केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

MORENA DISTRICT, MADHYA PRADESH

उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

Central Ground Water Board
Department of Water Resources, RD& GR
Ministry of Jal Shakti
Government of India

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

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NORTH CENTRAL REGION
BHOPAL
2021-22

CONTENTS

1. Introduction

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

1.1 Background of Aquifer Mapping

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

1.2 Scope of Study

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

1.3 Objectives

The objective of applying the hydrogeological and geophysical techniques is to provide more adequate and more precise (reduced uncertainty and ambiguity) information on aquifers – shallow and deep including dry and saturated zones with their geometry at reasonable scale (1: 50,000) in the area.

The tentative depth of the hydrogeological and geophysical exploration will be 200 m in hard rock area. However, the depth of exploration may vary depending on the geological conditions and requirements. Additional exploratory wells shall be drilled for validations of aquifer parameter estimations where borehole data are not available.

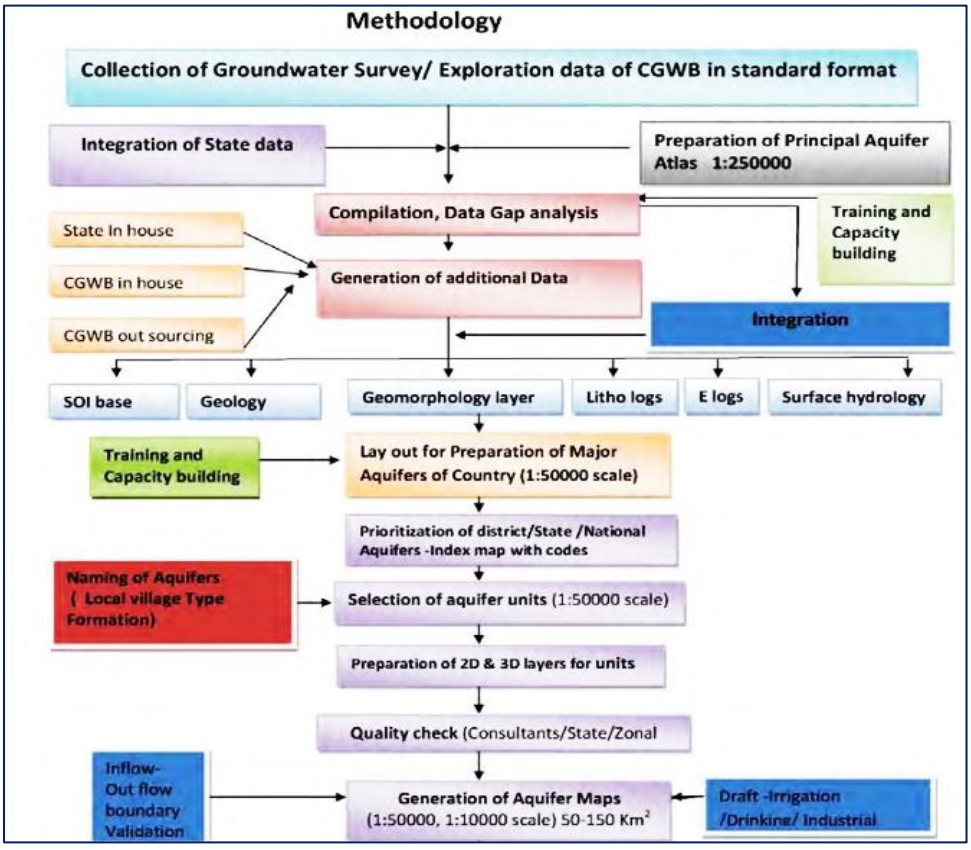
The information thus generated through additional drilling of boreholes shall be used for refinement of hydrogeological data base in terms of aquifer characterization, yield capacity, chemical quality, selecting areas for artificial recharge and sustainability under varied future demand scenario leading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

1.4 Approach and Methodology

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



1.5 Study Area

Morena district is located in the northern part of the State, bordered by Rajasthan on the West and Uttar Pradesh on the north. The adjacent districts are Gwalior and Bhind in the east and Sheopur in the South. The district comprises 7 blocks and 6 Tehsils in the district. The block headquarters are Ambah, Porsa, Morena, Joura, Pahargarh, Kailaras and Sabalgarh. Morena district covering an area of 4969Sq.km and lying between the North Latitudes 26^0 05'—26^0 42' and East Longitudes 77^0 05' 00"—78^0 30' 00" which falls under the survey of India Toposheet numbers 54 F & J.

The district is sub divided into seven administrative blocks with total area 4988.89 sq km shown in Table 1. The administrative divisions are shown in figure-2 and details are given in table–2. There are 489 gram panchayats and 820 villages in the district. As per census 2011, the total population of the district is 19,65,970.

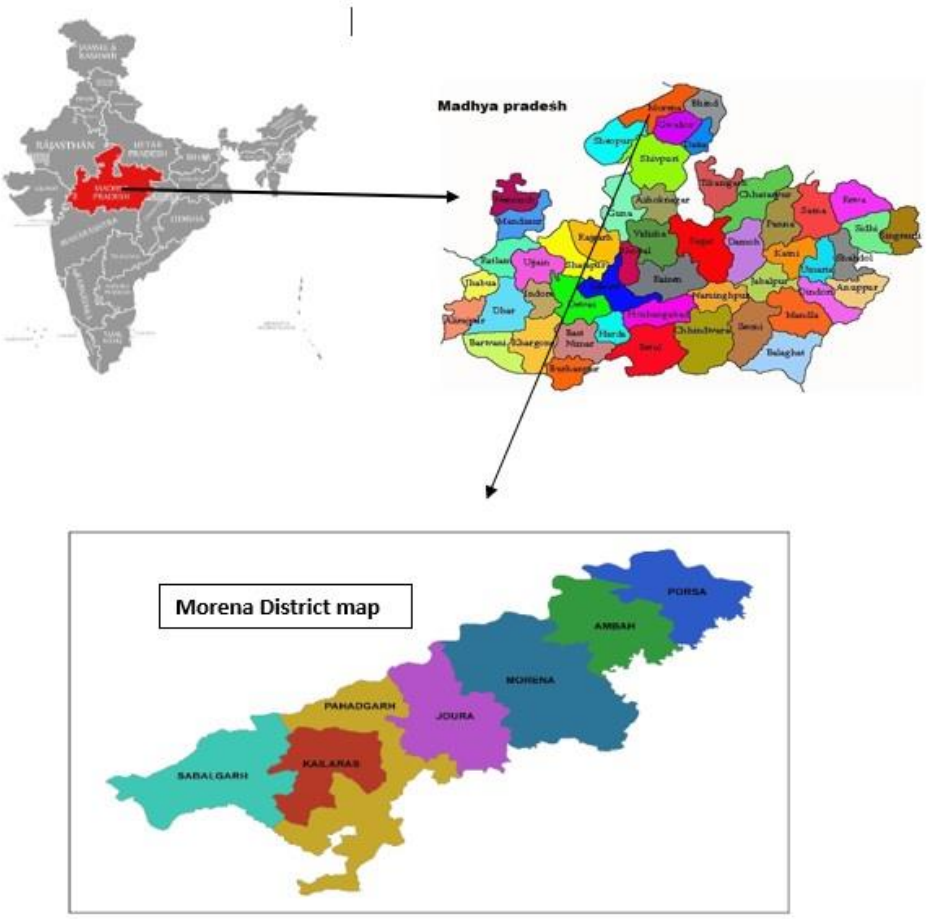
Table1: Administrative Units of Morena district

Total Blocks	Area (sq km)
Total Geographical Area (sq km)	4988.89
Recharge worthy Area (sq km)	4384.89(87.89%)
Hilly/Forest (sq km)	604 (8.26%)

Table 2: Block-wise area of the district

Block	Geographical Area (Sq Km)	Recharge Area (Sq Km)
AMBAH	511	511
PORSA	550	457
SABALGARH	730	580
KAILARAS	522.94	522.94
JOURA	685.95	572.95
MORENA	1067	1011
PAHADGARH	922	730
DISTRICT TOTAL	4988.89	4384.89

Fig 2: Location map of Morena district



1.6 RAINFALL AND CLIMATE

RAINFALL

The normal annual rainfall of Morena District is 753.7 mm. Morena District receive maximum rainfall during south west monsoon period i.e., June to September. About 91.8% of the annual rainfall received during monsoon season. Only, 8.2% of the annual rainfall takes place between October to May period. Thus surplus water for ground water recharge is available only during the south west monsoon period. The district has a total 41742 ha rainfed area. Where Pahargarh block has largest rainfed area 7881 ha. Porsa, Ambah, Kailaras and Joura has maximum irrigated area and minimum rainfed area.

Table 3: Annual rainfall

S no.	Year	Annual rainfall (mm)
1	2011	1373.84
2	2012	938.94
3	2013	1690.58
4	2014	994.43
5	2015	998.42
6	2016	1474.87
7	2017	835.49
8	2018	998.24
9	2019	1795.47
10	2020	1050.97

Table 4: Average Annual Rainfall of previous Five Years (in mm)

S no.	Blocks	Year wise rainfall (mm)			
		2015-16	2016-17	2018-19	2019-20
1	Ambah	22.25	45.17	63.43	76.58
2	Joura/pahargarh	45.33	39.17	60.37	54.42
3	Morena	68.18	50.58	77.42	83.75
4	Porsa	48.58	44.17	45.33	84.33
5	Sabalgarh	57.58	28.75	59.75	60.93
6	Kailaras	38.83	35.83	71.50	46.75
	Average	**878.28**	**1254.34**	**999.8**	**1663.97**

(DIP)

Climate & Temperature

The climate of Morena district, is characterized by a hot summer and general dryness except the south west monsoon season. The year may be divided into four seasons. The cold season, December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the south west monsoon season. October and November form the post monsoon or transition period. There is no meteorological observatory in Morena District. The nearest observatory is Gwalior. Hence all climatological parameters of Gwalior is used except rainfall to describe the climate of Morena District. The climate of this district is semi dry and generally dryness prevails in the region. The mean daily temperature in the months of May and June is maximum 44.0 celsius. In cold season the district has freezing cold and temperature drops to 2.80 celsius. During the monsoon season light air blows west to east. After the withdrawal of the monsoon and winter there is slight air that flows mostly from north to north western direction. Generally rainfall in the

district is irregular and on an average the annual rainfall recorded is 862.6 mm. About 92% of the rainfall in the district is received during June to September.

