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

SINGRAULI DISTRICT
MADHYA PRADESH

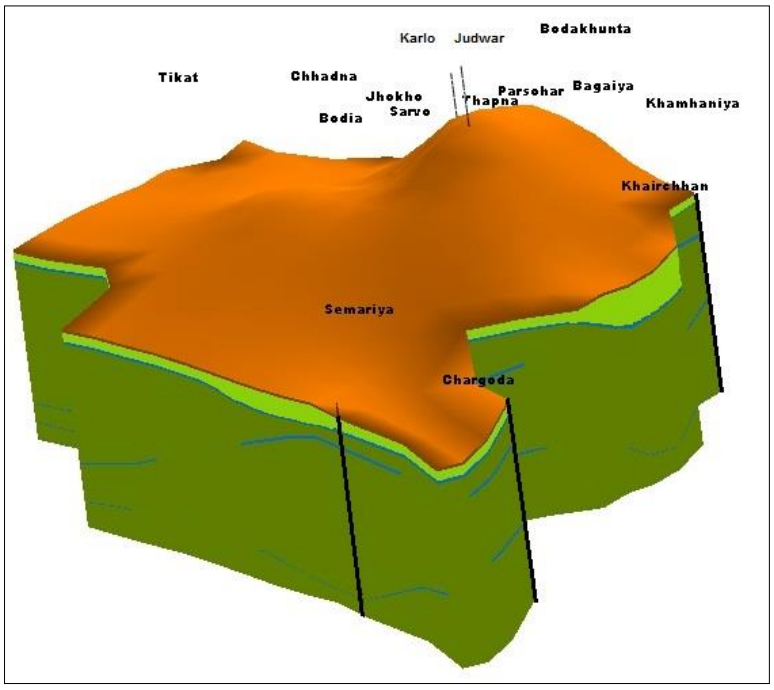
उत्तर मध्य क्षेत्र, भोपाल
North Central Region, Bhopal

Central Ground Water Board

Department of Water Resources, RD & GR

Ministry of Jal Shakti

Government of India



Aquifer Mapping and Ground Water Management Plan of Singrauli District, Madhya Pradesh

BY

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NORTH CENTRAL REGION

BHOPAL

2021-2022

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PREFACE

'Aquifer mapping' is a holistic approach for aquifer-based groundwater management. It may not be construed as aquifer geometry mapping only. In a broader perspective it can be defined as understanding the aquifers, ascertaining and establishing their quantity and quality sustainability through multi-disciplinary scientific approach integrating the techniques of geology, remote sensing, hydrogeology, geophysics, borehole drilling, hydrochemistry, hydrology, hydrometeorology, mathematical modelling, agriculture and soil science, water treatment and remediation, economics and social and environmental sciences.

Under the project on National Aquifer Mapping (NAQUIM to formulate sustainable Aquifer management plan, Central Ground Water Board (CGWB), North Central Region, Bhopal has taken up Singrauli district to prepare the 3-Dimensional Model and 2-Dimensional Aquifer Maps for the entire district and formulate Block-wise Aquifer Management Plan.

The study area occupies an area of 5672 Sq. Km. It is divided into, four administrative blocks viz Waidhan, Chitrangi and Deosar forming blocks. Singrauli district is underlain by various geological formations, forming different types of aquifers in the area. Main geological; units of the area are Archaean, Vindhyan sandstone, Gondwana, Gniess/Schist Limestone Deccan traps and alluvium.

The pre-monsoon depth to Water levels ranges from a minimum of 4.95 meters below ground level (mbgl) in Sarai village of Deosar block to a maximum of 17 mbgl in Karthua village of Chitrangi block of Singrauli district. The post-monsoon depth to Water levels ranges from a minimum of 2.71 m below ground level in Sarai village of Deosar block to a maximum of 7.75 m bgl in Kohara Khoh village of Deosar block of Singrauli district.

After the implementation of project interventions in the report, the stage of ground water development in Waidhan Block is expected to improve by 13.1% i.e. from 64.17 % to 51.07% and in Deosar block by 6.27% from 50.58% to 44.31%. In Chitrangi block the stage of ground water development may be increased from 21.73% to 69.75% by irrigation of additional 218.93 Sq.Km. area. Ground water extraction has been proposed through PMKSY in the block. Suitable ground water structures Dugwells, Dug cum Borewell and Borewell has been recommended in the area.

As per the Management plan prepared under NAQUIM of all the Block of Singrauli District, a total number of 257 Percolation Tanks, 2204 Recharge Shafts/Tube wells and 2204 Nala Bunds/Check Dams and 502 Village pond Cement Plugs have been proposed. Heavy siltation in Govind Vallabh Pant Sagar reservoir can be avoided by construction of various soil conservation structures like gabbion, staggered contour

trenches with plantation of vegetative check near all the waste dump sites of opencast mining area.

Results of these comprehensive studies will contribute significantly to ground water sustainable management tools. It will not only enhance the long-term aquifer monitoring networks but would also help in building the conceptual and quantitative regional ground-water-flow models for planners, policy makers and other stakeholders. I would like to place on record my appreciation for ***Dr.Rakesh Singh, Sc. D*** to compile this report. I hope that this report will serve as a valuable guide for sustainable development of ground water in the Singrauli District, Madhya Pradesh.

Rana Chatterjee
(Regional Director)

1.0 INTRODUCTION

National project on Aquifer Mapping (NAQUIM) had been taken up by CGWB to carry out detailed Hydrogeological investigation on toposheet scale of 1:50,000. The NAQUIM has been prioritised to study Over-exploited, Critical and Semi-Critical blocks as well as the other stress areas recommended by the State Govt. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers.

The vagaries of rainfall, inherent heterogeneity & unsustainable nature of hard rock aquifers, over exploitation of once copious alluvial aquifers, lack of regulation mechanism has a detrimental effect on ground water scenario of the Country in last decade or so. Thus, prompting the paradigm shift from "**traditional groundwater development concept**" to "**modern groundwater management concept**".

Varied and diverse Hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plans. The proposed management plans will provide the **"Road Map"** for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. Thus the crux of NAQUIM is not merely mapping, but reaching the goal-that of ground water management through community participation. The aquifer maps and management plans will be shared with the Administration Singrauli District for its effective implementation.

1.1 Objective and Scope

Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e., the aquifer map and management plan. The activities under NAQUIM are aimed at:

- Identifying the aquifer geometry,
- Aquifer characteristics and their yield potential

- Quality of water occurring at various depths,
- Aquifer wise assessment of ground water resources
- Preparation of aquifer maps and
- Formulate ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a **"Road Map"** to systematically manage the ground water resources for equitable distribution across the spectrum.

1.2 Approach and Methodology:

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behavior of ground water levels and status of ground water development in various aquifer systems to facilitate Major Aquifers planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps and generation of data for filling data gaps and preparation of aquifer maps. The overall methodology of aquifer mapping is presented once the maps are prepared, plans for sustainable management of ground water resources in the aquifers mapped shall be formulated and implemented through participatory approach involving all stakeholders. To achieve the objectives the following approach and methods have been adopted and stepwise details have been shown in the fig 1.

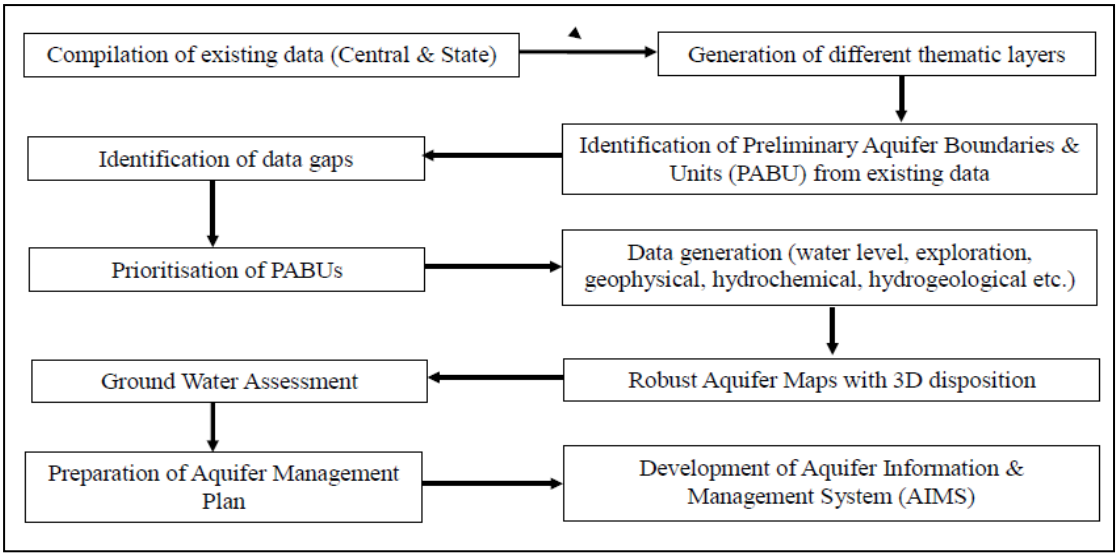


Fig 1: Steps of Methodology

1.3 Study area

The Singrauli district is located in the north eastern part of Madhya Pradesh having a geographical area of 5672 sq.km and extended by North latitudes 23°59′5" and 24°42′10" and east longitude 81°52′40" to 82°48′30" with its headquarter at Waidhan. It has been formed after disintegrating it from Sidhi district on 24th May 2008. The district is bounded in the West by Sidhi district, in the North and East by Mirzapur and Sonbhadra district of Uttar Pradesh respectively and by Koriya, Surajpur and Balrampur districts of Chhatisgarh in south. There are 3 development blocks Deosar, Chitrangi and Waidhan, and 824 villages in the district. As per census 2011, the total population of the district is 11,78,273.

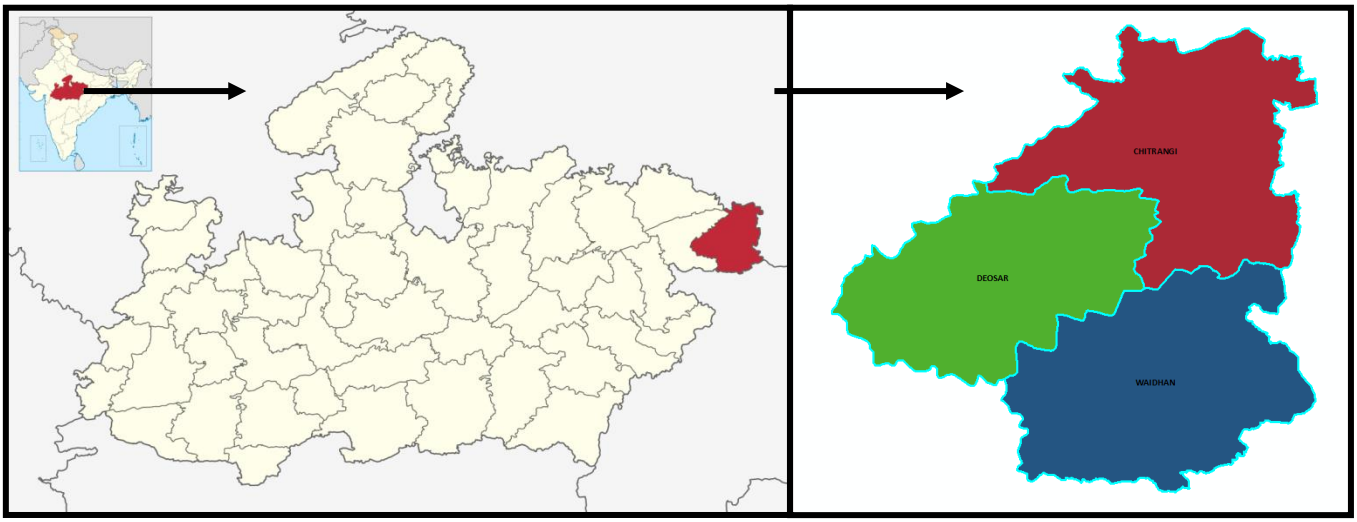


Fig 2: Index Map of Singrauli District

Fig 3: Panaromic view Showing Opencast coal Mining Singrauli district

The Singrauli district has been divided into 3 Blocks. There are 824 villages in the district. Total population of the district is 11,78,273. Detailed administrative divisions of the district are given in Table-1.

Table – 1: Area Details of Singrauli district.

Area Distribution In SQ KM	
Total Geographical Area (sq km)	5672.00
Recharge worthy Area (sq km)	4512.60
Hilly/Forest (sq km)	1159.40

Table – 2: Administrative Units of Singrauli district.

Block	Geographical Area (Sq Km)	Recharge Area (Sq Km)
Waidhan	1904	1399.00
Chitrangi	1946	1712.50
Deosar	1822	1401.10
Total	5672	4512.60

Singrauli is fast emerging as an energy hub of India, especially for electric power and coal and therefore locally it is also called Urjanchal (a Hindi word which means land of energy).The total installed capacity of all power plants at Singaruli is around ten percent of total installed capacity of India.

1.4 Climate and Rainfall

The climate of Singrauli district Characterized by hot summer & well distributed rainfall during south west monsoon. The year can be divided into four seasons. The winter commence from end of November and lasts till first week of March. The period for March to middle of June conditions hot weather. May is the hottest month of the year. The south west monsoon starts formmiddle of June and continues till end of September. October & November is the months of post monsoon/retreating of monsoon.

The temperature starts rising form beginning of February and reaches maximum during the month of May. The daily mean maximum temperature in May is 42.0^0C and daily mean minimum is 25.8^0c. The day temperature on individual days during the period April to first week June gets up to 44^0 to 45^0 C. Monsoon generally arrives

in the middle of June and there is an appreciation drop is temperature and the weather becomes pleasant. After withdrawal of monsoon in the first week of October there is slight increase in day's temperature, hot nights become progressively cooler. January is generally coldest month of the year. The maximum daily mean temperature in January is 24.3^{0c} and minimum daily temperature about 8.1^{0c}.

The summer season is the district period of the year. The humidity is the lowest in April i.e. about 35%, during south west monsoon the humidity is the highest due to heavy rains, attaining its maximum of about 85% in August. The humidity again decreases in October due to high temperature and retreating of monsoon. The daily mean annual relative humidity of Singrauli is 66%.

The wind velocity is high during the Premonsoon period as compared to post monsoon period. The highest wind velocity is in June about 6.50 km/hr and lowest in December about 1.6 km/hr. The daily annual mean wind velocity of Singrauli district is 3.6km/hr.

The normal rainfall of the district is 1294.9mm. The maximum rainfall takes place during south west monsoon period. Rainfall 89% of the annual rainfall takes place during monsoon period i.e. June to September. July is the wettest month of the year. Only 11% of the annual rainfall takes place between October to May period.

Table 3: Annual Ranfall Data – 2016 to 2020 (mm)

Year	2016	2017	2018	2019	2020
Rainfall	1298.3	866.9	924.2	1395	1294.9

(Source: Indian Meteorological Department)

1.5 Physiography

The district as a whole constitutes a undulated hilly terrain, major part of the district is covered by Kaimur hilly ranges. The district is divided into three physiographic divisions: - (i) Kaimur hilly ranges (ii) The Central part hilly ranges and (iii) Southern hilly ranges.

In the district three main rivers Son, Gopad and Rihand flows along with several tributaries along the valleys. The Kaimur range stretching from NE and SW direction and covered most part of the district. The central part of the district forms a series of hill ranges. The elevation of hills ranges varies between 142 and 823m above MSL. The physiography map is shown in fig.4

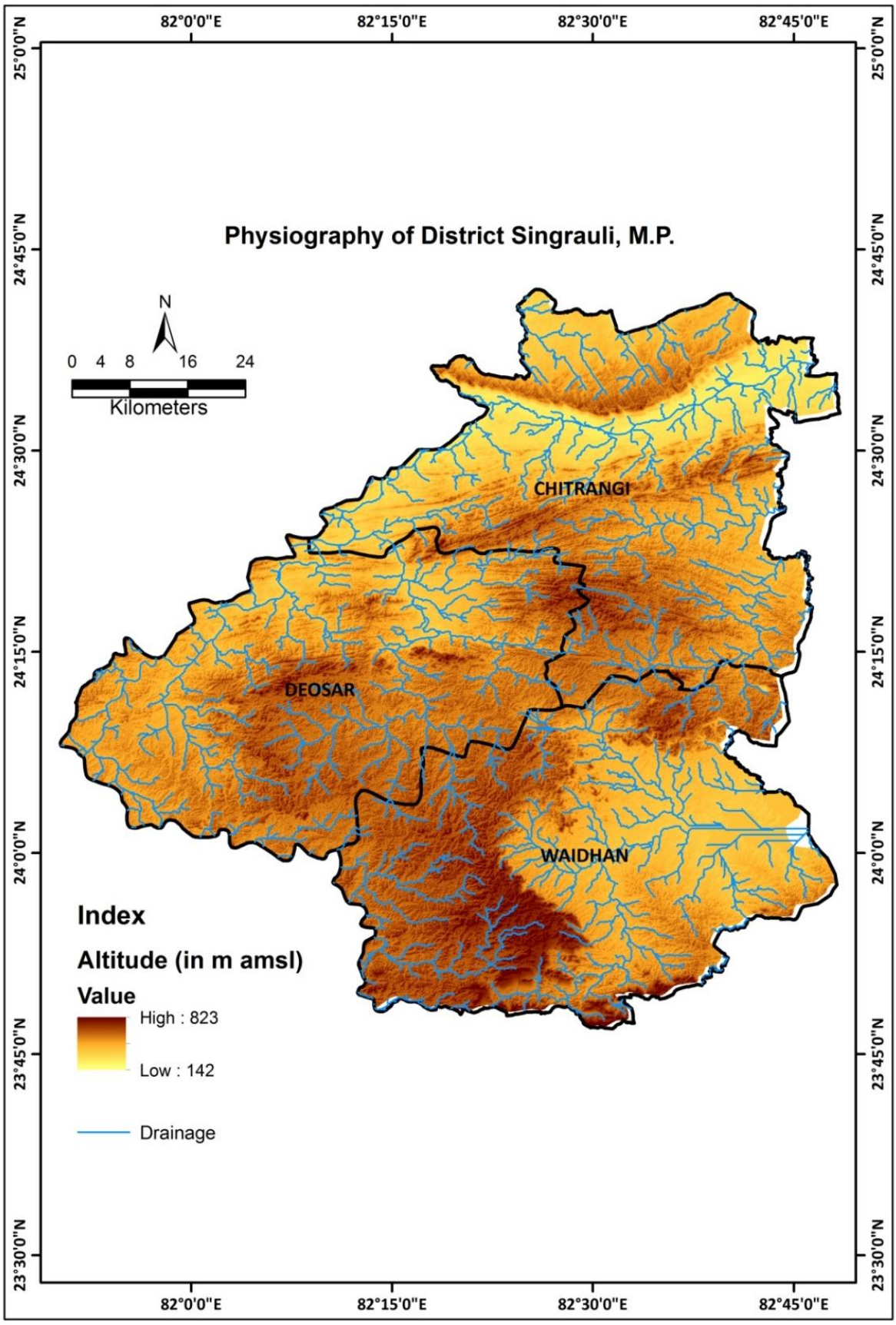


Fig. 4: Physiography Map of Singrauli District

1.6 Drainage

The district as a whole lies on Son sub basin of the Ganga basin. On localize scale there is surface water divide from south west to north east passed to Waidhan and Chitrangi. The area north west of this divide forming almost 80% of the district, is drained by the Gopad, Mahan and Gotan in to the son river and to the south east by the Rihand. The Son is perennial and Gopad is a ephemeral tendency is major part of its course. Most of the stream traversing in the area has their courses in rocky terrain with marginal sand cover in their channel section, except along the Son and Gopad where the sandy alluvium is comparatively thicker.

The Son: The Son flows west to east along the northern boundary of Singrauli district. The eastern course of the river is flowing along major lineament/ fault has cut deep gourge across the Kamur hill ranges. The river bed and banks are the thick sand alluvium overlies by sandstone, shale and lime stone of Vindhyan formation. The main tributaries of Son are Gopad and Gotan and it joins the right bank of the river.

The Gopad: The Gopad has northerly course from the western boundary with Sidhi district it joins Son in the north. The river originate from Waidhan , the river flows through the granitic formation and then crosses the Viudhyans, formation before entering the alluvial plains. The main tributaries of the Gopad are Mahan which join the river near village Khamhariya kalan in chitrangi block.

The Rihand: The Rihand has northen course of the district which originates from district Ambikapur of Chhatisgarh state it joins the son rivers in Sonbhadra district of Uttarpradesh, over which the Rihand dam has been constructed also known as Govind Vallabh Sagar. It is largest dam of India by volume. . The major catchment of the river lies in three states of Chhattisgarh, Madhya Pradesh and Uttar pradesh. The main tributaries of Rihand in the district are – Mayar, Kanchan and Baliya nala which join the reservoir in Waidhan, Singrauli district.

Drainage map and water bodies of the area shown in figure no 5 & 6

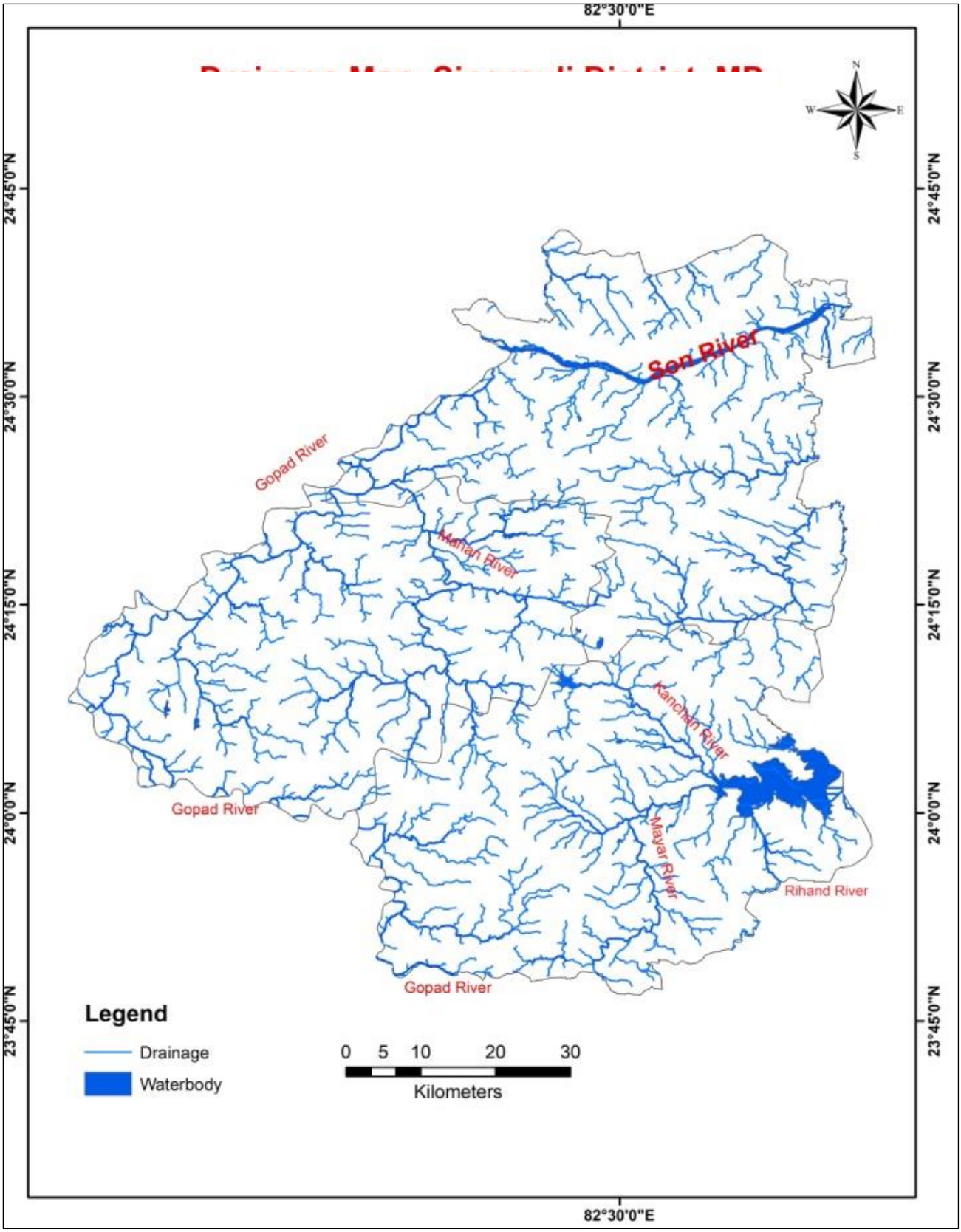
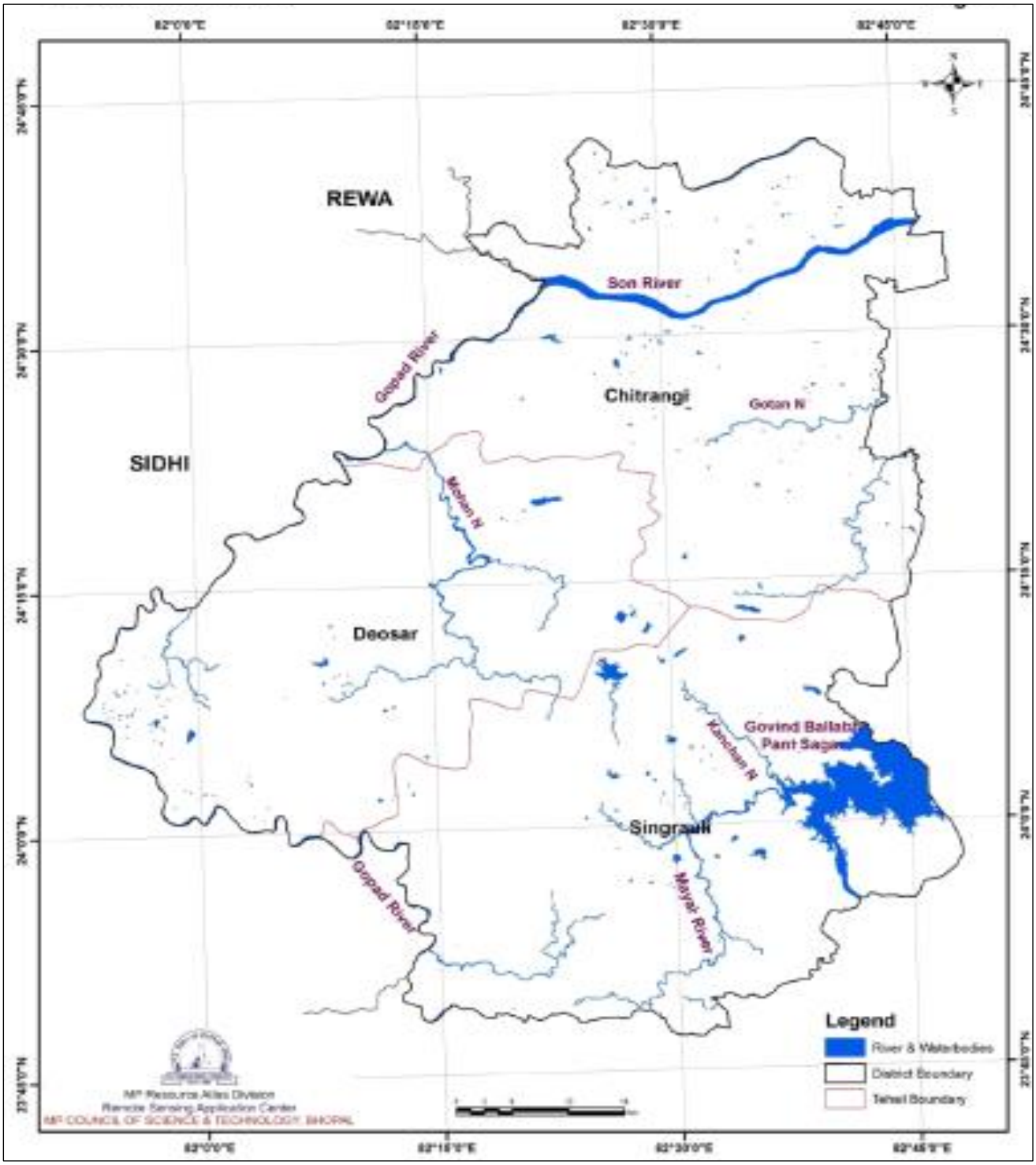


