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

JABALPUR DISTRICT, MADHYA PRADESH

उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

GOVERNMENT OF INDIA
CENTRAL GROUND WATER BOARD
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION
MINISTRY OF JAL SHAKTI

AQUIFER MAPPING AND MANAGEMENT PLAN JABALPUR DISTRICT, MADHYA PRADESH

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INTRODUCTION

Central Ground Water Board has pioneered extensive groundwater studies, in all the hydrogeological terrain of the country. It has remarkably brought out comprehensive regional picture of the aquifers in terms of their water quality and yield potential. To meet the challenges of growing groundwater demand and sustainability of the resource, an effective aquifer based groundwater management in the country, through adequate and precise information on aquifers in time and space at a scale as large as possible, is the most imperative and earnestly desired. The aquifer-mapping programme demands for a multi-disciplinary, multi-institutional, innovative and modern approach to arrive at a comprehensive aquifer data base under National Aquifer Mapping Programmer.

1.1 Background of Aquifer Mapping

'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. Out of these the Geophysical technique will help as a strong tool to identify the aquifer geometry precisely.

1.2 Scope of Study

At present a generalized picture of aquifer-dispositions and their characteristics are known from the existing hydrogeological and surface geophysical data, the borehole lithological and geophysical logs and the aquifer performance tests conducted by CGWB and other central and state agencies. But it is not enough to prepare aquifer maps because of the inadequate density of data vis-à-vis geological heterogeneities. The extrapolation and interpolation within the existing boreholes may not yield accurate information on aquifer disposition unless they are tied up further by close-grid geophysical measurements conducted in between. This has necessitated in a systematic mapping of aquifers. Further hydro-geological investigation either by geophysical technique or by exploration is proposed for the aquifer mapping. It is to provide adequate and precise subsurface information in terms of aquifer lithology and geometry leading to 3-dimensional aquifer dispositions. Also it is to establish the most appropriate technique or combination of techniques for identifying the aquifers in different hydrogeological terrains.

1.3 Objectives

The objective of applying the hydrogeological and geophysical techniques is to provide more adequate and more precise (reduced uncertainty and ambiguity) information on aquifers – shallow and deep including dry and saturated zones with their geometry at reasonable scale (1: 50,000) in the area.
The tentative depth of the hydrogeological and geophysical exploration will be 200 m in hard rock area. However, the depth of exploration may vary depending on the geological conditions and requirements. Additional exploratory wells shall be drilled for validations of aquifer parameter estimations where borehole data are not available.

The information thus generated through additional drilling of boreholes shall be used for refinement of hydrogeological data base in terms of aquifer characterization, yield capacity, chemical quality, selecting areas for artificial recharge and sustainability under varied future demand scenario leading to preparations of aquifer-management plans and recommendations to mitigate mining of aquifer.

1.4 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.

1.5 Study Area

Jabalpur district is located almost in the central part of Madhya Pradesh and it is having 15% tribal population to the total population of the district. The deposits of tale around Bhedaghat near the Marble rocks on the Narmda river, about 13 miles west of Jabalpur are the best known. The district lies between the North latitude 22˚49' and 23˚o 07' North and meridian of longitude 79˚21' and 80˚35' East. The district is bounded in the South east and east by Manda & Dindori districts, in the south by Seoni and in the south West Narsingpur district and in the west by Damoh district. The district falls in survey of India Top sheet Nos. 55m, 64A- and 55 N on 1:250,000 scale & occupies an over of 5221 sqkm. The district has been divided in to four Tehsils and seven development blocks (Fig 1). There are 1458 villages, given in Table 1**.**

Table 1 Administrative units of Jabalpur district

S.No.	Tehsil	Block	Area in sq. Km.	No of Villages
1.	Sihora	Sihora Majholi	464 623	151 210
2.	Patan	Patan Shahpura	1004 531	220 224
3.	Jabalpur	Panagar Bargi	706 683	208 242
4.	Kundam	Kundam	1210	189
			5221	1458

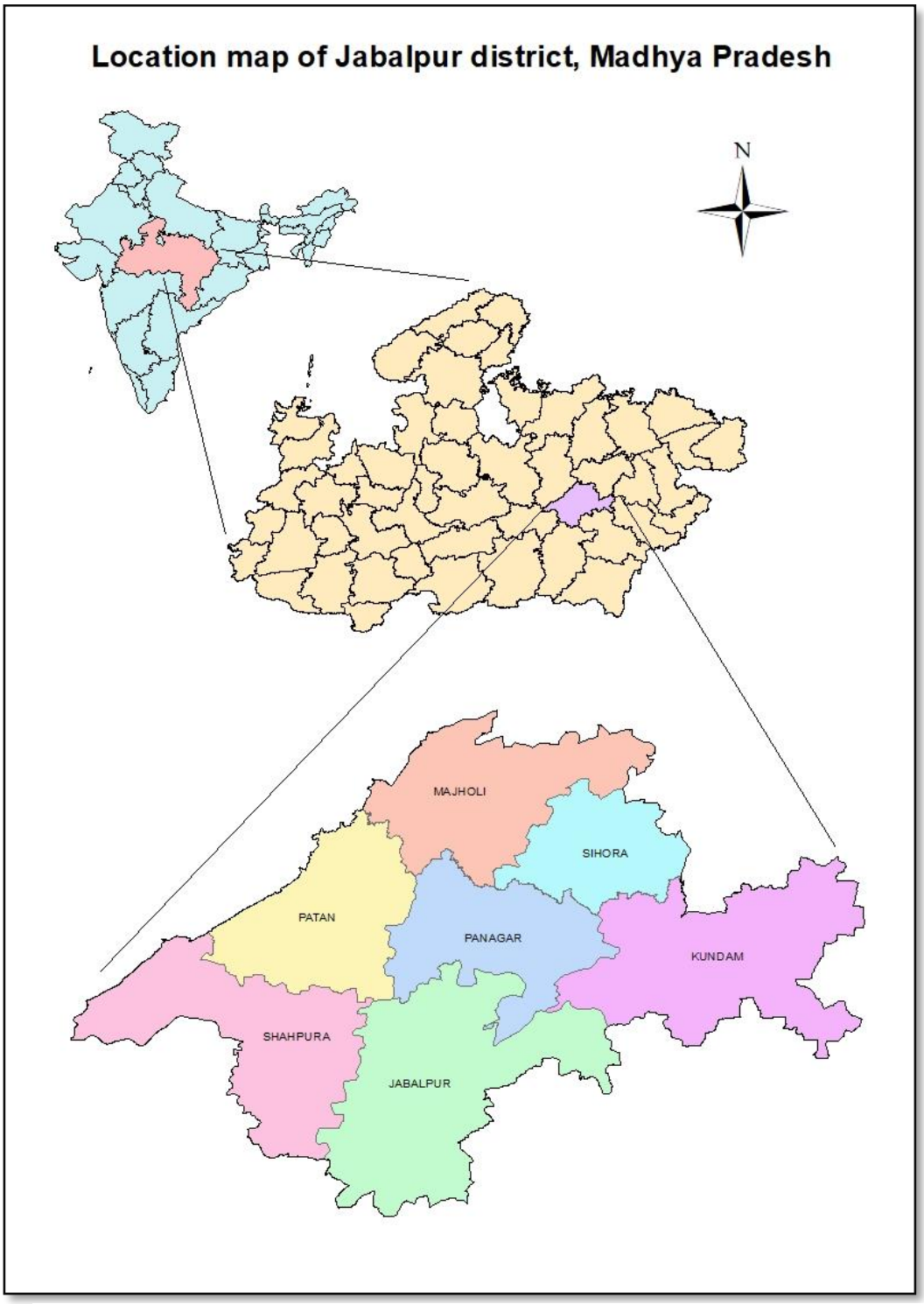


Figure 1 Location map of Jabalpur district

1.6 DEMOGRAPHY

As per 2011 Census, the total population of the district is 2460714 out of which 41.58% belong to rural areas. Sex ratio is 925 in Jabalpur. Total rural population of Jabalpur is 1023255.

Table 2 Demography of Jabalpur district

S.N.	NAME OF BLOCK	NO. OF GRAM PANCHYAT	NO. OF VILLAGES COVERED	MALE	FEMALE	SC	ST	GEN/OBC	TOTAL POPULATION
1	JABALPUR	86	192	85152	78370	18838	51010	93674	163522
2	KUNDAM	68	198	58924	59663	9144	86564	22879	118587
3	PANAGAR	78	208	73403	67873	19482	30580	91214	141276
4	PATAN	76	222	67624	62450	22129	20161	87784	130074
5	SHAHPURA	84	227	92097	86012	25482	45512	107115	178109
6	SIHORA	57	155	69526	66073	19856	27450	88293	135599
7	MAJHOLI	83	222	80305	75783	23947	33510	98631	156088
8	URBAN			751417	686042	243649	181982	1011827	1437459
TOTAL		**532**	**1424**	**1278448**	**1182266**	**382527**	**476769**	**1601417**	**2460714**

1.7 CLIMATE

RAINFALL

The average annual rainfall of Jabalpur District is 1279.50mm. Jabalpur received maximum rainfall received during south west monsoon period i.e. June to September. About 90% of the annual rainfall received during monsoon season. Only 10% of the annual rainfall takes place between October to May period. Thus surplus water for ground water recharge is available only during the south west monsoon period. Average rainfall amount & rainy days & average monthly rainfall (mm) is shown in figure 2& 3.

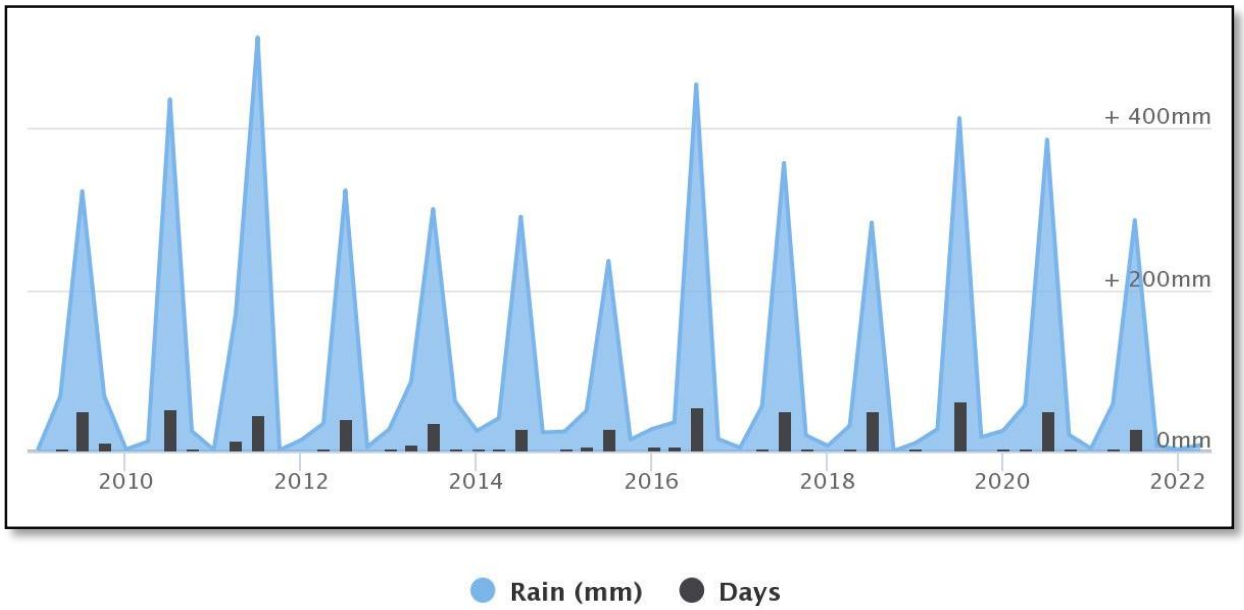


Figure 2 Average rainfall amount & rainy days

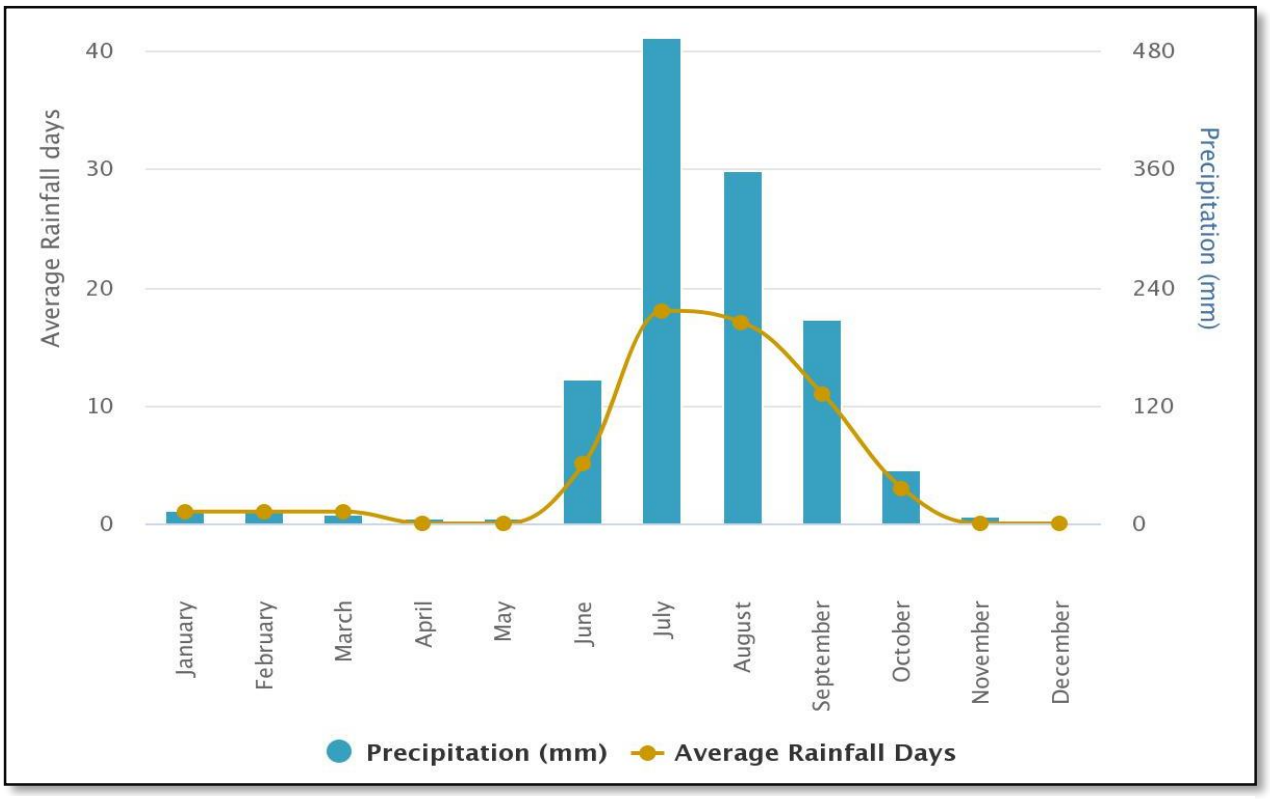


Figure 3 Average Rainfall (mm), Jabalpur district

TEMPERATURE

The climate of Jabalpur district can be divided into four seasons. The winter season commences from end of November and lasts till the end of Feb. The period from March to about the middle of June is the hot

season. The south west monsoon season from middle of June to end of September, October & end of November constitute the post monsoon or retreating monsoon season.

The January is the coldest month of the year. The average normal minimum temperature during the month is about 9.7°C. The individual day temperature comes as low as 1 or 2°C. From March onwards, the temperature starts rising and maximum temperature is observed during the month of May. The average normal maximum temperature is 42°C. The individual day temperature is as high as 46 or 47°C. On the arrival of monsoon the weather becomes pleasant. In October, on the retreating of monsoon the temperature rises slightly during the day time and nights become pleasant. The average annual normal temperature of Jabalpur district is 28.1°C.

Table 3 Average Weekly Temperature

Name of Block	Average Weekly Temperature (°C)								
	Period								
	Summer (April-May)			Winter (Oct.-Mar.)			Rainy (June-Sept)		
	Min.	Max.	Mean.	Min.	Max.	Mean.	Min.	Max.	Mean.
Jabalpur	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65
Panagar	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65
Kundam	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65
Patan	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65
Shahpura	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65
Sihora	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65
Majholi	21.4	42	31.7	9.7	34.5	22.1	23.3	38	30.65

(Source: DIP, Jabalpur, PMKSY)

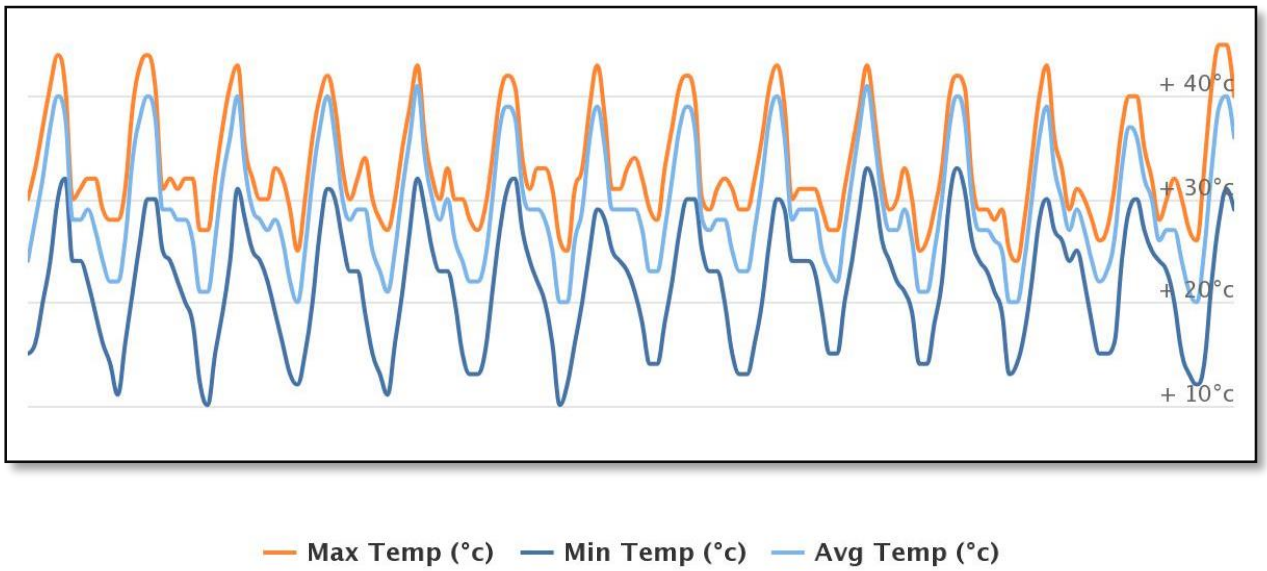


Figure 4 Max, Min & Average temperature

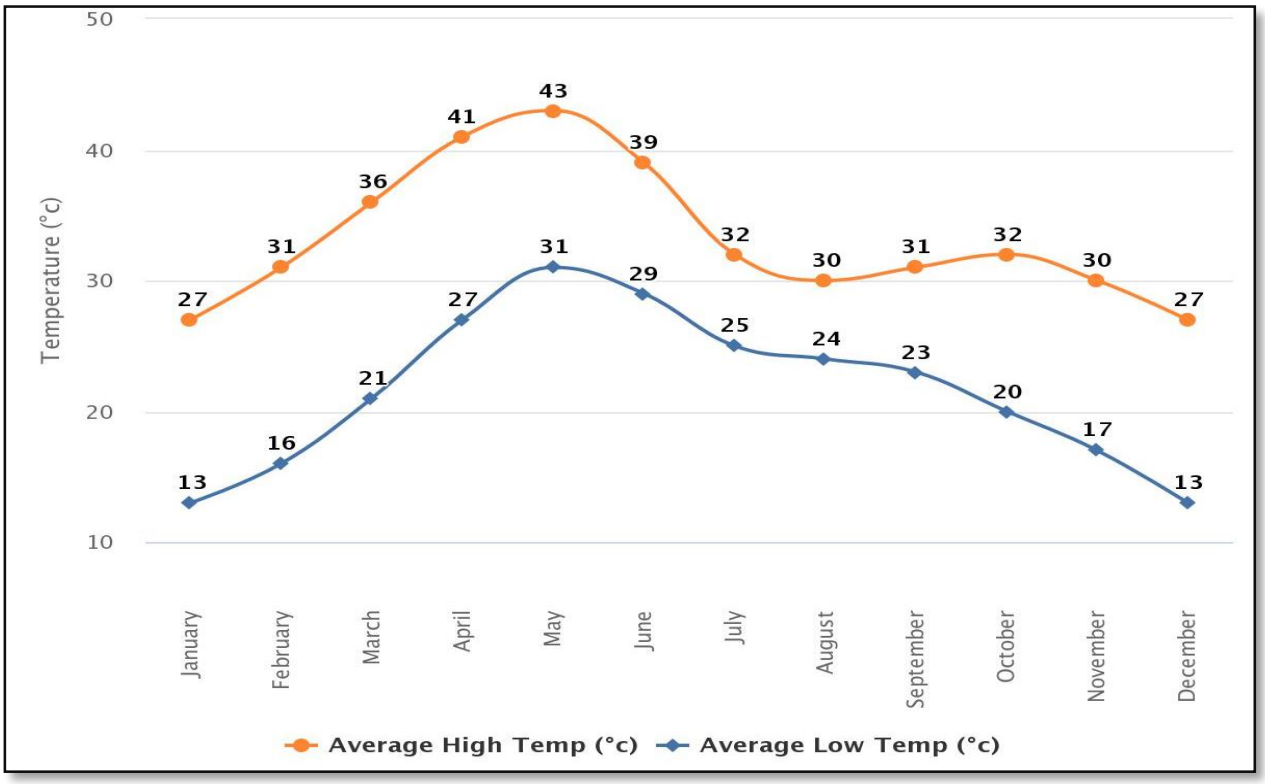


Figure 5 Average temperature (˚C), Jabalpur district

HUMIDITY

During the southwest monsoon the relative humidity is generally high exceeding about 88% in August. Humidity decreases in the post monsoon season. In the cold season it is fairly good over the district. The driest part of the year is the summer season with the humidity going down to 26% or less. May is the driest month of the year.