HUMIDITY & WIND

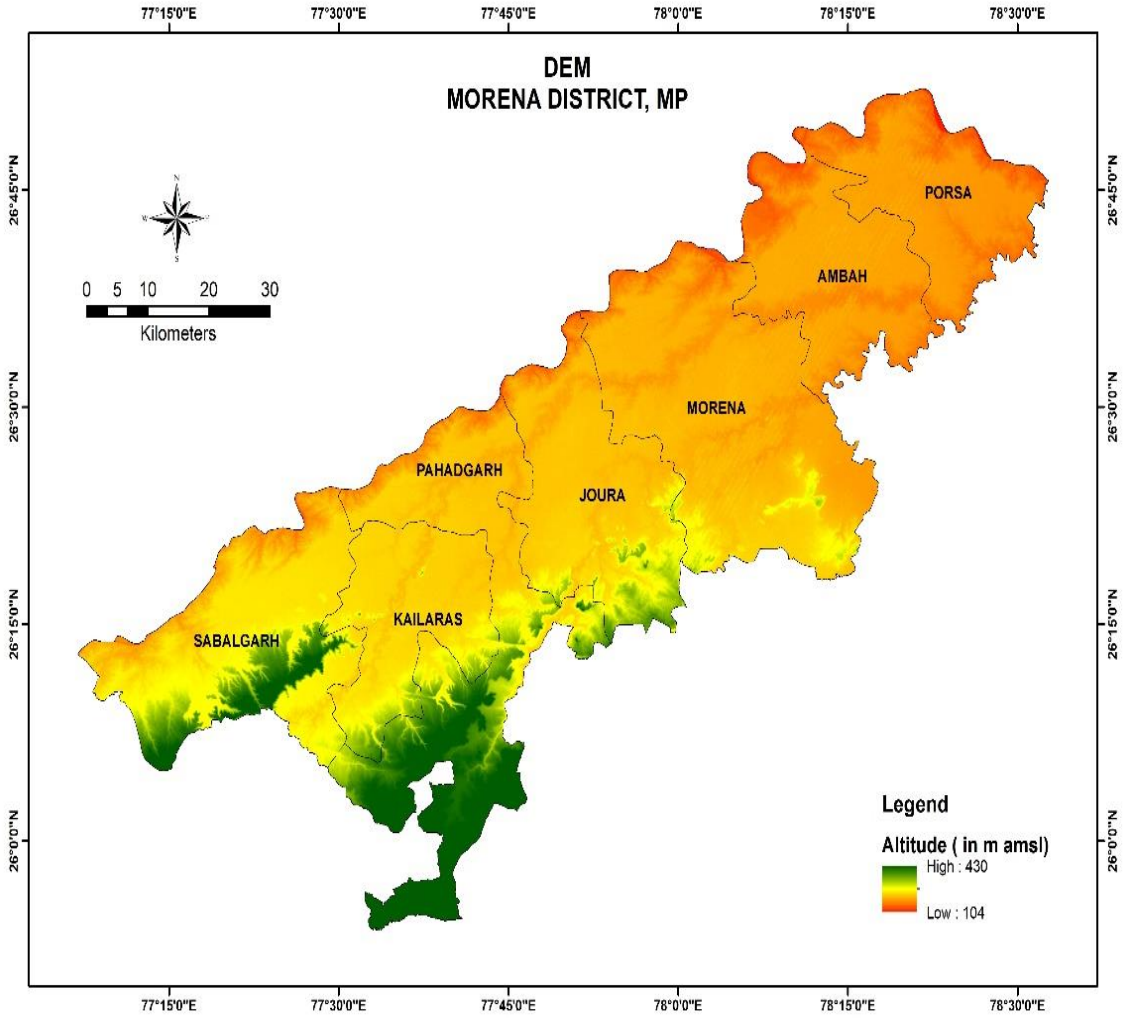
During the south west monsoon season the relative humidity generally exceeds 83% (August month). In the rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 26%. May is the driest month of the year.

The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity 11.3km/hr observed during the month of June and minimum 3.1 km/hr during the month of November. The average normal annual wind velocity of Morena District is 6.4 km/hr.

1.7 Physiography/DEM

The district lies on the meeting point of the Vindhyan Plateau and the low lying zone of Chambal Valley. The southern and the south-eastern parts of the district lie on the Vindhya Plateau and the northern part and the north-western belt along the Chambal lie in the valley. The plateau is the part of northern edge of the Malwa and the great Vindhya plateau which extends upto Gwalior and Morena district. The general height is about 300 meters above mean sea level. In this part the ridges and low hills of Bhander sandstones are marked, whose height is about 350 to 400 meters. The slope is towards south to north-west. The major part of the district is the part of Chambal valley whose average height is 160 meters from the mean sea level. The Chambal valley can be divided into two parts i.e. the first part is the bank of Chambal ravines where series of ravines deep gullies and ridges of dividing moulds are developed. On the other hand the main canal of Chambal of south-eastern plain part is very fertile. The Digital Elevation Model has been shown in the fig 4.

Fig 4: DEM map of Morena district

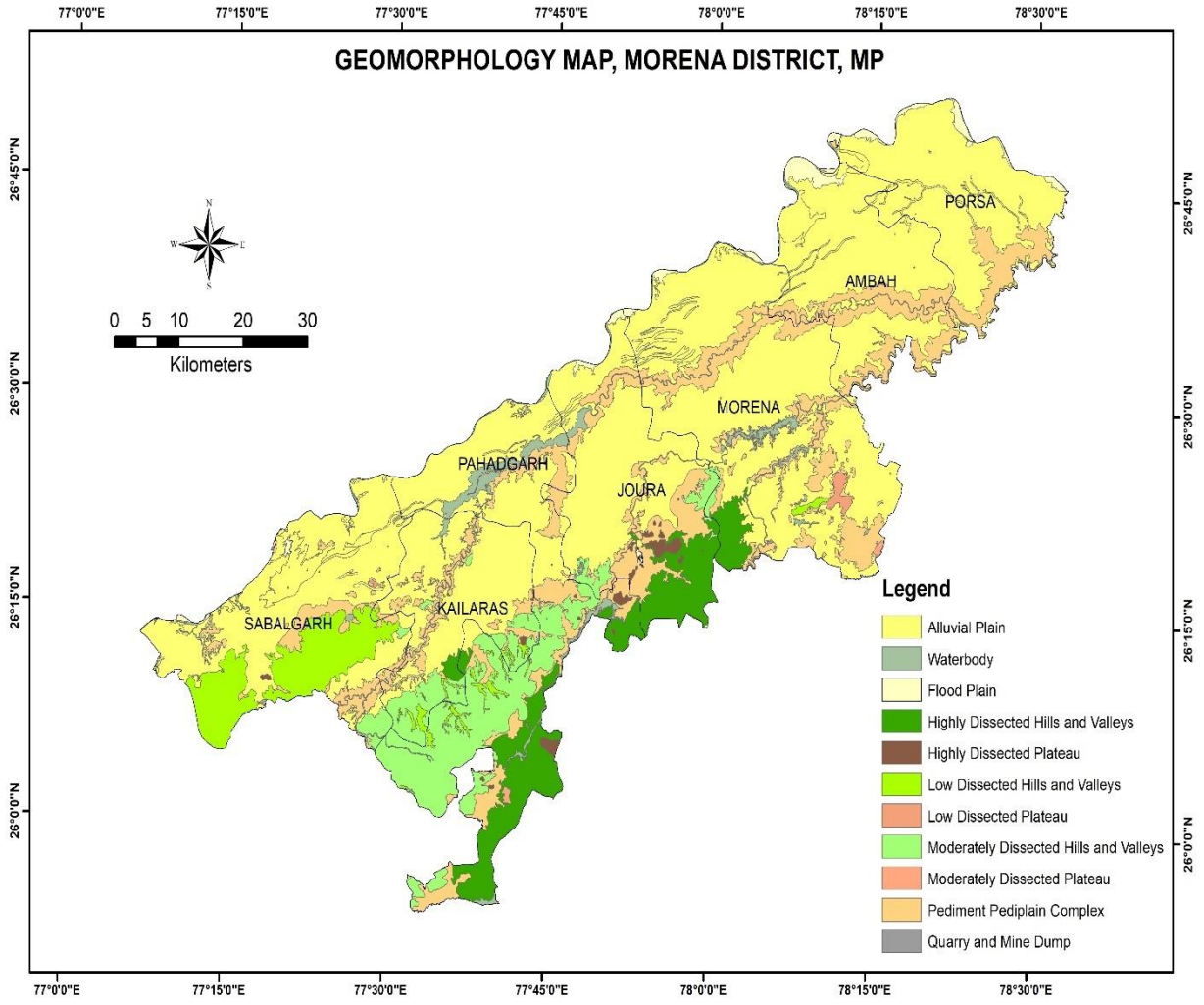


1.8 GEOMORPHOLOGY

Physiographically, the area is represented by north east – south west trending ridges and valleys (between 200 to 300 meters). The ridges are represented by sand stone and the valleys by shale. The minimum elevation 165 meters above m.s.l with general slope towards North.

Chambal is the main river which is flowing from southwest to northeast. Its tributaries Kunwari and Asan rivers drain the area. The overall drainage pattern in the district is dendritic.

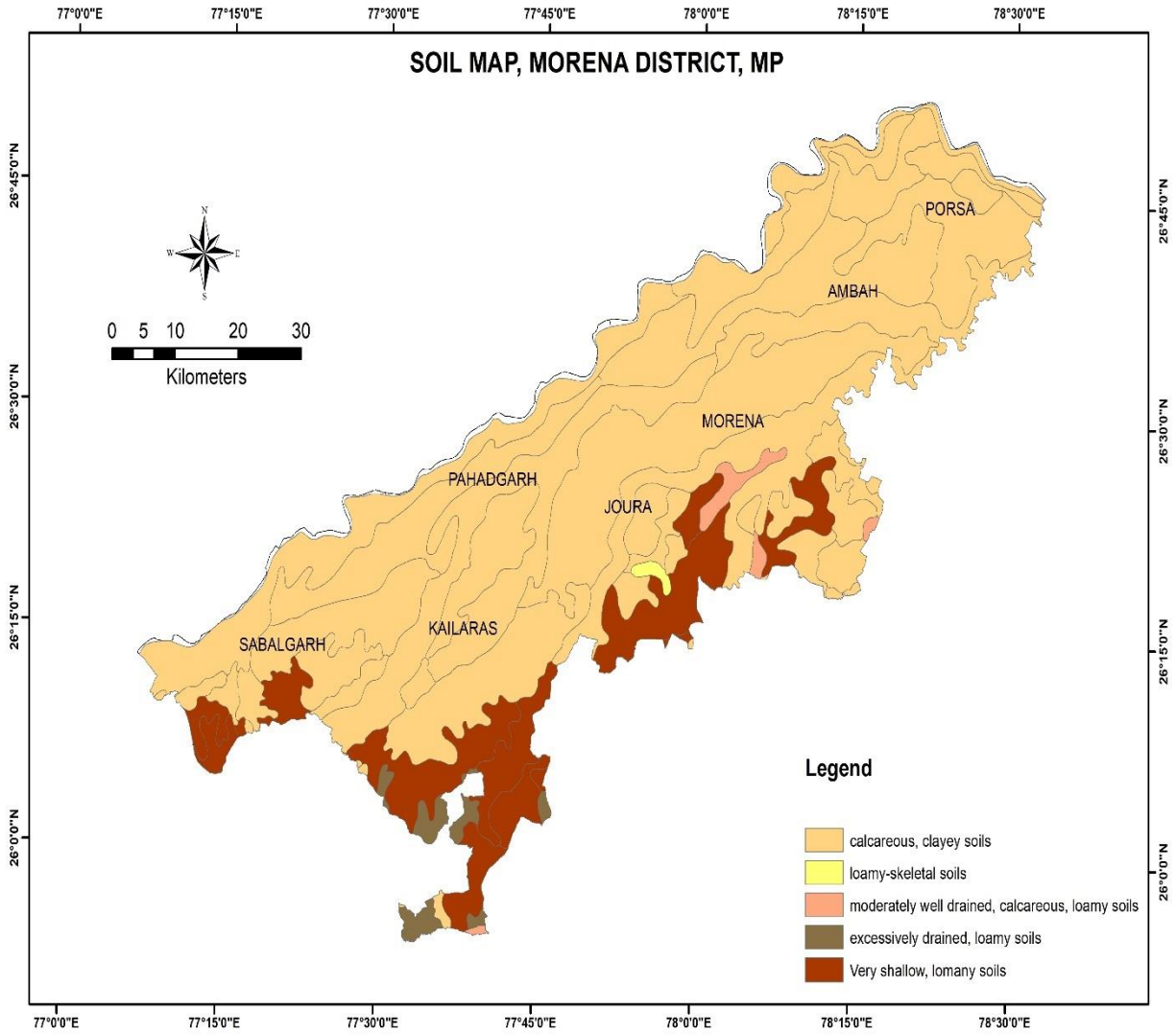
Fig 5: Geomorphology map of Morena district



1.9 SOIL COVER

Laterite forms flat and slightly undulatory capping over the rocks of Vindhyan super group. It occurs at two elevations between altitudes of 425 meters to 530 meters above MSL. It is dark reddish brown and red in colour and mainly consists of Hematite, Goethite, Gibbsite, few opaque and Quartz. Quaternary alluvium consisting of unconsolidated to consolidated yellowish brown sand silt and clay with gravel and pebbles, forms the youngest formation exposed in the area. The thickness of the alluvium varies from a meter to more than 180 m. Main soil of the district is Kanhari. Soil of the district is fertile and suitable for rabi and kharif both crops. The soil map of the Morena district is shown in the Fig 6.

