केंद्रीय 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

SIDHI 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 & Ground Water ManagementPlan of Sidhi District, Madhya Pradesh

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SOUTH EASTERN COASTAL REGION
CHENNAI
2022-2023

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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 Sidhi district to prepare the 3-Dimensional Model and 2-Dimensional Aquifer Maps for the entire district and formulate Block-wise Aquifer Management Plan.

Sidhi district occupies an area of 4854sq km out of which the ground water recharge worthy area is 4282 sq. km. and the rest is covered by hilly and forest area. The major rivers flowing through the area includes the Sindh, ken. The major part of the district is covered by the Granite, Sandstone and Shale, Vindhayan sandstones and Alluvium. Based on the 15 exploratory borewells drilled by CGWB, NCR under its Exploratory program, it has been observed that the yield varies from 1 to 4.5 lps. There are three aquifer zone demarcated in the Sidhi District.

The ground water occurs under unconfined condition and semi confined to confined condition. The pre monsoon water level in the year 2022 north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 9-12 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 12-15 m bgl constituting only about 15% of wells in this category have been observed only in small pocket in the northern and eastern part of Sidhi district Long term water level trend show declining in Sidhi Block.

As per the Management plan prepared under NAQUIM of all the Block of Sidhi District, a total number of 218 Percolation Tanks, 763 Check dam,Recharge Shafts/Tube wells and 872 Nala Bunds/ Cement Plugs and 400 Village Pond Cement Plugs have been proposed and these structures can recharge 186 MCM.

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 and 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.K.Paramasivam , Assistant Hydrogeologist*** to compile this report . I fondly hope that this report will serve as a valuable guide for sustainable development of ground water in the Sidhi District, Madhya Pradesh.

Chapter -1

1. Introduction

Groundwater is of paramount importance for an agriculture-based country like India. Being a predominant asset the use of groundwater, primarily for irrigation and for various development activities over the years has adversely affected the ground water regime in many parts of the country. This has in turn led to an emergent need for comprehensive and realistic information pertaining to various aspects of groundwater resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis which together brings in the concept of Aquifer Mapping and Management Plan.

1.1 Objectives and scope of the study

The primary objective of the Aquifer Mapping can be specified as "**Know your Aquifer, Manage your Aquifer**". Systematic mapping of an aquifer incorporates activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale.

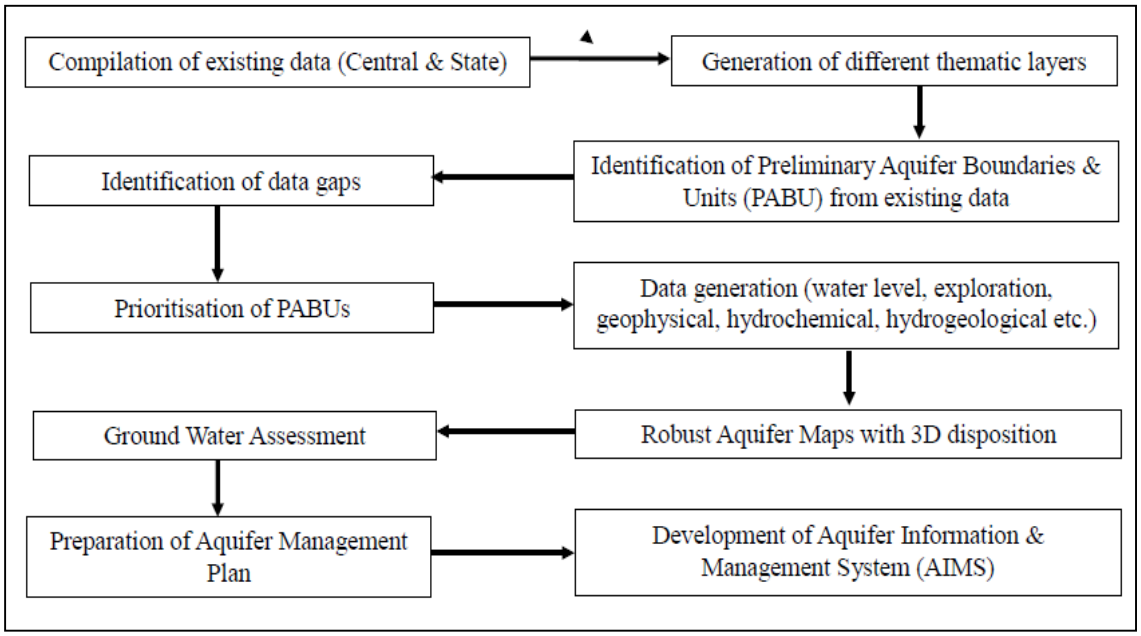
The two major objectives of the aquifer mapping is the delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000scale in general and further detailing up to 1: 10,000 scale in identified priority areas and the quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

1.2 Approach and Methodology

The aquifer mapping study in this report has been compiled on the basis of existing data that were assembled, analyzed and interpreted from available sources. The collected data was further prepared to generate regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2-D and 3-D aquifer dispositions and potentiometric maps eventually to define the aquifer geometry, type of aquifers, ground water regime behavior, hydraulic characteristics and geochemistry of multi-layered aquifer systems on 1:50000 scale. To achieve the objectives the following approach and methods have been adopted and stepwise details have been shown in the Fig 1.

- Data compilation
- Data gap analysis
- Data generation
- Preparation of block-wise aquifer maps and management plan

Fig 1: Aquifer mapping approach and methodology



1.3 Study Area

The geographical area of the district 4854 Sq.km. Sidhi district forms part of the hills and plateau of the Kymore range of mountains. It isextend by north latitude 23o 45' and 24o 45' and east longitudes 81o 15' and 83o 00' and lies in survey of India Toposheet Nos. 63H&Irespectively.

TheSidhi district is located at north eastern part of the state and bordered by the Koria district (in Chhattishgarh) on the southern, Shahdol and Satna in the west, Rewa district on the north and Singrauli in the east. Son River traverses the whole east-west extent of the district in the north, about 5 to 15 kilometers inside the boundary with rewa. Banas and Gopad, two of the major tributaries of Son, enter in the district from the south and meet with Son in the north. The national highway no. 75 leading Rewa to Singhrauli passes through major part of the district. The district divided into seven Tahsil, five Development blocks, 400 Gram Panchyat and 1063 villages. A detailed location map of the study area is shown in the Fig 2. & Table No.2.

Fig.2 Location map of Sidhi district

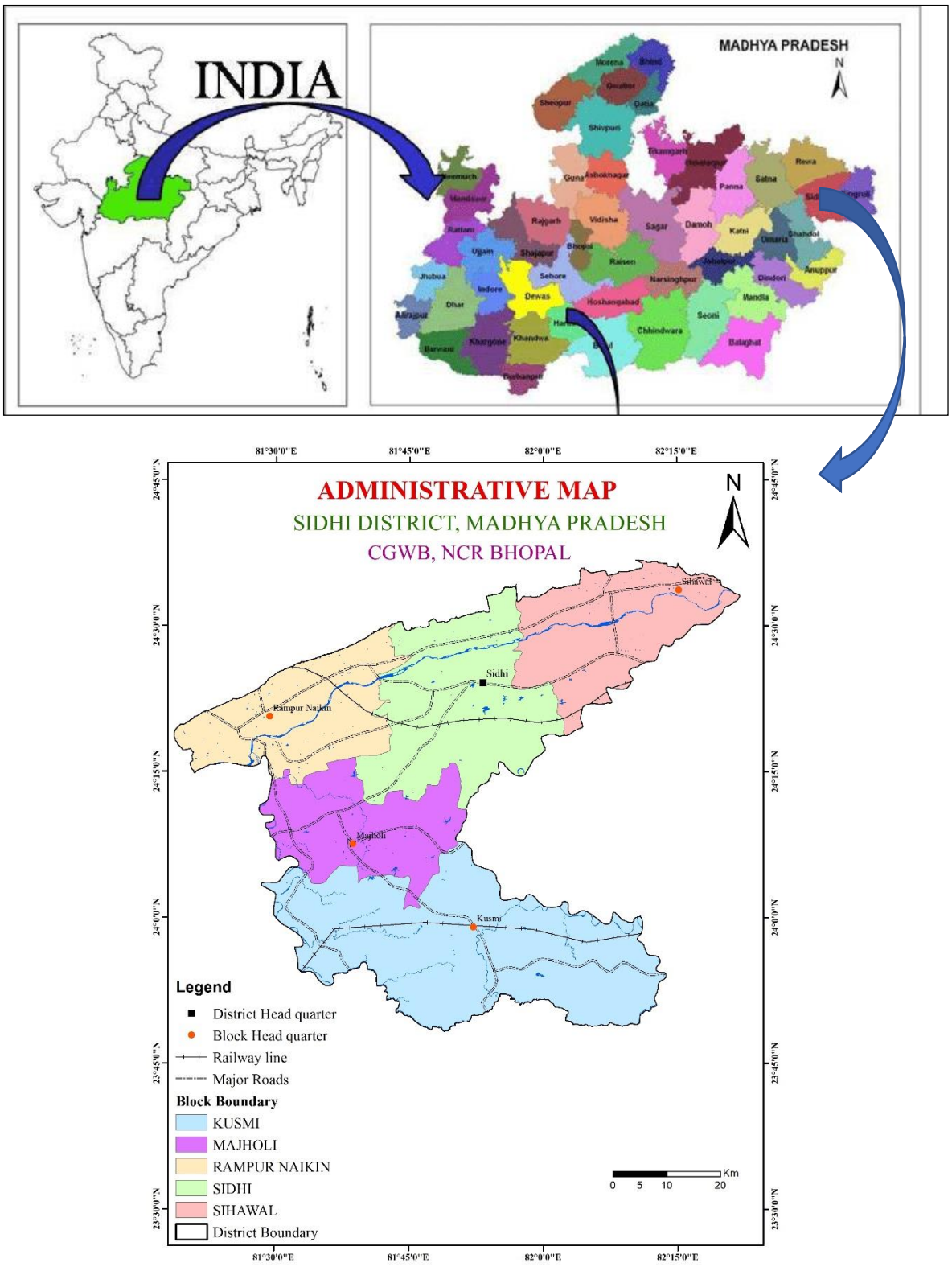


Table-2: SIDHI DISTRICT AT A GLANCE

S.No	Items	Statistics	
1	General Information		
	i) Geographical Area	4854.00 Sq.Km	
	District Head Quarter	Sidhi	
	ii) Administrative Division Number of Tehsil/Block Number of Villages (2012) Population (As per census 2011) Normal Annual Rainfall (mm)	 5 Block 1882 1126515 1154.2	
2.	Geomorphology		
	1. Major Physiographic Units :	Kaimur Range Central Part hills Southern Part hills	
	2. Major Drainage :	Son River, Gopad River, Banas nadi, Rihand River	
3.	Land use		
	a) Forest Area	433533 ha	
	b) Net area sown	275391 ha	
	c) Cultivable area	3745 ha	
4.	Major Soil Types	Red soil, Alluvial &Latertic soil	
5.	Area Under Principal Crops	Paddy, Wheat, Gram, Pulses, maize	
6.	Irrigation By Different Sources		
	Structures	**Nos.**	**Area (ha)**
	Dug Wells	11541	26970
	Tube wells/Bore wells	11541	12095
	Tanks/Ponds	17	453
	Canals	160	12453
	Other sources	10516	63431
	Net irrigated Area	-	266976
	Gross Irrigated Area	-	6343
7.	Number of Ground Water Monitoring		
	Wells of CGWB Dug Wells	34	
	No. of Piezometers	5	

Fig 3: Administrative Map

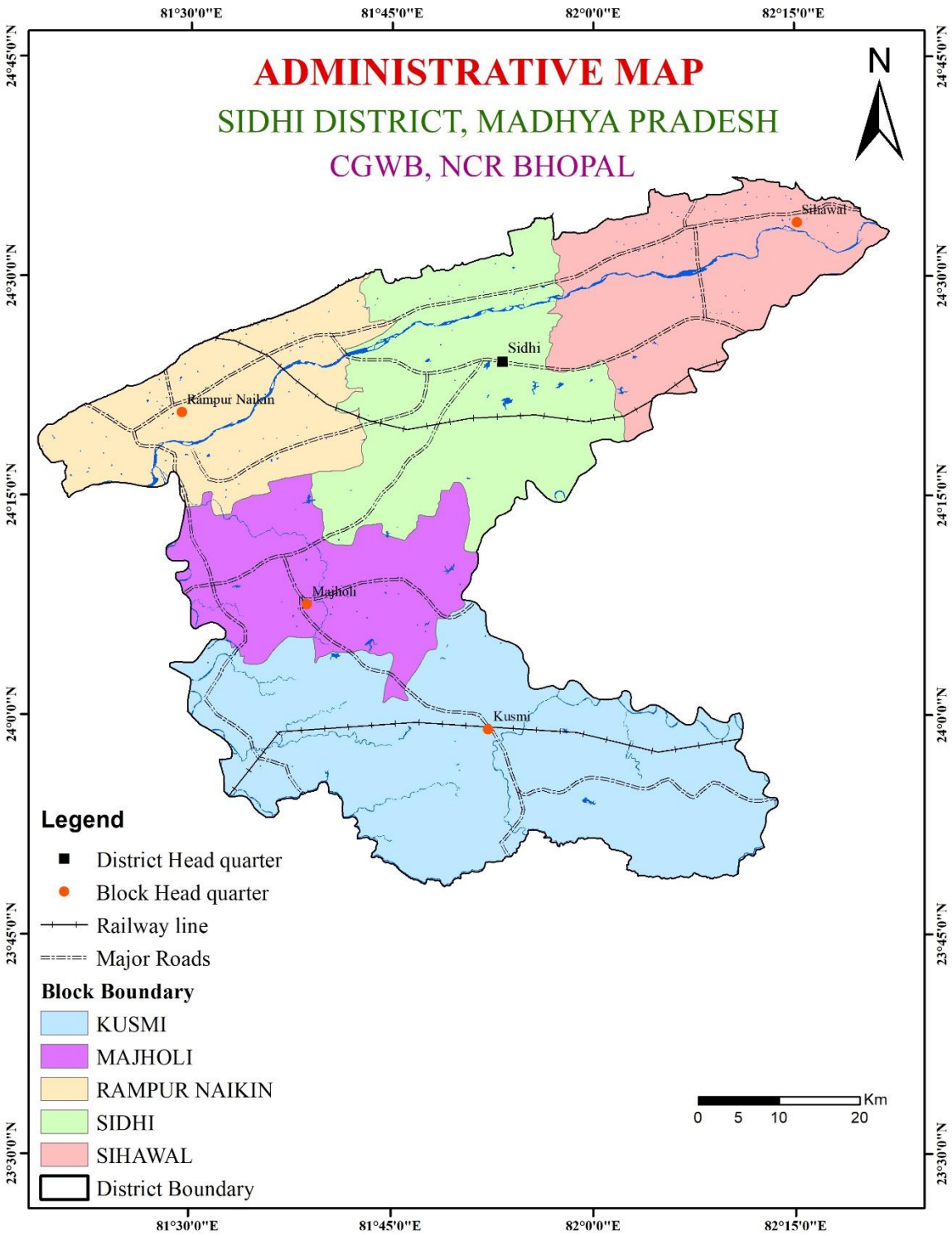


Table-2: Administrative Divisions

Name of Assessment Unit (Block)	Recharge worthy area in Sq.Km	Areal extent (in Sq. Km)			
		Total Geographical Area	Hilly Area	Command Area	Non command
Kusmi	706.17	1334	627.83	0	706.17
Mahjholi	667.84	737	69.16	0	667.84
Rampur Naikin	950.54	1194	243.46	171.1	779.44
Sidhi	619.5	844	224.5	95	524.5
Sihawal	660	745	85	222.8	437.2
Total	**3604.05**	**4854**	**1249.95**	**488.9**	**3115.15**

1.4 Climate and Rainfall

The climate of Sidhi district is characterized by a hot summer and general dryness except during the southwest monsoon season. The year may divide dint of our seasons. The cool season, December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the south west monsoon season. October and November form the post monsoon or transition period.

The normal annual rainfall of Sidhi district is 1132.7mm. Sidhi district received maximum rainfall received during southwest monsoon period i.e. June to September. About 89.7% of the annual rainfall received during monsoon season. Only10.9% of the annual rainfall takes place between October to May period. Thus, surplus water for groundwater recharge is available only during the southwest monsoon period.

The normal maximum temperature received during the month of May is 420 C and minimum during the month of Jannuary is 8.10C. The normal annual means maximum and minimum temperature of Sidhi district is 32.50C&18.60Crespectively.

During the south west monsoon season the relative humidity generally exceeds 85% (Augustmonth). In the rest of the year is direr. The driest part of the year is the summer season, when relative humidity's are less 35%. May is the driest month of the year.

The wind velocity is higher during the pre-monsoon period as compared to post monsoon period.The maximum wind velocity is 6.5km/hr. observed during the month of June and minimum 1.6km/hr. during the month of November.The average normal annual wind velocity of Sidhi district is3.6km/hr. Normal climatologically parameters of Sidhi Districtis given in Table N0.3.

Table No 3 Climate Data of Sidhi District

Climate data for Sidhi (1981–2010, extremes 1958–2011)													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Record high °C (°F)	32.8 (91.0)	37.4 (99.3)	42.2 (108.0)	48.8 (119.8)	46.6 (115.9)	47.4 (117.3)	43.2 (109.8)	39.2 (102.6)	39.0 (102.2)	39.6 (103.3)	36.4 (97.5)	34.6 (94.3)	48.8 (119.8)
Average high °C (°F)	24.6 (76.3)	27.9 (82.2)	33.5 (92.3)	39.2 (102.6)	41.9 (107.4)	39.1 (102.4)	33.5 (92.3)	32.3 (90.1)	32.6 (90.7)	33.0 (91.4)	29.9 (85.8)	26.4 (79.5)	32.8 (91.0)
Average low °C (°F)	8.8 (47.8)	11.5 (52.7)	16.1 (61.0)	21.9 (71.4)	26.3 (79.3)	27.6 (81.7)	25.7 (78.3)	25.2 (77.4)	24.2 (75.6)	19.9 (67.8)	13.8 (56.8)	9.1 (48.4)	19.2 (66.6)
Record low °C (°F)	0.8 (33.4)	2.0 (35.6)	4.6 (40.3)	11.8 (53.2)	17.0 (62.6)	20.0 (68.0)	17.0 (62.6)	17.4 (63.3)	18.2 (64.8)	12.0 (53.6)	4.0 (39.2)	1.0 (33.8)	0.8 (33.4)
Average rainfall mm (inches)	20.5 (0.81)	22.7 (0.89)	11.4 (0.45)	7.3 (0.29)	13.8 (0.54)	117.2 (4.61)	340.3 (13.40)	316.8 (12.47)	244.1 (9.61)	35.2 (1.39)	6.9 (0.27)	7.1 (0.28)	1,143.3 (45.01)
Average rainy days	1.9	1.8	1.1	0.6	1.7	6.5	14.0	14.3	10.1	1.8	0.5	0.8	55.0
Average relative humidity (%) (at 17:30 IST)	46	38	26	21	26	47	71	75	71	52	47	50	47
Source: India Meteorological Department													

1.5 Physiography and Soil

The district as a whole constitutes a hilly terrain with restricted plains along the course of rivers. The district can be divided into three physio graphic division

(1) Kaimur hilly range elevation rises up to 609 m amsl.

