केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

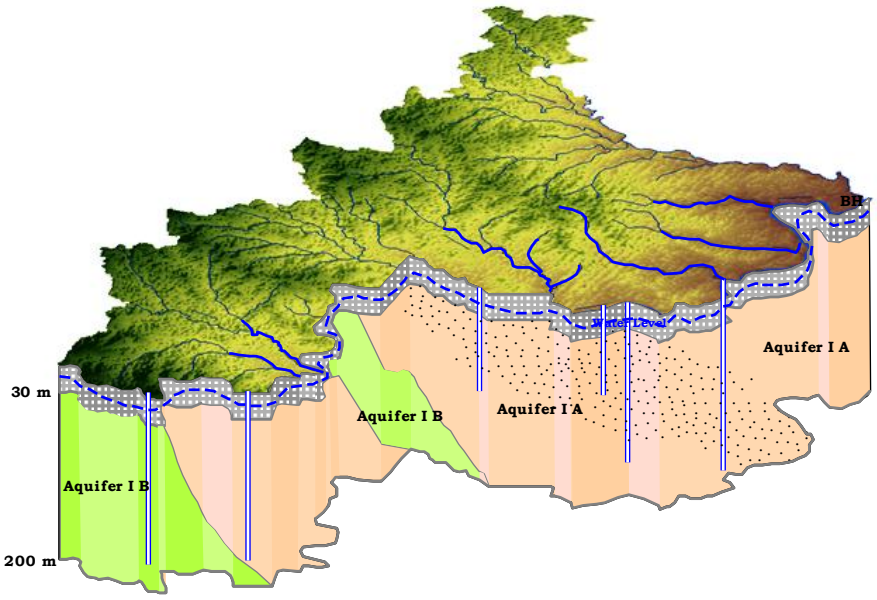
AQUIFER MAPPING

Bemetara and Saja Block, Bemetara District, Chhattisgarh

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattisgarh Region, Raipur

AQUIFER MAPPING
IN BEMETARA AND SAJA BLOCKS, BEMETARA DISTRICT, CHHATTISGARH



Central Ground Water Board
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Ministry of Water Resources,
Ganga Rejuvenation & River Development
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RAIPUR
2016

GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES
CENTRAL GROUND WATER BOARD

A REPORT ON AQUIFER MAPPING 2014-15

IN BEMETARA AND SAJA BLOCKS, BEMETARA DISTRICT, CHHATTISGARH

NORTH CENTRAL CHHATTISGARH REGION,
RAIPUR

December, 2015

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NORTH CENTRAL CHHATTISGARH REGION,
RAIPUR
MAY 2016

A Report on Aquifer Mapping 2014-15
In Bemetara & Saja Blocks, Bemetara District, Chhatisgarh

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1. Introduction

1.1 Objective

The groundwater is the most valuable resource for the country. However, due to rapid and uneven development, this resource has come under stress in several parts of the country. Central Ground Water Board (CGWB) is, therefore, involved in hydrogeological investigations for reappraisal of ground water regime. CGWB has also carried out ground water exploration in different phases with prime objective of demarcating and identifying the potential aquifers in different terrains for evaluating the aquifer parameters and also for developing them in future. The reports and maps generated from the studies are mostly based on administrative units such as districts and blocks and depict the subsurface disposition of aquifer on regional scale. However, due to paradigm shift in focus from development to management of ground water in last one decade, the need for more reliable and comprehensive aquifer maps on larger scale has been felt for equitable and sustainable management of the ground water resources at local scale.

1.2 Scope of study

The demand for ground water for various types of use is increasing day by day; consequently indiscriminate development of ground water has taken place and the ground water resource has come under stress in several parts of the country. On the other hand, there are also areas where adequate development of ground water resources has not taken place. These facts underscore the need for micro- level study of the aquifer systems of the country. The water resource managers and planners to develop and implement effective long term as well as short term aquifer management strategies, a host of of scientific questions must be answered. These questions can be best answered through a comprehensive process that integrates the the available scientific data. Aquifer mapping study thus is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and quality data is integrated to characterize the quantity, quality and movement of ground water in aquifers. It primarily depends on the existing data that are assembled, analysed and interpreted from available sources. The data gap analysis carried out helped to generate data from data newly collected through activities such as exploratory drilling, groundwater level monitoring on a regular basis for a considerable period and groundwater quality analysis. These existing as well as generated data were analysed in ordered to prepare regional hydrogeological, thematic, water quality maps, cross-sections, 2 –D and 3-D aquifer disposition and potentiometric maps.

The aquifer maps are the maps depicting aquifer disposition, giving lateral and vertical extension. The maps will also provide information on the quantity and quality. It explains the components of the Aquifer Classification System, outlines the assumptions underlying the map information presented and summarizes the content of an aquifer classification map. The goal is to help the map users understand the strengths and limitations of the information contained on the aquifer classification maps so that they can apply that information appropriately to their particular water and land management needs. The system and maps are designed to be used together and in conjunction with other available information as a screening tool for setting groundwater management priorities. These provide a way of comparing aquifers within a consistent hydrogeological context and prioritizing future actions at various planning levels. The maps may provide some background information for site-specific projects. However, the maps are not to be used for making site-specific decisions. The classification of an aquifer reflects the aquifer as a whole and at a specific time. Groundwater conditions, such as the degree of vulnerability and water quality, may vary locally and over time respectively. This variability in the data sometimes requires subjective decision-making and generalising of information for an entire aquifer.

1.3 Approach and Methodology

The activities under the aquifer project can be summarized as follows:

i) **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 the Central Ground Water Board and various other government organizations with a new set of data generated that broadly describe an aquifer system.The data were compiled, analysed, synthesized and interpreted from available sources. These sources were predominantly non-computerised data that were converted into computer based GIS data sets. On the basis of these available data, Data Gaps were identified.

ii) **Data Generation:** It was evident from the data gap that additional data should be generated to fill the data gaps in order to achieve the objective of the aquifer mapping programme. This was done by multiple activities like exploratory drilling, hydrochemical analysis, use of geophysical techniques as well as detail hydrogeological surveys.

iii)**Aquifer map Preparation:** On the basis of integration of data generated through various hydrogeological and geophysical studies, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out the Characterization of Aquifers. These maps may be termed as Aqifer Maps depicting spatial (lateral and vertical) variation of the aquifers existing within the study area, quality, water level and vulnerability (quality and quantity).

iv)**Aquifer Management Plan:** Based on the integration of these generated, compiled, analysed and interpreted data, the management plan has been prepared for sustainable development of the aquifer existing in the area.

1.4 Area Details

Under the aquifer mapping programme, an area comprising of 2 no of development blocks namely Saja and Bemetara of Bemetara district (part of undivided Durg district) was taken up covering an area of 1604 sq. km. The study area is situated in the west central part of Chhattisgarh state. It falls in the Survey of India's Topo Sheet Nos. 64G/2, 64G/5, 64G/6, 64G/9, 64G/10, 64F/8 and 64F/12 (1:50000 Scale) between latitudes 21°30'25''to 22°01'14"N and longitudes 81°08'23''to 81°46'19''E. The study area is bounded by Bilaspur district in the north, Kawardha district in the north-west, Rajnandgaon district in the south-west, Raipur district in the east, Dhamtari district in the south-east and Kanker district in the south (**Fig 1**). The district has a well developed road network. The important roads of district are Durg-Dhamdha-Bemetara Road, Kawardha- Bemetara- Simga Road, and Kumhari- Ahiwara- Bemetara Road etc.

1.4.1 Administrative Division

Two blocks of Bemetara district, namely Bemetara and Saja come under the study area. In all, a total of 306 no. of villages exist in the study area. The block headquarters are located at Saja and Bemetara towns. The administrative map for the study area is given in **Fig 1.**

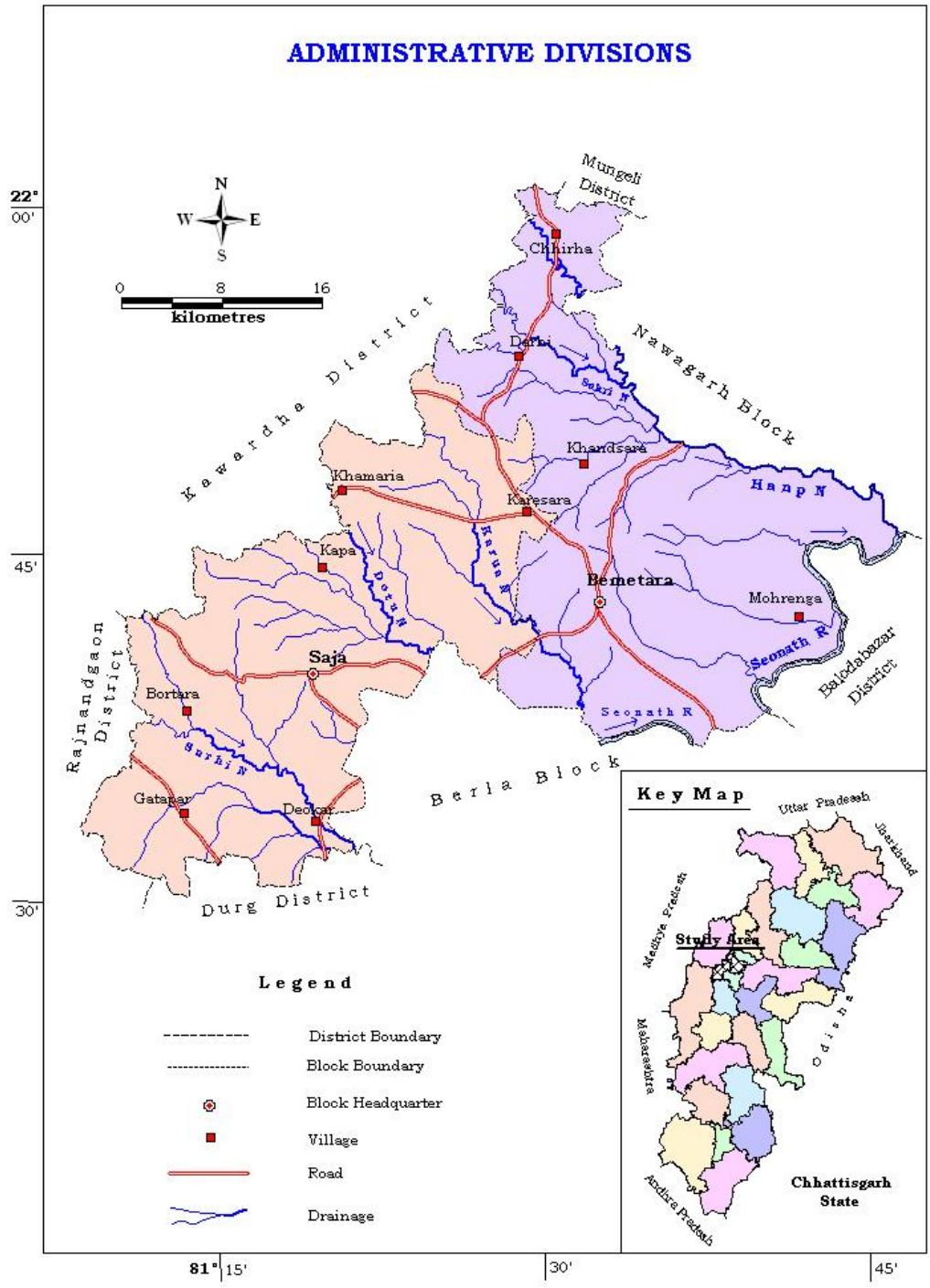
Table 1(A) Geographical location of the study area

Study Area (Blocks)	District	Area (Sq. Km)	Latitude		Longitude		Toposheet No (1:50000 Scale)
			From	To	From	To	
Bemetara & Saja Blocks	Bemetara	1604	21°30'25''N	22°01'14"N	81°08'23"E	81°46'19''E	64G/2, 64G/5, 64G/6, 64G/9, 64G/10, 64F/8 & 64F/12

Table 1(B) Administrative Divisions of the Area

Sl No	Name of Block	District	Area (Sq Km)	No of Tehsils	No of Development Blocks	No of Towns
1	Bemetara	Bemetara	794	1	1	1
2	Saja	Bemetara	810	1	1	1
Total			1604	2	2	2

Fig. 1 Administrative Map of Saja and Bemetara block area



1.5 Data Availability, Data Adequacy and Data gap Analysis

The hydrogeological data already available including number of key wells, VES, exploratory wells, chemical parameters have been collected and analysed which shows that in the study area the required number of ground water monitoring stations is 160 against which only 13 stations are available leading to the data gap of 147. Similarly, the required number of ground water exploratory wells is 20 against which only 8 stations are available leading to the data gap of 12. Likewise, the required number of ground water quality monitoring stations is 240 against which only 13 stations are available leading to the data gap of 227. Lastly, the required number of VES is 84 against which no VES data is available leading to the data gap of 84.

1.5.1 Data Gap Analysis 14-15

On the basis of the NHS data, VES data and chemical data available in the study area, the data gap analysis has been prepared to ascertain the data gap in the study area which is presented in Table 2(A).

Table 2(A) Data Gap Analysis

Toposheet No	Grid No	Data Gap Analysis for AQM Plan 14-15 CGWB, NCCR, Raipur														
		Data Require					Data Existing					Data Gap				
		EW	OW	VES	CHE Qua	WL moni	EW	OW	VES	CHE Qua	WL moni	EW	OW	VES	CHE Qua	WL moni
64G1	C3	0	0	3	9	6								3	0	6
64G2	B3	0	0	3	9	7								3	5	7
64G2	C1	1	1	2	4	3								2	10	3
64G2	C2	0	0	2	5	3	1	1						2	8	3
64G2	C3	1	1	3	9	6				1	1			3	10	5
64F4	C3	0	0	2	5	3								2	0	3
64G5	A3	0	0	0	0	0								0	3	0
64G5	B2	0	0	3	9	3								3	6	3
64G5	B3	0	0	3	9	7						1	1	3	12	7
64G5	C1			2	5	3						1	1	2	8	3
64G5	C2	1	1	3	9	7								3	12	7
64G5	C3	1	1	3	9	6	1	1		1	1			3	10	5
64G6	A1	1	1	3	9	7						1	1	3	12	7
64G6	A2	1	1	3	9	6								3	12	6
64G6	A3	0	0	2	6	3				1	1			2	9	2
64G6	B1	1	1	3	9	6								3	9	6
64G6	B2			2	5	3				1	1			2	4	2
64G6	B3			2	4	3	1	1		1	1			2	2	2
64G6	C1			3	9	7								3	9	7
64G6	C2	0	0	3	9	6								3	2	6
64G8	A3	0	0	0	0	0								0	0	0
64G9	A1	0	0	2	4	3				1	1			2	6	2

64G9	A2	0	0	2	6	3								2	10	3
64G9	A3	1	1	3	9	6						1	1	3	10	6
64G9	B2	0	0	3	9	6				2	2			2	0	4
64G9	B3			3	9	7	1	1						4	9	7
64G9	C3	0	0	5	7	9				1	1			5	7	8
64G10	A1			3	9	6				2	2	1	1	3	12	4
64G10	A2	1	1	3	9	6								3	6	6
64G10	B1	1	1	3	9	7				1	1	1	1	3	12	6
64G10	B2			2	9	3								2	5	3
64G10	C1	0	0	2	9	3				1	1			2	6	2
64G10	C2	0	0	3	9	6								3	1	6
64G13	A3	0	0	0	0	0								0	0	0
Total		**10**	**10**	**84**	**240**	**160**	**4**	**4**	**0**	**13**	**13**	**6**	**6**	**84**	**227**	**147**

Table 2(B) Summarised Data Gap Analysis

Activity	Required	Available	Gap
Exploration EW/OW	20	8	12
GW Monitoring	160	13	147
Quality monitoring	240	13	227
VES	84	0	84

1.6 Rainfall

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August and nearly 95% of the annual rainfall is received during during this period. The average annual rainfall for the study area is around 1423.5 mm (Average of the last three years i.e. 2012 to 2014) which is presented below in **Table 3**.

Table 3 Annual Rainfall (mm) in Bemetara district for the years (2012 to 2014)

District/Tehsil	2012	2013	2014	Average of 3 years for the block
Bemetara	1113	2074	1589	1592
Saja	1123	1466	1175	1255
Average of 3 years for study area	1423.5			

Source: IM

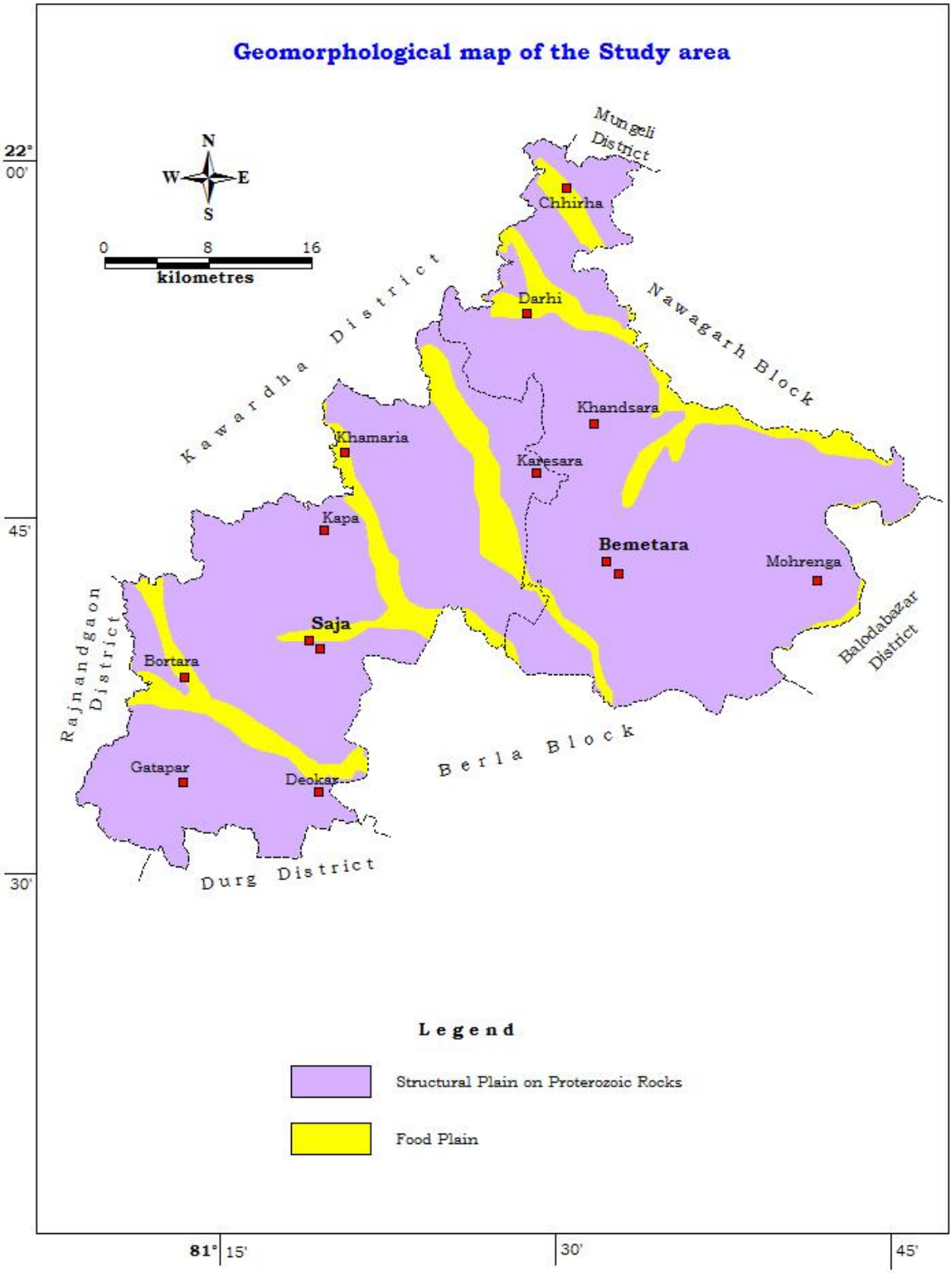
1.7 Physiography/Geomorphology

Geomorphologically the study area displays Structural Plains and Flood Plain which comes under the physiographic unit belonging to Chhattisgarh basin area.

The Central Chhattisgarh Plain is represented by Structural Plain on Proterozoic rocks which cover major area in the northern & central part of the district. This unit is developed over rocks of Purana sedimentary basin of Chhattisgarh. This unit has extensive cris-crossed fractures and joints. They are having gently sloping erosional surfaces and thin to moderate cover of soil.

Along with the above mentioned geomorphic unit, Flood Plain is also developed in the district especially in north-western and eastern part. It is formed by extensive deposition of alluvium by major river system in the district. This unit is normally flat/gently undulating land surface and located along river courses. This unit is primarily composed of unconsolidated fluvial materials like gravels, sand and silt. Fig 4 shows the Geomorphology in the study area.

Fig.2 Geomorphology Map of the Study area


Geomorphological map of the Study area
22° 00'
45'
30'
N
W
E
S
0
8
16
kilometres
Mungeli District
Chhirha
Darhi
Kawardha District
Nawagarh Block
Khandsara
Khamaria
Kanesara
Kapa
Bemetara
Mohrenga
Saja
Bortara
Rajnandgaon District
Baloda bazar District
Berla Block
Gatapar
Deokar
Durg District
Legend
Structural Plain on Proterozoic Rocks
Food Plain
81° 15'
30'
45'

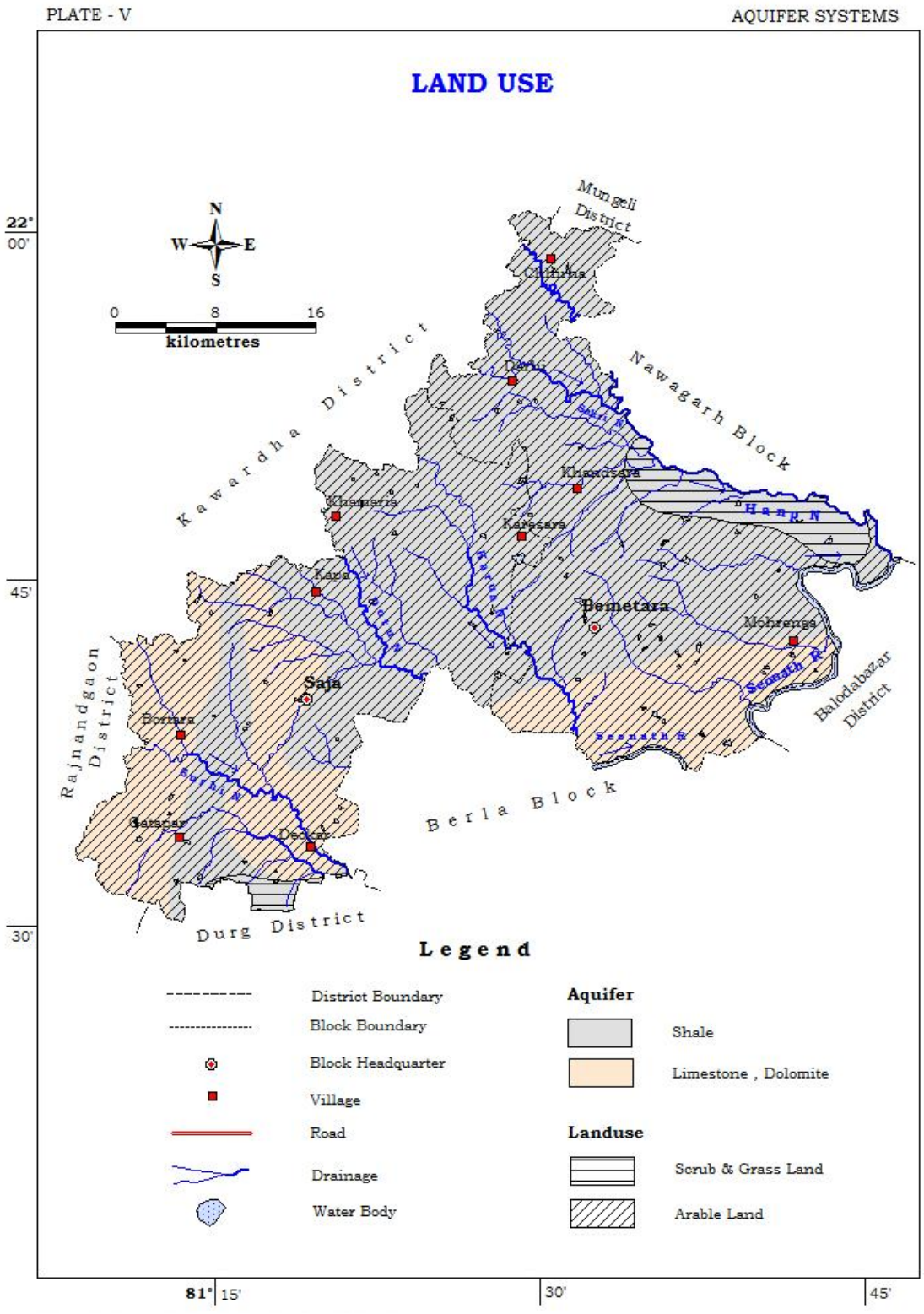
1.8 Land use

The scrub and Grass land and arable land in Bemetara block is 17.25 and 777.02 sq km and in Saja block scrub and Grass land and arable land area are 88.12 and 722.46 sq km respectively. There is no reserved forest and protected forest, other forest in the district

Table 4: Blockwise Land Use (Sq.Km)

Block	Reserved Forest	Protected Forest	Other Forest	Scrub and Grass Land	Arable Land	Total Area
Bemetara	NA	NA	NA	17.25	777.02	794.00
Saja	NA	NA	NA	88.12	722.46	810.00
Total area						1604.00

Fig.3 Land Use Map of the Study Area



1.9 Soil

Generally soils are classified on the basis of texture, mineral content and presence of salts and alkalies. However in present context the classification and distribution is adopted as per the soil orders in US soil taxonomy and their Indian equivalents. There are 12 orders in US soil taxonomy but only two orders are found in study area. They are described below in brief and given in **Table 5**. The distribution of these two different soil types in the study area is presented in **Fig 4**.

