केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Baloda Bazar District
Chhattisgarh

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattisgarh Region, Raipur

भारत सरकार

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जल शक्ति मंत्रालय, जल संसाधन, नदी विकास एवं गंगा संरक्षण बिभाग

Ministry of Jal Shakti, Water Resources, River Development & Ganga Rejuvenation Dept.

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Central Ground Water Board

बलौदा बाजार जिला, छत्तीसगढ़ के जलभृत नक्शे एवं भूजल प्रबंधन योजना

AQUIFER MAPPING AND MANAGEMENT PLAN REPORT BALODA BAZAR DISTRICT, CHHATTISGARH

By

Anusandhya Pradhan

Scientist B

केन्द्रीय भूमि जल बोर्ड

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सत्यमेव जयते

A REPORT ON

AQUIFER MAPPING & MANAGEMENT PLAN 2021-2022 IN BALODA BAZAR DISTRICT CHHATTISGARH

PREPARED BY

Miss Anusandhya Pradhan

Scientist B

UNDER THE SUPERVISION OF

Mrs Prachi Gupta

Scientist B

FOREWORD

Groundwater resources are being developed over years in order to meet domestic, irrigation and industrial requirements. The spatial distribution of availability of ground water resources however, is uneven and is being indiscriminately exploited by various users thereby creating relentless pressure. On the other hand, rapid urbanization, industrialization and land use changes has resulted decline of water levels in many parts of the country.

There is an urgent need for scientific approach for proper management of the available ground water resources for sustainability of this precious natural resource for present and future generation.

Central Ground Water Board has been in the forefront of activities for occurrence, development, and management of this resource through various scientific studies and techniques. Over the last four decades CGWB, NCCR, Raipur has gathered a huge amount of data regarding ground water resources of Chhattisgarh. Based on this experience aquifer mapping of Baloda Bazar district was prepared with the vast amount of data generated and available with North Central Chhattisgarh Region. The report embodies all the features of ground water and related aspects of the study area including physiography, meteorological conditions, hydrology, drainage, geomorphology, geology, hydrogeology, ground water resources, hydrochemistry, geophysics, ground water problems etc.

The report titled "A REPORT ON AQUIFER MAPS AND GROUNDWATER MANAGEMENT PLAN OF BALODA BAZAR DISTRICT, CHHATTISGARH" is prepared by Anusandhya Pradhan, Scientist-B under supervision of Prachi Gupta, Scientist-B. I appreciate the concerted efforts put by the author to make it possible to bring the report in its present shape. I hope this report will no doubt be useful and worthy for the benefit of Baloda Bazar and would be a useful document for academicians, administrators, planners and all the stakeholders in ground water.

Though utmost care has been taken to minimize the errors, some errors may have inadvertently crept in. It is expected that these mistakes will be taken in the proper spirit.

Dr. P. K. Naik
(REGIONAL DIRECTOR)

EXECUTIVE SUMMARY

Aquifer mapping 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. 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. Volumetric assessment of ground water and strategies for future development and management are the primary objectives of aquifer mapping.

Under the aquifer mapping Programme, Baloda Bazar District was taken up for study covering an area of 4509 sq. km. It falls in the Survey of India's Degree Sheet No. 64 G and 64 K between the East longitudes 81.6601 & 82.9857 and by North latitudes 21.8848 & 21.2622. The study area is surrounded by Raipur and Mahasamund districts on the south, Bemetara district in the west, Bilaspur and Janjgir-Champa district in the north, Raigarh and Mahasamund districts in the east. The district has a well-developed road network.
The total population of the study area as per 2011 Census is 1305343. The study area experiences sub-tropical climate. The average annual rainfall for the study area is around 993.5 mm (According to the latest data available in Directorate of Economics and Statistics site, Government of Chhattisgarh).

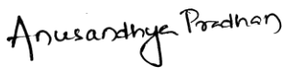
Geomorphologically the study area displays dissected pediplain made by Proterozoic shale- limestone dolomite area and Structural/Denudational hills and valleys which comes under the physiographic unit belonging to Chhattisgarh basin area.

The net sown area is 232581 Ha, while double-cropped area is 30169 Ha. The gross cropped area of the district is 261849 Ha. The net Irrigated cropped area is 94587 Ha, while the area under groundwater irrigation is 36575 Ha which is about 21.47 % of net cropped area.

Based on the exploratory drilling data generated for the block, the existing aquifer systems in the area may be divided into phreatic and fractured aquifer. The major aquifers present in the study area are Limestone and sandstone. Charmuria limestone and Gunderdehi shale are not very good yielding. Cavernous limestone of Chandi formation forms the good aquifer in the district. The alluvium blanket along the major rivers also form good repository of ground water.
As per 2020 ground water resource calculation stage of ground water development in the study area is only 41.45 %. So, there is broad scope of utilizing more ground water for future irrigation purpose and other purposes. There is also a need to focus more on sustainable development and management of groundwater. Artificial recharge should be carried out.

The major ground water issues identified during the survey in the study area are as follows: (i) Drying of Dug wells and handpumps during summer. (ii) Inherent hydrogeological character of aquifer. (iii) Drilling difficulties in limestone terrain. During pre-monsoon period, the water level is found to be deepest mostly in western and some parts in southern portion of the district. Similarly

during post-monsoon period deeper water level is observed in western and southern parts of the district. The deeper water level is occurring in areas where the ground water is being exploited heavily by construction of bore wells for irrigation purpose. Such irrigation bore wells are found in large number in the northern parts of Bhatapara and Simga.So far as Management strategies are concerned for ground water availability, for effective utilization of Ground water existing draft for irrigation may be coupled with micro irrigation system. Change in irrigation pattern, optimum use of available resource, use of ground water potential created after artificial recharge can lead to groundwater savings and increase in gross cropped area of the block.



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Acknowledgment

I would like to take an opportunity to thank ***Shri Sunil Kumar, Chairman, Central Ground Water Board*** *for giving an opportunity for preparation of Aquifer Map and Management plan of Baloda Bazar district of Chhattisgarh* ***and Shri Sateesh Kumar Member (East), CGWB*** *for giving valuable guidance, encouragement and suggestions during the preparation of this report. The author is thankful to* ***Dr. P. K Naik, Regional Director, Central Ground Water Board, NCCR, and Raipur*** *for extending valuable guidance and constant encouragement during the preparation of this report. I am very much delighted to express my deep sense of gratitude and regards to* ***Sh. A.K. Biswal, Scientist-E*** *for his continuous guidance and support during preparation of this report. I am deeply thankful to* ***Smt. Prachi Gupta, Scientist-B*** *for their valuable and meticulous guidance while preparing aquifer maps, 3-d disposition of aquifers and also for their constant encouragement, inspiration, affectionate supervision that I received continuously from her. I am also thankful to* ***Shri Rakesh Dewangan, Scientist-B*** *for the chemical analysis and valuable inputs on quality issues. The efforts made by* ***Sh. T.S. Chouhan, Draftsman*** *for digitization of maps are thankfully acknowledged. The author is also thankful to the state agencies for providing the various needful data. The author is thankful to Technical Section, Data Centre, Chemical Section, Report Processing Section and Library of CGWB, NCCR, Raipur for providing the various needful data. The help and co-operation of staffs of CGWB, NCCR, and RAIPUR is greatly recognizable. Their keen devotion and tenacity at work provided the necessary inspiration and courage to stand up to the winds of hope just as a sprouting seedling looks up towards the trees and dreams of becoming one. Last but not least, I would like to acknowledge my family members for their unselfish sacrifices, constant blessing and moral support at every stage.*

Anusandhya Pradhan

(Anusandhya Pradhan)

Scientist B

CGWB, NCCR, Raipur

AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN,

BALODA BAZAR DISTRICT, CHHATTISGARH

(06) BLOCKS- Baloda Bazar, Bhatapara, Bilaigarh, Simga, Palari & Kasdol Block)

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ABBREVIATIONS

a msl	above mean sea level
BDR	Basic Data Report
BW	Bore well
CGWB	Central Ground Water Board
Dia	Diameter
DTW	Depth to Water level
DW	Dug well
EC	Electrical Conductivity
EW	Exploratory Wells
GS	Gabion structures
GW/ gw	Ground Water
Ham	Hectare meter
HP	Hand pump (Shallow)
Lpcd	liters per capita per day
Lpm	liters per minute
Lps	liters per second
M	Meter
m bgl	meter below ground level
m2/day	Square meter/ day
m3/day	cubic meter/day
MCM/mcm	Million Cubic Meter
NCCR	North Central Chhattisgarh Region
NHNS/ NHS	National Hydrograph Network Stations
OW	Observation Well
PZ	Piezometer
STP	Sewage Treatment Plan
T	Transmissivity
TW	Tube well

1. INTRODUCTION

The total volume of fresh groundwater stored on Earth is between 8 and 10 million km3, and 96% of non-frozen freshwater. Groundwater provides almost 50% of all drinking water worldwide and 43% of all consumptive use of water for irrigation in agriculture. Changes in groundwater availability and quality impact human health, livelihoods, food security and national economic development. Many aquatic ecosystems and their biodiversity depend on groundwater. Failure to manage groundwater sustainably puts at risk massive benefits for human well-being, sustainable development and biodiversity conservation. The long-term viability of irrigation-based economies in our country is threatened, creating long-term risks for global food security. Over-exploitation of groundwater and contamination threatens drinking water supply for hundreds of millions of people. Degradation of groundwater reduces resilience of communities and economies to climate change.

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 involved in Hydrogeological investigations; major part of the country has been covered. 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. Volumetric assessments of ground water and strategies for future development and management, these reports are available for most parts the country in different 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.

1.1.Purpose and Scope

Abstraction of groundwater has at least tripled over the last 50 years in our country. Groundwater levels have declined significantly in major aquifers, reducing stream flows and causing the degradation of riparian and wetland ecosystems. 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 aquifer maps are the maps depicting aquifer disposition, giving lateral and vertical extension. The maps will also provide information on the quantity and quality. Aquifer mapping study is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and quality data is integrated to characterize the aquifers along with quantity, quality and movement of ground water in it. The purpose of aquifer mapping is to explore the ground water potentiality at depth up to 200m in hard rock area and 300m in soft rock area. The methodology includes historical data collection, compilation, analysis of data gap, data generation and followed by ground water management.

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. They 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, can vary locally and over time respectively. This variability in the data sometimes requires subjective decision-making and generalizing of information for an entire aquifer.

Under the aquifer mapping program, Baloda Bazar district covering an area of 4509 sq. km was taken up during the FY 2021-22.The area is covered in the Survey of India's Topo Sheet Nos. 64G and 64G K (1:50000 Scale) and fall lays between the East longitudes 81.6601 & 82.9857 and by North latitudes 21.8848 & 21.2622.

1.2 Location, Extent and Accessibility

The study area covers an area of 4509 sq. km. It is situated in the eastern part of Chhattisgarh state. It falls in the Survey of India's Topo Sheet Nos. 64G and 64K (1:50000 Scale) and fall lays between the East longitudes 81.6601 & 82.9857 and by North latitudes 21.8848 & 21.2622.

The study area is surrounded by Raipur and Mahasamund districts on the south, Bemetara district in the west, Bilaspur and Janjgir-Champa district in the north, Raigarh and Mahasamund districts in the east (**Fig 1**). The district has a well-developed road network.

1.3 Administrative Division

Table 1(A) Geographical location of the study area

Study Area	Area (Sq Km)	Latitude		Longitude		Toposheet No (1:50000 Scale)
		From	To	From	To	
Baloda Bazar	4509	21.2622	21.8848	81.6601	82.9857	64 G & 64 K

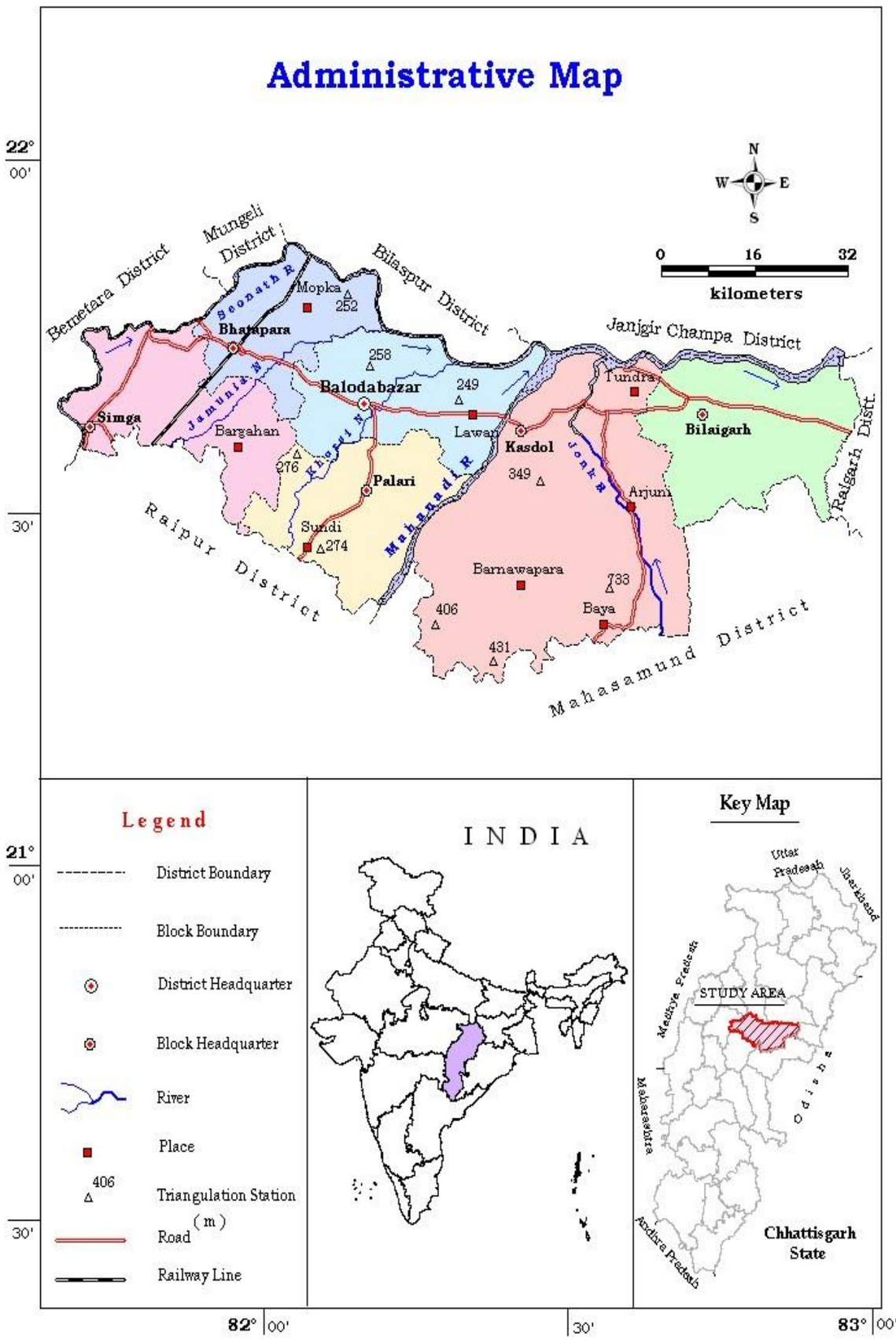
Table 1(B) Administrative Divisions of the Area

Sl No	Name of Block	District	Area (Hectare)
1	Baloda Bazar	Baloda Bazar	62320
2	Bilaigarh	Baloda Bazar	92692
3	Palari	Baloda Bazar	59468
4	Bhatapara	Baloda Bazar	47115
5	Kasdol	Baloda Bazar	176339
6	Simga	Baloda Bazar	61506

Table 1(C) Administrative Set Up of the Area

Sl. No.	Organizational Unit	Details of Organizational Unit
1	Sub Division	06 (Balodabazar, Bhatapara, Simga, Kasdol, Bilaigarh, Palari)
2	Tehsil	09 (Balodabazar, Bhatapara, Simga, Palari, Kasdol, Bilaigarh, Lawan, Suhela, Bhatgaon)
3	Sub Tehsil	02 (Nipniya, Sandi)
4	Block/Janpad Panchayat	06 (Balodabazar, Bhatapara, Simga, Palari,Kasdol, Bilaigarh)
5	Nagar Palika Parishad	02 (Balodabazar, Bhatapara)
6	Nagar Panchayat	07 (Simga, Palari, Lawan, Kasdol, Tundra, Bilaigarh, Bhatgaon)
7	Gram Panchayat	611
8	Total Village	961
9	Populated Village	940
10	Forest Village	61
11	Deserted Village	14

Fig.1 Administrative Map of the Study Area



1.4 Demography

According to 2011 census, Total Baloda Bazar population is 1305343 (Rural: 1139160, Urban: 166183) of which 651474 are male and 653869 are female. Literacy rate is 70.63%. Male literacy

is 82.795 and 58.57%. Population Density (Per Sq Km) is 349.60. Female-Male Ratio (Every 1000) is 1004. Population growth Rate (%) is 49.87.

The population break up i.e., rural- urban, male- female is given below in **Table 2**.

Table 2 Population break up

Population	Males	Females	Households
1305343	651474	653879	35466

Source: CG Statistical handbook- Census 2011

1.5 Pedology

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 three orders are found in study area. They are described below in brief and given in **Table 3**. The distribution of these two different soil types in the study area is presented in **Fig 2**.

Table 3 Soil Classification

Sl. No.	US soil taxonomy	Indian equivalents
1	Vertisol	Medium black soil
2	Ultisol	Lateritic soil
		Red and yellow soil
3	Alfisol	Red sandy soil
		Red loamy soil

A. Ultisols

The Indian equivalent of this soil found in Baloda Bazar district is Red and Yellow Soil. It is exposed in eastern and central part of the district vastly. 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. This clay has good bearing capacity and no shrink-swell property. They are red to yellow in colour and are quite acidic having pH less than 5. The red and yellow colour results from the accumulation of iron oxide which is highly insoluble in water.