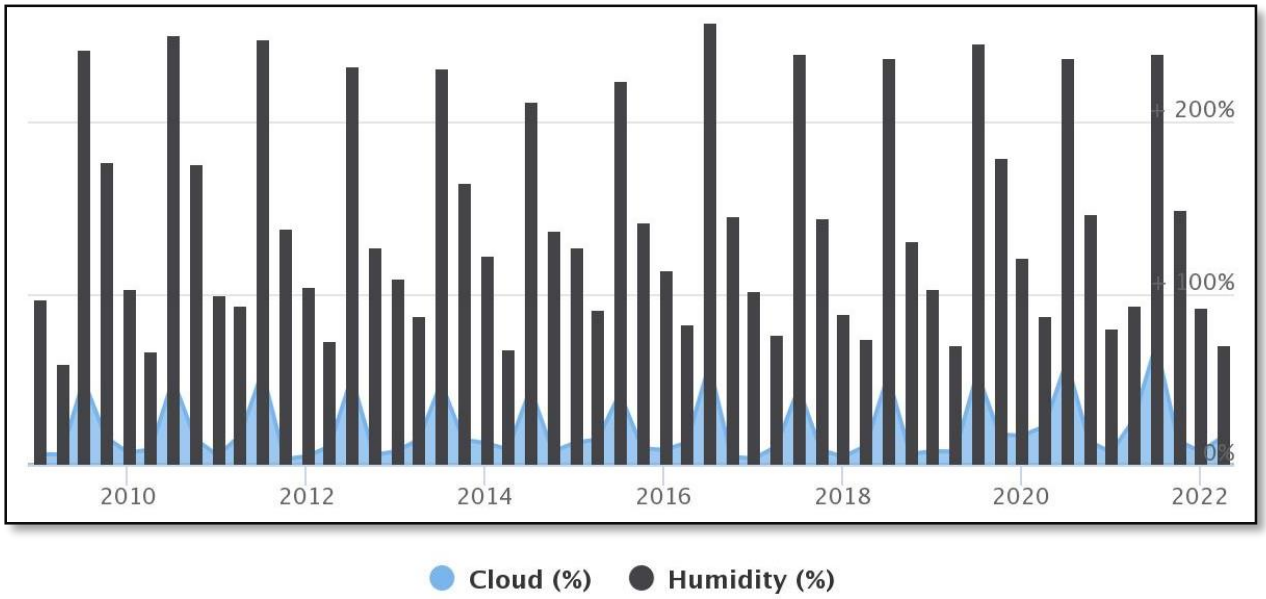


Figure 6 Average cloud & humidity

WIND VELOCITY

The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity 8.6 km/hr observed during the month of May. annual wind velocity of Jabalpur district is 5.3 km/hr.

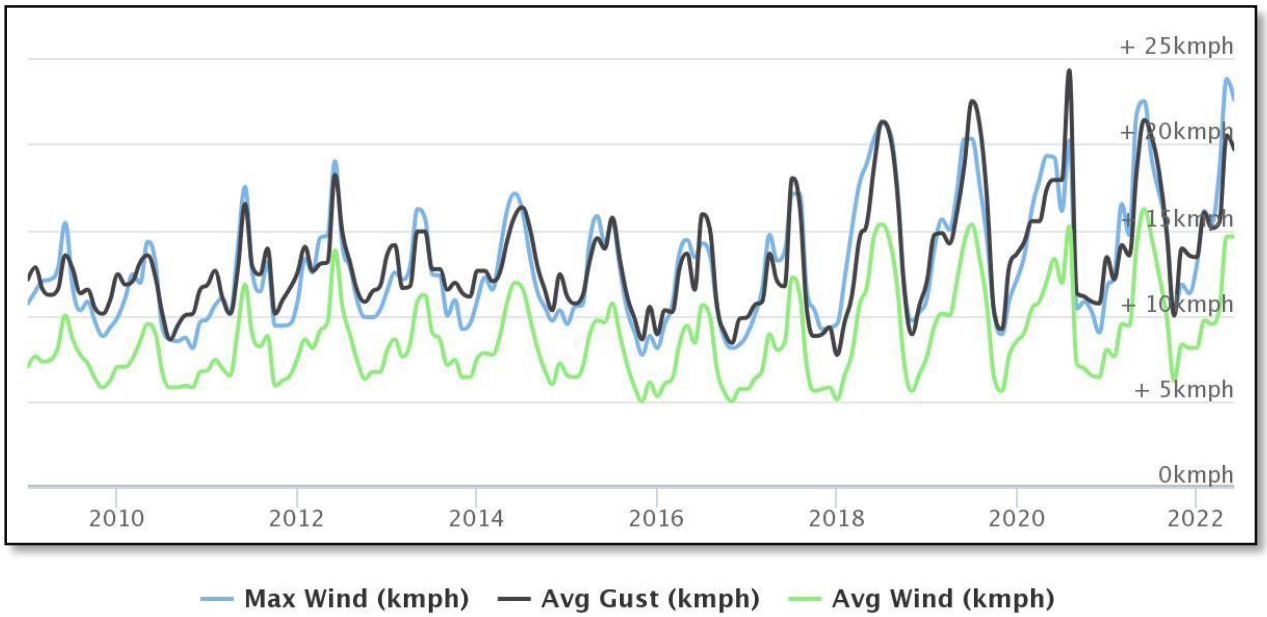


Figure 7 Average & Max wind speed

1.8 GEOMORPHOLOGY

Jabalpur district can broadly be divided in to three physiographic units.

1. The Vindhyan Tract
2. The South eastern plateaus of the Satpura
3. The Bhitright Range & the associated hill area.

The Bhander & Kaimur ranges of Vindhyan System attains & altitude of 530 mamsl & form the western boundary of the district. The Bhander range is in the form of ery abrupt & step scarp & at the foot of this escarpment flows the Hiran river.

The south eastern plateans of satpura are cut across by the Namada its south of Jabalpur & Deccan carps farming flat topped hills cover the whole area of satpuras in south east. The general height of table land is 460 mamsl south of Narmada & about 535 mamsl east of Jabalpur.

The Bhitrigarh range & associated hill area run across the northern part of the district from south west to north east. It consists of metamorphic rocks & meets the spur of satpuras at almost right angle. These have general elevation of 460 to 550 mamsl.

The range forms the watershed between the catchments of Hiran in the south & Katni in the north. Between the high lands of vindhyans in the west & Satpuras in east is low lying alluvial plain farmed due to Narmada & Hiran rivers & is called as the ‘Haveli’.

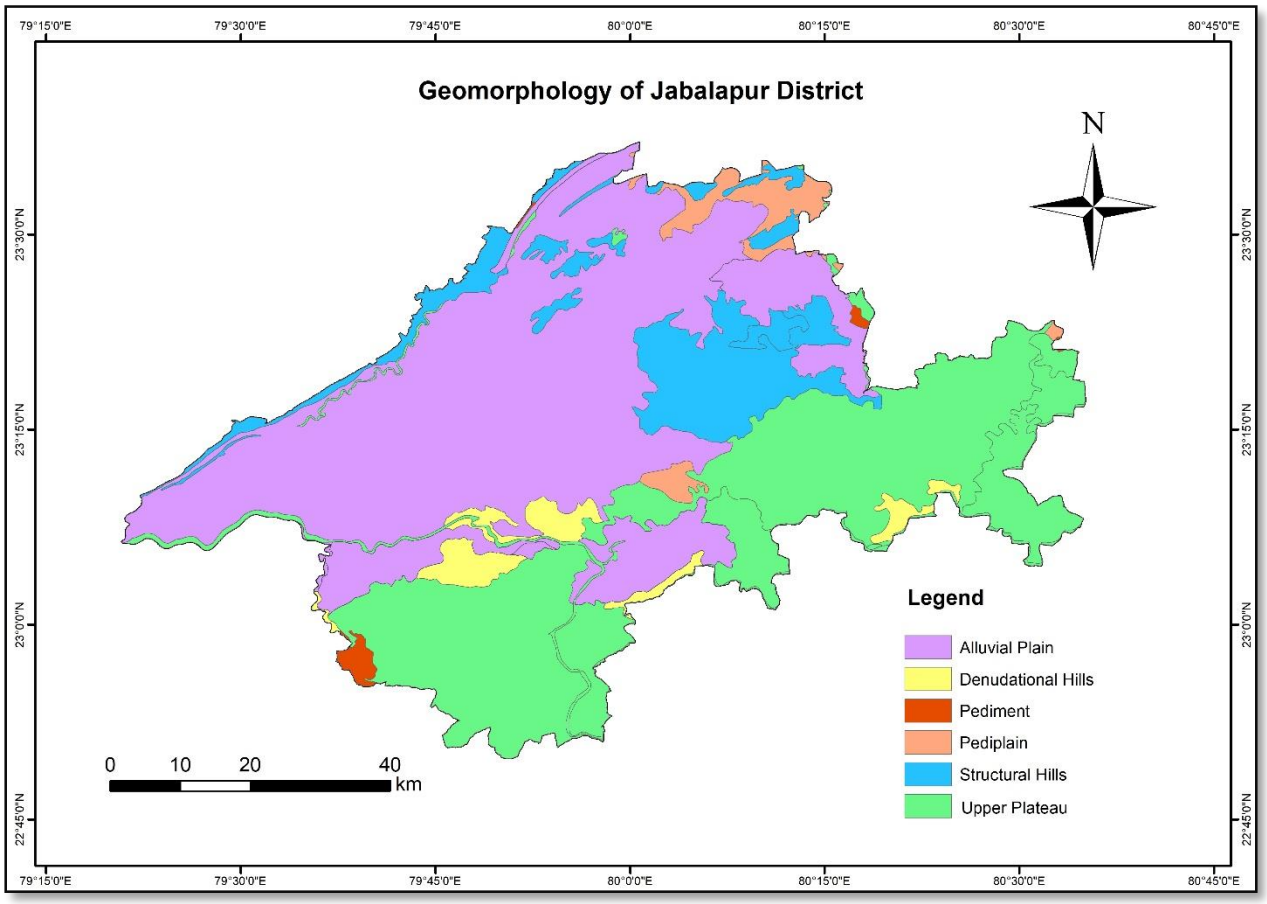


Figure 8 Geomorphology map of Jabalpur district

1.9 SOIL COVER

Jabalpur district is covered by three types of soils –

1. The loam to sandy loam confined to the river courses of the Narmada & Hiran falling in Shahpura & Patan blocks.
2. Medium black soil covering Kundam, Bargi, eastern parts of Shahpura, Panagar & Sihora blocks.
3. Deep block soil covering Shahpura, Patan & Sihora blocks. In the Narmada valley, the block soil is composed mainly of clay & silt washed down by rivers.

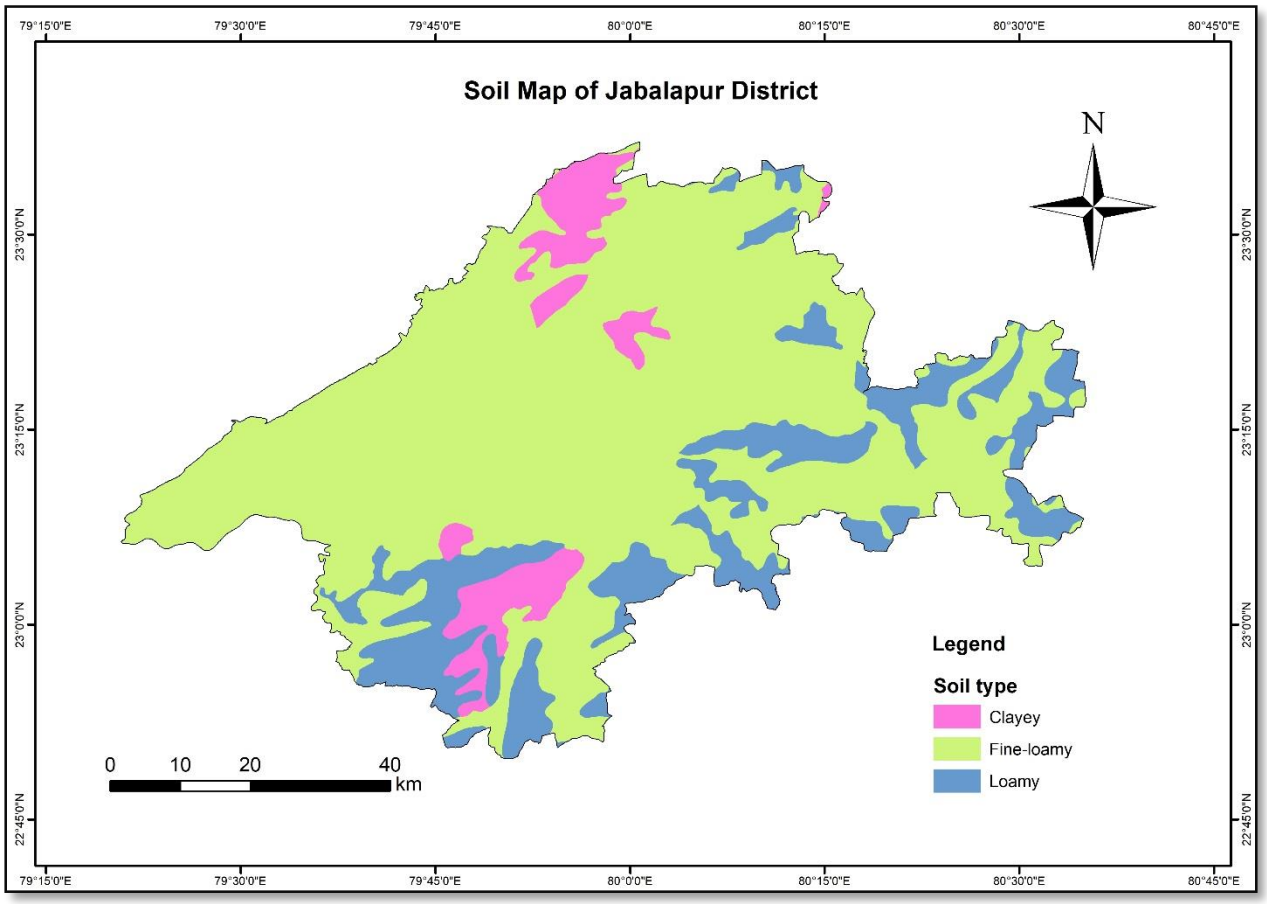


Figure 9 Soil map of Jabalpur district

1.10 GEOLOGY

The district is often called as the Museum of Geology. It exhibits very wide spectrum of rocks, ranging in age from Archaean to Pleistocene and recent period.

The **older metamorphic rocks** comprising of granite gneiss with enclaves of amphibolite and schist, are exposed in the central part of the district.

The volcano-sedimentary sequence of **Mahkoshal group**, trending in ENE-WSW direction, is exposed in the central and SW parts of the district. It comprises metavolcanic rocks, chemical precipitation and turbidites.

Dolerite dykes, amphibolites, granites and quartz veins intrude these rocks. These intrusives exhibit a peculiar ENE-WSW trend. The intrusive **Madan Mahal granite** occurs in the form of inselberg and conical hills near Jabalpur.

Vindhyan supergroup is represented by Kaimur, Rewa and Bhander groups which consist of sandstone, shale and glauconitic partings occur in the northern plateau and form of steep escarpments.

Gondwana supergroup is represented by Jabalpur group and comprises of alternate beds of course and pebbly sandstone and clay and are exposed in the east, central and SW parts of the district. The plant fossils are found within them**.**

Lameta group comprises of green glauconitic sandstone, grit, nodular siliceous limestone and clay in the SC parts of the district. Remains of Dinasaur fossils are encountered within it.

Deccan trap Basalt form extensive plateau in the southern part and comprises of 14 to 22 flows.

The **quarternary sediments** comprise mainly of clay and cacareous concretions.

Tight isoclinal folding of Mahakoshals, intense deformation of Vindhyans along its contact with Mahakoshals and general broad shallow synclinal uctures of Vindhyans are highlights of the structural features. The region is a part of Cruamansonata zone and exhibit a regional trend of ENE- WSW. The contact between Mahakoshals is faulted all along. It is intersected and interveined by no. of minor faults and microlineaments which trend in NNW-SSE to NW-SE direction. For A detailed geological set up and geological map of Jabalpur, please refer District Resource Map of Jabalpur district, published by Geological Survey of India A concise account of geological set up of the district is given below.

Table 4 Geological succession of Jabalpur district

Pleistocene to Recent	Recent		Alluvial soil Laterite
Upper Cretaceous to Eocene	Amarkantak group		Sills and dykes and flows of Deccan Trap Basalt and intertrappeans
Upper Cretaceous	Lameta group		Sandstone, clay, siliceous limestone and grit
Cretaceous to Carboniferous	Jabalpur group (Up. Gondwana)		Sndstone, clay, shales with thin coal seams
Neo to Meso Proterozoic	Vindhyan supergroup	Bhander	Sandstone, shales, siltstones
		Rewa	
		Kaimur	
Palaeo-Proterozoic	Intrusives		Quartz vein, Basic dykes, granite
	Mahkoshal group		Quartzite, BHQ/BHJ, conglomerate,chert breccia, phyllite, dolomite
Archaean			Granite gneiss with enclaves of amphibolites and schists

(District Survey Report, Directorate of Mining)

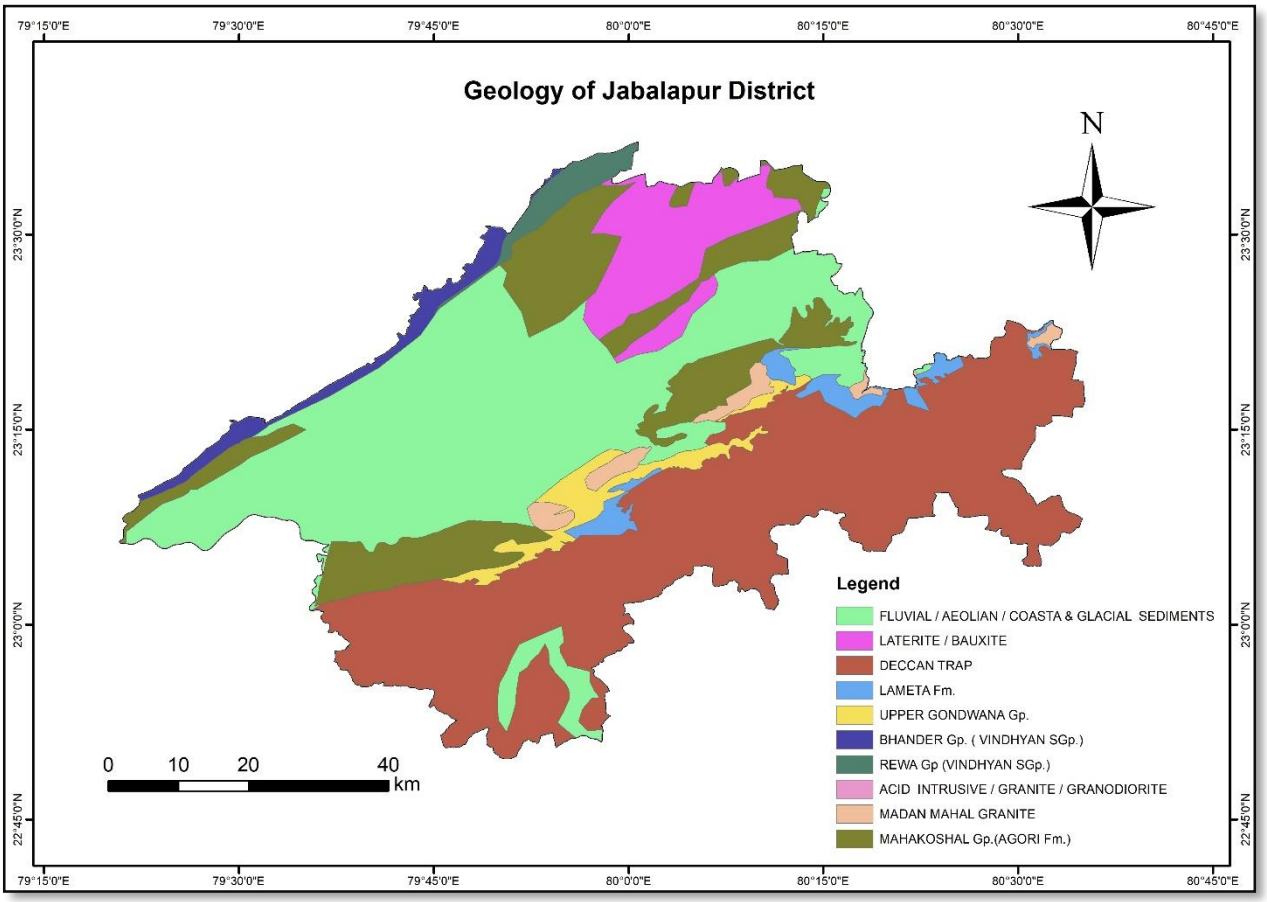


Figure 10 Geology map of Jabalpur district

1.11 DRAINAGE

The district is very fortunate in the sense that it is drained by Narmada in the SW part and its tributaries Hiran, Gaur, and Pariyat in the central and northern parts of the district. The whole area is a part of Great Narmada basin. The important rivers and streams of the district are briefed here:

Narmada River: it is the principal river of the district. It originates from Amarkantak (Lat. 22o 40' N and Long. 81o 46'E) in Anuppur district and enters the district through Mandla from the south at the trijunction of Jabalpur, Mandla and Seoni districts. A large size capacity "Bargi Dam" is constructed on this river for irrigation and electrification. In the district, the river persues a northerly course for 50 km across Satpuras and turns westerly near its confluence with Gaur (one of the right bank tributary). It forms a gorgeous "Dhuandhar Fall" of 30'. Thereafter, the river passes through the famous gorge of marble rocks of Bhadeghat. Beyond this, the river enters a plain and traverses the southern part the district and leaves the district atSankal after the confluence with Hiran river and also forms boundary with Narsinghpur district. The total length of river in the district is about 120 km. it enters the district through basaltic terrain and flows through Vindhyans and Gondwanas.

Hiran river: it is the 2nd most important river of the district and the principal right bank tributary of Narmada river in the district. It originates near Kundam (23o 19'N-80 o21'E) near the SE boundary of the district. It takes a northerlyu course for about 50 km through basaltic terrain and turns towards west and flows to Katangi through a zigzag course crossing from south of Sihora and Patan. From this point, it takes a SW direction and merges with Narmada between Sankal and Hirapur. Its main feeder streams are

Belkund, Sohar, Kair nala (from the north) and Kadri and Pariyat (from the south). Amongst them, Pariyat is the principal affluent one. The river is about 190 km long.

Gaur River: it originates near Niwas in Mandla district and forms the boundary with Mandla district for some distance. It runs towards north initially and then turns SW and join river Narmada in the right bank at about 12 south of Jabalpur. The total length of river is about 80 km of which about 50 km is in the district.

