केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

AQUIFER MAPPING REPORT

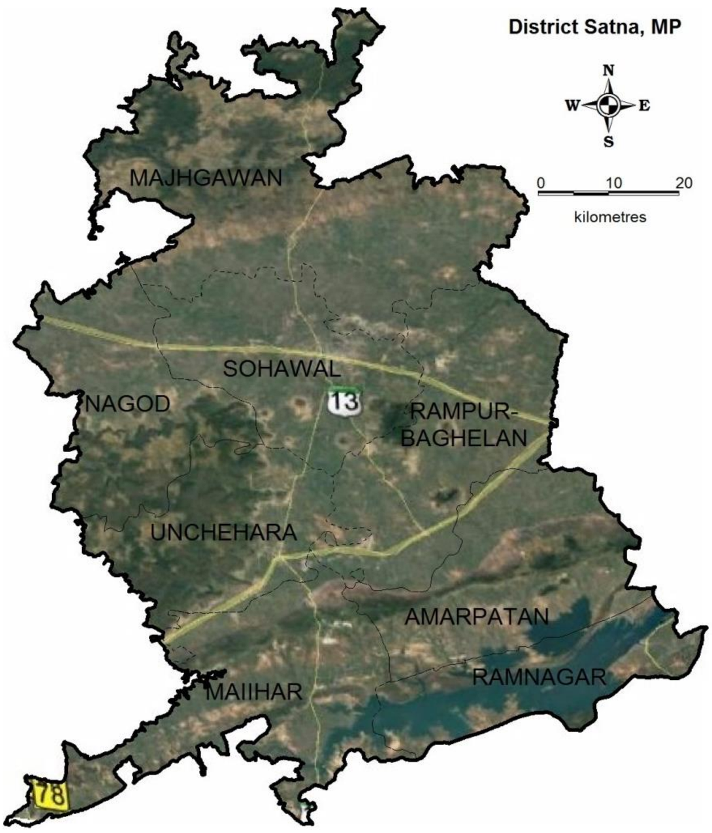
Satna District, Madhya Pradesh

उत्तरी मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

Government of India

AQUIFER MAPPING AND MANAGEMENT PLAN OF SATNA DISTRICT, MADHYA PRADESH



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CENTRAL GROUND WATER BOARD
NORTH CENTRAL REGION
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVANATION

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I would like to give my heartiest thanks to Mrs. Ritu K. Oraon, Scientist-B and Dr.K.Paramasivam, STA (HG) for their unparalleled assistance in various forms.

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FOREWORD

Groundwater being a valuable asset and its relatively easy accessibility in comparison to surface water sources is primarily used for irrigation. Satna district is located in northern part of Madhya Pradesh having geographical area of 7,424 Sq km. The recharge worthy area accounts for about 6721 sq. km. Satna district is one of representative district of Vindhya region of Madhya Pradesh and is predominantly occupied by agriculture area that forms the major economy of the region. Around 79.4% of population is rural and dependent on the cultivation practices. Ground water is main source of irrigation in the Satna district. However, under Bansagar project the irrigation facilities will further reduce the stress on the groundwater thereby enhancing the prosperity of the district.

Under the National Aquifer Mapping (NAQUIM) project, multidisciplinary approach has been adopted for preparation of aquifer maps and ground water management plan for Satna district. The report consists of the existing hydrogeological, chemical and geophysical data that were compiled for the preparation of aquifer maps. The collected data was further processed to generate regional hydrogeological maps, thematic maps, water quality maps, cross-sections, 2-D and 3-D aquifer dispositions.

The aquifer management plan for Satna district has been prepared in which the ground water resources can be enhanced by 182.67 MCM through construction of artificial recharge structures viz. 242 percolation tanks, 1457 check dams/nala bunds, 608 recharge shafts and ensuring water use efficiency through maintenance/renovation of 2015 existing water bodies/water conservation structures. Adoption of micro-irrigation techniques such as sprinkler irrigation has also been proposed, that will reduce the draft and conserve ground water resources by saving 41.10 MCM of resource from overall irrigation draft. The interventions suggested in the report will not only have a positive impact on the ground water regime but would also play a key role in augmenting the net cropping area and would ultimately enhance the agricultural productivity and economy of the district.

One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and Various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analysed, examined, synthesized and interpreted from available sources. These sources were predominantly non-computerized data, which was converted into computer based GIS data sets. On the basis of available data I would like to place on record my appreciation for the excellent work done by Ms. Neety Nagi, Sc 'B' under supervision of Dr. L. K. Mathur, Sc‘D’. I fondly hope that this report will serve as a valuble guide for sustainable development of ground water in the Satna District, Madhya Pradesh.

(Parvinder Singh)
Regional Director

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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.

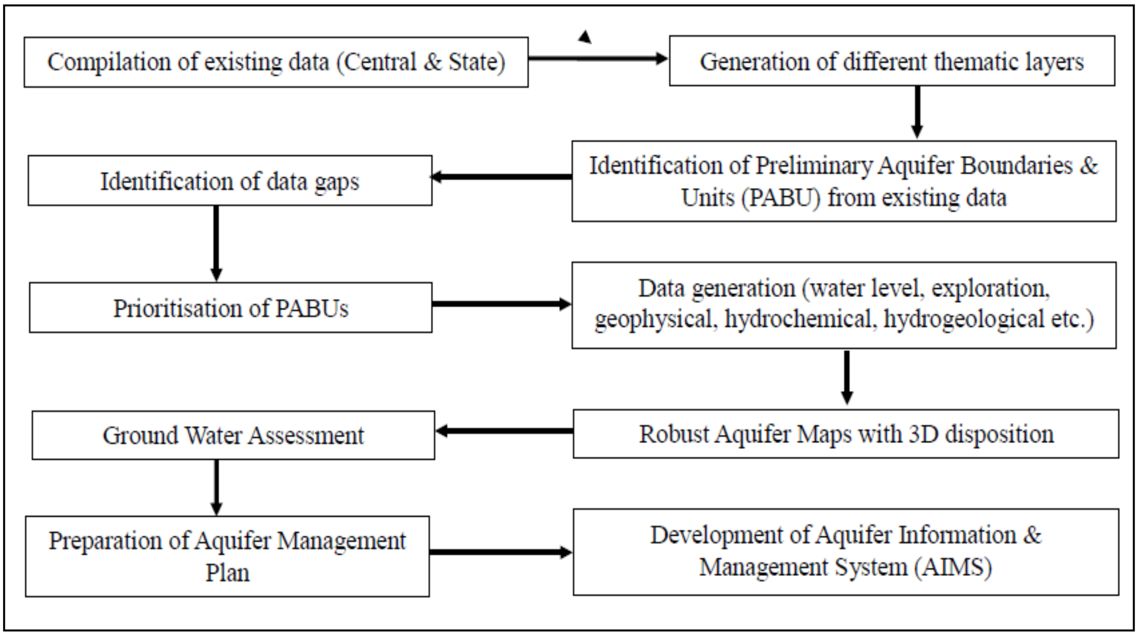
The two major objectives of the aquifer mapping is the delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale in general and further detailing up to 1: 10,000 scale in identified priority areas and the quantification of ground water availability and 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

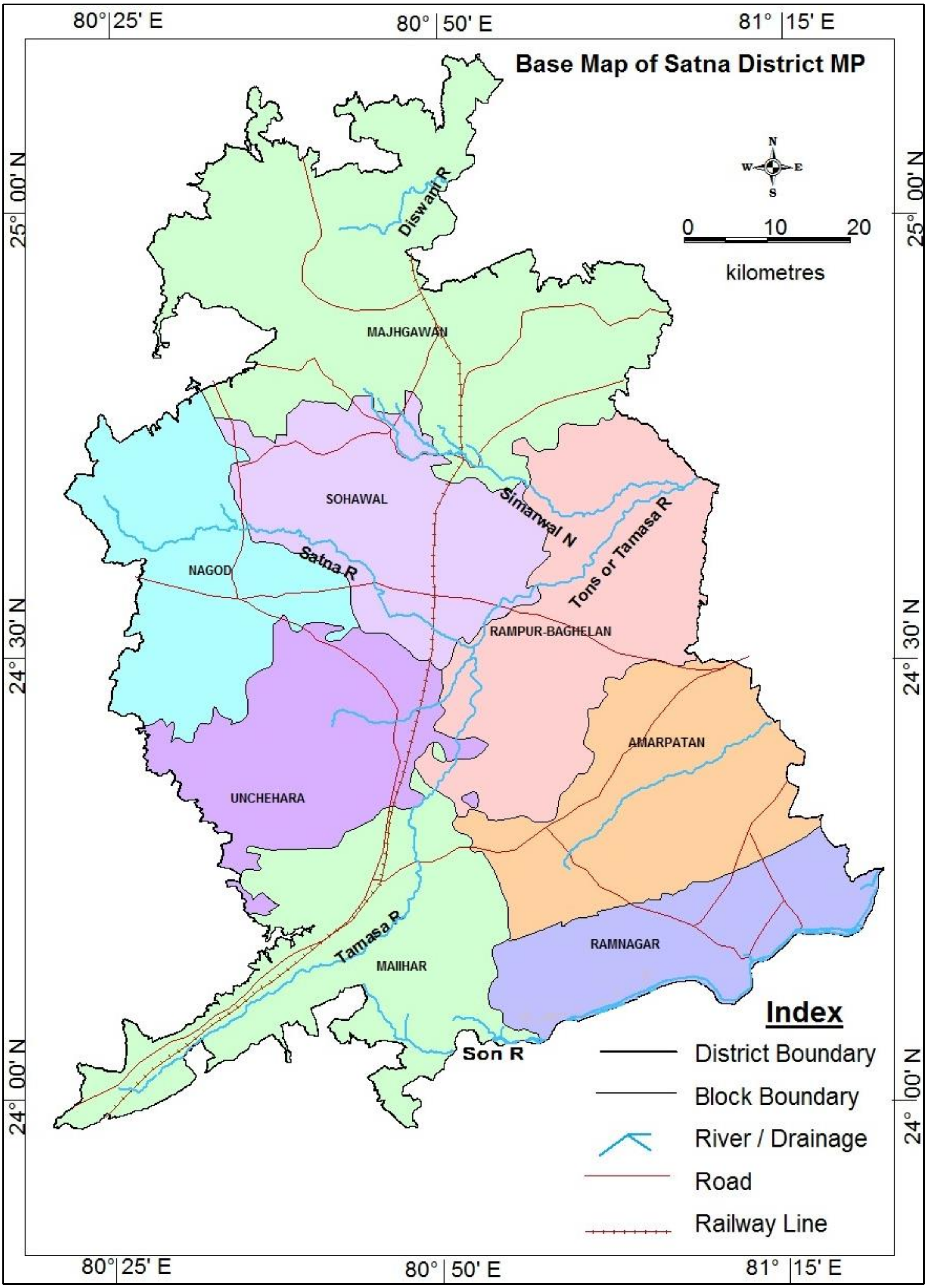


1.3 Area Details

Satna district is one of representative district of Vindhya region of Madhya Pradesh. It takes its name from the head quarter's town, Satna. In turn the town derives its name from the Satnariver, which flows through the vicinity and joins the tons river. The district is culturally and agriculturally rich. Satna district is famous for pilgrim stations namely Sharda Temple (at Maihar), Chitrakoot and Ramvan. Nearly 79.4 % of population is rural based and agriculture forms the major economic activity. The district is also having industrial and mining importance. There are three major Cement Plants located at Satna, Mankahri (in Rampur-Baghelan Block) and at Sarla Nagar (near Maihar town). District is also big producer of Lime Stone mineral.

Satna district is located in northern part of Madhya Pradesh having geographical area of 7,424 Sq km. It is bounded by the district of Chitrakoot (U.P.) in the north, by Katni and Umariya districts in south and Panna and Rewa districts form the western and eastern boundaries of the Satna district. The district lies between the latitudes 23°05'N and 25°12'N and longitudes 80°21'E and 81°23'E. It falls in parts of Survey of India Toposheets No. 63C/12, & 16, 63D/ 5, 6, 7, 8, 9, 10, 11, 12, 13, and 63D/14, & 15 (full), 16 (part) and also in parts of 63H/ 1, 2, 3, 7 & 8. It extends for about 132 Km from north to south and 102 Km from east to west. The district is well connected by roads with the state capital Bhopal and the adjacent district headquarters. Kanyakumari-Varanasi National Highway No.7 passes through southern part of the district. Katni-Allahabad broad gauge line of West-Central passes through the central part of the district. A detailed location map of the study area is shown in the fig 2.

Fig 2: Administrative Map



1.3.1 Administrative Details

The satna district is part of Rewa Commissionery. The district has been divided into 10 Tehsils and 8 Blocks. There are 1816 villages and 13 towns in the district. Total population of the district is 2,28,935. Detailed administrative divisions of the district are given in Table-1.

Table-1: Administrative Divisions

Block	Area (Sq.Km.)	No of Villages
Majhgawan	1584	295
Rampur-Baghelan	874	215
Nagod	919	244
Unchehara	897	211
Amarpatan	652	169
Ramnagar	601	207
Maihar	1125	240
Sohawal	772	235
Total	**7424**	**1816**

1.4 Data availability, adequacy, data gap analysis and data generation

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

1. Data compilation: The previous studies carried out by Central Ground Water Board and various Government organizations was collected. The Basic data reports of Exploratory wells/Observation wells/Piezometers drilled by CGWB, details of wells drilled by State PHED and district brochures published by CGWB was compiled and integrated for aquifer mapping. The Dynamic ground water resource book (2013) of CGWB and figures from the WRD were used for preparation of management plan.
2. 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.
3. 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.

4. Data Generation: The study of Satna district concentrated on the existing data, thus no new data was generated.

1.5 Rainfall distribution

The climate of Satna district is characterized by a hot summer with general dryness, except during the south-west monsoon season. The year may be divided into four seasons. The cold season from December to February is followed by the hot season from March to about 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 Satna district is 1046.00 mm. The district receives maximum rainfall during south-west monsoon period (i.e. June to September) and about 87.7% of annual rainfall is received during this period. Only 12.3% of the annual rainfall takes place between periods October to May. Thus, surplus water available for recharge to ground water is only during south-west monsoon period.

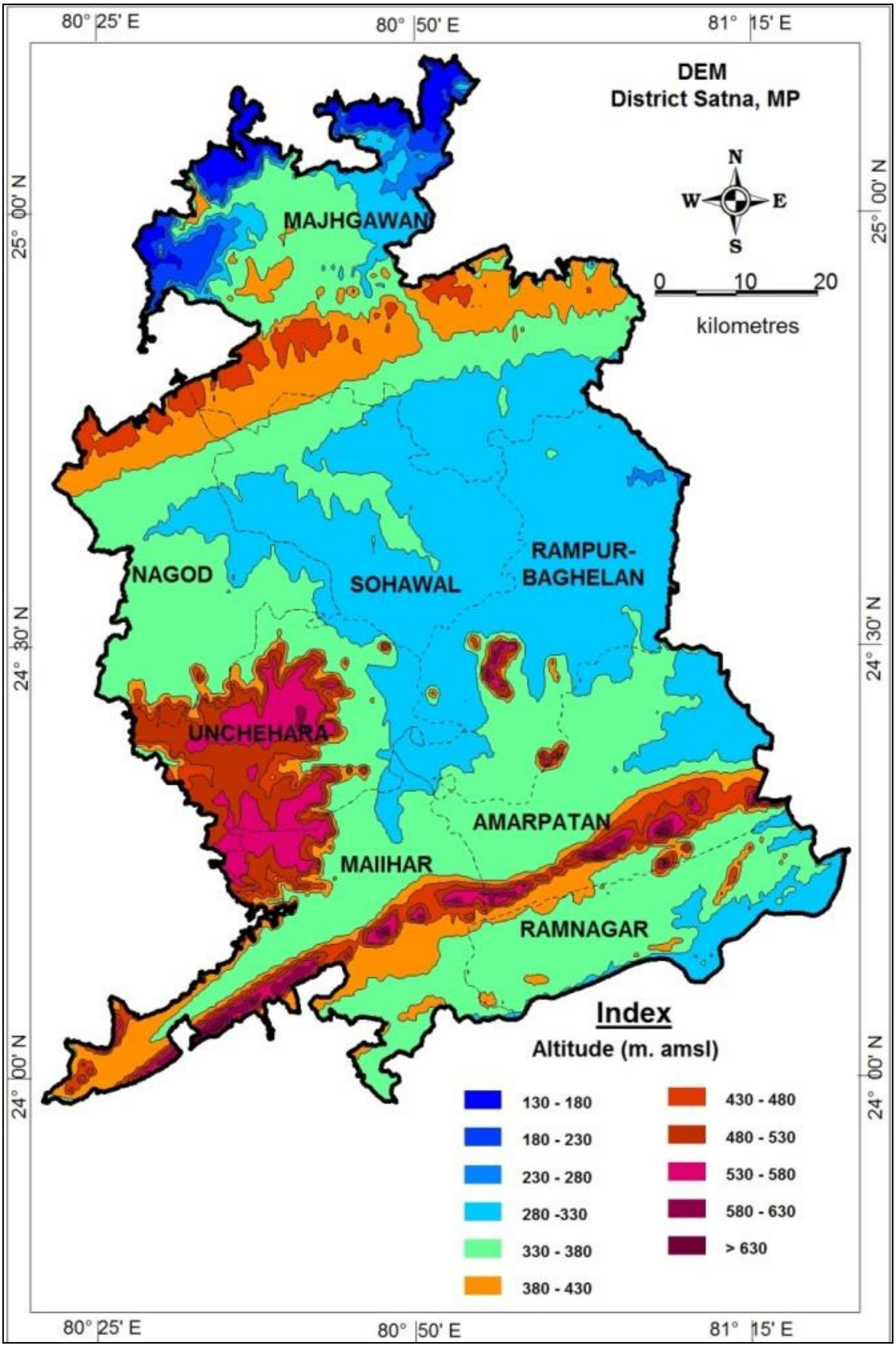
Table-2: Normal Climatological Parameters

S.N.	Climatic Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
1	Maximum Temp (ºC)	24.2	27.4	33.3	38.8	41.9	39.2	32.2	30.8	31.6	32.0	29.2	25.4	32.2
2	Minimum Temp (ºC)	8.7	11.3	16.4	22.3	26.7	27.9	25.1	24.5	23.8	19.6	13.1	9.0	19.0
3	Relative Humidity(%)	69	60	44	31	29	54	83	86	81	69	61	68	61
4	Rainfall(mm)	30.8	15.3	12.7	5.4	7.9	119.0	338.6	330.9	181.9	40.1	14.9	9.0	1106.5
5	Wind Speed (mph)	3.6	4.3	5.3	6.0	7.3	9.2	7.6	6.6	5.5	3.4	2.8	2.4	5.4

1.6 Physiography/Digital Elevation Model

Satna district is endowed with the diverse physiography. The maximum elevation of the district is 704 m above mean sea level (amsl), which is recorded near southern part of the district. The western portion of the region is also highly elevated. 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 280 to 380 m amsl. The Digital Elevation Model (DEM) is shown in the fig. 3.

Fig 3: Digital Elevation Model



1.7 Geomorphology

a) **Landforms:** Almost entire Satna district lies on the Vindhyan plateau, which extends from the Kaimur hill range in the south to the edge of the Ganga valley in the north. It is traversed by three prominent hill ranges from south-south west to north-north east and is occupied by a higher plateau in the south-western part of the district known as "Parasmania Pahar" which is part of Bhander series. Maximum elevation of the district is 704 m above mean sea level, which is recorded near "Papra Reserve Forest" on Kaimur hill range on southern part of the district. The southern and northern fringes of the district lie low in the respective valleys of the Son and the Yamuna rivers. Geomorphologically the district can be broadly divided into four major divisions as shown in fig 4.

   The Upper/central plateau occupies the major part of the district area, centrally located between the Kaimur range in south and Panna range in the north. The central plateau is studded by small isolated hillocks namely, Kaitha hill (601.7m amsl), Rampur (573m amsl) and Bida (627.6 mamsl). The structural hills mainly include the Kaimur hills and the Panna hills range. The Kaimur hill range is passing through southern part of the district from Maihar and Amarpatan Tehsils in ENE-WSW direction forming water divide between Tons and Son Sub-basins. The northern range which is also called as "Panna range" is low range with broken ridges extends through the northern part of the district, extending from south-west to north-east direction. The Paisuni and Banganga stream brises from northern face of Pannarane. The highest peak of Panna hill range is Digri (484m amsl). The son valley area is occurring as narrow strip, located south of Kaimur range. The Yamuna valley area is located on northern fringe of the district, below the Vindhyan plateau. It is part of the Ganga alluvial plain and characterized by the level plain with alluvial soil. Paisuni and Baghain rivers drain this area.

b) **Drainage:** Satna district is falling under the Ganga basin area. The Yamuna, the Tons and the Son are Sub-basins of the Ganga basin, which are draining the area. Except in small southern part, the district is mainly drained by river Tons and its tributaries. Tons is a perennial river, which flows in north and north-east direction. Its main tributaries are westerly flowing Seranji Nala, nort-easterly flowing Lilji Nala, Barua Nala and Beehar Nadi, northerly flowing Magardaha Nala, and easterly flowing Satna, Simrawal and Asrawal rivers. The "Paisuni or Mandakni" sacred river, which is a tributary of the river Yamuna drains northern part of the district (Chitrakoot area). Southeast part of the district is drained by Son river and its tributaries. ENE-WSW trending Kaimur hill range acts as a main water divide of the area, which separating Tons Sub-basin from the Son Sub-basin. A detailed hydrology map is presented in the fig. 5.

