(m)	(m)	From	To							mmhos/cm at 25°C	mg/l	mg/l
21	Kishangarh	27°52'30"	70°33'30"	EW	2000-2001	156.00	103.00	50 63 69 75 81 89 98	56 66 72 78 84 92 101	-do-	30.50	1000	3.70	-	-	1970	412	1.00
22	Kishangarh			OW-I	2000-2001	106.90	103.00	50 63 69 75 81 89 98	56 66 72 78 84 92 101	-do-	30.60	900	-	-	-	2210	568	1.26
23	Kishangarh			OW-II	2000-2001	106.40	103.00	50 63 69 75 81 89 98	56 66 72 78 84 92 101	-do-	60.60	900	-	-	-	2070	504	1.01
24	Ranau-II	27°29'15"	70°26'45"	EW	98-99	102.00	102.00	65 72 80 95	68 78 83 101	Alluvium	49.00	300	0.27	-	-	1570	192	4
25	Choudhariya	27°06'	70°55'	OW	93-94	208.90	158.00	90 102 132 150	96 120 138 156	Lst	11.11	440	8.93	-	-	8295	-	-

S. No	Location	Coordinates		Type of well	Year of cons.	Depth drilled	Depth constr.	Zones tapped		Formation tapped	SWL	Disc.	DD	Trans.	Stora	Chemical quality		
		Lat.	Long.					(mbgl)			(m)	(lpm)	(m)	m^2/day	(S)	EC	Cl	F
						(m)	(m)	From	To							mmhos/cm at 25°C	mg/l	mg/l
26	Asutar	27 12 00	70 10 00	EW	2001-02	125.00	118.00	68	74	Alluvium	58.70	200	4.60	-	-	12170	4225	0.83
27	Haboor	27 11 00	70 40 00	EW	2001-02	208.00	200.00	130 136 145	133 142 151	Sandstone	30.00	Meagre		-	-	4000	1079	1.38
28	Sanu	27 11 00	70 38 00	EW	2001-02	195.00	178.00	124 158	139 176	Limestone	104.40	200		-	-	4430	1108	1.92
29	Parewar	27 15 00	70 44 00	EW	2004-05	192.00	155.00	122 134	128 152	Sandstone	116.65	100	-	-	-	3580	959	2.17
30	Ranau-II	27°29'15"		SH	98-99	199.95	-	-	-	Alluvium Tr. Sandstone	-	-	-	-	-	-	-	-
31	Lanela	27°04'	71°48'	PZ	92-93	204.00	-	74 135 146 165 193	80 141 158 171 199	Shale Sst	35.26	19.8		-	-	-	-	-
32	Shekhowala	27°33'00"	71°42'30"	PZ	2008-09	186.00	51.00	30	36	Alluvium	16.17	250	-	-	-	4540	-	2.76

Annexure - II

Long term Water level data of National Hydrograph Stations, Ramgarh area, Jaisalmer district

BLOCK_NAME	DATE_TIME	SITE_ID	SITE_NAME	WATER_LEVEL
SAM	1/1/1989 0:00	W272910070160501	GAMNEWALI	64.05
SAM	5/1/1989 0:00	W272910070160501	GAMNEWALI	64.06
SAM	11/1/1989 0:00	W272910070160501	GAMNEWALI	64.04
SAM	1/1/1990 0:00	W272910070160501	GAMNEWALI	64.06
SAM	5/1/1990 0:00	W272910070160501	GAMNEWALI	63.23
SAM	11/1/1990 0:00	W272910070160501	GAMNEWALI	64.1
SAM	5/1/1991 0:00	W272910070160501	GAMNEWALI	63.95
SAM	11/1/1991 0:00	W272910070160501	GAMNEWALI	63.92
SAM	1/1/1992 0:00	W272910070160501	GAMNEWALI	63.94
SAM	5/1/1992 0:00	W272910070160501	GAMNEWALI	64.07
SAM	8/1/1992 0:00	W272910070160501	GAMNEWALI	63.97
SAM	11/1/1992 0:00	W272910070160501	GAMNEWALI	64.08
SAM	1/1/1993 0:00	W272910070160501	GAMNEWALI	63.95
SAM	5/1/1993 0:00	W272910070160501	GAMNEWALI	
SAM	8/1/1993 0:00	W272910070160501	GAMNEWALI	64.03
SAM	11/1/1993 0:00	W272910070160501	GAMNEWALI	62.6
SAM	1/1/1994 0:00	W272910070160501	GAMNEWALI	64.01
SAM	5/1/1994 0:00	W272910070160501	GAMNEWALI	63.78
SAM	11/1/1994 0:00	W272910070160501	GAMNEWALI	63.4
SAM	5/1/1995 0:00	W272910070160501	GAMNEWALI	63.98
SAM	11/1/1995 0:00	W272910070160501	GAMNEWALI	63.5
SAM	1/1/1996 0:00	W272910070160501	GAMNEWALI	63.3
SAM	5/1/1996 0:00	W272910070160501	GAMNEWALI	
SAM	11/1/1996 0:00	W272910070160501	GAMNEWALI	64
SAM	1/1/1997 0:00	W272910070160501	GAMNEWALI	64.07
SAM	5/1/1997 0:00	W272910070160501	GAMNEWALI	63.4
SAM	8/1/1997 0:00	W272910070160501	GAMNEWALI	63.9
SAM	11/1/1997 0:00	W272910070160501	GAMNEWALI	63.2
SAM	5/1/1998 0:00	W272910070160501	GAMNEWALI	63.86
SAM	11/1/1998 0:00	W272910070160501	GAMNEWALI	63.68
SAM	1/1/1999 0:00	W272910070160501	GAMNEWALI	63.22
SAM	5/1/1999 0:00	W272910070160501	GAMNEWALI	63.2
SAM	11/1/1999 0:00	W272910070160501	GAMNEWALI	63.24
SAM	1/1/2000 0:00	W272910070160501	GAMNEWALI	
SAM	1/1/2004 0:00	W272910070160501	GAMNEWALI	38.09
SAM	11/1/2004 0:00	W272910070160501	GAMNEWALI	
SAM	1/1/2011 0:00	W272910070160501	GAMNEWALI	62.24
SAM	1/10/2014 6:00	W272910070160501	GAMNEWALI	64.61
SAM	5/1/2000 0:00	W272910070160502	GAMANEWALA	62.9