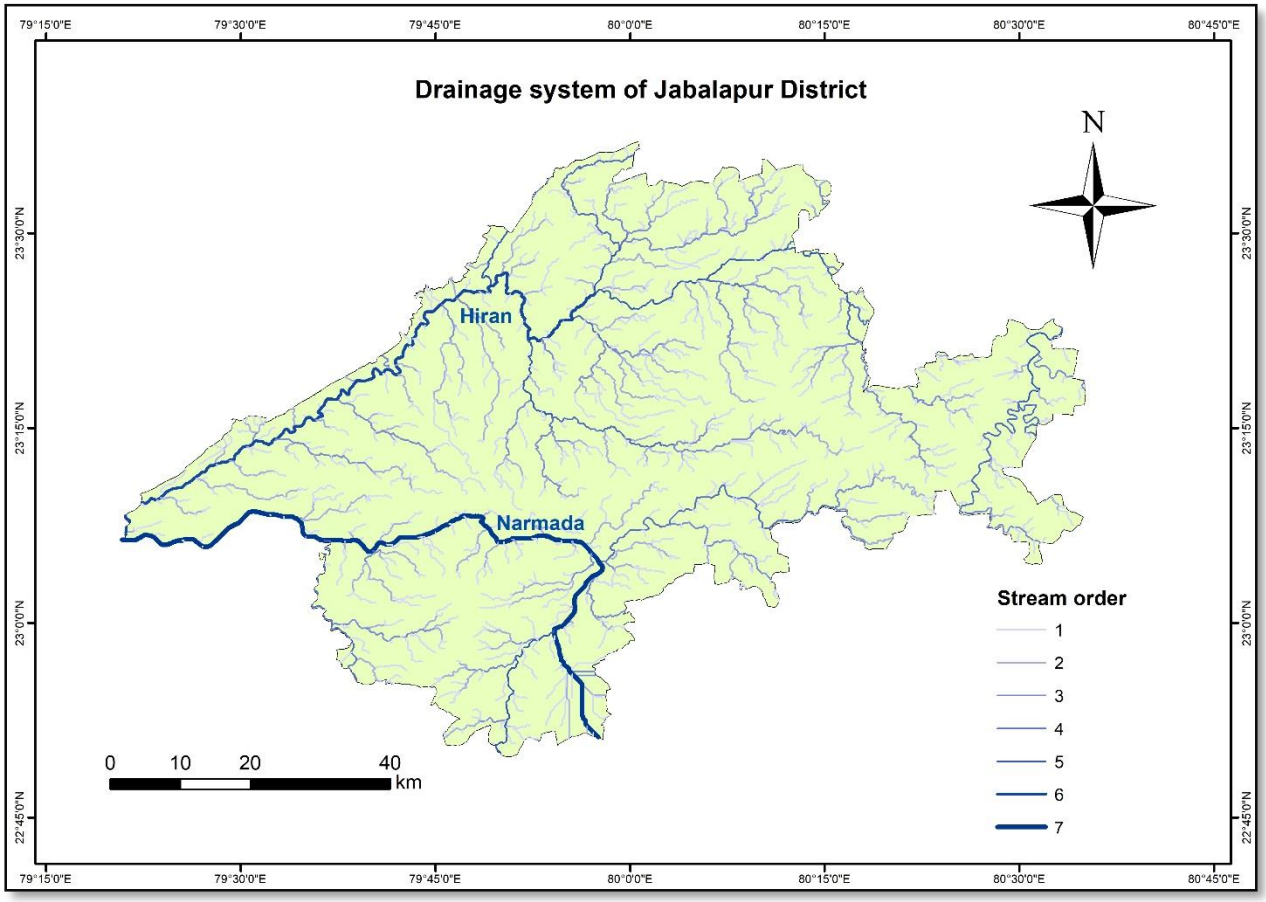


Figure 11 Drainage map of Jabalpur district

1.12. LAND USE

As per the district statistical handbook 2013, the total area of Jabalpur district was 519757 hectares (ha). Out of which, agricultural area is 272399 ha (52%), 52230 ha (10%) is under forests. 27840 ha (5%) is under waste land and 167288 ha (32%) is under other uses.

Table 5 Land use pattern of Jabalpur district

S no	NAME OF Block	TOTAL GEOGRAPHICAL AREA	GROSS CROPPED AREA	NET SOWN AREA	AREA SOWN MORE THAN ONCE	AREA UNDER FOREST	AREA UNDER WASTE LAND	AREA UNDER OTHER USES
1	JABALPUR	117022	43023	32927	10096	29100	5360	49635

2	KUNDAM	104243	49083	35068	14015	17652	15734	35789
3	PANAGAR	46458	45139	28297	16842	0	2718	15443
4	PATAN	60733	88863	49722	39141	1633	397	8981
5	SHAHPURA	81549	88227	55906	32321	428	1861	23354
6	SIHORA	49268	44486	28158	16328	2801	1178	17131
7	MAJHOLI	60484	72272	42321	29951	616	592	16955
	TOTAL	519757	431093	272399	158694	52230	27840	167288

(Source: Source: DIP, Jabalpur, PMKSY)

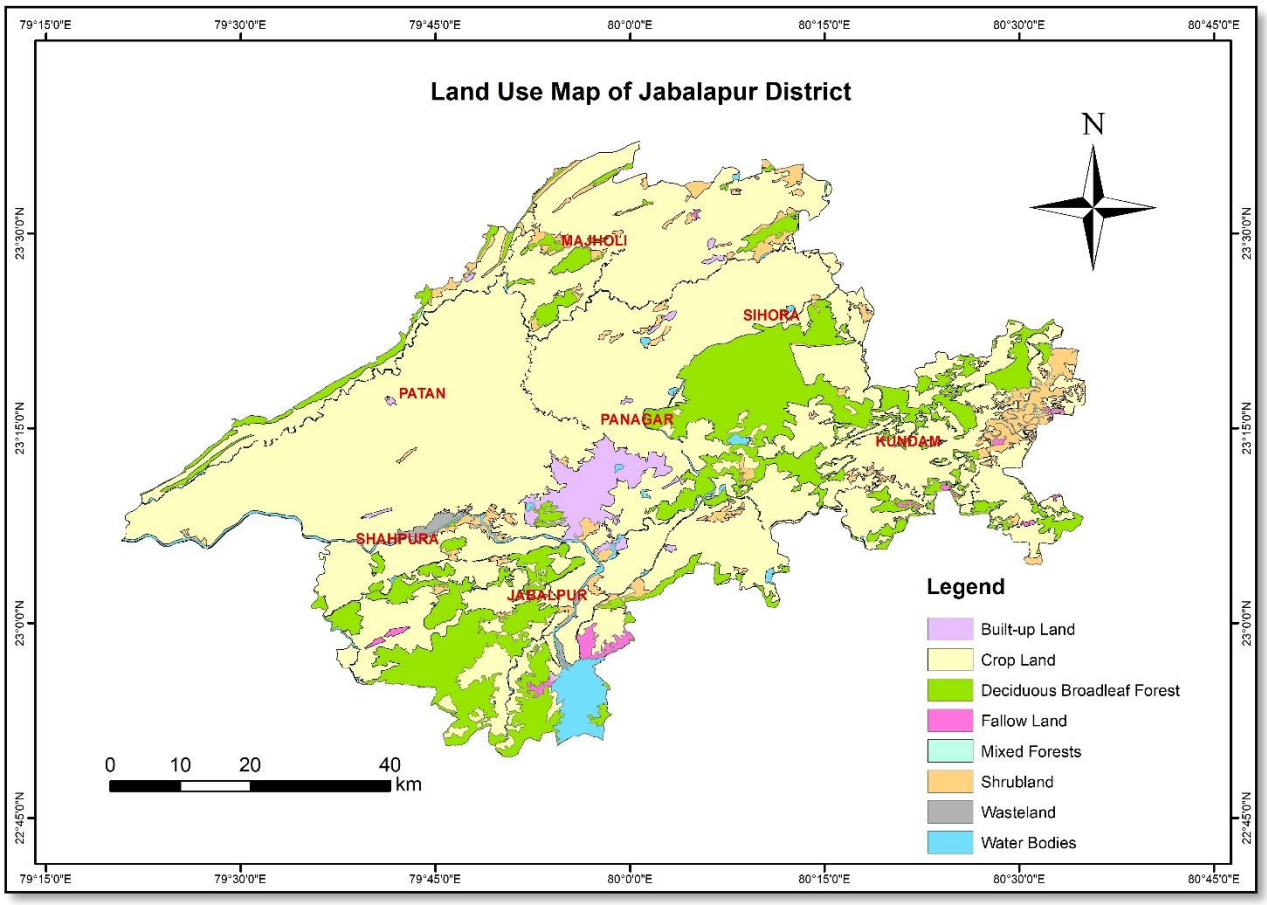


Figure 12 Land use map of Jabalpur district

1.13 IRRIGATION

The area irrigated by bore wells was 81500 ha (61.1% of the total irrigated area), by open-wells 26100 ha (19.5%), irrigated by canals was 9400 ha (7.05% of the total irrigated area) and by tanks 100 ha (0.08%). The total area under assured irrigation from various sources was only 133200 ha. This was 48.9% of the net sown area. Around 51.1% of the sown area in the district is dependent on rain-fed irrigation.

Table 6 Sources of Irrigation

Sources of Irrigation	Number	Area ('000 ha)	Percentage of total irrigated area
Canals	56	9.40	7.05
Tanks	36	0.1	0.08
Open wells	8010	26.1	19.5
Bore wells	8832	81.5	61.1
Lift irrigation schemes	NA		
Micro-irrigation	NA		
Other sources (Reservoir)	853	16.10	12.08
Total Irrigated Area		133.2	

1.14 AGRICULTURE

In kharif mainly rice, blackgram, kodo-kutki, pigeonpea, niger, maize & sorghum are cultivated, and in rabi wheat, chickpea, lentil, pea, mustard & linseed are grown prominently.

Mainly potato, onion, ginger, chilly & garlic etc. are grown under horticultural vegetable crops. crops. Mango, guava & orange are the main horticultural fruit crops.

Major crops cultivated in the district are shown in table 8:

Table 7 Major crops

Crop season	Major Crops cultivated	Area ('000 ha)
Kharif	Rice	60.2
	Blackgram	28.1
	Kodo-Kutki	11.5
	Pigeonpea	8.1
	Niger	6.0
	Maize	5.0
	Sorghum	4.3
Rabi	Wheat	88.6
	Chickpea	66.2
	Lentil	40.1
	Pea	36.4
	Mustard	03.9
	Linseed	02.5

(Source : Agriculture Contingency Plan, Jabalpur, NICRA-ICAR)

Chapter-2
DATA COLLECTION AND GENERATION

2.1 DATA AVAILABILITY

The compiled data were plotted on a 1:50000 scale map, and analysis of the data gap was carried out. The available data of the Exploratory wells drilled by Central Ground Water Board, North Central Region, Bhopal, Geophysical Survey carried out in the area, Ground water monitoring stations and ground water quality stations monitored by Central Ground Water Board were compiled and analysed for adequacy of the same for the aquifer mapping studies. The summarized table presenting the data requirement, data availability, and data gap analysis is presented in the following table.

Table 8 Data requirement & data availability

S.No	Items	Data Requirement	Data Availability
1	Rainfall Data	Meteorological stations spread over the project area.	worldweather.com
2	Soil	Soil map and Soil infiltration rate	Prepared in ArcGIS
3	Land Use	Latest Land Use Pattern	Prepared in ArcGIS
4	Geomorphology	Digitized Geomorphological Map	Prepared in ArcGIS
5	Geophysics	Geophysical data in each Quadrant	
6	Exploration Data	EW in each Quadrant with Aquifer Parameters	Exploratory wells along with aquifer parameters are available
7	Aquifer Parameters	Aquifer parameters for all the quadrants	
8	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters are given in Ground Water resource estimation
9	Discharge Parameters / Draft Data	Discharge parameters for different GW abstraction structures	Discharge parameters are given in Ground Water Resource Estimation GEC 2020
10	Geology	All the maps on a 1:50000 scale	Prepared in ArcGIS

2.2 DATA COLLECTION AND GENERATION

Data on all the attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis. The data generated and data collected from various state governments agencies is summarized in the table.

Table 9 Data generated & data collected for Aquifer Mapping

S.No	Items	Data Generated	Data Collected
1	Rainfall Data		worldweather.com
2	Ground Water Exploration		
3	GW Regime Monitoring	43 Key wells & 39 NHS	Not Available
4	Chemical Quality	58 Samples of Naquim in 2022 and 33 samples of NHS in 2022.	

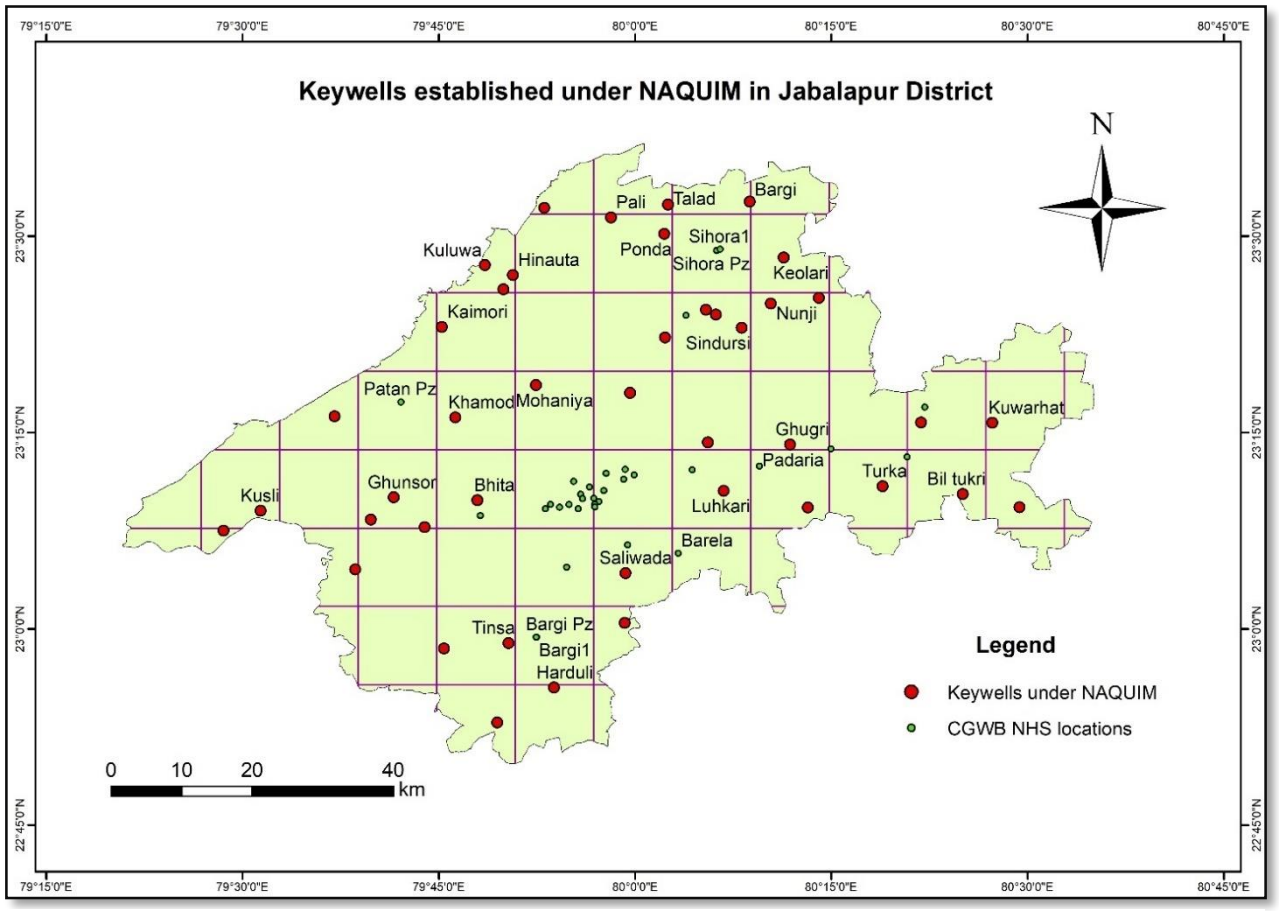


Figure 13 Key observation wells established under NAQUIM

43 nos. of groundwater samples were collected for analysis of basic parameters & 15 nos. of samples were collected for analysis of heavy metals in groundwater from handpumps, dugwells & borewells in the pre-monsoon season under NAQUIM. The groundwater sampling locations are shown in the fig 14.

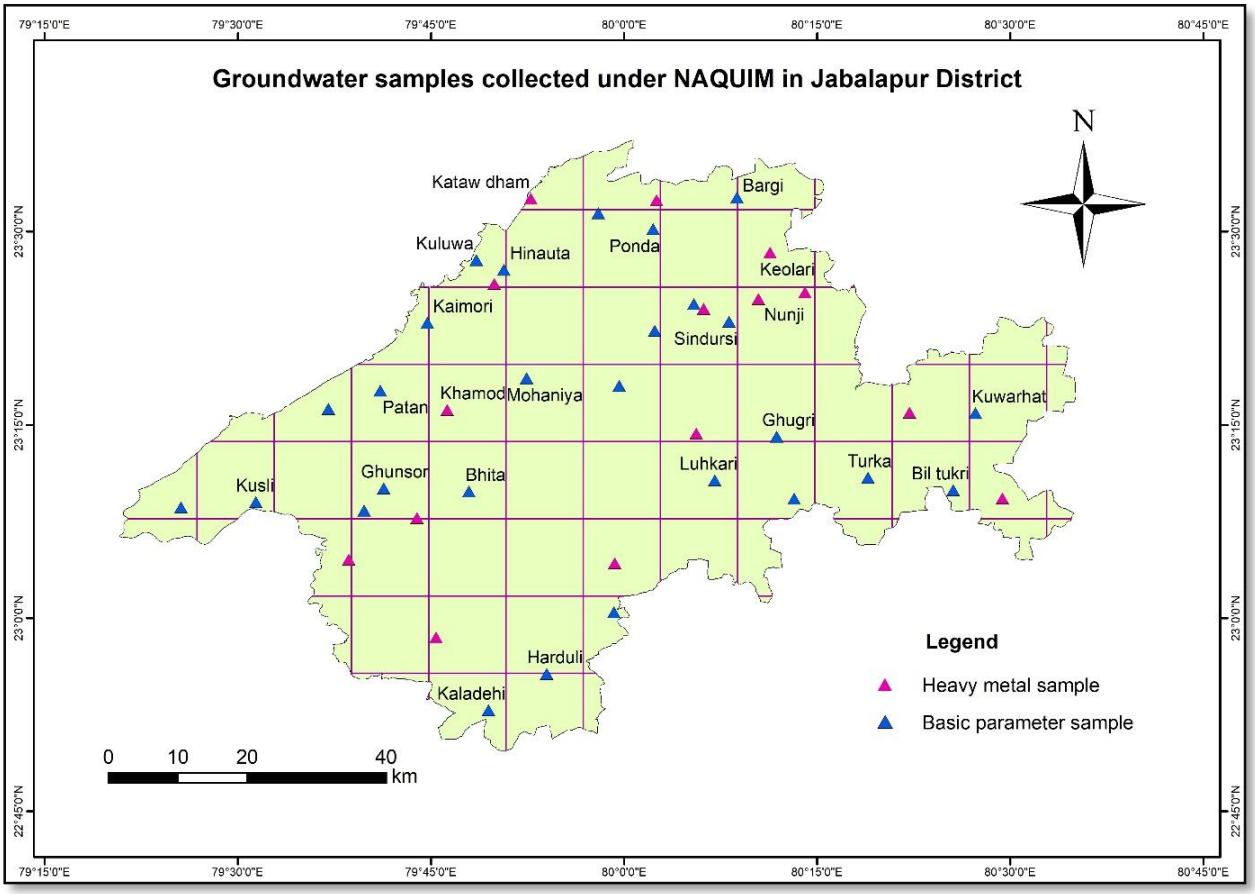


Figure 14 Ground water samples collected under NAQUIM

Figure 15 Sample collection from handpump

Figure 16 Samples preserved at 5˚C in chemical laboratory at CGWB, NCR, Bhopal

2.3 Hydrogeology

Description of rocks and their water bearing properties

District Jabalpur is a home of geology since formations ranging form lower proterozoic to Pleistocene age are exposed in the area different types of aquifers are formed by these rocks in the area main geological units of the area are Archeans, Gondwana, Lameta, Deccan Trap and Narmada alluvium. Occurrence & movement of ground water in hard rocks is mainly controlled by secondary porosity through Joints & fractures. Primary porosity in Gondwana sand stone & vesicular basalts in Deccan Traps play are important role in ground water movement. Lameta are also forming potential aquaifers made up of relatively loose & friable shale & sand stone. Ground water in general occurs under unconfined; Semi confined & confined conditions. The occurrence & movement of ground water in different geological formations in described below.

Mahakoshal Group : These formations consisting of quartzite's, shale, state and marble are hard, compact, recrystallized and have no primary porosity. There form poor aquifers. However, limestone's at places have solution cavities, which give rise to very high secondary porosity & permeability. The limestone formation is encountered at Patan at depth of 55mbgl yielded 41 lps of water for 5.36 meters of draw down.

Granites : Granites and granitic gneisses exposed mostly in and around Jabalpur town. These formations are quite hard and generally devoid of primary porosity. However, due to weathering of the top mantle, secondary porosity and permeability has developed which supports dug-wells. The joints and fractures close down after a depth of 40 to 50 meters. Ground water occurs under water table conditions and the tube wells in this formation, though very few, can sustain a maximum discharge of about three lps for appreciable draw downs. The yield of open wells ranges between 20 to 100m3/day.

Vindhyans : These are mostly sandstones belonging to the lower vindhyans and are devoid of any primary porosity. However, due to weathering, fracturing and jointing, the top portion of the formation behaves as a phreatic aquifer due to development of secondary porosity. These formations can thus support very low yielding open wells.

Gondwanas : These are sedimentary formations and are rich in granular zones forming moderately potential aquifers. Gondwana sandstones support both tube wells and dug-wells capable of yielding up to ten LPS of water for moderate drawdowns. The exploratory well at Bijna Magarmuha tapping alluvium and Gondwana sandstone yielded 8.5 LPS of water for a drawdown of 6.5 meters. Verma (1998) has reported that there is a cluster of dug-cum-bore-wells near village Rithari (230 14':800 03') and that each well has a command area of 8 to 16 hectares. The depth of these wells is upto 35 meters. The discharge of wells near pariyat tank is about 150 m3/day.

Lametas : These are infratrappean formations in which the top limestone, which is hard, compact and siliceous, is underlain by sandstone. The limestone are poor aquifers. However, the sandstones are semi-consolidated and have primary porosity also. However, these have a limited thickness of 8-10 meters and have poor to moderate permeability's. The Lametas overlying the Gondwanas and the Lameta-Gondwana contract can be explored for moderately potential aquifers.