Fig 4: Geomorphological Map

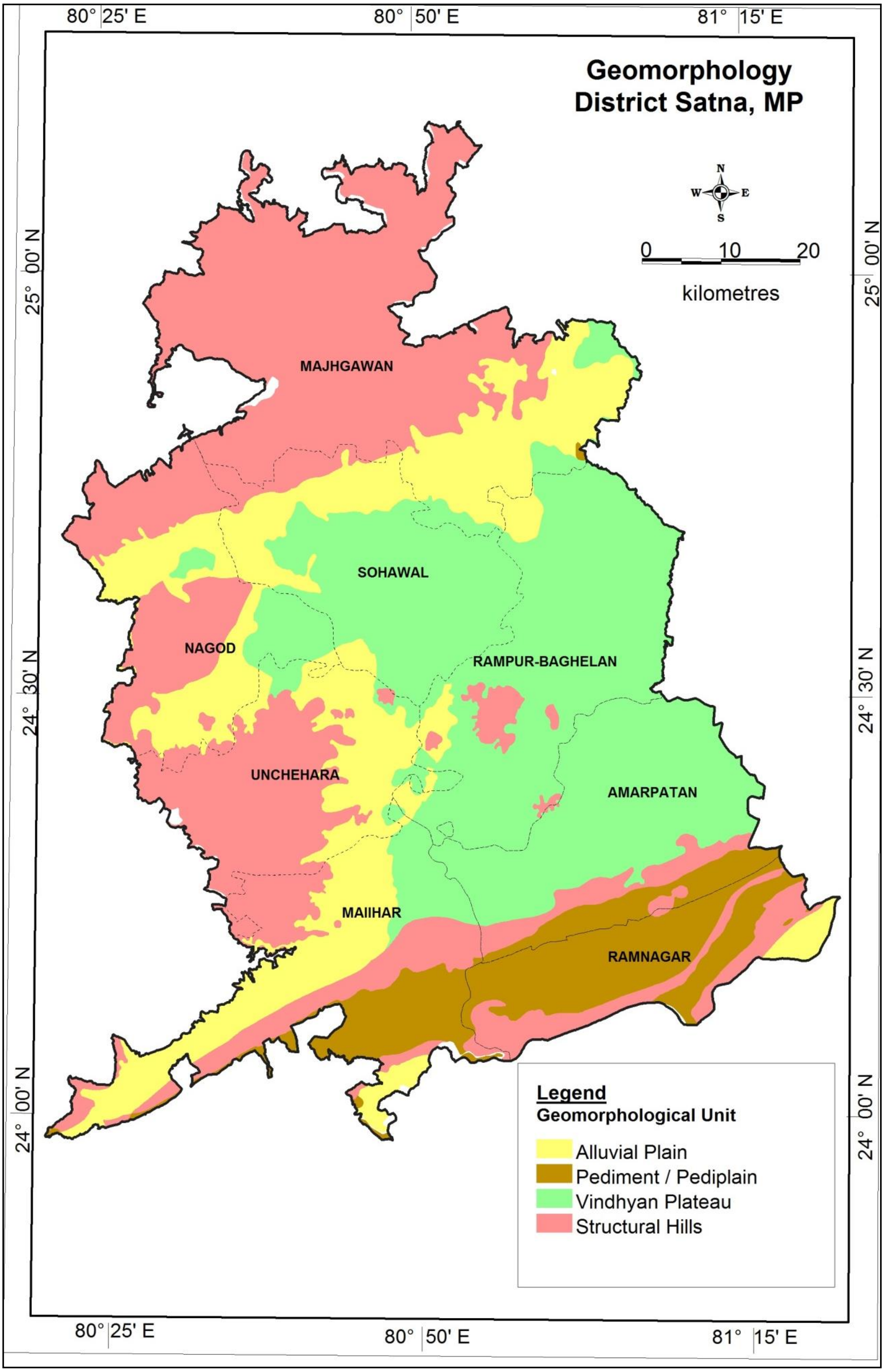
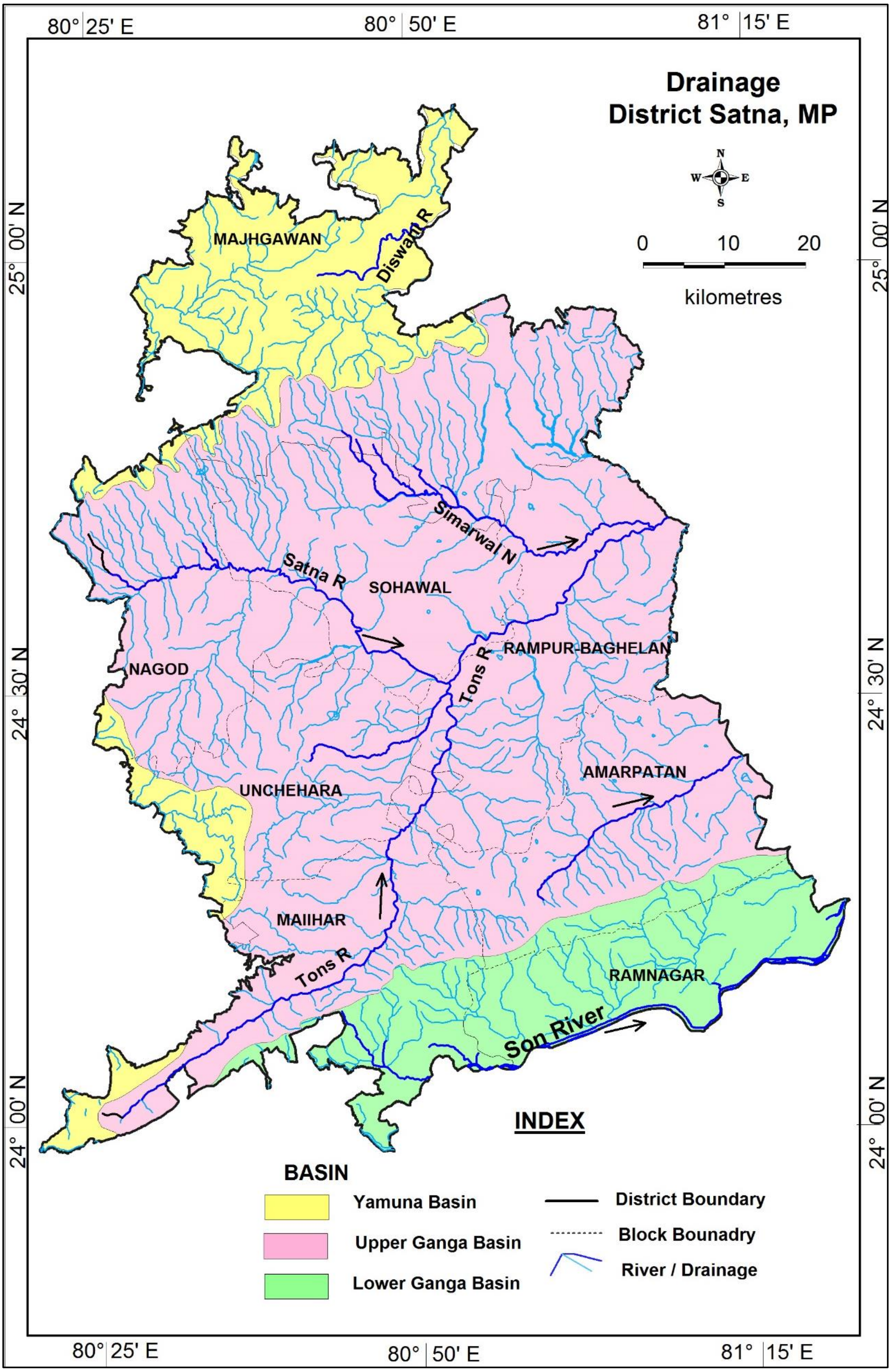


Fig 5: Drainage Map



1.8 Land-use

Satna district is predominantly occupied by agriculture area that forms the major economy of the region. Around 79.4% of population is rural and dependent on the cultivation practices. Urban areas have been occupied in small portions at Maihar and Amarpatan blocks. The rivers of the Ganga and Yamuna basin drain the entire area. Mining has been carried out at places in Maihar and Sohawal blocks. Remaining area is covered by dense forests that occupies major portions of Majhgawan and Nagod blocks. A map showing major land use pattern is presented in the fig. 6.

1.9 Soil cover

Satna district is mainly underlain by sedimentary rocks of Vindhyan Supergroup, except in small northern and southern part. The soil cover of the district has been broadly classified as alluvial, clayey and sandy soil and is depicted in the fig. 7. In plateau area of the district which is occupied by shales with quartzites, limestones, conglomerates and sandstones are covered by Red and Yellow Soils. Upland area of the district representing hill ranges is occupied by Skeletal or Gravelly soils. Northern part of area which is the extension of Gangatic Plains is covered by Alluvial Soil. Southern part of the district in Son valley area is underlain by thin and gravelly fertile "Alluvial soils".

1.10 Agriculture, Irrigation and Cropping patterns

Irrigation facilities in Satna district are in a developing phase. Ground water is main source of irrigation in the district. Out of total 1,40,553 Ha irrigated area, 1,32,114 hectares is irrigated from ground water sources, which is about 94% of total irrigation. About 20,955 tube wells and 17177 dug wells in the district were used for irrigation during year 2015. An area of about 8,439 Ha is irrigated through canals which accounts for only 6% of total irrigation of the district (Table-3).

Table-3: Area irrigated by different sources (*as per census 2015*)

Block	Area Irrigated by Ground Water			Area Irrigated by Surface Water		
	Dug Well (Ha)	Tube Well (Ha)	Total Area (Ha)	Ponds (Ha)	Canals (Ha)	Total Area (Ha)
Amarpatan	1804	13205	15009		274	274
Maihar	5867	15308	21175	13	856	869
Majhgawan	4773	7149	11922	350	1115	1465
Nagod	3348	16778	20126		723	723
Ramnagar	3527	1585	5112	32	1124	1156
Rampur Baghelan	1855	24439	26294		1586	1586
Sohawal	1379	15977	17356		1753	1753
Unchehra	6810	8310	15120	42	571	613
Total	**29363**	**102751**	**132114**	**437**	**8002**	**8439**

Fig 6: Landuse Map

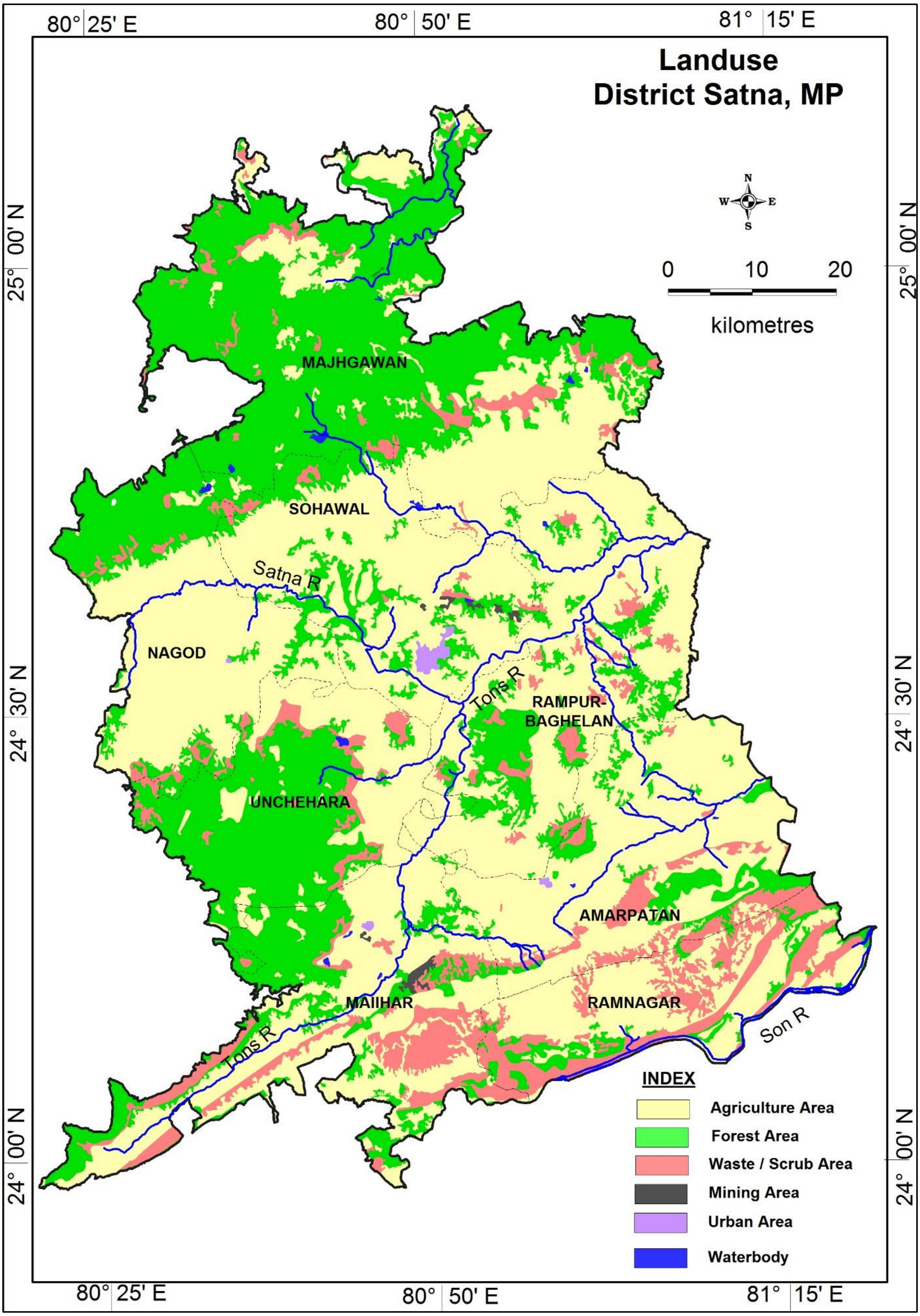
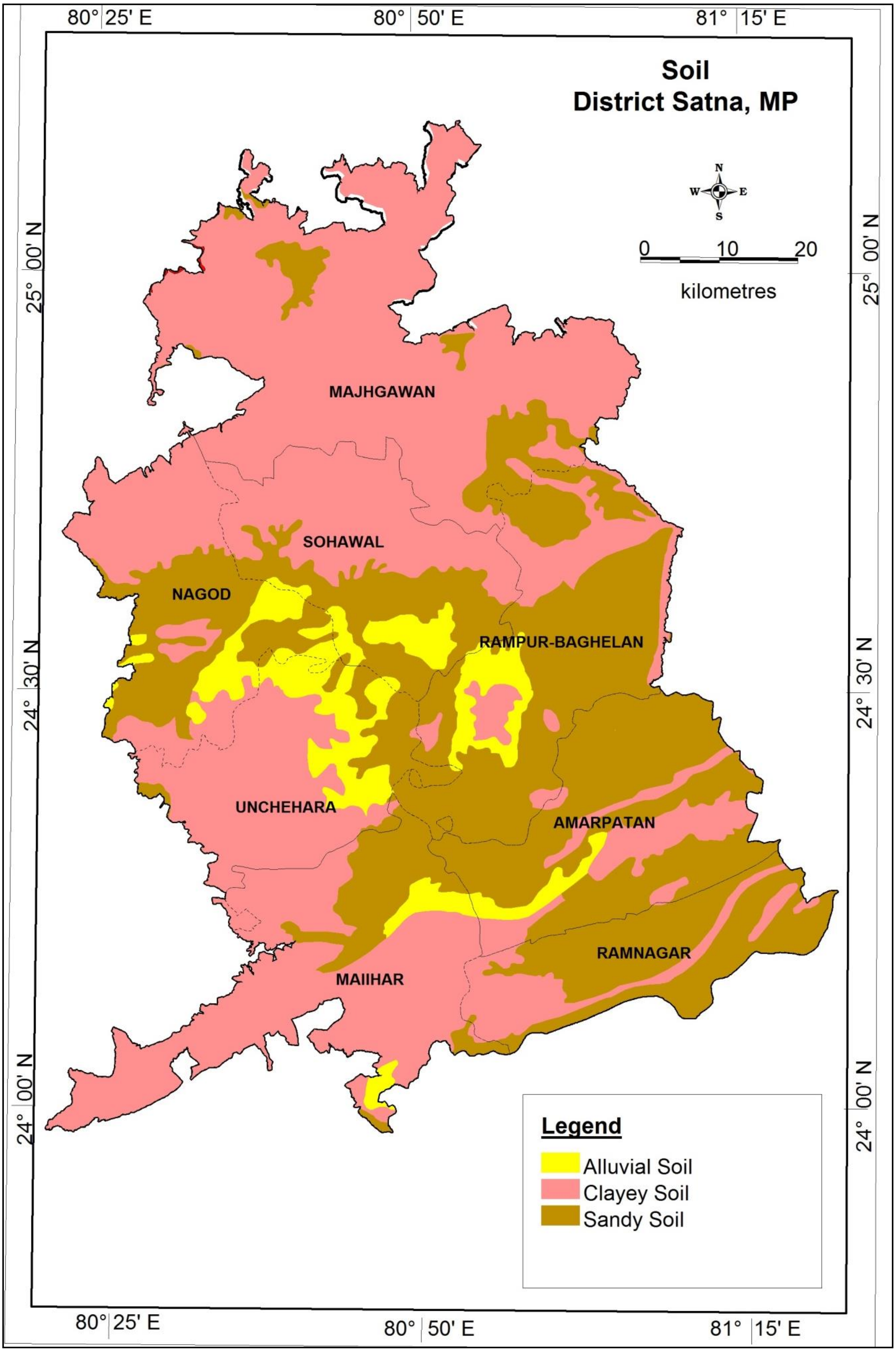


Fig 7: Soil Map



However, as per the data received from Water Resources Department, Madhya Pradesh canals systems have been designed under the Bansagar Dam project to irrigate around 89,671 Ha area (Table-4). Fig. 8 displays the map showing the canal command area developed under this project.

Table-4: Area irrigated by different canal systems under Bansagar Project

Canal system	Amarpatan	Maihar	Majhgawan	Ramnagar	Rampur Baghelan	Sohawal	Total
Purwa Canal					28702	8698	**37400**
Bahuti Canal	12000				1000		**13000**
Ramnagar Micro		2000		18000			**20000**
Majhgawan Micro			19271				**19271**
Total	**12000**	**2000**	**19271**	**18000**	**29702**	**8698**	**89671**

About 1,56,942 Ha area has been sown under Rabi crops, mainly Wheat, whereas 90,205 Ha area is covered by the Kharif crops including Rice, Jowar and Maize (Table-5).

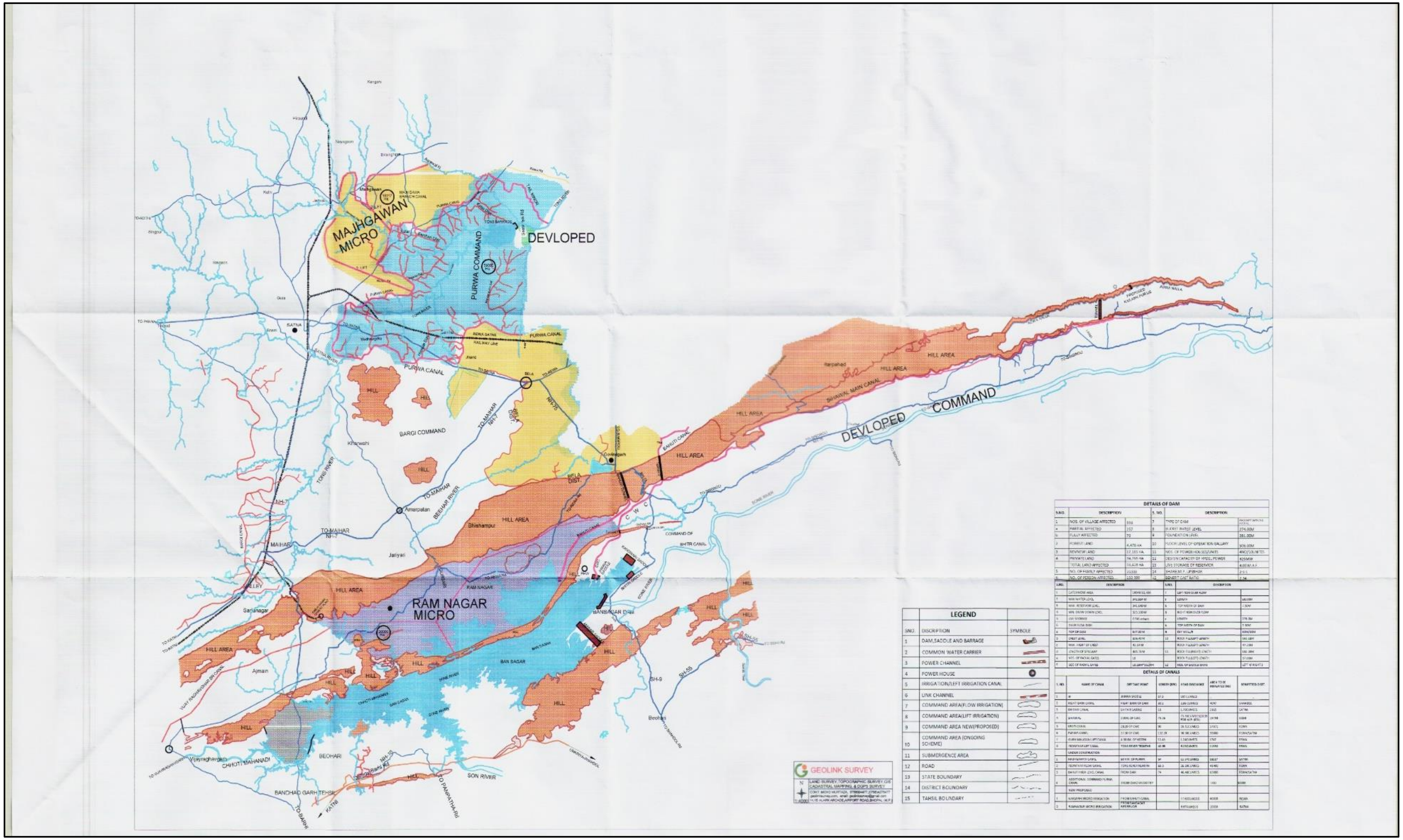
Table-5: Area irrigated under different crops

Block	Total Area Irrigated by Ground Water (Ha)	Total Area Irrigated by Surface Water Area (Ha)	Rabi Crop	Kharif Crop			
			Wheat (Ha)	Rice (Ha)	Jowar (Ha)	Maize (Ha)	Total (Ha)
Amarpatan	15009	274	15628	13706	27	17	13750
Maihar	21175	869	23149	16038	164	219	16421
Majhgawan	11922	1465	20126	8229	2011	16	10256
Nagod	20126	723	22719	11038	16	45	11099
Ramnagar	5112	1156	10048	11166	6	52	11224
Rampur Baghelan	26294	1586	28673	13625	20	1	13646
Sohawal	17356	1753	22310	7137	53	14	7204
Unchehra	15120	613	14289	6188	37	380	6605
Total	**132114**	**8439**	**156942**	**87127**	**2334**	**744**	**90205**

1.11 Prevailing water conservation/recharge practices

The Central Ground Water Board, under the Central Sector Scheme, has been extending technical and financial support to the State Government for implementing practices in rural and urban areas of the district. Ministry of Water Resources, Government of India had taken up Rampur-Baghelan block for implementation of dug well recharge scheme during year 2008-09. It was proposed to recharge 6728 irrigation wells of 3735 farmers of this block. In Satna district no water conservation/ artificial recharge project has been taken up by CGWB, however technical guidance for preparing DPR and other ground water recharge projects/schemes is being provided to PHED and other state departments.

