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

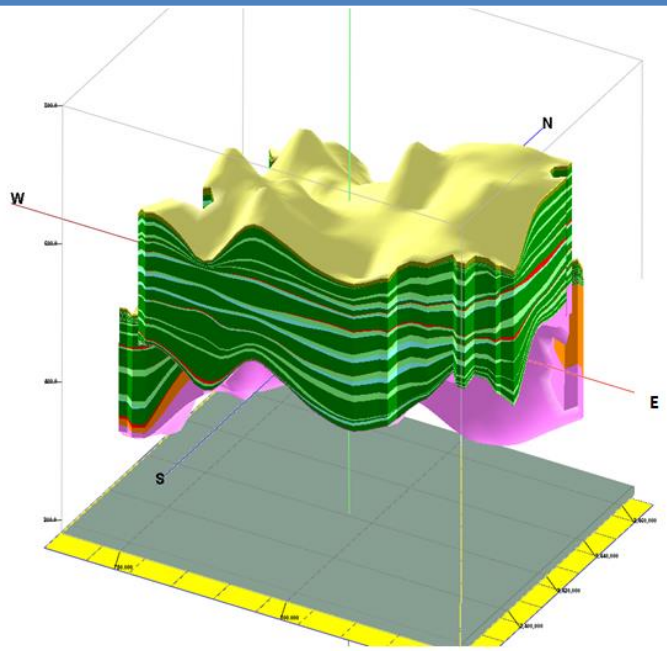
BETUL DISTRICT
MADHYA PRADESH

उत्तर मध्य क्षेत्र, भोपाल

North Central Region, Bhopal

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

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



BY
Chitta Ranjan Biswal
Scientist - B

NORTH CENTRAL REGION
BHOPAL
2019-2020

AQUIFER MAPPING AND GROUND WATER MANAGEMENT PLAN FOR BETUL DISTRICT

PART-I: DISTRICT WISE TECHNICAL REPORT

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AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN FOR BETUL DISTRICT

1. INTRODUCTION

National project on Aquifer Mapping (NAQUIM) had been taken up by CGWB to carry out detailed hydrogeological investigation on toposheet scale of 1:50,000. The NAQUIM has been prioritised to study Over-exploited, Critical and Semi-Critical blocks as well as the other stress areas recommended by the State Govt. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers.

The vagaries of rainfall, inherent heterogeneity & unsustainable nature of hard rock aquifers, over exploitation of once copious alluvial aquifers, lack of regulation mechanism has a detrimental effect on ground water scenario of the Country in last decade or so. Thus, prompting the paradigm shift from "**traditional groundwater development concept**" to "**modern groundwater management concept**".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plans. The proposed management plans will provide the **"Road Map"** for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. Thus the crux of NAQUIM is not merely mapping, but reaching the goal-that of ground water management through community participation. The aquifer maps and management plans will be shared with the Administration Betul District for its effective implementation.

1.1 Objective and Scope

Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e, the aquifer map and management plan. The activities under NAQUIM are aimed at:

- identifying the aquifer geometry,
- aquifer characteristics and their yield potential
- quality of water occurring at various depths,
- aquifer wise assessment of ground water resources
- preparation of aquifer maps and
- Formulate ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a **"Road Map"** to systematically manage the ground water resources for equitable distribution across the spectrum.

Betul district being spread over an area of 10,043 sq.km have been entirely covered during the Annual Action Plan of 2019-20.

1.2 Study area

Entire Betul District having area of 10,043 sq.km was selected for NAQUIM activities during the year 2019-20. The index map of the study area is presented in **Fig.1.1.**The district is situated in the south central part of the Madhya Pradesh state. It is bounded on the North by Hoshangabad district, on the West by Khandwa district, on the South by Amravati district (Maharashtra); and on the East by Chindwara district. The district lies between north latitude 21^0 22' and 22^0 24' and east longitude 77^0 04' and 78^0 33'.The district comprises of eight tehsils and ten community development blocks, which are Betul, Multai, Athner, Prabhat Pattan, Chicholi, Ghoda Dongri, Amla, Bhainsdehi, Bhimpur and Shahpur. Population of the district is 15, 75,362 and Density of the Population is 157/km²as per 2011 census.

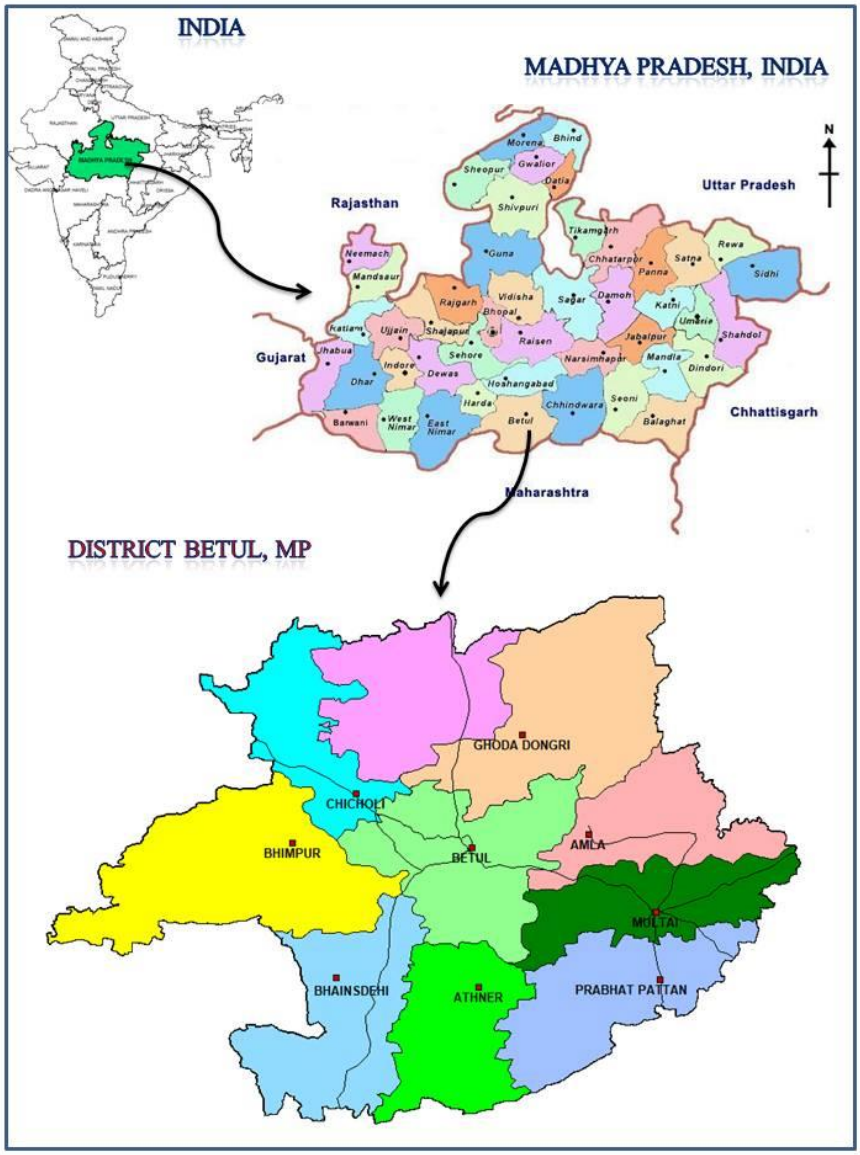

Fig. 1.1: Index map, Betul District.

1.3 Climate and Rainfall

The climate of Betul is characterized by a hot summer and general dryness except rainfall during the south- west monsoon season. The year can be divided into four seasons. The cold season, December to February is followed by summer season from March to about first week of June. The

period from the middle June to September is the south-west monsoon season. October and middle of November constitute the post monsoon or retreating monsoon season. May is the hottest month of the year with average temperature of 39.3°C. The minimum during the December is 10.3°C. The normal annual mean maximum and minimum temperature is 30.7°C and 17.9°C respectively.

The normal annual rainfall of Betul district is 999.8 mm. About 86.6% of annual rainfall is received during monsoon season. Only 13.4% of annual rainfall takes place between October to May.

Table 1.1: Annual Rainfall Data - 2014-2018 (mm)

Year	2014	2015	2016	2017	2018
Rainfall	2399.50	2725.66	2626.30	2612.60	2385.00

(Source: Indian Meteorological Department)

1.4 Physiography

The district has four physiographic divisions viz (i) Satpura plateau in Tawa and Morand valleys (ii) The Satpura plateau in central and (iii)The Satpura plateau in southern part of the district and (iv) Tapti valley. The maximum and minimum elevation of the district is 1089m and 358m above mean sea level respectively. The elevation is generally high towards east and southern part of the district and low elevation is towards western and northern side (**as per Fig.1.2**).

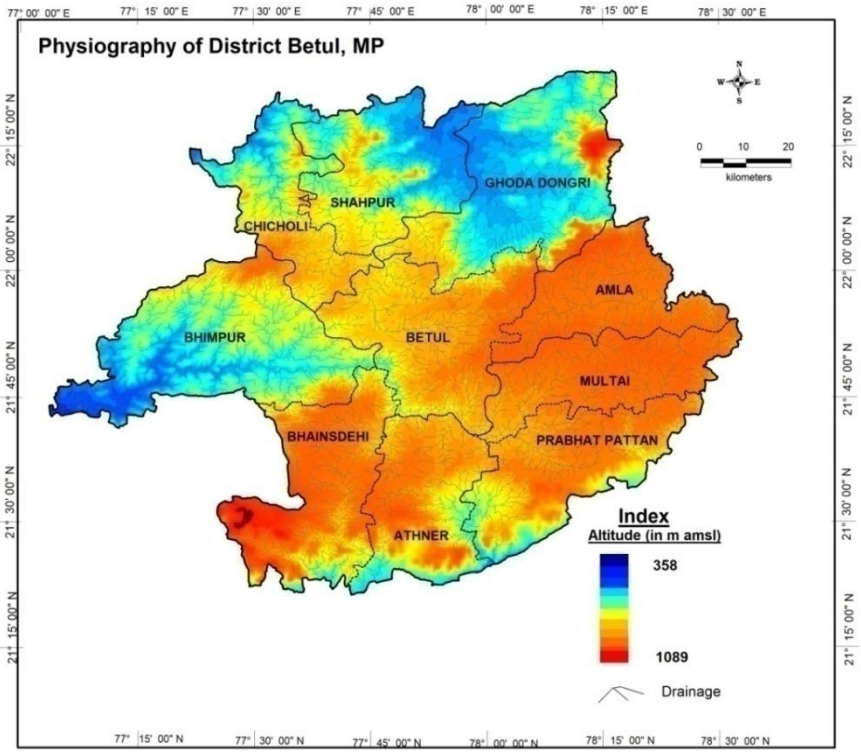

Fig. 1.2: Physiography.

1.5 Land Use, Agriculture, Irrigation and Cropping Pattern

Forest and agriculture are the prominent land use aspects in Betul district and forms 36.9% and 57.6% of total area respectively followed by the industrial and built-up structures. The spatial distribution of land use is presented in **Fig. 1.3**.

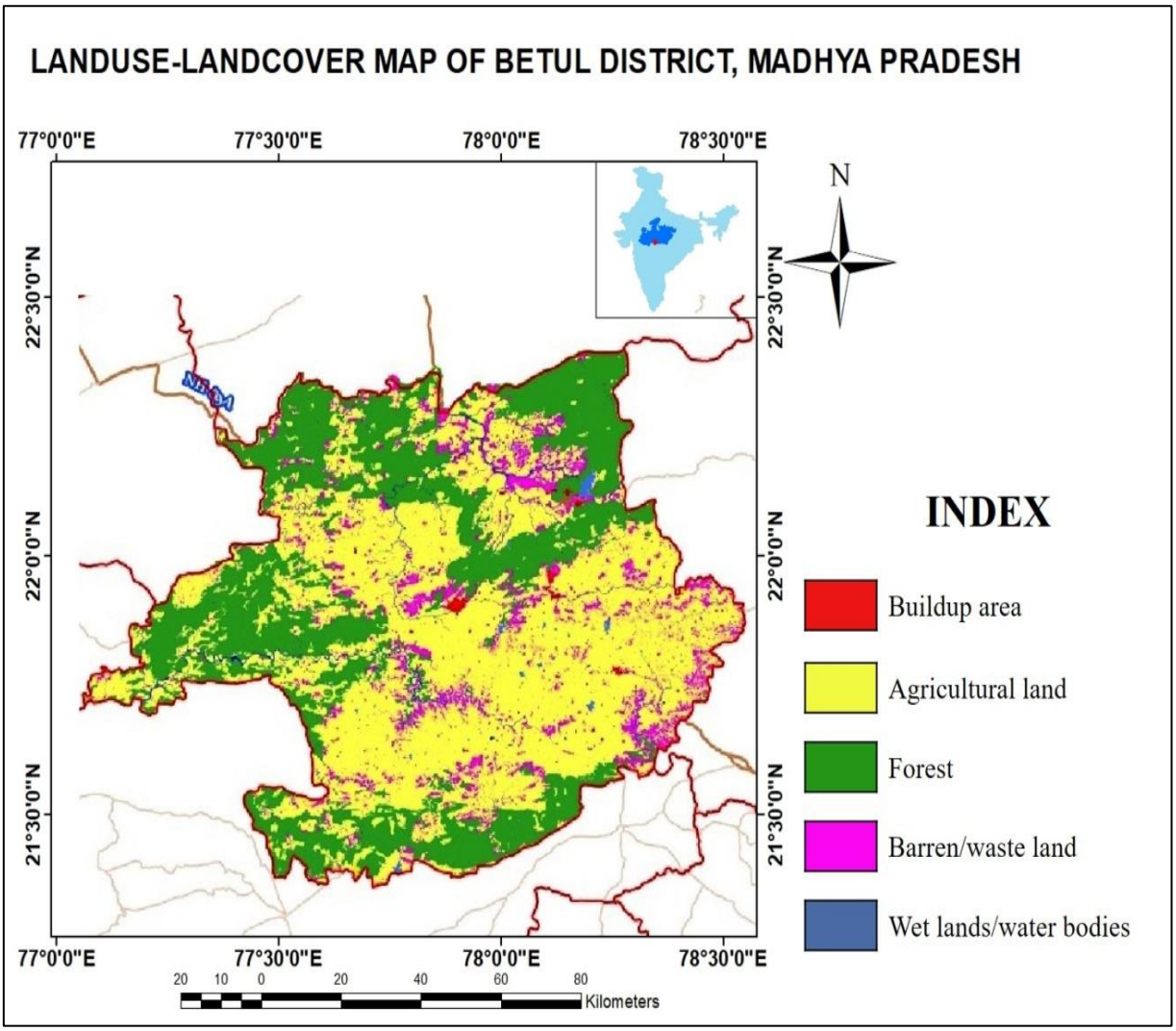

Fig.1.3: Land Use Map.

Table 1.2: Land Use (in sq.km)

Built up Area	Agricultural Land	Forest	Barren/ waste Lad	Water bodies/ Wetlands	**Total area**
87.55	5784.63	3705.48	343.68	121.64	**10043**

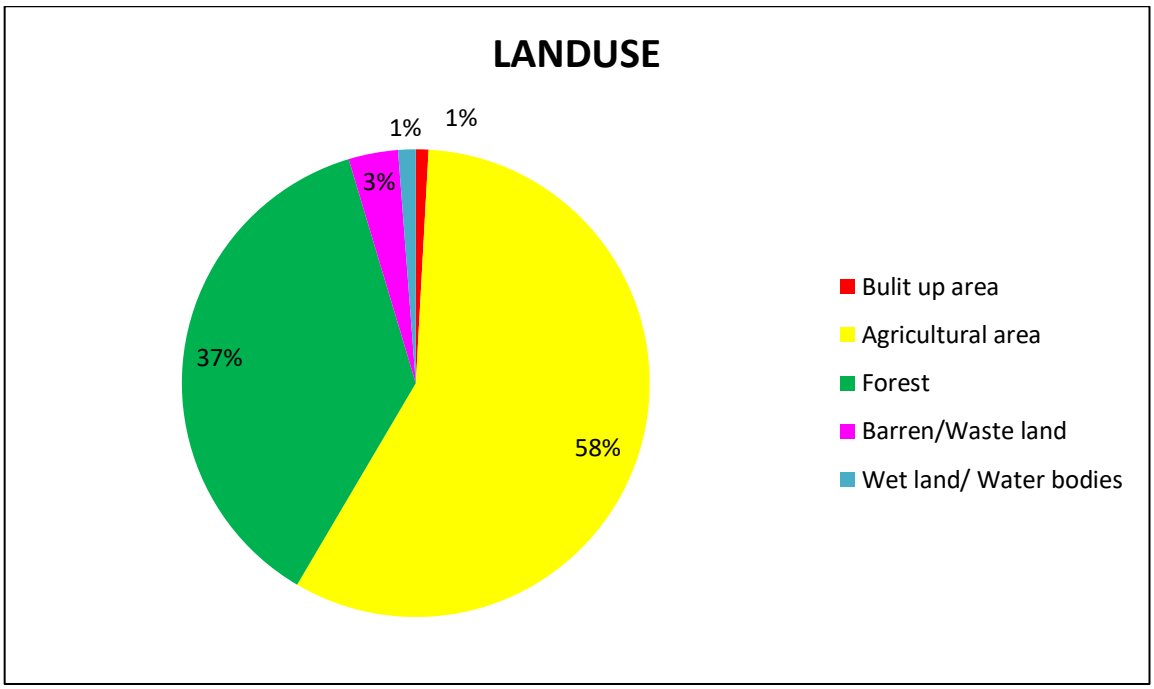

Fig.1.4: Land use Pie Chart.

Soybean is major crop of Betul district. It is cultivated in 2555.6 Sq. km under rain fed and 5.70 Sq. km under irrigated condition. Groundnut, Til, Ramtil are other oilseed crops grown in kharif season and Linseeds and Mustard are major oilseeds of Rabi season in the district. Oilseeds area is 2561.56 Sq. km in Betul district which is 42.17% of Gross Cultivated Area (GCA).Rice and Wheat are major cereals cultivated in Betul district. There are 1399.4 sq. Km rainfed and 386 sq. Km irrigated area covered by cereals in the district which is 29.39% of GCA.Coarse cereals in the district have third position in term of area of production. It covers total 725.99sq. Km including kharif and rabi area. Jowar, Maize, Kodo-Kutki are major coarse cereals cultivated in the district. Coarse cereals contribute 11.95% of GCA of Betul.Other Crops (Mainly sugarcane) also cultivated in 190.01 sq. Km in the district. Other crops contribute 3.13% of GCA of the district. Horticultural crops cover 106.02 sq. Km which is 1.75% of GCA of the district. Fiber crops have very little area only 3.31 sq. Km which is 0.06% of GCA of the district.

The climate of the district is congenial for successful cultivation for oilseed, pulses, cereals and horticultural crops like soybean, paddy, pigeon pea, maize in kharif and wheat, gram, sugarcane and pea in rabi are grown predominantly in the district. The total area under irrigation is 36% out of which 33% is double cropped in this district.(From Krishi Vigyan Kendra website, Betul)

The Ground water source (Open Well, bore well) based irrigation caters to the major area i.e., 72.3% of total irrigated area. 27.1 % of total irrigated area depends on surface water sources (canals, reservoirs,tanks).(Department of agriculture, Madhya Pradesh website)

Table 1.3: Irrigation by different sources.