BLOCK_NAME	DATE_TIME	SITE_ID	SITE_NAME	WATER_LEVEL
SAM	8/1/2000 0:00	W272910070160502	GAMANEWALA	62.87
SAM	11/1/2000 0:00	W272910070160502	GAMANEWALA	62.8
SAM	1/1/2001 0:00	W272910070160502	GAMANEWALA	62.58
SAM	5/1/2001 0:00	W272910070160502	GAMANEWALA	62.06
SAM	8/1/2001 0:00	W272910070160502	GAMANEWALA	62.6
SAM	11/1/2001 0:00	W272910070160502	GAMANEWALA	61.24
SAM	5/1/2002 0:00	W272910070160502	GAMANEWALA	62.16
SAM	8/1/2002 0:00	W272910070160502	GAMANEWALA	62.73
SAM	11/1/2002 0:00	W272910070160502	GAMANEWALA	61.62
SAM	1/1/2003 0:00	W272910070160502	GAMANEWALA	62.22
SAM	5/1/2003 0:00	W272910070160502	GAMANEWALA	60.69
SAM	8/1/2003 0:00	W272910070160502	GAMANEWALA	60.71
SAM	11/1/2003 0:00	W272910070160502	GAMANEWALA	60.69
SAM	1/1/2004 0:00	W272910070160502	GAMANEWALA	60.74
SAM	5/1/2004 0:00	W272910070160502	GAMANEWALA	60.64
SAM	8/1/2004 0:00	W272910070160502	GAMANEWALA	60.78
SAM	11/1/2004 0:00	W272910070160502	GAMANEWALA	60.87
SAM	1/1/2005 0:00	W272910070160502	GAMANEWALA	60.85
SAM	5/1/2005 0:00	W272910070160502	GAMANEWALA	60.54
SAM	8/1/2005 0:00	W272910070160502	GAMANEWALA	60.84
SAM	11/1/2005 0:00	W272910070160502	GAMANEWALA	60.74
SAM	1/1/2006 0:00	W272910070160502	GAMANEWALA	60.69
SAM	5/1/2006 0:00	W272910070160502	GAMANEWALA	60.53
SAM	8/1/2006 0:00	W272910070160502	GAMANEWALA	60.56
SAM	11/1/2006 0:00	W272910070160502	GAMANEWALA	60.59
SAM	1/1/2007 0:00	W272910070160502	GAMANEWALA	60.62
SAM	5/1/2007 0:00	W272910070160502	GAMANEWALA	60.64
SAM	8/1/2007 0:00	W272910070160502	GAMANEWALA	60.84
SAM	8/1/2007 6:00	W272910070160502	GAMANEWALA	60.84
SAM	11/1/2007 0:00	W272910070160502	GAMANEWALA	60.84
SAM	1/1/2008 0:00	W272910070160502	GAMANEWALA	60.49
SAM	5/1/2008 0:00	W272910070160502	GAMANEWALA	60.56
SAM	8/1/2008 0:00	W272910070160502	GAMANEWALA	60.59
SAM	11/1/2008 0:00	W272910070160502	GAMANEWALA	61.14
SAM	1/1/2009 0:00	W272910070160502	GAMANEWALA	60.74
SAM	5/1/2009 0:00	W272910070160502	GAMANEWALA	60.77
SAM	8/1/2009 0:00	W272910070160502	GAMANEWALA	60.44
SAM	11/1/2009 0:00	W272910070160502	GAMANEWALA	61.64
SAM	1/1/2010 0:00	W272910070160502	GAMANEWALA	61.64
SAM	5/1/2010 0:00	W272910070160502	GAMANEWALA	51.94
SAM	8/1/2010 0:00	W272910070160502	GAMANEWALA	61.68
SAM	11/1/2010 0:00	W272910070160502	GAMANEWALA	61.99

BLOCK_NAME	DATE_TIME	SITE_ID	SITE_NAME	WATER_LEVEL
SAM	5/1/2011 0:00	W272910070160502	GAMANEWALA	61.74
SAM	8/1/2011 0:00	W272910070160502	GAMANEWALA	52.64
SAM	1/10/2013 6:00	W272910070160502	GAMANEWALA	52.03
SAM	5/30/2013 6:00	W272910070160502	GAMANEWALA	64.34
SAM	8/30/2013 6:00	W272910070160502	GAMANEWALA	61.92
SAM	11/10/2013 6:00	W272910070160502	GAMANEWALA	62.34
SAM	1/10/2014 6:00	W272910070160502	GAMANEWALA	61.59
SAM	5/30/2014 6:00	W272910070160502	GAMANEWALA	73.02
SAM	5/1/2003 0:00	W272130070300001	Ramgarh2	50.65
SAM	8/1/2003 0:00	W272130070300001	Ramgarh2	46.64
SAM	11/1/2003 0:00	W272130070300001	Ramgarh2	46.71
SAM	8/1/2004 0:00	W272130070300001	Ramgarh2	46.73
SAM	11/1/2004 0:00	W272130070300001	Ramgarh2	46.6
SAM	1/1/2005 0:00	W272130070300001	Ramgarh2	46.74
SAM	5/1/2005 0:00	W272130070300001	Ramgarh2	46.8
SAM	8/1/2005 0:00	W272130070300001	Ramgarh2	46.76
SAM	11/1/2005 0:00	W272130070300001	Ramgarh2	46.7
SAM	1/1/2006 0:00	W272130070300001	Ramgarh2	46.75
SAM	5/1/2006 0:00	W272130070300001	Ramgarh2	46.69
SAM	8/1/2006 0:00	W272130070300001	Ramgarh2	46.59
SAM	11/1/2006 0:00	W272130070300001	Ramgarh2	46.7
SAM	1/1/2007 0:00	W272130070300001	Ramgarh2	46.7
SAM	5/1/2007 0:00	W272130070300001	Ramgarh2	46.7
SAM	8/1/2007 0:00	W272130070300001	Ramgarh2	46.62
SAM	8/1/2007 6:00	W272130070300001	Ramgarh2	46.62
SAM	11/1/2007 0:00	W272130070300001	Ramgarh2	46.75
SAM	1/1/2008 0:00	W272130070300001	Ramgarh2	47.13
SAM	5/1/2008 0:00	W272130070300001	Ramgarh2	46.64
SAM	8/1/2008 0:00	W272130070300001	Ramgarh2	46.65
SAM	11/1/2008 0:00	W272130070300001	Ramgarh2	46.69
SAM	1/1/2009 0:00	W272130070300001	Ramgarh2	46.77
SAM	8/1/2009 0:00	W272130070300001	Ramgarh2	46
SAM	11/1/2009 0:00	W272130070300001	Ramgarh2	47.5
SAM	1/1/2010 0:00	W272130070300001	Ramgarh2	46.8
SAM	5/1/2010 0:00	W272130070300001	Ramgarh2	46.8
SAM	8/1/2010 0:00	W272130070300001	Ramgarh2	46.9
SAM	11/1/2010 0:00	W272130070300001	Ramgarh2	46.8
SAM	1/1/2011 0:00	W272130070300001	Ramgarh2	49
SAM	5/1/2011 0:00	W272130070300001	Ramgarh2	49.5
SAM	8/1/2011 0:00	W272130070300001	Ramgarh2	49
SAM	11/1/2011 0:00	W272130070300001	Ramgarh2	46.9
SAM	1/1/2012 6:00	W272130070300001	Ramgarh2	46.7

BLOCK_NAME	DATE_TIME	SITE_ID	SITE_NAME	WATER_LEVEL
SAM	5/30/2012 6:00	W272130070300001	Ramgarh2	46.9
SAM	8/30/2012 6:00	W272130070300001	Ramgarh2	46.95
SAM	11/10/2012 6:00	W272130070300001	Ramgarh2	47.2
SAM	1/10/2013 6:00	W272130070300001	Ramgarh2	47.1
SAM	5/30/2013 6:00	W272130070300001	Ramgarh2	46.9
SAM	8/30/2013 6:00	W272130070300001	Ramgarh2	48.2
SAM	11/10/2013 6:00	W272130070300001	Ramgarh2	49.78
SAM	1/10/2014 6:00	W272130070300001	Ramgarh2	47.7
SAM	5/30/2014 6:00	W272130070300001	Ramgarh2	65.6