B. Vertisols

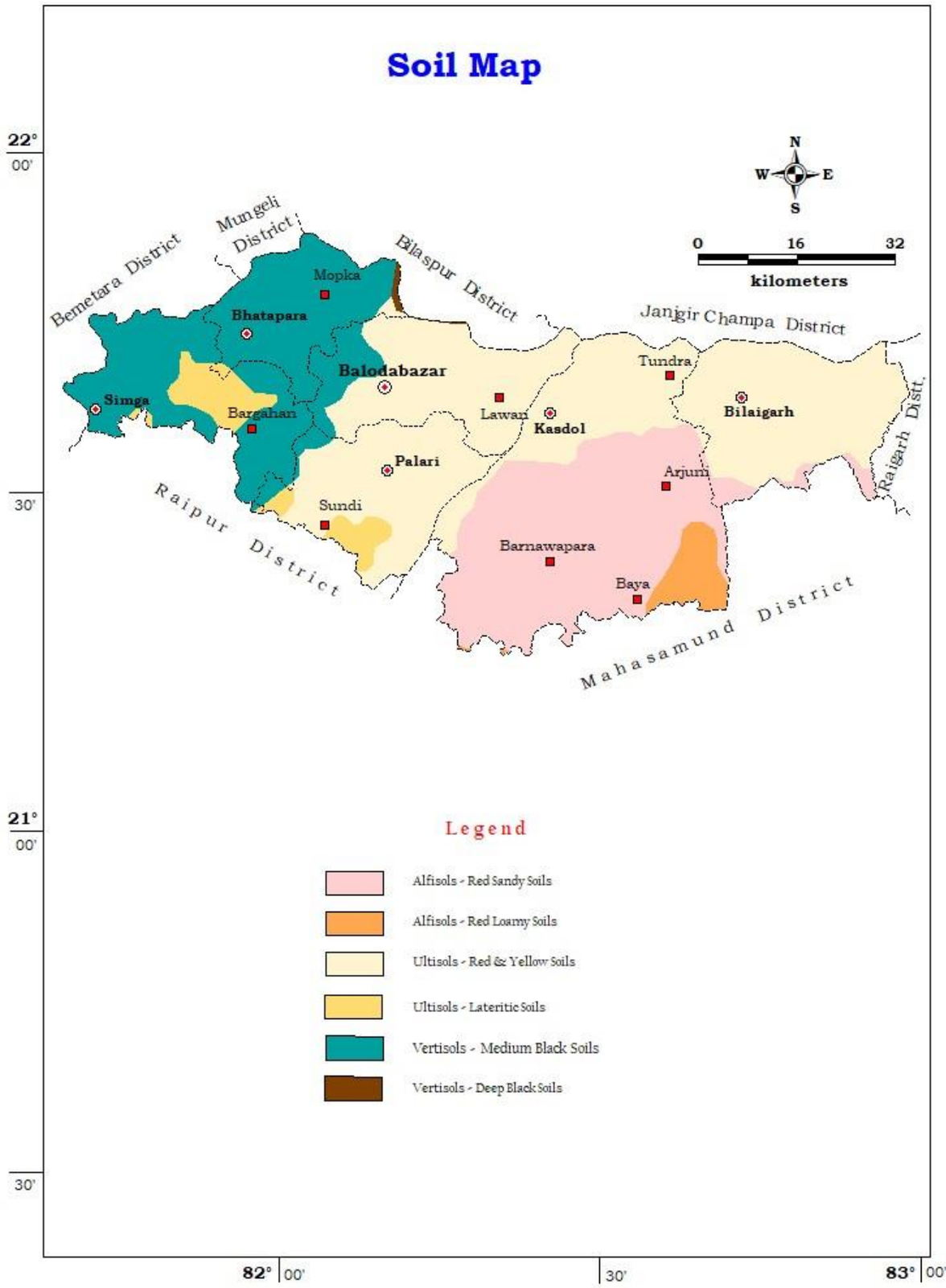
There are two types of Indian equivalent of this soil found in Baloda Bazar district namely medium black soil and deep black soil. They are exposed in major part of the block especially in western part. Vertisol is a soil in which the content of clay size particles is 30% or more by mass

in all horizons of the upper half-metre of the soil profile. They are characterized by a high content of expanding and shrinking clay known as montmorillonite. They may also be characterized by salinity and well defined layers of calcium carbonate or gypsum. Evidence of strong vertical mixing of the soil particles over many periods of wetting and drying can be observed in this type of soil. Vertisols typically form from highly basic rocks such as basalts and are found typically on level or mildly sloping topography in climatic zones that have distinct wet and dry seasons. Depending on the parent material and the climate, they can range from grey or red to the more familiar deep black. Vertisols contain high level of plant nutrients, but, owing to their high clay content, they are not well suited to cultivation without painstaking management. 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.

C. Alfisol

Alfisols are moderately leached soils that have relatively high native fertility. These soils have mainly formed under forest and have a subsurface horizon in which clays have accumulated. Alfisols are primarily found in temperate humid and subhumid regions of the world. The combination of generally favorable climate and high native fertility allows Alfisols to be very productive soils for both agricultural and silvicultural use. They are divided into five suborders: Aqualfs, Cryalfs, Udalfs, Ustalfs and Xeralfs. It is found mostly in south eastern part of the Baloda Bazar district.

Fig.2 Soil Map of the Study area



1.6 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 its impact on the local ground water regime. Rice is the major crop which is extensively cultivated during both Kharif and Rabi season. Wheat in some parts is also cultivated as Rabi crop.

Commercial Crops or Cash Crops are mostly taken over every year in the study area such as typical food and non-food cash crops like cereals, oilseeds, sugar cane, vegetables and fruits. While rain water is the only source during Kharif, the area is irrigated through ground water and other surface water sources during Rabi. The relevant data are presented in table 4(A, B, C).

Table 4(A) Agricultural pattern in Baloda Bazar District during the year 2018 (in ha)

District	Total geographical area	Revenue forest area	Area not available for cultivation	Agri culturable land	Agricultural Fallow land	Net Sown Area	Double cropped area	Gross cropped area
Baloda Bazar	450900	24611	36420	13806	18990	232581	30269	262849

*As per latest data available on State Govt site Directorate of Economics and Statistics, Chhattisgarh

Table 4(B) Cropping pattern in Baloda Bazar District during the year 2018(in ha)

District	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits / Vegetables	Reshe	Mirch Masala
			Wheat	Rice	Jowra & Maize (Resectively)	Other					
Baloda Bazar	232309	30540	3793	214556	0 & 349.39 respectively	28.61	18297	2652	11100	0	1584

*As per latest data available on State Govt site Directorate of Economics and Statistics, Chhattisgarh

Table 4(C) Area irrigated by various sources in Baloda Bazar District during the year 2018 (in ha)

District	No. of canals (Privat 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 Byother sources	Net Irrigated area	Irrigated area more than once	Gross Irrigated Area	% of irrigated area wrt. Net sown area
Baloda Bazar	6	90236	22065	19174	1608	1130	2193	996	1178	93743	10587	94587	40.30%

*As per latest data available on State Govt site Directorate of Economics and Statistics, Chhattisgarh

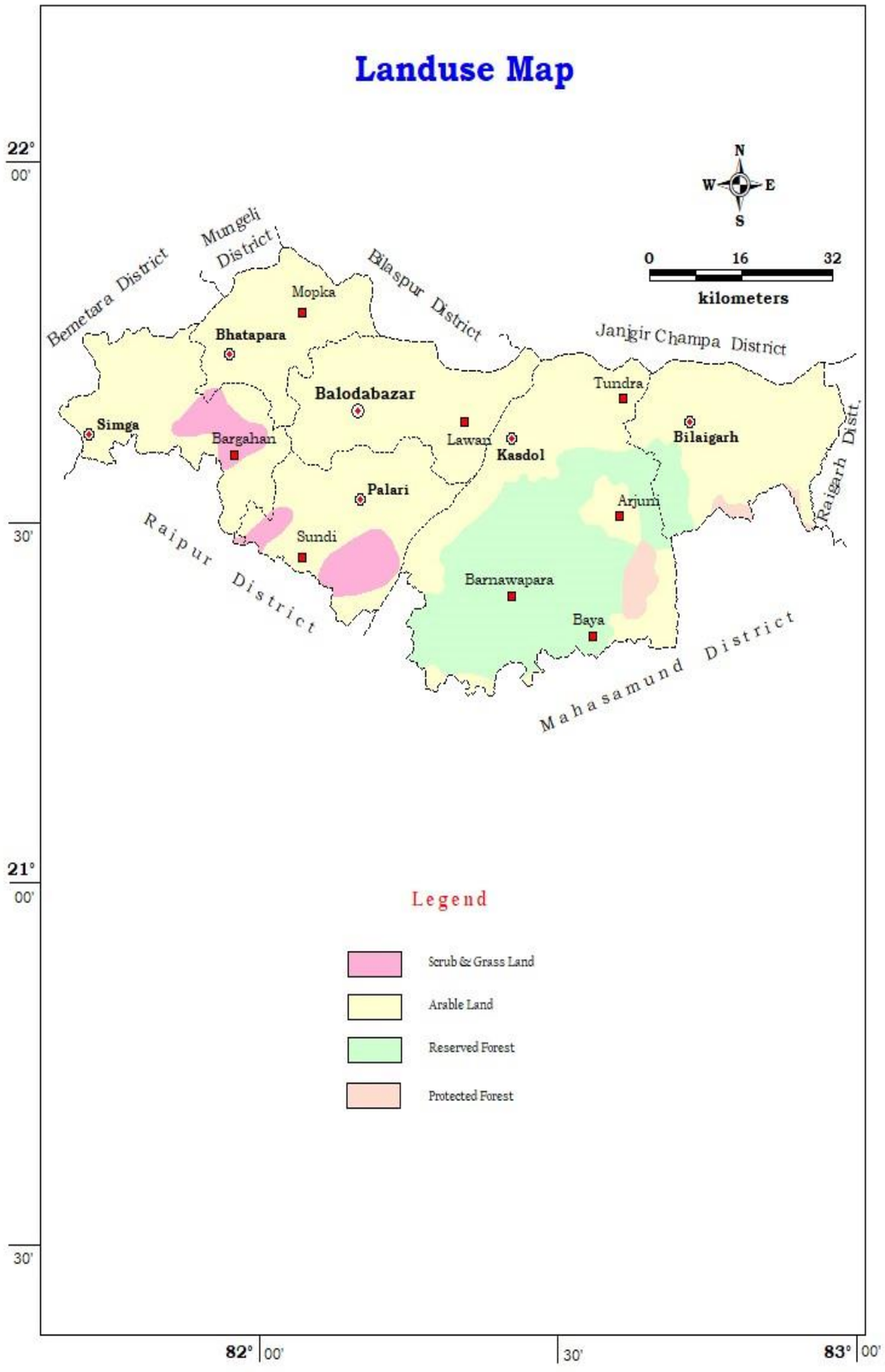
1.7 Land use

The Scrub land & Grass land, Reserved Forest land, Arable land and protected forest land in Baloda Bazar district is given in the following table.

Table 5: Land Use (Sq. Km)

District	Reserved Forest	Protected Forest	Other Forest	Scrub and Grass Land	Arable Land	Total Area
Baloda Bazar	1021	77.19	NA	235.48	3349	4682.67
Total area						4682.67

Fig.3 Land Use Map of the Study Area



1.8. Hydrometeorology

The study area experiences sub-tropical climate and is characterized by extreme summer and winter seasons. The summer months are from March to May and the months of April and May are the hottest. The rainy season extends from the month of June to September with well distributed rainfall through southwest monsoon. Monsoon generally breaks in the third week of June and is maximum in the months of July and August. Winter season is marked by dry and cold weather with intermittent showers during the months of December and January.

1.8.1 Temperature

The temperature in the study area changes continuously with the season and even in day and night. The temperature decreases progressively after October. The winter season lasts till February. January is the coldest month with mean daily maximum temperature at 30°C and the minimum is around 10°C. During winter season, the night temperature sometimes may drop below 10°C. The temperature increases rapidly from mid-February till May and sometimes up to mid-June (summer season). The mean daily maximum temperature in summer season goes up to 46°C and nights are slightly warmer during May and mid-June. The monsoon period is generally pleasant. With the withdrawal of the monsoon by the end of September, day temperature rises a little and then both day and night temperatures begin to drop rapidly.

1.8.2 Evaporation

The evaporation variations are almost sympathetic with the variations of temperature. The evaporation is maximum in the month of May and minimum during the months of December and January.

1.8.3 Humidity

The atmospheric humidity is usually low during summer months around 25%. However humidity slowly starts building up from third week of May and it reaches maximum around 85% during monsoon period. The humidity again decreases in winter season and it varies between 30 to 40% during winter season.

1.8.4 Wind Velocity

The wind flows easterly or westerly during the southwest monsoon period. During post-monsoon and winter seasons the wind directions are between north and east and sometimes westerly. The wind speed of more than 10 km/hr is recorded during the monsoon months (from June to September). In the post-monsoon and winter months (from October to February), the wind speed is less than 5 km/hr and in the summer months (March to May) the wind speed is more than 7 km/hr.

1.8.5 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 average annual rainfall for the study area is around 993.5 mm (Average of the last ten years i.e., 2012 to 2021).

Annual rainfall in all blocks of Baloda Bazar districts for the period of nine years from 2012 to 2021 is presented below in **Table 6**.

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.

Table 6 Annual Rainfall (mm) in Baloda Bazar district

Block/Tehsil	Year	Total
		In mm
Palari		
	2012	1016.0
	2013	1242.0
	2014	1223.3
	2015	736.4
	2016	812.2
	2017	580.5
	2018	968.6
	2019	973.0
	2020	869.0
	2021	764.0
Baloda bazar		
	2012	733.0
	2013	1196.8
	2014	1095.6
	2015	714.8
	2016	743.0
	2017	667.2
	2018	735.6
	2019	1016.3
	2020	805.1
	2021	1139.0
Bhatapara		
	2012	1018.2
	2013	1166.0
	2014	1354.0
	2015	816.8
	2016	996.4
	2017	1003.0
	2018	888.0
	2019	911.0
	2020	1211.0
	2021	903.0
Bilaigarh		
	2012	1288.0
	2013	1351.0
	2014	1424.2
	2015	613.6
	2016	599.0
	2017	622.4
	2018	728.0

	2019	886.0
	2020	919.0
	2021	785.0
Simga		
	2012	1019.2
	2013	1544.8
	2014	1401.4
	2015	1085.4
	2016	990.2
	2017	807.6
	2018	1289.2
	2019	1193.6
	2020	961.0
	2021	939.0
Kasdol	2012	1070.0
	2013	1346.0
	2014	1415.4
	2015	936.0
	2016	841.0
	2017	743.0
	2018	940.0
	2019	975.0
	2020	1616.0
	2021	1272.0

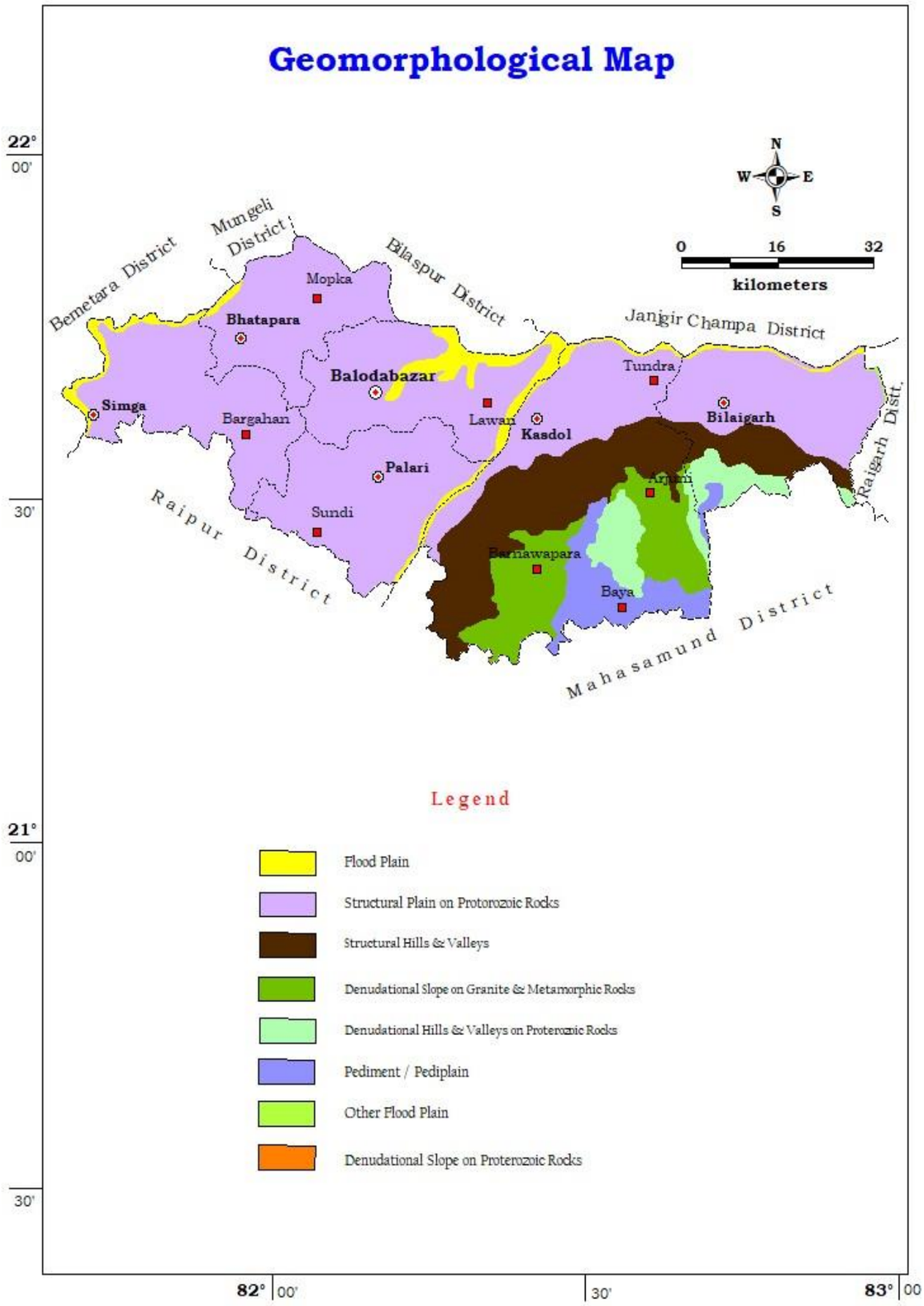
Source: *IMD*

1.9 Geomorphology and Drainage

1.9.1 Geomorphology

Geomorphologically the study area exhibits structural plain 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, north western and 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 northern, north-western, central and north-eastern part. It is formed by extensive deposition of alluvium by major river system in the block. 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. Other geomorphic features the study area also has are structural hills and valleys, pediplain, denudational slopes**. Fig 4** shows the Geomorphology in the study area.