IRRIGATION BY DIFFERENT SOURCES	Number of Structures	Area in Sq. km
Dug wells	68268	757.73
Tube wells/Bore wells	11231	351.51
Tanks/Ponds	46	98.42
Canals	108	319.7
Other Sources	-	126
Net Irrigated Area	-	1653.36

1.6 Geology

Betul district is underlain by various geological formations, forming different types of the aquifer in the area. Main geological units of the area areDeccan traps,Gondwana formations, Archaeans.Deccan traps comprising basaltic lava flows and most extensive rocks in the district. These rocks present in Betul, Multai, Bhimpura, Chicholi, Bhainsdehi, Atner and Prabhat pattan blocks.The Archaean rocks generally Granitoids cover approximately 20% of the total district area.The Archaeans are mainly occupying the Betul, Chicholi,Bhimpur, Shahpur and Amla blocks.The Gondwana formations comprise succession of sandstone, shales, and clays with seams of coal lying over the crystalline Archaean rocks.The Gondwana formations are mainlypresent inShahpur, Ghodadongri blocks and occur as patches inBhimpur block. The geological map of the district is shown in the **Fig.1.5.** The general stratigraphic succession of the district is presented in the **Table.1.4**

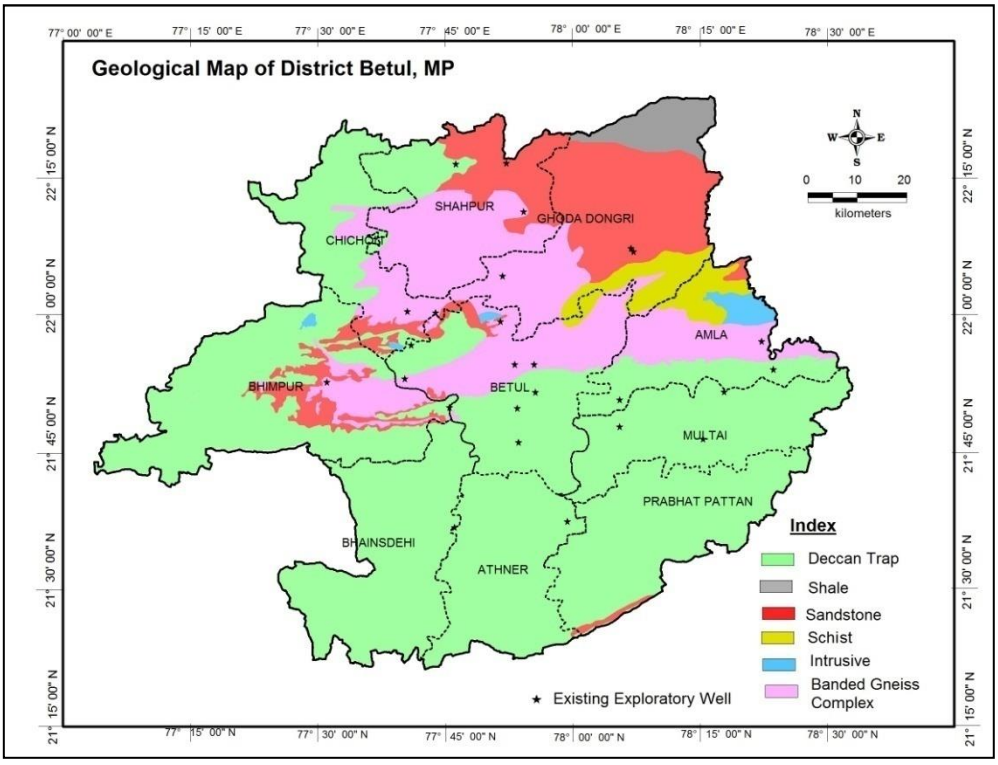

Fig.1.5: Geological Map.

Table 1.4: Tectono stratigraphic succession of Betul belt (after Chakraborty et.al., 2009)

DECCAN TRAPS		Basaltic lava flows and dolerite dykes
Intrusive contact / Disconformity		
GONDWANA SUPERGROUP		Conglomerate, sandstones, and shales
Unconformable / Tectonic Contact		
	INTRUSIVES	Basic dykes, pegmatites, quartz veins Homophanous Amphibole-Mica Granite, Porphyritic Granite
	Intrusive / Tectonic contact	
BETUL GROUP	PADHAR MAFIC – ULTRA MAFIC SUITE	Diorite, Epidiorite, Gabbro, Norite, Pyroxenite, hornblendite, Websterite, Harzburgite, Anorthosite, Diorite, talc – serpentinite rock, quartz – epidote rock
	Intrusive / Tectonic contact	
	SONAGHATI FORMATION	Intercalated sequence of quartzite and quartz-mica schist
	Conformable / Tectonic contact	
	BARGAON FORMATION	Meta-sediments (mica schists) Metarhyolite and felsic metatuff, Metabasalt and Amphibole – Chlorite schist
	Conformable / Tectonic contact	
	RANIPUR FORMATION	Phyllite, Banded Hematite / Magnetite quartzite, BIF Granulite, Meta-basalt, amphibolite, Carbonaceous phyllites Calcareous quartzite, calc-silicates, marble
	Un-conformable / Tectonic contact	
AMLA GNEISS	BASEMENT ROCK	Banded migmatite gneiss, quartzofeldspathic mica schist /gneiss

1.7 Soil cover

In the district, there are five types of soils namely kala soil (Black), Morand soil, Matbarra soils, Bardi soil, Sihar and retard soils. The southern central and eastern part of the district is covered by black cotton soil. Geologically the soils are divided according to their clay content and are shown in **Fig. 1.6**

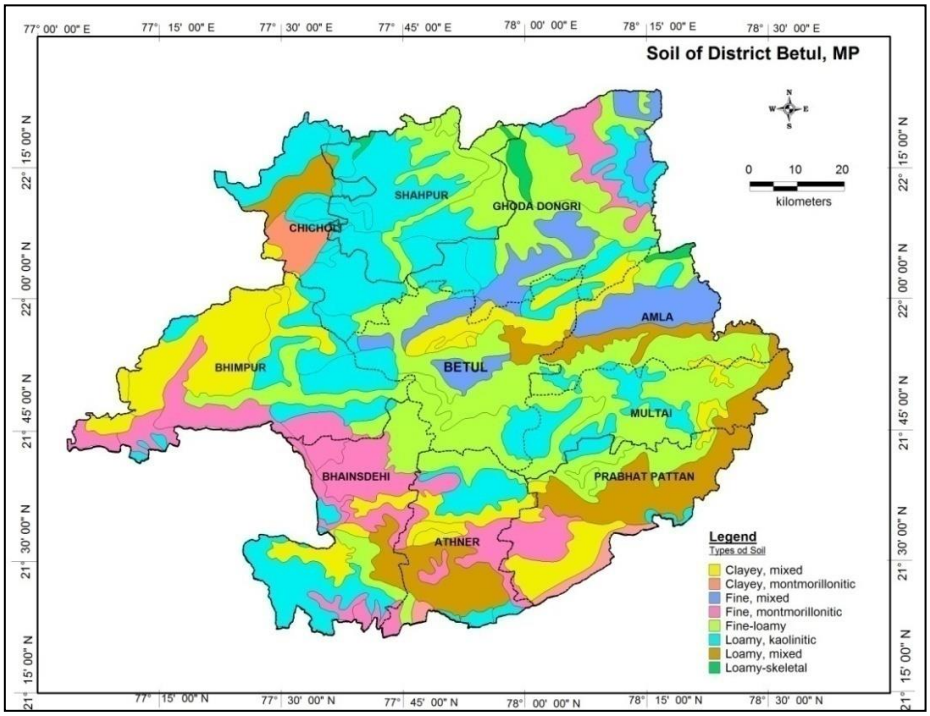

Fig.1.6: Soil Map.

1.8 Hydrology and Drainage

Rivers, lakes and man-made reservoirs are the main sources of surface water abstraction. The major rivers flowing in the district are the Ganjal River (a tributary of the Tapti River), the Morand River and theTawa River (tributaries of the Narmada River). The Tapti River originates from Multai in the Betul district. The development of reservoirs has usually been for irrigation, flood control and hydropower. There are over 135 medium and minor reservoirs in the district.The drainage of the district is diverted in all direction from the eastern high mass of Satpura plateau. The drainage map of the Betul district is shown in **Fig. 1.7.**Betul district three basins are present namely, Narmada, Tapi and Godavari Shown in **Fig.1.8.**

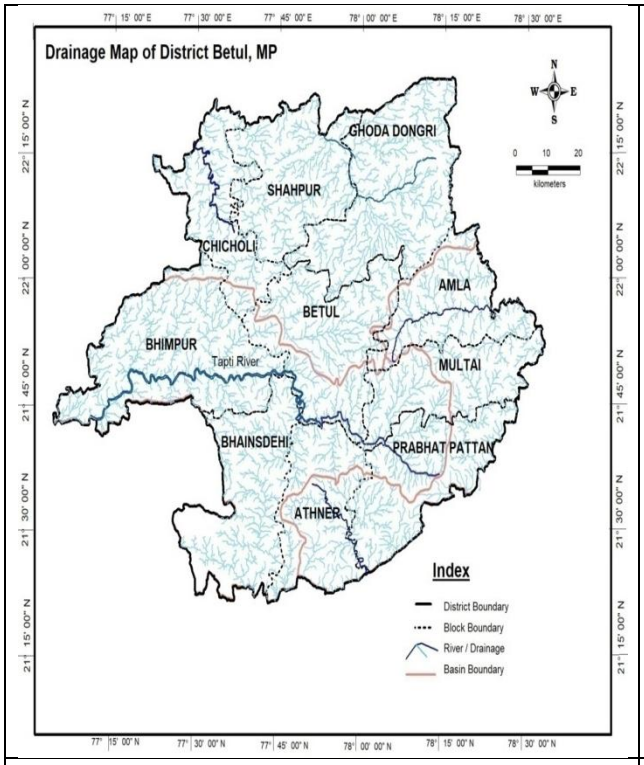

Fig.1.7: Drainage Map.

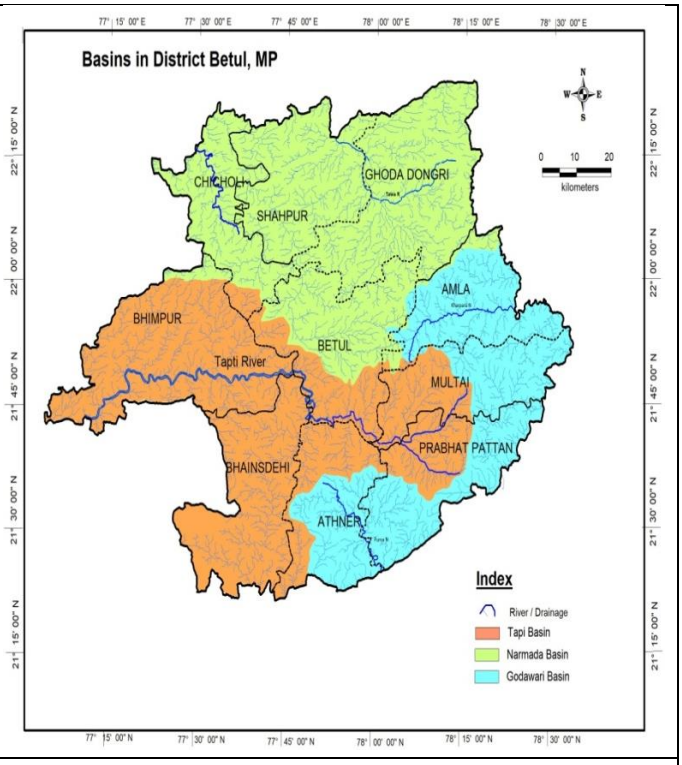

Fig.1.8: Basins of Betul District.

2. DATA COLLECTION AND GENERATION

2.1 Data Collection and Compilation

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

- Hydrogeological Data – Current and historical water levels along with water level trend data of monitoring wells representing Aquifer-I (Shallow aquifer) of CGWB. The weathered zone thickness (aquifer-I), lithologyand details of deeper aquifers (aquifer-II) of exploratory wells were also collected and compiled.
- Hydrochemical Data - Ground water quality data of monitoring wells of CGWB representing shallow aquifer and data from exploratory wells representing deeper aquifer.
- Exploratory Drilling – Ground water exploration data of exploratory wells of CGWB.
- Hydrometeorological Data - Long term rainfall data for the whole district and for each block fromIndian meteorological Department and Water Resource Department.
- Water Conservation Structures – Numbers, type and storage potential of water conservation structures prevailing in the area from Jilla Panchayat, Betul.
- Cropping Pattern Data – Data on prevailing cropping pattern from Krishi Vigyan Kendra, Betul district.

2.1.1Ground Water Exploration

Ground water exploration was carried out to assess the lithological disposition of shallow aquifer (Aquifer-I) and deeper aquifer (Aquifer-II). The locations of exploratory wells are shown in **Fig. 2.1**. The details of exploratory and observation wells are given in **Annexure-II.**

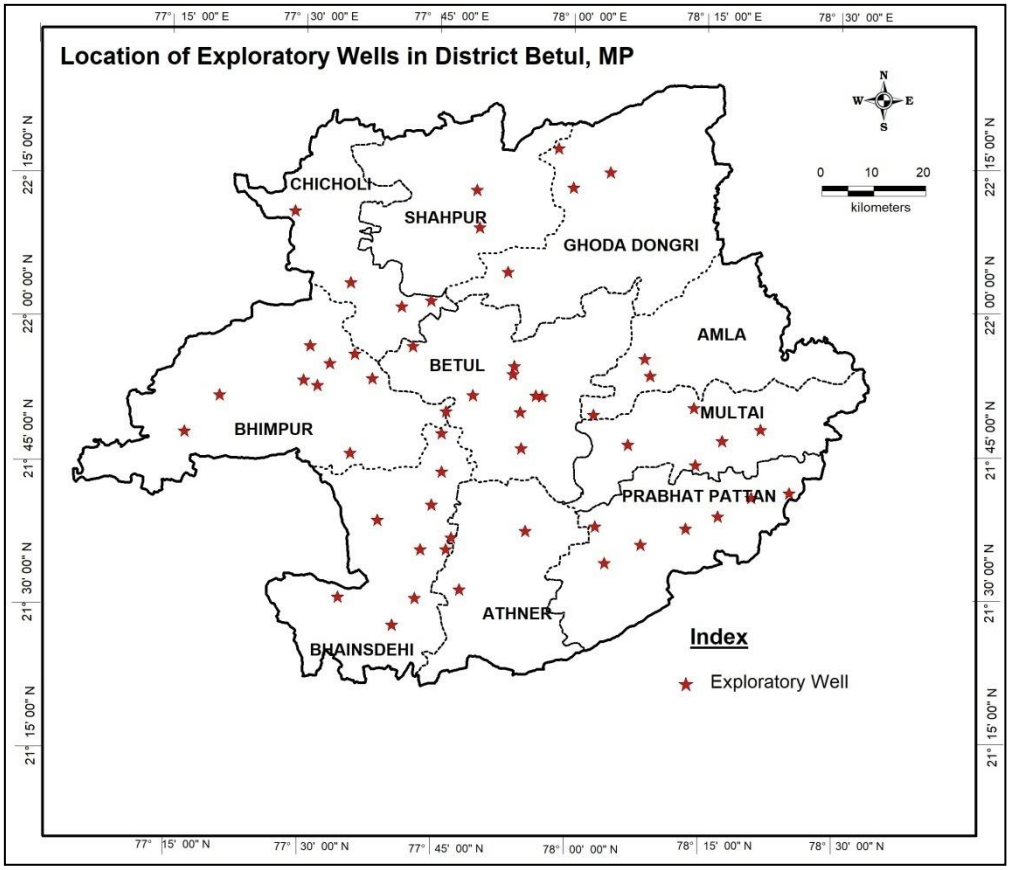

Fig.2.1: Locations of Exploratory Wells.

2.1.2 Ground Water Monitoring Wells

Central ground water board has been carrying out water level monitoring through ground water monitoring wells since last two decades. The water levels of the monitoring wells are being monitored four times in a year during the month January, May, August and November. The locations of monitoring wells are shown in **Fig. 2.2**.

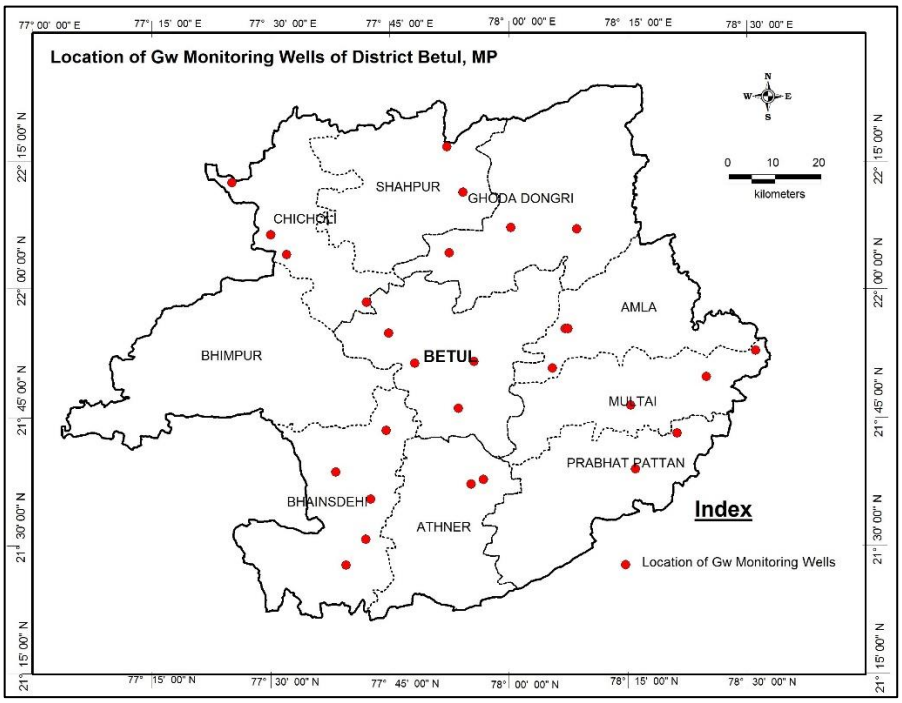

Fig.2.2: Locations of GW Monitoring Wells.

2.1.3 Ground Water Quality

The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. For assessment of ground water quality, samples from 27 wells (shallow dug wells representing phreatic aquifer) have been collected during pre-monsoon. Similarly for Aquifer – II, the ground water quality data of 43 exploratory/observation wells drilled during earlier exploration and current exploratory drilling activities were utilised.

2.1.4 Thematic Layers

The following 5 thematic layers were also generated on GIS platform which supported the primary database and provided precise information to assess the present ground water scenario and also to propose the future management plan.

- Drainage and Basin
- Soil
- Land Use – Land Cover
- Geology and Structure
- Physiography

The thematic layers such as geology, drainage, soil, land use-land cover have been described in Chapter - I.

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation, thematic layers was interpreted and integrated. Based on this the various aquifer characteristic maps on hydrogeology, aquifer wise water level scenario both current and long term scenarios, aquifer wise ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, aquifer wise yield potential, aquifer wise resources, aquifer maps were generated and as discussed in details.

3.1 Hydrogeology

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability.Betul district is underlain by various geological formations, forming different types of the aquifer in the area. Main geological units of the area are Deccan traps,Gondwana formations and Archaeans. The principal aquifers in the area are Basalt andAchaeans where the occurrence and movement of ground water primarily depends on the degree of interconnection of secondary pores/voids developed by fracturing and weathering. The hydrogeological map of area is prepared and presented in Fig.3.1.