Annexure- III

Annual Rainfall (mm) & Percentage Departures

Year	Ramgarh	Percentage Departure (%)
1970	121.5	-16.8
1971	154	5.5
1972	27	-81.5
1973	244.1	67.2
1974	33.8	-76.8
1975	240.6	64.8
1976	173	18.5
1977	244	67.1
1978	235	61.0
1979	123	-15.8
1980	75	-48.6
1981	133	-8.9
1982	72	-50.7
1983	137	-6.2
1984	66	-54.8
1985		
1986	125	-14.4
1987	15	-89.7
1988	42	-71.2
1989	259	77.4
1990	242.5	66.1
1991	36	-75.3
1992	154	5.5
1993	154	5.5
1994	326.6	123.7
1995	162.2	11.1
1996	116.8	-20.0
1997	231.6	58.6
1998	283	93.8
1999	182	24.7
2000	34	-76.7
2001	126	-13.7
2002	9	-93.8
2003	239	63.7

2004	29	-80.1
2005	57	-61.0
2006	157	7.5
2007	178	21.9
2008	139	-4.8
2009	111	-24.0
2010	386	164.4
2011	162	11.0
2012	183	25.3
2013	172	0.0
2014	32	-78.1
MEAN	**146**	
Standard Deviation (%)	**85.51**	

Annexure IV

1. RAMGARH EXPLORATORY WELL

27°22.65', 70°29.20'

CONSOLIDATED LITHOLOG , Ramgarh

00	3.00	3.00	Top soil light yellowish sandy mixed with stoney chips of lime stone
3.00	9.50		Silty clay light yellowish compact
9.50	34.25	6.50	Clay stone dark greenish grey compact moderately hard with thin laminae of calci lutite and calci arenite/
34.25	37.50	3.25	Clay stone variegated coloured greenish grey reddish brown yellow with spherical balls nodular with colour rings
37.50	43.75	6.25	Clay stone mixed with chalk powder mixed coloured mostly greenish grey .
43.75	53.00	9.25	Clay mixed with chalk powder and calci lutite whitish to whitish grey ,soft friable compact
53.00	62.25	9.25	Lime stone whitish grey compact hard
62.25	87.25	25.00	Clay stone greenish grey compact with chalk(?) calci Lutite whitish grey calcareous material in the form of striations and laminae
87.25	109.0	21.75	Clay stone dark greenish grey ,
109.0	124.75	15.75	Clay stone mainly greenish , grey with thin lamine of calcareous material very fine grianed calcilutie and abundance of fossils bottom ash gray .
124.75	143.50	18.75	Clay stone gray with shades of purple and brown with thin laminae of silt stone and chert(?) and lime stone and fossils cells.
143.50	171.50	28.0	Clay stone /shale mainly greenish gray with color laminae of brownish shade and fossils cells .
171.50	174.75	3.25	Shale greenish grey compact with granular material(?) chert (?)
174.75	184.25	9.50	Shale dark grey with varying shades compact and laminae of brownish colours with abundance of shell fragments . probably with ferruginous material
184.25	193.50	9.25	Shale dark grey compact with laminae and striations of limestone and probably chert
193.50	215.50	22.0	Shale compact carbonaceous dark black argillaceous
215.50	231.00	15.50	Shale with thin beds of lime stone calci Lutite to calci arenite . dark black hard compact , chert
231.00	237.25	6	Shale dark gray moderately hard to friable clayey
237.25	262.25	25	Shale ,gray with shades of light gray and light bluish with both calcareous and argillaceous cement
262.25	296.75	34.50	Shale black compact to soft friable , argillaceous .
296.75	300.50	3.75	Shale black with beds of lime stone and chert black colored.