Deccan Traps : Deccan trap form the most important formation in the district due to their large aerial extent. The weathered, jointed, fractured, and vesicular units of basalt form moderately potential aquifers. The zeolitic basalt in weathered form also makes good aquifers. The red bole bed, which is predominantly clay, is non-productive. These formations have highly variable yields, being higher in dug-wells. The yields range between 10 and 75 m3 /day. It has been observed that the yield increases substantially when bores extending down to the lower vesicular zone are drilled at bottom of the dug-wells.

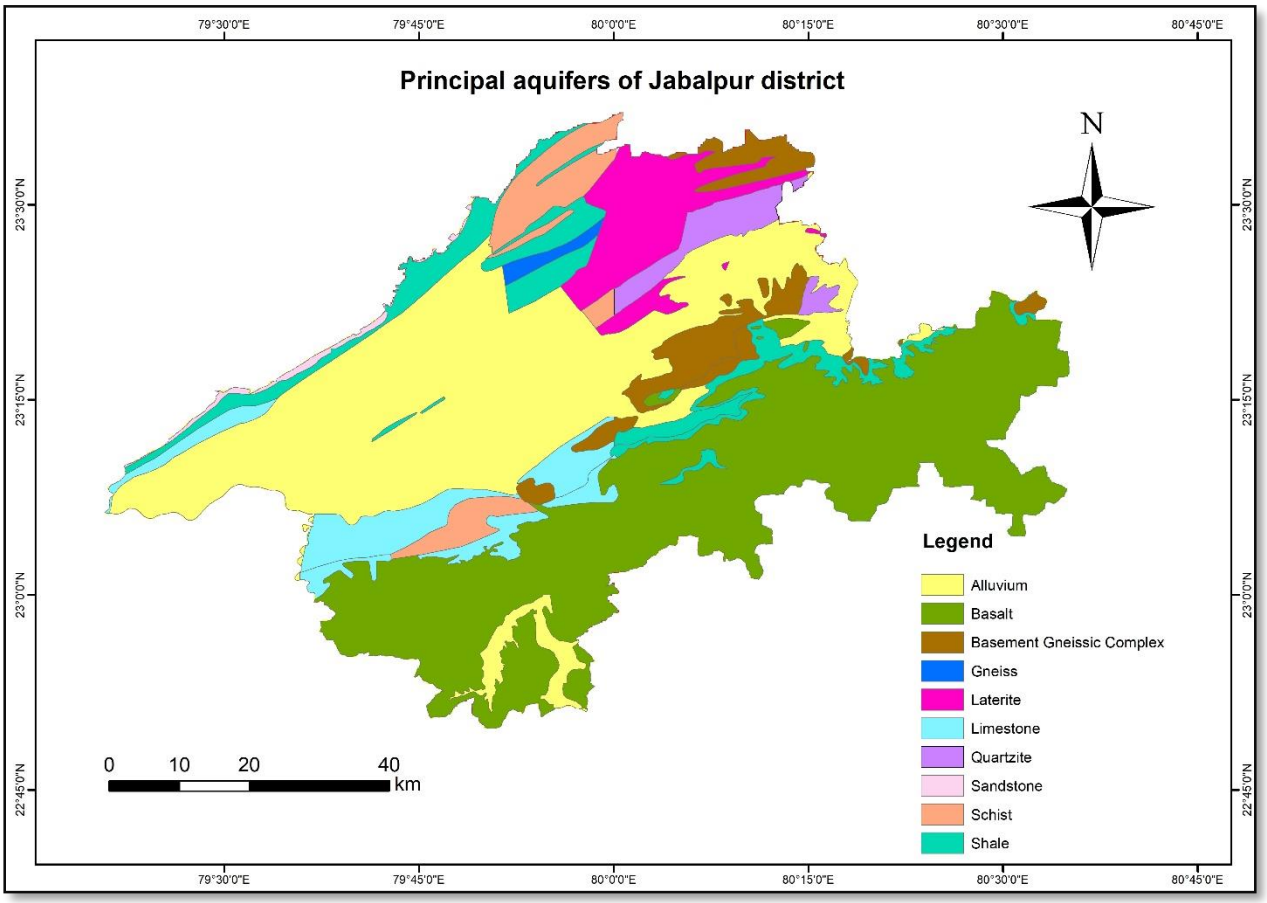


Figure 15 Principal aquifers of Jabalpur district

2.4 Ground water scenario

(ii) Water Levels

Water level data, including historical data are essential for not only to know the present ground water conditions but also for forecasting future trends in response to ground water reservoir operations. There are 39 monitoring wells of CGWB in Jabalpur district. Using the water level data of key observation wells monitored under NAQUIM, pre monsoon depth to water level map is prepared.

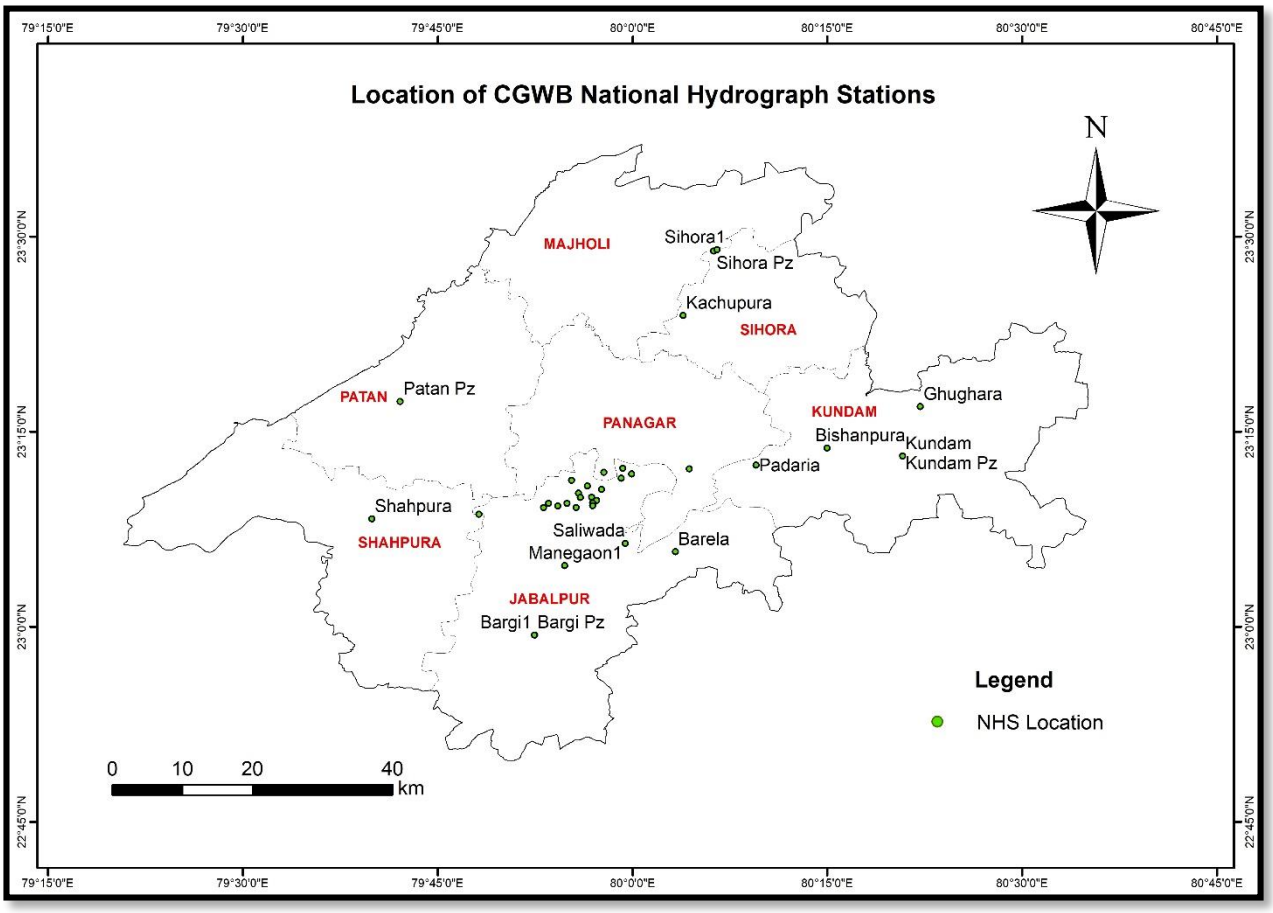


Figure 16 Locations of CGWB National Hydrograph stations

Pre Monsoon (June 2022)

Pre-Monsoon depth to water level in the year 2022 range from 0.9 mbgl at Ghugri to 20.12 mbgl at Sihora pz. Very shallow water level (0-2 mbgl) occur in few locations in Kundam block. Shallow water level (2-5 mbgl) occur majorly in Kundam block & in few places in Shahpura block. Medium water levels (5-10 mbgl) covers the most part of the district particularly Patan, Panagar, Shahpura & parts of Kundam, Jabalpur, Bargi blocks. Deep water levels (10-20 mbgl) occurs in Sihora, Majholi & parts of Bargi block. Pre-monsoon depth to water level map is shown in Fig.

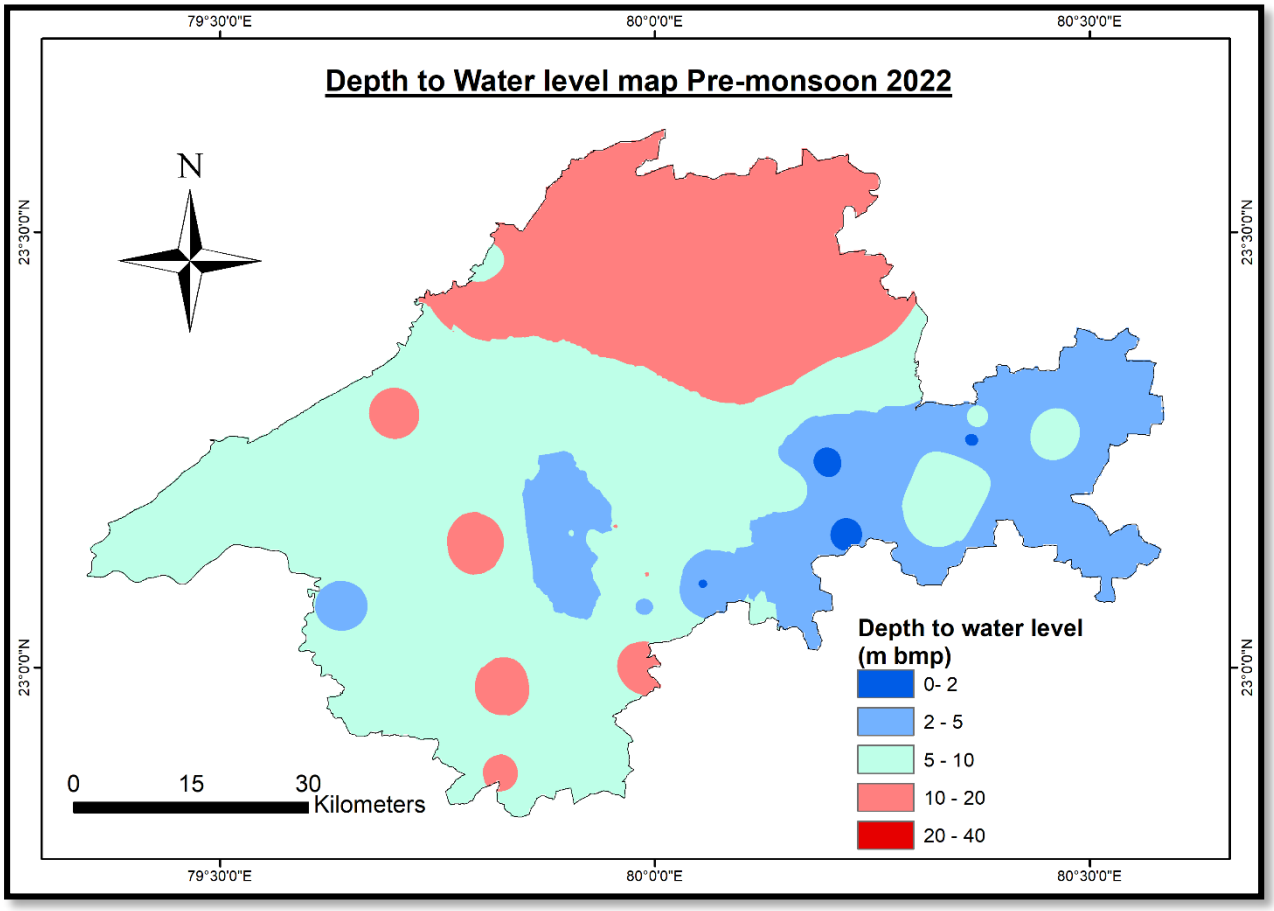


Figure 17 Pre-monsoon (2022) depth to water level map

Post Monsoon (Dec 2022)

Post-Monsoon depth to water level in the year 2022 range from 0.8 mbgl at Ghugri to 15.08 mbgl. Very shallow water level (0-2 mbgl) occur in few locations in Kundam block. Shallow water level (2-5 mbgl) occur majorly in Kundam, Panagar & parts of Bargi, Shahpura, Sihora, Majholi blocks. Medium water levels (5-10 mbgl) covers the most part of the district particularly Patan, Shahpura & parts of Kundam, Jabalpur, Bargi blocks. Deep water levels (10-20 mbgl) occurs in Sihora, Majholi & in few locations of Bargi, Patan blocks. Pre-monsoon depth to water level map is shown in Fig.

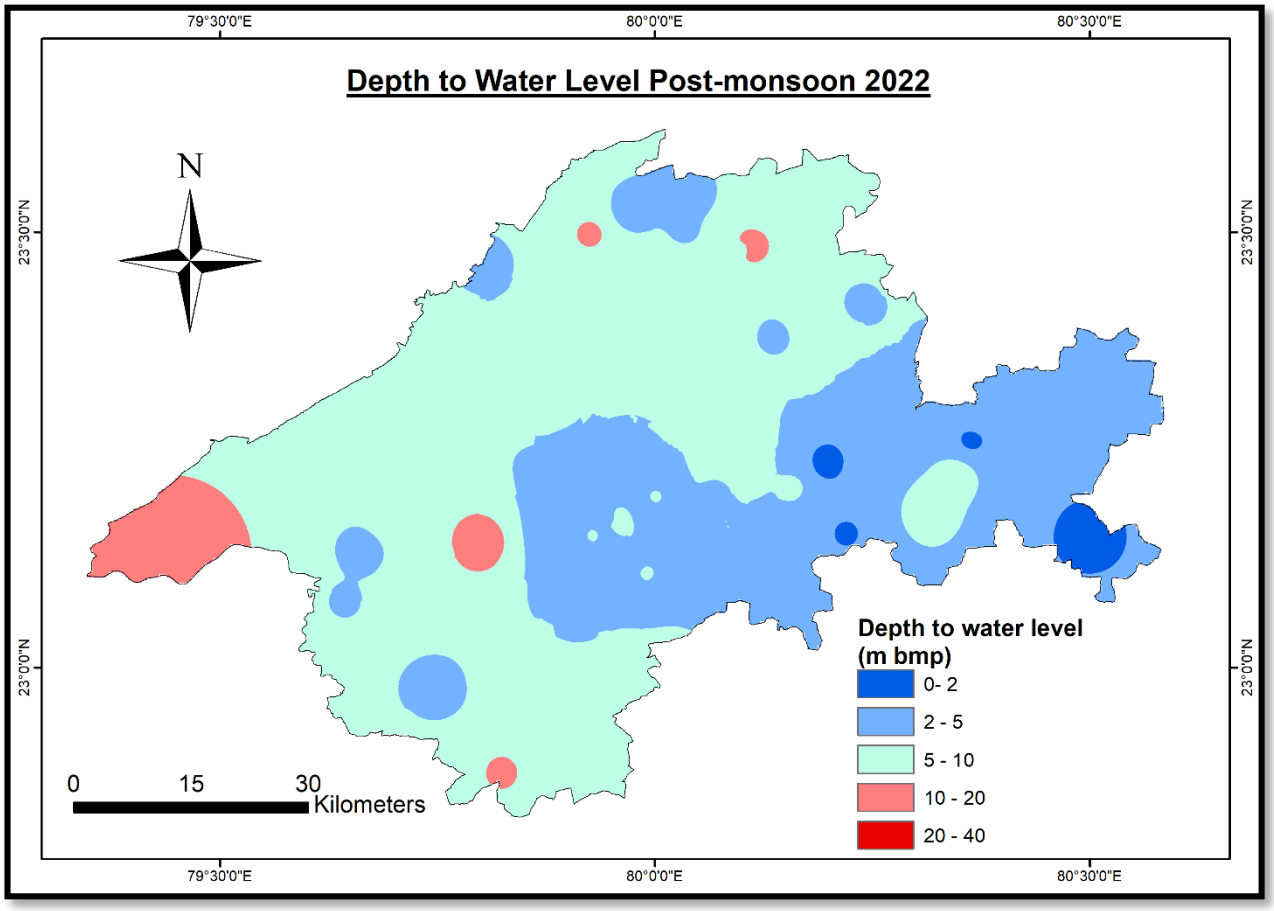


Figure 18 Post-monsoon (2022) depth to water level map

2.5 Ground water Exploration:

CGWB has drilled 34 exploratory borewells. On the basis of samples collected during drilling, 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 is given in Table 10.

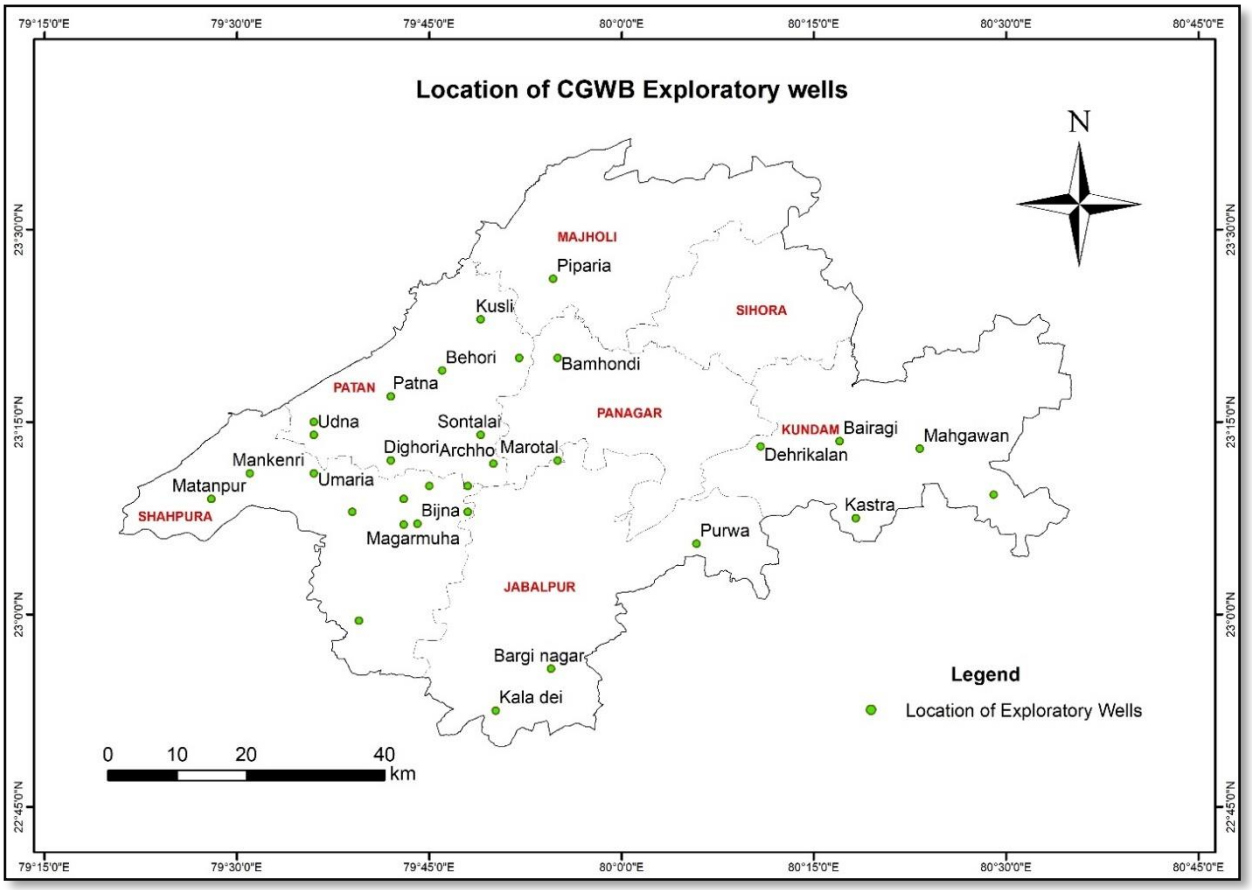


Figure 19 Locations of CGWB Exploratory wells

Table 10 Salient Features of the Exploratory Wells Constructed in Jabalpur District by CGWB, NCR, Bhopal

S No	Location	Lat	Long	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	Granular zones deciphered (mbgl)	Aquifer zones tapped (mbgl)	Discharge (lps)	Drawdown (m)	Specific capacity (lpm/m) of dd	T (m^2/day)	S
1	Matanpur	23.15	79.466667	78.8	75	Alluvium Quartzite at 78.00	78	39.50 -42.00 47.00 - 52.00 53.50- 55.00 57.00 - 63.00 65.00 - 69.00 71.00 - 73.00	16.44	21.83	10.42		3.00 x102
2	Mankenri	23.183333	79.516667	91.44	84.58	Alluvium Quartzite at 84.71	84.71	34.35 -46.18 58.97 - 84.58	11.58	19.40	9.32		2.70 x102
3	Umaria	23.183333	79.6	103.17	102.98	Alluvium Phyllite at 102.6		73.82 - 102.98	10.13	19.10	6.79		3.70 x102
4	Kuarur	23.25	79.6	76.2	66	Alluvium Quartzite at 76.04		25.00 -31.00 41.50 - 46.50 60.00- 64.00	16.9	14.83	0.89		3.06 x103
5	Udna	23.233333	79.6	112.47	44.45	Alluvium Slate at 103.32		15.13 -44.45	5.79	55.50	7.09		6.70 x102
6	Ghunsor	23.233333	79.6	112.47	44.45	Alluvium Slate at 103.32		34.75 - 53.04	2.62	35.00	11.4		3.60 x102
7	Dighori	23.2	79.7	52.7	52.7	Alluvium Conglomerate at 49.1		25.46 - 51.32	6.24	42.30	8		5.60 x102