Fig.4 Geomorphology Map of the Study area

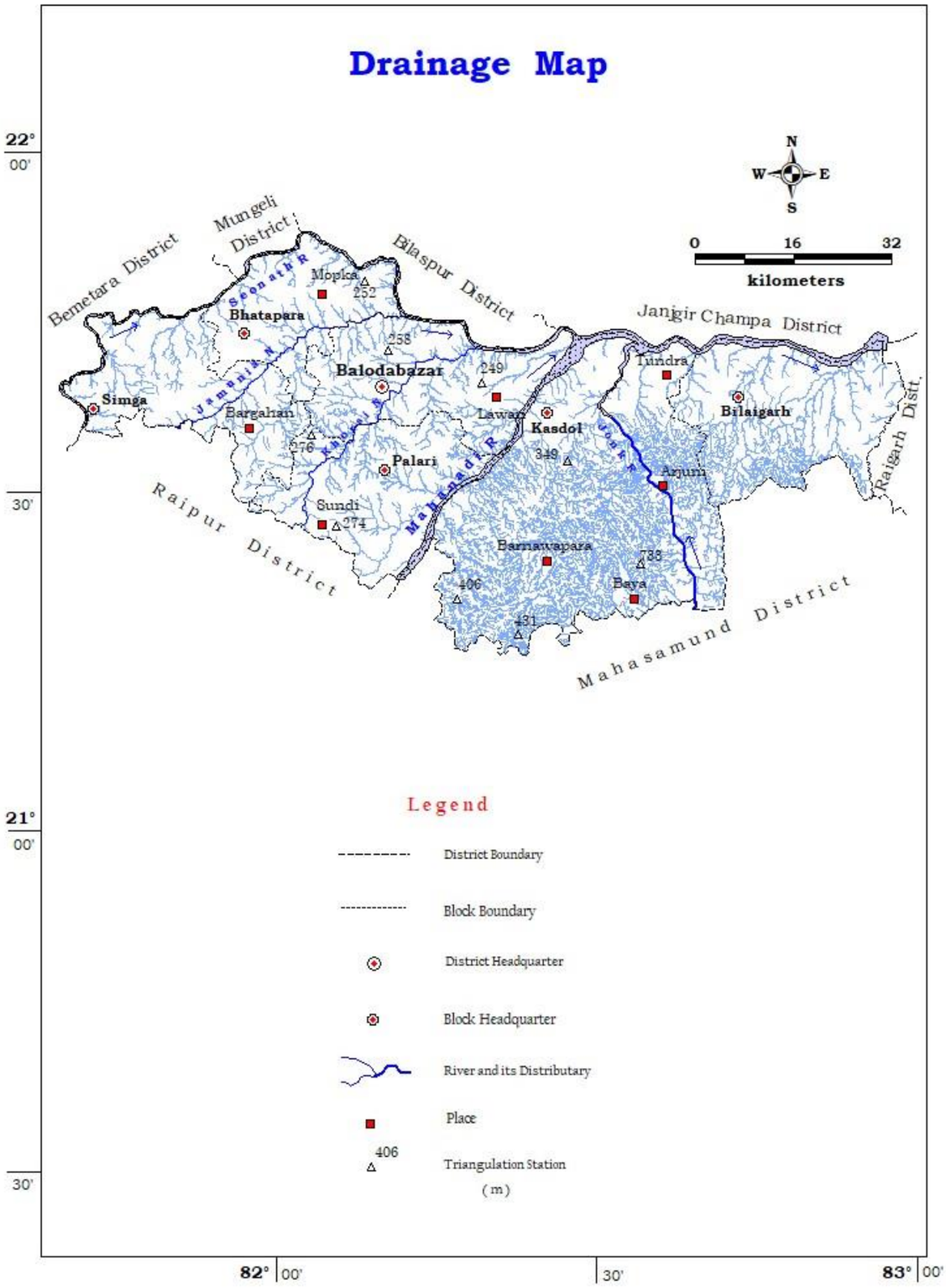


1.9.2 Drainage

The study area is mainly drained by Mahanadi River and its distributaries and tributaries. The area hence falls under Mahanadi river basin. Sheonath river, is the longest tributary to Mahanadi, flows through the upper north western peripherial part of the district along with its tributaries.

The drainage map is prepared and presented in **Fig 5.** From the figure, 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 except in south -eastern and eastern central part. The drainage density is found comparatively high in this area which is attributed to steep slope or non-planar area indicating somewhat high runoff and lower infiltration.

Fig.5 Drainage Map of the Study area



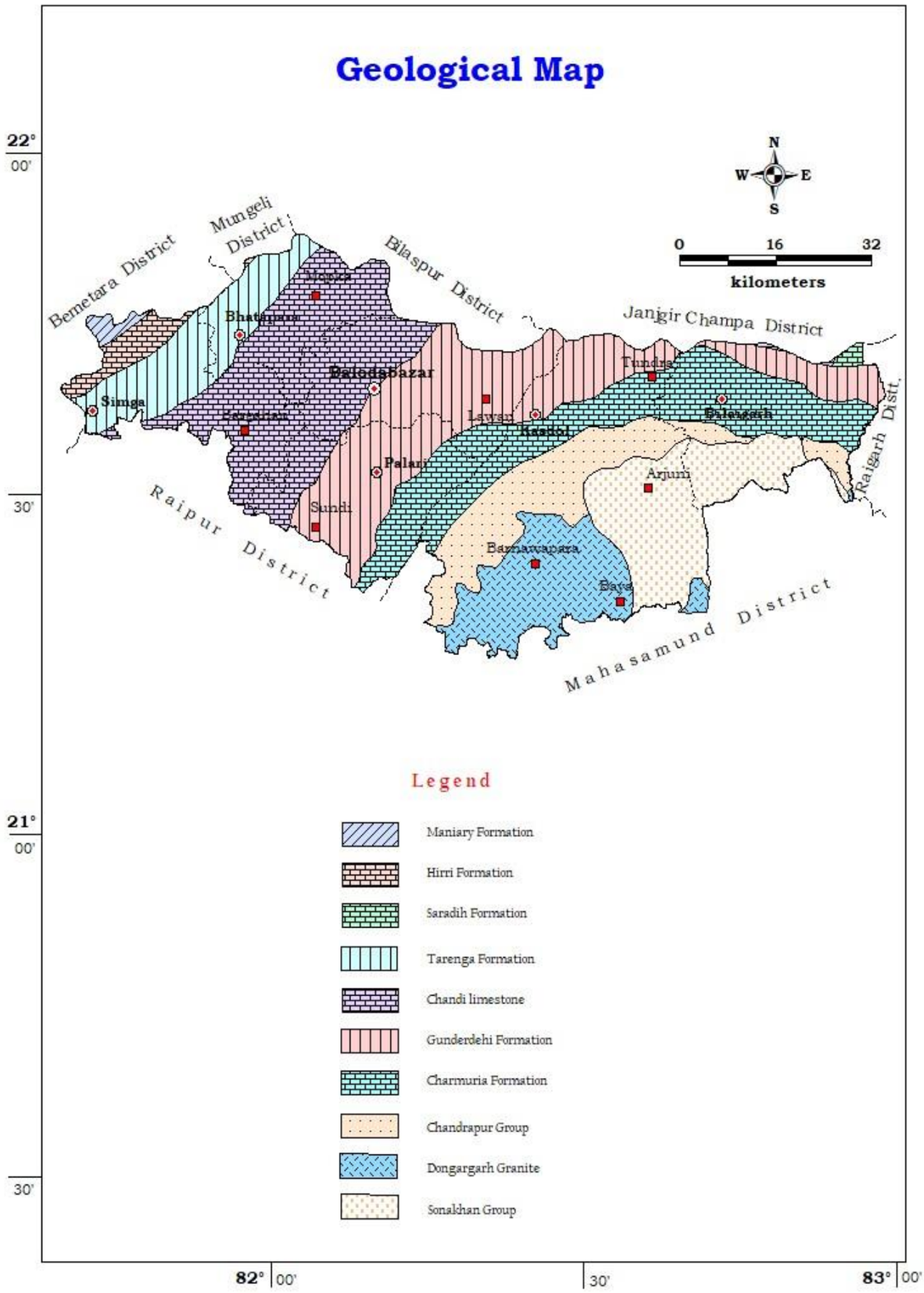
1.10 Geology

The district is underlined mainly by two distinct geological formations ranging in age from Achaean to Proterozoic. The Chhattisgarh super groups of rocks occupy major parts of the district comprising of shale, limestone, sandstone. Granites and phyllites intruded by quartz veins form the basement of the basin. The Chhattisgarh super group overlies granites. The contact between the Achaeans and the overlaying sedimentary is faulted along the western margin of the basin, which can be confirmed by the presence of highly sheared and brecciated rocks in this region while unconformity lies between these two in the remaining portions of the

basin, which can be quite evidenced by the presence of pebbly conglomerate bed at the basal portion of the sedimentary. The rocks of Chhattisgarh Super group are unconformably overlying the basement crystalline and are represented by the sandstone, limestone and shale sequence occupying the entire district except the south eastern part of the district. The rocks of Chhattisgarh super group have been classified into Chandrapur group and Raipur Group. The rocks of Chandrapur group are the oldest of Chhattisgarh Supergroup and can be further divided in to three formations viz Lohardih, Choparadih and Kansapathar arranged in the ascending order of superposition. The sequence shows a variable thickness ranging from 20 m to as much as 90 m. The maximum thickness is attained in the SE part, thinning westward as well as in northern side and directly overlying the crystalline basement. Raipur group comprising a predominantly argillite- carbonate sequence conformably overlies the Chandrapur group with a gradational contact. Raipur group has been subdivided into six formations representing three cycles of carbonate-argillite sedimentation viz Charmuria and Gunderdehi, Chandi and Tarenga and Hirri and Maniyari arranged in the ascending order of super position. The alluvium deposits in the area are mainly confined all along with the flood plains on either side extending 2 km at places. These comprise mostly gravels, coarse to medium sand and silts. It attains a thickness of 10 to 20 m along Mahanadi and Seonath River.

Hard rock mainly consists of limestone, shale, dolomite and sandstone belong to Chhattisgarh Supergroup of Proterozoic age. Ground water occurs in phreatic condition in the weathered mantle of these rocks, which extends up to a depth of 25 mbgl. The caverns formed in limestone and dolomites holds good amount of ground water which are limited mostly to around 80 meters. Limestone and sandstone form the main aquifer system in the area. Charmuria limestone and Gunderdehi shale are not very good yielding. Cavernous limestone of Chandi formation forms the good aquifer in the district. The alluvium blanket along the major rivers also form good repository of ground water.

Fig 6: The geological map of the study area



2. DATA COLLECTION AND GENERATION

2.1 Hydrogeological Data

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 8.

Based on the depth to water level of 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 maps have been prepared.

2.1.1 Pre-monsoon period

In the pre-monsoon period, it has been observed that in the study area, water level in Phreatic aquifer varies between 2.3 to 7.9 m bgl with average water level of 4.4 m bgl. In deeper fractured aquifer, water level varies between 3.2 to 12.36 m bgl with average water level of 6.37 m bgl shown in Table No. 7.

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

District Name	Phreatic		Fractured	
	Min	Max	Min	Max
Baloda Bazar	2.3	7.9	3.2	12.36

*Water Level (in mbgl)

Fig.7 Pre- monsoon Depth to water level Map of Phreatic Aquifer

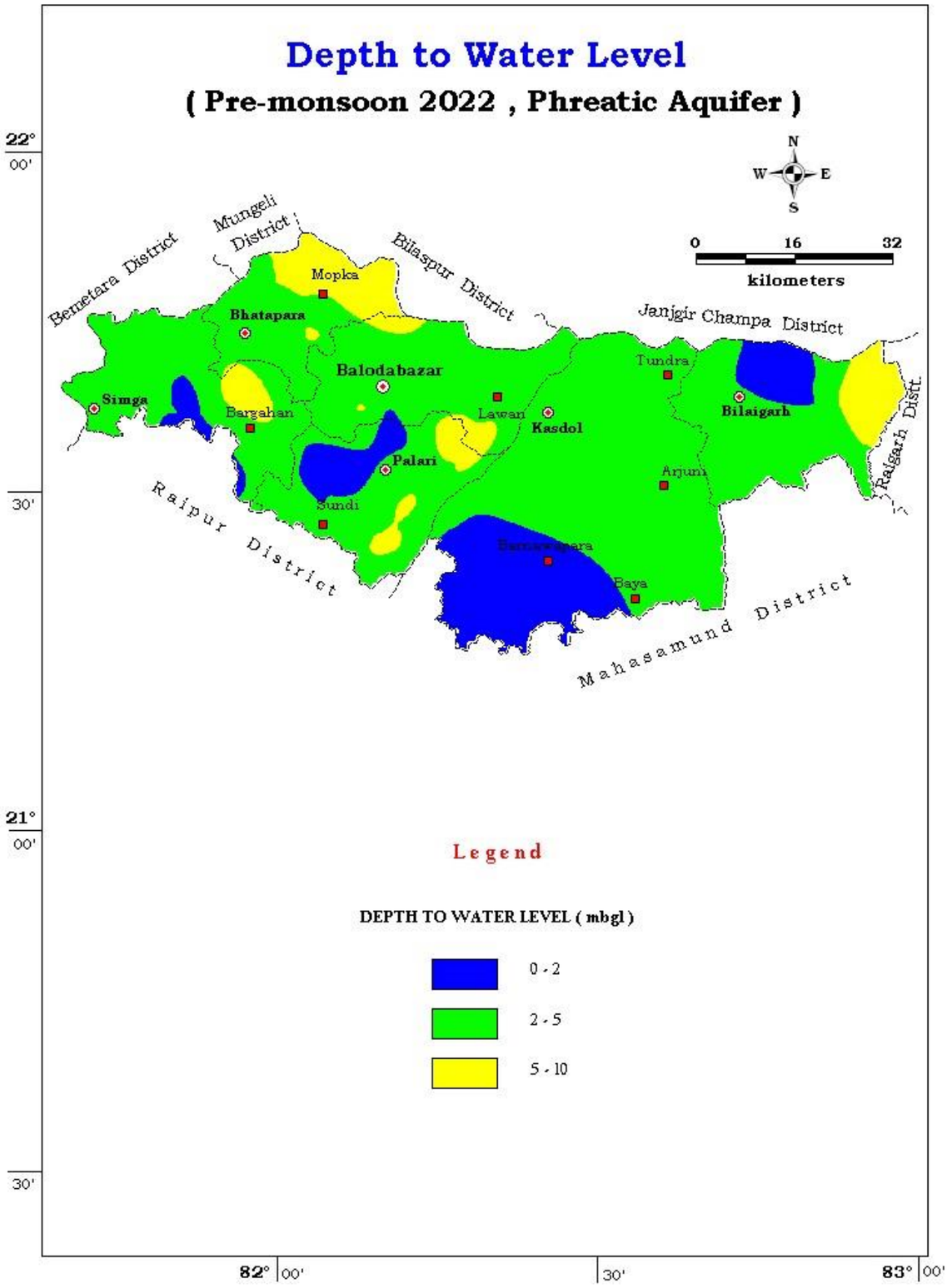
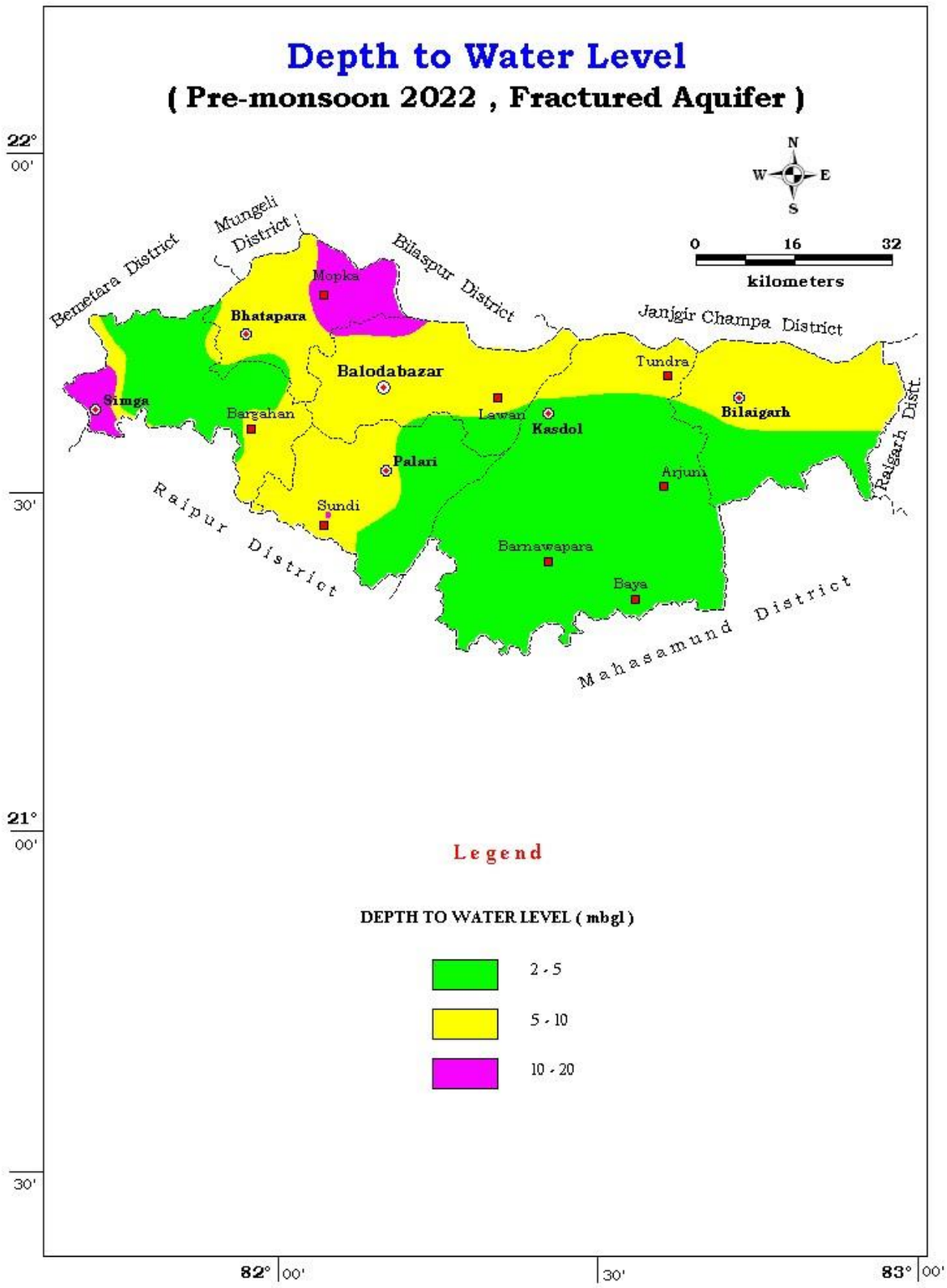


Fig.8 Pre- monsoon Depth to water level Map of Fractured Aquifer



2.1.2 Post-monsoon period

In the pre-monsoon period, it has been observed that in the study area, water level in Phreatic aquifer varies between 0.86 to 6.7 m bgl with average water level of 1.75 m bgl . In deeper fractured aquifer, water level varies between 1.2 to 10.82 m bgl with average water level of 5.28 m bgl shown in Table No. 8.