(2) The Central Part hilly ranges rises up to 548m.amsl.and

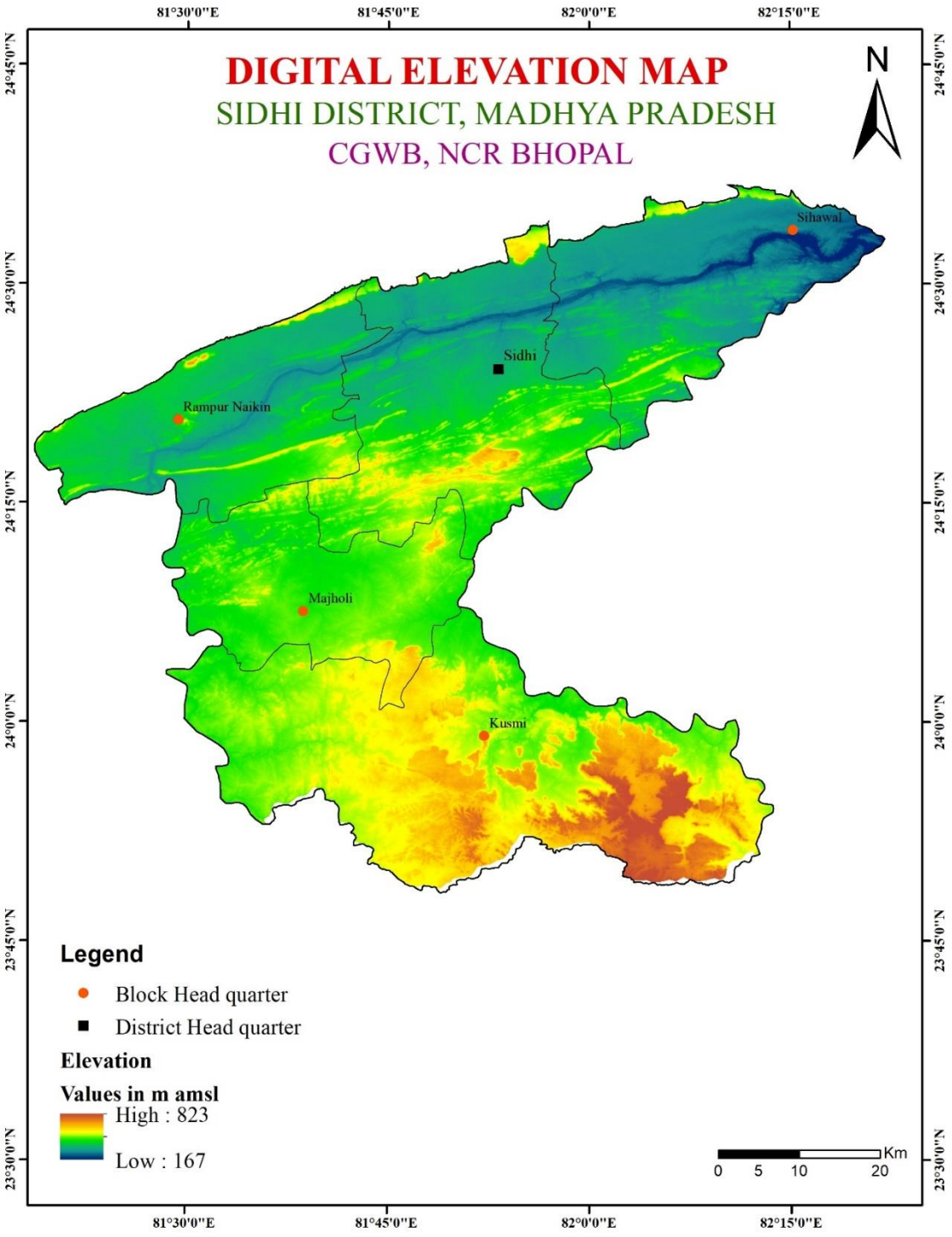
(3) Southernhillyrangesvariesbetween365and488mamsl.

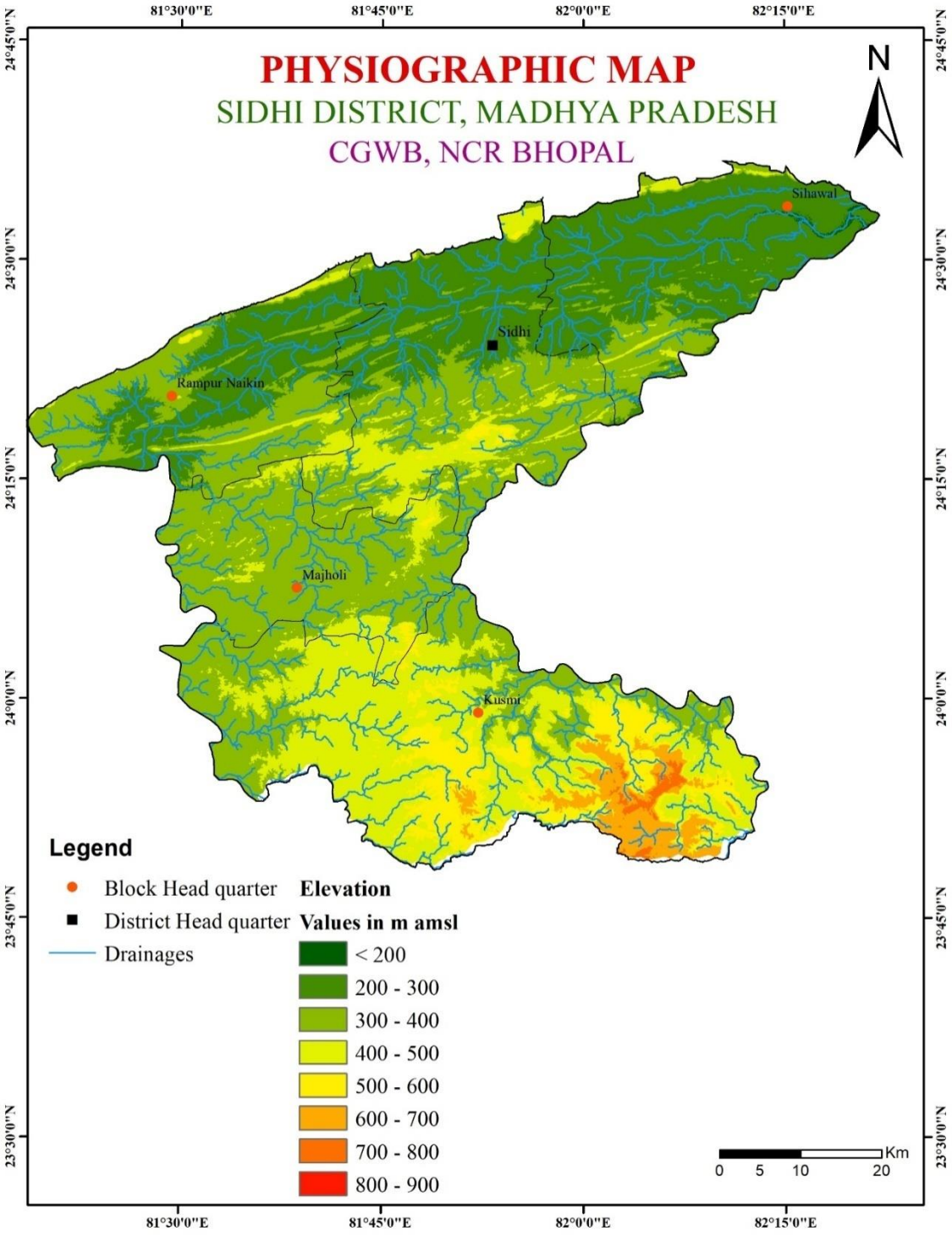
In the district four main river flowsalong with several nallahs and rivilutes.The major rivers are the

Son, Banas, Gopaland the Richand riveras shown in fig.1along the drainage course they forms valley fill.

The soil types in the district are mainly alluvium red sandy, red&yellow loamy, sandy, laterite soil and loam soil.

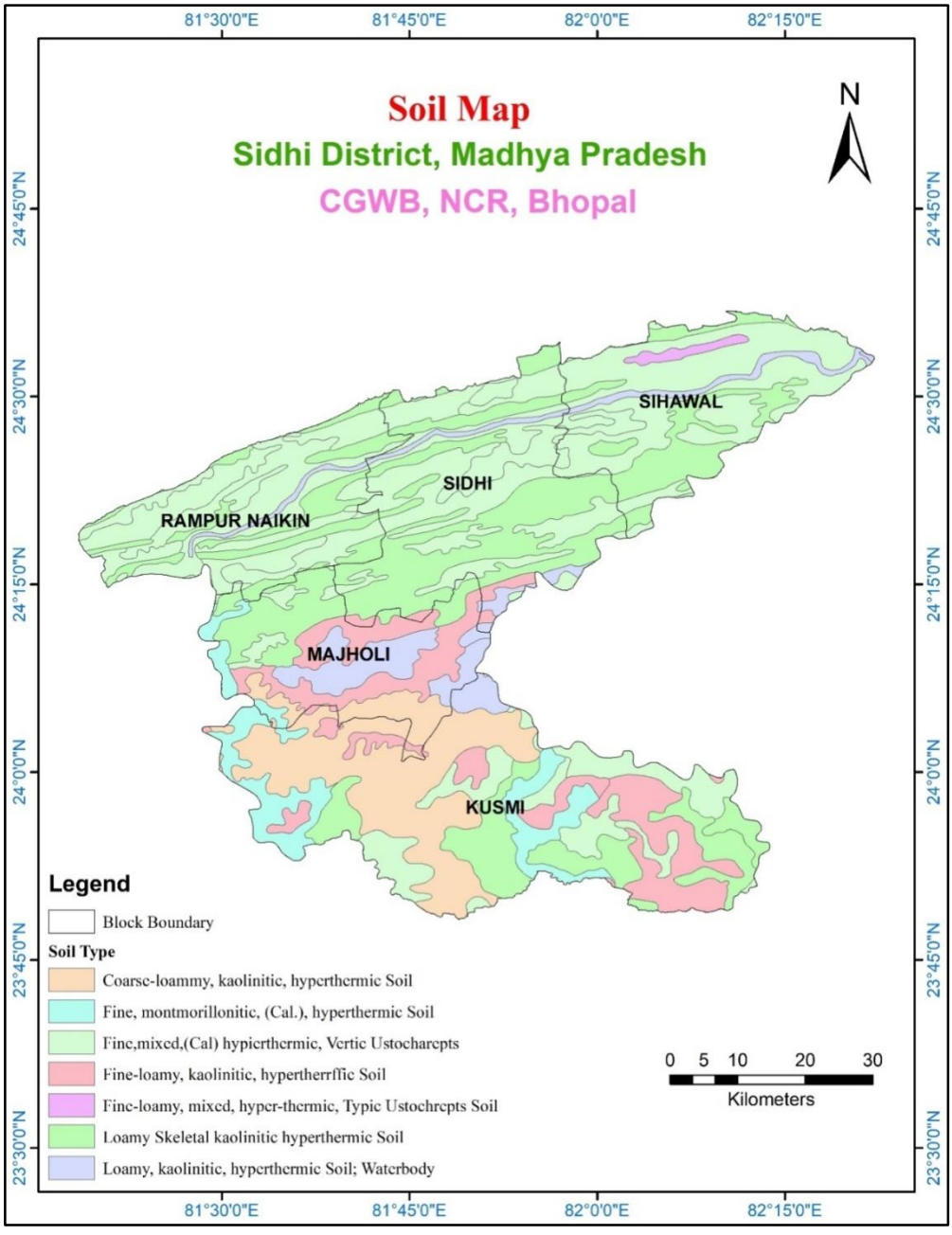
The alluvial soil is mostly restricted along the banks of major rivers like son, Banas and Rihand whose thickness varies from few meters to 25 meters. The red sand soil mostly occurs in the sandstone areas, the lateritic soils is generally observed in the plateau areas.


DIGITAL ELEVATION MAP
SIDHI DISTRICT, MADHYA PRADESH
CGWB, NCR BHOPAL
N
81°30'0"E
81°45'0"E
82°0'0"E
82°15'0"E
24°45'0"N
24°30'0"N
24°15'0"N
24°0'0"N
23°45'0"N
23°30'0"N
Sihawal
Sidhi
Rampur Naikin
Majholi
Kusmi
Legend
Block Head quarter
District Head quarter
Elevation
Values in m amsl
High : 823
Low : 167
0 5 10 20
Km


PHYSIOGRAPHIC MAP
SIDHI DISTRICT, MADHYA PRADESH
CGWB, NCR BHOPAL
N
81°30'0"E
81°45'0"E
82°0'0"E
82°15'0"E
24°45'0"N
24°30'0"N
24°15'0"N
24°0'0"N
23°45'0"N
23°30'0"N
Sihawal
Sidhi
Rampur Naikin
Majholi
Kusmi
Legend
Block Head quarter
District Head quarter
Drainages
Elevation
Values in m amsl
< 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
0 5 10 20
Km

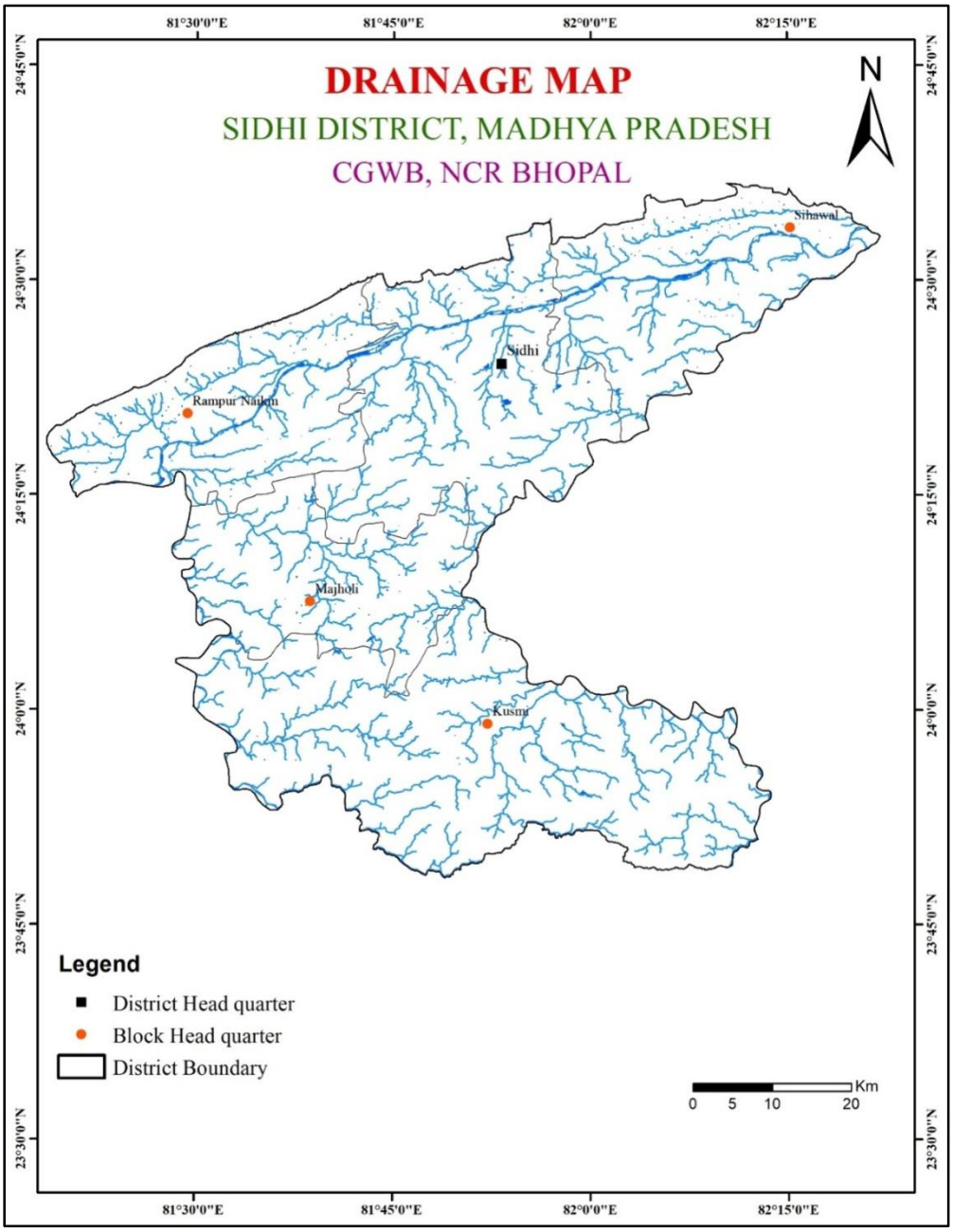
1.6 Soil

Soils of the area are characterized by black grey, red and yellow colours, often mixed with red and black alluvium and ferruginous red gravel or lateritic soils. These soils are commonly known as black soils. About 15% of the area is covered by sandy loam soils immediately on the banks of rivers. Remaining part is occupied by clay loam with big pockets of sandy clay loam and sandy loam. The permeability of the soil is low when the clay contains montmorillonite. They swell intensively when wet and shrink with deep cracks when dry. Intake of water is very rapid till the cracks disappear after complete wetting. The soils have been classified as Ustocherpts/Ustorthents/ Haplustalfs/Haplusterts as per pedological taxonomy as per pedological classification. The Map is shown in Fig.6



1.7 Drainage

Inthedistrictfourmajorriverandnumerousstreams,nalasoriginatingfromcentralandsouthernhighlandsanddischargingtheirwatertoeitheroneofthesefourmajorriver.Inthedistrictsomeriverflowingfromwesttoeastinthenorthernpartofthedistrict,TheBanasriverflowfromsouthofnorthinthewesternarea.TheGopadriverflowsinthecentralpartoftheareafromsouthtonorthandtheRihandriverinthesoutheastern partofthedistrictflowingfromsouthwesttonortheastdistrict. The drainage map is shown in Fig.7



1.8 Landuse

Sidhi district comprises of 05 development blocks, 07 Tehsils, 400 panchayats and 1063 villages. Total geographical area of the district is 472000 hectare, of which the gross cropped area is 284710 hectare, of which the net sown area is 193470 hectare and more than once crop area is 91240 hectare. Average crop intensity of whole district is 142 %,of which Sihawal and Rampur Naikin blocks has more than 150 % crop intensity resulting in irrigation facility of more than 43.78%. . Land use pattern of district 38.66 % area is covered by forest, 40.98% area is to be net cultivated , 5.2 % area is cultivable waste land and other 15.06 % area under other uses. The spatial distribution of land use is presented in Fig.8 and Table.4