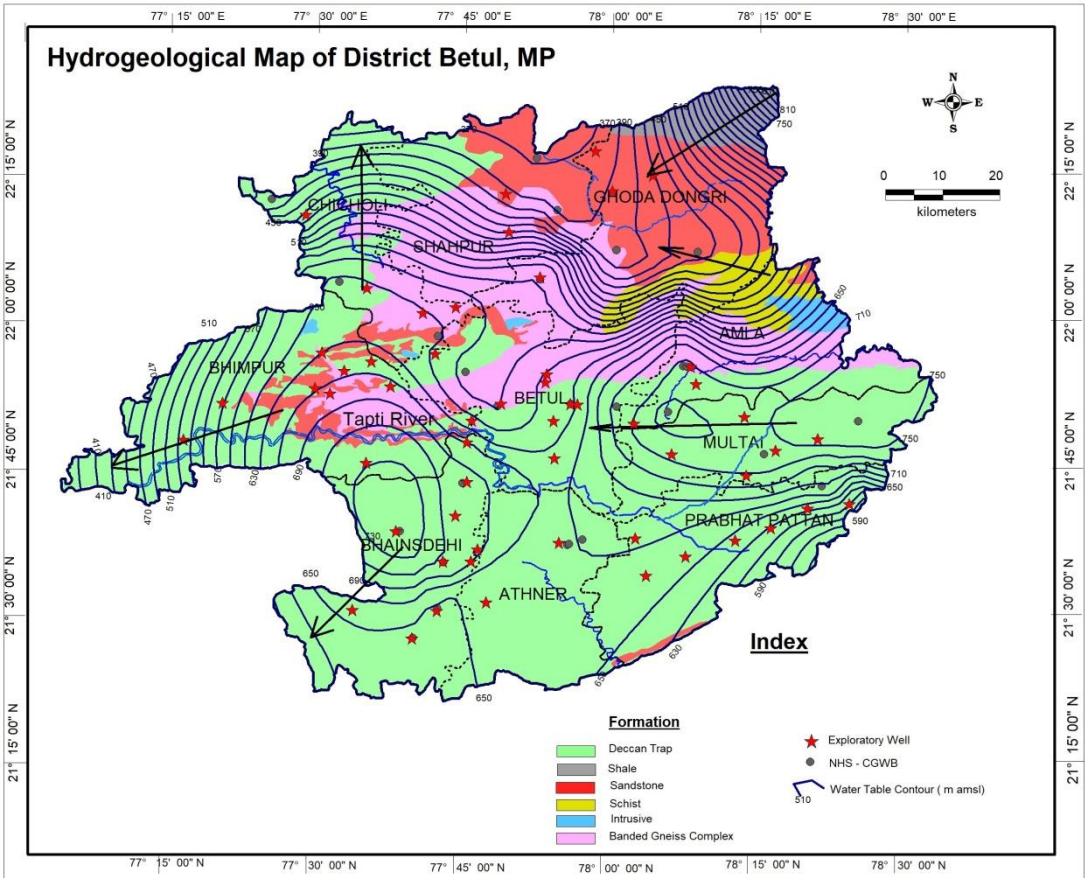

Fig. 3.1: Hydrogeology.

The water table elevation map was also prepared (**Fig.3.1**) to understand the ground water flow directions. In general, the groundwater movement in the NE part is towards the Tawa River, In the Northern part towards the Narmada River, in the central part the Movement is along the Tapi River, in the SW and SE part the groundwater movement is towards West and Southern side respectively. The occurrence of ground water is different geological formations is described below:

3.1.1 Deccan Traps

Deccan traps comprising basaltic lava flows and most extensive rocks in the district. There rocks occupying in Betul, Multai, Bhimpura, Chicholi, Bhainsdehi, Atner and Prabhat pattan blocks. Ground water occurs in the weathered, jointed and fractured basalts under Unconfined and semi-confined to confined conditions. The unconfined aquifer is restricted up to 15 m bgl while semi-confined and confined aquifers are encountered between 45 to 190 mbgl. The yield of shallow aquifer in this formation ranges between 60 to 300 lpm.

3.1.2Archaeans

The Archaean rocks generally Granitoids cover approximately 20% of the total district area. Quartz veins are common features and occur as thin strings. The Archaeans are mainly occupying the Betul, Chicholi,Bhimpur, Shahpur and Amla blocks. These rocks do not have primary porosity. The weathered part of the crystallineis the aquifer for open well and shallow tube wells. The thickness of these zones in the entire district area ranges from 2.5 to 30.00 m. In this formation, aquifers also occur where the rocks are jointed and fractured. The open wells that exist in this formation range in depth of 8.00-20.00 mbgl generally the column of water available during pre-monsoon season varies from 2.00 – 4.00 m. The general yield potential of Archaean formation less than 180 lpm. However at places the yield potential in deeper aquifer is found to the tune of 600 lpm.

3.1.3Gondwana Formations

The Gondwana formations comprise succession of sandstone, shales, and clays with seams of coal lying over the crystalline Archaean rocks.The Gondwana formations are mainlypresent inShahpur, Ghodadongri blocks and occur as patches inBhimpur block. In Gondwana formations groundwater occurs mostly in sandstone and at the contact zones. The yield potential of Gondwana ranges from 100 lpm to 300 lpm tapping semi confined and unconfined aquifers.

3.2 Water Level Scenario – Aquifer-I (Shallow Aquifer)

The present depth to water level scenario of shallow aquifer was generated by utilizing water level data of29 monitoring wells representing shallow aquifer.

3.2.1 Pre-Monsoon (May, 2019)

The **pre-monsoon** depth to water levels during May 2019 ranged between 2.45 (Multai) to 19.7 mbgl (Khedi). The water levels more than 9 mbgl are observed in major part and thewater levels of less than 9 mbgl are observed in northern and easternparts of the district. The pre-monsoon water level data is presented as **Annexure-V**, whereas depth to water level map is given in **Fig.3.2.**

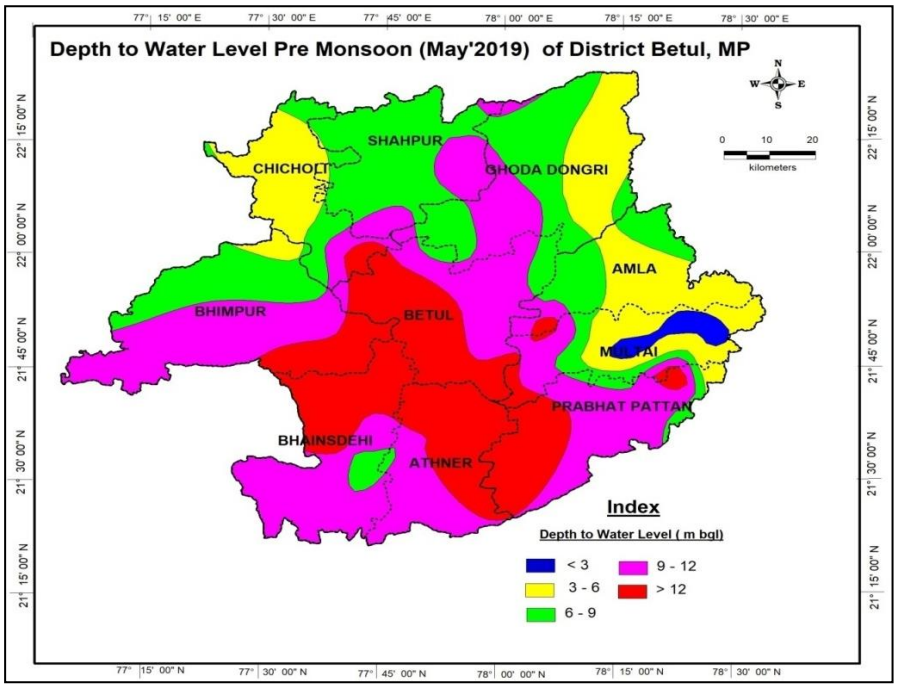

Fig. 3.2: Pre-monsoon (May 2019) Depth to Water Level of Shallow Aquifer.

3.2.2 Post-Monsoon (November, 2019)

The **post-monsoon** depth to water levels during Nov. 2019 ranged between 0.44 (Jhallar) to7.53 mbgl (Ghatpiparia). The shallow water levels within 3 mbgl are observed in major parts of the area. The water level between 3m to 6mbgl is observed in the southern most part and in the central part of Betul, Chicholi and Shahpur block.The pre-monsoon water level data is presented as **Annexure-V**, whereas depth to water level map is given in **Fig.3.3.**

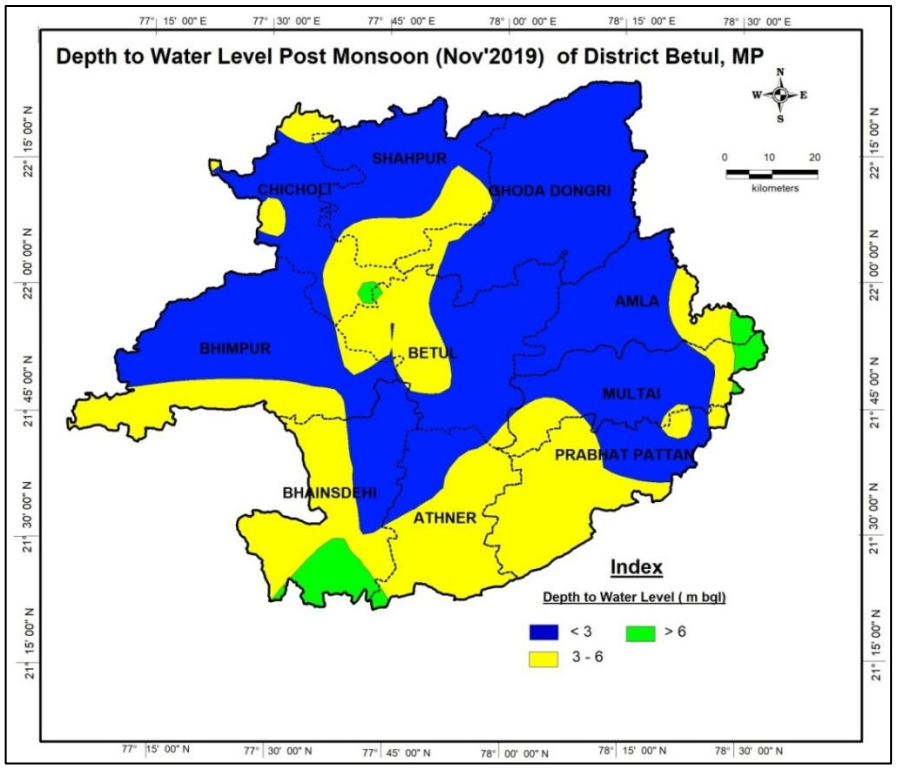

Fig. 3.3: Post monsoon (November 2019) Depth to Water Level of Shallow Aquifer.

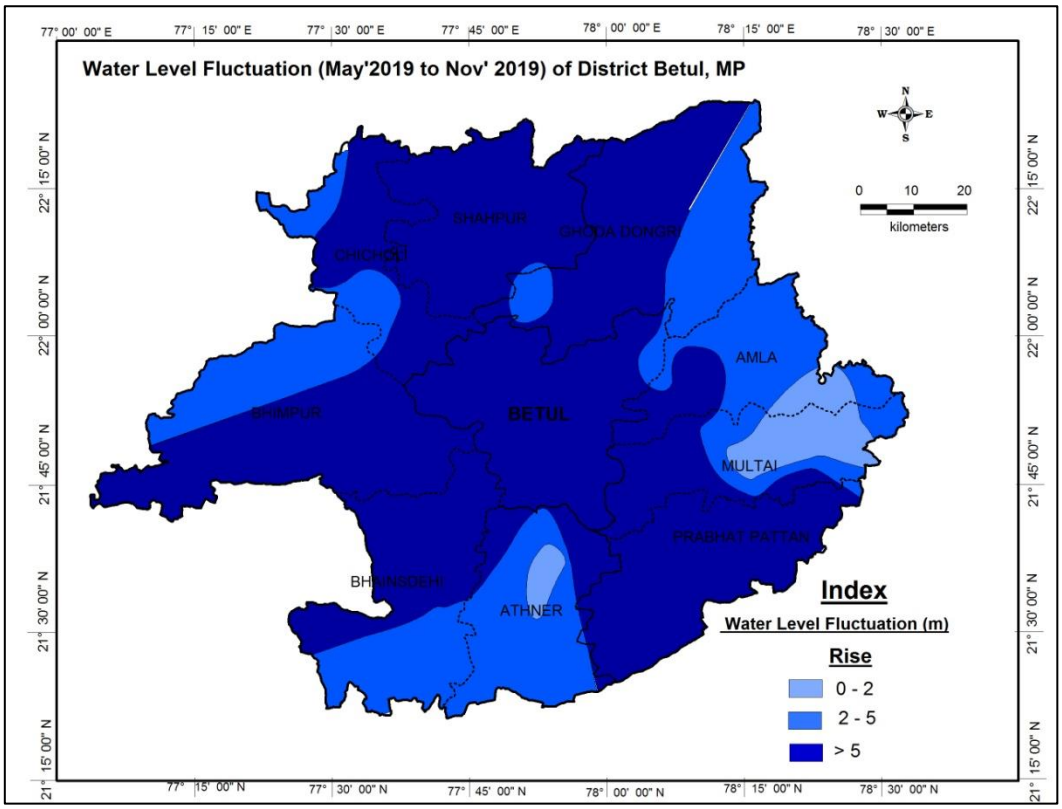

Fig. 3.4: Seasonal Fluctuation of Water Level.

3.2.3 Water level Fluctuation

The water level measured during pre and post monsoon period (2019) was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Kapasia (0.4m) while maximum water level fluctuation was observed at Khedi (13.78 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed (**Table 3.1**).

Table3.1: Analysis of Water Level Fluctuation.

S. No.	Category	Fluctuation Range	% of Wells
1.	Less water level fluctuation	0 to 2 m	10.71%
2.	Moderate water level fluctuation	2 to 5 m	28.57%
3.	High water level fluctuation	>5 m	60.72%

The analysis indicates that majority of the wells (60.72%) are falling in high fluctuation range indicating aquifer storage is not good, whereas moderate water level fluctuation are observed in 28.57 % wells and low water level fluctuation were observed in 10.71 % wells. The seasonal fluctuation map is presented as **Fig. 3.4** the perusal of map indicates that fluctuation of greater than 5 m is observed in major part of the area, whereas lower fluctuation of less than 2 m is observed in the north east, North West and south central part of the district.

3.2.4 Long Water Level Trend (2009-18)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data for the period 2009-18 have been computed and analyzed.

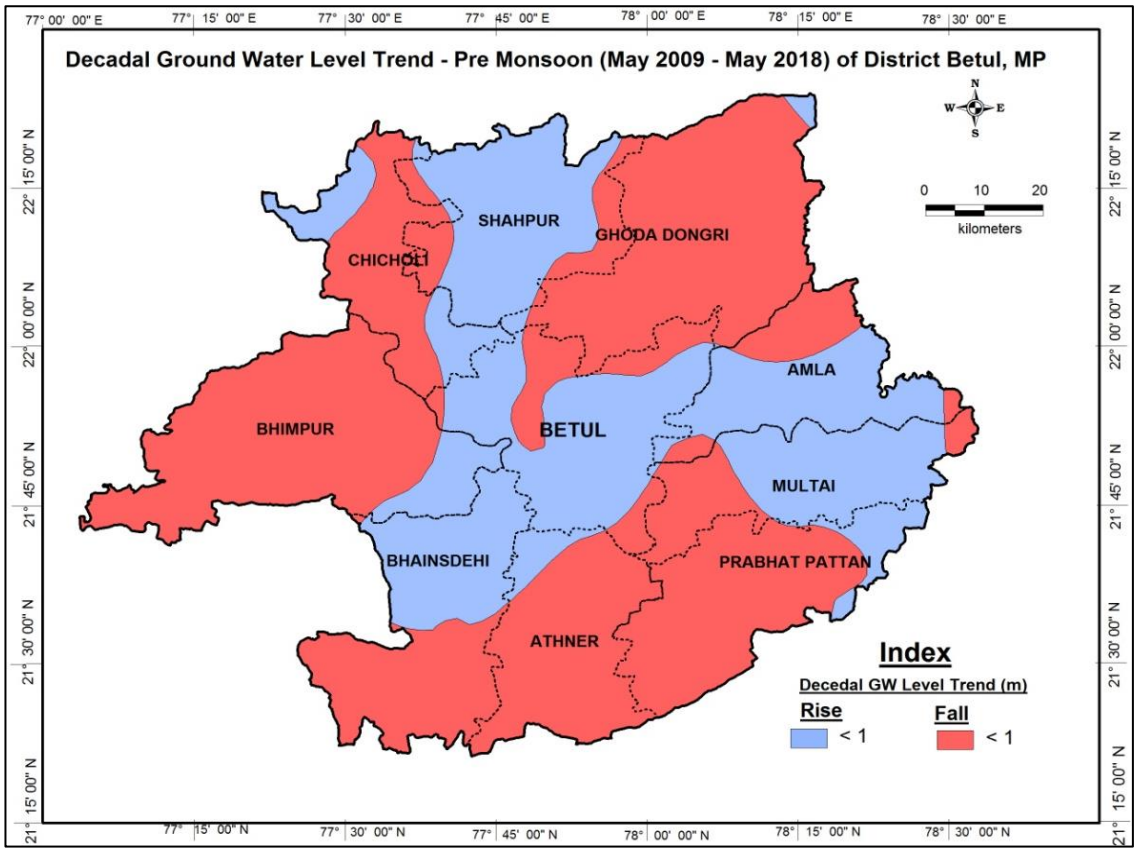

Fig. 3.5: Pre-monsoon Water Level Trend (May 2009-18) of Aquifer-I (Shallow Aquifer).

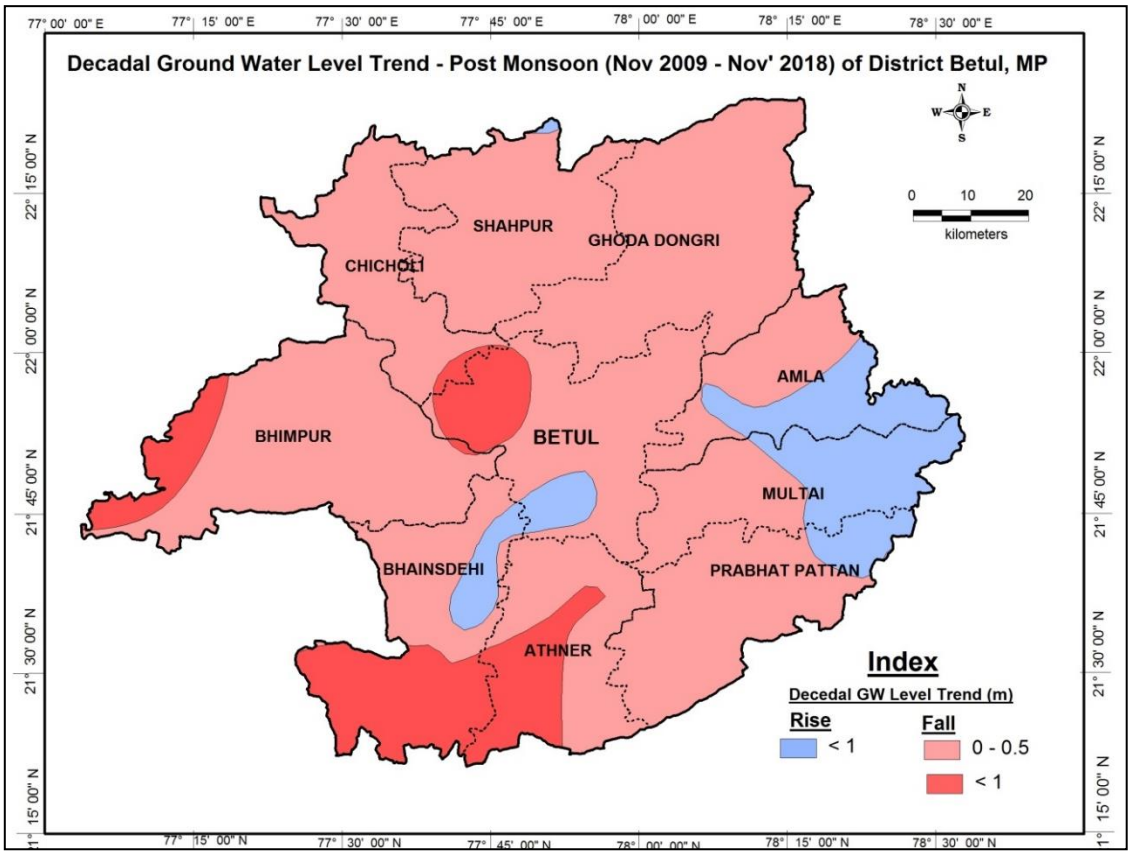

Fig. 3.6: Post-monsoon Water Level Trend (November 2009-18) of Aquifer-I (Shallow Aquifer).