Table 8: Aquifer wise Depth to Water Level (Pre-monsoon)

District Name	Phreatic		Fractured	
	Min	Max	Min	Max
Baloda Bazar	0.86	6.7	1.2	10.82

*Water Level (in mbgl)

Fig.9: Post- monsoon Depth to water level Map of Phreatic Aquifer

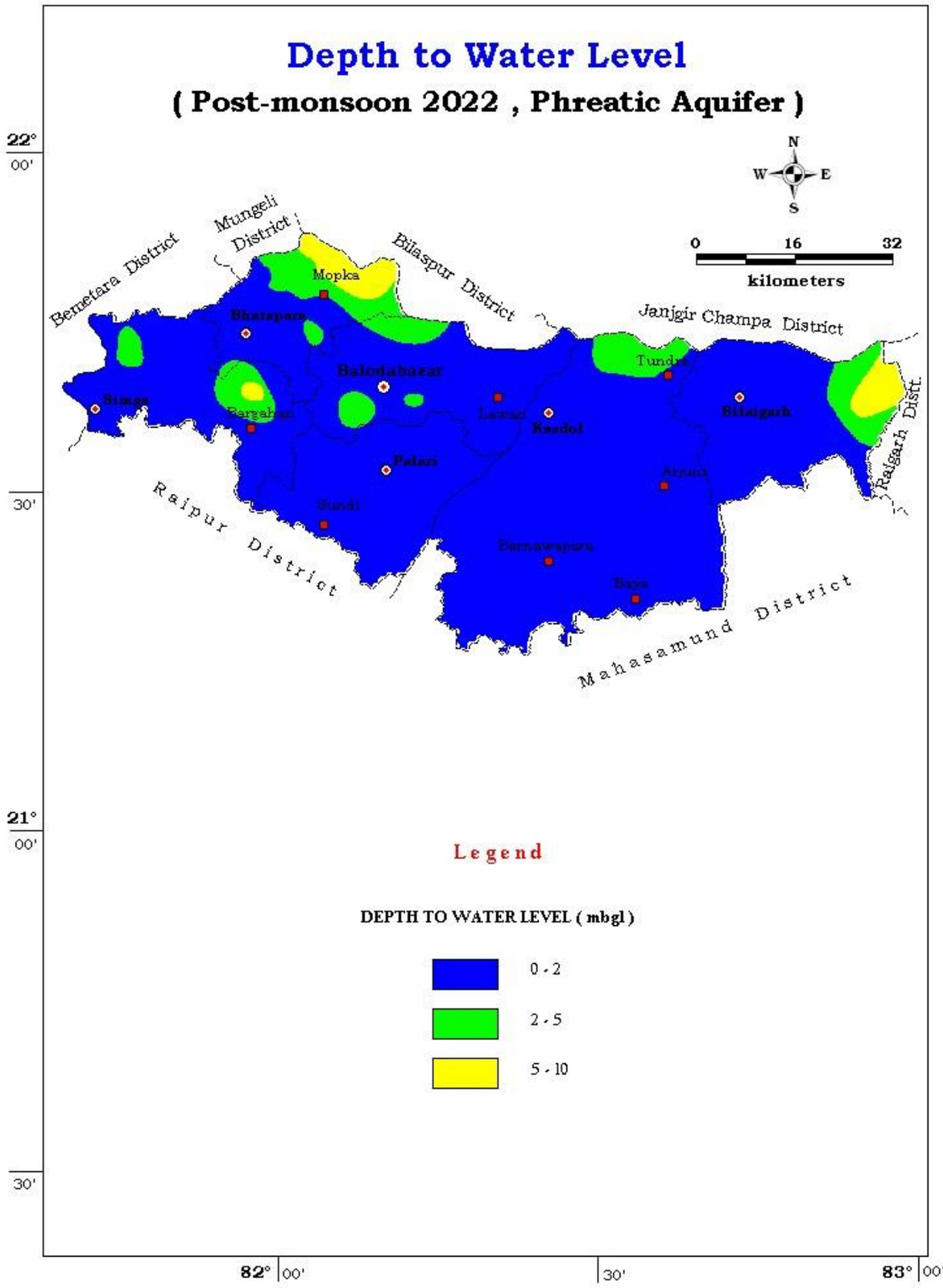
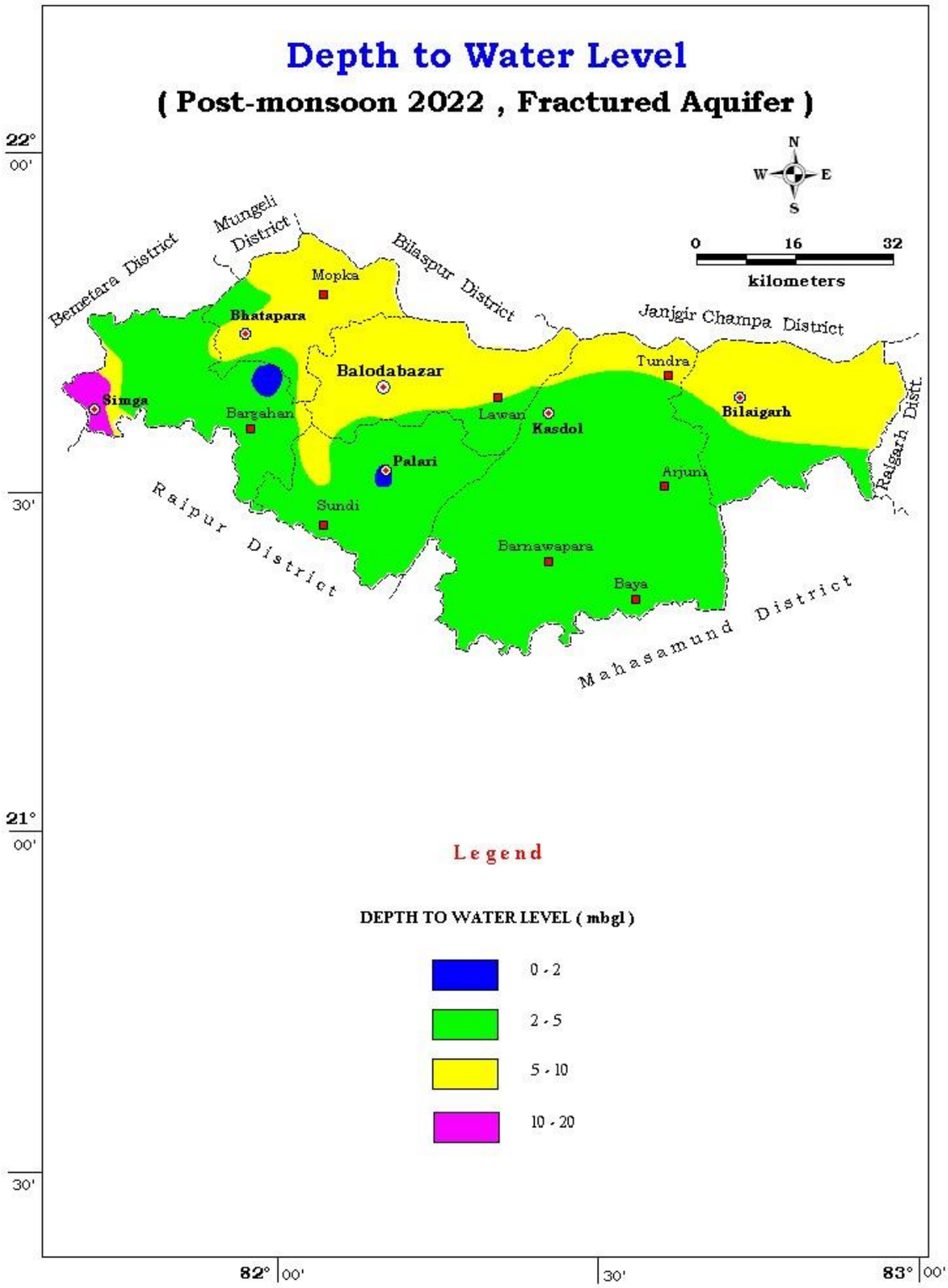


Fig.10: Post- monsoon Depth to water level Map of Fractured Aquifer



2.1.3 Seasonal water level fluctuation

It has been observed that in the study area, water level fluctuation in Phreatic aquifer vary between 1.2 to 1.44 m bgl. In deeper fractured aquifer, water level varies between 1.54 to 02.00 m bgl with average water level of 6.37 m bgl shown in Table No. 9.

Table 9: Aquifer wise Depth to Water Level Fluctuation (Pre-monsoon vs post-monsoon)

District Name	Phreatic		Fractured	
	Min	Max	Min	Max
Baloda Bazar	1.2	1.44	1.54	02.00

*Water Level (in mbgl)