Table 5: Soil Classification

Sl.No	US Soil Taxonomy	Indian Equivalents
1	Ultisols	Lateritic soil
2	Vertisols	Medium black soil
		Deep black soil

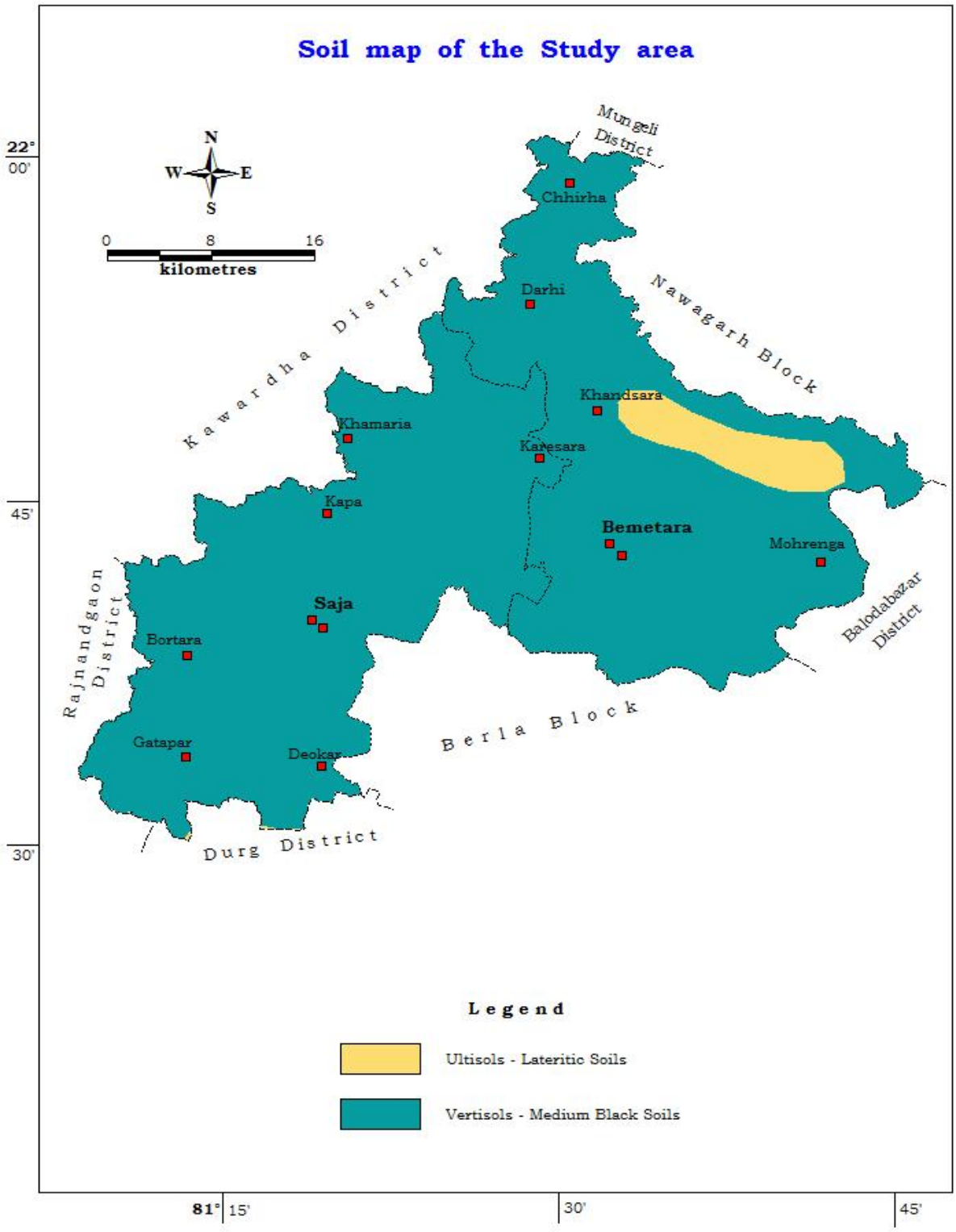
A. Ultisols

The Indian equivalent of this soil found in the study area is Lateritic soil. It is the ultimate product of continuous weathering of minerals in a humid climate. This is a highly weathered and leached acid soil with high levels of clay below top layer. They are characterized by a humus-rich surface horizon and by a layer of clay that has migrated below the surface horizon. This soil has variety of clay minerals but in many cases the dominant mineral is Kaolinite. It is red to yellow in color and is quite acidic having pH less than 5. The red and yellow color results from the accumulation of iron oxide which is highly insoluble in water.

B. Vertisols

The Indian equivalent of this soil in the study area is medium black soil. Vertisol is a soil in which the content of clay size particles is 30% or more by mass in all horizons of the upper half-metre of the soil profile. It is characterized by a high content of expanding and shrinking clay known as montmorillonite. It is also characterized by salinity and well defined layers of calcium carbonate or gypsum. Vertisol contains high level of plant nutrients, but, owing to it's high clay content, It is not well suited to cultivation. Vertisols are especially suitable for rice because they are almost impermeable when saturated. Rainfed farming is very difficult because vetisols can be worked only under a very narrow range of moisture conditions as they become very hard when dry and become very sticky when wet.

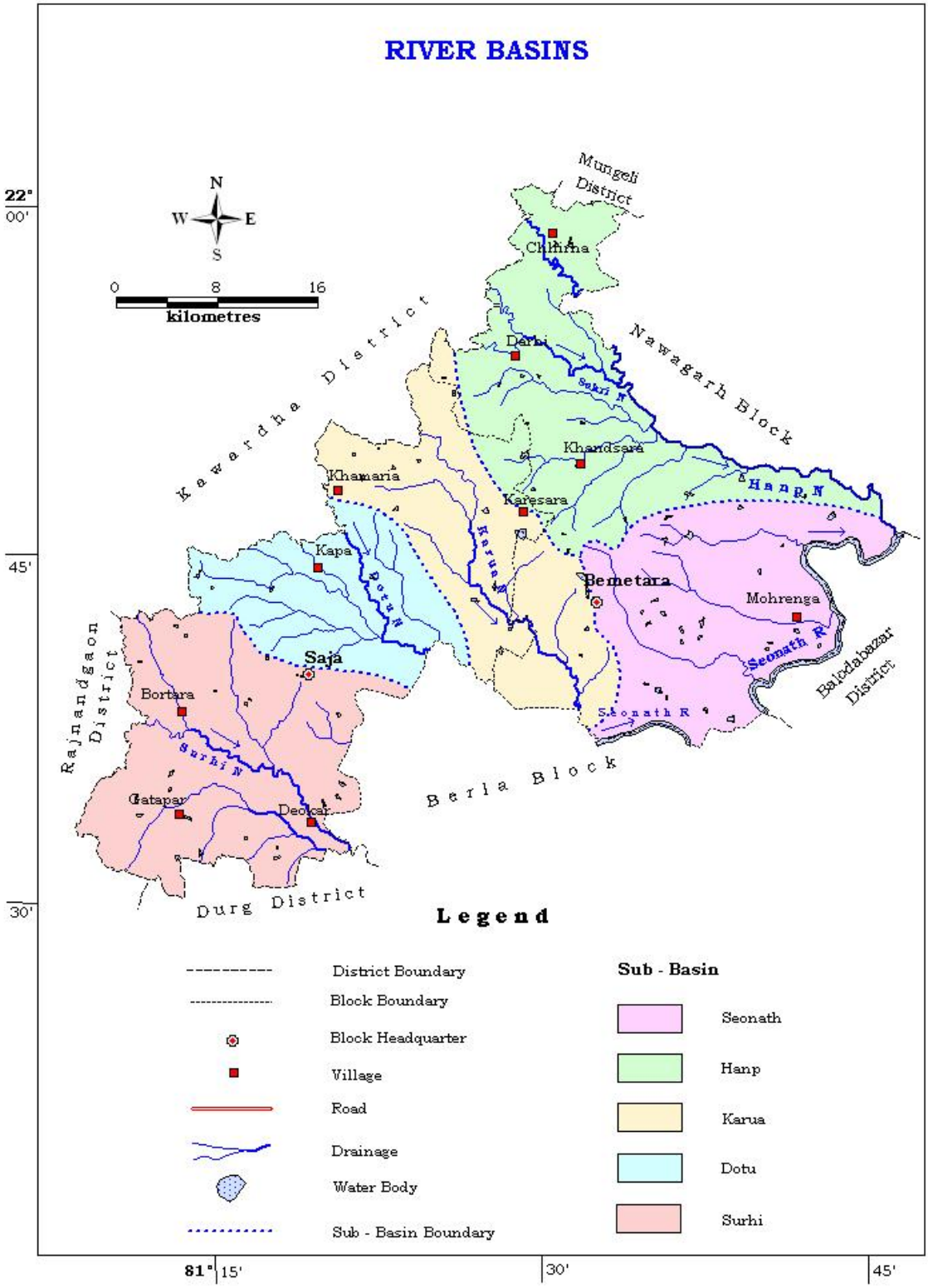
Fig.4 Soil Map of the Study area



1.10 Hydrology and Drainage

The study area is mainly drained by Sheonath and Hanp rivers and their tributaries. This river system comes under Mahanadi River basin. Sheonath river, a tributary to Mahanadi, flows through the upper eastern periphery to central and western part of the district along with its tributaries. Hanp river along with its tributaries flows through the northern part of the district and also joins Sheonath river in north-eastern part of the district. This entire drainage network is governed by the master slope in the district.

Fig.5 River Basin Map of the Study area



The River Basin map and Aquifer River Basin wise map prepared and presented in Fig 5 and 6**.** There are six sub-basins namely Sheonath, Hamp Nala, Korua Nala, Dotu Nala,Surhi Nala existing in the area. This river system comes under Mahanadi River basin.From the figures, it may be seen that, the drainage pattern of the area is dendritic to sub-dendritic in nature. Drainage density is more or less same in most of the part of the district. The drainage density is found comparatively low in the area which is attributed to plain area indicating somewhat low runoff and higher infiltration.

Table 6(A) River Basins

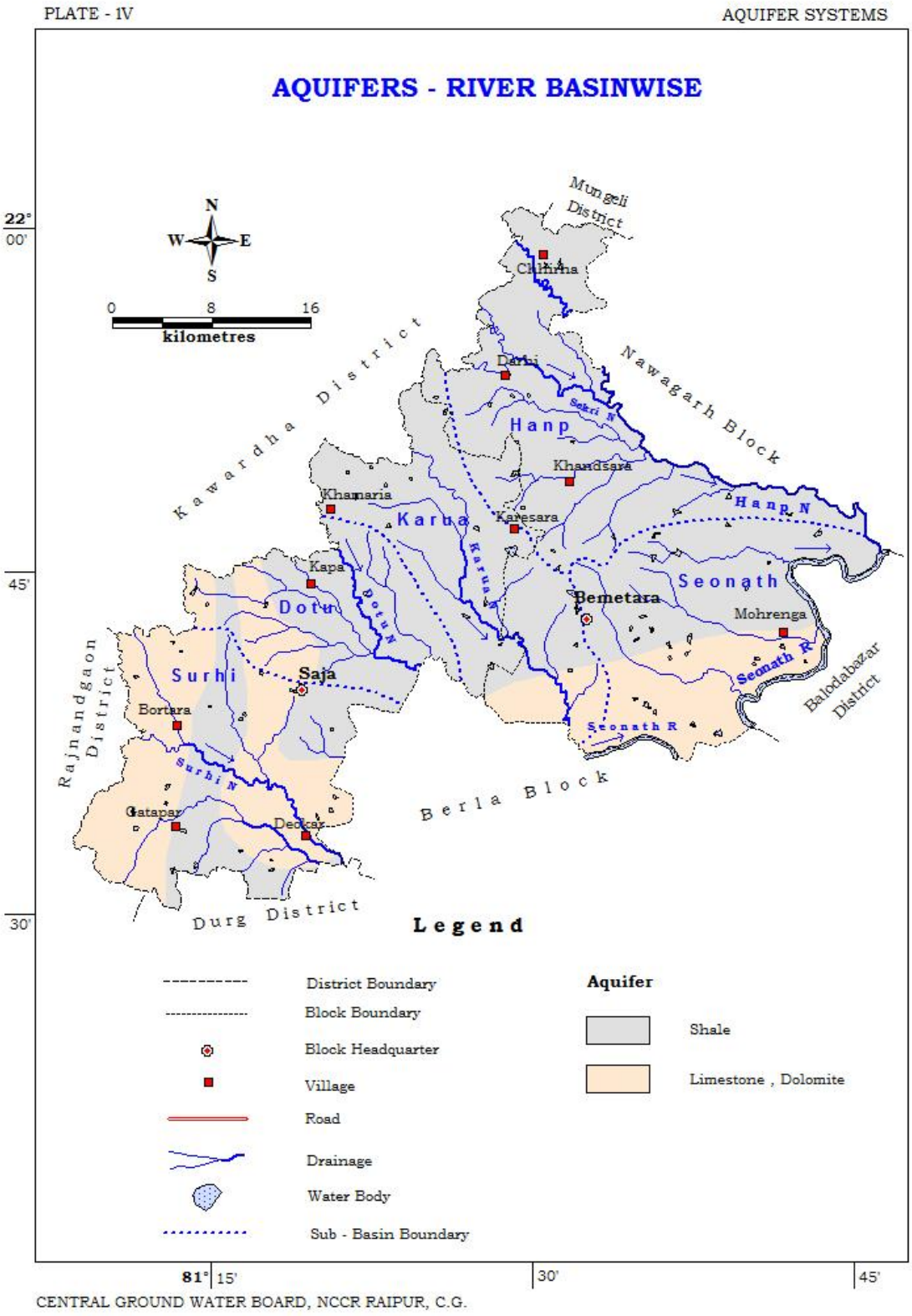
Basin/ Subbasin	Place of origin of main river	River catchment area	In Chhatishgarh	Major Tributaries
Mahanadi	Sihawa Hills, Dhamtari District (C.G)	1604	76150	Seonath, Hanp, Surhi, Karoa, Dotu

Area in sq.km.

Table 6(B) Major River Basins

Basin	Sub-Basin	Number of Water shed	Area (sq.km)
Mahanadi	Sheonath	1	325.34
Mahanadi	Hanp Nala	1	377.20
Mahanadi	Karrua Nala	1	311.14
Mahanadi	Dotu Nala	1	212.16
Mahanadi	Surhi Nala	1	378.19

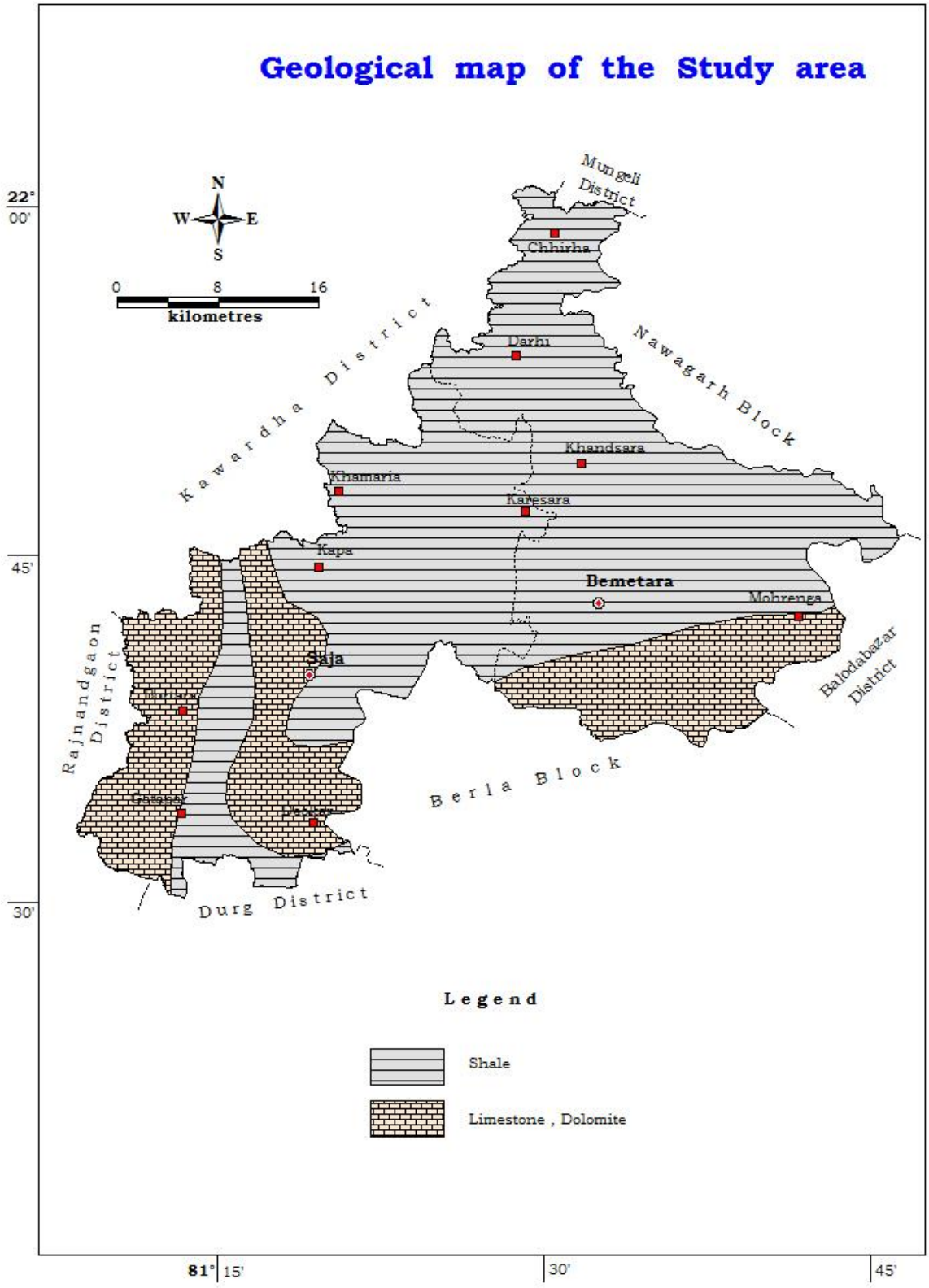
Fig.6 Aquifer River Basin wise Map of the Study area



1.11 Geology

Geologically, the study area comprises of rocks of Meso to Neo-Proterozoic sequence and is represented by the Chhattisgarh Supergroup consisting of the Raipur Group of rocks. Raipur Group comprises Charmuria Formation, Gunderdehi Formation and Chandi formation, Tarenga Formation, Hirri Formation and Maniyari Formation. But the study area is covered predominantly by Maniyari Formation and Tarenga Formation and also partly covered by Hirri Dolomite as well as Chandi formations underlain occasionally by the Khamaria Pebble Bed of Quaternary age. This group of rocks is mainly argillite-carbonate sequence & consists of limestone, shale, dolomite and sandstone.

Fig7: The geological map of the study area



1.12 Agriculture, Irrigation, Cropping Pattern

In the study area, ground water related agriculture data has been collected to understand the cropping pattern and thereby the related water requirement and it's impact on the local ground water regime. Rice is the major crop which is extensively cultivated during both Kharif and Rabi season. While rain water is the only source during Kharif, the area is irrigated mainly (about 89%) through ground water during Rabi. The relevant data are presented in table 8(A, B, C).

Table 7(A) Agricultural pattern in Bemetara district during the year 2013-14 (in ha)

Tehsil	**Total geographical area**	**Revenue forest area**	**Area not available for cultivation**	**Non agricultural & Fallow land**	**Agricultural Fallow land**	**Net sown area**	**Double cropped area**	**Gross cropped area**
Saja	45100	0	3840	3454	322	36917	24969	61886
Bemetara	72779	0	6153	7174	586	57856	34219	92075

Table 7(B) Cropping pattern in Bemetara district during the year 2013-14 (in ha)

Tehsil	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits / Vegetables	Reshe	Mirch Masala	Sugar-cane
			Wheat	Rice	Jowar & Maize	Others						
Saja	34791	61886	2727	23092	0	41	23747	8777	3173	6	5	310
Bemetara	51727	92075	3097	38264	0	748	36493	11036	1443	3	5	802

Table 7(C) Area irrigated by various sources in Bemetara district during the year 2013-14 (in ha)

Tehsil	No. of canals (private and Govt.)	Irrigated area	No.of bore wells/ Tube wells	Irrigated area	No. Of dug wells	Irrigated area	No. of Talabs	Irrigated area	Irrigated area by other sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of irrigated area wrt. Net sown area
Saja	11	14822	4123	15955	322	68	50	1298	79	15182	17040	32222	52
Bemetara	21	2539	5370	32095	109	23	45	295	51	19272	15731	35003	38

1.13 Water conservation/recharge practices

The `prevailing water conservation practices in Bemetara district are generally in the form of minor tanks, diversions, anicuts etc which are constructed and maintained by the state govt agencies. This is presented in Table no. 8

Table 8: summarized detail of water conservation structures in the study area

Block	Water conservation structure	Storage capacity (ham)	
		Command area	Non-command area
Bemetara	Minor tanks	840	760
	Diversions	100	40
	Anicut	300	750
Saja	Minor tanks	800	520
	Diversions	200	120
	Anicut	0	0

2.0 Data Collection and Generation

2.1 Hydrogeological Data The semi-consolidated rocks of study area mainly represented by Chhattisgarh Super Group of rocks (Predominantly by Maniyari Formation followed by Hirri, Tarenga and Chandi formations), which consists mainly of shale and limestore.In general two aquifers exist in the area although both are hydraulically connected. The first shallow unconfined/ phreatic aquifer between 0-30 mbgl and the second semi confined to confined aquifer below 30 mbgl. It has been found that within the second aquifer, there are 2-3 set of aquifers which are not well connected. The different sets of aquifers are of different thickness as well as of varying horizontal extent.

In the study area, key wells were established during the pre-monsoon period and have been subsequently monitored in the post-monsoon period. The key wells are distributed throughout the study area covering all the geological formations, the details of which are presented in the Table No 9 and Fig No 8.

Fig.8 Location of Key wells established in the study area

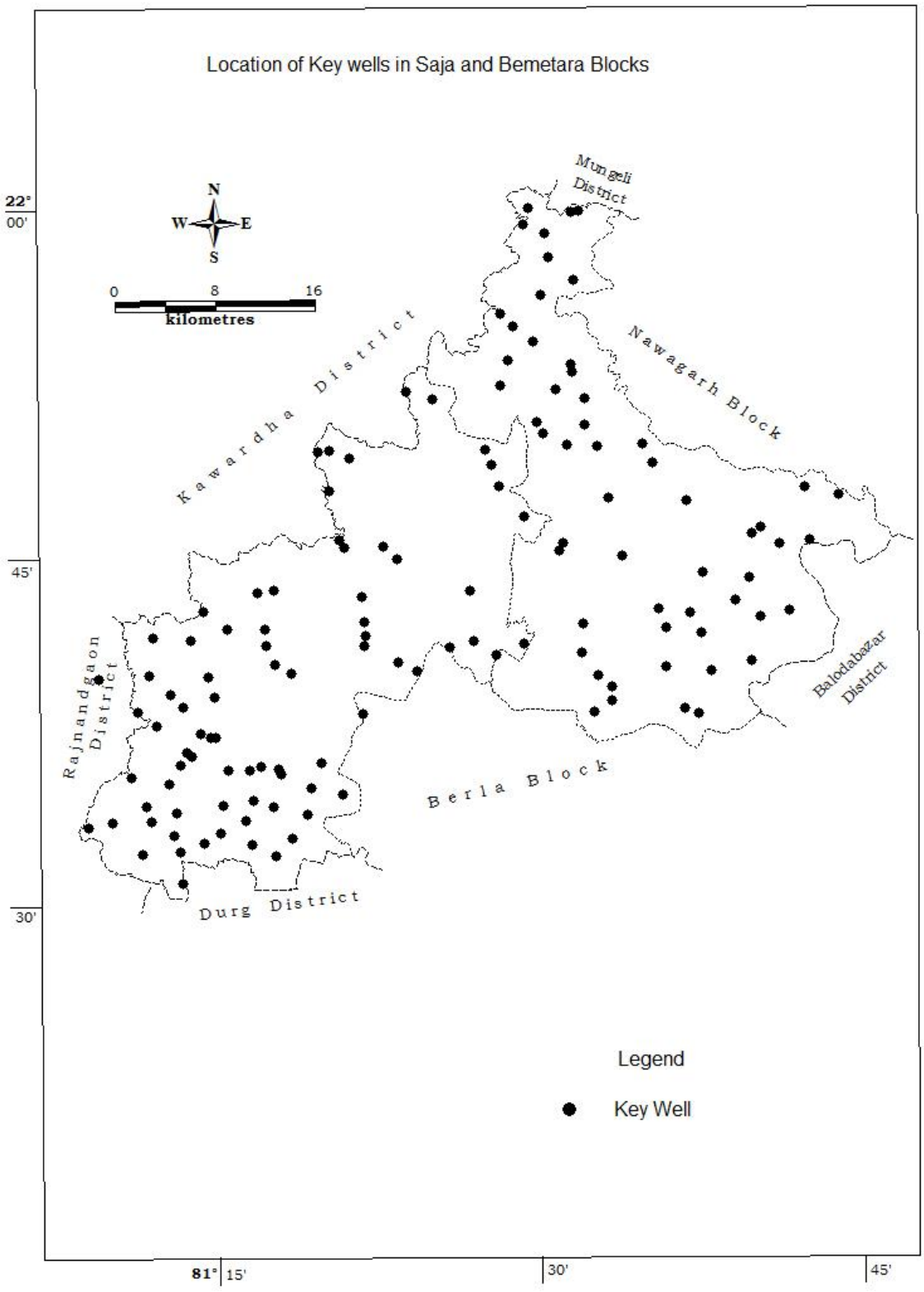


Table 9: Detail of Key (observation) Wells established in the study area

Sl no	Location	Lattitude	Longitude	T.S No	RL	Total depth(m)	Dia (m)	MP (magl)	WL- June, 14	WL- Aug , 14	WL- Nov,14	Location
1	Garra	21.7811	81.4853	64 G/5	296	14.5	2.4	0.5	11.1	8.7	10.6	Dw is in middle of village near talab & Jait Khamba
2	Sagauna	21.8033	81.4658	64 G/5	289	9.6	2.4	0.6	7.9	3.6	5.7	Dw is by the side of Primary school near road side .
3	Khursbod	21.8181	81.4594	64 G/5	290	9.5	4.1	0	7.4	5.6	6.3	Dw is in H/o Bhagwat sahu near road side in Nayapara.
4	Kanhera	21.8294	81.4553	64 G/5	294	10.6	3.1	0.4	9.4	7.5	8.4	Dw is in H/o Chandru Verma (Sarpanch) in Khalhe para.
5	Udiya	21.8656	81.4144	64 G/5	304	6.5	2.8	0	5.2	2.1	2	Dw is in H/o Punit Patel in front of talab.
6	Agrikalan	21.8711	81.3939	64 G/5	300	6.5	2.3	0.3	3.1	1.2	1.8	Dw is in H/o Karam das Manikpuri by the side of road opp to talab.
7	Rakhi	21.5811	81.3450	64 G/6	274	13.8	2.6	0.6	12.7	4.5	9.5	Dw is in front of Anganwadi Bhawan Rakhi.
8	Deorkar	21.5669	81.3178	64 G/6	273	8.5	2.6	0.6	6.9	5.7	6.7	Dw is in Gokul para near Hanuman Mandir.
9	Naukesa	21.5497	81.3058	64 G/6	274	10.3	3.2	0.3	8.2	4.8	6.8	Dw is infront of house of Sukhram Sahu in Sraddha suman chowk.
10	Sahaspur	21.5375	81.2928	64 G/6	274	12.8	1.4	0.4	3.4	1.4	2.6	Dw is located before board showing Shiv mandir & Hanuman
11	Bundeli	21.5450	81.2742	64 G/6	285	8.6	1.4	0	2.9	1.1	1.3	Dw is about 100m from Pr school infront of H/o Mohit Sahu.
12	Pendrawan	21.5531	81.2503	64 G/6	289	6.8	1.6	0	4.8	1.7	2.6	Dw in H/o Bharat Patel in Pendrawan Bhatapara.
13	Luk	21.5622	81.2694	64 G/6	274	14.6	2.3	0.6	8.1	1.8	3.2	Dw is in satnamipara near Jait Khamb & Shitla mandir.
14	Khursbod	21.5772	81.2753	64 G/6	274	9.8	1.6	0.6	8.4	4.7	6.8	Dw is infront of Ghasidas mandir near Jait Khamb
15	Gondmarra	21.5736	81.2525	64 G/6	286	9.3	1.8	0.3	7.1	1.9	2.7	Dw is near Shiv mandir 100m from middle schoolat the entry of village
16	Jamgaon	21.5725	81.2914	64 G/6	275	10.8	1.4	0.4	8.4	4.5	6.1	Dw is infront of Mahamaya mandir.
17	Akalwara	21.5856	81.3200	64 G/6	274	8.5	2.8	0.8	4.1	2.3	4.1	Dw is in front of Sai Dawakhana near Grampanchayat Bhawan & talab.
18	Hardua	21.6044	81.3281	64 G/6	274	9.8	2.9	0.4	5.9	3.5	6.9	Dw is within premises of Primary school.
19	Mohgaon	21.5994	81.2953	64 G/6	276	10.5	3.9	0.7	6.4	3.8	5.1	Dw is 100m away from main road near weekly market.
20	Basin	21.5958	81.2972	64 G/6	274	9.5	3.8	0	2.8	GL	1.8	Dw is in the field of Mohan thakur just at the entry of village.
21	Kohkabor	21.5983	81.2731	64 G/6	274	8.5	4.1	0.6	7.2	5.6	6.1	Dw is by the side of road leading to Tirriabhat infront of H/o nara singh
22	Tiriabhat	21.5986	81.2564	64 G/6	274	11.5	3.8	0.6	9.1	4.8	5.3	Dw is infront of Durga manch near middle school.
23	Atarjhola	21.6011	81.2819	64 G/6	274	9.8	2.4	0.5	7.4	4.8	5.7	Dw is by the side of samudayik Bhawan & Shiv mandir.
24	Khamharia	21.7992	81.3344	64 G/5	290	9.6	1.8	0.3	7.9	1.4	4.9	Dw is in front of Jamat mandir.
25	Umraonagar	21.8225	81.3500	64 G/5	300	7.9	2.5	0.4	3.9	1.4	2.1	Dw is in karma chowk in front of Govt middle school.
26	Gatapar	21.8286	81.3339	64 G/5	302	11.3	2.1	0	9.5	2.2	4.2	Dw is in H/o Ashok Rajput.
27	Kopedabri	21.8275	81.3256	64 G/5	300	12.6	2.3	0.5	3.3	1.5	2.2	Dw is in Mandalpara in front of H/o Gaukaran Singh.
28	Pendri	21.7594	81.3761	64 G/5	285	10.8	2.5	0.5	9.6	3	4.4	Dw is in H/o Bharat Singh Rajput in Lilapara chowk.
29	Kapa	21.7508	81.3869	64 G/5	280	13.4	2.6	0	7.8	N.A	3.5	Dw is in H/o Shyamlal sahu.
30	Bhainsamuda	21.6767	81.3872	64 G/6	280	10.3	6.5	0.3	9.4	8.8	8.8	Dw is near talab Bhainsamuda.
31	Jata	21.6683	81.3053	64 G/6	290	13.5	2.6	0.6	12.1	6	4.3	Dw is in satnamipara near Shitla mandir & talab.