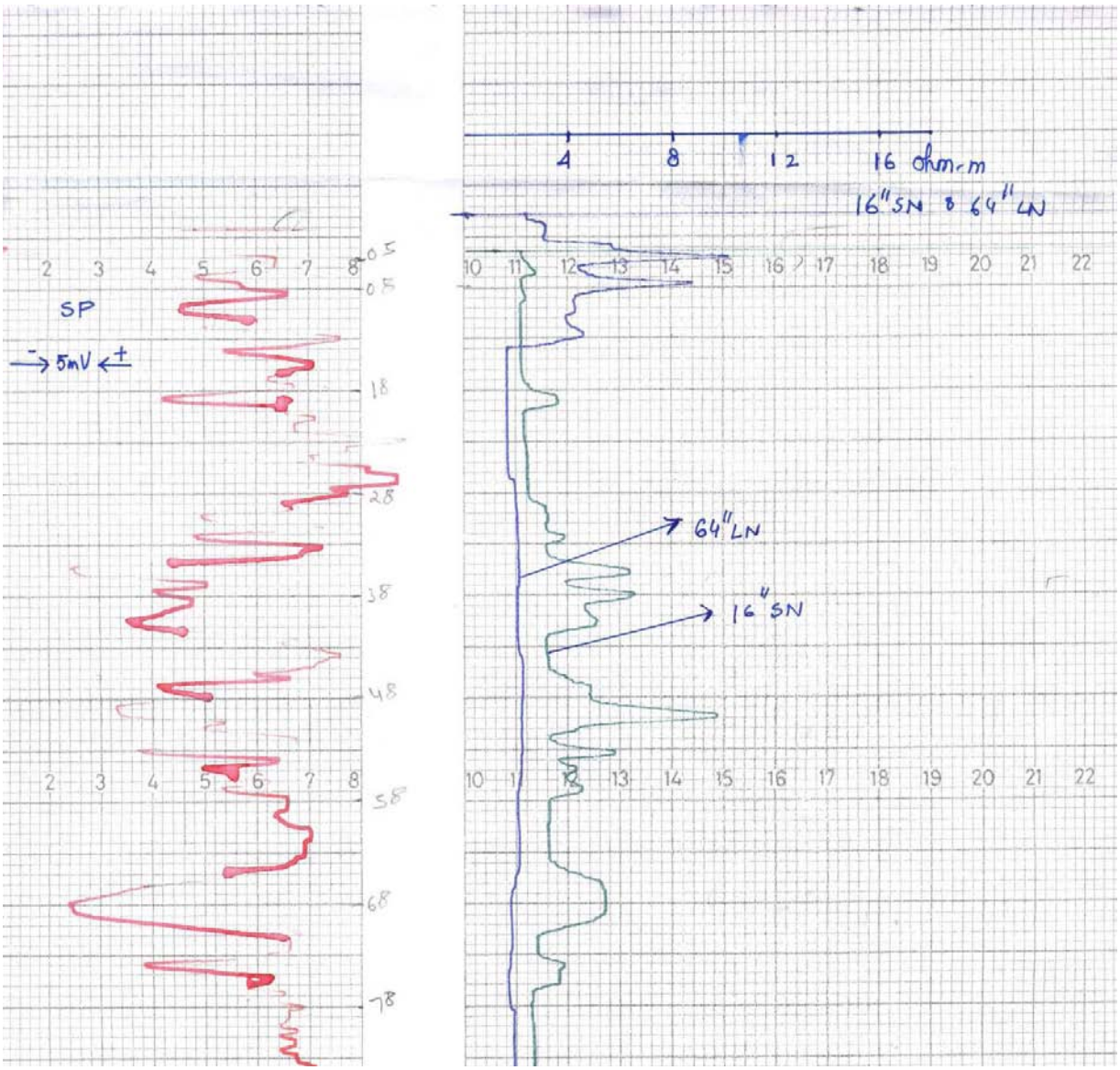
Drilling penetration rate, Ramgarh

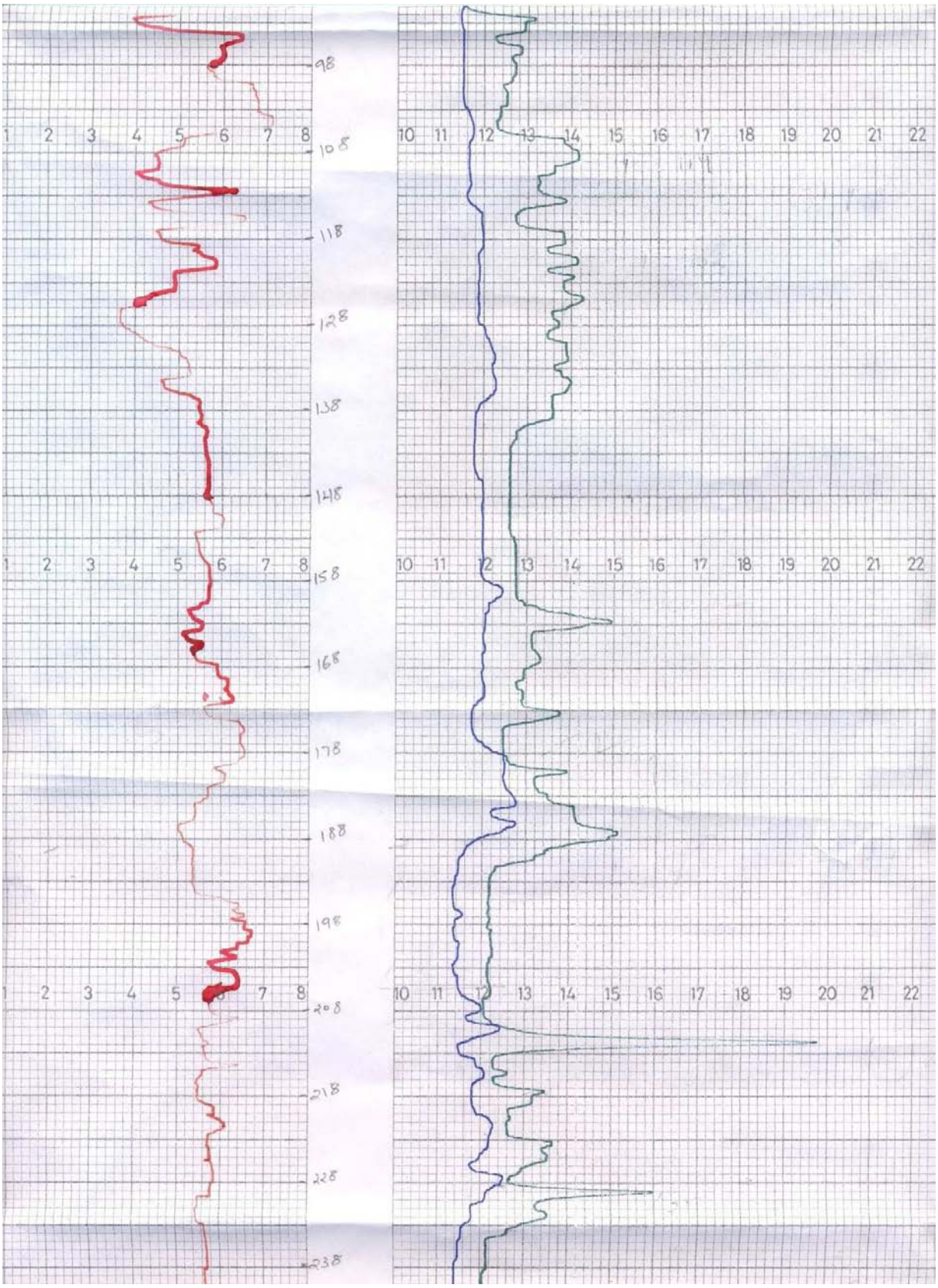
Drilling depth (m.)		Thickness(m.)	Time(minutes)	Penetration Rate
from	To			
0	3	3	130	43.33
3	6.5	3.5	135	38.57
6.5	9.5	3	130	43.33
9.5	12.5	3	160	53.33
12.5	15.5	3	95	31.67
15.5	18.75	3.25	45	13.85
18.75	21.75	3	40	13.33
21.75	25	3.25	55	16.92
25	28	3	165	55
28	31.25	3.25	135	41.54
31.25	34.25	3	85	28.33
34.25	37.5	3.25	140	43.08
37.5	40.5	3	90	30
40.5	43.75	3.25	150	46.15
43.75	46.75	3	50	16.67
46.75	50	3.25	100	30.77
50	53	3	70	23.33
53	56.25	3.25	90	27.69
56.25	59.25	3	55	18.33
59.25	62.25	3	80	26.67
62.25	65.25	3	35	11.67
65.25	68.5	3.25	50	15.38
68.5	71.5	3	70	23.33
71.5	74.75	3.25	70	21.54
74.75	77.75	3	100	33.33
77.75	81	3.25	100	30.77
81	84	3	50	16.67
84	87.25	3.25	35	10.77
87.25	90.25	3	150	50
90.25	93.5	3.25	350	107.69
93.5	96.5	3	205	68.33
96.5	99.75	3.25	45	13.85
99.75	102.75	3	10	3.33
102.75	106	3.25	55	16.92
106	109	3	15	5
109	112.25	3.25	25	7.69
112.25	115.25	3	35	11.67

Drilling depth (m.)		Thickness(m.)	Time(minutes)	Penetration Rate
from	To			
115.25	118.5	3.25	60	18.46
118.5	121.5	3	60	20
121.5	124.75	3.25	85	26.15
124.75	127.75	3	25	8.33
127.75	131	3.25	30	9.23
131	134	3	25	8.33
134	137.25	3.25	30	9.23
137.25	140.25	3	60	20
140.25	143.5	3.25	70	21.54
143.5	146.5	3	30	10
146.5	149.75	3.25	80	24.62
149.75	152.75	3	75	25
152.75	156	3.25	85	26.15
156	159	3	55	18.33
159	162.25	3.25	40	12.308
162.25	165.25	3	70	23.33
165.25	168.5	3.25	55	16.923
168.5	171.5	3	45	15
171.5	174.75	3.25	50	15.38
174.75	177.75	3	55	18.33
177.75	181	3.25	30	9.23
181	184.25	3.25	150	46.15
184.25	187.25	3	110	36.67
187.25	190.5	3.25	50	15.38
190.5	193.5	3	60	20
193.5	196.75	3.25	120	36.92
196.75	199.75	3	35	11.67
199.75	203	3.25	120	36.92
203	206	3	230	76.67
206	209.25	3.25	90	27.69
209.25	212.25	3	90	30
212.25	215.5	3.25	70	21.54
215.5	218.5	3	65	21.67
218.5	221.75	3.25	52	16
221.75	224.75	3	6	2
224.75	228	3.25	35	10.77
228	231	3	30	10
231	234.25	3.25	22	6.77
234.25	237.25	3	30	10