Fig 6: Soil map of Morena District



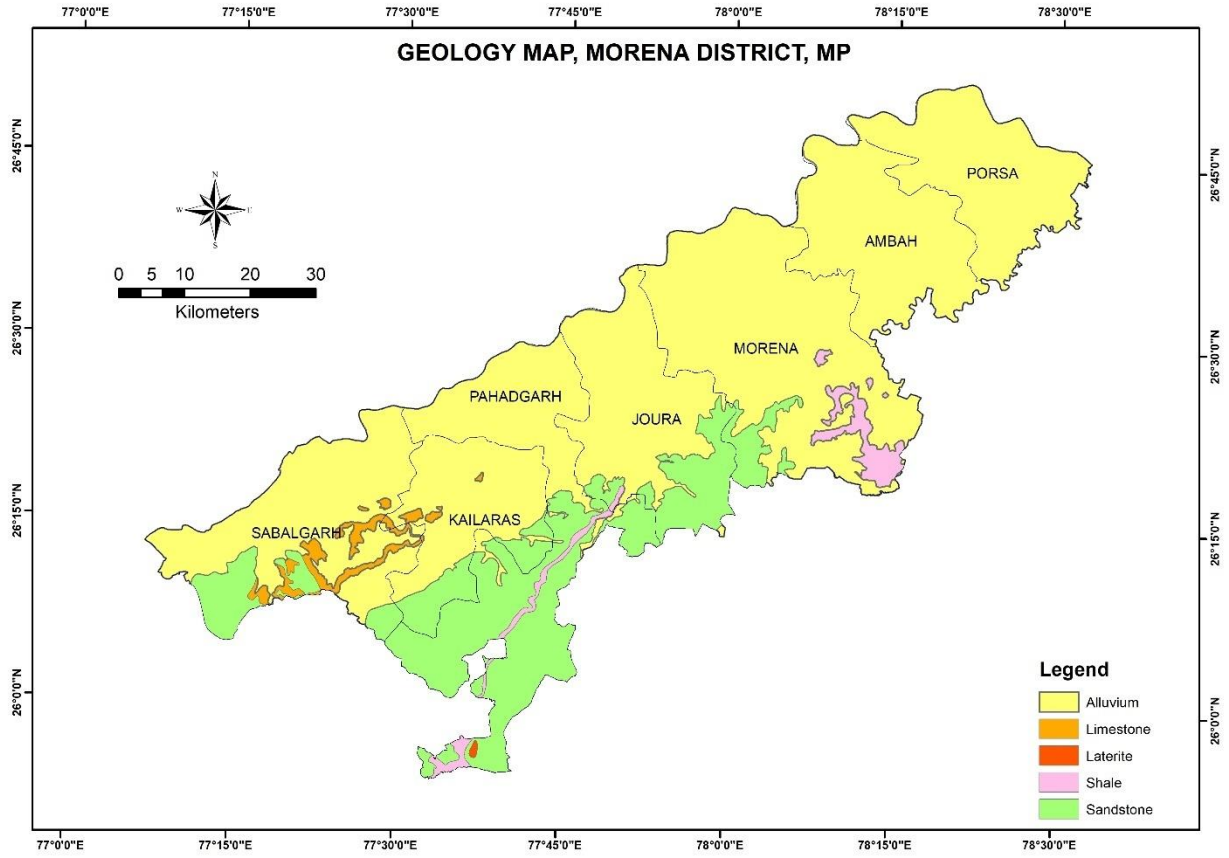
1.10 GEOLOGY

Vindhyan super group of rocks, sand stones and shales, laterite and alluvium are the rock types exposed in the area. The area exhibits good development of sedimentary structures viz., current bedding, ripple marks, rain prints, rib and furrow structures, ball and 3 pillow structures, mud cracks, clay balls, concretions, load and flute structures etc. The general strike of the bedding is North-South to NNE-SSW with varying dips of 4 to 10 degrees towards west and north. The deformational structures of the area are mainly represented by various sets of joints trending NW-SE, NE-SW, E-Wand NNE-SSW with vertical dips. The generalized geological succession is given below in table 4 and the hydrogeological map of district is shown in figure 7.

Table 5: General Geological Succession of Morena District

Age	Formation		Lithology
Recent to Pleistocene	Alluvium		Clay with Kankar Sand and river alluvium
	Laterite		Small capping of lateritic on hills and patches in river valley
Upper Pre-cambrian to Lower Palaeozoic	Vindhyan system	Upper Bhander series	Upper Bhander sandstones Sirbu shales at the base of scarps.
		Lower Bhander series	Lower Bhander sandstone but intercalated bands of shales known as Sanchi shale, Bhander limestone and ganurgarh shale

Fig 7: Geology of Morena district



1.11 DRAINAGE& HYDROLOGY

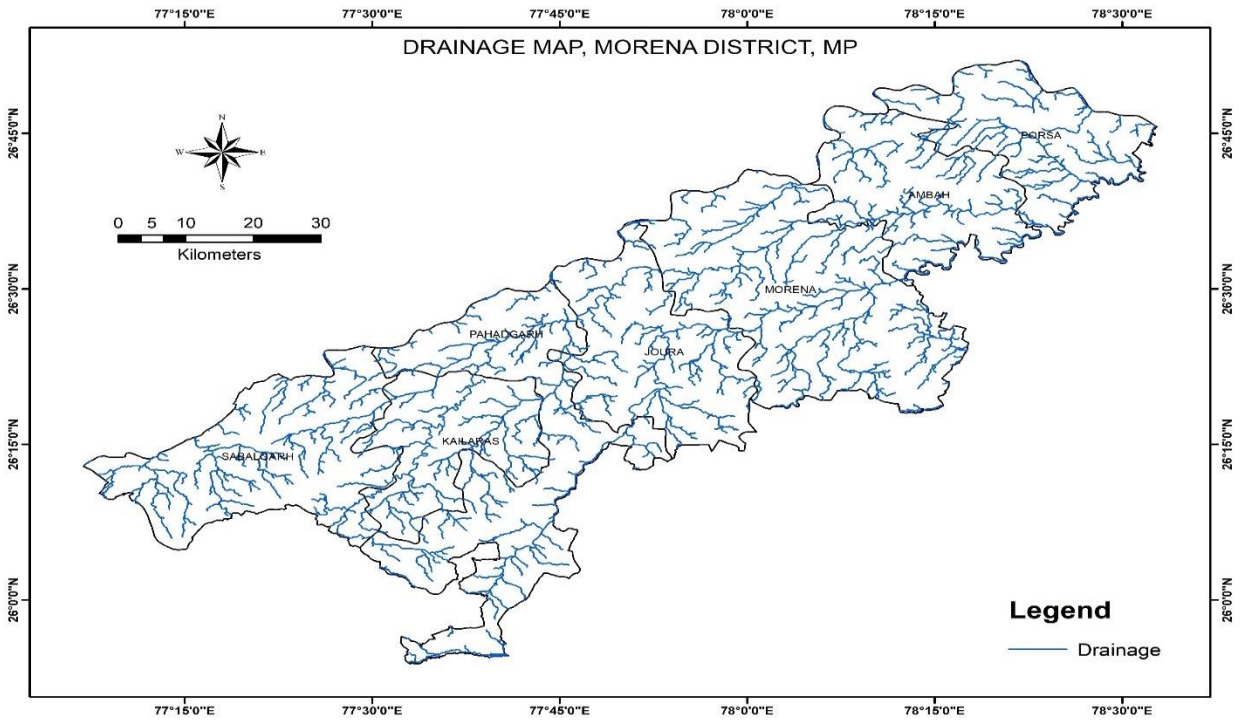
The district falls in drainage area of Ganges system. The whole water of the district drained out through Chambal river which joins the Yamuna. Generally, the flow of the water is towards north-east. Chambal is the main river of the district. Asan and Kunwari are the tributaries of Chambal river.

Chambal river: This river flows from west to north in the district. The Chambal river rises from the Janapao hills (854 meters) in Indore district.It enters Morena district north to Nitanvas and makes the inter-state natural boundary between Madhya Pradesh and Rajasthan and flows ahead. After identification of boundary of Uttar pradesh it joines Yamuna river in Etawa district. The Chambal valley has high banks with deep and widely development ravines by which it is known as Chambal ravines (Chambal Beehad).

Asan river: This river rises from the plateau of Deori in Vijaypur tahsil of Sheopur district. It flows north-easterly course in which there are two dams at Pagara and KutwarThe main tributary is Kunwari which joins at Sangoli village. On the right bank of the district the south or the Sank is the only tributary joining the Asan from the north-eastern course of Kutwar dam

The Kunwari river: The Kunwari river rises from the north-eastern plateau of Deogarh in Shivpuri district and enters Sabalgarh tehsil of Sheopur district. It flows towards north east at the middle part of the district and flows to Joura, Morena and Ambah tahsil and joins Asanriver. The small tributaries like Sole, and Son etc. are flowing in the district.

Fig 8: Drainage map of Morena dist



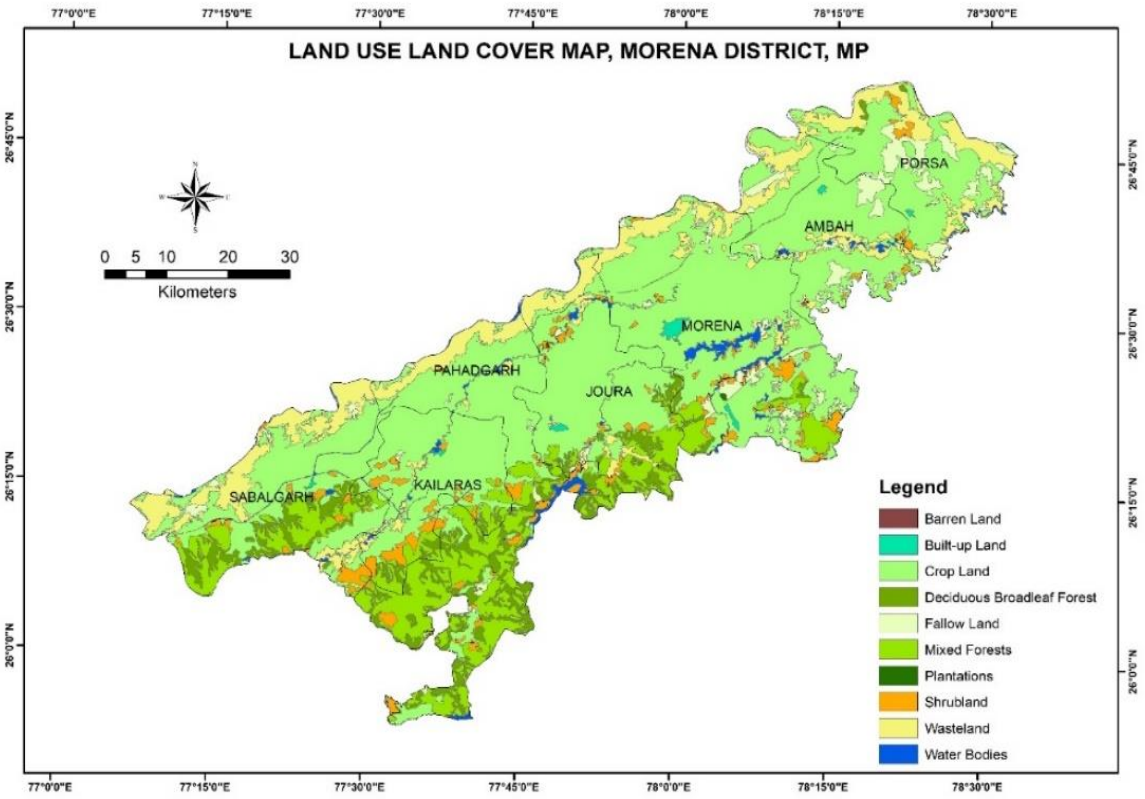
1.11 Land use

Out of total area, 501686 sq km is under cultivable area which is 459590 sq km of the total geographical area of the Morena district. Forest area is 51424, Area under wasteland is 88974 sq km and 41043 sq km is under other uses out of total geographical area. The block-wise land use pattern is given in Table no. 6

Table 6: Land use pattern

Block	Total Geographical Area	Area under agriculture			Area under forest	Area under wasteland	Area under other uses
		Gross cropped area	Net sown area	Cropping intensity			
Porsa	54919	63421	36102	174	0	8069	4974
Ambah	51122	62007	38478	163	393	4102	4178
Morena	106698	113559	68849	122	5987	9992	11313
Joura	66847	68271	38492	176	13304	5169	4714
Kailaras	52115	45670	27499	165	8411	9204	3927
Pahargarh	92495	44291	31554	132	9786	31289	5714
Sabalgarh	77490	62371	30414	201	13543	21149	6223
District	**501686**	**459590**	**271388**	**167**	**51424**	**88974**	**41043**

Fig 9: Land use map of Morena district



Main soil of the district is Kanhari. Total geographical area of the district is 501,686 hectares, out of which forest area 50,669 hectare as reported. The non agricultural land is 130,589 hectares, un-cultivable land is 18,860 hectares and cultivable waste land is 17,561 hectares. Total cropped area of the district is 268,173 hectares. Soil of the district is fertile and suitable for rabi and kharif both crops.

