केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Mandla District
Madhya Pradesh

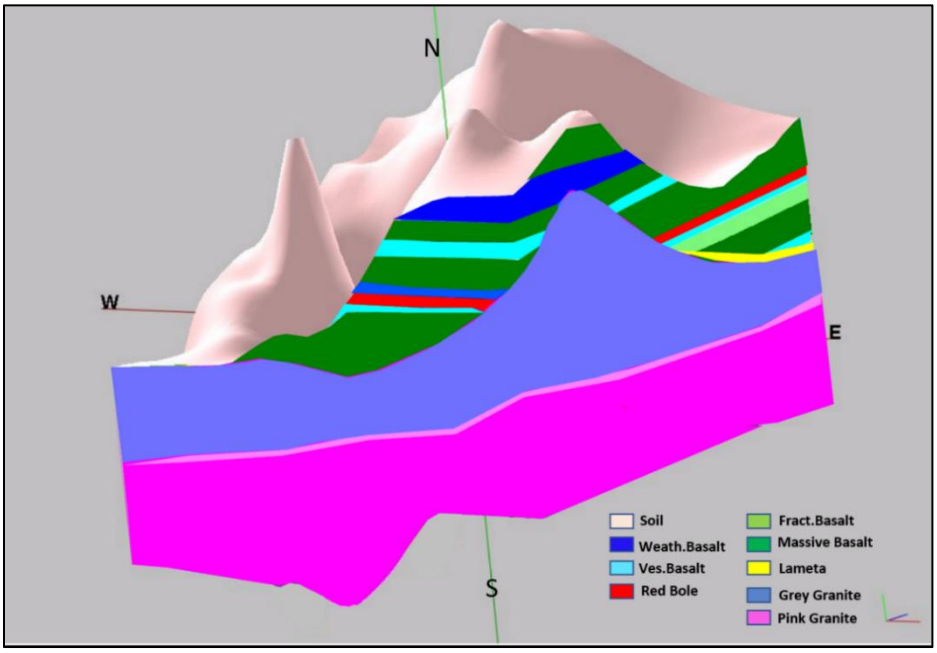
उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

Central Ground Water Board

Department of Water Resources, River Development & Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

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



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BHOPAL
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PREFACE

National Project on Aquifer Mapping (NAQUIM) is intended in knowing, understanding and managing the aquifers for sustainable development of groundwater which is the most important part for ensuring water security in India. The study involves a scientific process, where in a combination of geological, geophysical, hydrological and chemical analyses are applied to characterize the quantity, quality and sustainability of groundwater in aquifers. The result of these studies will contribute significantly to the resource management tools such as long term aquifer monitoring networks, conceptual and quantitative regional groundwater flow models which can be used by planners, policy makers and other stakeholders for sustainable development of groundwater.

Under the National Project on Aquifer Mapping (NAQUIM), Central Ground Water Board (CGWB), North Central Region, Bhopal has taken up Mandla district to prepare the aquifer maps of entire district in 1:50000 scale and formulate the block wise aquifer management plan. Geographical area of Mandla district is 7544 sq.km out of which recharge worthy area is 5740 sq.km. The district is mainly occupied by Deccan Trap Basalt, Gondwana Group of rocks, rock formations of Vindhyan Super Group and Archaean Granites in some portions. As per the Dynamic Ground Water Resources Assessment Report (2020), the annual Extractable Groundwater Resources in the district is 592.44 mcm and the total groundwater extraction for all uses is 93.45 mcm, resulting the stage of groundwater extraction 15.76%. Demand side management measures for sustainable development of groundwater is proposed in the district would enhance the agricultural productivity and economy of the district.

I would like to place on record, my appreciation of the efforts of **Mrs. Anakha Ajai, Scientist-B** for preparing the aquifer maps and management plan of Mandla district and compiling this report. I would also thank Mrs. Rose Anita Kujur, Scientist –E for taking painstaking efforts in scrutinizing the report. I sincerely hope that this report will serve as a valuable guide for sustainable development of groundwater in Mandla district, Madhya Pradesh.

Rana Chatterjee
(Regional Director)

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CHAPTER 1

INTRODUCTION

1.1 Introduction

National project on Aquifer Mapping (NAQUIM) is a programme being carried out by Central Ground Water Board for mapping and documentation of aquifers, their characteristics, inter relations and controls all over India in a 1:50,000 scale. In simple words, NAQUIM involves the detailed hydrogeological investigation of an area with more priority given to the planning for development and sustainability of aquifer. OCS blocks and other groundwater stressed areas are prioritised in NAQUIM studies. It is comprehensive approach on aquifer mapping comprising geomorphological, geological, hydrological and hydro chemical investigation of aquifer systems.

1.2 Purpose and Scope of study

The activities under NAQUIM are aimed at various aspects including identification of the aquifer geometry, aquifer characteristics and their yield potential, analysing and inferring chemical quality of water occurring at various depths, aquifer wise assessment of ground water resources, preparation of aquifer maps and formulating ground water management plan.
Mandla district being spread over an area of 7544 sq.km have been entirely covered during the Annual Action Plan of 2021-22.

1.3 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 no.1.

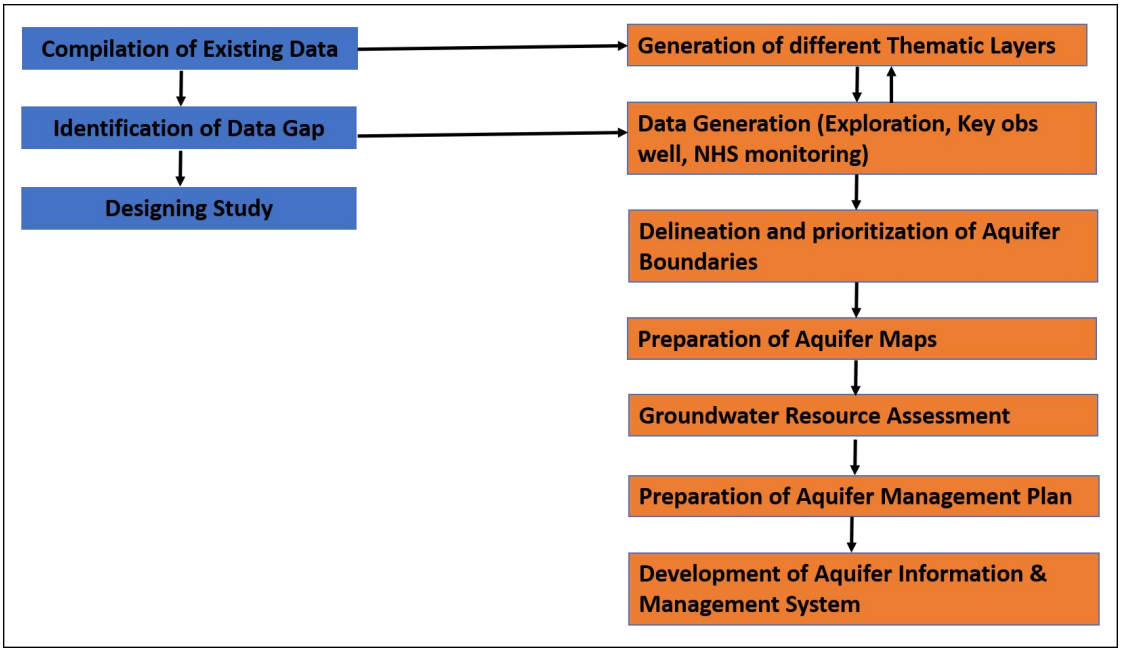

Fig. No 1: Aquifer mapping approach and methodology

1.4 Study Area- Location and Accessibility

Mandla district is situated towards the Southeast of Madhya Pradesh and bounded by Jabalpur district in the North, Balaghat district in the South, Dindori district in East and Seoni district in the West. and Northwest Respectively (fig.2). The area falls in survey of India toposheet No.s 64B/1, 64B/5, 64B/9, 64B/2, 64B/3, 64B/7 and 64B/11 and lies between north latitudes 22°11′51″ and 23°09 ′52″, east longitude 79°57 ′32″ and 81°12 ′ 0 ″. The district is drained mainly Narmada River and its tributaries.

It is connected by a good network of roads and railway. National Highway 12A, connecting Jabalpur and Balaghat is passing through the district. Important towns like Mandla, Bichhiya, Niwas etc. are connected by roads. All the villages in the study area are connected to this basic frame work by a secondary network of roads. The nearest railway station and airport are situated at Jabalpur. The district head quarter is 408 kms away from state capital Bhopal.

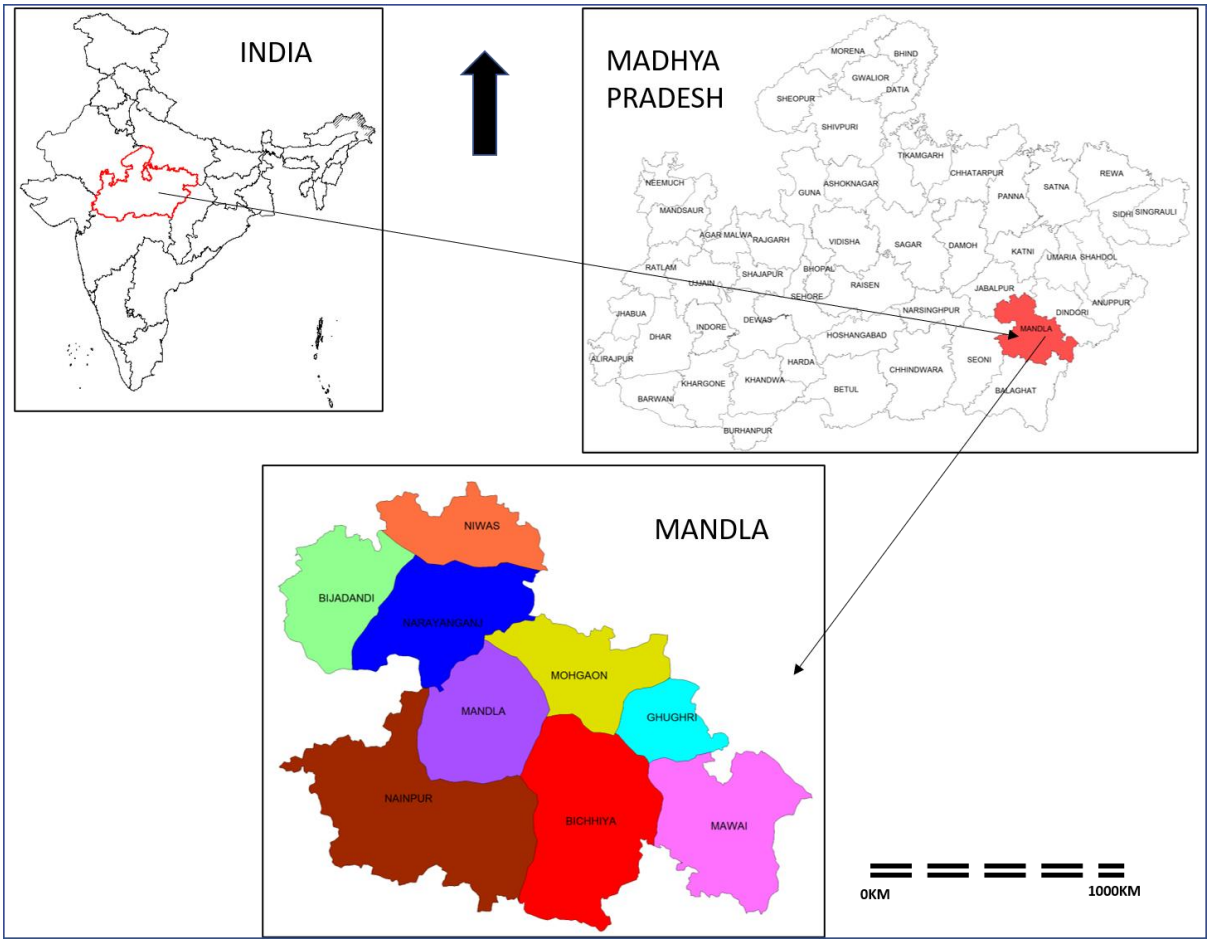

Fig. No. 2: Location Map of Mandla District

1.5 Population and Administrative Division

The district is sub divided into seven administrative 9 blocks and 6 Tehsils. The administrative divisions are shown in figure-1 and details are given in table–1. There are 278-gram panchayats and 1221 villages in the district (Table 1). As per census 2011, the total population of the district is 1053522.

Table 1: Administrative Units of Mandla district

Total Blocks	Area (sq. km)
Total Geographical Area (sq. km)	7544
Recharge worthy Area (sq. km)	5739.9(76.08 %)
Hilly/Forest (sq. km)	1804.1(23.91 %)

Table 2: Block-wise area of the district

Block	Geographical Area (Sq. Km)	Recharge Area (Sq. Km)
BICHHIYA	1099	879.2
BIJADNNDI	761	608.8
GHUGHRI	1101	880.8
MANDLA	617	493.6
MAWAI	1463	1170.4
MOHGAON	419	327.8
NAINPUR	798	638.5
NARAYANGANJ	440	352
NIWAS	846	388.8
DISTRICT TOTAL	**7544**	**5739.9**

As per the official census data 2011 of Mandla district, total population is 1,054,905 and population density is 120/km^2 (table 3). Total no. of male population is 525,272 and female population is 529,633. 12.34% of total population, i.e., 130,189 comes under urban population and the remain g 87.66% i.e., 924,716 comes under rural population.

Table 3: Population data of Mandla district

Si No.	Year	Population	± p.a%
1	1921	251,438	−0.47%
2	1931	290,034	+1.44%
3	1941	328,300	+1.25%
4	1951	356,304	+0.82%
5	1961	420,563	+1.67%
6	1971	539,873	+2.53%
7	1981	627,717	+1.52%
8	1991	779,414	+2.19%
9	2001	894,236	+1.38%
10	2011	1,054,905	+1.67%

1.6 Climate and Rainfall

1.6.1 Rainfall

The normal rainfall of Mandla district is 1115.29 mm. There is one rainy season when the district receives rain through the south-west monsoon in the months of June to October. About 88.87% of rain is received during the monsoon period, only 11.13% of the annual rainfall takes place during October to May. Details are given in table 4 &5.

Table 4: Annual rainfall of Mandla District

S.no.	Year	Annual rainfall (mm)
1	2016	1173.41
2	2017	1019.51
3	2018	1059.3
4	2019	1607.51
5	2020	1553.97
6	2021	1115.29

Table 5: Average Annual Rainfall of Previous Five Years (in mm)

S.no.	Mandla District Year wise rainfall (mm)	
	Year	Average rainfall (mm)
1	2017-18	84.95
2	2018-19	88.27
3	2019-20	133.95
4	2020-21	129.49
5	2021-22	92.94

1.6.2 Temperature

The climate of Mandla district characterized by a hot summer and general dryness except during the southwest 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 middle of June. The period from the middle of June to September is monsoon season. October and November form the post monsoon or transition period.

The January is the coldest month of the year. The individual day temperature comes as low as 1-2°C. From March onwards, the temperature starts rising and maximum temperature is observed during the month of May upto 44°C. On the arrival of monsoon, the weather becomes pleasant. In October, on the retreating of monsoon the temperature rises slightly during the day time.

1.6.3 Humidity & Wind

During the southwest monsoon season the relative humidity generally exceeds 88% (August month). In rest of the year is drier. During summer season, relative humidity is less than 38% and April 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 of 6.8 km/hr. is observed during the month of June and minimum 2.3 km/hr. during the month of December. The average normal annual wind velocity of Mandla district is 4.3 km/hr.

1.7 Soil types in Mandla district

The district is generally covered with black cotton soils covering almost three-fourths of the area. This part is occupied by deccan basalts. The rest part has red yellow mixed soils derived from sandstone, shale. The alluvial soils are found along the river courses. The higher elevations i.e., the hilly regions have a cover of murum which is made up of small rounded pieces of weathered deccan trap basalt. The Vindhyan and Bijawars have a thin cover of sandy loams (fig. no.3).
The black soils cover 70.8% area followed by red soil 11.8%, sandy loams 4.7% and sandy soil 3.5%. The dominant soil caps of the area represented by gently to very gently sloping, shallow

and moderately deep Ustorthents and Ustochrepts, respectively grading to nearly level, deep chromatists. The soil of the region falls in dry sub-humid region, the dominant soils capes of the area are represented by gentle to very gentle slope, shallow and moderately deep with the moisture index ranging from (-)03 to (-) 22. The clay content ranges between 63-65% decreasing abruptly to 54% in the sub-soil region. These are highly saturated soils and the exchange complex is dominantly saturated by divalent while the montmorillonite constitutes the dominant clay material in the exchange complex.

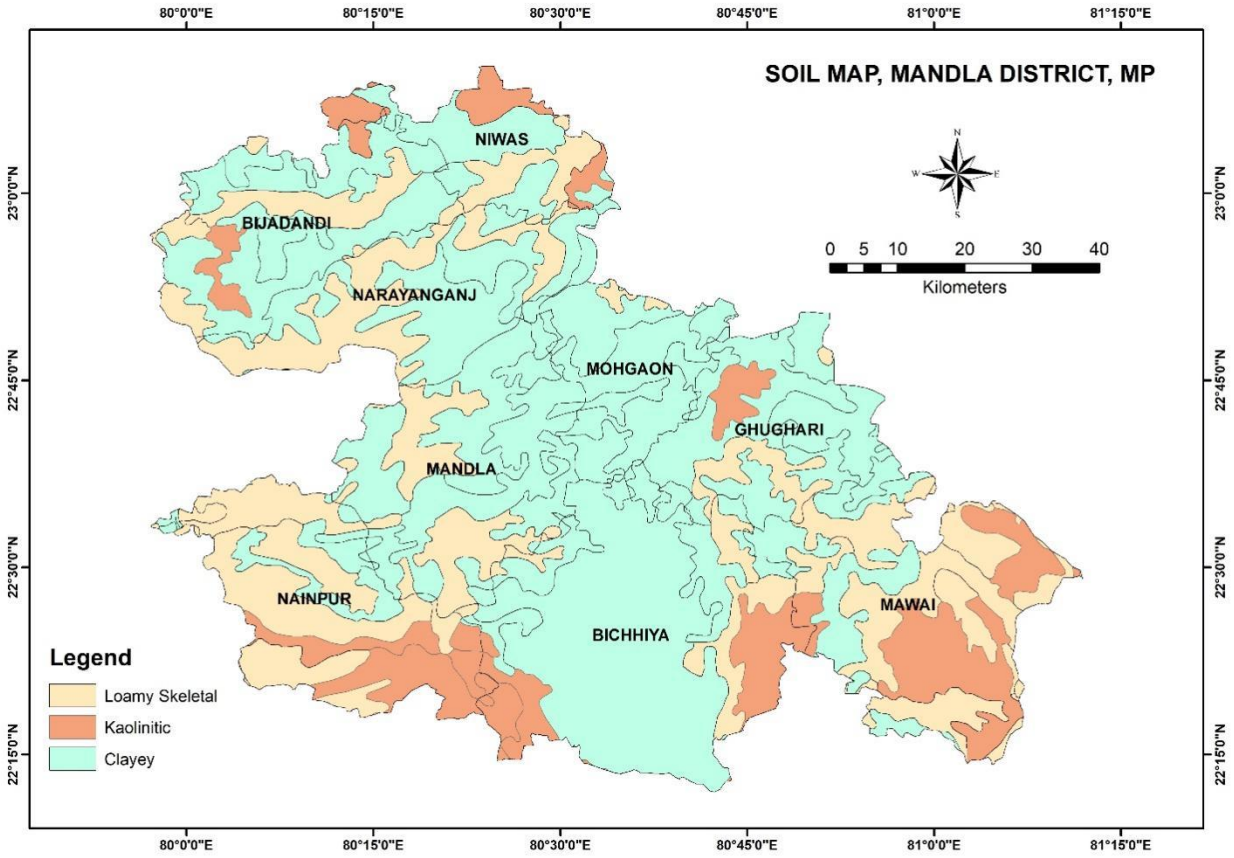

Fig No. 3: Soil map of Mandla district

1.8 Geomorphology of Mandla District

The major part of study area is characterized by a typical trappean-basaltic geomorphology comprising extensive plain, low lying hills and hill clusters with gentle Southerly slope. Eastern, South-eastern and Northern parts are highly undulating terrains with broad pointed topped hills of granites, terraces and isolated hills constituting mesas and butte. Central, Southwestern and Western parts of the district forms flat landmass having a moderately rolling topography with small mounds and hillocks and plains of Gondwana beds (fig. no.4).

The study area is a part of the Satpura Region with an elevation range of 364 to 958m aMSL and the average relief is 604 m aMSL. Maximum elevation is towards Mawai in Southeast, Bichhiya in South and Gughri in Northeast directions. Minimum elevation is towards Mandla and Nainpur in Central parts (fig.no.5).

The major hydro-geomorphological units in the study area can be classified into depositional landforms including alluvial plains and valley fills, structural landforms including lineaments and intrusive landforms consisted of basaltic dykes. The basaltic up-lands and Deccan plateau

basalts are main physiographic units in the study area which are acting as good groundwater occurring and control units along with Gondwana and granite. Details are given in table 6.

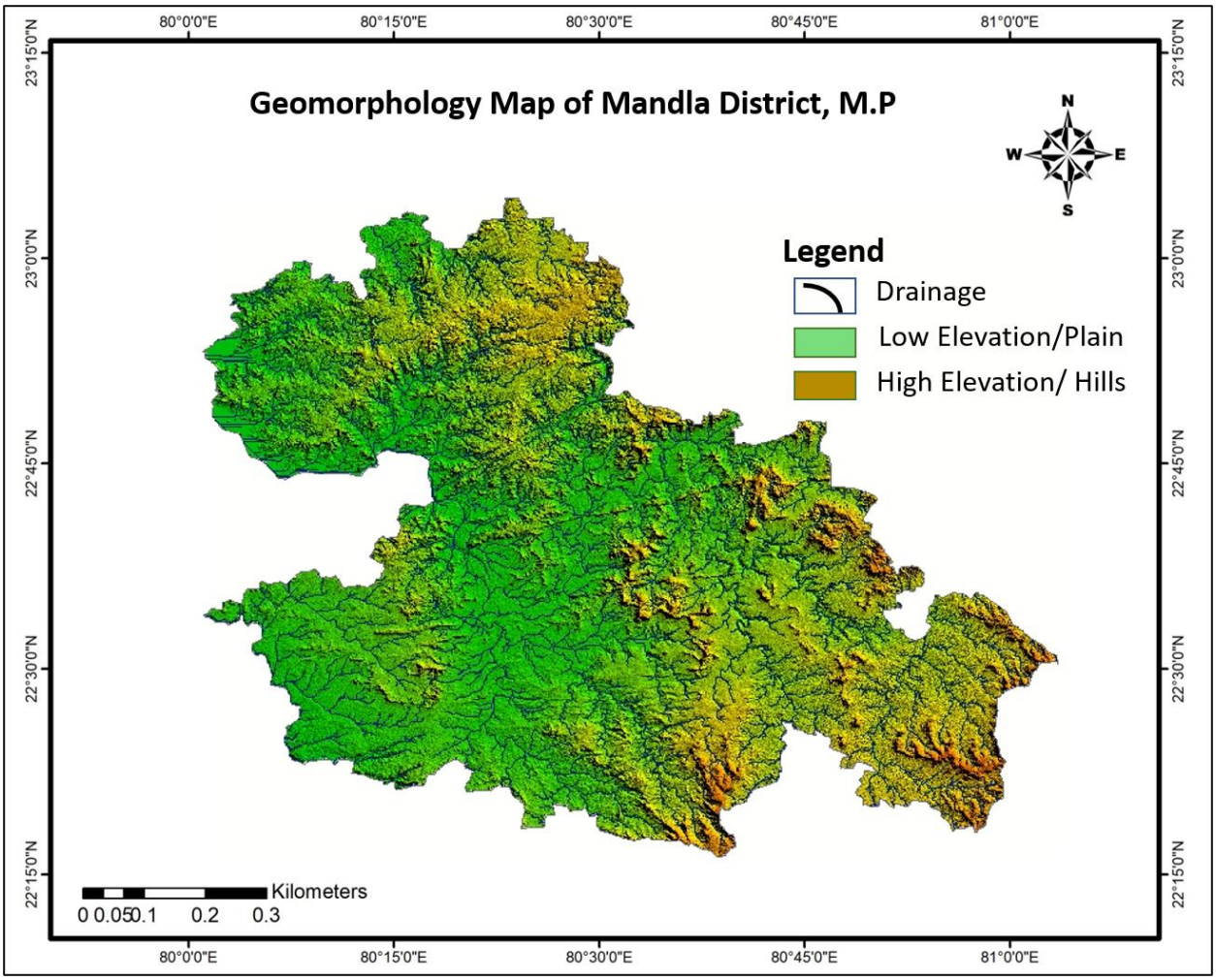

Fig No. 4: Geomorphology map of Mandla district

1.8.1 Lineaments

These are linear features in the form of faults, fractures, joints shear zones, contact zone and similar features which reflect the crustal structure. A majority of lineaments are seen to show E-W trend. As some of the lineaments are dislocation generated by structural disturbance, they provide channel for ground water movement especially at their intersection. The intersection areas of the lineaments thus have good to excellent ground water potential.

1.8.2 Dykes

These are dark grey, fine to medium grained, sparsely to moderately prophetic dense basalts. These generally have a NE-SE trend and act as a barrier as well as carrier of ground water and having good potential on the up-grading side.

Table 6: Hydro morphological units in Mandla district

Geomorphic Unit	Lithology	Structure	Description	Ground Water Occurrence
Basaltic Up-Land	Composed of basalts of deccan traps	-	Moderate relief upland with thin veneer of soil.	Poor to moderate along fractures.
Deccan Plateau	Composed of basalts of deccan traps	Fractured and jointed basalts.	Undulating topography with soil cover, normally cultivated.	Moderate to good along lineaments weathered zones and depression
Lineament	It may cut across various Lith units	Linear features	Fault lines, fractures joints shear zones contact shear zones, contact zones, other linear features and straight stream courses which are believed to reflect crustal structures.	Good, excellent at intersection of lineaments.
Lameta Sand	Composed of loose to semi compact sand	Loose sediments	A part of Gondwana formation which is highly collapsible	Good, excellent
Basement Granite	Composed of massive grey and pink granites	Intrusive emplacements as well as massive basement	Forms the Archean basement in the study area, exposed in some regions as truncated and pointed hillocks	Good if well connected fractures are available.