The decadal pre-monsoon water level trend analysis (**Fig 3.5**) indicates that during pre-monsoon period, the northeast, northwest and southern part of the district are showing falling trend. Rest part of the district is showing rising trend.

The decadal post-monsoon water level trend analysis (**Fig 3.6**) indicates that about 95% of the area showing declining trend. Maximum falling trend is ranged between 0 to 0.5 m/yr. Only a small Eastern part of the district and small part of Betul and Bhainsdehi block showing rise in water levels.

3.3 Ground Water Quality

The ground water samples were analysed for major chemical constituents. The aquifer wise ranges of different chemical constituents present in ground water are given in **Table 3.2.**The details of water quality analysis of Aquifer I and II are given in **Annexure VII and VIII**.

Table 3.2: Aquifer wise ranges of chemical constituents.

Constituents	BIS standards for drinking water	Aquifer – I (Shallow aquifer)			Aquifer-II (Deeper Aquifer)		
		Min.	Max.	No. of samples above MPL	Min.	Max.	No. of samples above MPL
pH	6.5-8.5	7.25	8.10	Nil	6.95	8.3	Nil
EC	-	265	1388	Nil	112	1543	-
TH	300-600	126	610	1	45	540	Nil
Calcium	75-200	30	178	Nil	6	204	1
Magnesium	30-100	9	40	Nil	2	29.2	Nil
Potassium	-	0.2	13.1	-	0.1	15.5	-
Sodium	-	10	104	-	6	166	-
Carbonate	-	Nil	Nil	-	Nil	Nil	-
Bi-carbonate	-	134	472	-	18	384	-
Chloride	250-1000	7	222	Nil	7	305	Nil
Nitrate	45	27	161	18	1	155	10
Fluoride	1-1.5	0.05	1.35	Nil	0.26	4.84	10

Note: All values except EC (µS/cm @ 25°C) and pH are in mg/l.

3.3.1 Ground Water quality of aquifer-I (Shallow aquifer):

As per chemical analysis of pre-monsoon 2018 of Betul District, the ground water of shallow aquifer in the area of Betul district is slightly acidic to neutral in nature and the pH of ground water ranged in between 7.25 to 8.10; the highest value of pH (8.10) has been observed in Jogli dug well. The electrical conductivity of ground water in Betul district ranged between 265 to 1388 µS/cm at 25°C and the maximum EC value at Athner (1388 µS/cm at 25°C). The electrical conductivity shows that the ground water is good to slightly saline in nature and at some locations i.e. Athner (1388 µS/cm at 25°C).The EC value map is presented in**Fig. 3.9.** The fluoride concentration was ranged in between 0.05 to 1.35 mg/l. In the district, fluoride concentration has not been observed more than BIS recommendation of fluoride concentration in drinking water i.e. 1.5 mg/l. The maximum concentration of fluoride has been recorded in the dug well of Jogli village i.e. 1.35 mg/l. In the district, nitrate concentration in ground water ranged in between 27 to 161 mg/l. About 33.3% ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l and 67.7% water samples recorded more than 45 mg/l as per BIS recommendation. The high nitrate concentration has been recorded in ground water of Bhainsdehi (47 mg/l), Gudagaon (49 mg/l), Jhallar (50 mg/l), Sasundra (51 mg/l), Masod New (52 mg/l), Multai-dw (52 mg/l), Jogli (53 mg/l), Gadha (54 mg/l), Shahpur (55 mg/l), Betul (67 mg/l), Chirapatala (68 mg/l), Khokharkheda (75 mg/l), Pathakhera (75 mg/l), Ghoradongri (76 mg/l), Kotal Kund (84 mg/l), Junapani (85 mg/l), Athner (110

mg/l) and Ghatpiparia (161 mg/l). The nitrate concentration map of Betul district presented in**Fig. 3.10.** Total hardness of ground water in the study area ranged in between 126 to 610 mg/l. The high concentration has been observed in the dug well of Betul (610 mg/l).

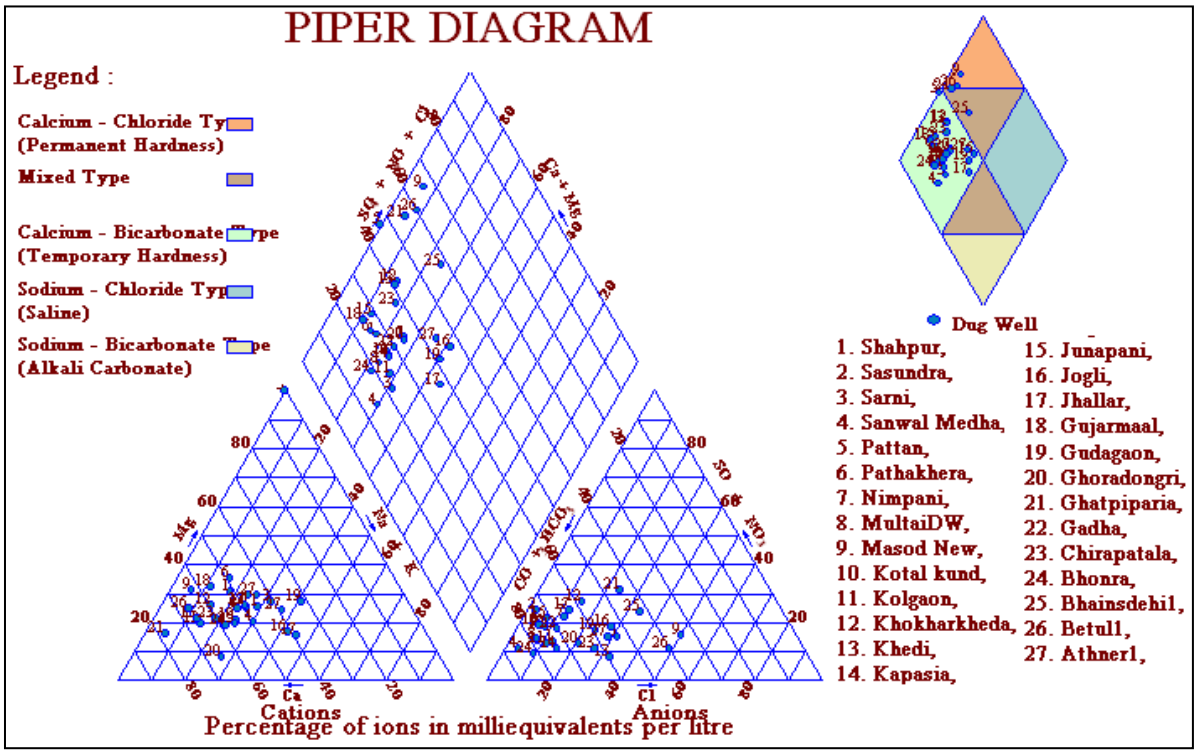

Fig.3.7: Piper Diagram.

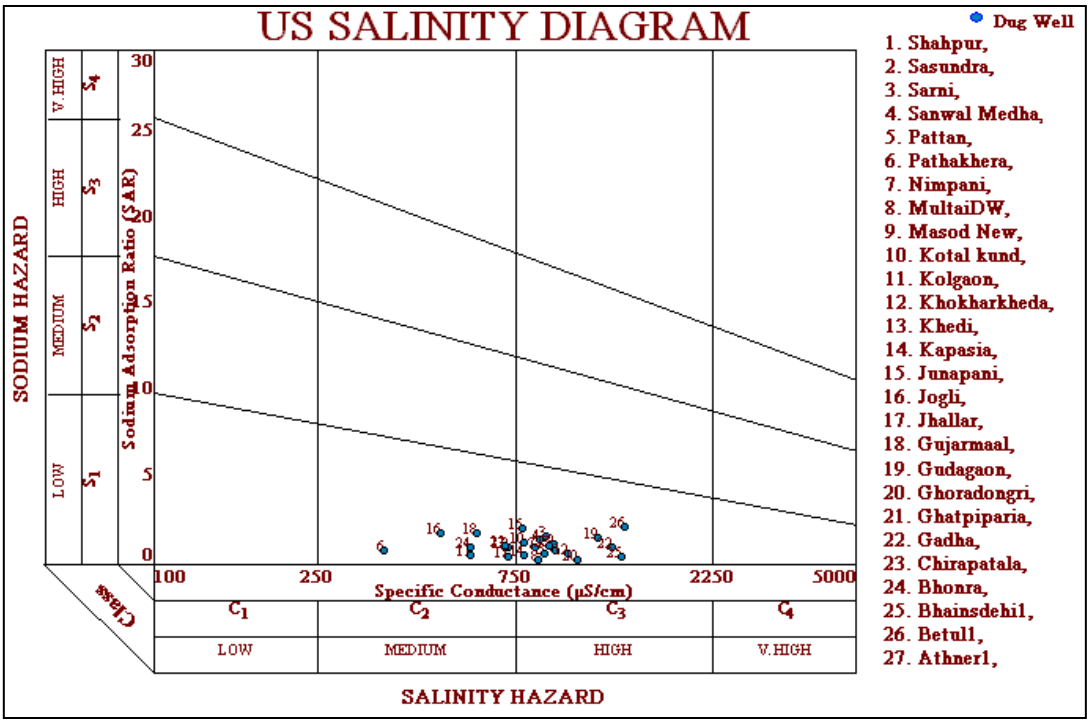

Fig.3.8: US Salinity diagram.

As per the piper diagram (**Fig.3.7**), water samples are Calcium Chloride (permanent hardness), Calcium Bi-carbonate (temporary hardness) and Mixed (Calcium-Magnesium-Chloride) types of water. The US Salinity Diagram**(Fig.3.8)** shows the ground water is medium to high salinity classes i.e. C_2S_1 and C_3S_1. The C_2S_1 and C_3S_1 classes of water may be used for irrigation purpose with proper soil management.

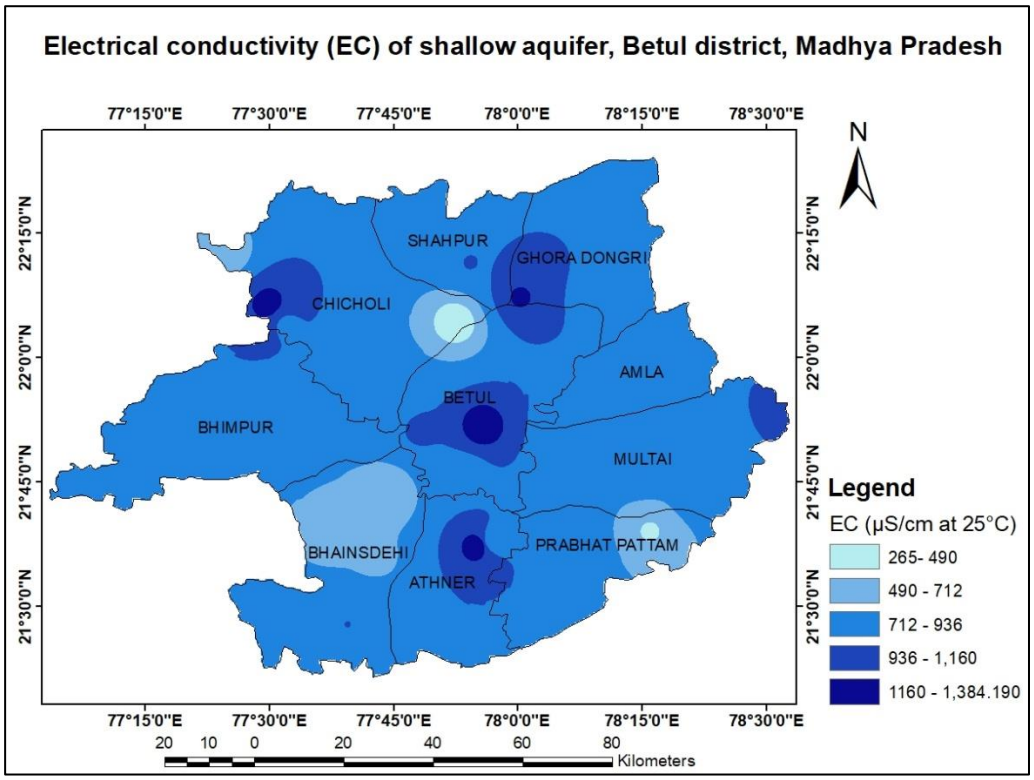

Fig.3.9: Electrical Conductivity of Aquifer-I (Shallow Aquifer).

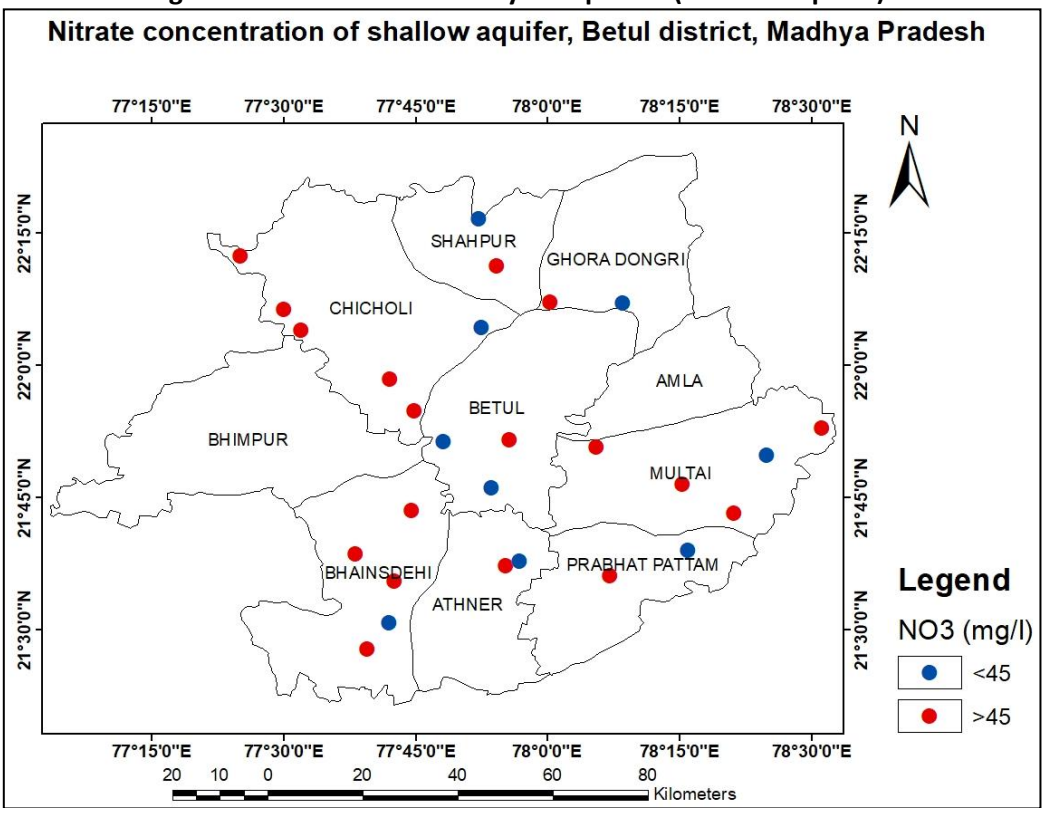

Fig.3.10: Nitrate of Aquifer-I (Shallow Aquifer).

3.3.2 Ground Water quality of aquifer-II (Deep aquifer):

As per the chemical analysis of the Groundwater samples collected during exploration, the ground water of deep aquifer in the area of Betul district is slightly acidic to neutral in nature and the pH of ground water ranged in between 6.95 to 8.30; the highest value of pH (8.30) has been observed in Chicholi EW. The electrical conductivity of ground water in Betul district ranged between 112 to 1543 µS/cm at 25°C and the maximum EC value at Betul (1543 µS/cm at 25°C). The electrical conductivity shows that the ground water is good to slightly saline in nature and at some locations i.e. Betul (1543 µS/cm at 25°C)**.** The fluoride concentration was ranged in between 0.26 to 4.84 mg/l. In the district, in 10 water samples the Fluoride value found above permissible limit i.e. 1.5 mg/l. The maximum concentration of fluoride has been recorded in the EW of Bhimpur i.e. 4.84 mg/l. In the district, nitrate concentration in ground water ranged in between 1 to 155 mg/l. About 10 ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l and rest 33 water samples recorded more than 45 mg/l as per BIS recommendation. The maximum concentration of fluoride has been recorded in the EW of Jin i.e. 155 mg/l. Total hardness of ground water in the study area ranged in between 45 to 540 mg/l. The high concentration has been observed in the EW of Betul (540 mg/l).

In case of Aquifer-II, it is observed that Total Hardness, pH and Magnesium are within permissible limit. Out of 43 samples taken from exploratory/observation wells, in 10 samples the Nitrate and Fluoride value found above permissible limit. The electrical-conductivity, Fluoride and Nitrate of Aquifer-II has been prepared and presented as **Fig. 3.11, 3.12 and 3.13 respectively**.

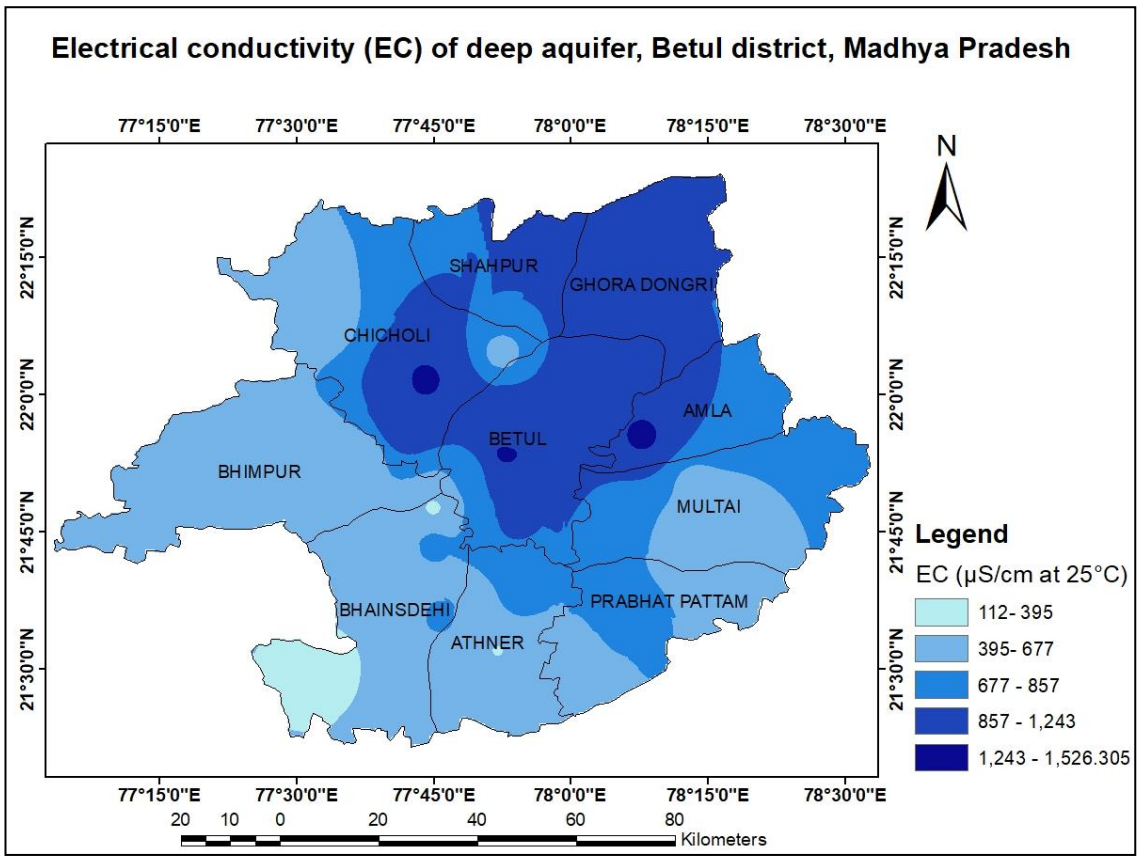

Fig.3.11: Electrical Conductivity of Aquifer-II (Deep Aquifer).