Fig 5: Drainage Map

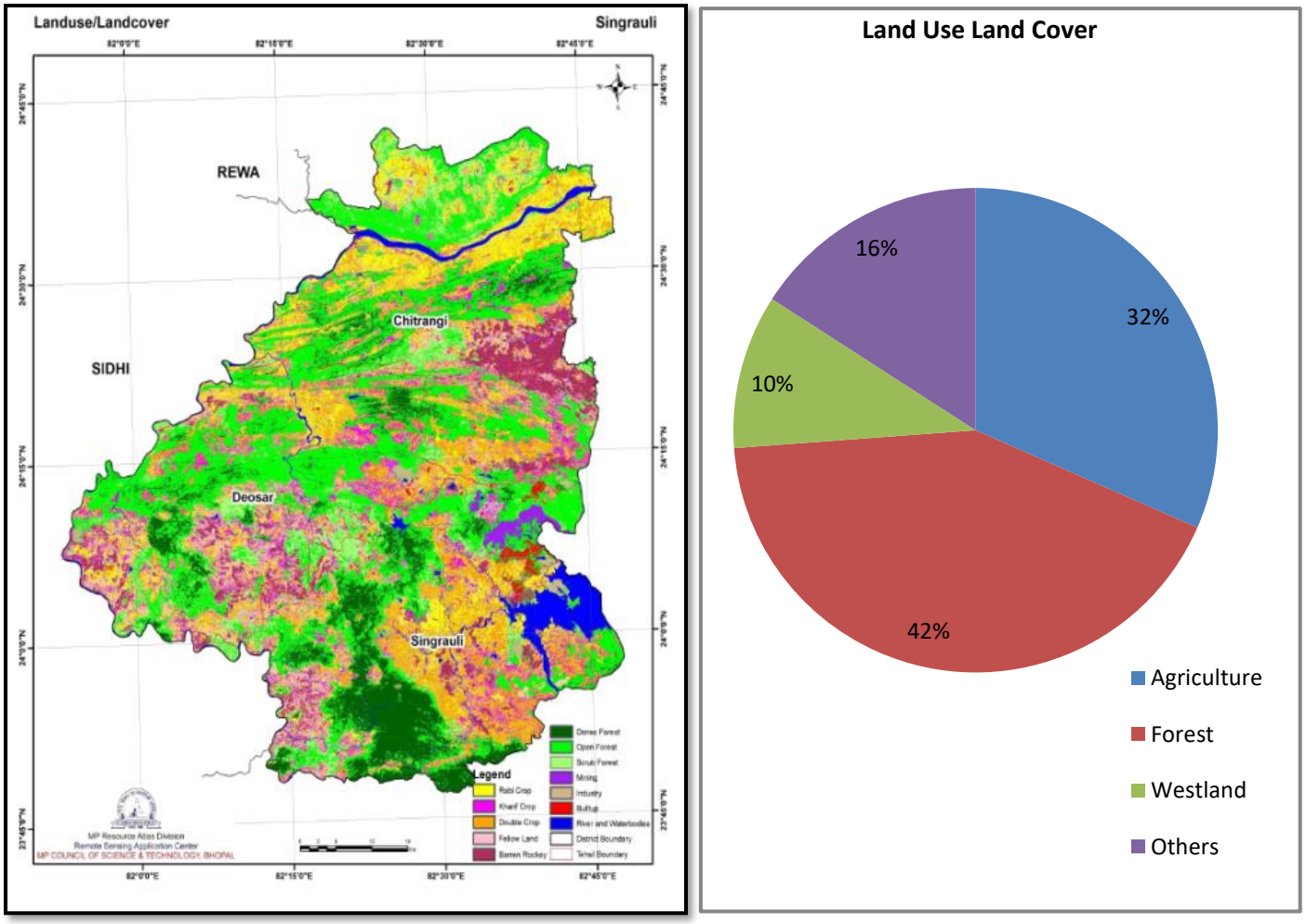


Source: MP Council of Science & Technology, Bhopal

Fig 6: Water bodies in Singrauli District

1.7 Land Use Pattern

Almost 42 percent of the total geographical area is under forest cover. Nearly 32 percent of the area is fit for cultivation, with cultivation of 2381.57 sq km out of total 4512.60 sq km of recharge worthy area. The district land use pattern is rapidly changing due to various mining activities. So far around 8% of the district is under mining cover. The land use land cove map and Pie- chart is shown in figure no 7.



Source: MP Council of Science & Technology, Bhopal

Fig 7: Land Use Land Cover Map and Pie Chart

Table 4: Land Use (in sq.km)

S. No.	Block	No. of villages covered	Total Geographical Area (sq km)	Area Under Agriculture				Area Under Forest (sq km)	Area Under Wasteland (sq km)	Area Under other/ mining uses (sq km)
				Gross Cropped Area (sq km)	Net Sown Area (sq km)	Area sown more than once (sq km)	Cropping Intensity			
1	Waidhan	271	1904	1906.55	509.75	178.33	158%	488.18	232.37	263.00
2	Deosar	231	1822	1845.59	572.85	172.49	151%	1131.8	186.21	315.62
3	Chitrangi	322	1946	1925.08	675.00	232.95	142%	775.38	165.17	322.51
	Total	**824**	**5672**	**5677.22**	**1757.6**	**583.77**	**150%**	**2395.36**	**583.75**	**901.13**

1.8 Agriculture, Irrigation and Cropping Pattern

Major food grains under cultivation in Kharif include Paddy, Maize, Arhar, Urad and Moong while Wheat, Gram, Mustard and Linseed (Alsi) are grown in Rabi. Besides these crops spices, medicinal, fruits (Mango, Guava) and seasonal vegetables (tomato, cauliflower, pea and Cucurbits, lady's finger) are also cultivated by the farmers in the district. Major spices under cultivation are Garlic, Coriander, Fenugreek, Chilies, and Turmeric. The area under fruits and spices remained limited in the district due to depleting irrigation and post harvest management facilities etc. cropping patterns and crop water requirement are give in table no 5 and 6.

Table 5: Cropping pattern and area distribution of Crops in singrauli district

Crop Type	Kharif (Area in ha)			Rabi (Area in ha)			Summer crop (Area in ha)			Total (Area in ha)		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
1	2	3	4	5	6	7	8	9	10	11	12	13
A) Cereals	2887	44018	46905	28167	5260	33427	-	-	-	31054	49278	80332
B) Coarse Cereals	-	58964	58964	6090	6258	12348	-	-	-	6090	65222	71312
C) Pulses	316	23840	24156	354	23329	23683	-	-	-	670	47169	47839
D) Oil Seeds	-	15169	15169	200	10935	11135	-	-	-	200	26104	26304
E) Fibre	-	588	588	-	0	0	-	-	-	0	588	588
Horticulture & Plantation Crop	5009	419	5428	6092	262	6354	561	0	561	11101	681	11782
Total	**8212**	**142998**	**151210**	**40903**	**46044**	**86947**	**561**	**0**	**561**	**49115**	**189042**	**238157**

Table 6: Crop Water Demand

Crops	Area Sown(Ha)	Irrigated Area(Ha)	Crop Water Demand(mm)	Water Potential Required(BCM)
(A)Cereals				
Rice	47452	2873	1200	0.569424
Wheat	33436	25646	500	0.16718
(B) Coarse Cereals (Maize)	25645	-	650	0.1666925
(C) Pulses	41641	519	400	0.166564
(D)Oil Seeds	26351	200	400	0.105404
(E) Fibre	588	-	2000	0.01176
Vegetables	6080	6080	700	0.04256
Fruit Plants	4970	4800	1800	0.08946
Total	186163	40118		1.3190445

1.9 Geology

The geology of the district reveals the occurrence of various rock formations as old as Granites of Achaean age to the Alluvium of Recent age. The other important formations outcropping in the district are Deccan trap of cretaceous – Eocene, Gondwanas of Paleozoic to Mesozoic, Sandstone Shale and limestone of Vindhayans and Phyllites, Quartzites, Schist, Gneisses and Granites of Archean age. The Geology of the district is shown in the Geological Map in figure no 8. The general Stratigraphic succession of the district is given as under:-

Table 7: General Stratigraphic Succession

Period	**Series/stage**	**Lithology**	
Recent Pleistocene	Alluvium	Alluvium and soil cap comprising clay, sand gravel etc.	
Cretaceous to Eocene	Deccan Traps	Basaltic Lava flows	
Permian to up carboniferous	Gondwanas	Upper Gondwana formation Ranging formation Talchir formation	Sandstone Shale Coal, Conglomerate and Glouconite
Cambrian	Vindhyans	Kaimur SeriesSemri Series	Porcellinite Sandstone Orthoquortzite and Conglometry
Pre Cambrian	Archeans	Phyite, Quartzites, Granite, Schist, Gneisses metabasic sedimentary andIntrusive	

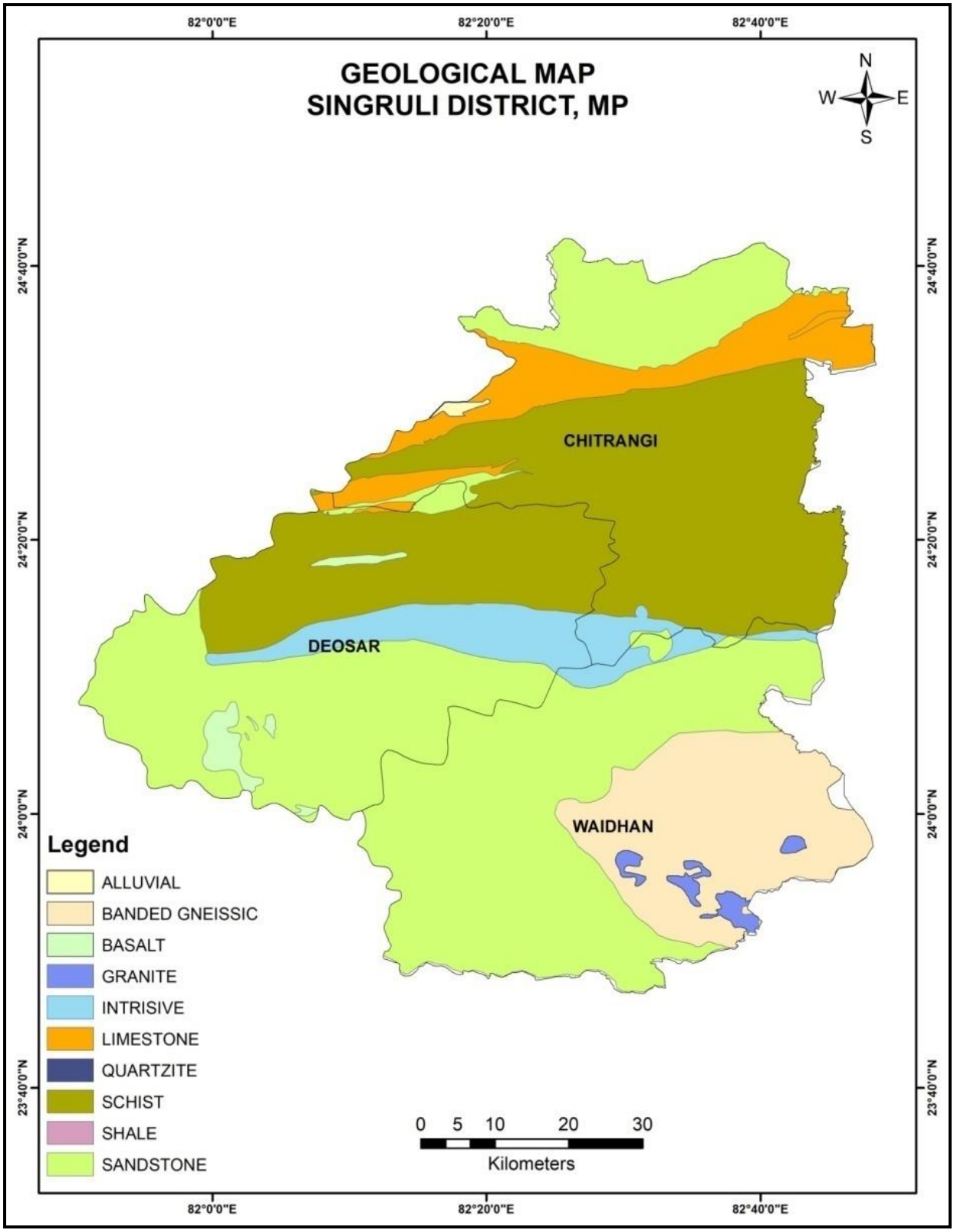
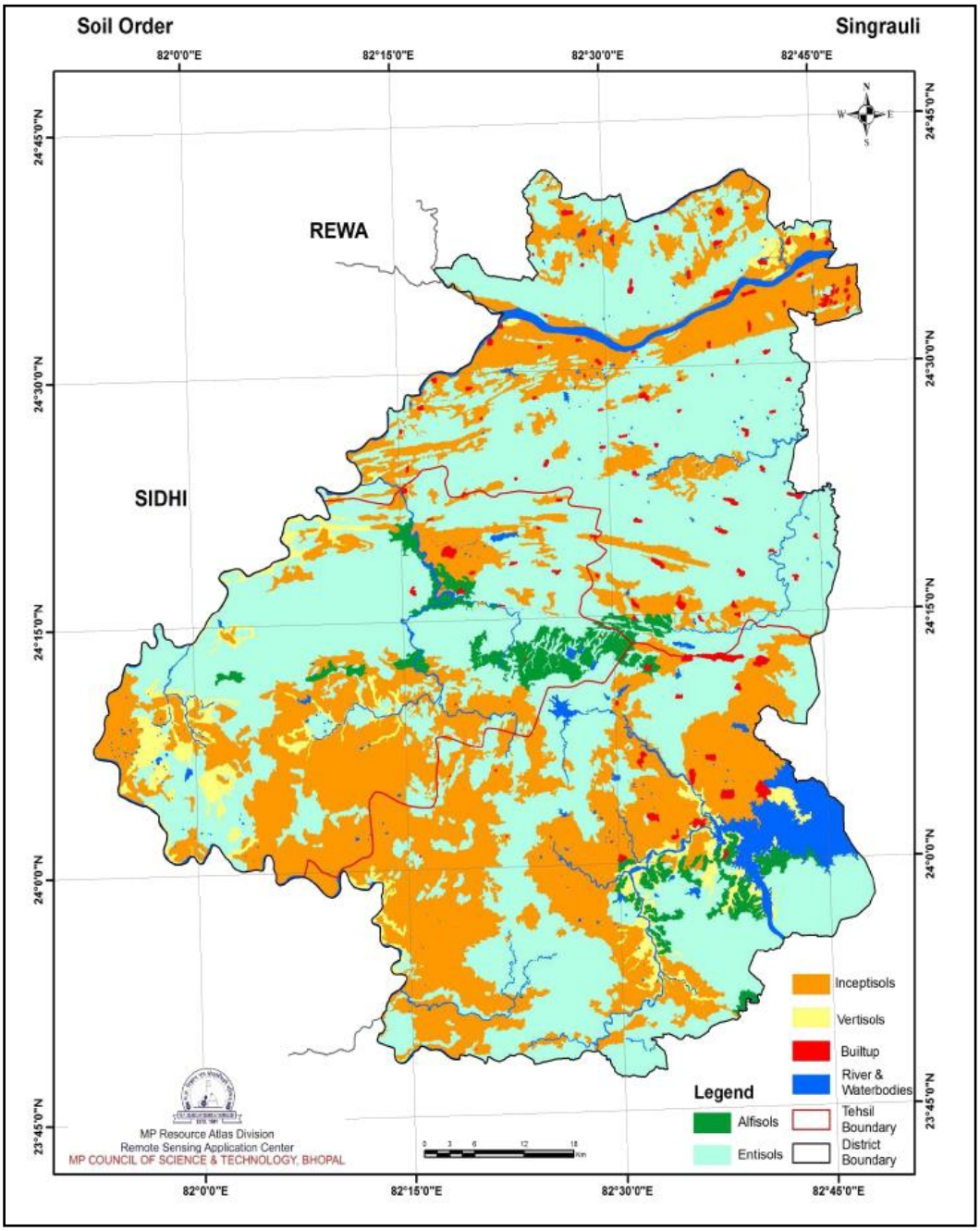


Fig.8: Geological Map.

1.10 Soil cover

The Singrauli District is generally covered with Alluvial soil, red sandy soil and yellow loamy sandy soil, lateritic soil and red loam soil. The district comprises sedimentary, crystalline and metamorphic rocks, weathered into red soil. Similarly the red colour of the laterite soil is more due to diffusion of Iron compounds rather than due to high proportion of Iron oxides. The alluvial soil is mostly restricted by along the banks of major rivers, whose thickness varies from few meters to 25 meters.



(Source: MP Council of Science & Technology Bhopal)

Fig.9: Soil Cover of District Singrauli

2.0 DATA COLLECTION AND GENERATION

The basic concept of aquifer mapping stands on these four major pillars. The aquifer mapping and management plan of Singrauli district is broadly carried out in following steps:

a. **Data compilation:** The previous studies carried out by Central Ground Water Board and various Government organizations was collected. The Basic data reports of Exploratory wells/Observation wells/ Piezometers drilled by CGWB, details of wells drilled by State Public Health and Engineering Department (PHED) and district brochures published by CGWB was compiled and integrated for aquifer mapping. The Dynamic Ground Water Resource (2020) of CGWB and figures from the Water Resource Department were used for preparation of management plan.
b. **Data adequacy:** The data compiled has been collected from the CGWB/ State departments. Thus, the adequacy of the data is supposed to be high and reliable for the specific study of aquifer mapping and management plan.
c. **Data gap analysis:** The identification of data gap was done after the detailed analysis, examination, synthesis and interpretation from available sources. This process incorporated the conversion of analog data in the form of digital data that could be processed readily on GIS platform.
d. **Data Generation:** Under NAQUIM project, 84 new key wells are established in the district including dugwells and borewells for regular monitoring of shallow as well as deep aquifer. 15 Exploratory wells are drilled upto 200m target depth to explore the Hydrogeological parameters of shallow and deep aquifers.

2.1 Data Gap Analysis for Ground Water Level Monitoring (Key Well Establishment)

Central Ground Water Board has setup its own monitoring wells which are monitored four times in a year. There are 20 such Dugwells and 4 Piezometers in the district which are located in Waidhan and Deosar block, which is shown in fig no. 10

Under NAQUIM study, 84 new key wells are established including Dugwells, Borewells and Handpumps for regular monitoring of shallow as well as deeper aquifer. 15 Exploratory wells are also constructed, down to the depth of 200 mbgl to explore the hydrogeological parameters of shallow and deep aquifers. 116 VES were carried out in the entire district to explore the subsurface horizon. Established 84 key wells including 15 exploratory wells 24 NHS monitoring wells and 116 VES are plotted on data gap map and is shown in fig no 11.

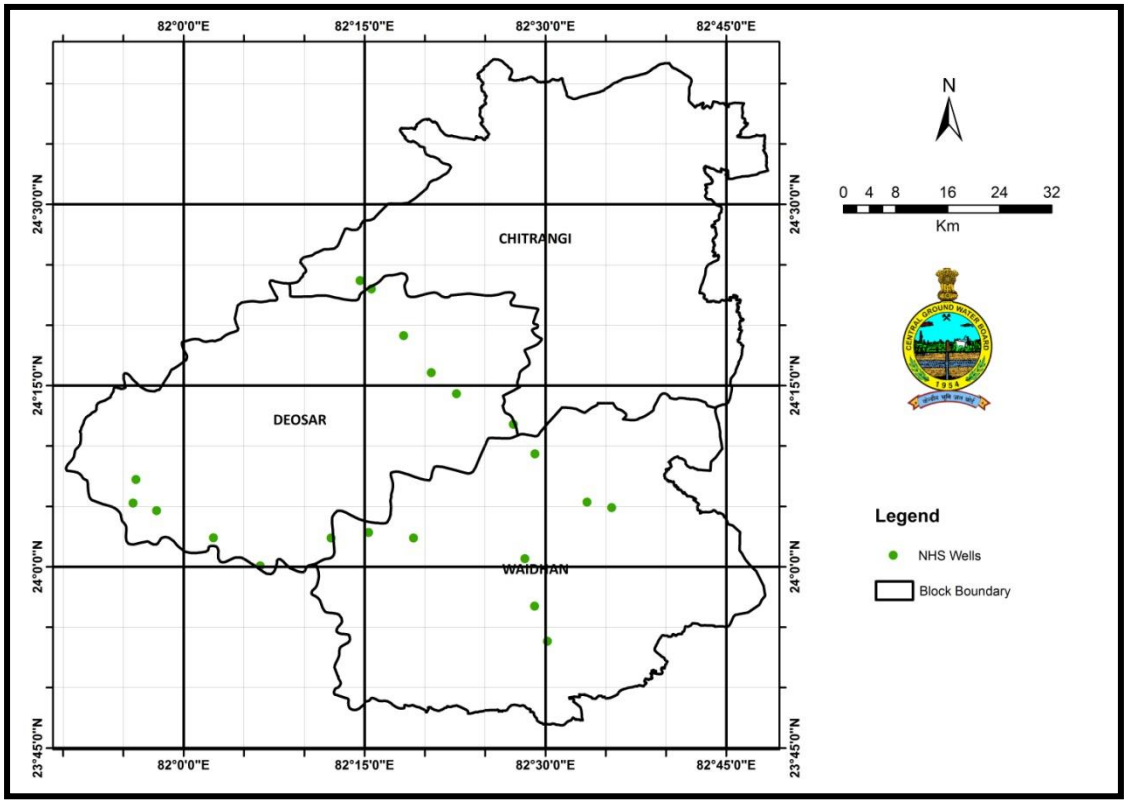


Fig.10: Data Gap Analysis Map showing Location of NHS Wells in grid of 5'

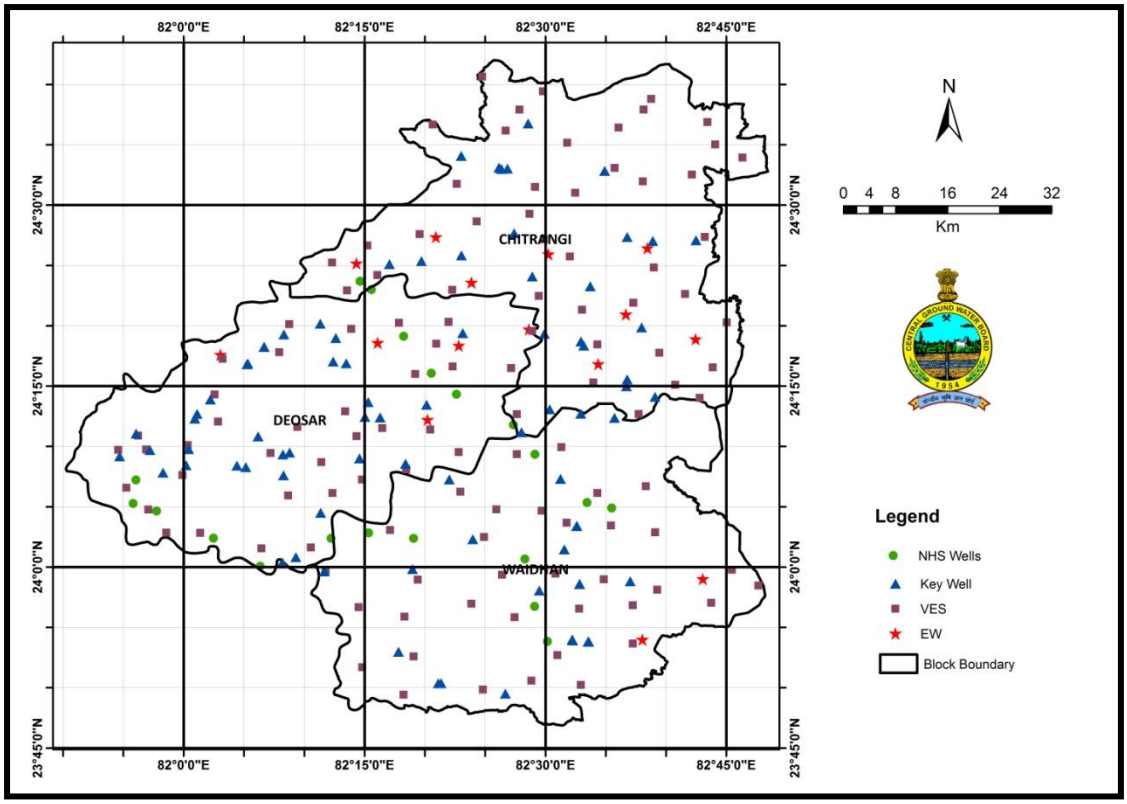


Fig.11: Location of Exploratory Wells , Key Wells established and NHS Well

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation, thematic layers was interpreted and integrated. Based on this the various aquifer characteristic maps on hydrogeology, aquifer wise water level scenario both current and long term scenarios, aquifer wise ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, aquifer wise yield potential, aquifer wise resources, aquifer maps were generated and as discussed in details.

2.2 Hydrogeology

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The district is underlain by various geological formations, forming different types of aquifer in the area. Main geological units of the area are Gondwana

formations and Archaeans. The principal aquifers in the area are weathered and fractured granitic gneiss, schist, phyllites sandstone and alluvial. The occurrence and movement of ground water in hard rock primarily depends on the degree of interconnection of secondary pores/voids developed by fracturing and extent of weathering. The hydrogeological map of area is prepared and presented in Fig.12

a) Archaeans

The Archaean rocks comprising mostly granitic gneiss, schist, phyllite, and quartzite cover approximately 40% of the total district area. Quartz veins are common features and occur as thin strings. The Archaean rocks are mainly covering the part of Deosar and Chitrangi blocks and some parts of Waidhan Block. These rocks do not have primary porosity. The weathered part of the crystalline is the aquifer for open well and shallow tube wells. The thickness of these zones in the entire district area ranges from 2.5 to 30.00 m. In this formation, aquifers also occur where the rocks are jointed and fractured. The open wells that exist in this formation range in depth of 4.00-19.00 mbgl generally the column of water available during pre-monsoon season varies from 4– 19.00 m. The general yield potential of Archaean formation is less than 120 lpm. However at places the yield potential in deeper aquifer is found to the tune of 450 lpm.

Transmissivity of the aquifers in the formation is 0.19 to 27.68 sqm per day as per pumping test reports of exploratory wells constructed by CGWB in 2021-2022.

b) Gondwana Formations

The Gondwana formations comprise succession of sandstone, shales, and clays with seams of coal lying over the crystalline Archaean rocks. Gondwana formations are represented by Talchir formation occupying the northern part of Waidhan and southern part of Deosar block of the district. In Gondwana formations groundwater occurs mostly in sandstone of semi consolidated in nature. The wells located in topographic lows and piercing the Talchir Sandstones yield vary between 100 to 300 lpm tapping semi confined and unconfined aquifers. The depth to water level in the upper gondwana formations

varies between 0.80 and 10.50 mbgl in post monsoon and between 5.6 to 10.65 mbgl in pre monsoon. The well discharge varies between 0.50 to 1 lps. Dug wells with diameter varying between 2 to 5 m with 6.85 to 17.15 m depth piercing the full thickness of weathered Jointed and fractured zones are observed in this formation.

c) Alluvium

The Alluvium comprising unconsolidated sand silt and clay mainly occur in small patches in the northwest part of Chitrangi block along the Son River and confluence of Mayar and Kanchan river. Marginal alluvium thickness vary from 60 to 100 m. Potential aquifers occurs in water table condition with yield ranging from 300 to 500lpm. The water table is sloping towards Son River and its tributaries as result of their effluent nature.