Fig. 8: Bansagar Project Index map (WRD, Madhya Pradesh)



2. Data collection and generation

2.1 Hydrogeological

Rainfall is the main source of ground water recharge in the Satna district. Various geological formations ranging in age from Archaeans to Recent occurs in different part of area and contributes to a complex geological set up in the district. However, Vindhyans are the main rock units of the area, covering more than 95% of geographical area of the district. Among Vindhyans, both Lower and Upper Vindhyans represent the area, but Lower Vindhyans mostly occupy the southern part of the area in Son Sub-basin. A comprehensive hydrogeological map is shown in the fig. 9.

2.1.1 Hydrogeology of the area

Occurrence and movement of ground water in hard rock is essentially by development and nature of secondary joints and fractures. Solution cavities in limestones also play an important role in groundwater movement at certain places. Ground water in general occurs under unconfined to semi-confined conditions. The occurrence and movement of ground water in different lithological units is majorly controlled by following formations:

Granite and Gneisses

Exposure of granite and granitic-gneisses is restricted in the northern fringe of Satna district forming hilly and forested area. Small patch of granite has been reported in south-eastern corner of the district in Son valley area, presently falling under submergence of Bansagar Reservoir. Ground water in granites occurs under phreatic conditions in weathered, fractured and jointed horizons.

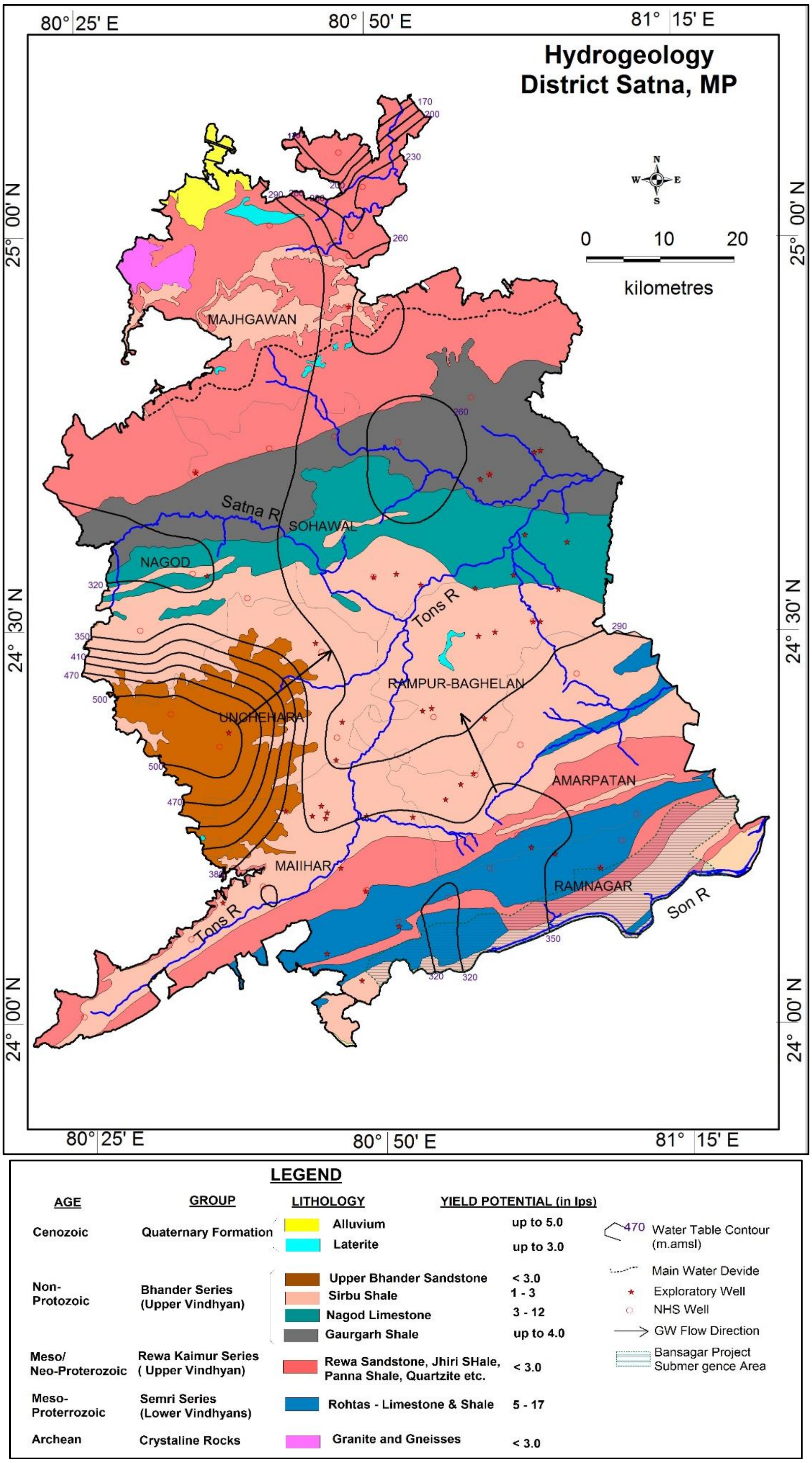
Khenjua, Porcellanite and Basal Stage formations (Semri-series, Lower- Vindhyans)

Lower Vindhyan rocks comprising basal conglomerate, Kajrahat limestone, Porcellanites, Glauconite beds, Fawn Limestone and Olive shales occurs in the southern part of the district. Small outcrops of sandstone of Porcellanite Stage has also been reported near village Bansakar in north-west corner of the district in Baghain water shed, overlying granites. GSI has also reported narrow bands of Kajrahat Lime stone near Chitrakoot and Gupt-Godawari areas in northern part of the district, overlying Granites. Khenjua Hill comprising of Glauconite beds, fawn limestone and olive shales forms ridge in southern part of the district almost parallel to Son river. Porcellanite and Basal stage formations of Son river valley are mostly submerged in Bansagar Reservoir area.

Rohtas Lime stone and Shales (Semri-series, Lower Vindhyan)

Rohtas limestone is light to dark grey in colour, fine grained and compact with shaly and sandy inter beds. These are thinly laminated, but massive form has also been reported from some areas. Ground water generally occurs under unconfined conditions at shallow depths. Physiographic locations and degree of Karstification (Development of solution channels/cavities) is important factor, which decides yield of ground water structure at

Fig 9: Hydrogeological Map



specific location. Massive limestone does not have porosity/permeability. CGWB exploratory wells drilled at Ajwain, Rivara and Ramnagar gone dry due to massive nature of Rohtas limestone. Exploratory wells drilled at Bhadanpur and Mirgauti were recorded high yield of 17 and 14.67 lps respectively. Depth to water levels recorded in CGWB Ground Water Monitoring Well vary from 10 to 14.86 m, bgl. Depth of open Wells ranges from 10m to 20m, bgl. in this formation.

Kaimur and Rewa Series formations (Upper Vindhyans)

Kaimur and Rewa Series formations of Upper Vindhyan together forms hilly and forested area and consists of two limbs of synclinal basin. Main rock units are hard and compact siliceous (Quartzitic) sandstone and shales. Northern limb is quite broad while southern limb is rather narrow, representing "Kaimur Hill Range". In Kaimur hill range except in establishment of Maihar Cement Plant, the entire area is barren. Ground water generally occurs in jointed, fractured and weathered horizons. Weathering of shales occurring between sandstones has created valley like structures in northern limb area of Kaimur and Rewa series formations. Inhabitation is mostly confined in valley areas of northern limb where some ground water is available for domestic and agriculture needs. Otherwise this is a scarce area from the ground water availability point of view. Pre-monsoon depth to water level in Majhgawan and Nakaila Ground Water Monitoring. Yield Potential of these formations is less than 3 lps.

Ganurgarh Shale (Bhander-Series, Upper Vindhyan)

Although shales are normally poorly permeable, but Ganurgarh shale due to its soft nature has undergone deep weathering (6-8m). Resultant weathering mantle supports development of dug wells for limited ground water exploitation. The presence of several joints and fissures has facilitated deeper percolation of ground water. Occurrences of solution cavities have been developed along the contact of Gypsum and Lime Stone. At deeper level gypsum bands are found in Ganurgarh shale. During excavation of "Bakiya Barrage Reservoir" lot of gypsum was reported in between Ganurgarh shale beds. Gypsum content supports development of artesian conditions, but quality of ground water is reported to be unsuitable, having excessive sulphate content. Ganurgarh shales form two limbs of syncline structure in the district. Width of northern limb is wide, whereas southern limb is narrow and pinches south-westwards.

Part of Ganurgarh Shale horizon is covered with alluvium received from Kaimur/ Rewa Sandstone, making it a good phreatic aquifer specially in southern limb area where its surface exposures are not seen due to overlying alluvial cover and providing good yield to dug wells located along foot hills of Kaimur hill range from Amdara, Ghunwara, Delha, Madai, Kharamseda, Tala to Mukundpur. Yield potential of Ganurgarh shale is less than 4 lps, but exploratory well drilled at village Jura has yielded 14 lps discharge during pumping test for 24 m drawdown, tapping Ganurgarh shale aquifer at depth having sulphate content 700 mg/litre making water non-potable for human consumption.

Bhander Lime Stone

This unit is hard and compact but jointed and fractured. Along the joints and planes of stratification "Grikes" and "Solution Cavities" get developed through the process of dissolution of country rock by circulating ground water. Often cavities are filled with yellow coloured plastic clay known as "Terra-Rosa". Cavernous Limestone hold good quantity of ground water, but quality may be slightly hard. General yield potential of Bhander (Nagod) Lime stone is 3 to 12 lps. Exploratory wells drilled at Kirpalpur (Satna-Anicut), Maihar-Stadium and Jhinna-Nala tapping Limestone aquifers have given good yields.

Sirbu Shale

Sirbu shale is younger unit of Upper Vindhyan having very thick horizon along Syncline axis. In low-lying topographic areas and in the weathered mantle, occurrence of ground water is of limited quantity yet enough to sustain dug wells for domestic/drinking purposes. The brownish red variety is more productive than the grayish shales. Due to its impervious nature, lot of small ponds are constructed in Sirbu shales which hold water even during summer season in Maihar and Amarpatan Blocks. These ponds are also used for production of water-nuts in abundance. General yield potential of Sirbu shale is 1 to 3 lps.

Upper Bhander Sand Stone

Upper Bhander sandstone is youngest unit of Vindhyan System hard and compact in nature and it forms hilly track in western part of the district. "Parasmaniya Plateau" of Unchehara Block is almost fully occupied by rocks of this group. Flagstone is also forming part of it at several places and flagstones mines are operative in the area. Normally ground water occurs under Phreatic conditions in shallow weathered and jointed rocks. Presence of joints and fractures provide secondary porosity so much so the feasibility for occurrence of ground water and its development through Dug wells/Dug-cum Bore well are reported to exists.

Laterite and Alluvium

Laterite is occurring as capping over hillocks on Kaimur/Rewa sandstone which is not important from ground water occurrence point of view. Alluvial unit comprising fine to medium sand with admixture of silty clay and gravel offers considerable primary porosity. Though its area is limited in the district but alluvium of recent age is an important aquifer being developed through open wells and shallow tube wells in the area. Main occurrence is in northern part of the area between Baboopur and Chitakoot with variable thickness and approximate average thickness is less than 30 m. Alluvial Ravines are reported to be developing in the Chitrakoot area due to headwards erosion. Two strips of alluvium also occur in the district, at foothills of both limbs of Rewa sand stones. Northern alluvial strip is passing through Singhpur, Jhali, Kothi and Birsinghpur.

Southern alluvial strip is starting from Amdara to Ghunwara, Madai, Katha, Tala and Mukundpur occurring at northern face of Kaimur hill range. Both strips of alluvium forms highly fertile land providing ground water for agriculture growth of the area through Dug Wells and shallow Tube Wells.

2.1.2 Water levels

Pre-monsoon water level (May 2016)

The pre-monsoon depth to Water levels ranges from a minimum of 2.7 meters below ground level (mbgl) in Rampur Baghelan block to a maximum of 18.88 m bgl in Majhgawan block of Satna district. Very shallow water levels up to 3 m bgl have been recorded in a small patch in eastern part of district. About 6.97% of monitoring wells recorded water level in the range of 3-6 m bgl category, spreading in patches and small pockets in the north-western and eastern part of area. About 37.20% of monitoring wells recorded water level in the depth range of 6-9 m bgl occurring in broad patches all over the region. Depth to water levels ranging 9-12 m bgl has been noticed predominantly in northern, western and in southern part of the area. About 34.88% of wells fall in this category. Deeper ground water levels ranging 12-15 m bgl constituting only about 6.97% of wells in this category have been observed only in small pocket in the northern and south-western part of Satna district. Ground water levels of more than 15 m bgl have been recorded in the north-north eastern part of the area. The pre-monsoon Depth to Water Level map has been shown in the Fig. 10.

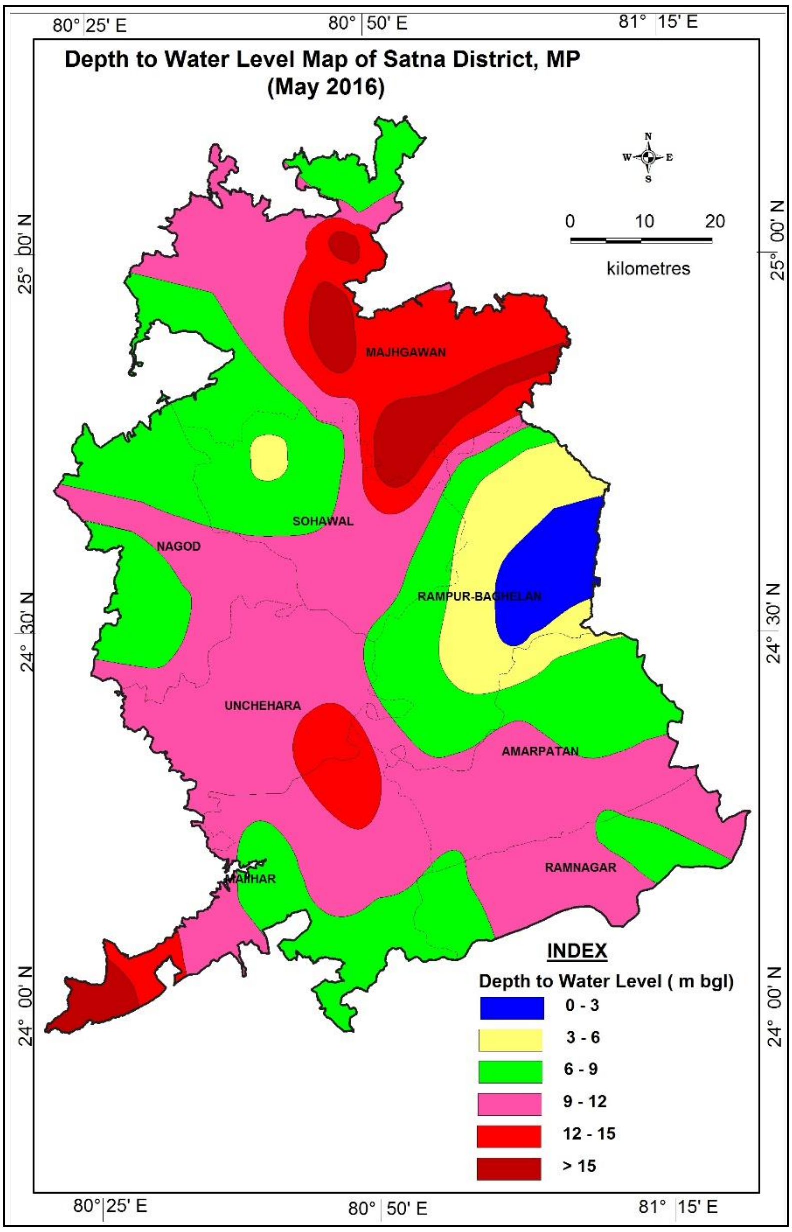


Fig 10: Depth to Water Level Map (2016)

Post-monsoon water level (Nov 2016)

The post-monsoon depth to Water levels ranges from a minimum of 0.9 m below ground level in Sohawal block to a maximum of 14.37 m bgl in Majhgawan block of Satna district. Very shallow water levels up to 3 m bgl have been recorded in patches scattered all over the district contributing to about 41.46% of total monitoring wells in Satna district.

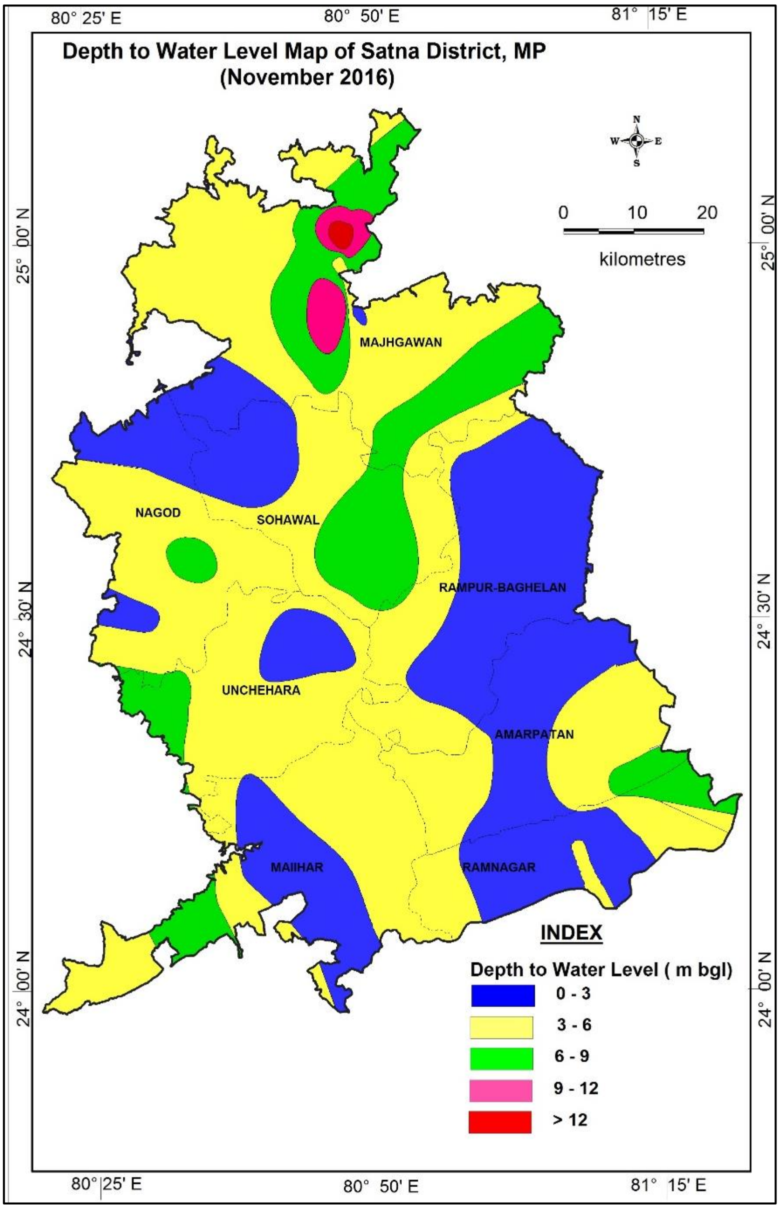


Fig 11: Depth to Water Level Map (2016)

About 31.70% of monitoring wells recorded water level in the range of 3-6 m bgl category, majorly occupying the central portion and patches in the north-eastern, and southern part of area. About 21.95% of monitoring wells recorded water level in the depth range of 6-9 m bgl occurring in pockets all over the region. Depth to water levels ranging 9-12 m bgl has been noticed predominantly in northern part of the district. About 2.44% of wells in the district fall in this category. Deeper ground water levels ranging 12-15 m bgl constituting only about 2.44% of wells in this category have also been observed in small pocket in the northern region. Ground water levels of more than 15 m bgl have not been recorded in Satna district. The pre-monsoon Depth to Water Level map has been shown in the Fig. 11.

2.2 Hydrochemical

The water samples were collected from National Hydrograph Stations in clean double stopped poly ethylene bottles from 45 different locations of Satna district. The pH of ground water of Satna district ranged in between 6.98 to 8.45. As per BIS recommendation, all water samples recorded within the permissible limit of 6.5 to 8.5 shows the ground water of the district as neutral to slightly alkaline in nature. The electrical conductivity of ground water in Satna district ranged between 333 to 3170 µS/cm at 25°C and the maximum EC value at Ramnagar (3170 µS/cm at 25°C). The electrical conductivity shows that the ground water in Satna district is good to slightly saline in nature.

The nitrate concentration in ground water ranged in between 1 to 197 mg/l. Around 72% of ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l and 28% of water samples recorded more than 45 mg/l as BIS recommendation. The highest concentration of nitrate has been detected in ground water of Amdra (197 mg/l), Kotar (151 mg/l), Birsinghpur (127 mg/l), Rampur (126 mg/l), Paras Maniya (90 mg/l), Pondipithourabad (87 mg/l) and Satna (76 mg/l). High concentration of nitrate in ground water may be due to anthropogenic activities or excessive use of fertilizers.

The sulphate concentration in ground water ranged in between 3 to 1385 mg/l. Approximately 81% of ground water samples were well within the acceptable limit of 200 mg/l for sulphate concentration as per BIS standards. Around 22% samples recorded sulphate concentration to be more than 400 mg/l which is above the permissible limits. The highest concentration of sulphate has been detected in ground water of Ramnagar (1385 mg/l), Rajarwar (1250 mg/l) and Bela Chibaura (1050 mg/l).