Fig.10: Seasonal Fluctuation of Depth to Water Level Map of Phreatic Aquifer

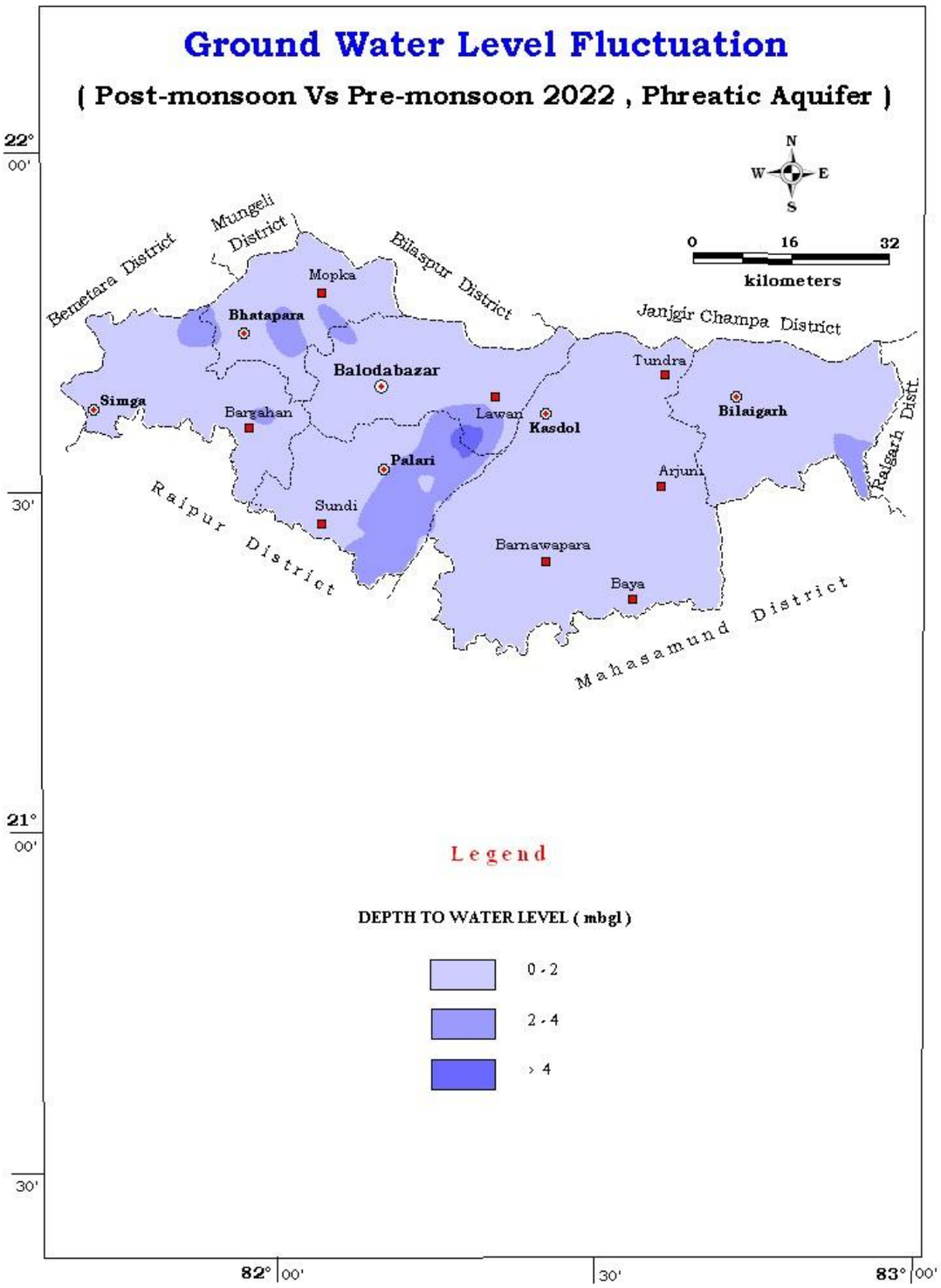


Fig.11: Seasonal Fluctuation of Depth to Water Level Map of Fractured Aquifer

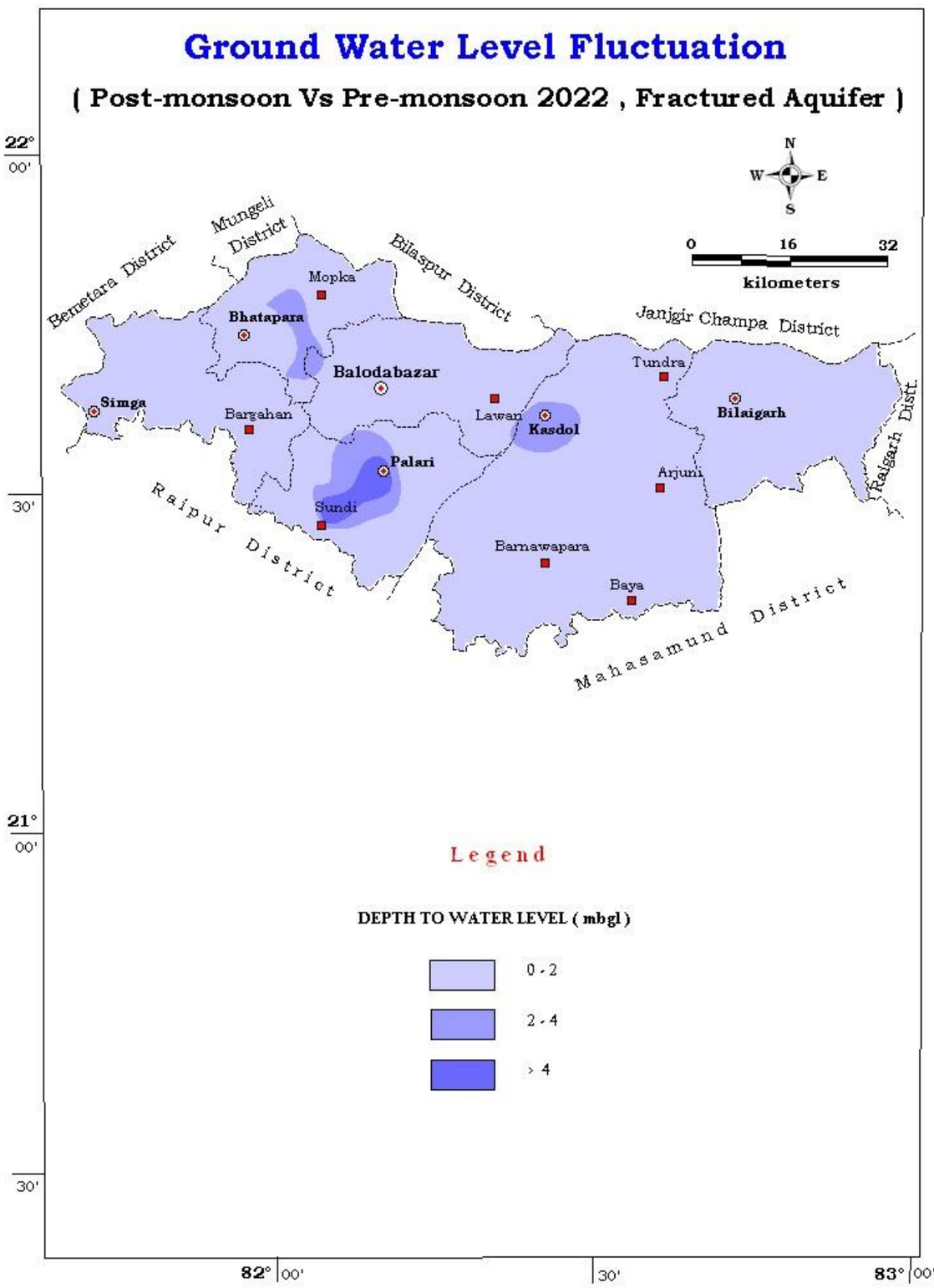


Table 10: Details of key wells established

Sl no	District	Location	Well Type	Latitude	Longitude	Post monsoon WL	Pre monsoon WL	Diameter	MP	Depth
1	Baloda Bazar	karda	DW	21.67623	82.383946	2.1	3.45	4.6	0.65	7.3
2	Baloda Bazar	khamaria	DW	21.63014	82.329717	0.86	2.9	4.1	0.2	8
3	Baloda Bazar	dharsiwa	DW	21.57484	82.300121	2.18	6.7	2.7	0.6	6
4	Baloda Bazar	saloni	DW	21.55022	82.272381			5.3	9.5	
5	Baloda Bazar	Khairi	DW	21.53112	82.269396	1.75	4.6	3.3	0.7	7.3
6	Baloda Bazar	Jora Dabri	DW	21.51781	82.265876	1.15	5	5.2	0.7	8.3
7	Baloda Bazar	Rohasi	DW	21.51986	82.241007	2.6	4.34	3.5	0.5	8.3
8	Baloda Bazar	Balodi	DW	21.53497	82.204131	0.5	3	8.51		6.3
9	Baloda Bazar	charoda	DW	21.45693	82.216576	1.1	4	4	0.6	7
10	Baloda Bazar	Odan	DW	21.48017	82.201058	2.1	5.6	3	0.7	7.3
11	Baloda Bazar	sahda	DW	21.43368	82.166873	2.55	5.65	2.1	0.5	6.5
12	Baloda Bazar	jarve	DW	21.44848	82.15554	1.1	4	5.5	0.4	8.5
13	Baloda Bazar	Sundra Van	DW	21.44287	82.118626	2	3.49	5	0.5	6.5
14	Baloda Bazar	khartora	DW	21.44677	82.064782	0.9	2.78	1.6	0.1	5.5
15	Baloda Bazar	khanduwa	DW	21.65264	81.711931	0.95	3.61	2.5	0.6	7.3
16	Baloda Bazar	Rohara	DW	21.73791	81.868882	1.27	3.45	7	0.3	11.3
17	Baloda Bazar	kholva	DW	21.75481	81.937984	0.8	2.7	2.7	0.3	7.8
18	Baloda Bazar	Datrengi	DW	21.79374	81.960608	1.75	3	1.9	0.3	5.5
19	Baloda Bazar	Lewai	DW	21.80774	81.990347	3.3	5	3		8.3
20	Baloda Bazar	Akaltara	DW	21.78544	82.013433	2.7	4.7	3	0.45	7
21	Baloda Bazar	Nipanya	DW	21.83341	82.043759	4.88	6.4	3.8	0.4	8.4
22	Baloda Bazar	Khapri	DW	21.84458	82.078401	6.7	7.9	2.5	0.4	8
23	Baloda Bazar	Dhawai Borsi	DW	21.747	82.089407	1.2	3.4	3.2	0.4	8.2
24	Baloda Bazar	Topa	DW	21.73123	82.057446	4	5.32	3.9	0.3	9.4
25	Baloda Bazar	Amlidih	DW	21.72039	82.035142	2.2	4.8	4	0.5	7.1
26	Baloda Bazar	Farhada	DW	21.66814	81.982939	1.2	2.3	4	0.4	11.2

27	BALODA BAZAR	karda	HP	21.67234	82.384319	6.12	7.3		0.35	
28	BALODA BAZAR	Balodi	HP	21.53456	82.203659	3.82	5		0.45	
29	BALODA BAZAR	charoda	HP	21.45693	82.216576	3.9	4.8			
30	BALODA BAZAR	sahda	HP	21.43368	82.166873	4.45	5.2		0.65	
31	BALODA BAZAR	khartora	HP	21.4473	82.071492	5.28	6.87			
32	BALODA BAZAR	Adbandha	HP	21.73012	81.77615	2.64	4.31			
33	BALODA BAZAR	Surajpur	HP	21.77007	81.953575	4.84	6.71		0.55	
34	BALODA BAZAR	Akaltara	HP	21.79348	82.013476	6.12	8.4		0.45	
35	BALODA BAZAR	Saimra	HP	21.82281	82.029275	6.82	7.93		0.75	
36	BALODA BAZAR	Dhaneli	HP	21.81357	82.088406	10.82	12.36		0.45	
37	BALODA BAZAR	Matiya	HP	21.6013	81.996831	5.32	6.7			
38	BALODA BAZAR	fahada	HP	21.66784	81.983123	1.2	3.2		0.45	
39	BALODA BAZAR	kamta	HP	21.62944	81.762188	3.82	4.3			

2.2 Hydrochemical Data

To know the hydro chemical behavior of the ground water in the study area, 21 nos. of ground water samples were collected from the key wells during pre-monsoon period of measurement (May, 2021). Also water samples were collected from borewells during exploration carried out in the area and analyzed 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. 11.

Table 11: Result of chemical analysis of ground water exploration year 2021-22

S.No.	District	Block	Village	Long.	Lat	Source	PH	EC	CO3	HCO3	Cl	No3	SO4	F	TH	Ca	Mg	Na	K	SiO2	U
1	Balodabazar	Simgha	Hadabandh	81.8417	21.6289	BW	7.1	1084	0	353.8	106.4	39.7	74.9	0.3	400	68	55.2	67.9	4.29	12	0
2	Balodabazar	Simga	Udela	81.85	21.60833	HP	7.2	1186	0	353.8	148.9	56.4	73.0	0.3	540	100	69.6	38	1.95	11	0
3	Balodabazar	Kasdol	Temri	82.4113	21.5758	BW	7.4	701	0	268.4	70.9	9.9	28.8	0.7	260	72	19.2	46.9	0.39	26	0
4	Balodabazar	Balodabazar	Amera	82.17806	21.59472	BW	7.1	753	0	317.2	70.9	10.5	22.6	0.6	300	108	7.2	40.9	0.78	12	0
5	Balodabazar	Kasdol	Aouri	82.26667	21.42083	BW	7.4	573	0	329.4	42.5	0.0	14.9	0.3	270	28	48	33.8	1.95	17	0
6	Balodabazar	Balodabazar	Arjuni	82.0653	21.6917	BW	7.2	749	0	231.8	78.0	19.8	63.8	0.4	310	56	40.8	32	0.78	8	0
7	Balodabazar	Balodabazar	Baloda bazar	82.1667	21.6556	HP	7	730	0	317.2	56.7	6.8	37.0	0.4	300	60	36	38	0.39	8	0
8	Balodabazar	Bilaigarh	Tundri	82.6434	21.6493	HP	7.3	616	0	335.5	14.2	0.0	24.0	1.5	250	44	33.6	32	1.56	18	0
9	Balodabazar	Bilaigarh	Bhatgaon	82.8122	21.6536	HP	7.2	1058	0	317.2	134.7	18.6	70.6	0.5	430	68	62.4	49.9	0.78	20	0
10	Balodabazar	Pallari	Bhatia	82.401	21.8896	HP	7.3	572	0	207.4	42.5	16.7	31.7	0.6	215	56	18	29	0.39	11	0
11	Balodabazar	Bilaigarh	Bilaigarh	82.725	21.6375	HP	7.1	465	0	237.9	21.3	0.0	14.9	0.4	200	64	9.6	18.9	0.39	11	0
12	Balodabazar	Simga	Damakheda	81.7597	21.7008	BW	7.1	972	0	244.0	106.4	24.8	98.9	0.3	430	100	43.2	20.9	0.78	15	0
13	Balodabazar	Simga	Darchura	81.79031	21.7136	BW	7.2	1240	0	305.0	134.7	63.9	####	0.1	470	104	50.4	47.2	22.6	9	0
14	Balodabazar	Palari	Devsundri	82.068	21.5222	BW	7.1	1228	0	183.0	241.1	18.0	73.9	0.2	500	152	28.8	38	0.78	13	0
15	Balodabazar	Kasdol	Kasdol	82.4333	21.6167	BW	7.3	702	0	256.2	70.9	9.3	28.8	0.7	250	64	21.6	46	0.39	26	0
16	Balodabazar	Simga	Khapri	81.97083	21.65	BW	7.5	383	0	183.0	28.4	0.6	14.9	0.6	180	44	55.2	13.8	0.39	9	0
17	Balodabazar	Palari	Kodwa	82.0836	21.4744	BW	7.4	1187	0	549.0	63.8	39.7	50.9	0.4	540	136	69.6	39.1	1.56	11	0
18	Balodabazar	Bilaigarh	Marban Gatadih	82.9172	21.5598	BW	7.3	458	0	237.9	14.2	0.0	21.6	0.3	170	64	19.2	27.6	3.12	8	0
19	Balodabazar	Kasdol	Mudhipar	82.28333	21.46667	DW	7.3	603	0	292.8	35.5	0.0	15.8	0.3	230	80	7.2	35	1.95	15	0
20	Balodabazar	Bilaigarh	Sarsiwa	82.9167	21.625	BW	7.3	416	0	256.2	14.2	0.0	20.6	0.3	200	52	48	23	3.12	9	0
21	Balodabazar	Kasdol	Sel	82.4915	21.6522	DW	7.3	253	0	134.2	21.3	0.0	7.7	0.3	120	28	40.8	9.66	2.34	19	0
22	Balodabazar	Simga	Simga	81.7042	21.625	DW	7.4	666	0	244.0	42.5	8.1	70.6	0.4	290	52	36	22.5	1.17	11	0
23	Balodabazar	Palari	Sandi	82.075	21.45	HP	7.7	751	0	305.0	70.9	0.6	21.6	0.7	270	72	33.6	48.3	2.34	13	0

2.3 Exploratory Data

2.3.1 Status of Groundwater Exploration

A total of 71 bore wells exist in the study area as on 31-03-2022 out of which 47 nos. are exploratory bore wells and 14 nos are observation bore wells. Table 12 summarizes the status of exploratory wells in the study area.

Table 12 Detail of Exploration in the study area

SL No	District	Block	location	Latitude	Longitude	Depth	casing	Formation	Zone encountered	SWL	Q	DD	T m2/day
1	BALODA BAZAR	Baloda bazar	Bhalukona	21.6139	82.3725	89.83	19.5	Charmuria Fm	14-18, 30				
2	BALODA BAZAR	Kasdol	Khapri	21.7	82.65	75	14	Charmuria Fm	14.5 - 16,55-64	4.15	2.2		
3	BALODA BAZAR	Bhatapara	Mopka	21.7978	82.0694	69.06	25	Chandi Fm-limestone	14.77-21.70,35	2.02	0.4	5.1	
4	BALODA BAZAR	Baloda bazar	Lawan	21.6367	82.3375	58.39	21	Charmuria Fm	58.39				
5	BALODA BAZAR	Simga	Darchura	21.7239	81.7889	70.02	11.5	Tarenga Fm-Cherty shale	17.2-25.18				
6	BALODA BAZAR	Simga	Lawar	21.6861	81.8333	47.95	10.5	Tarenga Fm- Cherty shale	4.26-9.74, 12.74-15.78 , 19.70-26.18 , 28.18-30.66 , 37.14-47.75	1.24	6	40	493
7	BALODA BAZAR	Simga	Motiari	21.725	81.8278	53.18	52.58	Tarenga Fm-Cherty shale	47.10- 50.1	7.65	2.5	15	13
8	BALODA BAZAR	Simga	Motiari OW	21.725	81.8278	60	50	Tarenga Fm-Cherty shale	47-50				

9	BALODA BAZAR	Simga	Rohara	21.7444	81.8617	70.02	35	Tarenga Fm-Cherty shale	Abandoned	5	0.2	8.5	
10	BALODA BAZAR	Simga	Marrakona	21.7419	81.865	110	12	Tarenga Fm	10--15,40	11.8	0.2		
11	BALODA BAZAR	Bhatapara	Bhatapara	21.725	81.9542	92	10	0-3 Clay, 3-8 Laterite, 8.92-00 Chandi fm	28-29.3-30-32, 60-62,68-69, 80.5-83 &88	18.8	11	12	47
12	BALODA BAZAR	Baloda bazar	Bharwadih	21.6375	82.0917	198.35	6	0.32.2 Chandi Fm 32.2-198.35 Gunderdehi Fm	14-16, 64-66, 104-106	23.3	0.5		
13	BALODA BAZAR	Bhatapara	Pasid	21.825	82.1292	134	8	0.0- 43 Chandi formation 43- 61.5 Gunderdehi 61.5-134.5 Charmuria	14-17, 128-128.8	10.7	1	50	0.965
14	BALODA BAZAR	Baloda bazar	Murhipar	21.6639	82.0806	199	4	0.0- 43 Chandi formation 43- 61.5 Gunderdehi 61.5-134.5 Charmuria	6.65-9.96, 18.83-21.83, 24.93-27.93, 107.17-110-27, 122.47-125.47, 126.47-128.57	1.24	2.8	24	3.16
15	BALODA BAZAR	Baloda bazar	Lahaud	21.6568	82.2321	196	9.9	0.0-116 Gunderdehi Fm 116- 196 Charmuria Fm	Dry				
16	BALODA BAZAR	Kasdol	Tundra	21.6792	82.6078	196	4.25	0.0- 129 Charmuria Fm 129-5-196 Chandrapur Fm	47-48 and 90-90.5	11.2	1		
17	BALODA BAZAR	Bilaigarh	Bhatagaon OW	21.6528	82.8083	220.86	30	0.0-104.88 Raigarh Fm 104.88-220.3Chhuipali Fm	22.4-56.7 , 76.2- 171.2	2.97	3		

18	BALODA BAZAR	Bilaigarh	Bhatagaon	21.6528	82.8083	198.1	30	0.0- 51.60 Raigarh Fm 51.5- 97 Chandrapur Fm 1.0- 97- 198.1 Chhuipali Fm (Singhora Group)	14-20, 27.30-47.70, 51.50- 190	2.6	8		
19	BALODA BAZAR	Kasdol	Tundri	21.7	82.6333	198	11.65	0-101.9 Charmuria Fm 101.9-198 Chandrapur Fm	14-16, 41.55-99.35, 104-105,149-156	0.31	5		
20	BALODA BAZAR	Baloda bazar	Turma	21.5875	82.3667	83.3	6	0.3.5 Soil, 3.5- 82.7 Charmuria Fm & 82.7- 83.3 Chandrapur	3.5-5, 9.7-12.8, 34.1-37.15, 82.7-83.3	3.7	10	35	20
21	BALODA BAZAR	Kasdol	Giroudpuri	21.6153	82.5639	62.4	3.5	0.0- 62.4 Chandrapur	60- 62.4	3.08	10	15	
22	BALODA BAZAR	Baloda bazar	Sunsuniya	21.7083	82.4528	196	9.8	0.0- 117 Gunderdehi Fm 117-196 Charmuria Fm	11.20-11.30	6.2	1		
23	BALODA BAZAR	Bhatapara	Arjuni	21.6917	82.0417	98.8	8.6	Tarenga Fm-Chety shale	14-16,95.3-99.3, 247.3-251.3	6.97	0.2	40	
24	BALODA BAZAR	Simga	Damakhera	21.6978	81.7703	300.45	12.5	Tarenga Fm-Chety shale	14-16,42.2,78	7.12	1	22	
25	BALODA BAZAR	Simga	Bishrampur	21.7417	81.7917	120.7	15.25	Tarenga shale& Chandi limestone	23.35-26.95, 30-9-34.6, 95-35-99-35, 120-120.7	7.43	40	21	197
26	BALODA BAZAR	Bhatapara	Deori	21.7792	81.9375	205.69	9	Tarenga Fm	14-16, 40-45, 65-70	6	4.8	22	13

27	BALODA BAZAR	Bhatapara	Deori OW	21.7792	81.9375	160	6	Tarenga Fm	14-16, 40-45, 65-70	5.4	7	25	
28	BALODA BAZAR	Simga	Bishrampur OW	21.7417	81.7917	68.87	20.2	Tarenga shale& Chandi limestone	14-16,68.87	5.81	6.8	21	43.04
29	BALODA BAZAR	Simga	Bishrampur OW	21.7417	81.7917	121.34	15	Tarenga shale& Chandi limestone	15-17,121.34	7.8	40	17	218.25
30	BALODA BAZAR	Bhatapara	Rohra	21.7333	81.9375	129.62	9.1	Tarenga Fm- Chety shale	14.3-15, 17.2-17.5, 22.2 -27-37-40, 45-46, 55-57	3.24	25		166
31	BALODA BAZAR	Simga	Simga	21.6244	81.7013	304.42	9	0-102 Tarenga Fm 102-304.Chandi Fm	14-16,42-46, 50.52,220.8-224.4	18.1	3.8	13	9.6
32	BALODA BAZAR	Bhatapara	Singarpur	21.8236	82.0194	251.3	25	Tarenga shale	14-16,40-60	4.12	25	36	
33	BALODA BAZAR	Bhatapara	Singarpur OW	21.8236	82.0194	216	24.5	Tarenga shale	14-16,40-61	5.25	25	50	
34	BALODA BAZAR	Palari	Chandi	21.5	82.0417	220.92	9	0.0-118.12 Chandi Fm 118-12-220.92 Gunderdehi Fm		6.85	7	22	1107.8
35	BALODA BAZAR	Bhatapara	Rohra OW	21.7333	81.9375	42.1	9.1	Tarenga Fm	15.6-16,36-41	4.19	35	6.4	166
36	BALODA BAZAR	Bhatapara	Rohra OW	21.7333	81.9375	137.2	9	Tarenga Fm- Chety shale	14.5-15.7,32.- 33.2, 35.5-46	3.99	35	19	166
37	BALODA BAZAR	Palari	Chherkapur	21.5875	82.2	300.52	9	Gunderdehi shale	9--12,35	2.07	0.2	45	
38	BALODA BAZAR	Kasdol	Tundri Ow	21.7	82.6333	196.12	8	0-100 Charmuria Fm 100-196.12 Chandarpur Fm	14-16, 104 & 188	0.6	2		