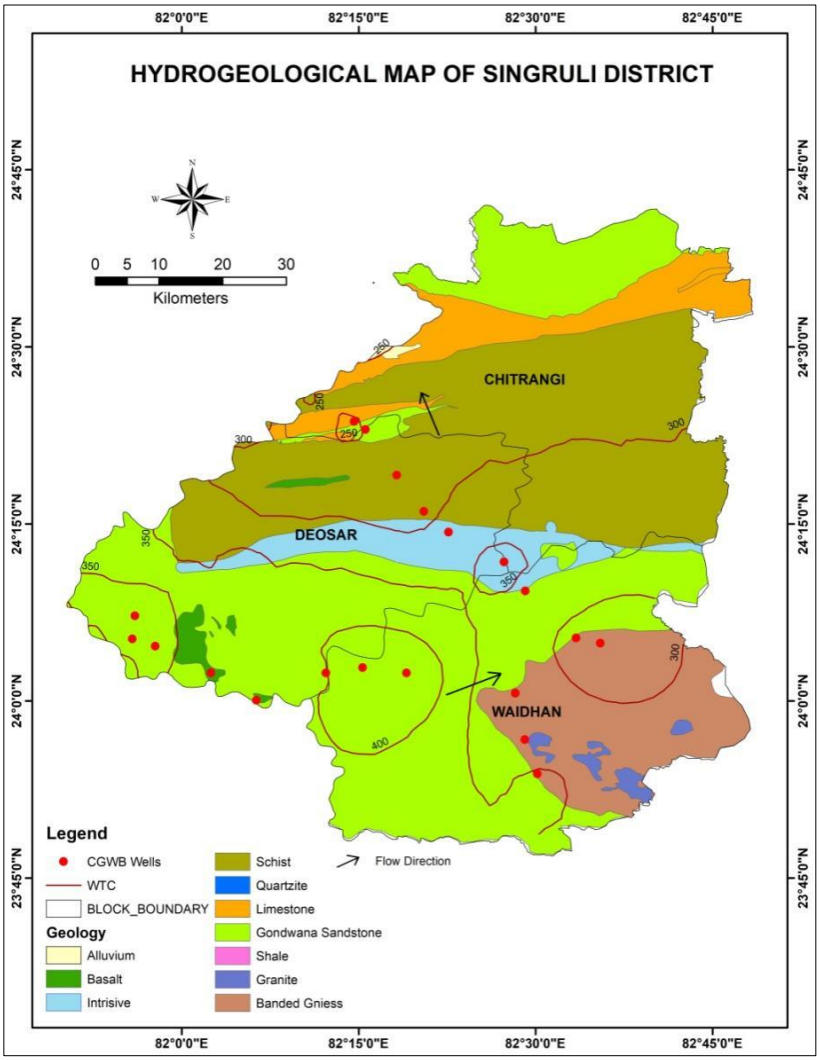


Fig.12: Hydrogeology of Singrauli District, M.P.

2.3 Depth to water level

2.3.1 Pre-Monsoon water level (May, 2021)

The **pre-monsoon** depth to water level during May 2021 ranged between 4.95 mbgl (Sarai) to 17 mbgl (Karthua). The water levels between 9 mbgl and 11 mbgl are observed in major part and the water levels of less than 7 mbgl are observed in South Western parts of the district. Water level more than 11 mbgl are observed in very limited area and mostly concentrated on the western part of the district. The pre-monsoon water level data is presented in **Annexure-II**, whereas depth to water level map is given in **Fig.13**

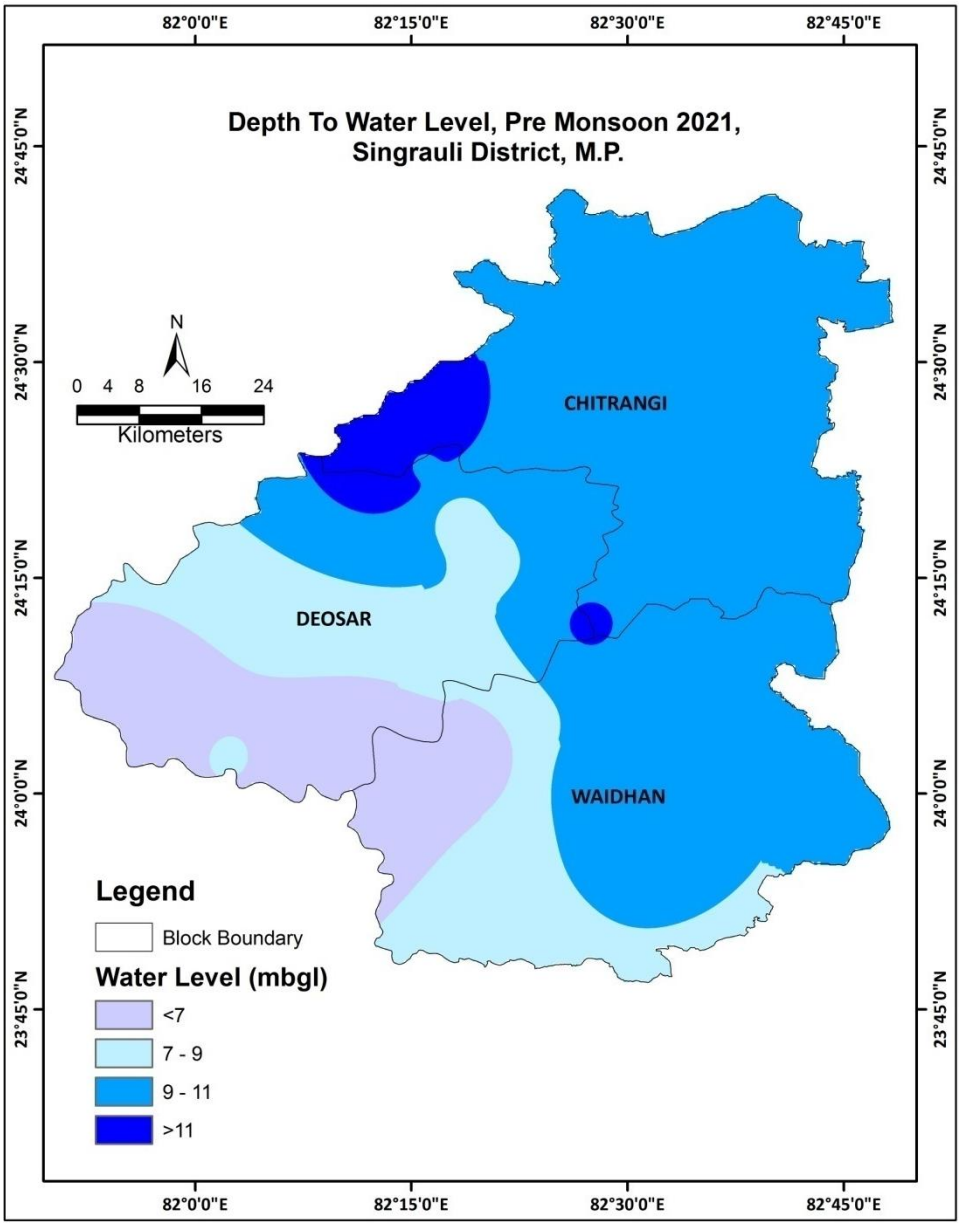


Fig 13: Depth to Water Level Map (May, 2021)

2.3.2 Post-Monsoon water level (November, 2021)

The **post-monsoon** depth to water levels during November 2021 ranged between 2.71 (Sarai) to 7.75 mbgl (Kohara Khoh). The shallow water levels between 2 mbgl and 4 mbgl is limited to very small areas. Water level more than 5mbgl are observed in major parts of the area. The water level between 4mbgl to 5mbgl is observed in major parts of Deosar and Waidhan block. The post-monsoon depth to water level data is presented in **Annexure-III**, whereas the map is given in **Fig.14**

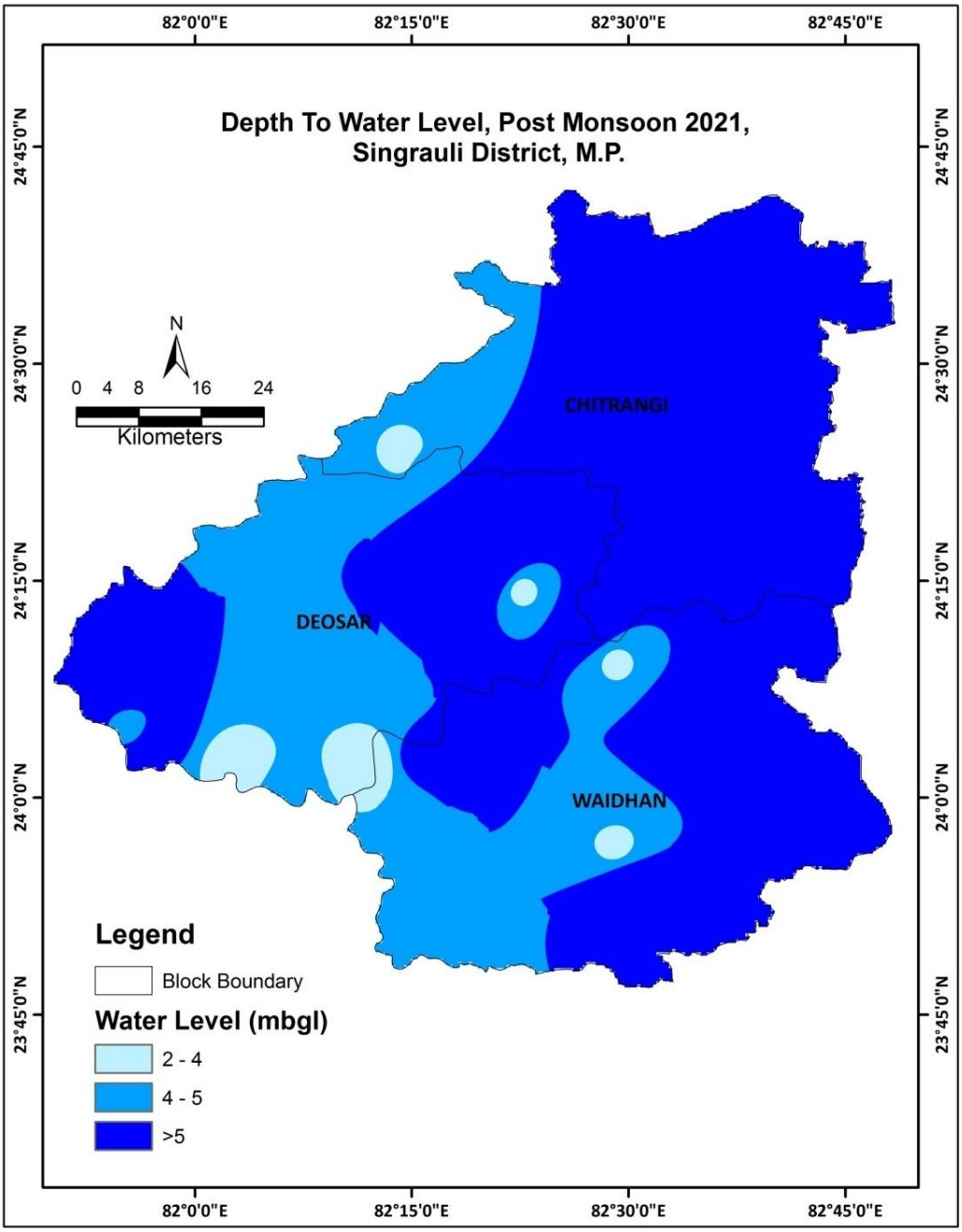


Fig 14: Depth to Water Level Map (Nov, 2021)

2.3.3 Water Level on the basis of Key wells, Post-Monsoon (November, 2021)

Water Level from the marked key wells was observed and contour map was plotted. The water levels were measured during November 2021 ranging from 0.8 mbgl (Sidhi Khurd) to 16.36 mbgl (Ghogra). Water level more than 10 mbgl was found in very limited area and that less than 4 mbgl was found mostly in Chitrangi block near Son River. Water Level between 4mbgl to 6 mbgl was found in major parts of the district. The map of Depth to Water Level Post-monsoon (May 2021) of Shallow Aquifer on the basis of Key Wells is given in **Fig.15**

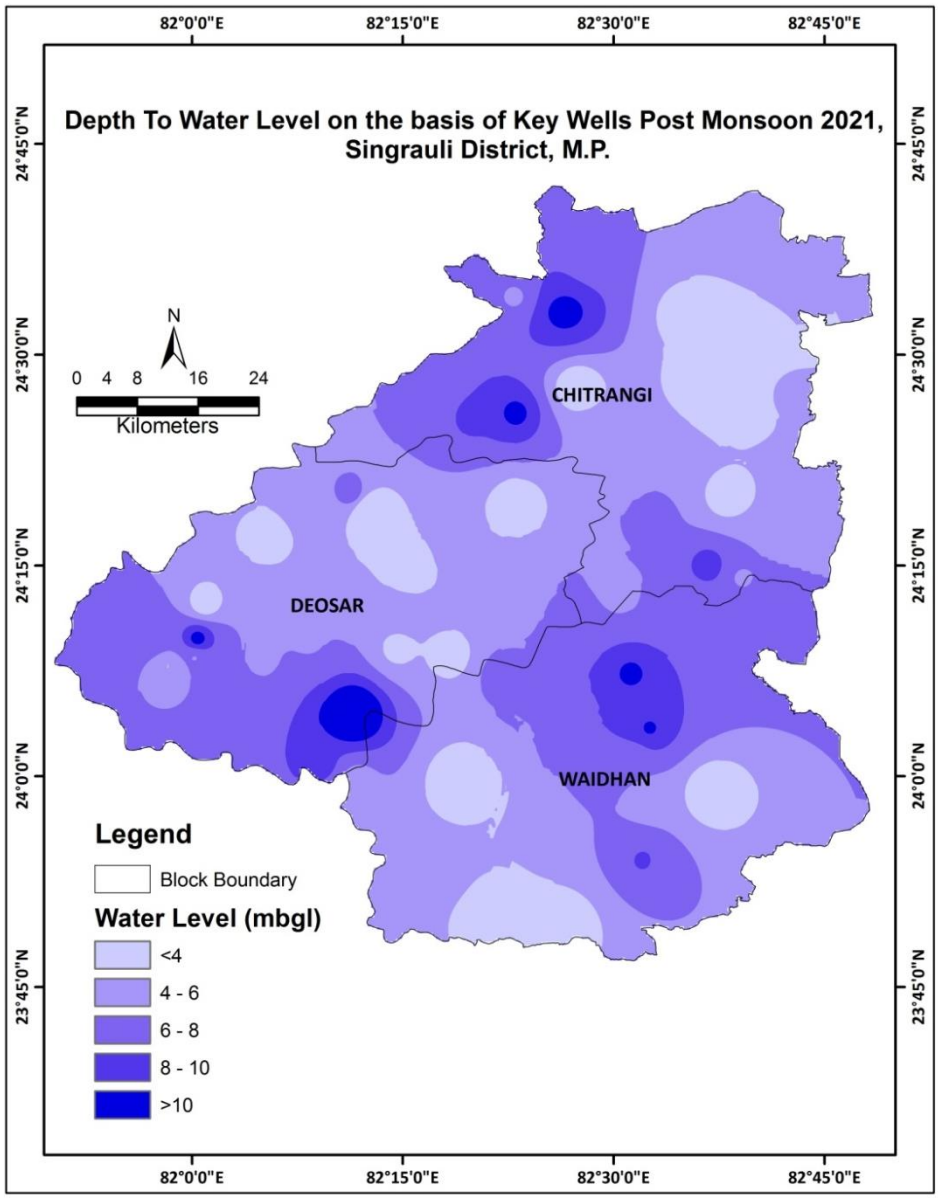


Fig.15: Depth to Water Level Post-monsoon (May 2021) of Shallow Aquifer on the basis of Key Wells

2.3.4 Water level Fluctuation

The water level measured during pre and post monsoon period (2021) was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Jamgadi (0.2m) while maximum water level fluctuation was observed at Karthua (13.78 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed (**Table 8**). Water level fluctuation of more than 5 m is observed in Northwest part of the districts in parts of Chitrangi and Deosar blocks.

Table 8: Analysis of Water Level Fluctuation.

S. No.	Category	Fluctuation Range	% of Wells
1.	Less water level fluctuation	0 to 2 m	43%
2.	Moderate water level fluctuation	2 to 5 m	28 %
3.	High water level fluctuation	>5 m	29%

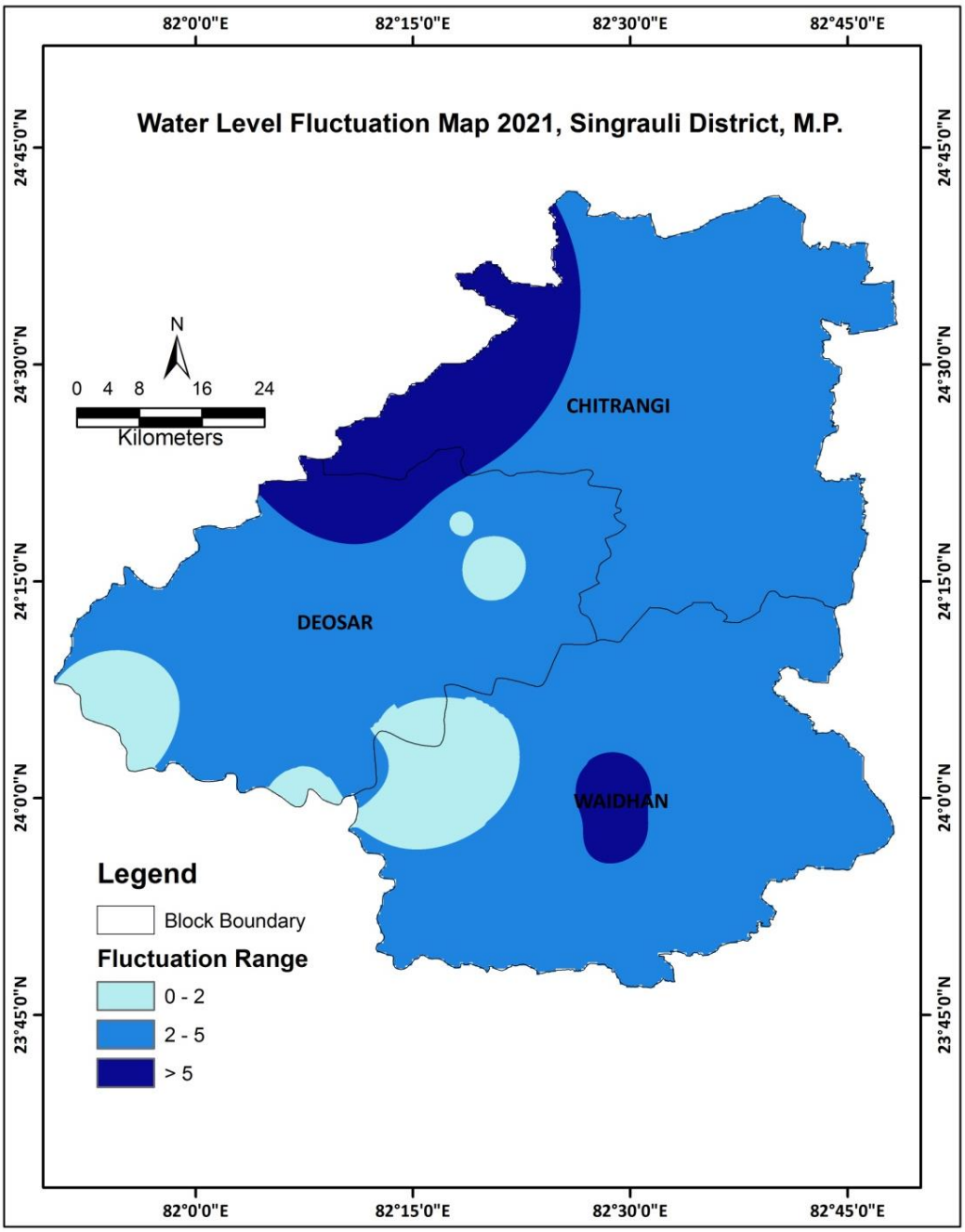


Fig.16 : Water Level Fluctuation Map 2021

The analysis indicates that majority of the wells (29%) are falling in high fluctuation range indicating aquifer storage is not good, whereas moderate water level fluctuation are observed in 28% wells and low water level fluctuation were observed in 43 % wells.

2.3.5 Long Water Level Trend (2012-2021)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data for the period 2020-21 have been computed and analyzed.

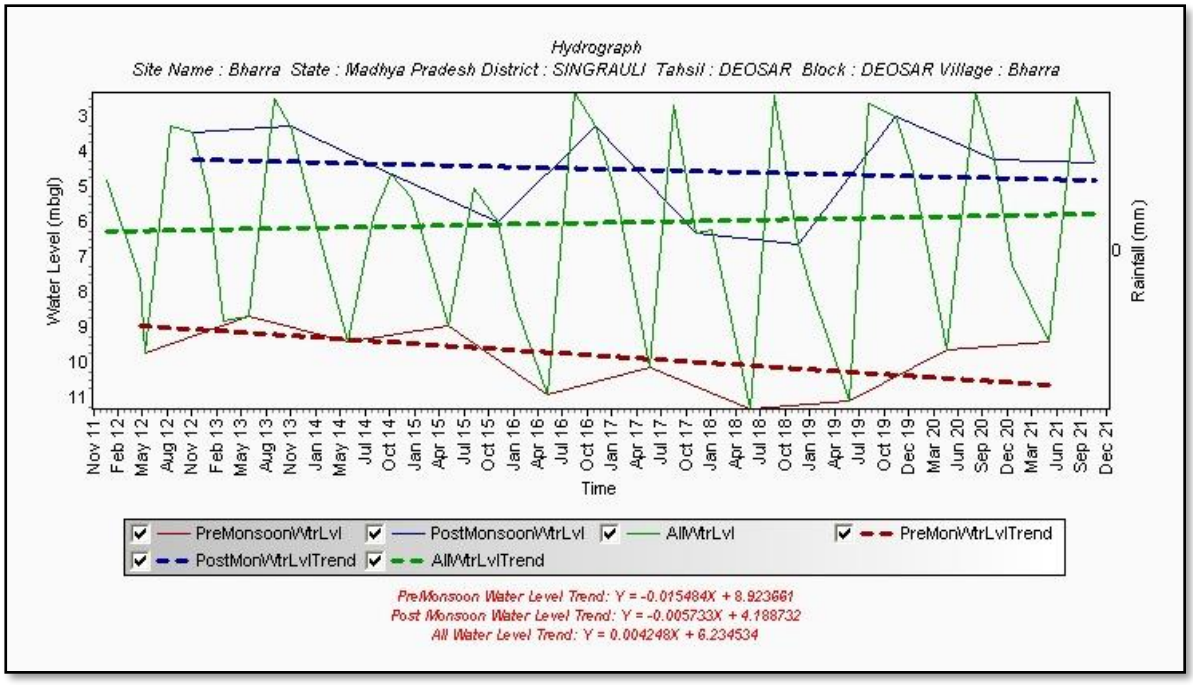


Fig.17(a): Hydrograph Site: Bharra, Block: Deosar

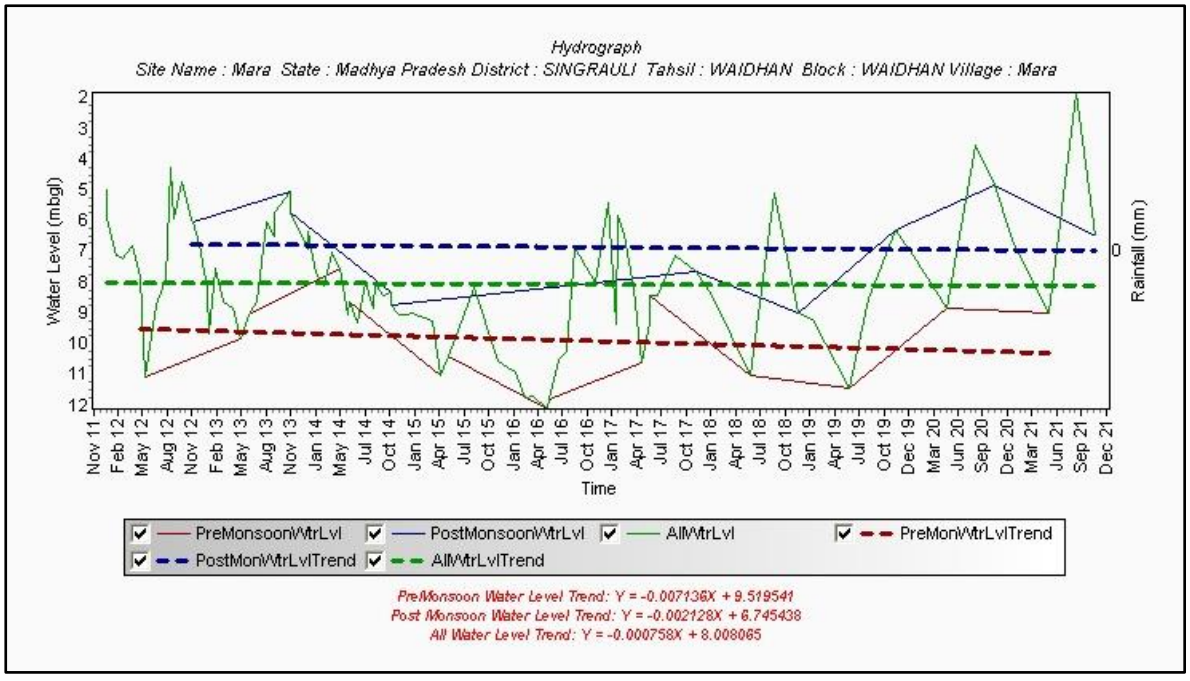


Fig.17(b): Hydrograph Site: Mara, Block: Waidhan

2.3.6 Water Level Trend Pre- Monsoon and Post Monsoon

The decadal pre-monsoon water level trend analysis (**Fig 18**) indicates that about 18% area of the district is showing falling trend during pre-monsoon period, in the west and southern part of the district. Rest part of the district is showing rising trend.

The decadal post-monsoon water level trend analysis (**Fig 19**) indicates that about 10% area of the district is showing declining trend in the south western part of the district and small parts of Deosar and Waidhan block. Maximum falling trend is ranged between 0 to 0.1 m/yr. Rest part of the district is showing rising trend.

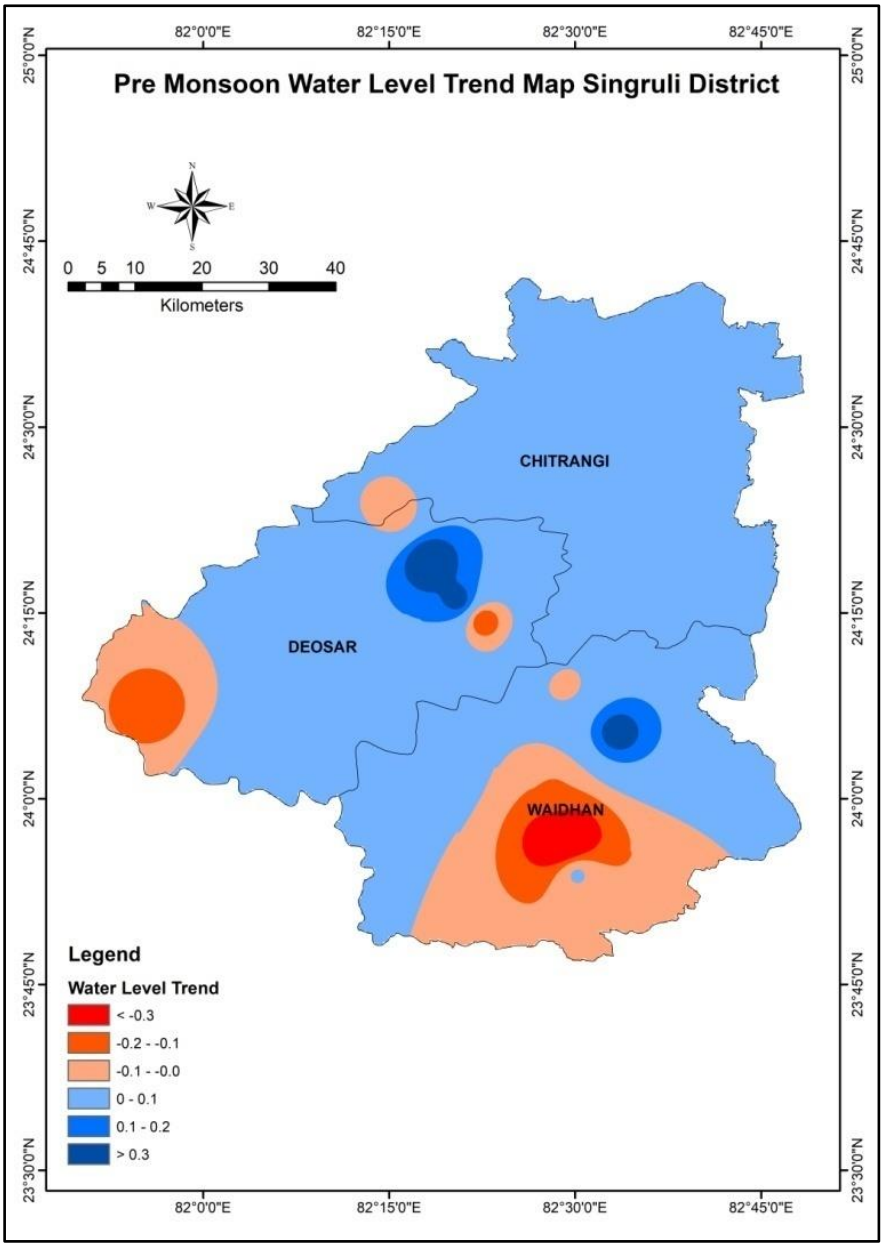


Fig.18: Pre-monsoon Water Level Trend (May 2012-21) of Aquifer-I (Shallow Aquifer).