8	Shahpura	23.133333	79.65	95.5	90.68	Alluvium Chlorite schist at	93.8	22.71 -27.89 28.65 - 34.44 40.84- 46.94 52.58 - 58.83 81.53 - 90.68	4.61	47.20	4.43		1.20 x103
9	Khirkakhera	23.15	79.716667	61.26	43.37	Alluvium Conglomerate at 61.3		30.05 - 42.75	8	42.00	3.23		2.20 x103
10	Patna	23.283333	79.7	69.2	67.9	Alluvium Clay		55.09 - 66.65	6.83	41.00	5.36		3.40 x103
11	Magarmuha	23.116667	79.716667	72.85		Alluvium Basalt at 70.71				0.00			
12	Sahajpur	23.166667	79.75	59.51		Alluvium Conglomerate at	53.64			0.00			
13	Bheraghat	23.133333	79.8	58.52	56.22	Alluvium / deccan Trap	at 57.91	24.00 -30.30 42.49 - 56.22	7.77	40.10	3.8		3.00 x103
14	Behori	23.316667	79.766667	129.61	90	Alluvium /Granite	at 128.70	45.00 -50.00 52.00 - 58.00 60.00- 64.00 66.00 - 69.00 81.00 - 88.00	6.4	3.03	11.5		1.72 x101
15	Sontalai	23.233333	79.816667	113.06		Alluvium / Dolomite	at 111.53			0.00			
16	Archho	23.195833	79.833333	121.7	49	Alluvium /Shale	at 98.00	24.00 -26.00 28.00 - 30.00 32.00- 34.00 35.50 - 42.50 43.50 - 46.00	5.12	14.00	7.17		3.98 x102
17	Marotal	23.2	79.916667	61.87		Alluvium / Shale	at 60.96						

18	Kusli	23.383333	79.816667	76.07	72	Alluvium / Granite	at 73.50	21.00 -23.00 24.00 - 25.00 27.00- 28.00 33.00 - 39.00 47.00 - 57.00 62.00 - 70.00	10.45	8.65	7.71		1.71 x103
19	Kankarkhera	23.333333	79.866667	65.1	62	Alluvium / Quartzite	at 64.00	30.00 -33.00 35.00 - 49.00 56.00- 60.00	7.49	42.40	9.18		1.38 x103
20	Bamhondi	23.333333	79.916667	115	85	Alluvium/ Quartzite	at 112.60	27.25 -31.50 36.50 - 39.50 41.00- 44.50 58.50 - 62.60 68.00 - 72.00 74.00 - 81.00	4.67	14.82	7.29		3.40 x102
21	Kastra	23.125	80.304167	148.5	148.5	Basalt, Lameta Sandstone		23.5 - 102.00 142.5 - 148.00	27.48	4.70	25.9		5.20 x101
22	Purwa	23.091667	80.097222	135.7		Basalt, Lameta Sandstone		129 - 135	110.4	0.11			
23	Hinota	23.944444	79.8375	183		Basalt			44.65				
24	Kaladehi	22.875	79.836111	176.9		Basalt			11.1				
25	Bargi nagar	22.929167	79.908333	115.9	115.9	Basalt		18 - 24 36 - 48 54 - 57 73 - 85 100 - 106 109 - 112	9.44	1.50	29.9		2.0 x101
26	Tilsani	23.9875	80.220833	181.9	180	Vesicular Basalt & Lameta sandstone		78.00 -80.00 82.00 - 84.00 85.00- 87.00 112.00 -118.00 136.00 - 138.00 150.00 -160.00 169.00 - 177.00	107	1.50			
27	Bairagi	23.225	80.283333	189.5	187	Vesicular Basalt & Lameta sandstone		146.00 - 149.00 152.00 - 155.00 171.00 - 184.00	114.72	2.00	3		

28	Mahgawan	23.215278	80.3875	175.9	175.5	Vesicular Basalt		166.00 - 175.5	84.12	1.22	20		
29	Bijna	23.117778	79.734444	58.48	53	Alluvium / Gritty Sandstone	at 41.0	31.00 - 34.00 41.00 - 43.00 48.00 - 53.00	24.74	8.50	6.49		1.36 x102
30	Hardlikalan	23.155556	80.483333	189.1	189.1	Basalt		121.00 - 139.00 143.5 - 168.5	3.95	4.93	55.44		
31	Bijna chargawan	22.991667	79.658333	113	112	Basalt/Lematas		88.00 - 91.00 95.00 - 112.00	21	8.80	17.43		0.635 x102
32	Piparia	23.436111	79.911111	76.81	47	Shales		32.00 - 44.00	16.83	1.00	10.2		
33	Dehrikalan	23.218056	80.180556	157.75	147	Basalt / Gondwana Sandstone	94.5	107.00 -113.00 120.00 - 123.00 132.00-144.00	93.8	2.62	0.26		
34	Bheraghat	23.166667	79.8	72.24	112	Alluvium /Basalt	at 70.7			0.00			

2.6 Hydro-chemical scenario

The water samples were collected from NAQUIM study in clean double stopper HDPE poly ethylene bottles from 43 nos. different locations for basic analysis and 12 nos. of ground water for heavy/ trace metal analysis of Jabalpur district during pre-monsoon 2022.

Quality of Ground Water for Drinking Purpose:

The ground water samples from Jabalpur district have varied range of pH from 7.11 to 8.10. 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 Kaladehi (8.10). The ground water of the study area can be assessed as slightly alkaline in nature. The electrical conductivity of ground water samples in Jabalpur district varies from 208 to 1806 µS/cm at 25°C. In the 33 nos. of ground water samples recorded electrical conductivity less than 1000µS/cm; 8 nos. of water samples recorded electrical conductivity in between 1000 to 1500 µS/cm at 25°C whereas 2 nos. of water samples recorded electrical conductivity more than 1500 µS/cm at 25°C namely Kaimri (1545 µS/cm at 25°C) and Shahpura Kaithra (1806 µS/cm at 25°C). So, overall ground water quality in Jabalpur district is good to slightly saline in nature. The maximum electrical conductivity has been observed in the water sample of Shahpura Kaithra (1806 µS/cm at 25°C).

The fluoride concentration in Jabalpur district lies in between 0.12 to 1.42 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 Bhita village i.e. 1.42 mg/l. Nitrate concentration in ground water samples of Jabalpur district falls within the 2 to 141 mg/l. It is observed that 30.23% samples have nitrate concentration more than the acceptable limit i.e. 45 mg/l, while rest 69.77% samples have concentration less than acceptable limit. Highest concentration (more than 100 mg/L) of nitrate is reported in the water samples of Kakarhata (105 mg/l), Kaimori (111 mg/l), Keolari (141 mg/l) villages. High nitrate in ground water samples may be due to anthropogenic activities or excessive use of fertilizers. The range of Total Hardness (as CaCO3) in ground water samples of study area is 40 to 896 mg/l. In all locations, total hardness concentrations are within the permissible limit of 600 mg/l except the village of Shahpura Kaithra i.e. 896 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 (Ca2+, Mg2+, Na+, K+) are plotted. In Anion triangle the major anions (HCO3-+CO32-, SO42-, Cl-) are plotted. These points are then projected to the central diamond shaped field. The piper diagram of Jabalpur district shows the ground water samples are Calcium-Bicarbonate type (35 nos.) i.e. temporary hardness; Mixed type i.e. Calcium-Magnesium Chloride type (2 nos.); Mixed type i.e. Calcium-Sodium Bi-carbonate type (5 nos.) and Sodium Chloride types (1 no.) 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 Jabalpur district is plotted on U.S. Salinity Laboratory diagram.

U.S. Salinity Laboratory diagram. The ground water samples of Jabalpur district are C1-S1 Class (Low Salinity & Low Sodium); C2-S1 Class (Medium Salinity & Low Sodium) and C3-S_1 Class (High

Salinity & Low Sodium) which means that these waters may be used for irrigation purpose for most of the crops. The ground water of C3-S1 Class may be used for irrigation, considering the salinity content of the ground water.

The analysis of heavy/ trace metal analysis in the ground water of Jabalpur district shows that the copper and nickel are below detectable limit whereas iron (0.012 to 0.787 mg/l), zinc (0.11 to 0.396 mg/l) and manganese (0.042 to 0.258 mg/l) are with the BIS permissible limit.

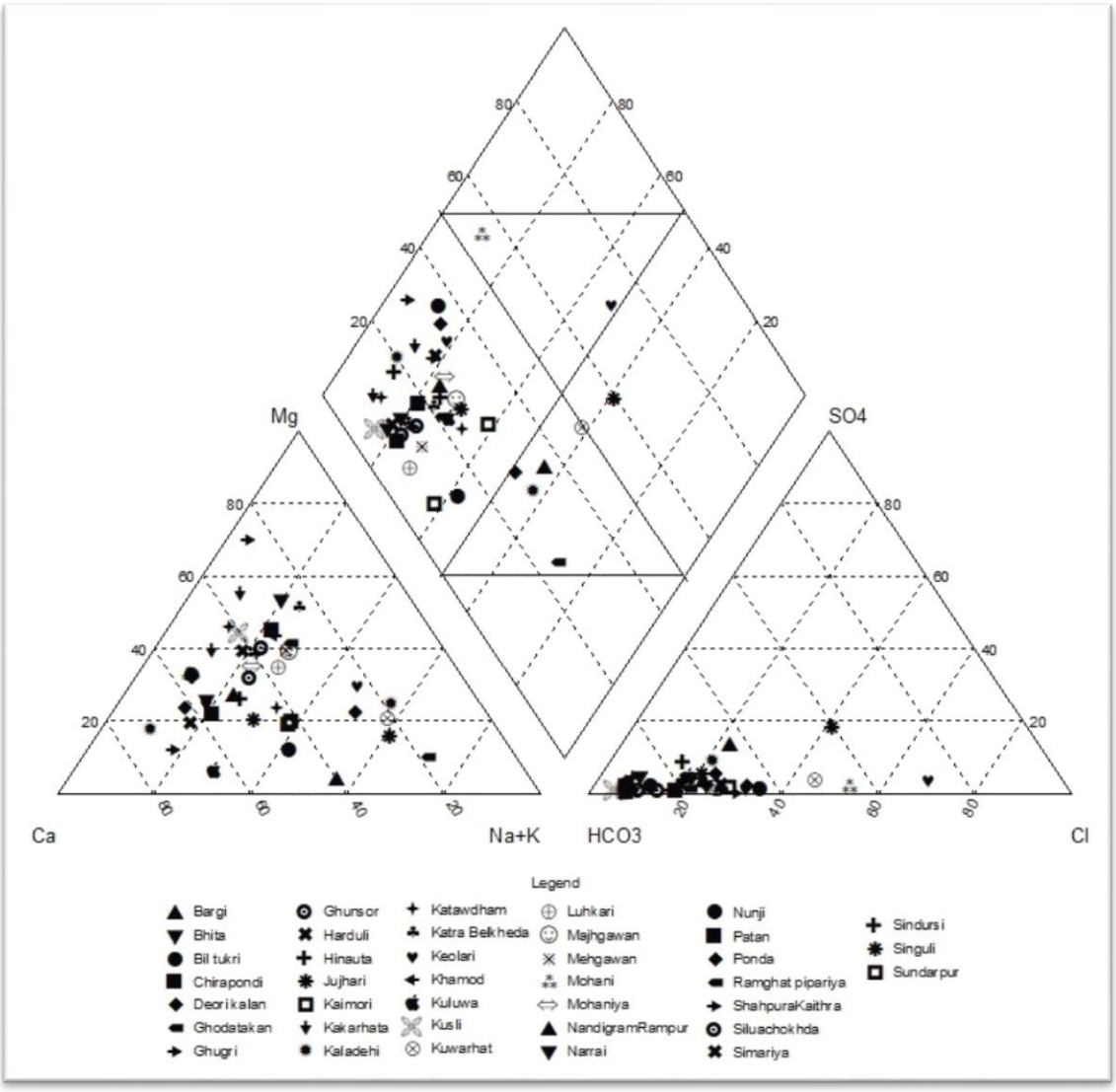


Figure 20 Hill Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Jabalpur District, Madhya Pradesh

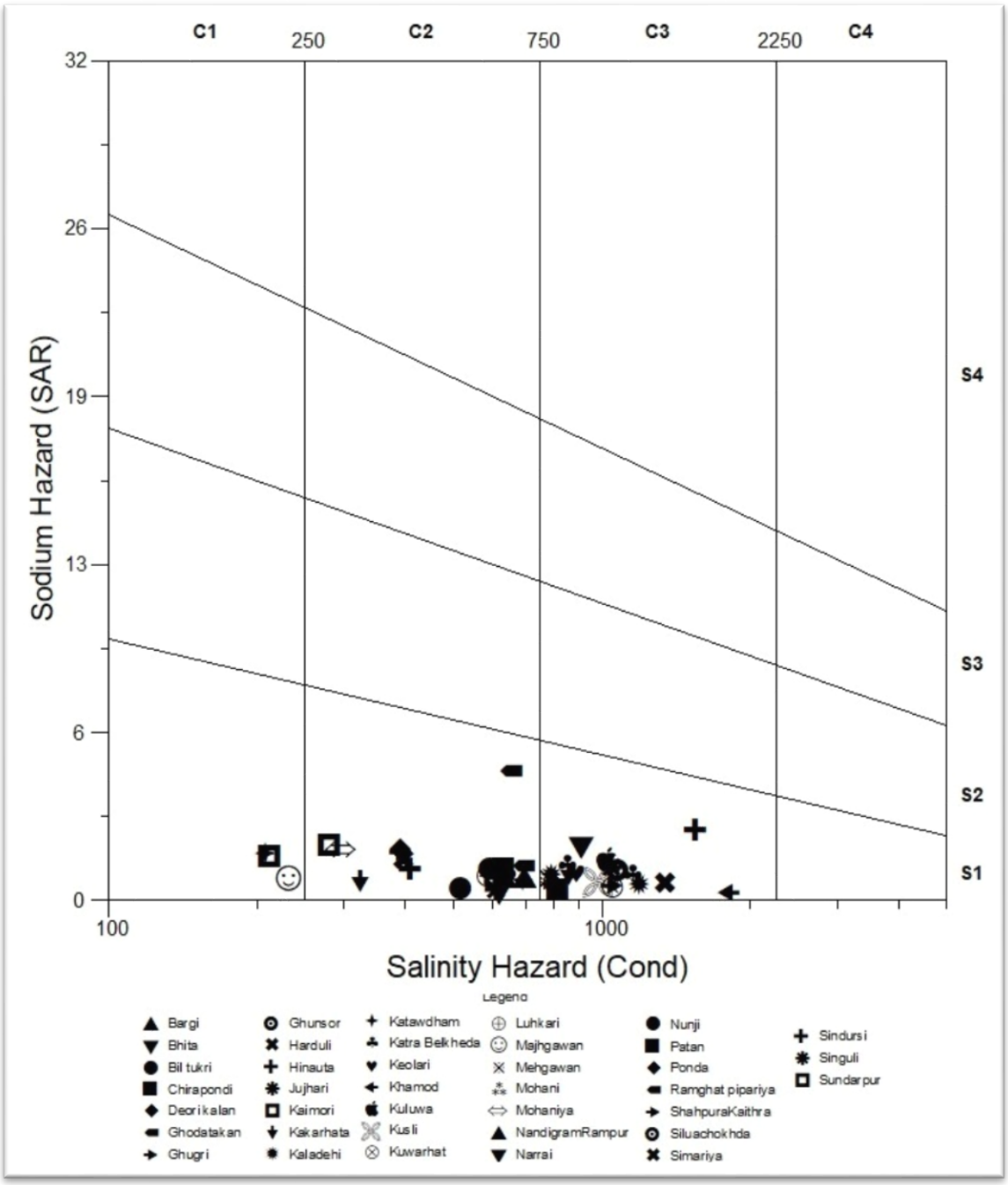


Figure 21 US Salinity Diagram for water samples collected from National Hydrograph Stations of Jabalpur District, Madhya Pradesh.

Table 11: Chemical analysis data of ground water of Jabalpur district under NAQUIM (pre-monsoon-2022)

S No.	District	Block	Location	Source	Lat.	Long.	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
1	Jabalpur	Panagar	Tiwari Kheda	BW	23.3005	79.9937	7.44	698	0	350	29	5	18	0.45	BDL	26	277	57	33	33	4.1	454
2	Jabalpur	Sihora	Nandigram Rampur	BW	23.3716	80.0393	7.19	210	0	72	15	12	3	0.18	BDL	22	45	16	1	25	1.4	137
3	Jabalpur	Sihora	Jujhari	HP	23.4061	80.0903	7.30	232	0	103	17	6	4	0.23	0.1	23	84	24	6	16	1.8	151
4	Jabalpur	Sihora	Simariya	BW	23.4002	80.1027	7.72	608	0	326	15	9	5	0.53	BDL	25	248	51	29	25	1.9	395
5	Jabalpur	Sihora	Sindursi	HP	23.3833	80.1358	7.11	322	0	145	17	13	5	0.27	BDL	43	129	34	11	18	3.0	209
6	Jabalpur	Sihora	Nunji	HP	23.4129	80.1736	7.30	1186	0	393	125	5	77	0.40	BDL	32	525	133	47	30	2.8	771
7	Jabalpur	Sihora	Singuli	HP	23.4213	80.2341	7.72	208	0	42	25	15	20	0.22	BDL	16	40	10	4	26	6.5	135
8	Jabalpur	Sihora	Keolari	HP	23.4727	80.1888	7.72	1156	0	374	105	5	141	0.36	BDL	43	475	133	35	48	2.7	751
9	Jabalpur	Majholi	Bargi	HP	23.5440	80.1459	7.21	888	0	356	61	14	51	0.38	BDL	21	337	87	29	45	2.6	577
10	Jabalpur	Majholi	Talad	BW	23.5406	80.0420	7.53	620	0	296	39	7	22	0.52	0.1	26	292	93	14	13	3.6	403
11	Jabalpur	Majholi	Ponda	HP	23.5031	80.0372	7.55	514	0	175	49	4	34	0.44	BDL	34	213	61	14	15	2.4	334
12	Jabalpur	Majholi	Majhgawan	HP	23.5239	79.9665	7.19	630	0	272	56	3	9	0.43	BDL	41	228	42	30	41	1.4	410
13	Jabalpur	Majholi	Kataw dham	BW	23.5427	79.8790	7.41	802	0	368	17	15	4	0.67	BDL	47	322	61	41	19	3.9	521
14	Jabalpur	Majholi	Kuluwa	DW	23.4630	79.8084	7.50	689	0	302	42	14	12	0.28	BDL	32	243	89	5	45	3.1	448
15	Jabalpur	Majholi	Hinauta	HP	23.4505	79.8442	7.46	1045	0	489	59	4	39	0.38	BDL	23	460	117	41	26	3.7	679
16	Jabalpur	Panagar	Mohaniya	DW	23.3102	79.8736	7.63	1078	0	453	96	8	3	0.52	BDL	31	416	91	46	53	6.8	701
17	Jabalpur	Patan	Kakarhata	HP	23.4324	79.8317	7.30	1342	0	531	98	9	105	0.43	BDL	28	589	131	64	37	2.4	872
18	Jabalpur	Patan	Kaimori	HP	23.3818	79.7450	7.32	1545	0	562	132	11	111	0.53	BDL	39	475	129	37	133	4.6	1004
19	Jabalpur	Patan	Katra Belkheda	HP	23.2705	79.6171	7.61	1042	0	411	54	15	82	0.37	BDL	27	386	50	64	56	4.6	677
20	Jabalpur	Patan	Patan	HP	23.2943	79.6842	7.49	855	0	453	20	8	8	0.40	BDL	31	337	57	47	41	4.2	556
21	Jabalpur	Patan	Khamod	HP	23.2693	79.7707	7.75	789	0	374	29	9	30	0.39	0.2	33	307	53	42	39	6.0	513
22	Jabalpur	Shahpura	Bhita	BW	23.1638	79.7988	7.84	689	0	350	20	14	12	1.42	BDL	44	282	38	46	29	5.5	448
23	Jabalpur	Shahpura	Ramghat pipariya	BW	23.1294	79.7318	7.89	856	0	374	56	5	19	0.18	BDL	28	312	53	43	54	1.1	556
24	Jabalpur	Shahpura	Ghunsor	HP	23.1679	79.6886	7.83	648	0	344	22	3	7	0.49	BDL	25	272	53	34	35	0.9	421
25	Jabalpur	Shahpura	Shahpura Kaithra	HP	23.1389	79.6633	7.44	1806	0	713	181	1	96	0.15	BDL	48	896	97	159	20	0.5	1174

26	Jabalpur	Shahpura	Mehgawan	HP	23.0756	79.6432	7.65	1025	0	537	44	5	7	0.29	BDL	35	371	67	49	65	0.8	666
27	Jabalpur	Shahpura	Kusli	HP	23.1498	79.5231	7.74	989	0	519	15	6	30	0.15	BDL	27	431	81	55	35	1.2	643
28	Jabalpur	Shahpura	Sundradehi	HP	23.1432	79.4262	7.69	1056	0	537	32	4	42	0.23	BDL	47	470	73	70	25	0.4	686
29	Jabalpur	Panagar	Silua chokhda	DW	23.0707	79.9876	7.81	589	0	260	25	2	29	0.37	0.1	19	228	53	23	32	1.3	383
30	Jabalpur	Panagar	Narrai	HP	23.0074	79.9868	7.63	778	0	411	20	3	22	0.24	BDL	28	317	87	24	32	0.8	506
31	Jabalpur	Bargi	Harduli	BW	22.9276	79.8997	7.30	787	0	356	76	9	33	0.19	BDL	34	351	107	20	35	0.5	512
32	Jabalpur	Bargi	Kaladehi	BW	22.8806	79.8242	8.10	295	0	115	20	12	4	0.34	BDL	28	59	10	8	34	1.5	192
33	Jabalpur	Bargi	Chirapondi	HP	22.9750	79.7564	7.54	640	0	308	39	2	12	0.30	BDL	42	267	77	18	32	0.8	416
34	Jabalpur	Panagar	Sundarpur	HP	23.2387	80.0932	7.40	912	0	435	20	2	92	0.34	BDL	38	292	81	22	82	1.8	593
35	Jabalpur	Kundam	Luhkari	HP	23.1780	80.1173	7.43	589	0	278	12	3	45	0.21	BDL	31	223	46	26	40	0.9	383
36	Jabalpur	Kundam	Ghugri	HP	23.2347	80.1975	7.42	812	0	290	64	2	72	0.12	BDL	42	337	115	12	15	32.0	528
37	Jabalpur	Kundam	Deori kalan	DW	23.1544	80.2199	7.98	389	0	103	20	6	77	0.19	BDL	29	89	20	10	42	1.5	253
38	Jabalpur	Kundam	Ghodatakan	BW	23.2658	80.3694	7.85	652	0	284	51	7	14	0.34	BDL	27	94	24	8	108	2.1	424
39	Jabalpur	Kundam	Turka	HP	23.1816	80.3155	7.99	389	0	48	69	5	65	1.20	BDL	35	104	18	14	42	0.8	253
40	Jabalpur	Kundam	Bil tukri	BW	23.1654	80.4259	8.06	396	0	211	17	4	2	0.72	BDL	27	119	38	6	39	1.5	257
41	Jabalpur	Kundam	Tauri	DW	23.1548	80.4896	7.24	408	0	145	22	6	71	1.07	BDL	26	139	36	12	32	0.8	265
42	Jabalpur	Kundam	Mohani	DW	22.2735	80.5562	7.26	608	0	121	83	4	65	0.25	BDL	34	257	65	23	13	2.1	395
43	Jabalpur	Kundam	Kuwarhat	HP	23.2649	80.4545	7.89	278	0	85	44	5	7	1.24	BDL	28	59	12	7	37	1.2	181