39	BALODA BAZAR	Bilaigarh	Bilaigarh	21.6386	82.725	153.93	12	Limestone	10-10.5,30	5	0.2		
40	BALODA BAZAR	Baloda bazar	Bharseli	21.675	82.1236	152.75	9	Limestone	30-32,56-70	11	5.7		
41	BALODA BAZAR	Kasdol	Gordha (EW)	21.65	82.4244	169	9.5	Limestone	14-16, 92.40-96.79	10.9	0.1		
42	BALODA BAZAR	Bilaigarh	Gopalpur (EW)	21.6419	82.8658	153.83	5.5	Limestone	24.29-28.29, 100.49-104.49	6.05	0.4		
43	BALODA BAZAR	Kasdol	Kotiyadih (EW)	21.6686	82.5744	153.83	2.69	Shale & Limestone	14-16, 112.00-115.00 134.97-138.59	2.35	3.2		
44	BALODA BAZAR	Kasdol	Kotiyadih (OW)	21.6686	82.5744	122.87	6.15	Limestone	15-19,111.63-115.25	4.23	0.2		
45	BALODA BAZAR	Bilaigarh	Nagarda (EW)	21.7019	82.7469	150.21	8.6	Shale	14-16,62.39-66.39	7.35	0.8		
46	BALODA BAZAR	Bilaigarh	Pauni (EW)	21.6633	82.6961	81.55	10	Fractured Sandstone	10-11, 66.31-68.31, 77.55-81.55	21.6	8.8	2.5	49.215
47	BALODA BAZAR	Bilaigarh	Pauni (OW)(	21.6633	82.6961	92.87	9.6	Fractured Sandstone	10-11, 63.50-66.39, 78.60-81.63	22.6	18	6.5	60.29
48	BALODA BAZAR	Kasdol	Borsi (EW)	21.5542	82.3758	169.04	5.58	Sandstone & Gneiss	14-18,45	Dry	Dry		
49	BALODA BAZAR	Kasdol	Amodi (EW)	21.6539	82.5308	130	8.2	Limestone/ Sandstone	38.45-42.45, 80.55-84.17, 95.79-99.79, 122.27-126.27	1.23	4.4		
50	BALODA BAZAR	Bilaigarh	Basurkuti (EW	21.6369	82.7444	154	11.5	Fractured Sandstone	25.00-28.00, 115.00-119.20	11.4	0.4		

51	BALODA BAZAR	Bilaigarh		21.6425	82.6547	153.83	5.55	Sandstone	54.77-58.77	5.79	0.8		
52	BALODA BAZAR	Kasdol	Temri (EW)	21.5772	82.4044	150.1	11.1	Sandstone & Gneiss	18-20, 92.78-96.78	8.9	0.8		
53	BALODA BAZAR	Kasdol	Amodi (OW)	21.6539	82.5308	152.75	7.66	Limestone/ Sandstone	50.00-53.69, 118.65-122.27, 137.57-141.57	0.97	3.2	4.7	19.1445
54	BALODA BAZAR	Baloda bazar	Bharseli (OW)	21.6796	82.1182	95	23	Limestone	25-29,35	8.6	5.7		

3. AQUIFER DEPOSITION AND HYDROGEOLOGY

3.1 Number of Aquifers

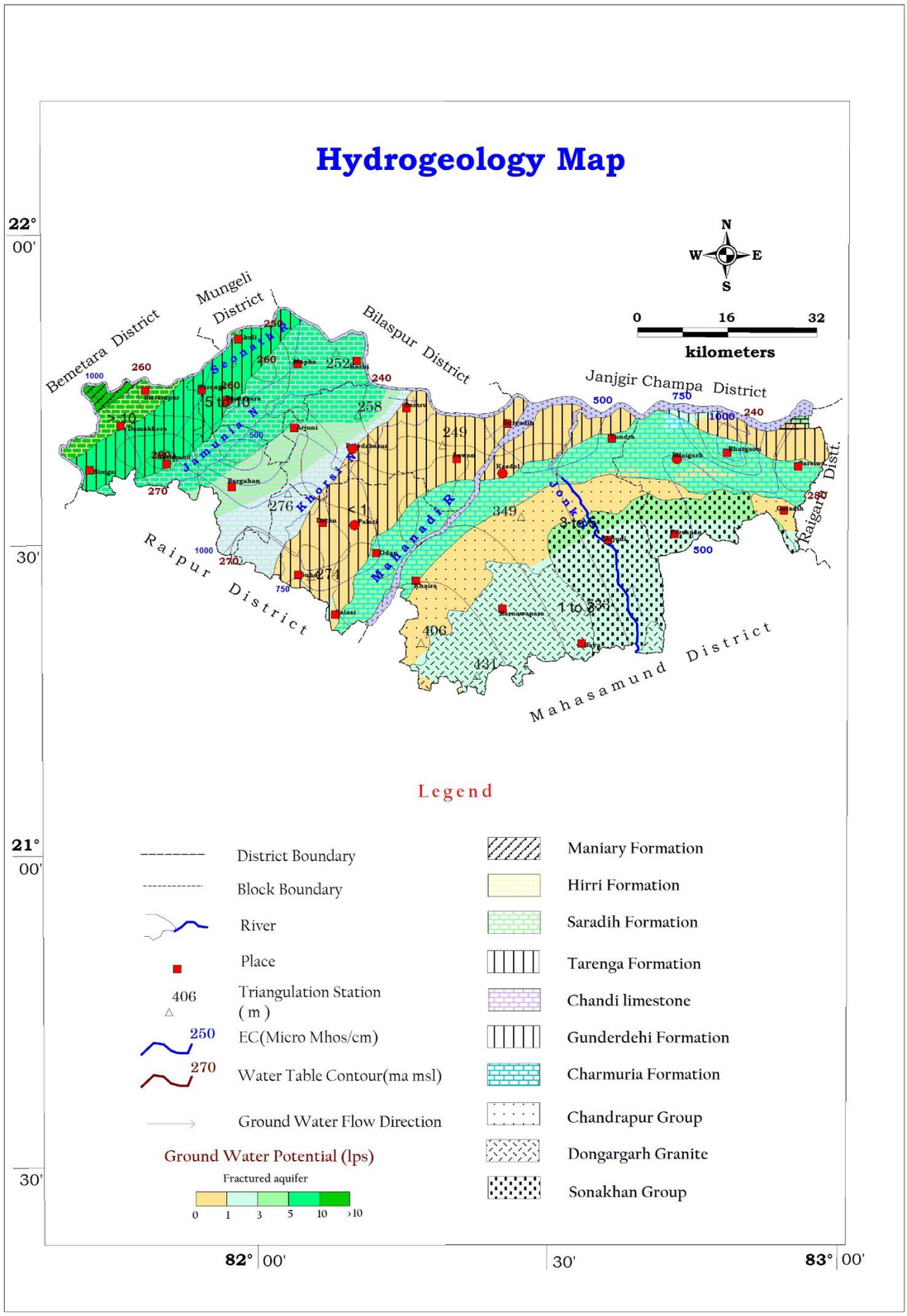
Based on the exploratory drilling data generated for the blocks (Table 12 (A) & 12(B)), the existing aquifer systems in the area may be divided into two namely phreatic and deeper fractured aquifer. The major aquifers present in the study area is 1. Shale (Tarenga and Gunderdehi), 2. Limestone (Charmuria and Chandi) 3. Sandstone (Chandrapur) and 4. Granite gneiss.

3.2 Basic characteristics of Aquifers

Hard rock areas in the district have been proved to be potential aquifers. Under ground water exploration programme 71 bore wells have been drilled in the district ranging in depth from 40 to 201 m. They have yielded up to 35 lps.

The aquifer parameters determined for various Formations based on preliminary yield test (PYT) results and aquifer performance test in the area shows that the limestone and dolomites of Chandi and Tarenga Formations have good transmissivity values. The yield of the wells drilled by CGWB in Chhattisgarh formation varies from 0.5 to 35 Ips. The transmissivity of this formation ranges from 4.00 to 450 m2/day and the specific capacity ranges between 2 and 20 Ipm of draw down and storativity ranges from 0.003 to 0.000224. The transmissivity value of Chandi Formation varies from 2.2 to 110 m^2/day where Tarenga Formation has transmissivity values ranging from 9.6 to 166 m^2/day. The limestone and shale of Charmuria and Gunderdehi Formations have very low transmissivity values varing between 1 and 2.5m^2/day. The yield of wells in granite complex ranges from negligible to 10 Ips with the average value around 2 to 5 Ips

Fig.12: Hydrogeology Map of Baloda Bazar District

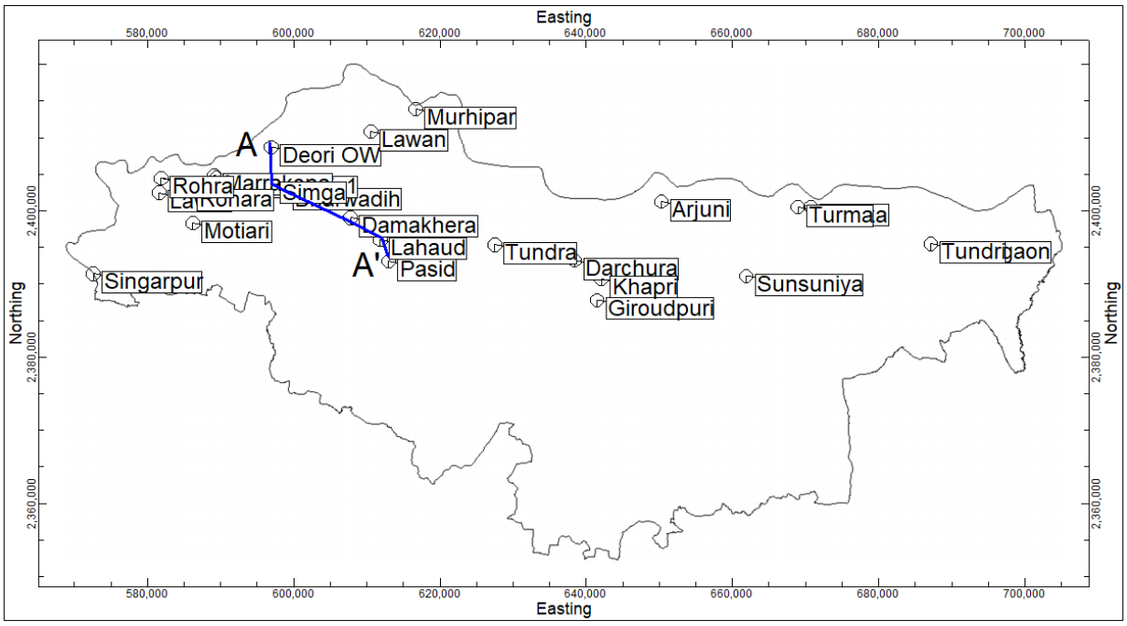


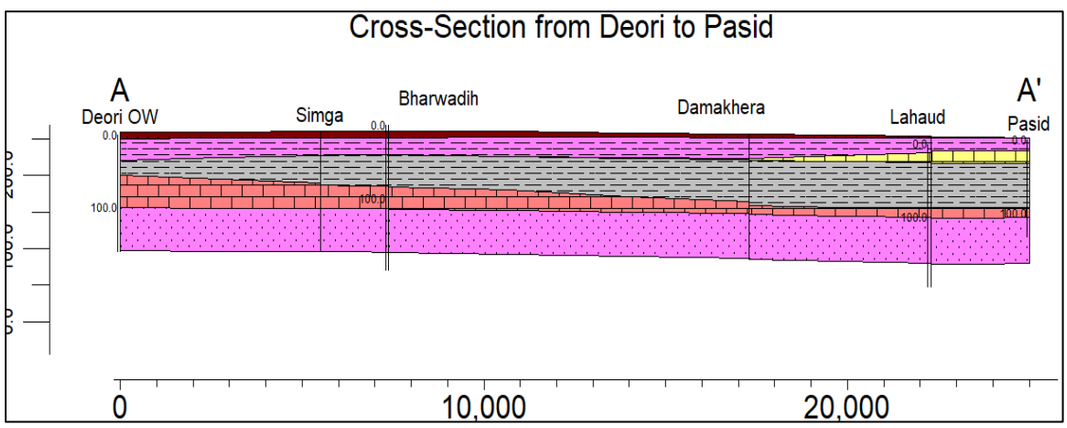
3.3 Geological cross-sections

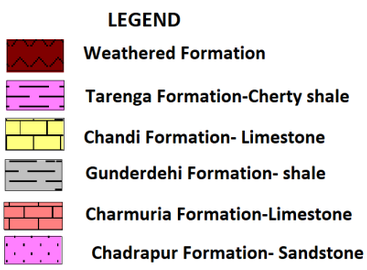
An attempt has been made to draw geological section along Deori- Pasid, Murhipar-Giroudpuri, Lawar- Bhatagaon and Singarpur-Bhatagaon in the study area based on available exploration data. The section lines are marked on Map and cross-sections are shown on Figure.

(A)Geological cross-section (A-A') along Deori- Pasid

Section A-A' of Baloda Bazar district shows a thin soil cover at Deori in the west which is gradually decreasing towards east and is thinnest at Pasid. Below the soil, Tarenga shale formation is encountered in the entire area. Chandi Limestone is encountered in Pasid and Lahaud only and it is missing in other locations. Then lies the Gunderdehi shale and Charmuria Limestone and Chandrapur sandstone from top to bottom.

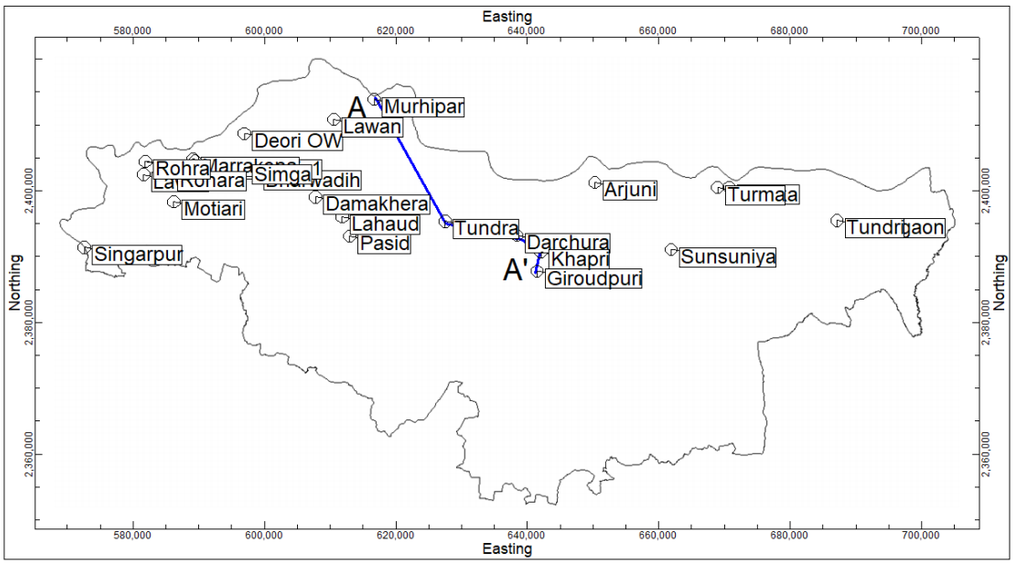


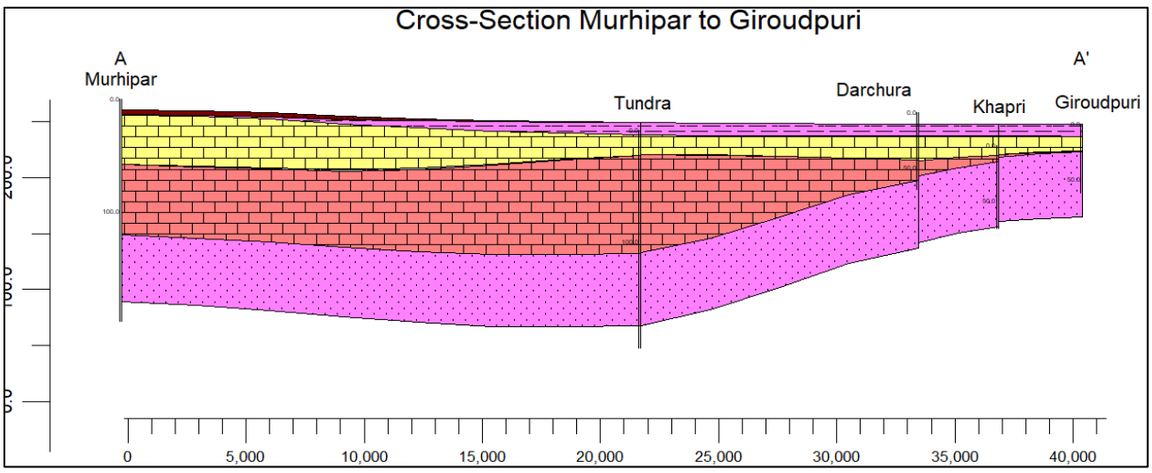


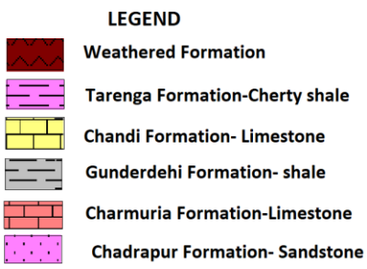


(B) Geological cross-section (A-A') along Murhipar-Giroudpuri

Section A-A' of Baloda Bazar district shows a thin soil cover at Murhipar in the west which is gradually decreasing in thickness towards east and vanished at Tundra. Hence weathered zone is missing at all locations except Murhipar. Tarenga shale formation is encountered in the entire area except Murhipar.