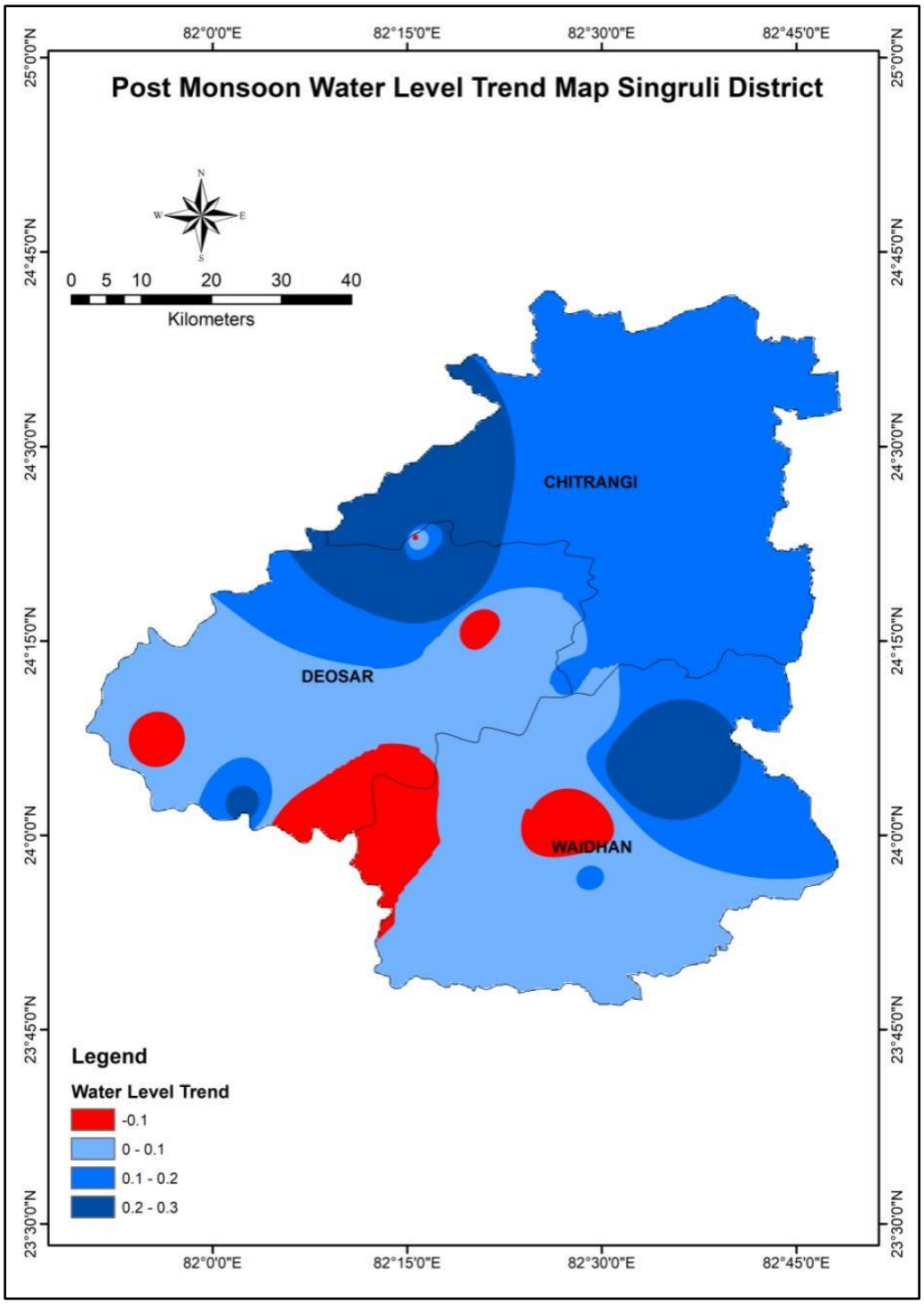


Fig.19: Post-monsoon Water Level Trend (November 2012-21) of Aquifer-I (Shallow Aquifer).

2.4 Exploratory drilling

Central Ground Water Board constructed 15 exploratory borewells (EW) in the area in the year 2021-22 and also 4 number of piezometers under National hydrology project for water level monitoring purpose. Core logs and borewells constructed by NCL, drilled at CMPDIL camp, Dudhichua Mines and Jaiprakash Power Ventures Limited, Amelia (North) Coal Mine are also incorporated. The salient details of EW, BW and PZ are given in table 9.

Ground water exploration was carried out to assess the lithological disposition, aquifer parameters and chemical quality of shallow aquifer (Aquifer-I) and deeper aquifer (Aquifer-II). The locations of exploratory wells are shown in **Fig. 20.** The details of exploratory wells and bore well of CMPDIL are given in Table 9.

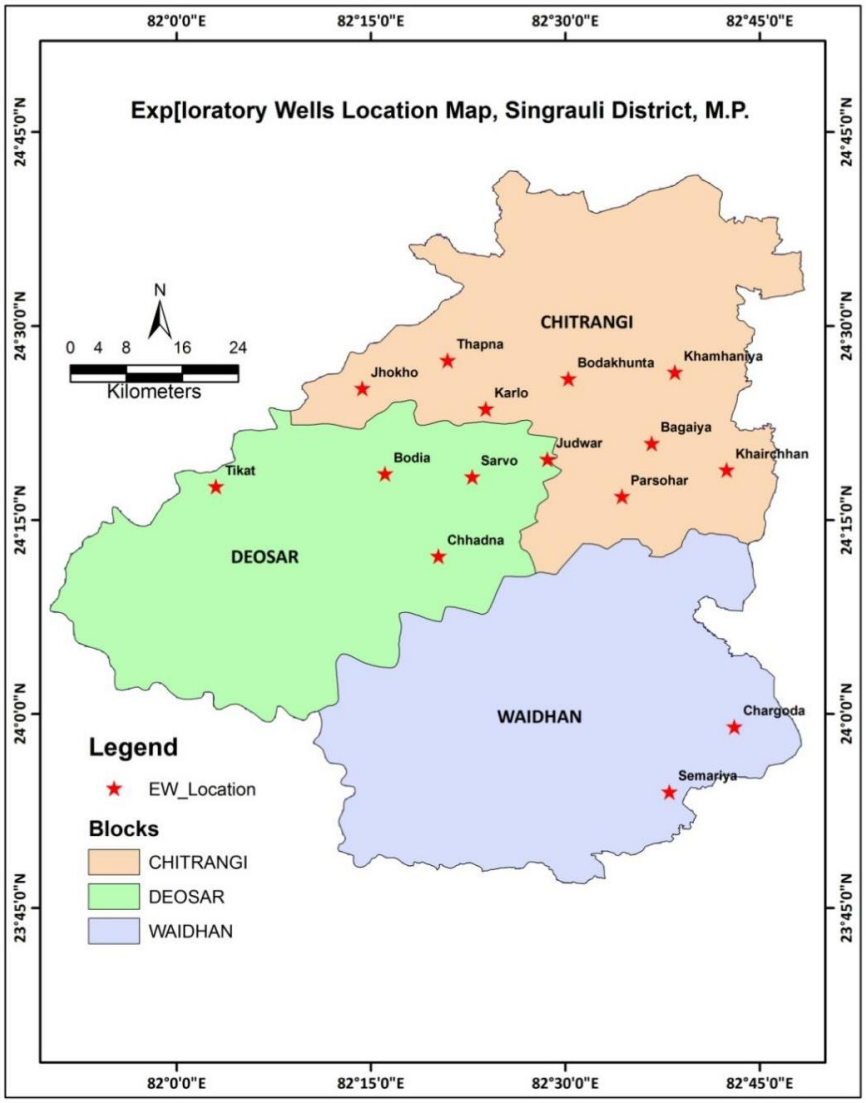


Fig.20: Map showing locations of Exploratory Wells of CGWB

Table 9: Salient Hydrogeological Details of Exploratory Wells of Singrauli district.

S. No.	Location	Lattitude	Longitude	Elevation amsl	Year of construction	Depth Drilled	Thickness of weathering (m)	Aquifer	Zone	SWL (mbgl)	Discharge (lps)	T m2/day	Sp. Capacity (lpm/m of dd)
1	Semariya	23.8995	82.6341	381.7	2021 -2022	204	17.7	Weathered/Fractured Schist	15.25–15.35, 28.40-28.90	9.5	0.43	0.98	1.6
2	Chargoda	23.9835	82.7175	288.8	2021 -2022	204	17.7	Weathered/Fractured Schist	14.2-14.30, 35.7-36.3, 102.4-102.9	16	0.75	1.3	0.92
3	Judwar	24.3282	82.4771	489.8	2021 -2022	204	39	Fractured schist	84.50 - 84.60, 135.70 - 135.85	24.5	1.74	2.08	4.56
4	Tikat	24.2930	82.0509	304.6	2021 -2022	204	17.72	weathered schist	9.20 - 9.30	17.48	0.40	0.20	0.22
5	Sarvo	24.3056	82.3804	337.1	2021 -2022	204	14.69	weathered schist	11.80 - 11.90	6.83	0.41	0.25	0.26
6	Bodia	24.3095	82.2683	304	2021 -2022	204	20.7	weathered schist	17.40 - 17.90	15.66	1.17	1.13	2.64
7	Chhadna	24.2032	82.3371	412.1	2021 -2022	204	17.62	weathered granitic gneiss	14.70 - 14.80	8.60	0.42	0.26	0.25
8	Bagaiya	24.3488	82.6113	390.5	2021 -2022	204	30.24	Weathered/Fractured schist	25.00 - 25.20, 157.40 - 157.50	15.12	2.44	6.16	12.55
9	Boda Khunta	24.4318	82.5042	389.7	2021 -2022	204	23.76	Fractured schist	33.00 - 33.10, 124.70 - 127.90, 163.50 - 163.70	19.03	2.44	4.10	9.79
10	Karlo	24.3930	82.3979	434.8	2021 -2022	204	18	Fractured schist	24.80 - 24.95, 133.70 - 133.90, 179.80 - 180.10	7.01	1.74	-	-
11	Khamhaniya	24.4403	82.6412	339.9	2021 -2022	204	36	Fractured schist	43.20 - 43.30, 76.50 - 76.90,	13.66	1.74	3.73	7.92
12	Khairchhan	24.3145	82.7076	329.6	2021 -2022	201	17.8	Weathered/Fractured schist	15.30 - 15.40, 39.00 - 39.50	29.16	2.44	7.03	11.83
13	Thapna	24.4557	82.3487	271.6	2021 -2022	204	18.6	Weathered/Fractured schist, Fractured Dolerite	15.40 - 15.50, 29.80 - 30.30, 92.80 - 93.20	12.72	1.74	2.35	5.18
14	Parsohar	24.2803	82.573	412.9	2021 -2022	204	23.78	Weathered/Fractured schist	17.70 - 18.10, 36.70 - 37.10, 55.10 - 55.80	11.5	8.20	-	-
15	Jhokho	24.4194	82.239	267.7	2021 -2022	91.5	18.68	Weathered/Fractured schist	13.50 - 14.00, 66.55 - 67.10, 84.70 - 85.20	12.61	6.71	27.69	31.83
16	CMPDI Exploration Camp, Singrauli	24.1945	82.6670	402	1999	126.00	23.00	Unconsolidated sand and fractured Semiconsolidated Sandstone	8.0-19.0, 35.0-49.0, 90.0-110.0	23.8	5	15.19	15.13

In the granitic gneiss/schist/phyllites formation, potential aquifer are having moderate to high yield under weathered condition. In the entire 200 meter depth exploratory drilling, the cumulative yields recorded from 0.40 to 8 liters/second with average drawdown of 12 to 69 m in the pumping duration of 100 to 1000 minutes. Static water level varies from 7.01 to 29.16 mbgl. Depth of weathered and semi weathered fractured rocks are observed at depth between 9 and 30 m in shallow aquifer. Exploratory wells having low yield in the range of 0.5 -1.0 lps were observed at 6 Exploratory Wells namely Semariya, Chargoda, Tikat, Sarvo, Bodia and Chhadna with water bearing zones encountered at depth 9 to 35 mbgl within weathered zone at shallow depth. Exploratory wells having yield in the range of 1.0-3.0 lps were observed at 7 Exploratory Wells namely Judwar, Bagaiya, Boda Khunta, Karlo, Khamhaniya, Khairchhan and Thapna with water bearing zones encountered between depth 45 to 180mbgl. High yielding exploratory wells having yield 6.0 – 8.0 lps were observed at 2 locations namely Parsohar and Jhokho with potential bearing zone encountered between depth range 36 -55 meter below ground level.

While correlating the various core logs drilled by NCL within the gondwana formation and one aquifer parameters test carried out at CMPDI, with the lithologs of CGWB Exploratory Wells, it is observed that main water bearing zones are encountered between 8 to 23 mbgl within the weathered sandstone and between 35-49, 90-110 and 150-187mbgl in semi consolidated fractured sandstone with cumulative discharge of 5 lps and Transmissivity 15.19 sqm/ day.

2.5 Hydrochemistry

The water samples were collected from National Hydrograph Stations in clean double stoppered poly ethylene bottles from 20 different locations of Singrauli district during May 2020 and 14 nos of exploratory wells collected at the time of exploration and pumping test. The location of NHS Wells of Singrauli District is shown in Fig.21. Ground water chemical quality data of NHS wells 2020 is given in Table 10.

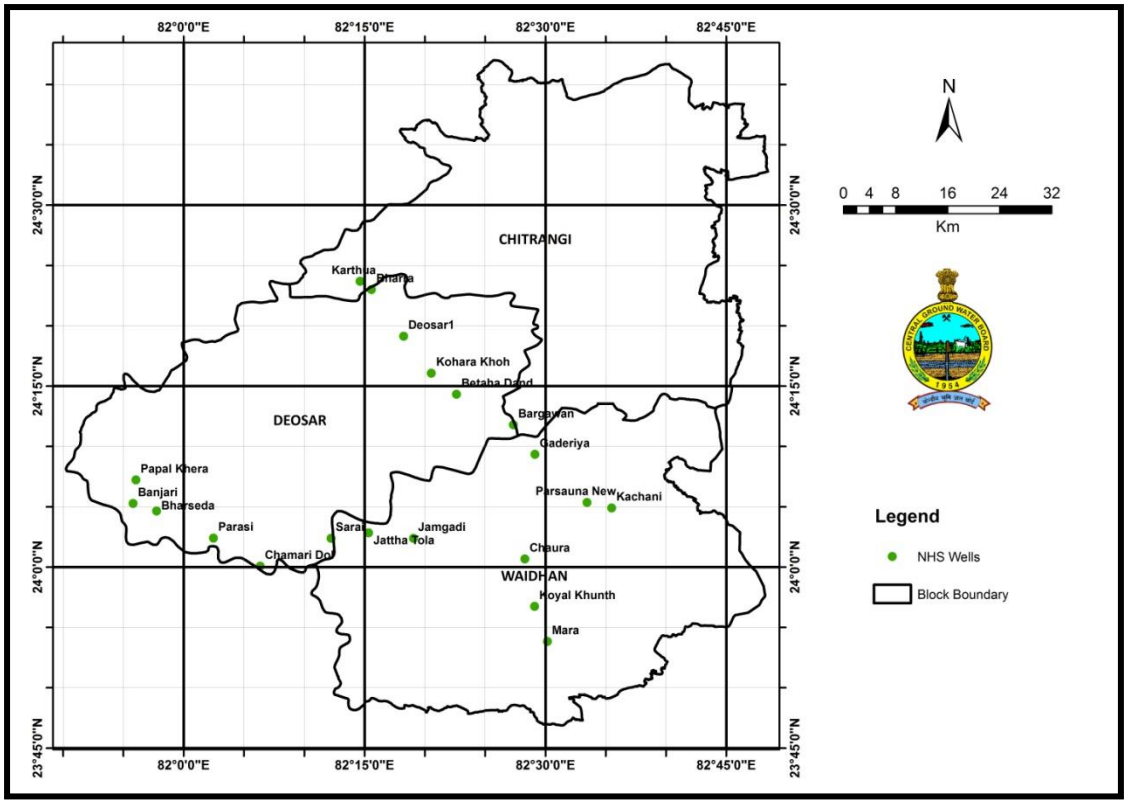


Fig.21 : NHS Well Location Map of Singrauli District.

Table 10: Ground water chemical quality data of NHS wells 2020

Constituents/ Site Name	pH	EC	TH	Ca	Mg	Na	K	HCO3	Cl	NO3	F
BIS standards for drinking water	6.5-8.5	-	300-600	75-200	30-100	-	-	-	250-1000	45	1-1.5
Banjari	7.24	765	252	63	23	52	2.2	213	102	27	0.12
Bargawan	7.63	987	282	71	25	85	1.8	425	77	12	0.97
Bharra	8.02	322	81	12	12	34	0.8	106	30	16	0.05
Bharseda	8.08	445	187	42	20	11	1.5	149	35	8	0.05
Chamari Dol	7.92	532	162	38	16	42	2.4	181	57	28	0.34
Chaura	7.47	965	202	42	24	124	1.9	317	155	22	0.42
Deosar1	7.89	687	217	73	8	52	2.6	280	47	26	0.56
Gaderiya	7.62	512	197	42	22	22	2.2	156	60	28	0.42
Jamgadi	7.96	543	172	46	14	42	2.4	218	40	26	0.32
Jattha Tola	7.86	423	111	24	12	38	3.1	137	35	31	0.62
Kachani	7.96	1289	303	85	22	152	3.5	93	352	5	1.01
Karthua	7.82	742	177	53	11	81	2.9	87	127	105	0.25
Kohara Khoh	7.23	466	162	38	16	26	1.9	162	35	26	0.62
Koyal Khunth	7.68	788	273	73	22	48	1.5	205	100	68	0.38
Mara	7.35	1142	399	103	35	72	2.1	380	132	49	0.43
Papal Khera	7.42	698	207	65	11	58	2.2	305	27	43	0.42
Parasi	7.33	712	197	63	10	62	4.9	237	47	66	0.38
Parsauna New	7.34	545	172	53	10	38	3.2	224	32	39	0.52
Sarai	7.62	723	237	65	18	52	3.5	255	70	44	0.35

Table 11: Ground water Chemical Data of Exploration wells of Singrauli District Madhya Pradesh

S. No	Test Parameters	Unit	Bagaiya	Parsohar	Jhokho	Boda Khunta	Khamaniha	Khairchhan	Thapna	Tikat	Sarvo	Bodia	Judwar	Chhadna	Semariya	Chargoda
1	pH	-	7.64	7.91	7.52	7.6	7.87	7.69	7.66	8.11	7.54	7.18	7.95	7.36	7.79	7.9
2	Conductivity	µmhos/cm	679	573.2	820	916.3	698.4	550.3	794.2	1240	1018	780.4	413.6	862.7	731.5	1028
3	Total Hardness as CaCO3	mg/lit	142	108	234	280	118	66	152	286	252	98	126	176	88	52
4	Chlorides as Cl	mg/lit	14.99	15.99	20.99	13.99	15.99	11.99	21.99	78.97	20.99	25.99	10.99	22.99	19.99	33.98
5	Total Dissolved Solid	mg/lit	347.2	295.5	428.7	480	366.5	289.2	416.7	631.2	524.4	411.6	270	438.5	383.1	54
6	Nitrate as NO3	mg/lit	15.1	1.86	5.23	11.21	4.22	2.47	7.8	17.57	5.27	10.8	1.93	3.34	15.79	47.1
7	Calcium as Ca	mg/lit	24.04	4	5.61	40.88	9.61	5.61	9.61	7.21	50.5	6.41	17.63	64.92	4	3.2
8	Magnesium as Mg	mg/lit	22.35	23.81	53.46	43.25	22.84	12.63	31.1	61.64	30.61	19	19.92	3.4	18.95	10.69
9	Sulphates as SO4	mg/lit	43.94	29.29	2.77	18.2	3.9	25.94	15.28	68.06	6.22	20.73	16.23	0.88	2.77	247.23
10	Iron as Fe	mg/lit	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
11	Fluoride as F	mg/lit	<0.10	<0.10	<0.10	1.16	<0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
12	Bi Carbonate alkalinity (as CaCO3)	mg/lit	<2.00	8	<2.00	<2.00	6	<2.00	<2.00	<2.00	<2.00	<2.00	4	<2.00	<2.00	<2.00
13	Carbonate alkalinity (as CaCO3)	mg/lit	92	104	202	166	138	80	144	286	384	166	92	310	136	198
14	Sodium as Na	mg/lit	7.4	12.46	12.45	14.86	11.4	10.96	14.85	8.2	6.74	15.42	9.8	6.18	14.2	10.42
15	Potassium as K	mg/lit	3.2	3.05	5.86	7.5	5.3	4.62	6.75	2.3	2.8	4.92	5.12	1.5	6.79	6.2
16	Manganese as Mn	mg/lit	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20			<0.20	<0.20		<0.20	<0.20

In Aquifer –I, it is observed that in all 19 samples, Total Hardness, pH and Magnesium are within permissible limit.

In case of Aquifer-II, it is observed that Total Hardness, pH and Magnesium are within permissible limit. Out of 16 samples taken from exploratory/observation wells, in 1 sample the Nitrate value was found above permissible limit.

2.6 Geophysical Studies

A total of 116 VES were carried out in Singrauli district. The geo-electrical characteristics of the weathered and semi-weathered zones are given in Table 3. Based on the interpreted results of 116 VES, it is observed that at 53 VES sites the weathered zone is absent. At 40 VES the weathered zone is having the depths more than 9 meters which can be considered for shallow depths ground water tube wells. At the rest 23 VES the weathered zone is very thin, less than the depth range 9 meter. At 11 VES sites the weathered zone in Gondwana and Vindhyan terrain extends more than the depth 20 m depth. The thickening of weathered zone at these sites as well as other sites appears to be structurally controlled. These range of resistivity i.e., 50-300 ohm m at shallow depths (more than 9m) are considered as semi weathered formation aquifer and that of at deeper depths, these are considered as less compact formation. At deeper depth these resistivities may be less than 50 ohm-m in Gondwana or Vindhyan terrain. Hence these are also considered as less compact formation in general. The range 50-150 ohm-m is preferred for aquifers in general. The range is less than 50 ohm m may be due to quality or mixed up with clay with sandstone in Gondwana or Vindhyan formation. On the basis of these considerations 83 sites are detected to be semi weathered zones/ Less compact zones which are given in the table. The fractured zones have been delineated at so many sites. These are generally delineated on the basis of curve break techniques and current increase methods. These fracture zones are generally available when the overall resistivity of the curve is little lesser than the very high resistivity. Most of the cases the when the depths of the less compact formation is more or depth to the compact formation is not available, the probability of presence of fractures are more. On the basis of these considerations in 110 no's of VES the fracture zones are detected. In a few cases the fractures may be dry and feeble.

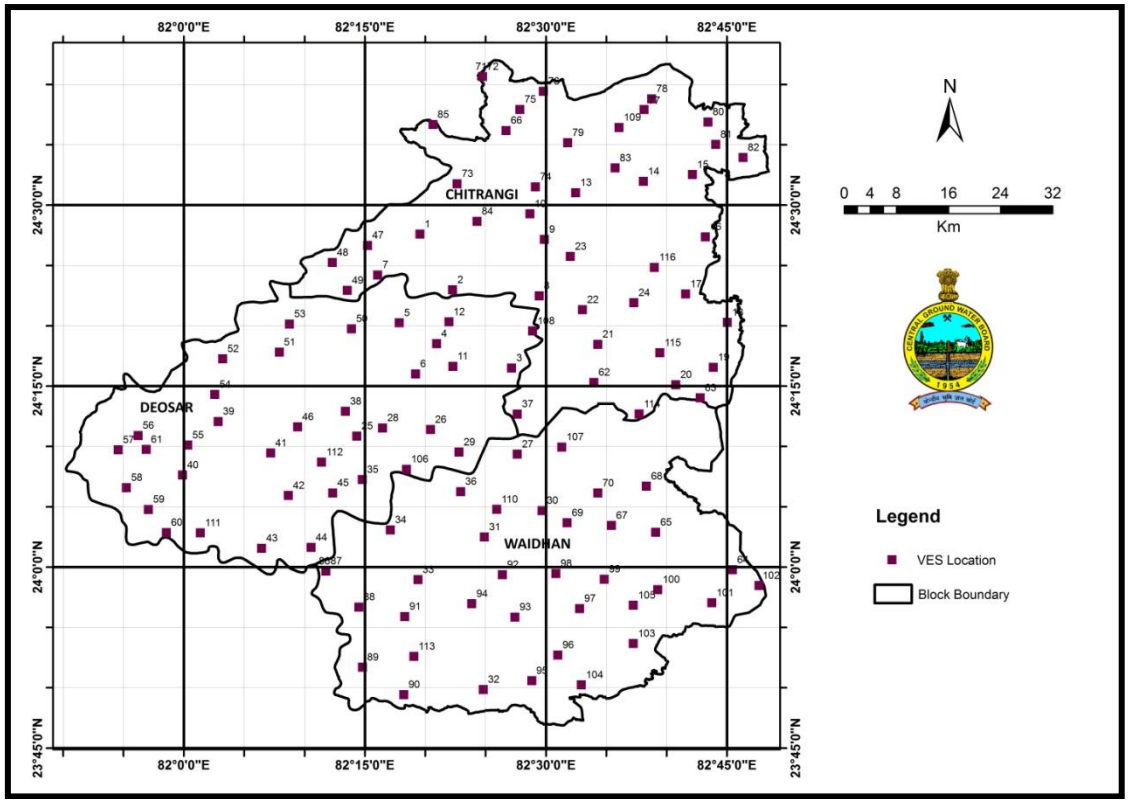


Fig.22: Location of 116 VES covering entire part of the district

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The lithological data collected from CGWB Borewells, Piezometers and State Ground Water Piezometers were studied, compiled and integrated as per Rockworks software format to prepare the 3-Dimensional Stratigraphic model, 2-Dimensional Cross section and Fence diagrams. The sub-surface lithology of the Singrauli district as inferred from the 3-D Model, 2-D Section and Fence diagram is presented below.

3.1 3-D Lithological Model

A 3-Dimensional lithological model was prepared for the Singrauli district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB (Fig 23). A comprehensive analysis was made as per lithology and stratigraphy of the area.

The data generated from ground water monitoring wells, micro level hydrogeological inventories, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. This particularly includes the information on geometry of aquifers and hydrogeological information of these aquifers. In the area, the two aquifer systems has been deciphered as listed below:

a. **Aquifer –I (Shallow Aquifer)**
b. **Aquifer – II (Deeper Aquifer)**

The 3-D Model results showed that the region is dominantly occupied by Granitic Gneiss/Schist. The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone, underlain by Weathered Schist which has been considered as shallow aquifer (upto a depth of 30-35 mts). Compact Massive Gneiss/Schist was encountered in few bore wells mainly in Deosar block. The Fractured Schist that forms the deeper aquifer (from 55-180mts) are mainly found in Chitrangi block.