Chapter-2
DATA COLLECTION AND GENERATION

The data collection and compilation for various components was carried out as given below:

- Hydrogeological Data – Current and historical water levels along with water level trend data of monitoring wells representing Aquifer-I (Shallow aquifer) of CGWB. The weathered zone thickness (aquifer-I), lithological details of deeper aquifers (aquifer- II) of exploratory wells were also collected and compiled.

- Hydrochemical Data - Ground water quality data of monitoring wells of CGWB representing shallow aquifer and data from exploratory wells representing deeper aquifer.

- Exploratory Drilling – Ground water exploration data of exploratory wells of CGWB.

- Hydrometeorological Data - Long term rainfall data for the whole district and for each block from Indian meteorological Department and Water Resource Department.

- Cropping Pattern Data – Data on prevailing cropping pattern from District Irrigation Plan, Jhabua district.

- For data generation 63 no's of key wells have been established throughout the district and collected Pre-monsoon water sample.

- Again, for data generation 89 no's of Key observation wells Water level data collected from Water Resource Department.

2.1 DATA AVAILABILITY

- The compiled data were plotted on a 1:50000 scale map, and analysis of the data gap was carried out. The summarized table comprising the data requirement and data availability is represented in the following **Table: 7**
-

- **Table: 7 Various data for NAQUIM Study.**

S. No	Items	Data Requirement	Data Availability
1	Rainfall Data	Meteorologicalstations spread over the project area.	India-Wris
2	Soil	Soil map	Prepared
3	Land Use	Latest Land UsePattern	Prepared from Land Sat 8 Imagery in GIS
4	Geomorphology	Digitized Geomorphological Map	Bhukosh
5	Exploration Data	EW in each Quadrant withAquifer Parameters	24 exploratory wells drilled
6	Aquifer Parameters	Aquifer parameters for all the quadrants	Available
7	Groundwater Level	Decadal water level data	CGWB monitoring wells data

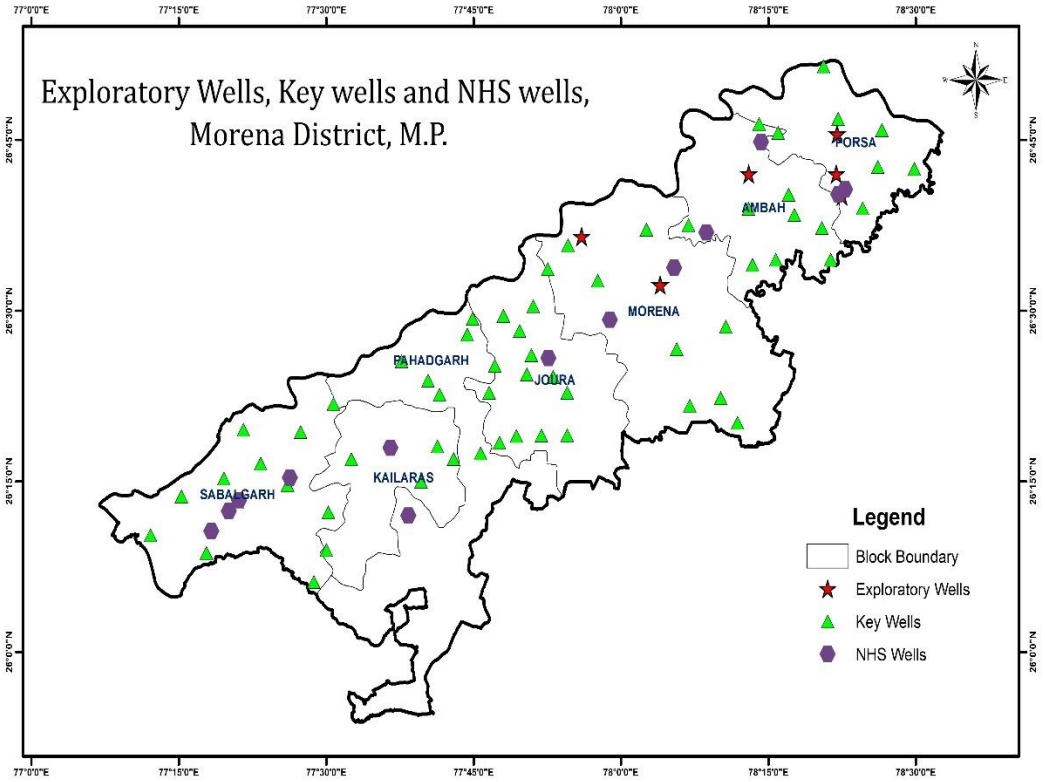
2.2 DATA COLLECTION AND GENERATION

- Data on all the attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis. The data generated and data collected from various state governments agencies are summarized in the following **Table: 8**

- **Table: 8 Data Generated and Data collected for Aquifer Mapping Area.**

S.No	Items	Data Generated	Data Collected
1	GW Regime Monitoring	23 Key observation wells established & 100 Key observation wells of WRD	Pre-monsoon depth to water level
2	Chemical Quality	23 Samples collected during June, 2022 for Basic element analysis	GW Samples submitted for chemical analysis to generate the quality data
3	Exploration	26 Exploratory wells drilled	Lithologs, Aquifer geometry and aquifer parameters measured

Fig 10: NHS, Exploratory and Key wells map of Morena district



2.3 Hydrogeology:

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. Vindhyan super group of rocks, sandstones shales, limestone, laterite and alluvium are the major rock types exposed in the area

Description of rocks and their water bearing properties

Vindhyan System

Sandstones:

The sandstones are hard and compact with siliceous matrix and as such are devoid of primary porosity and permeability. But wherever they are weathered and jointed secondary porosity and permeability is

developed and made them water bearing. It is observed that sandstones in general are poorly and moderately weathered (2 to 4 meters) and at places they are jointed and do not posses sufficient ground water potential. Ground water occurs under water table condition and exists in weathered portions and in jointed zones

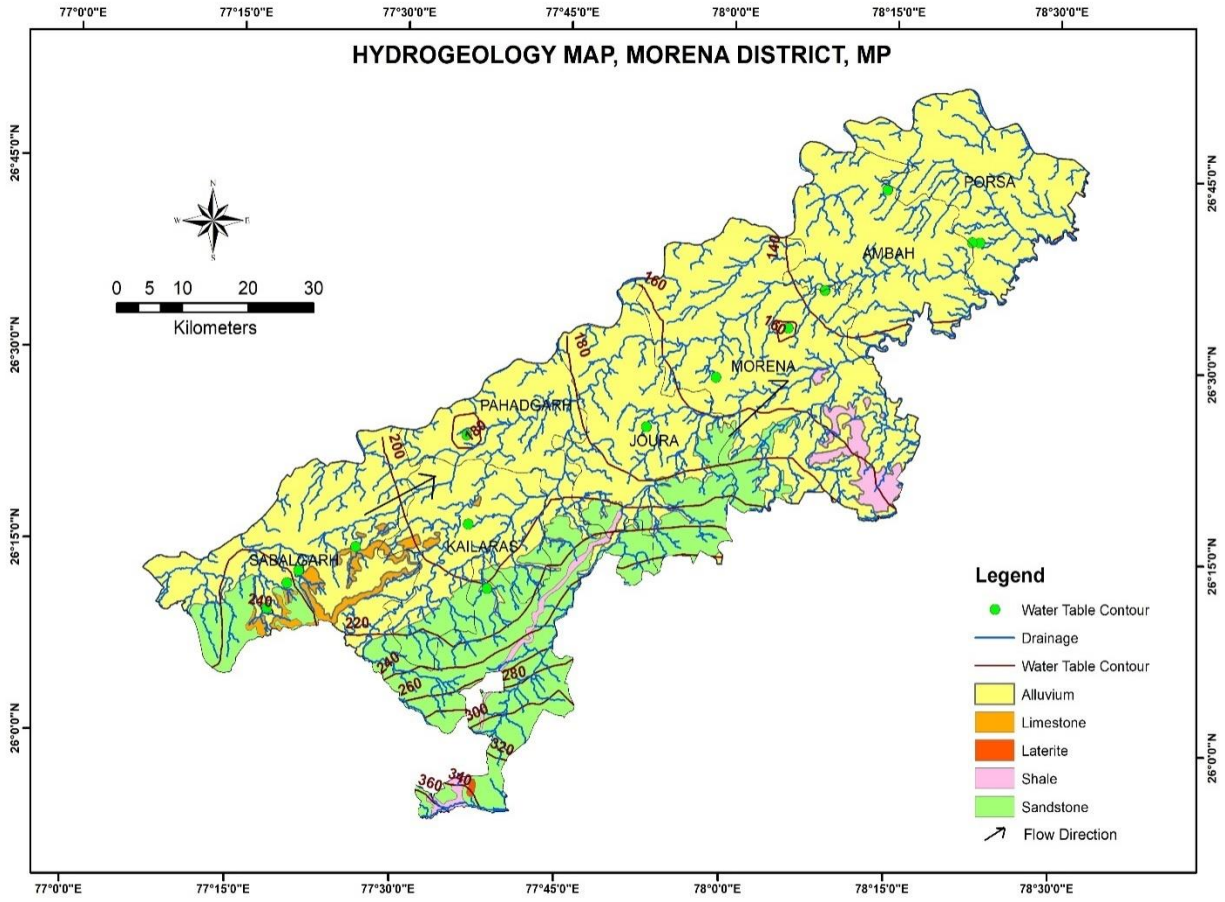
Shale:

The shales are fine grinded and compact and are porous but are not permeable. At most places in most of the area shales are devoid of ground water but near river beds they form water bearing due to the presence of bedding planes and joints. Ground water occurs under water table conditions

Alluvium

The water holding capacity in alluvium mainly depends upon the thickness and the aerial extent. It is found that along the banks of Chambal and Kanwari rivers, gully erosion is very common and spread over 1 to 2 Km away from the banks. It is more clayey and silty and as such has poor to moderate water bearing capacity. One or two aquifers are present in the formation and ground water is found to be under phreatic as well as semi confined to confined conditions.

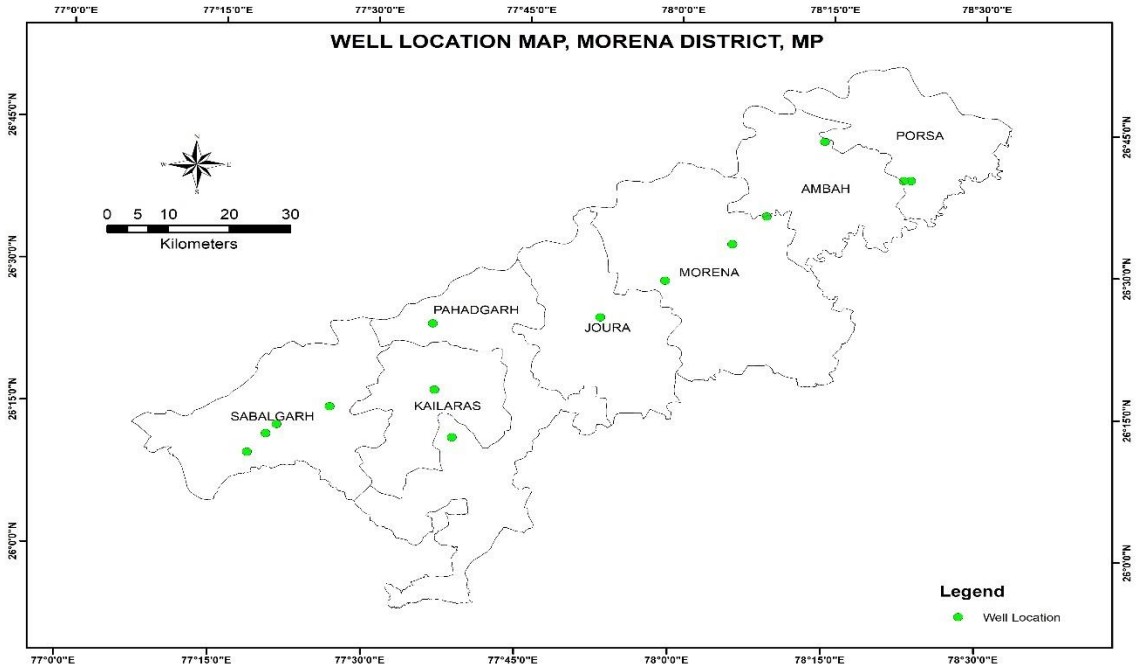
Fig 11: Hydrogeology of Morena district



2.4. Ground water scenario

Water level data, including historical data are essential for not only to know the present ground water conditions but also for forecasting future trends in response to ground water reservoir operations. There are 14 monitoring wells in Morena district (fig 11),16 dug wells established during key wells establishment and 89 monitoring wells of state department are present. Using the water level data of NHS, state monitoring wells and key wells, pre and post monsoon depth to water level maps are prepared.