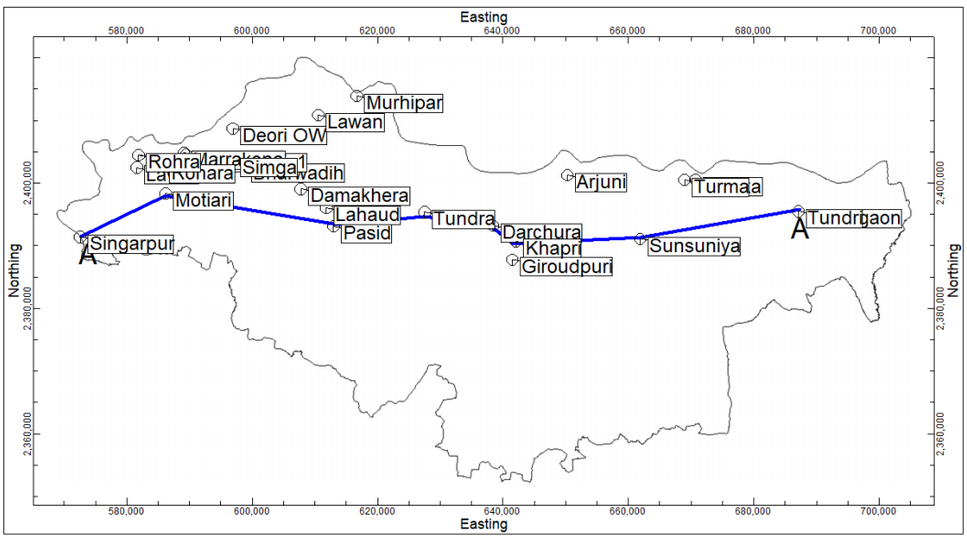


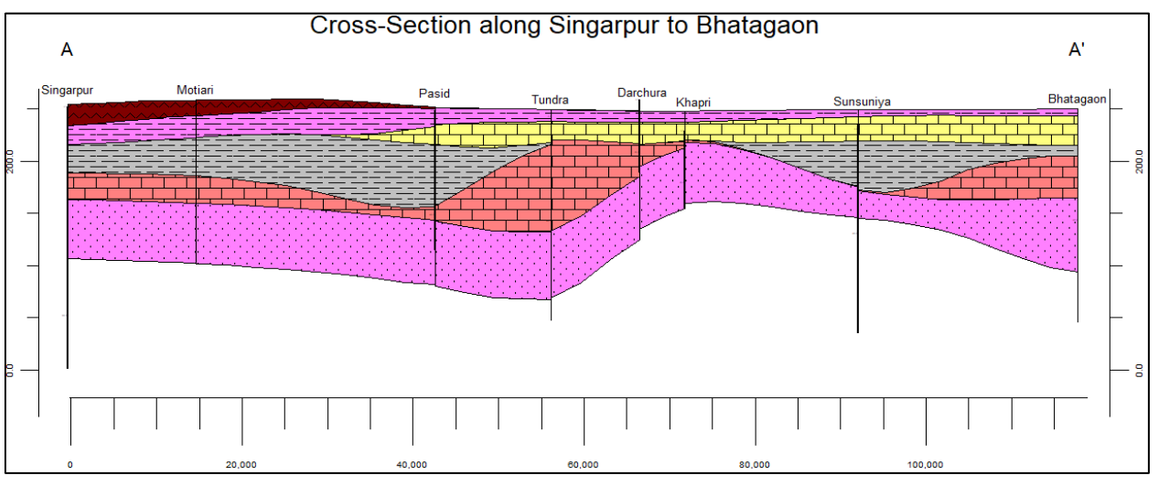




(C) Geological cross-section (A-A') along Singarpur - Bhatagaon

Section A-A' of Baloda Bazar district shows a thin soil cover at Singarpur, Motiari and Pasid in the west which is gradually decreasing in thickness towards east and vanished at Tundra. Hence weathered zone is missing afterwards. Alternate layers of shale and limestone present with Chandrapur sandstone at base



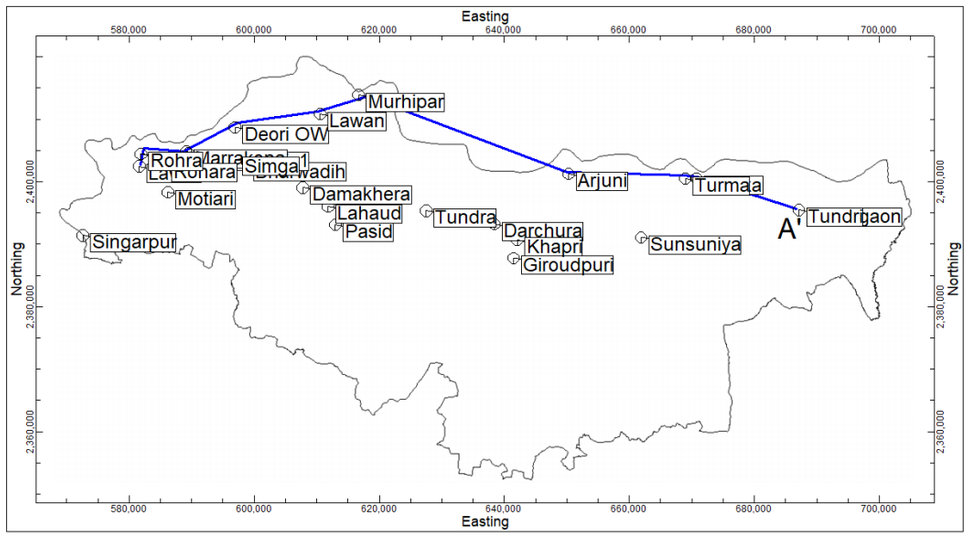


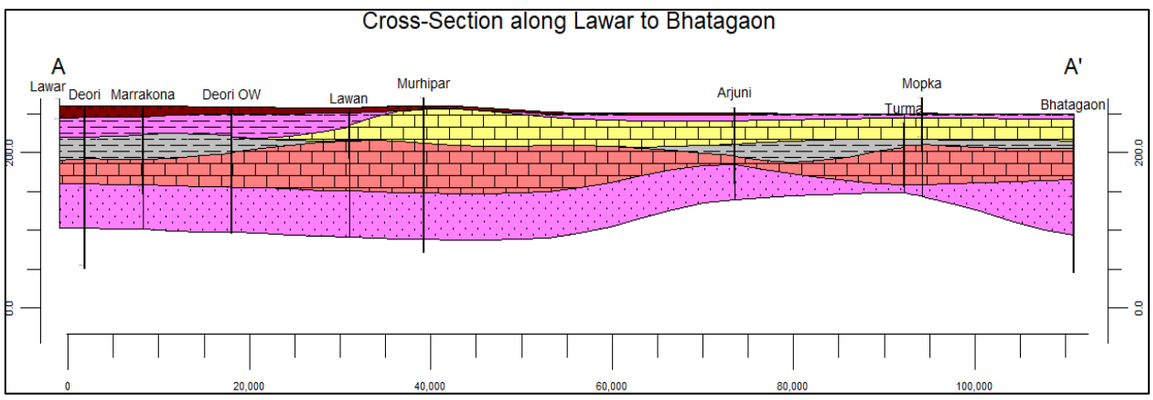
LEGEND

- **Weathered Formation**
- **Tarenga Formation-Cherty shale**
- **Chandi Formation- Limestone**
- **Gunderdehi Formation- shale**
- **Charmuria Formation-Limestone**
- **Chadrapur Formation- Sandstone**

(D)Geological cross-section (A-A’) along Lawar-Bhatagaon

Section A-A’ of Baloda Bazar district shows a thicker soil cover at Lawar in the west which is gradually decreasing towards east and is thinnest at Bhatagaon. Below the soil, alternate layers of shale and limestone are present with Chandrapur sandstone at the bottom.

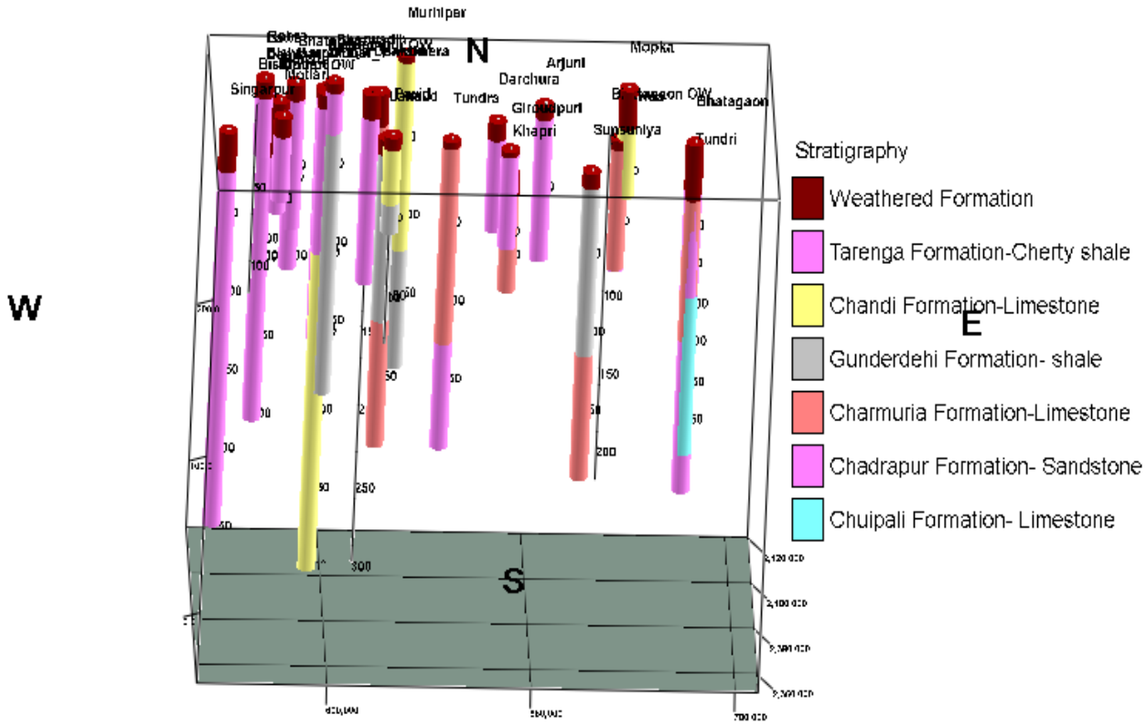


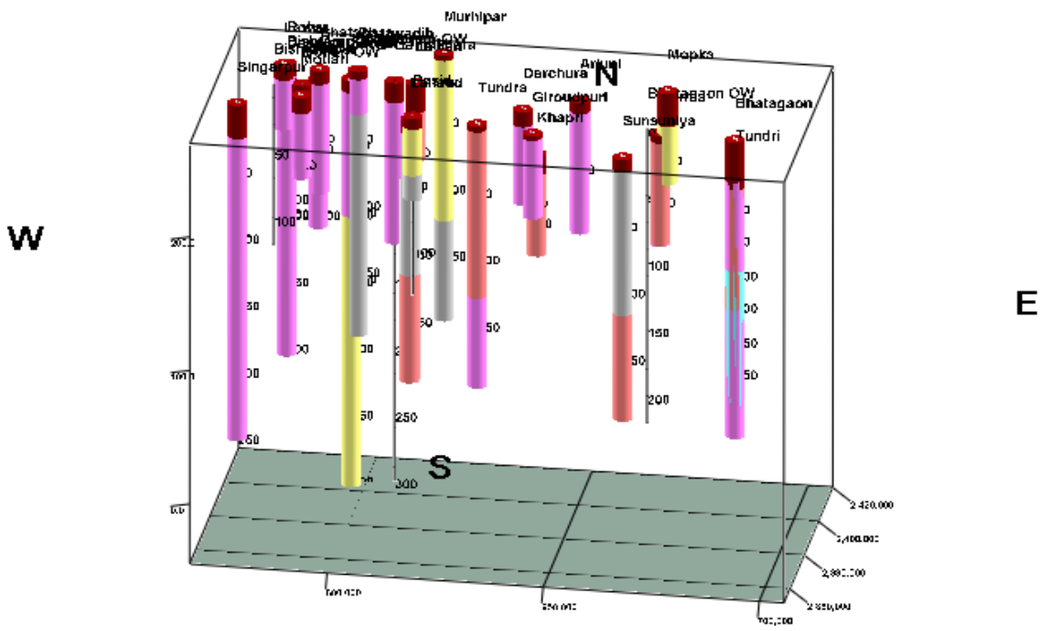


LEGEND

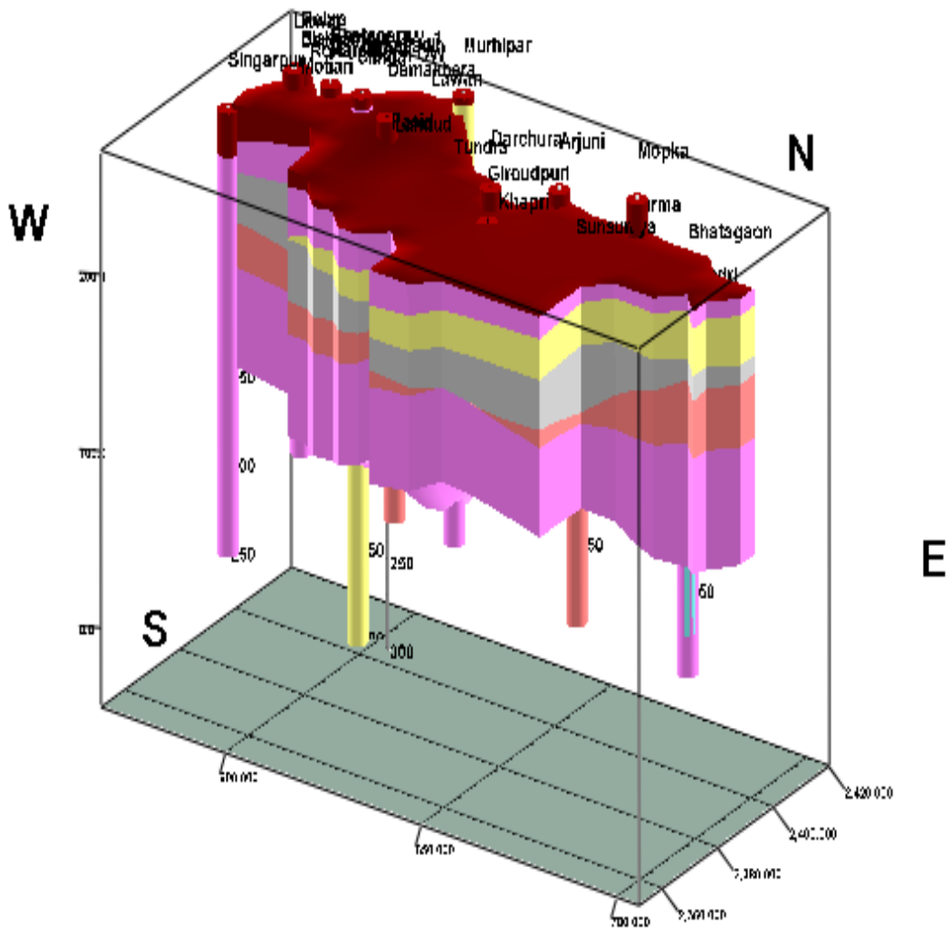
- **Weathered Formation**
- **Tarenga Formation-Cherty shale**
- **Chandi Formation- Limestone**
- **Gunderdehi Formation- shale**
- **Charmuria Formation-Limestone**
- **Chadrapur Formation- Sandstone**

(E) Three- dimensional Stratigraphy Logs and Aquifer Disposition in Baloda Bazar





Stratigraphy
Weathered Formation
Tarenga Formation-Cherty shale
Chandi Formation-Limestone
Gunderdehi Formation- shale
Charmuria Formation-Limestone
Chadrapur Formation- Sandstone
Chuipali Formation- Limestone



Stratigraphy

- Weathered Formation
- Tarenga Formation-Cherty shale
- Chandi Formation-Limestone
- Gunderdehi Formation- shale
- Charmuria Formation-Limestone
- Chadrapur Formation- Sandstone
- Chuipali Formation- Limestone

The transmissivity of this Chhattisgarh formations' ranges from 4.00 to 450 m2/day and the specific capacity ranges between 2 and 20 Ipm/m of draw down and storativity ranges from 0.003 to 0.000224.

4. GROUND WATER RESOURCE ENHANCEMENT AND MANAGEMENT PLAN

In the ground water resource estimation, the unit of assessment to ground water resources has been taken as the smallest administrative unit i.e. Block. The hilly areas (slope greater than 20%) have been excluded from the computations. The assessment unit has been divided into command and non-command areas and ground water resources have been estimated separately for command and non-command areas. The ground water recharge in the monsoon season and non- monsoon season has also been estimated separately. The water level data collected by CGWB through NHS monitoring and from state ground water survey, has been utilized for resource estimation. The rainfall data from Indian Meteorological Department has been incorporated in the assessment. The irrigation data for tube wells and dug wells were provided by Water Resources Department. The state could not get success to obtain the stream data from the concern department. The domestic dug wells & bore wells data are not available, therefore per capita consumption of 60 liters per day per person for rural areas and 100 liters per day per person for urban areas have been taken into consideration. The data of ground water withdrawal for industries incorporated from the NOC issued by CGWA and from State Industries Department. The stage of Ground Water Development stands at 41.45% in Baloda Bazar district. Hence the district is categorized as "Safe**".** Where net ground water availability for future use is 30095.9 ham. The various extraction details along with the categorisation based on the resource assessment made, up to 200m depth are given in Table 13 & 14.