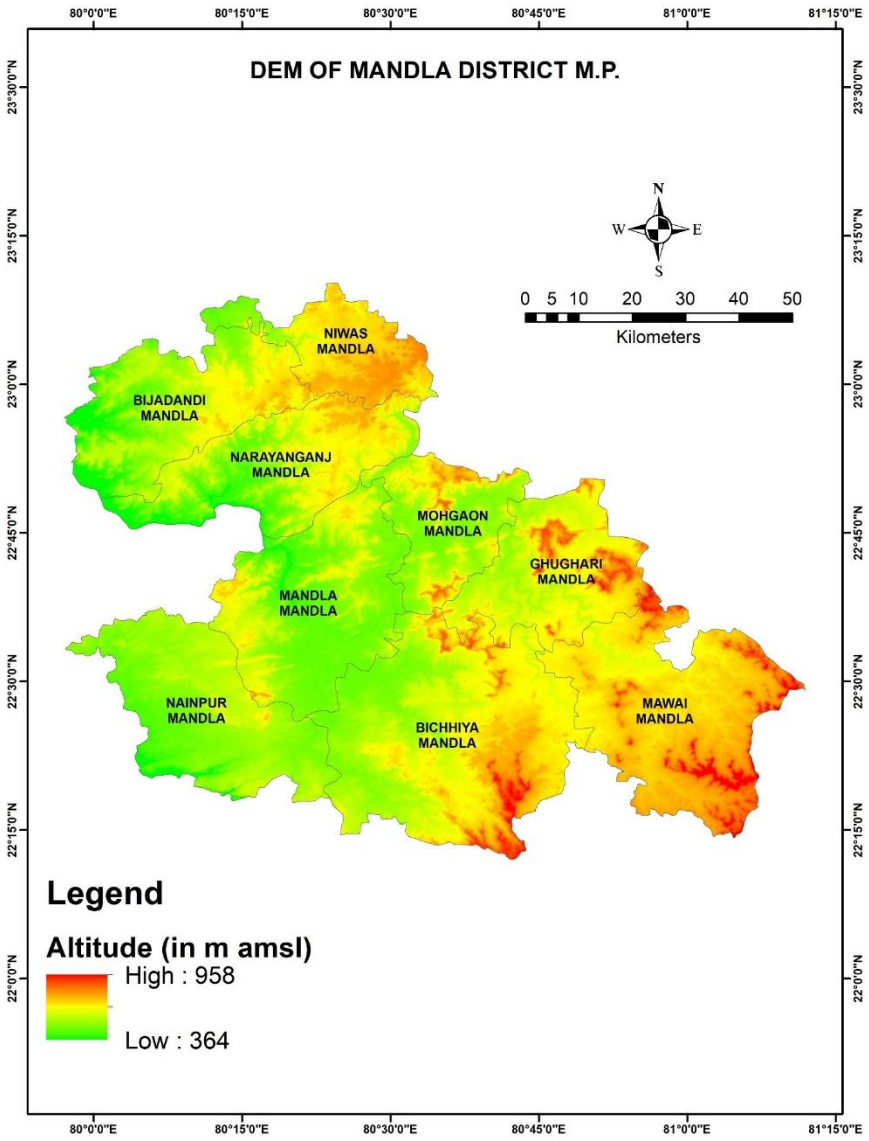

Fig.No.5 Digital Elevation Map of Mandla district

1.9 Drainage of Mandla District

The Area forms water divided between the major Narmada basin in the north and the Wainganga (Part of the Godavari basin) in the southwest. The Narmada River and its tributaries drain the northern and northern western part of the area. Banjar river flowing northwards in the south-central part is major tributary to the Narmada River. The Wainganga River following in southerly direction and its tributaries, drain the southwestern part.

Tributaries of these rivers are intermittent and the streams are flashier with peak flows occurring during monsoon season after the soil moisture deficits have been replenished. Smaller streams in the area ephemeral and usually short seeping in the head water area and gain run off in the downstream. As the streams in the district are ephemeral, domestic water supply depends upon groundwater, which is generally confined to weathered vesicular/amygdaloidal basalt, occurring in the top portion of lava flows. In summer as the water table goes down the water resources dry up. This causes the permanent exploitation of deeper aquifer. Drainage map is given as fig.no.6.

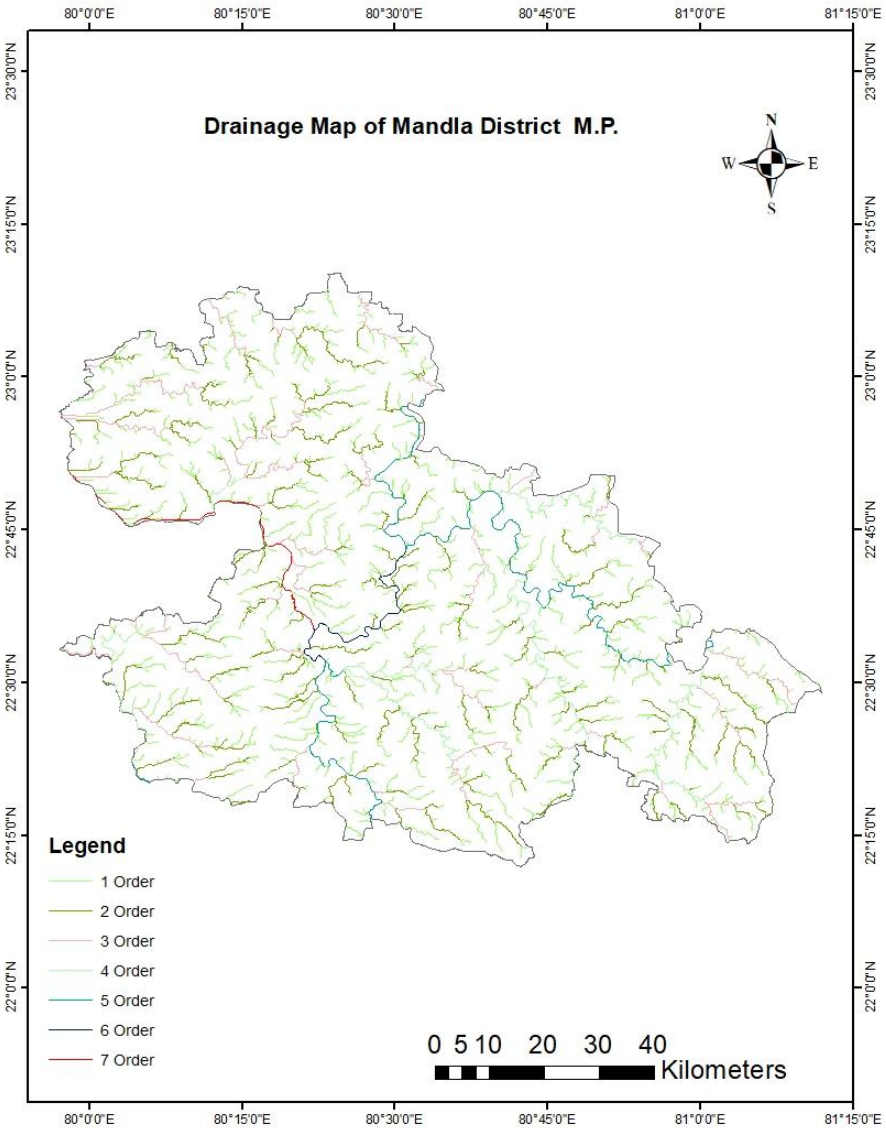

Fig. No.6: Drainage Map of Mandla District

1.10 Land use and Cropping Pattern

Out of total area, 7544 sq km is under cultivable area which is 35.69% of the total geographical area of the Mandla district. Forest area is 15.2%, 5.66% is area under non-agricultural uses, cultural wasteland is 5.21%, barren land is 1.4%, fallow land is 8.16% (fig.no.7). The land use pattern is given in Table 7.

Table 7: Land use Pattern of Mandla district

Si No.	Type of Area	Area (Sq.km)
1	Total Geographical Area	7544
2	Forest Area	1150
3	Area under non-agricultural uses	427.66
4	Barren Land	106.31
5	Cultural Wasteland	393.3
6	Fallow Land	615.70

7	Net sown area	2183.3
8	Gross sown area	6271.8
9	Net Irrigated area	199
10	Gross Irrigated Area	255.5

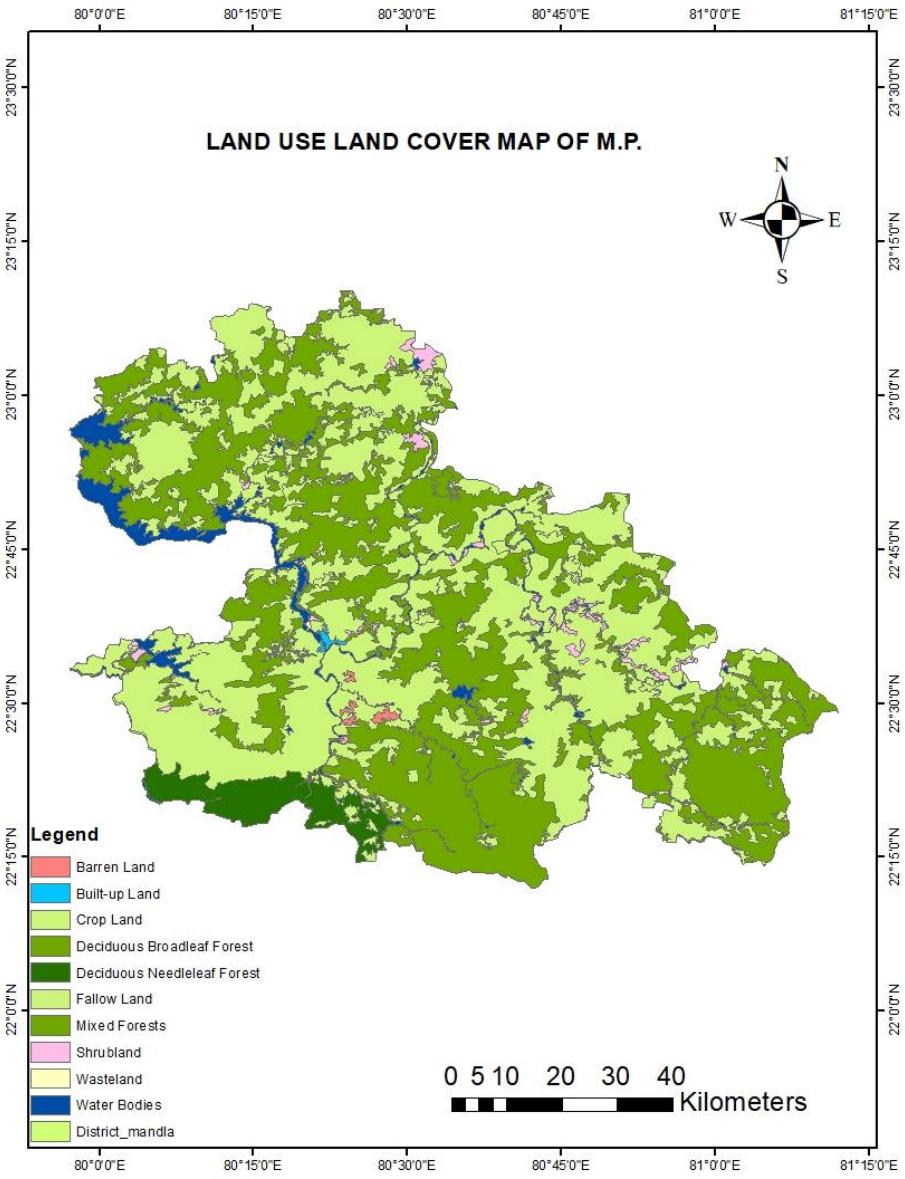

Fig.No.7: Land use landcover map of Mandla district

The area irrigated by borewell is 106300 ha (41.4% of the total irrigated area), by open-wells 42700 ha (16.6%), irrigated by canals is 39900 ha (15.5% of the total irrigated area) and by tanks 4800 ha (1.8%). The net area under irrigation is 255500 ha and the area under rainfed irrigation is 275900 ha. Details are given in table 8.

Table 8: Irrigation data of Mandla district

Irrigation	**Area (ha)**		
Net irrigated area	**199**		
Gross irrigated area	255.5		
Rainfed area	275.9		
Sources of irrigation	**Number**	**Area**	**Percentage of total irrigated area**
Canals	11	39.9	**15.5**
Tanks	23	4.8	**1.8**
Open wells	11816	42.7	**16.6**
Bore wells	16057	106.3	**41.4**
Lift irrigation schemes	NA	-	**-**
Micro-irrigation	NA	-	**-**
Other sources (reservoir)	03	61.90	**24.14**
Total irrigated area	-	255.50	**-**

Major crops cultivated in Mandla district includes paddy, maize, wheat, peas, mustard and lentil. Area under Kharif crops is 191.1Sq.Km and area under Rabi crops is 87.5Sq.km. Details are given in table 9.

Table 9: Cropping details of Mandla district

Kharif			Rabi		
Area	Avg. Yield Kg/Sq.km	Production (tons)	Area	Avg. Yield Kg/Sq.km	Production (tons)
191.1	610	118.4	87.5	654	57.2

1.11 Geology of Mandla District

Table :10 Geological succession of Mandla

AGE	**LITHOSTRATIGRAPHIC UNIT**	**LITHOLOGY**
Recent to sub recent	Alluvium, Laterite	Sandy loam, silty sand, coarse medium laterite
Cretaceous to Eocene	Deccan Trap	Basaltic lava flows and older dolerite dykes and sills.
Lower Cretaceous	Gondwana	White clays and mediumgrained sandstone
Late Norian to Rhaetic	Mandla formation of Amarkantak group	Coarse-grained sandstone variegated shale and clays.
Upper Permian	Lameta group	Coarse grained sandstone grey shale, red shale, red green and mottled clay with thin coal bands

AGE	LITHOSTRATIGRAPHIC UNIT	LITHOLOGY
Late Permian	Barakar	Sand stone, Shales and Coal seams
Upper Carboniferous to Lower Permian	Talchir	Tillite, sandstone and greenshale

1.11.1 Archean:

The oldest rock is the area belongs to the Archean that comprises granite Gneisses and schist. These rocks occur the southwestern part of Mandla area. Granite rock is generally well-jointed and fractured up to depth to 10 to 150 mbgl.

1.11.2 Lameta bed

This group of rocks is formed of sedimentary laid prior to the eruption of lava flows to the Deccan traps. It is unconformable overlies the granite gneisses and is mainly exposed below Deccan trap in the central and eastern part of Mandla area Its contact with Deccan trap slops from east (510 m amsl) to west (430m amsl). In the eastern part due to step faults this contact goes up to 680 m amsl. These rocks occur as small pockets bordering the great mass of lava flow along its northern boundary. The rocks comprise limestone and sandstone and occur over an area of about 90 sq. km. The rock is fine to medium grained and compact in nature and form thickness in the range of 1 to 6 m thickness

1.11.3 Deccan traps:

Deccan trap are the most extensive geological formation of the Mandla district. They are differentiated into a succession of basaltic flows as interflow zone of red/green below of varying thickness. The 500 m thick lava sequence of Mandla area has been divided into four formations on the basis of lithe characters, type of flow and their long-distance continuity. All the formation exhibits thickening in the centre, thinning out in the marginal area.

1.11.4 Characteristic of basaltic flows:

Basaltic lava flows of Narmada basin of Mandla area mainly of two types

1. Simple flow and 2. Compound flow

The simple flows are characterized by 1-7 m thick vesicular and amygdular and 20-70 cm thick lower vesicular zone. The compound flows comprise number of flow unity and show large variation in thickness and aerial extent as well as thinning and pinching units. These units exhibit pahohoe character such as chilled and ropy surface basalt zones of pipe amygdular, vesicle cylinder etc.

1.11.5 Intertrappean bed

Intertrappean beds mark definite Stratigraphic horizons in the lava sequence and have been used to divide the lava sequence into four formations. Episodic nature of volcanism is also evident from the presence of fairly persistent Intertrappean beds these bed form 1-10 thick sedimentary sequence consisting of limestone, chart clay. It is exposed all along the valley of Narmada and Banjar River. Along Chalked to Malpur, Bamhni banjar to Mugdare and exhibit thickening in the centre area. It also shown a gradient of 1:200 toward WSW. The limestone of this bed shows development of nodules at places.

1.11.6 Infratrapean bed:

The lava pile is underlain by 2-3 m thick sequence of sedimentary rocks which are fairly persistent as to area and have been correlated with the lameta bed of Jabalpur are it comprise hard sandstone occurs along Ganghi, Chechile along chakar nala near Nainpur.

1.11.7 Structure:

The Deccan lava pile of Mandla area is bounded by Narmada – Son lineament to the north and Tapti lineament to the south. The reactivation of these lineaments during upper cretaceous period result into **formation of a rift basin.** The initial volcanism, which follows the deposition of lameta formation, was sub aqueous in nature as evident from the presence of Pillow lava in many parts of the area and gradient of lava pile suggest easterly source.

1.11.8 Intrusive:

A few thin ENE-WSW trending basaltic dykes interlude the lava sequence. These dykes are confined to the marginal area along major ENE-WSW trending faults. A porphyritic dyke has been observed is Burner River section Jhingartola in the southern part of area and abets 2-3 km length of dyke in the area below Chairaidongri, Bamhni. Detailed geological map of Mandla district is given as fig.no.8.

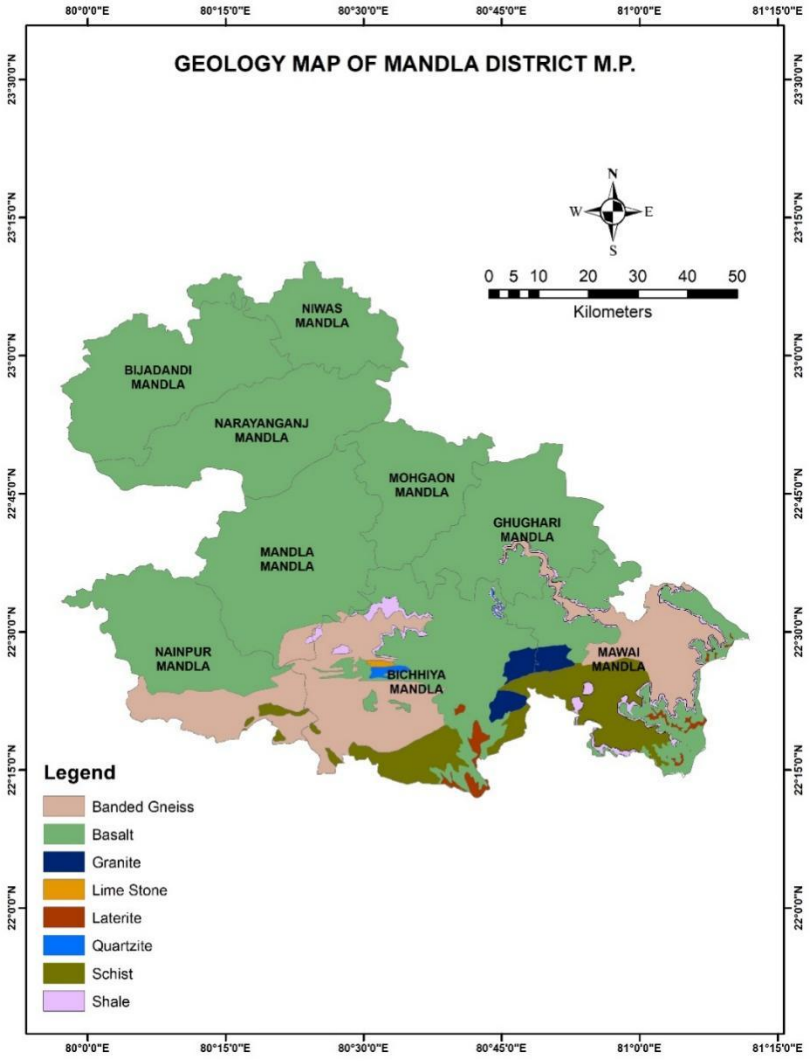

Fig. No.8: Geology Map of Mandla District

1.11.9 Regional Geology

Classification of lava flows

GSI has carried out extensive mapping of Mandla. The Southern fringe of Son Narmada (SONATA) lineament zone, the ENE-WSW trending major technique zone activity from plateau porters to the recent. ENE-WSW trending central Indian technique zone CCITE is located in southern part. This sub divided the area into two major crystal provinces. The area to the south of the ITE from part of deccan lava sequence of Mandla region.

The lava sequence consists mainly of pahohoe flows which are simple and compound nature. A flow is rase the gradient of flows varies from 1:200 to 1: 500 towards north west and west coinciding with the paleo slope based on the presence of inter trappean beds, mega scope character of flows such as grain size porphyricity and mineralogical constituents, presence of bole beds. The lava sequence of the area has been classified as given in table 11. Flows showing highly porphyritic and glomeroporphyritic texture form marker flow for correction of the flow sequence.

Table 11: Classification lava sequence.

	Lava stratigraphy	Lava flows	Nature & character
Amarkantak group (Deccan trap)	Linga formation	Non porphyritic lava flows 4 flows	Dark brownish black greenish non porphyritic hand & compact rock
Creteceous	Pipardehi formation	Highly porphyritic basalt fen (3 fen)	Dark grey, fine to medium grain porphyritic ha & compact rock
	Dhuma formation	"Aa" and compounds "pahoehoe" basalt flow (8 flow)	Black to greyish black non porphyritic hard & compact with porphyritic texture in flow
	Mandla formation	Basaltic flows	Dark grey fine to medium grain highly pumping hand campus.

1.11.10 Mandla Formation

It occurs in the north-central and eastern part and unconformably over the lameta group and granite gneiss. It consists of one compounded flow and three to four simple flows (table 12).

Table: 12 Lava sequence & Deccan traps of Mandla area.

Formation	**Flows**	**Type of flow & litho characters**	**Thickness (m)**
	Kosamghat	Chert limestone clay/ red bole	1-10
Mandla flows	Chabi	Compound aphyric	20-40
	Bataundha	Compound porphyritic	10-20

Formation	Flows	Type of flow & litho characters	Thickness (m)
		aphyric/aphyric	
	Sarwahi	Compound porphyritic aphyric	20-40
	Kathautiya	Compound porphyritic aphyric/aphyric	20

In the eastern part of the area, the basalt flow is highly porphyritic simple. The thickness decreases from 40 min the west to 15 m in the central part the rock is fine grain to medium grained hard, compact, highly porphyritic with feldspar phenocryst varying in length from 1 mm to 7mm. The rock at place is characterized by glomero phyritic texture compound flow of the Mandla formation consists of 2-7 flow units and show variation thickness from 20 m to 100 m due to pinching and swelling of different units within short distances. The basalt flows commonly show pahoehoe characters with ropy structure, pipe vesicle and bun structures. Some of the flow short acylindrically vesicles at the base.

1.11.11 Dhuna formation:

It comprises two flows and varies in thickness from 50 m to 80m. the lower flow shows glomeroporphyritic texture correlation of the flows. it is developed mainly in the central and north eastern part with thickness varying from 50 m in the east to 15; m in the west. In the east central part this shows thinning and pinches at ultimately. This flow forms liner ridges of 15 km to 30 km length which possible represent structurally controlled paleo channel filled by this flow. The channel show gradient 1:2000 towards WSW.

1.11.12 Linga formation:

It forms the top most part of the lava sequence and consists of flow in the section 2-3 flow are generally exposed and their top is covered with lateritic. This is mainly exposed in the northern part. Fairly persistent Intertrappean bed marks the lower contact of this formation this contact is exposed between 780-800m amsl in north-eastern part and between 660 m – 700 m amsl in the north central part. All the flows are dark brownish black to greyish black fine to medium grained and non-porphyritic the top of this formation is character by the presence of laterite which varies in thickness from 2 m to 70 m.

CHAPTER 2
DATA COLLECTION AND GENERATION

2.1 Data Collection and Compilation

Data for various components were collected and compiled for NAQUIM studies in Mandla district as discussed below.

Hydrogeological Data

- 10-year water level data along with trend of monitoring wells of CGWB viz. National Hydrograph Stations representing Aquifer-I (Shallow aquifer) are collected.
- The weathered zone thickness (aquifer-I), lithological details of deeper aquifers (aquifer-II) of exploratory wells were also collected and compiled.

Hydro chemical Data

- Ground water quality data shallow aquifer of NHS monitoring wells of CGWB are collected and compiled.
- Groundwater quality data from exploratory wells representing deeper aquifer are collected and compiled.

Exploratory Drilling

- Data of groundwater exploration carried out in Mandla district by CGWB are collected.

Hydro meteorological Data

- 5-year rainfall data for the whole district (block wise) from Indian meteorological Department and Water Resource Department are collected.

Statistical Data

- Data of prevailing cropping pattern from District Irrigation Plan, Mandla district.
- Data of existing surface water irrigation structures from District Irrigation Plan, Mandla district.
- Data of prevailing land use pattern, Mandla district from Dept. of Statistics, Economics and Planning, M.P.
- Demography data of Mandla district from Dept. of Statistics, Economics and Planning, M.P.

2.2 Groundwater Exploration in Mandla district

During the course of detail hydrogeological studies carried out in the district during (2005-08, 2019-20). A total 54 wells have been constructed and pumping test were carried out on selected in wells in deccan trap (in different flows) by CGWB, NCR, Bhopal (fig.no.9). The analysis of the yield test data reveals that percentage of recuperation of wells tapping jointed and highly weathered vesicular units locate favourable hydrogeological environment is three times more than the wells tapping poorly jointed and zeolitic units of the flow. The percentage of recuperation is also higher in the wells tapping inter trappean zones.

The details of bore wells drilled and aquifer detail are given in annexure 6.

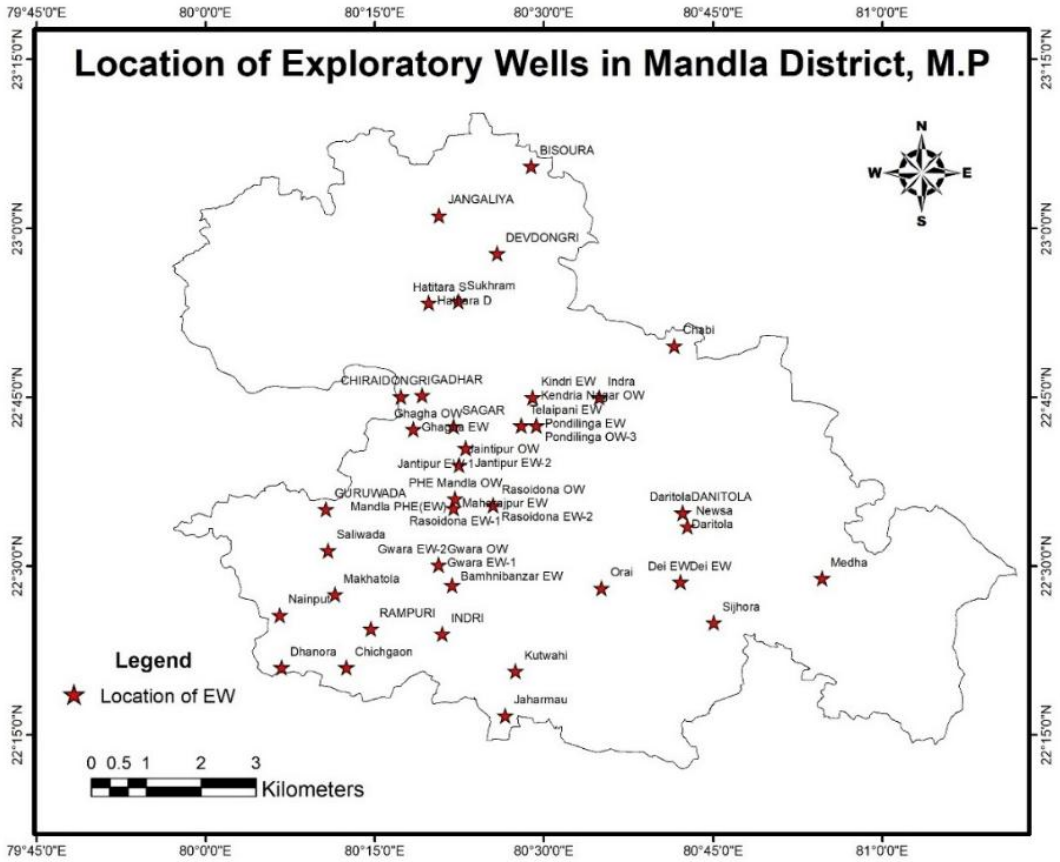

Fig.No.9 Location of Exploratory wells in Mandla district

2.3 Depth to water level Monitoring

Water level in the 31 NHS monitoring wells (fig.no.10) in the study area was measured during pre and post monsoon periods by central ground water board as key wells falling in the study area so that the long-term data about the area could also be fruitfully utilizes.