Drilling depth (m.)		Thickness(m.)	Time(minutes)	Penetration Rate
from	To			
237.25	240.5	3.25	135	41.54
240.5	243.5	3	45	15
243.5	246.75	3.25		
246.75	249.75	3	135	45
249.75	253	3.25	24	7.38
253	256	3	15	5
256	259.25	3.25	135	41.54
259.25	262.25	3	40	13.33
262.25	265.5	3.25	115	35.38
265.5	268.5	3	35	11.67
268.5	271.75	3.25	170	52.31
271.75	274.75	3	85	28.33
274.75	278	3.25	120	36.92
278	281	3	15	5
281	284.25	3.25	30	9.23
284.25	287.25	3	35	11.67
287.25	290.5	3.25	15	4.62
290.5	293.5	3	45	15
293.5	296.75	3.25	65	20
296.75	300.5	3.75	150	40

Ramgarh – Geophysical log

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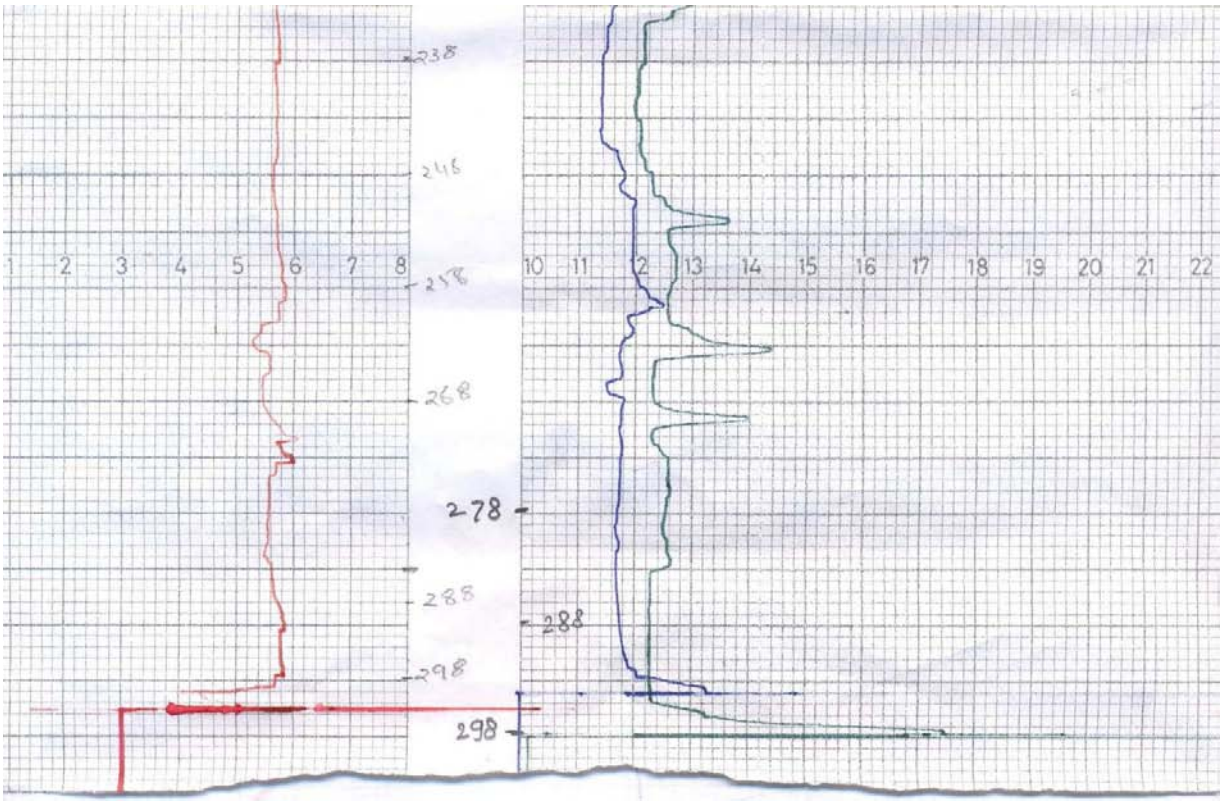
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1 2 3 4 5 6 7 8
10 11 12 13 14 15 16 17 18 19 20 21 22

2. MAITYWALA EXPLORATORY WELL

Co-ordinates: 70°21'21", 27°29'

COMPOSITE LITHOLOG, MAYATIWALA

Depth Range		Lithology
From	To	
0	10	Surface Sandy Soil
10	13	Loose Sand
16	20	Coarse grained sand and gravel & calcareous concretion
20	26	Fine sand with calcareous concretions
26	33	Fine sand with increased calcareous concretions
33	52	Marl
52	65	Argillaceous Limestone
65	72	Siltstone
72	85	Calcareous siltstone and fine grained sandstone
85	98	Fine to medium grained sandstone
98	114	Calcareous Siltstone
114	118	Fine grained sandstone
118	134	Calcareous Siltstone
134	150	Fine to medium grained calcareous sandstone
150	160	Fine to medium grained sandstone
160	167	Fine grained sandstone
167	170	Siltstone well cemented
170	186	medium to coarse grained sandstone
186	193	Calcareous sandstone poorly cemented
193	199	Coarse grained ferruginous sandstone
199	206	Coarse grained sandstone with ferruginous and calcareous content
206	239	Coarse grained calcareous sandstone
239	242	Medium grained calcareous sandstone
242	245	Fine to medium grained sandstone
245	252	Ferruginous sandstone
252	262	Limestone
258	262	Claystone
262	279	Medium grained sandstone
275	283	Fine to medium grained sandstone
283	292	Claystone