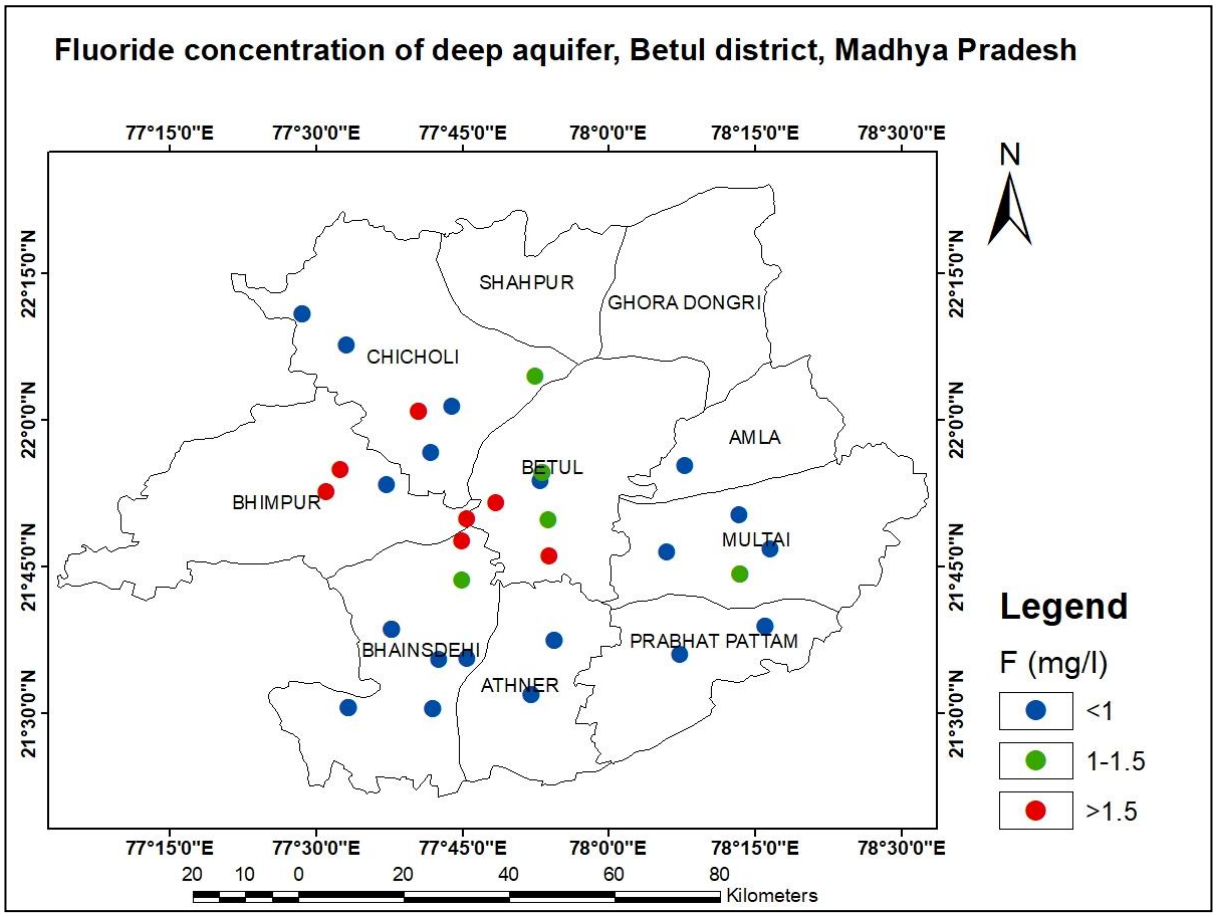

Fig.3.12: Fluoride concentration of Aquifer-II (Deep Aquifer).

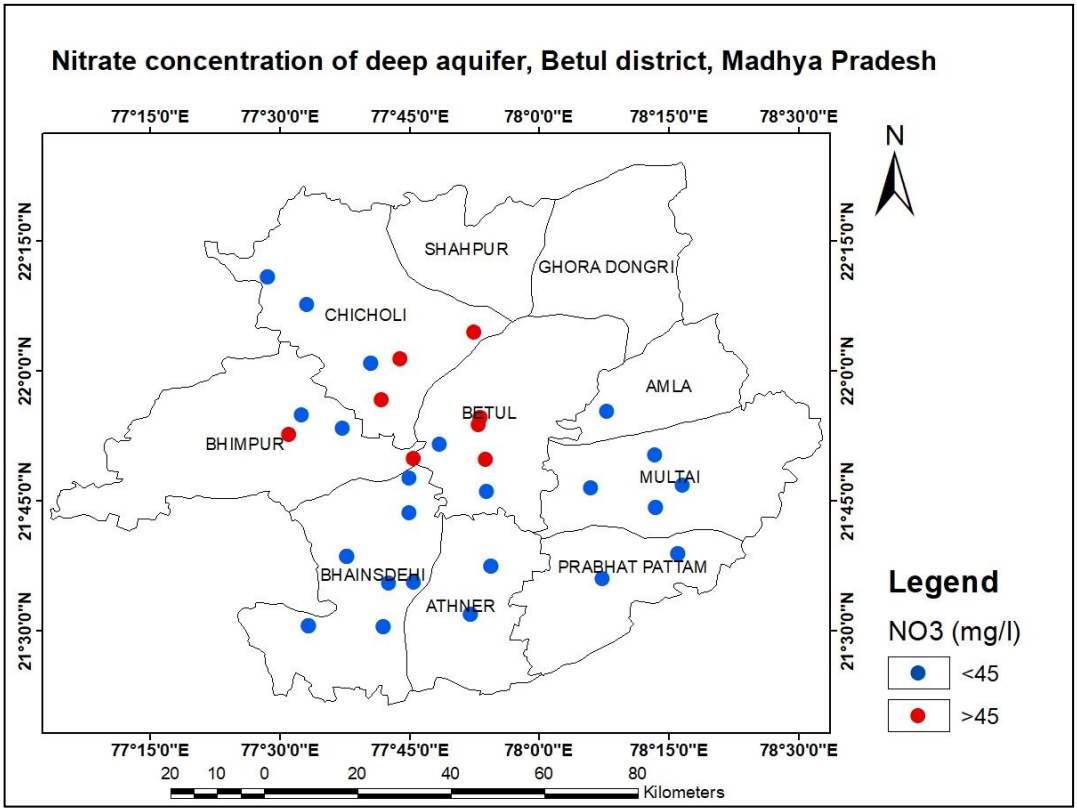

Fig.3.13: Nitrate concentration of Aquifer-II (Deep Aquifer).

3.4 3-D and 2-D Aquifer Disposition

The data generated from ground water monitoring wells, micro level hydrogeological inventories, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. This particularly includes the information on geometry of aquifers and hydrogeological information of these aquifers. In the area the two aquifer systems has been deciphered as listed below:

a. **Aquifer –I (Shallow Aquifer)**
b. **Aquifer – II (Deeper Aquifer)**

3.4.1 Fence Diagram and 3D model

As the area is covered with hard rocks, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 30m. The fractured /jointed basalt and Granitoids, Gondwana sandstones form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.3.12**and 3-D representation is presented in **Fig. 3.13**. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

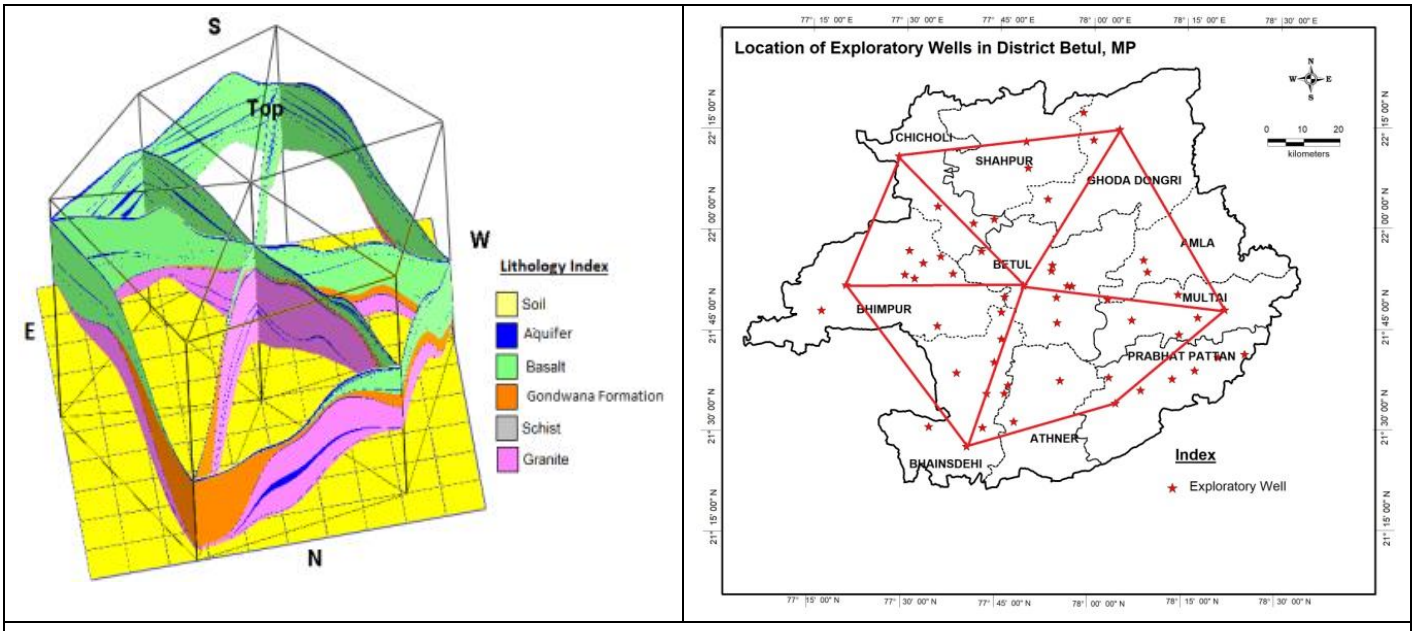

Fig.3.14: Fence Diagram.

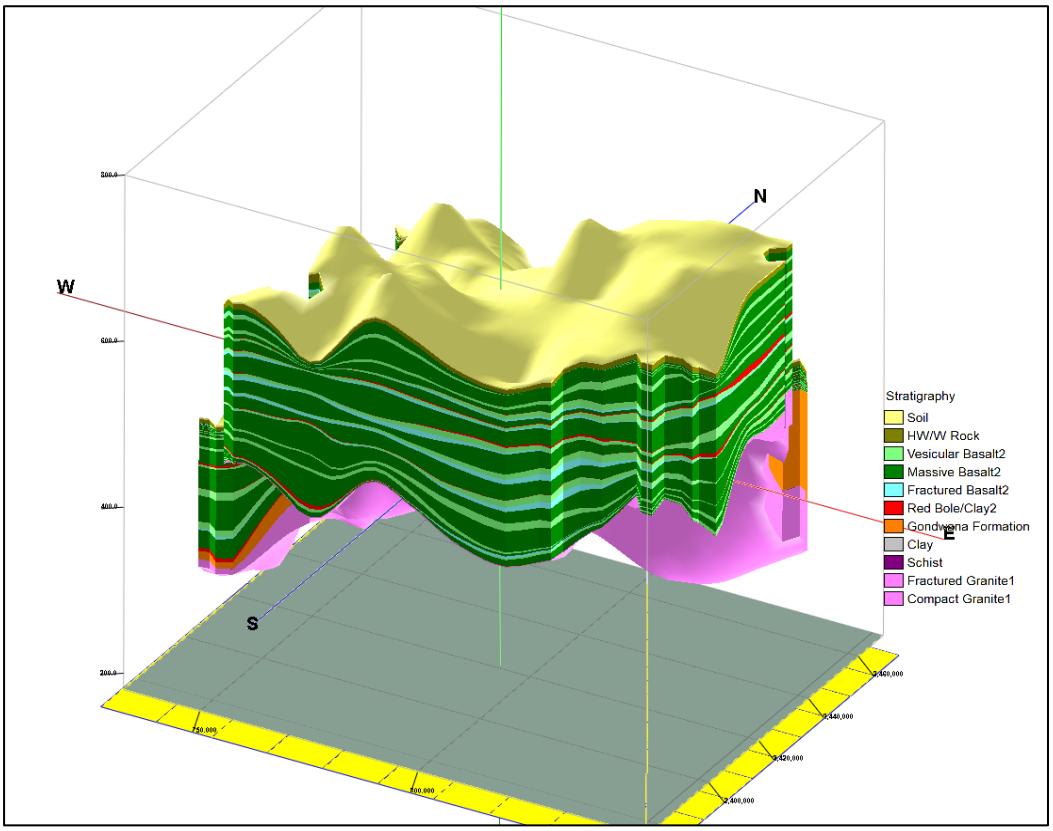

Fig.3.15: 3-D disposition of Aquifers.

3.4.2 Hydrogeological Cross Sections

To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared viz. A-A' representing north west – south east direction and B-B' representing north – south direction.

3.4.2.1 Hydrogeological Cross Section A-A'

Hydrogeological cross section A-A'(**Fig.3.16**) represents North West –South East direction and data of 9 exploratory wells i.e., Gawasen, Alampura, Chicholi, Jin, Khedi, Surgaon, Kolgaon, Bisnor, Masod has been utilised.

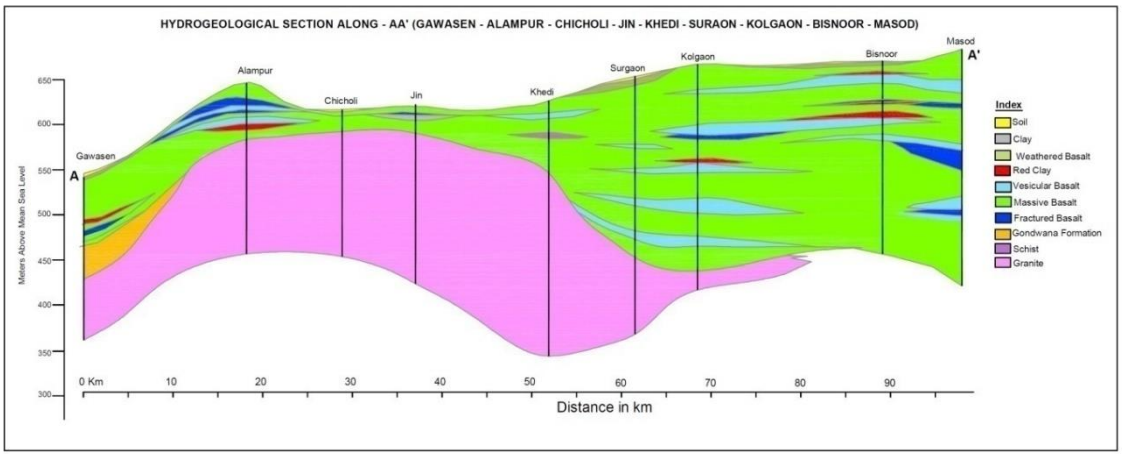

Fig.3.16: Hydrogeological Cross Section A-A'.

3.4.2.2 Hydrogeological Cross Section B-B'

Hydrogeological cross section B-B'(**Fig.3.17**) represents east – west direction and data of 10 exploratory wells i.e., Kamod, Basinda, Jaora, Chikhali, Khedi, Surgaon, Saikheda, Sandiya, Birolijhilpa, Khambarahas been utilised.

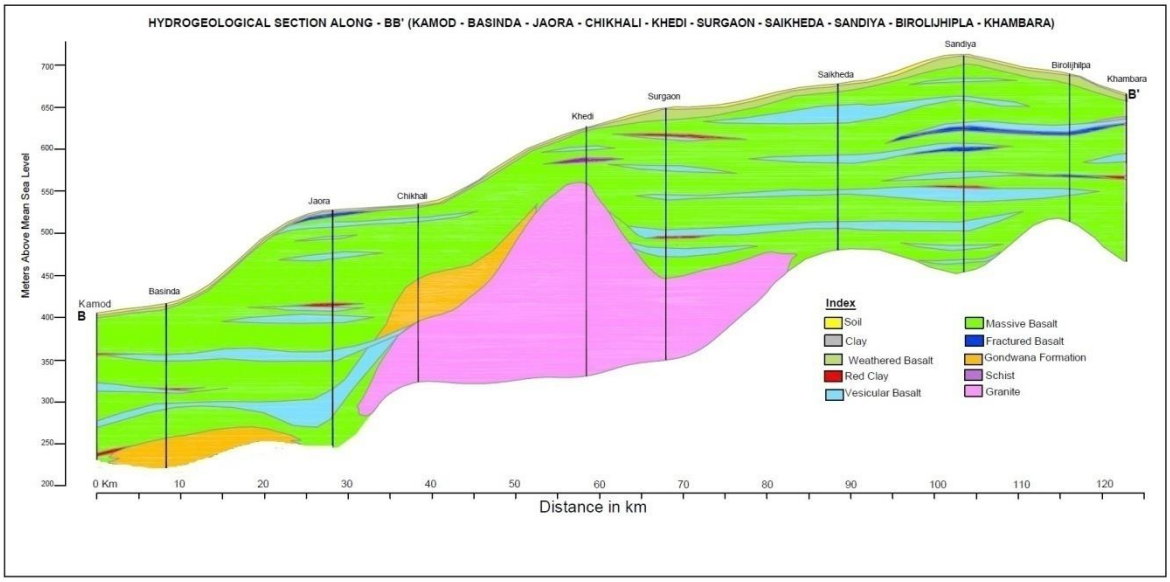

Fig.3.17: Hydrogeological Cross Section B-B'.

3.4.2.3 Hydrogeological Cross Section C-C'

Hydrogeological cross section C-C' (**Fig.3.18**) represents north – south direction and data of 10 exploratory wells i.e., Kamod, Basinda, Jaora, Chikhali, Khedi, Surgaon, Saikheda, Sandiya, Birolijhilpa, Khambara has been utilised.

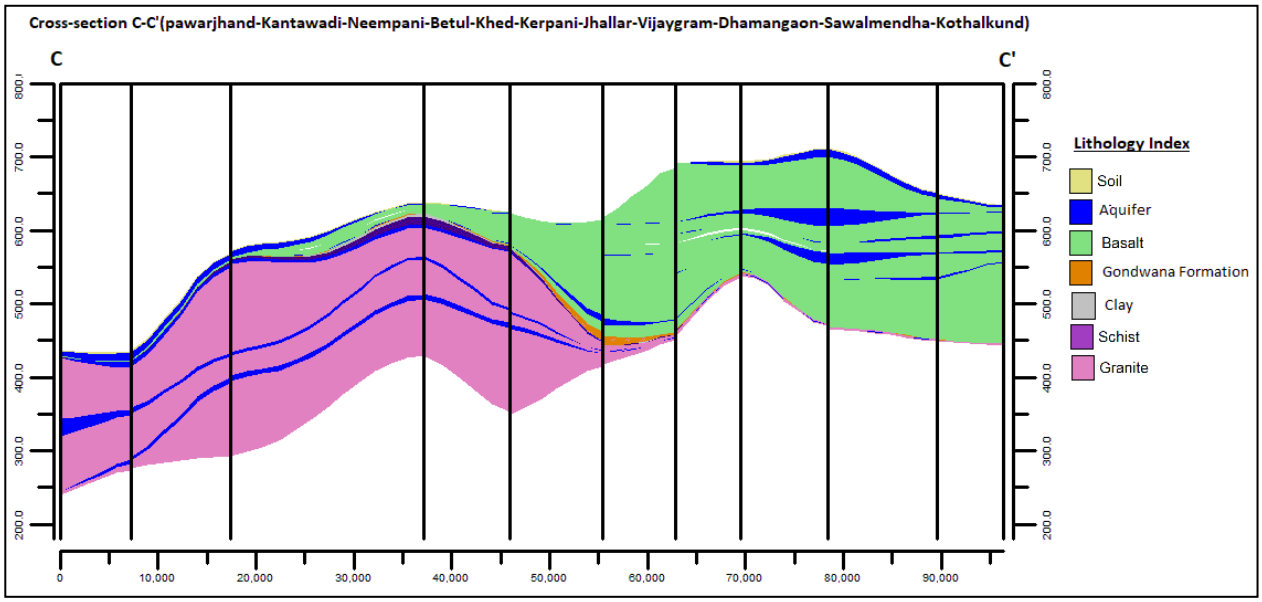

Fig.3.18: Hydrogeological Cross Section C-C'.