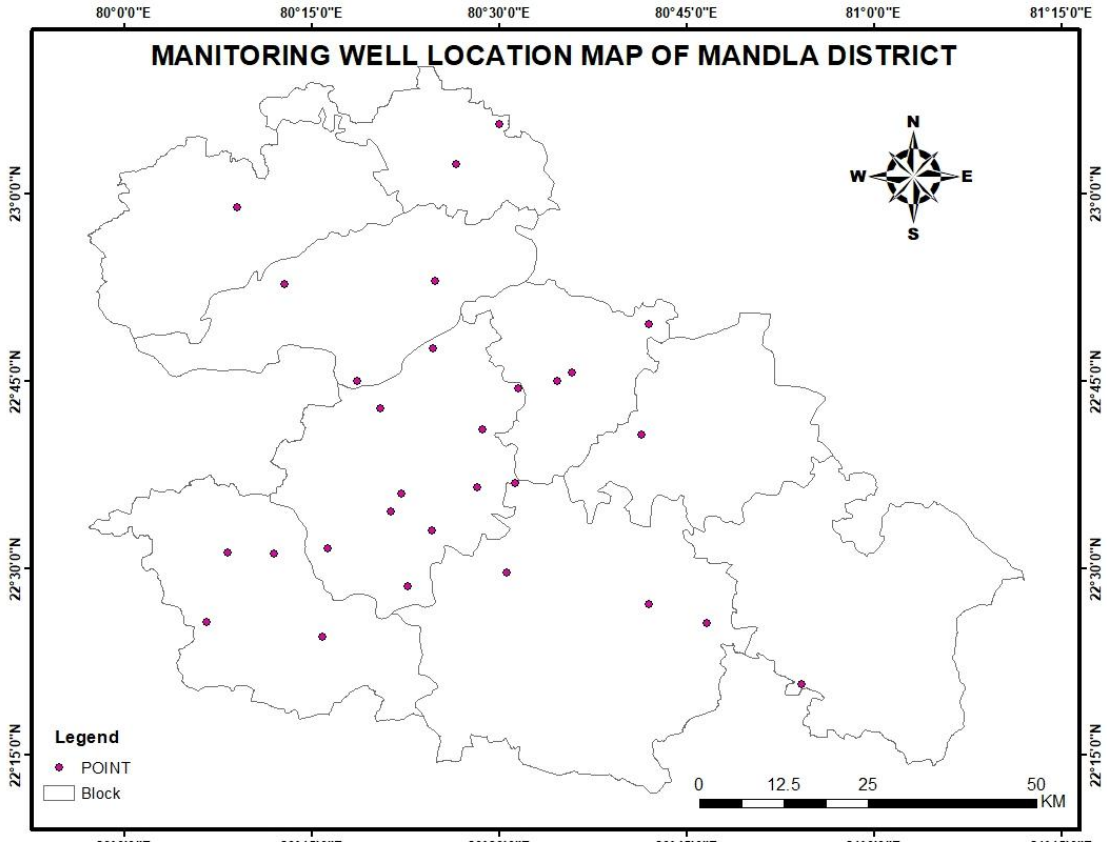

Fig. No.10: Location of NHS Monitoring wells of Mandla district

2.4 Hydro chemical data of Mandla District

The water samples were collected from National Hydrograph Stations in clean double stoppered poly ethylene bottles from 28 different locations of Mandla district during May 2020.

The samples were analysed for 14 basic parameters at the chemical lab of CGWB, NCR, Bhopal. As the occurrence of groundwater is mainly in basaltic aquifer, almost all the basic parameters falls under permissible limit as per BIS standards except of Fluoride. Interpretation of chemical data is discussed in detail in coming chapters.

2.5 Surface Water Resources data of Mandla district

The surface water resources in the Mandla district area have a connecting network of canals created through medium and minor irrigation. There are 18 irrigation projects in the area.

2.5.1 Irrigation Projects

There are no major irrigation projects in the area. However medium irrigation dam and 16 minor irrigation tanks are constructed in the Mandla and Nainpur blocks as given below. In both blocks, canal water is released for 100 days during non-monsoon period and 10 days during monsoon period. Details are given in table13

Table 13: Surface Water Irrigation Schemes

Blocks	No of irrigation schemes		Left irrigation schemes
Mandla	01	14	04
Nainpur	02	02	-
Total	03	16	04

2.5.2 Medium Irrigation Scheme

Dhuandhar tank and Thanwar tank are constructed in Nainpur block and Matyare tank is construct in the vicinity of Mandla block area under medium irrigation schemes. These irrigation schemes are at Dhundhar stream, Thanawar river and Matyari river respectively. Details given in tables 14-15.

Table14: Water spread area irrigation scheme

Salient feature	**Matiyari tank**	**Dhundhar**	**Thanwar tank**
1 Water spread area (Ha)	433.8	102.02	428.3
2. Number of days water available during A. Monsoon B. Non monsoon	 10 days 100 days	 10 days 100 days	 10 days 100 days
3. Designed discharge (Ha-m/day) A. Monsoon B. Non-Monsoon		 4.80	 15.0

Table 15: Canal Irrigation Structure

Block	**Canal system/ scheme**	**Total length of canal**	**Design depth**	**Base width**	**Side slope**	**Wetted pre**	**Water area**	**Canal seepage**	**No of days running**	
	Project	**(m)**	**(m)**	**(m)**	**(ratio)**	**(m)**	**(mSq.)**		**Mon.**	**Non. Mon.**
Mandla										
	Matyari									
	(a) QBC	19000	1.42	1.5	1.51	7.44	14.13	4.0	10	110
	(b) LBC	18000	1.25	1.34	1.51	6.56	11.80	4.0	10	110
Mohgaon block										
	Nighori	2100	0.38	2.01	-	1.88	0.287	20	10	120
	Jhandatoli	1530	0.38	2.01	-	1.88	0.287	20	10	120
Bijadandi block										
	Bijdandi Tank	610	-	0.6	2.01	1.68	0.1024	20	10	120
	Dhanwahi	1830	-	0.3	2.01	0.98	0.179	20	10	120
	Khapa	6660	-	0.3	2.01	2.91	1.938	20	10	120
Nainpur blcok										
	Dhundhar	19350	0.9	1.20	1:2	4.02	7.77	20	10	120
	Thanwar	48000	1.52	6.71	1:5:1	10.31	49.48	20	10	120

2.5.3 Minor Irrigation Projects:

Structures under minor irrigation project have been constructed in the district. Local storage capacity of these projects is 05.3 mcm and canal length 11083 m. The common area of these structure is 2092 ha (table 16).

Table16: Minor Irrigation Projects

Minor irrigation project	**Catchment area (Sq. Km)**	**Gross storage mcm**	**Live storage mcm**	**Crop area CHA**	
				Kharif	**Rabi**
Jantipur	5.05	1.60	1.412	435	
Jhalpani	4.92	0.781	0.655	368	
Mawai	3.10	0.861	0.792	81	97
Barbuspur	3.75	1.32	1.23	122	101
Deori	0.90	0.202	0.179	60	5
Mohgaon mali	2.48	0.546	0.182	182	
Bineka	14.48			177	
Semarkhape	17.09			142	
Bakon	16.83			101	
Jharmart	8.02			100	
Bagdori	10.13			121	
Total	**86.72**			**320.92**	**203**

2.5.4 Lift Irrigation Schemes (LIS)

There are 3 lift irrigation schemes in the area at Khairi Tharka and mandli table 4.5. The command area of schemes is about 1183 ha. These left irrigation schemes irrigation rabi crops area about 637 Ha (table 17).

Table No. 17 Lift irrigation schemes.

LIS	**Area (Ha)**	**Crop area Ha**	
		Kharif	**Rabi**
Khairi	690	279	411
Tharka	323	170	153
Manadehi	170	97	73
Total	1183	446	637

CHAPTER 3
DATA INTERPRETATION AND AQUIFER MAPPING

3.1 Hydrogeological data interpretation

3.1.1 Occurrence of Ground Water

Deccan trap basalt forms the major aquifer in the district. The distinct geohydrological features of lava flows is the significant primary porosity in the form of vesicles, formed due to escape of gases at a later stage of cooling. Secondary porosity is developed due to fracturing during culling of the lavas tectonic disturbances and weathering. The vesicular porosity is considerably reduced by filling up with minerals like zeolites and silica to from amygdales. One flow is separated from the other by sedimentary beds, deposited during quiescent period between successive expulsions. Flows are nearly conformable in stratification from effective confining layers. Alternating sequences of previous and compact horizon function as a multi aquifer system. If the flow dips at angles gentler than the land surface slope, artesian condition may result to cause free flow in wells.

Shallow ground water occurs in the weathered vesicular jointed and fractured zones of basaltic flows. When the weathered layer is continuous, the aquifer is likely to be extensive but of low permeability on higher ground the weathered basalt may be thin or will be restricted to the joints and will be localized in occurrence. In the shallow weathered jointed and fractured basaltic rocks, ground water occurs generally under unconfined conditions at some places under semi confined to confined conditions due to the presence of thick silty clays overlying the jointed rocks.

At deeper level ground water occurs under semi confined to confined conditions in the fractures jointed section, at the flow contacts and at some places in the vesicular amygdaloidal section. The recharge to the deep zones up to 60m occurs from the shallow aquifer through the deep joints and contact zones. Shallow aquifers are also noticed in alluvium (sandy and gravely) Alluvium pre dominantly clayey, occurs along the river courses.

Gondwana Sandstone and fractured granite acts as aquifer in Mawai and Bicchiya blocks. Both pink and grey granite developed secondary porosity as fractures and joints in deep aquifers. Gondwana sandstone is semi-compact with secondary porosity forming deeper aquifer along with loose Lameta sand. Hydrogeology map is given in fig.no.11.

3.1.2 Aquifer System and Aquifer Parameters

Geology of the study area is constituted by hard rocks as well as alluvium. Major portion of the study area is mainly covered by the weathered basalts except the occurrence of sandstone and granite towards East and Southeast. Basalt has low to moderate permeability. The occurrence of ground water is in general moderate, but it forms potential (higher yielding) aquifers wherever it occurs in topographic depression and low-lying areas and tapped by most dug wells and shallow tube wells. The water level depth during pre-monsoon period ranges from 2.5 to 10.5 mbgl. The yields of the dug wells and shallow tube wells from 5-8lps.

Fractured sandstone and granite forms good aquifers towards the East and South east. Wells yield ranged from 3-4lps. Massive granite with high elevation are exposed at some parts of the district. Massive basalt is also exposed at some part of the district.

Average discharge of bore wells ranges from 2-8 lps in most parts of the district. At Gagha, discharge of bore wells were observed is 27lps and in Telaipani and Pondilinga, discharge observed is 15lps. Specific yield of deeper aquifer is 0.02 except for Mawai where the specific

yield is 0.015. Fractured vesicular basalt, fractured and jointed massive basalt act as major aquifer in the district. Weathered basalt and fractured vesicular basalt are observed in dug wells which is acting as the aquifer at shallow depths.

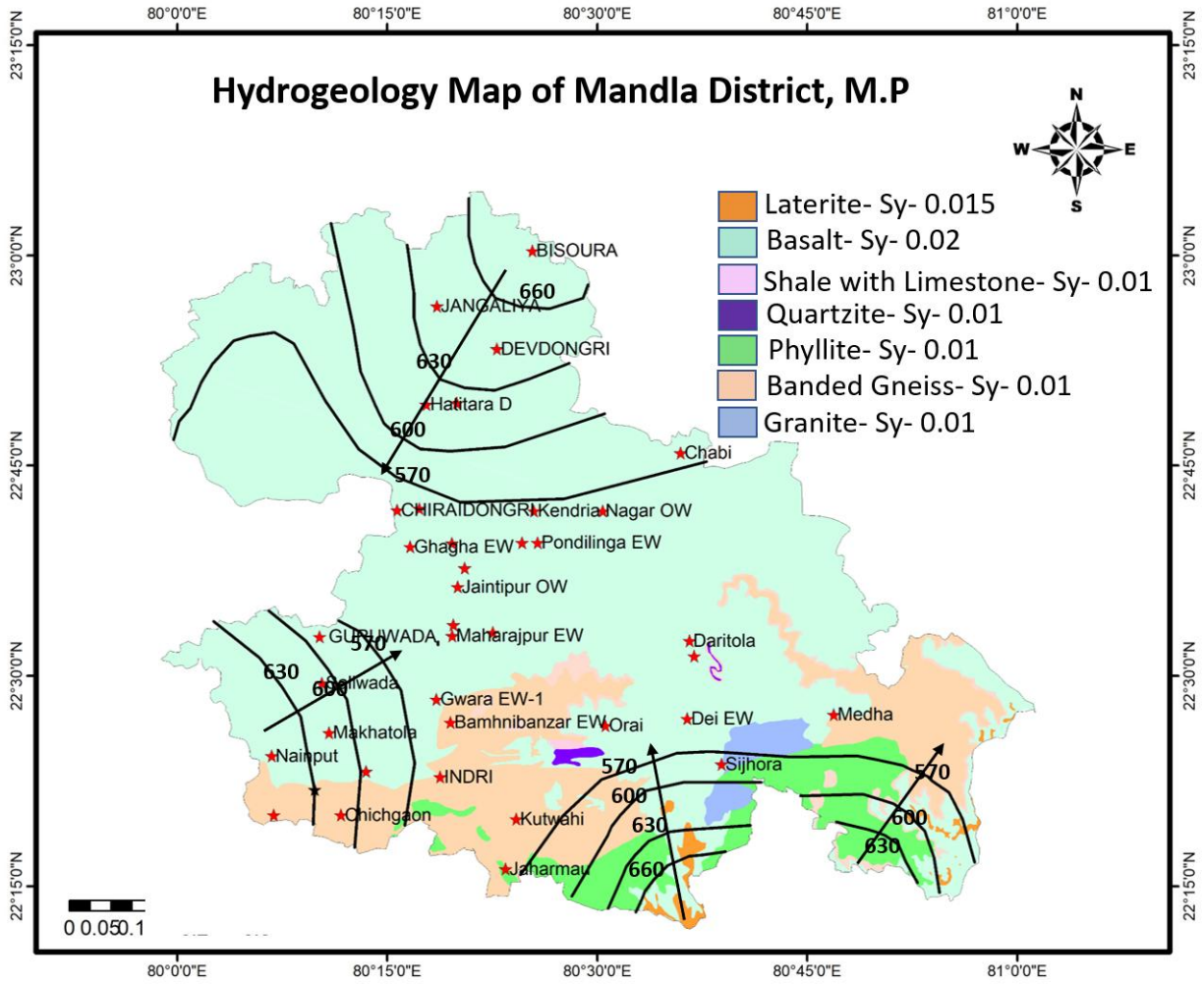

Fig No.11: Hydrogeology map of Mandla district

3.2 Water level in Mandla district

In Mandla district, it has been observed that in most of the places, water table is subdued replica of the land surface. Close to hills and high grounds, water table lies at comparatively higher altitudes than in valleys. The configuration of the water table confirm to the land surface to a greater degree in board undulating terrains than in rugged terrains. The addition to the primary control of topography, water table is also influenced by geologic control like dykes and permeability of water bearing rocks. Local variation in abstraction and depletion from the ground water reservoirs are also reflected in the water table. In very permeable formation the water table may tend to be flat, irrespective of the topographic highs and lows.

3.2.1 Pre monsoon water level

The depth to water levels monitored in 31 NHS monitoring wells during May 2021 has been used to prepare the pre monsoon depth to water level map of the district. The map shows that the depth to water levels during pre monsoon period in general rages 3-6 mbgl. The water level ranges 5 to 10 mbgl occur in north-eastern parts of the study area with small pocket in the central. Shallow water levels (0-3m bgl) occur as pocket in central part of the area around north west (fig.no.12).

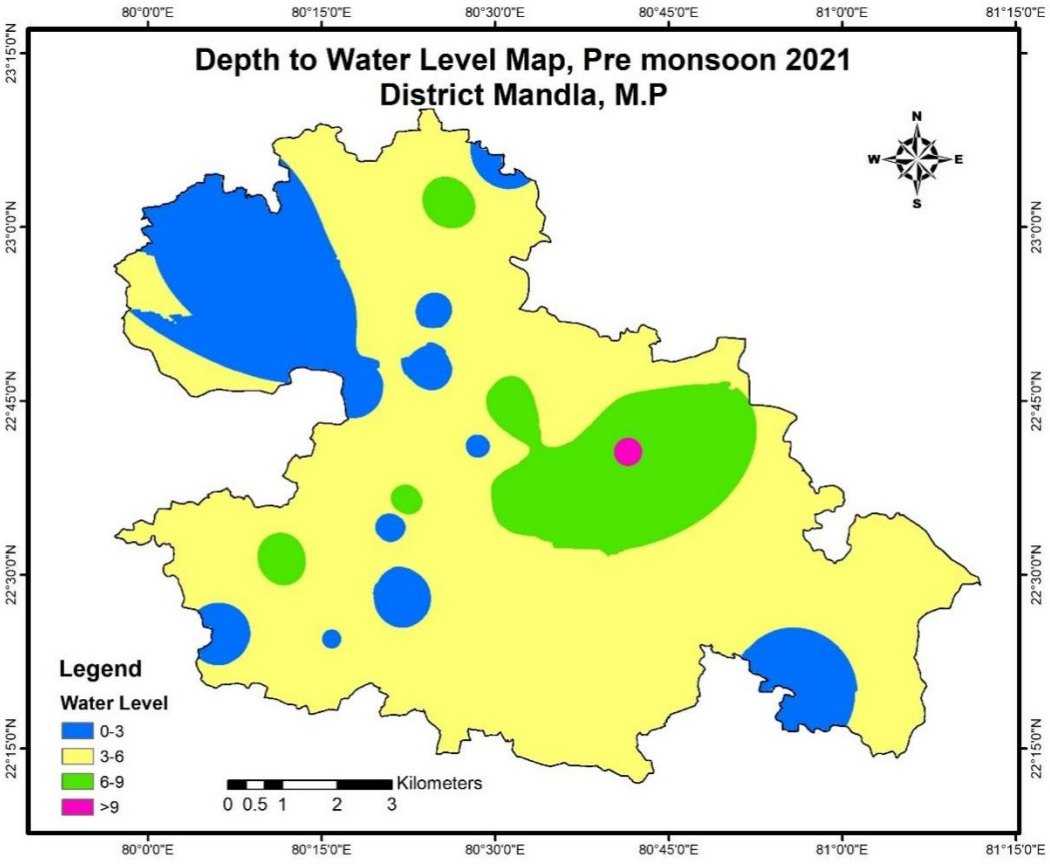

Fig. No.12: Pre monsoon water level map of Mandla district

3.2.2 Post Monsoon Water Level

The post monsoon depth to water levels were monitored during November 2021 and has been used to prepared the post monsoon depth to water level maps The map shows water logging condition in 50% of the district. The average post monsoon water level map for 2021 shows that the general depth to water level during post monsoon period over the study area ranges from 3-6 mgl. Shallow water level (0-3m) occur in the western part of the area, deeper water level > 6 mbgl area also encountered in central part near Chabi(fig.no.13).

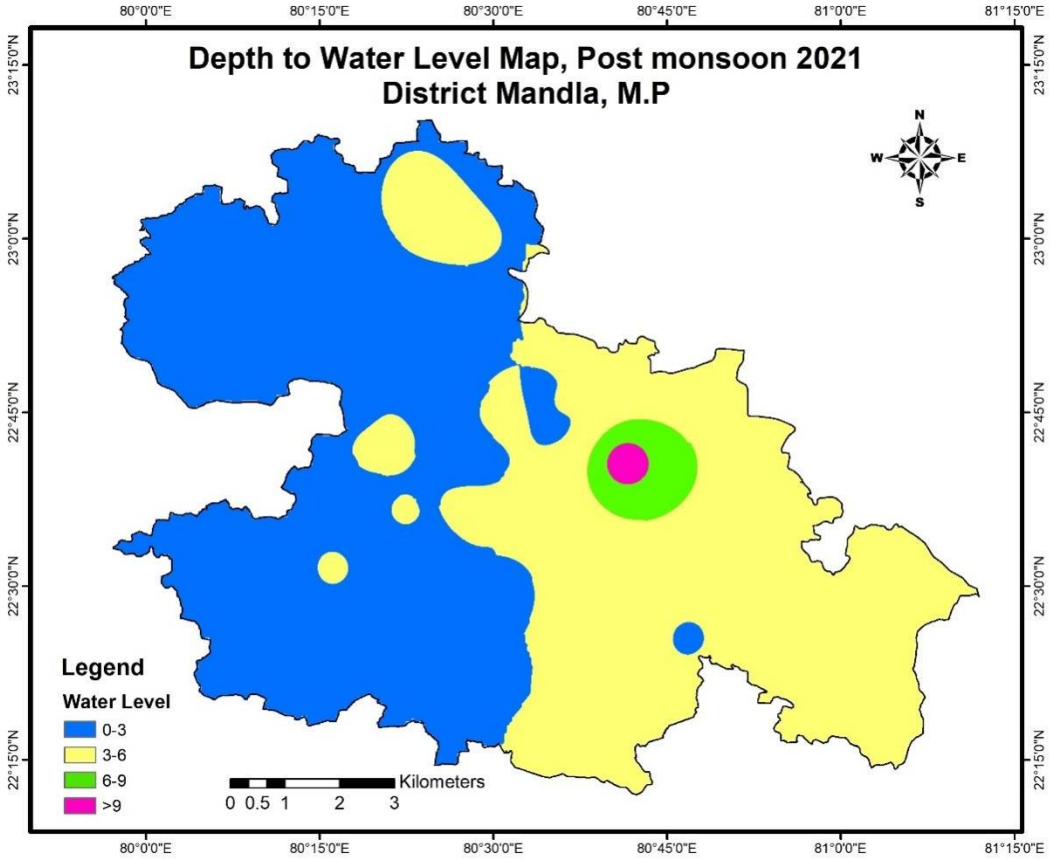

Fig. No. 13: Post monsoon water level map of Mandla district

3.2.3 Annual Water Level Fluctuation

The fluctuation between pre and post monsoon period water level for the year 2021 had calculated to determine the effect of rainfall on recharge. A general rise of water levels over the entire survey area is observed and average fluctuation of the area is 0-2 m recorded in 70% of the total study area the fluctuation range is 4-5 m higher level of water level fluctuation observed in central part(fig.no.14).

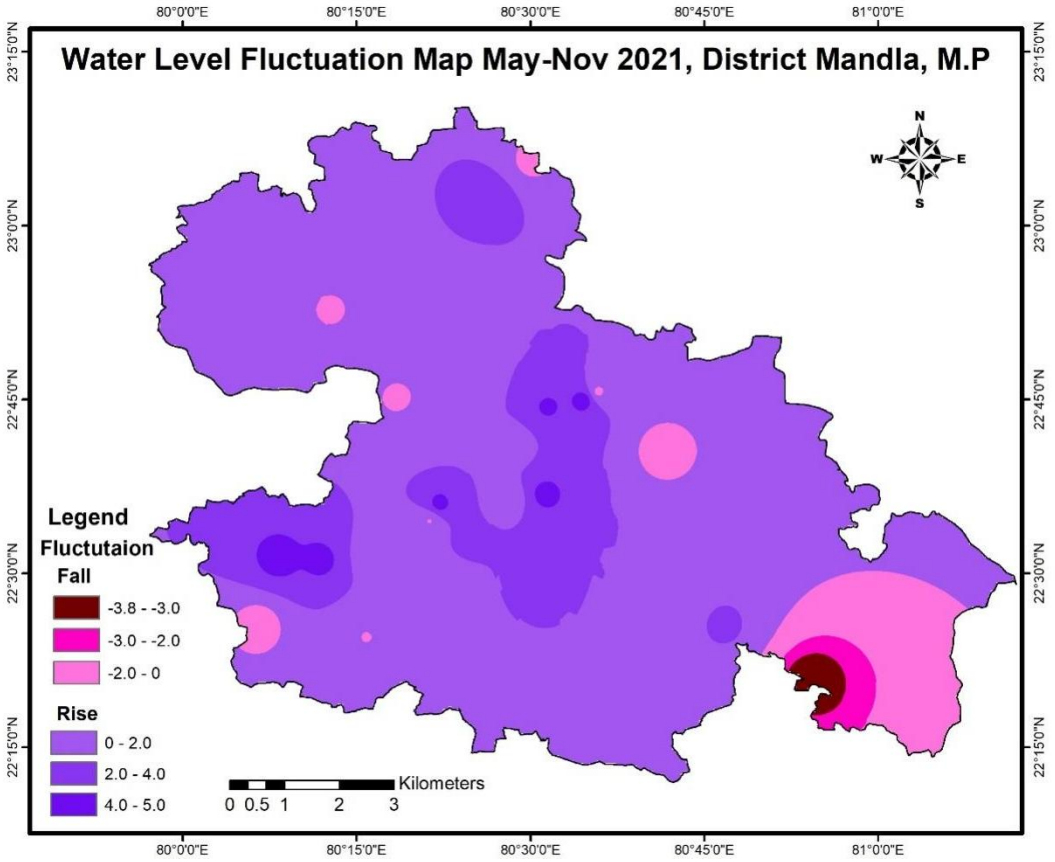

Fig. No. 14: Annual water level fluctuation map of Mandla district

3.2.4 Decadal Water Level Trend

The trend of the ground water levels of an area over a period of time reflects the behaviour of ground water over time. In order to understand the long trend water level trend in Mandla district, Decadal water level fluctuation map and hydrographs of Mandla district were analysed. The Decadal water level trend map (2010-21) shows both falling and rising trend in the district (fig.no.15&16). The decadal water level trends indicates that pre monsoon water levels are showing rise in major part of the district and the post monsoon water levels are declining in Bicchiya, Gughri and parts of Mawai blocks. This indicates that during monsoon period, due to the geomorphological and hydrogeological setup, natural recharge to ground water in Mandla district is taking place in a slow rate. It may also caused due to the extraction of groundwater for irrigation and other uses during post monsoon.