292	300	Fine to medium grained sandstone

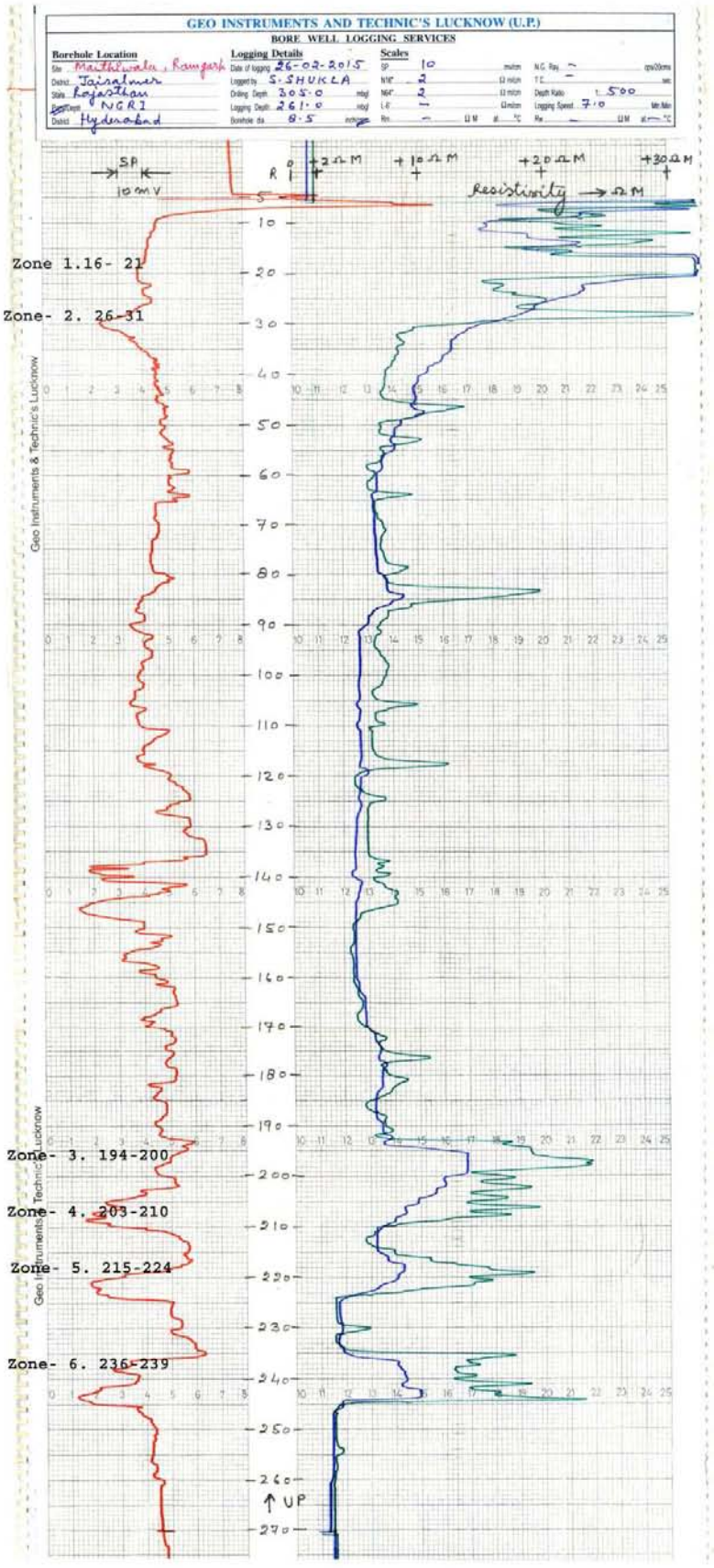
Drill Time Log, Mayatiwala

Corrected Depth		Drilling time	
From	To	(minutes)	min/m
0.00	3.00	65	21.67
3.00	6.50	205	58.57
6.50	9.50	55	18.33
9.50	12.50	85	28.33
12.50	15.75	70	21.54
15.75	18.75	40	13.33
18.75	22.00	65	20.00
22.00	25.00	35	11.67
25.00	28.25	65	20.00
28.25	31.25	105	35.00
31.25	34.50	85	26.15
34.50	37.50	100	33.33
37.50	40.75	35	10.77
40.75	43.75	55	18.33
43.75	47.00	75	23.08
47.00	50.00	130	43.33
50.00	53.25	50	15.38
53.25	56.25	100	33.33
56.25	59.50	90	27.69
59.50	62.50	55	18.33
62.50	65.75	80	24.62
65.75	68.75	145	48.33
68.75	72.00	90	27.69
72.00	75.00	25	8.33
75.00	78.25	40	12.31
78.25	81.25	30	10.00
81.25	84.50	45	13.85
84.50	87.50	55	18.33
87.50	90.75	45	13.85
90.75	93.75	51	17.00
93.75	97.00	50	15.38
97.00	100.00	45	15.00
100.00	103.25	165	50.77

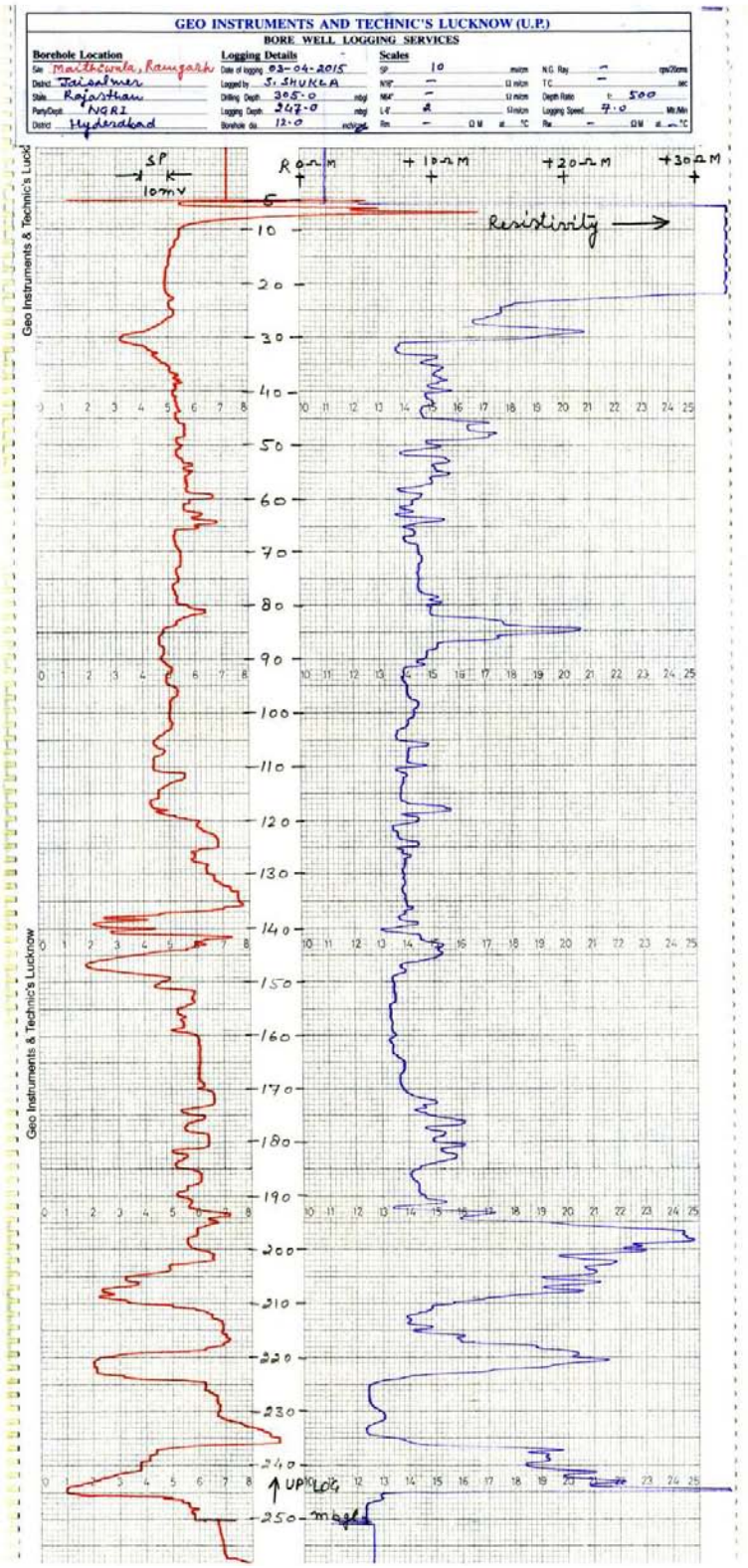
Corrected Depth		Drilling time	
From	To	(minutes)	min/m
103.25	106.25	55	18.33
106.25	109.50	60	18.46
109.50	112.50	140	46.67
112.50	115.75	60	18.46
115.75	118.75	75	25.00
118.75	122.00	95	29.23
122.00	125.00	55	18.33
125.00	128.25	75	23.08
128.25	131.25	75	25.00
131.25	134.50	40	12.31
134.50	137.50	40	13.33
137.50	140.75	60	18.46
140.75	143.75	75	25.00
143.75	147.00	55	16.92
147.00	150.00	30	10.00
150.00	153.25	40	12.31
153.25	156.25	45	15.00
156.25	159.50	40	12.31
159.50	162.50	45	15.00
162.50	165.75	55	16.92
165.75	168.75	65	21.67
168.75	172.00	70	21.54
172.00	175.00	90	30.00
175.00	178.25	80	24.62
178.25	181.25	70	23.33
181.25	184.50	135	41.54
184.50	187.50	60	20.00
187.50	190.75	120	36.92
190.75	193.75	60	20.00
193.75	197.00	115	35.38
197.00	200.00	60	20.00
200.00	203.25	180	55.38
203.25	206.25	65	21.67
206.25	209.50	110	33.85
209.50	212.50	70	23.33
212.50	215.75	65	20.00
215.75	218.75	90	30.00
218.75	221.75	90	30.00