32	Amlidih	21.6744	81.2919	64 G/6	287	13.4	4.5	0	6.1	2.1	3.1	Dw is in field of Dinesh Singh rajput in amlidih before entry of village.
33	Beltara	21.7264	81.2789	64 G/6	292	7.5	2.3	0.3	5.7	4.8	3.7	Dw is located in middle of village.
34	Belgaon	21.7281	81.2914	64 G/6	290	8.4	2.3	0	7.5	3.3	3.3	Dw is inh/o Ishwar in front of Grampanchayat Bhawan.
35	Sambalpur	21.7003	81.2550	64 G/6	299	12.3	4.3	0.7	4.8	1.1	2.2	Dw is in middle of village near big banyan tree.
36	Bharda	21.6878	81.2853	64 G/6	287	10.5	2.1	0.4	5.6	1.4	2.5	Dw is in front of Mahamaya mandir and Pooja mandap.
37	Bargada	21.6997	81.2844	64 G/6	290	9.8	2.2	0	6.4	2.3	3.3	Dw is in Verma para behind Shiv mandir.
38	Hadahuli	21.7642	81.3422	64 G/5	280	9.6	2.6	0.3	8.3	2.8	3.9	dw is in front of Gram panchayat Bhawan.
39	Bharampuri	21.7583	81.3458	64 G/5	280	10.35	1.6	0.4	8.9	4.4	4.4	Dw is in village side in front of H/o Ashok Das.
40	Bija	21.6700	81.4025	64 G/6	275	13.1	2.8	0.4	12.1	11.9	11.9	Dw is behind Hanuman temple & Govt Pr school.
41	Hadahuli	21.6917	81.4464	64 G/6	276	11.1	2.4	0.4	7.8	3.6	4.5	Dw is near talab 100m NE of talab.
42	Motisara	21.6872	81.4275	64 G/6	275	8.6	1.6	0.4	7.7	N.A	4	Dw is in H/o Jeevanlal Patel by the side of road leading to Rudra.
43	Hardas	21.7281	81.4433	64 G/6	273	10.6	1.6	0	7.9	N.A	3.8	Dw is behind govt PDS shop.
44	Chijgaon	21.7233	81.3594	64 G/6	275	12.3	2.5	0.5	10.4	6.2	7.8	Dw is in the H/o Jethu ram in Sitla Chowk.
45	Lalpur	21.7050	81.3611	64 G/6	275	10.4	1.9	0.4	8.5	1.1	3.7	Dw is near shiv mandir chowk.
46	Khamdih	21.6958	81.3622	64 G/6	268	9.8	2.3	0.4	5.6	1.2	2.1	dw is in middle of village near Banyan tree.
47	Kestara	21.6886	81.3617	64 G/6	270	9.3	3.5	0.6	7.8	5.2	3.7	Dw is in mehar para inn kestara.
48	Surajpura	21.6394	81.3603	64 G/6	275	12.1	2.1	0	7.9	4.3	5.9	Dw is in H/o Behari Thakur in Adivasi para.
49	Gadadih	21.5461	81.2372	64 G/2	290	8.7	5.6	0.3	7.6	4.3	6.5	Dw is near PDS shop Gadadih
50	Gatapar	21.5678	81.2158	64 G/2	290	8.8	3.6	0.5	6.7	3	5.2	Dw is by the sideof Primary school.
51	Gabradih	21.5517	81.2144	64 G/2	295	9.7	2.7	0.6	2.3	1.4	2.5	Dw is near talab.
52	Hathidob	21.5394	81.2194	64 G/2	290	9.2	3.2	0.5	3.4	1.1	3.5	Dw is in middle of village near trijunction about 50m away from mandir.
53	Sondongri	21.5169	81.2211	64 G/2	310	12.9	4.3	0.6	10.8	6.4	3.1	Dw is in Meharpara.
54	Kurlu	21.5725	81.1933	64 G/2	290	6.7	1.6	0	3.8	0.9	1.8	Dw is in H/o Lomash opp to karam pan center bybthe side of road.
55	Jano	21.5617	81.1964	64 G/2	290	9.7	2.5	0.5	3.7	1.3	3.4	Dw is behind Anganwadi centre.
56	Rano	21.5383	81.1903	64 G/2	300	9.5	1.4	0.3	4	1.4	3.9	Dw is in satnami mohalla near jait khamb & Radahaswami satsang kendra.
57	Chinchanmeta	21.5606	81.1669	64 G/2	300	7.3	1.3	0	5.6	0.9	2.4	Dw is in H/o Santosh singh.
58	Sohagpur	21.5569	81.1478	64 G/2	312	9.5	1.4	0.5	7.7	5.5	5.9	Dw is in front of Govt high school near Durga manch.
59	Patarjhori	21.6636	81.1558	64 G/2	310	9.8	2.6	0.3	7.5	4.2	6.3	Dw is in H/o Sukhiram Verma in Negipara.
60	Patharikhurd	21.5928	81.1808	64 G/2	295	12.8	2.5	0	10.7	6.5	6.8	Dw is in middle of village near Sahada Devta.
61	Parpodi	21.5889	81.2106	64 G/2	290	12.1	2.1	0.4	4.2	1.4	2.8	Dw is in Muslim mohala on LHS of Bhatgaon road.
62	Bhatgaon	21.6025	81.2194	64 G/2	290	11.3	2.2	0.3	5.5	2.9	4.6	Dw is near Jatri prtikshalaya and atal chowk.
63	Bodera	21.6114	81.2242	64 G/2	285	10.5	3.2	0.5	6.2	1.1	2.8	Dw is in gondpara near Banyan tree behind Pr school.
64	Kamkabeda	21.6089	81.2278	64 G/2	280	10.3	3.1	0.6	8.5	3.5	5.2	Dw is near shiv mandir on LHS road leading to Shivpuri near talab.
65	Kutru	21.6250	81.2344	64 G/2	280	10.8	3.2	0.5	8.5	6.5	7.8	Dw is in front of Rang manch Kutru.

66	Sonpuri	21.6217	81.2425	64 G/2	280	12.3	3.1	0.5	11.1	7.9	8.7	Dw in H/o Punni patel about 100m away from Pr school.
67	Sonpandar	21.6217	81.2464	64 G/2	275	10.5	2.6	0.4	8	5.4	6.8	Dw is behind Samudayik bhawan.
68	Suwartola	21.6653	81.2408	64 G/2	290	16.1	3.2	0.5	13.5	8.6	9.5	Dw is on LHS on Nawagaon road in front of PHC &Shikari dera.
69	Munglatola	21.6511	81.2456	64 G/2	290	9.6	3.2	0.5	3.4	1.3	2.5	Dw is in front of middle school on LHS of road.
70	Bortara	21.6439	81.2206	64 G/2	288	15.1	3.2	0.6	11.4	3.4	4.8	Dw is in front of Radha krishna mandir in bortara.
71	Lolesara	21.6533	81.2117	64 G/2	290	12.8	3.2	0.6	11.6	7.6	7.1	Dw is near mahamaya temple, shiv mandir & big banyan tree.
72	Dhap	21.6669	81.1950	64 G/2	298	13.5	2.6	0.6	11.6	6.8	8.5	Dw is in Gauntiapara behind Hanuman temple.
73	Kongiyakalan	21.6400	81.1856	64 G/2	295	11.5	1.9	0.4	6.1	4.3	5.1	Dw is near transformer between gandhi chowk & middle school on RHS.
74	Tumdipar	21.6306	81.2008	64 G/2	290	11.5	3.2	0.5	7.6	3.8	5.4	Dw is near Shiv temple.
75	Kehka	21.6939	81.1981	64 G/2	305	18.2	3.4	0.4	16.5	8.25	10.5	Dw is opp to primary school Kehka.
76	Piparia	21.6922	81.2267	64 G/2	300	14.8	2.8	0.8	4.6	2.1	3.4	Dw is near grampanchayat bhawan, Piparia.
77	Karamtara	21.7122	81.2367	64 G/2	300	7.5	2.8	0.4	3.2	2.2	2.8	Dw is near Primary school Karamtara.
78	Bemetara	21.70421	81.53089	G/10	295	13.00	3.65	0.90	8.52	N.A	2.59	Beldarpara, Adj to Durg-Bemetara-kawardha road trijunction
79	Kanteli	21.69637	81.51041	G/10	272	8.80	2.80	0.00	7.10	N.A	5.82	Adj to H/O Mahendra verma (shop)
80	Bhurki	21.71179	81.48505	G/6	271	9.30	2.80	0.60	6.90	4.08		Entrance of village, opp to pond,beside Primary school
81	Ninwa	21.68186	81.46407	G/6	262	11.60	2.70	0.45	9.25	4.62	3.58	Inside village, opp to pond near Sheetala temple
82	Dundra	21.68963	81.48531	G/6	260	13.30	2.45	0.25	12.35	6.92	5.71	Inside village (100m from Dhamdha main road), in front of Temple
83	Khilora	21.68336	81.52992	G/10	270	1.80	1.80	0.25	8.25	2.43	2.86	Inside village, Sheetalapara, behind Sheetala temple,
84	Jeori	21.6415	81.53922	G/10	265	14.10	2.90	0.50	12.38	1.98	2.04	Beside road to Amora, adj to Samudaik
85	Bijabhat	21.65885	81.55344	G/10	270	14.00	2.60	0.65	6.82	3.25	3.83	about 50m towards Bemetara from welcome gate,
86	Farri	21.66714	81.54254	G/10	268	15.00	2.30	0.50	13.50	1.90	2.02	Inside village,adj to Neem tree & Durga chowk
87	Talla	21.67371	81.59508	G/10	270	12.00	3.00	0.40	11.80	4.78	4.25	Near Jaitkham & satnam Bhawan, adj to Sankar, Durga Temple
88	Jeeya	21.67131	81.63065	G/10	262	14.00	1.75	0.00	10.48	2.12	2.20	End of village (Amliha Chowk), H/O Kejuram Verma
89	Pathra	21.64342	81.60999	G/10	260	12.20	2.00	0.30	3.84	3.36	4.18	H/O Pankaj Tiwari,inside village,opp to pond and Sheetala temples
90	Jeora	21.64066	81.62001	G/10	270	12.50	2.35	0.45	3.40	2.55	2.55	Beside NH, at the end of village,Satnam Bhawan
91	Arjuni	21.67807	81.66091	G/10	258	12.80	2.20	0.30	10.27	0.96	1.60	Beside road to Kusmi, near Mahamaya temple & adj to pond,
92	Mohranga	21.71439	81.69097	G/10	255	14.50	2.35	0.45	10.85	2.04	2.20	Inside village, near hanuman temple & overhead tank
93	Jogipur	21.70991	81.66863	G/10	258	9.50	2.10	0.00	8.95	6.23	5.25	Adj to road, inside village, in the compound of Bhakaru mandle
94	Balasamund	21.72195	81.64912	G/10	267	11.50	2.90	0.60	11.30	5.83	4.92	Gaudagudi, in front of H/O Chandu Sahu,
95	Ghatoli	21.73807	81.65945	G/10	265	10.00	1.65	0.40	9.67	4.85	5.08	Badeipara, ,H/O Rameswar Sahu, near Mahamaya Temple

96	Birampur	21.76926	81.66179	G/9	260	8.30	2.00	0.45	5.42	5.12	3.30	Sahupara, near Hanuman & Mahamaya Temple, Bitkuli end of village
97	Bitkuli	21.77453	81.66797	G/9	260	o	2.75	0.40	6.92	4.20	5.72	Adj to road to Channu, behind Rahul kirana shop & Krishi Kendra ,
98	Nawagaon	21.77639	81.65749	G/9	260	6.50	2.85	0.20	3.42	1.28	2.48	Adj to Shiv (Rukhar Baba) Temple, Dabripara
99	Usalpur	21.76191	81.68257	G/9	255	10.00	1.70	0.00	5.35	5.07	5.20	H/O Daya Githlahore, near Jaitkham
100	Tuma	21.765	81.70644	G/9	250	10.50	3.35	0.45	9.14	7.38	7.57	Adj to Vet. Dispensary near Hanuman Temple
101	Muthpuri	21.79718	81.72819	G/9	255	15.00	2.20	0.70	10.92	9.83	8.62	H/O Ramdas Madile, near Krishi Kendra located on main road
102	Raweli	21.80347	81.70187	G/9	260	9.60	2.50	0.40	9.42	5.86	6.66	Near Mahamaya Temple & big pond
103	Dhangaon	21.83349	81.57639	G/9	270	11.30	1.75	0.00	9.77	N.A	7.71	H/O Mohit Sharma, Sahupara, opp to Samsan ghat
104	Nari	21.79315	81.6111	G/9	265	15.00	2.35	0.50	11.12	8.08	5.35	Babapara, near Mahamaya Temple,
105	Bhansuli	21.76558	81.63415	G/9	265	5.30	2.10	0.30	3.8(15)	1.28	1.10	Adj to Sai Ram Temple
106	Piparbhata	21.70214	81.59492	G/10	268	14.00	2.00	0.50	12.46	N.A		End of village, roadside, adj to pond, near Shiv Temple
107	Kusmi	21.69807	81.62232	G/10	266	10.50	3.20	0.80	9.85	1.49	1.92	Opp to Middle School & Gram Panchayat Office,
108	Khurmuri	21.71228	81.61395	G/10	272	14.80	1.70	0.30	14.32	1.90	5.80	50m from Bemetara- Balsamund road, near jaitkham,
109	Bhaisa	21.74178	81.62307	G/10	273	15.00	2.65	0.70	12.83	8.30	6.82	Thakurdevpara, adj to pond, near Thakurdev Chabutara
110	Dhara	21.73926	81.59605	G/10	273	9.00	78.0	0.20	5.10	N.A	2.7	Agricultural well, adj to big pond, end of village near H/O Mohtaram sahu
111	Baba Mohtara	21.71532	81.58923	G/10	280	11.50	3.50	0.60	10.93	2.07	2.66	Adj to Bemetara- Balsamund road, behind mahamaya Temple
112	Bilai	21.75329	81.56133	G/9	280	13.50	1.75	1.40	12.70	10.92	11.23	H/O Ghasiram Sahu, near durga Chowk
113	Jhal	21.79487	81.55035	G/9	272	13.30	1.3 x1.3	0.25	12.80	7.74	6.05	H/O Mohan Singh Verma, palpara, near Mahamaya Temple
114	Jhalam	21.81987	81.58405	G/9	270	7.20	1.60	0.00	6.72	3.20	3.92	Inside village, in front of H/O Parameswar Pal,
115	Chamri	21.83225	81.54147	G/9	268	7.50	2.30	0.20	7.22	3.42	3.94	H/O Jaitaram sahu, adj to road, opp to Shiv Temple
116	Lolesara	21.75694	81.51228	G/9	285	11.00	1.60	0.00	4.12	2.50	3.22	H/O Jirakhan Sahu (Sarpanch), in the garden
117	Hemabandh	21.86666	81.53152	G/9	273	6.60	3.25	0.00	4.65	2.06	2.35	H/O rekhalalChaturvedi (Satnami), beside Dadhi- Bemetara metal road,
118	Mohtara	21.84723	81.53148	G/5	290	13.00	2.10	0.40	6.18	2.94	4.18	Beside Dadhi- Bemetara metal road, opp to Hanuman Temple
119	Bhainsbor Khurd	21.87243	81.50976	G/9	275	6.80	1.50	0.00	6.22	2.02	1.88	H/O Sitaram Sahu, opp to Primary School,
120	Semariya	21.84933	81.49435	G/5	290	11.80	2.40	0.00	4.33	1.28	2.38	H/O Ram Jarokh Sahu, beside road to Dadhi
121	Kathatiya	22.00291	81.48846	G/5	285	9.60	1.30	0.25	8.92	4.72	5.18	Inside village, at vill trijunction, 200m from bus stand towards Udtala,
122	Udtala	21.99077	81.48391	G/5	285	15.00	3.40	0.40	11.04	N.A	4.14	In front of Primary School, opp to Shiv Temple & Mahamaya Temple
123	Birsingi	21.96751	81.50376	G/9	282	12.00	1.95	0.80	10.90	5.82	6.24	Inside village, near Shiv Temple and in front of Mahamaya Temple

124	Nawagaon Kalan	21.98527	81.5007	G/9	290	6.20	1.35	0.00	3.74	0.76	0.82	On Nawagaon-Chhirra road, at the border of two villages,
125	Birampur	22.00028	81.52063	G/5	282	8.80	1.40	0.50	8.12	3.26	2.40	H/O Biswaha yadav, near Primary School
126	Sonpuri	22.00095	81.52744	G/9	290	7.60	1.15	0.50	7.07	2.46	3.22	H/O Bhop Singh Rajput, backside,beside Birampur- Sonpuri road,
127	Sarangpur	21.95166	81.52314	G/9	280	12.70	2.80	0.55	9.17	4.22	4.24	Charghat-Nawagarh road, 50m before trijunction to modhe
128	Sukhatal	21.94093	81.49744	G/5	284	6.50	2.10	0.40	2.32	N.A	0.85	Guru Ghasirdas Mandir Chowk, adj to two ponds,
129	Karamtara	21.91813	81.47597	G/5	280	15.00	2.40	0.00	11.06	7.78	9.02	Satnami mahalla, 100m from ghoreghat-Lalpur road, owner - Babulal
130	Lalpur	21.92722	81.46702	G/5	280	9.50	1.80	0.00	5.92	2.56	2.87	Adj to Lalpur-Modhe road, inside village, H/O Chandi patel, near
131	Kapa	21.85164	81.47165	G/5	285	8.00	1.50	0.30	5.84	(0.7)	W.C	Govt well, inside village, at road junction. Partly covered with cement slab
132	Janta	21.87798	81.43751	G/5	290	7.65	2.90	0.25	5.68	1.22	3.41	H/O Suren Chandrakar, in the garden, 300m from primary School,
133	Pendri	21.89142	81.44262	G/5	291	8.50	4.00	0.50	7.72	2.54	4.87	Inside village, near Primary School, adj to H/O Badri Master
134	Kodwa	21.89988	81.44437	G/5	285	6.00	2.50	0.20	3.02	1.62	2.31	H/O Amrika/Nandkumar Chandrakar, , 50m from Shiv Temple
135	Gidwa	21.89983	81.45984	G/5	282	9.20	3.55	0.80	3.33	2.46	2.73	Adj to Bajrangbali Temple (approach from shiv Temple)
136	Dadhi NHS	21.89392	81.4728	G/5	280	9.10	1.60	0.00	6.12	N.A	2.83	At road trijunction (Umariya-Chhirra-dadhi), near welcome gate,
137	Damaidih	21.90715	81.49227	G/5	275		2.60	0.65	11.62	8.27	9.08	Opp to Durga Manch, inside village, at road junction to Ghoreghat
138	Newaspur	21.88569	81.52168	G/9	272	13.20	1.70	0.25	12.42	N.A	7.35	H/O Narayan (Satnami), near end of village,200m before Primary School
139	Naurangpur	21.89121	81.52086	G/9	270	11.00	2.60	0.50	6.73	1.92	2.95	H/O Kansilal Ratre, 50m from Pipal Chowk, inside village
140	Arbandha	21.91916	81.52007	G/9	274	6.60	1.80	0.30	3.14	N.A	W.C	H/O Devi Singh, backside, roadside, opp to Mahamaya Temple & pond,
141	Baiji	21.76238	81.51499	G/9	286	11.70	1.30	0.00	10.06	1.18	1.73	H/O phagua/ Narendra Verma & Pratap Verma, beside Kawardha road,
142	Bahera	21.76282	81.48264	G/5	282	8.85	1.80	0.00	6.22	N.A	4.62	Adj to village road, H/O Shiv Kumar (Ballu) Verma,
143	Betar	21.85403	81.43816	G/5	288	10.00	1.70	0.20	2.42	1.08	2.03	H/O Baldao sahoo,backside, inside village, near Shiv Temple & pond,
144	Umariya	21.85646	81.44711	G/5	290	11.00	2.20	0.40	3.26	1.20	2.67	H/O Kanhaiyalal Sahu, Brahmanpara, adj to Umariya-Dadhi Road,
145	Chilphi	21.87573	81.46651	G/5	280	11.30	2.95	0.45	6.52	2.97	3.41	Govt well, beside Umariya-Dadhi Road, 100m from Primary School,
146	Bansapar	21.84081	81.49956	G/9	285	11.60	2.90	0.60	9.84	1.18	2.05	Govt well, Ghanadih end of village, adj to small Shiv Temple,
147	Ghanadih	21.83262	81.51826	G/9	275	8.40	2.15	0.60	5.92	1.31	2.05	Bansapur end of village, adj to Bansapar-Ghanadih road,
148	Amora	21.64901	81.55359	G/1	265	10.20	2.60	0.50	8.55	1.62	2.02	Beside Berla Road, 50m from Hanuman Temple

*N.A- Not Approachable **W.C- Well Collapsed

2.2 Hydrochemical Data

To know the hydro chemical behaviour of the ground water in the study area, 202 nos. of ground water samples were collected from the key wells and (NHNS) during pre-monsoon period of measurement (June, 2014). Also water samples were collected from borewells during exploration carried out in the area and analysed in the chemical laboratory of Central Ground Water Board, NCCR, Raipur for determination of various chemical parameters. The results and findings are presented in Table no. 10

Table 10: Result of chemical analysis of ground water exploration year 2014-15

S.No.	Location	Distt	Source	pH	EC in µS	Concentration in mg/L									
						F^-	Cl^-	SO_4^{2-}	CO_3^-	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
L3-1	Amora	Bemetara	EW	7.9	532	0.6	21	76	nil	189	215	40	28	21	1.2
L3-2	Dhara	Bemetara	EW	8	828	0.7	14	262	nil	165	330	40	55	56	1.7
L7-1	Khurusbod	Bemetara	EW 2nd Aquifer	7.7	1364	0.9	25	721	nil	128	820	264	38	48	2
L7-2	Dadhi	Bemetara	EW 1st Aquifer	7.8	1048	0.7	57	271	nil	214	355	64	47	85	14
L7-3	Dadhi	Bemetara	EW 2nd Aquifer	7.9	990	0.8	46	262	nil	177	330	68	38	87	8.7
L7-4	Dadhi	Bemetara	OW 2nd Aquifer	7.8	1017	0.8	46	301	nil	195	345	76	37	86	8.3
L11-1	Birsinghi	Bemetara	EW	8	1241	0.7	21	598	nil	165	610	114	78	73	2.2
L11-2	Birsinghi	Bemetara	OW	7.8	1385	0.8	21	660	nil	238	680	96	106	79	2.3
L13-1	Tipni	Bemetara	EW	7.8	599	0.7	18	95	nil	226	225	44	28	34	1.1
L13-2	Tipni	Bemetara	OW	7.9	598	0.7	25	84	nil	220	220	44	26	33	1.3
L13-3	Jhal	Bemetara	EW	7.8	609	0.9	11	154	nil	159	245	70	17	18	1.4
L14-1	Muswadih	Bemetara	EW	7.9	590	0.5	60	21	nil	244	265	44	37	10	1.1
L15-1	Jhal	Bemetara	OW	7.7	607	1.0	14	143	nil	177	255	72	18	16	1.2
L15-2	Sahaspur	Bemetara	EW	7.9	619	0.8	25	98	nil	207	225	54	22	29	1.6
L15-3	Sahaspur	Bemetara	OW	7.8	1042	0.9	71	239	nil	214	305	68	32	98	3
L16-1	Barja	Bemetara	EW	8	488	0.6	7	31	nil	220	220	44	26	9	0.8
L16-2	Barja	Bemetara	OW	8.2	555	0.6	36	44	nil	244	255	48	32	12	0.9
L16-3	Amora	Bemetara	EW	8	581	0.5	25	58	nil	244	255	56	28	15	0.9
L16-4	Amora	Bemetara	EW	8	547	0.6	21	56	nil	220	225	44	28	15	0.9
L16-5	Amora	Bemetara	EW	8.2	613	0.6	25	64	nil	250	275	52	35	17	1
L16-6	Amora	Bemetara	EW	7.7	1763	1.2	21	1029	nil	183	1155	368	56	94	2.3

L16-7	Amora	Bemetara	EW	7.6	1958	1.3	43	1163	nil	250	1345	430	65	66	57.5
L17-1	Tipni	Bemetara	EW	7.7	700	0.8	25	109	nil	238	255	58	26	29	1.1
L17-2	Tipni	Bemetara	EW	7.8	603	0.7	21	138	nil	214	250	42	35	39	1.3
L17-3	Tipni	Bemetara	EW	8.2	549	0.7	28	106	nil	159	200	38	25	30	1.2
L17-4	Tipni	Bemetara	EW	7.7	733	0.7	18	111	nil	268	270	50	35	31	1.2
L17-5	Beltara	Bemetara	EW	7.8	509	0.5	14	21	nil	262	185	22	31	28	1.5
L17-6	Beltara	Bemetara	OW	8	495	0.6	11	12	nil	256	165	24	25	28	1.2
L17-7	Piparia	Bemetara	EW	7.8	905	0.9	107	66	nil	317	310	36	53	52	17.8

2.3 Geophysical Data

Geophysical surveys (Vertical Electrical Sounding or VES) have been conducted in the study area in Bemetara and Saja blocks to delineate the disposition of the existing aquifer system and 45 nos. of soundings were carried out.