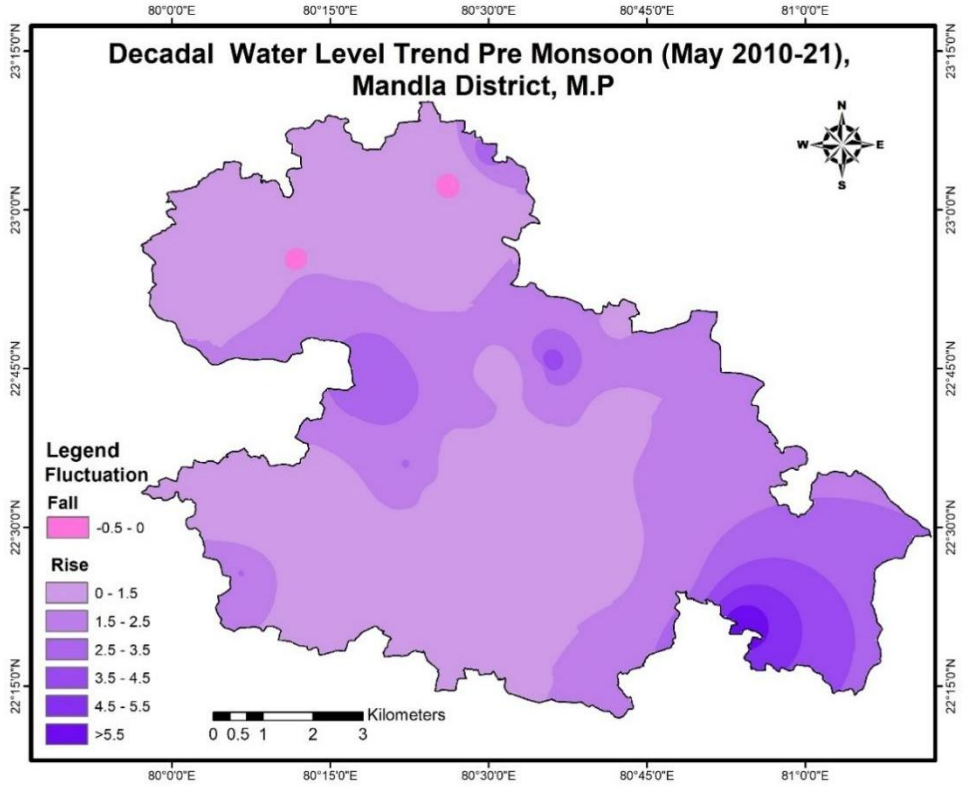

Fig. No.15: Decadal Water Level Trend Map (Premonsoon) of Mandla district

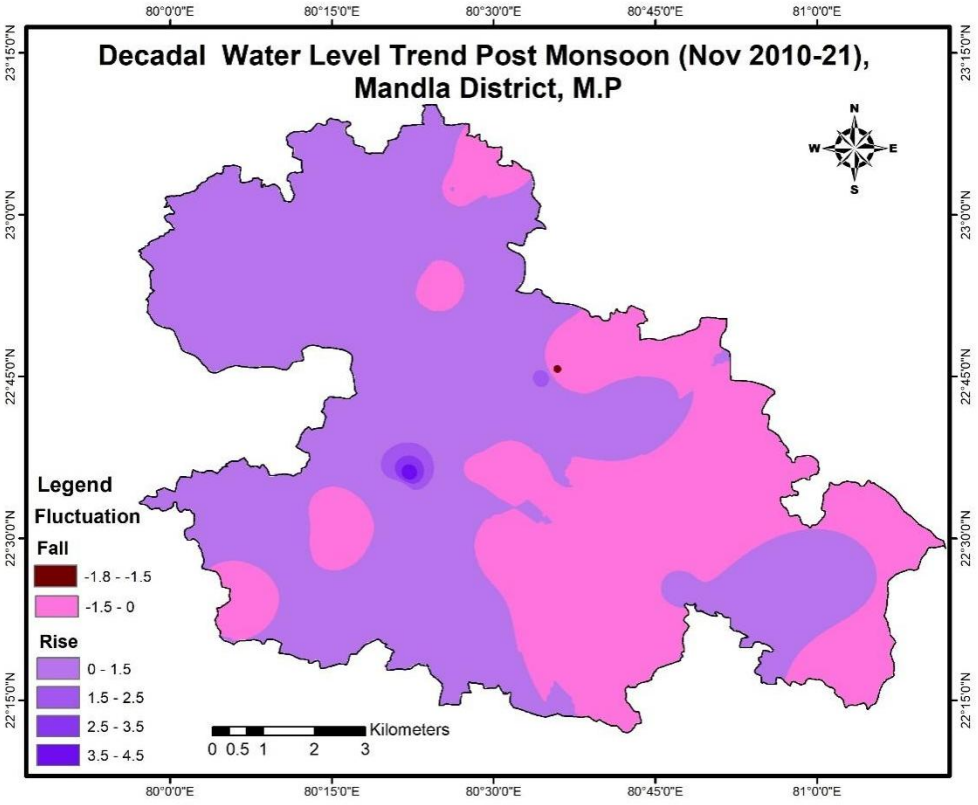

Fig. No.16 Decadal Water Level trend map (post monsoon) of Mandla district

Hydrograph monitored by central ground water board in the study area, it is observed that over a period of last 10 years (2011-21) that the post monsoon levels have declining in the district in three blocks namely Bichhiya, Bijadandi and Ghugri. Hydrographs of Mandla district are given in fig.no. 17 to 24.

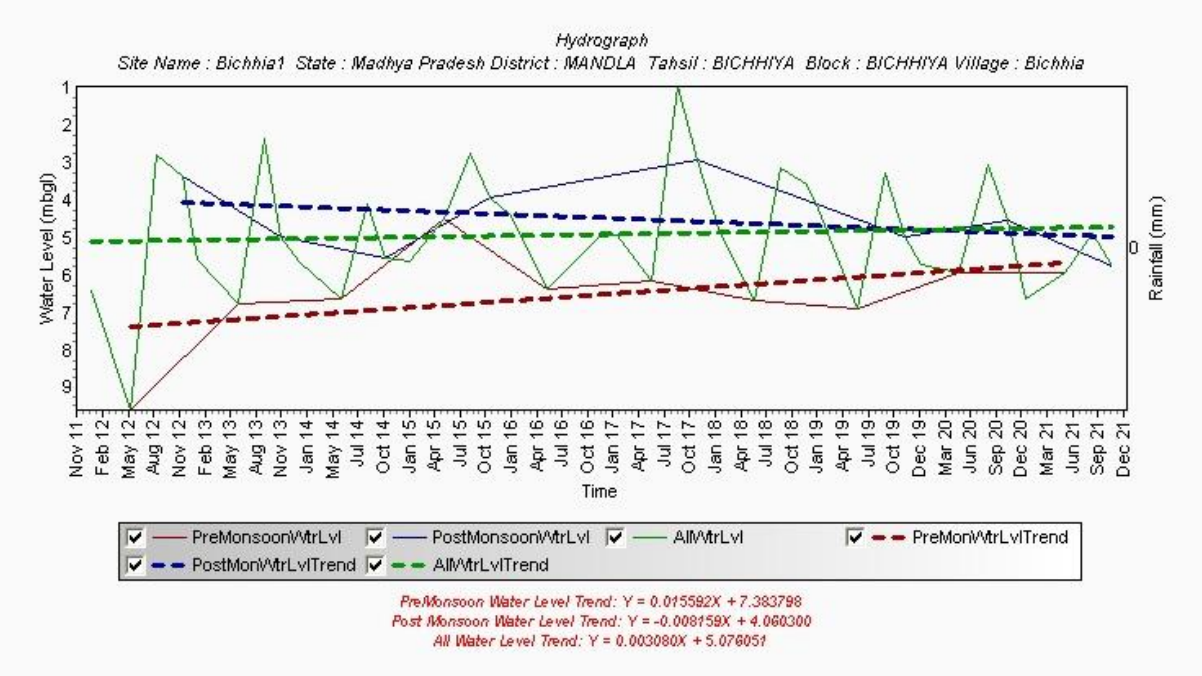

Fig. No. 17: Hydrograph of Bichhiya dug well, Bicchiya Block

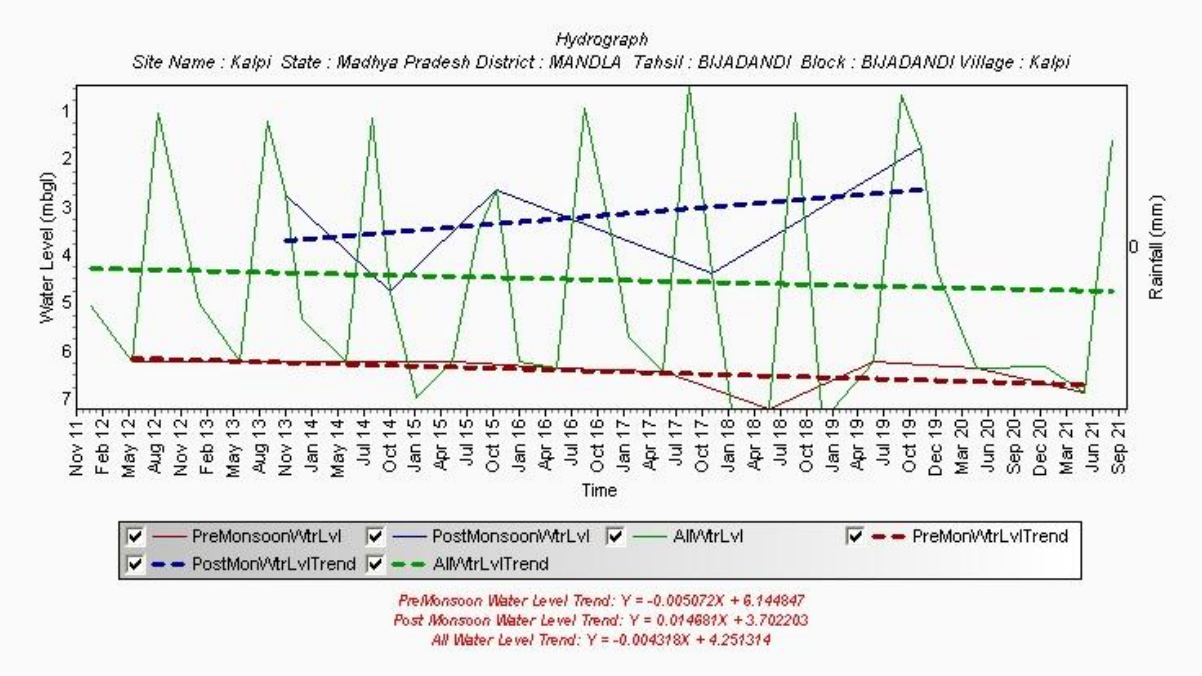

Fig. No. 18: Hydrograph of Kalpi dug well, Bijadandi Block

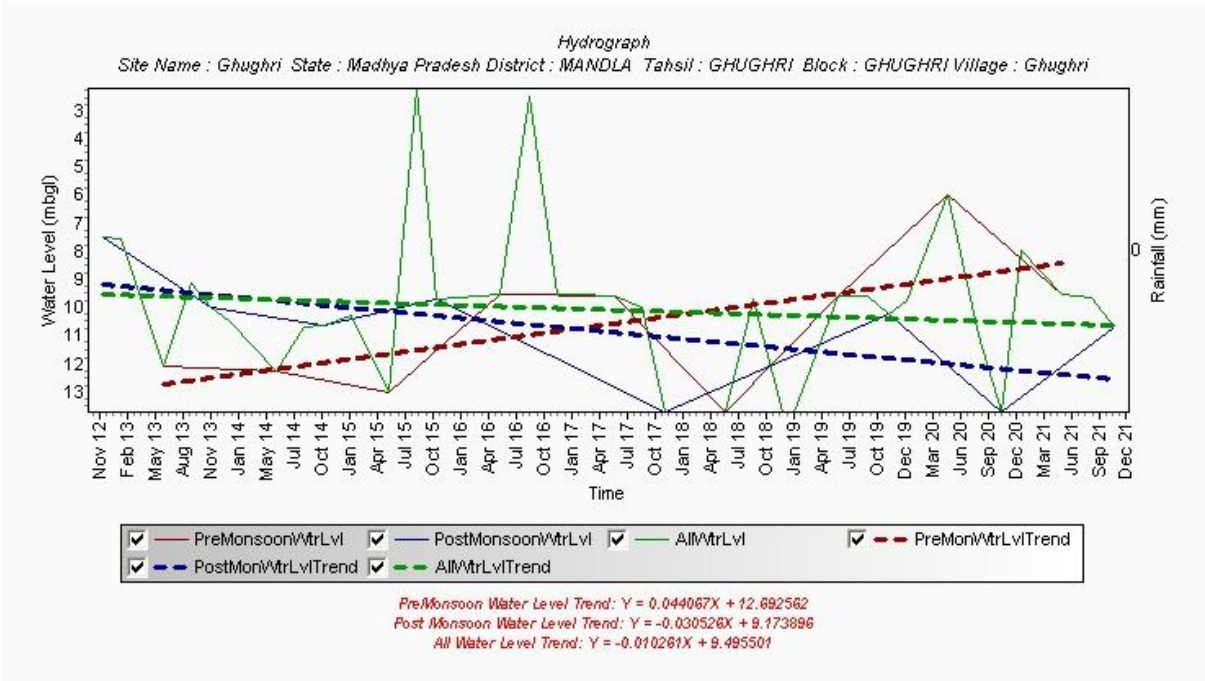

Fig. No. 19: Hydrograph of Ghugri dug well, Ghugri Block

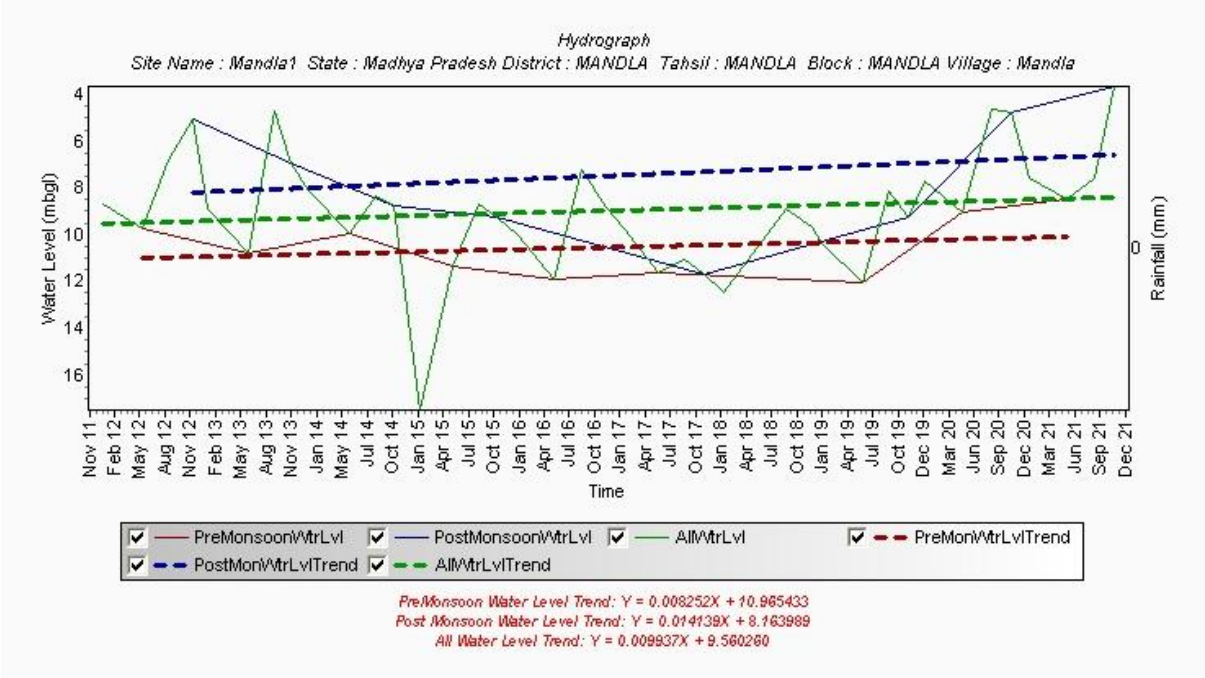

Fig. No. 20: Hydrograph of Mandla dug well, Mandla Block

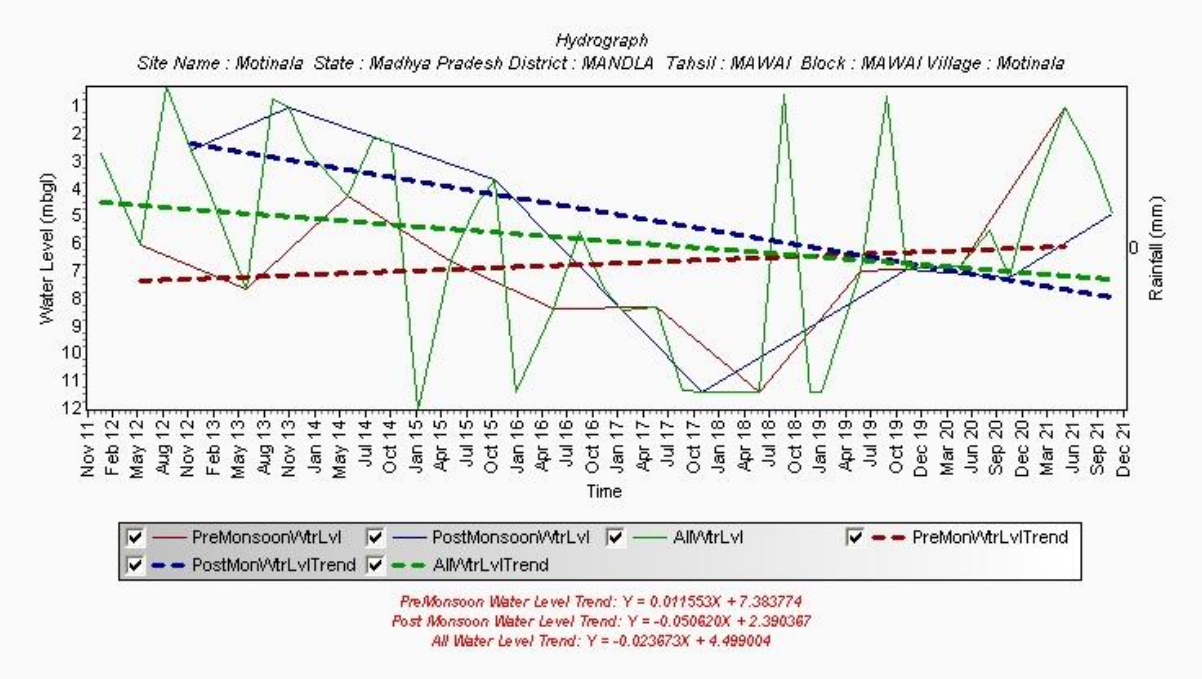

Fig. No. 21: Hydrograph of Monitola dug well, Mawai Block

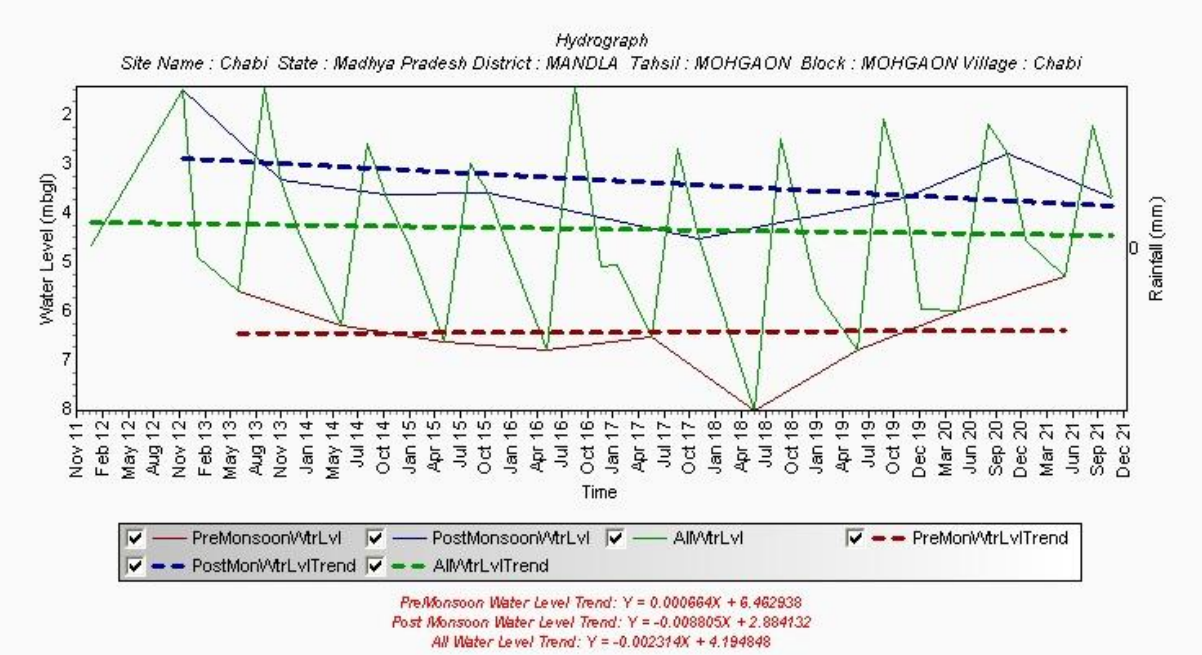

Fig. No. 22: Hydrograph of Chabi dug well, Mohgaon Block

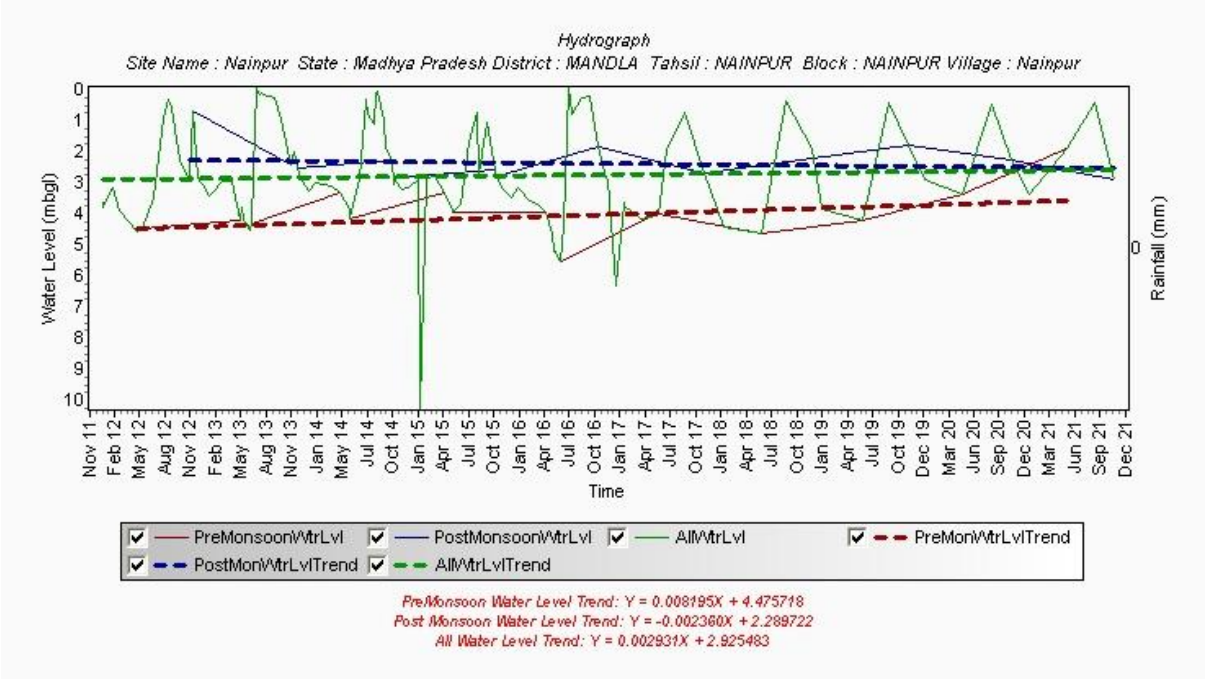

Fig. No. 23: Hydrograph of Nainpur dug well, Nainpur Block

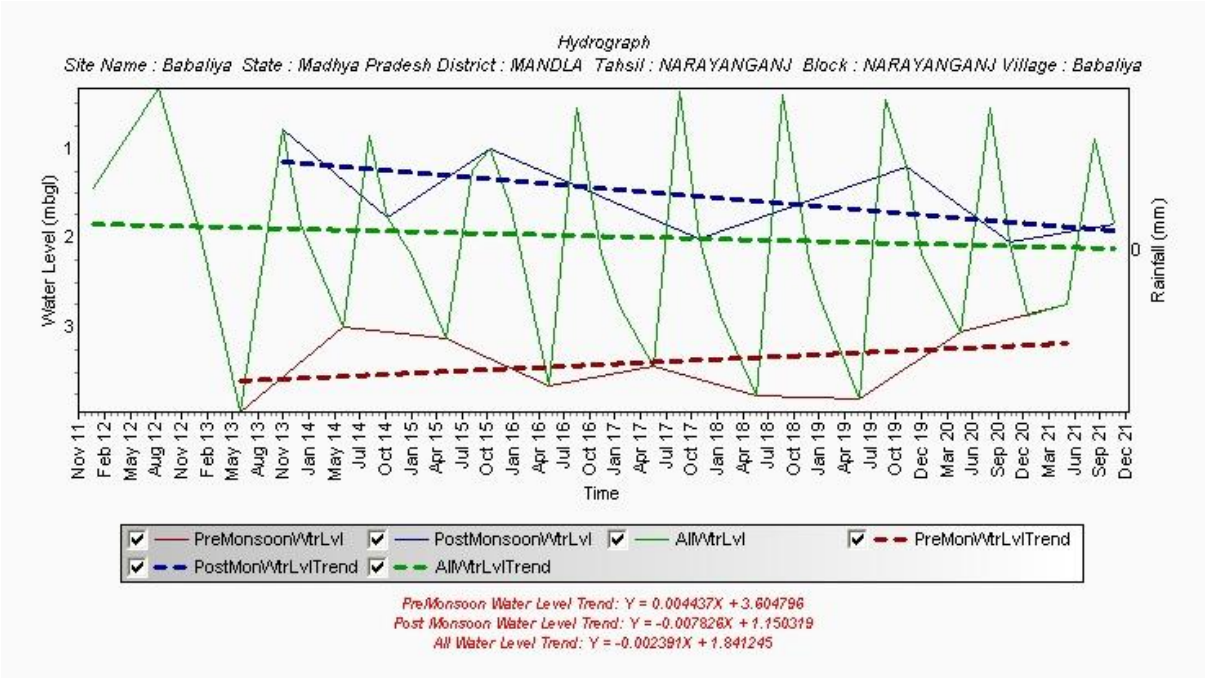

Fig. No. 24: Hydrograph of Babaliya dug well, Narayanganj Block

3.3 Hydro chemical Data Interpretation

3.3.1 Quality of Ground Water for Drinking Purpose:

The ground water samples from Mandla district have varied range of pH from 7.08 to 8.40. 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 Manikpur (8.40). The pH of ground water can be assessed as neutral to slightly alkaline in nature. The electrical conductivity of ground water samples in Mandla district varies from 310 to 1513 µS/cm at 25°C. In the district, 26 (89.7%) locations of sample show EC less than 1000 µS/cm while 2 (10.3%) locations of sample show EC in between 1000 to 1500 µS/cm from Kudomali New (1007) and Mandla (1513 µS/cm) villages. So, overall ground water quality of Mandla district is good to saline in nature in few pockets of the districts.