xx

Corrected Depth		Drilling time	
From	To	(minutes)	min/m
221.75	224.75	50	16.67
224.75	228.00	50	15.38
228.00	231.00	80	26.67
231.00	234.25	25	7.69
234.25	237.25	15	5.00
237.25	240.50	140	43.08
240.50	243.50	65	21.67
243.50	246.75	85	26.15
246.75	249.75	255	85.00
249.75	253.00	255	78.46
253.00	256.00	450	150.00
256.00	259.25	150	46.15
259.25	262.25	30	10.00
262.25	265.50	80	24.62
265.50	268.50	60	20.00
268.50	271.75	120	36.92
271.75	274.75	70	23.33
274.75	278.00	60	18.46
278.00	281.25	65	20.00
281.25	284.50	110	33.85
284.50	287.50	55	18.33
287.50	290.75	125	38.46
290.75	293.75	85	28.33
293.75	297	225	69.23
297	300	40	13.33



Clay Base Line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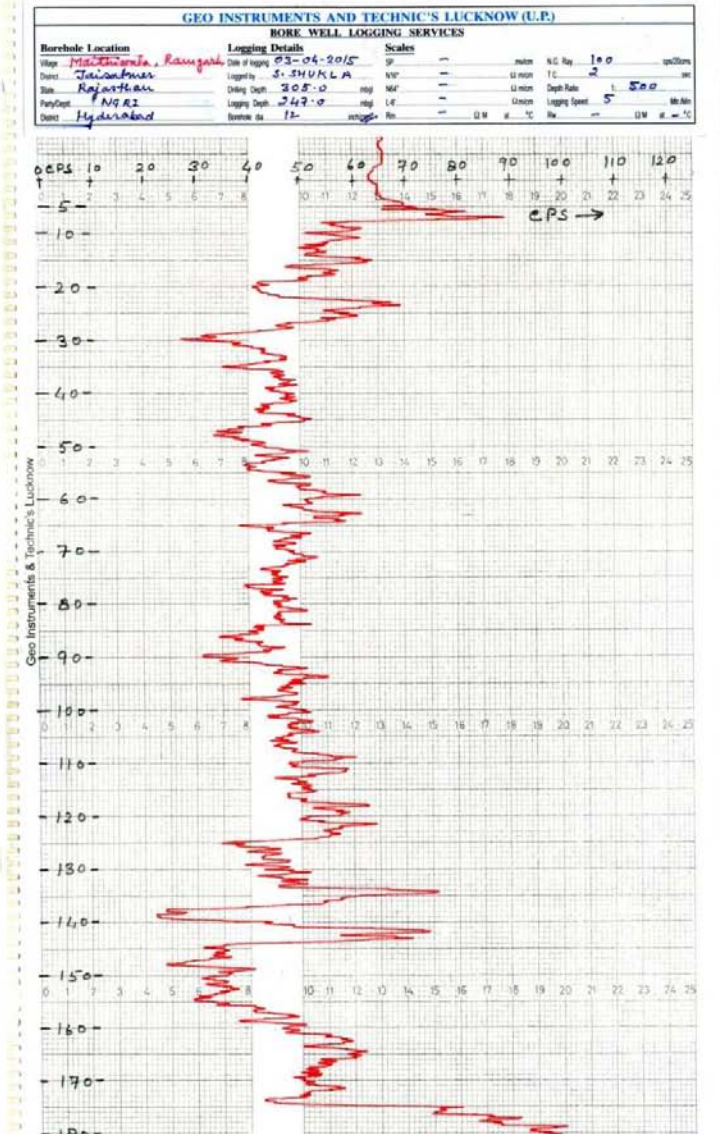
BORE WELL LOGGING SERVICES
Borehole Location
Site Maithwada, Ramgarh
District Jaisalmer
State Rajasthan
Party/Dept. NGRI
District Hyderabad
Logging Details
Date of logging 03-04-2015
Logged by S. SHUKLA
Drilling Depth 305.0 mtrs
Logging Depth 247.0 mtrs
Borehole dia. 12.0 inches
Scales
SP 10 mv/cm
N16" — Ω m/cm
N64" — Ω m/cm
L# R Ω m/cm
Res. — Ω M at — °C
N.G. Ray — cps/20cms
T.C. — sec
Depth Ratio 1: 500
Logging Speed 7.0 Mt./Min
Ra — Ω M at — °C
SP
K
10mV
R 0 Ω M
+ 10 Ω M
+ 20 Ω M
+ 30 Ω M
Resistivity
UP LOG
Geo Instruments & Technic's Lucknow
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Village Malthuanta, Ramgarh
District Jaisalmer
State Rajasthan
Party/Dept NGRI
District Hydrabad
Logging Details
Date of logging 03-04-2015
Logged by S. SHUKLA
Drilling Depth 305.0 mbgl
Logging Depth 247.0 mbgl
Scales
Depth Ratio 1: 500
Logging Speed 5
CPS
Geo Instruments & Technic's Lucknow