Table no. 11

S.No.	Location	**Block**	**District**	Longitude(X)	Latitude(Y)	Resistivity in (ohm-m)					Layer Thickness in (m)				**Fracture Zones Identified from Factor Calculation method in (mbgl)**
						ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	**h_1**	**h2**	**h3**	**h4**	
1	Khati	Saja	Bemetara	81.41315	21.7841	27.4	3.07	21	170	----	1.00	1.06	31.9	----	**30-40,50-60,70-80,150-200**
2	Tharakpur	Saja	Bemetara	81.38713	21.76115	11.6	39.8	8110	-----	-----	4.06	39.8	------	-----	**30-50**
3	Khamariya	Saja	Bemetara	81.32396	21.79053	17.5	1.38	12.7	342	-----	0.98	1.67	29.5	-----	**6-10,30-40,100-120**
4	Tipni	Saja	Bemetara	81.368716	21.813516	12.46	5.74	31.58	258.3	-----	1.48	4.11	43.21	-----	**12-15,90-120**
5	Agrikalan	Saja	Bemetara	81.40105	21.86953	21	6.57	19.5	608	------	1.20	1.25	41.3	-----	**40-50,60-80,90-120**

6	Sukhatal	Saja	Bemetara	81.43046	21.82603	9.61	2.62	39.2	359	----	1.81	1.84	55.7	-----	**100-150**
7	Chikhli	Saja	Bemetara	81.39523	21.8196	10.8	60.4	8.64	51.5	2730	1.20	1.31	8.76	90.5	**20-25,30-60,70-80,90-120**
8	Nawagaon	Saja	Bemetara	81.39295	21.78936	12.5	47.7	657	-----	-----	5.65	39.2	-----	------	**100-120**
9	Karesara	Saja	Bemetara	81.45665	21.78115	26.3	5.0	12.7	276	-----	0.81	2.24	22.9	----	**40-50,80-90,120-150**
10	Sahaspur	Saja	Bemetara	81.29826	21.5399	22	11.5	2858	-----	-----	6.93	9.46	-----	------	**20-30,50-80**
11	Rajpur	Saja	Bemetara	81.263516	21.528683	95.19	426.7	2109	1235	-----	1.098	14.06	23.07	------	**30-40,120-150**
12	Pendrawan	Saja	Bemetara	81.2523	21.546783	293	125	29.7	1107	9.70	1.48	2.45	18.1	42.9	**15-30,50-70,80-90**
13	Khurusbor	Saja	Bemetara	81.25776	21.5875	9.86	29.2	421	-----	-----	2.04	29.7	-----	------	**30-50,100-150**
14	Keotara	Saja	Bemetara	81.28476	21.66475	62.23	38.81	81.39	253.1	1218	0.92	2.33	12.52	103	**50-60,100-150**
15	Parasbor	Saja	Bemetara	81.342883	21.63426	6.07	218	-----	-----	-----	3.57	----	-----	-----	**100-150**
16	Saja	Saja	Bemetara	81.29875	21.0671483	100	57.4	182.0	18.1	144	1.20	1.31	2.73	5.71	**90-150**
17	Sambalpur	Saja	Bemetara	81.251383	21.70735	21.2	360	30.4	622.0	-----	4.67	5.04	11.6	-----	**60-90,100-200**
18	Beltara	Saja	Bemetara	81.30076	21.72756	18.7	50.1	9.24	76.5	674	2.24	1.64	4.94	55.7	**30-40,70-80,100-120**
19	Karachua	Bemetara	Bemetara	81.498816	21.797816	15.5	32.9	53.5	340.0	----	2.32	6.14	65.2	---	**120-150**
20	Khandsara	Bemetara	Bemetara	81.51846	21.817383	12.8	5.21	55.9	159.0	-----	1.20	1.31	24.7	-----	**100-120,150-200**
21	Bera	Bemetara	Bemetara	81.46106	21.84153	18.95	9.118	60.7	317.9	----	1.60	1.28	39.43	-----	**50-60,100-200**

22	Majhgaon	Bemetara	Bemetara	81.48246	21.969483	56.44	8.45	1.91	42.81	2005	0.48	5.4	3.54	59.46	**25-30,40-60,100-120**
23	Amchodih	Bemetara	Bemetara	81.455483	21.95516	132.8	16.56	3.76	24.09	432.7	0.50	2.43	4.39	34.86	**15-20,25-30,60-70,100-120**
24	Janta	Bemetara	Bemetara	81.42793	21.875116	16.0	7.16	154.0	20.40	419.0	1.36	1.27	8.05	12	**100-120**
25	Pendritarai	Bemetara	Bemetara	81.6047	21.78295	28.83	16.17	38.81	224.5	-----	5.34	5.91	38.76	-----	**30-40**
26	Singhanpuri	Bemetara	Bemetara	81.628883	21.82555	4.11	27.0	148.0	-----	-----	2.83	40.8	-----	-----	**80-90**
27	Dhangaon	Bemetara	Bemetara	81.57643	21.82705	8.96	50.5	266.0	-----	------	3.99	45.7	-----	------	**25-30,120-200**
28	Dholia	Bemetara	Bemetara	81.545483	21.766916	48.38	21.56	45.85	252.8	-----	1.16	7.87	56.5	------	**10-15,40-50,120-150**
29	Arjuni	Bemetara	Bemetara	81.663116	21.68483	7.21	29.1	171.0	4289	-----	0.58	7.08	85.3	------	**60-70,100-200**
30	Muhrenga	Bemetara	Bemetara	81.69	21.70996	6.37	3.65	1034	-----	----	1.90	1.09	----	-----	**100-150**
31	Bala mohtara	Bemetara	Bemetara	81.579116	21.718383	33.0	50.3	7.69	32.6	9098	1.64	2.41	4.51	70.8	**40-50,60-70,80-90,120-150**
32	Bal Samund	Bemetara	Bemetara	81.648716	21.728483	5.17	46.25	255.9	----	----	6.67	63.77	----	----	**Nil**
33	Dholiya	Bemetara	Bemetara	81.5408	21.578	17.0	8.5	170	——	----	1.70	2.32	-----	------	**Nil**
34	Gunarbod	Bemetara	Bemetara	81.5632	21.6834	22.0	14	41.5	770.0	-----	4.40	6.00	11.0	-----	**40-50,100-200**
35	Pandarbhatta	Bemetara	Bemetara	81.5619	21.7786	7.00	250	----	-----	-----	3.25	------	------	------	**100-120**
36	Baiji	Bemetara	Bemetara	81.514	21.7626	26.0	4.25	27	185.0	------	1.50	1.52	33.5	-----	**50-60,70-80,120-140**
37	Mohbhatta	Bemetara	Bemetara	81.55	21.7161	110.0	84	620	-----	------	2.50	8.70	------	------	**Nil**

38	Bhonabhatta	Bemetara	Bemetara	81.5724	21.7161	13.0	5.75	70.0	170.0	----	1.41	1.80	26.0	----	**100-120,150-160**
39	Jhal	Bemetara	Bemetara	81.5523	21.7906	36.0	52.0	802	-----	-----	2.5	16.5	-----	**-----**	**30-40,60-70,90-110**
40	Saigona	Bemetara	Bemetara	81.4687	21.8012	22.0	13.0	1024	------	------	2.8	4.8	------	------	**10-15,30-40**
41	Jeora	Bemetara	Bemetara	81.3919	21.7898	22.0	8.0	36.0	400.0	------	1.4	5.0	22.0	-----	**40-50,80-100**
42	Guwara	Bemetara	Bemetara	81.3482	21.7746	56.0	180.0	16.0	62.0	1200	1.2	3.0	13.50	23.5	**30-40,60-70**
43	Jhalam	Bemetara	Bemetara	81.5751	21.8236	13.0	7.5	55.0	270.0	-----	1.85	4.1	50.5	-----	**100-110**
44	Khondsara II	Bemetara	Bemetara	81.5268	21.8256	30.0	15.0	82.0	350.0	-----	2.10	3.9	25.0	-----	**Nil**
45	Kosa	Bemetara	Bemetara	81.644	21.8211	110.0	78.0	700.0	-----	------	3.20	10.0	-----	------	**Nil**

2.4 Exploratory Data

2.4.1 Status of Groundwater Exploration

A total of 35 bore wells exist in the study area as on 31-03-2015 out of which 20 nos. are exploratory bore wells and 12 nos are observation bore wells in the study area. Table 12 (A, B) summarizes the status of exploratory wells in the study area.

Table 12(A) Detail of Exploration in the study area (old)

Sl No	Location	Block	Lat	Long	Type of well	Drilling Depth (m)	Casing Length (m)	Formation	Zones encountered	Water Level	Draw down (m)	Discharge (lps)	Transmissivity (m^2/day)	Storativity
1	Andhiyarkhor	Bemetara	21.83	81.6	EW	269.49	9.7	Maniyari Fn	25-84	11.41	8.18	18	1125.65	
2	Bemetara	Bemetara	21.72	81.53	EW	124.8	15.8	Maniyari Fn & Hirri Dolomite	22-37, 96-97	18.07	3.93	18	533.94	0.00003
3	Birampur	Bemetara	21.775	81.661	EW	259.02	9	Maniyari Fn	19-23, 31-33, 72-74	2.73	35.47	16	422.2	
4	Chorbhati	Bemetara	21.669	81.588	EW	148.57	7.4	Hirri Dolomite	56-68, 76-87, 128-131	13.06	19.8	3.5	2215	
5	Khati	Saja	21.776	81.425	EW	205.75	11.5	Maniyari Fn	12-31, 42-46, 49-53, 64-68,133-137	6.25	4.09	16.5	111.45	
6	Saja	Saja	21.66	81.317	EW	122.75	11.6	Hirri Dolomite	32-36, 65-70	14.11	17.99	4.55	119.88	

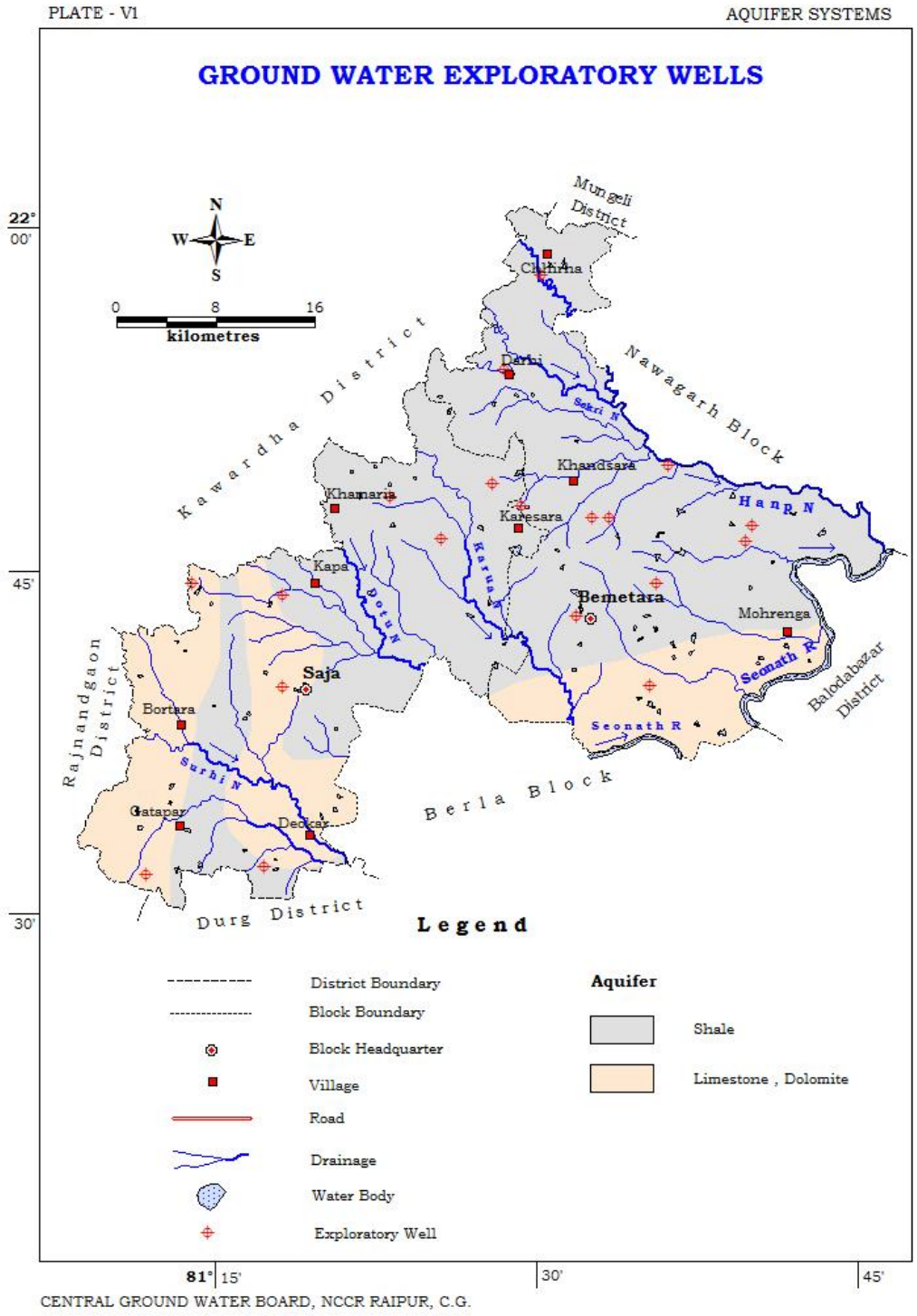
Table 12(B) Exploration in the study area (2014-15)

Sl. No.	Location	Block	Lat	Long	Topo sheet No.	Type of Well	Drlling Depth (m)	Casing length (m)	Formation	Zone encountered (mbgl)	Water level (mbgl)	Drill time discharge (lps)	Draw down (m)	Discharge during Test (lps)	Transmissivity (m2/day)	Storativity
1	Dhara	Bemetara	21°44'37.01"N	81°35'21.29"E	64G/10	EW	112.6	12	Maniari Shale	18.00-21.10, 54.60-57.70	11.11	12.02	2.46	21	188.29	$52.4*10^{-4}$
2	Dhara	Bemetara	21°44'37.01"N	81°35'21.29"E	64G/10	OW	112.6	6	Maniari Shale	18.00-21.10, 51.60-54.60	10.99	17.68	2.32	18.97		
3	Khurusbod	Saja	21°48'53.31"N	81°27'48.60"E	64G/5	EW	204.1	8.5	Maniari Shale	24.10-27.20, 48.50-51.60	21.43	4.364	1.93	18.409	237.52	$4.8*10^{-6}$
4	Khurusbod	Saja	21°48'53.31"N	81°27'48.60"E	64G/5	OW	204.1	12	Maniari Shale	21.10-24.10, 36.30-39.40	20.67	4.364	-	-	-	
5	Dadhi	Bemetara	21°53'57.39"N	81°28'23.47"E	64G/5	EW	204	32.8	Maniari Shale	27.20-30.20,57.70-60.70	10.5	4.364	1.13	4.364	219.48	$1.9* 10^{-8}$
6	Dadhi	Bemetara	21°53'57.39"N	81°28'23.47"E	64G/5	OW	204	30.5	Maniari Shale	27.20-31.20,57.70-60.70	8.41	-	0.41	2.498		
7	Birsinghi	Bemetara	21°58'2.09"N	81°30'6.85"E	64G/9	EW	69.9	20.5	Maniari Shale	18.00-21.10, 36.30-39.40, 45.50-48.50, 51.60-54.60, 66.80-69.90	2.47	16.51	1.47	18	$8.08*10^{-5}$	
8	Birsinghi	Bemetara	21°58'2.09"N	81°30'6.85"E	64G/9	OW	69.9	23.5	Maniari Shale	24.10-27.10, 36.30-39.30, 45.50-48.50, 57.70-60.70, 66.80-69.80	2.19	16.51	1.52	16		

9	Jhal	Bemetara	21°47'29.6"N	81°33'16.0"E	64G/9	EW	204	-	Maniari Shale	11.90-15.00,63.80-66.80, 100.40-103.40	1.69	6.189	-	-	366	$3.80*10^{-6}$
10	Jhal	Bemetara	21°47'29.6"N	81°33'16.0"E	64G/9	OW	204	6.1	Maniari Shale	11.90-15.00,60.70-63.80, 88.20-91.20, 127.80-130.90	1.73	7.8	1.34	15.261		
11	Sahaspur	Bemetara	21°32'10.40"N	81°17'15.29"E	64G/9	EW	204.1	18.5	Maniari Shale	30.20-33.30, 51.60-54.60,76.00-79.00	12.23	3.353	4.25	2.498		
12	Sahaspur	Bemetara	21°32'10.40"N	81°17'15.29"E	64G/9	OW	204.1	18	Maniari Shale	51.60-54.60, 79.00-82.10	18.38	2.126	4.46	2.126		
13	Ninawa	Bemetara	21°40'45.7"N	81°27'33.6"E	64G/	EW	106.5	18.5	Maniari Shale	79.00 - 82.10	13.37	1.217	1.13	2.54	71.602	$2.58*10^{-10}$
14	Ninawa	Bemetara	21°40'45.7"N	81°27'33.6"E	64G/	OW	106.5	18.5	Maniari Shale	72.90 - 76.00 94.30 - 97.30	13.67	2.126	5.3	0.771	96.3	
15	Amora	Bematara	21°38’55”	81°33’42”	64G/10	E/W	92.2	12	Maniari Shale	34-37,70-76,83-86	7.07	16.4	2.08	6.66	113.19	$7.3*10^{-4}$
16	Amora	Bematara	21°38’55”	81°33’42”	64G/10	O/W	92.2	12	Maniari Shale	74-77,80-83,86-89	6.87	16	0.89			
17	Tipni	Saja	21°48’28”	81°21’07”	64G/5	E/W	202	24	Maniari Shale	40-43.	18.5	6	3.01	6	114.91	$6.9*10^{-4}$
18	Tipni	Saja	21°48’28”	81°21’07”	64G/5	E/W	202	24	Maniari Shale	40-43	18.25	6	1.15			
19	Muswadih	Saja	21°35’30”	81°18’00”	64G/6	E/W	202	17	Maniari Shale	25-28	2.8	1.2	32.5	1.2		
20	Barga	Saja	21°43’30”	81°26’20”	64G/6	E/W	52.5	22.5	Maniari	34-37,46-49	9.1	18.97	7.18		584.6	$21.6*10^{-4}$

									Shale							
21	Barga	Saja	21°43’30”	81°26’20”	64G/6	O/W	55.6	22.5	Maniari Shale	34-37,46.5-49.5	8.76	18	7			
22	Beltara	Saja	21°44’30”	81°16’00”	64G/6	E/W	73.9	19.5	Maniari Shale	22-25,34-37	8.63	18.97	11.15		1906.80	$4.01*10^{-3}$
23	Beltara	Saja	21°44’30”	81°16’00”	64G/6	O/W	73.9	19.5	Maniari Shale	22-25,34-37	9.3	18.97	11			
24	Piparia	Saja	21°42’15”	81°13’32”	64G/2	E/W	134	10.3	Maniari Shale	64.7-67.8,86-89,128-131	24.45	3	12.38			
25	Piparia	Saja	21°42’15”	81°13’32”	64G/2	O/W	147	10.3	Maniari Shale	64.7-67.8,86-89,128-131	24.4	3				
26	Rano	Saja	21°31’50”	81°11’45”	64G/2	E/W	202	19	Maniari Shale	119-122	4.38	1	35.87			
27	Nawagaon	Saja	21°39’50"	81°15′00″	64G/2	E/W	80	6.5	Maniari Shale	73.90-80	18	10.75				
28	Nawagaon	Saja	21°39’50"	81°15′00″	64G/2	o/w	202	6	Maniari Shale	80-83,183.7-186.7	23.1	0.8	17.3			
29	Mohabhata	Saja	22°36’29"	81°17′58″	64G/6	E/W	128	9	Maniari Shale	125-128	9.7	15				

Fig.9 Location Map of the Exploratory Wells in the Study Area



3. Data Interpretation, Integration and Aquifer Mapping

3.1 Hydrogeological Data

Based on the depth to water level periodical monitoring data of the key wells established in the study area, pre-monsoon and post-monsoon depth to water level maps as well as seasonal fluctuation and water table contour maps have been prepared.

Pre-monsoon period

In the pre-monsoon period, it has been observed that in Bemetara block, the minimum water level is 2.32 mbgl in Shale formation while the maximum is 14.32 mbgl. In Dolomite formation the minimum water level is 3.4 mbgl while the maximum is 13.50 mbgl. Limestone is not encountered in this block.

In Saja block, the minimum water level is 2.90 mbgl in Shale formation while the maximum is 12.10 mbgl. In Dolomite formation the minimum water level is 2.80 mbgl while the maximum is 12.70 mbgl. In Limestone formation, the minimum water level is 3.20 mbgl in Shale formation while the maximum is 16.50 mbgl.
The detail of aquifer wise Pre-monsoon Water Level is presented in table 13 and in fig 9.

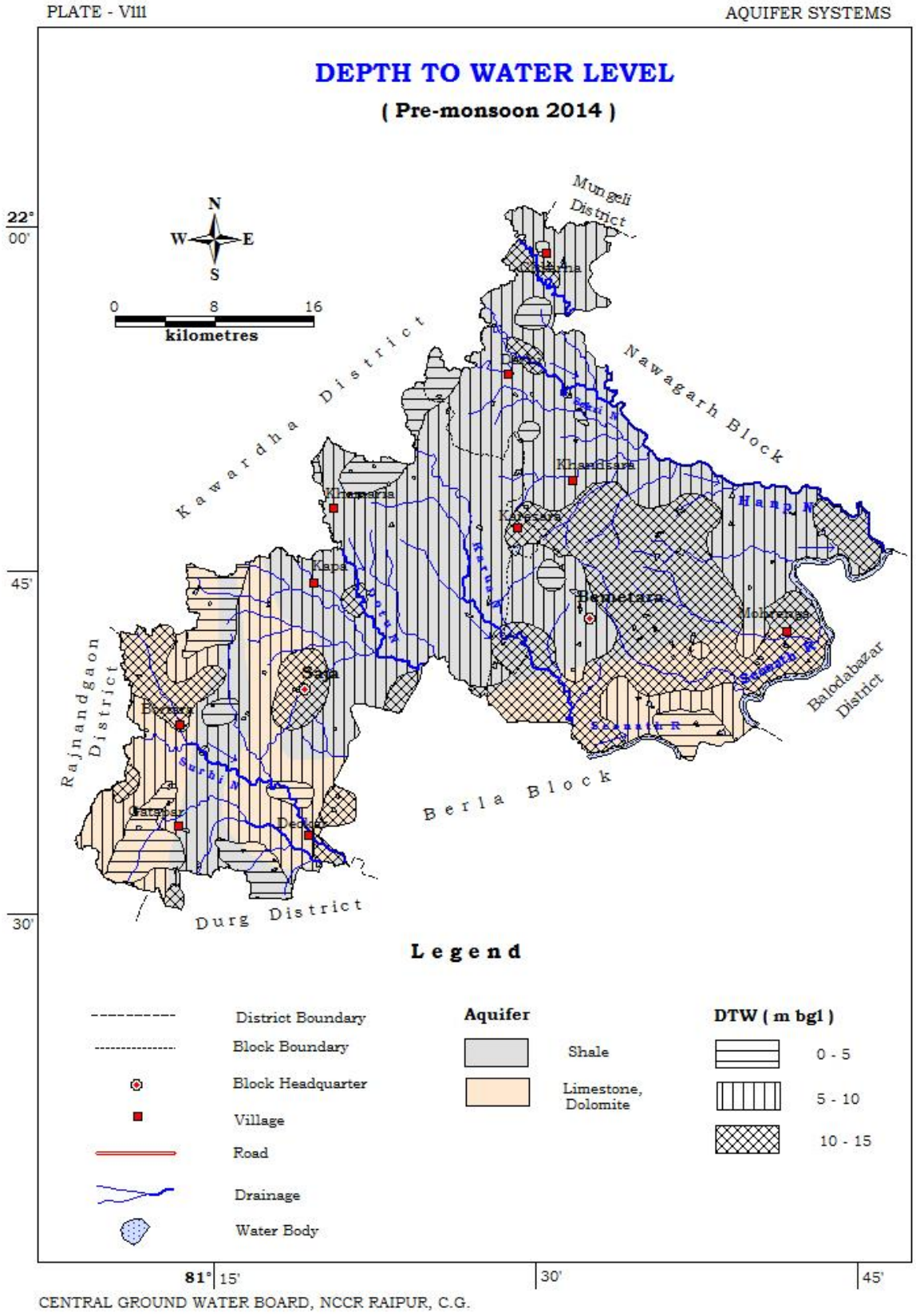
Table 13: Aquifer wise Depth to Water Level (Pre-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Bemetara	2.32	14.32	3.40	13.50	-	-
Saja	2.90	12.10	2.80	12.70	3.20	16.50

Water Level (in mbgl)

• The premonsoon water level in 10 % of wells are within 0-5 mbgl and in 70 % wells within 5-10 mbgl, in 20% wells 10-15 mbgl, in 4 % well more than 15 mbgl
• Min water level- 2.3 mbgl (Gabradih)
• Max water level- 16.50 mbgl (Kehka)

Fig.10 Pre- monsoon Depth to water level Map



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Post-monsoon period

In the post-monsoon period, it has been observed that in Bemetara block, the minimum water level is 0.82 mbgl in Shale formation while the maximum is 9.02 mbgl. In Dolomite formation the minimum water level is 1.60 mbgl while the maximum is 5.25 mbgl.

In Saja block, the minimum water level is 1.30 mbgl in Shale formation while the maximum is 11.90 mbgl. In Dolomite formation the minimum water level is 1.80 mbgl while the maximum is 9.50 mbgl. In Limestone formation, the minimum water level is 1.80 mbgl while the maximum is 10.50 mbgl.
The detail of aquifer wise Post-monsoon Water Level is presented in table 14 and in fig 10.