Fig 12: Monitoring well locations of NHS map

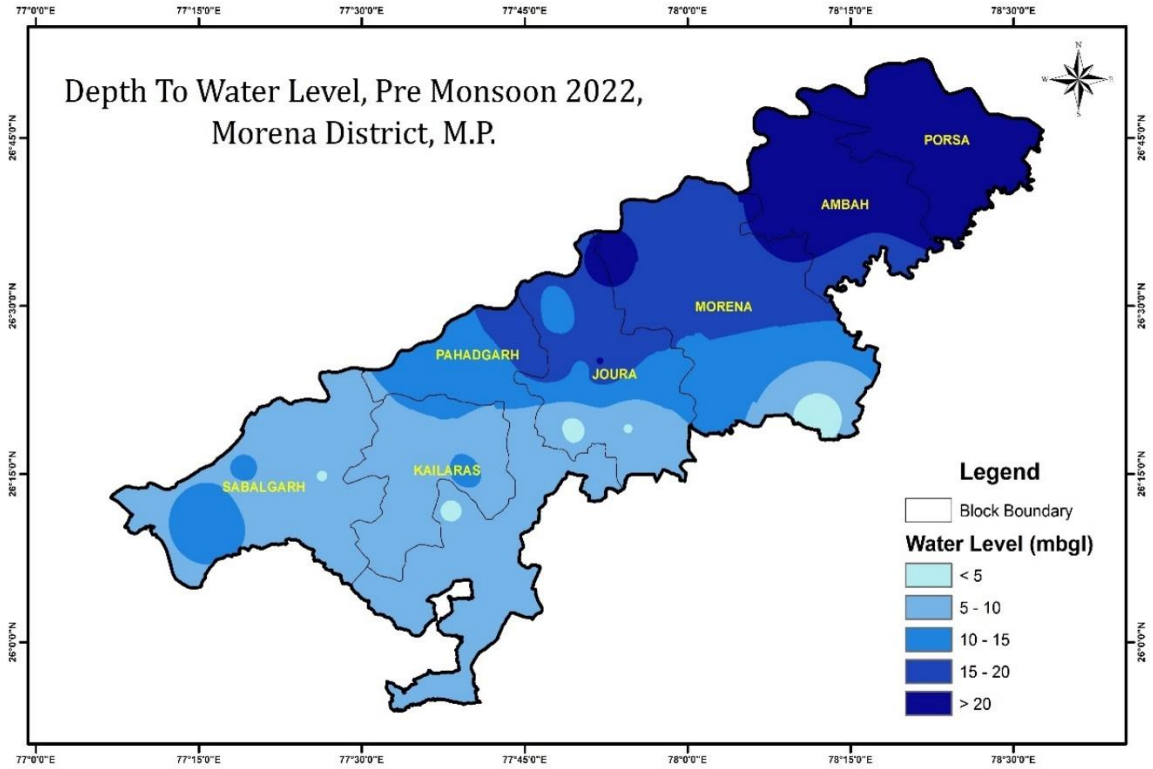


Pre Monsoon (May 2022)

Pre-Monsoon depth to water level in the year 2022 range from 3 to 23.4 mbgl. Shallow water level (<5.00 m) occur in the isolated patches in SE and in some central parts. The pre-monsoon depth to Water levels ranges from a minimum of 3.04 meter below ground level (mbgl) in Joura block to a maximum of 30.2 mbgl in Porsa block of Morena district. Monitoring wells recorded water level in the range of 5-10 mbgl category, spreading in southeastern and western part of area mainly in Kailaras, Sabalgarh and some parts of the Joura blocks. Monitoring wells recorded water level in the depth range of 10 - 15 mbgl occurring in the central part and NE parts extending from Pahargarh, some parts of Joura and Morena blocks. Depth to water levels ranging 15-20 mbgl has been noticed predominantly in northern and northeastern part of the area mainly in Morena and

Joura blocks. Deeper ground water levels ranging greater than 20 m bgl have been observed in the north eastern part of Morena district mainly in Ambah and Porsa blocks and most of the wells in these blocks have been observed dry upto 35.4 m in the field survey.. The pre-monsoon Depth to Water Level map has been shown in the Fig. 13.

Fig 13: Pre-monsoon depth to water level map

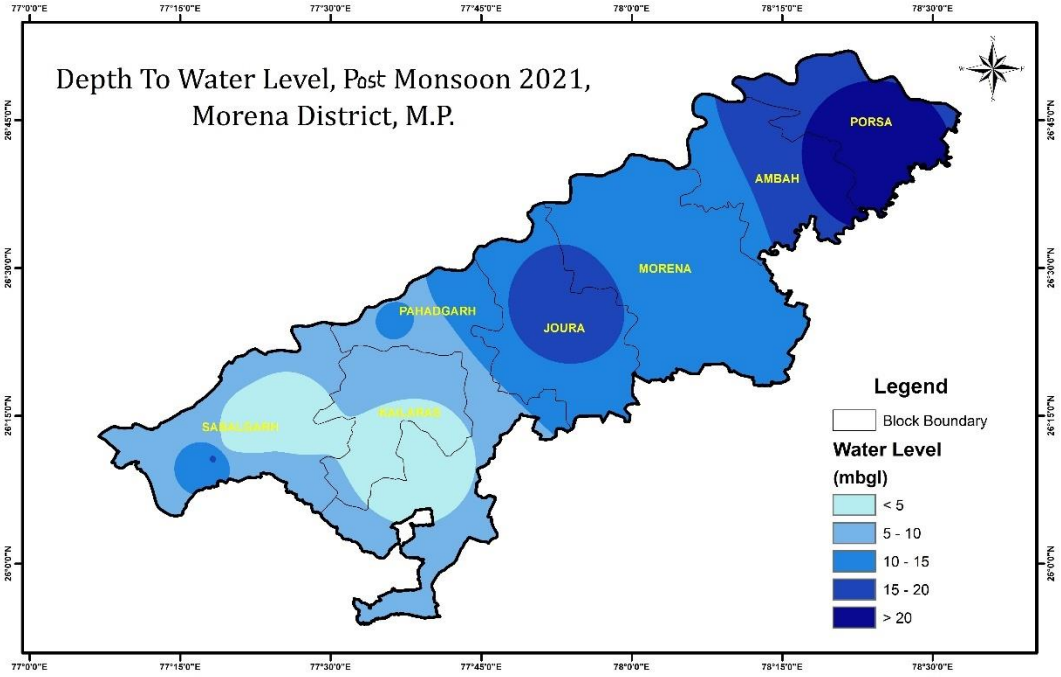


Post Monsoon November 2021.

During post monsoon period, water level ranges from 1.71 to 30.2 mbgl. Shallow Water level (<5mbgl) occurs in isolated patches in the south western (SW) region in Sabalgarh and Kailaras blocks while deep water levels (> 20 mbgl) observed in the NE parts of Morena district in Porsa and Ambah blocks (Fig 9). The post-monsoon depth to Water levels ranges from a minimum of 1.71 m below ground level in Pahargarh block to a maximum of 30.2 m bgl in Porsa block of Morena district. Monitoring wells recorded water level in the range of 5-10 mbgl category, spreading in southeastern and western part of area mainly in Kailaras, Sabalgarh and Pahargarh blocks. Monitoring wells recorded water level in the depth range of 10 - 15 mbgl occurring in the

central part and NE parts in Joura and Morena blocks. Depth to water levels ranging 15-20 mbgl has been noticed predominantly in NE part of the area mainly in Ambah and Porsa blocks and in some isolated patches in Joura block. Deeper ground water levels ranging greater than 20 m bgl have been observed in the north eastern part of Morena district mainly in Porsa block mainly and also some parts in Ambah block. The post-monsoon Depth to Water Level map has been shown in the Fig. 14.

Fig 14: Post-monsoon depth to water level map



2.5 Ground water Exploration:

11 exploration borewells have been drilled in Morena district. On the basis of samples collected during drilling, lithologs have been prepared. The aquifer parameters are calculated on the basis of pumping tests. The salient details of the some of the drilled bore wells is given in Table 9.

Table 9 .Hydrogeological details of CGWB exploratory tubewells.

S.No	Location	Latitude/Longitude	Yearof Construction	Depth Drilled(mbgl)	Depth ofConstructionmbgl)	Major Lithologyencountered	ZonesTapped	Static WaterLevel(mbgl)	Discharge(Lps)	Drawdown(m)	T(m^2/day)	S
1	Porsa-I	26º 42'00" 78º 21'55"	1984-85	107.43		Alluvium	52-69 94-106	18.32	33.70	4.47	2580	$2.8X10^{-5}$
2	Porsa-II	26º 40'05" 78º 22'30"	1984-85	117	114	Alluvium	42.50-75.00	17.98	30.83	4.56	5050	$9.5X10^{-5}$
3	Ambah	26º 42'00" 78º 13'00"	1984-85	122.5		Alluvium	27-30 42-48 50-56 89-80 88-99100-107	16.13	11.80	1.35	1765	$7.47X10^{-4}$
4	Mahua	26º 45'30" 78º 22'00"	1984-85	164.75	168.5	Alluvium	0-163.75 AlluviumV.Sst.At 163.75	23.04	8.38	2.36	825	$2.5X10^{-4}$
5	Jigni	26º 32'15" 78º 04'00"	1984-85	83.78	82	Alluvium	-	13.07	57.20	4.17	5465	$0.16X10^{-3}$
6	Piprai	26º 36'30" 77º 56'00"	1984-85	87	80	Alluvium	-	25.29	16.02	11.28	470	$0.33X10^{-4}$
7	Pahadgarh	-	2001	115.85	-	Sst,shale	101.14-114	-	.5	-	-	-
8	Kanhar	-	2001	160.43	-	-		64-66 124-129	2.5	-	-	-
9	Mara	-	2001	91.46	-	-		7.45-12.02 37.18-36.44	1.0	-	-	-
10	Dhonda	-	-	2001	200	-	Dry	-	-	-	-	-
11	Areti	-	-	2001	171.97	-	-	17-18.5 110-115	1.85	-	-	-

2.6 Hydrochemical scenario of Morena district

The water samples were collected from National Hydrograph Stations in clean double stoppered poly ethylene bottles from 14 different locations of Morena district during May 2020.

Quality of Ground Water for Drinking Purpose:

The ground water samples from Morena district have varied range of pH from 7.25 to 8.08. As per BIS (IS 10500:2012) recommendation, all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, the maximum pH recorded in the water sample of Daboh (8.03). The pH of ground water can be assessed as neutral to slightly alkaline in nature. The electrical conductivity of ground water samples in Morena district varies from 561 to 2324 µS/cm at 25°C.

The electrical conductivity from Morena district shows variability, 9 locations of sample shows EC less than 1500 µS/cm; 4 locations of sample shows EC in between 1500 to 2000 µS/cm; 1 locations of sample shows EC more than 2000 µS/cm from Pahargarh villages i.e. 2324 µS/cm. So, overall ground water quality of Morena district is good to saline in nature in few pockets of the districts.

The fluoride concentration in Morena district lies in between 0.22 to 1.60 mg/l, which represent that all the samples are within the permissible limit i.e. 1.5 mg/l of BIS standard except the village Huseinpur dug well i.e 1.60 mg/l.