3.5 Aquifer Characteristics

Basalt of the area comprises two distinct units viz, upper vesicular unit and lower massive unit. The massive basalt is hard, compact and does not have primary porosity and is impermeable. Weathering, jointing and fracturing induces secondary porosity in massive unit of basalt. In vesicular basalt, when vesicles are interconnected constitutes good primary porosity and when the vesicles are filled/ partly filled the porosity is limited. Ground water occurs under phreatic/ unconfined to semi-confined conditions in basalts.

Granitoids also doesn't have primary porosity and is impermeable. So the aquifers formed when the rock is weathered, fractured and jointed.

Based on the ground water exploration carried out in the Betul district, the following two types of aquifers can be demarcated and the details are given below in **Table 3.3**.

Table 3.3: Aquifer Characteristics.

Major Aquifer	**Basalt /Granitoids/ Sandstone**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Granitoids	Jointed / Fractured Basalt/Granitoids/Sandstone
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	0.44 to 19.7	10 to 112.8
Weathered / Fractured rocks thickness (m)	2 to 14	0.5 to 17
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 25 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$
Suitability for drinking/ irrigation	Suitable for both drinking and agriculture, except high Nitrate at places	Suitable for both drinking and agriculture, except high Nitrate and Fluoride at places

4. GROUND WATER RESOURCES

The ground water resources have been assessed for two types of aquifer existing in the area i.e., Aquifer-I and Aquifer-II. The details of the assessment are discussed below.

4.1 Ground Water Resources – Aquifer-I

The ground water resource assessment has been carried out for Betul district and the salient features of the resources are given in **Table 4.1, 4.2 and 4.3.**

As per **Table 4.1**, out of the total 1004300 ha area, recharge worthy areas are 29248 ha in command areas and 827202 ha in non-command areas, whereas 147850 ha area is not worthy for recharge on account of its hilly nature.

Table 4.1: Ground Water Recharge worthy Areas for Resource Estimation.

District	Predominant Formation	Total Geographical Area (ha)	Hilly Area (ha)	Ground Water Recharge Worthy Area	
				Command area (ha)	Non-command area (ha)
Betul	Basalt, Achaeans,Gondwana Sandstone	1004300	147850	29248	827202

4.1.1 Recharge Component

During the monsoon season, the rainfall recharge is the main recharge parameter, which is estimated as the sum total of the change in storage and gross draft. The change in storage is computed by multiplying groundwater level fluctuation between pre and post monsoon periods with the area of assessment and specific yield. Monsoon recharge can be expressed as:-

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

Where,

h = rise in water level in the monsoon season, Sy = specific yield

A = area for computation of recharge, DG = gross ground water draft

The monsoon ground water recharge has two components- rainfall recharge and recharge from other sources. The other sources of groundwater recharge during monsoon season include seepage from canals, surface water irrigation, tanks and ponds, ground water irrigation, and water conservation structures.

During the non-monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non-monsoonrecharge.

The season wise assessment of recharge from various components such as rainfall and other sources was done and presented in **Table4.2** and **Fig.4.1**. During monsoon season recharge from rainfall contributes maximum component (87832.29 ham) and recharge from other sources is 4914.79 ham, whereas during non-monsoon season, recharge from rainfall is 15543.34 ham and the recharge from other sources is 17950.96 ham. The total annual ground water recharge is 125969.36 ham and net ground water availability after natural discharge is estimated as 119671.78 ham.

Table 4.2: Recharge Components evaluated for Resource Estimation.

Command / Non-Command / Total	Recharge from rainfall during monsoon season (ham)	Recharge from other sources during monsoon season (ham)	Recharge from rainfall during non-monsoon season (ham)	Recharge from other sources during non-monsoon season (ham)	Total Annual Ground Water Recharge (ham)	Environmental flow in non-monsoon period (ham)	Net Annual Ground Water Availability (ham)
Command	2818.61	1223.88	616.92	4358.14	6011.65	443.69	8454.96
Non-Command	85013.68	3690.91	14926.42	13592.82	117070.71	5853.89	111216.82
Total	**87832.29**	**219.90**	**15543.34**	**17950.96**	**125969.36**	**6297.58**	**119671.78**

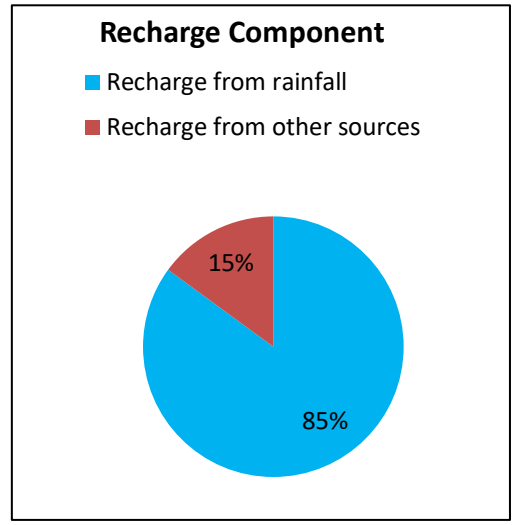

Fig.4.1: Recharge from various sources.

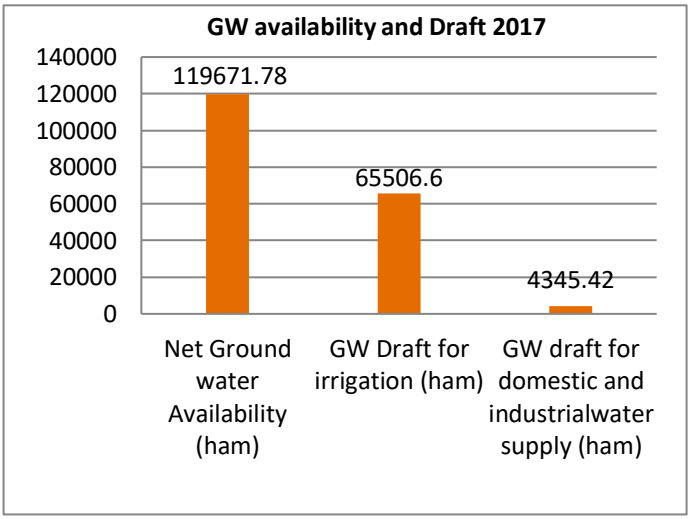

Fig.4.2: GW availability and Draft.

The utilisation of available ground water resources for various purposes is provided in **Table 4.3** and **Fig.4.2**. The annual gross draft for all uses is estimated at 69852.02 ham with irrigation sector being the major consumer having a draft of 65506.60 ham. The annual draft for domestic and industrial use was estimated as 4345.42 ham. The allocation for domestic & industrial requirement supply up to next 25 years is about 3187.93 ham and ground water available for future irrigation is 50977.25 ham. The stage of ground water development is 58.37%.

Table 4.3: Dynamic Ground Water Resources Availability, Draft and Stage of GW Development.

Command / Non-Command / Total	Net Annual Ground Water Availability (ham)	Existing Gross Ground Water Draft for irrigation (ham)	Existing Gross Ground Water Draft for domestic and industrial water supply (ham)	Existing Gross Ground Water Draft for All uses (ham)	Allocation for Domestic and industrial water supply (ham)	Net Ground Water Availability for future irrigation development (ham)	Stage of Ground Water Development (%)	Category
Command	8454.96	1556.36	397.7	1954.06	481.13	6417.47	23.11	-
Non Command	111216.82	63950.24	3947.72	67897.96	2706.8	44559.78	61.05	-
Total	**119671.78**	**65506.60**	**4645.42**	**69852.02**	**3187.93**	**50977.25**	**58.37**	**Safe**

Table 4.4: Static Ground Water Resources of Aquifer-I.

	Units	
Recharge worthy Area	Sq. km	8564.5
Pre-monsoon (average) depth to water level	m	9.36
Av. depth of Dug well	m	11.735
Specific yield(Sy)%	Fraction	0.016
Saturated thickness of aquifer (ST)	m	2.375

4.2 Ground Water Resources – Aquifer-II

The ground water resource of the Aquifer –II was also assessed to have the correct quantification of resources so that proper management strategy can be framed. To assess these resources, the average thickness of fractures in deeper aquifers from exploratory wells was calculated and the following formula for static ground water resources was utilised i.e.,

GWR =Recharge worthy Area x Thickness of fractures in deep aquifer x Specific yield

By applying above formula, the ground water resource of Aquifer-II was estimated as 445.251 MCM and is presented below in **Table 4.5**.

Table 4.5: Ground Water Resources of Aquifer-II.

	Units	Total
Recharge worthy Area	Sq.km	8564.5
Thickness of fracture in deeper aquifer	M	5.24
Specific yield(Sy)%	Fraction	0.01
Resource (A * Sy * ST)	MCM	**445.251**

5. GROUND WATER RELATED ISSUES

In the district there are many Groundwater issues both in quantity and quality wise. All the issues are described as follows.

5.1 Declining Water Level

The decline in the water level observed in major part of the district. The pre and post monsoon declining trend of onehydrograph prepared and presented in the **Fig.5.1**. The block wise decline in the trend of the hydrographs has been shown in the **Part-II**.

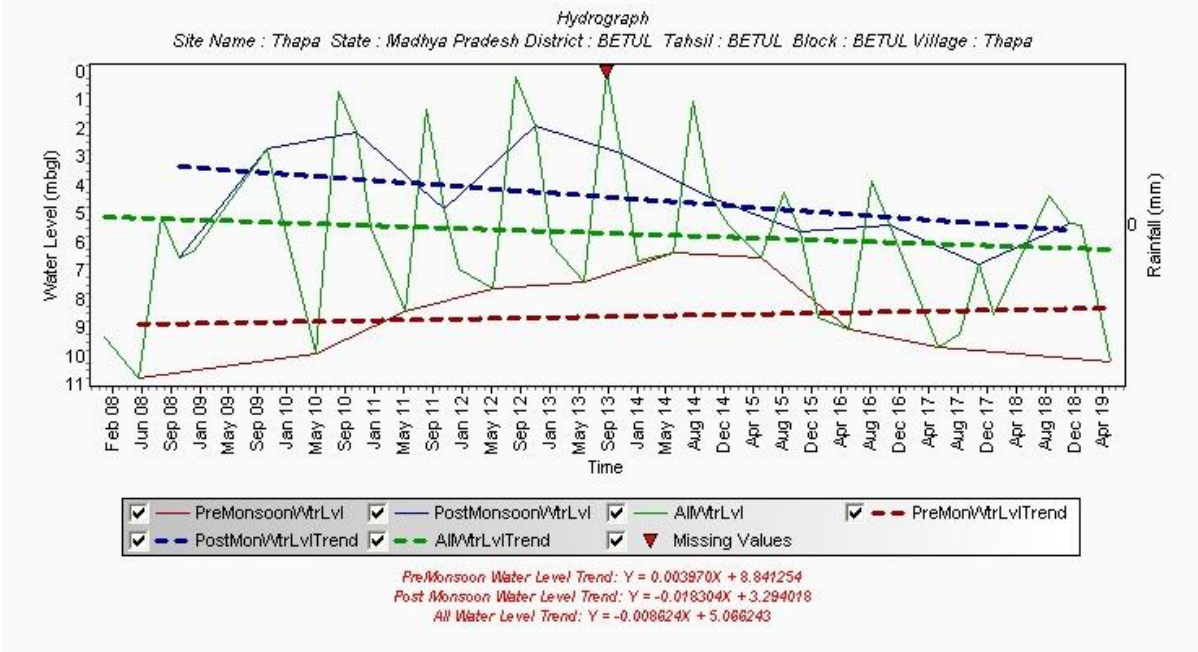

Fig.5.1: Hydrograph (2008-19), village- Thapa, Betul Block, Betul District.

5.2 Low Ground Water Potential / Limited Aquifer Thickness / Sustainability

Thedistrict is covered mostly with hard rock i.e. Deccan trap basalt and Achaean Granitoids. These hard rocks don't haveprimary porosity and are impermeable. So they can form aquifers only when they are weathered, fractured and jointed. So the depth of weathering in shallow aquifer and aquifer thickness in deeper aquifers are limited. Sustainability of both the aquifers is limited.

5.3 Deeper Water Levels in Aquifer-II

In Betul district, deeper water levels of more than 20 mbgl have been observed during pre-monsoon season in deep aquifers.

5.4 Inferior Ground Water Quality

Out of the 27 groundwater samples collected from dug wells i.e. from shallow aquifers, in 18 samples the Nitrate concentration recorded more than permissible limit i.e. 45 mg/l as per BIS recommendation. Out of 43 groundwater samples taken from exploratory/observation wells i.e from deep aquifers, in 10 samples the Nitrate and Fluoride value found above permissible limit.The details about groundwater quality of both shallow and deep aquifers have been already discussed in **Chapter-3**.

5.5 Increasing stage of Ground Water Extraction

Out of the 10 blocks, Multai and Betul blocks have the stage of groundwater extraction are 80.30% and 79.10 % respectively which are categorised as semi-critical, other 8 blocks are come under safe category. But the stage of extraction for each blocks are increasing in every year. The increasing stage of Ground water extraction for the block Mulai and Betul are presented as histogram in the **Fig.5.2** and **Fig.5.3** respectively.

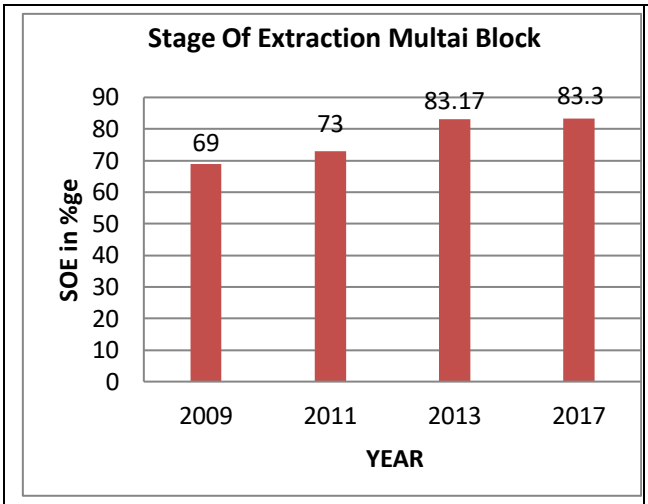

Fig.5.2: stage of groundwater extraction, Mulati block.

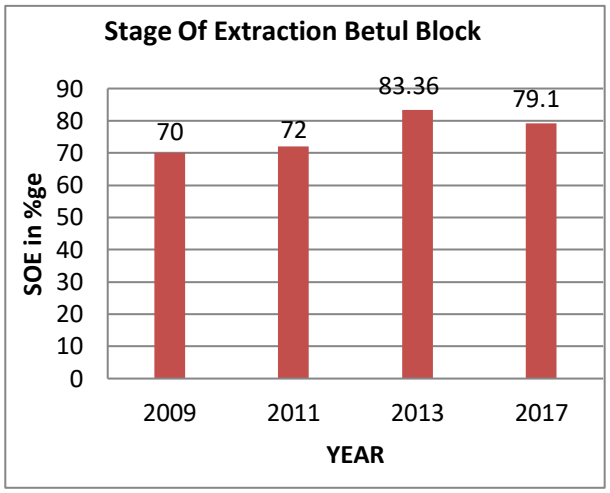

Fig.5.3: stage of groundwater extraction, Betul block.

6. PROPOSED MANAGEMENT STRATEGY

As discussed in previous chapter, there are many groundwater related issues owing to many socio-economic and hydrogeological reasons. The groundwater management plan for Betul district has been made keeping in view the area specific details and includes the strategies like enhancing the ground water resources through the construction of artificial recharge structures such as percolation tanks, check dams/nala bunds, recharge shafts, etc. and ensuring water use efficiency through maintenance/renovation of existing water bodies/water conservation structures. Also, adoption of micro irrigation technique such as sprinkler irrigation has been proposed, that would not only conserve ground water resources by reducing the draft, but would also increase the net cropping area thereby augmenting the agricultural economy of the district.

6.1 Supply side Management

Artificial recharge to ground water is one of the most efficient, scientifically proven and cost effective technology to mitigate the problems of over exploitation of ground water resources. The artificial recharge techniques simultaneously rejuvenates the depleted ground water storage, reduces the ground water quality. The supply side management plan for Betul district has been formulated using the basic concepts of hydrogeology. Sub-surface storage is calculated by multiplying the total area with the respective specific yield (considering the variable lithology) and the unsaturated zone thickness obtained by subtracting 3 mts from the post-monsoon water level. Thus, the surface water requirement to completely saturate the sub-surface Storage is obtained by multiplying a factor of 1.33 to available storage potential. A runoff coefficient factor of 0.3 has been considered for Betul district to calculate the total surface water runoff, 30% of which accounts to the non-committed runoff which is available to sustain the proposed artificial recharge structures. Further, the number of structures has been calculated by allotting 35%, 20% and 35% of non-committed runoff to Percolation tanks, Recharge shafts/Tube wells and Nala bunds/Check dams/Cement Plugs respectively. The remaining runoff is considered to restore the pre-existing village tanks, ponds and water conservation structures. A detailed calculation of the proposed artificial recharge structures is presented in the **Table 6.1**.

Out of 10043 sq.km geographical area of Betul district, about 8564.5 sq.km., area has been identified for ground water development, wherein 258percolation tank (@ Rs.20 lakh/percolation tank),1804 nala bund, Check dam, Cement plug (@10 lakh/structure), 515 recharge shaft/tube well(@5 lakh/structure), 1399 number of ponds/ village tanks to be renovated (@2 lakh/structure) are recommended to be constructed in feasible areas. This accounts to a total of Rs. 285.73crores to successfully implement the supply side management strategy. **Table 6.2** represents the complete financial outlay plan for the district.

In Betul district already many recharge structures are constructed (as per the data collected from Jilla Panchayat office, Betul). But due to non-availability proper coordinates of the already constructed recharge structures, the feasible sites for the proposed recharge structures cannot be pinpointed. The total numbers of recharge structures constructed in the district are presented in the **Table 6.3**. Block wise supply side management strategy will be discussed in **Part-II.**

Table 6.1: Ground Water Management– Supply Side.

	Units	
Total Area	Sq Km	10043
Area suitable for recharge		8564.5
Sub-surface storage	MCM	193.7574
Surface water required		257.6973
Surface water (Run-off) available		2873.771
Non-committed Run-off		862.1313
Percolation tank	No's	258
Recharge shaft/ Tube well		515
NB/ CD/ CP		1804
No of Villages		1399

Table 6.2: Ground Water Management– Demand Side.

Structures	Number	Cost in Crores
Percolation Tanks	258	51.6
NB/ CD/ CP	1804	180.4
Recharge shaft/ Tube well	515	25.75
Renovation of Village Ponds	1399	27.98
Total Cost		**285.73**

Table 6.3: Already constructed Recharge structure.