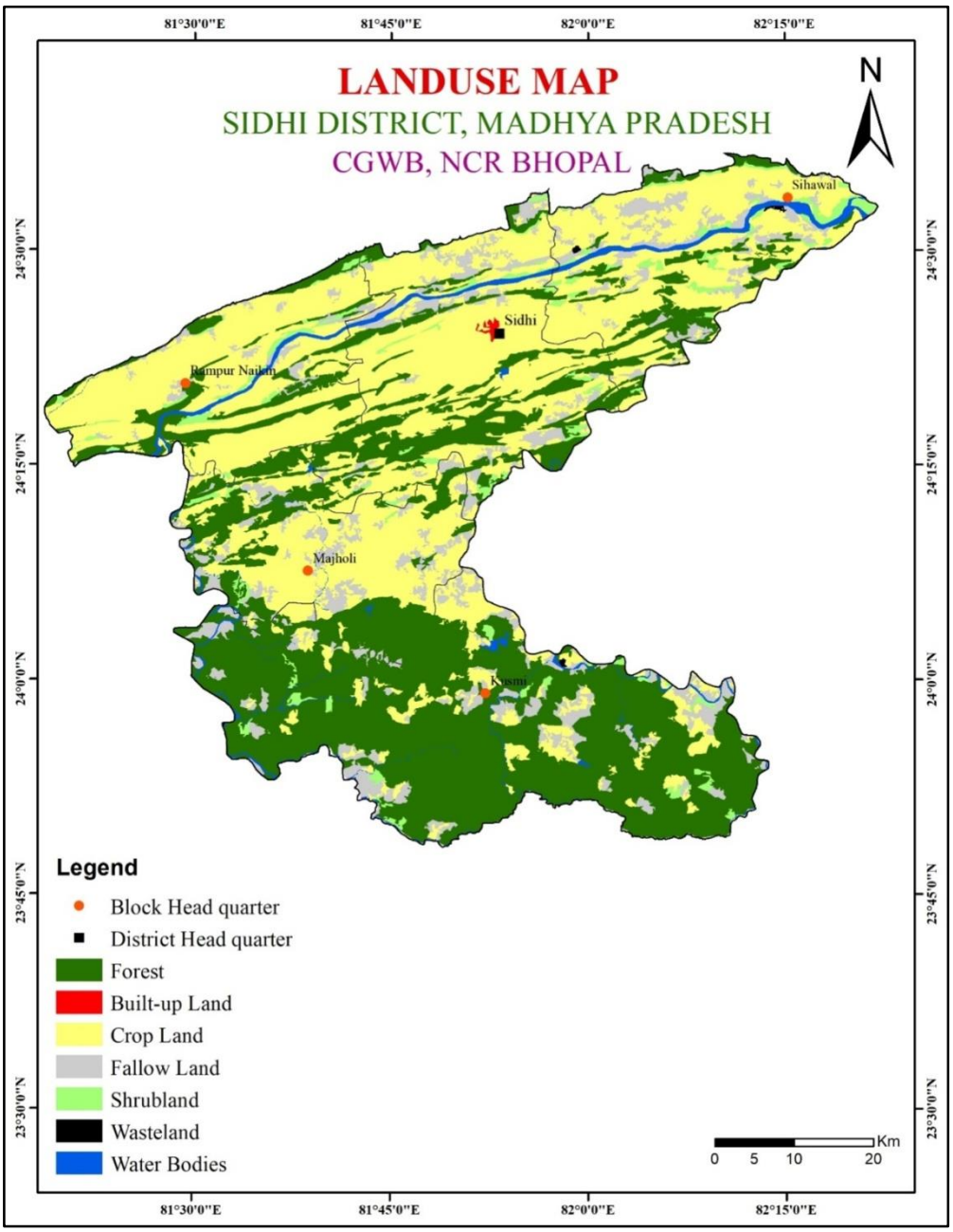


Table.4. Landuse Classification in Sidhi district

Area in Ha

S. No.	Block	Name of the Gram Panchayat	Name of the Villages Covered	Total Geographical	Area under Agriculture				Area under Forest	Area under wasteland	Area under Other users
					Gross Cropped Area (1)	Net Sown Area (2)	Area Sown more than once Area (1-2)	Cropping Intensity (%)			
1	2	3	4	5	6	7	8	9	10	11	12
1	Majhauli	53	129	72500	52210	38500	13710	132.2	29432	3900	1668
2	Kusmi	42	132	145000	39850	33300	26550	119.66	86250	4100	22750
3	Rampur Naikin	90	288	77900	75308	43900	18881	171.54	22329	6500	8491
4	Shihawal	100	300	74500	54425	31480	15472	172.97	14461	3642	17197
5	Sidhi	115	214	102100	62917	46290	16627	141.1	30017	6770	21023
Total		**400**	**1063**	**472000**	**284710**	**193470**	**91240**	**147.15**	**182489**	**24912**	**71129**

1.9 Cropping Pattern

The topography and geomorphology of the district do not indicate a land that can be put to sustained use under irrigation Land irrigability map of the district , drawn on the basis of remote sensing image , shows that the about 35 percent area has severe limitation for sustained irrigation, one third is classified as having moderate limitations for sustained use under irrigation and rest area classified under non suitable for irrigation .

water conservation techniques the water table is not getting recharged. Due to lack of proper infrastructure the electric supply is intermittent and erratic disturbing the voltage supply to household connection and also affecting the density of pumps in the district.

Kharif crops locally known as the unihari, is the main agricultural crop of the district.But, unusually for a district with limited irrigation, the rabi crop , known as Siyari farmers a substantial part of the cultivation.

The kharif crop in Sidhi currently covers about 1.693 lakh hectare . The rabi crop thus has always covered a fairly large area in the district. The main rabi crops of the district , besides Wheat, Barley, Gram, Lentil, Linseed, Rapeseed – mustard, Pea. The Main kharif crops are Paddy , Maize, Jowar, Kodo-kutaki, Pigeon pea, , Blackgram, Green gram, and Sesame . This great variety of Kharif and Rabi crops is the most distinctive feature of agriculture in Sidhi.

An average of gross irrigated area under crops during 2015-16 is about 1.1647 lakh hectare. Most (47%) of this is used for rabi crops ; but it can suffice to irrigated only 58.98 % percent of total rabi crop area. The total area under rabi cultivation in the district is 92925 hectares.

As much as about 80 per cent of the irrigated area under crops is accounting for wheat crop during rabi season. Of 1.16 lakh hectares gross irrigated area, about 58 thousand hectares is occupied by wheat.
(Table 5.)

1.10 Data collection and Generation

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

Data compilation: The previous studies carried out by Central Ground Water Board and various Government organizations were 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.

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.

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.

Data Generation: The study of Sidhi district concentrated on the existing data; thus, no new data was generated, from the Data gap analysis for new exploratory wells proposed for data generation.

Chapter-2

2. Data collection and generation

2.0 Hydrogeology

Aquifer System and Aquifer Parameters and aquifer parameters

Archaeans :

This group is generally comprises of granite, gneisses, schist phyllites and quartzites, where ground water occurs under phreatic conditions.

The thickness of weather zones generally varies between 8.0 to 10 mbgl. with te depth of dug wells ranged between 3.0 to 18 mbgl. and depth to water ranging between 2.0 to 18 mbgli.e. dry. The well discharge varies between 144 m3/day to 432.5m3/day during pre-monsoon.

Vindhyan

The limestone, sandstone and shales, covers large part in Son basin Sidhi district. The depth of dug wells ranges between 8.0-35 mbgl. with depth to water table varying between 6.0-31.0 mbgl. The seasonal fluctuation of water level varied between 1.0 to 9.0 mbgl.

Lower Gondwana :

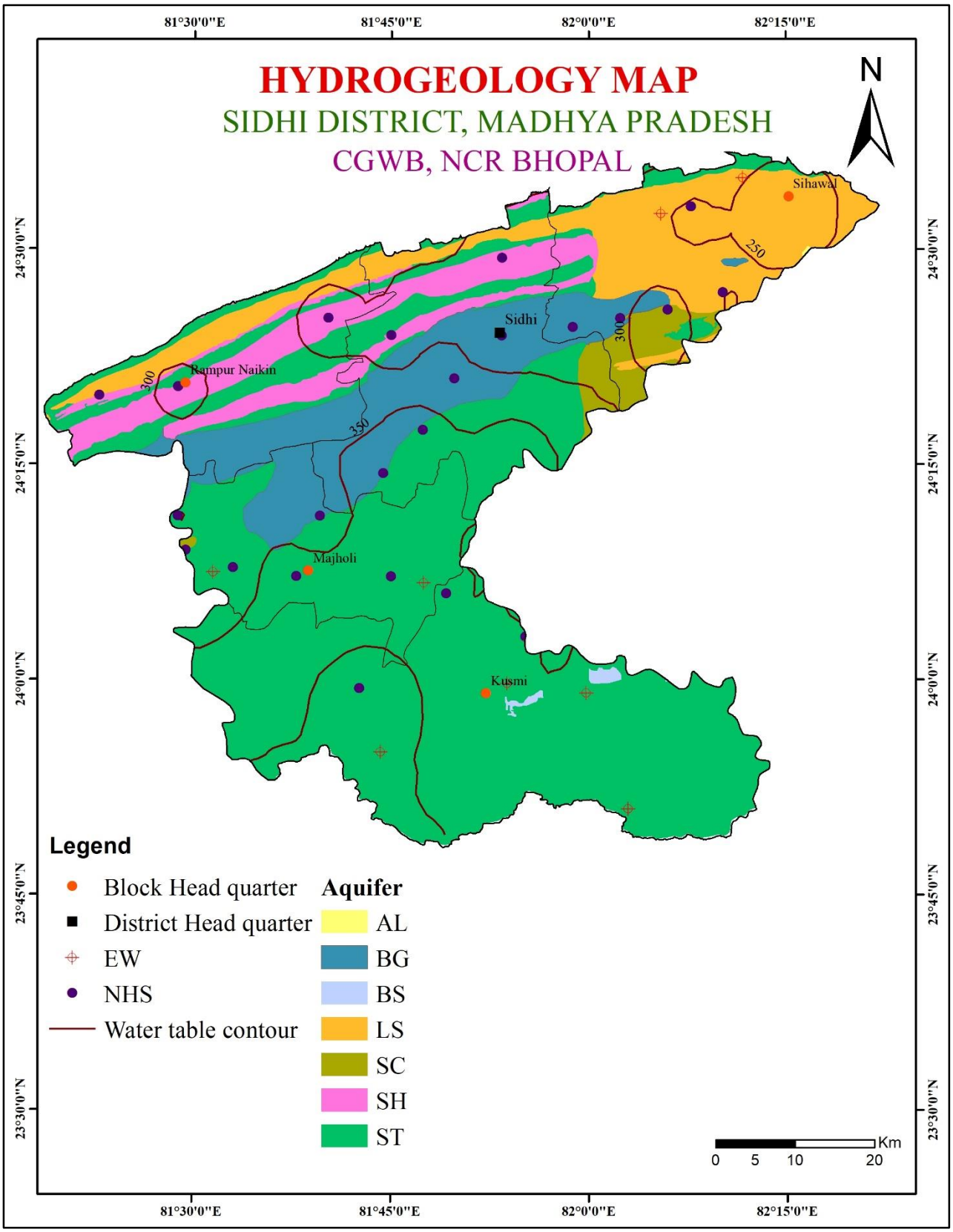
Talchir and Barakar occurs in south central part of the district. The depth of dug wells ranges between 6 to 10 m and depth to water level varying between 3.0 to 6.0 mbgl. Talchir sandstone and shale's having yield from 288 to 520 m3/day as Barkar sandstone are high yielding formation and yield range between 300 to 600 m3/day. It is also observed that rate of recuperation in water level is high in the wells tapping Barkar sandstone, when compared to the Talchir formation.

Upper Gondwana:

The upper Gondwana formation mainly consists of sandstone and clay and appears as hilly terrain in the southern part of the district. The depth of water level varies from 2 to 16 mbgl and the yield of wells varies from 100 to 144 m3/day in summer season and fluctuation in water level shows a wide from 1.30 to 9.70 m. The upper Gondwana sandstone is gritty and with pebbles at places. The well yield varies from 200 to 500 m3/day.

Alluvium:

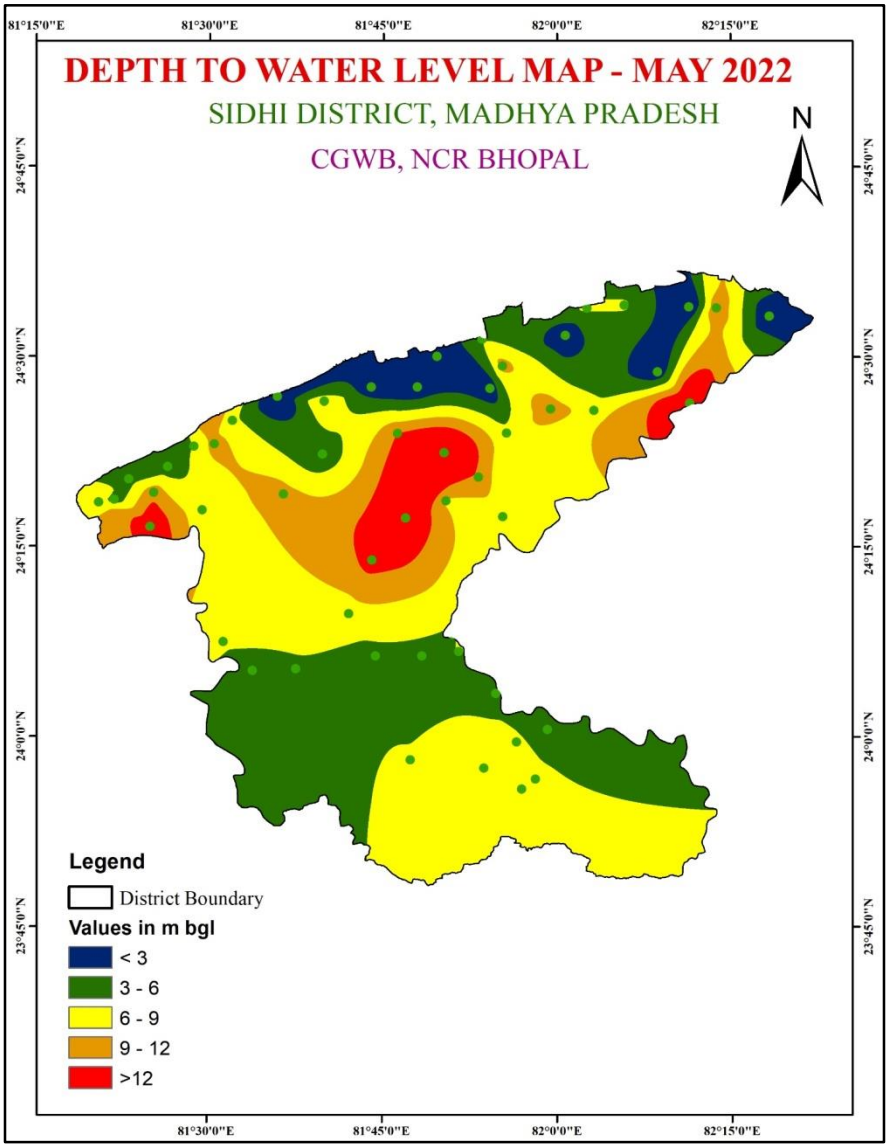
The alluvium cover of 2.0 to 30 m thickness occupy in the Son sub basin. The depth of the wells varied between 10.0 to 25.0 mbgl with depth to water level varying between 8.0 to 23.0 mbgl. the wells tapping alluvium yield are moderate to high in te range of 58 to 150 m3/day.


HYDROGEOLOGY MAP
SIDHI DISTRICT, MADHYA PRADESH
CGWB, NCR BHOPAL
N
81°30'0"E
81°45'0"E
82°0'0"E
82°15'0"E
24°30'0"N
24°15'0"N
24°0'0"N
23°45'0"N
23°30'0"N
Sihawal
Sidhi
Rampur Naikin
Majholi
Kusmi
250
300
300
350
Legend
Block Head quarter
District Head quarter
EW
NHS
Water table contour
Aquifer
AL
BG
BS
LS
SC
SH
ST
Km
0 5 10 20

2.2 Depth to Water levels

Pre-monsoon water level (May 2022)

The pre-monsoon depth to Water levels ranges from a minimum of 3.1 meters below ground level (mbgl) atBaldhain RampurNaikenblock to a maximum of 21.0 m bglat PadukurKhrd at Sidhi block of Sidhi district. About 16% very shallow water levels up to 2-5m bgl have been recorded in a small patch in part of district. About 50 % of monitoring wells recorded water level in the range of 5-10 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 10-20 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging >20 m bgl constituting only about 4% of wells in this category have been observed only in small pocket in the northern and south-western part of Sidhi district. Ground water levels of more than 20 m bgl have been recorded in the eastern part of the area. The pre-monsoon Depth to Water Level map has been shown in the Fig. 10. Key well location and Depth to water level in Sidhi District shown in Table.6



2.2.1 Post-monsoon water level (Nov 2022)

The post-monsoon depth to Water levels ranges from a minimum of 1.21 m below ground level in Rampur Naiken block to a maximum of 17.53 m bgl Rampur Naiken block of Sidhi district. Very shallow water levels up to 3 m bgl have been recorded in patchesscattered all over the district contributing to about 10 % of total monitoring wells in Sidhi district.

About 10 % of monitoring wells recorded water level in the range of less than 3 mbgl category, majorly occupying the central portion and patches in the north-eastern, and southern part of area. About 60% of monitoring wells recorded water level in the depth range of 3-6 m bgl occurring in pockets all over the region. About 15% Depth to water levels ranging 6-9 m bgl has been noticed predominantly in northern and western part of the district. About 15% Ground water levels of more than 9 m bgl have not been recorded in Sidhi district. The post-monsoon Depth to Water Level map has been shown in the Fig. 11.

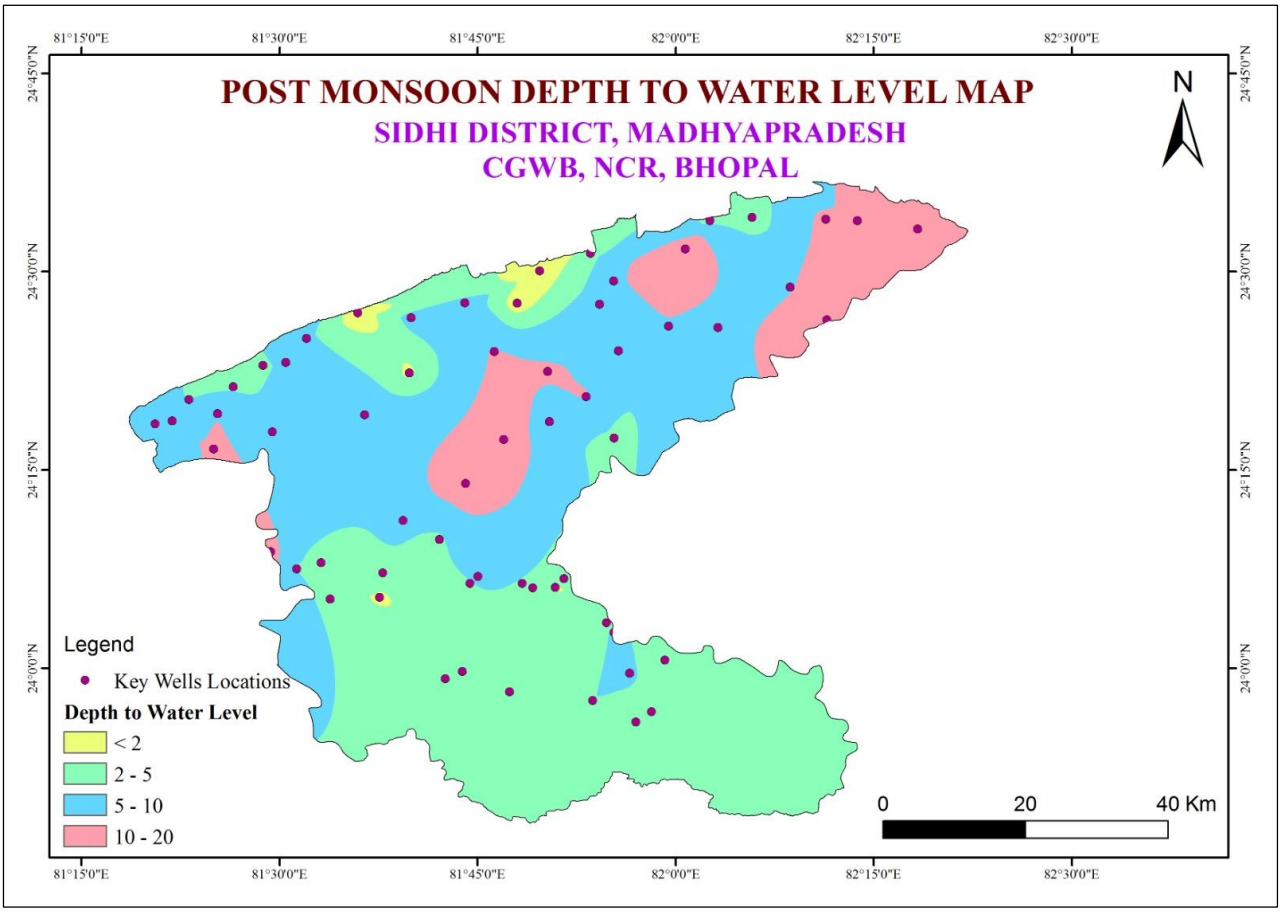


Table.6 Key well location and Depth to water level in Sidhi District

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Diam	WL mamp	DTW mbgl
1	Rampur Naiken	Malgoan	DW	24.3079	81.3423	0.54	9.13	1.56	8.78	8.24