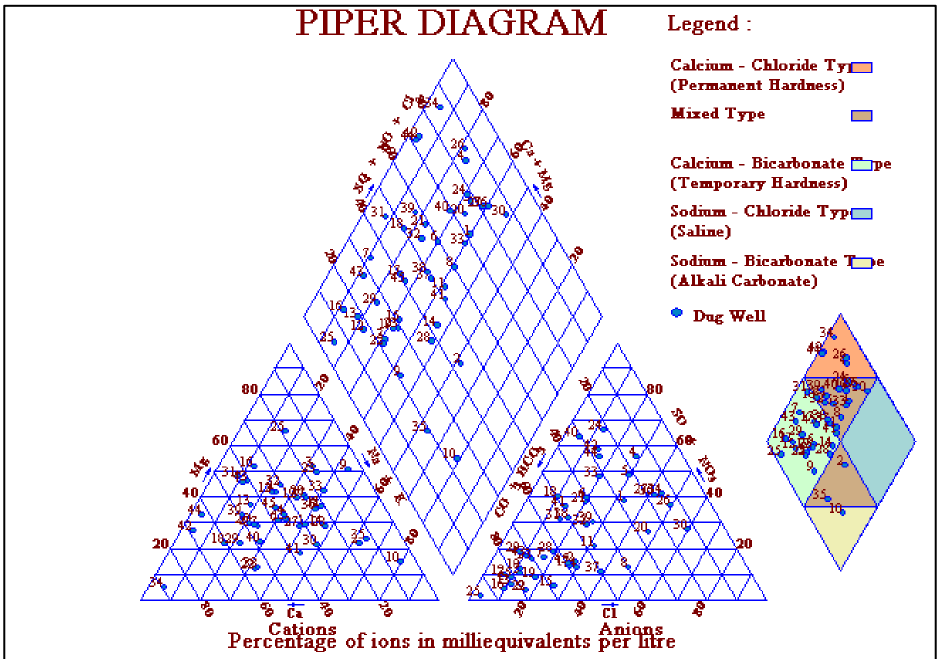
Total hardness of ground water in the study area ranged in between 110 to 1060 mg/l. The maximum concentration has been observed in the dug well of Rampur (1060 mg/l). The US Salinity Diagram of Satna district shows that the ground water ranges in low to high salinity classes i.e. C_2S_1, C_3S_1, and C_3S_2. The samples falling in C_3 and C_4 classes should not be used for irrigation purpose unless proper management.

CGWB has analyzed water samples collected from various locations in Satna district including the National Hydrograph Monitoring Stations (NHS), Key wells established under the National Aquifer Mapping Project (NAQUIM) and the Exploration wells. A brief comparison of significant parameters from a total of 64 water samples has been made in the Table No. 7 and a detailed chemical analysis of all parameters is provided in Table no. 6.

Table 6: Distribution of parameters in samples

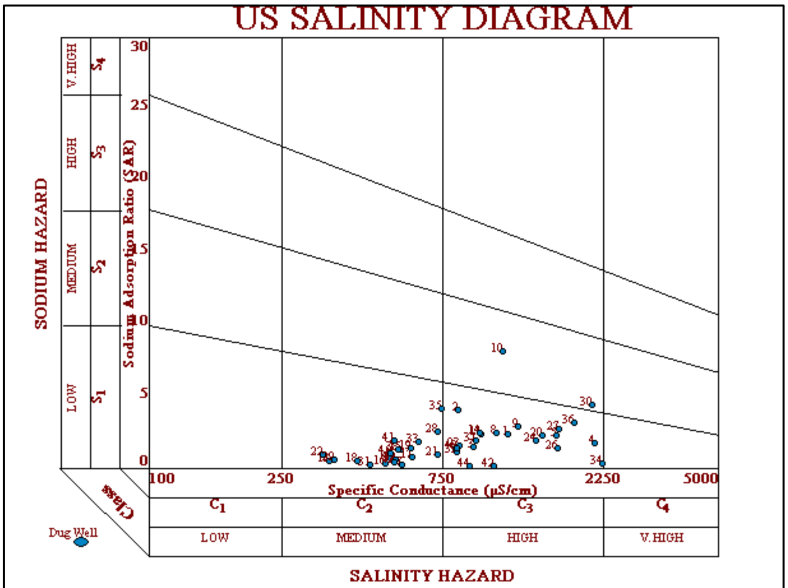
EC (μS/cm)	**% of samples**	**NO_3^{2-} (mg/l)**	**% of samples**	**SO_4^{2-} (mg/l)**	**% of samples**
<500	7.81	<45	71.88	<200	81.25
500-1000	45.31	45-100	21.88	200-400	21.88
>1000	46.88	>100	6.24	>400	21.87

Fig 12: Hill Piper Diagram representing classification of water samples collected from National Hydrograph Stations



1	Maihar New	10	Jaso	19	Chitrakoot	28	Uchehara	37	Pathraundha
2	Kusendi	11	Jaitwara	20	Birsinghpur	29	Singhpur	38	Paras maniya
3	Kothi	12	Govindpur	21	Bhatanwara New	30	Satna	39	Pahari
4	Kotar	13	Gorsari	22	Bhadanpur	31	Sagauni New	40	Naraura
5	Kemar	14	Gobrao Kalan	23	Barethia	32	Sabhaganj	41	Nakaila
6	Kakra	15	Dureha	24	Barakalan	33	Rivara	42	Nagod
7	Jowa	16	Devra	25	Babupur	34	Rampur1	43	Mukundpur
8	Jhukehi	17	Chowraha	26	Amdara	35	Ramnagar_Bamhnadi	44	Mauhari katra
9	Jhali	18	Chorhata	27	Amarpatan1	36	Pondipithourabd	45	Majhagawa

Fig 13: US Salinity Diagram for water samples collected from National Hydrograph Stations



1	Maihar New	10	Jaso	19	Chitrakoot	28	Uchehara	37	Pathraundha
2	Kusendi	11	Jaitwara	20	Birsinghpur	29	Singhpur	38	Paras maniya
3	Kothi	12	Govindpur	21	Bhatanwara New	30	Satna	39	Pahari
4	Kotar	13	Gorsari	22	Bhadanpur	31	Sagauni New	40	Naraura
5	Kemar	14	Gobrao Kalan	23	Barethia	32	Sabhaganj	41	Nakaila
6	Kakra	15	Dureha	24	Barakalan	33	Rivara	42	Nagod
7	Jowa	16	Devra	25	Babupur	34	Rampur1	43	Mukundpur
8	Jhukehi	17	Chowraha	26	Amdara	35	Ramnagar_Bamhnadi	44	Mauhari katra
9	Jhali	18	Chorhata	27	Amarpatan1	36	Pondipithourabd	45	Majhagawa

Table 7: Chemical Analysis Results of Water samples collected from NHS and NAQUIM Monitoring stations

S.No.	District	Village	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	TH	Ca	Mg	Na	K
1	Satna	Golhata	7.45	2050	0	134.244	17.73	825	40	1.07	940	208	102.144	42	1.9
2	Satna	Tikuri	7.52	1020	0	195.264	35.46	260	32	1.13	460	64	72.96	22	3.8
3	Satna	Aber shivar	7.23	895	0	213.57	53.19	155	38	1.57	345	48	54.72	46	0.8
4	Satna	Lakhanwah	7.58	780	0	152.55	17.73	202	37	0.74	335	54	48.64	24	1.6
5	Satna	Bachhaura	7.36	1245	0	164.754	56.736	350	42	1.06	515	58	89.984	50	2.2
6	Satna	Rajarwar	7.28	2850	0	91.53	28.368	1250	34	1.1	1290	362	93.632	50	6.1
7	Satna	Gadwa khurd	7.34	1280	0	122.04	24.822	450	31	1.1	490	116	48.64	65	3.1
8	Satna	Bihara	7.33	590	0	170.856	35.46	65	47	0.97	250	34	40.128	20	2.4
9	Satna	Pipracha	7.7	580	0	219.672	24.822	38	38	1.16	265	38	41.344	8	3.3
10	Satna	Patihera/pateria	7.43	650	0	213.57	24.822	80	31	1.12	305	44	47.424	7	4.6
11	Satna	Mankhari	7.56	1860	0	134.244	219.852	460	35	0.48	655	130	80.256	122	4
12	Satna	Hinauti	7.21	2345	0	164.754	99.288	805	52	0.91	855	56	173.888	145	5.6
13	Satna	Sijahata	7.31	1520	0	140.346	74.466	485	47	0.68	635	94	97.28	60	1.1
14	Satna	Karmau	7.01	880	0	122.04	85.104	160	64	0.48	340	80	34.048	45	1.6
15	Satna	Ramnagar	7.28	3170	0	91.53	21.276	1385	33	1.37	1415	388	108.224	71	1.5
16	Satna	Janadanpur	7.11	1205	0	128.142	31.914	400	39	0.81	345	38	60.8	116	2.7
17	Satna	Bela chibaura	7.36	2560	0	115.938	35.46	1050	55	0.67	1120	34	251.712	62	0.5
18	Satna	Ganjan	7.34	1185	0	115.938	17.73	420	42	0.76	455	36	88.768	64	0.6
19	Satna	Rampur	7.07	1521	0	109.836	63.828	520	52	0.48	650	36	136.192	52	4.4
20	Satna	Harsh nagar	7.75	678	0	158.652	53.19	87	49	0.52	255	22	48.64	38	0.9
21	Satna	Jamuna shivar	7.29	841	0	189.162	60.282	145	36	0.82	355	52	54.72	30	1.8
22	Satna	Bariha	7.36	977	0	152.55	10.638	300	41	0.68	385	26	77.824	47	0.5
23	Satna	Chormari	7.05	2220	0	152.55	216.306	605	57	0.65	995	66	201.856	50	0.8
24	Satna	Daldal	7.36	1080	0	213.57	31.914	275	38	0.67	330	28	63.232	95	1
25	Satna	Chhibaura	6.84	720	0	140.346	63.828	115	41	0.57	340	30	64.448	10	0.5
26	Satna	Chhibaura	7.36	1235	0	189.162	74.466	300	55	0.47	510	54	91.2	50	1.5
27	Satna	Sagauni	7.29	1310	0	158.652	28.368	430	38	0.55	480	76	70.528	80	1.3
28	Satna	Tuni	7.43	1201	0	128.142	53.19	360	50	0.94	525	44	100.928	28	8.9
29	Satna	Rimar	7.37	1010	0	128.142	14.184	330	44	0.54	370	20	77.824	61	1
30	Satna	Ramnagar_Bamhnadi	7.8	750	0	366	28	10	29	0.76	135	18	21.9	110	0.9

31	Satna	Jowa	8.05	572	0	226	35	19	33	0.44	250	48	31.67	9	9.9
32	Satna	Govindpur	8.01	527	0	256	14	8	22	0.94	200	36	26.79	23	8
33	Satna	Sagauni New	7.53	460	0	146	25	34	45	0.3	210	40	26.79	9	0.2
34	Satna	Devra	8.08	509	0	262	18	8	5	0.61	220	36	31.65	13	2.4
35	Satna	Pondipithourabd	7.92	1850	0	183	277	290	87	1.32	545	88	79.12	173	2.3
36	Satna	Rampur1	6.98	2250	0	183	355	350	126	1.23	1060	402	13.86	28	2.8
37	Satna	Kotar	7.69	2135	0	207	230	480	151	0.72	800	142	108.37	118	2
38	Satna	Chorhata	8.05	421	0	146	18	94	2	0.29	185	54	12.22	17	1
39	Satna	Jhali	8.42	1269	36	567	82	26	1	1.05	345	12	76.6	125	3
40	Satna	Pahari	7.61	548	0	140	53	53	34	0.72	225	54	21.95	22	0.4
41	Satna	Chowraha	7.93	614	0	220	60	34	7	0.12	220	54	20.73	26	12.7
42	Satna	Babupur	8.21	542	18	287	7	5	1	0.05	225	20	42.57	17	3.7
43	Satna	Chitrakoot	8.21	607	12	281	46	10	27	0.29	210	34	30.43	46	1.8
44	Satna	Nakaila	7.85	540	0	159	28	60	43	0.99	150	40	12.21	55	0.2
45	Satna	Jaitwara	7.96	977	0	281	113	70	40	0.24	275	40	42.6	91	2.6
46	Satna	Birsinghpur	7.76	1488	0	238	255	97	127	0.41	490	74	74.25	118	2.1
47	Satna	Majhagawa	7.35	530	0	189	50	3	43	0.59	190	38	23.14	33	0.9
48	Satna	Rivara	7.84	638	0	122	46	117	39	0.23	190	22	32.85	59	0.4
49	Satna	*Bhadanpur	8.29	333	6	146	21	4	3	0.13	110	36	4.91	24	0.7
50	Satna	Amdara	7.57	1661	0	134	294	146	197	0.07	645	160	59.76	83	1.2
51	Satna	Kusendi	8.21	841	18	293	99	59	13	0.22	160	26	23.13	119	3.5
52	Satna	Jhukehi	8.1	1088	0	262	184	60	8	0.34	310	48	46.25	99	2.8
53	Satna	Gorsari	8.21	348	6	201	18	10	4	0.56	155	34	17.06	14	3.9
54	Satna	Amarpatan1	7.67	1670	0	189	241	324	16	0.53	505	106	58.48	143	9.3
55	Satna	Kakra	7.91	823	0	183	53	120	31	0.33	280	62	30.47	55	4.7
56	Satna	Mauhari katra	7.45	905	0	153	53	210	40	0.48	435	114	36.61	8	0.4
57	Satna	Uchehara	7.9	730	0	275	50	52	20	0.23	190	34	25.57	80	1.2
58	Satna	Paras maniya	7.42	555	0	165	35	15	90	0.1	185	60	8.58	42	0.7
59	Satna	Satna	7.45	2100	0	153	443	220	76	0.98	540	124	56.07	235	0.3
60	Satna	Kothi	8.21	933	30	397	43	33	22	0.94	315	30	58.39	60	14
61	Satna	Singhpur	7.82	360	0	159	11	12	27	0.03	140	40	9.77	18	0.9
62	Satna	Nagod	7.47	1075	0	171	57	270	40	0.76	515	148	35.43	10	0.8
63	Satna	Pathraundha	7.4	950	0	287	131	30	29	0.65	305	46	46.25	78	0.6
64	Satna	Jaso	8.45	1137	30	433	46	61	2	0.48	115	12	20.68	201	6.1

2.3 Geophysical

CGWB has also carried out Geophysical resistivity surveys in 78 locations of Satna District, Madhya Pradesh (Fig. 14). The interpreted resistivity values determined from VES is influenced primarily by variations in effective porosities and the pore fluid conductivity. Many reasonable assumptions have been adopted while deducing the resistivity distributions for different litho-units and deriving hydrogeological significance. Each layer is assumed to have an isotropic uniform resistivity. It is believed that the resistivity variations obtained with the processing of all VES represent different subsurface rock units.

The major geological formation like limestone, Sandstone and Shale have been characterized by the resistivity ranges of the order of 1000 - 2500, 800-2000 and 250-800 ohm-m respectively. The fractured limestone/ sandstone/ shale is characterized by relatively low resistivity of the order of 50 -100 ohm-m. These low resistivity zones are considered as favorable sites for groundwater exploration.

The alternate occurrence of low and high resistivity layers indicates successive shale and limestone formation but at places their exact thickness could not be ascertained by VES. The correlation of VES with exploratory borewells has been shown in the fig. 15. A geophysical analysis of few Vertical Electrical Sounding conducted in Satna district is presented in the Table 8.

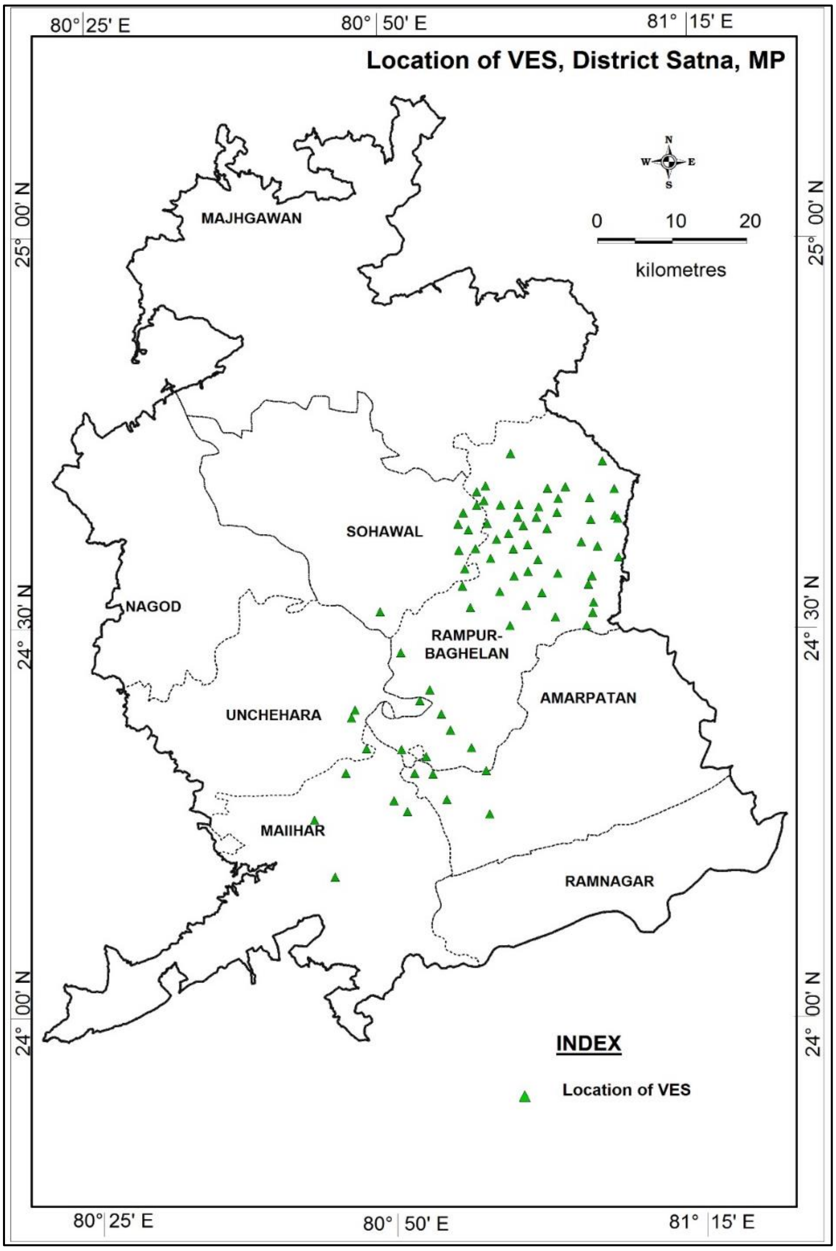


Fig 14: Map showing locations of VES

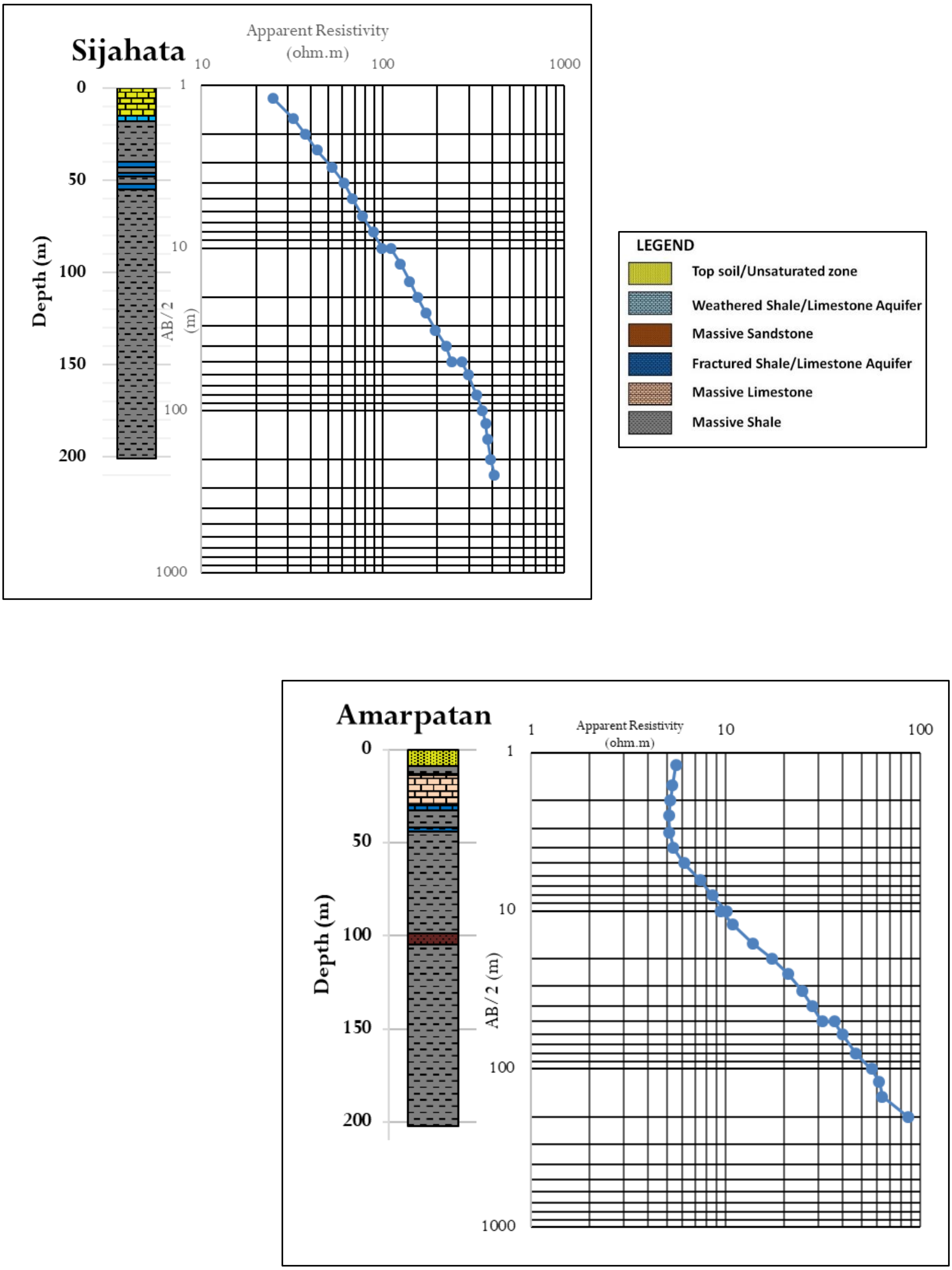


Fig 15: Correlation of VES with litholog of Exploratory borehole

Table 8: Geophysical Analysis of Vertical Electrical Sounding

S.No.	Location	Lat/ Long	Elevation	Geoelectrical layers Resistivity and thickness											Total H
				ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	h_1	h_2	h_3	h_4	h_5	
1	Bihara	24.724, 81.004	379.7	25	19	23	49	77		8	11.2	6.5	9.8		37
2	Golhata	24.715, 81.132	282	7	34	1050	48	14500		1.3	18	13.3	19.1		54.6
3	Gaajan	24.641, 81.153	289.7	6	18	62	195	1094		1.3	2.4	88.3	74.6		166.7
4	Korigawan	24.52, 81.119	330.6	46	18.6	2.37	20.4	7124		1	9.26	1.33	70		81.5
5	Maihar	24.178, 80.76	344	30	19	144	182	75	145	4	10	7.5	21	24	66.4
6	Uchehara	24.383, 80.783	335.8	31	14	209	150	304	2500	5	8	3	80	27	123
7	AmarPatan	24.316, 80.97	359.4	15	52	80	390	45	78	4	10	21	35	46	116
8	BandhiMauhar	24.52, 80.823	307.8	6.35	4.26	73	5.5			1.25	10.4	36.2		47.8	96
9	Barreh	24.345, 80.95	340.9	14.2	1.11	407	3.24	7.74		1.14	1.36	5.5	20.9		28.9
10	Bilhati	24.344, 80.804	322.8	5.98	30	398	5.8	217		4.48	22.8	24.4	49.2		101
11	Bilhati B	24.344, 80.804	322.8	7	40	60	390	45	78	4	11	23	39.5	55.5	133
12	Chapna	24.311, 80.896	345.1	67	3.47	245	9.5	70		2.15	3	2	14.5		21.5
13	Chorhata	24.389, 80.908	325.5	12.8	135	6.3	10300			5.8	12.6	29.3			47.7
14	Chorhata B	24.389, 80.908	325.5	15	65	40	15	6000		4.3	11.7	39	44		99
15	Dhanneh	24.312, 80.775	334.8	5.5	2.4	5.7	58.8	825	130	1.2	0.5	10.3	28.5	40.5	81
16	Jarmohara	24.345, 80.95	340.9	3	12	158	96			3.4	2	9.5			15
17	Jura	24.263, 80.861	343	3.5	11.5	29	3200			5.5	6	44.5			56