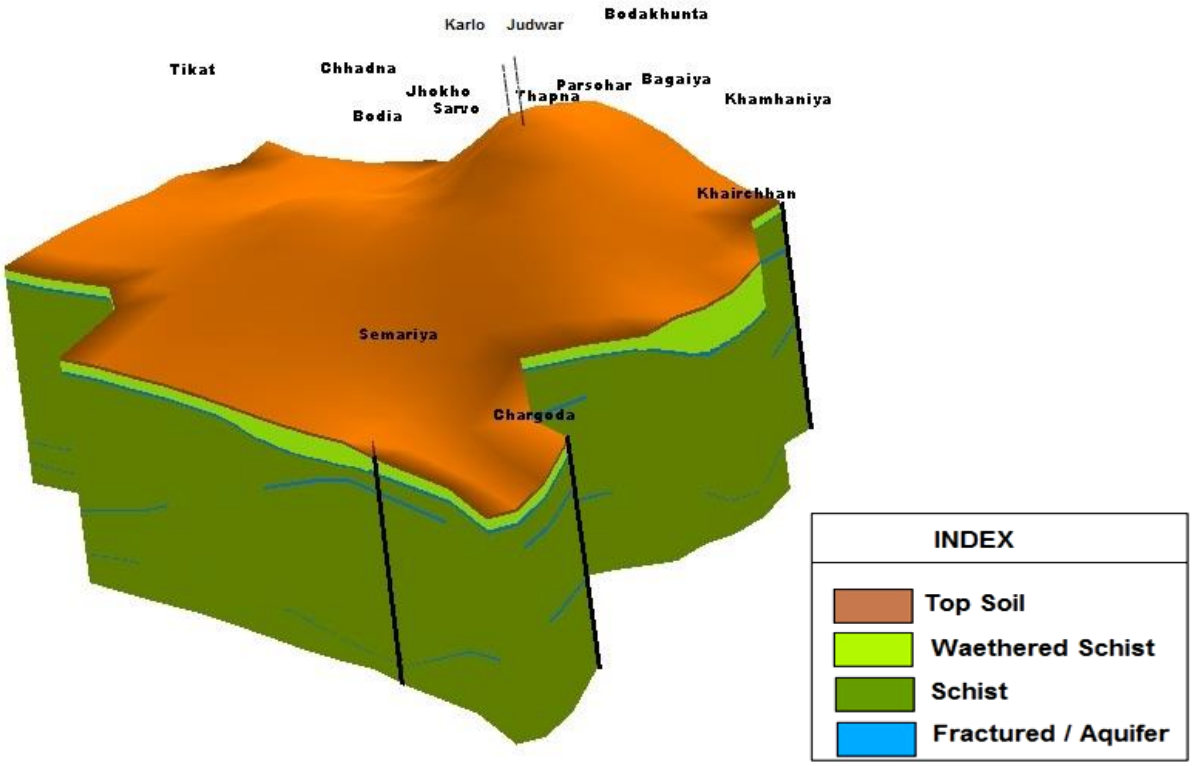


Fig.23: 3-D Lithological Model of Singrauli District, Madhya Pradesh

3.2 Fence Diagram

The Fence diagram was also prepared using the Rockworks software (Fig. 24). The pattern for the Fence was chosen as such to cover the maximum portion of the region to represent the enhanced picture of the sub-surface as deciphered from the 3-D Stratigraphic model. It has also been interpreted from the diagram that the shallow and deeper aquifers are not in connection to each other.

As the area is covered with hard rocks, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 30m. The fractured /jointed basalt and Granitoids, Gondwana sandstones form the deeper aquifer. 3-D representation is presented in **Fig. 23**. The fence diagram indicating the disposition of various aquifers is presented in **Fig.24.** The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

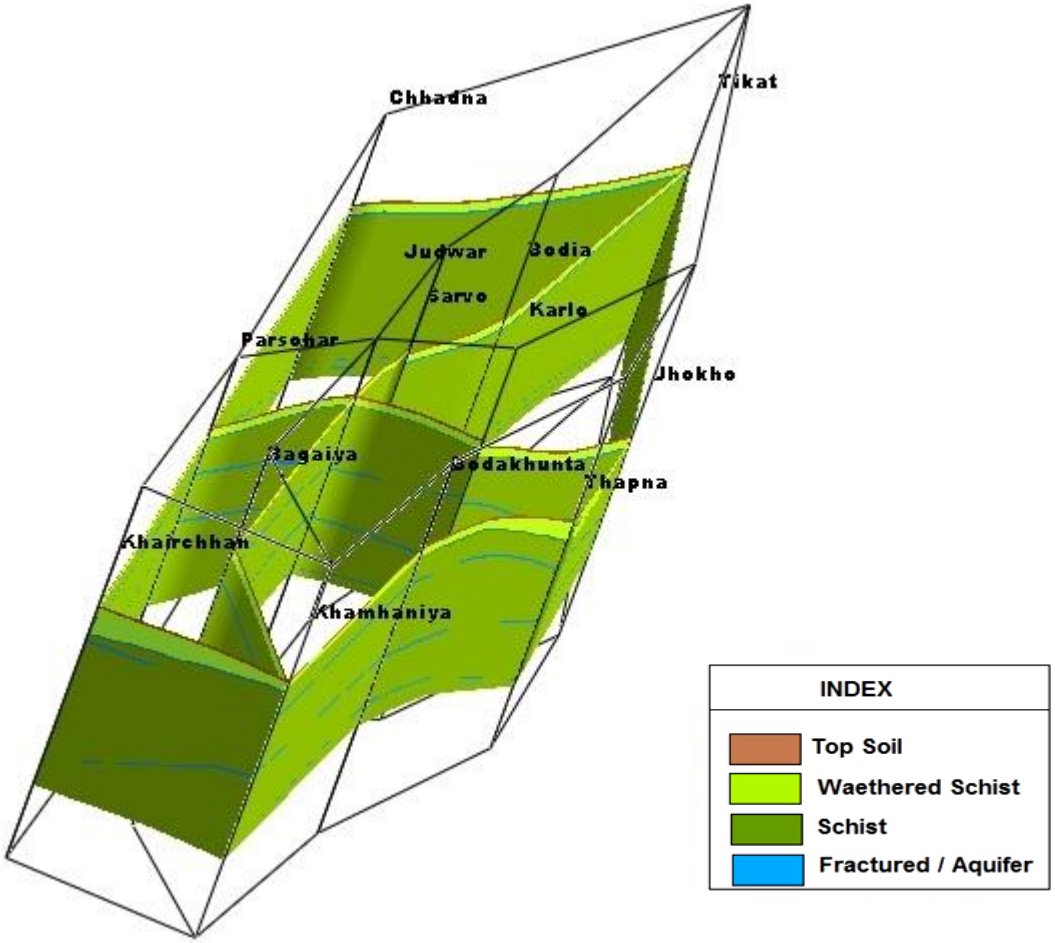


Fig.24: Fence Diagram, Singrauli District, Madhya Pradesh

3.3 2-D Cross Section

The 2D cross-section shows that the shallow aquifer comprising of Weathered Schist/Gniess is continuing from 8-30 m bgl occurs as narrow pinches in the some wells of Singrauli district. While in the deeper aquifers fractured Schist /Gniess occurs encountered at depth ranges between 55- 180 mbgl.

To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared.

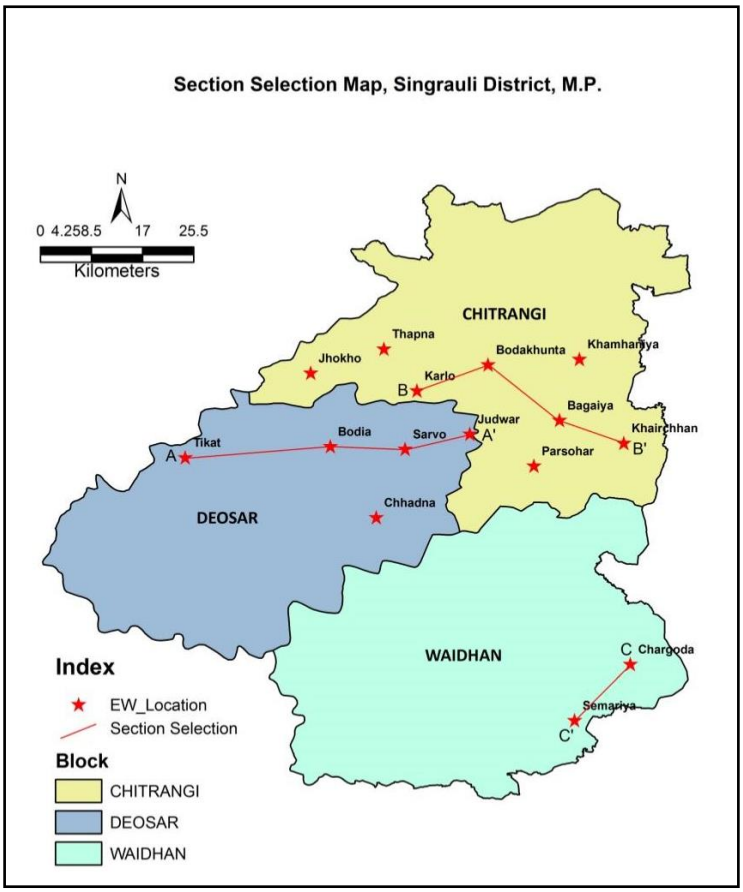


Fig.25: EW Location and 2D Cross Section AA', BB' and CC' Singrauli District

Hydrogeological Cross Section A-A'

Hydrogeological cross section A-A' (**Fig.26**) represents North West –South East direction and data of 4 exploratory wells i.e., Tikat, Bodia, Sarvo and Judwwar has been utilised.

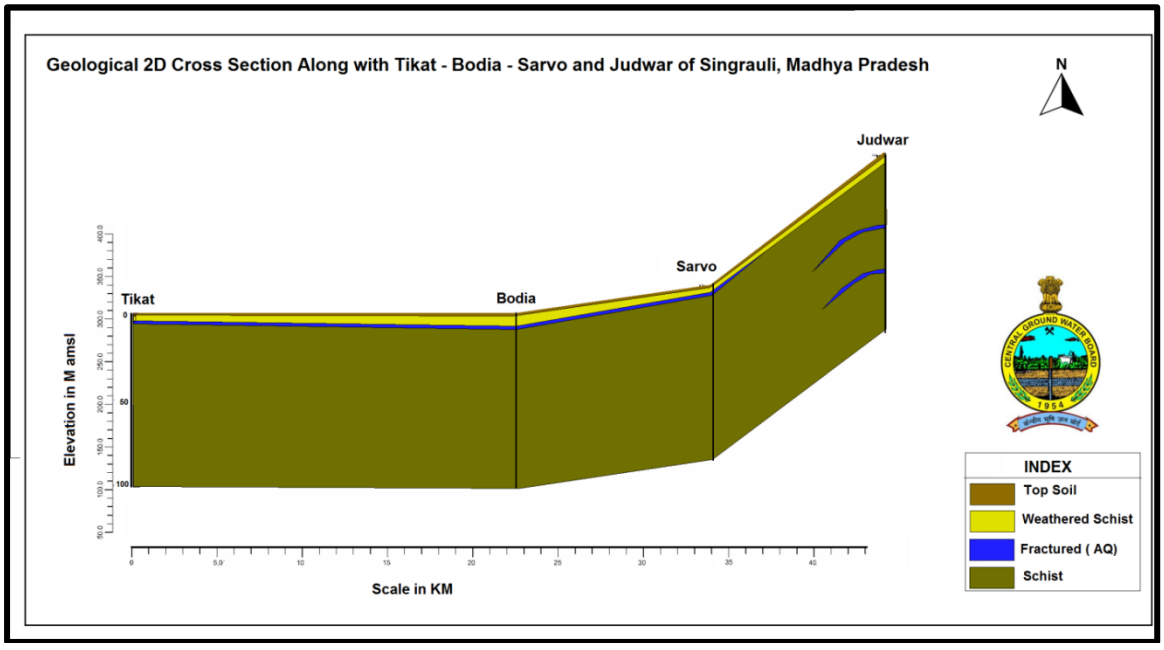


Fig.26: Hydrogeological Cross Section A-A'.

Hydrogeological Cross Section B-B'

Hydrogeological cross section B-B'(**Fig.27**) represents east – west i.e., Karlo, Bodakhunta, Bagaiya, & has been utilised.

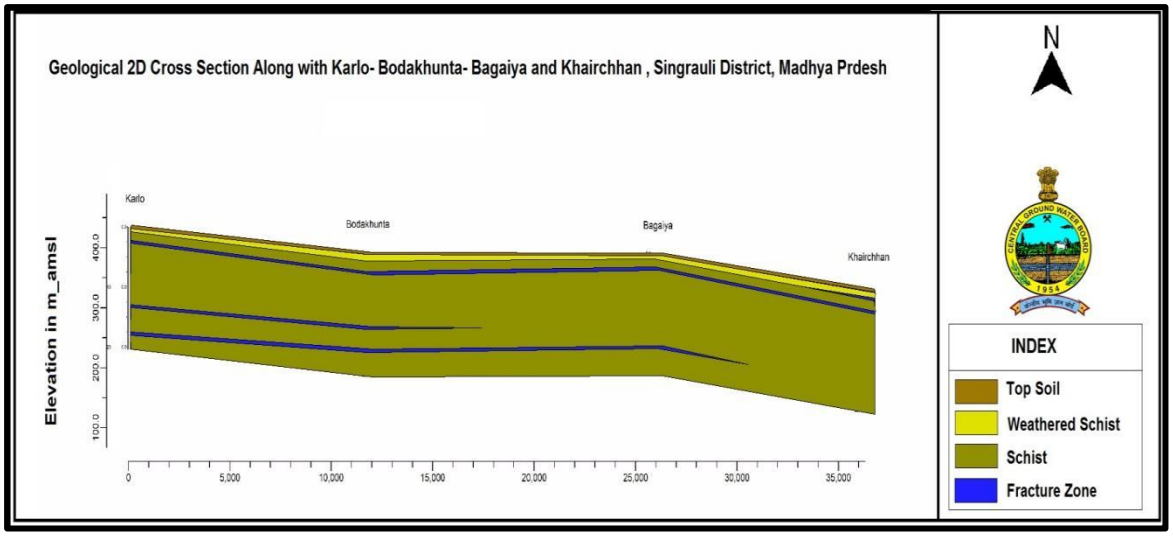


Fig.27: Hydrogeological Cross Section B-B'.

Hydrogeological Cross Section C-C'

Hydrogeological cross section C-C' (**Fig.28**) represents north – south direction and data of 2 exploratory wells i.e., Chargoda, & Semariya has been utilised.

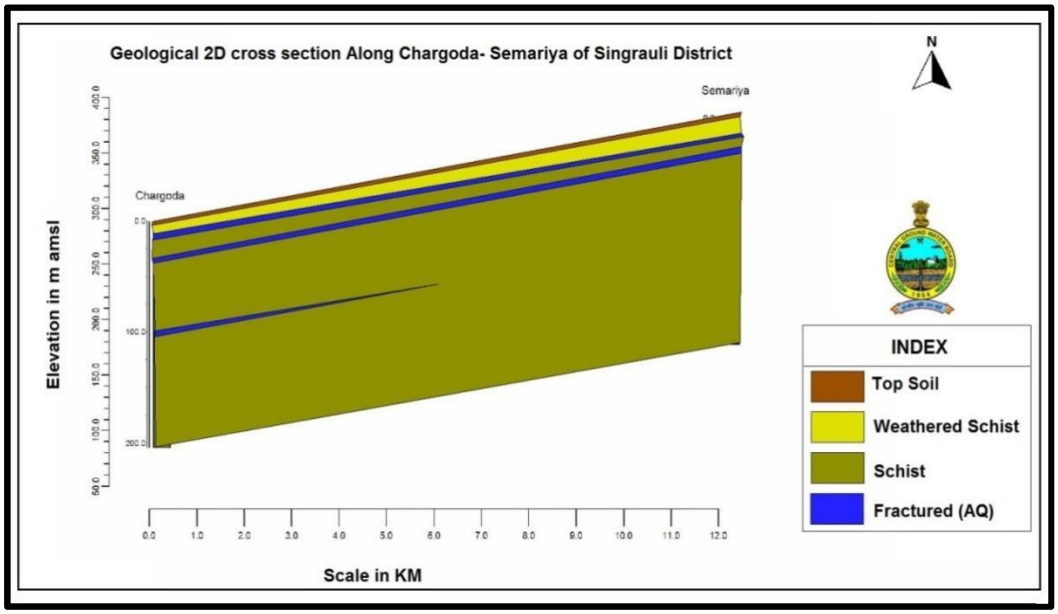


Fig.28: Hydrogeological Cross Section C-C'.

3.4 Aquifer Characteristics

Schist of the area is hard, compact and does not have primary porosity and is impermeable. Weathering, fracturing induces secondary porosity in schist/ gneiss in the area in fractured schist is an aquifer in unconfined and confined condition. Ground water occurs under phreatic/ unconfined to semi-confined and confined conditions.

Granitoids also doesn't have primary porosity and is impermeable. So the aquifers formed when the rock is weathered, fractured and jointed.

Based on the ground water exploration carried out in the Singrauli district, the following two types of aquifers can be demarcated and the details are given below in **Table 12**

Table 12: Aquifer Characteristics.

Major Aquifer	**Gondwana/Granitoids/ Schist**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Gondwana Sandstone / Granitoids / Schist /	Gondwana Sandstone /Jointed / fractured Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	2.7 to 19.7	6.83 to 29.16
Weathered / Fractured rocks thickness (m)	2 to 24	0.50 to 3
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield lps	-	0.27 to 8
Transmissivity (m^2/day)	-	0.20 to 27.69
Specific Capacity	-	0.22 to 31.83
Suitability for drinking/ irrigation	Suitable for both drinking and agriculture	Suitable for both drinking and agriculture

3.5 Geophysical Studies

Geo-Electrical Cross Sections

In hard rock areas comprising basalt, granite gneiss, schist, quartzite, and phyllite etc. preparation of cross-sections and fence is not justified because of the rapid hydrogeological variations. However, Cross sections, Fence Diagram and 3D model has been prepared with very limited practical applicability. The Cross sections, Fence Diagram and 3D model analysis up to depth 200 mbgl is showing below.

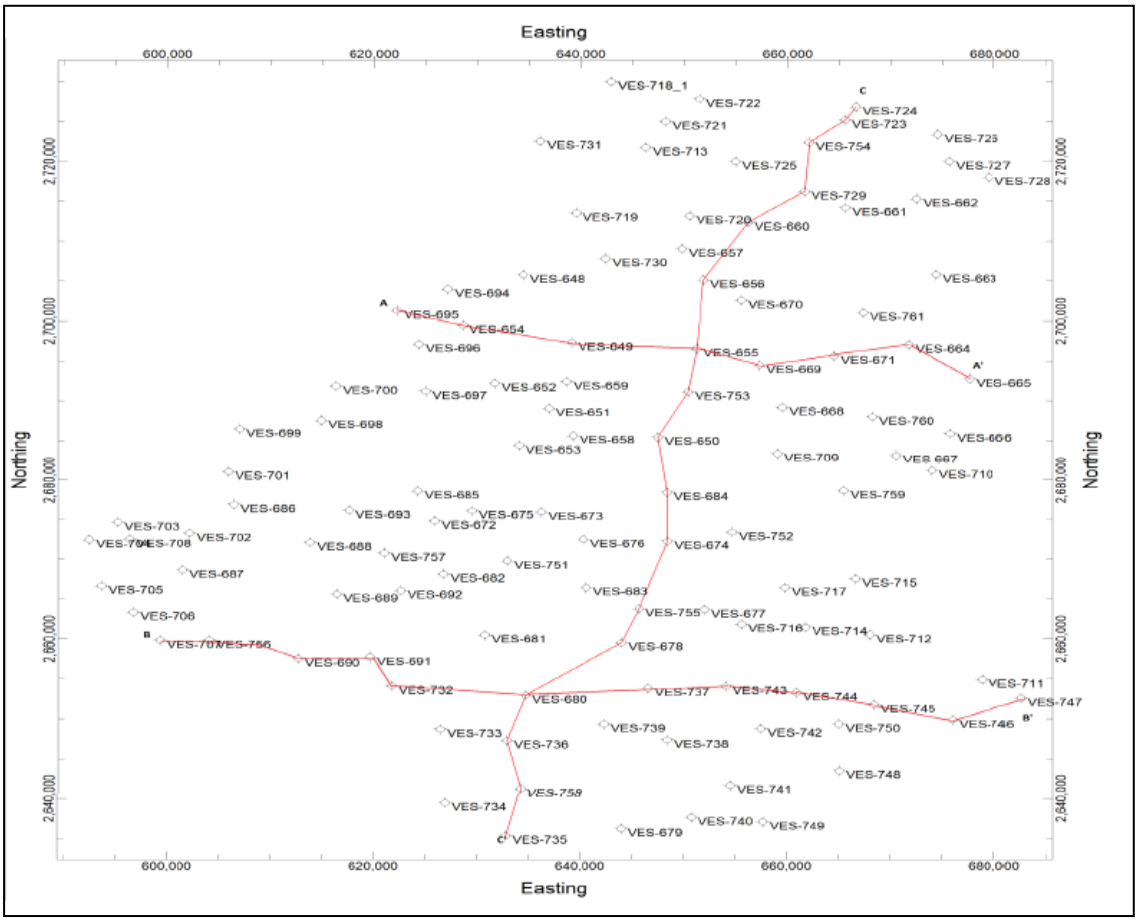


Fig.29: VES Location and Geo-electrical Cross Section AA', BB' and CC' Singrauli District

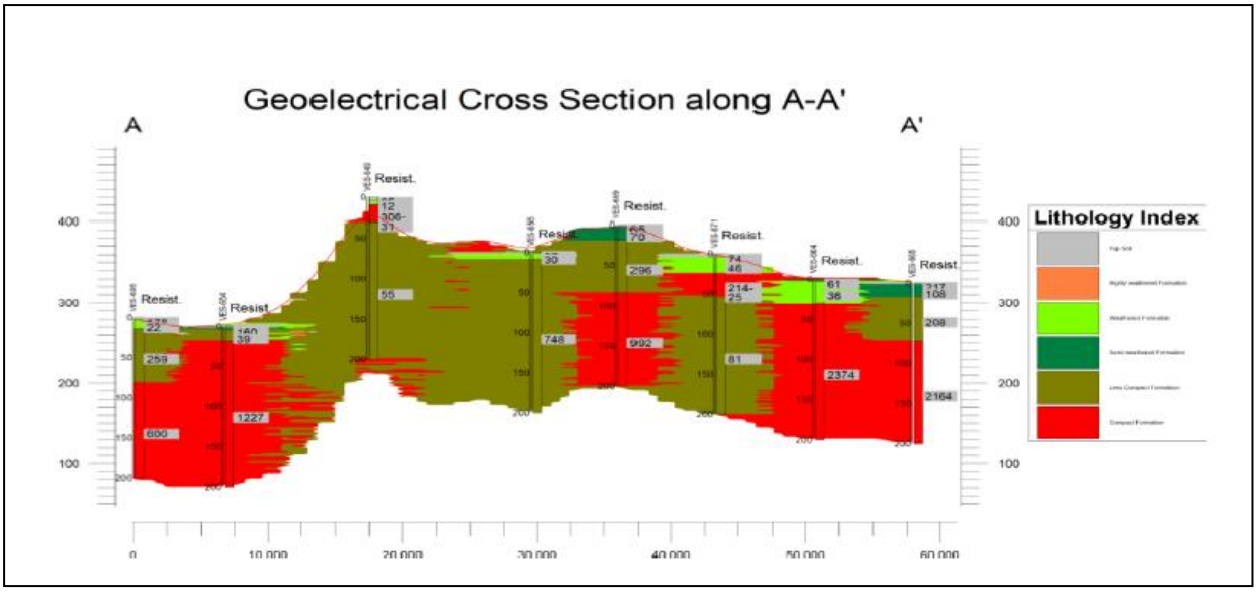


Fig.30: Geoelectrical Cross Section along AA' Singrauli District

Cross section AA' has been prepared in West-East direction and passing through the VES No. 695, 654, 649, 655, 669, 671, 664 and 665. In this section found that depth to the weathered formation varies from depth range 4 – 30 mbgl and resistivity range 12 -108 ohm.m and less compact formation depth range 18 89 mbgl and resistivity range 39 -259 ohm.m. The weathered formation found maximum depth 30 m at VES no. 664 below this layer found compact formation. The less compact formation found maximum depth 200 mbgl at VES 665. Below this depth found compact formation. It is observed that left side of this section weathered zone thickness is shallower than right side of this section and in central part of this section at most part of covered less compact formation.

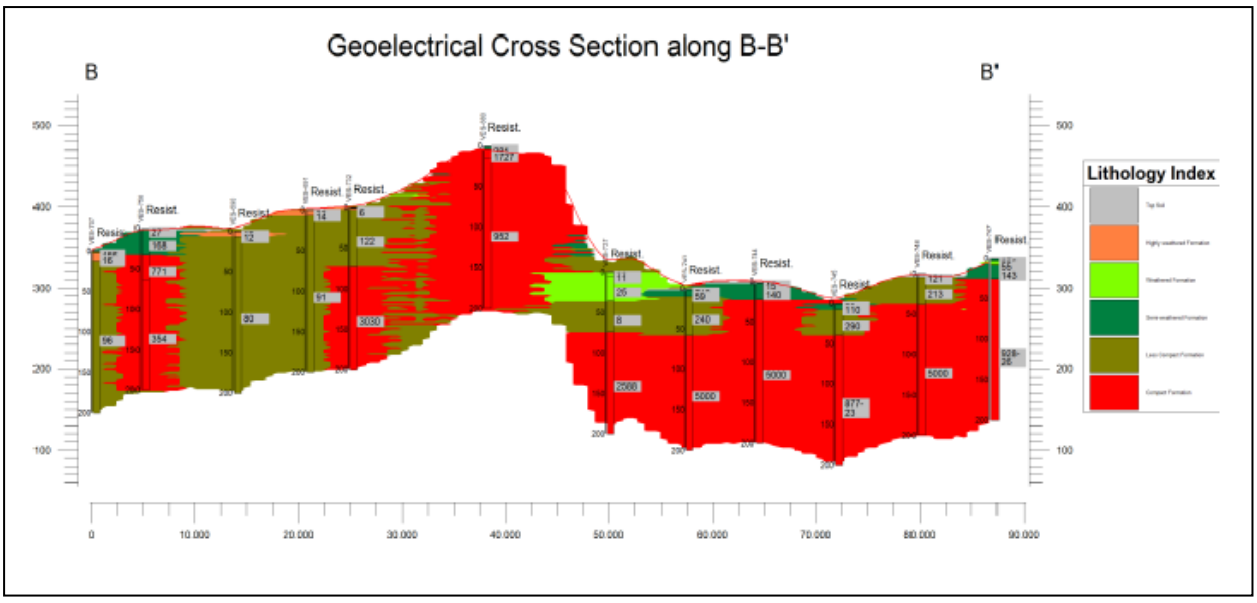


Fig.31: Geo-electrical Cross Section along BB' Singrauli District

Cross section BB' has been prepared in West-East direction and passing through the VES NOs 707,756,690,691,732,680,737,743,744,745,746 and 747. In this section found that depth to the weathered formation varies from depth range 3-32mbgl and resistivity range 6- 140mbgl and Less compact formation depth range 7-112mbgl and resistivity range is 86-122 ohm.m. The weathered formation found maximum depth 32m at VES no. 743 below this layer found Compact formation. The Less compact formation found maximum depth is 112mbgl at VES 691. Below this depth found compact formation. It is observed that left side of this section Less compact formation thickness is more than the right side and in central part of this section Compact formation exist after that 4 m weathered formation at VES 680.