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Diam	WL mamp	DTW mbgl
2	Rampur Naiken	Budugona	DW	24.3116	81.36419	0	7.5	5	3.69	3.69
3	Rampur Naiken	Bagwar	DW	24.3386	81.3852	0.27	6.5	4.2	4.71	4.44
4	Rampur Naiken	Bahad	DW	24.2763	81.4162	0	15.7	1.8	15.22	15.22
5	Rampur Naiken	Leguchuwa	DW	24.3209	81.4212	0.33	12.2	4	11.58	11.25
6	Rampur Naiken	Birpur	DW	24.3549	81.4412	0.45	7.43	3.5	4.43	3.98
7	Rampur Naiken	Gorigoan	DW	24.3818	81.4786	0.23	8.98	4	6.42	6.19
8	Rampur Naiken	Amdol	DW	24.3853	81.50775	0	10.19	2	10.15	10.15
9	Rampur Naiken	Padkhuri	HP	24.4158	81.5338	0.5	9.55	4.5	7.45	6.95
10	Rampur Naiken	Padkhuri Kurd	HP	24.44911	81.44911	0.5	50	0.0168	21.5	21
11	Sidhi	Biliyar	BW	24.4588	81.90377	0.2	13.1	3	dry	
12	Sidhi	Madugaon	DW	24.5232	81.8923	0.3	11.27	2	6.12	5.82
13	Sidhi	Chhandini	HP	24.50094	81.82779	0.5	50	0.0168		
14	Sidhi	Shivpurva	HP	24.46028	81.79942	0.5	50	0.0168		
15	Sidhi	Dhalia	HP	24.46045	81.73347	0.2	13.3	3.2	dry	
16	Sidhi	Harthika	DW	24.44177	81.66563	0.35	13.93	1.5	10.48	10.13
17	Sidhi	Mohania	HP	24.44796	81.44796	0.5	40	0.168		0
18	Sidhi	Amarpur	HP	24.4479	81.5985	0.5	40	0.168		0
19	Sidhi	Badavrah	DW	24.39915	81.77084	0	15.43	1.5	12.13	12.13
20	Sidhi	Karoudiya tola	DW	24.3422	81.8868	0.3	12.85	5	11.55	11.25
21	Sidhi	Morcha	DW	24.3106	81.8405	0.42	11.2	3.2	8.96	8.54
22	Sidhi	CharuaPawai	DW	24.28811	81.7827	0.5	18.2	2.5	18.02	17.52
23	Sidhi	Banjari	BW	24.3742	81.838	0.5	50	0.208	21.01	20.51
24	Sidhi	Kakdijhar	DW	24.4001	81.9274	0.5	8.86	3	7.45	6.95
25	Sidhi	Sarpur	DW	24.43148	81.9908	0.85	12.92	2.5	11.45	10.6
26	Sihawal	Kushiyari	DW	24.4297	82.05298	0.2	11.26	2.5	7.93	7.73
27	Sihawal	Muthvani	DW	24.439	82.19061	0.7	19.11	4.5	18.57	17.87
28	Sihawal	Dadhiya	BW	24.48047	82.1444	0	11.67	3.12	dry	
29	Sihawal	Ladpad Khurd	DW	24.5644	82.22901	0.8	15.74	4	12.53	11.73
30	Sihawal	Bahor	DW	24.55352	82.30541	0	19.32	3	dry	
31	Sihawal	Gohari	DW	24.5659	82.1895	0.7	13.2	3.5	dry	

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Diam	WL mamp	DTW mbgl
32	Sihawal	Baghaudi	DW	24.5682	82.0964	0	8.32	2	6.58	6.58
33	Sihawal	Bithouli	DW	24.5641	82.0429	0	14.56	2	6.86	6.86
34	Sidhi	Naghuwan	BW	24.5284	82.01174	0	18.92	1.5	dry	
35	Sidhi	Madahilia Khurd	DW	24.4882	81.92143	0.7	15.87	4	11.36	10.66
36	Sidhi	Baniadola	DW	24.29017	81.92191	0.6	8.1	4.5	7.53	6.93
37	Majhoili	Shikara	DW	24.19147	81.8694	0.72	10.23	4.2	8.18	7.46
38	Majhoili	Kamchand	DW	24.13457	81.85075	0.3	7.58	4.2	6.11	5.81
39	Kusmi	Nandgoan	DW	24.1068	81.8062	0.15	7.46	2	5.01	4.86
40	Kusmi	Shankarpur	DW	24.11255	81.85894	0.1	6.4	2	6.21	6.11
41	Kusmi	Rampur	DW	24.05725	81.91227	0	7.48	2.3	4.73	4.73
42	Kusmi	Chagogar	DW	23.9937	81.9418	0.25	8.4	1.5	7.19	6.94
43	Kusmi	Ladkheri	DW	24.00982	81.9864	0.5	5.45	4.5	3.82	3.32
44	Kusmi	BilhaMangwan	DW	23.94493	81.96925	0.5	8.27	4	8.27	7.77
45	Majhoili	Rauhal	DW	23.93192	81.9493	0.4	8.2	2.5	8.11	7.71
46	Majhoili	Marauli	DW	23.95909	81.89504	0.6	11.4	5	9.43	8.83
47	Majhoili	JagadaAmagoan	DW	23.97002	81.79005	0	7.1	2	6.16	6.16
48	Majhoili	Kasadol	DW	24.1065	81.74009	0	5.55	3	5.08	5.08
49	Majhoili	Gangei	DW	24.16205	81.7015	0	9.56	4.5	7.43	7.43
50	Majhoili	Kamah	DW	24.2326	81.7347	0.5	14.1	2.3	14	13.5
51	Rampur Naiken	Baldha	DW	24.37203	81.6633	0	8.97	2.1	3.1	3.1
52	Rampur Naiken	Gaurdaha	DW	24.31931	81.6071	0.8	12.45	4.5	11.13	10.33
53	Rampur Naiken	Chandgarh	DW	24.29812	81.4906	0.45	8.1	3.5	7.04	6.59
54	Majhoili	Chamradol	DW	24.125	81.5215	0.2	7.16	2	6.69	6.49
55	Majhoili	Dheem	DW	24.08722	81.56346	0.4	6.57	4.8	4.87	4.47
56	Majhoili	Nebhua	DW	24.0894	81.6256	0	7.68	4.5	5.59	5.59

2.3 Ground water exploration and aquifer parameters& Geophysical

CGWB ground water exploration programme in Sidhi district exploration was taken up during FSP 90-91 & 93-94. The drilling was done with target depth of 100-150 mbgl with a density of one borehole per 250 Sq.km has been contemplated. One bore well at Madwas was drilled upto 300 mbgl and it was abandoned due to negligible discharge. A total of 17 bore holes of 37.2 mbgl to 190 mbgl was drilled and yield potential ranging between 0.01 lps (Kusmi) in sandstone, Shale and Gondwana formation and as high as 11.45 lps at Ghopari. The summarised data of exploratory boreholes is given in table No.15 and their location is shown in Fig. No. 11. Exploration done by CGWB is restricted to Vindhyan formation, in Sidhi district limestone and shales of Vindhyan cover an aerial extent of 2490 Sq.km in the Son sub basin in Sidhi district.

The weathered and jointed zones as well as contact zones between shales, sandstone or limestone formations are important for ground water occurrence in these rock types.

At certain favorable locations of the area, tapping this formation, confined conditions do occur which is a significant feature in the groundwater development.

CGWB under its exploration program drilled 3 borewells (Fig. 11). On the basis of samples collected during exploration, lithologs have been prepared. The aquifer parameters are calculated on the basis of pumping tests. The salient details of the some of the drilled bore wells and piezometers are given in Table No 3. 16 EW and 47 VES have been proposed in Sidhi district. Fig.11 illustrates the locations, existing EW details are shownTable.7

Fig 11: Map showing locations of Existing Exploratory Wells & Proposed EW & VES

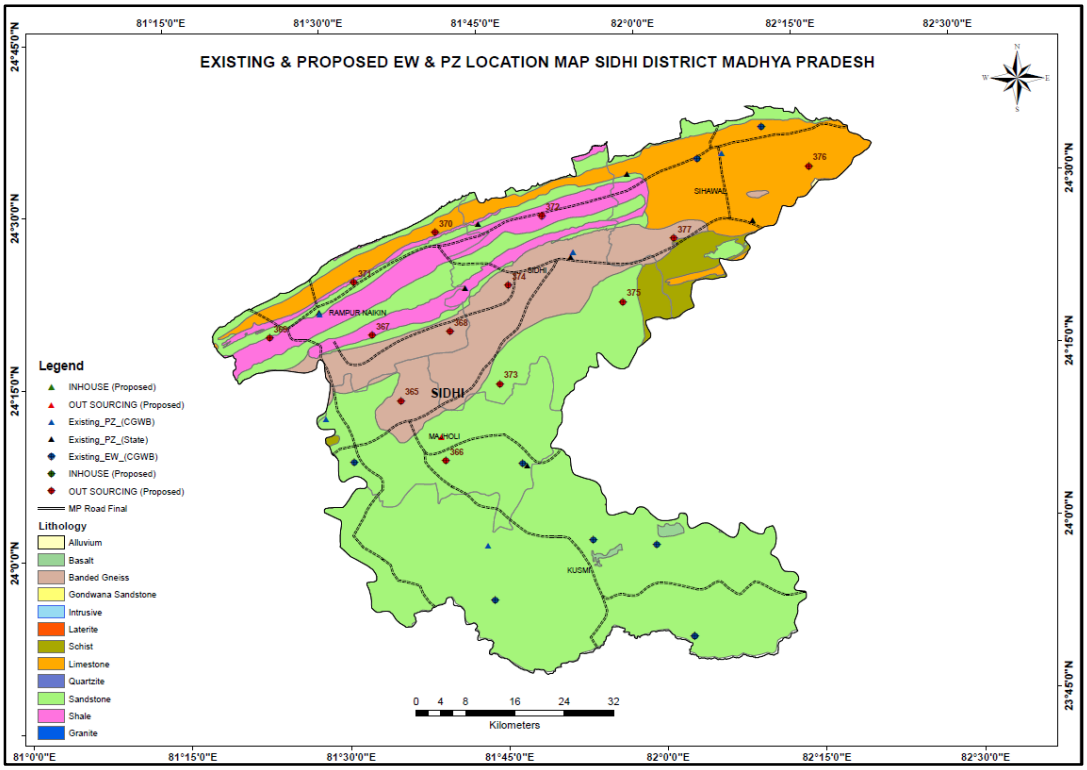


Table 7: Salient Hydrogeological Details of Exploratory Wells of Sidhi district.

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	SWL (mbgl) / Date	Discharge (lps)	Draw down (m)	Specific capacity (lpm/m) of dd	T (m^2 / day)	S
1	Ghopari	24.583333	82.195833	1990-99	39.8	38	Sandstone	22-37.1 88-94 125-150	12.69	11.45	4.14	1164.76	12.8X10-4
2	Haiki	23.916111	81.7375	1990-99	156.25	152	Sandstone	41-53 87-115 125-150	Free flow	10.25	40.45	69.49 39.08 (OW)	
3	Tansar	24.045833	81.925	1990-99	156.25	149	Sandstone	58-70 126-136 138-146	19.5	1.73	20.3	7.579	
4	Bastua	23.995833	81.897222	1990-99	156	155	Sandstone	47.5-57.5 69.5-108.5 114.5-117.5 127.5-154.5	3.6	9.07	26.95	152.42, 139.7	
5	Rajnulan	24	82.508333	1990-99	145.51	143	Sandstone	NA	26	0.69	24		
6	Sarai	24.041667	82.205556	1990-99	83	76	Sandstone	41.0-75.0	3.1	2.85	31.25		

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	SWL (mbgl) / Date	Discharge (lps)	Draw down (m)	Specific capacity (lpm/m) of dd	T (m^2 / day)	S
7	Chamaridol	24.125	81.525	1990-99	83	76	Sandstone	41.0-75.0	3.1	2.85	31.25		
8	Tikar	24.541667	82.091667	1990-99	42	42	Sandstone	22-25 25-34.6	13.96	1.82	28.96		
9	Kusmi (EW)	23.984722	81.997222	1990-99	196.9	190	Sandstone & shale of Gondwana formation	40-41 6.56-64 69-71 81-120 135-144 160-171 189-181		0.01	26.9		
10	Madwas (EW)	24.1125	81.791667	1990-99	300.4		Abandoned			0.00	9.96		

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	SWL (mbgl) / Date	Discharge (lps)	Draw down (m)	Specific capacity (lpm/m) of dd	T (m^2 / day)	S
11	Bhadoura (EW)	23.85	82.05	1990-99	301.5		Sandstone	60-63 68-73 78-83 87-90 104-110 119-131 147-152 157-163 168-172 193-196 210-214 230-233 249-257		0.05	26.9		
12	ShankarpurBhadaura (OW)	23.85	82.05	1990-99	221.22		Sandstone	121-139 148-152 199-215	5.35	1.56	28.96		
13	Mahuwagaon (EW)_	24.108333	81.958333	1990-99	114.21		Sandstone	29-35 45-47 55-58 60-68 72-76 78-98	7.28	2.22			

Chapter-3

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 Sidhi district as inferred from the 3-D Model, 2-D Section and Fence diagram is presented below.

3.1 3-D Lithologicalmodel

A 3-Dimensional lithological model was prepared for the Sidhi district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB(Fig 17a & 17b) and field well inventory data . A comprehensive analysis was made as per lithology and stratigraphy of the area. The location details with RL values and their corresponding stratigraphic details as per the Rockworks format is provided in the Annexures- I and II.

The 3-D Model results showed that the region is dominantly occupied by Sandstone Shaleand Alluvium respectively. The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone, underlain by Alluvium, weathered Sandstone and Shale and which has been considered as shallow aquifer (upto a depth of 30 mts). Massive Shae sand stone was encountered in few bore wells mainly occupying the southern region of Sidhi. This overlies the Alluvium Fractured Sandstone shale and Granite that forms the deeper aquifer (from 30-200 mts). The fractured aquifer lies between and predominantly Alluvium ,Fractured Sandstone shale and Granite.

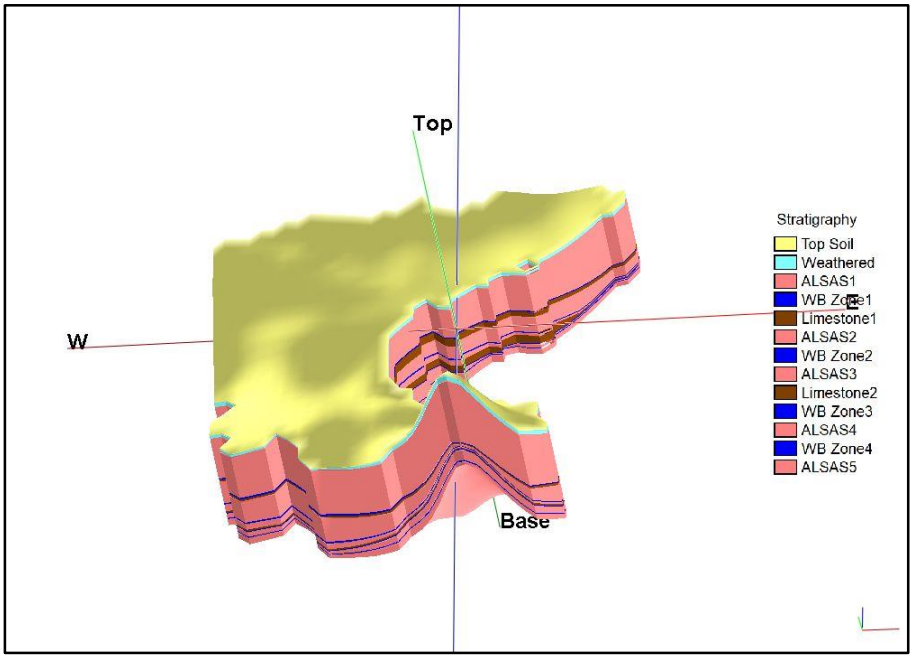
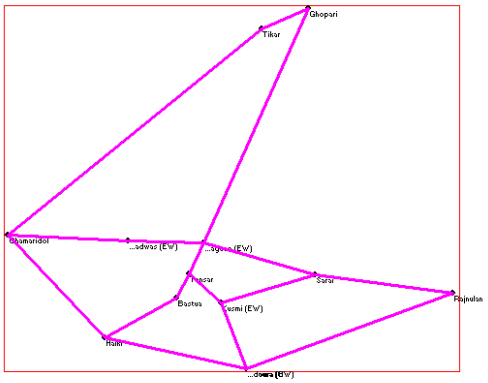


Fig 17a: 3-D Lithological Model ofSidhi District, Madhya Pradesh

3.2 Fence Diagram

The Fence diagram was also prepared using the Rockworks software(Fig. 18). 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.



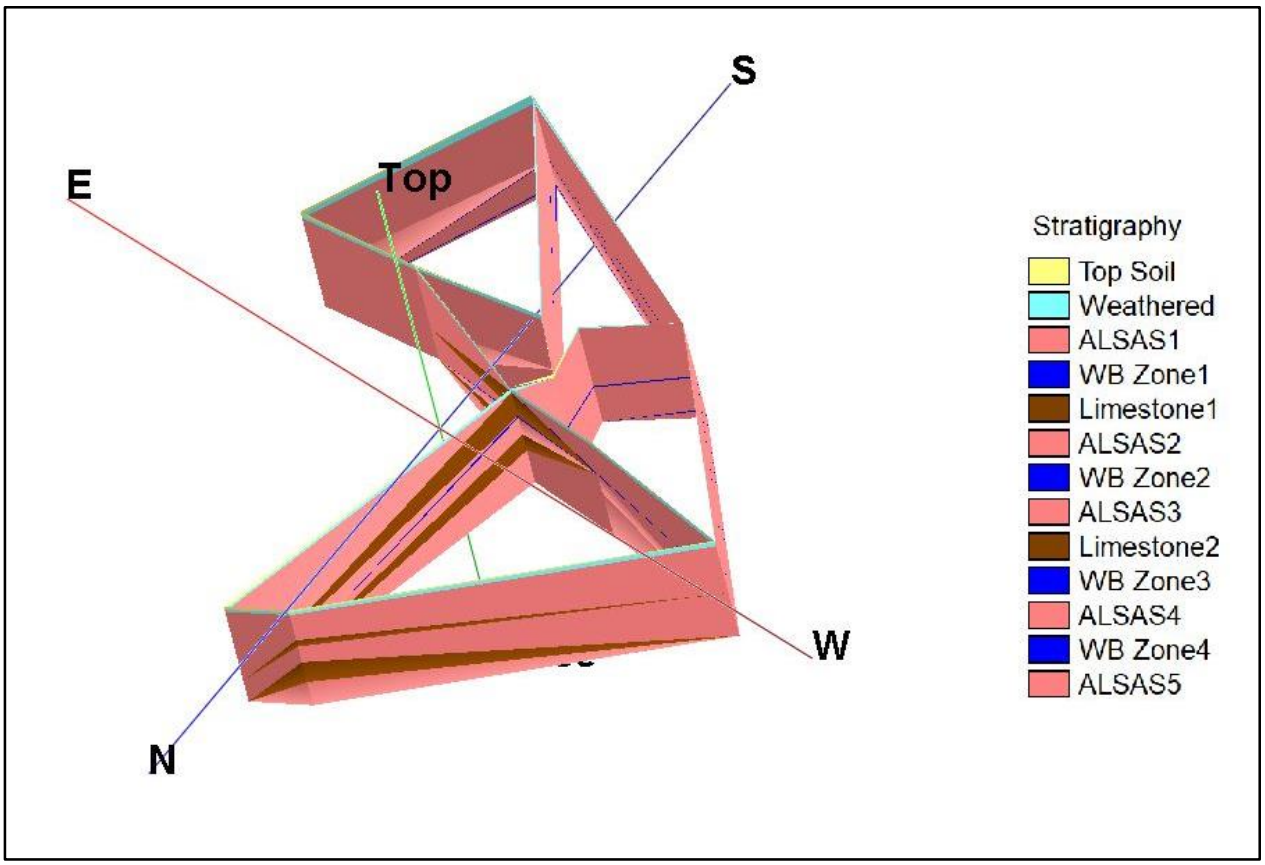


Fig 18: Fence Diagram,Sidhi District, Madhya Pradesh

3.3 2-D Cross Section

2-Dimensional cross-section along the section line A-A' (SW-NE), covering the wells Sihaval Block has been prepared using Rockworks (Fig. 19 and 19.a). The cross-section shows that the shallow aquifer is not continuing for the whole region and occurs as narrow pinches in the western portion of Sidhi. The deeper aquifers whereas, occurs throughout the section line and can be encountered at depth where fractures are present.