18	Kanihari	24.42, 80.892	320.7	12.2	2.29	76	1040			1.2	1.3	81.5			84
19	Kanihari B	24.42, 80.892	320.7	8	48	3000	100	186	375	2.6	2.6	3.3	17.4	45	71
20	Kartah	24.312, 80.871	340.7	29	7	3000	187	3000	175	3.1	5.6	11	47	32.5	100
21	Kharamsera	24.26, 80.975	363.2	6.5	1.5	1200	6800			4.75	3.25	16.5			24.5
22	Kharamsera B	24.26, 80.975	363.2	5	16	32	6000			9.7	3.6	5.7			19
23	Kharwahi	24.406, 80.878	320.7	33	13	37	8500	320	167	1.85	1.16	10.7	9.5	56	79
24	Korigawan	24.52, 81.119	330.6	46	18.6	2.37	20.4	7124		1	9.26	1.33	70		81.5
25	Lakhha	24.368, 80.921	331.5	14	9.3	90	2.5	600		1.12	3.75	30	64.5		100
26	Magraura	24.343, 80.853	327.7	4	19	32	6000	75	1200	5	2.8	11	20	40	79
27	Mantola	24.334, 80.887	340.3	7	24	65	215	6000	240	2	12	24	14	27.7	80
28	Nothanwala	24.279, 80.916	365.7	10	6	17	6000	75	300	1.3	12	3	3.5	70	90
29	Nothanwala B	24.279, 80.916	365.7	18	0.07	18.5	0.5	33	4750	1	0.03	2.25	1.15	60.8	65
30	Pallanpur	24.394, 80.788	333.5	5	3	940	21	480		1.3	9	11	52		73
31	Pallanpur B	24.394, 80.788	333.5	4	7	45	375	108	235	5.3	4.4	3.5	29	98	140
32	Sahjana	24.467, 80.851	311.5	9	5	77	4	5		1	7.3	20.32	53.7		82.4
33	Tilaura	24.277, 80.842	344.1	81	45	153	70	6000	150	19	13.7	34	13.3	29	109
34	Udaipur	24.252, 80.732	364.4	8	145	25	17			10.5	11	115			136.5
35	Udaipur B	24.252, 80.732	364.4	9	19	106	45	25	15	7.5	2.5	6.5	52	95	164

2.4 Exploratory drilling

CGWB under its exploration program drilled 52 borewells and 12 Piezometers (Fig. 16). 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 is given in Table No 9 & 10.

Fig 16: Map showing locations of Exploratory Wells

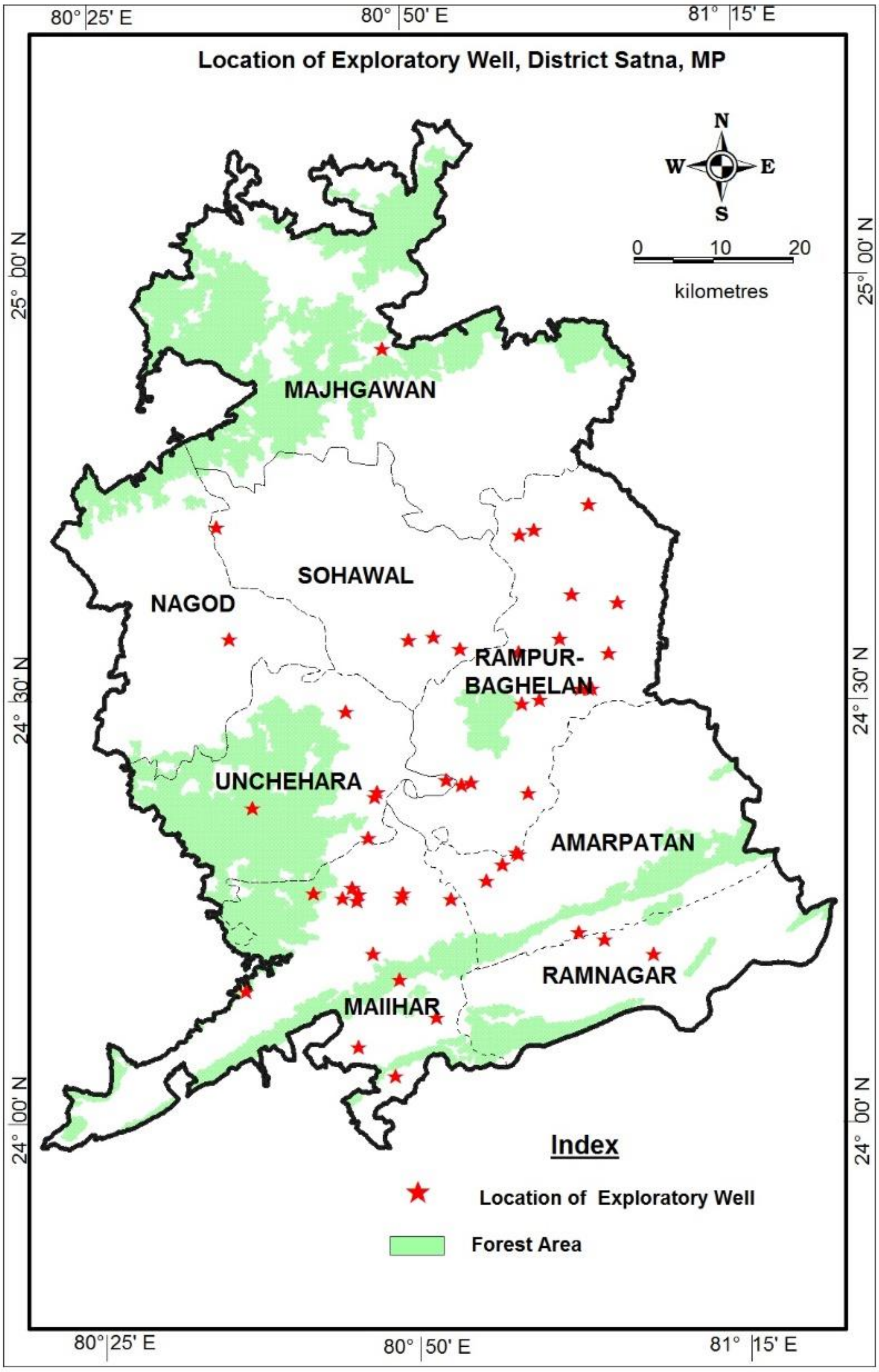


Table 9: Salient Hydrogeological Details of Exploratory Wells

S.No	Location	Longitude/ Latitude	Depth (m)	Aquifer zones	SWL (mbgl)	Yield (lpm)	Draw-Down (m)	T (m^2/day)	Storativity
1	Bhadanpur	80.821, 24.166	50.10	21.00to24.00 35.00 to 50.0	5.59	1020	17.2	746.0	$1.1x10^{-3}$
2	Maihar (Town)	80.758, 24.275	202.30	40.00to48.00	6.70	72	46.0	-	-
3	Ajwain	80.767, 24.086	146.40	Dry	-	-	-	-	-
4	Rivara	80.86, 24.121	201.30	Dry	-	-	-	-	-
5	Amatara	80.816, 24.052	201.30	16.00to18.00	16.5	01	-	-	-
6	Allaha- Talab	80.708, 24.268	201.30	18.00to21.00 91.00to97.00	5.92	132	34.3	-	-
7	Ghunwara	80.620, 24.151	190.90	04.00to08.00 59.70to62.80 81.10to84.10	2.83	132	9.20	10.86	-
8	Udaipur	80.823, 24.263	201.30	09.00to18.50 49.00to51.00 164.0to173.0	13.1	200	52.0	2.51	-
9	Maihar (Stadium)	80.746, 24.263	201.30	18.00to21.00 67.00to70.00	27.1	733	31.0	27.6	$6.9X10^{-4}$
10	Bihata	80.786, 24.196	215.30	No zone	18.4	poor	-	-	-
11	Unchehara	80.788, 24.383	191.90	98.00to112.6	14.6	660	14.7	58.0	-
12	Jura	80.888, 24.261	148.40	26.00to38.00 48.00to65.00 81.00to95.00	11.3	850	12.8	27.0	$2.6X10^{-2}$
13	Kotar	80.982, 24.693	142.30	20.00to38.00	9.50	90	35.0	-	-
14	Ram Nagar	81.088, 24.214	203.30	Dry	-	-	-	-	-

15	Rampur-Baghelan	81.067, 24.511	203.30	29.00 to 32.00	-	48	-	-	-
16	Kirpalpur (satna-anicut)	80.899, 24.558	50.80	24.00to46.00	-	336	-	-	-
17	Satna	80.864, 24.572	203.30	36.00to45.00 98.00to103.0	19.5	150	29.5	-	-
18	Amarpatan	80.972, 24.317	202.10	14.00to17.00 42.00to46.00	19.98	60	24.4	-	-
19	Chorhata	80.914, 24.40	142.30	60.00to63.00	17.50	168	40.0	-	-
20	Jhinna-Nala	80.955, 24.303	203.10	17.00to22.00	12.24	155	18.0	17.7	1.2X10^{-4}
21	Mirgauti	81.054, 24.222	124.00	13.50to17.00 30.00to35.00	6.93	880	9.90	150.0	1.17X10^{-3}
22	Nagod	81.598, 24.569	203.30	8.00to14.00 20.00to24.00 50.00to64.00	29.88	180	34.0	70.0	-

Table 10: Salient Hydrogeological Details of Piezometers

S.No	Location	Longitude/ Latitude	Depth Drilled (m) b.g.l.	Aquifer zones	SWL (m) b.g.l.	Yield (LPS)
1	Amarpatan (Shallow)	80.976, 24.314	36.70	13.20to13.80 30.00to30.50	10.10	2.33
2	Kotar (Shallow)	80.995, 24.699	30.90	18.00to19.00	2.12	4.0
3	Maihar (Deep)	80.764, 24.26	61.67	43.00to47.00 57.00to61.00	17.60	35.8
4	Maihar (Shallow)	80.764, 24.26	35.50	24.50to25.30 27.00to28.00	15.06	0.02
5	Majhgawan	80.797, 24.914	40.42	20.00to22.50	8.20	2.33
6	New RamNagar (Deep)	81.151, 24.196	57.84	33.00to33.40 48.00to48.50	7.26	2.33
7	New Ramnagar (Shallow)	81.151, 24.196	27.71	14.50to15.50	4.63	6.33
8	Parasmaniya (Shallow)	80.628, 24.369	30.75	07.00to12.00	5.25	0.016
9	Rampur (Shallow)	81.056, 24.511	30.55	18.50to19.00 25.00to25.50	6.80	4.0
10	Satna (Shallow)	80.832, 24.568	27.44	16.00to17.20	7.80	2.33
11	Singhpur (Deep)	80.582, 24.702	61.74	09.50to11.00 43.00to45.00	13.50	2.33
12	Singhpur (Shallow)	80.582, 24.702	31.13	09.50to11.00	5.60	2.33

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

3.1 3-D Lithological model

A 3-Dimensional lithological model was prepared for the Satna 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). 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 shales, limestones and sandstone respectively. The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone, underlain by Weathered Shale/Limestone which has been considered as shallow aquifer (upto a depth of 30 mts). Massive sandstone was encountered in few bore wells mainly occupying the eastern region of Satna. This overlies the Fractured Shales/Limestones that forms the deeper aquifer (from 30-200 mts). The fractured aquifer lies between Massive Limestones and predominantly Massive Shales.

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

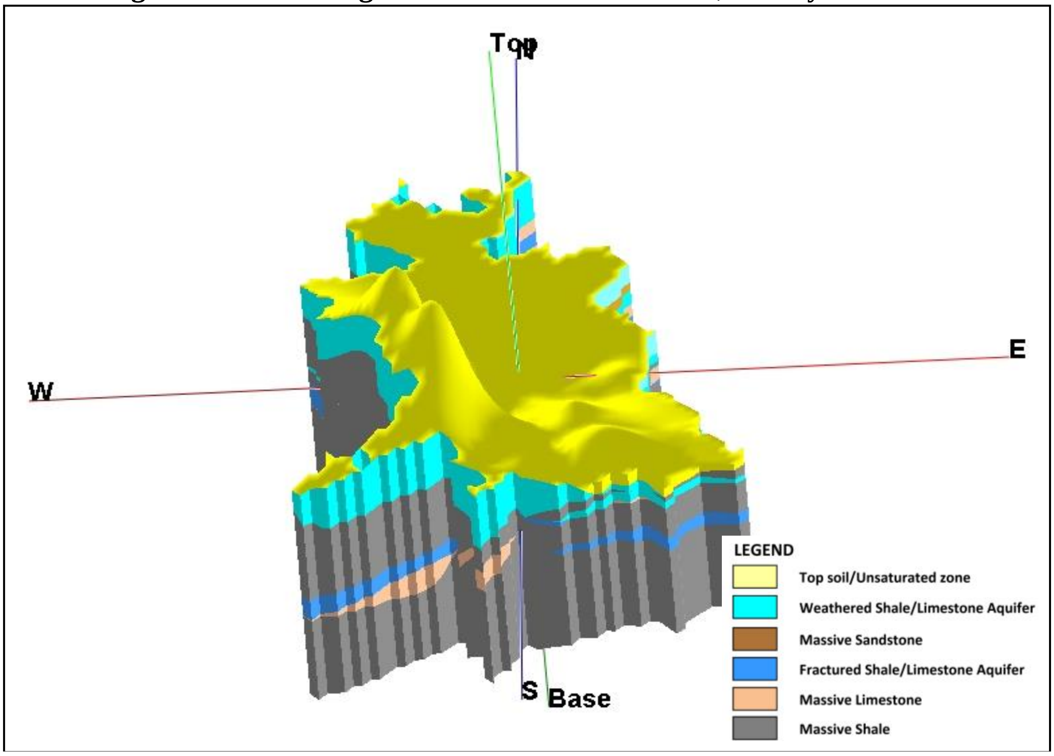
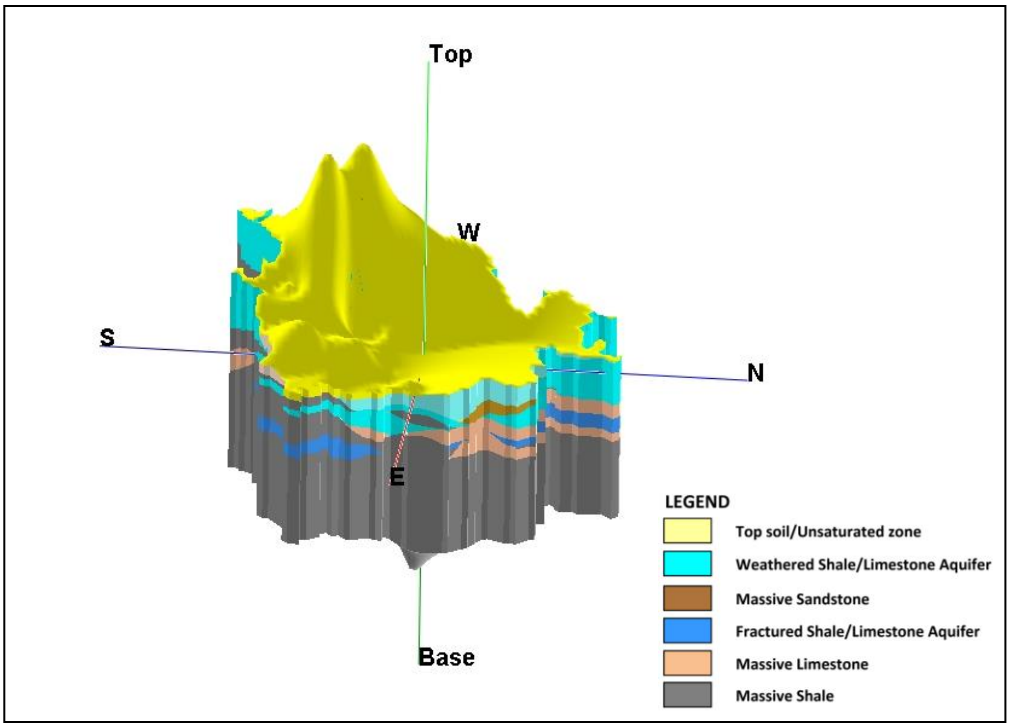


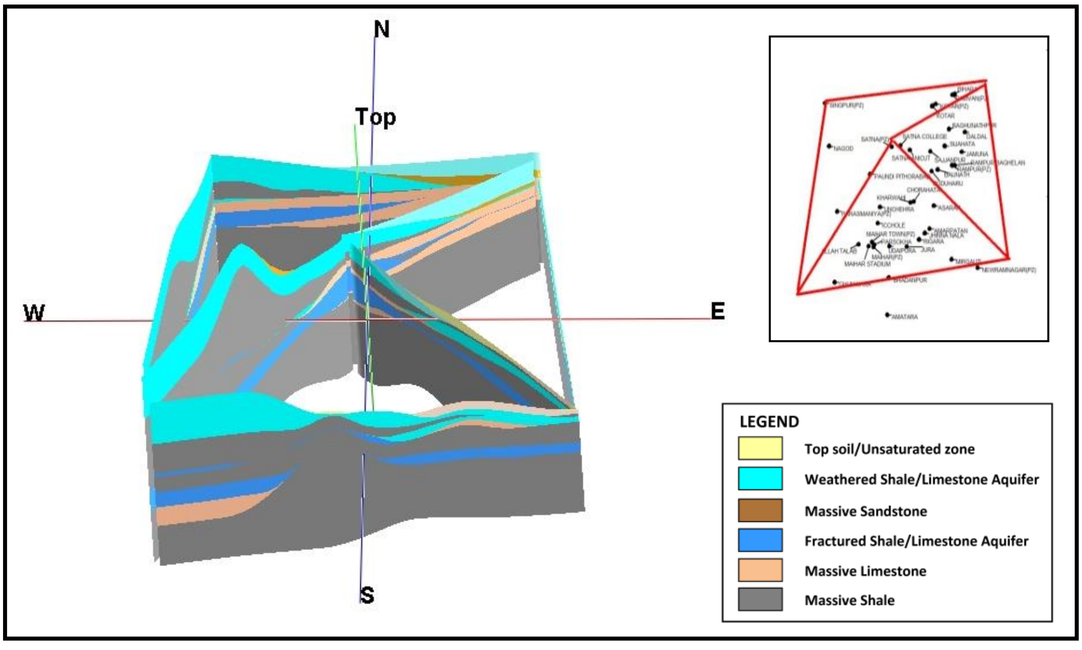
Fig 17b: 3-D Lithological Model of Satna District, Madhya Pradesh



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.