The nitrate concentration in the Morena districts ranges in between 5 to 224 mg/l. In the district, 28.6% samples have nitrate concentration more than the acceptable limit i.e. 45 mg/l, while rest 71.4% samples have concentration less than acceptable limit.Highest concentration of nitrate has been recorded in the village of Huseinpur (47 mg/l), Ranipura 951 mg/l), Mangrol (148 mg/l) and Pahargarh (224mg/l).

The total hardness in the ground water of the districts ranges between 190 to 800 mg/l. In the district, 85.7.5% of ground water samples recorded less than BIS permissible limit while 14.3% of ground water samples recorded more than BIS permissible limit i.e. 600 mg/l. The maximum concentration of total hardness has been observed in the village of KheraMewda (605 mg/l) and Mangrol (800 mg/l).

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

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

Quality of Ground Water for Irrigation Purpose:

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

The USSL diagram shows that the districts falls under C_2-S_1 Class (Medium Salinity & Low Sodium); C_3-S_1 Class (High Salinity & Low Sodium); C_3-S_2 Class (High Salinity & Medium Sodium); C_3-S_3 class (High Salinity & High Sodium) and C_4-S_2 class (Very High Salinity & Medium Sodium). Very High Salinity & Medium to High Sodium classes of water may be used for irrigation with proper soil management.

Fig. 15 Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Morena District, Madhya Pradesh

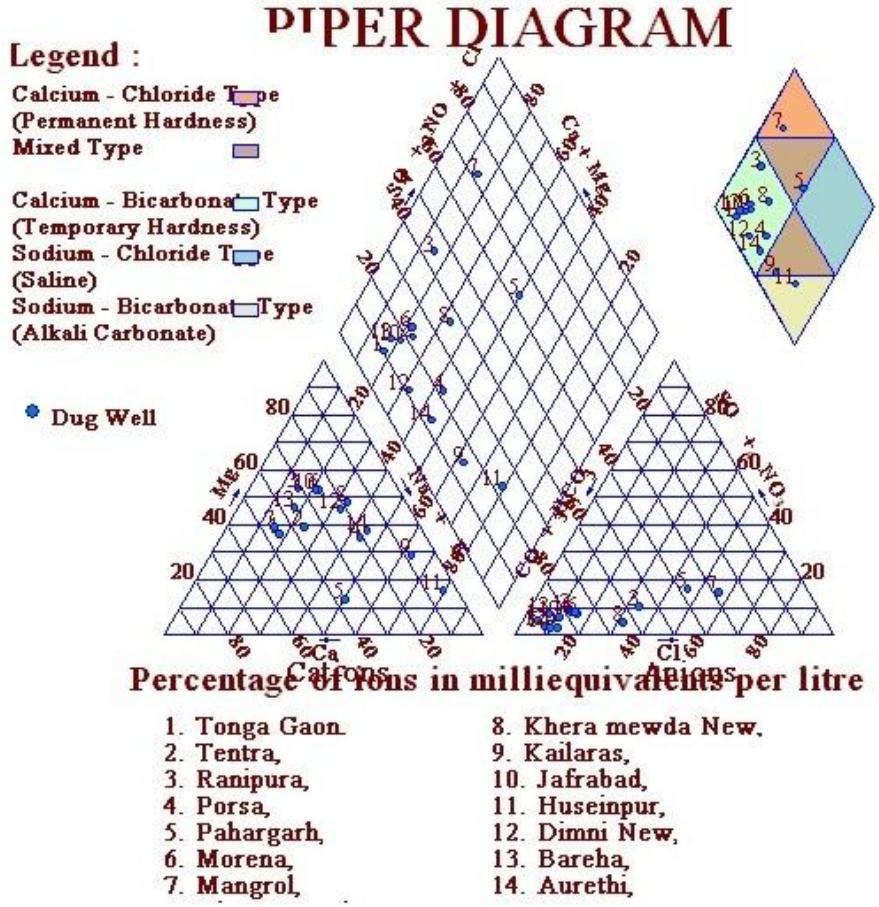
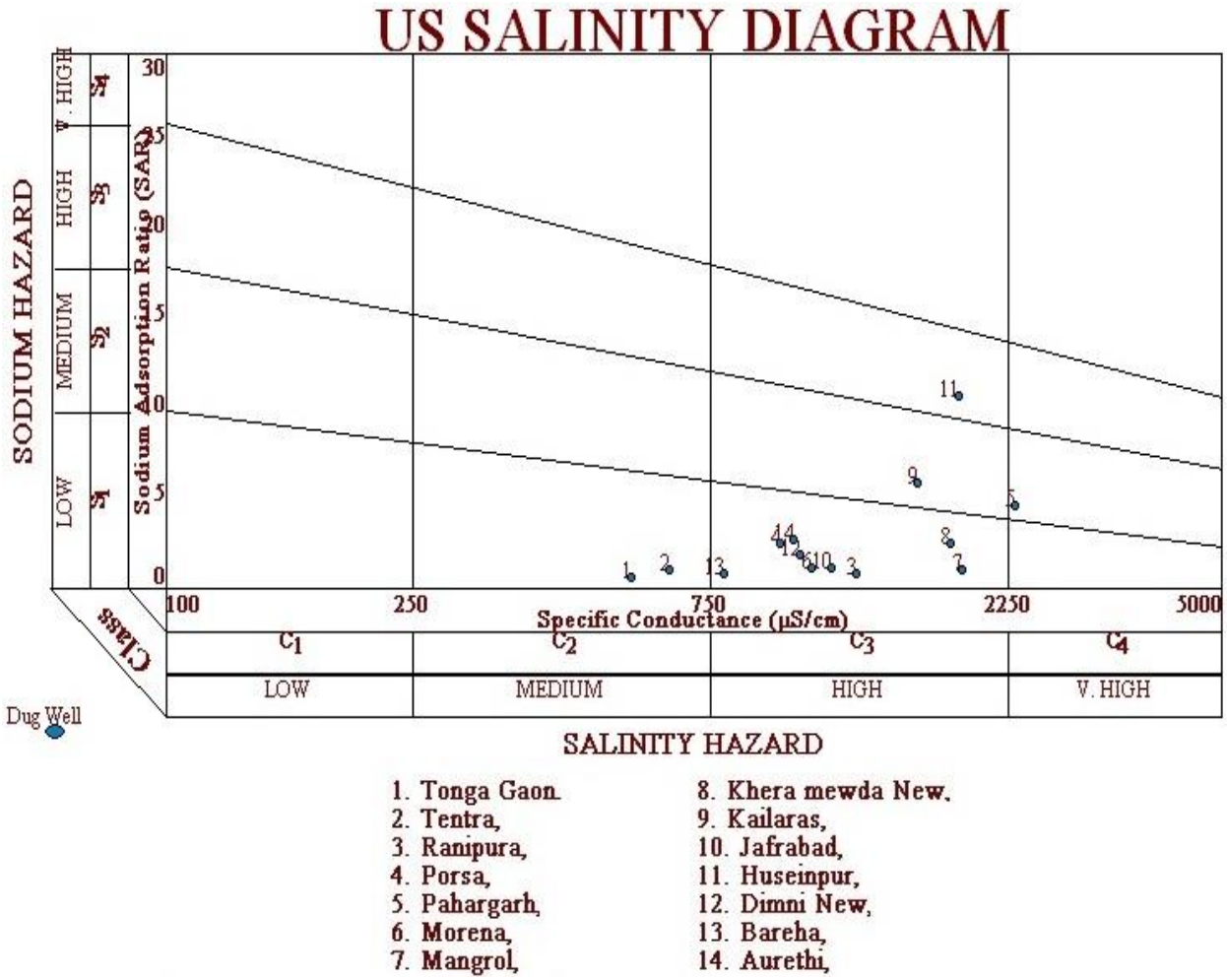


Fig.16 US Salinity Diagram for water samples collected from National Hydrograph Stations of Morena District, Madhya Pradesh



1. Tonga Gaon.
2. Tentra,
3. Ranipura,
4. Porsa,
5. Pahargarh,
6. Morena,
7. Mangrol,
8. Khera mewda New.
9. Kailaras,
10. Jafrabad,
11. Huseinpur,
12. Dimni New,
13. Bareha,
14. Aurethi,

S. No.	District	Block	Location	Lat.	Long.	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
						at 25°C	µS/cm at 25°C	mg/l													
1	Morena	Porsa	Aurethi	26.678	78.380	7.71	1025	0	526	37	8	8	0.27	0.05	22	275	34	46	104	0.4	666
2	Morena	Porsa	Bareha	26.747	78.238	7.51	793	0	399	20	7	30	0.31	0.08	28	320	56	44	32	0.2	515
3	Morena	Porsa	Dimni New	26.615	78.145	7.80	1048	0	539	32	11	6	0.56	0.10	34	345	44	57	78	0.3	681
4	Morena	Joura	Huseinpur	26.405	77.603	8.01	1888	0	805	95	33	47	1.60	0.05	18	190	16	36	340	0.9	1227
5	Morena	Joura	Jafrabad	26.431	77.877	8.05	1181	0	563	47	14	28	0.52	0.08	26	455	60	74	56	0.5	768
6	Morena	Kailaras	Kailaras	26.299	77.609	7.98	1615	0	762	67	19	5	0.56	0.13	38	295	24	57	232	0.3	1050
7	Morena	Morena	KheraMewda	26.563	78.090	7.55	1834	0	654	195	24	19	0.22	0.14	42	605	66	107	139	0.6	1192
8	Morena	Sabalgarh	Mangrol	26.223	77.352	7.25	1908	0	303	367	20	148	0.41	0.09	48	800	172	90	66	0.5	1240
9	Morena	Morena	Morena	26.487	77.981	8.03	1096	0	484	60	9	40	0.55	0.17	37	420	54	69	55	0.4	712
10	Morena	Pahadgarh	Pahargarh	26.200	77.639	8.08	2324	0	508	375	15	224	0.23	0.21	49	575	170	36	256	16.9	1511
11	Morena	Porsa	Porsa	26.671	78.369	7.96	973	0	442	47	17	27	0.30	0.18	29	270	40	41	96	0.6	632
12	Morena	Sabalgarh	Ranipura	26.206	77.335	7.54	1288	0	418	152	23	51	0.62	0.08	22	535	78	83	45	0.3	837
13	Morena	Sabalgarh	Tentra	26.177	77.305	7.75	649	0	297	30	19	11	0.46	0.05	24	240	46	30	35	1.0	422
14	Morena	Kailaras	Tonga Gaon	26.255	77.438	7.69	561	0	278	10	8	7	0.48	0.08	20	225	50	24	22	0.8	365

Chapter- 3
GROUND WATER RESOURCES

3.1 Dynamic Ground water Resources:

Morena district is underlain by vindhyan super group of rocks i.e., sandstones shales, limestone, laterite and alluvium are the major rock types exposed in the area. Dynamic ground water resources of the district have been estimated on block-wise basis Out of 4,98,889 ha of geographical area, 4,38,489 ha (88%) is ground water recharge worthy area and 60,400 ha (12%) is hilly area.

There are seven number of assessment units (block) in the district which fall under command 224789 (45.65%) and non-command 213700 (42.83%) sub units. All blocks of the district are under safe category. The highest stage of ground water development is computed as 59.93% in Ambah block.

The net ground water availability in the district 37719.42 ham and ground water draft for all uses is 25400.69 ham, making stage of ground water development 39.82% as a whole for district. After making allocation for future domestic and industrial supply for year 2025, balance available ground water for future irrigation would be 6348.42 ham.