Annexure - V

Water level in Ramgarh area, Jaisalmer district, Rajasthan

Sno.	Location	LatD	LatM	LatS	LongD	LongM	LongS	Elevation (m)	mp (agl.)	Jan-13	Mar-13	May-13	Jun-13	Aug-13	Sep-13	Oct-13	Dec-13	Jan-14	Feb-14	May-14	Nov-14	Feb-15
MW1	Naval sigh ki dhani	27	19	7	70	33	1	177	1.1	-	53.85	56.4	63.7	64.73	76.2	-	77.64	65.98	86.47	81	-	-
MW2	Gamnewala	27	29	33	70	16	47	110	0.85	-	61.85	60.76	65.25	69	69.3	61.9	73.18	61.5	77.5	72.93	61.81	61.85
MW3	Gamnewala	27	29	13	70	16	47	111	0.7	-	72.5	65.2	66.46	66.5	67.2	65.24	72.7	64.67	71.6	65.2	64.99	64.88
MW4	Joga (shallow)	27	19	49	70	37	18		0.45	-	-	-	4.25	-0.45	1.85	-0.45	3.91	4.05	3.8	4.05	-	-
MW5	Joga (Deep)	27	19	49	70	37		207	0.6	-	67.57	67.8	3.9	-0.6	67.7	77.09	77.55	67.41	67.57	67.99	67.66	67.47
MW6	Netshi	27	17	43	70	30	20	168	0.6	-	-	3.2	1.5	1.4	-0.6	-0.6		-	-	1.5	3.47	-
MW7	Jiya desar	27	15	45	70	31	5	183	0.75	-	-	4.05	2.05	3.95	1.05	1.05	1.15	-0.75	-0.75	2.05	4.17	-
MW8	Raypal	27	22	20	70	30	50	168	0.5	-	-		3.5	-0.5	-0.5	1.3	3.2	-0.5	-0.5	3.5	3.39	-
MW9	Derasar(Sheuba)	27	24	7	70	39	35	155	0.5	-	-	3.7	4.15	-0.5	-0.5	-0.5	1.9	-0.5	-0.5	4.15	5.9	-
MW10	Mayati wala	27	29	1	70	21	24	117	1.2	-	-	65.15	65.4	65.4	65.3	65.7	65.57	65.02	65.35	65.4	65.28	62.18
MW11	Samarthwala	27	24	14	70	16	26	117	1.2	-	-	66	63.7	63.75	63.65	63.7	64	63.3	62.6	63.7	63.56	63.42
MW12	Sanu	27	14	55	70	38	59	214	1.2	112.5	-	105.48	-	106	92.8	97.6	111.92	105.45	106.2	-	105.8	-
MW13	Ramgarh	27	21	49	70	30	21	148	0.5	48.1	47.53	47.45	66.1	0.7	-	-	55.6	48.2	62.41	66.1	47.59	47.22
MW14	Ramgarh ignp	27	22	7	70	29	20	150		-	-	-	-	-	-	-	-	-	-	-	42.82	42.78

Annexure - VI

Chemical analysis of water samples (May-June, 2013) of Ramgarh area, Jaisalmer district, Rajasthan

Sl. No.	SITE	Date	pH	EC in µmhos/cm at 25°C	CO3	HCO3	Cl	SO4	NO3	PO4	TH	Ca	Mg	Na	K	F	TDS
	KHIRAR BERI	5.5.13	7.8	1520	0	232	213	300	90	0.05	480	60	80	190	1.5	0.35	988
	Biprasar	5.5.13	7.9	760	0	220	142	120	16	0.09	200	48	19	150	2	0.4	494
	JIYADESAR	5.5.13	8.1	730	0	256	128	110	16	0.05	180	20	32	160	1	0.48	475
	BUNDAH	18.6.13	8	1580	0	378	213	130	32	0.10	240	52	27	250	1.1	0.65	1027
	MAYATIWALA	18.6.13	8.56	8620	0	354	2485	750	52	0.25	600	120	73	1850	18	0.8	5603
	JOGA(KHARIN)	19.6.13	7.92	1880	0	854	156	280	14	0.06	450	100	49	360	1	0.38	1222
	SAMARTHWALA TALAI	18.6.13	8.48	8540	0	1830	2308	420	15	0.29	1150	140	195	1850	25	0.35	5551
	GAMNEWALA	13.8.13	8.14	4890	0	427	1420	110	25	0.02	750	160	85	800	1.6	3.1	3179
	BIPRASAR AQDRT	13.8.13	8	780	0	195	107	2	19	0.00	150	48	7	100	1	0.45	507
	HUKU SINGH KI DHANI	13.8.13	7.1	280	0	134	7	25	6	0.00	130	40	7	20	1	0.4	182
	JOGA	20.9.13	7.12	520	0	244	36	5	4	0.00	200	60	12	29	1	0.35	338
	DERASAR	20.9.13	7.05	290	0	159	21	5	2.8	0.00	70	20	5	50	1	0.32	189
	BIPRASAR NETSI	20.9.13	7.1	280	0	122	21	5	2.8	0.00	120	32	10	12	1	0.32	182
	JIYADESAR	20.9.13	7.05	730	0	366	92	5	1	0.00	300	80	24	65	1	0.3	475
	TEJPOLA	20.9.13	7.18	650	0	329	36	4	1	0.00	250	80	12	40	1	0.35	423
	GAMHAWALA	20.9.13	8.1	4850	0	439	1598	120	19.4	0.25	800	200	73	900	9.5	0.65	3153
	Maayatiwala dw	20.2.14	8	7010		366	2272	700	80.00	0.65	1000	280	73	1500	55	0.88	4557
	Samrathwala dw	20.2.14	7.8	6400		464	2130	400.0	15.00	0.60	500	120	49	1520	26	0.20	4160
	Gamnewala tw	20.2.14	7.96	4660		354	1349	360.0	18.00	0.40	750	240	36	850	5	0.95	3029
	Biprasar netsi pond	20.2.14	7.88	440		134	50	40.0	4.00	0.02	150	56	2	60	1	0.05	286
	Jiyadesar dw	20.2.14	8	580		350	40	35.0	1.00	0.03	300	80	24	62	1	0.05	377
	Hema dw	20.2.14	7.8	480		230	35	36.0	34.00	0.02	150	44	10	63	1	0.05	312

Sl. No.	SITE	Date	pH	EC in µmhos/cm at 25°C	CO3	HCO3	Cl	SO4	NO3	PO4	TH	Ca	Mg	Na	K	F	TDS
	Derasar seasonal pond	20.2.14	7.95	620		260	60	60.0	3.00	0.05	270	80	17	45	1	0.05	403
	Joga shallow dw	20.2.14	8	1090		380	92	120.0	22.00	0.05	330	104	17	120	1	0.20	709
	Raypal Kharin dw	20.2.14	8.12	3710		586	923	140.0	11.00	0.06	700	200	49	568	13.8	0.60	2412
	parewar tw	20.2.14	8	3380		268	852	480.0	7.00	0.08	700	200	49	560	11.8	1.80	2197

Principal Authors

P.K. Parchure, Regional Director
Rana Chatterjee, Scientist 'D'
NGRI Team (*Geophysics*)

Other Contributors

Hydrogeology:	Sh Binoy Ranjan, Scientist ‘C’
Geophysics:	Dr. S.L. Dhabai, Scientist 'C'
Water Chemistry	Sh. Yashveer Singh, Scientist 'B'
	Dr. J.P. Garg, Asstt. Chemist
	Smt. Aruna Saini, Asstt. Chemist
	Dr. Prerna Mathuria, STA (Chemist)
Drawing & Cartography	Sh J.K.Tandon, Draftsman
Advanced Geophysical Techniques:	NGRI, CSIR, Hyderabad
Borehole construction:	Div. I Ahmedabad/ Div XII Jodhpur