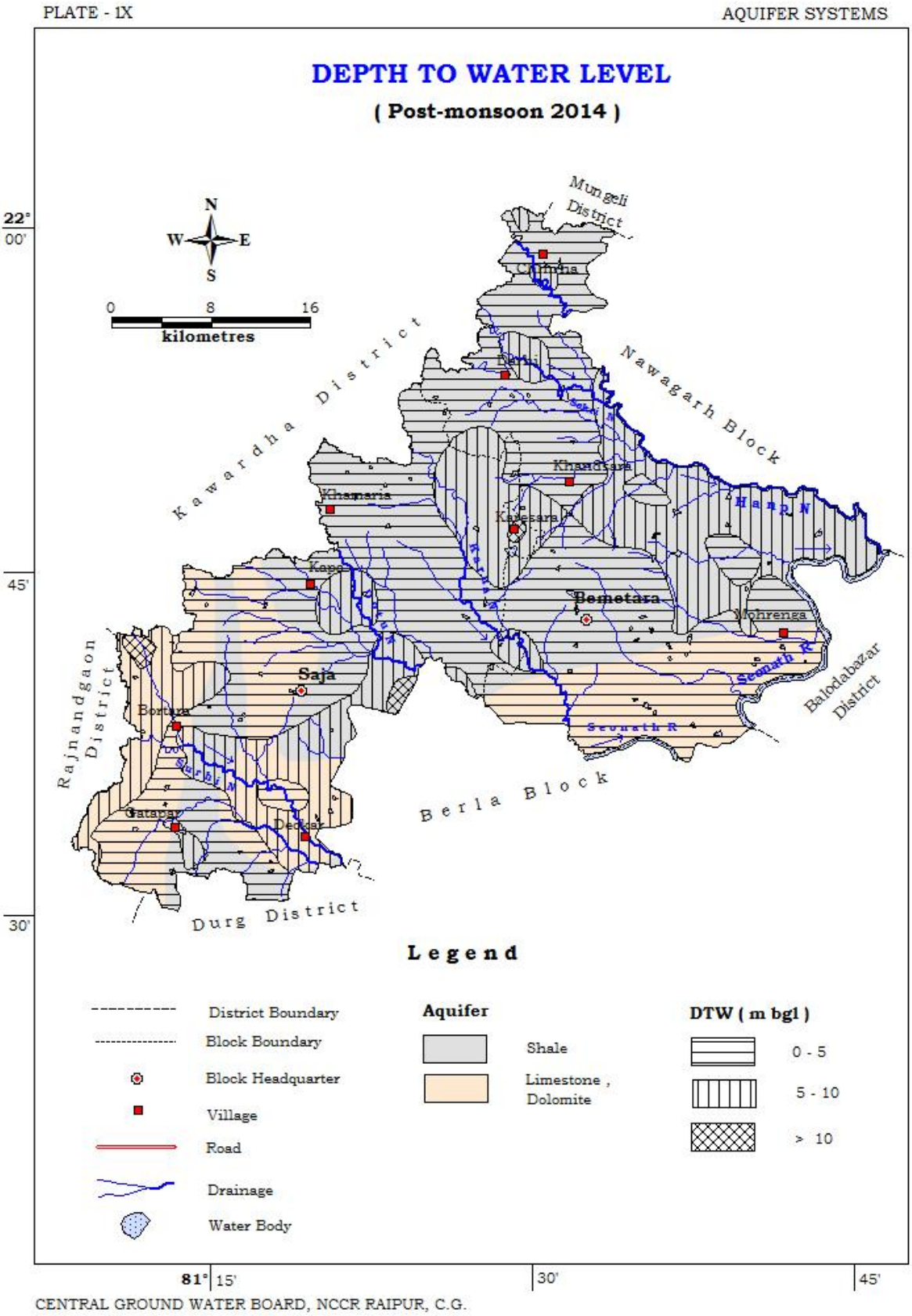
Table 14: Aquifer wise Depth to Water Level (Post-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Bemetara	0.82	9.02	1.60	5.25	-	-
Saja	1.30	11.90	1.80	9.50	1.80	10.50

Water Level (in mbgl)

• The postmonsoon water level in 70 % of wells are within 0-5 mbgl and in 25 % wells within 5-10 mbgl in 5% wells more than 10 mbgl
• Min water level- 0.82mbgl (Nawagaon Kalan)
• Max water level- 11.90 mbgl (Bija)

Fig.11: Post- monsoon Depth to water level Map



Seasonal water level fluctuation

It has been observed that in Bemetara block, the minimum water level fluctuation is 0.15 mbgl in Shale formation while the maximum is 9.02 mbgl. In Dolomite formation the minimum water level is 1.60 mbgl while the maximum is 5.25 mbgl.

In Saja block, the minimum water level is 1.30 mbgl in Shale formation while the maximum is 11.90 mbgl. In Dolomite formation the minimum water level is 1.80 mbgl while the maximum is 9.50 mbgl. In Limestone formation, the minimum water level is 1.80 mbgl while the maximum is 10.50 mbgl.
The detail of aquifer wise water level fluctuation is presented in table 15 and in fig 11.

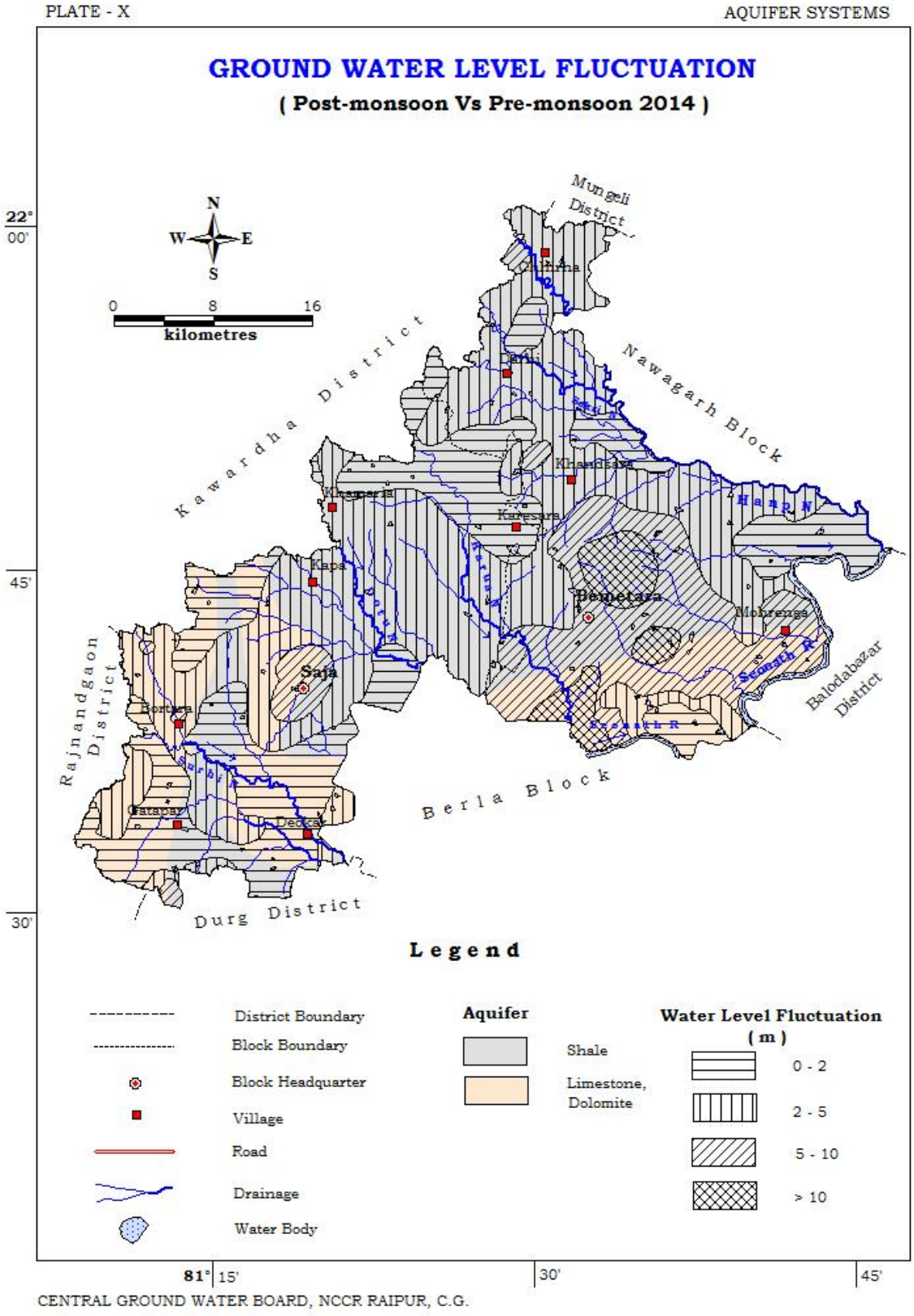
Table 15: Aquifer wise Depth to Water Level Fluctuation (Pre-monsoon vs Post-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Bemetara	0.15	12.7	0.85	11.48	-	-
Saja	0.2	7.7	0.2	7.8	0.1	6.6

Water Level (in mbgl)

• The seasonal water level fluctuation in 30 % of wells are within 0-2 m and in 40 % well within 2- 5m, in 25% wells 5-10 m, 5% wells more than 10 mbgl
• Min water level- 0.5m (Garra)
• Max water level- 11.48m (Farri)

Fig.12: Seasonal Fluctuation of Depth to Water Level Map



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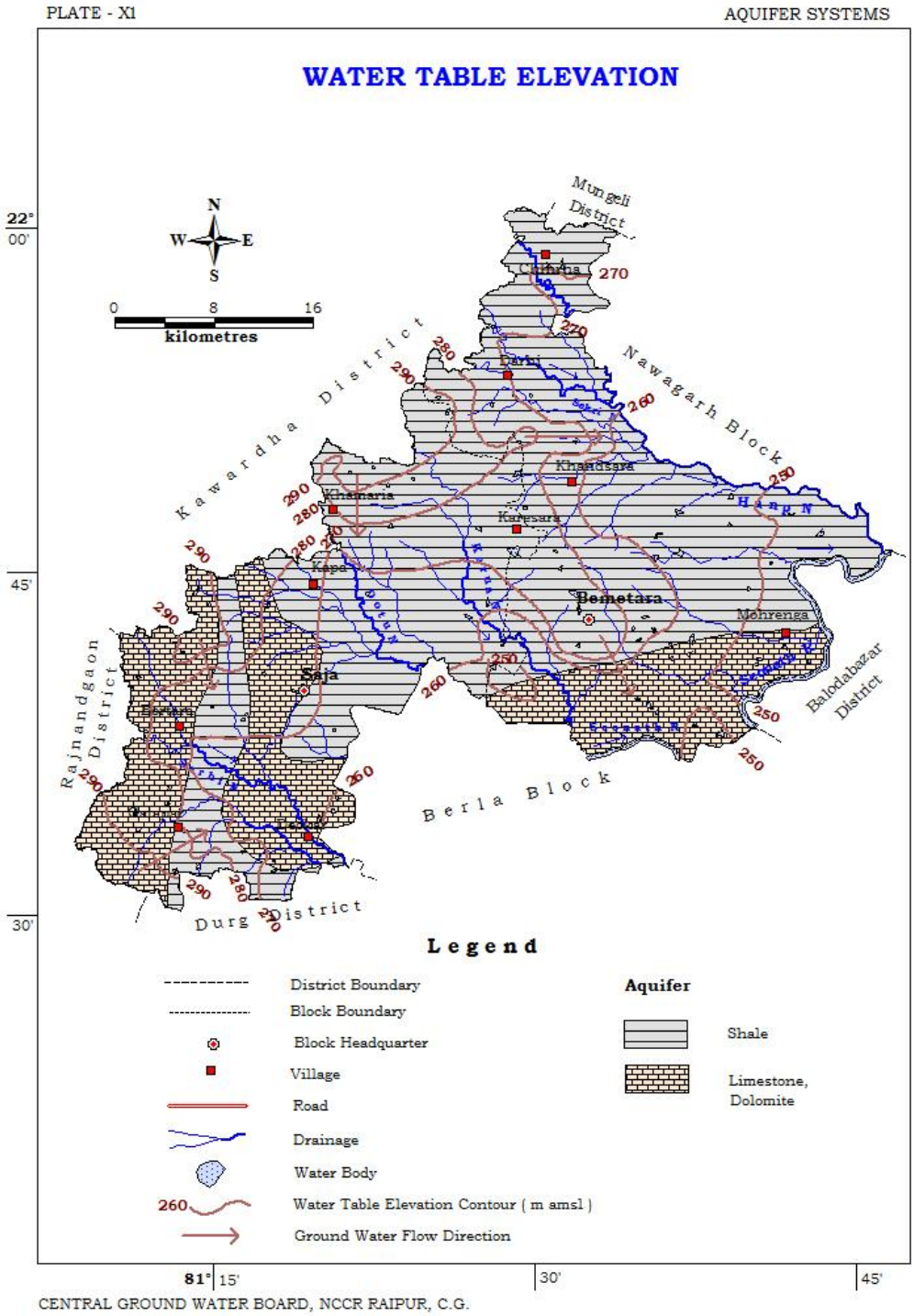
Water table contour

The water **table** contour map has also been prepared for the study area, presented in fig.12, shows that the general hydraulic gradient is northwest to southeast direction.

Fig.13: Water table Contour Map



3.2 Hydrochemical Data

The ground water samples have been submitted in the chemical laboratory for analysis of 12 parameters. They are pH, EC, TH, Ca, Mg, Na, K, Cl, F, HCO_3, NO_3 and SO_4. The result of chemical analysis of 95 nos. of ground water samples is awaited. However, on the basis of the chemical analysis report of the water samples collected from the existing wells (NHNS) in the area, the following table has been prepared.

Table 16: Area affected by Salinity, Fluoride, Nitrate and Arsenic in Ground Water

Sl.No.	Parameter	Block/Area
1	EC > 3000 µS/cm	nil
2	Fluoride (>1.5mg/litre)	Nil
3	Nitrate (>45 mg/litre)	Bemetara/northern part
4	Arsenic (>0.05 mg/litre)	nil

3.3 Geophysical Data

Fig. 14 Panel Diagram (Geophysical) of Aquifer Disposition

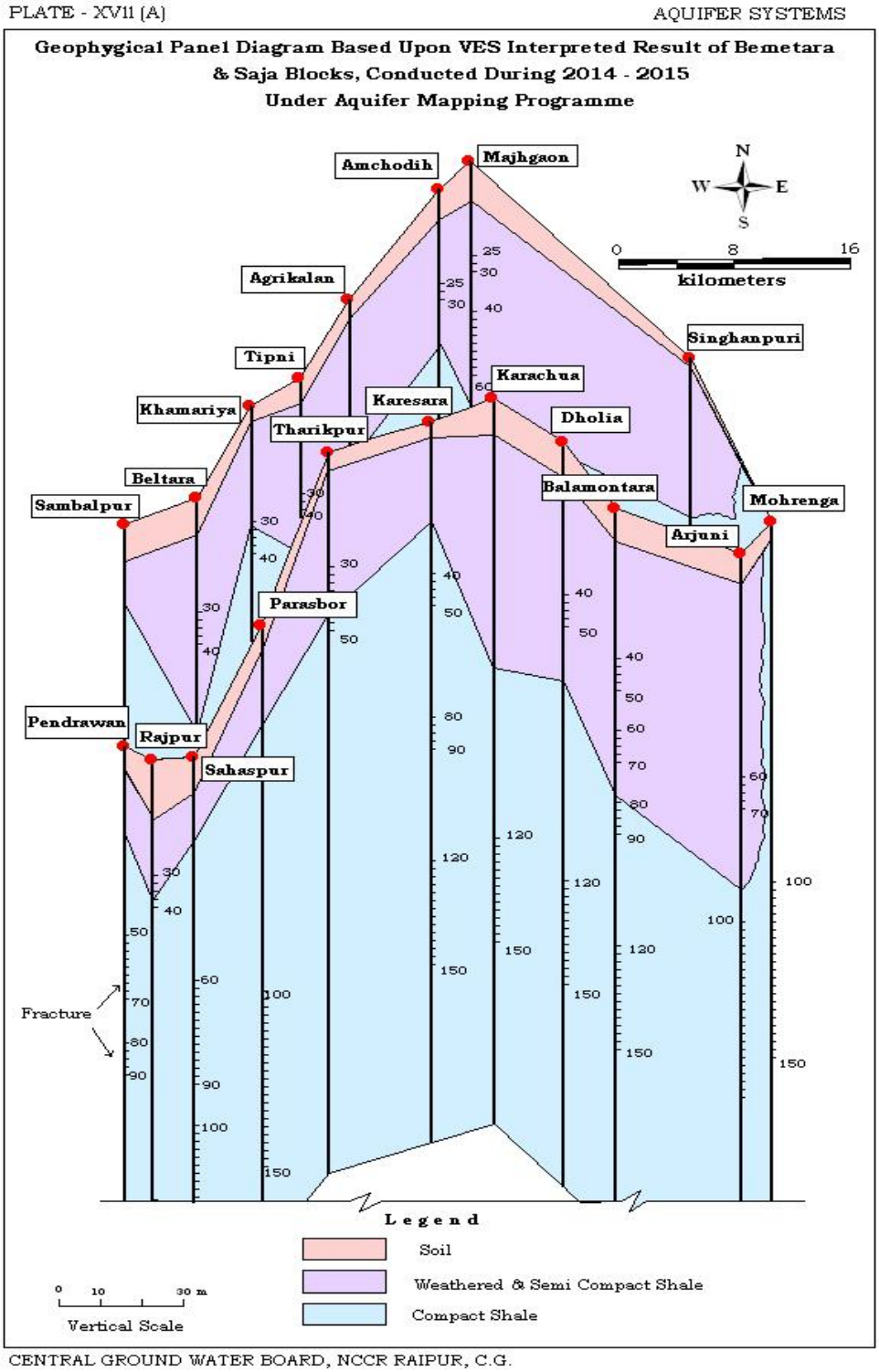
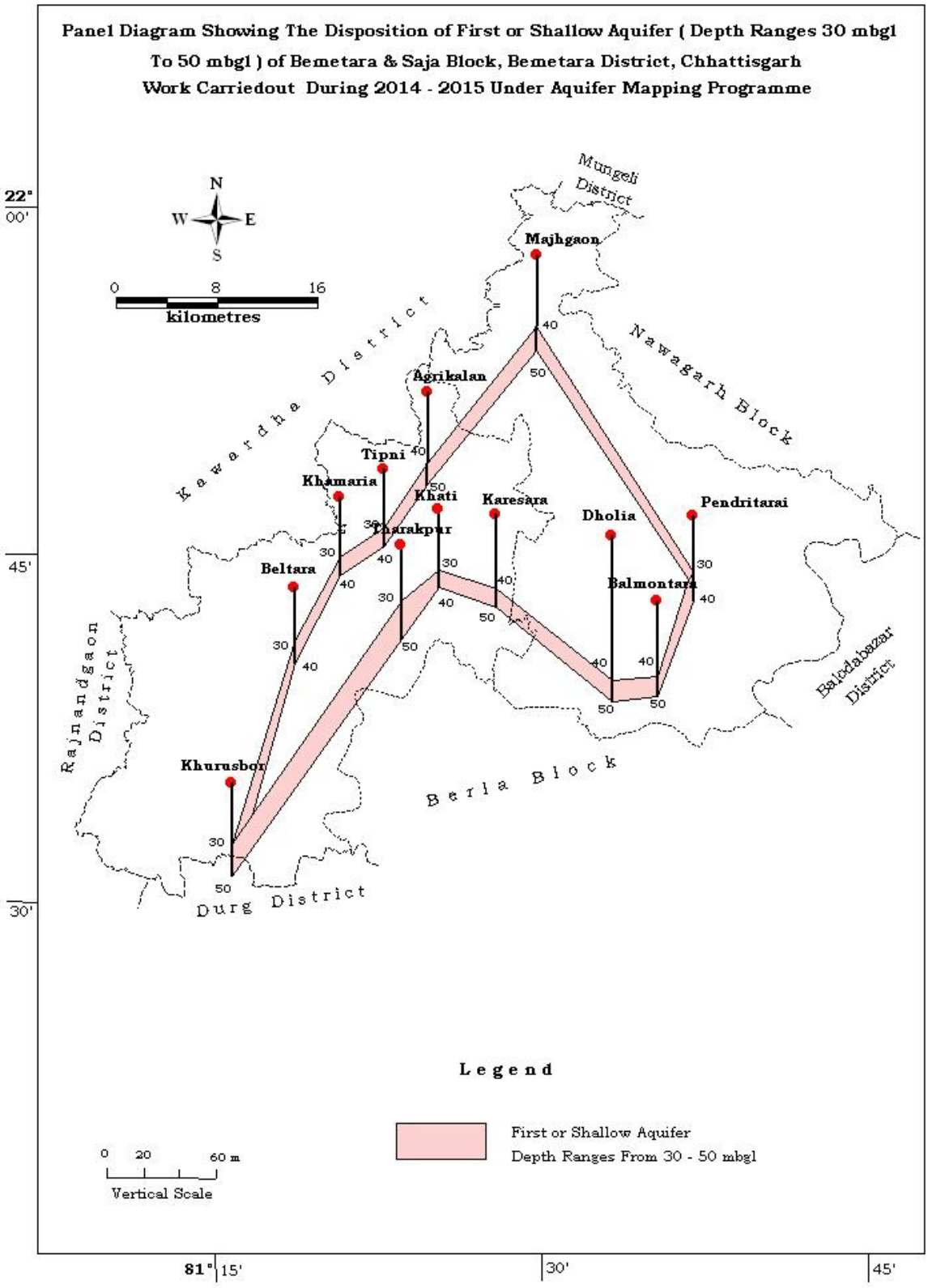
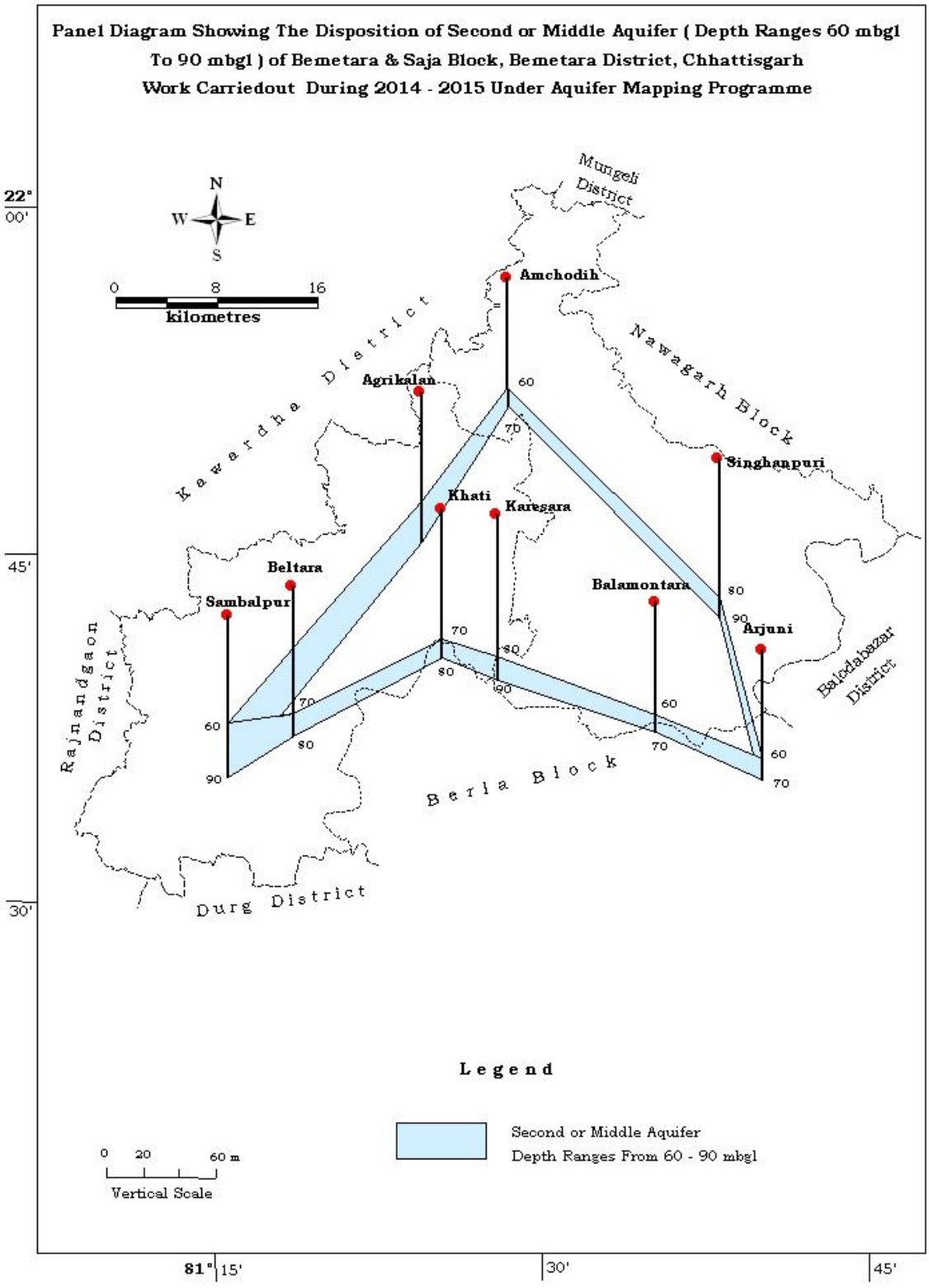


Fig. 14(A) Panel Diagram of First Aquifer



As per the geophysical study, the first or top aquifer is about 10 m thick in the depth range of 30-40 m in the central part of the study area in an east- west direction and also in the western part in a north –south direction from Tipni to Beltara of saja Block. In the northern part there is an area in NE-SW direction (Majhgaon of Bemetara Block and Agricalan of Saja Block) the aquifer thickness remains the same but in the depth range of 40-50 m. There is also an area located in Saja Block in the southern part of central study area (Tarakpur) extending down to south (Khurushbod) where the aquifer thickness is much more (20 m) in the depth range of 30-50 m.

Fig. 14(B) Panel Diagram of Second Aquifer



As per the geophysical study, the second or middle aquifer which underlies the first or top aquifer is of varying thickness (10-30 m) at different places and also located at different depth range. It is rather thin (10 m) in the 60-70 m depth range in the northern part of the study area near Amchodih in Bemetara Block which gradually increses towards west where it goes upto 30 m in the depth range of 60-90 m in Sambalpur area in Saja Block. It again reduces to 10 m thickness towards east in the depth range of 70-80 m in Beltara areain Saja Block and eventually in the depth range of 60-70 m near Arjuni village in Bemetara Block in the eastern part of the study area. The thickness of the aquifer remains the same towards north in Singhanpuri village in Bemetara

3.4 Groundwater Exploration

Based on the exploratory drilling data generated for the Saja and Bemetara blocks, the existing aquifer system in the area may be divided into two namely phreatic and deeper fractured aquifer. These are presented in Fig no 15 and 16.