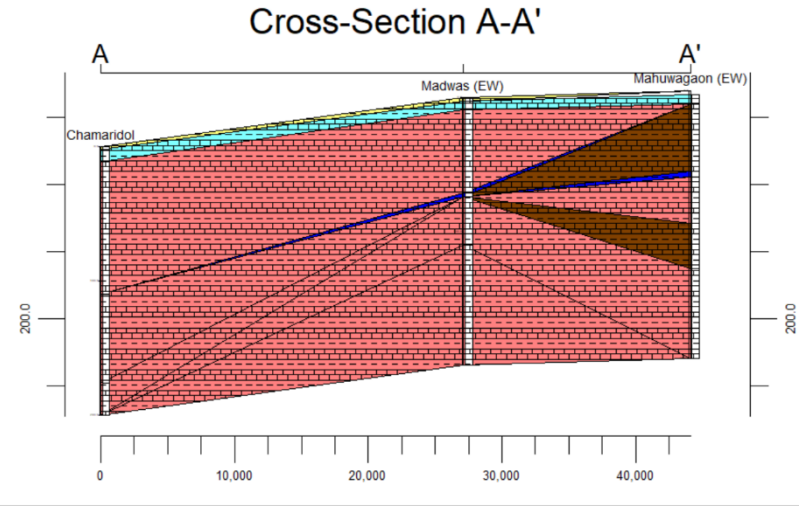


Fig 19: 2-D Cross section along A-A' (W-E), Sidhi District, Madhya Pradesh

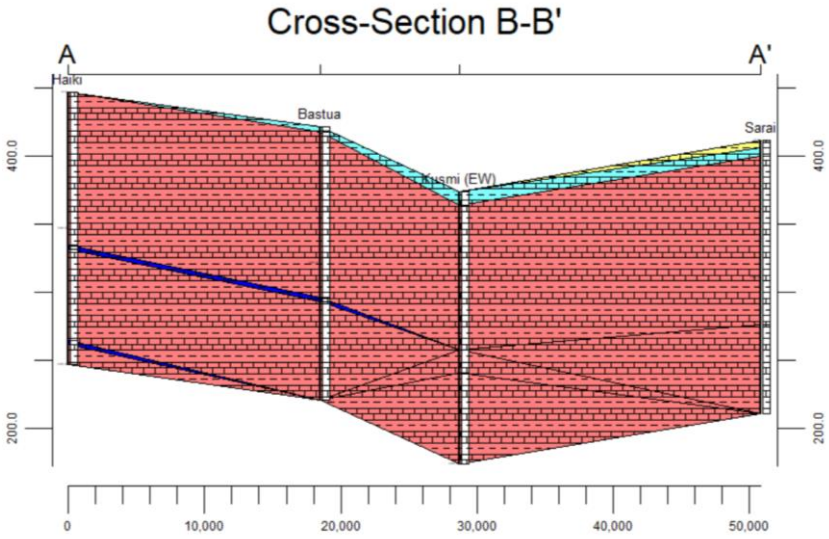


Fig 19a: 2-D Cross section along B B' (N-S), Sidhi District, Madhya Pradesh

5. Ground Water Resources

5.1 Dynamic Ground Water Resource (As on March 2022)

Sidhi district is underlain by Vindhyan limestone sandstone, Archaean granite Gondwana sandstone and Alluvium Dynamic ground water resources of the district have been estimated for base year-2021-22 on block-wise basis. Out of 485400 ha of geographical area, 360405 ha (74%) is ground water recharge worthy area and 124995 ha (26%) is hilly area. There are five number of assessment units (block) in the district which fall under non-command (87%) and three under command (13%) sub units. All blocks of the district are categorized as safe. The highest stage of ground water extraction is computed as 65.56% (43.56% in 2019-20) Sidhi block. The annual extractable ground water availability in the district 30912 ham and ground water extraction for all uses is 11214 ham, making stage of ground water extraction 36.28% (23.21% in 2019-20) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 3157 ham. (Table 8).

Table 7: Dynamic Ground Water Resources of Sidhi district (2022)

Assessment Unit Name	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	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 (%)	Categorization (Over-Exploited/Critical/Semicritical/Safe/Saline)
Kusmi	9858.73	985.88	8872.85	1723.68	0	223.1391	1946.82	246.81	6902.36	21.941	safe
Majholi	6109.62	610.97	5498.65	1520.64	0	420.8457	1941.49	465.49	3512.52	35.308	safe
Rampurnaikin	8369.44	418.47	7950.97	1575.08	806.5661	645.1236	3026.77	713.55	4855.77	38.06	safe
Sidhi	4630.71	231.53	4399.18	2061.288	0	822.9604	2884.24	910.25	1427.65	65.563	safe
Sihawal	4488.6	298.16	4190.44	671.72	0	742.6465	1414.37	821.42	2697.3	33.75	safe
District Total	**33457.1**	**2545.01**	**30912.09**	**7552.408**	**806.56**	**2854.71**	**11213.69**	**3157.52**	**19395.6**	**36.276**	

1.1 Ground Water Resource & Draft- (Outcome of NAQUIM)

The Ground Water Resource of Sidhi district has been calculated block-wise considering the variable lithology and their associated aquifer parameters like specific yield. The In-storage resource for the shallow aquifer below zone of fluctuation (upto 30 mbgl) is computed to be around 616.02mcm. The static resource for the deeper aquifer (30-200 mbgl) is computed as 140.117mcm. The block-wise details of ground water resources and draft as an outcome of NAQUIM are presented in the Table no 8.

Table 8: Ground Water Resources of Shallow & Deeper Aquifers (Outcome of NAQUIM)

Block	Kusmi	Mahjholi	Rampur Naikin	Sidhi	Sihawal	Total
Shallow Aquifer						
Dynamic Resources (MCM)	88.73	126.09	45.57	100.00	97.86	458.25
Instorage Resources (MCM)	17.18	15.12	60.95	24.99	39.54	157.00
Total Resources (MCM)	105.91	141.21	106.52	124.99	137.40	616.02
Irrigation	17.24	15.21	15.75	20.61	6.72	75.52
Domestic+Industries	2.23	4.21	14.52	8.23	7.43	36.61
Deeper Aquifer						
Static Resources (MCM)	21.185	35.062	35.645	18.585	29.700	140.177
GW Draft (MCM	19.47	19.41	30.27	28.84	14.14	112.14
Total GW Resources (MCM)	127.09	176.27	142.17	143.57	167.10	756.20

5. Geophysical Studies

Surface Geophysical Surveys:

During year 1991, 40 shallow and deep VES (Schlumberger) were conducted in Sidhi district with the objective to select some favorable locations for groundwater exploration. The surveyed area covers about 2500 sq km area over Gondwana formation of the district. The important locations covered by surveys include Deori, Pathraula, Bitkhuri, Baharwar, Amha, Dhumadol, Majhgawan, Bastua, Kota, Nagpokhar, Kundaur, Chamordol, Tala, Majhauli, Chuhiya, Tamsar, Chokari, Kusmi, Nauriha, Mahgawan, Parasi, Keslar, Songarh, Sarai, Bhaiatola, Dongri, Dauhani, Gannai, Sajapur, Rajmilan, Singrauli and Bargawan. The current electrode separation varies between 400 to 1400 m. The VES results indicated 4 to 5 geoelectrical layer sequence of Gondwana shales and sandstone. Because of wide variation in elevation due to hilly terrain the results of VES could not be correlated properly in space, but few geo-electrical sections have been prepared. A geoelectrical cross-section across Gopad river between 158

Kundaur and Dauhani over Gondwana formation is drawn. Topographically the area on both the sides of river is on higher elevation. The top geo-electrical layer with 100 ohm-m resistivity extends on either side of the river. Below this, a layer with 300 ohm-m resistivity, is restricted to the south-west side of the river. The layer with the resistivity value of 175 ohm-m extending on either side of river is representative of upper Gondwana formation comprising sandstone and shale. This layer overlies a highly resistive and compact sandstone layer (resistivity more than 1000 ohm-m). The layer with 175 ohm-m of resistivity may be favorable for artificial recharge by making a The Surface Geophysical methods have been used for many years to support the groundwater exploration programme.

6. Ground Water Quality of Sidhi District

2.4 Hydrochemistry

The water samples were collected from Key wells in clean double stopper poly ethylene bottles from 50 different locations of Sidhi district during May 2022. Samples are submitted to Chemical lab NCR, for analysis.

Hydro-chemical scenario of Sidhi District

The water samples were collected from NAQUIM study in clean double stopper HDPE poly ethylene bottles from 55 nos. different locations for cation and anion analysis and 18 nos. of ground water for heavy/ trace metal analysis of Sidhi district during pre-monsoon 2022.

Quality of Ground Water for Drinking Purpose:

The ground water samples from Sidhi district have varied range of pH from 6.95 to 7.74 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 Padkuhri (7.74). The ground water of the study area can be assessed as neutral to slightly alkaline in nature. The electrical conductivity of ground water samples in Sidhi district varies from 175 to 1554 µS/cm at 25°C. In the 54 nos. of ground water samples recorded electrical conductivity less than 1000 µS/cm and one no. of sample recorded maximum electrical conductivity (more than 1000 µS/cm) at Budugona village i.e. 1554 µS/cm. So, overall ground water quality in Sidhi district is good to slightly saline in nature at few locations are moderately saline in nature.

The fluoride concentration in Sidhi district lies in between 0.13 to 1.17 mg/l, which represents that all the samples are within the permissible limit i.e. 1.5 mg/l as per BIS (IS 10500 : 2012). The maximum fluoride concentration has been observed in the water sample of Biliyar village i.e. 1.17 mg/l. Nitrate concentration in ground water samples of Sidhi district falls within the 3 to 33 mg/l. It is observed that all water samples have nitrate concentration within the permissible limit of 45 mg/l. The maximum concentration has been recorded in the village of Shankarpur (33 mg/l). If some location has been observed high nitrate concentration in ground water samples may be due to anthropogenic activities or excessive use of fertilizers. The range of Total Hardness (as $CaCO_3$) in ground water samples of study area is 35 to 371 mg/l. It is observed that all water samples have total hardness within the permissible limit of 600 mg/l. Highest total hardness has been observed at Budugona village i.e (371 mg/l).

The analysis of heavy/ trace metal analysis in the ground water of Sidhi district shows that the copper and nickel are below detectable limit whereas concentration of iron ranges between 0.013 to 0718 mg/l. The maximum concentration of iron has been observed in the village of Kasadol (0.718 mg/l) i.e. within the permissible limit of 1.0 mg/l. The zinc concentration

ranges between 0.051 to 0.62 mg/l. The maximum concentration of manganese has been observed in the village of Dadhiya (0.485mg/l) i.e. more than BIS permissible limit of 0.3 mg/l. The maximum concentration of zinc has been observed in the village of Mohania (0.62 mg/l) i.e. within the permissible limit of 15 mg/l. The manganese concentration ranges between 0.012 to 0.485 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. The piper diagram of Sidhi district shows the ground water samples are Mixed type i.e. Calcium-Magnesium Chloride type; Mixed type i.e. Calcium-Sodium Bi-carbonate type; Calcium-Bicarbonate type i.e. temporary hardness and Sodium Chloride types i.e. saline in nature.

Quality of Ground Water for Irrigation Purpose:

In 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 Sidhi district is plotted on U.S. Salinity Laboratory diagram. U.S. Salinity Laboratory diagram, the ground water samples of Sidhi district are C_1-S_1 Class (Low Salinity & Low Sodium); C_2-S_1 Class (Medium Salinity & Low Sodium) and C_3-S_1 Class (High Salinity & Low Sodium). The ground water of C_3-S_1 class may be used for irrigation purpose for most of the crops considering the salinity content of the ground water.

Fig : Hill Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Sidhi District, Madhya Pradesh

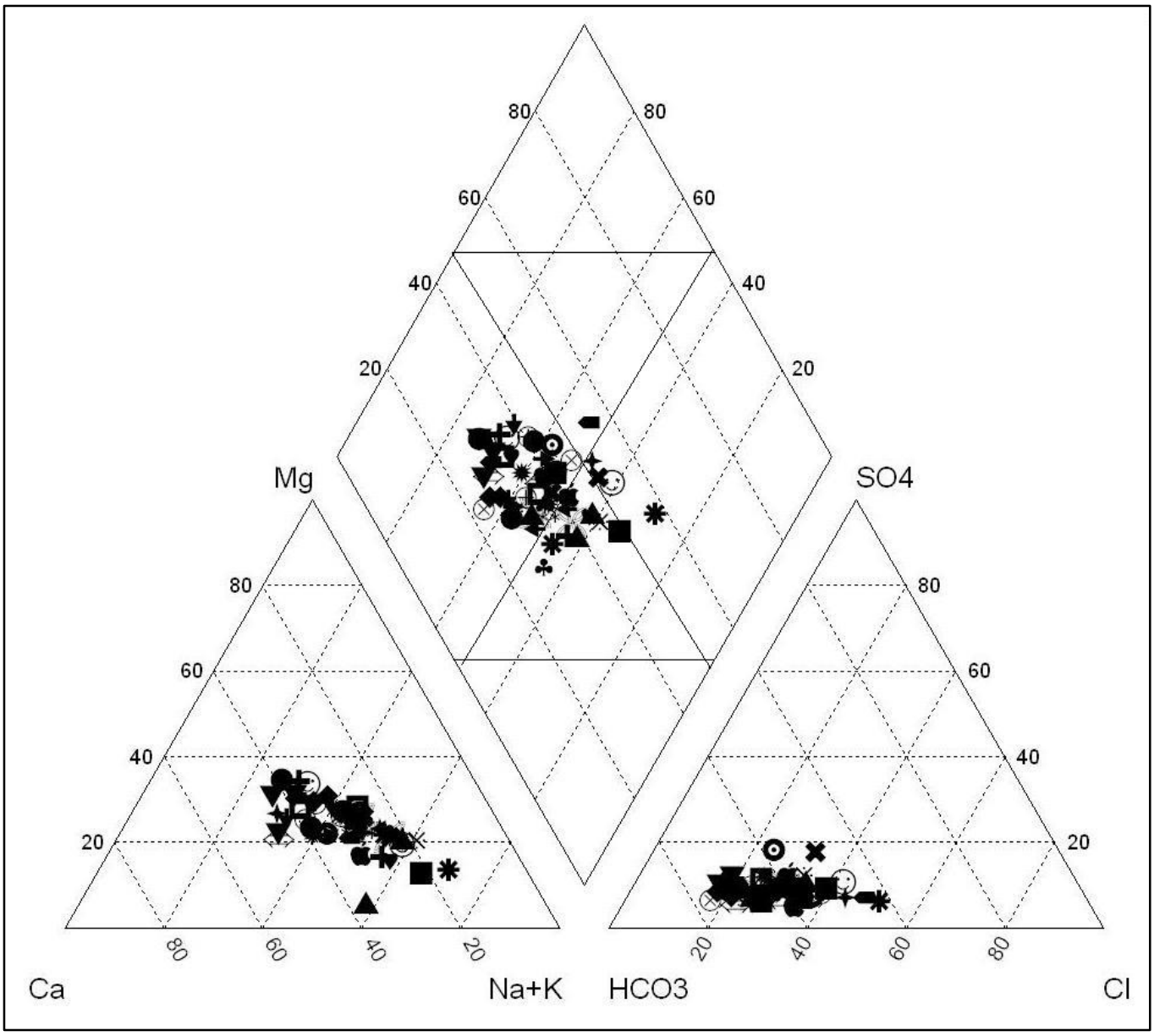


Fig : US Salinity Diagram for water samples collected from National Hydrograph Stations of Sidhi District, Madhya Pradesh.

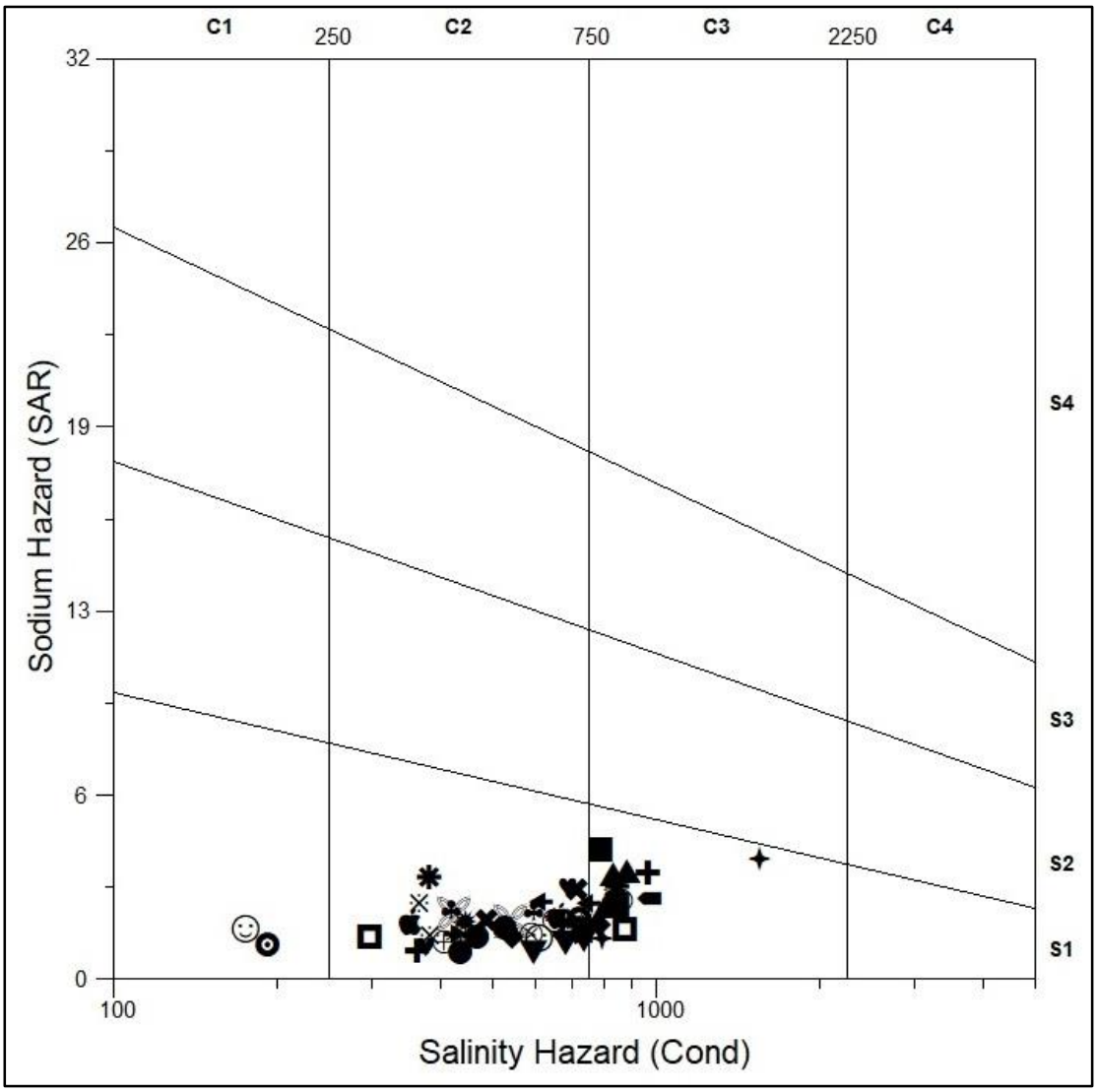

C1
250
C2
750
C3
2250
C4
32
26
19
13
6
0
Sodium Hazard (SAR)
S4
S3
S2
S1
100
1000
Salinity Hazard (Cond)