The fluoride concentration in Mandla district lies in between 0.04 to 1.18 mg/l, which represent that all the samples are within the permissible limit i.e. 1.5 mg/l of BIS standard. The maximum concentration of fluoride has been observed in the dug well of Manikpur village i.e. 1.18 mg/l.

The nitrate concentration in the Mandla districts ranges in between 1 to 104 mg/l. In the district, 13.8% samples have nitrate concentration more than the acceptable limit of 45 mg/l, while rest 86.2% samples have concentration less than acceptable limit. Highest concentration of nitrate has been recorded in the village of Babaliya (104 mg/l).

The total hardness in the ground water of the districts ranges between 20 to 505 mg/l. In the district, all the ground water samples recorded total hardness within the BIS permissible limit of 600 mg/l. The maximum concentration of total hardness has been observed in the village of Mandla i.e. 505 mg/l. Chemical data is given as annexure 4.

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

In the district; piper diagram shows that the samples are Calcium-Bicarbonate type (temporary hardness) and Mixed type types of water (fig.no.25).

3.3.2 Quality of Ground Water for Irrigation Purpose:

The classification of water for irrigation purpose, it is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. The chemical data of all the water samples from Mandla district is plotted on U.S. Salinity Laboratory diagram (fig.no.26).

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

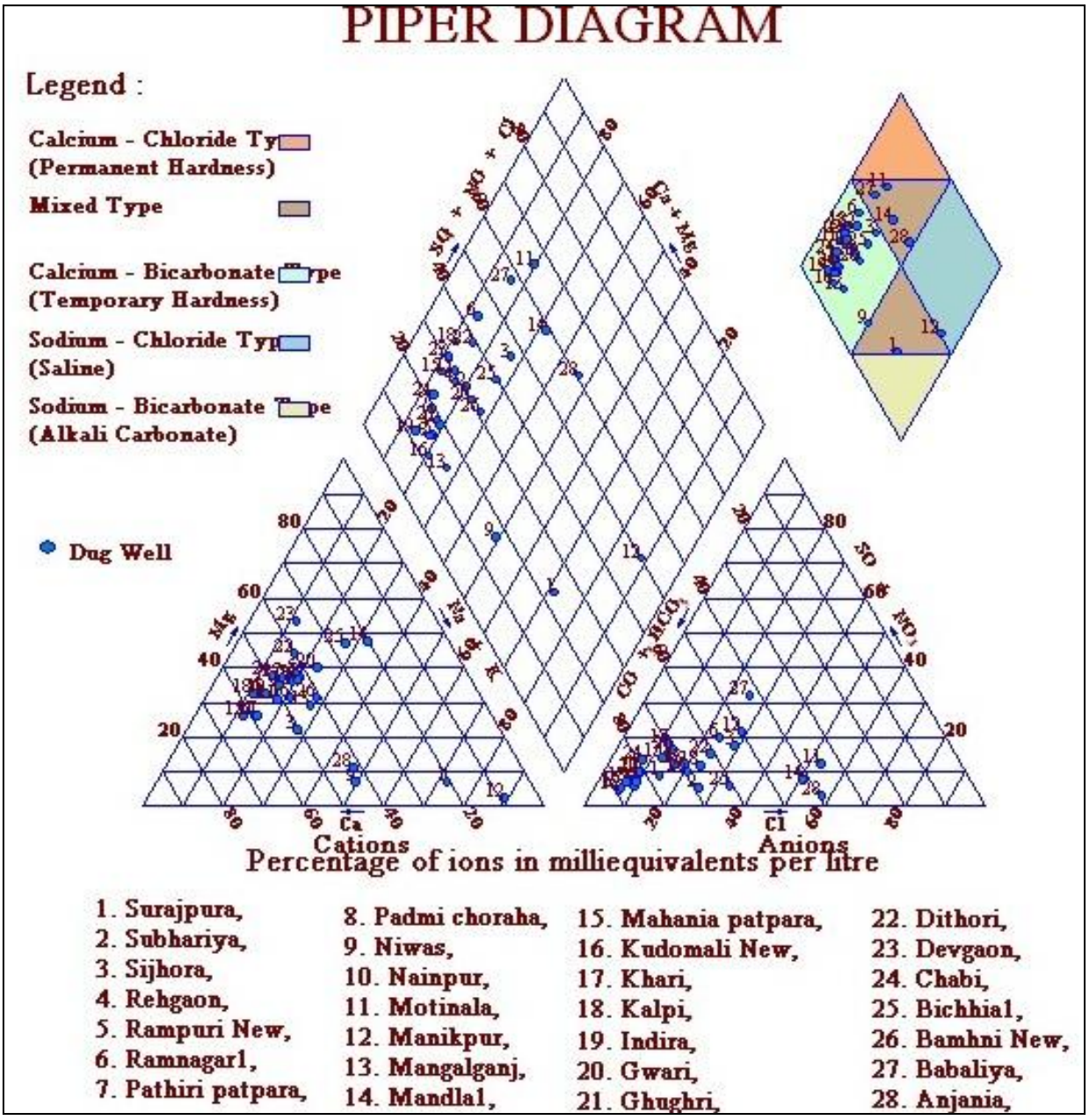

Fig.No.25: Piper Diagram representing classification of water samples collected from National Hydrograph Stations, Mandla District, Madhya Pradesh

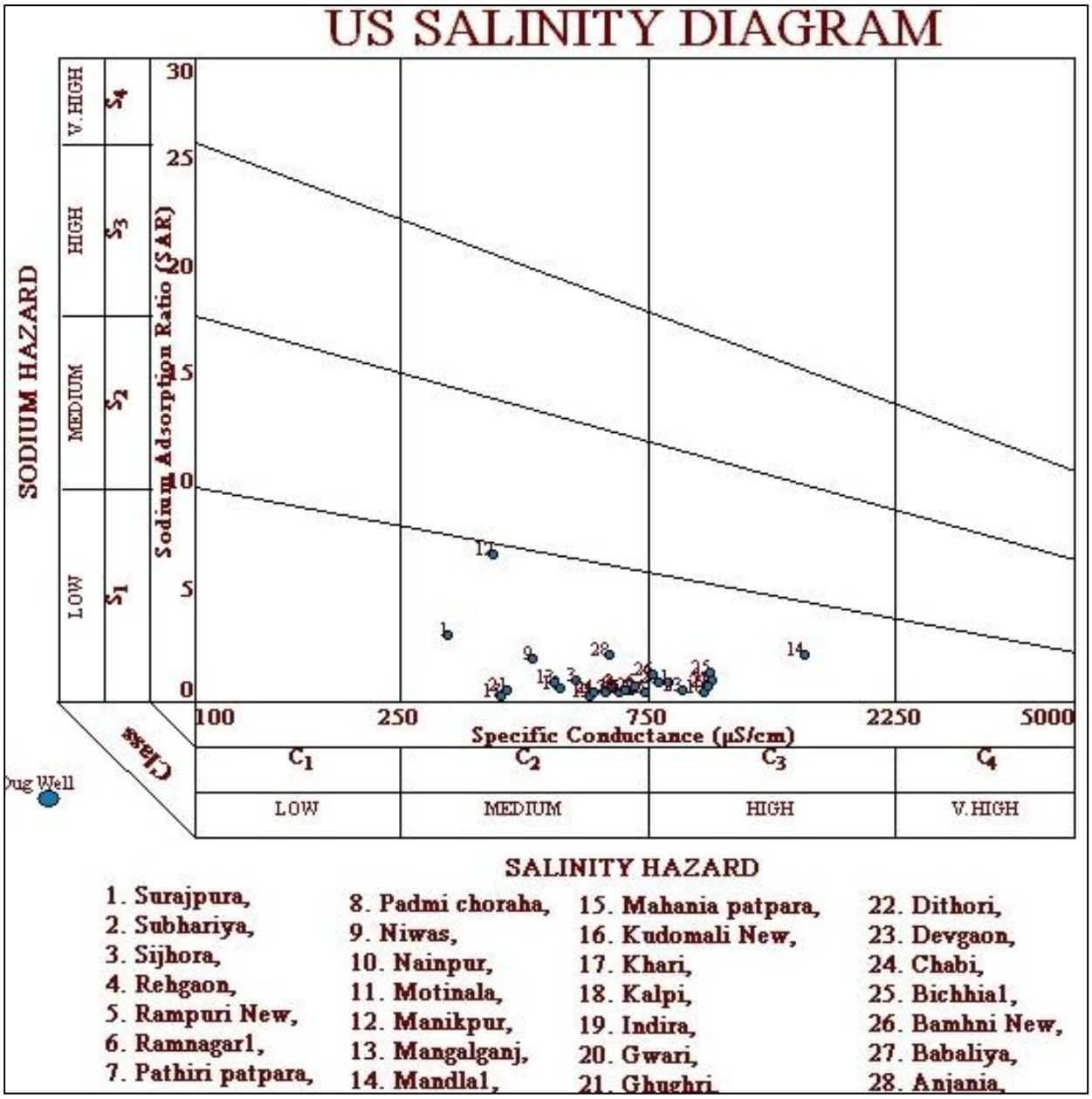

Fig.No.26: US Salinity Diagram for water samples collected from National Hydrograph Stations of Mandla District, Madhya Pradesh

3.4 Three-Dimensional and 2- Dimensional Aquifer model and Sections

Aquifer maps (3D), and 2-D aquifer sections had been prepared for the entire district using Rockworks software based on the borehole data for understanding aquifer disposition in subsurface which can be used for planning and construction of artificial recharge structures. The 3D aquifer model and block wise sections prepared are given (fig no. 27, 28,29 &30).

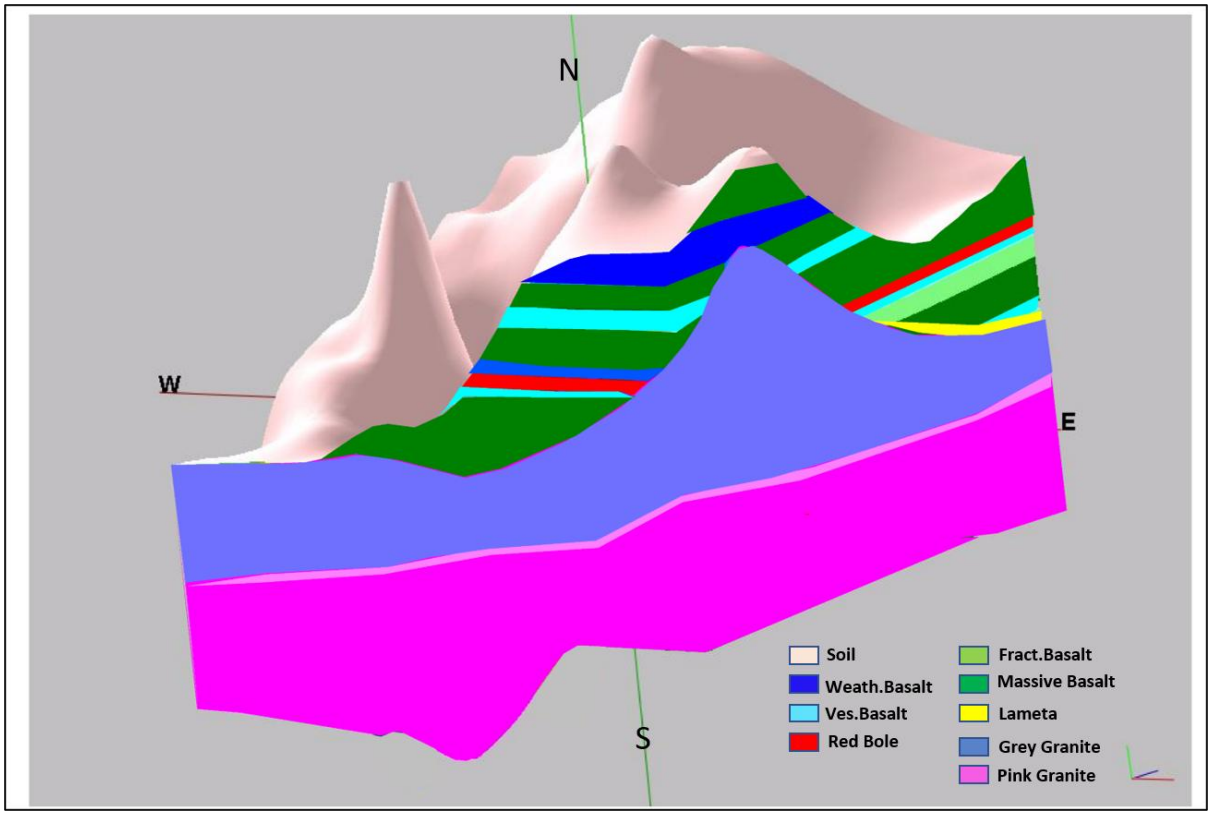

Fig. No.27: 3-Dimensional Aquifer model of Mandla district

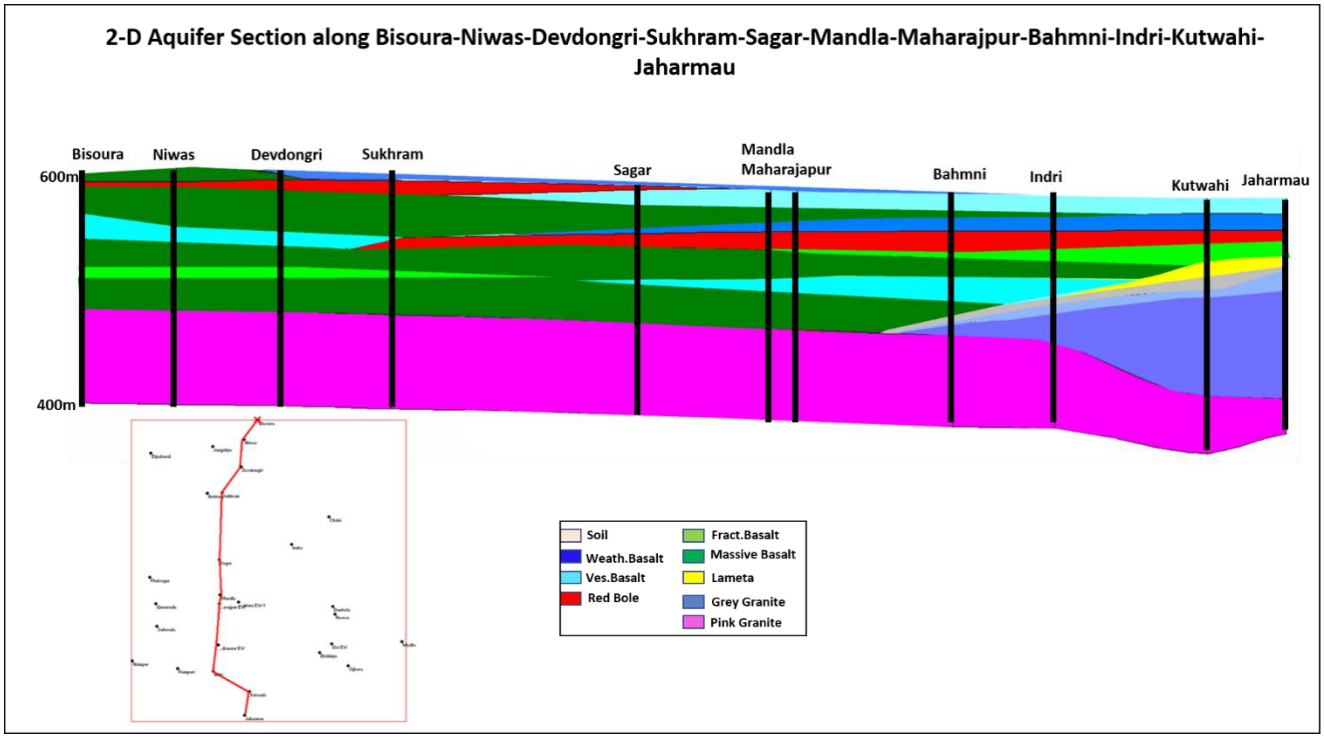

Fig. No.28: 2-D Aquifer section of Mandla district along Bisoura-Kutwahi

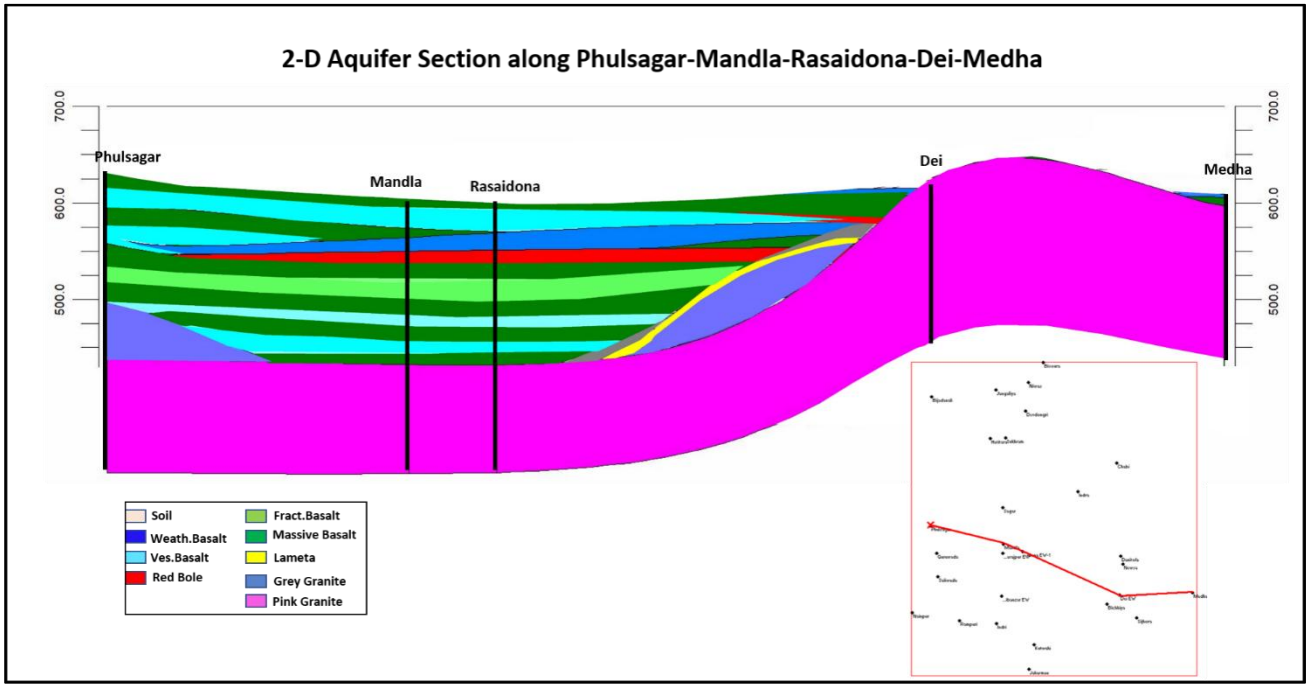

Fig. No.29: 2-D Aquifer section of Mandla district along Phulsagar-Medha

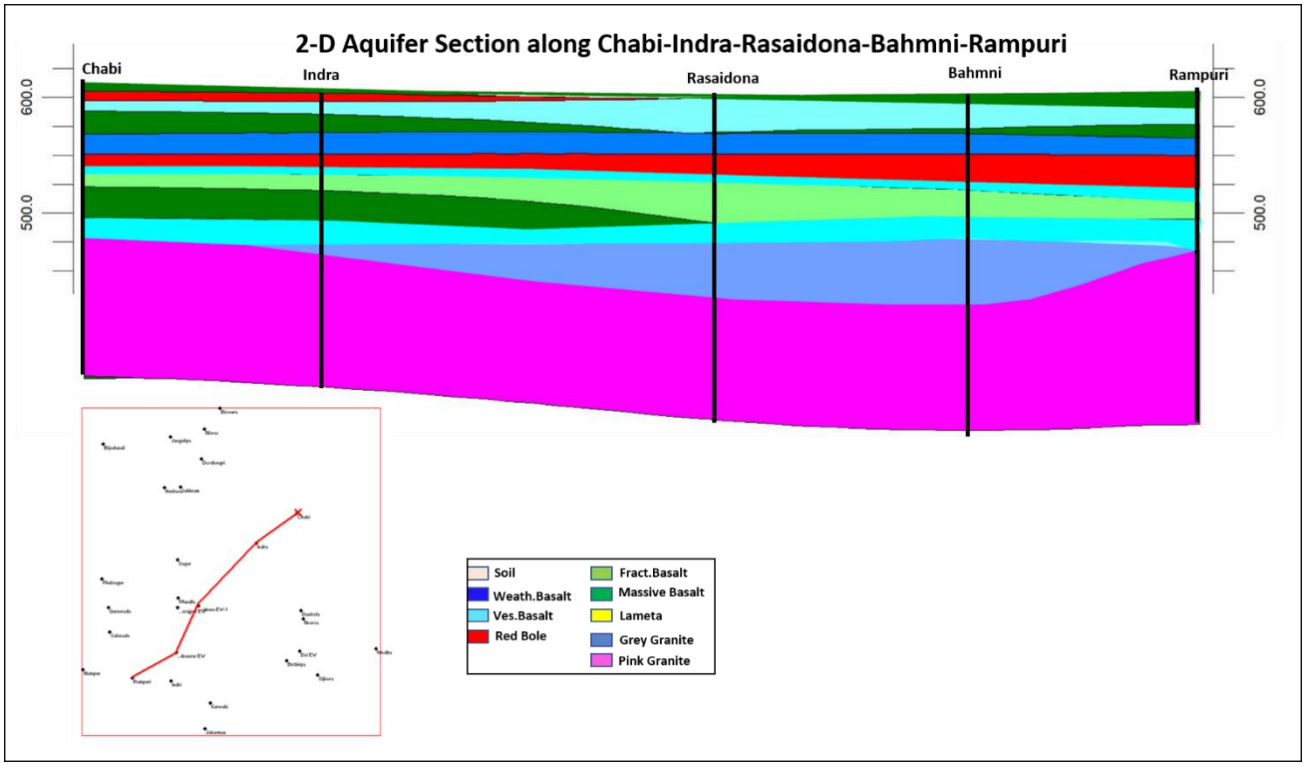

Fig. No.30: 2-D Aquifer section of Mandla district along Chabi-Rampuri

CHAPTER 4
GROUNDWATER RESOURCES

4.1 Groundwater Resources of Mandla district

4.1.1 Annual Extractable Groundwater Resources in Mandla district

The block wise groundwater resources is estimated for Mandla district as per GEC 2015. Major source of recharge is rainfall and is calculated using rainfall infiltration factor method and water level fluctuation methods. The unaccounted natural discharge through river and nallas have been calculated by multiplying the factor 0.05 by total annual recharge and net ground water availability for command and non-command area have been calculated by subtracting the unaccounted natural discharge from annual total ground water recharge. The block wise stage of extraction of groundwater is calculated in percentage by dividing current annual gross ground water draft by net ground water availability in command and non-command area based on long term water level trend each block and has been categorized (fig.no.31). The results (as on March 2020) are given in table 18 below:

Table 18: Dynamic groundwater resources as per GWRE March 2020

Si. No.	Assessment Unit	Annual Extractable Ground Water Recharge (Ham)	Existing Gross Ground Water Draft for Irrigation in Ham	Existing Gross Ground Water Draft for Domestic & Industrial Water supply in Ham	Existing Gross Ground Water Draft for All Uses in Ham (11+12)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization
1	MANDLA	7157.88	911.25	440.1243	1351.38	488.16	5758.46	18.88	**safe**
2	NIWAS	2077.52	686.88	162.44544	849.33	180.17	1210.47	40.88	**safe**
3	MAWAI	4246.34	936.36	251.16672	1187.53	278.57	3031.41	27.97	**safe**
4	MOHGAON	2614.23	1051.38	197.66064	1249.04	219.23	1343.62	47.78	**safe**
5	NARAYANGANJ	4942.61	714.42	218.23569	932.66	242.05	3986.14	18.87	**safe**
6	BIJADNNDI	6721.56	220.32	192.09585	412.41	213.06	6288.19	6.14	**safe**
7	NAINPUR	7442.12	1007.91	342.72186	1350.63	380.13	6054.08	18.15	**safe**
8	BICHHIYA	13523.96	1132.65	379.52919	1512.18	420.94	11970.37	11.18	**safe**
9	GHUGHRI	10517.93	247.05	241.79571	488.84	268.18	10002.71	4.65	**safe**
		59244.15	**6908.22**	**2425.78**	**9334**	**2690.49**	**49645.45**	**15.76**	**Safe**

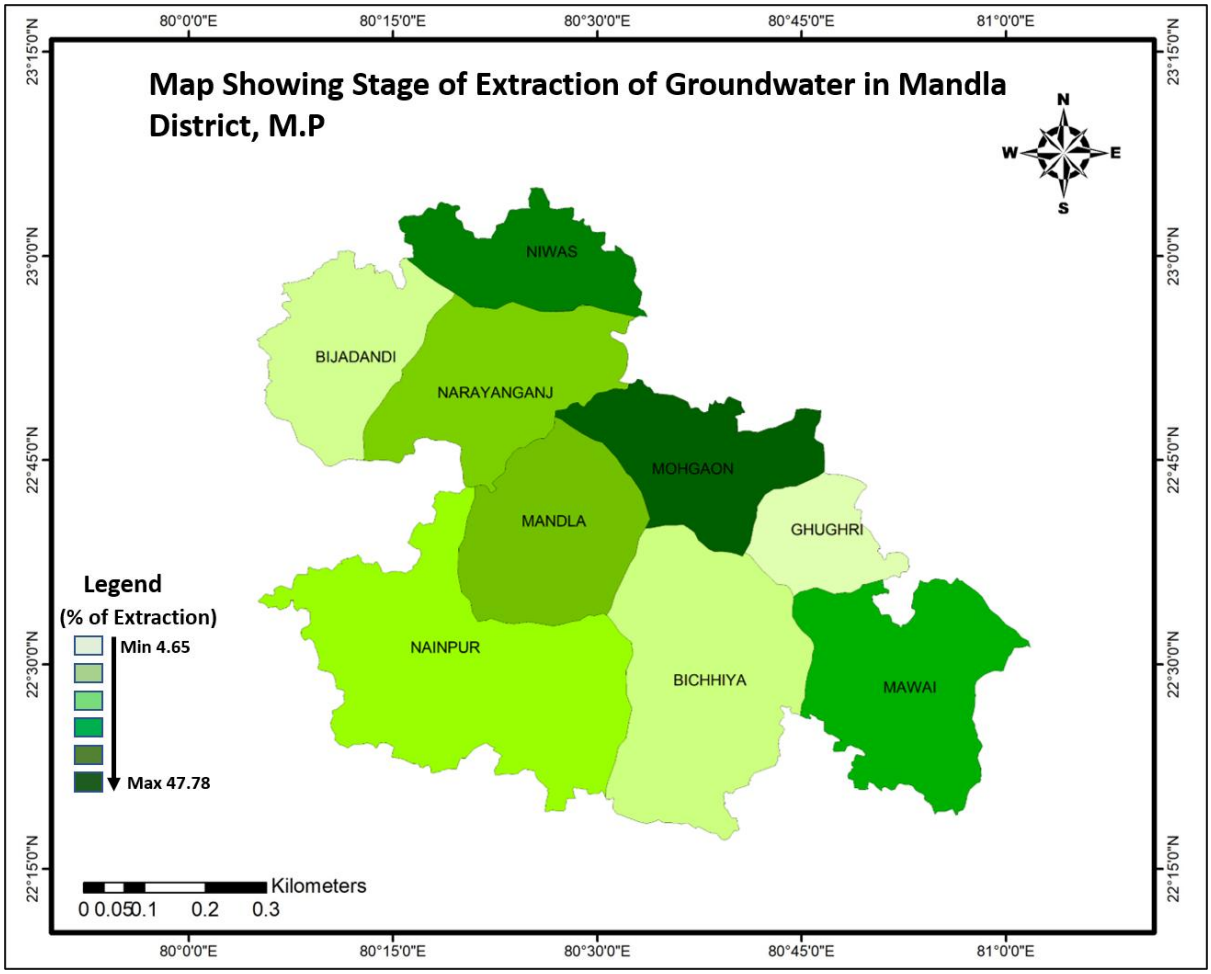

Fig. No.31: Map showing stage of extraction of groundwater of Mandla district as on March 2020

As a part of NAQUIM project 2020-21, groundwater resources of dynamic and static aquifers were calculated using water level fluctuation methods draft is calculated using unit draft method for each block in Mandla district as given in the tables 19-22 below.