Table 12: Trace/ Heavy metal analysis of ground water of Jabalpur district under NAQUIM (pre-monsoon-2022)

S. No.	District	Block	Location	Source	Lat.	Long.	Fe	Cu	Ni	Zn	Mn
							mg/l				
1	Jabalpur	Sihora	Simariya	BW	23.4002	80.1027	0.016	BDL	BDL	0.396	0.258
2	Jabalpur	Sihora	Nunji	HP	23.4129	80.1736	0.122	BDL	BDL	BDL	0.069
3	Jabalpur	Sihora	Singuli	HP	23.4213	80.2341	0.012	BDL	BDL	0.11	BDL
4	Jabalpur	Sihora	Keolari	HP	23.4727	80.1888	0.23	BDL	BDL	BDL	BDL
5	Jabalpur	Majholi	Talad	BW	23.5406	80.0420	0.012	BDL	BDL	BDL	BDL
6	Jabalpur	Majholi	Kataw dham	BW	23.5427	79.8790	0.142	BDL	BDL	BDL	BDL
7	Jabalpur	Patan	Kakarhata	HP	23.4324	79.8317	0.081	BDL	BDL	BDL	BDL
8	Jabalpur	Patan	Khamod	HP	23.2693	79.7707	0.066	BDL	BDL	BDL	BDL
9	Jabalpur	Shahpura	Ramghat pipariya	BW	23.1294	79.7318	0.028	BDL	BDL	BDL	BDL
10	Jabalpur	Shahpura	Mehgawan	HP	23.0756	79.6432	0.021	BDL	BDL	BDL	BDL
11	Jabalpur	Panagar	Silua chokhda	DW	23.0707	79.9876	0.457	BDL	BDL	BDL	0.042
12	Jabalpur	Bargi	Chirapondi	HP	22.9750	79.7564	0.787	BDL	BDL	BDL	BDL
13	Jabalpur	Panagar	Sundarpur	HP	23.2387	80.0932	0.532	BDL	BDL	0.088	BDL
14	Jabalpur	Kundam	Ghodatakan	BW	23.2658	80.3694	0.222	BDL	BDL	BDL	0.068
15	Jabalpur	Kundam	Tauri	DW	23.1548	80.4896	0.335	BDL	BDL	BDL	BDL

Chapter-3
DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The lithological data collected from 9 CGWB Exploratory Borewells & 4 piezometers were studied, compiled and integrated as per Rockworks software format to prepare the 3-Dimensional Stratigraphic model and 2-Dimensional Cross sections. The 2-D elevation map of the exploratory borewells & piezometers is given in fig 22. From the 3-D Model and 2-D Section presented in the fig 23, 24 & 25, it has been interpreted that the major water bearing zones has been encountered in weathered/fractured basalts and fractured basalt/sandstone formations.

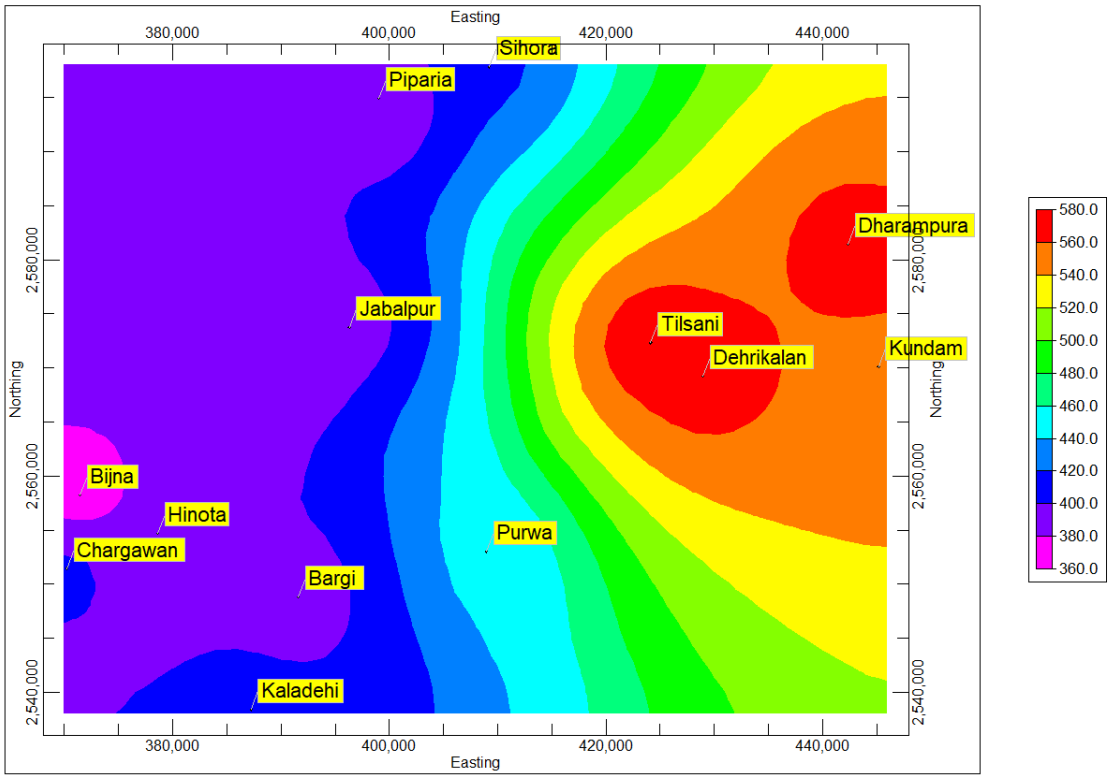


Figure 22 2-D elevation map of Exploratory borewells & piezometers

3.1 3-D Lithological & 3-D Stratigraphic model

A 3-Dimensional Lithological & Stratigraphic model was prepared for the Jabalpur district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB. 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 occupied by basalts, sandstone & granite. The sub surface lithology has been broadly classified into top soil/ unsaturated zone, underlain by weathered basalt/ sandstone which has been considered as shallow aquifer (upto a depth of 30 mts) and Deeper Aquifer (30-200) mts.

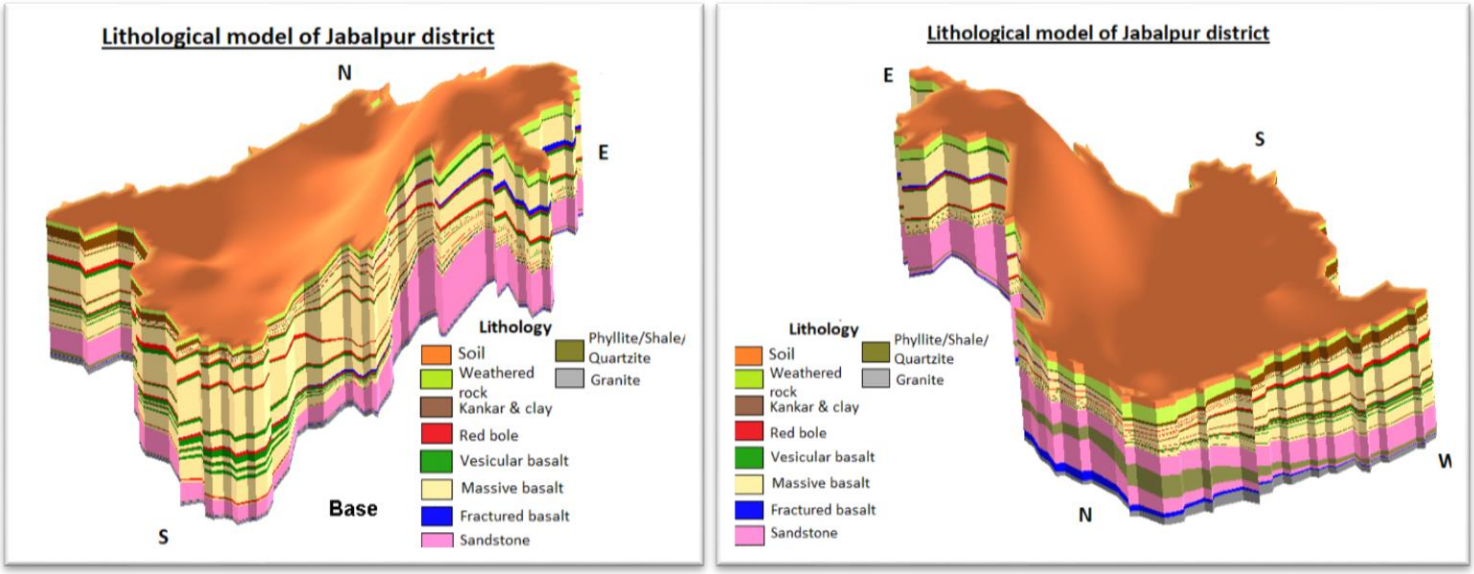


Figure 23 3-D lithological model of Jabalpur district

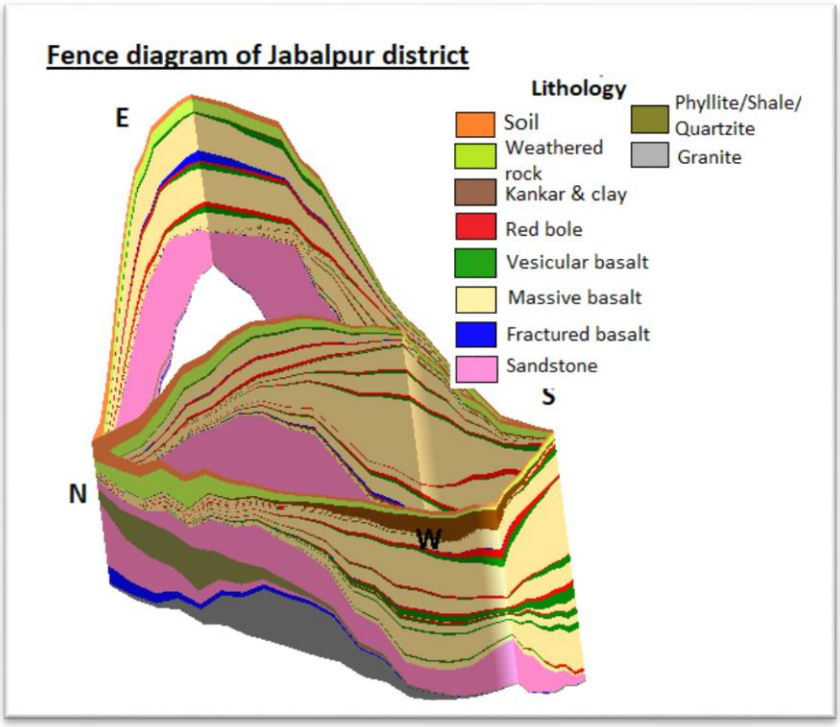


Figure 24 Fence diagram of Jabalpur district

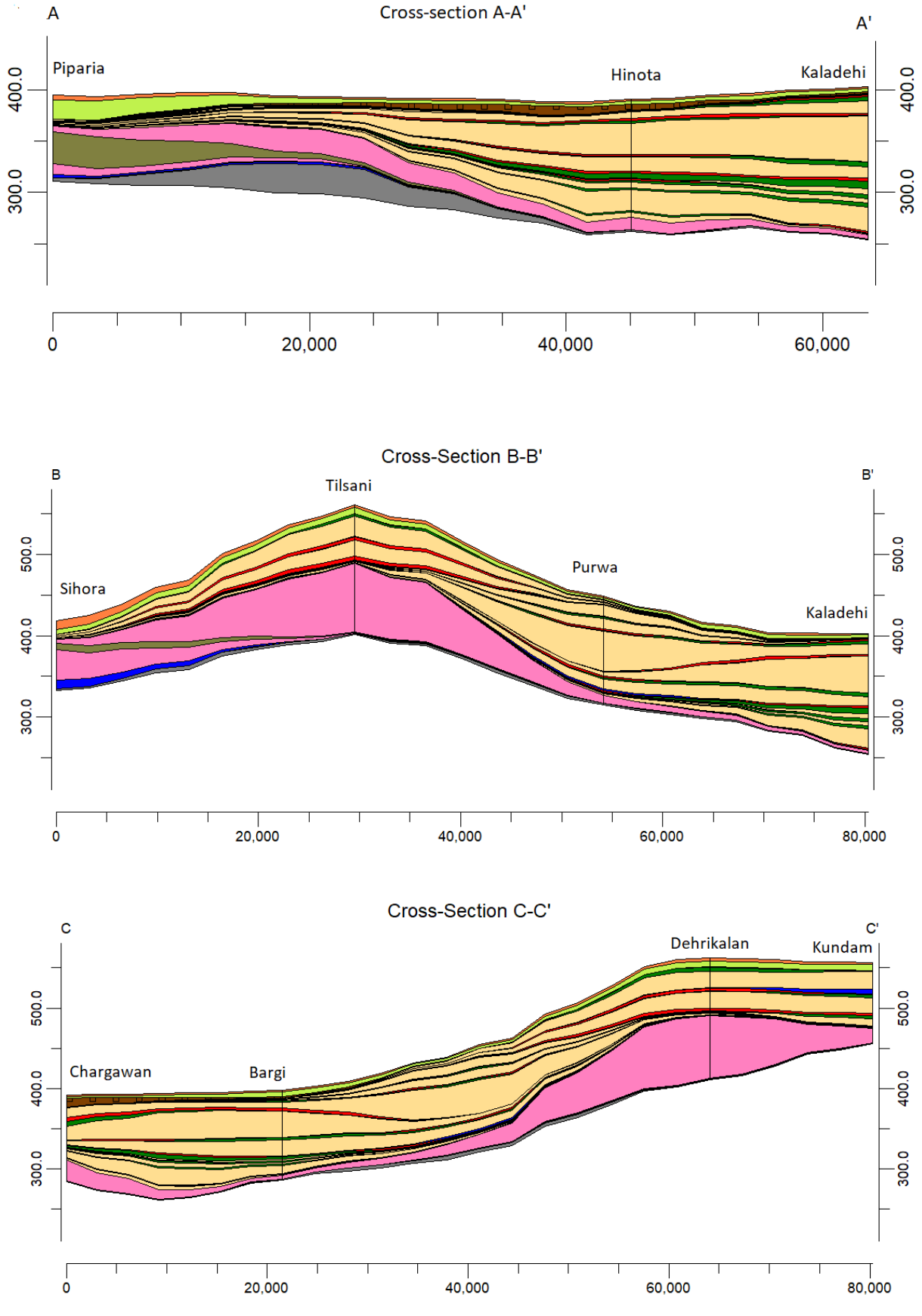


Figure 25 2-D Cross-sections of Jabalpur district

Chapter-4
GROUND WATER RESOURCES

4.1 Dynamic Ground Water Resource Estimation

Central Ground Water Board and Ground Water Survey and Development Agency (GSDA) have jointly estimated the ground water resources of Jabalpur district based on GEC-15 methodology. Block wise ground water resources for the year 2020 have been discussed here. During the monsoon season, the rainfall recharge is the main recharge parameter, which is estimated as the sum total of the change in storage and gross draft. The change in storage is computed by multiplying groundwater level fluctuation between pre and post-monsoon periods with the area of assessment and specific yield. Monsoon recharge can be expressed as:-

$R = h \times Sy \times A + DG$

where h = rise in water level in the monsoon season, Sy = specific yield A = area for computation of recharge, DG = gross ground water draft

The monsoon ground water recharge has two components- rainfall recharge and recharge from other sources. The other sources of groundwater recharge during monsoon season include seepage from canals, surface water irrigation, tanks and ponds, ground water irrigation, and water conservation structures. During the non-monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non-monsoon recharge. The unit extraction of dug well and tube well and the number of dug well and tube well in command and non-command area have been used to assess the total ground water extraction.

Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis & has been given in Table. Out of 5453.65 sq km of geographical area, 4505.38 sq km (83%) is ground water recharge worthy area and 948.27 sq km (17%) is hilly area.

There are eight number of assessment units (seven blocks and one urban area) in the district which fall under non-command (82%- Kundam and Majholi) and command (18%) sub units. All the assessment units are categorized as safe except the Jabalpur Urban area, which assessed first time this year and is categorized as critical. The highest stage of ground water extraction is computed as 90.66% in Jabalpur_Urban.

The annual extractable ground water resource in the district is 589.97 mcm and ground water extraction for all uses is 283.80 mcm, making stage of ground water development 49.24% (42.47% 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 296.89 ham.

Table 13 Dynamic Ground Water Resource Estimation (As on March 2020)

Assessment Unit Name	Ground Water Extraction for Irrigation 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
BARGI	2631	553.61	3184.62	601.79	4542.56	40.96	safe
KUNDAM	973	305.62	1278.62	332.21	2654.76	32.29	safe
PANAGAR	5493.2	586.39	6086.07	637.41	4098.24	59.46	safe
PATAN	5594	322.04	5916.04	350.06	7004.99	45.69	safe
JABALPUR	92.4	580.45	672.85	743.48	69.29	90.66	critical
MAJHOLI	2802.5	386.44	3188.94	420.07	2572.43	55.03	safe
SHAHPURA	5119.5	466.40	5585.89	506.99	6138.2	47.48	safe
SIHORA	2801.8	335.72	3137.52	364.93	2608.95	54.32	safe
DISTRICT TOTAL	**25507.4**	**3536.67**	**29050.55**	**3956.94**	**29689.42**	**49.24**	

Chapter-5
GROUND WATER RELATED ISSUES

5.1 Declining ground water level

The pre-monsoon water level monitoring under NAQUIM shows that the water levels in dugwells have fallen down in many parts of the district. Most dugwells are reported dry in Sihora & Majholi blocks. Out of 41 dugwells monitored, 19 dugwells are reported dry in the premonsoon season.

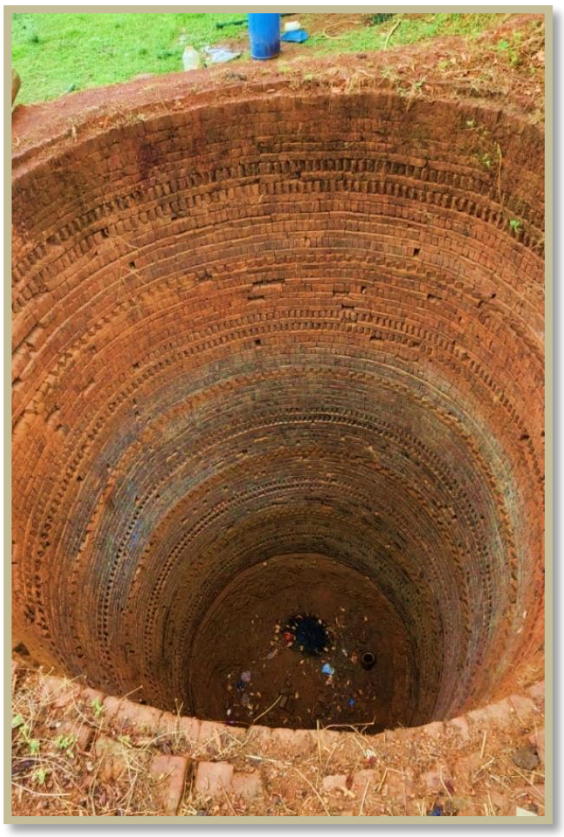


Figure 26 Dry dugwell at village Nunji, Sihora block

Figure 27 Dry dugwell at village Hinauta, Majholi block

5.2 Stage of Ground Water Extraction

Ground Water Resource Estimation reveals that out of 8 blocks of the district 1 block (Jabalpur) has 90% stage of ground water development & is categorized as critical.

Over all stage of ground water development of the district is computed as 49.24% as per Ground Water Resource Estimation, which has deteriorated from 42.47% in Ground Water Resource Estimation 2017.

5.3 Urbanisation

Urbanisation in Jabalpur has posed groundwater problems in varied ways. Scarcity of water has led to the digging of borewells wells in every plot of the newly-constructed colonies. This has further aggravated the problem with the fall of the water level in the urban area & in nearby blocks.

Deforestation has resulted in decreased groundwater recharge. 70 per cent of the forest cover in Khandari and 30 per cent of forest cover in Pariyat catchment has been removed. Most of the rain that fell recharged groundwater aquifers because of the dense green cover which, acted as a barrier for surface runoff. Now, with the forest cover removed, the runoff flows away wasted.

5.4 Ground water quality

High fluoride is reported at Jain Dharamsala, Jabalpur city. Excessive nitrate content is reported in the district at Adhartal naka in Jabalpur city which may be due to sewage contamination in groundwater.

Chapter-6
GROUND WATER MANAGEMENT STRATEGIES

District Ground Water Management Plan

There is a need of sustainable water conservation and management practices through an integrated approach for the optimal utilization of ground water resources in the district. The ground water management plan for Jabalpur 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.

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 problems and also improves the sustainability of wells in the affected areas. Artificial recharge structures are advised for areas having water levels deeper than 3mbgl.

Figure 26 Baori (stepwell) at Jujhari village, Sihora block

Restoration of the pre-existing village tanks, ponds and water conservation structures should also be considered.

The supply side management plan for all the blocks of Jabalpur 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 Jabalpur 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 no. 14.

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. 6 lakh each for Nala bunds/Check Dams/Cement Plugs, Rs. 1 lakh each for for Nala bunds/Cement Plugs, Rs. 60,000 each for Recharge shafts and Rs. 2.5 lakhs each for renovation of Village tanks/ponds/WCS. This accounts to a total of Rs.513.10 Crores to successfully implement the supply side management strategy. Table no. 13 represents the complete financial outlay plan for the district.