4.1 Existing and Future Water Demand (2025)

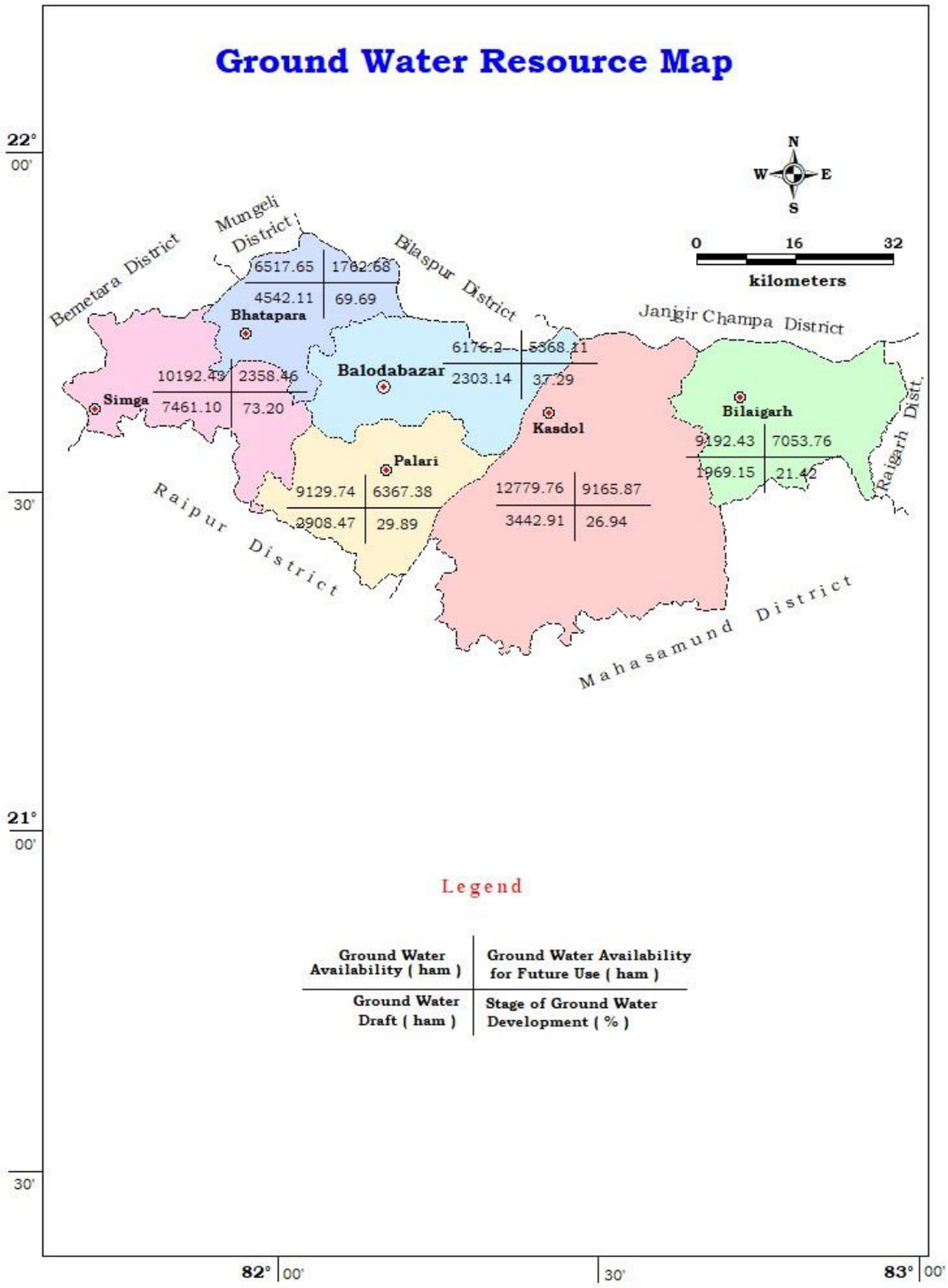
Table: 13 Ground water Resource availability in Baloda Bazar district

Name of District	Total Annual Ground Water Recharge	Total Natural Discharges	Annual Extractable Ground Water Resource (3=1-2)	Current Annual Ground Water Extraction(Ham)				Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use (9=3-4-5-8)	Stage of Ground Water Extraction (%) (7/3 *100)	Categorization (Over-Exploited /Critical/Semi critical /Safe/Saline
				Irrigation	Industrial	Domestic	Total (7=4+5+6)				
	1	2	3	4	5	6	7	8	9		
BALODA BAZAR	60529.55	5941.32	54588.23	17550.27	459.4088	4617.168	22626.88	6482.56	30095.96	41.45	Safe

Table: 14 Ground water Resource availability in Six Blocks of Baloda Bazar district in Ham

Assessment Unit Name	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham) (3=1-2)	Current Annual Ground Water Extraction (Ham)				Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham) (9=3-4-5-8)	Stage of Ground Water Extraction (%) (7/3 *100)	Categorization (Over-Exploited /Critical/Semi critical /Safe/Saline)
				Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham) (7=4+5+6)				
	1	2	3	4	5	6	7	8	9		
BALODA BAZAR	6738.41	562.21	6176.2	1177	223.2	902.9355	2303.14	1407.89	3368.11	37.29	Safe
BHATAPARA	7241.83	724.18	6517.65	3870.825	16	655.2841	4542.11	868.04	1762.78	69.69	Safe
BILAIGARH	10213.82	1021.39	9192.43	1299.287	1	668.8486	1969.15	838.37	7053.76	21.42	Safe
KASDOL	14199.75	1419.97	12779.78	2825.853	0	617.0508	3442.91	768.05	9185.87	26.94	Safe
PALARI	10810.81	1081.07	9729.74	2111.218	11.19143	786.0556	2908.47	1239.95	6367.38	29.89	Safe
SIMGA	11324.93	1132.5	10192.43	6266.087	208.0174	986.9936	7461.1	1360.26	2358.06	73.20	Semi-Critical

Fig. 13: Ground Water Resource Map of Baloda Bazar District



4.2 GROUND WATER RELATED ISSUES

Ground water level was monitored in both dug wells and piezometers and two different scenario of water level was observed which is indicative of presence of two different aquifers in the district. As can be seen from the depth to water level map during pre-monsoon period, the water level is found to be deepest mostly in western and some parts in southern portion of the district. Similarly during post-monsoon period deeper water level is observed in western and southern parts of the district. The deeper water level is occurring in areas where the ground water is being exploited heavily by construction of bore wells for irrigation purpose. Such irrigation bore wells are found in large number in the northern parts of Bhatapara and Simga

- **Drying of Dug wells and handpumps during summer-** At several places of northern and southern part of Baloda bazar district phreatic aquifer i.e. zone of dug wells dried up in summer due to large number of shallow borewells in the area.
- **Inherent hydrogeological character of aquifer-** The fractures are also very localized which results very low yield and less transmissivity in aquifers. Good potential confined in structurally low laying areas where limestone occur whereas in shale formation areas, it is poorly yielding.
- **Contamination:** No quality problem was reported from the district. All the analyzed parameters, in all stations fall well within safe limits for drinking as well as irrigation purpose as prescribed by the BIS. The pH value ranges from 7.1 to 7.3 and is within the prescribed limit by BIS. The Electrical Conductivity (EC) value ranges from 465 to 1240 micro siemens/cm. All of the samples have EC value well within the range. The northern part of the district near Bhatapara has marginally higher value of EC. The Cl- varies from 14 mg/l to 241.1 mg/l. The Total Hardness (TH) value ranges from 200 mg/l to 540 mg/l. The Ca+2 values vary from 28 mg/l to 152 mg/l and Mg+2 values vary from 7.2 mg/l to 69.6 mg/l. Almost all the values of the analyzed parameters fall under the safe category for both drinking and irrigation purpose.

4.3 GROUND WATER MANAGEMENT STRATEGY

- It has been observed during fieldwork, there is colossal wastage of groundwater through private well and public water supply system. So, Information, Education and Communication (IEC) activities need to be organized to sensitize people on the issues of depleting groundwater resource. Massive awareness campaigns are essential to aware people about the importance of community participation in saving water.

- Desiltation of existing Tanks and Talabs to be carried out for efficient storage of rainwater.

- Also Rain water harvesting structures may be constructed in villages to reduce stress on groundwater. It has been observed that the demand of ground water is increasing for irrigation, industrial and domestic uses. At locations where water level is declining, we have to go for artificial recharge on a long-term sustainability basis, the flow of ground water is towards the major drainage indicating that the water in the river is nothing but the base flow. So, the suitable obstruction structures may be constructed on the tributaries of major rivers like Mahanadi and Seonath to check the base flow, which can enhance the pre monsoon depth to water level in the district. Recharge to ground water may be taken up in areas where post monsoon depth to water level is more than 3 mbgl. As limestone and dolomite are the major rock types in these areas of depleted water level, percolation tanks and recharge well method can be adopted for artificial recharge.

- The different types of artificial structures feasible in the blocks are described in table 16. Probable sites are also identified for the construction of Artificial Recharge structure such as percolation tank, Nala bunding/ cement plug/ check dam, Gully Plugs/ gabion structures in district as shown in figure 14 and details of the sites has been provided in Table 16.

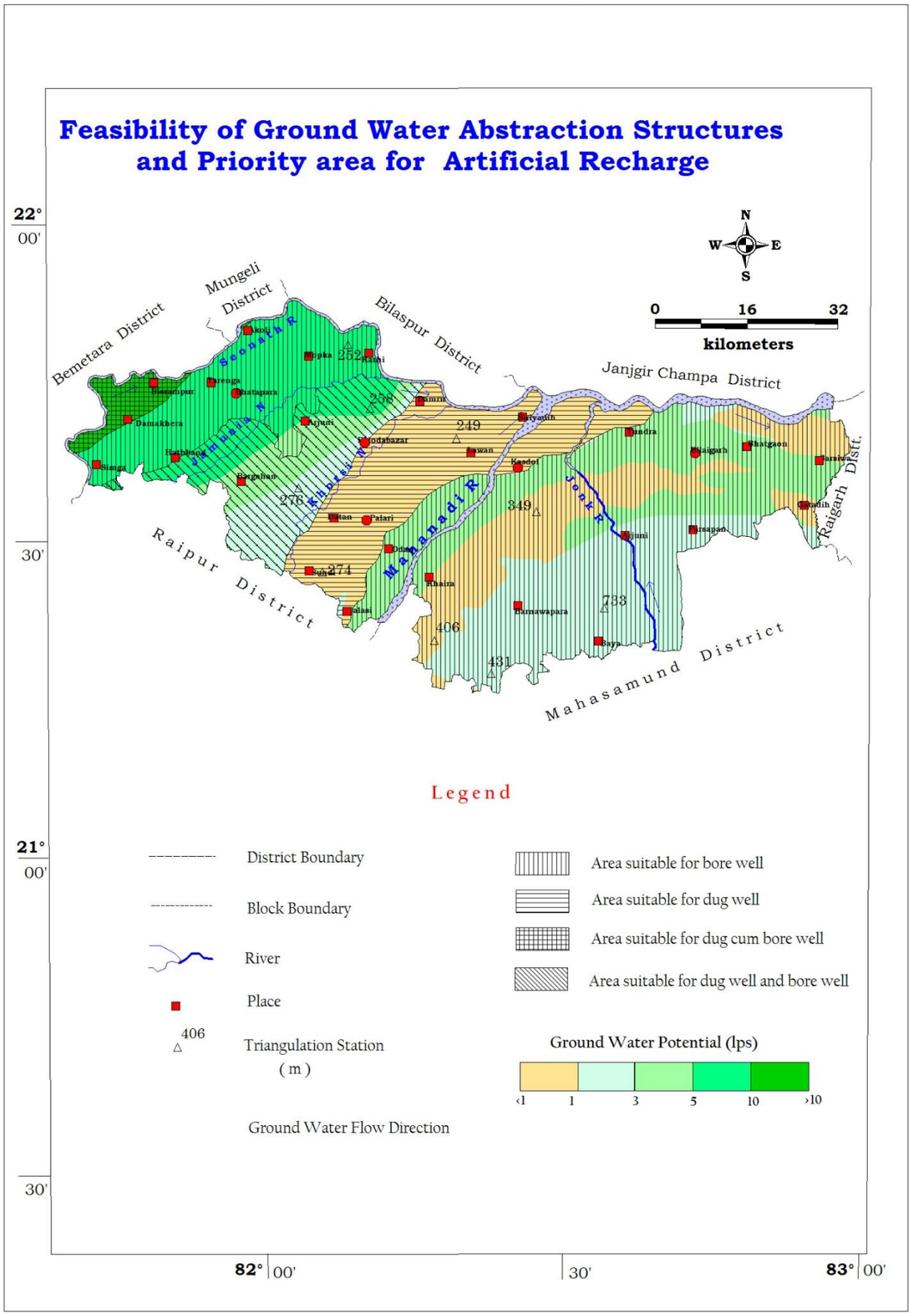
Table 15 Types of Artificial Recharge structures feasible

District	Total area (Ha)	Post Monsoon Water Level (m bgl)	Area Identified for Artificial Recharge* Sq. Km	Volume of vadose zone available for recharge(mcm)	Sub surface storage potential (mcm)	Surface Water Requirement (mcm)	Type of Structure	Types of artificial recharge structures feasible* and their numbers	Unit cost Rs in Million	Total costs (unit cost x number)
BALODA BAZAR	499440	2.879	996.09	3703.29	52	69	P	157	4	628
							NB & C	529	0.3	158.7
							RS	1271	0.5	635.5
							G	947	0.05	47.35

Table 16 Details of Artificial Recharge structures feasible Block wise in Baloda Bazar district

S. No	**Block**	**Total area (Ha)**	**Recharge Worthy Area (Ha)**	**Area Identified for Artificial Recharge* Sq. Km**	**Volume of vadose zone available for recharge (mcm)**	**Sub surface storage potential (mcm)**	**Surface Water Requirement (mcm)**	**Type of Structure**			
								Percolation tank recharge capacity 0.2 mcm	**Nala bunding cement plug/ check dam recharge capacity 0.03 mcm**	**Gravity head /Dug well/ tube well/ recharge shaft recharge capacity 0.008 mcm**	**Gully plugs Gabion structures recharge capacity 0.007 mcm**
1	Baloda bazar	62320	62320	120.46	181	1.807	2.403	6	20	45	34
2	Bhatapra	47115	47115	251.62	377	6.416	8.534	21	71	160	122
3	Bilaigarh	92692	92692	7.02	11	0.105	0.140	0	1	3	2
4	Kasdol	176339	176339	279.82	420	4.197	5.582	14	47	105	80
5	Palari	59468	59468	34.72	52	0.885	1.177	3	10	22	17
6	Simga	61506	61506	402.46	954	18.13	24.109	60	201	452	344

Fig. 14: Sites for Artificial recharge



- Abandoned tube well and dug well may be used for the recharge through shaft especially in urban and water stressed areas.
- In urban areas STP may be installed for the treatment of sewage water in proper numbers to avoid contamination of ground water. Treatment of sewage water in village through soak pit for the individual houses and Seechewal model or similar model for community level may be adopted to avoid contamination of ground water. Treated water may also be reused for irrigation and other industrial purposes.
- The ground water in the district is developed mainly for irrigation and domestic needs. The agricultural sector is consuming most of the ground water and since 90% of the net sown area is under paddy, ground water is being used at present mainly to grow paddy. Paddy needs flood irrigation with high crop water requirement. Change in cropping pattern in the district and further efficient use of ground water resource can enhance the productivity as well as area of irrigation. Secondly the command area of Palari block shows poor ground water development. Since maximum areas of these blocks come under command area, this need special attention before it turns to water logged area. Baloda bazar and Simga blocks show higher ground water development as there is very less or absence of canal irrigation system in these blocks. So these blocks should be brought under canal command area. The alluvium covered hard rock areas of the district need suitable techniques to construct ground water abstraction structures so as to increase the yield and sustainability of the structures.

Table 15 Potential of Additional GW abstraction structure creation

S. No	District	Block	Annual Extractable Ground Water Recharge (mcm)	GW available due to Supply side intervention (mcm)	Annual Extractable GW available after supply side intervention (mcm)	Current Annual GW Extraction (mcm)	Double cropped area (Sq.km)	10% double cropped area proposed for micro-irrigation (Sq.km)	Water saving due to micro irrigation (mcm)	Ground water extraction after demand side intervention (mcm)	Stage of Ground Water Extraction (%)	GW Available for development to stage of GW extraction (50%)	Nos. of dug well abstraction structures to be constructed	Nos. of Bore wells abstraction structures to be constructed
1	Baloda Bazar	Baloda Bazar	68.16	1.807	69.967	24.85	439.01	43.901	17.5604	7.2896	10.42	27.69	831	969
2		Bhatapara	66.27	6.416	72.686	35.51	344.23	34.423	13.7692	21.7408	29.91	14.60	438	511
3		Bilaigarh	86.52	0.105	86.625	12.1	407.45	0	0	12.1	13.97	31.21	936	1092
4		Kasdol	128.66	4.197	132.857	26.02	436.91	0	0	26.02	19.58	40.41	1212	1414
5		Palari	95.27	0.885	96.155	19.19	482.85	0	0	19.19	19.96	28.89	867	1011
6		Simga	99.69	18.127	117.817	59.07	432.44	43.24	17.29	41.77	35.46	17.14	514	600

5. CONCLUSION:

For effective utilization of Ground water existing draft for irrigation may be coupled with micro irrigation system. Change in irrigation pattern, optimum use of available resource, use of ground water potential created after artificial recharge can lead to groundwater savings and increase in gross cropped area of the district (Table 10).

Table 16 Detail of groundwater saved through change in cropping pattern and other interventions

Block	Existing Gross Ground Water Draft for Irrigation in MCM	Additional Saving of GW after using Micro Irrigation methods in MCM(Assumin g 30 % saving)	GW recharge through Artificial recharge structure in MCM	Total GW Resourc Enhance ment in MCM	Stage of Ground Water Extracti o n (%) As per 2020 GWRE	Expected Stage of Ground Water Extractio n (%) after interventi on n
Baloda Bazar	11.77	17.5604	1.807	19.3674	37.29	10.42
Palari	21.11218	0	0.885	0.885	29.89	19.96
Kasdol	28.25853	0	4.197	4.197	26.94	19.58
Bhatapara	38.70825	13.7692	6.416	20.1852	69.69	29.91
Simga	62.66087	17.29	18.13	35.42	73.20	35.46
Bilaigarh	12.99287	0	11	11	21.42	13.97
Total (Baloda Bazar)	175.5027	48.6196	42.435	6236.860	55.71667	35.9811 1

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