Blocks	Percolation Tank	Farm pond	Contour Bunding	Earthen Bunding	Gabions	Loose Boulder structure	Stone Bund	Check Dam	Stop Dam
Amla	29	61	4	94	9	29	16	1876	23
Athner	64	32		14		3	5	2133	3
Betul	17	152		28	31	4	17	1772	17
Bhainsdehi	34	124	4	8		8		3493	31
Bhimpur	11	112	2	18	1	6	3	3786	9
Chicholi	4	31		31	3		65	1556	24
Ghoradongri	19	45		28	3	2	2	1077	5
Multai	7	23	1	10	3	4	6	1425	18
P.Pattan	24	261	7	15	3	1	6	2233	5
Shahpur	9	86	3	46	1	13	9	2814	47
Total	**218**	**927**	**21**	**292**	**54**	**70**	**129**	**22165**	**182**

6.2 Demand Side Management

However, considering the low storage potential of hard rock aquifer in the area the above ground water development plan should also be coupled with ground water augmentation plan, so that there is no stress on ground water regime of the area. Micro irrigation technologies such as drip and sprinkler systems are being increasingly promoted as technological solutions for achieving water conservation. Micro irrigation comprises two technologies—drip and sprinkler irrigation. Both saves conveyance losses and improve water application efficiency by applying water near the root-zone of the plant some benefits of the micro-irrigation have been listed below:

- The increase in yield for different crops ranges from 27 per cent to 88 per cent and water saving ranges from 36 per cent to 68 per cent vis-à-vis conventional flow irrigation systems (Phansalker and Verma, 2005).
- It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.

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

- It reduces the energy needs for pumping, thus reducing energy per ha of irrigation because of its reduced water needs. However, overall energy needs of the agriculture sector may not get reduced because most farmers use the increased water efficiency to bring more area under irrigation.

Table 6.4: Proposed demand Side Interventions

Net GW Availability	MCM	1196.721
Gross Draft		695.6898
Stage of Development	%	62.92
Saving by Sprinkler in MCM	MCM	131.0132
Additional recharge created by AR		238.81943
After intervention of AR Structure Net GW AvL.		1435.5404
After intervention of AR Structure & utilisation of 60% of additional GW created.		143.29166
Draft after sprinkler & additional area created for agriculture		707.96826
Stage of Development W/O GW use for additional Area Irrigation		49.317194
Additional area irrigated by GW after intervention		35822.914

PART-II: BLOCK WISE AQUIFER MAPS AND MANAGEMENT PLANS

1. AQUIFER MAPS AND MANAGEMENT PLAN OF AMLA BLOCK

1. 1 SALIENT INFORMATION			
Block	**Amla**		
Area		Sq Km	1120
Population (2011 CENSUS)			1,45,911
Normal Rainfall(2005-14)		millimeter	986.07
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	616.26
	Net sown area		363.2
	Area sown more than once		253.06
	Cropping intensity	%	170%
	Area under forest	Sq Km	37.55
	Area under Waste land		11.11
Data Utilised	Monitoring Wells for Water Level		Dw-1 , Pz-2
	Monitoring Wells for Quality		Dw-1
Water level behaviour	Pre-monsoon WL	meter	6.87
	Post-monsoon WL		2.3
	Pre-monsoon WL Trend	(m /yr)	Rising 0.024054
	Post-monsoon WL Trend		Falling 0.010552 Rising 0.003348

1.2 AQUIFER DISPOSITION		
Major Aquifer	**Basalt /Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Granitoids	Jointed / Fractured Basalt/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	2.3 to 6.87	10 to 32
Weathered / Fractured rocks thickness (m)	2 to 15	0.5 to 3
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 2.38 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day

1.2.1 3-D Aquifer Disposition and Fence Diagram

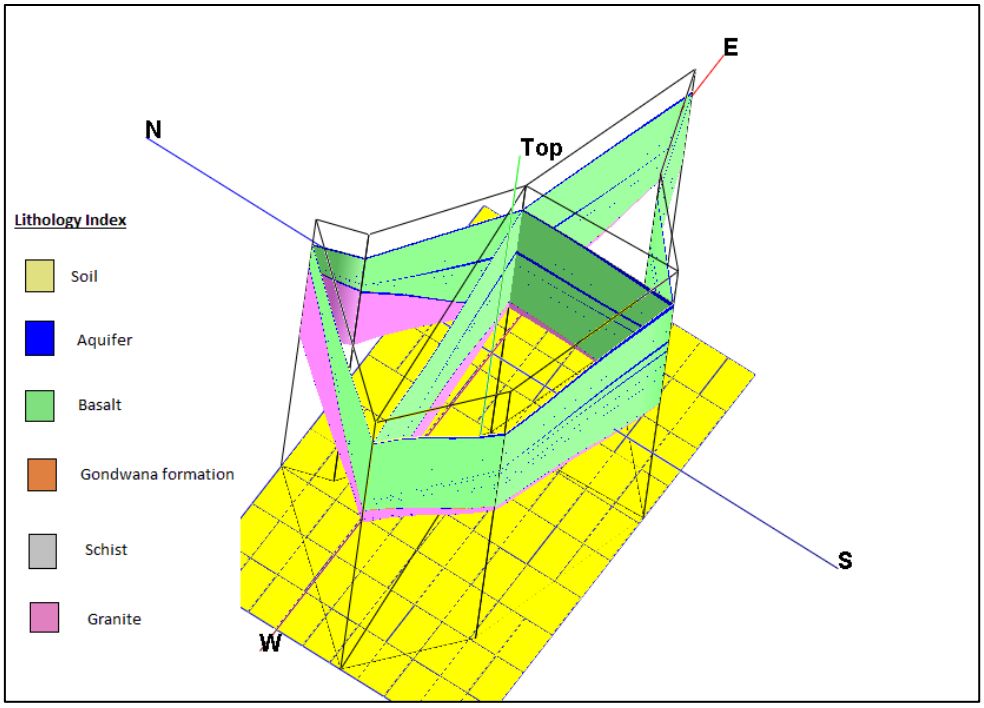

Fig.1.1: Fence Diagram.

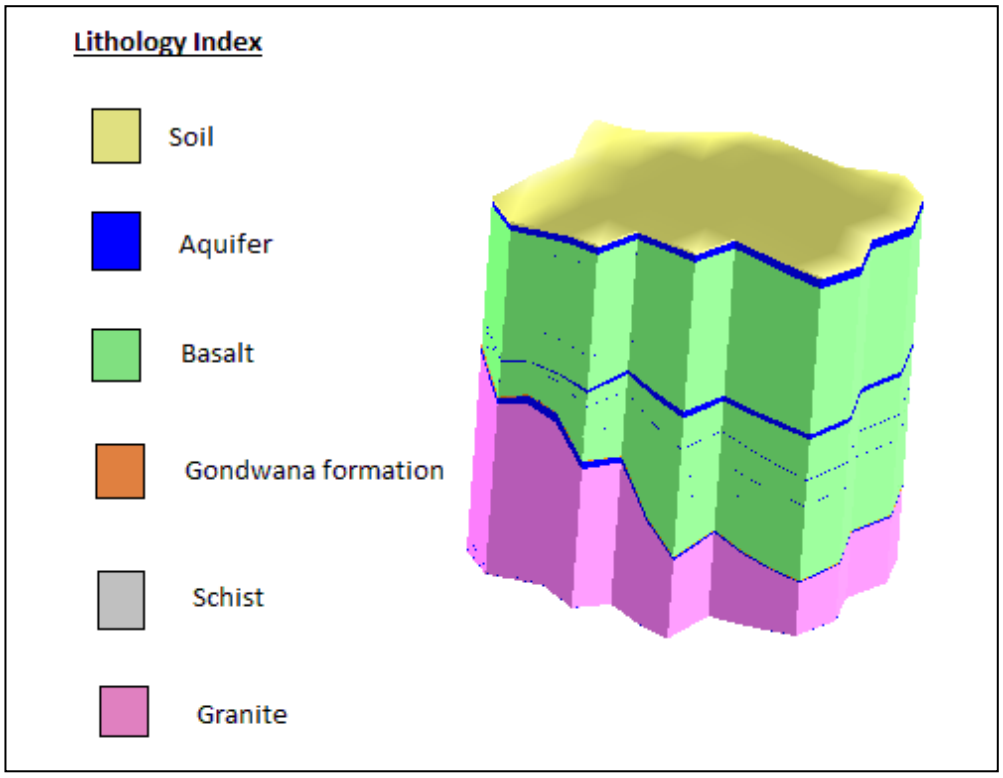

Fig.1.2: 3D model.

As the area is covered with hard rocks, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 15 m. The fractured /jointed basalt and Granitoids form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.1.1**and 3-D representation is presented in **Fig.1.2**. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

1.3 GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES

DYNAMIC GROUNDWATER RESOURCES 2017	Type of Rock formation	Achaean Granite, Deccan trap Basalt	
	Recharge worthy area	Sq Km	1083
	Command area		73.81
	Non-Command area		1009.19
	Recharge From Rain Fall During Monsoon Season	MCM	158.17
	Recharge From other sources During Monsoon Season		10.69
	Recharge From Rain Fall During Non-Monsoon Season		16.4
	Recharge From other sources During non-Monsoon Season		48.59
	Total Recharge		233.85
	Annual Extractable Groundwater Recharge		221.77
	Existing Gross Ground Water Draft for Irrigation		119.08
	Existing Gross Ground Water Draft for Industrial Water Supply		0.08
	Existing Gross Ground Water Draft for Domestic Water Supply		0.45
	Existing Gross Ground Water Draft for All Uses		119.62
	Annual GW Allocation for for Domestic Use as on 2025		3.14
	Net Ground Water Availability for Future Irrigation Development		99.46
	Stage of Ground Water Extraction	**%**	53.94%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	40.450
Static Resource Of Deep Aquifer			33.032

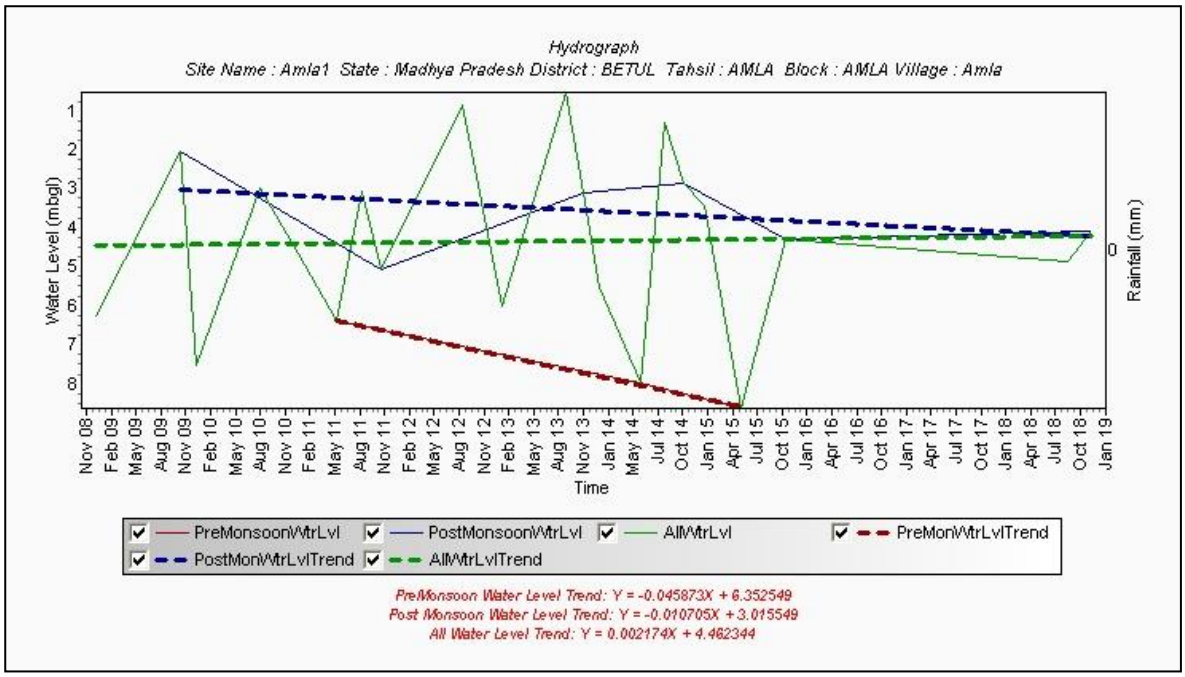

Fig.1.3: Hydrograph (2008-19), Village-Amla, Block- Amla, Betul District.

1.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block(**Fig.1.3**)
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt in the southern part and Achaean Granitoids in the northern part there is restricted depth of weathering (< 20 m) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.

1.4 MANAGEMENT PLAN FOR AMLA BLOCK		
Rainfall	meter	0.98607
Area	Sq Km	1120
Area suitable for recharge		1083
Average post-monsoon water level	Meter	5.77
Unsaturated zone		2.77
Average SP Yield	%	0.015
Sub-surface storage	MCM	44.999
Surface water required		59.85
Surface water (Run-off) available		320.37
Non-committed Run-off		96.11
Percolation tank		60
Recharge shaft/ Tube well		120
NB/ CD/ CP		419
No of Villages		158

Type of Structures	**Number**	**Cost in Crores**
Percolation Tanks	60	12
NB/ CD/ CP	419	41.9
Recharge shaft/ Tube well	120	6
Renovation of Village Ponds	158	3.16

1.5 DEMAND SIDE INTERVENTIONS		
Net GW Availability	MCM	221.773
Gross Draft		119.6198
Stage of Development	%	53.94
Saving by Sprinkler in MCM	MCM	23.817
Additional recharge created by AR		44.99865
After intervention of AR Structure Net GW AvL.		266.77165
After intervention of AR Structure &utilisation of 60% of additional GW created.		26.99919
Draft after sprinkler & additional area created for agriculture		122.8
Stage of Development W/O GW use for additional Area Irrigation	%	46.03
Additional area irrigated by GW after intervention	Sq Km	6750

2. AQUIFER MAPS AND MANAGEMENT PLAN OF ATHNER BLOCK

2.1 SALIENT INFORMATION			
Block	**Athner**		
Area		Sq Km	853
Population			94,878
Normal Rainfall(2005-14)		millimeter	830.96
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	588.63
	Net sown area		443.36
	Area sown more than once		145.27
	Cropping intensity	%	133%
	Area under forest	Sq Km	66.76
	Area under Waste land		29.68
Data Utilised	Monitoring Wells for Water Level		Dw-2
	Monitoring Wells for Quality		Dw-2
Water level behaviour	Pre-monsoon WL	Meter	8.45
	Post-monsoon WL		3.2
	Pre-monsoon WL Trend	m /yr	Falling 0.019 to 0.027
	Post-monsoon WL Trend (m /yr)		Falling 0.014 to 0.027

2.2 AQUIFER DISPOSITION		
Major Aquifer	**Basalt**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt	Jointed / Fractured Basalt
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)		10 to 25
Weathered / Fractured rocks thickness (m)	1 to 19	up to 8
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 16 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

2.2.1 3-D Aquifer Disposition and Fence Diagram

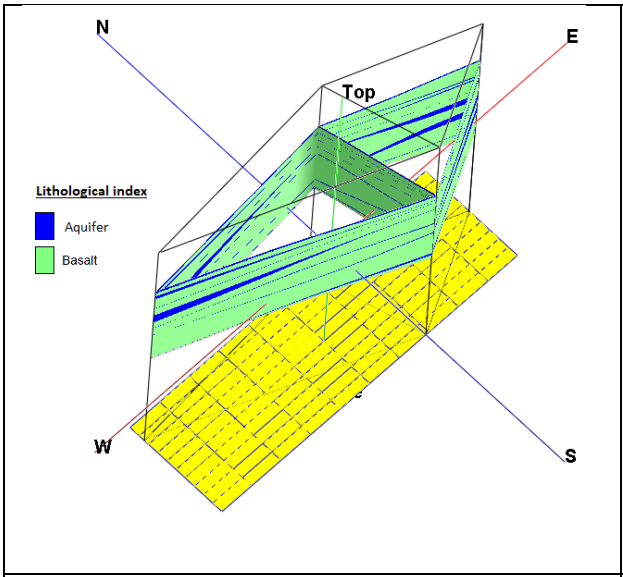

Fig.2.1: Fence Diagram

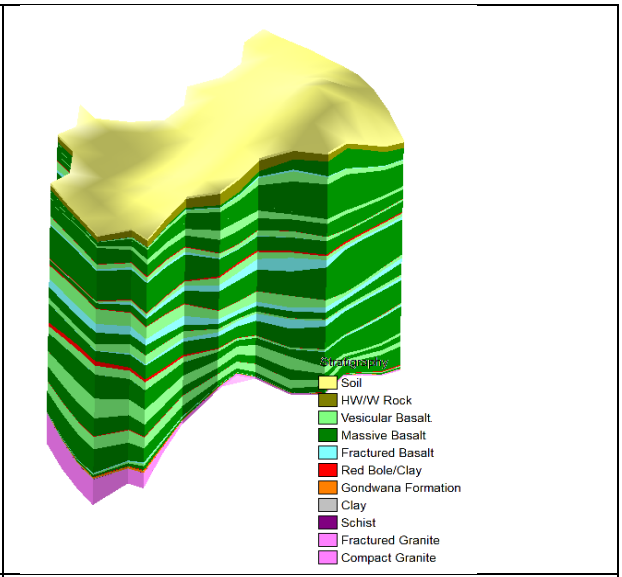

Fig.2.2: 3D Model

As the area is covered with hard Deccan trap basalt, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 19m. The fractured /jointed basalt form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.2.1**and 3-D representation is presented in **Fig. 2.2**. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

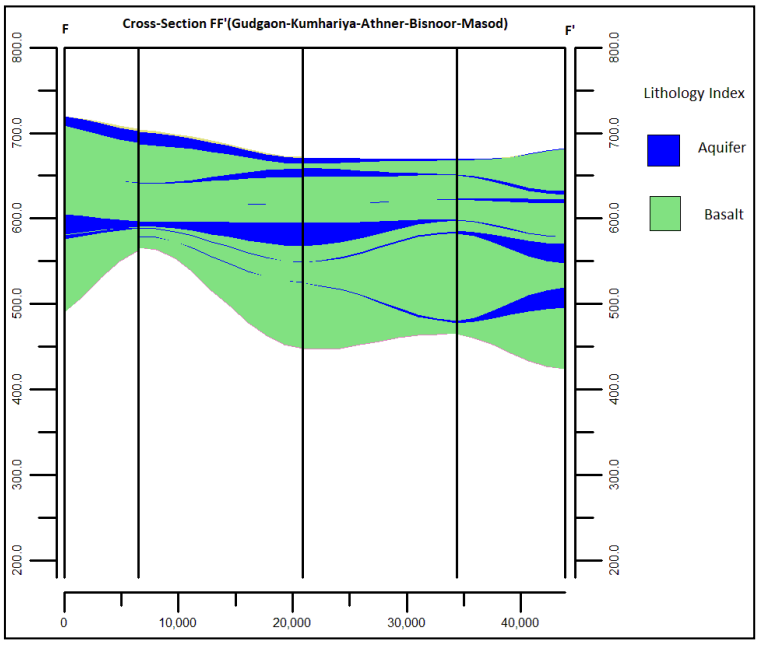

Fig.2.3: Cross-section.

Hydrogeological cross section F-F' (**Fig.1.3**) represents a section through the block Athner along west-East direction and data of 5 exploratory wells i.e., Gudgaon, Kumhariya, Athner, Bisnoor, Masod has been utilised.The shallow aqufer extends up to 19 meter in the block. The maximum thickness of deeper aqufer is 8 meter.

2.3 GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES			
Dynamic Groundwater Resources 2017	Type of Rock formation	Deccan trap Basalt	
	Recharge worthy area	Sq Km	533
	Command area		14.57
	Non-Command area		518.43
	Recharge From Rain Fall During Monsoon Season	MCM	54.73
	Recharge From other sources During Monsoon Season		3.04
	Recharge From Rain Fall During Non-Monsoon Season		9.03
	Recharge From other sources During non-Monsoon Season		16.4
	Total Recharge		83.2
	Annual Extractable Groundwater Recharge		78.71
	Existing Gross Ground Water Draft for Irrigation		45.14
	Existing Gross Ground Water Draft for Industrial Water Supply		0.381
	Existing Gross Ground Water Draft for Domestic Water Supply		2.159
	Existing Gross Ground Water Draft for All Uses		47.68
	Annual GW Allocation for for Domestic Use as on 2025		2.25
	Net Ground Water Availability for Future Irrigation Development		30.947
	Stage of Ground Water Extraction	**%**	60.57%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	36.990
Static Resource Of Deep Aquifer			26.650

2.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and postmonsoon in major part of the block **(Fig.2.4)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt and Granitoids there is restricted depth of weathering (< 20 m) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Athner the nitrate concentration in the shallow aquifer is 110mg/l which is above the permissible limit.
	Deep Aquifer: At The location Jaora the Fluoride concentration (1.52 mg/l) and Nitrate concentration (69mg/l) is above permissible limit.