Table 14 Ground Water Management– Supply Side, Jabalpur District, Madhya Pradesh

Sl. No	Assessment Unit Name	Area (Sq.KM)	Normal Annual Rainfall (mm)	Average Post-monsoon Water Level (m bgl)	Suitable Area for AR (sq.km)	Un Saturated Zone	Specific Yield	Sub-surface storage (mcm)	Surface water required (mcm)	Runoff MCM	Non Commited Runoff	Percolation tanks	Check Dams	No of Recharge shaft in each CD	no of nala bunds/cement plugs	no of village ponds/ Farm Ponds
1	Bargi	683.44	1279.5	4.78	383.81	1.78	0.02	13.67	18.18	157.2	47.16	32	273	273	273	91
2	Jabalpur	263	1279.5	4.48	236.7	1.48	0.02	6.99	9.30	60.5	18.15	16	139	139	139	46
3	Kundam	1210	1279.5	5.11	832	2.11	0.02	35.09	46.66	278.3	83.49	82	700	700	700	233
4	Majholi	622.65	1279.5	9.44	622.65	6.44	0.02	80.25	106.74	143.2	42.96	187	1601	1601	1601	534
5	Panagar	442.79	1279.5	3.28	424.59	0.28	0.02	2.34	3.11	101.8	30.55	5	47	47	47	16
6	Patan	1004	1279.5	5.40	1004	2.40	0.02	48.28	64.21	230.9	69.28	112	963	963	963	321
7	Shahpura	531.21	1279.5	5.12	471.09	2.12	0.02	19.93	26.50	122.2	36.65	46	398	398	398	133
8	Sihora	463.84	1279.5	7.14	463.84	4.14	0.02	38.37	51.03	106.7	32.00	89	765	765	765	255
	Total	5220.93	1279.5	5.59	4438.68	12.09	0.02	244.91	325.73	1200.8	360.24	569	4886	4886	4886	1629

Table 15 Financial Outlay Plan- Supply Side Management, Jabalpur District, Madhya Pradesh

Sl. No	Assessment Unit Name	Suitable Area for AR (sq.km)	Sub-surface storage (mcm)	Surface water required (mcm)	Non Commited Runoff	no of percolation tanks	cost of percolation tanks in crores @0.20 crores per pt	no of Check Dams	cost (Crores)	No of Recharge shaft in each CD	cost (Crores)	no of nala bunds/cement plugs	cost (Crores)	no of village ponds/ Farm Ponds	cost (Crores)
1	Bargi	383.81	13.67	18.18	47.16	32	6.4	273	16.38	273	1.638	273	2.73	91	2.275
2	Jabalpur	236.7	6.99	9.30	18.15	16	3.2	139	8.34	139	0.834	139	1.39	46	1.15
3	Kundam	832	35.09	46.66	83.49	82	16.4	700	42	700	4.2	700	7	233	5.825
4	Majholi	622.65	80.25	106.74	42.96	187	37.4	1601	96.06	1601	9.606	1601	16.01	534	13.35
5	Panagar	424.59	2.34	3.11	30.55	5	1	47	2.82	47	0.282	47	0.47	16	0.4
6	Patan	1004	48.28	64.21	69.28	112	22.4	963	57.78	963	5.778	963	9.63	321	8.025
7	Shahpura	471.09	19.93	26.50	36.65	46	9.2	398	23.88	398	2.388	398	3.98	133	3.325
8	Sihora	463.84	38.37	51.03	32.00	89	17.8	765	45.9	765	4.59	765	7.65	255	6.375
	Total	4438.68	244.91	325.73	360.24	569	113.8	4886	293.16	4886	16.56	4886	48.86	1629	40.725

6.2 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:

- 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.

Adoption of Sprinkler irrigation techniques would save 30% of gross ground water draft for irrigation. 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.

Post-Intervention Impact: The impact of groundwater management plans on the groundwater system in the critical block of the district, after its implementation is evaluated and the outcome shows significant improvement in groundwater scenario in the block as seen in table. It can be seen that after proposed supply side and demand side interventions, there would be improvement in Stage of Ground water extraction from 90.66% to 72.96% in the block.

Table 16 Post-Intervention Impact, Jabalpur urban, Jabalpur District, Madhya Pradesh

Block	Net GW Availability (MCM)	GW Draft for Irrigation (MCM)	GW Draft for Domestic & Industrial (MCM)	Gross Draft (MCM)	Stage of Development (%)	Saving by microirrigation in (MCM)	Additional recharge created by AR (MCM)	After intervention of AR Structure Net GW AvL. (MCM)	Draft after sprinkler (MCM)	Stage of Development after intervention(%)
JABALPUR URBAN	7.42	0.92	5.80	6.73	90.66	2.02	6.99	14.41	10.51	72.96

6.3 Development Plan

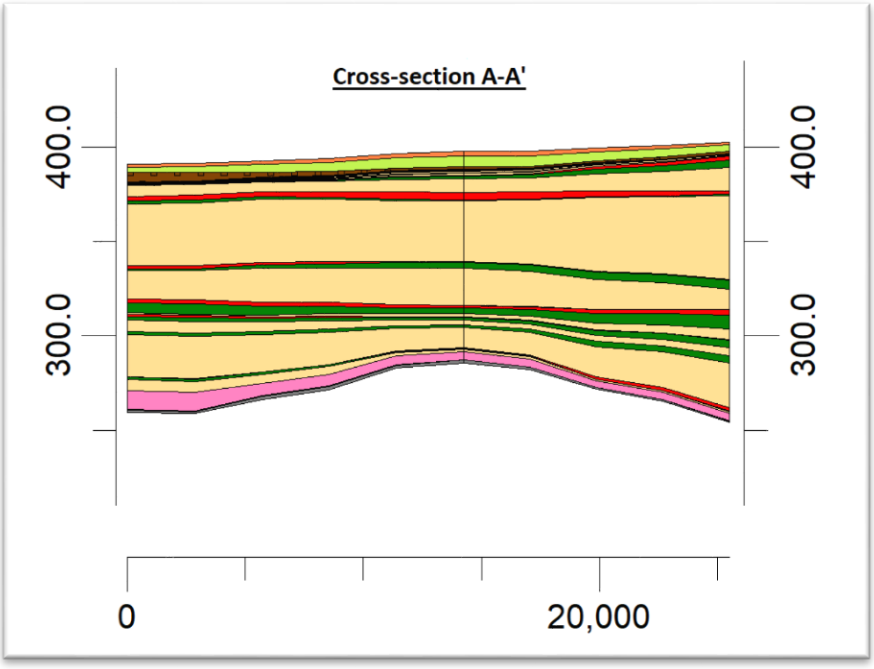
In the safe blocks, the ground water development plan has been proposed in the view of developing the additional ground water resources available after supply side and demand side interventions to bring the stage of ground water development up to 70%. About 122.47 MCM of ground water would be available. This ground water can be used to irrigate additional 191.12 sq.km area. For this purpose, it is proposed to construct 7453 dugwells and 1243 borewells. The block wise details are given in Table 17.

Table 17 Development plan of Safe blocks of Jabalpur district

Block	GW Resources Available for Development and Bring Stage of GWD upto 70% from present SOD (MCM)	Proposed no. of DW (@ 1.5 ham for 90% of GWR Available)	Proposed no. of BW* (@ 1.0 ham for 10% of GWR Available)	Additional area that can be brought under assured GW irrigation with av. CWR of 0.65 m
Bargi	27.56	1654	276	42.4
Kundam	23.54	1412	235	36.22
Majholi	16.22	973	162	24.95
Panagar	10.88	653	109	16.74
Patan	31.99	1919	320	49.22
Shahpura	4.95	297	50	7.62
Sihora	9.08	545	91	13.97
TOTAL	**122.47**	**7453**	**1243**	**191.12**

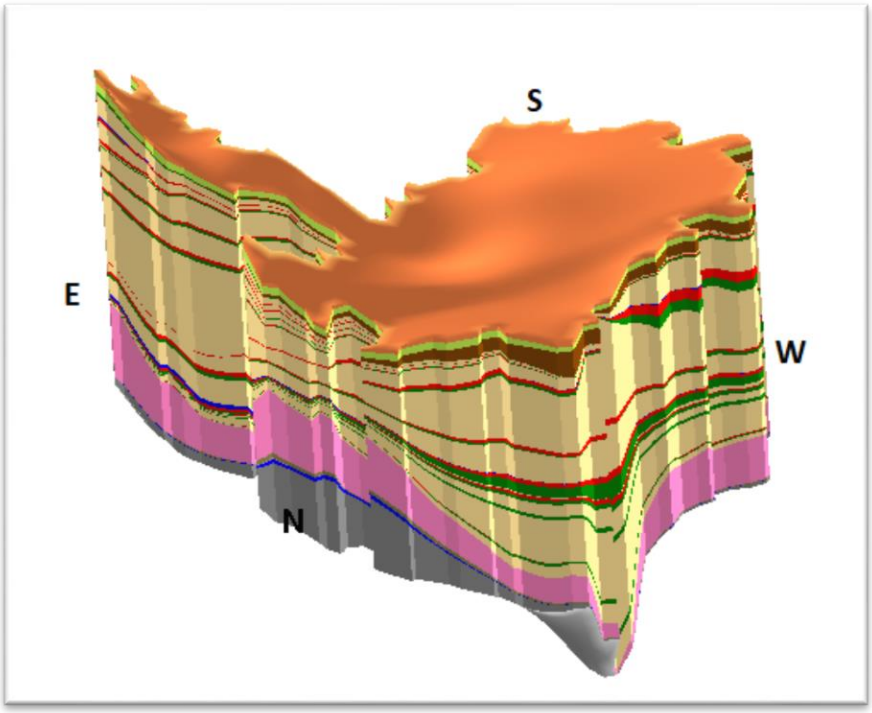
Bargi block Management plan

Recharge worthy area	383.81
Annual Extractable GW resource	77.75
Total extraction	31.85
Stage of GW extraction (%)	40.96
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	27.56
I. Artificial recharge structures	
Percolation tanks	32
Check Dams with Recharge shaft	273
Nala bunds/cement plugs	273
Village ponds/ Farm Ponds	91
II. Abstraction structures	
Dugwells	1654
Borewells	276



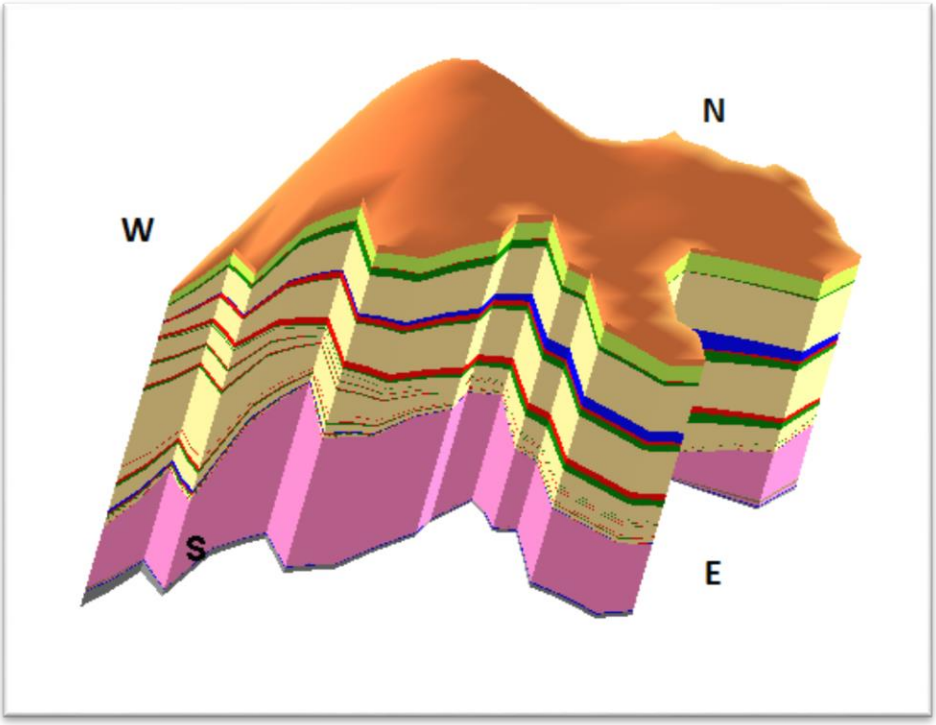
Jabalpur block Management plan

Recharge worthy area	236.7
Annual Extractable GW resource	7.42
Total extraction	6.73
Stage of GW extraction (%)	90.66
Category	Critical
Annual Extractable GW resource after supply side & demand side inerventions	14.41
Stage of GW extraction after intervention(%)	72.96
Percolation tanks	69
Check Dams with Recharge shaft	139
Nala bunds/cement plugs	139
Village ponds/ Farm Ponds	46



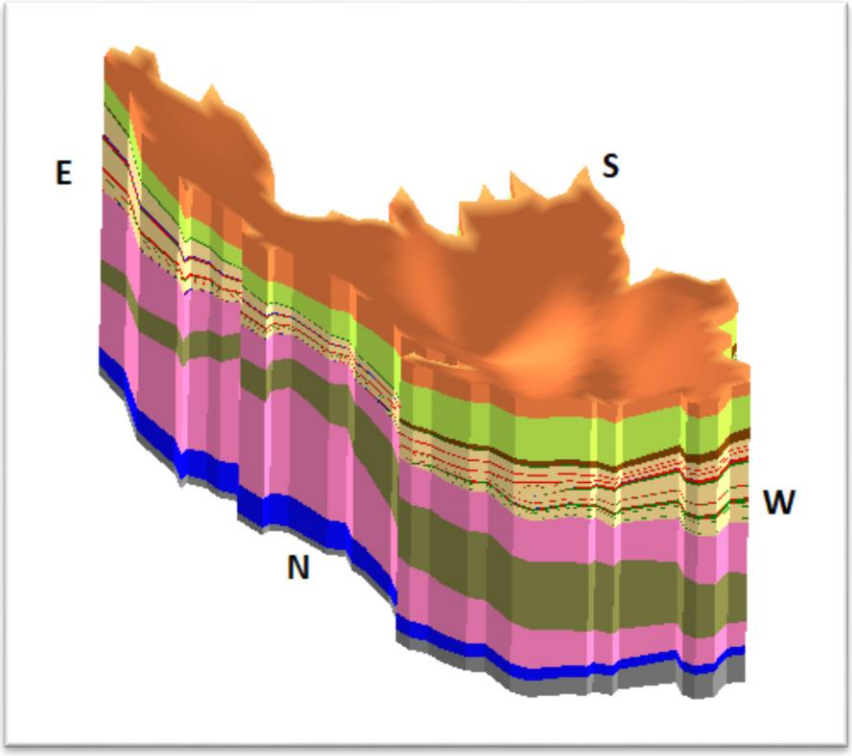
Kundam block Management plan

Recharge worthy area	832
Annual Extractable GW resource	39.60
Total extraction	12.79
Stage of GW extraction (%)	32.29
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	23.54
I. Artificial recharge structures	
Percolation tanks	82
Check Dams with Recharge shaft	700
Nala bunds/cement plugs	700
Village ponds/ Farm Ponds	233
II. Abstraction structures	
Dugwells	1412
Borewells	235



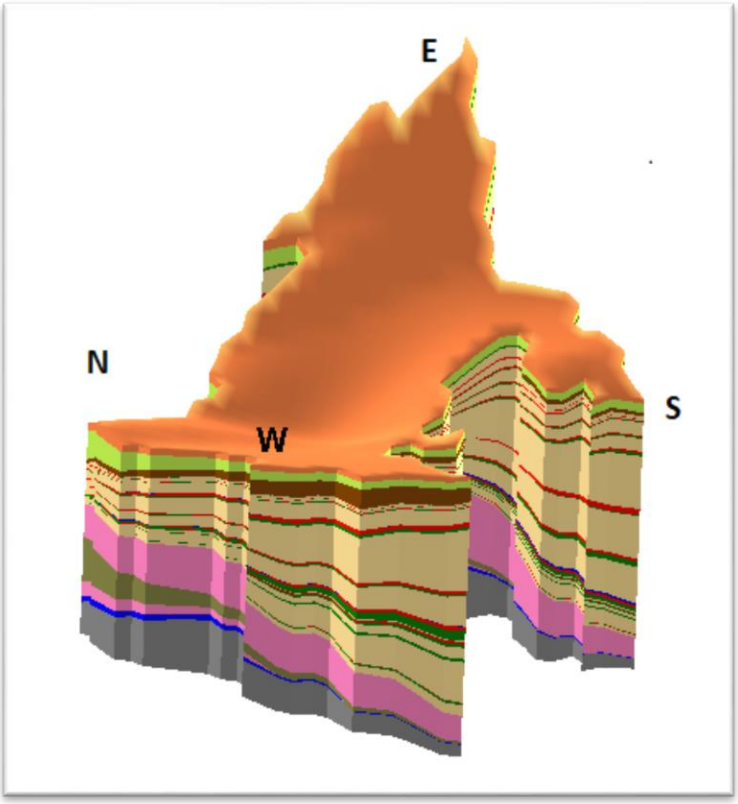
Majholi block Management plan

Recharge worthy area	622.65
Annual Extractable GW resource	57.95
Total extraction	31.89
Stage of GW extraction (%)	55.03
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	16.22
I. Artificial recharge structures	
Percolation tanks	187
Check Dams with Recharge shaft	1601
Nala bunds/cement plugs	1601
Village ponds/ Farm Ponds	534
II. Abstraction structures	
Dugwells	973
Borewells	162



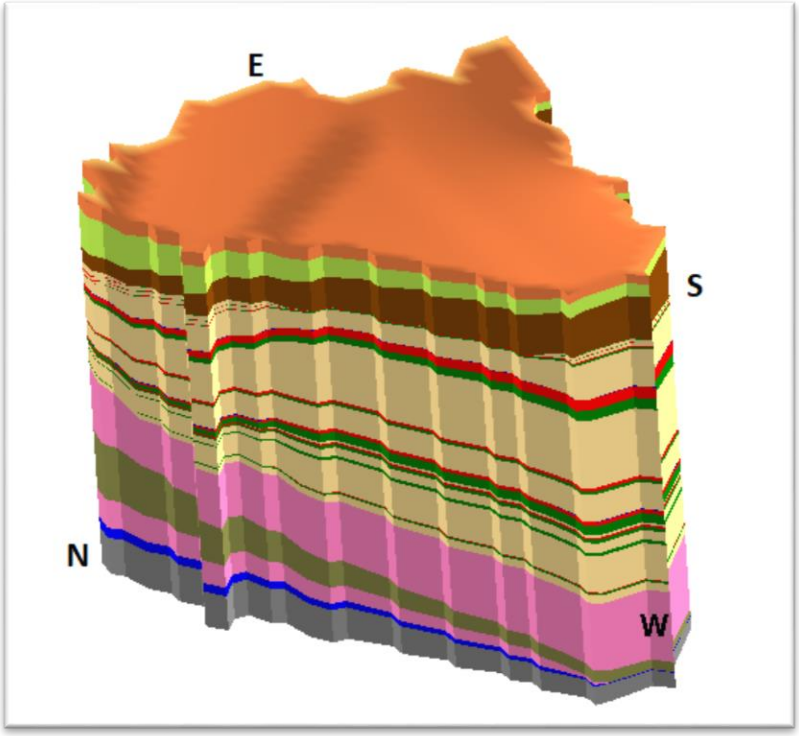
Panagar block Management plan

Recharge worthy area	424.59
Annual Extractable GW resource	102.35
Total extraction	60.80
Stage of GW extraction (%)	59.40
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	10.88
I. Artificial recharge structures	
Percolation tanks	5
Check Dams with Recharge shaft	47
Nala bunds/cement plugs	47
Village ponds/ Farm Ponds	16
II. Abstraction structures	
Dugwells	653
Borewells	109



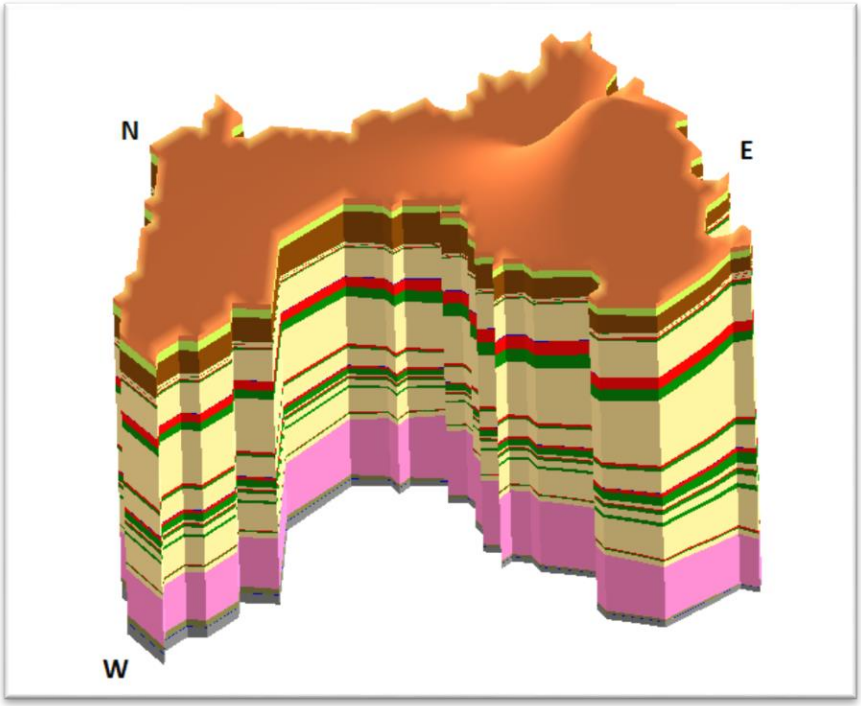
Patan block Management plan

Recharge worthy area	1004
Annual Extractable GW resource	129.49
Total extraction	59.16
Stage of GW extraction (%)	45.69
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	31.99
I. Artificial recharge structures	
Percolation tanks	112
Check Dams with Recharge shaft	963
Nala bunds/cement plugs	963
Village ponds/ Farm Ponds	321
II. Abstraction structures	
Dugwells	1919
Borewells	320



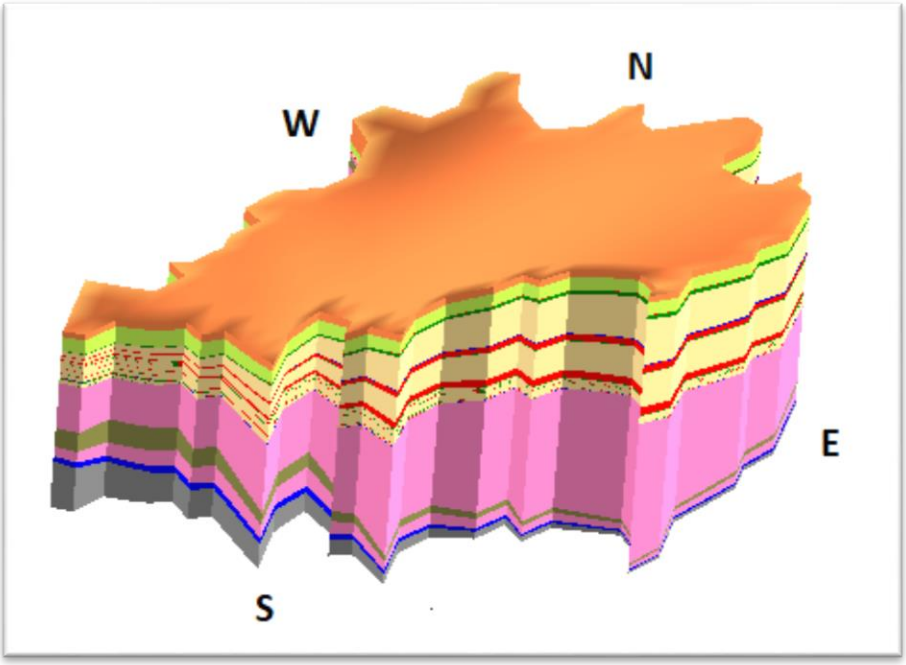
Shahpura block Management plan

Recharge worthy area	471.09
Annual Extractable GW resource	117.65
Total extraction	55.86
Stage of GW extraction (%)	47.48
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	4.95
I. Artificial recharge structures	
Percolation tanks	46
Check Dams with Recharge shaft	398
Nala bunds/cement plugs	398
Village ponds/ Farm Ponds	133
II. Abstraction structures	
Dugwells	297
Borewells	50



Sihora block Management plan

Recharge worthy area	463.84
Annual Extractable GW resource	57.76
Total extraction	31.38
Stage of GW extraction (%)	54.32
Category	Safe
GW Resources Available to bring Stage of GW extraction upto 70% (mcm)	9.08
I. Artificial recharge structures	
Percolation tanks	89
Check Dams with Recharge shaft	765
Nala bunds/cement plugs	765
Village ponds/ Farm Ponds	255
II. Abstraction structures	
Dugwells	545
Borewells	91



Chapter-6
CONCLUSIONS AND RECOMMENDATIONS

The highly diversified occurrence and considerable variations in the availability and utilization of groundwater makes its management a challenging task. Scientific development and management strategy for groundwater has become imperative to avert the looming water crisis. In this context, various issues such as, prioritization of areas for development of groundwater resources vis-a-vis its availability, augmentation of groundwater through rainwater harvesting and artificial recharge, pricing and sectoral allocation of resources and participation of the stakeholders must be considered. In view of the above, for the present study area a systematic, economically sound and politically feasible framework for groundwater management is required.