Table 10: Dynamic Ground Water Resources (as on March 2020)

Assessment Unit / District	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Industrial Water Supply in Ham	Existing Gross Ground Water Draft for Domestic Water Supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham (4+5+6))	Annual GW Allocation for Domestic Use as on 2025 in Ham	Net Ground Water Availability for Future Irrigation Development in Ham (3-4-5-8)	Stage of Ground Water Extraction in % {(7/3)*100}	Category
1	4	5	6	7	8	9	10	
AMBAH	3271.32	0	700.41237	3971.73	773.6	2582.47	59.93	Safe
PORSA	2061.236	0	614.90382	2676.17	673.14	2865.37	48.68	Safe
SABALGARH	3632.6016	0	618.09903	4250.7	697.3	7568.68	35.72	Safe
KAILARAS	2285.26	0	560.56773	2845.82	645.06	4585.54	37.86	Safe
JOURA	2602.4976	0	707.88903	3310.38	762.38	5240.3	38.47	Safe
MORENA	3611.2608	0	1960.79241	5572.06	2349.05	11068.73	32.72	Safe
PAHADGARH	2355.0912	0	418.73895	2773.83	447.89	3808.33	41.96	Safe
DISTRICT TOTAL	19819.3	0	5581.4	25400.69	6348.42	37719.42	39.82	

3.2 GROUND WATER RELATED ISSUES

A) Declining of ground water level

The long-term water level trend analysis indicates decreasing water level. Out of 14 Hydrograph Stations, 11 stations are showing declining trend both during pre and post monsoon season (Fig. 16).

B) Stage of Ground Water Extraction

Ground Water Resource Estimation reveals that the stage of ground water extraction is deteriorating gradually since 2011 upto 2017 and then it is increasing from 2017 upto 2020.

Over all stage of ground water development of the district is computed as 39.83% in 2020 which has been increased from 35.56 % as per GWRE 2017 which has decreased from 39.12% in 2013 and 41 %in 2011.

Fig 16: Hydrographs showing declining water level trend during pre and post-monsoon at sites Huseinpur, Kailaras, Sabalgarh& declining water level trend in post monsoon at Bareha, District Morena, Madhya Pradesh

Fig 16 (a): Bareha village, BlockPorsa

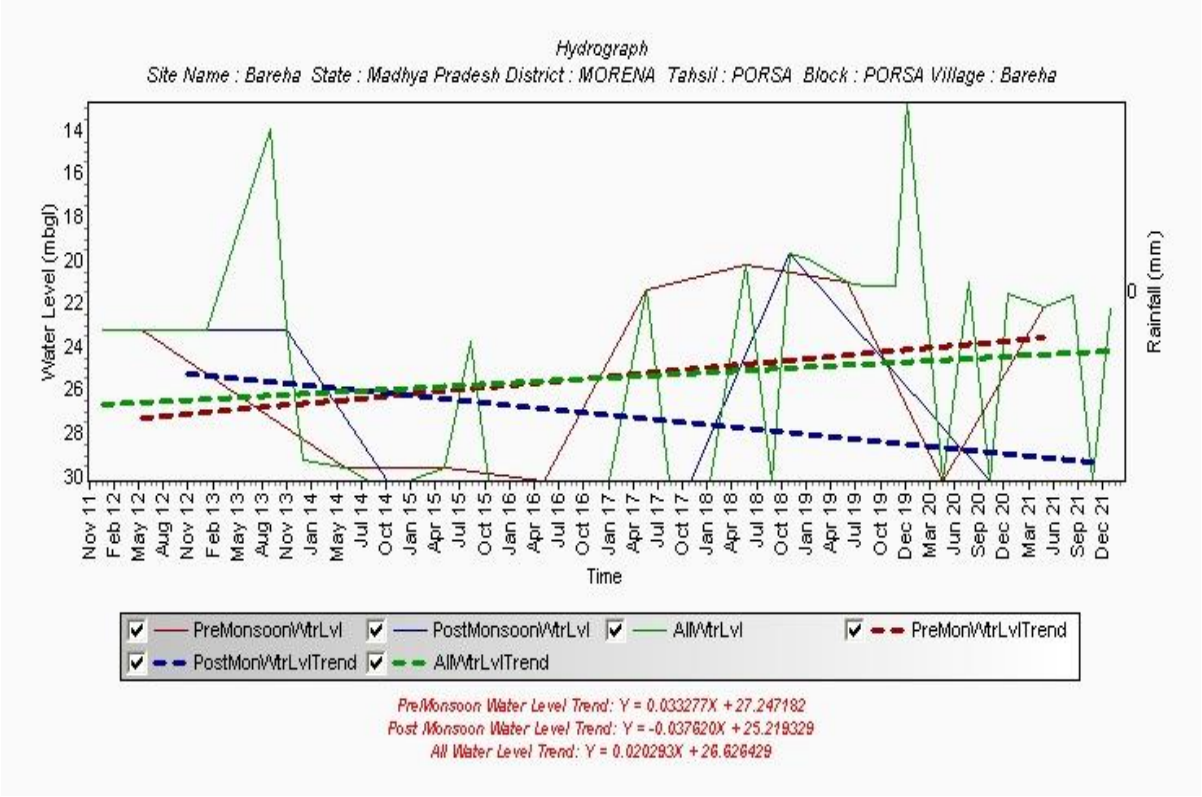


Fig 16(b): Huseinpur village, Block joura

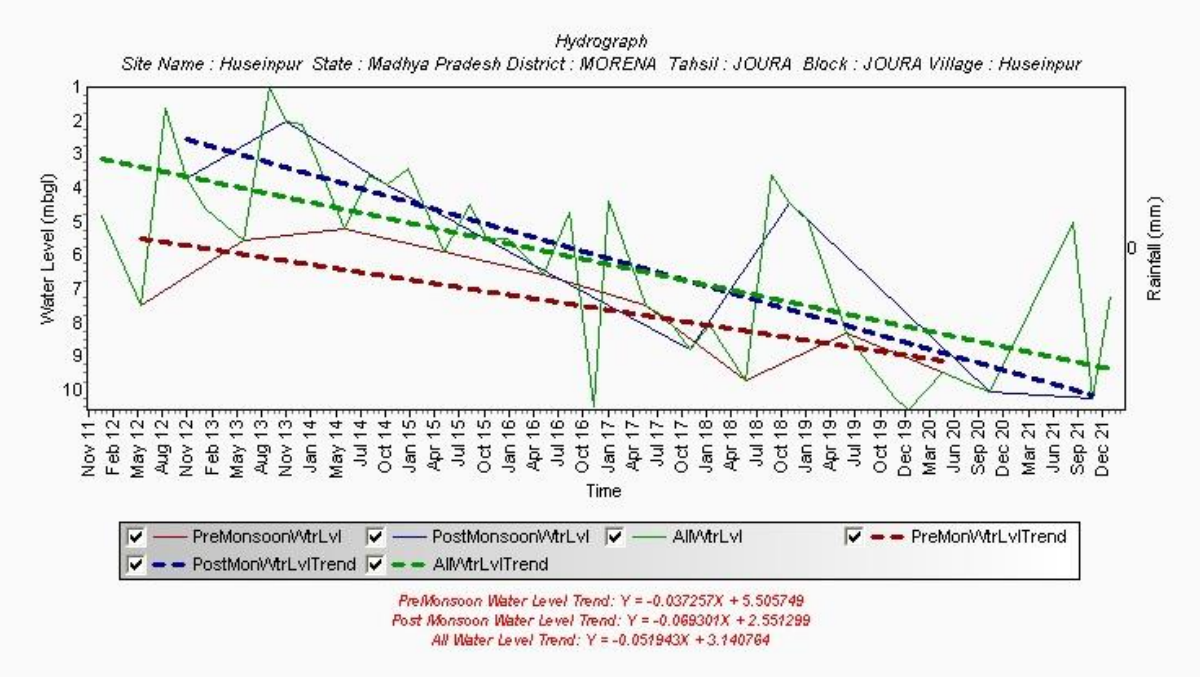
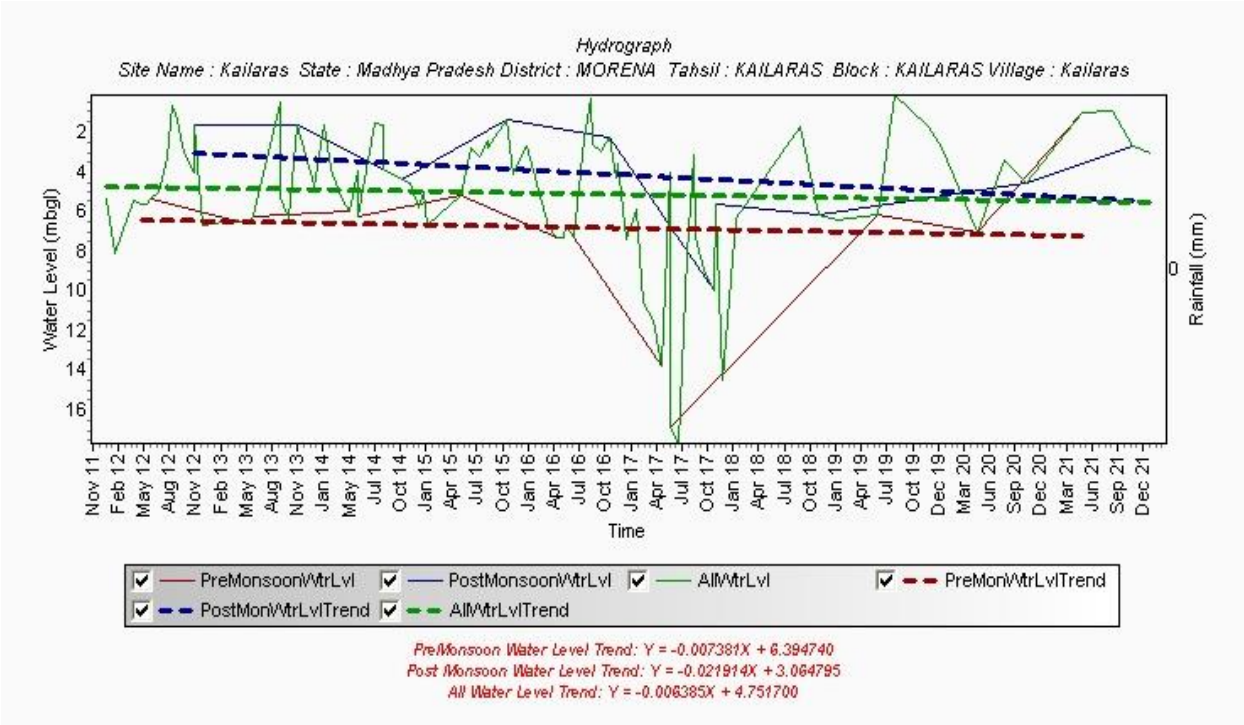
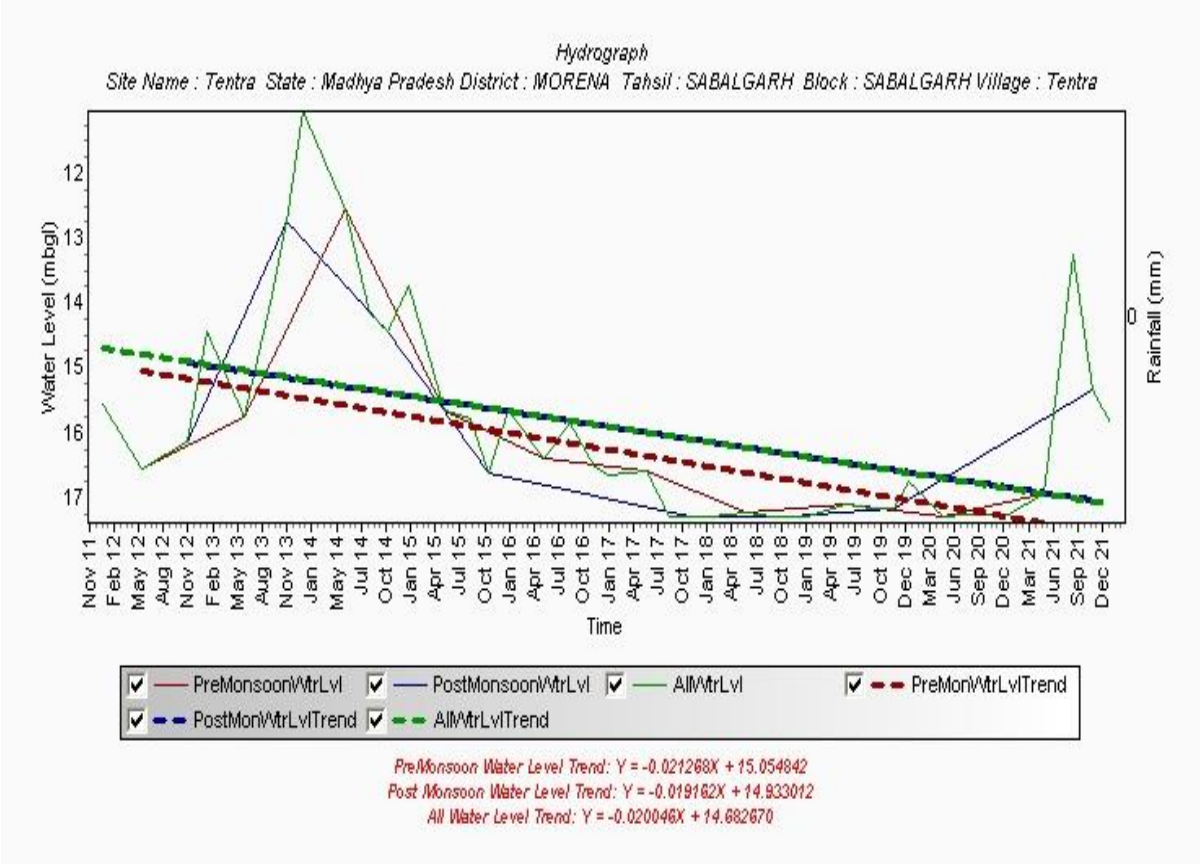


Fig 16 (c): Kailaras (Shallow), Block Kailaras





C) Ground water quality

The nitrate concentration in the Morena districts ranges in between 5 to 224 mg/l. In the district, 28.6% samples have nitrate concentration more than the acceptable limit i.e. 45 mg/l.Highest concentration of nitrate has been recorded in the village of Huseinpur (47 mg/l), Ranipura 951 mg/l), Mangrol (148 mg/l) and Pahargarh (224mg/l).