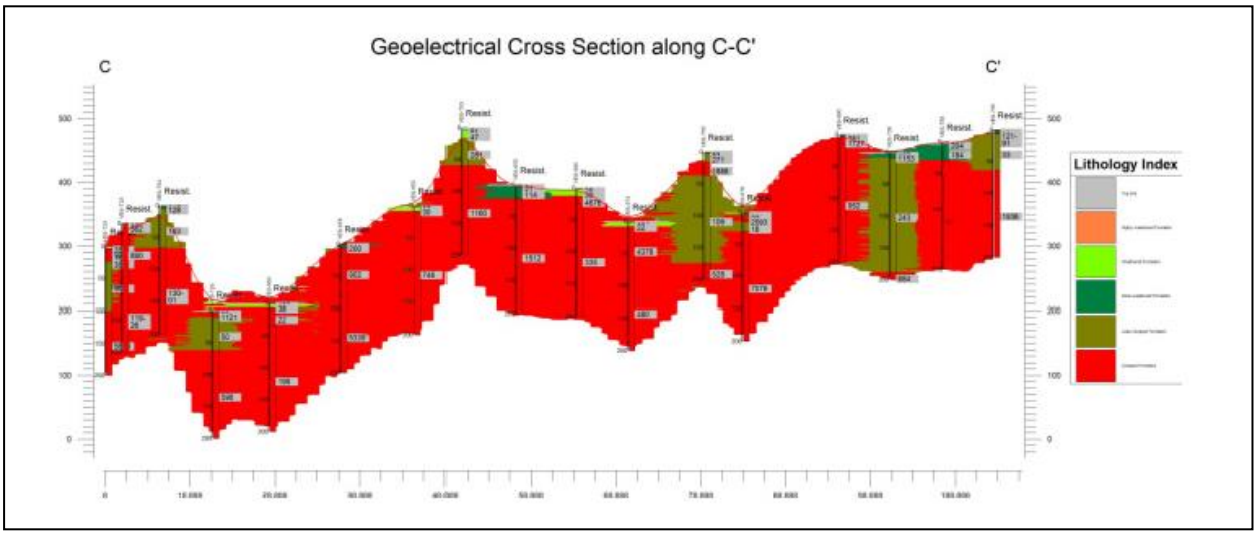


Fig.32: Geo-electrical Cross Section along CC' Singrauli District

Cross section CC' has been prepared in North-South Direction and passing through the VES Nos 724, 723, 754, 729, 660, 656, 655, 753, 650, 684, 674, 755, 678, 680, 736, 758 and 735. In this section found that depth to the weathered formation varies from depth range 3-34mbgl and resistivity range 22-114 ohm.m and less compact formation depth range 30-187mbgl and resistivity range is 16-243 ohm.m. The weathered formation found maximum depth 34m at VES no. 660 below this layer found Compact formation. The Less compact formation found maximum depth up to 187mbgl at VES 736. Below this depth found compact formation. It is observed that from this section left side of this section first showing compact formation up to depth of 23mbgl after that less compact formation upto depth of 100mbgl and then compact formation towards. In Central Part of this section showing Compact formation after a very thin layer of weathered formation. Right Side of this section showing compact formation after very thin layer of semi weathered layer and less compact formation except the VES 736. The VES 736 shown that less compact formation upto depth of 187mbgl. This layer may be ambiguity.

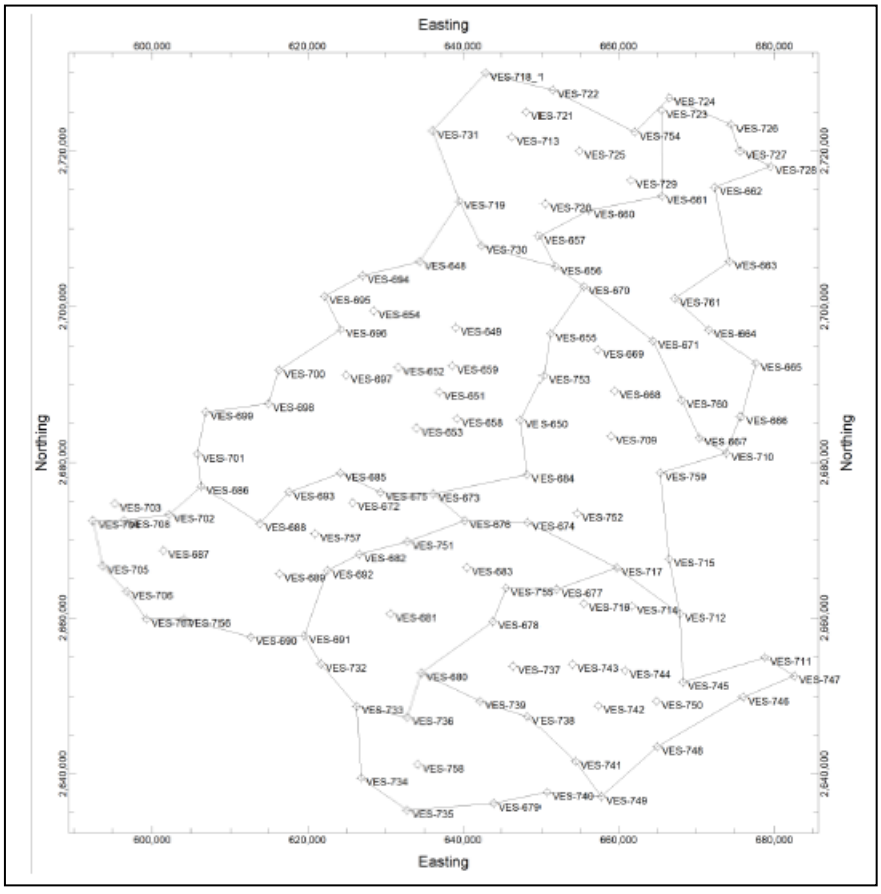


Fig.33: Lithological Fence Location Map with VES no Singrauli District

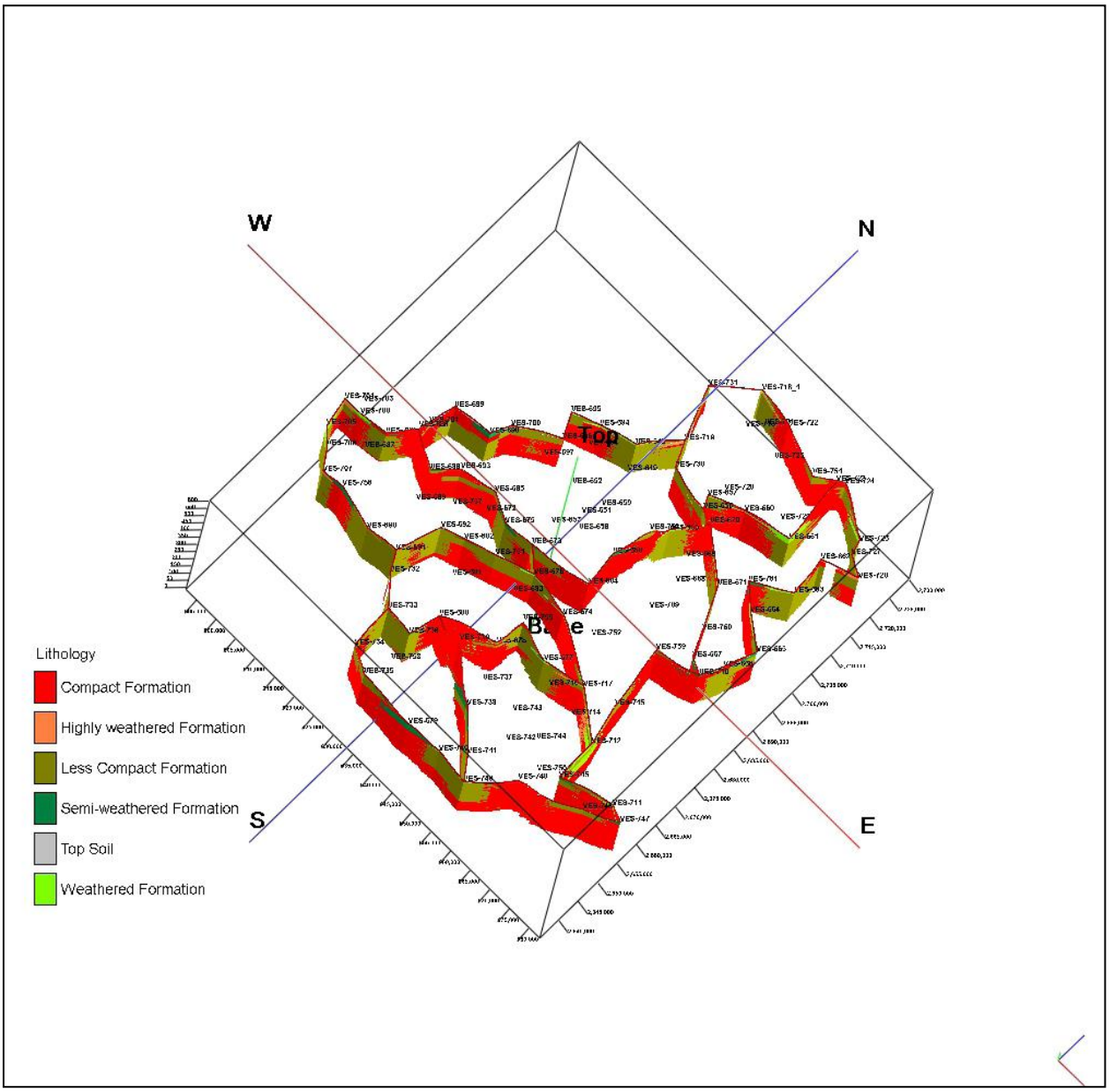


Fig.34: Lithological Fence Diagram, Singrauli District.

The observation of Lithological Fence Diagram of Singrauli District, found that shallow weathered formation and in some VES point found deeper less compact formation and below this found Compact Formation.

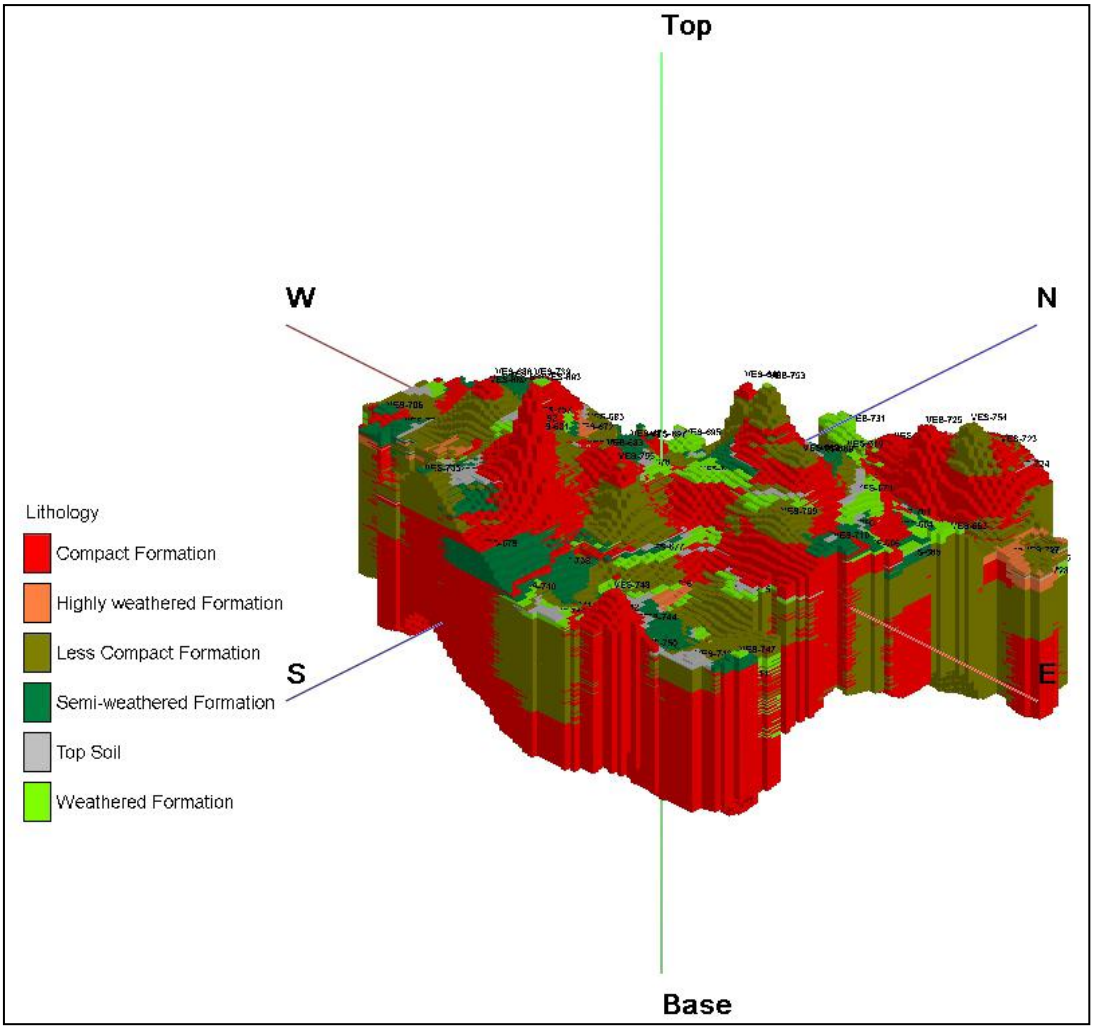


Fig.35: Lithological 3D Model, Singrauli District.

The observation of Lithological 3D Model of Singrauli District, found that shallow weathered Formation and in some VES point found deeper less compact formation and after that compact formation in study area. According to the 3D model map, central part of this district weathered formation is more thick in comparison to other part of this district. In Eastern side less compact formation is more deep. In Southern side of this district thin layer of semi weathered formation is found and after that compact formation lithology is more prominent up to bottom depth.

Weathering thickness observed at the depth ranges 9 and more than 20 mbgl covering 30% area of the district is highly suitable for ground water recharge. The suitable recharge structures are percolation tanks, recharge shafts and check dam can be constructed for better augmentation of ground water recharge potential. Weathering thickness of entire district is shown in fig.36 and given in Table No. 13

Table 13: Weathered Zone on the basis of 116 VES

No of VES	Weathered Zone	Recommendation
53	Absent	Cannot be considered for shallow tube wells/dug wells
40	9-20mbgl	Can be considered for shallow depth tube wells/ dug wells and suitable for recharge
23	0-9mbgl	Can be considered for dugwells
11	>20mbgl	Can be considered for shallow depth tube wells and suitable for recharge

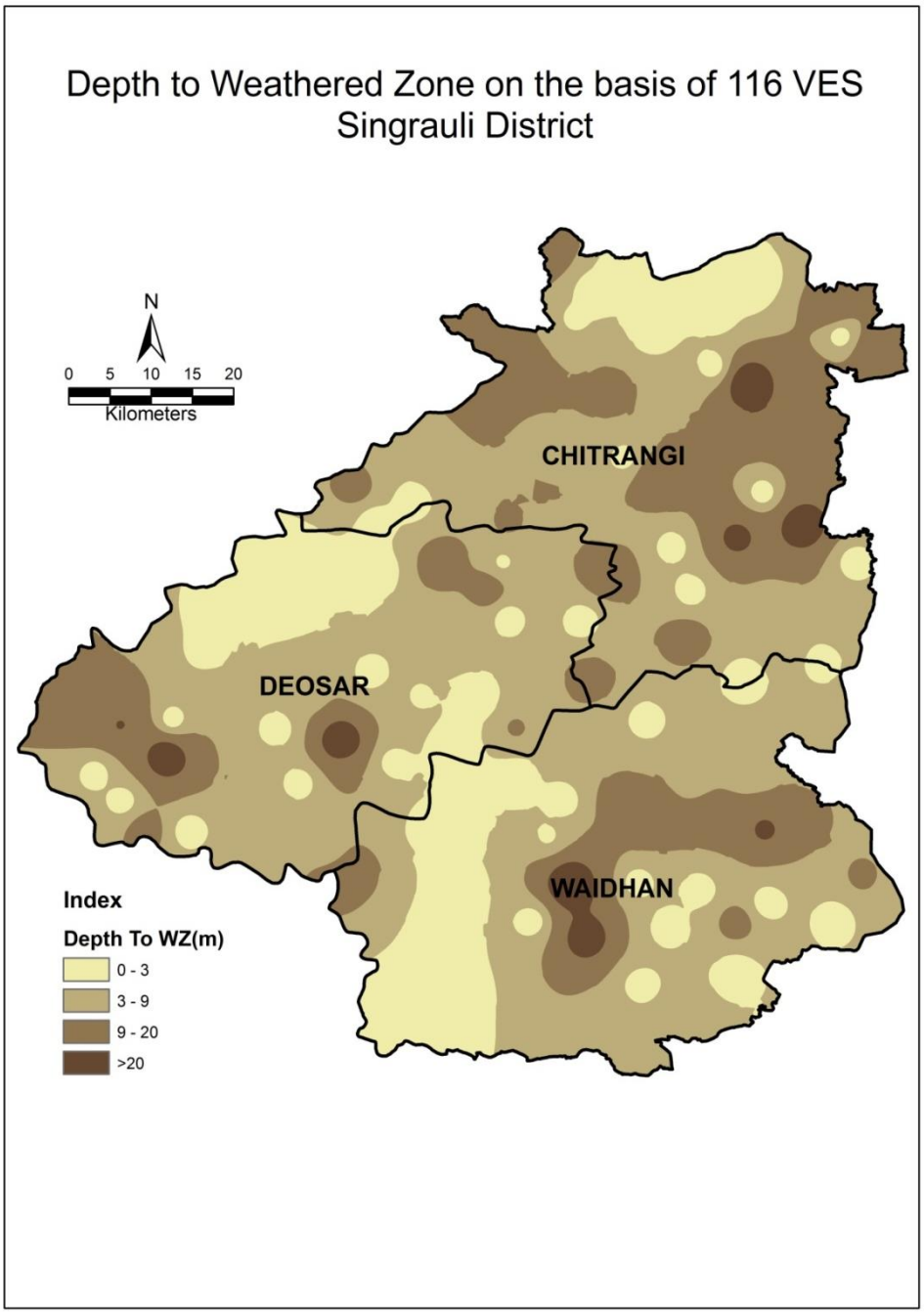


Fig:36: Depth to Weathered Zone on the basis of 116 VES Singrauli District

3.6 Hydrochemistry

Quality of Ground Water for Drinking Purpose:

The ground water samples from Singrauli district have varied range of pH from 7.23 to 8.08. As per BIS (IS 10500:2012) recommendation, all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, the maximum pH recorded in the water sample of Bharseda (8.08). The pH of ground water can be assessed as neutral to slightly alkaline in nature. The electrical conductivity of ground water samples in Singrauli district varies from 322 to 1289 µS/cm at 25°C. In the district, 17 locations of sample shows EC less than 1000 µS/cm while 2 locations of sample shows EC in between 1000 to 1500 µS/cm from Mara (1142) and Kachani (1289 µS/cm) villages. So, overall ground water quality of Singrauli district is good to saline in nature in few pockets of the districts.

The fluoride concentration in Singrauli district lies in between 0.01 to 1.01 mg/l, which represent that all the samples are within the permissible limit i.e. 1.5 mg/l of BIS standard. The maximum concentration of fluoride has been observed in the dug well of Kachani village i.e. 1.01 mg/l. The nitrate concentration in the Singrauli districts ranges in between 5 to 105 mg/l. In the district, 21% samples have nitrate concentration more than the acceptable limit of 45 mg/l, while rest 79% samples have concentration less than acceptable limit. Highest concentration of nitrate has been recorded in the village of Karthua (105 mg/l).

The total hardness in the ground water of the districts ranges between 81 to 395 mg/l. In the district, all the ground water samples recorded total hardness within the BIS permissible limit of 600 mg/l. The maximum concentration of total hardness has been observed in the village of Mara i.e. 395 mg/l.

Piper diagram has three parts: a Cation triangle, an Anion triangle, and a Central diamond-shaped field. In Cation triangle, the relative percentages of the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) are plotted. In Anion triangle the major anions ($HCO_3^{-}+CO_3^{2-}$, SO_4^{2-}, Cl^{-}) are plotted. These points are then projected to the central diamond shaped field.

In the district; piper diagram shows that the samples are Calcium-Bicarbonate type (temporary hardness) and Mixed type types of water.

Quality of Ground Water for Irrigation Purpose:

The classification of water for irrigation purpose, it is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. The chemical data of all the water samples from Singrauli district is plotted on U.S. Salinity Laboratory diagram.

The USSL diagram shows that the districts falls under C_2-S_1 Class (Medium Salinity & Low Sodium); C_3-S_1 Class (High Salinity & Low Sodium). The ground water of the district may be used for irrigation with proper soil management.

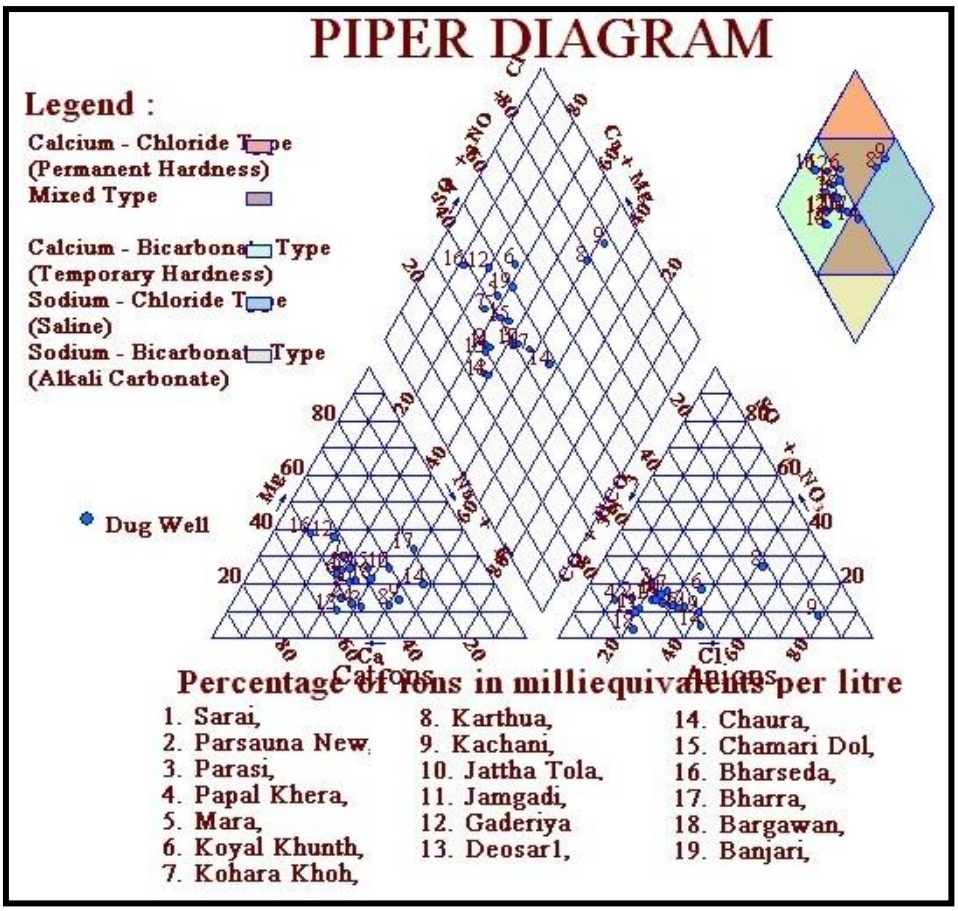


Fig.37: Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Singrauli District, Madhya Pradesh

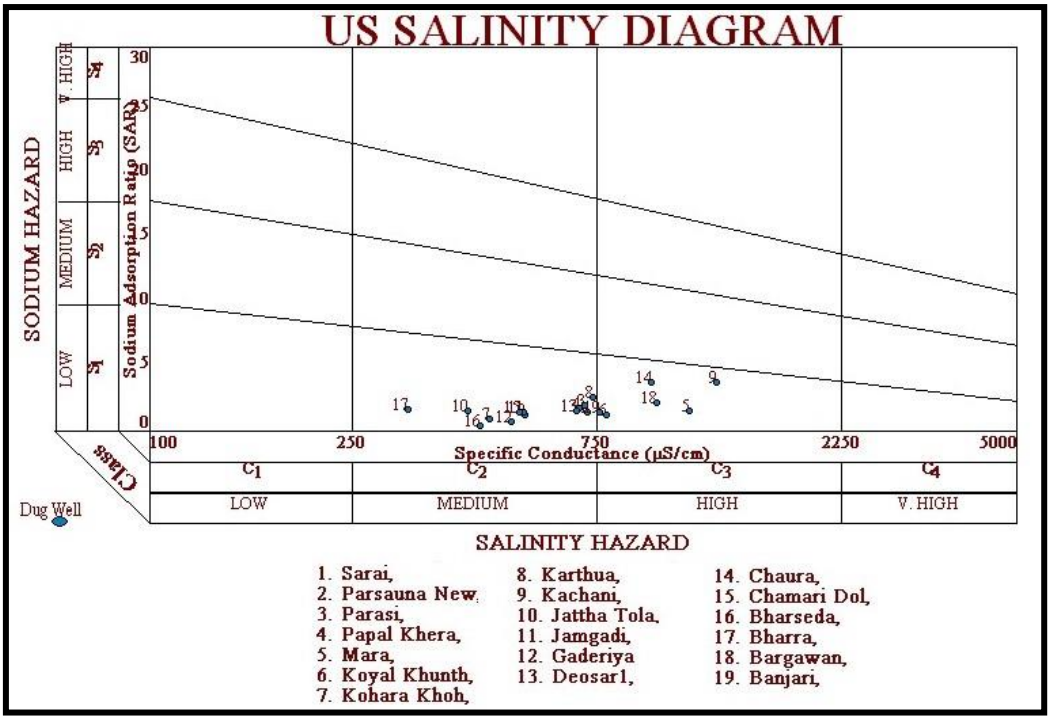


Fig.38: US Salinity Diagram for water samples collected from National Hydrograph Stations of Singrauli District, Madhya Pradesh

Table 14: Comparative study of 10 years chemical data

Monitoring Well	EC in 2020	EC in 2011	Percentage increase	NO3 in 2020	NO3 in 2011	Percentage increase/decrease
Bargawan	987	680	45.15	12	17	-29.41
Bharra	322	160	101.25	16	7	128.57
Deosar1	687	370	85.68	26	17	52.94
Mara	1142	590	93.56	49	7	600

A large increase in EC is recorded in the Bharra village of Deosar block in a span of 10 years. Huge increment in Nitrate levels has also been recorded in some of the monitoring wells. A record 600% increase in Nitrate level can be seen in Mara village monitoring well of Waidhan block. Also an increase in pH value is observed in all the monitoring wells of the district.

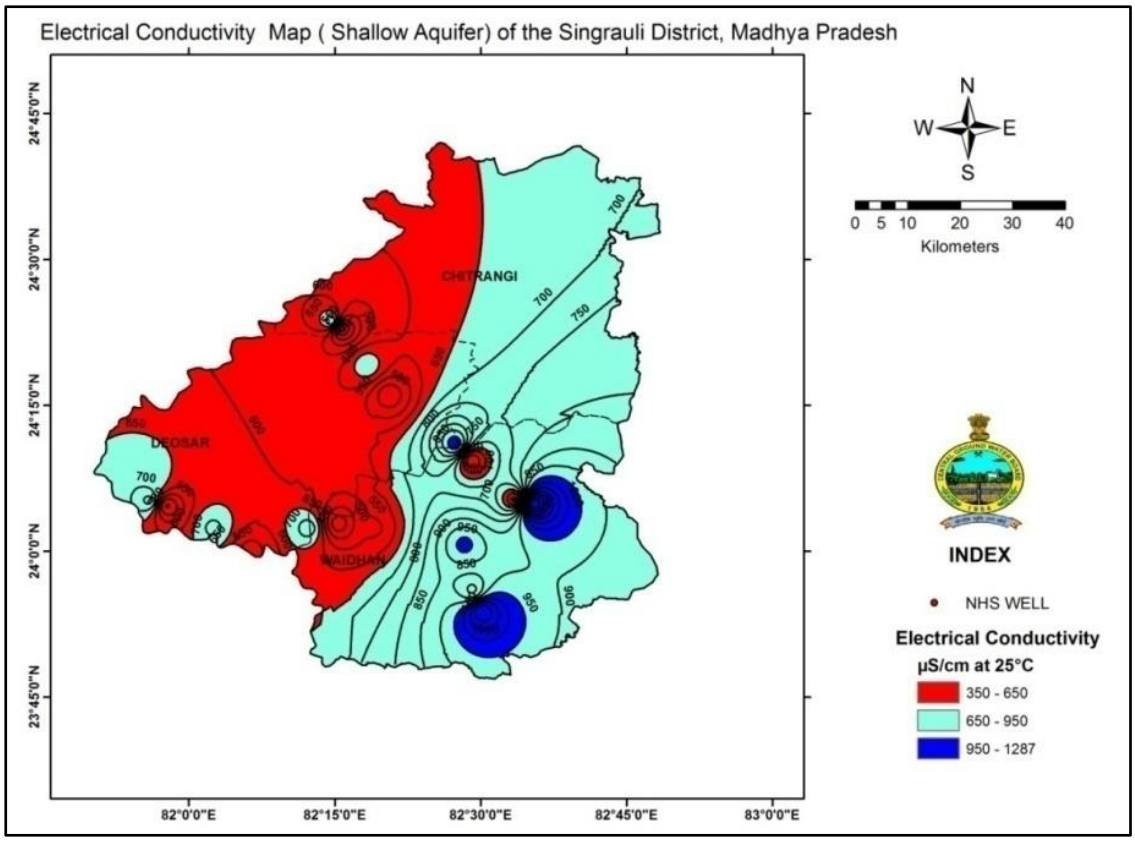


Fig.39: Electrical Conductivity of Aquifer-I (Shallow Aquifer).