Table: Chemical analysis data of ground water of Sidhi district under NAQUIM (pre-mansoon-2022)

S. No.	District	Block	Location	Source	Lat.	Long.	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
							at 25°C	µS/cm at 25°C	mg/l													
1	Sidhi	Rampur Naiken	Malgoan	DW	24.3079	81.3423	7.56	793	0	311	71	21	15	0.63	0.15	28	277	69	25	53	1	515
2	Sidhi	Rampur Naiken	Budugona	DW	24.3116	81.3642	7.28	1554	0	445	233	49	24	0.77	BDL	34	371	77	43	184	1.2	1010
3	Sidhi	Rampur Naiken	Bagwar	DW	24.3386	81.3852	7.58	786	0	329	56	25	13	0.51	0.11	29	243	50	29	67	1.1	511
4	Sidhi	Rampur Naiken	Bahad	DW	24.2763	81.4162	7.45	722	0	287	47	33	26	0.29	0.14	30	248	55	26	51	0.9	469
5	Sidhi	Rampur Naiken	Leguchuwa	DW	24.3209	81.4212	7.58	873	0	336	81	23	18	0.65	BDL	36	287	67	29	66	0.4	567
6	Sidhi	Rampur Naiken	Birpur	DW	24.3549	81.4412	7.65	671	0	238	66	31	11	0.76	BDL	25	228	57	20	48	0.9	436
7	Sidhi	Rampur Naiken	Gorigoan	DW	24.3818	81.4786	7.53	885	0	275	100	42	25	0.62	BDL	29	183	63	6	116	0.5	575
8	Sidhi	Rampur Naiken	Amdol	DW	24.3853	81.5078	7.39	741	0	317	44	35	9	0.42	0.14	22	252	67	20	53	1.9	482
9	Sidhi	Rampur Naiken	Padkhuri	HP	24.4158	81.5338	7.74	407	0	140	42	19	5	0.53	0.18	23	129	28	14	33	0.8	265
10	Sidhi	Rampur Naiken	Padkhuri Kurd	HP	24.4491	81.4491	7.59	609	0	226	56	24	8	0.71	0.21	26	203	42	24	44	1.1	396
11	Sidhi	Sidhi	Biliyar	DW	24.4588	81.9038	7.13	295	0	110	25	15	4	1.17	0.11	31	79	16	10	30	0.7	192
12	Sidhi	Sidhi	Madugaon	DW	24.5232	81.8923	7.5	443	0	159	37	23	13	0.27	BDL	19	114	26	12	48	1.2	288
13	Sidhi	Sidhi	Chhandini	DW	24.5009	81.8278	7.53	542	0	207	47	20	11	0.33	0.12	23	144	30	17	57	1.9	352
14	Sidhi	Sidhi	Shivpurva	DW	24.4603	81.7994	7.12	434	0	177	32	18	6	0.47	BDL	31	158	34	18	26	0.8	282
15	Sidhi	Sidhi	Dhalia	HP	24.4605	81.7335	7.67	649	0	244	51	27	21	0.56	0.15	23	183	40	20	63	0.5	422
16	Sidhi	Sidhi	Harthika	DW	24.4418	81.6656	7.54	598	0	232	37	32	15	0.23	BDL	25	213	50	22	35	1.1	389
17	Sidhi	Sidhi	Mohania	HP	24.4480	81.4480	7.15	689	0	214	76	30	26	0.17	0.1	22	144	36	13	90	1.3	448
18	Sidhi	Sidhi	Amarpur	HP	24.4479	81.5985	7.44	812	0	317	69	27	18	0.24	0.14	32	218	46	25	85	0.9	528
19	Sidhi	Sidhi	Badavrah	DW	24.3991	81.7708	7.18	525	0	220	34	21	7	0.51	BDL	24	149	32	17	50	1.5	341
20	Sidhi	Sidhi	Karoudiya tola	DW	24.3422	81.8868	7.48	427	0	171	29	18	10	0.26	BDL	21	124	26	14	39	2.2	278
21	Sidhi	Sidhi	Morcha	DW	24.3106	81.8405	7.16	752	0	299	61	26	13	0.27	0.16	29	193	44	20	83	0.8	489
22	Sidhi	Sidhi	CharuaPawai	DW	24.2881	81.7827	7.04	662	0	226	76	14	21	0.36	0.21	33	183	38	22	67	0.9	430
23	Sidhi	Sidhi	Banjari	BW	24.3742	81.8380	7.32	965	0	342	91	37	32	0.45	0.22	25	213	53	19	122	1.1	627
24	Sidhi	Sidhi	Kakdijhar	DW	24.4001	81.9274	7.68	852	0	287	103	26	12	0.37	0.17	33	228	48	26	89	1	554
25	Sidhi	Sidhi	Sarpur	DW	24.4315	81.9908	7.34	669	0	238	71	18	16	0.23	BDL	24	183	38	22	67	1.7	435
26	Sidhi	Sihawal	Kushiyari	DW	24.4297	82.0530	7.53	714	0	201	77	55	27	0.72	BDL	36	160	34	18	89	2.1	464
27	Sidhi	Sihawal	Muthvani	DW	24.4390	82.1906	6.99	354	0	116	35	19	8	0.14	0.14	28	85	22	7	40	1.3	230
28	Sidhi	Sihawal	Dadhiya	BW	24.4805	82.1444	7.31	864	0	268	114	31	14	0.35	BDL	28	225	52	23	94	0.5	562
29	Sidhi	Sihawal	Ladpad Khurd	DW	24.5644	82.2290	7.2	844	0	323	72	28	23	0.25	BDL	32	195	42	22	103	1.1	549

S. No.	District	Block	Location	Source	Lat.	Long.	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
30	Sidhi	Sihawal	Bahor	DW	24.5535	82.3054	7.3	697	0	238	82	22	8	0.18	0.16	26	200	50	18	66	1.2	453
31	Sidhi	Sihawal	Gohari	DW	24.5659	82.1895	7.46	693	0	287	54	16	11	0.48	0.17	29	230	64	17	51	1.9	450
32	Sidhi	Sihawal	Baghaudi	DW	24.5682	82.0964	7.54	792	0	238	106	32	16	0.75	BDL	28	135	34	12	119	0.6	515
33	Sidhi	Sihawal	Bithouli	DW	24.5641	82.0429	7.48	738	0	281	72	23	9	0.63	0.13	23	225	58	19	65	1.5	480
34	Sidhi	Sidhi	Naghuwan	BW	24.5284	82.0117	7.21	427	0	146	42	19	10	0.54	0.11	22	95	20	11	53	0.7	278
35	Sidhi	Sidhi	Madahilia Khurd	DW	24.4882	81.9214	7.29	533	0	214	35	22	18	0.19	BDL	24	160	34	18	47	2.1	346
36	Sidhi	Sidhi	Baniadola	DW	24.2902	81.9219	7.26	484	0	171	50	18	8	0.39	BDL	31	125	26	15	52	1.3	315
37	Sidhi	Majhoili	Shikara	DW	24.1915	81.8694	7.69	685	0	268	59	20	13	1.02	BDL	28	235	52	26	48	1.2	445
38	Sidhi	Majhoili	Kamchand	DW	24.1346	81.8508	7.41	965	0	250	153	29	24	0.77	0.14	34	255	62	24	102	0.5	627
39	Sidhi	Kusmi	Nandgoan	DW	24.1068	81.8062	7.42	591	0	268	35	17	6	0.42	0.15	25	190	46	18	48	1.1	384
40	Sidhi	Kusmi	Shankarpur	DW	24.1126	81.8589	7.7	835	0	287	82	35	33	0.55	0.11	27	175	36	21	110	2.3	543
41	Sidhi	Kusmi	Rampur	DW	24.0573	81.9123	7.13	383	0	159	30	12	4	0.47	0.24	16	110	24	12	36	1.8	249
42	Sidhi	Kusmi	Chagogar	DW	23.9937	81.9418	7.15	421	0	171	25	20	15	0.13	0.1	19	95	20	11	53	0.5	274
43	Sidhi	Kusmi	Ladkheri	DW	24.0098	81.9864	6.95	363	0	134	35	11	8	0.25	BDL	22	125	26	15	25	0.8	236
44	Sidhi	Kusmi	BilhaMangwan	DW	23.9449	81.9693	7.23	379	0	92	64	10	9	0.29	BDL	20	55	12	6	60	0.6	246
45	Sidhi	Majhoili	Rauhal	DW	23.9319	81.9493	6.99	432	0	140	47	19	11	0.23	0.14	25	120	28	12	42	0.9	281
46	Sidhi	Majhoili	Marauli	DW	23.9591	81.8950	7.7	595	0	220	57	21	14	0.38	0.11	21	155	32	18	65	1	387
47	Sidhi	Majhoili	JagadaAmagoan	DW	23.9700	81.7901	7.28	466	0	153	52	15	17	0.17	0.13	19	145	36	13	40	0.6	303
48	Sidhi	Majhoili	Kasadol	DW	24.1065	81.7401	7.21	722	0	232	92	23	16	1.08	BDL	27	210	52	19	69	1.3	469
49	Sidhi	Majhoili	Gangei	DW	24.1621	81.7015	7.09	367	0	104	37	18	24	1.1	BDL	19	70	14	9	51	1	239
50	Sidhi	Majhoili	Kamah	DW	24.2326	81.7347	7.16	543	0	232	32	20	13	0.18	0.12	24	175	38	19	43	1.5	353
51	Sidhi	Rampur Naiken	Baldha	DW	24.3720	81.6633	7.08	192	0	61	15	15	6	0.58	0.14	15	50	10	6	19	1	125
52	Sidhi	Rampur Naiken	Gaurdaha	DW	24.3193	81.6071	7.15	821	0	299	74	33	25	0.59	BDL	31	210	46	23	92	0.9	534
53	Sidhi	Rampur Naiken	Chandgarh	DW	24.2981	81.4906	7.63	614	0	201	57	29	32	1.06	0.15	24	145	30	17	73	1.1	399
54	Sidhi	Majhoili	Chamradol	DW	24.1250	81.5215	7.08	377	0	134	35	10	14	0.24	0.11	15	120	26	13	29	0.8	245
55	Sidhi	Majhoili	Dheem	DW	24.0872	81.5635	7.12	175	0	49	25	8	3	0.25	BDL	22	35	8	4	23	1.2	114

Table: Trace/ Heavy metal analysis of ground water of Sidhi district under NAQUIM (pre-mansoon-2022)

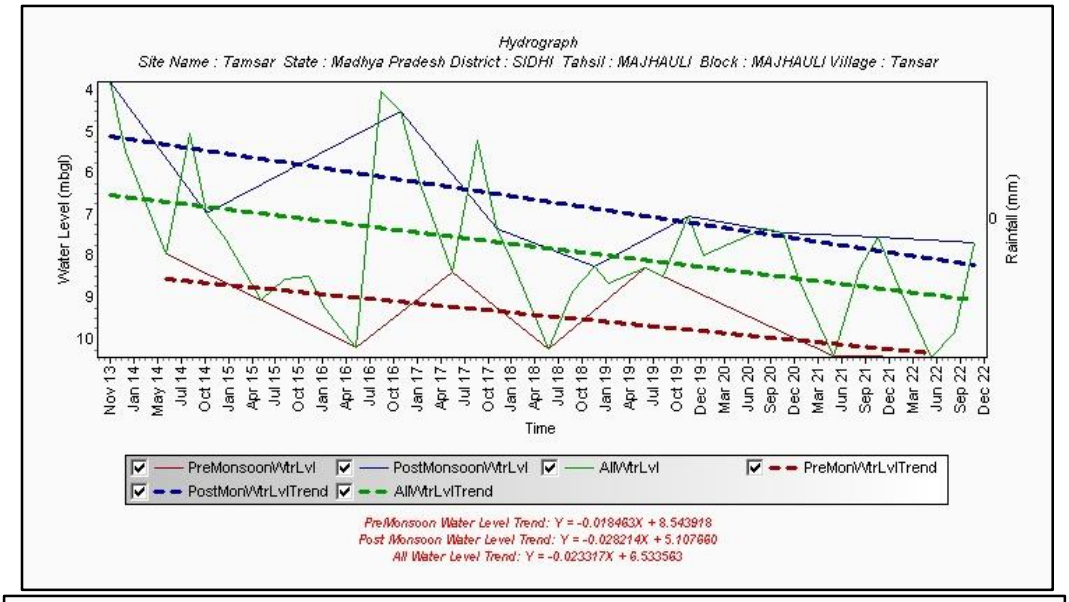
S. No.	District	Block	Location	Source	Lat.	Long.	Fe	Cu	Ni	Zn	Mn
							mg/l				
1	Sidhi	Rampur Naiken	Malgoan	DW	24.3079	81.3423	0.068	BDL	BDL	0.079	BDL
2	Sidhi	Rampur Naiken	Bahad	DW	24.2763	81.4162	0.017	BDL	BDL	BDL	BDL
3	Sidhi	Rampur Naiken	Birpur	DW	24.3549	81.4412	0.325	BDL	BDL	BDL	BDL
4	Sidhi	Rampur Naiken	Padkhuri	HP	24.4158	81.5338	BDL	BDL	BDL	BDL	BDL
5	Sidhi	Sidhi	Madugaon	DW	24.5232	81.8923	0.044	BDL	BDL	BDL	0.012
6	Sidhi	Sidhi	Mohania	HP	24.4480	81.4480	0.012	BDL	BDL	0.62	0.016
7	Sidhi	Sidhi	Morcha	DW	24.3106	81.8405	0.021	BDL	BDL	BDL	BDL
8	Sidhi	Sidhi	Kakdijhar	DW	24.4001	81.9274	0.263	BDL	BDL	BDL	BDL
9	Sidhi	Sihawal	Dadhiya	BW	24.4805	82.1444	0.039	BDL	BDL	0.215	0.485
10	Sidhi	Sihawal	Gohari	DW	24.5659	82.1895	BDL	BDL	BDL	BDL	BDL
11	Sidhi	Sidhi	Madahilia Khurd	DW	24.4882	81.9214	BDL	BDL	BDL	BDL	0.012
12	Sidhi	Majhoili	Kamchand	DW	24.1346	81.8508	0.59	BDL	BDL	0.334	0.071
13	Sidhi	Kusmi	Rampur	DW	24.0573	81.9123	0.048	BDL	BDL	BDL	BDL
14	Sidhi	Majhoili	Rauhal	DW	23.9319	81.9493	0.372	BDL	BDL	BDL	0.041
15	Sidhi	Majhoili	Kasadol	DW	24.1065	81.7401	0.718	BDL	BDL	0.182	BDL
16	Sidhi	Rampur Naiken	Gaurdaha	DW	24.3193	81.6071	0.028	BDL	BDL	0.051	BDL
17	Sidhi	Majhoili	Chamradol	DW	24.1250	81.5215	0.018	BDL	BDL	BDL	0.018
18	Sidhi	Majhoili	Nebhua	DW	24.0894	81.6256	0.221	BDL	BDL	BDL	0.018

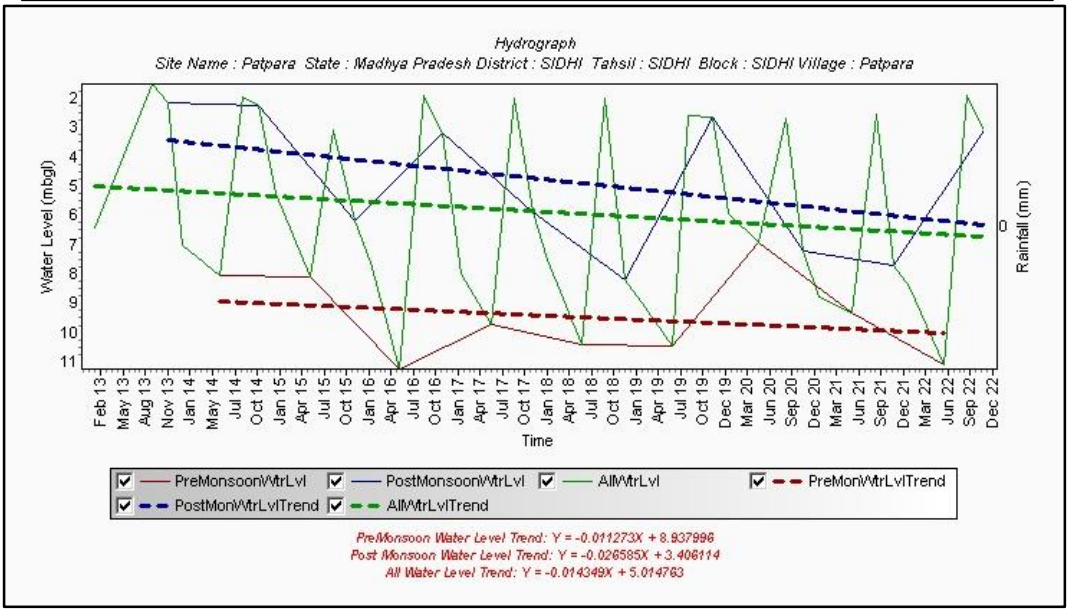
7. Ground Water Related Issues

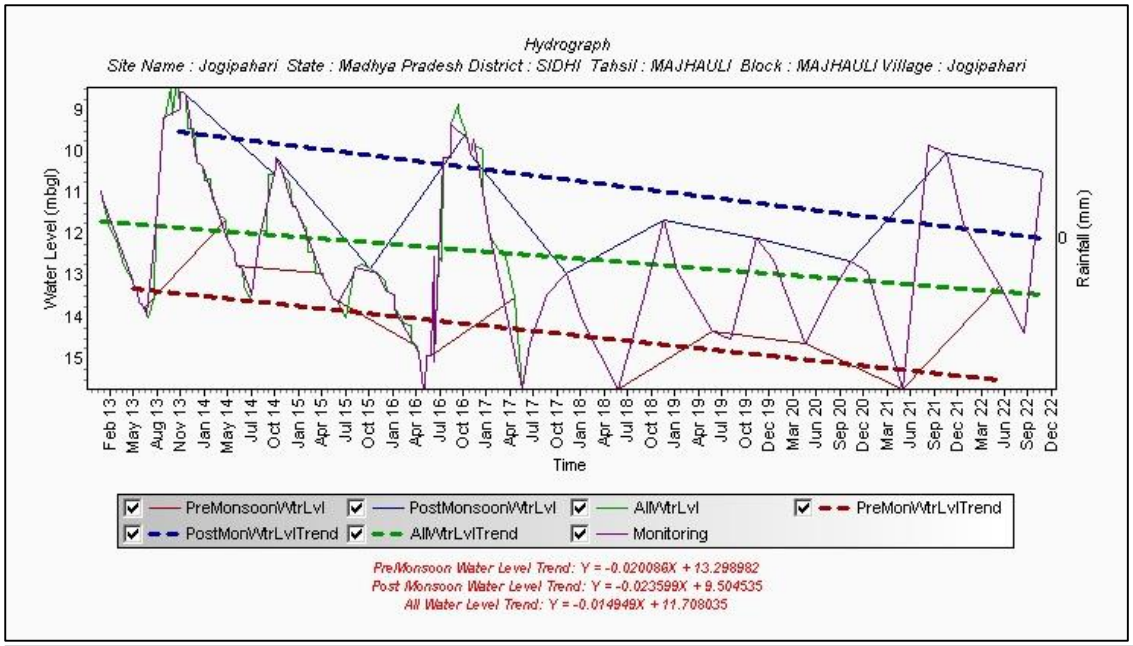
7.1 Declining of water level

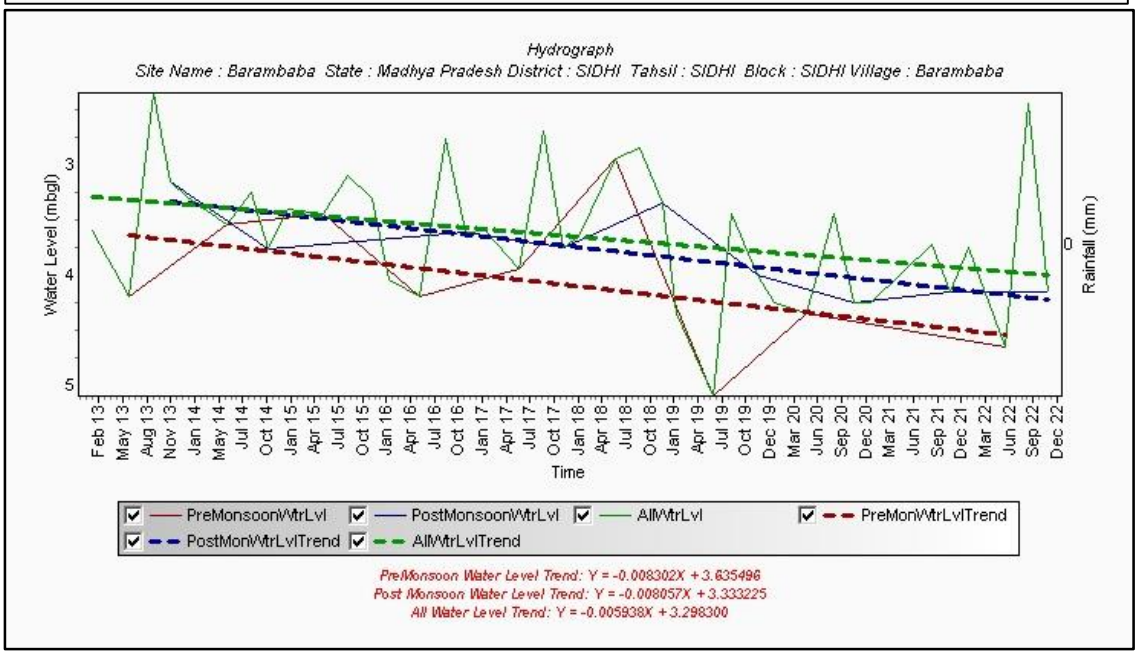
The long-term water level trend analysis indicates mixed results. During pre-monsoon season, out of 33 Hydrograph Stations, 2 are showing declining trend(Fig. 17). Similarly, during post-monsoon season, out of 21 stations 4 stations are showing falling trend in the district and all stations of Tansar, Patpara,Jogi Pahari and BharamparaSidhi and Majhuliblocks are showing depletion of water levels in the area. Ground Water Resource Estimation also reveals that out of 5 Blocks of the district stage of ground water Extraction are increasing compare with previous estimation.