The total hardness in the ground water of the districts ranges between 190 to 800 mg/l. In the district, 85.7.5% of ground water samples recorded less than BIS permissible limit while 14.3% of ground water samples recorded more than BIS permissible limit i.e. 600 mg/l. The maximum concentration of total hardness has been observed in the village of KheraMewda (605 mg/l) and Mangrol (800 mg/l).

3.4 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 are 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.

A) District Ground Water Management Plan

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

B) Supply Side Management

Artificial recharge to ground water is one of the most efficient, scientifically proven and cost effective technology to mitigate the problems of over exploitation of ground water resources. The artificial recharge techniques simultaneously rejuvenates the depleted ground water storage, reduces the ground water quality problems and also improves the sustainability of wells in the affected areas.

The supply side management plan for Morena 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 surface water required 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 Morena district to calculate the total surface water runoff, 30% of which accounts for 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%, 45% and 15% of non-committed runoff to Percolation tanks, Recharge shafts and Nala bunds/Cement Plugs respectively.

C) 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.

1. It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.

2. It saves costs of hired labour and other inputs like fertilizer.

3. 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.

Summary

- Morena district occupies an area of 4988.89 sq km out of which the ground water recharge worthy area is 4384.89 sq. km. and the rest is covered by hilly and forest area. The major river draining the area includes the river chambal & its tributaries.

- The major part of the district is covered by Deccan traps and and remaining areas are covered by alluvium and Vindhyan formations.

- Morena district comprises of seven blocks, namely Ambah, Porsa, Morena, Kailaras, Pahargarh, Sabalgarh and Joura.

- The phreatic aquifer is recharged during monsoon and sustains for 3 to 4 months.

- All the blocks (Ambah, Porsa, Morena, Joura, Kailaras, Pahargarh and Sabalgarh) are categorized as Safe. But safe category does not mean that the blocks have plenty of water it says amount of extraction of water is less because there is less no of tubewells.

- The management plan to be proposed to manage the ground water resources and to arrest further decline in water levels which comprises two components namely supply-side management and demand side management.

- As a part of Supply side Management, implementation of recharge & conservation structures as Check dam, Percolation tank, Nala bund etc. can be proposed to overcome the groundwater availability related issues.

- As a part of Demand side Management, micro-irrigation techniques can be adopted in water intense cropping like rice & wheat areas. Change in cropping patterns is not proposed in any of the blocks.

- The ground water development plan to be proposed for the safe blocks as Joura, Morena, Pahargarh, Sabalgarh,Kailaras and Porsa with less SGWE in view of the developing additional ground water resources available after supply side interventions to bring the stage of ground water development up to 60% but not beyond that. In order to do so, number of borewells & Dug wells can be constructed to use the available resources.

- IEC activities and capacity building activities needs to be aggressively propagated to establish the institutional framework for participatory ground water management. These types of programmes have helped the general public to understand the problems, that they will face in future if the ground water is continued to be exploited in unplanned way.

- These interventions also need to be supported by regulations for deeper aquifer and hence it is recommended to regulate/ban deeper tube wells/bore wells of more than 60 m depth in these blocks, so that the deeper ground water resources are protected for future generation and also serve as ground water sanctuary in times of distress/drought.

ANNEXURE-I

TABLE-1 DETAILS OF KEY WELLS ESTABLISHED DURING 2022 JUNE 2022 IN MORENA DISTRICT

Sl.no	District	Block	Location name	Latitude	Longitude
1	Morena	Ambah	Khadiyahar	26.5656	78.21398
2	Morena	Ambah	Mai	26.57945	78.28817
3	Morena	Ambah	Purawas Kala	26.61318	78.26554
4	Morena	Morena	Labhanpura	26.44776	78.06644
5	Morena	Ambah	Lahar	26.62585	78.11284
6	Morena	Ambah	Johan	26.68936	78.13766
7	Morena	Ambah	Kisroli	26.74632	78.12897
8	Morena	Ambah	Pancholi	26.60604	78.18399
9	Morena	Ambah	Kamtari	26.64126	78.21133
10	Morena	Ambah	Thara	26.69945	78.28587
11	Morena	Ambah	Bidosa	26.57392	78.3541
12	Morena	Ambah	Kothar Kalan	26.6222	78.37563
13	Morena	Joura	Maina basai	26.35727	77.94947
14	Morena	Joura	Loha basai	26.31699	77.90913
15	Morena	Joura	Badona	26.3821	77.88606
16	Morena	Joura	Umedgarh bansi	26.46622	77.8888
17	Morena	Joura	Bagchinni	26.47449	77.82063
18	Morena	Joura	Guda chambal	26.52951	77.82449
19	Morena	Joura	Khandoli	26.55368	77.88063
20	Morena	Joura	Khandoli	26.56099	77.87565
21	Morena	Joura	Khaintri	26.5982	77.9068
22	Morena	Joura	Pahawali	26.46332	77.95741
23	Morena	Joura	Chandpura	26.31192	77.88535
24	Morena	Joura	Buravalli	26.32104	77.80486
25	Morena	Joura	Galetha	26.50672	77.85432
26	Morena	Joura	Nidhan	26.37064	77.80123
27	Morena	Joura	Nidhan	26.37169	77.7981
28	Morena	Kailaras	Madhovpur	26.31035	77.70334
29	Morena	Kailaras	Budha Sitara	26.25843	77.67964
30	Morena	Kailaras	Golpura	26.28702	77.54299
31	Morena	Kailaras	Nagawani	26.2108	77.52945
32	Morena	Kailaras	Dongravalli	26.15339	77.51132
33	Morena	Morena	Phoolpur	26.36009	78.11043
34	Morena	Morena	Bijayapura	26.37996	78.08417
35	Morena	Morena	Dhanela	26.40119	78.04625
36	Morena	Morena	Nayakpura	26.62609	77.95086
37	Morena	Morena	Gospur	26.62294	78.04629

38	Morena	Morena	Ganjrampur	26.52565	78.03705
39	Morena	Morena	Anjaudha	26.53594	78.12694
40	Morena	Morena	Madan basai	26.463	78.11686
41	Morena	Morena	Bichola	26.4637	78.12192
42	Morena	Morena	Bamroli	26.47964	78.19407
43	Morena	Morena	Arduani	26.46047	78.19103
44	Morena	Morena	Rithaura kalan	26.39506	78.25335
45	Morena	Morena	Bhatpura dang	26.37119	78.20443
46	Morena	Morena	Malkhan pura	26.42321	78.11836
47	Morena	Morena	Bani	26.42321	78.11836
48	Morena	Morena	Bani	26.42907	78.11674
49	Morena	Morena	Palpura	26.58176	78.0398
50	Morena	Morena	Hingona Khurd	26.53875	77.9511
51	Morena	Pahargarh	Chechedi	26.38249	77.66606
52	Morena	Pahargarh	Sherpur	26.37721	77.69201
53	Morena	Pahargarh	Kunwarpur	26.28587	77.78637
54	Morena	Pahargarh	Bichpura	26.29441	77.85973
55	Morena	Pahargarh	Bampura	26.22643	77.74091
56	Morena	Pahargarh	Tejpur	26.46263	77.70426
57	Morena	Pahargarh	Tejpur	26.46817	77.70376
58	Morena	Pahargarh	Baidpura	26.38676	77.53062
59	Morena	Pahargarh	Mara	26.1048	77.65599
60	Morena	Porsa	Barwai	26.77333	78.23444
61	Morena	Porsa	Adhannpura	26.74696	78.27264
62	Morena	Porsa	Rithaura Marjadgarh	26.78611	78.2923
63	Morena	Porsa	Useth Purani	26.85819	78.34369
64	Morena	Porsa	Mahua	26.78108	78.36806
65	Morena	Porsa	Tarani	26.62712	78.32573
66	Morena	Porsa	Garhi Porsa	26.65377	78.41976
67	Morena	Porsa	Dondari	26.72161	78.46546
68	Morena	Porsa	Bhadawali	26.73037	78.50944
69	Morena	Porsa	Kuraitha	26.75585	78.45226
70	Morena	Sabalgarh	Gaji kheda	26.31584	77.35068
71	Morena	Sabalgarh	Banwara	26.30879	77.35431
72	Morena	Sabalgarh	Jugthipura	26.20213	77.45201
73	Morena	Sabalgarh	Rampura Kalan	26.16684	77.46343
74	Morena	Sabalgarh	Kishorgarh	26.32665	77.44836
75	Morena	Sabalgarh	Gondoli	26.22893	77.25394
76	Morena	Sabalgarh	Kaimara Kalan	26.1944	77.19019
77	Morena	Sabalgarh	Banwara	26.33129	77.3501
78	Morena	Sabalgarh	Jawahargarh	26.15038	77.29371
79	Morena	Sabalgarh	Gulali	26.21192	77.35559

ANNEXURE-II

Table-2 Details of Exploratory Wells Drilled in Morena District

S.No	Location	Latitude	Longitude	Depth drilled in mbgl
1	Porsa-I	26º 42'00"	78º 21'55"	107.43
2	Porsa-II	26º 40'05"	78º 22'30"	117
3	Ambah	26º 42'00"	78º 13'00"	122.5
4	Mahua	26º 45'30"	78º 22'00"	164.75
5	Jigni	26º 32'15"	78º 04'00"	83.78
6	Piprai	26º 36'30"	77º 56'00"	87

ANNEXURE-III

Table-3 Locations of NHS Wells in Morena District

Sl no	DISTRICT	BLOCK	VILLAGE	LATITUDE	LONGITUDE
1	MORENA	JOURA	Jafrabad	26°25'50" N	77°52'36" E
2	MORENA	KAILARAS	Kailaras	26°17'57" N	77°36'31" E
3	MORENA	KAILARAS	Tonga Gaon	26°15'19" N	77°26'17" E
4	MORENA	MORENA	Khera Mewda New	26°33'46" N	78°5'24" E
5	MORENA	MORENA	Morena	26°29'13" N	77°58'52" E
6	MORENA	PAHADGARH	Pahargarh	26°12'0" N	77°38'21" E
7	MORENA	PORSA	Aurethi	26°40'40" N	78°22'49" E
8	MORENA	PORSA	Bareha	26°44'50" N	78°14'15" E
9	MORENA	PORSA	Dimni New	26°36'53" N	78°8'41" E
10	MORENA	PORSA	Porsa	26°40'14" N	78°22'7" E
11	MORENA	SABALGARH	Mangrol	26°13'21" N	77°21'7" E
12	MORENA	SABALGARH	Ranipura	26°12'23" N	77°20'5" E
13	MORENA	SABALGARH	Tentra	26°10'38" N	77°18'18" E