Fig.15 Disposition of (Phreatic or 1st) Aquifer of the Study Area

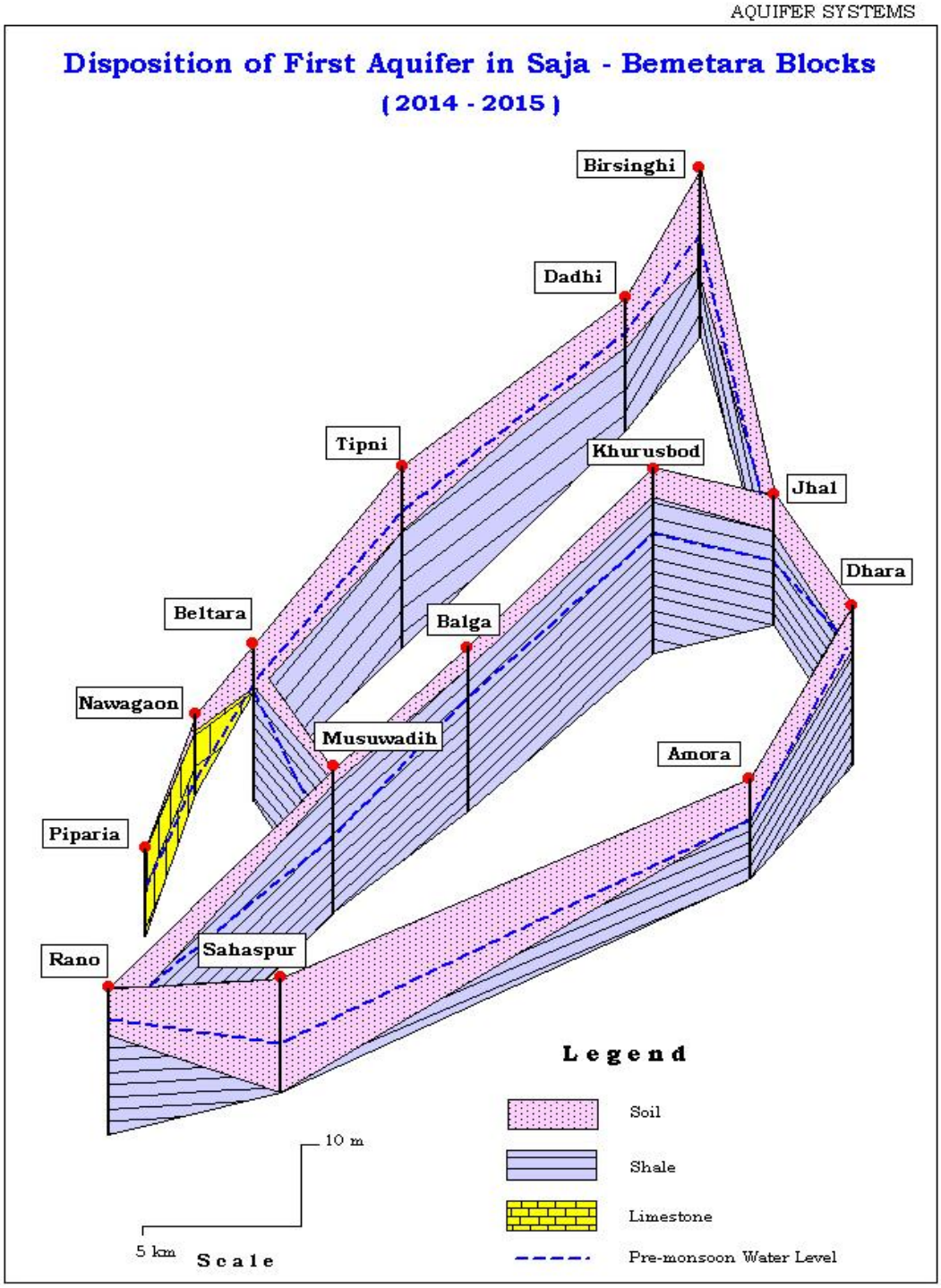
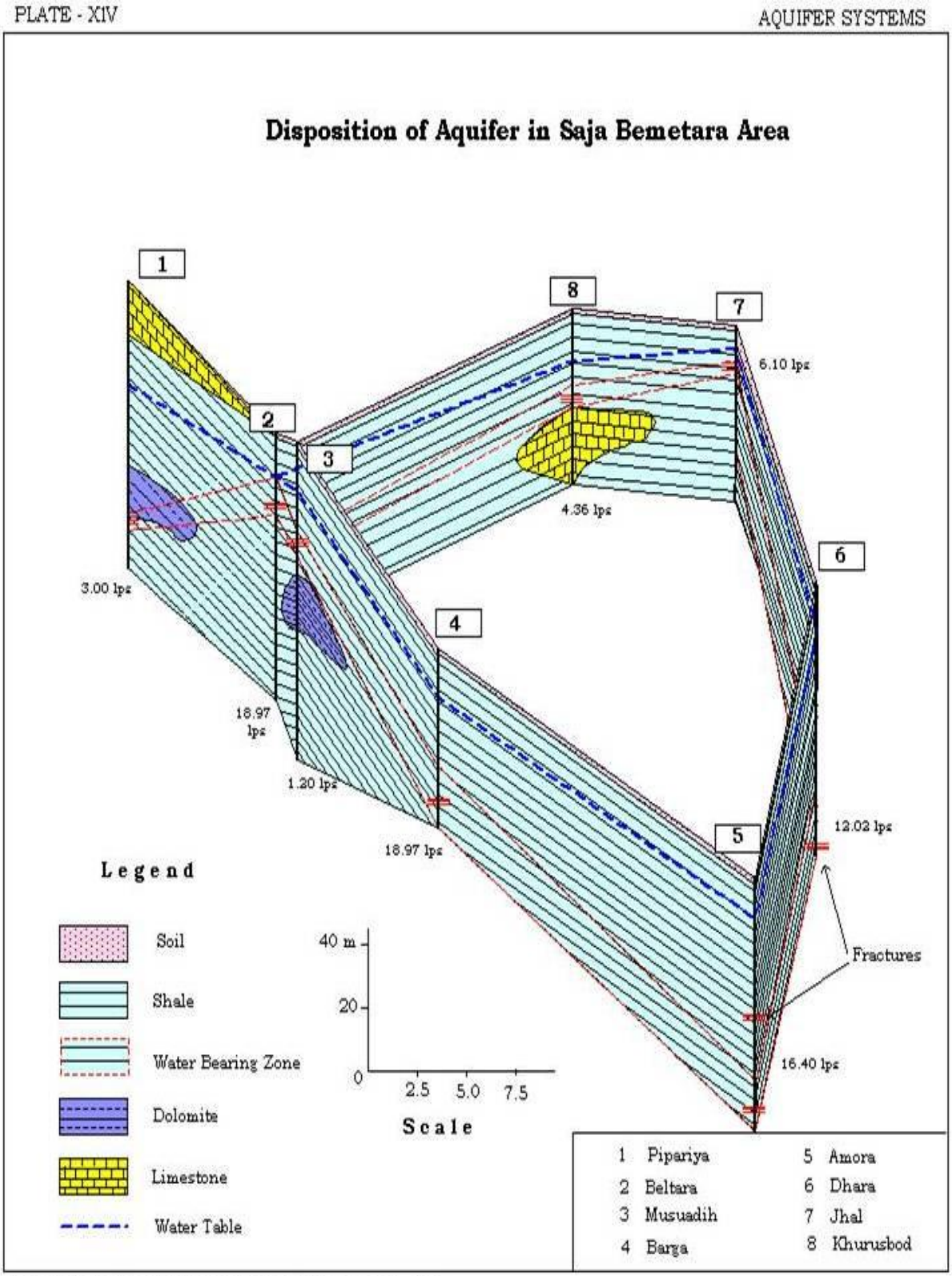


Fig.16 Disposition of (Deeper or 2nd) Aquifer of the Study Area



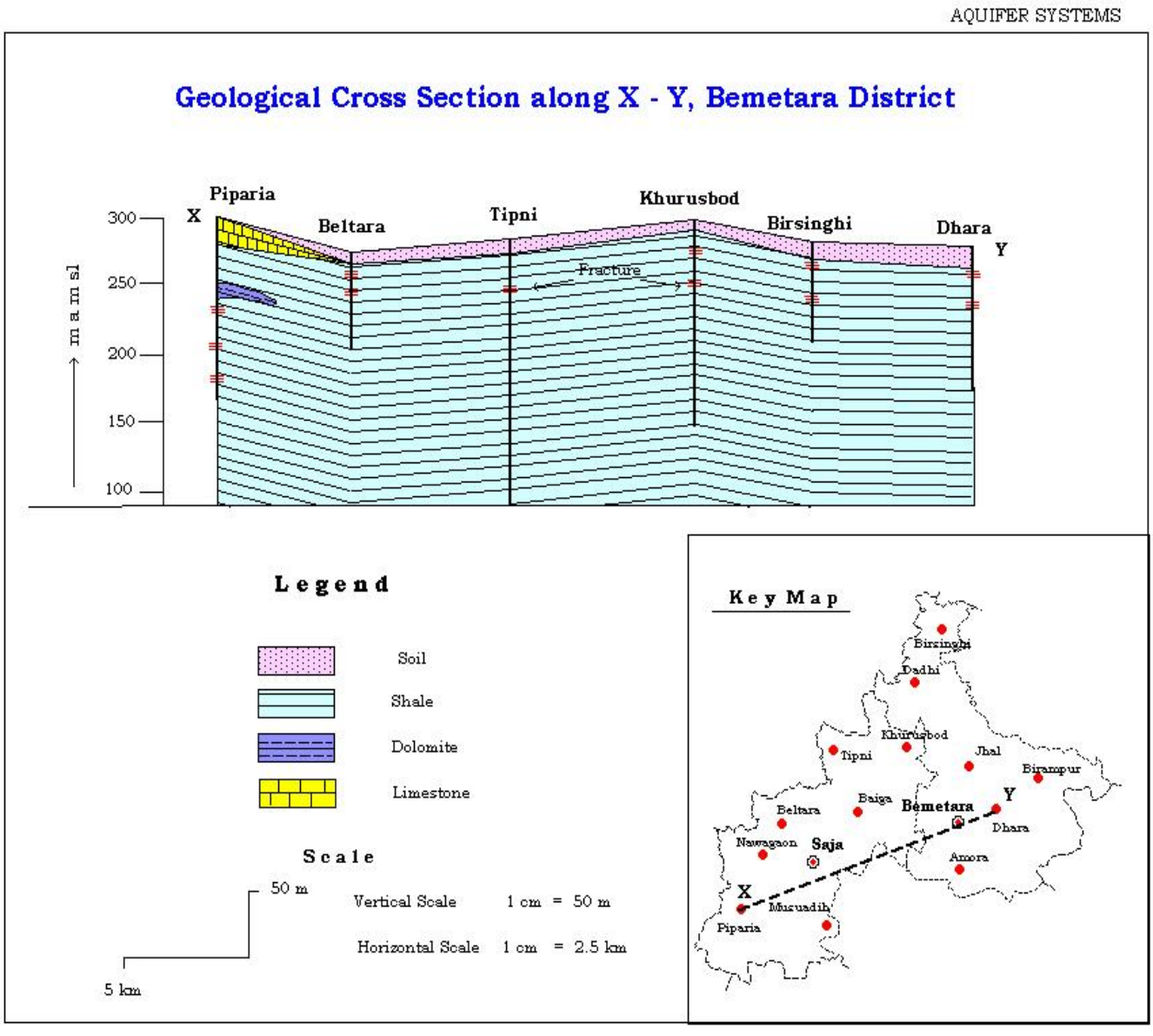
3.4.1 Geological cross-sections

An attempt has been made to draw geological section along Piparia-Dhara (X-Y). Nawagaon-Birsinghi (A-B) and Khurushbod-Dhara (C-D) in the study area based on available exploration data. The section lines are marked on Map and cross-sections are shown on Figure.

3.4.1 (A) Geological cross-section (X-Y) along Piparia-Dhara

Section X-Y falling in Saja and Bemetara Blocks shows a thin soil cover at Piparia in the west in Saja block which is gradually increasing towards east and is thickest at Dhara. Below the soil, shale formation is encountered in the entire area except at Piparia where shale is overlain by limestone and a thin layer of dolomite is encountered which is intervening the shale formation.

Fig.17 (A) Geological cross-section (X-Y) along Piparia-Dhara



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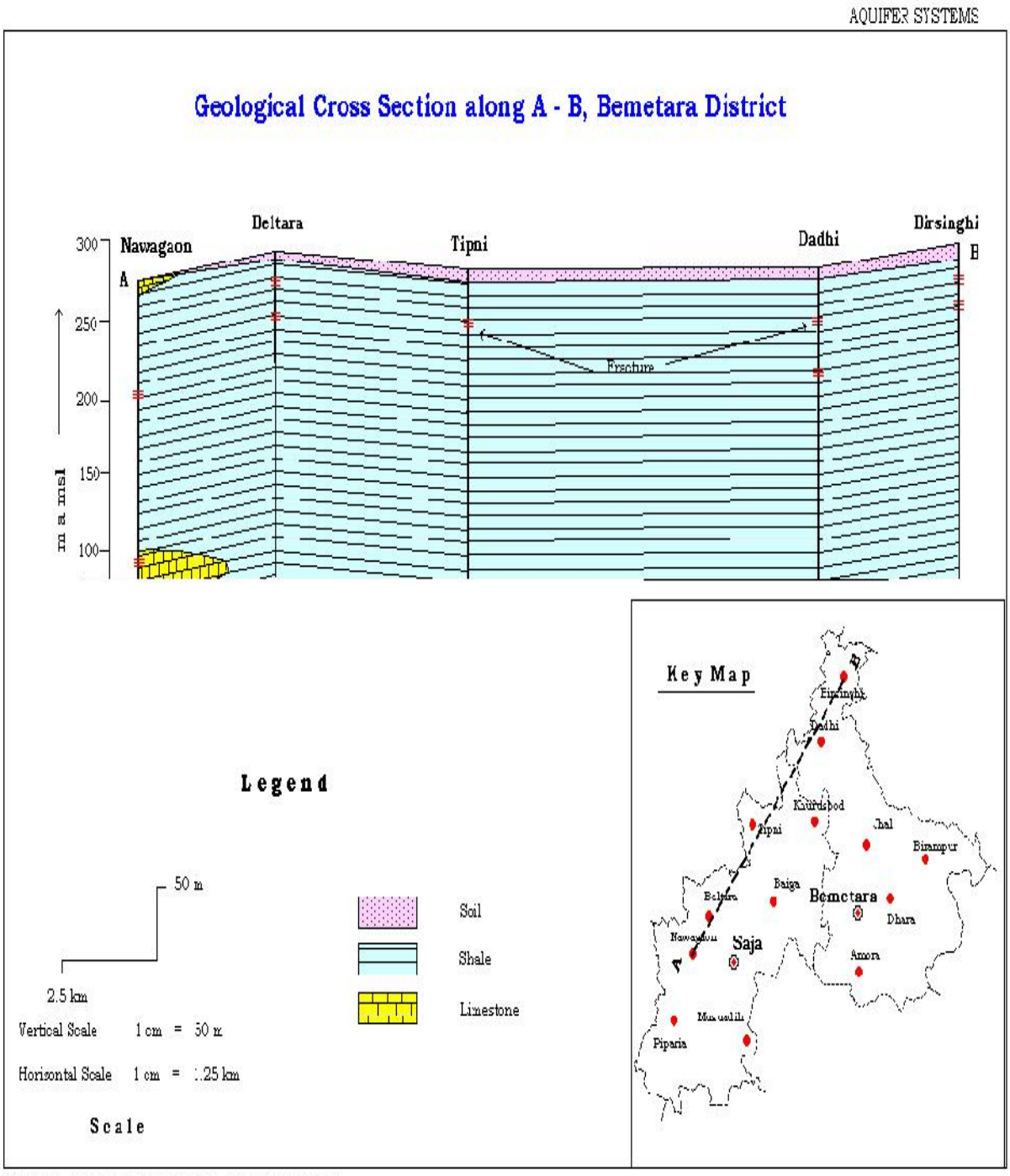
3.4.1(B) Geological cross-section (A-B) along Nawagaon-Birsinghi

Section A-B shows a top soil cover followed by shale formation in the entire area except a thin layer of limestone which overlies the shale formation at Nawagaon.

Fig. 17 (B) Geological cross-sections (A-B) along Nawagaon-Birsinghi



3.4.2 Isopach

Isopachs are contour lines of equal thickness over an area. Fig depicts the equal thickness of aquifer in the area which is based on the lithology and water-bearing formation. Most of the area covering the central and entire western part of the study area having aquifer thickness less than 20 m while the area around Karesara located in the north-central part of the area and also some part located in the extreme south western part near Deokar having aquifer thickness of 20-40 m. The entire eastern part extending from north to south has the aquifer thickness of 40-60 m. A small patch toward the north of Bemetara town has aquifer thickness in the range of 60-80 m. The aquifer material in most of the study area is gypsiferrous shale formation which is extensively fractured. In general, the thickness of of aquifer is reducing from eastern to western side of the study area.

Fig. 18(A) Isopach Map for First Aquifer

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ISOPACH MAP

(I Aquifer)

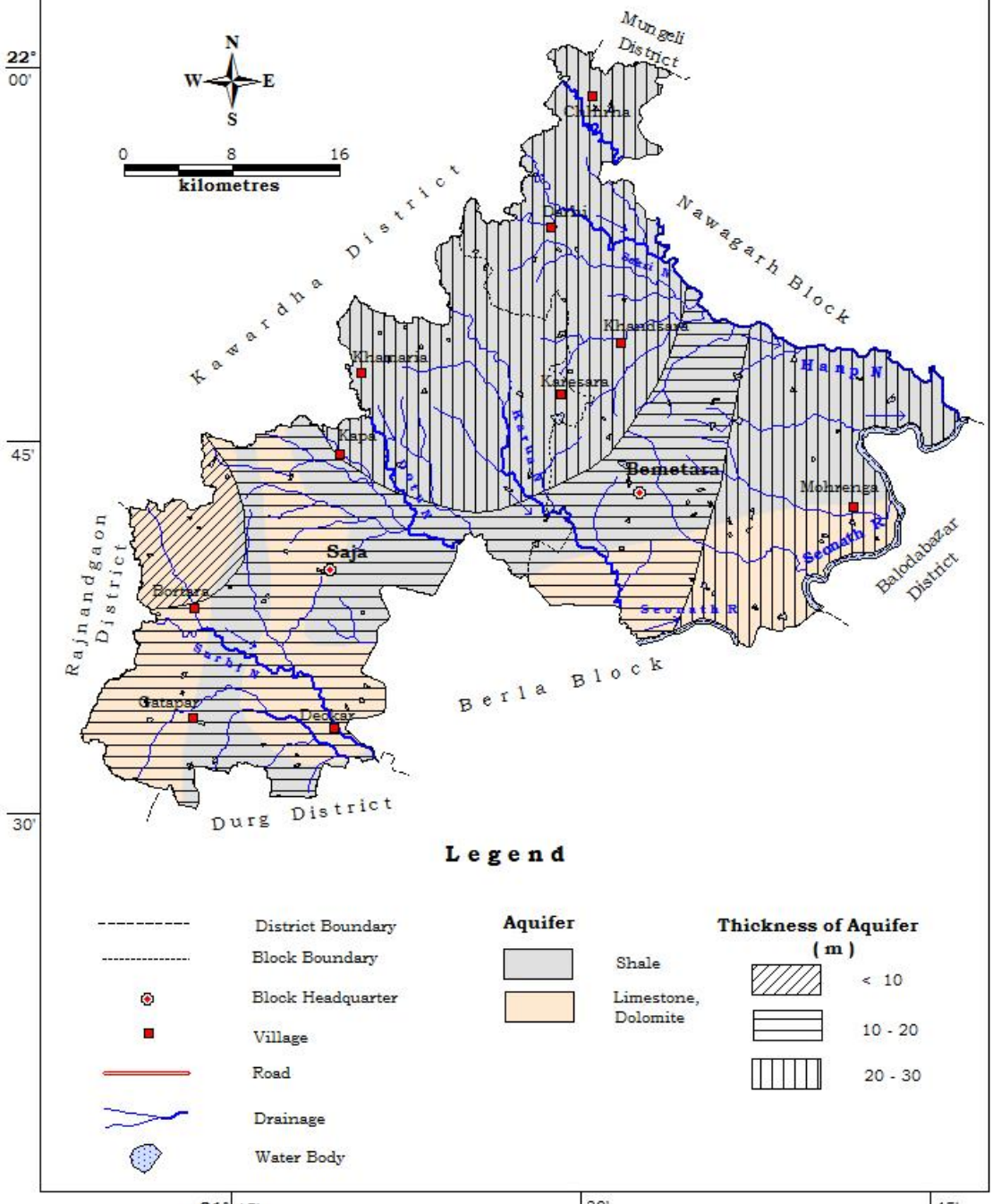
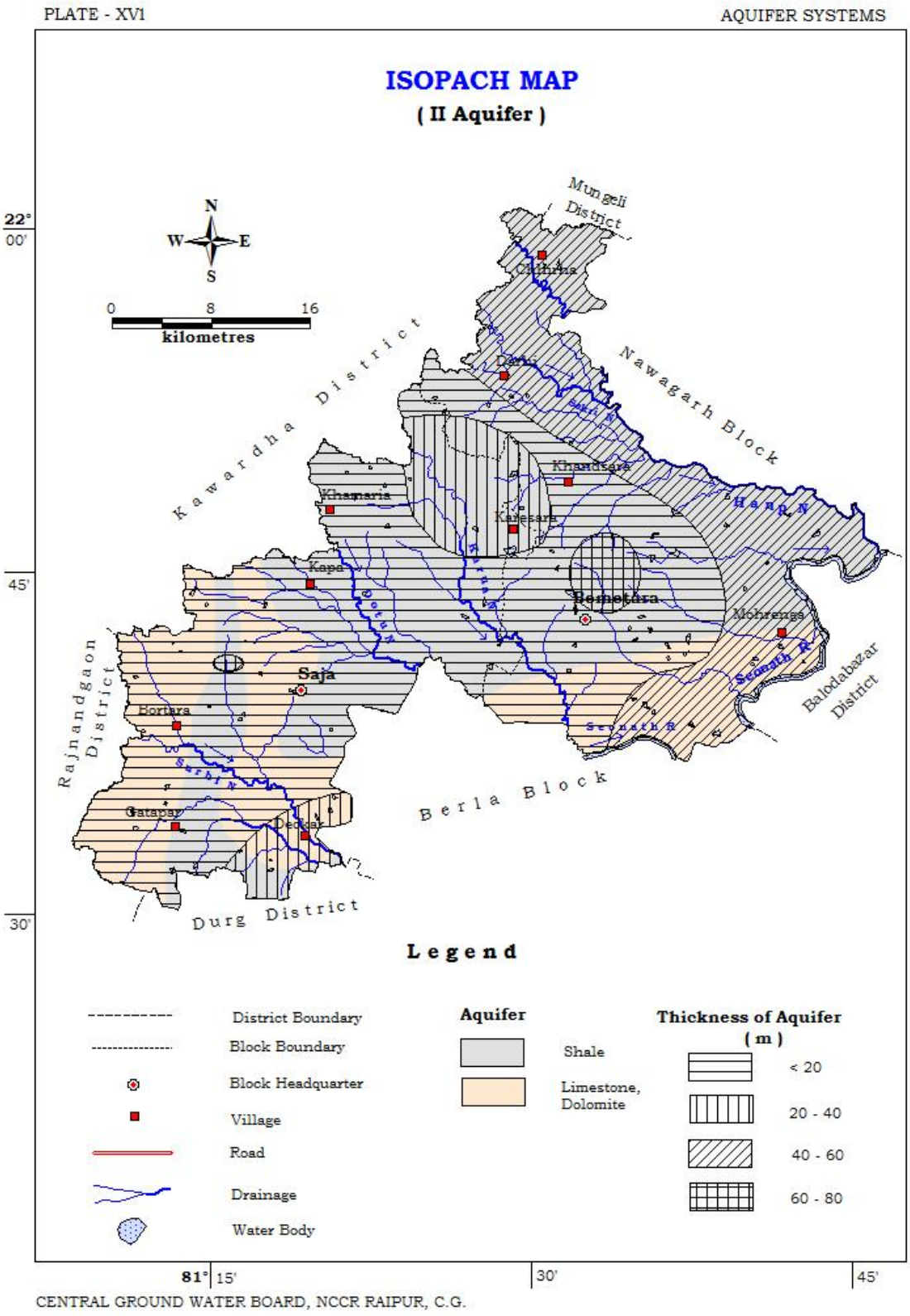


Fig. 18(B) Isopach Map for Second Aquifer



3.4.3 Results of GW Exploration

The detail drilling results of exploratory bore wells drilled in study area is presented in Table 12 (A & B).The semi-consolidated rocks of study area mainly represented by Chhattisgarh Super Group of rocks (Predominantly by Maniyari Formation followed by Hirri, Tarenga and Chandi formations) which consists mainly of shale and limestore. A total of 35 no. of exploratory wells are drilled in this formation.The depth of bore wells drilled in this area varies from 52.0 mbgl at Barga to 269.49 mbgl at Andhiyarkhor. The discharge varies from 1.20 lps at Muswadih to 21.0 lps at Dhara and the maximum draw down was 35.87 m at Rano while the least is .0.41 m at Dadhi. The depth range of potential zones encountered during exploratory drilling varies from 25 to 137.0 mbgl. The static water level varies between 1.69 and 24.45 mbgl. The transmissivity value varies from 111.45 to 584 m^2/ day and the storativity value varies from $3.0X10^{-5}$ to $7.3X10^{-4}$.

During AAP 2014-15 the Ground water exploration has taken up in the blocks of Saja and Bemetara of district Bemetara.The area is located in the west-central part of Chhattisgarh State. It is bounded by Raipur district in the east, Bilaspur in the north Rajnandgaon district in west and Durg district in the south, the area lies between north latitude 21°30'25" to 22°01'14" and east longitude of 81°08'23" to 81°46'19" covers an area of 1604 sq.km.The status of exploratory borewells drilled in each formation and their depth range, zone encountered and discharge variation is tabulated in (Table 12B) and is discussed below.The area explored formed

Saja and Bemetara blocks cover the middle part of the district. The depth of exploration of ground water through drilling was carried out down to the depth of 202 mbgl. Most of the wells drilled in Maniyari shale. The yield of these exploratory wells range between 1 to 18.97 litres per second for a drawdown ranging between 0.41 and 32.5 mts, static water level ranged between 1.69 and 24.45 mbgl. The trasmissivity is found to the tune of 115m^2/day and storativity is computed to the tune of $6.9X10^{-4}$.

Raipur Group

Raipur Group of rocks of the study area is represented by Chandi, Tarenga, Hirri and Maniyari formations. This group of rocks is mainly an argillite-carbonate sequence & consists of limestone, shale, dolomite and sandstone. The formation wise drilling results are given below:

Chandi Formation

The bottom most (Newari member) formation comprises a dominant stromatolitic limestone sequence. The comprises of stromatolitic limestone and dolomite which is pink to light grey in colour and thickly bedded followed by dark grey flaggy limestone (Pendri member) with intercalations of calcareous shale and Deodongar sandstone of lensoid shape. The topmost unit (Nipania member) comprises of pink to purple dolomitic limestone. Towards the upper part it changes into bedded limestone and purple shale and is devoid of stromatolitic structure. This formation has good ground water potential due to development of caverns at places. The deep seated fractures have been encountered in this formation during drilling. In total, 3 exploratory and 2 observation wells drilled in this formation. The water level at the site Rano was 4.38 mbgl for a drawdown of 35.9 m while the discharge of Ground water found 1 lps.

Maniyari Formation: This Formation consists of gypsiferous grey siltstone and shale and followed upward by reddish brown calcareous and non-calcareous shale with limestone and dolomite. The red shale is less fissile. The laminated grey shale is composed of clay and silt. The alternate clay and silt define the laminated character. The terrain is generally gently sloping plain terrain. Because of its marine origin and calcareous nature, this formation is highly porous and permeable. It also possesses gypsum veins and lenses which easily get dissolved and creating

thereby innumerable interconnected cavities/cavernous zones. These interconnected cavities/cavernous zones in this formation are acting as storage reservoirs and conduit system for accumulation and movement of ground water and thus making it very high in ground water potential. It is having potential in the order of 3-18 lps (litres per second) with transmissivity value of 69 – 1500 m^2/day.

Tarenga Formation: This Formation comprises predominantly an argillite-dolomite sequence. The shales are cherty and calcareous. This formation has good ground water potential at places. It has moderate potential in the tune of 1-5 lps with transmissivity value of 10 – 200 m^2/day.

Hirri Formation: This Formation comprises dark grey, bedded dolomite associated with light grey laminated argillaceous dolomite. This formation has also less ground water potential in the order of 1-3 lps (litres per second) with transmissivity value of 69 –1500 m^2/day.