Table19: Static Groundwater resources of 1st aquifer in Mandla district

Shallow Aquifer											
	Unit	**BICHHIYA**	**BIJADANDI**	**GUGHRI**	**MANDLA**	**MAWAI**	**MOHGAON**	**NAINPUR**	**NARAYANGANJ**	**NIWAS**	**TOTAL**
Recharge worthy Area (A)	Sq km	879.2	608.8	880.8	493.6	1170.4	327.8	638.5	352	388.8	**5739.9**
Premonsoon (average) depth to water level	m	6.69	4.63	10.58	6.6	5.46	6.72	4.84	4.03	5.01	
Av. depth of Dug well	m	10.32	6.95	13.5	10.6	12.5	10.5	9.4	6.9	8.5	
Specific yield (Sy)%	Fraction	0.02	0.02	0.02	0.02	0.015	0.02	0.02	0.02	0.02	
Saturated thickness of aquifer (ST)	m	3.63	2.32	2.92	4	7.04	3.78	4.56	2.87	3.49	
Resource (A * Sy * ST)	**MCM**	**63.8**	**28.2**	**51.4**	**39.5**	**123.6**	**24.8**	**58.2**	**20.2**	**27.1**	**436.96**

Table 20: Static Groundwater resources of 2nd aquifer in Mandla district

Static Resources/In-storage											
BLOCK		**BICHHIYA**	**BIJADANDI**	**GUGHRI**	**MANDLA**	**MAWAI**	**MOHGAON**	**NAINPUR**	**NARAYANGANJ**	**NIWAS**	**TOTAL**
Recharge worthy Area(A)	Sq km	879.2	608.8	880.8	493.6	1170.4	327.8	638.5	352	388.8	**5739.9**
Thickness of fracture in deeper aquifer (ST)	m	4.5	9.3	5.1	9.3	4.3	3.1	9.5	4.7	4.6	
Specific yield (Sy)%	Fraction	0.02	0.02	0.02	0.02	0.015	0.02	0.02	0.02	0.02	
Resource (A * Sy * ST)	**MCM**	**79.1**	**113.2**	**89.8**	**91.8**	**75.5**	**20.3**	**121.3**	**33.1**	**35.8**	**660.0**

Table 21: Total Groundwater Resources of Mandla district

Groundwater Resources										
	BICHHIYA	**BIJADANDI**	**GUGHRI**	**MANDLA**	**MAWAI**	**MOHGAON**	**NAINPUR**	**NARAYANGANJ**	**NIWAS**	**TOTAL**
First Aquifer										
Dynamic Resources (MCM) (GWRA 2020)	135.24	67.22	105.18	71.58	42.46	26.14	74.42	49.43	20.78	**592.44**
Static Resources (MCM)	63.8	28.2	51.4	39.5	123.6	24.8	58.2	20.2	27.1	436.96
Total Resources (MCM)	**199.07**	**95.46**	**156.62**	**111.07**	**166.06**	**50.92**	**132.65**	**69.63**	**47.91**	**1029.40**
Utilizable Resources (MCM)	**129.40**	**62.05**	**101.80**	**72.19**	**107.94**	**33.10**	**86.22**	**45.26**	**31.14**	**669.11**
Irrigation	6.80	1.32	1.48	5.47	5.62	6.31	6.05	4.29	4.12	**41.45**
Domestic + Industries	3.80	1.92	2.42	4.40	2.51	1.98	3.43	2.18	1.62	**24.26**
GW Draft (MCM)	10.59	3.24	3.90	9.87	8.13	8.28	9.47	6.47	5.75	65.71
Second Aquifer										
Static Resources (MCM)	**79.1**	**113.2**	**89.8**	**91.8**	**75.5**	**20.3**	**121.3**	**33.1**	**35.8**	**660.0**
GW Draft (MCM	4.53	0.88	0.99	3.65	3.75	4.21	4.03	2.86	2.75	27.63
Total GW Resources (MCM)	**208.52**	**175.29**	**191.64**	**164.00**	**183.43**	**53.42**	**207.54**	**78.35**	**66.91**	**1329.11**
Gross Ground Water Draft for irrigation (MCM)	11.33	2.20	2.47	9.11	9.36	10.51	10.08	7.14	6.87	69.08
Gross Ground Water Draft (MCM)	15.12	4.12	4.89	13.51	11.88	12.49	13.51	9.33	8.49	93.34

CHAPTER 5
GROUNDWATER RELATED ISSUES

5.1 Groundwater Contamination

5.1.1 Higher concentration of Fluoride in groundwater

Higher than permissible limits of Fluoride in groundwater in Mandla district ranges from 1.5 to 24.8 ppm (fig.no.32 &33). Both shallow aquifer and deep aquifers are affected fluoride contamination which can cause dental and skeletal fluorosis in humans as well as livestock. Geogenic problem of higher fluoride concentration have affected area of 1444 Sq km, which covers parts of block area of Mandala. Mohagon and Nainpur. There are 442 villages are being affected which is about 35.20 % of total 1255 villages. In the rural drinking water supply there are 6063 hand pump have been constructed, by PHED out of which 16.55% hand pump having fluoride. The well drilling and construction is primarily aspects to have fluoride well Based on the integrated ground water development and Management studies of Mandla area it is found that geogenic cause of fluoride is due particular nature of basaltic lava flows and granite.

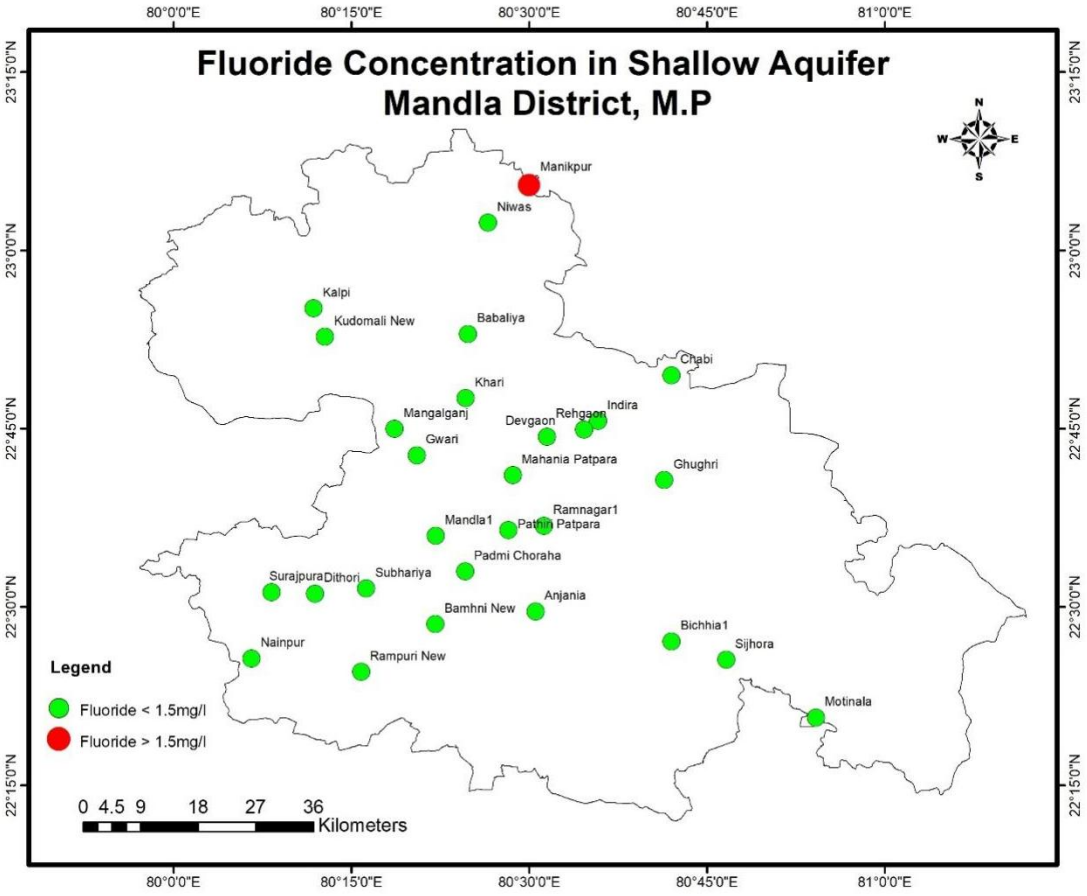

Fig. No.32: Map showing Fluoride con. in groundwater in shallow aquifer of Mandla district

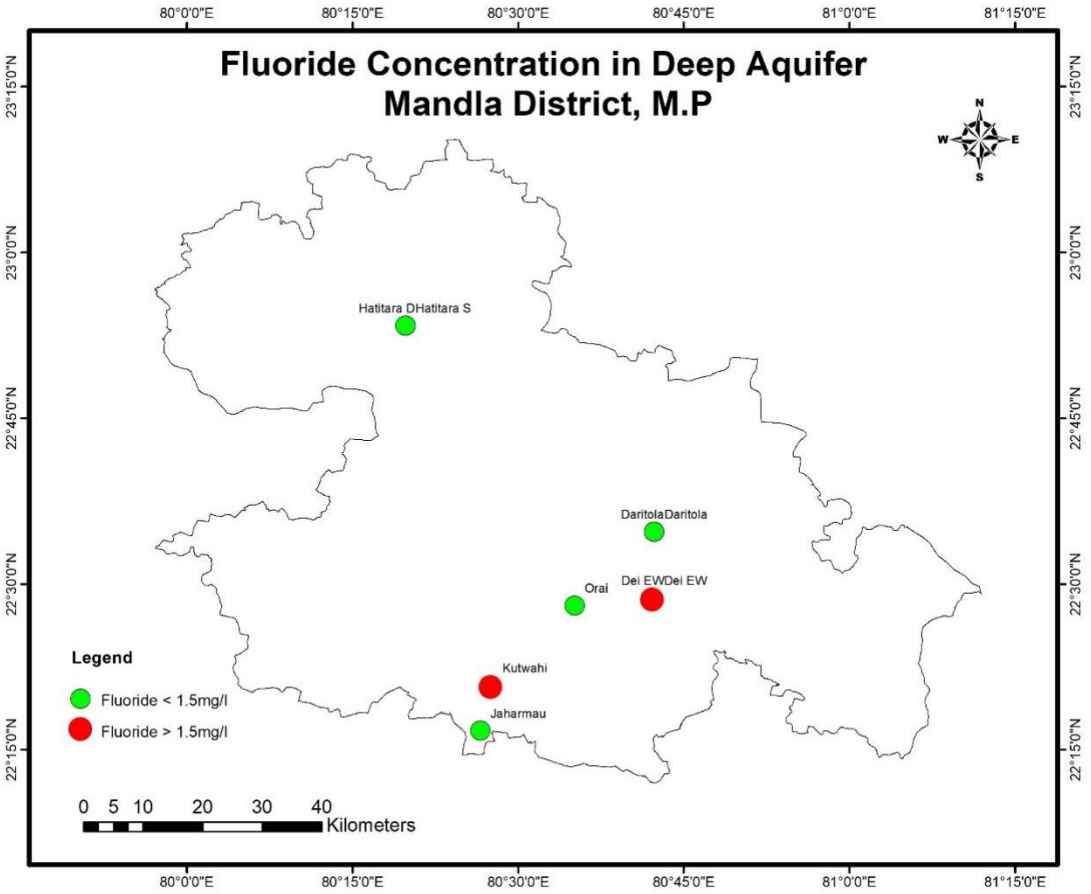

Fig. No.33: Map showing Fluoride con. in groundwater in deep aquifer of Mandla district

5.2 Scope for Additional Groundwater Development

In Mandla district, all the blocks fall under safe category and stage of groundwater extraction is poor in blocks including Gughri (5%), Bijadnadi (6%), Bicchiya (12%) and the overall stage of extraction is 15.376%. The maximum stage of groundwater extraction as per GWRE 2020 is 48%, which is in Mohgaon block. In view of prevailing hydrogeological conditions, there is scope for further development of groundwater in all 9 blocks which would help in the agricultural and industrial development of the district, leading to the overall development of the district. This issue needs to be addressed and additional groundwater development needs to be undertaken in the district through various schemes of Central and State Government like Jal Jeevan Mission, PMKSY (GW) etc.

CHAPTER 6
GROUNDWATER MANAGEMENT STRATEGIES AND AQUIFER MANAGEMENT PLAN

6.1 Groundwater Resources Management Plan

Based on the aquifer disposition, available resources and storage space, a management plan had been developed for each of the blocks in the district by proposing suitable methods including additional draft, additional area for irrigation etc. for proper utilization of available resources. As per the resource estimation 2020, groundwater available for future irrigation is 26.9mcm, pre and post monsoon water levels are shallow and stage of groundwater extraction ranges from 4.65% to 47.78%. Overall stage of groundwater extraction of the district is 15% which indicates that groundwater can be developed in future for sustainable development of the district.

6.2 Calculation and distribution of additional draft

In each block, additional draft is proposed for sustainable development of groundwater. Based on existing annual extractable groundwater resources available in each block, additional draft is calculated so that the stage of groundwater extraction may increase to 50-55%.
50% of the total additional draft calculated is proposed for domestic and industrial purpose and the remaining 50% is proposed for utilising for agriculture.

6.2.1 Distribution of additional draft for domestic and industrial purpose

50% of this additional draft proposed may be utilized for domestic and industrial uses. Hydrogeologically, major part of the district is covered by basaltic aquifer. Hence 70% of the draft is proposed to be extracted from dug wells (shallow aquifer). The remaining 30% is proposed to be extracted from additional bore wells constructed in area underlained by Shale, limestone, Granite etc (deep aquifer). Number of additional dug well and bore well is calculated by dividing the draft proposed by unit draft during non-monsoon season of dug well and bore well in the block respectively.

6.2.2 Distribution of additional draft for agriculture

Being a tribal district, agricultural area utilised in Mandla district is comparatively less in Mandla district. Therefore, remaining 50% of additional draft proposed, may be utilised for agricultural purposes for economic development of the district. 60% of the draft proposed, may be utilised for cultivation of wheat. As per the Indian Council of Agricultural Research, average crop water requirement of wheat is 0.4 m. The additional area for cultivation of wheat is calculated based on this standard norm. 20% of the additional draft proposed may be utilized for cultivation summer crops including corn, coarse cereals, tomato, cucumber etc. The standard crop water requirement of these crops is assigned as 0.2 m. The remaining 20% of the draft proposed may be utilized for cultivation of short-term crops so that double/triple cropping can be practiced in the district. Water requirement of these crops varies from 0.2m to 0.4m as per ICAR. Based on this standard area for double/triple cropping is calculated for each block.

6.3 Management plan of Bichhiya block

Existing stage of groundwater extraction in Bicchiya block is 11.18%, total annual extractable groundwater resource available is 135.24 mcm. Gross groundwater draft for all uses from dynamic and static aquifer is 15.12 mcm. Based on the available data, management plan had been prepared for Bichhiya block. The proposed management plan prepared for Bicchiya block using the methodology discussed above is given in table no. 22.

Table 22: Proposed management plan for Bichhiya block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures for Domestic / Industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional draft proposed (40% of Annual Extractable GW) (mcm)
Bichhiya	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	18.93	8.11	29	5	16.23	5.41	5.41	40.57	18.03	13.52	54.1

In Bichhiya block, total additional draft proposed is 54.1mcm, which is 40% of annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 29 new dug wells (70%) and 5 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 40.57sq.km additional area which will utilise the 60% of additional draft, 16.23mcm. In the remaining area, 18.03 sq.km is proposed for summer crops which will utilise 20% of additional draft, 5.41mcm and 13.52 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 5.41 mcm.
After extraction of the additional groundwater, gross draft will be 66.22 mcm. Based on this, the projected stage of groundwater extraction calculated is 48.9% as given in table 23.

Table 23: Projected stage of extraction for Bichhiya block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
12.12	54.1	66.22	135.24	**11.18**	**48.9**

6.4 Management plan of Bijadandi block

Existing stage of groundwater extraction in Bijadandi is 6.14%, total annual extractable groundwater resource is 67.22mcm. Gross existing groundwater draft for all uses is 4.12 mcm. Based on the available data, management plan had been prepared for Bijadandi block as table 24 below.

Table 24: Proposed management plan for Bijadandi block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures for domestic/industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional draft proposed (45% of Annual Extractable GW) (mcm)
Bijadandi	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	10.59	4.54	16	4	9.07	3.02	3.02	22.69	10.08	7.56	30.25

In Bijadandi block, total additional draft proposed is 30.25 mcm, which is 45% of annual extractable groundwater. In this 50% is utilized for domestic and industrial purpose through 16 new dug wells (70%) and 4 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 22.69 sq.km additional area which will utilise the 60% of additional draft, 9.07 mcm. In the remaining area, 10.08 sq.km is proposed for summer crops which will utilise 20% of additional draft, 3.02 mcm and 7.56 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 3.02 mcm.

After extraction of the additional groundwater, gross draft will be 34.37 mcm. Based on this, the projected stage of groundwater extraction calculated is 51.1 % as given in table 25.

Table 25: Projected stage of extraction for Bijadandi block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
4.12	30.25	34.37	67.22	**6.14**	**51.1**

6.5 Management plan of Gughri block

The stage of groundwater extraction is 4.65%, total dynamic groundwater resource available is 105.18mcm. gross groundwater draft for all uses is 4.89mcm. Based on the available data, management plan had been prepared for Gughri block as given in table 26 below.

Table 26: Proposed management plan for Ghugri block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures for Domestic/Industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional draft proposed (40% of Annual Extractable GW) (mcm)
Gughri	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	14.73	6.31	23	6	12.62	4.21	4.21	31.55	14.02	10.52	42.07

In Gughri block, total additional draft proposed is 42.07mcm, which is 40% of annual extractable groundwater resources. In this 50% is utilized for domestic and industrial purpose through 23 new dug wells (70%) and 6 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 31.55 sq.km additional area which will utilise the 60% of additional draft, 12.62 mcm. In the remaining area, 14.02 sq.km is proposed for summer crops which will utilise 20% of additional draft, 4.21 mcm and 10.52 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 4.21 mcm.

After extraction of the additional groundwater, gross draft will be 49.69 mcm. Based on this, projected stage of groundwater extraction calculated is 44.5% as given in table 27 below.

Table 27: Projected stage of extraction for Gughri block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
4.89	42.07	46.96	105.18	**4.65**	**44.5**

6.6 Management plan of Mandla block

Existing stage of groundwater extraction is 18.88%, annual extractable groundwater resource available is 71.58 mcm. Gross groundwater draft for all uses is 13.51 mcm. Based on the available data, management plan had been prepared for Mandla block as given in table 29 below.

Table 28: Proposed management plan for Mandla block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures for Domestic/Industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional draf t proposed (30% of Annual Extractable GW) (mcm)
Mandla	**Dug Well**	**Bore Well**	**Dug well**	**Bore Well**	**Wheat**	**Summer Crops**	**Double/triple cropping**	**Wheat**	**Summer Crops**	**Double/triple cropping**	
	7.52	3.22	18	4	6.44	2.15	2.15	16.11	7.16	5.37	21.47

In Mandla block, total additional draft proposed is 21.47mcm, which is 30% of annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 18 new dug wells (70%) and 4 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 16.11sq.km additional area which will utilise the 60% of additional draft, 6.44 mcm. In the remaining area, 7.16 sq.km is proposed for summer crops which will utilise 20% of additional draft, 2.15 mcm and 5.37 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 2.15 mcm.

After extraction of the additional groundwater, gross draft will be 34.99 mcm. Based on this, projected stage of groundwater extraction calculated is 48.9% as given in table 29.

Table 29: Projected stage of extraction for Mandla block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
13.51	21.47	34.99	71.58	**18.88**	**48.9**

6.7 Management plan of Mawai block

Existing stage of groundwater extraction is 27.97%, total dynamic groundwater resource available is 42.46mcm. gross groundwater draft for all uses 11.88 mcm. Based on the available data, management plan had been prepared for Mawai block as given in table 31 below.

Table 30: Proposed management plan for Mawai block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional drat proposed (24% of Annual Extractable GW) (mcm)
Mawai	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	3.57	1.53	5	1	3.06	1.02	1.02	7.64	3.40	2.55	10.19

In Mawai block, total additional draft proposed is 10.19 mcm, which is 24% of annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 5 new dug wells (70%) and 1 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 7.64sq.km additional area which will utilise the 60% of additional draft, 3.06 mcm. In the remaining area, 3.40 sq.km is proposed for summer crops which will utilise 20% of additional draft, 1.02 mcm and 2.55 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 1.02 mcm.

After extraction of the additional groundwater, gross draft will be 22.07 mcm. Based on this, the projected stage of groundwater extraction calculated is 52% as given in table 31.

Table 31: Projected stage of extraction for Mawai block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
11.88	10.19	22.07	42.46	**27.97**	**52**

6.8 Management plan of Mohgaon block

Existing stage of groundwater extraction is 47.78%, total annual extractable groundwater resource available is 26.14mcm. Gross groundwater draft for all uses is 12.49 mcm. Based on the available data, management plan had been prepared for Mohgaon block as given in table 32 below.

Table 32: Proposed management plan for Bichhiya block

Block	Additional Draft Proposed through new abstraction structures for Domestic/ Industrial (mcm)		No. of Structures for Domestic/Industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional drat proposed (12% of Annual Extractable GW)
Mohgaon	**Dug Well**	**Bore Well**	**Dug well**	**Bore Well**	**Wheat**	**Summer Crops**	**Double/triple cropping**	**Wheat**	**Summer Crops**	**Double/triple cropping**	**(mcm)**
	1.10	0.47	2	0	0.94	0.31	0.31	2.35	1.05	0.78	3.14

In Mohgaon block, total additional draft proposed is 3.14 mcm, which is 12% of annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 2 new dug wells (70%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 2.35sq.km additional area which will utilise the 60% of additional draft, 0.94 mcm. In the remaining area, 1.05 sq.km is proposed for summer crops which will utilise 20% of additional draft, 0.31 mcm and 0.78 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 0.31 mcm.

After extraction of the additional groundwater, gross draft will be 15.63 mcm. Based on this, projected stage of groundwater extraction calculated is 59.8% as given in table 33.

Table 33: Projected stage of extraction for Mohgaon block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
12.49	3.14	15.63	26.14	**47.48**	**59.8**

6.8 Management plan of Nainpur block

Existing stage of groundwater extraction is 18.15%, annual extractable groundwater resource available is 74.42 mcm. Gross groundwater draft for all uses is 13.51 mcm. Based on the available data, management plan had been prepared for Nainpur block as given in table 34 below.

Table 34: Proposed management plan for Nainpur block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures		Additional Draft Proposed through irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional drat proposed (30% of Annual Extractable GW) (mcm)
Nainpur	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	7.81	3.35	12	4	6.70	2.23	2.23	16.74	7.44	5.58	22.33

In Nainpur block, total additional draft proposed is 22.33 mcm, which is 30% of annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 12 new dug wells (70%) and 4 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 16.74 sq.km additional area which will utilise the 60% of additional draft, 6.70 mcm. In the remaining area, 7.44 sq.km is proposed for summer crops which will utilise 20% of additional draft, 2.23 mcm and 5.58 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 2.23mcm.

After extraction of the additional groundwater, gross draft will be 35.83 mcm. Based on this, projected stage of groundwater extraction calculated is 48.1% as given in table 35.

Table 35: Projected stage of extraction for Nainpur block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
13.51	22.33	35.83	74.42	**18.15**	**48.1**

6.9 Management plan of Narayanganj block

Existing stage of groundwater extraction is 18.87%, annual extractable groundwater resource available is 49.43 mcm. Gross groundwater draft for all uses is 9.33 mcm. Based on the available data, management plan had been prepared for Narayanganj block as given in table 36 below.

Table 36: Proposed management plan for Narayanganj block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures for Domestic/Industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional drat proposed (30% of Annual Extractable GW) (mcm)
Narayanganj	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	5.19	2.22	8	2	4.45	1.48	1.48	11.12	4.94	3.71	14.83

In Narayanganj block, total additional draft proposed is 14.83 mcm, which is 30% of annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 8 new dug wells (70%) and 2 new bore wells (30%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 11.12 sq.km additional area which will utilise the 60% of additional

draft, 4.45 mcm. In the remaining area, 4.94 sq.km is proposed for summer crops which will utilise 20% of additional draft, 1.48 mcm and 3.71 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 1.48 mcm.
After extraction of the additional groundwater, gross draft will be 24.15 mcm. Based on this, projected stage of groundwater extraction calculated is 48.9% as given in table 37.

Table 37: Projected stage of extraction for Narayanganj block

Existing Gross draft (mcm)	Additional Draft Proposed (mcm)	Projected draft (mcm)	Annual Extractable GW (mcm)	Existing Stage of groundwater Extraction (%)	Projected Stage of groundwater Extraction (%)
9.33	14.83	24.15	49.43	**18.87**	**48.9**

6.10 Management plan of Niwas block

Existing stage of groundwater extraction is 40.88%, annual extractable groundwater resource available is 20.78 mcm. Gross groundwater draft for all uses is 8.49 mcm. Based on the available data, management plan had been prepared for Niwas block as given in table 38 below.