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 block wise aquifer maps and aquifer management plans of Jabalpur district.

Geographically, Jabalpur district covers an area of 5655 sq. km, out of this 4439 sq. km area is occupied by forest. Geologically, the area is occupied by Basalt and Alluvium formations. As per Ground water assessment year 2020 the average stage of ground water development is 49.24%. As per Ground water assessment 2020 the stage of ground water development is safe for all the blocks except Jabalpur block. Declining water level, deteriorating stage of ground water development and nitrate contamination in the urban area are the major issues in the district.

Pre-Monsoon depth to water level in the year 2022 range from 0.9 mbgl to 20.12 mbgl. Very shallow water level (0-2 mbgl) occur in few locations in Kundam block. Deep water levels (10-20 mbgl) occurs in Sihora, Majholi & parts of Bargi block. Post-Monsoon depth to water level range from 0.8 mbgl to 15.08 mbgl. Very shallow water level (0-2 mbgl) occur in few locations in Kundam block. Deep water levels (10-20 mbgl) occurs in Sihora, Majholi & in few locations of Bargi, Patan blocks.

The management plan has been proposed to manage the ground water resources and to arrest further decline in water levels. The management plan comprises two components namely supply-side management and demand side management. As a part of Supply side Management, artificial recharge structures is advised. A total of 569 percolation tanks, 4886 check dams with recharge shafts, 4886 nala bunds/cement plugs & 1629 farm ponds are proposed for artificial recharge. As a part of Demand side Management, micro-irrigation techniques are proposed to be adopted which would save 30% of gross ground water draft for irrigation.

The ground water development plan has been proposed in safe blocks in view of the developing additional groundwater resources available after supply side interventions to bring the stage of ground water development up to 70%. Additional volume of ground water can bring additional area under assured ground water irrigation. A total of 7453 dugwells & 1243 borewells are proposed to bring 191.12 sq km under assured irrigation.

Thus, the focus of proposed management plan was to use ground water very effectively with supply and demand side interventions. These interventions also need to be supported by regulation for deeper aquifer and hence it is recommended to regulate deeper tubewells/borewells of more than 60 m depth in these Blocks, so that the deeper ground water resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought.

Recommendations

- Land based interventions like construction of lined farm ponds, rehabilitation of existing farm ponds along with horticulture plantation as may be feasible to take on to increase the availability of irrigation water during both kharif (July to October) as well as rabi (October to March) season.
- Sustainable management of the area is required to be done to improve the quality and quantity of the groundwater and regular monitoring is therefore recommended.
- The interventions above need to be supported by regulation on extraction from deeper aquifer. So, the deeper ground water resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought.
- In terms of the critical issues for the drinking water such as source sustainability, water quality management and better operation and maintenance, it is important that strong grassroots awareness is generated. Thus, IEC activities and capacity building activities needs to be aggressively propagated to establish the institutional framework for participatory ground water management. Awareness among stakeholders & their participation for ground water recharge and conjunctive use of available resource. Farmers should be trained for adopting more efficient irrigation techniques and water conservation practices and boosting recharge.
- As it is peek time to move to multi-disciplinary approach to save more water viz. Diversification in agriculture (horticulture, vegetables, green houses, agro-forestry, fodder crops, Diversification of Livelihoods (Agriculture, Animal Husbandry, Self-Employment), limiting extensive groundwater withdrawals which will in turn require limiting agricultural electricity subsidies provided by state governments and rationing of power.

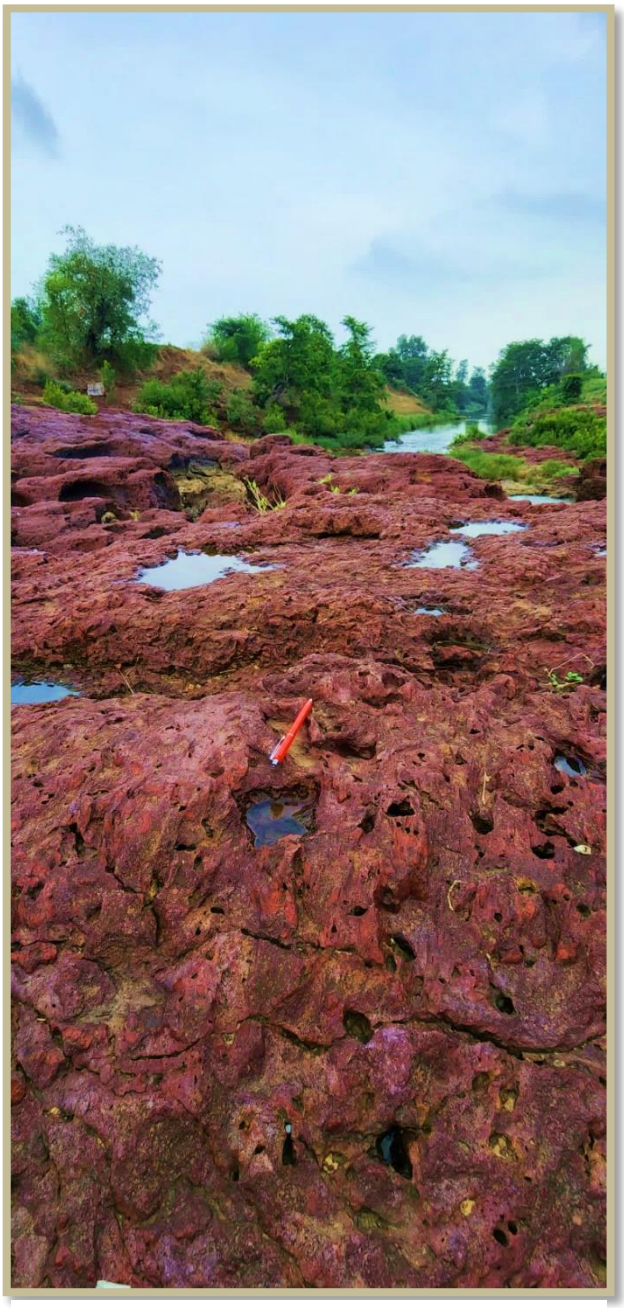


Figure 29 Laterite outcrop near Mohla village, Block Sihora

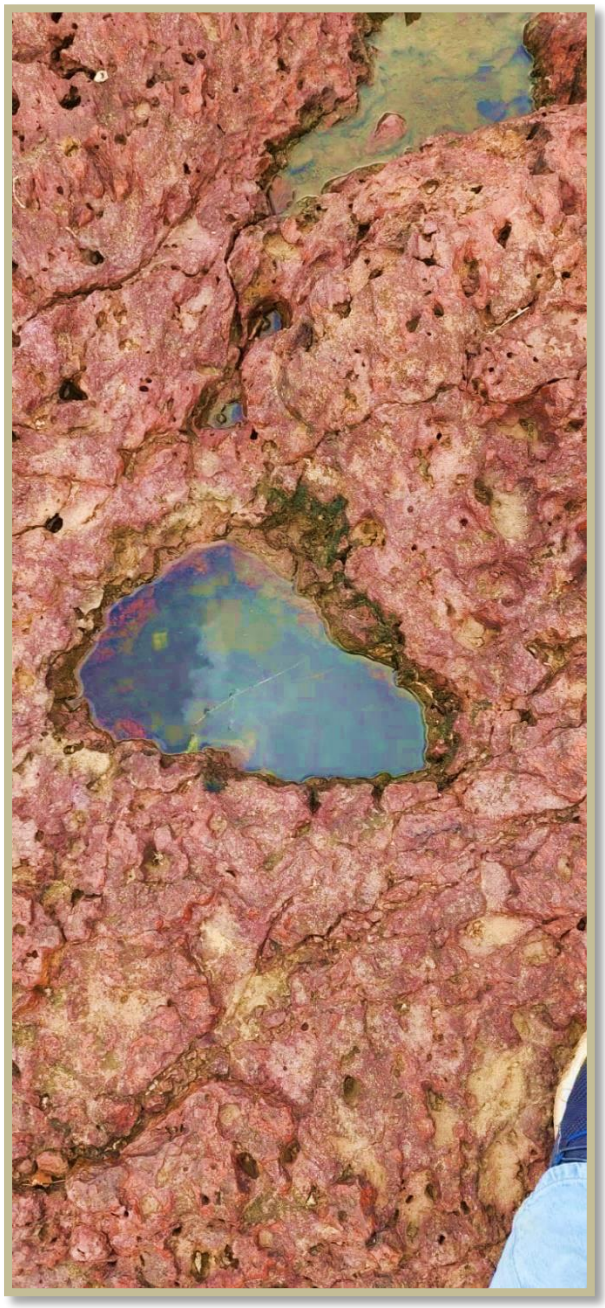


Figure 30 Water gets filled in cavities of lateritic rock

Figure 27 Sandstone shale exposed at Majholi block, Jabalpur district

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District Agriculture Contingency Plan, Jabalpur, NICRA-ICAR.

Annexure I

Key observation wells established under NAQUIM in Jabalpur district											
S no.	Block	Village	Lat	Long	Well type	Depth	Dia	Casing	MP	PRE	POST
1	Sihora	Nandigram Rampur	23.370955	80.038136	DW	8.8	5	8.75	0	Dry	8.55
2	Sihora	Jujhari	23.40609	80.090281	DW	15.65	7.30*7.30	Fully curbed	1.7	14.15	6.33
3	Sihora	Sindursi	23.38326	80.135791	DW	9.59	3.35	Fully curbed	0.75	Dry	3.4
4	Sihora	Nunji	23.414191	80.172796	DW	11.77	2.12	Fully curbed	0.75	Dry	8.8
5	Sihora	Singuli	23.4212591	80.234094	DW	13	2.7	3	0.6	11.85	3.98
6	Sihora	Keolari	23.472625	80.189018	DW	13.35	2.7	Fully curbed	0.3	Dry	8.9
7	Majholi	Bargi	23.543963	80.145932	DW	9	2.35	Fully curbed	0.75	Dry	6.5
8	Majholi	Talad	23.540325	80.04181	DW	12.5	3.15	Fully curbed	1.2	Dry	2.47
9	Majholi	Ponda	23.502864	80.037153	DW	14.7	2.85	7.45	1.35	12.55	4.4
10	Majholi	Pali	23.523906	79.969218	DW	7.6	4.05	6.3	0.3	Dry	3.19
11	Majholi	Khango	23.5359731	79.884386	DW	12.4	2.9	Fully curbed	0.2	Dry	Dry
12	Majholi	Kuluwa	23.462991	79.808359	DW	12	6	9	1	9.2	4.2
13	Majholi	Hinauta	23.450503	79.844177	DW	10.5	2.9		0.8	Dry	Dry
14	Panagar	Mohaniya	23.310194	79.873562	DW	9	2	Fully curbed	0.3	8.7	7.4
15	Patan	Kakarhata	23.432333	79.832257	DW	18	4.45	Fully curbed	1.35	11.6	Dry
16	Patan	Kaimori	23.384199	79.753816	DW	5.25	2.4	Fully curbed	0	Dry	Dry
17	Patan	Khamod	23.269317	79.770692	DW	10.2	3.2	Fully curbed	0.7	Dry	Dry
18	Shahpura	Bhita	23.163785	79.798848	DW	7.3	1.25	Fully curbed	0	Dry	Dry
19	Shahpura	Ramghat pipariya	23.129427	79.731771	DW	9.2	3.85	Fully curbed	0	Dry	Dry
20	Shahpura	Ghunsor	23.167423	79.692288	DW	10.2	3	Fully curbed	0.5	9.7	6.2
21	Shahpura	Shahpura Kaithra	23.138948	79.663277	DW	7.4	3.5	Fully curbed	1.4	Dry	Dry
22	Shahpura	Mehgawan	23.075556	79.643249	DW	7	3.4	Fully curbed	0.7	3.8	4.8
23	Shahpura	Kusli	23.150252	79.522657	DW	9.7	2	Fully curbed	0.2	Dry	Dry
24	Shahpura	Jhalon	23.1251	79.475421	DW	17	5		1.5	Dry	14.2
25	Panagar	Silua chokhda	23.07071	79.98763	DW	10	5.3	Fully curbed	1.15	4.45	3.19
26	Panagar	Narrai	23.007387	79.98678	DW	15	4.1	5.7		13.2	9.45
27	Bargi	Harduli	22.925075	79.896622	DW	7.9	4	4.6	0.65	7.2	6.55
28	Bargi	Kaladehi	22.880616	79.824179	DW	10.5	5.7	2	0.4	10.3	10.5
29	Bargi	Tinsa	22.981788	79.838526	DW	13.3	5.2	13	0.45	13.26	9.48
30	Bargi	Chirapondi	22.975042	79.756404	DW	5.6	3.45	Fully curbed	1,50	Dry	3.25
31	Panagar	Sundarpur	23.23746	80.092618	DW	9.75	5	Fully curbed	0.8	Dry	7.9
32	Kundam	Luhkari	23.175777	80.112738	DW	11.45	2		0	Dry	Dry
33	Kundam	Ghugri	23.234729	80.197483	DW	6.09	2.87	Fully curbed	0.9	0.9	0.8
34	Kundam	Deori kalan	23.154403	80.219935	DW	5	4.2		0.9	1.4	1.68
35	Kundam	Ghodatakan	23.262687	80.364257	DW	4.2	5.4	Fully curbed	0	1.3	1.05
36	Kundam	Turka	23.1816	80.315137	DW	8.05	4	Fully curbed		6.15	6.9
37	Kundam	Bil tukri	23.171595	80.417304	DW	5.9	5.2	Fully curbed	0.85	3.4	2.6

38	Kundam	Tauri	23.154758	80.489562	DW	6.33	2.35	Fully curbed	0.75	3.28	1.07
39	Kundam	Mohani	22.273539	80.55622	DW	4.03	4.8	Fully curbed	0.3	3.64	2.2
40	Kundam	Kuwarhat	23.262237	80.454891	DW	5.85	3.7	Fully curbed	0.35	5.35	2.7

Annexure II

Groundwater samples collected for Basic parameters analysis under NAQUIM in Jabalpur district							
Sl. No.	**District**	**Block**	**Location**	**Latitude**	**Longitude**	**Source**	**Date of Collection**
1	Jabalpur	Panagar	Tiwari Kheda	23.3005105	79.9936837	BW	17.6.2022
2	Jabalpur	Sihora	Nandigram Rampur	23.371612	80.039316	BW	17.6.2022
3	Jabalpur	Sihora	Jujhari	23.40609	80.090281	HP	17.6.2022
4	Jabalpur	Sihora	Simariya	23.400191	80.10267	BW	17.6.2022
5	Jabalpur	Sihora	Sindursi	23.38326	80.135791	HP	17.6.2022
6	Jabalpur	Sihora	Nunji	23.412863	80.17361	HP	17.6.2022
7	Jabalpur	Sihora	Singuli	23.4212591	80.234094	HP	17.6.2022
8	Jabalpur	Sihora	Keolari	23.472743	80.188774	HP	17.6.2022
9	Jabalpur	Majholi	Bargi	23.543963	80.145932	HP	18.6.2022
10	Jabalpur	Majholi	Talad	23.540569	80.041952	BW	18.6.2022
11	Jabalpur	Majholi	Ponda	23.503113	80.037226	HP	18.6.2022
12	Jabalpur	Majholi	Majhgawan	23.523851	79.966519	HP	18.6.2022
13	Jabalpur	Majholi	Kataw dham	23.542675	79.878962	BW	18.6.2022
14	Jabalpur	Majholi	Kuluwa	23.462991	79.808359	DW	18.6.2022
15	Jabalpur	Majholi	Hinauta	23.450503	79.844177	HP	18.6.2022
16	Jabalpur	Panagar	Mohaniya	23.310194	79.873562	DW	19.6.2022
17	Jabalpur	Patan	Kakarhata	23.432378	79.831657	HP	19.6.2022
18	Jabalpur	Patan	Kaimori	23.381785	79.744964	HP	19.6.2022
19	Jabalpur	Patan	Katra Belkheda	23.270531	79.617074	HP	19.6.2022
20	Jabalpur	Patan	Patan	23.294278	79.684155	HP	19.6.2022
21	Jabalpur	Patan	Khamod	23.269317	79.770692	HP	19.6.2022
22	Jabalpur	Shahpura	Bhita	23.163785	79.798848	BW	20.6.2022
23	Jabalpur	Shahpura	Ramghat pipariya	23.129427	79.731771	BW	20.6.2022
24	Jabalpur	Shahpura	Ghunsor	23.167942	79.688638	HP	20.6.2022
25	Jabalpur	Shahpura	Shahpura Kaithra	23.138948	79.663277	HP	20.6.2022
26	Jabalpur	Shahpura	Mehgawan	23.075556	79.643249	HP	20.6.2022
27	Jabalpur	Shahpura	Kusli	23.149846	79.523086	HP	20.6.2022
28	Jabalpur	Shahpura	Sundradehi	23.143223	79.426163	HP	20.6.2022
29	Jabalpur	Panagar	Silua chokhda	23.07071	79.98763	DW	21.6.2022
30	Jabalpur	Panagar	Narrai	23.007387	79.98678	HP	21.6.2022
31	Jabalpur	Bargi	Harduli	22.927583	79.899739	BW	21.6.2022
32	Jabalpur	Bargi	Kaladehi	22.880616	79.824179	BW	21.6.2022
33	Jabalpur	Bargi	Chirapondi	22.975042	79.756404	HP	21.6.2022
34	Jabalpur	Panagar	Sundarpur	23.238662	80.09321	HP	21.6.2022
35	Jabalpur	Kundam	Luhkari	23.177959	80.11729	HP	22.6.2022
36	Jabalpur	Kundam	Ghugri	23.234729	80.197483	HP	22.6.2022
37	Jabalpur	Kundam	Deori kalan	23.154403	80.219935	DW	22.6.2022
38	Jabalpur	Kundam	Ghodatakan	23.265785	80.369357	BW	22.6.2022
39	Jabalpur	Kundam	Turka	23.181552	80.315501	HP	22.6.2022
40	Jabalpur	Kundam	Bil tukri	23.165404	80.425938	BW	23.6.2022

41	Jabalpur	Kundam	Tauri	23.154758	80.489562	DW	23.6.2022
42	Jabalpur	Kundam	Mohani	22.273539	80.55622	DW	23.6.2022
43	Jabalpur	Kundam	Kuwarhat	23.264942	80.454546	HP	23.6.2022

Groundwater samples collected for Heavy metals analysis under NAQUIM in Jabalpur district							
Sl. No.	**District**	**Block**	**Location**	**Latitude**	**Longitude**	**Source**	**Date of Collection**
1	Jabalpur	Sihora	Simariya	23.400191	80.10267	BW	17.6.2022
2	Jabalpur	Sihora	Nunji	23.412863	80.17361	HP	17.6.2022
3	Jabalpur	Sihora	Singuli	23.4212591	80.234094	HP	17.6.2022
4	Jabalpur	Sihora	Keolari	23.472743	80.188774	HP	17.6.2022
5	Jabalpur	Majholi	Talad	23.540569	80.041952	BW	18.6.2022
6	Jabalpur	Majholi	Kataw dham	23.542675	79.878962	BW	18.6.2022
7	Jabalpur	Patan	Kakarhata	23.432378	79.831657	HP	19.6.2022
8	Jabalpur	Patan	Khamod	23.269317	79.770692	HP	19.6.2022
9	Jabalpur	Shahpura	Ramghat pipariya	23.129427	79.731771	BW	20.6.2022
10	Jabalpur	Shahpura	Mehgawan	23.075556	79.643249	HP	20.6.2022
11	Jabalpur	Panagar	Silua chokhda	23.07071	79.98763	DW	21.6.2022
12	Jabalpur	Bargi	Chirapondi	22.975042	79.756404	HP	21.6.2022
13	Jabalpur	Panagar	Sundarpur	23.238662	80.09321	HP	21.6.2022
14	Jabalpur	Kundam	Ghodatakan	23.265785	80.369357	BW	23.6.2022
15	Jabalpur	Kundam	Tauri	23.154758	80.489562	DW	23.6.2022