Fig 17: Hydrographs showing declining water level trend during Pre-monsoon and Post-Monsoon at sites Sidhi and Bajana, Behat and NayagoanSidhi District, Madhya Pradesh


Hydrograph
Site Name : Tamsar State : Madhya Pradesh District : SIDHI Tahsil : MAJHAULI Block : MAJHAULI Village : Tansar
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.018463X + 8.543918
Post Monsoon Water Level Trend: Y = -0.028214X + 5.107660
All Water Level Trend: Y = -0.023317X + 6.533563


Hydrograph
Site Name : Patpara State : Madhya Pradesh District : SIDHI Tahsil : SIDHI Block : SIDHI Village : Patpara
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.011273X + 8.937996
Post Monsoon Water Level Trend: Y = -0.026585X + 3.406114
All Water Level Trend: Y = -0.014349X + 5.014763


Hydrograph
Site Name : Jogipahari State : Madhya Pradesh District : SIDHI Tahsil : MAJHAULI Block : MAJHAULI Village : Jogipahari
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Monitoring
PreMonsoon Water Level Trend: Y = -0.020086X + 13.298982
Post Monsoon Water Level Trend: Y = -0.023599X + 9.504535
All Water Level Trend: Y = -0.014949X + 11.708035


Hydrograph
Site Name : Barambaba State : Madhya Pradesh District : SIDHI Tahsil : SIDHI Block : SIDHI Village : Barambaba
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.008302X + 3.635496
Post Monsoon Water Level Trend: Y = -0.008057X + 3.333225
All Water Level Trend: Y = -0.005938X + 3.298300

8. Ground Water Management Strategies

Groundwater has been contributing more to agricultural wealth than surface irrigation since ages. Tube wells are now the largest source of irrigation in the country. Since this sector has almost no dependence on the government, it is growing at a rapid rate and it is estimated that one million wells are added every year (Shah and Deb, 2004). Being an individually managed source, ground water irrigation is also a more efficient form of irrigation, with crop yields per cubic meter of water being 1.2 to 3 times higher than surface irrigation. However, since this sector has grown through investment by individual farmers, with little state involvement compared to canal irrigation, government support for understanding this sector and improving its performance is negligible. The major issues for the future growth of groundwater irrigation is declining resource base, demand driven growth, and a lack of policy and regulatory framework. Since groundwater extraction is primarily driven by the needs of the population and the density of farmer population and not the quality of resource, groundwater irrigation is scaling up even in such hard rock areas causing irreversible depletion of the resource base (Shah and Deb, 2004).To warrant the current situation effective groundwater management strategies needs to be evolved.

8.1. DistrictGround Water Management Plan (Outcome of NAQUIM)

Sidhi district has been facing problems of ground water exploitation which in turn are depleting the ground water resources in the non-command area especially in Sidhi. This has led to evolve sustainable water conservation and management practices through an integrated approach. The ground water management plan for Sidhi district has been made keeping in view the area specific details and includes the strategies like enhancing the ground water resources through 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 techniques 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.

Supply Side Management – Augmentation of Ground Water Resources through Artificial Recharge

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 rejuvenate the depleted ground water storage, reduces the ground water quality problems and also improves the sustainability of wells in the affected areas.

The supply side management plan for Sidhi 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. The volume of ground water recharge generated through pre-existing rain water harvesting/water conservation structures is subtracted from the sub-surface storage to assess the available storage potential. 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 0.23 has been considered for Sidhi 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%, 35% and 20% of non-committed runoff to Percolation tanks, Recharge shafts/Tube wells and Nala bunds/Check dams/Cement Plugs respectively. The remaining 10 % 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 no. 11.

A financial outlay plan has also been chalked out, assuming the cost for the artificial recharge structures to be Rs. 20 lakhs each for percolation tanks, Rs. 10 lakhs each for Nala bunds/Check Dams/Cement Plugs, Rs. 5 lakhs each for Recharge shafts/Tube wells and Rs. 2 lakhs each for renovation of Village tanks/ponds/WCS. This accounts to a total of Rs. 186 Crores to successfully implement the supply side management strategy. Table no. 12 represents the complete financial outlay plan for the district.

8.1.2. Demand Side Management

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:

1. 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).
2. It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.
3. It saves costs of hired labour and other inputs like fertilizer.
4. 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.

Adoption of Sprinkler irrigation techniques in 50% of the area irrigated by ground water has been suggested for the Sidhi district Also, the 60% of additional recharge created by construction of artificial recharge structures can be utilized to increase the total cropping area, thereby enhancing the productivity and economy of the district.

Table 11: Ground Water Management– Supply Side, Sidhi District, Madhya Pradesh

Block	Rainfall (m)	Area suitable for recharge (Sq Km)	Average post-monsoon water level (m)	Unsaturated zone (m)	Average SP Yield (%)	Sub-surface storage (mcm)	Surface water required (mcm)	Surface water (Run-off) available (mcm)	Non-committed Run-off (mcm)	Percolation tank	CD/Recharge shaft/ Tube well	NB/ CP	No of Villages
Kusmi	1.13	**706.17**	3.346667	0.35	0.015	3.67	4.88	176.54	52.96	5	17	20	42
Mahjholi	1.13	**667.84**	4.460909	1.46	0.015	14.63	19.46	433.19	129.96	19	68	78	53
Rampur Naikin	1.13	**950.54**	6.830769	3.83	0.015	54.62	71.29	237.64	71.29	71	250	285	90
Sidhi	1.13	**619.5**	8.395	5.40	0.015	50.13	46.46	154.88	46.46	46	163	186	112
Sihawal	1.13	**660**	9.3175	6.32	0.015	62.54	75.81	252.71	75.81	76	265	303	103
Total	**1.13**	3604.05	**4.62**	**2.17**	0.015	**186**	**218**	**1255**	**376**	**218**	763	872	**400**

District	Area Suitable for AR	Volume of Surface Water available for AR (MCM)	Volume of Water required for recharge (MCM)	Proportionate Surface water for planning AR (MCM)	Percolation Tanks structure Nos	cost (crores)	NB/ CP structure Nos	cost (crores)	CD/Recharge shaft/ Tube well	cost (crores)	Renovation of Village Pondsstructure Nos	cost (crores)	Total Cost of RS in crores
Kusmi	**706.17**	4.90	6.51	6.51	5	1.00	20	2.00	17	0.85	42	0.84	4.69
Mahjholi	**667.84**	19.51	25.95	25.95	19	3.89	78	7.80	68	3.40	53	1.06	16.15
Rampur Naikin	**950.54**	72.83	71.29	71.29	71	14.26	285	28.50	250	12.50	90	1.80	57.06
Sidhi	**619.5**	66.84	46.46	46.46	46	9.29	186	18.60	163	8.15	112	2.24	38.28
Sihawal	**660**	83.39	75.81	75.81	76	15.16	303	30.30	265	13.25	103	2.06	60.77
TOTAL	3604.05	**247**	**226**	**226**	218	43.61	872	87.20	763	38.15	**400**	8.00	176.96

Table 12: Financial Outlay Plan- Supply Side Management, Sidhi District, Madhya Pradesh

8.2. Post-Intervention Impact

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table no 14. It can beenrevised that the Stage of groundwater development for the entire Sidhi district, would increase to 41.97 % as compared to the present stage of ground water development of 36.27 % after implying and successful implementation of proposed interventions.

Table 114: Post-Intervention Impact, Sidhi District, Madhya Pradesh

Block	Annual Extractable Ground Water Resource (Ham)	Gross Draft	Stage of Ground Water Extraction (%)	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
Kusmi	88.7285	19.468	21.941	3.45	3.67	92.3985	2.2020	18.22	19.72	6
Mahjholi	54.9865	19.415	35.308	3.04	14.63	69.6165	8.7780	25.15	36.13	22
Rampur Naikin	79.5097	30.268	38.06	3.15	54.62	134.1297	32.7720	59.89	44.65	82
Sidhi	43.9918	28.842	65.563	4.12	46	89.9918	27.6000	52.32	58.14	69
Sihawal	41.9044	14.144	33.75	1.34	62.54	104.4444	37.5240	50.32	48.18	94
Total	**309.1209**	**112.137**	**36.276**	**15.10**	**181.46**	**490.5809**	**108.8760**	**205.91**	**41.97**	**272**

8.3 Block-Wise Mapping and Management Plan

1. **Block: Kusmi**

Geographical area	**1334**Sq. km (NAQUIM Recharge worthy area 706.1Sq. Km)
Basin/Sub Basin	Ganga Basin
Principal Aquifer System	Sandstone,Shale&Granite
Major Aquifer System	Weathered/Fractured Sandstone,Shale&Granite
Normal Annual Rainfall	1132.00mm
Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 4 Observation Wells : 0 Piezometer Well: 1
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL(m bgl): 3.85-6.95 Yield (lps): 1 to 3 Specific yield :0.015 % Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL(m bgl): 11 - 20 Yield (lps): Meager to 10 Specific yield :0.094
Ground water Monitoring Status	NHS: DW:0, Piezometer Well: 1

Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 88.72 MCM GW Draft: 19.46MCM Stage of GW Development: 21.94%
Existing and Future water Demand	Present Demand for All Uses: 19.46 MCM Future Demand for Domestic and Industrial Use:2.46 MCM

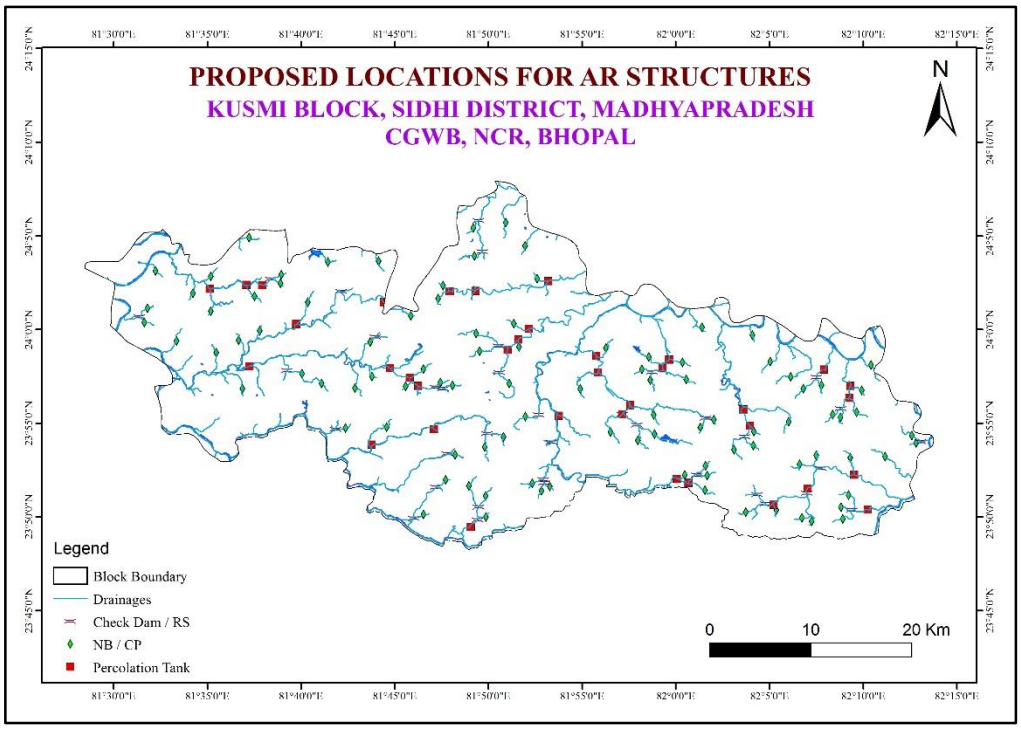


Fig 18: Artificial Recharge Structures location Map of Kusmi Block

Salient Features

Block	**Kusmi**
Shallow Aquifer	
Dynamic Resources (MCM)	88.73
Instorage Resources (MCM)	17.18
Total Resources (MCM)	**105.91**
Irrigation	17.24
Domestic+Industries	2.23
Deeper Aquifer	
Static Resources (MCM)	21.185
GW Draft (MCM	19.47
Total GW Resources (MCM)	127.09

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	26	5.2(Rs 20 Lakh Per Structure)
NB /CP	224	2.24(Rs 1.0 Lakh Per Structure)
CD	224	13.44(Rs 6.0 Lakh Per Structure)
Recharge Shaft	224	2.24(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	75	1.87(Rs2.5 Lakh Per Structure)
Total Cost		26.25**Crores**

2.Block: Majholi

Geographical area	**737**Sq. km (NAQUIM Recharge worthy area 667Sq. Km)
Basin/Sub Basin	Ganga Basin
Principal Aquifer System	Sandstone,Shale&Granite
Major Aquifer System	Weathered/Fractured Sandstone,Shale&Granite
Normal Annual Rainfall	1132.00mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 1 Observation Wells : 0 Piezometer Well: 1
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL(m bgl): 3.85-6.95 Yield (lps): 1 to 3 Specific yield :0.015 % Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL(m bgl): 11 - 20 Yield (lps): Meager to 4.4 Specific yield :0.094
Ground water Monitoring Status	NHS: 7DW, Piezometer Well: 1

Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 54.98 MCM, GW Draft:19.41 MCM Stage of GW Development: 35.30%
Existing and Future water Demand	Present Demand for All Uses:19.41 MCM Future Demand for Domestic and Industrial Use: 4.65MCM

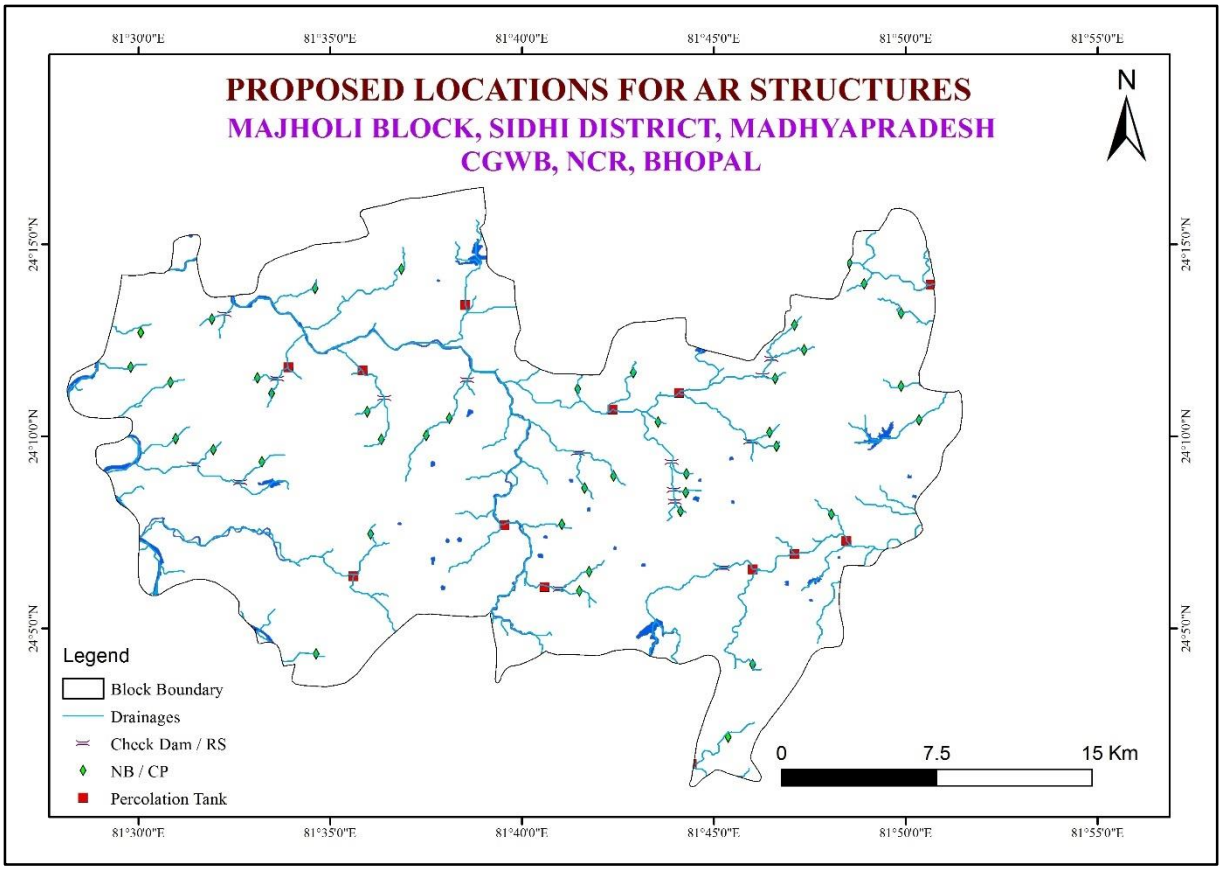


Fig 18: Artificial Recharge Structures location Map of Majholi Block

Salient Features

Block	**Mahjholi**
Shallow Aquifer	
Dynamic Resources (MCM)	126.09
Instorage Resources (MCM)	15.12
Total Resources (MCM)	**141.21**
Irrigation	15.21
Domestic+Industries	4.21
Deeper Aquifer	
Static Resources (MCM)	35.062
GW Draft (MCM	19.41
Total GW Resources (MCM)	176.27