Table 38: Proposed management plan for Niwas block

Block	Additional Draft Proposed through new abstraction structures for Domestic/Industrial (mcm)		No. of Structures for Domestic/Industrial		Additional Draft Proposed for irrigation (mcm)			Additional Irrigated Area proposed to be Created (sq.km)			Gross additional drat proposed (15% of Annual Extractable GW) (mcm)
Niwas	Dug Well	Bore Well	Dug well	Bore Well	Wheat	Summer Crops	Double/triple cropping	Wheat	Summer Crops	Double/triple cropping	
	1.09	0.47	2	0	0.93	0.31	0.31	2.34	1.04	0.78	3.12

In Niwas block, total additional draft proposed is 3.12 mcm, which is 15% annual extractable groundwater of dynamic resources. In this 50% is utilized for domestic and industrial purpose through 2 new dug wells (70%). The remaining 50% is utilised through additional irrigation in block. Wheat is proposed in 2.34 sq.km additional area which will utilise the 60% of additional draft, 0.93 mcm. In the remaining area, 1.04 sq.km is proposed for summer crops which will utilise 20% of additional draft, 0.31mcm and 11.50 sq.km is proposed for double/triple cropping which will utilise 20% of additional draft, 0.31 mcm.

After extraction of the additional groundwater, gross draft will be 11.61 mcm. Based on this, projected stage of groundwater extraction calculated is 55.9% as given in table 39.

Table 39: Projected stage of extraction for Niwas block

Existing Gross draft (mcm)	**Additional Draft Proposed (mcm)**	**Projected draft (mcm)**	**Annual Extractable GW (mcm)**	**Existing Stage of groundwater Extraction (%)**	**Projected Stage of groundwater Extraction (%)**
8.49	3.12	11.61	20.78	**40.88**	**55.9**

6.11 Outcome of NAQUIM studies in Mandla district

As per the NAQUIM studies, scope of additional groundwater development is there in the district. Therefore, additional extraction of groundwater is proposed in all 9 blocks for agricultural, industrial and domestic purposes. Additional draft for each block is calculated based on the existing groundwater draft, annual extractable groundwater resources as per GWRE 2020 and existing stage of groundwater extraction. 50% of this additional draft is utilized for domestic and industrial purpose. Based on the block wise unit draft, number of dug wells and bore wells are calculated. In Mandla district, total 115 additional dug well and 26 bore well are proposed (fig.no.34). 50% of the additional draft proposed is utilized for creation of additional area for irrigation for wheat, summer crops and double/triple cropping. Compiled details of the same are given in tables 40-42.

Table 40: Management plan proposed for Mandla district

Block	Additional Draft for Domestic/Industrial (mcm)			No. of Proposed abstraction Structures for Domestic/Industrial	
	Proposed Draft	Draft from Bore well	Draft from Dug well	Dug well	Bore well
BICHHIYA	27.05	8.11	18.93	29	5
BIJADANDI	15.12	4.54	10.59	16	4
GUGHRI	21.04	6.31	14.73	23	6
MANDLA	10.74	3.22	7.52	18	4
MAWAI	5.10	1.53	3.57	5	1
MOHGAON	1.57	0.47	1.10	2	0
NAINPUR	11.16	3.35	7.81	12	4
NARAYANGANJ	7.41	2.22	5.19	8	2
NIWAS	1.56	0.47	1.09	2	0
Total	**100.74**	**30.22**	**70.53**	**115**	**26**

Table 41: Management plan proposed for Mandla district

Block	Additional of Draft proposed for Irrigation (mcm)				Additional Irrigated Area proposed to be Created (Sq.Km)			
	Proposed Draft	Wheat	Summer crops	Double/triple cropping	Wheat	Summer crops	Double/Triple cropping	Total
BICHHIYA	27.05	16.23	5.41	5.41	16.23	40.57	18.03	74.83
BIJADANDI	15.12	9.07	3.02	3.02	9.07	22.69	10.08	41.84
GUGHRI	21.04	12.62	4.21	4.21	12.62	31.55	14.02	58.19
MANDLA	10.74	6.44	2.15	2.15	6.44	16.11	7.16	29.71
MAWAI	5.10	3.06	1.02	1.02	3.06	7.64	3.40	14.1
MOHGAON	1.57	0.94	0.31	0.31	0.94	2.35	1.05	4.34
NAINPUR	11.16	6.70	2.23	2.23	16.74	7.44	5.58	29.76
NARAYANGANJ	7.41	4.45	1.48	1.48	11.12	4.94	3.71	19.77
NIWAS	1.56	0.93	0.31	0.31	2.34	1.04	0.78	4.16
Total	**100.74**	**60.45**	**20.15**	**20.15**	**78.56**	**134.33**	**63.81**	**276.7**

Table No.42: Projected Stage of Groundwater Extraction of Mandla district

Block	Area suitable for recharge (Sq Km)	Annual Extractable Groundwater	Total Existing Draft	Stage of GW Extraction	Additional draft Proposed	Gross Draft	Projected stage of GW Extraction
BICHHIYA	879.2	135.24	15.12	11.18	54.10	66.22	48.9
BIJADANDI	608.8	67.22	4.12	6.14	30.25	34.37	51.1
GUGHRI	880.8	105.18	4.89	4.65	42.07	46.96	44.6
MANDLA	493.6	71.58	13.51	18.88	21.47	34.99	48.9

MAWAI	1170.4	42.46	11.88	27.97	10.19	22.07	52.0
MOHGAON	327.8	26.14	12.49	47.78	3.14	15.63	59.8
NAINPUR	638.5	74.42	13.51	18.15	22.33	35.83	48.1
NARAYANGANJ	352	49.43	9.33	18.87	14.83	24.15	48.9
NIWAS	388.8	20.78	8.49	40.88	3.12	11.61	55.9
Total	**5739.9**	**592.45**	**93.34**	**15.76**	**201.49**	**291.83**	**49.3**

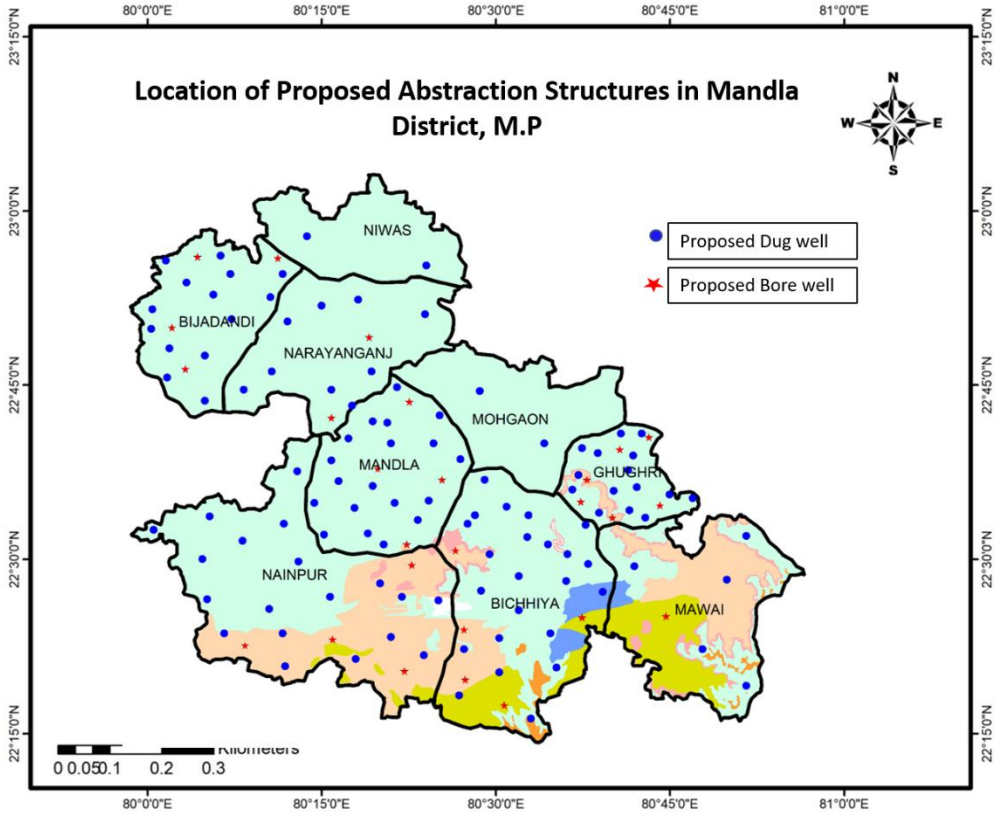

Fig. No.34: Proposed Abstraction Structures in Mandla District

6.12 Management of Fluoride Contamination in groundwater

As a part of the management strategies, solution for fluoride contamination is as given below.

1. Artificial recharge of wells contaminated with Fluoride and dilution: this is the most effective and simplest method for getting fluoride free water from deep borewells. Due to shallow water levels and unavailability of subsurface storage, it is not possible to recharge the shallow aquifers. However, deep aquifers can be recharged through existing borewells/hand pumps etc.
2. Lowering of well assembly: Another method for obtaining fluoride free water from affected wells is lowering of assembly for sealing the contaminated zone thereby tapping only the available fresh water zone above or below fluoride affected aquifer (fig.no.35).
3. Chemical treatment known as Nalgonda technique in which contaminated water is mixed with alum, lime and bleaching powder.

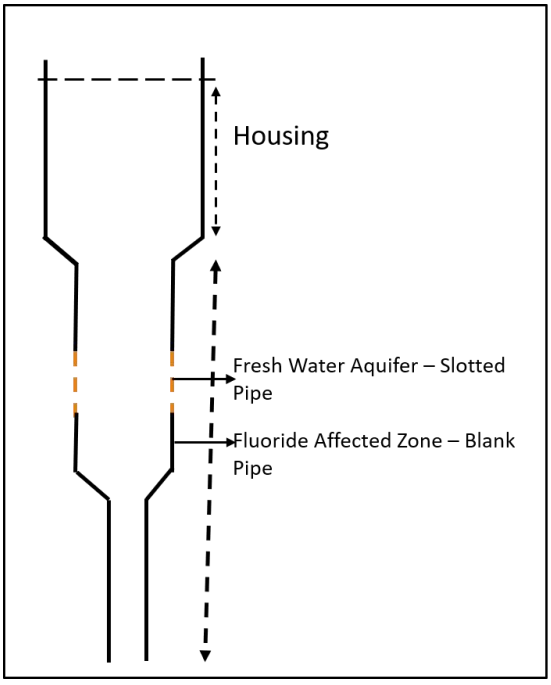

Fig. No. 35: Well Assembly for fluoride contaminated well

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1 Conclusions

The area under present study comprises of Bichhiya, Bijadandi, Gughri, Mandla, Mawai, Mohgaon, Nainpur, Narayanganj, and Niwas blocks of Mandla district. The total area covered is 7544 sq. kms.

Physiographically, the area is a part of Satpura region. The entire study area is characterized by a typical trappean geomorphology comprising extensive plains, low lying hills and hill clusters with gently northerly slope underlained by Gondwana and Basement granite

The area is part of Narmada basin and Godavari Basin. The drainage pattern is dendritic to sub dendritic with moderate drainage density.

The major aquifers in the district comprise of alluvium, vesicular/amygdaloidal basalt and fractured/jointed basalts of deccan traps acts as a multi aquifer system in the district, fractured Gondwana sandstone and fractured granite.

The aquifer occurring in the study area are moderate to highly potential. Vesicular, weathered fracture and jointed zone sustain tube wells of upto 27 lps discharge.

10 years water level data reveals that the pre monsoon water level have shown rising trend in the study area and post monsoon water level shows declining trend. Most part of the district have shallow water levels during pre-monsoon and water logging condition in post monsoon.

As per block wise ground water resources estimation March 2020, all blocks fall under safe category.

Occurrence of collapsible layers including vesicular basalt, red bole and Lameta beds result in filling up of bore wells in the area.

The area falls mainly under tribal area and agriculture is practiced minimum in the district.

The quality of ground water in general in the study area is suitable for domestic, industrial and irrigation uses. Presence of high concentration of fluoride in deeper aquifer is a major issue in the district.

Outcome of NAQUIM studies suggest that scope of additional groundwater development is there in the district.

As the part of NAQUIM studies, 141 additional extraction structures are proposed in the district including dug wells and bore wells for domestic and industrial use. Total additional irrigated area of 276.7 sq.km is proposed to be created in the district. Total additional draft of 201.5 mcm is proposed in the district for irrigation, industrial and domestic purposes.

7.2 Recommendations

- Additional draft may be utilized in all 9 blocks for development of groundwater.
- Additional area may be irrigated in all 9 blocks.
- Summer crops and double/triple cropping methods may be practiced.
- In fluoride affected areas, chemical treatment of groundwater, alternate drinking water supply methods etc. may be practiced. In addition to this, recommended well assembly may be followed while constructing bore wells in the fluoride affected areas.

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ANNEXURES

Annexure-1

Pre-Monsoon and Post-monsoon water level data with Fluctuation

District	Longitude	Latitude	Site	WL_May-21	WL_Nov-21	Fluctuation
Mandla	80.7	22.45166667	Bichhia	5.94	5.74	0.2
Mandla	80.77722222	22.42611111	Sijhora	5.1	2.7	2.4
Mandla	80.15055556	22.98194444	Khamher Kheda	1.6	1.2	0.4
Mandla	80.69	22.67777778	Ghughri	9.5	10.7	-1.2
Mandla	80.525	22.73916667	Devgaon	8.75	4.45	4.3
Mandla	80.34166667	22.7125	Gwari	4.7	3.9	0.8
Mandla	80.41111111	22.79277778	Khari	2.3	1.7	0.6
Mandla	80.47694444	22.68472222	Mahania patpara	2.2	1.5	0.7
Mandla	80.355	22.57527778	Maharajpur	0.8	0.9	-0.1
Mandla	80.36888889	22.6	Mandla	8.45	3.65	4.8
Mandla	80.41027778	22.55	Padmi choraha	4.95	2.45	2.5
Mandla	80.47055556	22.60833333	Pathiri patpara	4.5	4	0.5
Mandla	80.52083333	22.61388889	Ramnagar	8.45	3.65	4.8
Mandla	80.57722222	22.74944444	Rehgaon	5.85	0.75	5.1
Mandla	80.90333333	22.34527778	Motinala	1.03	4.93	-3.9
Mandla	80.7	22.825	Chabi	5.3	3.7	1.6
Mandla	80.59722222	22.76111111	Indira	3.2	3.6	-0.4
Mandla	80.50916667	22.49361111	Anjania	5	2.4	2.6
Mandla	80.36777778	22.47638889	Bamhni New	1.35	0.95	0.4
Mandla	80.19888889	22.51944444	Dithori	7.6	2.9	4.7
Mandla	80.10972222	22.42777778	Nainpur	1.9	2.9	-1
Mandla	80.26416667	22.40861111	Rampuri New	2.91	2.95	-0.04
Mandla	80.27083333	22.52611111	Subhariya	4.05	3.25	0.8
Mandla	80.1375	22.52083333	Surajpura	5.98	1.08	4.9
Mandla	80.41444444	22.88277778	Babaliya	2.75	1.85	0.9
Mandla	80.21333333	22.87916667	Kudomali New	1.6	1.7	-0.1
Mandla	80.31055556	22.75027778	Mangalganj	2.13	2.43	-0.3
Mandla	80.5	23.09166667	Manikpur	0.8	1.4	-0.6
Mandla	80.44222222	23.03916667	Niwas	6.5	3.8	2.7
Mandla	80.43944444	23.03916667	Niwas-d	7.05	4.1	2.95
Mandla	80.43944444	23.03916667	Niwas-s	6.83	4.1	2.73

Annexure -2

Decadal Water Level Trend- Post Monsoon

District	Block	SiteName	Longitude	Latitude	Decadal Trend
Mandla	Narayanganj	Mangalganj	80.31056	22.75028	3.37571
Mandla	Nainpur	Nainpur	80.10972	22.42778	2.51333
Mandla	Niwas	Rampuri New	80.26417	22.40861	0.7125
Mandla	Nainpur	Bamhni New	80.36778	22.47639	0.80125
Mandla	Nainpur	Dithori	80.19889	22.51944	0.336667
Mandla	Nainpur	Surajpura	80.1375	22.52083	0.465714
Mandla	Nainpur	Subhariya	80.27083	22.52611	0.091429
Mandla	Mandla	Padmi choraha	80.41028	22.55	1.37556
Mandla	Mohgaon	Mahrajpur	80.355	22.57528	2.45375
Mandla	Mandla	Mandla1	80.36889	22.6	2.54
Mandla	Mandla	Gwari	80.34167	22.7125	3.484
Mandla	Mandla	Khari	80.41111	22.79278	2.15
Mandla	Narayanganj	Kudomali New	80.21333	22.87917	2.41125
Mandla	Narayanganj	Babaliya	80.41444	22.88278	0.695556
Mandla	Bijadnandi	Kalpi	80.19722	22.91889	-0.495
Mandla	Bijadnandi	Khamher Kheda	80.15056	22.98194	1.19
Mandla	Niwas	Niwas-d	80.43944	23.03917	-0.35111
Mandla	Niwas	Niwas-s	80.43944	23.03917	-0.26778
Mandla	Niwas	Niwas	80.44222	23.03917	0.114
Mandla	Niwas	Manikpur	80.5	23.09167	3.074
Mandla	Mawai	Motinala	80.90333	22.34528	5.979
Mandla	Bichhiya	Sijhora	80.77722	22.42611	2.082
Mandla	Bichhiya	Bichhia1	80.7	22.45167	0.867
Mandla	Nainpur	Anjania	80.50917	22.49361	0.478
Mandla	Mandla	Pathiri patpara	80.47056	22.60833	0.355
Mandla	Mandla	Ramnagar1	80.52083	22.61389	0.271
Mandla	Ghugri	Ghughri	80.69	22.67778	1.21625
Mandla	Mandla	Mahania patpara	80.47694	22.68472	2.02889
Mandla	Mandla	Devgaon	80.525	22.73917	0.258824
Mandla	Mandla	Rehgaon	80.57722	22.74944	1.86625
Mandla	Mohgaon	Indira	80.59722	22.76111	4.34
Mandla	Mohgaon	Chabi	80.7	22.825	1.37778

Annexure -3

Decadal Water Level Trend- Post Monsoon

District	Block	SiteName	Latitude	Longitude	Decadal Trend
Mandla	Nainpur	Nainpur	22.42778	80.10972	-0.358235
Mandla	Bijadnandi	Khamher Kheda	22.98194	80.15056	0.985
Mandla	Narayanganj	Babaliya	22.88278	80.41444	-0.182222
Mandla	Mohgaon	Indira	22.76111	80.59722	-1.79556
Mandla	Mohgaon	Mahrajpur	22.57528	80.355	0.28375
Mandla	Bichhiya	Bichhia1	22.45167	80.7	-1.369
Mandla	Nainpur	Bamhni New	22.47639	80.36778	0.7925
Mandla	Nainpur	Anjania	22.49361	80.50917	-0.3
Mandla	Nainpur	Dithori	22.51944	80.19889	0.053125
Mandla	Nainpur	Surajpura	22.52083	80.1375	0.938571
Mandla	Nainpur	Subhariya	22.52611	80.27083	-1.44714
Mandla	Mandla	Padmi choraha	22.55	80.41028	0.025556
Mandla	Mandla	Mandla1	22.6	80.36889	4.388
Mandla	Mandla	Pathiri patpara	22.60833	80.47056	-0.189
Mandla	Mandla	Ramnagar1	22.61389	80.52083	-0.589
Mandla	Ghugri	Ghughri	22.67778	80.69	0.114
Mandla	Mandla	Mahania patpara	22.68472	80.47694	0.28
Mandla	Mandla	Gwari	22.7125	80.34167	0.168
Mandla	Mandla	Devgaon	22.73917	80.525	0.922143
Mandla	Mandla	Rehgaon	22.74944	80.57722	2.34375
Mandla	Narayanganj	Mangalganj	22.75028	80.31056	0.46
Mandla	Mandla	Khari	22.79278	80.41111	0.173333
Mandla	Mohgaon	Chabi	22.825	80.7	-0.098
Mandla	Narayanganj	Kudomali New	22.87917	80.21333	1.35125
Mandla	Niwas	Niwas-d	23.03917	80.43944	0.018889
Mandla	Niwas	Niwas-s	23.03917	80.43944	-0.354444
Mandla	Niwas	Niwas	23.03917	80.44222	-0.042
Mandla	Niwas	Manikpur	23.09167	80.5	-0.102
Mandla	Niwas	Rampuri New	22.40861	80.26417	0.025
Mandla	Bichhiya	Sijhora	22.42611	80.77722	0.112
Mandla	Mawai	Mangli	22.28806	80.99861	-0.176
Mandla	Mawai	Motinala	22.34528	80.90333	0.558

Annexure-4 : Chemical Quality data of Mandla district

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	Mandla	Nainpur	Anjania	22.494	80.509	7.08	638	0	140	122	8	1	0.10	0.09	22	165	52	9	65	4.5	415
2	Mandla	Narayanganj	Babaliya	22.883	80.414	7.33	982	0	231	82	58	104	0.25	0.12	35	405	90	44	35	3.0	638
3	Mandla	Nainpur	Bamhni New	22.476	80.368	7.43	775	0	310	57	11	31	0.14	0.16	33	275	62	29	48	1.5	504
4	Mandla	Bichhiya	Bichhia1	22.452	80.700	7.56	991	0	346	115	14	16	0.50	0.08	29	355	50	56	60	1.3	644
5	Mandla	Mohgaon	Chabi	22.825	80.700	7.26	595	0	267	17	19	23	0.11	0.09	25	250	56	27	17	2.0	387
6	Mandla	Mandla	Devgaon	22.739	80.525	7.42	879	0	346	57	33	20	0.13	0.14	42	380	60	56	23	1.7	571
7	Mandla	Nainpur	Dithori	22.519	80.199	7.21	685	0	243	57	10	49	0.11	0.05	29	285	54	36	22	5.5	445
8	Mandla	Ghughri	Ghughri	22.678	80.690	7.24	403	0	182	12	11	9	0.04	0.06	18	160	40	15	15	2.1	262
9	Mandla	Mandla	Gwari	22.713	80.342	7.25	789	0	322	40	40	25	0.09	0.08	34	295	56	38	36	11.0	513
10	Mandla	Mohgaon	Indira	22.761	80.597	7.54	583	0	310	15	13	2	0.20	0.09	38	250	62	23	11	14.2	379
11	Mandla	Bijadandi	Kalpi	22.919	80.197	7.29	970	0	358	77	25	33	0.07	0.27	41	425	108	38	22	6.4	631
12	Mandla	Mandla	Khari	22.793	80.411	7.11	392	0	158	17	20	16	0.05	0.09	49	160	44	12	9	7.6	255
13	Mandla	Narayanganj	Kudomali New	22.879	80.213	7.52	1007	0	523	25	9	18	0.09	0.08	55	390	94	38	47	2.3	655
14	Mandla	Mandla	Mahania Patpara	22.685	80.477	7.52	746	0	322	35	43	7	0.25	0.12	43	320	90	23	17	6.5	485
15	Mandla	Mandla	Mandla1	22.600	80.369	7.57	1513	0	358	265	54	2	0.16	0.29	29	505	60	86	111	1.8	983
16	Mandla	Narayanganj	Mangalganj	22.750	80.311	7.33	498	0	231	12	12	5	0.15	0.09	40	175	42	17	29	3.0	324
17	Mandla	Niwas	Manikpur	23.092	80.500	8.40	380	36	49	42	41	1	1.18	0.08	20	20	6	1	70	7.7	247
18	Mandla	Mawai	Motinala	22.345	80.903	7.23	829	0	158	145	19	35	0.40	0.09	34	325	70	36	37	1.2	539
19	Mandla	Nainpur	Nainpur	22.428	80.110	7.44	510	0	243	17	21	3	0.28	0.09	27	200	44	22	21	2.4	332
20	Mandla	Niwas	Niwas	23.039	80.442	7.33	451	0	213	15	12	2	0.22	0.06	46	110	38	4	49	1.1	293
21	Mandla	Mandla	Padmi Choraha	22.550	80.410	7.59	640	0	310	17	18	4	0.20	0.09	36	255	56	28	24	4.9	416
22	Mandla	Mandla	Pathiri Patpara	22.608	80.471	7.32	628	0	292	20	24	7	0.11	0.18	42	260	72	19	18	5.6	408
23	Mandla	Mandla	Ramnagar1	22.614	80.521	7.28	668	0	219	57	20	53	0.08	0.08	39	290	72	27	19	2.7	434
24	Mandla	Nainpur	Rampuri New	22.409	80.264	7.47	715	0	346	25	11	11	0.16	0.10	43	285	60	33	28	5.6	465
25	Mandla	Mandla	Rehgaon	22.749	80.577	7.63	700	0	286	40	29	14	0.05	0.34	35	285	66	29	22	8.4	455
26	Mandla	Bichhiya	Sijhora	22.426	80.777	7.30	551	0	170	55	31	17	0.17	0.08	47	195	54	15	33	1.9	358
27	Mandla	Nainpur	Subhariya	22.526	80.271	7.36	650	0	267	60	15	2	0.25	0.16	26	255	54	29	28	5.1	423
28	Mandla	Nainpur	Surajpura	22.521	80.138	7.84	310	0	134	15	12	1	0.85	0.09	18	40	12	2	45	5.3	202

Annexure-5
Location of Exploratory wells in Mandla district

Si No.	District	Site	Latitude	Longitude	RL
1	Mandla	Bamhnibanzar EW	22.47194	80.36444	454.8
2	Mandla	Bichhiya	22.45167	80.66667	611
3	Mandla	Bijadanali	23.00028	80.16056	546.6
4	Mandla	Bisoura	23.0923	80.4816	654.4
5	Mandla	Chabi	22.82638	80.69305	491.3
6	Mandla	Danitola	22.5792	80.7054	576.4
7	Mandla	Dei EW	22.47675	80.70228	615.8
8	Mandla	Devdongri	22.9631	80.4309	689
9	Mandla	Guruwada	22.5847	80.1779	507.9
10	Mandla	Hatitara	22.89	80.33	592
11	Mandla	Indra	22.75	80.5817	483.9
12	Mandla	Indri	22.4	80.35	466
13	Mandla	Jaharmau	22.279	80.443	509.1
14	Mandla	Jangaliya	23.0194	80.3452	629
15	Mandla	Kutwahi	22.3447	80.4583	476.2
16	Mandla	Maharajpur EW	22.58583	80.36694	442.7
17	Mandla	Mandla	22.61111	80.36889	445.8
18	Mandla	Medha	22.4822	80.9113	675.6
19	Mandla	Nainpur	22.42778	80.10972	448.1
20	Mandla	Newsa	22.55903	80.71225	584.5
21	Mandla	Niwas	23.03917	80.43944	663.7
22	Mandla	Phulsagar	22.648	80.233	653.2
23	Mandla	Rampuri	22.4074	80.2443	489.4
24	Mandla	Rasoidona EW-1	22.59028	80.425	467.3
25	Mandla	Sagar	22.7073	80.3665	446.8
26	Mandla	Saliwada	22.52361	80.18132	510.8
27	Mandla	Sijhora	22.41667	80.75139	694
28	Mandla	Sukhram	22.892	80.3737	603.8