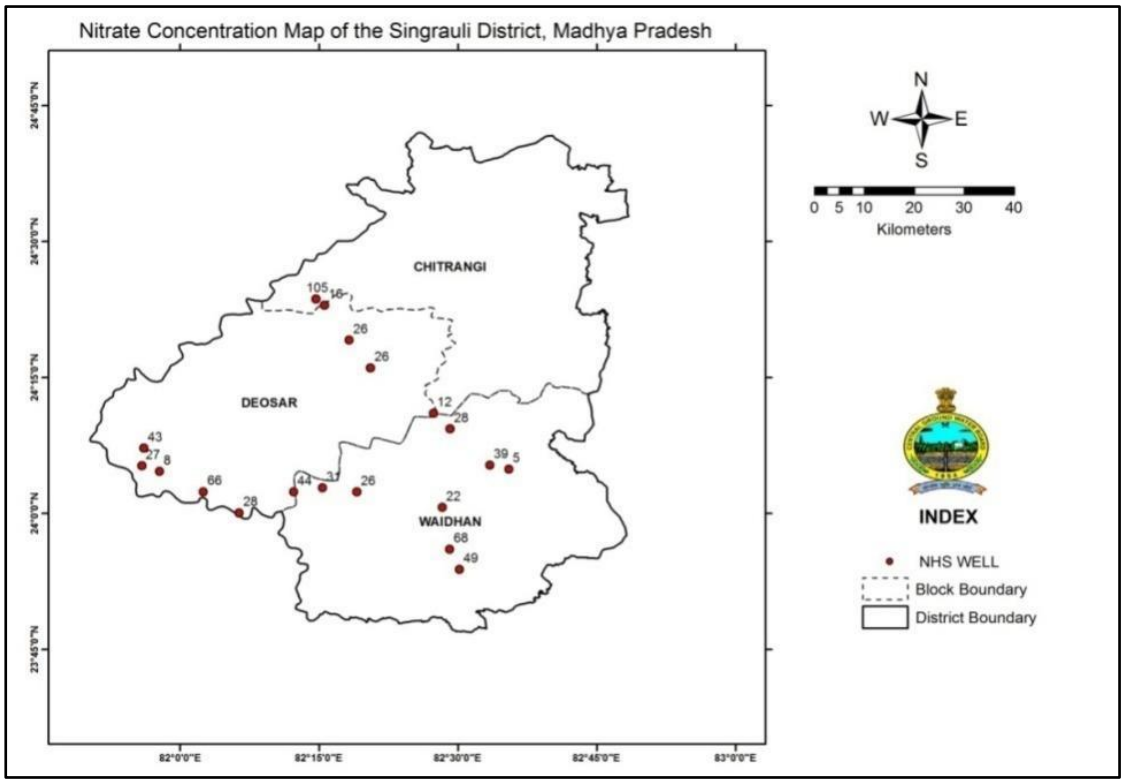


Fig.40: Concentration of Nitrate of Aquifer-I (Shallow Aquifer).

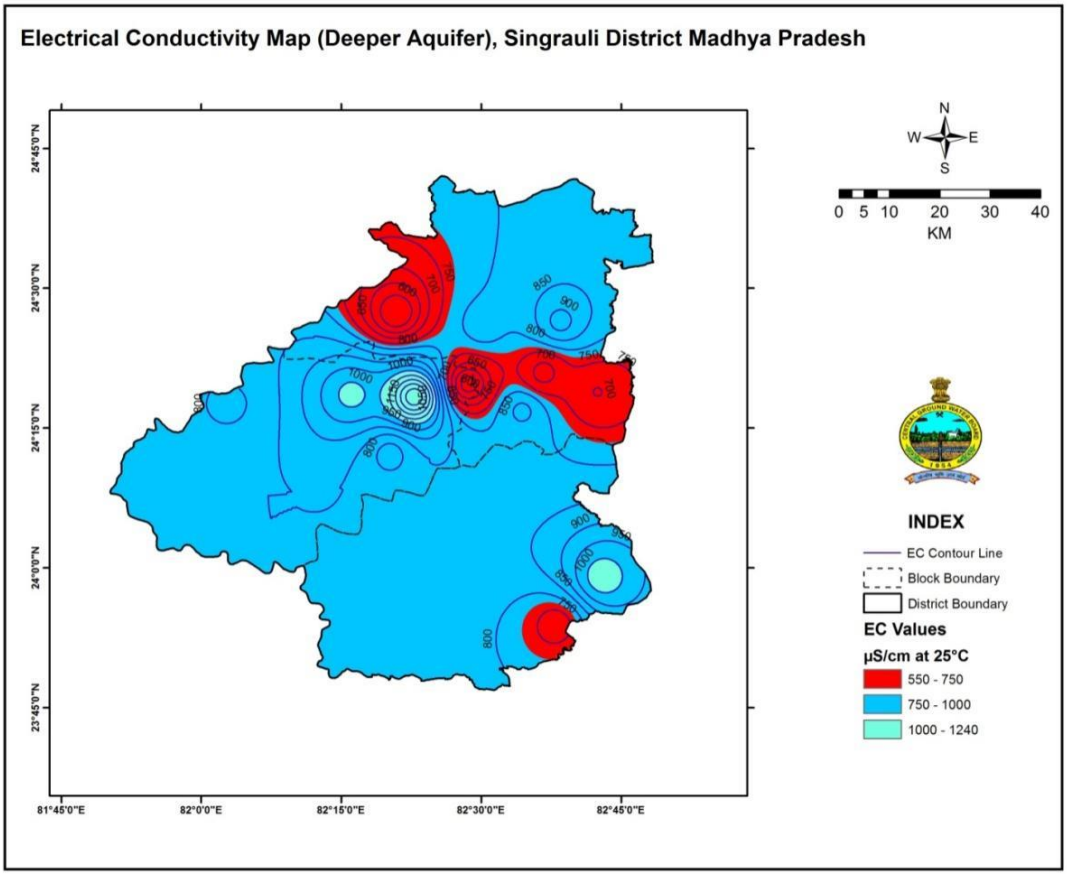


Fig.41: Electrical Conductivity of Aquifer-II (Deep Aquifer).

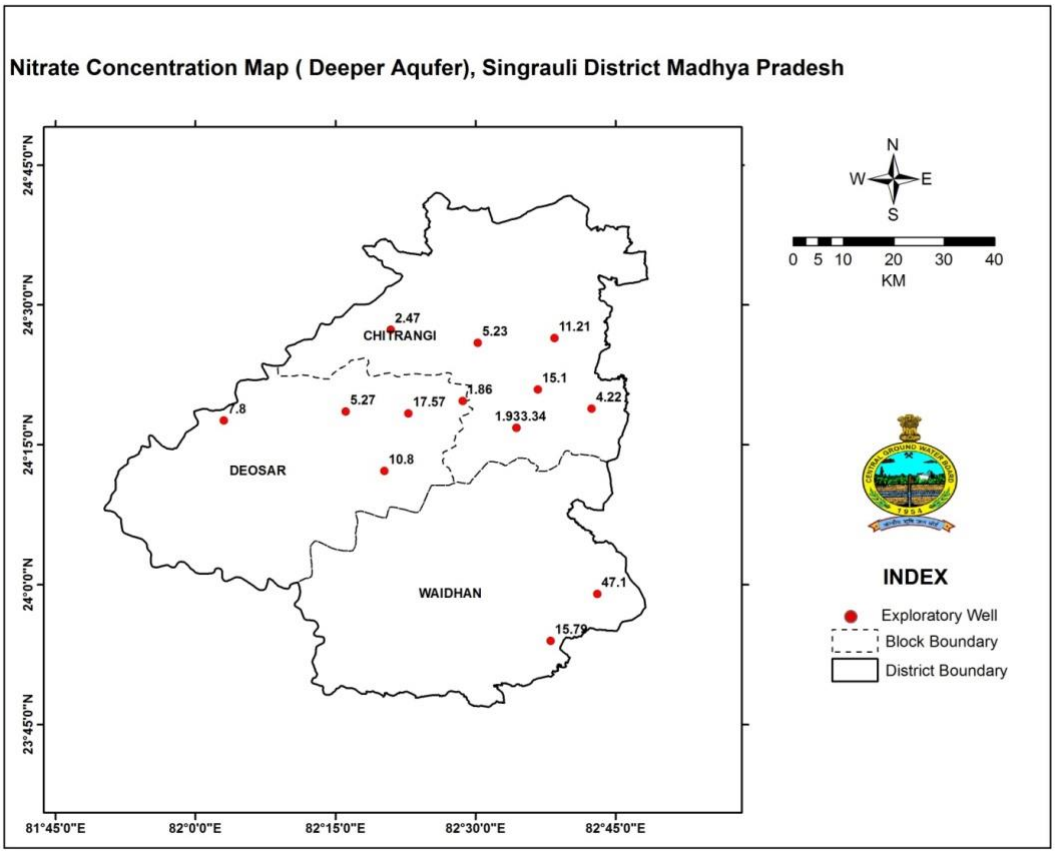


Fig.42: Nitrate concentration of Aquifer-II (Deep Aquifer).

4.0 GROUND WATER RESOURCES

The ground water resources have been assessed for two types of aquifer existing in the area i.e., Aquifer-I and Aquifer-II. The details of the assessment are discussed below.

4.1 Dynamic Ground water Recourses:

Singrauli district is mainly underlain by Granite, Gniess ,Lime stone, Vindhyan Sandstone and Shale , Alluvium and Gondwana.

Dynamic ground water resources of the district have been estimated on block-wise basis. Out of 5672 sq. km of geographical area, 4512.60 (79.56%) is ground water recharge worthy area and 1159.40 sq. km is forest and hilly area (20.44%). There are three assessment units (block) in the district all 3 blocks fall under safe category namely Waidhan, Chitrangi and Deosar. Three blocks with stage of ground water development being Waidhan 64.17%, Chitrangi 21.73%, and Deosar 50.58 %.

The net ground water availability in the district is 340.53 MCM and ground water draft for all uses is 130.75 MCM, making stage of ground water development to 38.27% as a whole for the district. Table 5.1 shows the Dynamic Ground Water Resource Assessment estimated by CGWB for the year 2020.

Table15: Assessment Unit Wise Area Details(2020)

Assessment Unit	Type of Rock Formation	Recharge Worthy area of formation (in Ha)	Areal extent (in Ha)			
			Total Geographical Area	Hilly Area	Ground Water Recharge Worthy Area	
					Command Area	Non-Command Area
WAIDHAN	Gondwana sandstone	139900	190400	50500	4452	135448
CHITRANGI	Archaean granite, Gondwana sandstone	171250	194600	23350	0	171250
DEOSAR	Archaean granite, Gondwana sandstone	140110	182200	42090	2150	137960
DISTRICT TOTAL		451260	567200	115940	6602	444658

Table 16: Assessment Unit Wise Recharge (2020)

Assessment Unit Name	Recharge Worthy Area(Ha)	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources-Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources-Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
WAIDHAN	139900	7221.63	334.58	0	1170.21	8726.42	872.64	7853.78
CHITRANGI	171250	18287.99	200.58	0	706.45	19195.02	959.75	18235.27
DEOSAR	140110	7835.18	254.88	0	759.5	8849.56	884.96	7964.6
DISTRICT TOTAL	451260	33344.8	790.04	0	2636.16	36771	2717.35	34053.65

Table 17: Assessment Unit Wise Extraction (2020)

Assessment Unit Name	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Category
WAIDHAN	7853.78	4637.61	0	402.89	5040.49	475.85	2740.33	64.18	safe
CHITRANGI	18235.27	3015.9	0	947.21	3963.11	1118.73	14100.64	21.73	safe
DEOSAR	7964.6	3204.9	0	824.25	4029.15	973.5	3786.2	50.59	safe
DISTRICT TOTAL	34053.65	10858.41	0	2174.35	13032.75	2568.08	20627.17	38.27	

4.2 Static Ground Water recourses:

The Ground Water Resource of Singrauli District has also been calculated block wise as an outcome of NAQUIM. The In-storage resource for the shallow aquifer below zone of fluctuation (upto 30 mbgl) is computed to be around 399.99 MCM. The In-storage resource for the deeper aquifer (30-200 mbgl) is computed as 203.067 MCM.

Table 18: In-storage Ground Water Resources of Aquifer-I.

	Units	
Recharge worthy Area	Sq. km	4512.60
Pre-monsoon (average) depth to water level	m	8.54
Av. depth of Dug well	m	11.86
Specific yield(Sy)%	Fraction	0.016
Saturated thickness of aquifer (ST)	m	5.54
In-storage Ground Water Resource	MCM	**399.99**

4.2.1 Ground Water Resources – Aquifer-II

The ground water resource of the Aquifer –II was also assessed to have the correct quantification of resources so that proper management strategy can be framed. To assess these resources, the average thickness of fractures in deeper aquifers from exploratory wells was calculated and the following formula for static ground water resources was utilized i.e., GWR =Recharge worthy Area x Thickness of fractures in deep aquifer x Specific yield. By applying above formula, the ground water resource of Aquifer-II was estimated as 203.067 MCM and is presented below in **Table 19**.

Table 19: In-storage Ground Water Resources of Aquifer-II.

	Units	**Total**
Recharge worthy Area	Sq.km	4512.60
Thickness of fracture in deeper aquifer	M	3
Specific yield(Sy)%	Fraction	0.015
Resource (A * Sy * ST)	MCM	**203.067**

4.3 Water Requirement/Demand:

4.3.1 Domestic Water Demand

Population of the district in 2011 was 1178273 which in 2022 are projected to be 1423718. The expected Water demand in 2022 is 0.074033 BCM per annum.

Table 20: Domestic Water Demand

Block	Population in 2011	Projected Population in 2022	Gross Water Demand in 2022 (BCM)
Waidhan	517197	618749	0.032496
Deosar	315615	382005	0.019831
Chitrangi	345461	422965	0.021706
	1178273	1423718	0.074033

(Source : CWC, Department of Water Resource in District and Status Report)

4.3.2 Industrial Water Demand

Many power industries and those supporting mining activities has been set up in the district which are extracting groundwater on a large scale. Future ground water requirement of all such industries accounts to 8600.53 m3/day which is 31,39,193.45 m^3 per year.

Table 21: Industrial Water Demand

S.No	Project Name	Category	Block	Net Ground Water Requirement(m3/day)	Net Ground Water Requirement (m3/year)
1	Jaypee Nigrie Super Thermal Power Plant (A Division of Jaiprakash Power Ventures Ltd.)	Power generation unit	Deosar	490.5	179032.5
2	Powergrid Corporation of India Ltd.(A Gov. of India Enterprise)	Power Sector	Waidhan	10	3650
3	Usmani Mineral	Packaged Drinking Water	Waidhan	5	1825
4	Mahavir Coal Resources Pvt. Ltd.	Coal Washery	Chitrangi	685	250025
5	M/S Chitrangi Power	Power	Chitrangi	7400	2701000

S.No	Project Name	Category	Block	Net Ground Water Requirement(m3/day)	Net Ground Water Requirement (m3/year)
	Pvt. Ltd.	Sector			
6	M/S Usmani Mineral	Packaged Drinking Water	Waidhan	10.03	3660.95
Total				**8,600.53**	**31,39,193.45**

4.3.3 Infrastructure Demand

Future Ground water requirement by the infrastructure sector in the district accounts to 7514 m^3/day which is 27,42,610 m^3/year.

Table 22: Infrastructure Demand

S.No.	Project Name	Category	Block	Net Ground Water Requirement(m3/day)	Net Ground Water Requirement(m3/year)
1	Indian Oil Corporation Limited (Marketing Division)	Transport Depot	Waidhan	2	730
2	Powergrid Corporation Of India Ltd	Power Grid Station	Waidhan	10	3650
3	Vinayak Sales	Petroleum Retail Outlet	Deosar	2	730
4	M/S Sasan Power Ltd.	Residential township	Waidhan	7500	2737500
Total				**7,514**	**27,42,610**

4.3.4 Mining Dewatering and Extraction-Demand

A lot of Mining activities are undergoing in the district which dewater a huge amount of groundwater. Deep open cast mines cutting the aquifers are responsible for emptying the shallow/deep aquifers. The mines are mostly concentrated in Waidhan block. The future Ground Water Requirement (dewatering + extraction) of mining industry of the district sums up to 53,792.7 m^3/day and 19634335.5 m^3/year.

Table 23: Mining Dewatering and Extraction

S.No.	Project Name	Category	Block	Net Ground Water Requirement(m3/day)	Net Ground Water Requirement(m3/year)
1	KHADIA OPENCAST PROJECT	Coal	Waidhan	1828	667220
2	M/S NORTHERN COALFIELDS LIMITED DUDHICHUA PROJECT	Coal	Waidhan	1903	694595
3	BANDHA COAL MINE	Coal	Deosar	2682	978930
4	KHADIA OPENCAST PROJECT	Coal	Waidhan	2481	905565
5	M/S NORTHERN COALFIELDS LIMITED DUDHICHUA PROJECT	Coal	Waidhan	2388	871620
6	DHIRAULI COAL BLOCK	Coal	Waidhan	1936	706640
7	BINA EXTN PROJECT	Coal	Waidhan	1653.01	603348.7
8	JHINGURDA OCP	Coal	Chitrangi	3960	1445400
9	BLOCK-B PROJECT	Coal	Chitrangi	4501	1642865
10	NIGAHI PROJECT-NORTHERN COALFIELDS LIMITED	Coal	Waidhan	5941	2168465
11	AMLOHRI	Coal	Waidhan	10501	3832865
12	SULIYARI COAL MINE	Coal	Waidhan	6623.69	2417647
13	JAYANT PROJECT	Coal	Waidhan	5185	1892525
14	AMELIA (NORTH) COAL MINE	Coal	Waidhan	2210	806650
Total				**53,792.7**	**1,96,34,335.5**

5.0 GROUND WATER RELATED ISSUES

5.1 Declining Water Level

The decline in the water level is observed in major part of the district. The pre and post monsoon declining trend of hydrograph is prepared and presented in the **Fig.43(a) and 43(b)**.

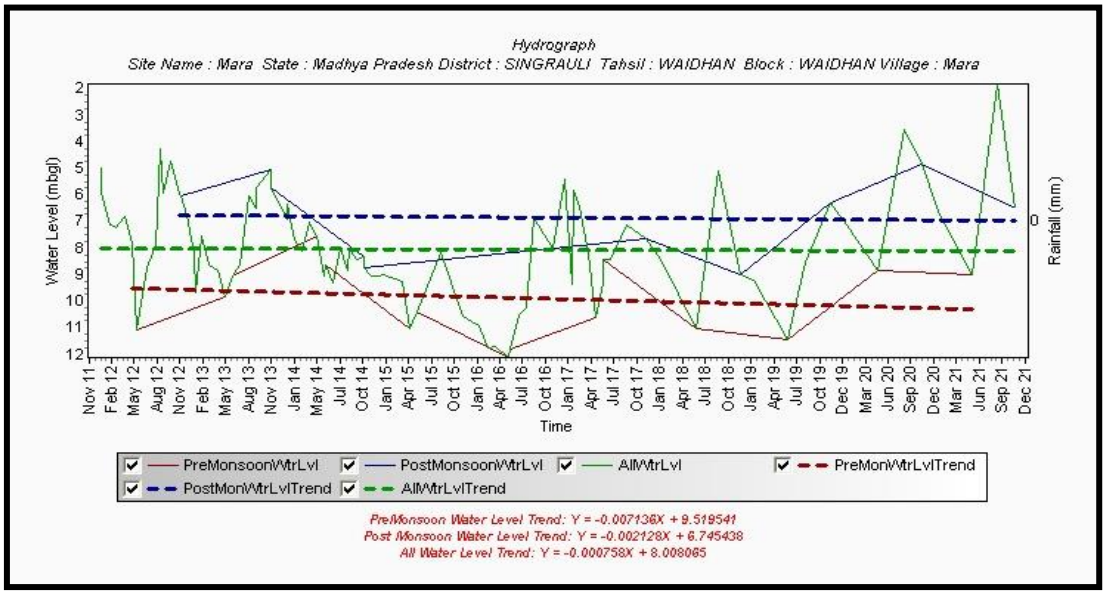


Fig.43(a): Hydrograph (2011-21), village-Mara, Block Waidhan, District Singrauli.

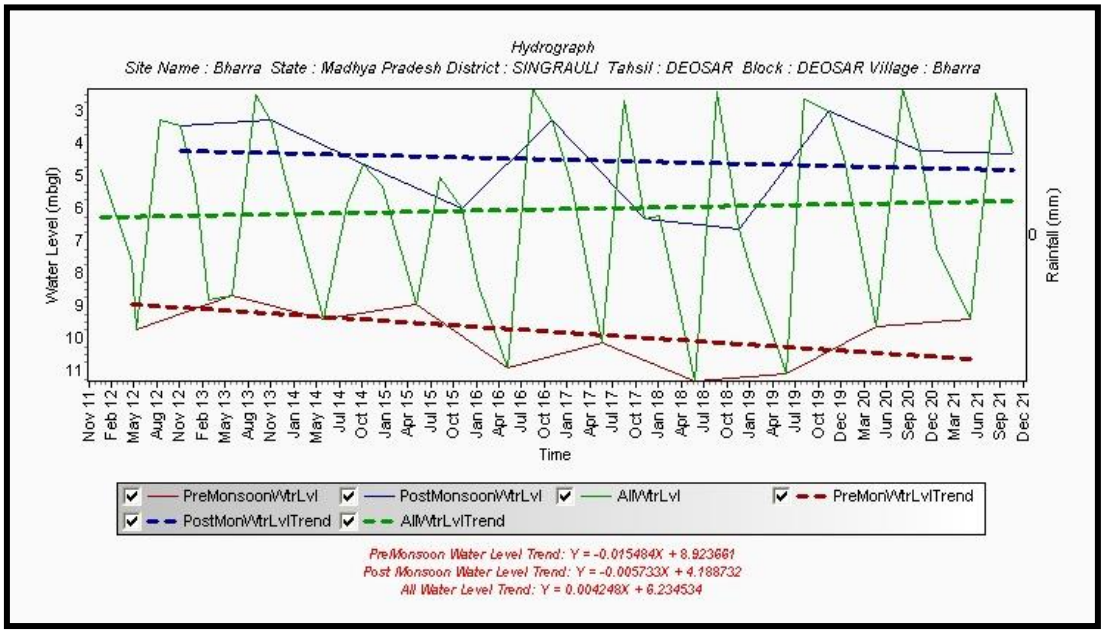


Fig.43(b) Hydrograph (2011-21), Village- Bharra, Block Deosar, District Singrauli.

5.2 Low Ground Water Potential / Limited Aquifer Thickness / Sustainability

The area under Archean- Schist and Gneiss don't have primary porosity and are impermeable. So they can form aquifers only when they are weathered, fractured and jointed.

So, the depth of weathering in shallow aquifer and its aquifer thickness in deeper aquifers are limited. Therefore sustainability of both the aquifers are limited in this condition.

5.3 Water Quality

District Singrauli is known for its coal reserves and is the energy capital of the country, generating about 10 per cent of India's coal-based power. Big industries like National Thermal Power Corporation (NTPC) and various open cast coal mines were found to dispose fly ash slurry, generated from their super thermal power plant in the reservoir and contaminated by effluent from coal mining projects in the area. These effluent from the major mining projects in the area is discharging in the vicinity of the reservoir. Ballia Nala is the major carrier of discharging effluents in the reservoir.

5.4 High Siltation

Govind Vallabh Pant Sagar, is the major source of water supply to industries is under threat of high siltation and the reservoir capacity is gradually reducing day by day. During high intensity rainfall, unconsolidated non-cohesive sand and silt of open cast waste dumps of various open cast coal mines are carrying maximum silt load in the reservoir through various streams without any checks.

5.5 Dewatering

Singrauli district is under major open cast mining activity for extraction of coal and huge quantity of ground water is dewatered from the various mines. About 53792 KL/day is dewatered by around 14 mines in the district. The mining depth has reached about 200m depth, due to dewatering of water from mining pits the aquifers in the buffer area are gradually diminishing.

5.6 Ground Water Abstraction

Settlement of district population are scattered and most of the areas are not properly electrified particularly in the settlements of marginal farmers. Farming is mostly dependent on groundwater through dugwells/tubewells. Borewells are not being properly abstracted due to lack of power supply and are not pumped out to full capacity. Therefore the stage of ground water extraction is only 21.73% in Chitrangi Block.

5.7 Increasing stage of Ground Water Extraction

Due to various open cast mining for coal particularly in Waidhan block, huge quantity of water is dewatered. Also, groundwater is extracted heavily due to rapid rate of

industrialization/urbanization.

Dynamic ground water resources of the district have been estimated for base year - 2019/20 on block-wise basis. Out of 5,67,200 ha of geographical area, 4,51,260 ha (80%) is ground water recharge worthy area and 1,15,940 ha (20%) is hilly area. There are three number of assessment units (block) in the district which fall under non-command (86%) and two under command (14% -Deosar, Waidhan) sub units. All the blocks of the district are categorized as safe. The highest stage of ground water extraction is computed as 64.18% in Waidhan block. The annual extractable water availability in the district 56361.39 ham and ground water extraction for all uses is 13032.75 ham, making stage of ground water extraction 38.27% (28.13% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 20627.17 ham.

Table 24: Comparitive Resource 2016-17 and 2019-20.

District	Annual Extractable Groundwater Resource (ham)		Total Ground Water Extraction (ham)		Stage of Ground Water Extraction (%)	
	2016-17	2019-20	2016-17	2019-20	2016-17	2019-20
Singrauli	37232.04	34053.65	10472.9	13032.75	28.13	38.27

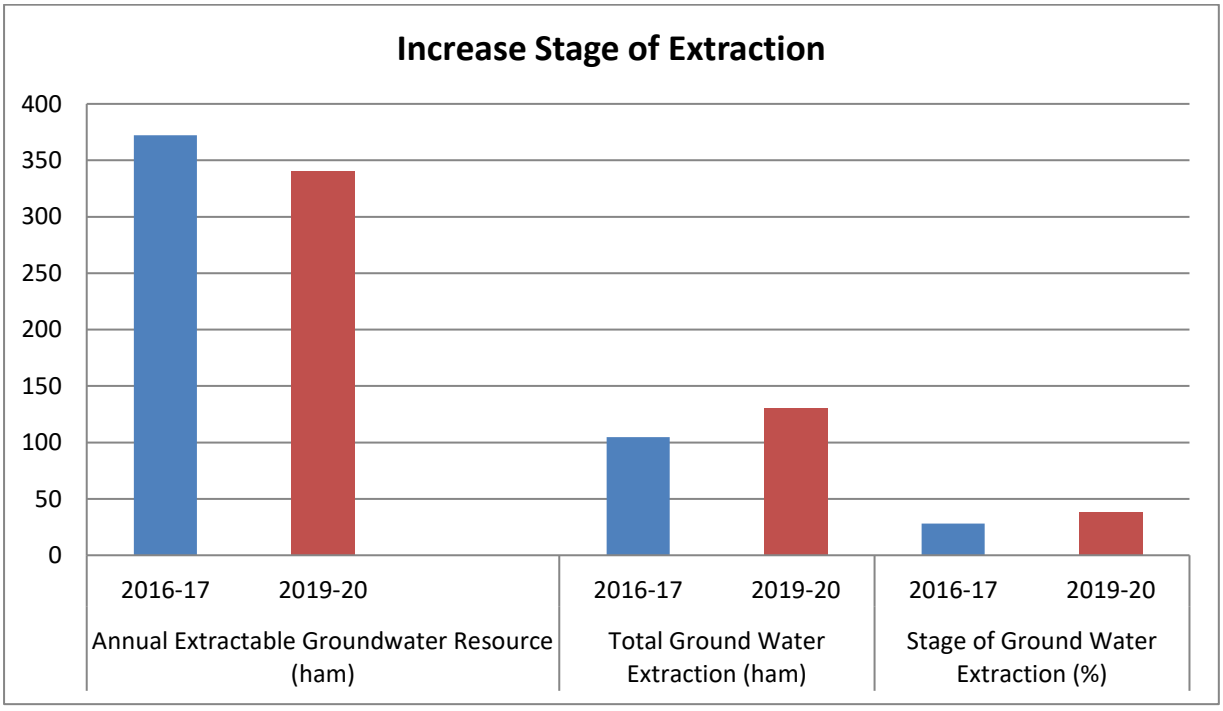


Fig.44: Comparative Stage of Extraction of year 2016-17 and 2019-20

6.0 GROUND WATER MANAGEMENT STRATEGIES

As discussed in previous chapter, there are many groundwater related issues owing to many socio-economic and hydrogeological reasons. The groundwater management plan for Singrauli district has been made keeping in view the area specific details and includes the strategies like enhancing the ground water resources through the construction of artificial recharge structures such as percolation tanks, check dams/nala bunds, recharge shafts, etc. and ensuring water use efficiency through maintenance/renovation of existing water bodies/water conservation structures. Also, adoption of micro irrigation technique such as sprinkler irrigation has been proposed, that would not only conserve ground water resources by reducing the draft, but would also increase the net cropping area thereby augmenting the agricultural economy of the district.