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	26	5.2(Rs 20 Lakh Per Structure)
NB /CP	224	2.24(Rs 1.0 Lakh Per Structure)
CD	224	13.44(Rs 6.0 Lakh Per Structure)
Recharge Shaft	224	2.24(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	75	1.87(Rs2.5 Lakh Per Structure)
Total Cost		26.25**Crores**

3.Block: Rampur Naikan

Geographical area	**1194**Sq. km (NAQUIM Recharge worthy area 950.5Sq. Km)
Basin/Sub Basin	Ganga Basin
Principal Aquifer System	Sandstone,Shale&Granite
Major Aquifer System	Weathered/Fractured Sandstone,Shale&Granite
Normal Annual Rainfall	1132.00mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 0 Observation Wells : 0 Piezometer Well: 1
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL(m bgl): 3.85-6.95 Yield (lps): 1 to 3 Specific yield :0.015 % Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL(m bgl): 11 - 20 Yield (lps): Meager to 10 Specific yield :0.094
Ground water Monitoring Status	NHS: DW:6, Piezometer Well: 1

Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 79.5 MCM GW Draft: 30.26 MCM Stage of GW Development: 38.06%
Existing and Future water Demand	Present Demand for All Uses: 30.26 MCM Future Demand for Domestic and Industrial Use: 7.13 MCM

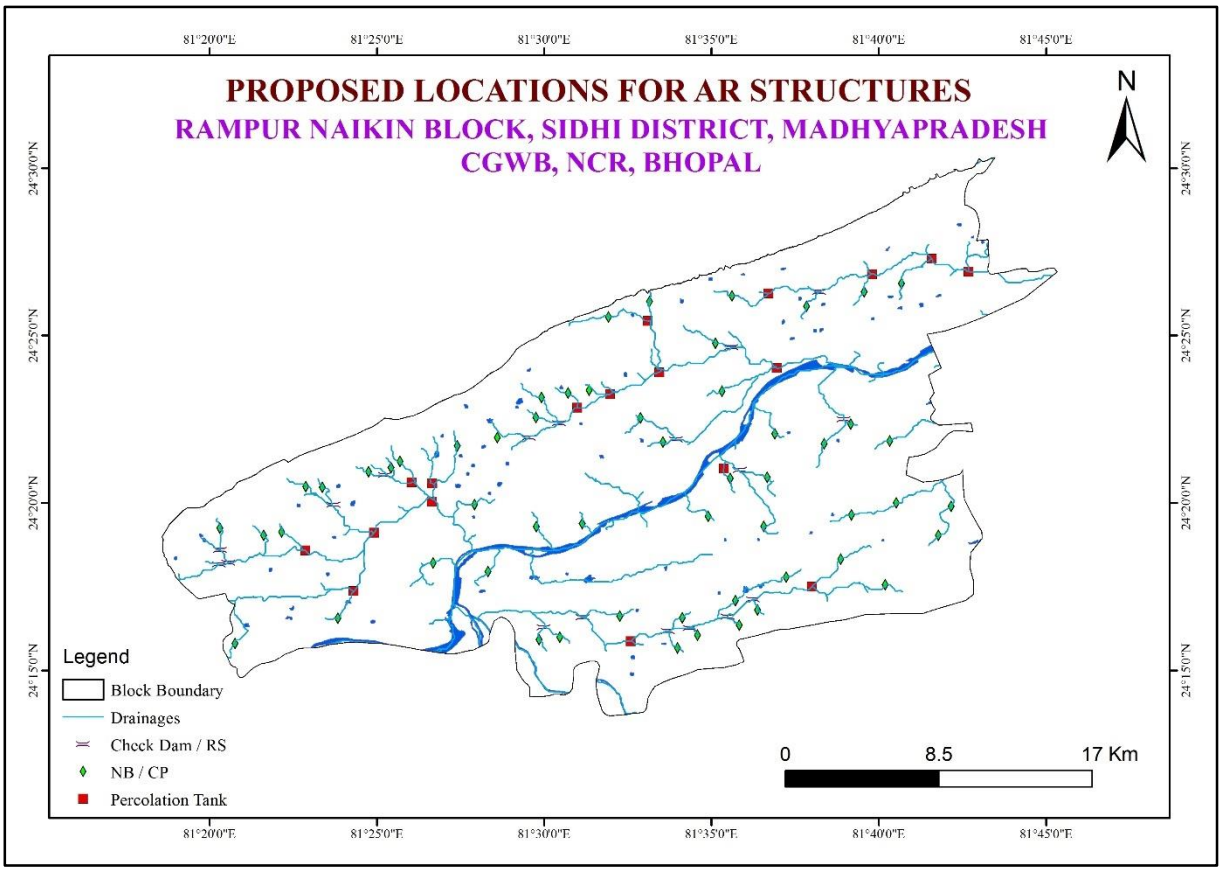


Fig 18: Artificial Recharge Structures location Map of Rampur NaikinBlock

Salient Features

Block	**Rampur Naikin**
Shallow Aquifer	
Dynamic Resources (MCM)	45.57
Instorage Resources (MCM)	60.95
Total Resources (MCM)	**106.52**
Irrigation	15.75
Domestic+Industries	14.52
Deeper Aquifer	
Static Resources (MCM)	35.645
GW Draft (MCM	30.27
Total GW Resources (MCM)	142.17

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	26	5.2(Rs 20 Lakh Per Structure)
NB /CP	224	2.24(Rs 1.0 Lakh Per Structure)
CD	224	13.44(Rs 6.0 Lakh Per Structure)
Recharge Shaft	224	2.24(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	75	1.87(Rs2.5 Lakh Per Structure)
Total Cost		26.25**Crores**

4.Block: Sidhi

Geographical area	**844**Sq. km (NAQUIM Recharge worthy area 619Sq. Km)
Basin/Sub Basin	Ganga Basin
Principal Aquifer System	Sandstone,Shale&Granite
Major Aquifer System	Weathered/Fractured Sandstone,Shale&Granite
Normal Annual Rainfall	1132.00mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 0 Observation Wells : 0 Piezometer Well: 0
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL(m bgl): 3.85-6.95 Yield (lps): 1 to 3 Specific yield :0.015 % Aquifer II : Depth of Occurrence (m bgl): 30 m to 300m, Thickness average (m): 0.2 to 3 DTWL(m bgl): 11 - 20 Yield (lps): Meager to 10 Specific yield :0.094
Ground water Monitoring Status	NHS: 8 DW, Piezometer Well: 1

Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 43.99 MCM GW Draft: 20.61 MCM Stage of GW Development: 65.56%
Existing and Future water Demand	Present Demand for All Uses:20.61 MCM Future Demand for Domestic and Industrial Use: 9.10 MCM

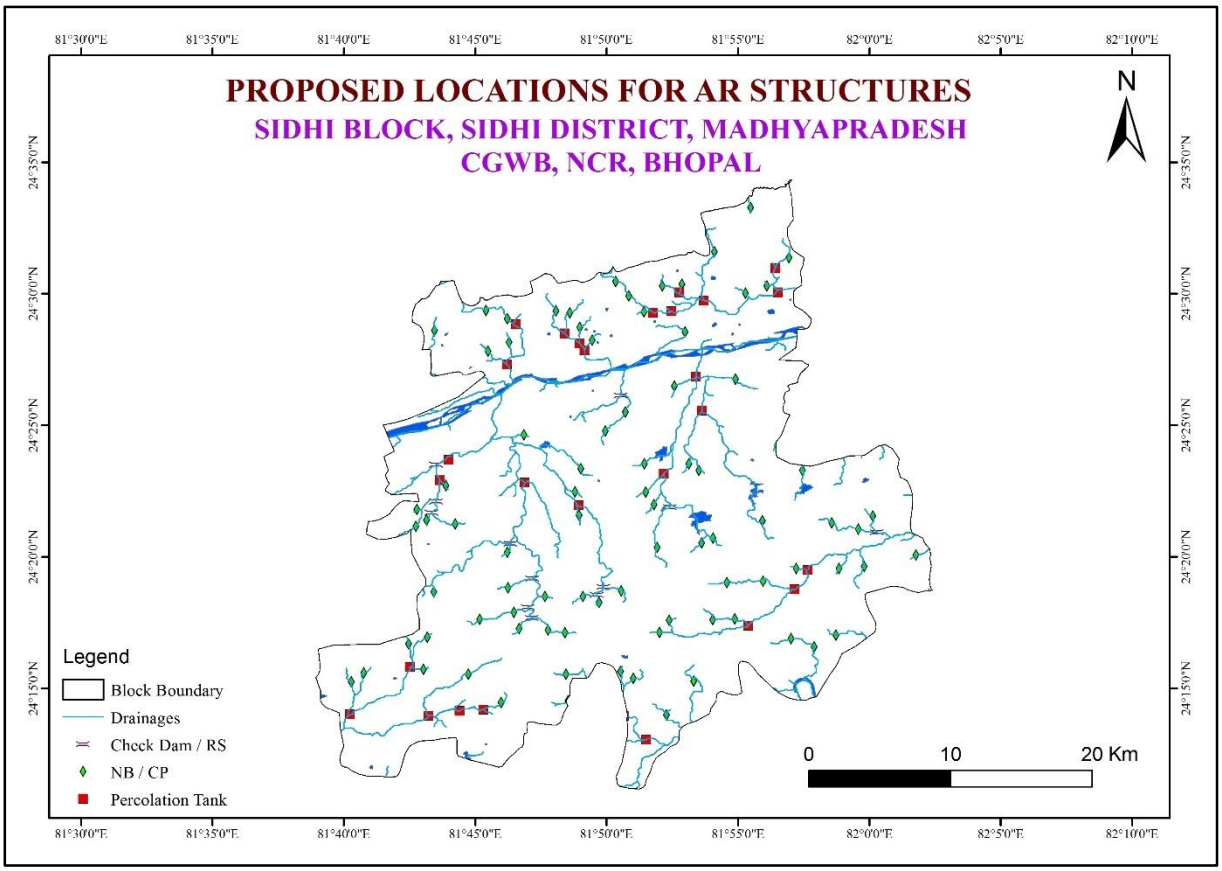


Fig 18: Artificial Recharge Structures location Map of Sidhi Block

Salient Features

Block	**Sidhi**
Shallow Aquifer	
Dynamic Resources (MCM)	100.00
In storage Resources (MCM)	24.99
Total Resources (MCM)	**124.99**
Irrigation	20.61
Domestic Industries	8.23
Deeper Aquifer	
Static Resources (MCM)	18.585
GW Draft (MCM	28.84
Total GW Resources (MCM)	143.57

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	26	5.2(Rs 20 Lakh Per Structure)
NB /CP	224	2.24(Rs 1.0 Lakh Per Structure)
CD	224	13.44(Rs 6.0 Lakh Per Structure)
Recharge Shaft	224	2.24(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	75	1.87(Rs2.5 Lakh Per Structure)
Total Cost		26.25**Crores**

5.Block: Sihawal

Geographical area	**745**Sq. km (NAQUIM Recharge worthy area 660 Sq. Km)
Basin/Sub Basin	Ganga Basin
Principal Aquifer System	Sandstone,Shale&Granite
Major Aquifer System	Weathered/Fractured Sandstone,Shale&Granite
Normal Annual Rainfall	1132.00mm

Aquifer Disposition	Two Types of Aquifer System: Shallow Aquifer System (Aquifer-I): Depth range from 3 to 30m, Alluvium, Weathered Sandstone/Shale/Granite. Deeper Aquifer System (Aquifer-II): Depth range from 30-200m, Fractured Shale /sandstone/Granite.
Status of GW Exploration	Exploratory wells: 2 Observation Wells : 0 Piezometer Well: 1
Aquifer Characteristics	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15 DTWL(m bgl): 3.85-6.95 Yield (lps): 1 to 3 Specific yield :0.015 % Aquifer II : Depth of Occurrence (m bgl): 30 m to 200m, Thickness average (m): 0.2 to 3 DTWL(m bgl): 11 - 20 Yield (lps): Meager to 4.5 Specific yield :0.094
Ground water Monitoring Status	NHS: DW:7, Piezometer Well: 1

Groundwater Quality	Generally shallow and Deeper Aquifer Groundwater Quality potable.
Aquifer potential	Mainly aquifer potential in Alluvium& Fracture Sandstone/Shale.
Groundwater Resource	GW Availability: 41.9 MCM GW Draft:14.14MCM Stage of GW Development: 20.96%
Existing and Future water Demand	Present Demand for All Uses:14.14MCM Future Demand for Domestic and Industrial Use: 8.21 MCM

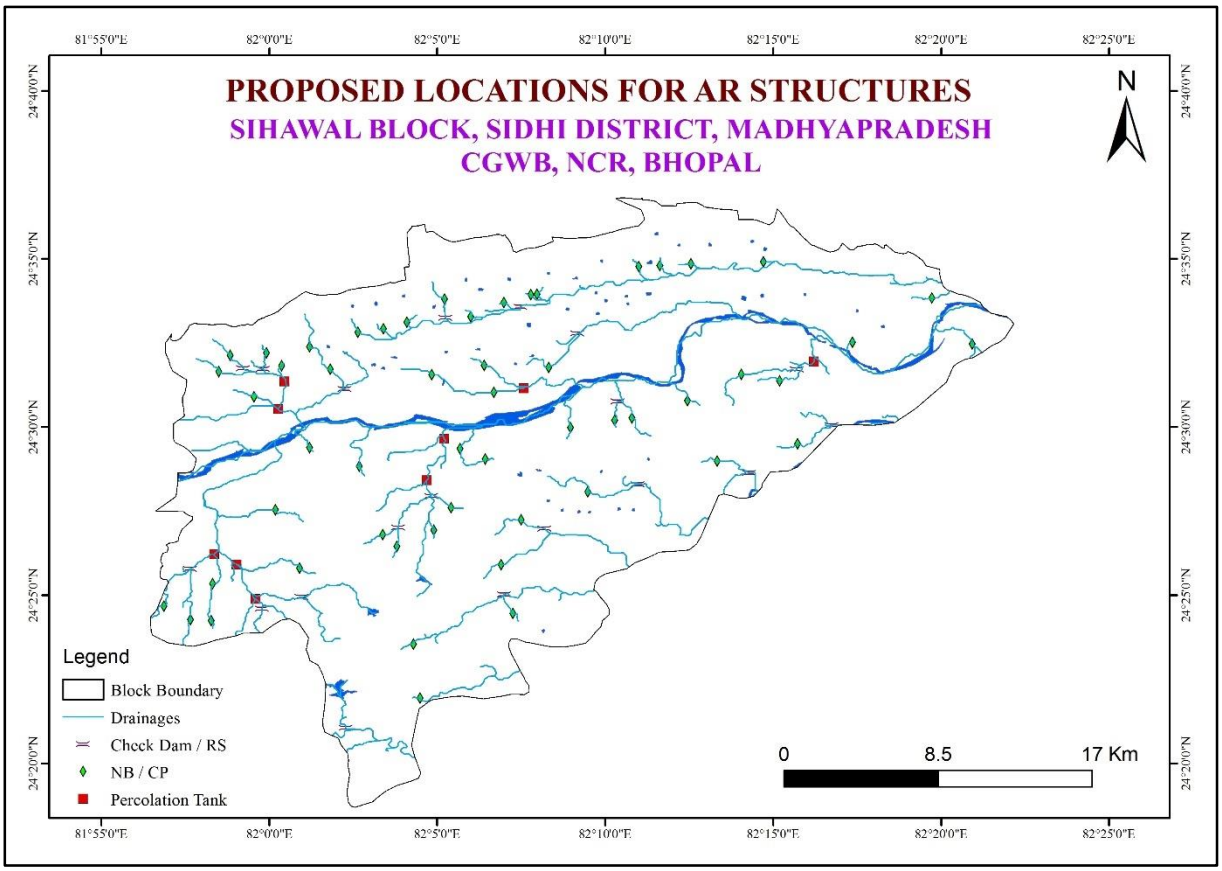


Fig 18: Artificial Recharge Structures location Map of Sihawal Block

Salient Features

Block	**Sihawal**
Shallow Aquifer	
Dynamic Resources (MCM)	97.86
Instorage Resources (MCM)	39.54
Total Resources (MCM)	**137.40**
Irrigation	6.72
Domestic+Industries	7.43
Deeper Aquifer	
Static Resources (MCM)	29.700
GW Draft (MCM	14.14
Total GW Resources (MCM)	167.10

TYPE OF STRUCTURE	**NUMBER**	**COST IN INR CRORES**
Percolation Tanks	26	5.2(Rs 20 Lakh Per Structure)
NB /CP	224	2.24(Rs 1.0 Lakh Per Structure)
CD	224	13.44(Rs 6.0 Lakh Per Structure)
Recharge Shaft	224	2.24(Rs 1.0 Lakh Per Structure)
Renovation of Village Ponds	75	1.87(Rs2.5 Lakh Per Structure)
Total Cost		26.25**Crores**

7. Conclusions and Recommendations

On the basis of NAQUIM studied in the area, the following conclusions are drawn.

The studied area occupies an area of 4854 Sq. Km. It is divided into, four administrative blocks vizKusmi, Moholi, Rampur Naikan, Sidhi, Sihawalforming blocks.

The maximum elevation is 823 m amsl in Kusmi Block and minimum elevation is 167m amsl in Sihawal Block .The minimum elevation has been recorded in the southern and northern fringes of the district. The major portion of the district lies within an elevation range of about 400 to 300 m amsl.

Entire Sidhi district falls under the Ganga basinand its tributariesform the main source of surface water in the area. Son flows along the northern boundary of the district main rivers which drains the area of the district which drains the area of the district are Son.

Sidhi district is underlain by various geological formation, forming different types of aquifers in the area. Main geological; units of the area are Archaean, upper Vindhyan, Gondwana and alluvium.

The pre-monsoon depth to Water levels ranges from a minimum of 3.1 meters below ground level (mbgl) atBaldhain RampurNaikenblock to a maximum of 21.0 m bglat PadukurKhrd at Sidhi block of Sidhi district. About 16% very shallow water levels up to 2-5m bgl have been recorded in a small patch in part of district. About 50 % of monitoring wells recorded water level in the range of 5-10 m bgl category,

The post-monsoon depth to Water levels ranges from a minimum of 1.21 m below ground level in Rampur Naiken block to a maximum of 17.53 m bgl Rampur Naiken block of Sidhi district. Very shallow water levels up to 3 m bgl have been recorded in patchesscattered all over the district contributing to about 10 % of total monitoring wells in Sidhi district.

Sidhi district is underlain by Vindhyan limestone sandstone, Archaean granite Gondwana sandstone and Alluvium Dynamic ground water resources of the district have been estimated for base year-2021-22 on block-wise basis. Out of 485400 ha of geographical area, 360405 ha (74%) is ground water recharge worthy area and 124995 ha (26%) is hilly area. There are five number of assessment units (block) in the district which fall under non-command (87%) and three under command (13%) sub units. All blocks of the district are categorized as safe.

Long term water level trend show declining in Sidhi block

On the prevailing hydrogeological conditions and data collected, the following recommendations are made for the development & management of ground water.

- After the implemented of project interventions in the report, the stage of ground water development is expected to improve by 10 % i.e. from 36.2 % to41.97 % for the Sidhi district and additional area for the irrigation will be 272 Sq.Km.

- As per the Management plan prepared under NAQUIM of all the Block of Sidhi District, a total number of 218 Percolation Tanks, 763 Check Dams ,Recharge Shafts/Tube wells and 872 Nala Bunds/Check Dams Cement Plugs and 400 Village pond have been proposed and these structures can recharge 186 MCM.
- Financial expenditure is expected to be Rs 176 Crores in Sidhi District for sustainable development and management of ground water resources.
- The number of artificial recharge structure and financial estimation has been proposed based on the CGWB Master plan 2020. It may be differ from the field condition as well as changes in dynamic Ground water resources.

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