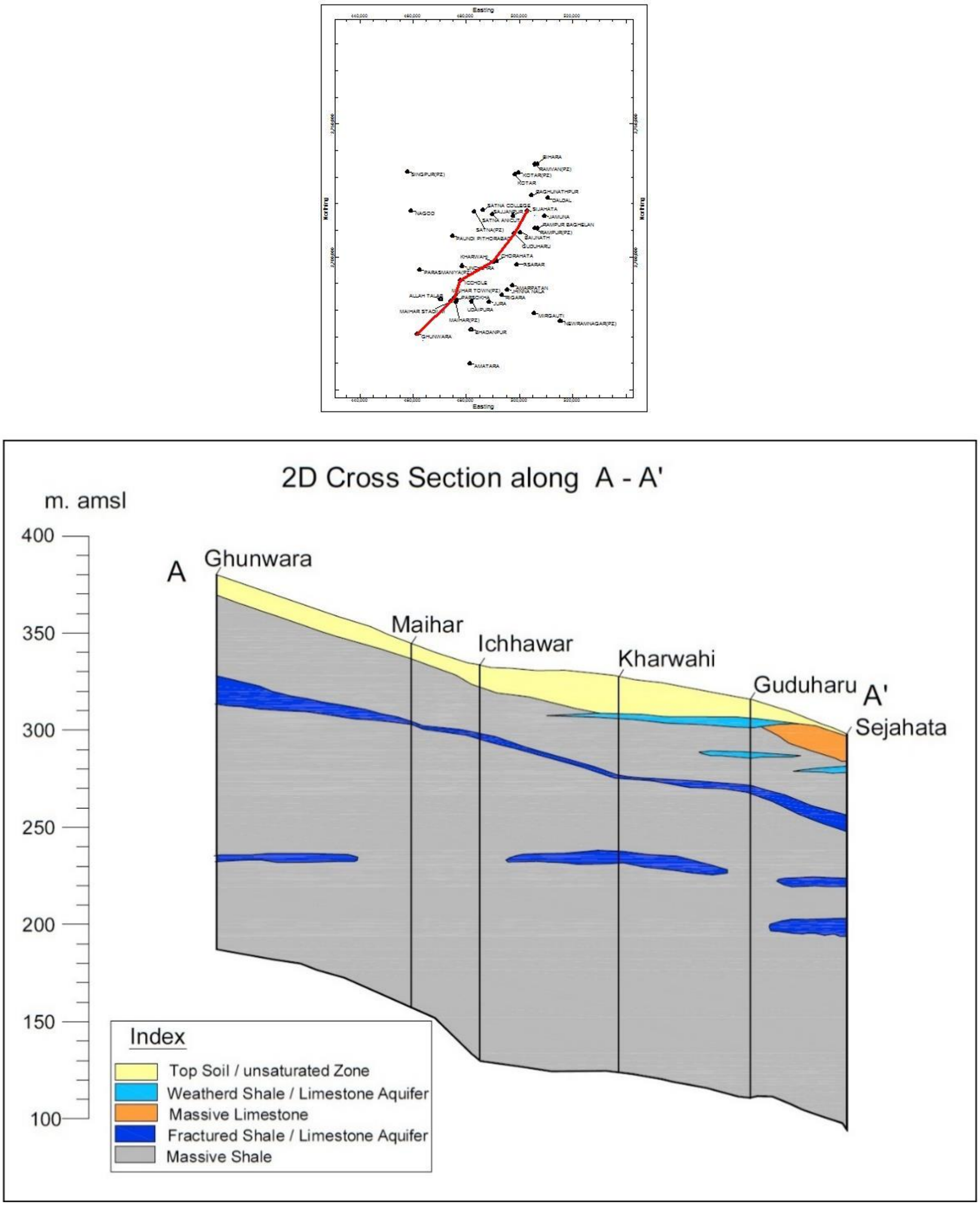
Fig 18: Fence Diagram, Satna District, Madhya Pradesh



3.3 2-D Cross Section

2-Dimensional cross-section along the section line A-A' (SW-NE), covering the wells Ghunwara, Maihar, Ichhawar, Kharwahi, Guduharu and Sejahata has been prepared using Rockworks and later refined in AutoCAD (Fig. 19). The cross-section shows that the shallow aquifer is not continuing for the whole region and occurs as narrow pinches in the northern portion of Satna. 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' (SW-NE), Satna District, Madhya Pradesh



4. Ground Water Resources

4.1 Dynamic Ground Water Resource (2013)

Satna district is underlain by Vindhyan Shale, Limestone and Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated on block-wise basis. Out of 7,502 sq. km of geographical area, 6,721 sq. km (89%) is ground water recharge worthy area and 781 sq. km is hilly area (11%). There are eight assessment units (block) in the district out of which five blocks fall under non-command category whereas Rampur Baghelan, Sohawal and Unchehra falls under both command as well as non-command category. Amarpatan, Maihar, and Nagod blocks of the district are categorized as semi-critical, Sohawal block as critical (non-command), Rampur Baghelan as over-exploited (non-command) and rest as safe. The highest stage of ground water development is computed as 103.48% in non-command area of Rampur Baghelan block. The net ground water availability in the district is 613.81 mcm and ground water draft for all uses is 444.58 mcm, making stage of ground water development to 72% as a whole for district (Table 11).

Table 11: Dynamic Ground Water Resources (2013)

Assessment Unit / District	Command / Non-Command	Net Ground Water Availability (MCM)	Gross Ground Water Draft (MCM)			Stage of Ground Water Development %	Category
			Irrigation	Domestic & Industrial	All Uses		
Amarpatan	Non Command	64.26	51.41	5.59	57.00	88.71	Semi Critical
	Block Total	64.26	51.41	5.59	57.00	88.71	
Maihar	Non Command	74.42	54.15	9.81	63.96	85.94	Semi Critical
	Block Total	74.42	54.15	9.81	63.96	85.94	
Majhgawan	Non Command	110.24	40.53	5.95	46.48	42.17	Safe
	Block Total	110.24	40.53	5.95	46.48	42.17	
Nagod	Non Command	86.89	68.45	5.82	74.27	85.47	Semi Critical
	Block Total	86.89	68.45	5.82	74.27	85.47	
Ramnagar	Non Command	34.59	16.39	3.59	19.98	57.78	Safe
	Block Total	34.59	16.39	3.59	19.98	57.78	
Rampur Baghalan	Command	34.91	3.70	1.49	5.19	14.87	Safe
	Non Command	103.36	101.64	5.32	106.96	103.48	Over Exploited
	Block Total	138.27	105.34	6.80	112.15	81.11	
Sohawal	Command	5.79	0.69	0.82	1.51	26.03	Safe
	Non Command	45.04	36.05	5.09	41.14	91.33	Critical
	Block Total	50.83	36.73	5.91	42.64	83.89	
Unchehra	Command	13.78	0.43	0.28	0.71	5.15	Safe
	Non Command	40.53	23.20	4.18	27.38	67.56	Safe
	Block Total	54.31	23.63	4.46	28.09	51.72	
SATNA	District Total	613.81	396.65	47.94	444.58	72.43	

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

The Ground Water Resource of Satna 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 502.61 mcm. The static resource for the deeper aquifer (30-200 mbgl) is computed as 284.77 mcm. The block-wise details of ground water resources and draft as an outcome of NAQUIM is presented in the Table no 12.

Table 12: Ground Water Resources (Outcome of NAQUIM)

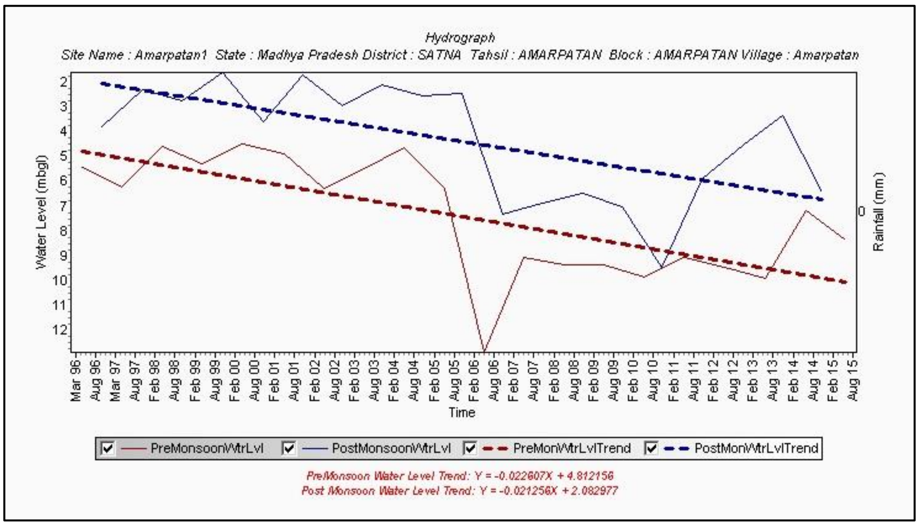
Block	Amarpatan	Maihar	Majhgawan	Nagod	Ramnagar	Rampur Baghelan	Sohawal	Unchehra	Total
SHALLOW AQUIFER (0-30 m)									
Dynamic Resource (MCM)	64.26	74.42	110.24	86.89	34.59	138.27	50.83	54.31	613.81
In-storage (MCM)	50.63	82.96	98.43	50.72	6.57	46.25	138.72	28.33	502.61
Total (MCM)	114.88	157.38	208.67	137.61	41.16	184.52	189.55	82.64	1116.42
DEEPER AQUIFER (30-200 m)									
Static Resources (MCM)	15.04	17.21	7.11	27.49	5.00	18.29	34.72	2.36	127.22
NET GROUND WATER RESOURCE									
Total GW Resources (MCM) (Dynamic+In-storage+ Static)	137.52	175.41	240.99	158.75	45.59	207.41	207.61	100.41	1273.69
GROSS GROUND WATER DRAFT									
Gross Ground Water Draft for all uses (MCM)	57.00	63.96	46.48	74.27	19.98	112.15	42.64	28.09	444.58

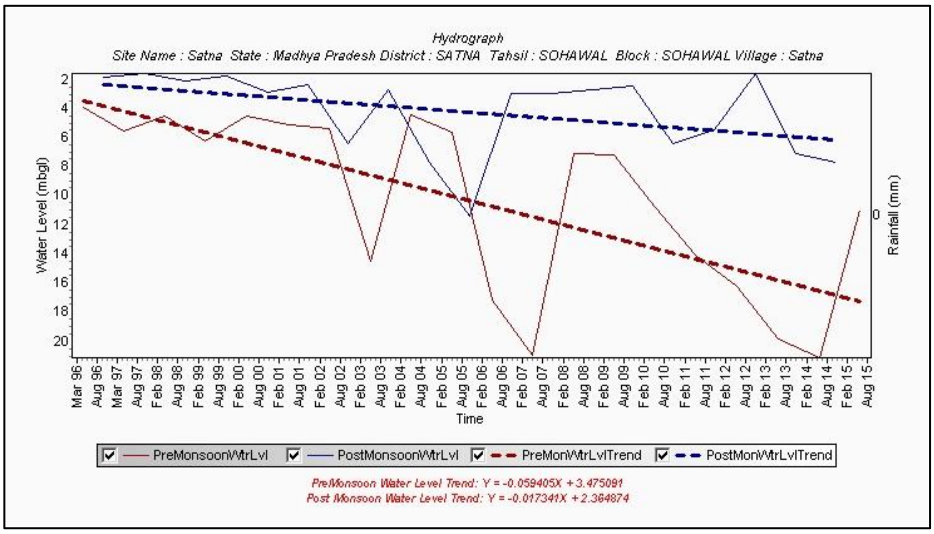
5. Ground Water Related Issues

5.1. Declining of water level

The long-term water level trend analysis indicates mixed results. During pre-monsoon season, out of 35 Hydrograph Stations, 18 are showing declining trend (Fig. 20). Similarly, during post-monsoon season, out of 35 stations 26 stations are showing falling trend in the district and all stations of Rampur-Baghelan and Nagod blocks are showing depletion of water levels in the area. Ground Water Resource Estimation also reveals that out of 8 Blocks of the district 5 Blocks have crossed 70% stage of ground water development. Non-command area of Rampur Baghelan is Over-exploited, Nagod and Sohawal are critical blocks, Amarpatan and Maihar falls in the semi-critical category and Majhgawan, Ramnagar and Unchehara blocks are Safe. Over all stage of ground water development of the district is computed as 72.43%, which cautions for further uncontrolled withdrawal of ground water.

Fig 20: Hydrographs showing declining water level trend during Pre-monsoon and Post-Monsoon at sites Amarpatan and Satna, Satna District, Madhya Pradesh





In Satna district there are three major Cement Plants located at Satna, Mankahari and Sarla Nagar (near Maihar). Industrial water supply for these industries seems to be inadequate. As reported, major industrial water requirement is fulfilled from rain water storage in Lime Stone Mines of these industries. However partial requirement is also met from tube wells drilled in their area. Continued heavy withdrawal of ground water around the industries for water supply is causing adverse effect in ground water regime of the area, including depletion of water table.

5.2. Ground water quality

The samples analyzed for Satna district has shown that the ground water is contaminated at various locations (Fig. 21). The district faces problem of excessive sulphate content in deeper ground water system of the area as observed in CGWB exploratory wells at various locations namely, Maihar, Allha-Talab, Ghunwara, Unchehara, Jura, Chorahata, Jhinna-Nala and Nagod. Excessive sulphate in water is laxative and its concentration more than 200 mg/ liters causes stomach disorder in human.

Excessive nitrate content is reported in the district at Amdara, Unchehara, Kirpalpur, Rampur-Baghelan, Kotar, Nagod and Amarpatan. High nitrate content in ground water of these areas is perhaps from seepage of sewerage into ground water system of the area, causing local pollution and contamination of ground water.

The EC values higher than 1000 µS/cm has also been found at places in Satna district. Although the district does not face salinity problems but the higher value of more than 3000 µS/cm has been found at Ramnagar.

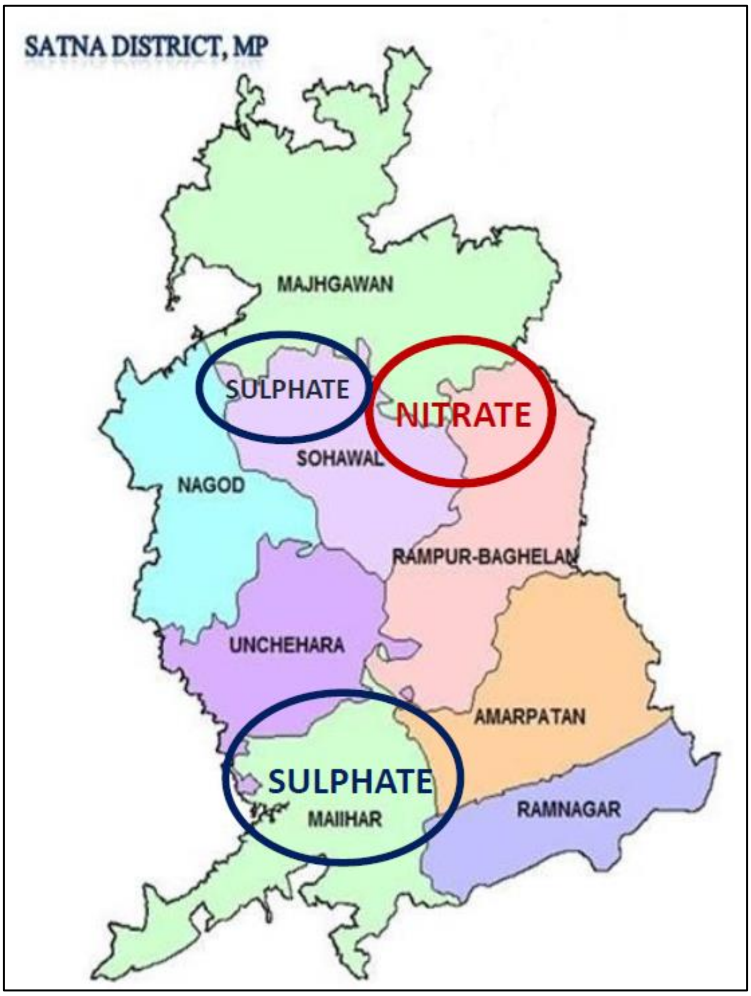


Fig 21: Ground water quality problem areas

6. 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.

6.1. District Ground Water Management Plan (Outcome of NAQUIM)

Satna district has been facing problems of ground water exploitation which in turn are depleting the ground water resources in the area. This has led to evolve sustainable water conservation and management practices through an integrated approach. The ground water management plan for Satna 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.

6.1.1. 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 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 Satna 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 Satna 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%, 25% and 30% 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. 13.

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. 264.80 Crores to successfully implement the supply side management strategy. Table no. 14 represents the complete financial outlay plan for the district.

6.1.2. 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.

Table 13: Ground Water Management– Supply Side, Satna District, Madhya Pradesh

Station	Area (Sq.Km)	Area suitable for recharge (Non-command) (Sq.Km)	Rainfall (m)	Average post-monsoon water level (m)	Unsaturated zone (m)	Average SP Yield (%)	Sub-surface storage (MCM)	GW Recharge through RWH Structures Constructed (MCM)
	1	2	3	4	5	6	7	8
Amarpatan	652.31	532.31	1.1138	3.23	0.23	0.06/0.01/0.02	2.503	0.843
Maihar	1125.72	924	0.87364	4.74	1.74	0.06/0.01/0.01	19.645	0.239
Majhgawan	1631	1206.41	1.0738	4.91	1.91	0.1/.015/0.01	47.131	0.763
Nagod	950	915	0.8349	5.45	2.45	0.1/.015/0.01	27.554	0.976
Ramnagar	600.54	323.54	1.02372	4.31	1.31	0.015	6.358	0.324
Rampur Baghelan	873.94	478.92	0.9006	4.3	1.3	0.015/0.02	11.194	0.486
Sohawal	771.92	684.94	0.94156	4.74	1.74	0.16/0.02	38.447	2.0232
Unchehra	896.91	759.23	0.925	5.61	2.61	0.015/0.02	36.245	0.744
District Total	**7502.34**	**5824.35**					**189.076**	**6.397**

Station	Available Storage Potential (MCM)	Surface water required (MCM)	Surface water (Run-off) available (MCM)	Non-committed Run-off (MCM)	Percolation tank	Recharge shaft/ Tube well	NB/ CD/ CP	No of Village tank, Village pond
	9	10	11	12	13	14	15	16
Amarpatan	1.660398	2.20832934	150.0313	45.00939	2	6	13	225
Maihar	19.4055	25.809315	258.9156	77.67468	26	65	155	76
Majhgawan	46.3677825	61.66915073	375.13	112.539	62	154	370	130
Nagod	26.5787925	35.34979403	218.5	65.55	35	88	212	230
Ramnagar	6.033561	8.02463613	138.1242	41.43726	8	20	48	113
Rampur Baghelan	10.70834	14.2420922	201.0062	60.30186	14	36	85	170
Sohawal	36.42384	48.4437072	177.5416	53.26248	48	121	291	840
Unchehra	35.5005395	47.21571754	206.2893	61.88679	47	118	283	231
District Total	**182.6787535**	**242.9627422**	**1725.5382**	**517.66146**	**242**	**608**	**1457**	**2015**

Table 14: Financial Outlay Plan- Supply Side Management, Satna District, Madhya Pradesh

Block	Area Suitable for AR	Volume of Surface Water available for AR (MCM)	Volume of Water required for recharge (MCM)	Percolation Tanks		NB/ CD/ CP		Recharge shaft/ Tube well		Renovation of Village Ponds		Total Cost of ARS in crores
				structure	cost	structure	cost	structure	cost	structure	cost	
				Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	
Amarpatan	532.31	150.03	2.78	2	0.4	13	1.3	6	0.3	225	4.5	**6.5**
Maihar	924	258.92	19.99	26	5.2	155	15.5	65	3.25	76	1.52	**25.47**
Majhgawan	1206.41	375.13	50.81	62	12.4	370	37	154	7.7	130	2.6	**59.7**
Nagod	915	218.50	27.55	35	7	212	21.2	88	4.4	230	4.6	**37.2**
Ramnagar	323.54	138.12	9.89	8	1.6	48	4.8	20	1	113	2.26	**9.66**
Rampur Baghelan	478.92	201.01	16.986	14	2.8	85	8.5	36	1.8	170	3.4	**16.5**
Sohawal	684.94	177.54	41.47	48	9.6	291	29.1	121	6.05	840	16.8	**61.55**
Unchehra	759.23	206.29	36.24	47	9.4	283	28.3	118	5.9	231	4.62	**48.22**
Total	**5824.35**	**1725.54**	**205.74**	**242**	48.4	**1457**	145.7	**608**	**30.4**	**2015**	**40.363**	**264.8**

Adoption of Sprinkler irrigation techniques in 50% of the area irrigated by ground water has been suggested for the Satna 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. A summarized table for the demand side management is given in the Table no. 15.

Table 15: Groundwater Management- Demand Side Management

Block	Area Irrigated by Tube Well (Ha)	Area Irrigated by Tube Well (Sq.Km)	50% Area Irrigated by Tube Well (Sq.Km)	Groundwater draft saved by Sprinkler Irrigation @0.08 m (MCM)
Amarpatan	13205	132.05	66.02	5.28
Maihar	15308	153.08	76.54	6.12
Majhgawan	7149	71.49	35.74	2.85
Nagod	16778	167.78	83.89	6.71
Ramnagar	1585	15.85	7.92	0.63
Rampur Baghelan	24439	244.39	122.19	9.77
Sohawal	15977	159.77	79.88	6.39
Unchehra	8310	83.1	41.55	3.32
Total	**102751**	**1027.51**	**513.75**	**41.10**

6.2. Post-Intervention Impact

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table no 16. It can be envisaged that the Stage of ground water development for the entire Satna district, would reduce to 65.09% as compared to the present stage of ground water development of 72.10% after implying and successful implementation of proposed interventions.

Table 16: Post-Intervention Impact, Satna District, Madhya Pradesh

Assessment Unit / District	Net Ground Water Availability (MCM)	Existing Gross Ground Water Draft for All Uses (MCM)	Stage of Ground Water Development %	Groundwater saved by Sprinklar irrigation (MCM)	Additional recharge created by AR (MCM)	Net Groundwater availability after intervention of AR Structures (MCM)	Additional draft created after utilisation of 60% of Net GW available from AR Structures (MCM)	Total draft (Existing Gross Ground Water Draft & Sprinkler irrigation) (MCM)	Additional area irrigated by GW after intervention (Sq. Km)	Stage of Development after interventions %
Amarpatan	64.26	57.00	88.71	5.28	1.66	65.92	1.00	52.72	2.49	79.97
Maihar	74.42	63.96	85.94	6.12	19.41	93.83	11.64	69.48	29.11	74.05
Majhgawan	110.24	46.48	42.17	2.86	46.37	156.60	27.82	71.44	69.55	45.62
Nagod	86.89	74.27	85.47	6.71	26.58	113.47	15.95	83.50	39.87	73.59
Ramnagar	34.59	19.98	57.78	0.63	6.03	40.62	3.62	22.97	9.05	56.55
Rampur Baghelan	138.27	112.15	81.11	9.78	10.71	148.97	6.43	108.80	16.06	73.03
Sohawal	50.83	42.64	83.89	6.39	36.42	87.26	21.85	58.11	54.64	66.60
Unchehra	54.31	28.09	51.72	3.32	35.50	89.82	21.30	46.07	53.25	51.29
District Total	**613.81**	**444.58**	**72.10**	**41.10**	**182.68**	**796.49**	**109.61**	**513.09**	**274.02**	**65.09**

6.3. Block-wise Ground Water Management Plan (Outcome of NAQUIM)

As per directions of Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, Aquifer Management Plan for Satna district has been prepared block-wise. The plan for each block discusses the broad framework of ground water situation in the block, status of water availability (both surface and ground water), feasibility of artificial recharge and other water conservation structures and their numbers and cost estimates.

To ensure the proper implementation of management plan, the suggested interventions are advised to be followed in a phase manner. The ground water stressed areas such as over-exploited and critical blocks shall be taken up in the First phase with a proposed expenditure of Rs 84.55 Crores whereas the semi-critical and safe areas will be covered in the Second phase with the expected expenditure of Rs. 180.25 Crores. Table no. 17 shows the blocks segregated as per the phase wise management plan. A summarized management plan for all the blocks has been discussed further. The proposed artificial recharge structures have been marked in the block-wise drainage map taking into consideration the command area covered under Bansagar irrigation project.