3.5 Aquifer Mapping

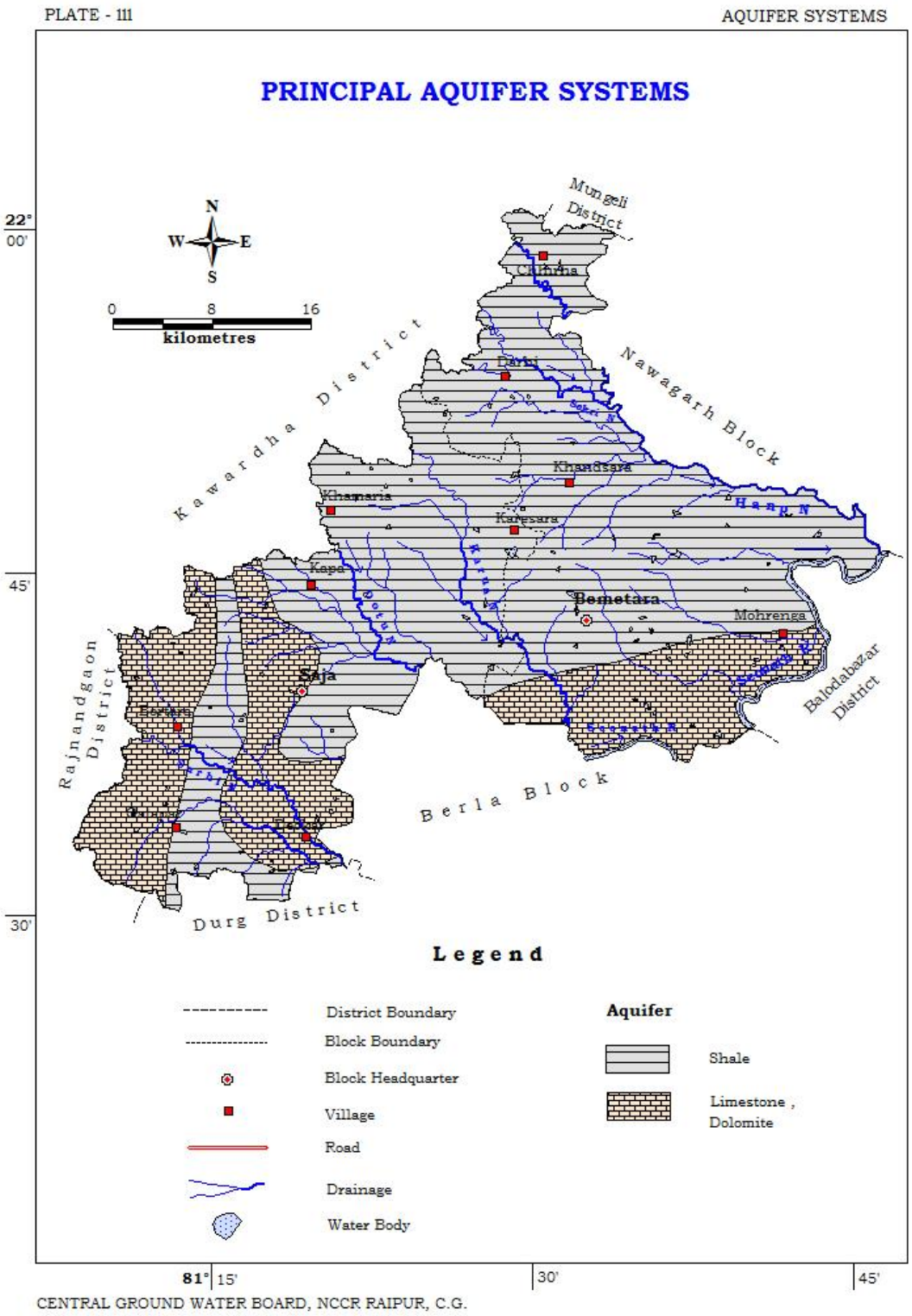
In the study area, from hydrogeological study, the aquifer system has been delineated and has been divided into two groups namely Aquifer A or shale aquifer and Aquifer B or limestone and dolomite aquifer. Together these aquifers cover the entire study area almost in equal proportion. Blockwise, the shale aquifer covers 31.58% area in Saja and 38.76% area in Bemetara blocks. The limestone and dolomite aquifer covers 18.9% area in Saja and 10.73% area in Bemetara blocks. The block wise distribution of principal aquifer systems are represented in table 17

Table 17: Block wise Distribution of Principal Aquifer Systems

Sl no	Block	Shale	%	Limestone & Dolomite	%	Total Area	%
1	Saja	506.7	31.58	303.22	18.9	810	50.5
2	Bemetara	621.67	38.76	172.18	10.73	794	49.5
Total		1128.37	70.34	475.4	29.63	1604	100

Area in sq.km

Fig.19: Principal Aquifer System of the Study Area



4. Ground water resource

The ground water resource of the study area has been assessed down to the depth of 200 mbgl. The shale aquifer (Aquifer 1A) existing in the area has the dynamic resource of 16780 Ham and the limestone aquifer (Aquifer 1B) has 3565 Ham. Similarly, The limestone and dolomite aquifer (Aquifer 1B) existing in the area has the in-storage resource of 23470 Ham and the limestone aquifer (Aquifer 1B) has 5490 Ham. Overall, the total (dynamic & in-storage) resource of the shale aquifer is 40211 Ham and the net ground water draft is 12924 Ham. The average weathered thickness is 16.5 m and the average depth to water level is 10.4 mbgl. Similarly, the total (dynamic & in-storage) resource of the limestone and dolomite aquifer is 9046 Ham and the net ground water draft is 2827 Ham. The average weathered thickness is 18.5 m and the average depth to water level is 18.5 mbgl.

Blockwise, the Net ground water availability (Ham) of Bemetara and Saja blocks is 11860.47 and 8441.88 Ham and the ground water Draft for all uses for Bemetara and Saja Bblocks is 8948.31 and 6807.87 Ham respectively. The ground water resources for future uses for Bemetara and Saja Block is 291.34 and 1632.84 Ham respectively.

The stage of groundwater development in these two blocks is more than 75% and hence these are placed in the 'Semi-critical' category.

The block wise ground water resource and draft in detail and their categorization are summarized and presented in table 18 (A) , 18(B) and 18(C)

Table 18(A) Block wise ground water resource (Ham) of study area

Block	Resource	Aquifer 1A	Aquifer 1B	Total
Bemetara	Dynamic	11000	905	118061
	In-storage	14100	1170	152066
Saja	Dynamic	5780	2660	84041
	In-storage	9370	4320	136089
	Total	40200	9000	492057

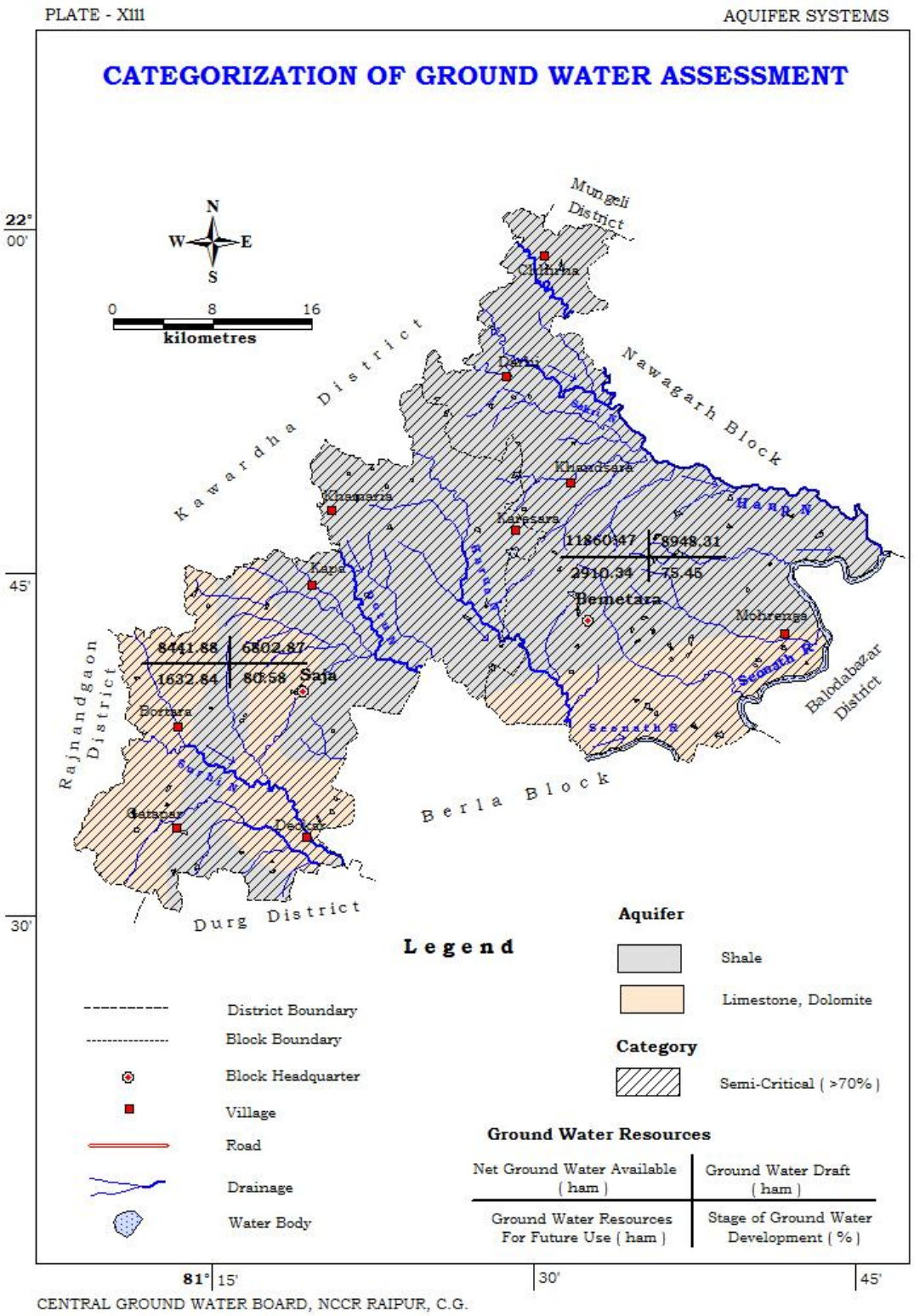
Table 18 (B) Categorization of Assessment Unit

Sl. No	District	Block	Stage of Ground water development (%)	Categorisation
1	Bemetara	Bemetara	75.45	Semi-Critical
2		Saja	80.58	Semi-Critical

Table18(C): Block wise dynamic Groundwater Resource

SL. No	District	Assessment Unit / Block	Recharge From Rain Fall During Monsoon Season in Ham	Recharge From Other Sources During Monsoon Season in Ham	Recharge From Rain Fall During Non Monsoon Season in Ham	Recharge From Other Sources During Non Monsoon Season in Ham	Total Annual Recharge in Ham	Natural Discharge During Non Monsoon Period In Ham	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic & Industrial Water Supply in Ham	Net Ground Water Availability for Future Irrigation Development in Ham
1	Bemetara	Bemetara	5006.60	1699.23	1023.12	4846.04	12574.99	714.52	11860.47	8460.84	487.47	8948.31	489.29	291.34
2		Saja	5608.66	1084.31	660.53	2026.36	9379.86	937.98	8441.88	6527.78	275.09	6802.87	281.26	1632.84

Fig. 20: Map showing Categorisation of Ground water assessment



5. Ground water related Issues

Issues related to groundwater in the area

1. Drying up of Dugwells during pre-monsoon.
2. Lowering of Water Level during Pre-monsoon. (Decadal 2 to 5m)
3. Deepening of common development depth for ground water withdrawal from 50 m to 150 m for tubewells.
4. The occurrence of high nitrate quantity in pocket in the shallow aquifer is reported in northern part of Bemetara block although it's sporadic nature may be attributed to anthropogenic source.

The stage of Ground Water Development stands at 75.48 in Bemetara block leading to it's categorization as "Semi-Critical"

Reasons for Excessive ground water draft for agricultural use:

i) Ground Water Draft for Irrigation is 14989 Ham which is 95% of Gross draft

ii) Availability of Potential Aquifer: Maniyari shale covering about 70.3% of the area being very productive with borewell discharge ranging from 3 to 18 lps.

iii) Availability of Power in rural area: In 2014-15, the power production capacity in the state touched 16,000 MW with the contribution of both public and private sector power plants. In Chhattisgarh, power available at subsidized cost has been continuously leading to long duration and uncontrolled pumping of ground water withdrawal.

6. Management Strategies

The two blocks Saja and Bemetera falls in semi-critical category. The stage of ground water development in two blocks is 80.58% and 75.45 % respectively. Hence, there is little scope for further ground water development. Rather, it is important to pin-point areas in respect to their aquifer potential, long term water level trend. It is also important to urgently adopt to suitable measures in order to arrest the declining water level trend as well as to augment the ground water resources.

The management strategies are described as following:

i) The Gypsiferous shale in the area forms the most promising aquifer. The area located around Birsinghi, Dadhi, Jhal, Dhara villages in Bemetara block within the in shale formation form potential aquifer down to the depth of 90 m while the same exists in limestone formation around village Amora at the contact of shale and limestone formation.

ii) In the Saja block, the area around Tipni, Barga,Beltara, Piparia and Nawagaon within the shale formation, there exists potential aquifer down to the depth of 40 to 80 m. The limestone in the western part of Saja block forms poor aquifer.

iii) The study area as a whole has good ground water potential. However at some places, e.g Muswadih and Rano ground water exploration has yielded only meagre discharge. The quality of ground water in almost entire area is potable. However, value of Nitrate higher than permissible limit is reported in Darhi in shallow aquifer in northen part of Bemetara which may be attributed to anthropogenic activities.

iv) High stage of ground water development as well as declining water level in this area warrants groundwater conservation which can be achieved through efficient use of ground water as well as adoption of drip irrigation method, change in cropping pattern i.e

switching over to less water-consuming crops, recycling in waste water, conservation of rain water etc. In many areas where the water level is quite deep, recharge of groundwater is necessary in near future through artificial structures. Therefore, rest of the study area is recommended for artificial recharge of groundwater by means of construction of suitable structures like percolation tank, nala bandh and check dam, recharge shaft and gully plugs observing the local conditions prevailing in the area. In addition, this artificial recharge of ground water is recommended in the area covering Jeori, Farri, Piparbhata villages located in Bemetara Block as well as in the area around Saja town where water level fluctuation is more than 10 m. Area suitable for Artificial Recharge in these aquifers is 56.25%, 7.4%, 16.24% respectively of the total study area. Area Suitable for Conservation in Shale, Limestone and Dolomite aquifer are 14.07%, 5.91% respectively.

Table 19: Aquifer wise Ground water Management Plan

Sl.No	Name of Aquifer	Area Covered	Area Suitable for Artificial Recharge	
			Area	%
1	Shale	1128.37	819	56.25
2	Limestone & Dolomite	475.4	344	23.54

Area in sq.km.

Table 20: Types of Artificial Recharge Structures proposed

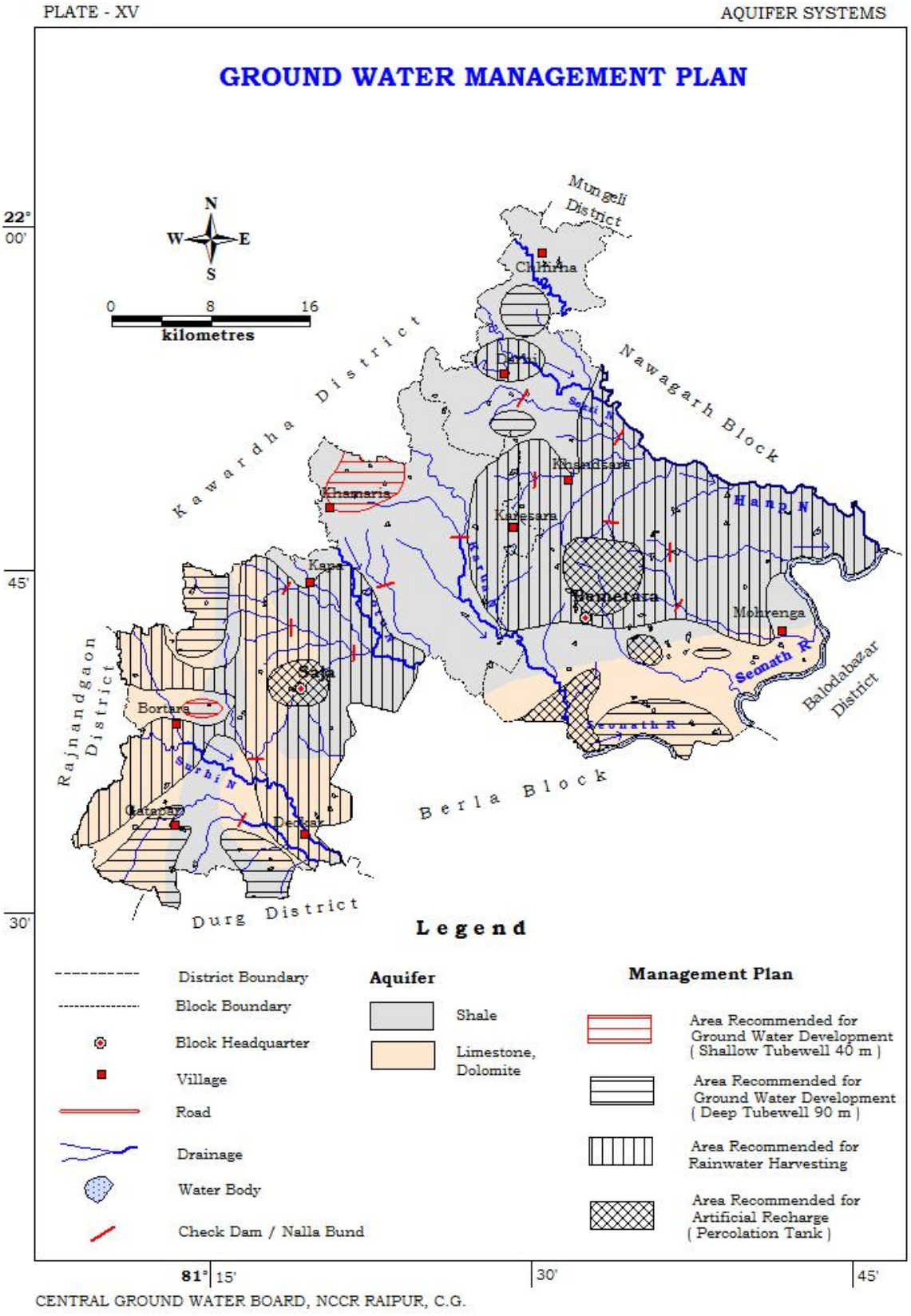
Block	Percolation Tank	Nala Bund & Check Dam	Recharge Shaft	Gully Plug
Bemetara	41	138	248	331
Saja	40	135	242	323

Source: Master Plan of Chhattisgarh

v) The areas covering the villages Chamari, Jhal, Ataria, Raweli, Mau, Kosa, Bemetara, Mohtara, Khurmuri in the eastern part as well as Bandhi, Chilpi, Karesara in the central part in Bemetara Block as well as in the Saja Block in the eastern part at Gotwani, Keshtara, Khamdihi, Lalpur, towards north Thelka and Bodka, towards south Tendubhata, Mohagaon, towards west Rampura, Sambalpur, Bharda, Tiriabhata are recommended for rain water harvesting where water level is more than 5 m in the post-monsoon period.

The map of ground water management plan through artificial recharge is presented in Fig 20.

Fig. 21: Ground water Management Plan through Artificial Recharge



Aquiferwise availabily of unsaturated zone

The volume of pore space in the formation available for recharge in the unsaturated zone of Aquifer A up to a desirable depth (say 3 mbgl) is 118.696 x 10^6 m^3 considering the void space depth is 7.4 m, total study area is 1604 sq. km and the specific yield of shale as 0.01. Similarly, the volume of pore space in the formation available for recharge in the unsaturated zone of Aquifer B up to a desirable depth (say 3 mbgl) is 340.85 x 10^6 m^3 considering the void space depth is 7.4 m, total study area is 1604 sq. km and the specific yield of shale as 0.025. This is summarised in Table 21.

Table 21: Summarised detail of Volume of porous space available for recharge in Aquifer A & B

Formation	Area (sq.m)	Water Level (upto 3 mbgl) in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m3)
Shale	1604 x 10^6	7.4	0.01	118.696 x 10^6
Limestone & Dolomite	1604 x 10^6	8.5	0.025	340.85 x 10^6

Rain water being the only primary source for recharge, it has been calculated that shale aquifer may be recharged about 41.1292 x 10^6 m^3 assuming the average annual rainfall as 1592 mm (average of last 3 years) and the infiltration factor of shale as 0.03-0.05 (say 0.04).

Similarly, in the limestone as well as dolomite aquifer, it has been calculated that shale aquifer may be recharged about 61.6938 x 10^6 m^3 assuming the average annual rainfall as 1592 mm (average of last 3 years) and the infiltration factor of shale as 0.06.

This is summarised in Table 22.

Table 22: Detail of Volume of porous space available for further recharge in Aquifer A & B

Formation	Area (sq.m)	Annual (average of last three years) rainfall (m)	Infiltration Factor for the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Shale	1604 x 10^6	1.295	0.04	81.7912	36.9048 x 10^6
Lst & Dolomite	1604 x 10^6	1.295	0.06	122.6868	218.1632 x 10^6

To meet the requirement for further recharge in both the aquifers as indicated in table 22, artificial recharge of groundwater through different methods is necessary. For this purpose, other method like change in cropping pattern, **t**ransfer of ground water from adjoining blocks, leveling of land resulting in irrigation efficiency etc are also to be adopted.

Change in cropping pattern

Paddy is extensively cultivated (88% of total cropped area) in Bemetara block during the Rabi season using huge quantity (89% of total irrigated area) of groundwater through pumping. As paddy requires more water than wheat, change in cropping pattern may be adopted during cultivation in Rabi season, thus saving ground water to some extent which can be discerned from table 23(A,B,C).

Table 23(A): Detail of groundwater saved through change in cropping pattern

Paddy cultivation area in Rabi season (ha)	Water required (m) per ha (m)		Difference (m)	Total saving of water (ham)
	Paddy	Wheat		
1558	1.5	0.5	1	1558

Table 23(B) Area covered by paddy cultivation during Rabi season

Area covered by Paddy cultivation in Rabi season (hectre)		
Bemetara	Saja	Total area
1500	58	1558

Table 23(C) Saving of water through change in cropping pattern from paddy to wheat

Water required per hactre (m)		Difference (m) per hactre	Total saving of water (ham)
Paddy	Wheat		
0.8	0.5	0.3	467.4

Transfer of ground water from adjoining blocks:

The stage of groundwater development in the study are is more than75% and hence it has been categorized as "Semi-critical". In order to avoid further deterioration as well as to bring it back to "Safe" category, groundwater may be transferred on long term basis from adjoining blocks without deterioration of their groundwater scenario.

In view of the growing water demand for agricultural as well as human consumption in adjoining blocks, 65% stage of development may be assumed as safe category instead of conventional 70%. Assuming 70% as safe limit for stage of development for Saja and Bemetara blocks, it has been ascertained from the Aquifer Mapping Study of the Saja and Bemetara Blocks that an excess of about 1640 ham of groundwater is drawn from the aquifer of the area resulting an enhancement of stage of development from 70% to about 78% in the area. If this quantity of water is compensated from adjacent areas to replenish the aquifer of the study area, then the stage of development of groundwater is likely to improve from 78% to 70%. During the Aquifer Mapping Study, it has been observed that there are only three blocks (Sahaspur Lohara, Nawagarh and Simga) out of all the blocks surrounding the study area that show comparatively less ground water development but the groundwater flow regime in the area indicates that groundwater is already flowing from Sahaspur Lohara towards the study area. That implies that further withdrawal from this block is not advisable. This leaves the option that groundwater from two other blocks namely Simga and Nawagarh can be withdrawn and transferred to the study area in order to reduce the ground water draft.

Assuming the 65% as safe limit for stage of development, excess groundwater (about 1427 ham) can be withdrawn from these two blocks to replenish the demand in Saja and Bemetara blocks. This will in turn bring down the stage of development of groundwater from 78% to 70.55% which is actually very close to the safe limit (70%) for stage of ground water development.

Table 24(A) Existing Groundwater Scenario in Saja & Bemetara Blocks

Sl No	Block	Stage of GW development (%)	Net GW Resources (ham)	Groundwater being withdrawn above safe limit	
				%	Quantity (ham)
1	Bemetara	75.45 (76)	11860.47	6	712
2	Saja	80.58 (81)	8441.88	11	928
Total		**77.58 (78)**	**20302.56**	**17**	**1640**

Table 24(B) Existing Groundwater Scenario in the Adjoining Safe Blocks

Sl No	Block	Stage of GW development (%)	Net GW Resources (ham)	Groundwater to be drawn from Other Blocks	
				%	Quantity (ham)
1	Nawagarh	51.68 (52)	5608.7	13	729
2	Simga	57.66 (58)	9973.28	7	698
3	Sahaspur Lohara	47.39 (48%)	10783.17	17*	1833
Total					1427

* Transfer of groundwater from this block is not being considered as the block is contributing through hydraulic gradient.

Table-24(C) Groundwater Scenario in Saja & Bemetara Blocks after transfering of groundwater down the draft by borrowing GW from Safe blocks (Ref: Table 24B)

Net GW Resources (ham)	Net GW Draft (ham)	Proposed transferable GW resources from adjoining blocks (ham)	Reduction in GW Draft (ham) (2-3)	Improved stage of development (%) (4)/(1)*100
1	2	3	4	5
20302.35	15751.18	1427	14324.2	70.55

Land Levelling:

Also irrigation water can be saved to some extent (about 15%) through leveling of land through which the irrigation canal passes. This in turn will reduce the deficit between the demand and supply of water and thus the extraction of ground water will be minimized to some extent.

BLOCK-WISE AQUIFER MAPS AND MANAGEMENT PLANS

Salient Informations:

1.0 Block : Bemetara, Area: 794 sq. km

1.1 District/State: Bemetara/ Chhattisgarh

1.2 Population: The total population of Bemetara block as per 2011 Census is 215304 out of which rural population is 187078 while the urban population is only 28226 comprising 107820 males and 107484 females. The Block wise population break up i.e. rural- urban, male- female is given below in Table 1.

Table 1 Population Break Up

Tehsil	Total population (No)	Male (No)	Female (No)	Rural population (No)	Urban population (No)
Bemetara	215304	107820	107484	187078	28226

Source: CG Census, 2011

1.3 Rainfall

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. The average annual rainfall for the study area is around 1592 mm (Average of the last three years i.e. 2012 to 2014).
Annual rainfall in Bemetara district for the period of five years from 2012 to 2014 is presented below in Table 2.

Table 2 Annual Rainfall (mm) in Bemetara district for the years (2012 to 2014)

District/Tehsil	2012	2013	2014	Average of 3 years for the block
Bemetara	1113	2074	1589	1592

1.4 Agriculture and Irrigation

Agriculture is practiced in the area during kharif and Rabi season every year. During the Kharif, cultivation is done through rainfall while during the Rabi season, it is done mainly through ground water as well as partly through surface water like ponds and other sources. Ground water contributes about 95% of the total irrigation. The groundwater abstraction structures are generally borewells /tubewells, Dugwells. The principal crops in the block are Rice, Wheat along with Pulses, Tilhan, Fruits and Vegetables etc. In some areas, double cropping is also practiced.