6.1 Supply side Management

Artificial recharge to ground water is one of the most efficient, scientifically proven and cost effective technology to mitigate the problems of over exploitation of ground water resources. The artificial recharge techniques simultaneously rejuvenates the depleted ground water storage, reduces the ground water quality. The supply side management plan for Singrauli district has been formulated using the basic concepts of hydrogeology. Sub-surface storage is calculated by multiplying the total area with the respective specific yield (considering the variable lithology) and the unsaturated zone thickness obtained by subtracting 3 mts from the post-monsoon water level. Thus, the surface water requirement to completely saturate the sub-surface Storage is obtained by multiplying a factor of 1.33 to available storage potential. A runoff coefficient factor of 0.3 has been considered for Singrauli district to calculate the total surface water runoff, 30% of which accounts to the non-committed runoff which is available to sustain the proposed artificial recharge structures. Further, the number of structures has been calculated by allotting 35%, 20% and 35% of non-committed runoff to Percolation tanks, Recharge shafts/Tube wells and Nala bunds/Check dams/Cement Plugs respectively. The remaining runoff is considered to restore the pre-existing village tanks, ponds and water conservation structures. A detailed calculation of the proposed artificial recharge structures is presented in the **Table 25**.

Out of 5672 sq.km geographical area of Singrauli district, about 4512.60 sq.km. is recharge worthy are area and water management / AR recharge in proposed in two blocks

recharge worthy are 3726 sq km has been identify for ground water development, wherein 257 percolation tank (@ Rs.20 lakh/percolation tank), 2204 Check dam, and 2204 Cement plug, Nalabunds (@10 lakh/structure), 2204 recharge shaft/tube well(@5 lakh/structure), 502 number of ponds/ village tanks to be renovated (@2 lakh/structure) are recommended to be constructed in feasible areas. This accounts to a total of Rs. 219.86 crores to successfully implement the supply side management strategy. **Table 26** represents the complete financial outlay plan for the district.

In Singrauli district already many recharge structures are constructed (as per the data collected from Jilla Panchayat office, Singrauli). But due to non-availability proper coordinates of the already constructed recharge structures, the feasible sites for the proposed recharge structures cannot be pinpointed.

Table 25: Management plans and Detailed calculations of the proposed artificial recharge structures

Sl. No	Block	Area (Sq.KM)	Normal Annual Rainfall (mm)	Average Post-monsoon Water Level - 2021 (m bgl)	Suitable Area for AR (sq.km)	Un-Saturated Zone (m)	Specific Yield	Sub-surface storage (mcm)	Sub-Surface water required (mcm)	Runoff /sq.km	Runoff (mcm)	Non Commuted Runoff (mcm)	No of percolation tanks	No of Check Dams	No of Recharge shaft in each CD	No of nala bunds/cement plugs	No of village ponds/ Farm Ponds in each village
1	Waidhan	1904	1120.7	5.95	1399	2.95	0.03	123.81	164.67	0.15	285.6	85.68	150	1285	1285	1285	271
2	Deosar	1822	1120.7	5.99	1401.1	2.99	0.011	46.08	61.29	0.15	273.3	81.99	107	919	919	919	231
	Total	**3726**			**2800.1**			**169.89**	**225.96**		**558.9**	**167.67**	**257**	**2204**	**2204**	**2204**	**502**

Table 26: Cost estimation of the Recharge structures

Structures	Number	Cost in Crores
Percolation Tanks	257	46.26
Check Dam	2204	88.16
Nala Bund/ CP	2204	22.04
Renovation of Village Ponds	502	12.55
Total Cost		**169.01**

6.2 Demand Side Management

However, considering the low storage potential of hard rock aquifer in the area the above ground water development plan should also be coupled with ground water augmentation plan, so that there is no stress on ground water regime of the area. Micro irrigation technologies such as drip and sprinkler systems are being increasingly promoted as technological solutions for achieving water conservation. Micro irrigation comprises two technologies—drip and sprinkler irrigation. Both saves conveyance losses and improve water application efficiency by applying water near the root-zone of the plant some benefits of the micro-irrigation have been listed below:

- The increase in yield for different crops ranges from 27 per cent to 88 per cent and water saving ranges from 36 per cent to 68 per cent vis-à-vis conventional flow irrigation systems (Phansalker and Verma, 2005).
- It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.
- It saves costs of hired labour and other inputs like fertilizer.
- It reduces the energy needs for pumping, thus reducing energy per ha of irrigation because of its reduced water needs. However, overall energy needs of the agriculture sector may not get reduced because most farmers use the increased water efficiency to bring more area under irrigation.

Table 27: Post Intervention after Implementation of the Recharge structure

Block	Net GW Availability	GW Draft for Irrigation	GW Draft for Domestic & Industrial	Gross Draft	Stage of Development	Saving by Sprinklar in MCM	Additional recharge created by AR	After intervention of AR Structure Net GW AvL.	After intervention of AR Structure & utilisation of 60% of additional GW created.	Draft after sprinkler & additional area created for agriculture	Stage of Development W/O GW use for addidtional Area Irrigation	Additional area irrigated by GW after intervention
Waidhan	78.53	46.37	4.79	50.40	**64.17**	13.91	85.68	164.2100	51.408	83.87	**51.07**	12852
Deosar	79.64	32.04	3.18	40.29	**50.58**	9.61	81.99	161.63	49.194	71.62	**44.31**	12299
Total	158.17	78.41	7.97	90.69	**57.38**	23.52	167.67	325.840	100.602	155.489	47.72	25150.5

Table 28: Increasing the Stage of Extraction in Chitrangi Block (in MPKSY)

Block	Net GW Availability (MCM)	GW Draft for Irrigation (MCM)	GW Draft for Domestic & Industrial (MCM)	Gross Draft (MCM)	Stage of Development (%)	Additional GW Draft created after utilisations of 30% of Net GW available	Total GW draft after utilisation of 30% of net GW available in mcm	Additional area irrigated by GW after intervention (sq km)	Stage of Development (%)after intervention
Chitrangi	182.35	30.15	9.47	39.62	21.73	87.57	127.19	218.925	69.75
Total	**182.35**	**30.15**	**9.47**	**39.62**	**21.73**	**87.57**	**127.19**	**218.93**	**69.75**

6.3 Block-wise Ground Water Management Plan

6.3.1 WAIDHAN BLOCK

The stage of ground water extraction in Waidhan Block is 64.18% which brings the block under safe category.

Exploration in Waidhan Block

Two wells were drilled under NAQUIM project in the hard rock terrain of Waidhan block. The wells were drilled upto 204m depth to achieve the targeted depth and detailed lithologs were made. Formation encountered was mainly Schist with presence of secondary minerals in fractured zones. Depth of Overburden was found to be around 17-18 mbgl after which massive Schist was found upto 204mbgl. Water saturated Fractured Schist was found in both the wells at a shallow depth of 28 and 36mbgl, although the cumulative discharge was found to be less than 1LPS.

Table 29: Details of Exploration in Waidhan Block

S. No.	Location	Year of construction	Depth Drilled	Thickness of weathering (m)	Aquifer	Zone	SWL (mbgl)	Discharge (lps)
1	Semariya	2021 - 2022	204	17.7	Weathered/Fractured Schist	15.25–15.35, 28.40-28.90	9.5	0.43
2	Chargoda	2021 - 2022	204	17.7	Weathered/Fractured Schist	14.2-14.30, 35.7-36.3, 102.4-102.9	16	0.75

Table 30: Management Plan – Waidhan Block

Management Plan		
Rainfall	meter	1.1207
Area	Sq Km	1904
Area suitable for recharge		1399
Average post-monsoon water level	Meter	5.95
Unsaturated zone		2.95
Average SP Yield	%	0.008

Sub-surface storage	MCM	33.02
Sub-Surface water required		43.91
Surface water (Run-off) available		285.6
Non-committed Run-off		85.68
Percolation tank		77
Check Dams		659
Recharge Shaft in Each Check Dam		659
Nala bunds/cement plugs		659
Village Ponds		271

Table 31: Cost Estimate of Recharge Structures – Waidhan Block

Structures	Number	Cost in Crores
Percolation Tanks	77	15.4
Check Dams	659	39.54
Recharge Shaft in Each Check Dam	659	6.59
Nala bunds/cement plugs	659	6.59
Village Ponds	271	6.78

6.3.2 DEOSAR BLOCK

The stage of ground water extraction in Deosar Block is 50.59% which brings the block under safe category.

Exploration in Deosar Block

Table 32: Details of Exploration in Deosar Block

S. No.	Location	Year of construction	Depth Drilled	Thickness of weathering (m)	Aquifer	Zone	SWL (mbgl)	Discharge (lps)
1	Judwar	2021 - 2022	204	39	Fractured schist	84.50 - 84.60, 135.70 - 135.85	24.5	1.74
2	Tikat	2021 - 2022	204	17.72	weathered schist	9.20 - 9.30	17.48	Meagre
3	Sarvo	2021 - 2022	204	14.69	weathered schist	11.80 - 11.90	6.83	Meagre
4	Bodia	2021 - 2022	204	20.7	weathered schist	17.40 - 17.90	1.17	0.43
5	Chhadna	2021 - 2022	204	17.62	weathered granitic gniess	14.70 - 14.80	8.60	Meagre

Table 33: Management Plan – Deosar Block

Management Plan		
Rainfall	meter	1.1207
Area	Sq Km	1822
Area suitable for recharge		1401.10
Average post-monsoon water level	Meter	5.67
Unsaturated zone		2.67
Average SP Yield	%	0.011
Sub-surface storage	MCM	41.15
Sub-Surface water required		54.73
Surface water (Run-off) available		273.3
Non-committed Run-off		81.99

Percolation tank		96
Check Dams		821
Recharge Shaft in Each Check Dam		821
Nala bunds/cement plugs		821
Village Ponds		231

Table 34: Cost Estimate of Recharge Structures – Deosar Block

Structures	Number	Cost in Crores
Percolation Tanks	96	19.2
Check Dams	821	49.26
Recharge Shaft in Each Check Dam	821	8.21
Nala bunds/cement plugs	821	8.21
Village Ponds	231	5.78

6.3.3 CHITRANGI BLOCK

The stage of ground water extraction in Chitrangi Block is 21.73% which brings the block under safe category.

Exploration in Chitrangi Block

Table 35: Details of Exploration in Chitrangi Block

S. No.	Location	Year of construction	Depth Drilled	Thickness of weathering (m)	Aquifer	Zone	SWL (mbgl)	Discharge (lps)
1	Bagaiya	2021 - 2022	204	30.24	Weathered/Fractured schist	25.00 - 25.20, 157.40 - 157.50	15.12	2.44
2	Boda Khunta	2021 - 2022	204	23.76	Fractured schist	33.00 - 33.10, 124.70 - 127.90, 163.50 - 163.70	19.03	2.44
3	Karlo	2021 - 2022	204	18	Fractured schist	24.80 - 24.95, 133.70 - 133.90, 179.80 - 180.10	7.01	1.74
4	Khamhaniya	2021 - 2022	204	36	Fractured schist	43.20 - 43.30, 76.50 - 76.90,	13.66	1.74
5	Khairchhan	2021 - 2022	201	17.8	Weathered/Fractured schist	15.30 - 15.40, 39.00 - 39.50	29.16	2.44
6	Thapna	2021 - 2022	204	18.6	Weathered/Fractured schist, Fractured Dolerite	15.40 - 15.50, 29.80 - 30.30, 92.80 - 93.20	12.72	1.74
7	Parsohar	2021 - 2022	204	23.78	Weathered/Fractured schist	17.70 - 18.10, 36.70 - 37.10, 55.10 - 55.80	-	8.20
8	Jhokho	2021 - 2022	91.5	18.68	Weathered/Fractured schist	13.50 - 14.00, 66.55 - 67.10, 84.70 - 85.20	-	6.71

Table 36: Increasing the Stage of Extraction in Chitrangi Block (in MPKSY)

Block	Chitrangi
Net GW Availability (MCM)	182.35
GW Draft for Irrigation (MCM)	30.15
GW Draft for Domestic & Industrial (MCM)	9.47
Gross Draft (MCM)	39.62
Stage of Development (%)	21.73
Additional GW Draft created after utilisations of 30% of Net GW available	87.57
Total GW draft after utilisation of 30% of net GW available in mcm	127.19
Additional area irrigated by GW after intervention (sq km)	218.93
Stage of Development (%)after intervention	69.75

7.0 CONCLUSION & RECOMMENDATIONS

- A thorough study was carried out based on data gap analysis, data generated in-house; data acquired from State Govt. departments and GIS maps prepared for various themes. All the available data was brought on GIS platform and an integrated approach was adopted for preparation of aquifer maps and aquifer management plans of Singrauli district.
- The study area is spanning over 5672 sq.km, out of which 1159.40 sq.km is hilly area and area suitable for recharge is 4512.60 sq.km.
- The major rivers flowing in the district is the Son River, and its tributaries Gopad, Gotan, Mahan, Rihand, Kanchan and Mayar.
- Main geological units of the area are Archean- Schist and Gneiss, Gondwana formations, and recent Alluvium.
- The pre-monsoon depth to water levels during May 2021 ranged between 4.95 to 17 mbgl and the post-monsoon depth to water levels during Nov. 2021 ranged between 2.71 to 7.75 mbgl.
- About 29% of monitoring wells of the district are showing high fluctuation range (pre-monsoon WL & post-monsoon WL) indicating aquifer storage capacity of the district is not good.
- For Shallow aquifers the electrical conductivity of ground water ranged between 322 to 1289 µS/cm at 25°C, pH ranged in between 7.23 to 8.08, fluoride concentration was ranged in between 0.05 to 1.01 mg/l, nitrate concentration ranged in between 5 to 105 mg/l. Total hardness ranged in between 81 to 399 mg/l.
- For deep aquifers the electrical conductivity of ground water ranged between 413.6 to 1240 µS/cm at 25°C,pH ranged in between 7.18 to 8.11, fluoride concentration was ranged in between <0.10 to 1.16 mg/l, nitrate concentration ranged in between 1.86 to 47.1 mg/l. Total hardness ranged in between 52 to 286 mg/l.
- During monsoon season recharge from rainfall contributes maximum component (33344.8 ham) and recharge from other sources is 790.04 ham, whereas during non-monsoon season, recharge from rainfall is 36771 ham and the recharge from other sources is 2636.16 ham.
- The Annual Extractable Ground Water Resources is 34053.65 ham. The annual gross Extraction for all uses is estimated as 13032.75 ham with irrigation sector being the major consumer having a draft of 10858.41 ham, resulting the stage of ground water extraction to be 38.27 % as a whole for district. The Singrauli district falls under safe category.

- All 3 blocks of the district are under safe category (64.18%, 50.59% & 21.73% Stage of Development in Waidhan, Deosar and Chitrangi respectively).
- On the basis of the exploratory bore wells drilled by CGWB, NCR under its NAQUIM program, it has been observed that the yield varies from 0.40 to 8.20lps.
- As per the Management plan prepared under NAQUIM of all the Block of Singrauli District, a total number of 257 Percolation Tanks, 2204 Recharge Shafts/Tube wells and 2204 Nala Bunds/Check Dams/Cement Plugs have been proposed and financial expenditure is expected to be Rs 169.01 Crores in Singrauli District for sustainable development and management of ground water resources.
- In Singrauli district, the main ground water issues are Declining Water Level, Low Ground Water Potential / Limited Aquifer Thickness / Sustainability, Water Quality, High Siltation, Dewatering, Ground Water Abstraction and Increasing stage of Ground Water Extraction.
- Siltation can be controlled by identifying the area suitable, method and structures like afforestation/plantation, vegetative checks, gabion structures and staggered contour trenches so that we can prevent high siltation during heavy rainfall in that area.
- Solar based power supply is recommended for adequate abstraction of water through borewells/dugwells to increase groundwater draft and increasing the cropping intensity. Government Scheme PMKSY (HKKP) solar based pumping may be implemented in the area.

ANNEXURE-I

Details of Key Wells

S. No.	Locations	Lat	Long	Depth	W_L mbmp	W_L mbgl	Type	Casing
1	Dhauni(Deep)	24.1401	82.0734	33.5	31.1	30.1	BW	6
2	Barkha(Deep)	24.1582	82.1463	90	8.44	7.24	BW	15
3	Ghogra(Deep)	24.0751	82.1893	63	20.34	18.84	BW	35
4	Dudhmania(Deep)	24.0064	82.1363	63.3	6.42	6.02	BW	20
5	Barwani(Deep)	24.2594	82.6128	63.33	22.05	21.05	BW	15
6	Pachuwar	24.3224	82.4984	70	14.41	12.91	BW	20
7	Kalhua Tola(Deep)	23.8253	82.4445	90	28.2	27.1	BW	60
8	Karaundia(Bore)	24.6128	82.4761	63	22	21.58	BW	7
9	BICCHI	24.5519	82.4357	55	9.08	8.38	BW	55
10	BELMANI	24.2317	82.0369	120	2.31	1.69	BW	12
11	KUNDWAR	24.2811	82.0887	100	34.15	33.7	BW	40
12	PARSOHAR	24.3042	82.1110	25	8.43	8.13	BW	18
13	PARSOHAR	24.3045	82.1112	90	8.53	7.98	BW	24
14	NAGURAHA PANCHAYAT CHATHANIYA	24.2840	82.2064	60	11.8	11.35	BW	20
15	NAGURAHA PANCHAYAT CHATHANIYA	24.2815	82.2246	90	26.76	26.26	BW	20
16	PURANI DEOSAR	24.2066	82.2713	90	23.58	23.38	BW	6
17	Bindul(Deep)	23.8396	82.3557	93	8.71	8.71	BW	60
18	Pondi	24.1305	81.9714	7.54	4.45	3.95	DW	7
19	Dhauni(DW)	24.1381	82.0858	9.3	6	5.5	DW	8.5
20	Barkha(DW)	24.1557	82.1371	13.5	5.75	5.29	DW	12.5
21	Mahrail	24.1268	82.1379	10.5	8.3	7.89	DW	8
22	Ghogra(DW)	24.0751	82.1893	19.5	16.36	16.36	DW	15
23	Dudhmania(DW)	24.0137	82.1549	11.3	8.9	8.7	DW	10
24	Hatta	23.9941	82.1941	8.85	5	4.6	DW	8
25	Bichhiya	24.4185	82.2842	9.72	7.4	7.1	DW	9
26	Dhawai	24.4227	82.3286	11.7	8.9	8.4	DW	10.5

27	Gerue	24.4561	82.6128	4.6	1.55	1.55	DW	4.2
28	Suda	24.4506	82.6481	6.7	3.4	3.4	DW	6.5
29	Jharkatia	24.4516	82.7080	8.6	4.3	4.2	DW	8
30	Berdaha	24.4305	82.3838	12.2	11	10.75	DW	10.8
31	Harriya	24.1220	82.5207	11.8	11	10.5	DW	11
32	Daga	24.1864	82.4667	14.32	7.7	6.96	DW	13
33	Mahdeiya	24.2120	82.5487	10.7	6.35	6.15	DW	10.1
34	Khirwa	24.2352	82.6514	9.75	5.8	5.8	DW	9.5
35	Kareila	24.2499	82.6119	15.1	9.8	9.3	DW	14.5
36	Amlihawa	24.3311	82.6327	5.7	2.8	2.45	DW	5.4
37	Chhuleinya	24.3233	82.3855	8.2	2.5	2.15	DW	8.1
38	Jarha	24.0245	82.5259	12.35	7.35	7.35	DW	12.2
39	Dudhitola(DW)	23.9001	82.5369	10.75	8.5	8.5	DW	9.1
40	Kalhua Tola(DW)	23.8253	82.4445	9.45	2.5	2.5	DW	9.34
41	Bhalyatola	23.9972	82.3161	7	2.4	1.65	DW	6.8
42	Kolhua	24.2244	82.3357	9.07	5.56	5.11	DW	9
43	Obari(DW)	24.1428	82.3065	10.9	3.35	2.7	DW	10.5
44	Gannai	24.1502	82.2430	5.68	3.67	3.22	DW	5.2
45	Mahuli	24.1805	82.1027	16.9	4.92	4.92	DW	16
46	SIDHI KHURD	23.9806	82.6171	6.85	1.3	0.8	DW	5.4
47	CHACHAR	23.9765	82.5470	10.2	4.55	4.55	DW	9
48	KHUMIYA	23.8972	82.5588	10.16	6.2	6.2	DW	6
49	KHUTAR	24.0567	82.5429	12.05	10.25	10.25	DW	11.5
50	PACHAUR	24.1211	82.3671	11.9	7.95	7.2	DW	11
51	GODWALI	24.2181	82.5057	9.8	5.4	4.65	DW	8
52	GORBI	24.2061	82.5954	17.15	7.7	7.15	DW	16.2
53	BAGDARI	24.3059	82.5528	10.3	6.3	6.3	DW	10
54	BAGDARI	24.3116	82.5491	7.3	6.9	6.3	DW	6.5
55	PATTHARKATTI	24.3878	82.5617	12.2	6.4	5.9	DW	11.8
56	SAGNARA	24.4016	82.4818	9.5	5.85	5.65	DW	9
57	SERWA	24.4612	82.4566	11.3	5.05	1.05	DW	10
58	MACHI KALA	24.5474	82.5818	4.2	2.7	2.7	DW	4
59	BICCHI	24.5504	82.4474	13.6	10.6	10.6	DW	12
60	BICCHI	24.5499	82.4391	12.45	11.5	11	DW	11.5
61	ATRAILA	24.5681	82.3834	7.4	5.9	5.7	DW	6.5

62	NIGRIE	24.1531	81.9114	9.4	6.95	6.55	DW	8.5
63	JOBA	24.1846	81.9343	10.2	7	6.9	DW	4.2
64	JOBA	24.1618	81.9533	10.9	8.2	7.6	DW	10
65	RAJANIYA	24.1407	82.0034	8.25	6.32	5.92	DW	7
66	NAYATOLA	24.1631	82.0067	16.6	11.2	11.2	DW	14
67	BELMANI	24.2051	82.0153	6.85	2.5	2.15	DW	5
68	KUNDWAR	24.2804	82.0873	7.25	3.3	2.95	DW	6
69	MAJHGAWAN	24.3214	82.1384	9	5	4.55	DW	6
70	SARONDHA TOLA LULI DEVI	24.3363	82.1887	9.75	7.9	7.55	DW	8
71	NAGURAHA PANCHAYAT CHATHANIYA	24.3164	82.2102	5.85	1.5	1	DW	4.5
72	KABSA KUTI	24.2279	82.2548	7.85	2.3	2.3	DW	6
73	BEHERAHA	24.2076	82.2505	7.2	6	6	DW	6
74	Bindul(DW)	23.8396	82.3517	7.95	2.75	2.75	DW	7.9
75	Rauhal	23.8830	82.2968	10.5	4.75	4.75	DW	10
76	Karaundia(DW)	24.6129	82.4759	8.6	6.6	6.15	DW	6
77	Rampa	23.9677	82.4913	25	15.2	14.52	HP	12
78	Dudhitola(HP)	23.8988	82.5375	36.2	16.2	15.41	HP	12
79	Amiliya(HP)	24.0385	82.3994	70	28.4	27.42	HP	66
80	Obari(HP)	24.1428	82.3065	60	7.1	6.24	HP	42
81	CHACHAR	23.9768	82.5471	90	5.2	4.6	HP	10
82	KHUMIYA	23.8970	82.5596	90	6.8	6.2	HP	12
83	KHUTAR	24.0573	82.5431	90	12.2	11.6	HP	12
84	BELMANI	24.2116	82.0184	60	12	11.6	HP	6

Note: The data is collected between 23/11/2021 to 2/12/2021

ANNEXURE-II

Water Level Details of Shallow Aquifer Pre-Monsoon, 2021

S.No.	Site Name	Block Name	Lattitude	Longitude	Depth	Water Level
1	Banjari	DEOSAR	24°5'16" N	81°55'49" E	6.22	5.32
2	Bargawan	DEOSAR	24°11'47" N	82°27'21" E	12.5	11.3
3	Bharra	DEOSAR	24°23'0" N	82°15'35" E	13.5	9.4
4	Chamari Dol	DEOSAR	24°0'4" N	82°6'21" E	9.5	5.85
5	Chaura	WAIDHAN	24°0'40" N	82°28'18" E	13	10.65
6	Deosar1	DEOSAR	24°19'8" N	82°18'15" E	18.95	8.32
7	Jamgadi	WAIDHAN	24°2'23" N	82°19'4" E	8.15	5.6
8	Jattha Tola	WAIDHAN	24°2'50" N	82°15'21" E	7.7	6.9
9	Karthua	DEOSAR	24°23'41" N	82°14'38" E	19.5	17
10	Kohara Khoh	DEOSAR	24°16'4" N	82°20'33" E	11.4	8.75
11	Koyal Khunth	WAIDHAN	23°56'44" N	82°29'6" E	14.5	9.4
12	Mara	WAIDHAN	23°53'50" N	82°30'10" E	13	9.03
13	Parasi	DEOSAR	24°2'24" N	82°2'29" E	9.8	7.15
14	Sarai	DEOSAR	24°2'23" N	82°12'14" E	8.4	4.95

ANNEXURE-III

Water Level Details of Shallow Aquifer Post-Monsoon, 2021

S.No.	Site Name	Block Name	Lattitude	Longitude	Depth	Water Level
1	Banjari	DEOSAR	24°5'16" N	81°55'49" E	6.22	4.4
2	Bargawan	DEOSAR	24°11'47" N	82°27'21" E	12.5	6.5
3	Betaha Dand	DEOSAR	24°14'19" N	82°22'38" E	8.15	3.45
4	Bharra	DEOSAR	24°23'0" N	82°15'35" E	13.5	4.3
5	Bharseda	DEOSAR	24°4'39" N	81°57'46" E	11.6	6.35
6	Chamari Dol	DEOSAR	24°0'4" N	82°6'21" E	9.5	4.4
7	Chaura	WAIDHAN	24°0'40" N	82°28'18" E	13	4.95
8	Deosar1	DEOSAR	24°19'8" N	82°18'15" E	18.95	6.6
9	Gaderiya	WAIDHAN	24°9'20" N	82°29'8" E	6	3.55
10	Jamgadi	WAIDHAN	24°2'23" N	82°19'4" E	8.15	5.4
11	Jattha Tola	WAIDHAN	24°2'50" N	82°15'21" E	7.7	5.7
12	Karthua	DEOSAR	24°23'41" N	82°14'38" E	19.5	3.5
13	Kohara Khoh	DEOSAR	24°16'4" N	82°20'33" E	11.4	7.75
14	Koyal Khunth	WAIDHAN	23°56'44" N	82°29'6" E	14.5	3.4
15	Mara	WAIDHAN	23°53'50" N	82°30'10" E	13	6.53
16	Papal Khera	DEOSAR	24°7'13" N	81°56'3" E	12	6.05
17	Parasi	DEOSAR	24°2'24" N	82°2'29" E	9.8	2.85
18	Parsauna New	WAIDHAN	24°5'21" N	82°33'27" E	9.3	6.1
19	Sarai	DEOSAR	24°2'23" N	82°12'14" E	8.4	2.71

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