Table 17: Phase wise management plan for Satna district

Block	Percolation Tanks		NB/ CD/ CP		Recharge shaft/ Tube well		Renovation of Village Ponds		Total Cost of RS in crores
	structure	cost	structure	cost	structure	cost	structure	cost	
	Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	
PHASE-I									
Amarpatan	2	0.4	13	1.3	6	0.3	225	4.5	**6.5**
Rampur Baghelan	14	2.8	85	8.5	36	1.8	170	3.4	**16.5**
Sohawal	48	9.6	291	29.1	121	6.05	840	16.8	**61.55**
Total	**64**	**12.8**	**389**	**38.9**	**163**	**8.15**	**1235**	**24.7**	**84.55**
PHASE-II									
Maihar	26	5.2	155	15.5	65	3.25	76	1.52	**25.47**
Majhgawan	62	12.4	370	37	154	7.7	130	2.6	**59.7**
Nagod	35	7	212	21.2	88	4.4	230	4.6	**37.2**
Ramnagar	8	1.6	48	4.8	20	1	113	2.26	**9.66**
Unchehra	47	9.4	283	28.3	118	5.9	231	4.62	**48.22**
Total	**178**	**35.6**	**1068**	**106.8**	**445**	**22.25**	**780**	**15.6**	**180.25**

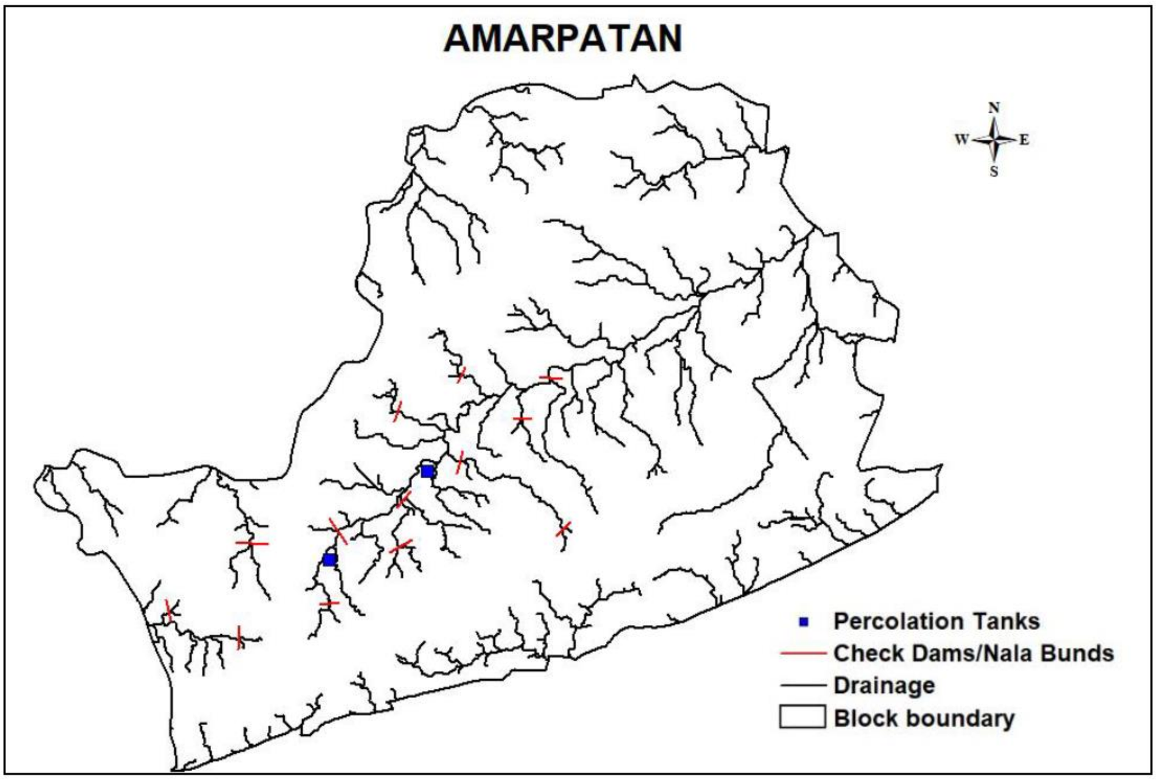
1. Block Amarpatan

Salient features

Area (Sq Km)	652.31
Area Suitable for Recharge-NC (Sq.Km)	532.31
Rainfall (m)	1.1138
Average Post Monsoon DTW in (mbgl)	3.23
Unsaturated Zone (m)	0.23
Average Specific Yield	0.06/0.01/ 0.02
Sub Surface Storage Available (MCM)	2.503
Recharge through RWH structures (MCM)	0.843
Available Storage Potential (MCM)	1.660
Surface Water Required (MCM)	2.2088
Runoff Available (MCM)	150.03
Non-committed Runoff available (MCM)	45.01

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	2	0.4 (Rs 20 Lakh Per Structure)
NB/CD/CP	13	1.3 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	6	0.3 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	225	4.5 (Rs 02 Lakh Per Structure)
Total Cost		**6.50 Crores**

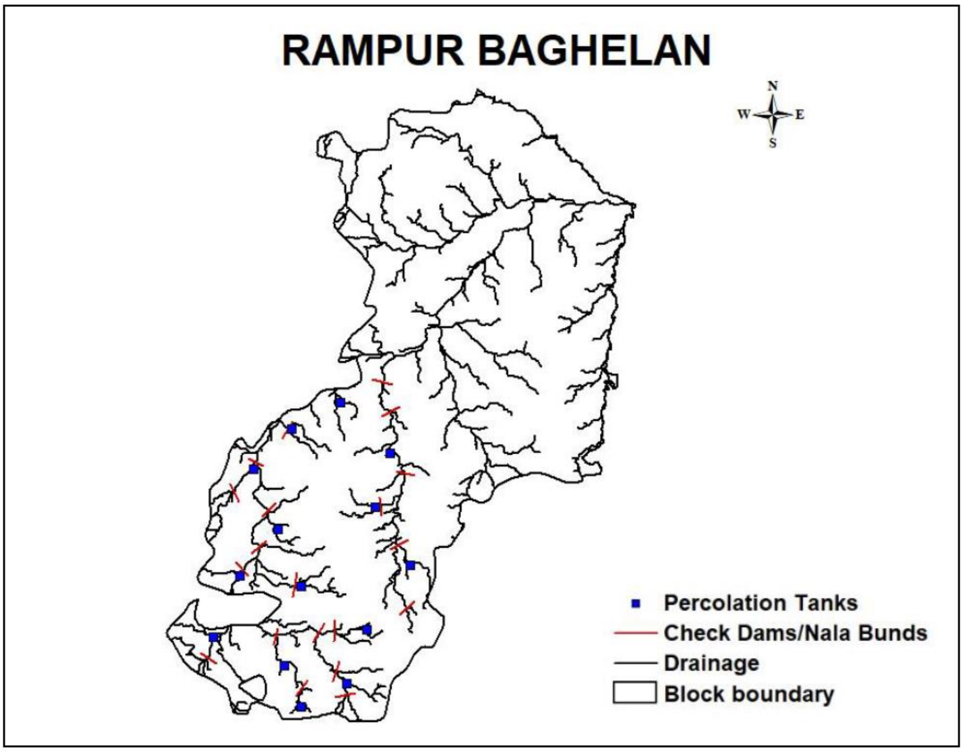
2. Block Rampur Baghelan

Salient features

Area (Sq Km)	873.94
Area Suitable for Recharge-NC (Sq.Km)	478.92
Rainfall (m)	0.9006
Average Post Monsoon DTW in (mbgl)	4.3
Unsaturated Zone (m)	1.3
Average Specific Yield	0.015/0.02
Sub Surface Storage Available (MCM)	11.194
Recharge through RWH structures (MCM)	0.486
Available Storage Potential (MCM)	10.708
Surface Water Required (MCM)	14.24
Runoff Available (MCM)	201.01
Non-committed Runoff available (MCM)	60.30

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	14	2.8 (Rs 20 Lakh Per Structure)
NB/CD/CP	85	8.5 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	36	1.8 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	170	3.4 (Rs 02 Lakh Per Structure)
Total Cost		**16.5 Crores**

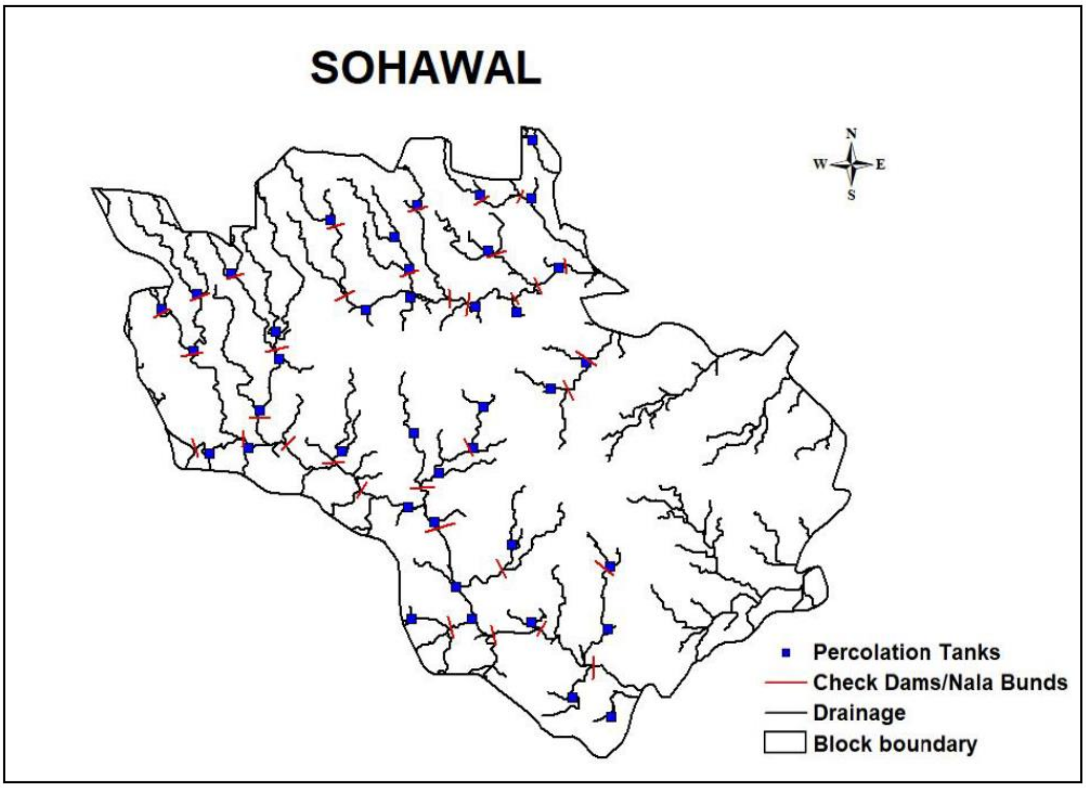
3. Block Sohawal

Salient features

Area (Sq Km)	771.92
Area Suitable for Recharge-NC (Sq.Km)	684.94
Rainfall (m)	0.942
Average Post Monsoon DTW in (mbgl)	4.74
Unsaturated Zone (m)	1.74
Average Specific Yield	0.16/0.02
Sub Surface Storage Available (MCM)	38.447
Recharge through RWH structures (MCM)	2.023
Available Storage Potential (MCM)	36.423
Surface Water Required (MCM)	48.443
Runoff Available (MCM)	177.54
Non-committed Runoff available (MCM)	53.26

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	48	9.6 (Rs 20 Lakh Per Structure)
NB/CD/CP	291	29.1 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	121	6.05 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	840	16.8 (Rs 02 Lakh Per Structure)
Total Cost		**61.55 Crores**

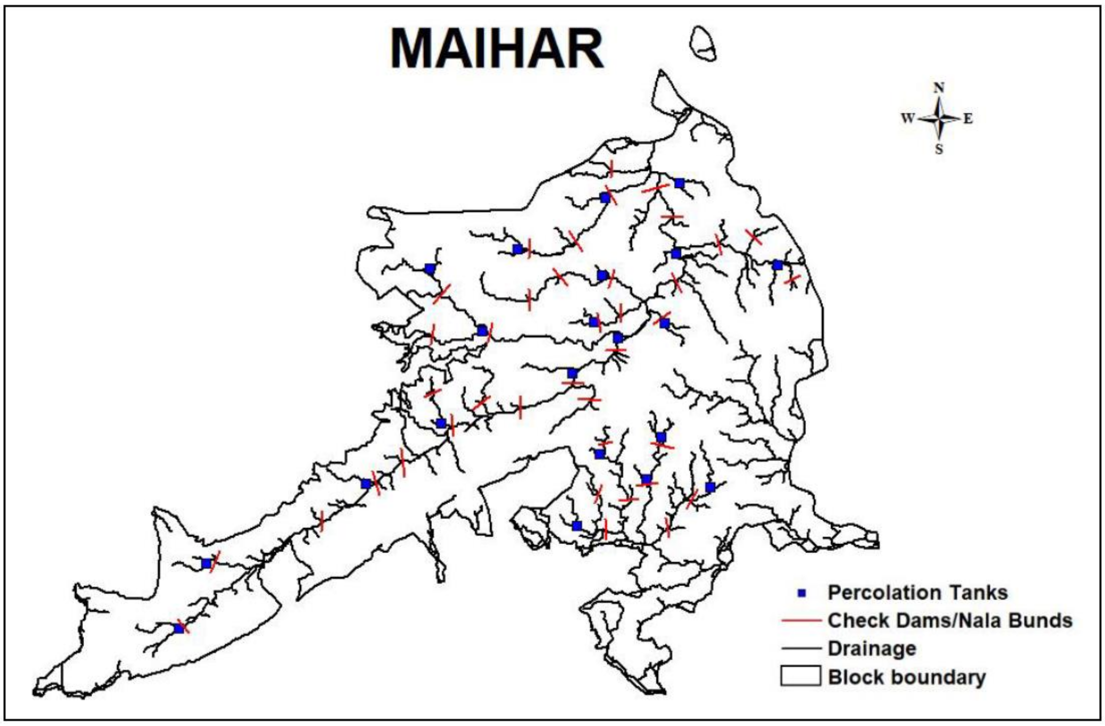
4. Block Maihar

Salient features

Area (Sq Km)	1125.72
Area Suitable for Recharge-NC (Sq.Km)	924.00
Rainfall (m)	0.87364
Average Post Monsoon DTW in (mbgl)	4.74
Unsaturated Zone (m)	1.74
Average Specific Yield	0.06/0.01/0.01
Sub Surface Storage Available (MCM)	19.645
Recharge through RWH structures (MCM)	0.239
Available Storage Potential (MCM)	19.405
Surface Water Required (MCM)	25.809
Runoff Available (MCM)	258.915
Non-committed Runoff available (MCM)	77.674

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	26	5.2 (Rs 20 Lakh Per Structure)
NB/CD/CP	155	15.5 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	65	3.25 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	76	1.52 (Rs 02 Lakh Per Structure)
Total Cost		**25.47 Crores**

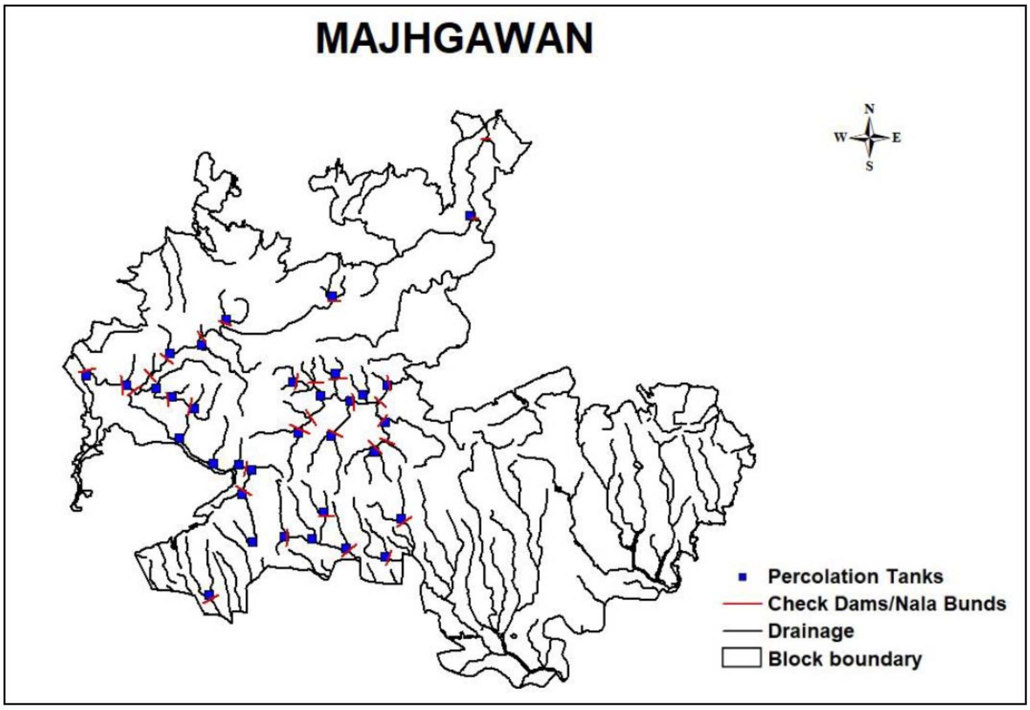
5. Block Majhgawan

Salient features

Area (Sq Km)	1631
Area Suitable for Recharge-NC (Sq.Km)	1206.41
Rainfall (m)	1.0738
Average Post Monsoon DTW in (mbgl)	4.91
Unsaturated Zone (m)	1.91
Average Specific Yield	0.1/.015/0.01
Sub Surface Storage Available (MCM)	47.131
Recharge through RWH structures (MCM)	0.763
Available Storage Potential (MCM)	46.367
Surface Water Required (MCM)	61.669
Runoff Available (MCM)	375.13
Non-committed Runoff available (MCM)	112.539

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



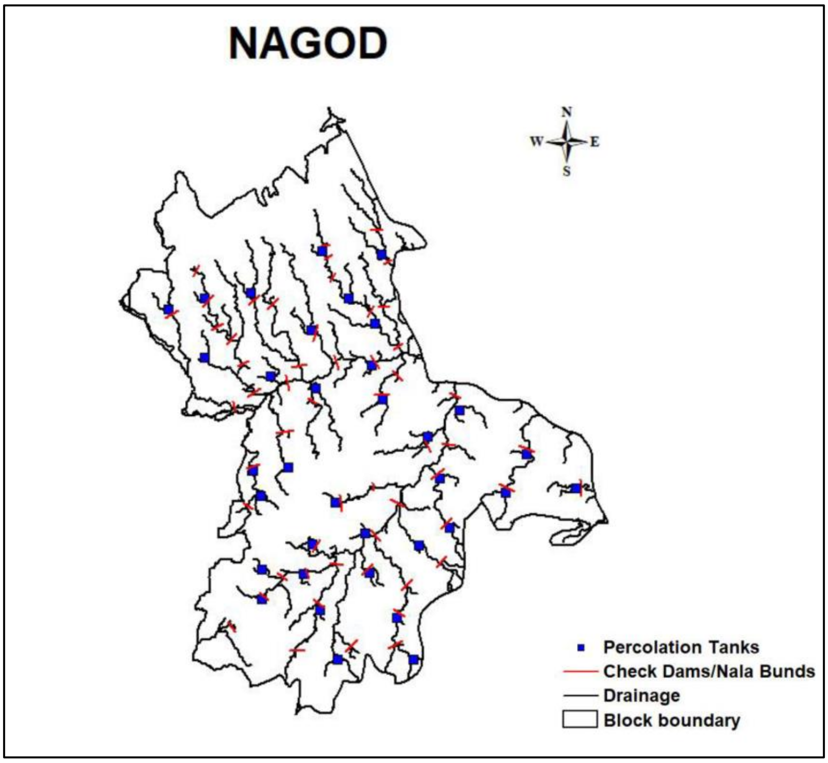
TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	62	12.4 (Rs 20 Lakh Per Structure)
NB/CD/CP	370	37.0 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	154	7.7 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	130	2.6 (Rs 02 Lakh Per Structure)
Total Cost		**59.70 Crores**

6. Block Nagod

Salient features	
Area (Sq Km)	950
Area Suitable for Recharge-NC (Sq.Km)	915
Rainfall (m)	0.8349
Average Post Monsoon DTW in (mbgl)	5.45
Unsaturated Zone (m)	2.45
Average Specific Yield	0.1/.015/0.01
Sub Surface Storage Available (MCM)	27.55
Recharge through RWH structures (MCM)	0.976
Available Storage Potential (MCM)	26.578
Surface Water Required (MCM)	35.35
Runoff Available (MCM)	218.50
Non-committed Runoff available (MCM)	65.55

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	35	7 (Rs 20 Lakh Per Structure)
NB/CD/CP	212	21.2 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	88	4.4 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	230	4.6 (Rs 02 Lakh Per Structure)
Total Cost		**37.20 Crores**

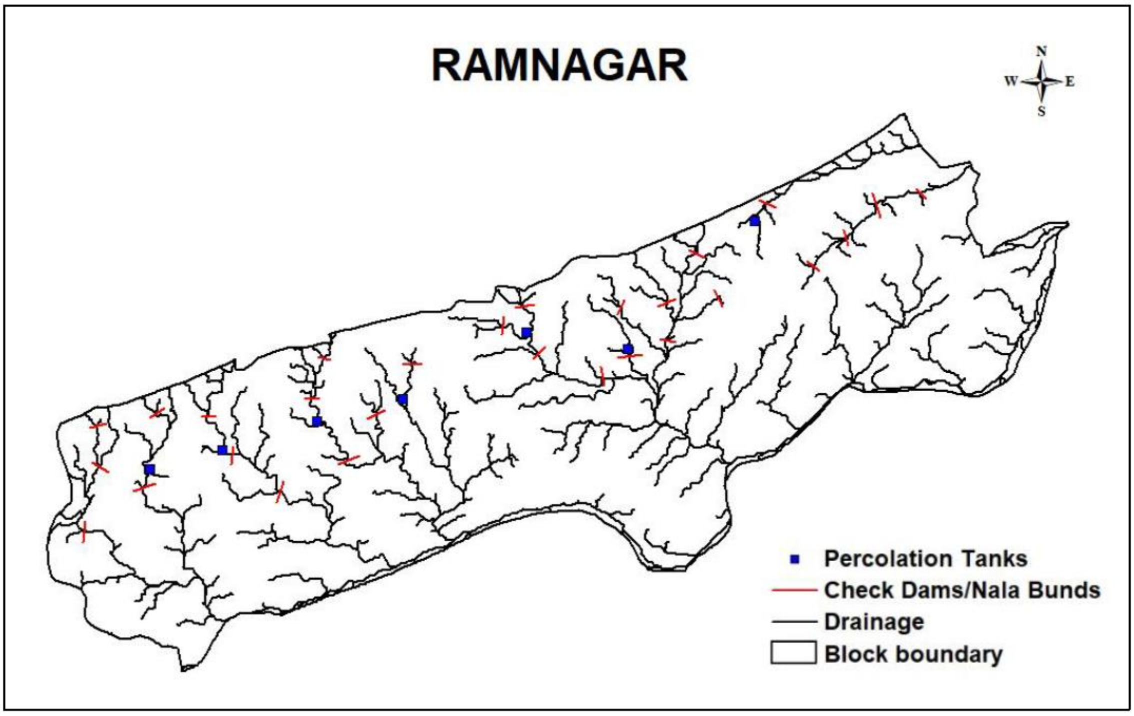
7. Block Ramnagar

Salient features

Area (Sq Km)	600.54
Area Suitable for Recharge-NC (Sq.Km)	323.54
Rainfall (m)	1.02372
Average Post Monsoon DTW in (mbgl)	4.31
Unsaturated Zone (m)	1.31
Average Specific Yield	0.015
Sub Surface Storage Available (MCM)	6.358
Recharge through RWH structures (MCM)	0.324
Available Storage Potential (MCM)	6.033
Surface Water Required (MCM)	8.024
Runoff Available (MCM)	138.124
Non-committed Runoff available (MCM)	41.437