Annexure-6
Litho logs used for preparation of 2-D and 3-D Aquifer Maps

From	To	Thickness	Lithology of EW Bisoura
0	1.8	1.8	Upper Soil loose adhering soil
1.8	13.2	11.4	Basalt Massive hard and compact
13.2	34.5	21.3	Basalt Fractured,
34.5	49.8	15.3	Basalt Massive ,Less compact, Minor amount of vesicles are present
49.8	52.2	2.4	Basalt Vesicular
52.2	80.3	28.1	Basalt Massive
80.3	88.6	8.3	Basalt Vesicular, secondary fillings are present.
88.6	92.4	3.8	Basalt Amygdaloidal
92.4	147.4	55	Basalt Massive
147.4	151.7	4.3	Basalt Vesicular
151.7	202.2	50.5	Basalt Massive

Drilling Depth		Thickness (m)	Lithology of EW Chabi
From (mbgl)	To (mbgl)		
0	8.4	8.4	Top soil
8.4	16.8	8.4	Fractured Basalt, Pale black in colour
16.8	42	25.2	Massive Basalt
42	72	30	Light black colored Basalt
72	78.3	6.3	Highly rugged Basalt
78.3	95.7	17.4	Massive Basalt
95.7	98.6	2.9	Red bole Bed
98.6	134.8	36.2	Massive Basalt
134.8	142	7.2	Sand sized rounded fragments, K-Feldspar predominant

From	To	Thickness	Lithology of EW Chiraidongri
0	9.6	9.6	Upper soil mixed with Clay
9.6	23.7	14.1	Basalt Fractured
23.7	46.2	22.05	Basalt Massive (Dark and compact)
46.2	64.5	18.3	Basalt Vesicular (Minor amount of green colored minerals are present)
64.5	85.9	21.4	Basalt Massive (Dark and compact)

85.9	101.1	15.2	Basalt Vesicular (Minor amount of dolomitic patches are present)
101.1	113.3	12.2	Basalt Massive (Dark and compact)
113.3	128.6	15.3	Basalt Vesicular
128.6	149.9	21.3	Basalt Amygdaloidal
149.9	168.2	18.3	Basalt Massive, Traces of reddish clay are present
168.2	183.5	15.3	Basalt Vesicular
183.5	201.8	18.3	Basalt Massive

From(mtr)	To (mtr)	Thickness(mtr)	Lithology EW Danitola
0	7.9	7.9	Basalt Weathered, Grey , Moderately hard in nature
7.9	32.3	24.4	Massive Basalt, black, hard in nature
32.3	35.3	3	Intertrappean Clay
35.3	38.4	3.1	Vesicular Basalt, greenish grey, moderately hard in nature
38.4	41.5	3.1	Fractured Basalt, black, hard in nature, Angular grain
41.5	58.9	17.4	Massive Basalt, black, hard in nature
58.9	62.8	3.9	Lameta Sand

From(mtr)	To (mtr)	Thickness(mtr)	Lithology EW Dei
0	7.9	7.9	Basalt Weathered, Grey , Moderately hard in nature
7.9	32.3	24.4	Massive Basalt, black, hard in nature
32.3	35.3	3	Intertrappean Clay
35.3	38.4	3.1	Vesicular Basalt, greenish grey, moderately hard in nature
38.4	47.5	9.1	Massive Basalt, black, hard in nature
47.5	50.6	3.1	Red Bole
50.6	53.6	3	Basalt Weathered, Grey , Moderately hard in nature
53.6	65.8	12.2	Massive Basalt, black, hard in nature
65.8	71.9	6.1	Lameta Sand
71.9	111.6	39.7	Granite massive, hard and compact, medium grained , Grey to white in colour
111.6	126.9	15.3	Granite massive, hard and compact, grey- pink color, medium-coarse grained

126.9	166.4	39.5	Granite massive, hard and compact, medium grained , Grey to white in colour
166.4	200	33.6	Granite massive, hard and compact, grey- pink color, medium-coarse grained

From	To	Thickness	Lithology of EW Devdongri
0	3	3	Upper Soil loose adhering soil
3	20.1	17.1	Basalt Weathered mixed with soil
20.1	38.4	18.3	Basalt Massive
38.4	68.9	30.5	Basalt Massive ,Less compact, Minor amount of vesicles are present
68.9	75	6.1	Basalt Vesicular
75	87.2	12.2	Redbole Bed
87.2	94	6.8	Basalt Vesicular
94	148.1	54.1	Basalt Massive
148.1	152.7	4.6	Basalt Vesicular, Green colored minerals are present
152.7	181.6	28.9	Basalt Massive
181.6	200	18.4	Basalt massive along with Patches of Dolomite

From	To	Thickness	Lithology of EW Gadhar
0	12.9	12.9	Basalt weathered
12.9	37.3	24.4	Basalt Massive (Minor amount of vesicles are present)
37.3	76.9	39.6	Basalt Massive(Dark and compact)
76.9	89.1	12.2	Basalt Vesicular (Minor amount of green colored minerals are present)
89.1	107.4	18.3	Basalt Vesicular
107.4	119.6	12.2	Basalt Vesicular (Clay contentment is present)
119.6	125.7	6.1	Basalt Massive (Dark and compact)
125.7	153.2	27.5	Basalt Vesicular(Green colored secondary fillings are present)
153.2	162.3	9.1	Basalt Amygdaloidal
162.3	189.8	27.5	Basalt Vesicular
189.8	200	10.2	Basalt Massive

From	To	Thickness	Lithology of EW Guruwada
0	3	3	Upper Soil loose adhering soil
3	20.1	17.1	Basalt Weathered mixed with soil
20.1	38.4	18.3	Basalt Massive
38.4	68.9	30.5	Basalt Massive ,Less compact, Minor amount of vesicles are present
68.9	78	9.1	Basalt Vesicular
78	87.2	9.2	Redbole Bed
87.2	94.4	7.2	Basalt Vesicular
94.4	125.4	31	Basalt Massive
148.1	157.2	9.1	Basalt Vesicular, Green colored minerals are present
157.2	181.6	24.4	Basalt Massive
181.6	200	18.4	Basalt massive along with Patches of Dolomite

From(mtr)	To(mtr)	Thickness(mtr)	Lithology EW1 (Indra)
0	10.9	10.9	Basalt Weathered, Grey , Moderately hard in nature
10.9	65.8	54.9	Basalt Massive, Dark colour, Hard and massive
65.8	84.1	18.3	Basalt Fractured, Angular grains, Moderately Hard
84.1	93.3	9.2	Basalt Massive, Dark colour, Hard and massive
93.3	96.3	3	Red bole , moderately hard
96.3	102.4	6.1	Vesicular Basalt, greenish grey, moderately hard in nature
102.4	126.8	24.4	Massive Basalt, black, hard in nature
126.8	127.8	1	Lameta, Sandy formation. Highly collapsible

From(m)	To (m)	Thickness(m)	Lithology EW Jaharmau
0	1.8	1.8	Top soil
1.8	4.1	18.3	Granite weathered, Medium hard in nature, white color

4.1	20.1	16	Granite massive, hard and compact, medium grained , Grey to white in colour
20.1	23.4	3.3	Granite Fractured, Grey color, Medium grained and medium hard
38.4	166.5	128.1	Granite massive, hard and compact, medium grained , Grey to white in colour
166.5	200	33.5	Granite massive, hard and compact, grey- pink color, medium-coarse grained

From (mtr)	To (mtr)	Thickness(mtr)	Lithology EW Kutwahi
0	7.9	7.9	Granite weathered, Medium hard in nature, white color
7.9	32.3	24.4	Granite massive, hard and compact, medium grained , Grey to white in colour
32.3	44.5	12.2	Granite Fractured, Grey color, Medium grained and medium hard
44.5	123.8	79.3	Granite massive, hard and compact, grey-pink color, medium-coarse grained
123.8	129.9	6.1	Granite massive,hard, black color minerals are ferromagnesian minerals
129.9	203.1	73.2	Granite massive, hard and compact, grey-pink color, medium-coarse grained

Drilling Depth		Thickness (m)	Lithology EW Medha
From (mbgl)	To (mbgl)		
0	5.98	5.98	Clay rich top soil, pale brown in color and have adhering property.
5.98	16.2	10.22	Sandstone clay rich zone are also present
16.2	58	41.8	Sandstone, Dark black in colour.
58	78	20	Sandstone, Red in colour, Quartz predominant
78	150	72	Granite, Dark in colour.
150	203	53	Granite ,Hornblende and green colored minerals are predominant

From	To	Thickness	Lithology EW Newsa
0	7.9	7.9	Basalt Weathered, Grey , Moderately hard in nature
7.9	21.2	13.3	Massive Basalt, black, hard in nature
20.1	26.2	6.1	Red Bole, compact in nature(Dry)
26.2	32.3	6.1	Sand (Dry)

From	To	Thickness	Lithology of EW Rampuri
0	6.8	6.8	Basalt weathered
6.8	15.9	9.1	Basalt Massive
15.9	17.5	1.6	Granite weathered, Moderately hard
17.5	37.3	19.8	Granite compact and hard predominant of pink colour
37.3	73.9	36.6	Granite, coarse grained grayish brown colour
73.9	92.2	18.3	Granite orthoclase predominant.
92.2	122.7	30.5	Granite greyish white colour
122.7	144	21.3	Granite minor amount of Quartz predominating
144	171.5	27.5	Granite ,Quartz rich hard and compact .

From	To	Thickness	Lithology of EW Sagar
0	9.8	9.8	Basalt weathered
9.8	25.1	15.3	Basalt Massive (weathered)
25.1	46.4	21.3	Basalt Fractured
46.4	61.7	15.3	Basalt weathered
61.7	104.4	42.7	Basalt Massive
104.4	122.7	18.3	Basalt Massive (weathered)
122.7	153.2	30.5	Basalt Massive (Dark and compact)
153.2	202	48.8	Sand Fine to medium grained particles (Lameta formation)

From (mtr)	To (mtr)	Thickness(mtr)	Lithology EW Saliwada
0	10.9	10.9	Basalt Weathered, Grey , Moderately hard in nature
10.9	20.1	9.2	Basalt Fractured, Angular grains, Moderately Hard
20.1	59.5	39.4	Massive Basalt,black,hard in nature
59.5	62.8	3.3	Intertrappean Clay
62.8	65.8	3	Vesicular Basalt, greenish grey, moderately hard in nature
65.8	90.2	24.4	Massive Basalt,black,hard in nature
90.2	93.3	3.1	Red bole Red bole, moderately hard
93.3	102.4	9.1	Basalt Weathered, Grey , Moderately hard in nature
102.4	117.7	15.3	Massive Basalt, black, hard in nature

117.7	120.7	3	Intertrappean Clay
120.7	123.8	3.1	Red bole
123.8	129.9	6.1	Vesicular Basalt, greenish grey, moderately hard in nature
129.9	166.5	36.6	Massive Basalt, black, hard in nature
166.5	175.6	9.1	Clay (Very collapsible)

Drilling Depth		**Thickness (m)**	**Lithology EW Sijora**
From (mbgl)	**To (mbgl)**		
0	9.02	9.02	Drifted top soil and Sand, pale brown in color
9.02	12	2.98	Sand , predominant of quartz
12	90	78	Pink Granite, normative amount of quartz are present.
90	157.2	67.2	Granite dark and compact, mafic minerals such as Hornblende and mica are present
157.2	177	19.8	Granite, pink colour, Feldspar rich (Orthoclase)
177	201	24	Granite , Massive and compact dark in appearance

From	**To**	**Thickness**	**Lithology of EW Hatitara**
0	1.8	1.8	Upper soil
1.8	22.3	20.5	Basalt Fractured
22.3	31.5	9.2	Basalt Vesicular
31.5	55.9	24.4	Basalt Massive (Dark and compact)
55.9	62	6.1	Basalt Vesicular
62	80.4	18.4	Basalt Massive
80.4	88.2	7.8	Basalt Vesicular
88.2	165	76.8	Basalt Massive (Dark and compact)
165	200	35	Basalt Amygdaloidal

From	**To**	**Thickness**	**Lithology of EW Jangaliya**
0	25.2	25.2	Basalt highly weathered ,pyroxene rich
25.2	37.4	12.2	Basalt Massive hard and compact
37.4	43.6	6.2	Basalt Vesicular
43.6	58.7	15.1	Basalt Massive

58.7	74	15.3	Basalt Amygdaloidal, secondary fillings are present
74	98.4	24.4	Basalt Massive
98.4	104.5	6.1	Basalt Highly weathered rounded fragments
104.5	125.8	21.3	Basalt Massive
125.8	138	12.2	Basalt fractured
138	140.4	2.4	Basalt Vesicular
140.4	180	39.6	Basalt Massive
180	183.1	3.1	Basalt Vesicular
183.1	200	16.9	Basalt Massive

From (m)	**To (m)**	**Thickness (m)**	**Lithology of EW Sukhram**
0	10.1	10.1	Massive Basalt,black,hard in nature
10.1	12.4	15.3	Vesicular Basalt, greenish grey, moderately hard in nature
12.4	43.7	18.3	Massive Basalt,black,hard in nature
43.7	49.8	6.1	Vesicular Basalt, greenish grey, moderately hard in nature
49.8	65	15.2	Massive Basalt,black,hard in nature
65	71.1	6.1	Vesicular Basalt, greenish grey, moderately hard in nature
71.1	83.3	12.2	Massive Basalt,black,hard in nature
83.3	89.4	6.1	Vesicular Basalt, greenish grey, moderately hard in nature
89.4	123	33.6	Massive Basalt,black,hard in nature
123	129.1	6.1	Massive Basalt,black,very hard in nature
129.1	135.2	6.1	Clay,grey in colour,soft in nature
135.2	141.3	6.1	Vesicular Basalt, greenish grey, moderately hard in nature
141.3	170.8	29.5	Massive Basalt,black,hard in nature

From (m)	**To (m)**	**Thickness (m)**	**Lithology of EW Mandla**
0	4.25	4.25	Amygdaloidal basalt, grayish black semi-weathered to hard vesicles, sub angular to sub rounded, fine to medium grained
4.25	17.45	13.2	Massive basalt, grayish black, fine to medium

			hard
17.45	18.5	1.05	Red bole reddish fine & sticky
18.5	23.55	5.05	Vesicular basalt, grayish black, hard, fine to medium sub rounded vesicles, interconnected
23.55	26.55	3	Massive basalt, grayish black, hard compact, sub angular, fine to medium grained.
26.55	36.75	10.2	Massive basalt grayish black
36.75	38.75	2	Fractured basalt, grayish black, hard compact fractured.
38.75	47.95	9.2	Vesicular basalt, grayish black. Fine to medium, sub angular to sub rounded interconnected vesicles

From (m)	To (m)	Thickness (m)	Lithology of EW Niwas
0	2	2	Soil, followed by clay
2	6.25	4.25	Basalt
6.25	12.5	6.25	Vescicular
12.5	17	4.5	Basalt, vescicular, hard.
17	52.5	35.5	Basalt hard, massive
52.5	58.85	6.35	Basalt, Semi weathered,
58.85	98.7	39.85	Basalt hard, massive
98.7	109.98	11.28	Massive

From (m)	To (m)	Thickness (m)	Lithology of EW Nainpur
0	1.5	1.5	Black Cotton Soil, Clayey
1.5	6.4	4.9	weatheredwith cl
6.4	8	1.6	Bould
8	21.3	13.3	Basalt, Hard and Massive,
21.3	24	2.7	Red bole, clayey
24	30.25	6.25	Gneiss highly weathered
30.25	42.23	11.98	Weathered
42.23	60.1	17.87	Gneiss, hard, massive,

From (m)	To (m)	Thickness (m)	Lithology of EW Bichhiya
0.00	0.60	0.60	soil
0.60	3.30	2.70	Basalt, Semi Weathered Bouldrs

3.30	19.50	16.20	Basalt hard,Massive
19.50	19.80	0.30	Clay,Plastic and Sticky
19.80	24.00	4.20	Lameta S.St.with Mica Flakes
24.00	30.24	6.24	gneiss weathered with qtz pebl

From (m)	To (m)	Thickness (m)	Lithology of EW Indri
0.00	7.92	7.92	Weathered granite
7.92	20.10	12.18	Fracture granite
20.10	23.10	3.00	Granite hard
23.10	77.91	54.81	Massive Granite
77.91	87.09	9.18	Granite Compact
87.09	132.72	45.63	Massive Granite
132.72	233.75	101.03	Massive Granite
233.75	296.65	62.90	fractured granite

From (m)	To (m)	Thickness (m)	Lithology of EW Bahmini Banjar
0.00	4.25	4.25	Sticky clay
4.25	20.45	16.20	Weathered granite
20.45	29.45	9.00	Granite hard & compact
29.45	29.65	0.20	Fracture granite
29.65	133.35	103.70	Granite hard & compact
133.35	142.45	9.10	Granite,hard,massive

From (m)	To (m)	Thickness (m)	Lithology of EW Maharajpur
0.00	4.25	4.25	soil/weathered basalt
4.25	11.35	7.10	Clay soft
11.35	17.95	6.60	Vesi.basalt/m.hard to soft
17.95	26.55	8.60	Massive Basalt/commpact
26.55	35.75	9.20	Vesi.basalt/m.hard to soft
35.75	38.75	3.00	Vesi.basalt/m.hard to soft
38.75	40.60	1.85	Red Bole.
40.60	41.85	1.25	Vesi.basalt/m.hard to soft
41.85	44.85	3.00	Clay (Stickey)
44.85	47.95	3.10	sand
47.95	50.95	3.00	Sand
50.95	60.15	9.20	Sand
60.15	62.15	2.00	Granite fractured / pegmatite
62.15	182.15	120.00	Granite Fresh Hard with Quart

From (m)	To (m)	Thickness (m)	Lithology of EW Phulsagar
0.00	8.00	8.00	Massive Basalt/commpact
8.00	10.50	2.50	Clay (Stickey)
10.50	26.30	15.80	Basalt fractured /hard
26.30	34.40	8.10	Basalt fractured jointed
34.40	35.40	1.00	Vesicular Basalts /hard
35.40	56.75	21.35	Massive Basalt/commpact
56.75	65.85	9.10	Basalt semi hard
65.85	78.00	12.15	compact Basalts + jointed
78.00	84.00	6.00	Ves. Basalts(vesicles filled)
84.00	102.40	18.40	Basalt semi hard
102.40	105.50	3.10	Fractured Basalt
105.50	111.50	6.00	Fractured Basalt
111.50	112.00	0.50	Clay /red bole
112.00	120.65	8.65	Vesicular Basalt.
120.65	142.00	21.35	Basalt semi hard
142.00	148.00	6.00	Basalt semi hard
148.00	149.00	1.00	Red bole/stickey clay
149.00	154.20	5.20	Vesicular Basalt.
154.20	156.00	1.80	Clay, hard, plastic
156.00	158.00	2.00	Sandy clay
158.00	166.30	8.30	Sandy clay
166.30	169.30	3.00	Weathered granite
169.30	187.60	18.30	Granite hard,Semi Weathered
187.60	190.70	3.10	Granite hard & compact

From (m)	To (m)	Thickness (m)	Lithology of EW Rasaidona
0.00	1.10	1.10	B C Soil
1.10	8.25	7.15	Clay (Stickey)
8.25	11.35	3.10	Basalt weathered
11.35	12.50	1.15	Clay /red bole
12.50	14.35	1.85	Vesicular Basalts/ weathered
14.35	17.45	3.10	Basalt weathered, vescicular
17.45	20.45	3.00	Vesi Basalts+vesicle filled mi
20.45	43.85	23.40	Basalt compact/poorly jointed
43.85	47.95	4.10	Lameta
47.95	63.15	15.20	GranitGneiss highly weathered
63.15	84.50	21.35	Biotite Granite Gneiss hard

From (m)	To (m)	Thickness (m)	Lithology of EW Bijadanali
0.00	0.45	0.45	Sandy soil
0.45	4.85	4.40	Weathered basalt
4.85	8.30	3.45	Basalt massive fractured
8.30	12.50	4.20	Clay sticky
12.50	14.10	1.60	Vesicular Basalt.
14.10	26.30	12.20	Massive Basalt fractured
26.30	29.40	3.10	Fractured Basalt
29.40	56.75	27.35	massive Basaltsfractured
56.75	57.50	0.75	Vesicular Basalt.
57.50	62.80	5.30	Vesi.weathered Basalts
62.80	78.00	15.20	Massive fractered Basalts
78.00	80.25	2.25	Red Bole.
80.25	83.25	3.00	Fractured Basalt
83.25	87.50	4.25	Vesicular Basalt.
87.50	92.45	4.95	Hard jointed basalt
92.45	95.45	3.00	Fractured Basalt
95.45	147.75	52.30	Massive Jointed Basalt
147.75	149.50	1.75	Red bole + clay
149.50	159.40	9.90	Massive Basalt/compact
159.40	162.00	2.60	Fractured Basalt

Annexure-7
Location of proposed abstraction structures in Mandla district

Si No.	District	Bore Well		Dug well	
		Lat	Long	Lat	Long
1	Mandla	22.5742	80.3213	23.05015	80.30814
2	Mandla	22.8983	80.0197	22.7819	80.14819
3	Mandla	23.017	80.07	22.80685	80.20226
4	Mandla	22.9996	80.205	22.91706	80.21803
5	Mandla	22.7942	80.0888	22.93786	80.27209
6	Mandla	22.9215	80.3747	22.96905	80.34644
7	Mandla	22.7942	80.2867	22.7611	80.31039
8	Mandla	22.7044	80.447	22.92538	80.18424
9	Mandla	22.5482	80.4627	22.97321	80.22028
10	Mandla	22.7855	80.4375	22.97529	80.11215
11	Mandla	22.3658	80.1391	22.98984	80.00627
12	Mandla	22.47	80.3778	22.96489	80.05132
13	Mandla	22.3543	80.469	22.92122	80.08061
14	Mandla	22.3601	80.3276	23.03975	80.10314
15	Mandla	22.7305	80.8931	22.84012	79.98149
16	Mandla	22.6032	80.9622	22.88587	79.98599
17	Mandla	22.6089	80.8208	22.82972	80.0333

18	Mandla	22.6552	80.7706	22.78398	80.04907
19	Mandla	22.6466	80.9025	22.77358	80.10314
20	Mandla	22.6958	80.8146	22.84012	80.11215
21	Mandla	22.3832	80.9402	22.90874	80.13017
22	Mandla	22.3311	80.7769	22.35352	80.09187
23	Mandla	22.2559	80.5789	22.55731	79.98374
24	Mandla	22.3398	80.5538	22.58227	80.09413
25	Mandla	22.5337	80.5444	22.48245	80.07385
26	Mandla	22.4585	80.8177	22.50117	80.17072
27	Mandla	-	-	22.57395	80.23605
28	Mandla	-	-	22.67168	80.27435
29	Mandla	-	-	22.50117	80.29237
30	Mandla	-	-	22.42838	80.11215
31	Mandla	-	-	22.40343	80.26984
32	Mandla	-	-	22.31817	80.24732
33	Mandla	-	-	22.38264	80.191
34	Mandla	-	-	22.57395	80.18424
35	Mandla	-	-	22.4367	80.20226
36	Mandla	-	-	22.67584	80.32841
37	Mandla	-	-	22.59682	80.31039
38	Mandla	-	-	22.55731	80.35995
39	Mandla	-	-	22.62385	80.34869
40	Mandla	-	-	22.53236	80.3194
41	Mandla	-	-	23.00856	80.53567
42	Mandla	-	-	22.93162	80.51314
43	Mandla	-	-	22.85676	80.36671
44	Mandla	-	-	22.78398	80.37347
45	Mandla	-	-	22.81101	80.57171
46	Mandla	-	-	22.71535	80.7249
47	Mandla	-	-	22.61138	80.73617
48	Mandla	-	-	22.69664	80.78347
49	Mandla	-	-	22.81101	80.45231
50	Mandla	-	-	22.76526	80.39149
51	Mandla	-	-	22.74447	80.52215
52	Mandla	-	-	22.64673	80.54243
53	Mandla	-	-	22.72159	80.38698
54	Mandla	-	-	22.70703	80.46583
55	Mandla	-	-	22.75486	80.46809
56	Mandla	-	-	22.66129	80.40726
57	Mandla	-	-	22.70496	80.53792
58	Mandla	-	-	22.64881	80.49737
59	Mandla	-	-	22.64881	80.63479
60	Mandla	-	-	22.47829	80.40275
61	Mandla	-	-	22.40343	80.45682
62	Mandla	-	-	22.49701	80.50188
63	Mandla	-	-	22.32025	80.4771
64	Mandla	-	-	22.59474	80.56946
65	Mandla	-	-	22.62801	80.58523

66	Mandla	-	-	22.51572	80.67083
67	Mandla	-	-	22.5989	80.66633
68	Mandla	-	-	22.44086	80.58973
69	Mandla	-	-	22.41591	80.69561
70	Mandla	-	-	22.54068	80.61001
71	Mandla	-	-	22.49077	80.74292
72	Mandla	-	-	22.30777	80.73842
73	Mandla	-	-	22.34105	80.6821
74	Mandla	-	-	22.4575	80.6483
75	Mandla	-	-	22.32649	80.59199
76	Mandla	-	-	22.24747	80.68661
77	Mandla	-	-	22.56355	80.70462
78	Mandla	-	-	22.38056	80.56946
79	Mandla	-	-	22.48245	80.56721
80	Mandla	-	-	22.45334	80.75193
81	Mandla	-	-	22.58642	80.40951
82	Mandla	-	-	22.5989	80.48836
83	Mandla	-	-	22.53236	80.45457
84	Mandla	-	-	22.54899	80.50413
85	Mandla	-	-	22.72575	80.92089
86	Mandla	-	-	22.49909	80.81952
87	Mandla	-	-	22.55731	80.79699
88	Mandla	-	-	22.4575	80.79023
89	Mandla	-	-	22.39927	80.78347
90	Mandla	-	-	22.34936	81.0065
91	Mandla	-	-	22.29738	81.0966
92	Mandla	-	-	22.55939	81.10562
93	Mandla	-	-	22.50532	80.86232
94	Mandla	-	-	22.46581	81.02452
95	Mandla	-	-	22.62385	80.77221
96	Mandla	-	-	22.6093	80.99748
97	Mandla	-	-	22.63425	80.93215
98	Mandla	-	-	22.72367	80.87359
99	Mandla	-	-	22.68416	80.8443
100	Mandla	-	-	22.6197	80.87359
101	Mandla	-	-	22.59266	80.92089
102	Mandla	-	-	22.58019	80.81501
103	Mandla	-	-	22.71951	80.81727
104	Mandla	-	-	22.68208	80.90512
105	Mandla	-	-	22.64049	80.8443
106	Mandla	-	-	22.56979	80.87359