Table 3A Agricultural pattern in Bemetara district during the year 2013-14 (in ha)

Tehsil	**Total geographical area**	**Revenue forest area**	**Area not available for cultivation**	**Non agricultural & Fallow land**	**Agricultural Fallow land**	**Net sown area**	**Double cropped area**	**Gross cropped area**
Bemetara	72779	0	6153	7174	586	57856	34219	92075

Table 3B Cropping pattern in Bemetara district during the year 2013-14 (in ha)

Tehsil	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits / Vegetables	Reshe	Mirch Masala	Sugar-cane
			Wheat	Rice	Jowar & Maize	Others						
Bemetara	51727	92075	3097	38264	0	748	36493	11036	1443	3	5	802

Table 3C Area irrigated by various sources in Bemetara district during the year 2013-14 (in ha)

Tehsil	No. of canals (private and Govt.)	Irrigated area	No.of bore wells/ Tube wells	Irrigated area	No. Of dug wells	Irrigated area	No. of Talabs	Irrigated area	Irrigated area by other sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of irrigated area wrt. Net sown area
Bemetara	21	2539	5370	32095	109	23	45	295	51	19272	15731	35003	38

1.5 Groundwater Resource Availability and Extraction

Broadly, based on the existing geological formations, the aquifer system of Bemetara block area is divided in two parts, namely Aquifer A or Shale Aquifer and Aquifer B or Limestone/Dolomite Aquifer. The average weathered thickness is 16.5m in Aquifer A while the same for Aquifer B is 18.5m. Based on the resource assessment, total dynamic groundwater resource of Bemetara block is 11861 Ham out of which Aquifer A has 10956 Ham and Aquifer B has 905 Ham. The total in storage or static resource of the area is 15266 Ham out of which Aquifer A has 14101 Ham and Aquifer B has. 1165 Ham.This is presented in the following table 4:

Table 4 Availability of ground water resource down to 200m depth

Block	Resource	Aquifer 1A	Aquifer 1B	Total
Bemetara	Dynamic	10956	905	11861
	In-storage	14101	1165	15266

Resource in Ham

1.6 Existing and Future Water Demand

The existing demand for irrigation in the area is 8460.84 Ham while the same for domestic and industrial field is 487.47 Ham. To meet the future demand for ground water, a total quantity of 291.34 ham of ground water is available for future use.

1.7 Water Level Behavior

Pre-monsoon water level: In the pre-monsoon period, it has been observed that in Bemetara block, the minimum water level is 2.32 mbgl in Shale formation while the maximum is 14.32 mbgl. In Dolomite formation the minimum water level is 3.4 mbgl while the maximum is 13.50 mbgl.

Table 5: Aquifer wise Depth to Water Level (Pre-monsoon)

Block Name	Shale		Dolomite	
	Min	Max	Min	Max
Bemetara	2.32	14.32	3.40	13.50

Water Level (in mbgl)

Post-monsoon water level: In the post-monsoon period, it has been observed that in Bemetara block, the minimum water level is 0.82 mbgl in Shale formation while the maximum is 9.02 mbgl. In Dolomite formation the minimum water level is 1.60 mbgl while the maximum is 5.25 mbgl.

Table 6: Aquifer wise Depth to Water Level (Post-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Bemetara	0.82	9.02	1.60	5.25	-	-

Water Level (in mbgl)

Seasonal water level fluctuation: In the post-monsoon period, it has been observed that in Bemetara block, the minimum water level fluctuation is 0.15 mbgl in Shale formation while the maximum is 9.02 mbgl. In Dolomite formation the minimum water level is 1.60 mbgl while the maximum is 5.25 mbgl.

Table 7: Aquifer wise Depth to Water Level Fluctuation (Pre-monsoon vs Post-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Bemetara	0.15	12.7	0.85	11.48	-	-

Water Level (in mbgl)

Water level trend: The available long term data indicates a lowering trend of water level during the pre- monsoon period which is in the tune of 2-5 m over a decade.

2.0 Aquifer Disposition

Geologically, the study area comprises of rocks of Meso to Neo-Proterozoic sequence and is represented by the Chhattisgarh Supergroup consisting of the Raipur Group of rocks. In the study area, Raipur Group of rocks of Precambrian sedimentary province is represented predominantly by Maniyari Formation and Tarenga Formation and also partly covered by Hirri Dolomite as well as Chandi formations underlain occasionally by the Khamaria Pebble Bed of Quaternary age.

Maniyari Formation: This Formation consists of gypsiferous grey siltstone and shale and followed upward by reddish brown calcareous and non-calcareous shale with limestone and dolomite. The red shale is less fissile. The laminated grey shale is composed of clay and silt. The alternate clay and silt define the laminated character. The terrain is generally gently sloping plain terrain. Because of its marine origin and calcareous nature, this formation is highly porous and permeable. It also possesses gypsum veins and lenses which easily get dissolved and creating thereby innumerable interconnected cavities/cavernous zones. These interconnected cavities/cavernous zones in this formation are acting as storage reservoirs and conduit system for accumulation and movement of ground water and thus making it very high in ground water potential. It is having potential in the order of 3-18 lps (litres per second) with transmissivity value of 69 – 1500 m^2/ day.

Tarenga Formation: This Formation comprises predominantly an argillite-dolomite sequence. The shales are cherty and calcareous. This formation has good ground water potential at places. It has moderate potential in the tune of 1-5 lps with transmissivity value of 10 – 200 m^2/ day..

Hirri Formation: This Formation comprises dark grey, bedded dolomite associated with light grey laminated argillaceous dolomite. This formation has also less ground water potential in the order of 1-3 lps (litres per second) with transmissivity value of 69 – 1500 m^2/ day.

Chandi Formation: This Formation comprises a dominant stromatolitic limestone sequence. The bottom most (Newari member) comprises of stromatolitic limestone and dolomite which is pink to light grey in colour and thickly bedded followed by dark grey flaggy limestone (Pendri member) with intercalations of calcareous shale and Deodongar sandstone of lensoid shape. The topmost unit (Nipania member) comprises of pink to purple dolomitic limestone. Towards upper part it changes into bedded limestone and purple shale and is devoid of stromatolitic structure.

This formation has moderate ground water potential due to development of caverns at places. It yields in the order of 1-5 lps (litres per second) with transmissivity value of 1 – 400 m^2/ day.

3.0 Aquifer wise resource availability and extraction

Existing scenario: As per the dynamic ground water resource estimation, 2015, the net dynamic ground water resource of Bemetara block is 11860.47 Ham. The present net ground water draft is 8948.31 Ham out of which the ground water draft for irrigation is 8460.84 Ham while the same for domestic as well as industrial use is 487.47 Ham.
The stage of ground water development in the block is 75.45% and hence it has been categorized as semi-critical.

Table 8: Block wise ground water resource (Ham) of study area

Block	Resource	Aquifer 1A	Aquifer 1B	Total
Bemetara	Dynamic	11000	905	118061
	In-storage	14100	1170	152066

Table 9: Categorization of Assessment Unit

Block	Stage of Ground water development (%)	Categorisation
Bemetara	75.45	Semi-Critical

Future scenario (2025): After meeting up all existing demands, the dynamic ground water resource left for future use till 2025 remains 780.63 Ham out of which 489.29 Ham is allotted for domestic and industrial use while the same for irrigation development is 291.34 Ham.
This is summarized in the following table: 15

Table 10: Ground water resource assessment for Bemetara block

District	Assessment Unit / Block	Recharge From Rain Fall During Monsoon Season in Ham	Recharge From Other Sources During Monsoon Season in Ham	Recharge From Rain Fall During Non Monsoon Season in Ham	Recharge From Other Sources During Non Monsoon Season in Ham	Total Annual Recharge in Ham	Natural Discharge During Non Monsoon Period In Ham	Net Ground Water Availability in Ham	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham	Allocation For Domestic & Industrial Water Supply in Ham	Net Ground Water Availability for Future Irrigation Development in Ham
Bemetara	**Bemetara**	5006.60	**1699.23**	1023.12	**4846.04**	**12574.99**	**714.52**	**11860.47**	**8460.84**	**487.47**	**8948.31**	**489.29**	**291.34**

3.1 Chemical quality of ground water and contamination**:** The ground water samples collected from the area are analysed for 12 parameters. They are pH, EC, TH, Ca, Mg, Na, K, Cl, F, HCO_3, NO_3 and SO_4. On the basis of the chemical analysis report of these samples, the following table has been prepared which indicates that in general the ground water in the area is potable and fit for all types of consumption except sporadic occurrence of nitrate at shallow depth which may be attributed to anthropogenic activities.

Table 11: Area affected by Salinity, Fluoride, Nitrate and Arsenic in Ground Water

Sl.No.	Parameter	Block/Area
1	EC > 3000 µS/cm	nil
2	Fluoride (>1.5mg/litre)	Nil
3	Nitrate (>45 mg/litre)	Bemetara/northern part
4	Arsenic (>0.05 mg/litre)	nil

3.2 Other issues like sustainability etc.

Issues related to groundwater in the area

i) Drying up of Dugwells during pre-monsoon.
ii) Lowering of Water Level during Pre-monsoon. (Decadal 2 to 5m)
iii) Deepening of common development depth for ground water withdrawal from 50 m to 150 m for tubewells.
iv) The stage of Ground Water Development stands at 75.48 in Bemetara block leading to it's categorization as "Semi-Critical"

Reasons for Excessive ground water draft for agricultural use:
i) Ground Water Draft for Irrigation is 8460.84 Ham which is 95% of Gross draft
ii) Availability of Potential Aquifer: Maniyari shale covering about 70.3% of the area being very productive with borewell discharge ranging from 3 to 18 lps.
iii) Availability of Power in rural area: In 2014-15, the power production capacity in the state touched 16,000 MW with the contribution of both public and private sector power plants. In Chhattisgarh, power available at subsidized cost has been continuously leading to long duration and uncontrolled pumping of ground water withdrawal.

4.0 Aquifer wise space available for recharge and proposed interventions

The volume of pore space in the formation available for recharge in the unsaturated zone of Aquifer A up to a desirable depth (say 3 mbgl) is 58.756 x 10^6 m^3 considering the void space depth is 7.4 m, area of the block is 794 sq. km and the specific yield of shale as 0.01.
Similarly, the volume of pore space in the formation available for recharge in the unsaturated zone of Aquifer B up to a desirable depth (say 3 mbgl) is 146.89 x 10^6 m^3 considering the void space depth is 7.4 m, area of the block is 794 sq. km and the specific yield of shale as 0.025.
This is summarized in Table 12.

Table 12: Summarized detail of Volume of porous space available for recharge in Aquifer A & B

Formation	Area (sq.m)	Water Level (upto 3 mbgl) in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space available for recharge (m3)
Shale	794 x 10^6	7.4	0.01	58.756 x 10^6
Limestone & Dolomite	794 x 10^6	8.5	0.025	168.725 x 10^6

Rain water being the only primary source for recharge, it has been calculated that shale aquifer may be recharged about 41.1292 x 10^6 m^3 assuming the average annual rainfall as 1592 mm (average of last 3 years) and the infiltration factor of shale as 0.03-0.05 (say 0.04).
Similarly, in the limestone as well as dolomite aquifer, it has been calculated that shale aquifer may be recharged about 61.6938 x 10^6 m^3 assuming the average annual rainfall as 1592 mm (average of last 3 years) and the infiltration factor of shale as 0.06.This is summarized in Table 13.

Table 13: Detail of Volume (of porous space available for further recharge in Aquifer A & B

Formation	Area (sq.m)	Annual (average of last three years) rainfall (m)	Infiltration Factor for the formation	Volume of porous space recharged directly through rainwater (m^3)	Volume of porous space left for further recharge through other methods (m^3)
Shale	794 x 10^6	1.295	0.04	41.1292 x 10^6	17.6268 x 10^6
Lst & Dolomite	794 x 10^6	1.295	0.06	61.6938 x 10^6	107.0312 x 10^6

To meet the requirement for further recharge in both the aquifers as indicated in table 15, artificial recharge of groundwater through different methods is necessary. For this purpose, certain artificial recharge structures are to be constructed in the area in both the formations in the

area covering Jeori, Farri, Piparbhata villages located in Bemetara block, the detail of which is presented in table 14.

Table 14: Detail of artificial recharge structures suggested in Bemetara block area

Block	Percolation Tank	Nala Bund & Check Dam	Recharge Shaft	Gully Plug
Bemetara	41	138	248	331

Source; Master plan of Chhatisgarh

5.0 Change in cropping pattern

Paddy is extensively cultivated (88% of total cropped area) in Bemetara block during the Rabi season using huge quantity (89% of total irrigated area) of groundwater through pumping. As paddy requires more water than wheat, change in cropping pattern may be adopted during cultivation in Rabi season, thus saving ground water to some extent which can be discerned from table 15.

Table 15: Detail of groundwater saved through change in cropping pattern

Paddy cultivation area in Rabi season (ha)	Water required (m) per ha (m)		Difference (m)	Total saving of water (ham)
	Paddy	Wheat		
1500	1.5	0.5	1	1550

5.1 Alternate Water Sources

5.1.1 Land Levelling:

Also irrigation water can be saved to some extent (about 15%) through leveling of land through which the irrigation canal passes. This in turn will reduce the deficit between the demand and supply of water and thus the extraction of ground water will be minimized to some extent.

5.1.2 Transfer of ground water from adjoining blocks:

The stage of groundwater development in Bemetara block is 75.45% and hence it has been categorized as “Semi-critical”. In order to avoid further deterioration as well as to bring it back to “Safe” category, groundwater may be transferred on long term basis from adjoining blocks without deterioration of their groundwater scenario.

BLOCK-WISE AQUIFER MAPS AND MANAGEMENT PLANS

Salient Informations:

1. Block : Saja

Area: 810 sq. km

District/State: Bemetara/ Chhattisgarh

Population: The total population of Saja block as per 2011 Census is 117436 out of which rural population is 102077while the urban population is only 15359 comprising 58655 males and 58781females. The Block wise population break up i.e. rural- urban, male- female is given below

Table 1 Population Break Up

Tehsil	Total population (No)	Male (No)	Female (No)	Rural population (No)	Urban population (No)
Saja	117436	58655	58781	102077	15359

Source: CG Census, 2011

Rainfall

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. The average annual rainfall for the study area is around 1255 mm (Average of the last three years i.e. 2012 to 2014).
Annual rainfall in Saja Block for the period of three years from 2012 to 2014 is presented below

Table 2 Annual Rainfall (mm) in Saja Block for the years (2012 to 2014)

District/Tehsil	2012	2013	2014	Average of 3 years for the block
Saja	1123	1466	1175	1255

Source: IMD

Agriculture and Irrigation

Agriculture is practiced in the area during kharif and Rabi season every year. During the Kharif, cultivation is done through rainfall while during the Rabi season, It is done through ground water as well as partly through surface water like ponds and other sources. The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops in the block are Rice, Wheat along with Pulses, Tilhan, Fruits and Vegetables etc. In some areas, double cropping is also practiced. The agricultural pattern,cropping pattern and area irrigated data of Saja block is given in Table 3 (A,B,C).

Table 3A Agricultural pattern in Saja Block during the year 2013-14 (in ha)

Tehsil	Total geographical area	Revenue forest area	Area not available for cultivation	Non agricultural & Fallow land	Agricultural Fallow land	Net sown area	Double cropped area	Gross cropped area
Saja	45100	0	3840	3454	322	36917	24969	61886

Table 3B Cropping pattern in Saja Block during the year 2013-14 (in ha)

Tehsil	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits/ Vegetables	Reshe	Mirch Masala	Sugar-cane
			Wheat	Rice	Jowar & Maize	Others						
Saja	34791	61886	2727	23092	0	41	23747	8777	3173	6	5	310

Table 3 C Area irrigated by various sources in Saja Block during the year 2013-14 (in ha)

Tehsil	No. of canals (private and Govt.)	Irrigated area	No.of bore wells/ Tube wells	Irrigated area	No. Of dug wells	Irrigated area	No. of Talabs	Irrigated area	Irrigated area by other sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of irrigated area wrt. Net sown area
Saja	11	14822	4123	15955	322	68	50	1298	79	15182	17040	32222	52

Groundwater Resource Availability and Extraction

Based on the resource assessment made the dynamic ground water resources of Sajja block is given below. Table-4

Block	Resource	Aquifer I A	Aquifer I B	Total
Saja	Dynamic	57.80	26.61	84.41
	In-Storage	93.74	43.15	136.89

Existing and Future Water Demand (2025)

The existing demand for irrigation in the area is 6527.78 Ham while the same for domestic and industrial field is 275.09 Ham. To meet the future demand for ground water, a total quantity of 1632.84 ham of ground water is available for future use.

Water Level Behavior

Pre- monsoon water level: In the pre-monsoon period, it has been observed that in Saja block, in Shale formation the minimum water level is 2.90 mbgl while the maximum is 12.10 mbgl. In Dolomite formation the minimum water level is 2.80 mbgl while the maximum is 12.7 mbgl. . In Limestone formation the minimum water level is 3.20 mbgl while the maximum is 16.50 mbgl.

Table 5: Aquifer wise Depth to Water Level (Pre-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Saja	2.90	12.10	2.80	12.70	3.20	16.50

Water Level (in mbgl)

Post- monsoon water level: In the post-monsoon period, it has been observed that in Saja block, in Shale formation the minimum water level is 1.30 mbgl while the maximum is 11.90 mbgl. In Dolomite formation the minimum water level is 1.80 mbgl while the maximum is 9.50 mbgl. . In Limestone formation the minimum water level is 1.80 mbgl while the maximum is 10.50 mbgl.

Table 6: Aquifer wise Depth to Water Level (Post-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Saja	1.30	11.90	1.80	9.50	1.80	10.50

Water Level (in mbgl)

Seasonal water level fluctuation: The water level fluctuation data indicates that in Saja block, in Shale formation the minimum water level fluctuation is 0.2 mbgl while the maximum is 7.7 mbgl. In Dolomite formation the minimum water level fluctuation is 0.2 mbgl while the maximum is 7.8 mbgl. In Limestone formation the minimum water level fluctutation is 0.1 mbgl while the maximum is 6.6 mbgl.

Table 7: Aquifer wise Depth to Water Level Fluctuation (Pre-monsoon vs Post-monsoon)

Block Name	Shale		Dolomite		Limestone	
	Min	Max	Min	Max	Min	Max
Saja	0.2	7.7	0.2	7.8	0.1	6.6

Water Level (in mbgl)

2. Aquifer Disposition

Geologically, the study area comprises of rocks of Meso to Neo-Proterozoic sequence and is represented by the Chhattisgarh Supergroup consisting of the Raipur Group of rocks. In the study area, Raipur Group of rocks of Precambrian sedimentary province is represented predominantly by Maniyari Formation and Tarenga Formation and also partly covered by Hirri Dolomite as well as Chandi formations underlain occasionally by the Khamaria Pebble Bed of Quaternary age.

Maniyari Formation: This Formation consists of gypsiferous grey siltstone and shale and followed upward by reddish brown calcareous and non-calcareous shale with limestone and dolomite. The red shale is less fissile. The laminated grey shale is composed of clay and silt. The alternate clay and silt define the laminated character. The terrain is generally gently sloping plain terrain. Because of its marine origin and calcareous nature, this formation is highly porous and permeable. It also possesses gypsum veins and lenses which easily get dissolved and creating thereby innumerable interconnected cavities/cavernous zones. These interconnected cavities/cavernous zones in this formation are acting as storage reservoirs and conduit system for accumulation and movement of ground water and thus making it very high in ground water

potential. It is having potential in the order of 3-18 lps (litres per second) with transmissivity value of 69 – 1500 m^2/ day.

Tarenga Formation: This Formation comprises predominantly an argillite-dolomite sequence. The shales are cherty and calcareous. This formation has good ground water potential at places. It has moderate potential in the tune of 1-5 lps with transmissivity value of 10 – 200 m^2/ day.

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Hirri Formation: This Formation comprises dark grey, bedded dolomite associated with light grey laminated argillaceous dolomite. This formation has also less ground water potential in the order of 1-3 lps (litres per second) with transmissivity value of 69 – 1500 m^2/ day.

Chandi Formation: This Formation comprises a dominant stromatolitic limestone sequence. The bottom most (Newari member) comprises of stromatolitic limestone and dolomite which is pink to light grey in colour and thickly bedded followed by dark grey flaggy limestone (Pendri member) with intercalations of calcareous shale and Deodongar sandstone of lensoid shape. The topmost unit (Nipania member) comprises of pink to purple dolomitic limestone. Towards upper part it changes into bedded limestone and purple shale and is devoid of stromatolitic structure. This formation has moderate ground water potential due to development of caverns at places. It yields in the order of 1-5 lps (litres per second) with transmissivity value of 1 – 400 m^2/ day.

Table 8: Block wise Distribution of Principal Aquifer Systems

Block	Shale	%	Dolomite & Limestone	%	Total Area	%
Saja	506.70	31.58	303.22	18.90	810.0	50.5

3.0 Ground water Resource,extraction contamination and other issues

Table.9 Aquifer wise resource availability and extraction

SL. No	District	Assessment Unit / Block	Recharge From Rain Fall During Monsoon Season in Ham	Recharge From Other Sources During Monsoon Season in Ham	Recharge From Rain Fall During Non Monsoon Season in Ham	Recharge From Other Sources During Non Monsoon Season in Ham	Total Annual Recharge in Ham (4+5+6+7)	Natural Discharge During Non Monsoon Period In Ham	Net Ground Water Availability in Ham (8-9)	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham (11+12)	Allocation For Domestic & Industrial Water Supply in Ham	Net Ground Water Availability for Future Irrigation Development in Ham (10-11-14)
1	Bemetara	Saja	5608.66	1084.31	660.53	2026.36	9379.86	937.98	8441.88	6527.78	275.09	6802.87	281.26	1632.84

Table 10 Categorization of Assessment Unit

Sl. No	District	Block	Stage of Ground water development (%)	Categorisation
2	Bemetara	Saja	80.58	Semi-Critical

The Saja block falls in semi-critical category. The stage of Ground water development is 80.58%. The Net Ground water availability (Ham) is 8441.88 Ham. The Ground water draft for all uses is 6802.87 Ham. The Ground water resources for future uses for Saja Block is 1632.84 Ham. There is little scope for further Ground water development.

Chemical Quality of Ground water and contamination

Hydrochemical Data

Results of chemical analysis

To know the hydro chemical behaviour of the ground water in the study area, 202 nos. of ground water samples were collected from the key wells and (NHNS) during pre-monsoon period of measurement (June, 2014).The ground water samples have been submitted in the chemical laboratory for analysis of 12 parameters. i.e pH, EC, TH, Ca, Mg, Na, K, Cl, F, HCO_3, NO_3 and SO_4. On the basis of the chemical analysis of the water samples collected from the existing wells (NHNS) in the area, the following table has been prepared.

Table 11: Area affected by Salinity, Fluoride, Nitrate and Arsenic in Ground Water

Sl.No.	Parameter	Block/Area
1	EC > 3000 μS/cm	nil
2	Fluoride (>1.5mg/litre)	Nil
3	Nitrate (>45 mg/litre)	nil
4	Arsenic (>0.05 mg/litre)	nil

All the parameters are within safe permissible limits. The ground water is suitable for all uses i.e domestic ,industrial and agricultural purposes.however in some areas in northern part of Bemetara district the nitrate content in ground water is above permissible limits. i.e (>45 mg/litre)

Other issues like sustainability etc. related to groundwater in the area

1.Drying up of Dugwells during pre-monsoon.
2.Lowering of Water Level during Pre-monsoon. (Decadal 2 to 5m)
3.Deepening of common development depth for ground water withdrawal from 50 m to 150 m for tubewells.
4.The stage of Ground Water Development stands at 80.58% in Saja block leading to it's categorization as " Semi-Critical"

Reasons for Excessive ground water draft for agricultural use:

i)Ground Water Draft for Irrigation is 6527.78 ham which is 95% of Gross draft
ii).Availability of Potential Aquifer: Maniyari shale covering about 70.3% of the area being very productive with borewell discharge ranging from 3 to 18 lps.
iii) Availability of Power in rural area: In FY 2014-15, the power production capacity in the state touched 16,000 MW with the contribution of both public and private sector power plants. In Chhattisgarh, power available at subsidized cost has been continuously leading to long duration and uncontrolled pumping of ground water withdrawal.

4.0 Aquifer wise space available for recharge and proposed interventions

The volume of formation available in the unsaturated zone of Aquifer A up to a desirable depth (say 3 mbgl) is 59.94 x 10^6 m^3 considering the void space depth is 7.4 m and the block area is 810 sq. km. Assuming the specific yield of shale as 0.01, the volume of pore space available in the unsaturated zone in the shale aquifer comes to 59.94 x 10^6 m^3.

Similarly, the volume of formation available in the unsaturated zone of Aquifer A up to a desirable depth (say 3 mbgl) is 172.125 x 10^6 m^3 considering the void space depth is 8.5 m and the block area is 810 sq. km. Assuming the specific yield of limestone and dolomite as 0.025, the volume of pore space available in the unsaturated zone in the shale aquifer comes to 172.125 x 10^6 m^3. This is summarised in Table 12

Table 12 Summarised detail of Volume of porous space available for recharge in Aquifer A & B

Formation	Area (sq.m)	Water Level (upto 3 mbgl)in unsaturated zone (m)	Sp. Yield for the formation	Volume of porous space for recharge (m3)
Shale	810 x 10^6	7.4	0.01	59.94 x 10^6
Lst & Dolomite	810 x 10^6	8.5	0.025	172.125 x 10^6

Rain water being the only primary source for recharge, it has been calculated that shale aquifer may be recharged about 40.662 x 10^6 m^3 assuming the average annual rainfall as 1255 mm (average of last 3 years) and the infiltration factor of shale as 0.03-0.05.
Similarly, in the limestone as well as dolomite aquifer, it has been calculated that shale aquifer may be recharged about 60.993 x $10^6 m^3$ assuming the average annual rainfall as 1255 mm (average of last 3 years) and the infiltration factor of shale as 0.06. The volume of pore space left for further recharge through other means in shale aquifer is 19.278 x 10^6 m^3 for lime stone/Dolomite aquifer volume of pore space available is 111.132x 10^6 m^3 .This is summarised in Table 13.

Table 13: Detail of Volume (of porous space available for further recharge in Aquifer A & B

Formation	Area (sq.m)	Annual (average of last three years) rainfall (m)	Infiltration Factor for the formation	Volume of porous space recharged directly through rainwater (m3)	Volume of porous space left for further recharge through other methods (m3)
Shale	810 x 10^6	1.255	0.04	40.662 x 10^6	19.278 x 10^6
Lst & Dolomite	810 x 10^6	1.255	0.06	60.993 x 10^6	111.132x 10^6

To meet the requirement for further recharge in both the aquifers as indicated in table 12, artificial recharge of groundwater through different methods is necessary. For this purpose, in the Saja Block in the eastern part at Gotwani, Keshtara, Khamdihi, Lalpur, towards north Thelka and Bodka, towards south Tendubhata, Mohagaon, towards west Rampura, Sambalpur, Bharda, Tiriabhata certain artificial recharge structures are to be constructed. the detail of which is presented in table 14.

Table 14: Details of artificial recharge structures suggested in Saja block area

Block	Percolation Tank	Nala Bund & Check Dam	Recharge Shaft	Gully Plug
Bemetara	40	135	242	323

Source; Master plan of Chhatisgarh

5. Change in cropping pattern

Paddy is extensively cultivated (88% of total cropped area) in Saja block during the Rabi season using huge quantity (89% of total irrigated area) of groundwater through pumping. As paddy requires more water than wheat, change in cropping pattern may be adopted during cultivation in Rabi season, thus saving ground water to some extent which can be discerned from table 15.

Table 15: Detail of groundwater saved through change in cropping pattern

Paddy cultivation area in Rabi season (ha)	Water required (m) per ha (m)		Difference (m)	Total saving of water (ham)
	Paddy	Wheat		
58	1.5	0.5	1	58

Land Levelling:

Also irrigation water can be saved to some extent (about 15%) through leveling of land through which the irrigation canal passes. This in turn will reduce the deficit between the demand and supply of water and thus the extraction of ground water will be minimized to some extent.

.**Transfer of ground water from adjoining blocks:**

The stage of groundwater development in Saja block is 80.58 % and hence it has been categorized as “Semi-critical”. In order to avoid further deterioration as well as to bring it back to “Safe” category, groundwater may be transferred on long term basis from adjoining blocks without deterioration of their groundwater scenario.