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	8	1.6 (Rs 20 Lakh Per Structure)
NB/CD/CP	48	4.8 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	20	1.0 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	113	2.26 (Rs 02 Lakh Per Structure)
Total Cost		**9.66Crores**

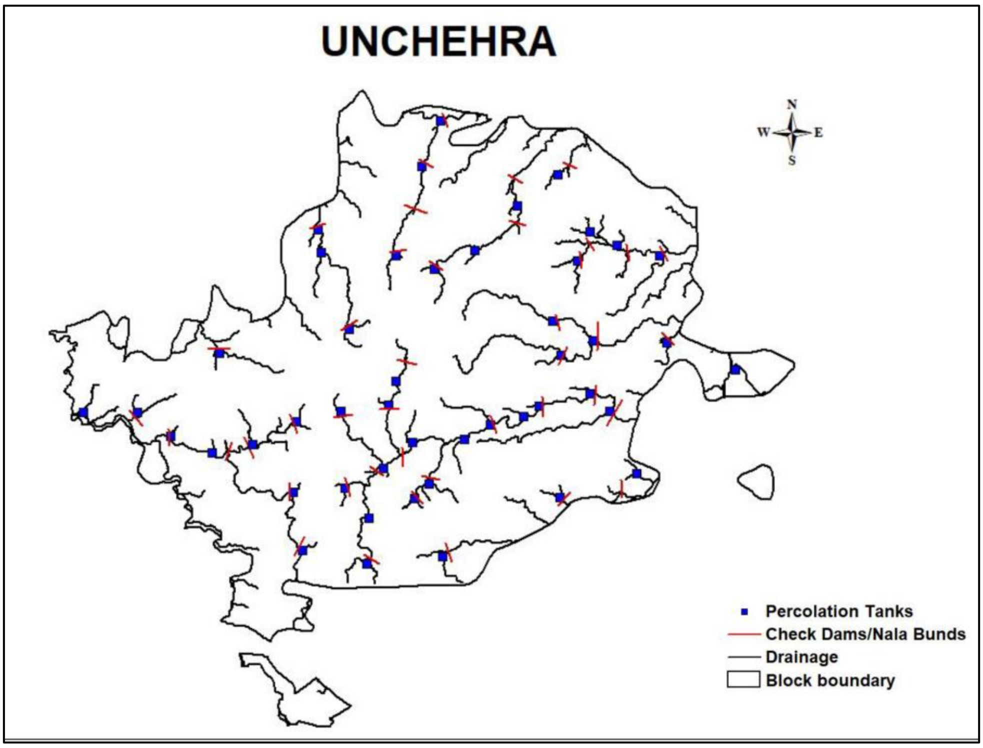
8. Block Unchehra

Salient features

Area (Sq Km)	896.91
Area Suitable for Recharge-NC (Sq.Km)	759.23
Rainfall (m)	0.925
Average Post Monsoon DTW in (mbgl)	5.61
Unsaturated Zone (m)	2.61
Average Specific Yield	0.015/0.02
Sub Surface Storage Available (MCM)	36.24
Recharge through RWH structures (MCM)	0.744
Available Storage Potential (MCM)	35.50
Surface Water Required (MCM)	47.215
Runoff Available (MCM)	206.289
Non-committed Runoff available (MCM)	61.89

Resources

SHALLOW AQUIFER (0 - 30 m)	
Dynamic Resources (MCM)	64.26
In-storage (MCM)	50.63
Total Resources (MCM)	114.88
Gross Ground water draft for Irrigation	7.34
Gross Ground water draft Domestic+Industries	5.594
GW Draft (MCM)	12.94
DEEPER AQUIFER (30 - 200 m)	
Static Resources (MCM)	41.927
Gross Ground water draft for Irrigation	44.06



TYPE OF STRUCTURE	NUMBER	COST IN INR CRORES
Percolation Tanks	47	9.4 (Rs 20 Lakh Per Structure)
NB/CD/CP	283	28.3 (Rs 10 Lakh Per Structure)
Recharge Shaft/ Tube Wells	118	5.9 (Rs 05 Lakh Per Structure)
Renovation of Village Ponds	231	4.62 (Rs 02 Lakh Per Structure)
Total Cost		**48.22 Crores**

Annexure-I

Locations details of Exploration Borewells

S.NO.	WELL	BLOCK	LONG	LAT	RL
1	Amarpatan	Amarpatan	80.972	24.317	552
2	Jhinna Nala	Amarpatan	80.955	24.303	358.7
3	Mirgauti	Amarpatan	81.054	24.222	335.9
4	Rigara	Amarpatan	80.933	24.283	360
5	Allah Talab	Maihar	80.708	24.268	316.3
6	Amatara	Maihar	80.816	24.052	399
7	Bhadanpur	Maihar	80.821	24.166	295
8	Ghunwara	Maihar	80.62	24.151	335.7
9	Jura	Maihar	80.888	24.261	317.4
10	Maihar Stadium	Maihar	80.746	24.263	380
11	Maihar Town(Pz)	Maihar	80.758	24.275	317
12	Maihar(Pz)	Maihar	80.764	24.26	332.9
13	Parsokha	Maihar	80.767	24.267	330.1
14	Udaipura	Maihar	80.823	24.263	344.6
15	Nagod	Nagod	80.598	24.569	350
16	Newramnagar(Pz)	Ramnagar	81.151	24.196	328.4
17	Asarar	Rampur Baghelan	80.988	24.387	293.4
18	Baijnath	Rampur Baghelan	81.003	24.498	297.7
19	Bihara	Rampur Baghelan	81.067	24.73	355
20	Chorahata	Rampur Baghelan	80.914	24.4	345
21	Daldal	Rampur Baghelan	81.104	24.613	354.9
22	Guduharu	Rampur Baghelan	80.98	24.493	380.7
23	Jamuna	Rampur Baghelan	81.092	24.553	326.8
24	Kharwahi	Rampur Baghelan	80.901	24.397	338.8
25	Kotar	Rampur Baghelan	80.982	24.693	541.6
26	Kotar(Pz)	Rampur Baghelan	80.995	24.699	344
27	Raghunathpur	Rampur Baghelan	81.045	24.622	344.4
28	Rampur Baghelan	Rampur Baghelan	81.067	24.511	289
29	Rampur(Pz)	Rampur Baghelan	81.056	24.511	314.7
30	Ramvan(Pz)	Rampur Baghelan	81.058	24.728	311
31	Sijahata	Rampur Baghelan	81.029	24.57	290.4
32	Sajjanpur	Sajjanpur	80.975	24.554	364
33	Satna Anicut	Sohawal	80.899	24.558	295.4
34	Satna College	Sohawal	80.864	24.572	291
35	Satna(Pz)	Sohawal	80.832	24.568	309.9
36	Singpur(Pz)	Sohawal	80.582	24.702	317.8
37	Icchole	Unchehra	80.78	24.334	297.6
38	Parasmaniya(Pz)	Unchehra	80.628	24.369	339.3
39	Paundi Pithorabad	Unchehra	80.75	24.484	332
40	Unchehra	Unchehra	80.788	24.383	324.9

Annexure-II

Lithological details of Exploration Borewells

Bore	Depth1	Depth2	Stratigraphy
Allah Talab	0	18	Highly Weathered Shale
Allah Talab	18	21	Fractured Shale Aq I
Allah Talab	21	91	Massive Shale I
Allah Talab	91	93	Fractured Shale Aq II
Allah Talab	93	201	Massive Shale II
Amarpatan	0	9	Highly Weathered Shale
Amarpatan	9	13	Massive Shale I
Amarpatan	13	14	Fractured Limestone Aq I
Amarpatan	14	30	Massive Limestone I
Amarpatan	30	33	Fractured Limestone Aq II
Amarpatan	33	42	Massive Shale II
Amarpatan	42	44	Fractured Shale Aq II
Amarpatan	44	99	Massive Shale III
Amarpatan	99	105	Massive Sandstone I
Amarpatan	105	202	Massive Shale IV
Amatara	0	5	Highly Weathered Shale
Amatara	5	16	Massive Limestone I
Amatara	16	18	Fractured Limestone Aq I
Amatara	18	20	Massive Limestone II
Amatara	20	201	Massive Shale I
Asarar	0	4	Highly Weathered Shale
Asarar	4	16	Massive Shale I
Asarar	16	17	Fractured Shale Aq I
Asarar	17	40	Massive Shale II
Asarar	40	42	Fractured Shale Aq II
Asarar	42	59	Massive Shale III
Asarar	59	62	Fractured Shale Aq II
Asarar	62	202	Massive Shale IV
Baijnath	0	12	Highly Weathered Limestone
Baijnath	12	13	Weathered Limestone Aq
Baijnath	13	18	Massive Limestone I
Baijnath	18	32	Massive Shale I
Baijnath	32	33	Fractured Shale Aq II
Baijnath	33	35	Massive Shale II
Baijnath	35	38	Fractured Shale Aq II
Baijnath	38	41	Massive Shale III
Baijnath	41	43	Fractured Shale Aq II
Baijnath	43	51	Massive Shale IV
Baijnath	51	54	Fractured Shale Aq II
Baijnath	54	201	Massive Shale IV
Bhadanpur	0	3	Highly Weathered Shale
Bhadanpur	3	21	Massive Shale I
Bhadanpur	21	24	Fractured Shale Aq I
Bhadanpur	24	35	Massive Shale II
Bhadanpur	35	37	Fractured Shale Aq II

Bhadanpur	37	50	Massive Shale III
Bihara	0	5	Highly Weathered Shale
Bihara	5	14	Weathered Limestone Aq
Bihara	14	18	Massive Limestone I
Bihara	18	20	Fractured Limestone Aq I
Bihara	20	29	Massive Limestone II
Bihara	29	60	Massive Shale I
Bihara	60	62	Fractured Shale Aq II
Bihara	62	85	Massive Shale Ii
Bihara	85	87	Fractured Shale Aq II
Bihara	87	93	Massive Shale III
Chorahata	0	3	Highly Weathered Shale
Chorahata	3	60	Massive Shale I
Chorahata	60	63	Fractured Limestone Aq II
Chorahata	63	99	Massive Shale II
Chorahata	99	142	Massive Limestone I
Daldal	0	13	Highly Weathered Shale
Daldal	13	33	Massive Shale I
Daldal	33	36	Fractured Shale Aq II
Daldal	36	160	Massive Shale II
Daldal	160	163	Fractured Shale Aq II
Daldal	163	201	Massive Shale III
Ghunwara	0	5	Highly Weathered Shale
Ghunwara	5	8	Fractured Sandstone Aq I
Ghunwara	8	54	Massive Shale I
Ghunwara	54	56	Fractured Sandstone Aq II
Ghunwara	56	64	Massive Sandstone I
Ghunwara	64	143	Massive Shale II
Ghunwara	143	145	Fractured Shale Aq II
Ghunwara	145	191	Massive Shale III
Guduharu	0	10	Highly Weathered Shale
Guduharu	10	15	Weathered Shale Aq
Guduharu	15	28	Massive Shale I
Guduharu	28	30	Fractured Shale Aq I
Guduharu	30	43	Massive Shale II
Guduharu	43	46	Fractured Shale Aq II
Guduharu	46	202	Massive Shale III
Icchole	0	10	Highly Weathered Shale
Icchole	10	31	Massive Shale I
Icchole	31	33	Fractured Shale Aq II
Icchole	33	202	Massive Shale II
Jamuna	0	23	Highly Weathered Shale
Jamuna	23	25	Fractured Shale Aq I
Jamuna	25	44	Massive Shale I
Jamuna	44	46	Fractured Shale Aq II
Jamuna	46	201	Massive Shale II
Jhinna Nala	0	8	Highly Weathered Shale
Jhinna Nala	8	10	Fractured Limestone Aq I
Jhinna Nala	10	17	Massive Shale I
Jhinna Nala	17	22	Fractured Limestone Aq I

Jhinna Nala	22	80	Massive Shale II
Jhinna Nala	80	105	Massive Sandstone I
Jhinna Nala	105	203	Massive Shale III
Jura	0	2	Highly Weathered Shale
Jura	2	26	Massive Sandstone I
Jura	26	28	Fractured Sandstone Aq I
Jura	28	48	Massive Limestone I
Jura	48	50	Fractured Limestone Aq II
Jura	50	81	Massive Limestone II
Jura	81	83	Fractured Sandstone Aq II
Jura	83	148	Massive Sandstone II
Kharwahi	0	19	Highly Weathered Shale
Kharwahi	19	22	Weathered Shale Aq
Kharwahi	22	34	Massive Shale I
Kharwahi	34	37	Fractured Shale Aq II
Kharwahi	37	51	Massive Shale II
Kharwahi	51	52	Fractured Shale Aq II
Kharwahi	52	202	Massive Shale III
Kotar	0	9	Highly Weathered Shale
Kotar	9	20	Massive Shale I
Kotar	20	22	Fractured Limestone Aq I
Kotar	22	38	Massive Limestone I
Kotar	38	142	Massive Shale II
Kotar(Pz)	0	11	Highly Weathered Shale
Kotar(Pz)	11	12	Weathered Shale Aq
Kotar(Pz)	12	18	Massive Limestone I
Kotar(Pz)	18	19	Fractured Limestone Aq I
Kotar(Pz)	19	31	Massive Limestone II
Maihar Stadium	0	3	Highly Weathered Shale
Maihar Stadium	3	12	Massive Sandstone I
Maihar Stadium	12	15	Fractured Sandstone Aq I
Maihar Stadium	15	40	Massive Sandstone II
Maihar Stadium	40	58	Massive Shale I
Maihar Stadium	58	61	Fractured Limestone Aq II
Maihar Stadium	61	201	Massive Shale II
Maihar Town(Pz)	0	3	Highly Weathered Shale
Maihar Town(Pz)	3	40	Massive Shale I
Maihar Town(Pz)	40	42	Fractured Shale Aq II
Maihar Town(Pz)	42	48	Massive Shale II
Maihar(Pz)	0	1.3	Highly Weathered Shale
Maihar(Pz)	1	13	Weathered Shale Aq
Maihar(Pz)	13	57	Massive Shale I
Maihar(Pz)	57	59	Fractured Limestone Aq II
Maihar(Pz)	59	62	Massive Limestone I
Mirgauti	0	13	Highly Weathered Limestone
Mirgauti	13	17	Weathered Limestone Aq
Mirgauti	17	25	Massive Shale I
Mirgauti	25	27	Fractured Limestone Aq I
Mirgauti	27	35	Massive Limestone I
Mirgauti	35	124	Massive Shale II

Nagod	0	8	Highly Weathered Shale
Nagod	8	14	Weathered Shale Aq
Nagod	14	20	Massive Shale I
Nagod	20	22	Fractured Limestone Aq I
Nagod	22	50	Massive Limestone I
Nagod	50	52	Fractured Shale Aq II
Nagod	52	203	Massive Shale II
Newramnagar(Pz)	0	11	Highly Weathered Shale
Newramnagar(Pz)	11	15	Massive Shale I
Newramnagar(Pz)	15	17	Fractured Shale Aq I
Newramnagar(Pz)	17	48	Massive Shale II
Newramnagar(Pz)	48	49	Fractured Shale Aq II
Parasmaniya(Pz)	0	1	Highly Weathered Shale
Parasmaniya(Pz)	1	2	Weathered Shale Aq
Parasmaniya(Pz)	2	7	Massive Shale I
Parasmaniya(Pz)	7	9	Fractured Shale Aq I
Parasmaniya(Pz)	9	31	Massive Sandstone I
Parsokha	0	34	Highly Weathered Shale
Parsokha	34	38	Weathered Shale Aq
Parsokha	38	202	Massive Shale I
Paundi Pithorabad	0	7	Highly Weathered Shale
Paundi Pithorabad	7	8	Weathered Shale Aq
Paundi Pithorabad	8	202	Massive Shale I
Raghunathpur	0	5	Highly Weathered Limestone
Raghunathpur	5	12	Massive Limestone I
Raghunathpur	12	15	Fractured Limestone Aq I
Raghunathpur	15	30	Massive Shale I
Raghunathpur	30	33	Fractured Shale Aq II
Raghunathpur	33	54	Massive Shale II
Raghunathpur	54	56	Fractured Shale Aq II
Raghunathpur	56	97	Massive Shale III
Raghunathpur	97	122	Massive Limestone II
Raghunathpur	122	125	Fractured Limestone Aq II
Raghunathpur	125	134	Massive Limestone II
Rampur Baghelan	0	2	Highly Weathered Shale
Rampur Baghelan	2	4	Fractured Sandstone Aq I
Rampur Baghelan	4	32	Massive Sandstone I
Rampur Baghelan	32	63	Massive Shale I
Rampur Baghelan	63	99	Massive Limestone I
Rampur Baghelan	99	154	Massive Shale II
Rampur Baghelan	154	163	Massive Sandstone I
Rampur Baghelan	163	178	Massive Shale III
Rampur Baghelan	178	202	Massive Sandstone II
Rampur(Pz)	0	2	Highly Weathered Shale
Rampur(Pz)	2	13	Weathered Shale Aq
Rampur(Pz)	13	18	Massive Shale I
Rampur(Pz)	18	19	Fractured Shale Aq I
Rampur(Pz)	19	25	Massive Shale II
Rampur(Pz)	25	26	Fractured Shale Aq I
Rampur(Pz)	26	30	Massive Shale III

Ramvan(Pz)	0	12	Highly Weathered Shale
Ramvan(Pz)	12	14	Weathered Shale Aq
Ramvan(Pz)	14	16	Massive Shale I
Ramvan(Pz)	16	18	Fractured Shale Aq I
Ramvan(Pz)	18	30	Massive Shale II
Rigara	0	16	Highly Weathered Shale
Rigara	16	22	Weathered Shale Aq
Rigara	22	31	Massive Shale I
Rigara	31	34	Fractured Shale Aq II
Rigara	34	71	Massive Shale II
Rigara	71	74	Fractured Shale Aq II
Rigara	74	77	Massive Shale III
Rigara	77	80	Fractured Shale Aq II
Rigara	80	90	Massive Shale IV
Sajjanpur	0	9	Highly Weathered Limestone
Sajjanpur	9	10	Weathered Limestone Aq
Sajjanpur	10	30	Massive Shale I
Sajjanpur	30	33	Fractured Shale Aq II
Sajjanpur	33	54	Massive Shale II
Sajjanpur	54	56	Fractured Shale Aq II
Sajjanpur	56	201	Massive Shale III
Satna Anicut	0	3	Highly Weathered Limestone
Satna Anicut	3	11	Weathered Limestone Aq
Satna Anicut	11	24	Massive Limestone I
Satna Anicut	24	26	Fractured Limestone Aq I
Satna Anicut	26	51	Massive Limestone II
Satna College	0	14	Highly Weathered Shale
Satna College	14	36	Massive Shale I
Satna College	36	38	Fractured Limestone Aq II
Satna College	38	60	Massive Limestone I
Satna College	60	78	Massive Shale II
Satna College	78	84	Massive Limestone II
Satna College	84	88	Massive Shale III
Satna College	88	98	Massive Limestone II
Satna College	98	203	Massive Shale IV
Satna(Pz)	0	6	Highly Weathered Shale
Satna(Pz)	6	12	Weathered Shale Aq
Satna(Pz)	12	16	Massive Shale I
Satna(Pz)	16	35	Massive Limestone I
Satna(Pz)	35	36	Fractured Limestone Aq II
Sijahata	0	15	Highly Weathered Limestone
Sijahata	15	18	Weathered Limestone Aq
Sijahata	18	40	Massive Shale I
Sijahata	40	43	Fractured Shale Aq II
Sijahata	43	46	Massive Shale II
Sijahata	46	48	Fractured Shale Aq II
Sijahata	48	52	Massive Shale III
Sijahata	52	55	Fractured Shale Aq II
Sijahata	55	201	Massive Shale IV
Singpur(Pz)	0	9	Highly Weathered Shale

Singpur(Pz)	9	11	Weathered Shale Aq
Singpur(Pz)	11	44	Massive Sandstone I
Udaipura	0	9	Highly Weathered Shale
Udaipura	9	18	Weathered Limestone Aq
Udaipura	18	49	Massive Shale I
Udaipura	49	51	Fractured Sandstone Aq II
Udaipura	51	80	Massive Sandstone I
Udaipura	80	122	Massive Limestone I
Udaipura	122	128	Massive Shale II
Udaipura	128	137	Massive Limestone II
Udaipura	137	164	Massive Shale III
Udaipura	164	166	Fractured Sandstone Aq II
Udaipura	166	173	Massive Sandstone II
Udaipura	173	201	Massive Shale IV
Unchehra	0	13	Highly Weathered Shale
Unchehra	13	25	Massive Shale I
Unchehra	25	28	Fractured Shale Aq I
Unchehra	28	43	Massive Shale II
Unchehra	43	45	Fractured Shale Aq II
Unchehra	45	86	Massive Shale III
Unchehra	86	89	Fractured Shale Aq II
Unchehra	89	95	Massive Shale IV
Unchehra	95	98	Fractured Shale Aq II
Unchehra	98	112	Massive Shale IV