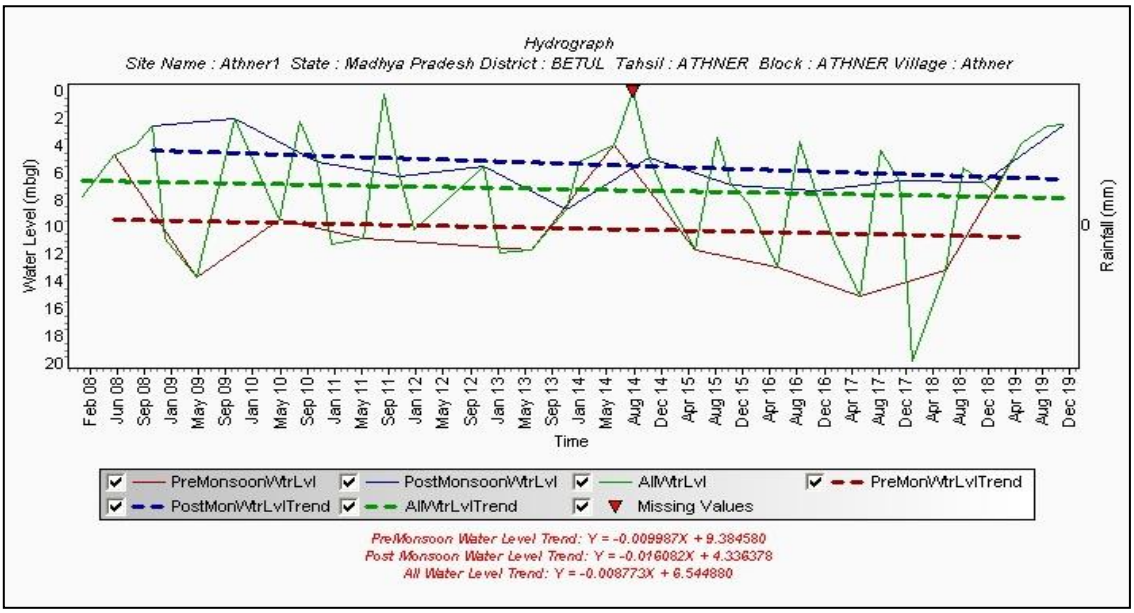

Fig.2.4: Hydrograph (2008-19), village-Athner

2.4 MANAGEMENT PLAN		
Rainfall	Millimeter	830.96
Rainfall	meter	0.83096
Area	Sq Km	853
Area suitable for recharge		533
Average post-monsoon water level	Meter	4.77
Unsaturated zone		1.77
Average SP Yield	%	0.02
Sub-surface storage	MCM	18.868
Surface water required		25.09
Surface water (Run-off) available		132.87
Non-committed Run-off		39.86
Percolation tank		25
Recharge shaft/ Tube well		50
NB/ CD/ CP		176
No of Villages		101

Structures	Number	Cost in Crores
Percolation Tanks	25	5
NB/ CD/ CP	176	17.6
Recharge shaft/ Tube well	50	2.5
Renovation of Village Ponds	101	2.02

2.5 DEMAND SIDE INTERVENTIONS		
Net GW Availability	MCM	78.718
Gross Draft		47.68
Stage of Development	%	60.57
Saving by Sprinkler in MCM	MCM	9.028
Additional recharge created by AR		18.8682
After intervention of AR Structure Net GW AvL.		97.5862
After intervention of AR Structure &utilisation of 60% of additional GW created.		11.32092
Draft after sprinkler & additional area created for agriculture		49.97292
Stage of Development W/O GW use for additional Area Irrigation		51.20900291
Additional area irrigated by GW after intervention		2830.23

3. AQUIFER MAPS AND MANAGEMENT PLAN OF BETUL BLOCK

3.1. Salient Information			
Block	**Betul**		
Area		Sq Km	1150
Population			1,66,219
Normal Rainfall(2005-14)		millimeter	1137.7
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	887.44
	Net sown area		528.96
	Area sown more than once		358.48
	Cropping intensity	%	168%
	Area under forest	Sq Km	123.25
	Area under Waste land		30.33
Data Utilised	Monitoring Wells for Water Level		Dw-4
	Monitoring Wells for Quality		Dw-3
Water level behaviour	Pre-monsoon WL	mbgl	12.72
	Post-monsoon WL		3.12
	Pre-monsoon WL Trend	m /yr	Rising 0.003 to 0.02 Falling 0.0026
	Post-monsoon WL Trend		Rising 0.0067 Falling 0.0183 to 0.03

3.2. AQUIFER DISPOSITION		
Major Aquifer	**Basalt /Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Granitoids	Jointed / Fractured Basalt/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	3.12 to 12.72	13.52 to 50
Weathered / Fractured rocks thickness (m)	2 to 31	0.5 to 13
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 16 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

As the area is covered with hard Deccan trap basalt and Granitoid, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 31m. The fractured /jointed basalt form the deeper aquifer. The fence

diagram indicating the disposition of various aquifers is presented in **Fig.3.1.**The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence.

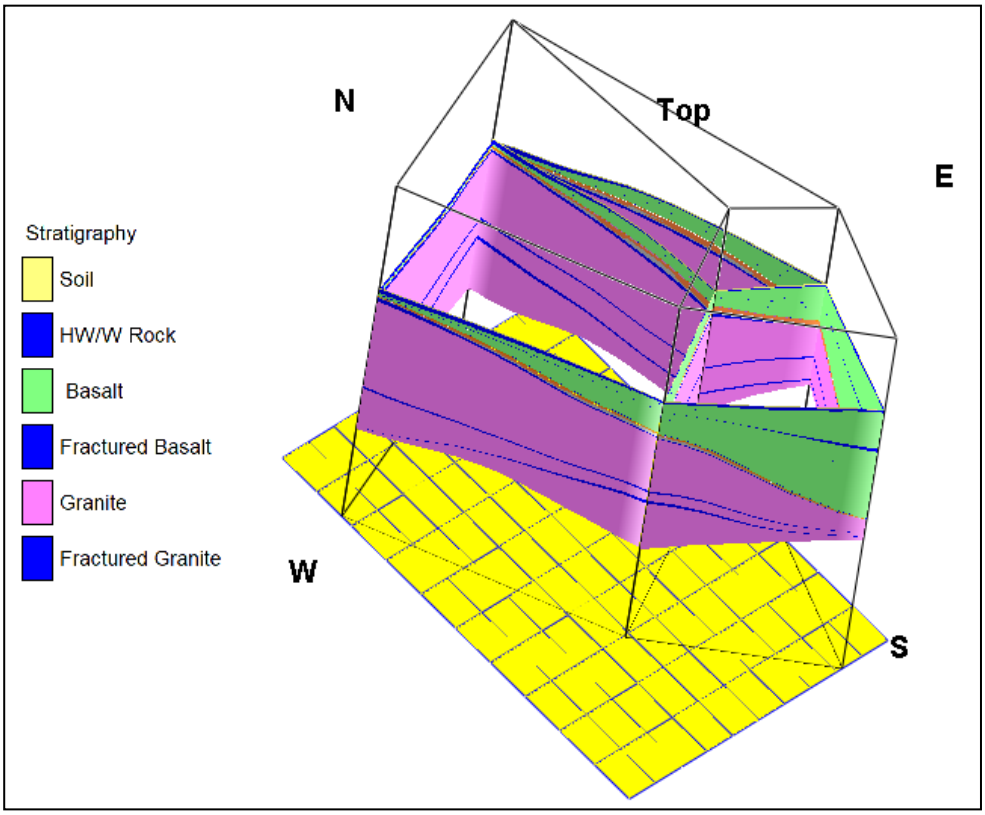

Fig. 3.1: Fence Diagram.

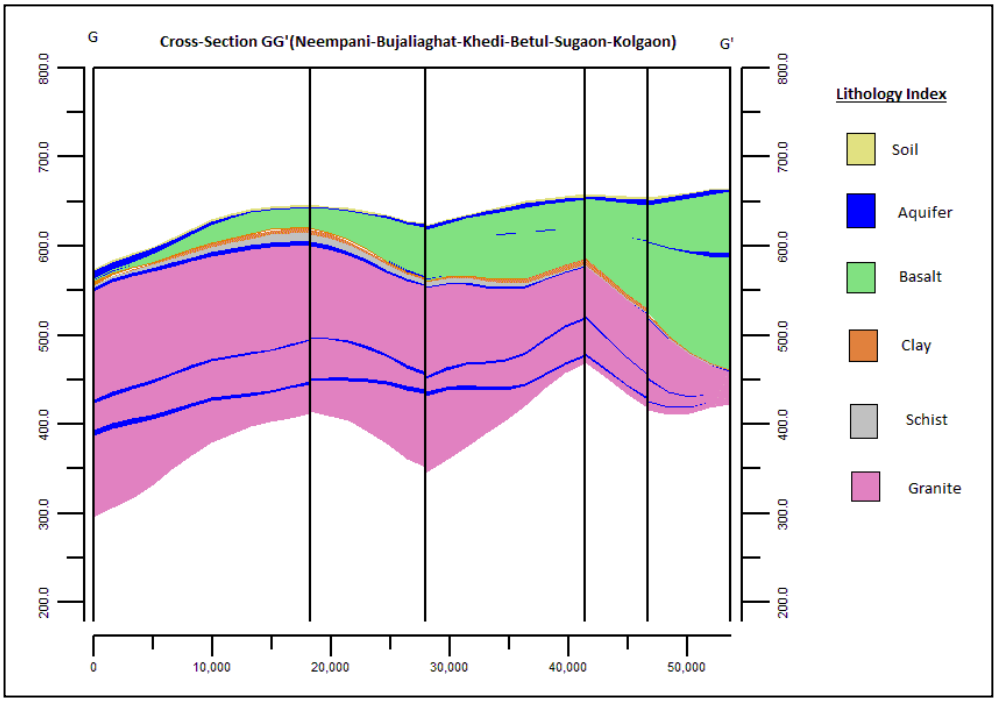

Fig. 3.2: Cross-section.

Hydrogeological cross section G-G’ (**Fig.3.2**) represents a section through the block Betul along north-south direction and data of 6 exploratory wells i.e., Neempani, Bujhaliaghat, Khedi, Betul, Surgaon, Kolgaon has been utilised.

3.3 Ground water resource, extraction, contamination and other issues			
Dynamic Groundwater Resources 2017	Type of Rock formation	Achaean Granite, Deccan trap Basalt	
	Recharge worthy area	Sq Km	1030
	Command area		68.4
	Non-Command area		961.6
	Recharge From Rain Fall During Monsoon Season	MCM	60.5871
	Recharge From other sources During Monsoon Season		9.1578
	Recharge From Rain Fall During Non-Monsoon Season		48.2607
	Recharge From other sources During non-Monsoon Season		23.8289
	Total Recharge		141.8345
	Annual Extractable Groundwater Recharge		134.7238
	Existing Gross Ground Water Draft for Irrigation		102.187
	Existing Gross Ground Water Draft for Industrial Water Supply		0.6565
	Existing Gross Ground Water Draft for Domestic Water Supply		3.7204
	Existing Gross Ground Water Draft for All Uses		106.5639
	Annual GW Allocation for Domestic Use as on 2025		5.7927
	Net Ground Water Availability for Future Irrigation Development		26.0876
	Stage of Ground Water Extraction	**%**	79.10%
	Category		**Semi Critical**
Static Resource Of Shallow Aquifer		MCM	14.214
Static Resource Of Deep Aquifer			46.350

3.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block **(Fig.3.3)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt and granitoids, there is restricted depth of weathering in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Betul the Total hardness and nitrate concentration in the shallow aquifer is 614mg/l and 65 mg/l respectively which is above the permissible limit.
	Deep Aquifer: At The location Betul the Calcium concentration (204 mg/l) and Nitrate concentration (151mg/l) of deeper aquifer is above permissible limit. At location Bujhalighat and Surgaon the Nitrate Concentration are 48mg/l and 60 mg/l respectively are above the permissible limit. At Khedi and Kolgaon the Fluoride conc. are 2.53mg/l and 4.25 mg/l respectively which are also above the permissible limit
Increasing Stage of Ground water Extraction	Now the Stage of Extraction of the Block Betul is at Semi-Critical (79.1 %)

3.4. MANAGEMENT PLAN FOR BETUL BLOCK		
Rainfall	Millimeter	1137.7
Rainfall	meter	1.1377
Area	Sq Km	1150
Area suitable for recharge		1030
Average post-monsoon water level	Meter	3.39
Unsaturated zone		0.39
Average SP Yield	%	0.02
Sub-surface storage	MCM	8.034
Surface water required		10.69
Surface water (Run-off) available		351.55
Non-committed Run-off		105.46
Percolation tank		11
Recharge shaft/ Tube well		21
NB/ CD/ CP		75
No of Villages		193

Structures	Number	Cost in Crores
Percolation Tanks	11	2.2
NB/ CD/ CP	75	7.5
Recharge shaft/ Tube well	21	1.05
Renovation of Village Ponds	193	3.86

3.5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	134.724
Gross Draft		106.564
Stage of Development	**%**	79.1
Saving by Sprinkler in MCM	**MCM**	20.4374
Additional recharge created by AR		39.552
After intervention of AR Structure Net GW AvL.		174.276
After intervention of AR Structure &utilisation of 60% of additional GW created.		23.7312
Draft after sprinkler & additional area created for agriculture		109.8578
Stage of Development W/O GW use for additional Area Irrigation		63.03667745
Additional area irrigated by GW after intervention		5932.8

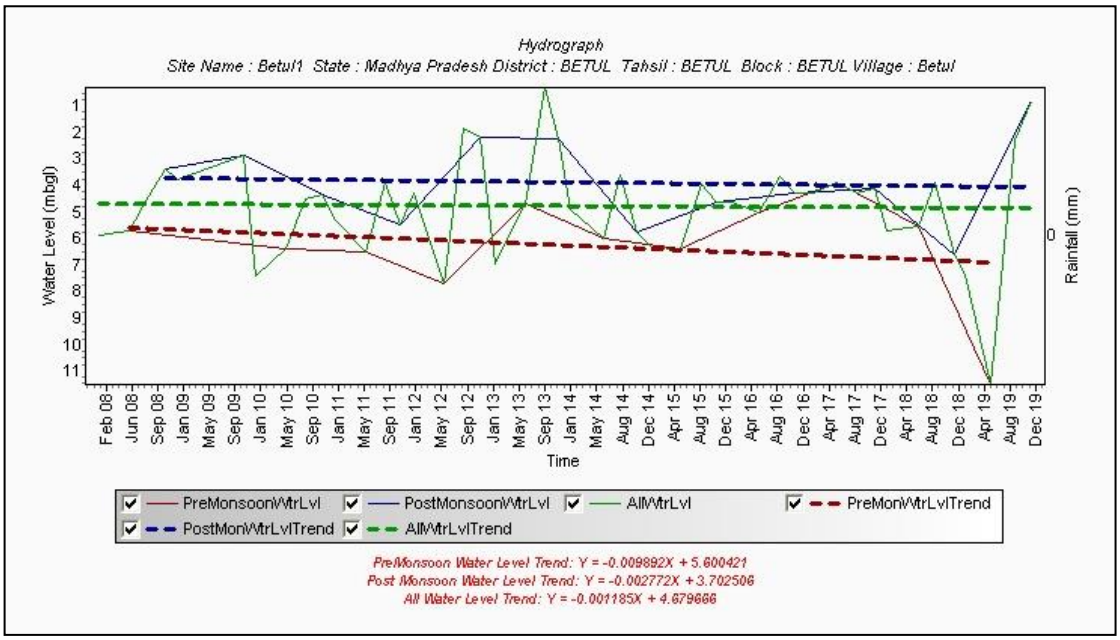

Fig.3.3:Hydrograph (2008-19), village –Betul.

4. AQUIFER MAPS AND MANAGEMENT PLAN OF BHAINSDEHI BLOCK

4.1. Salient Information			
Block		**Bhainsdehi**	
Area		Sq Km	1257
Population			1,26,410
Normal Rainfall(2005-14)		millimeter	1172.26
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	649.14
	Net sown area		501.5
	Area sown more than once		147.64
	Cropping intensity	%	129%
	Area under forest	Sq Km	148.43
	Area under Waste land		30.47
Data Utilised	Monitoring Wells for Water Level		Dw-5
	Monitoring Wells for Quality		Dw-5
Water level behaviour	Pre-monsoon WL	mbgl	10.71
	Post-monsoon WL		2.82
	Pre-monsoon WL Trend	m /yr	Rising from 0.0062 to 0.055 Falling from 0.0058 to 0.0262
	Post-monsoon WL Trend		Rising from 0.000012 to 0.0035 Falling from 0.0142 to 0.174

4.2. AQUIFER DISPOSITION		
Major Aquifer	**Basalt / Gondwana Formations/Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Gondwana Formations/Granitoids	Jointed / Fractured Basalt/Gondwana Formations/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	2.82 to 10.71	12 to 113
Weathered / Fractured rocks thickness (m)	2 to 24	up to 17
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 24 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

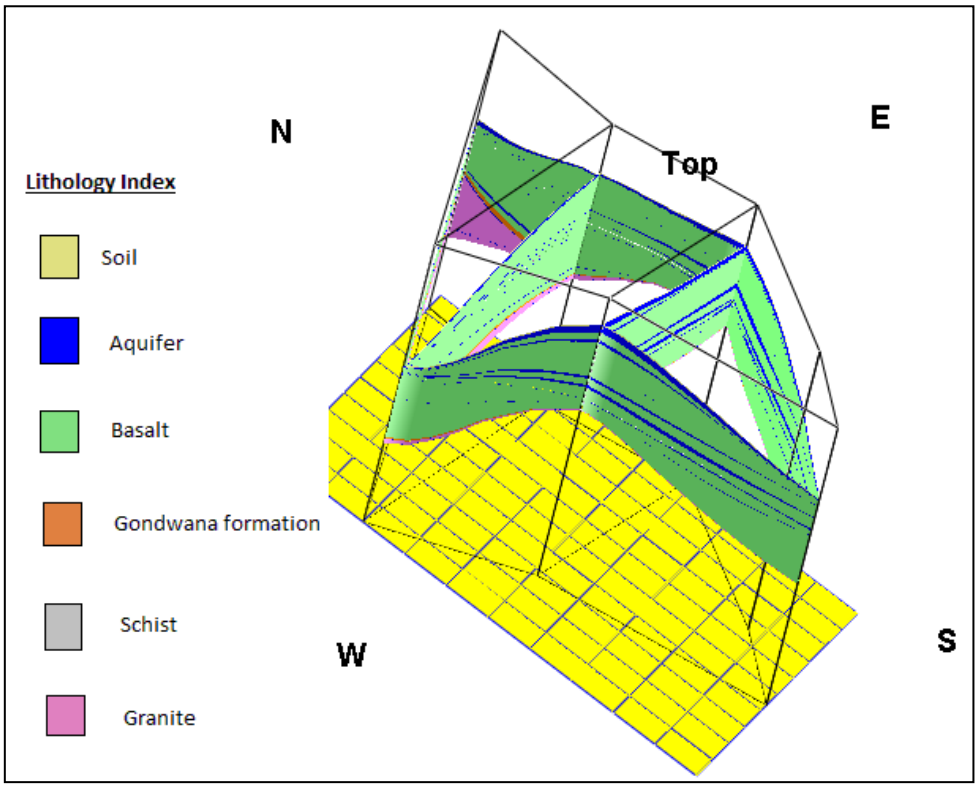

Fig.4.1: Fence Diagram.

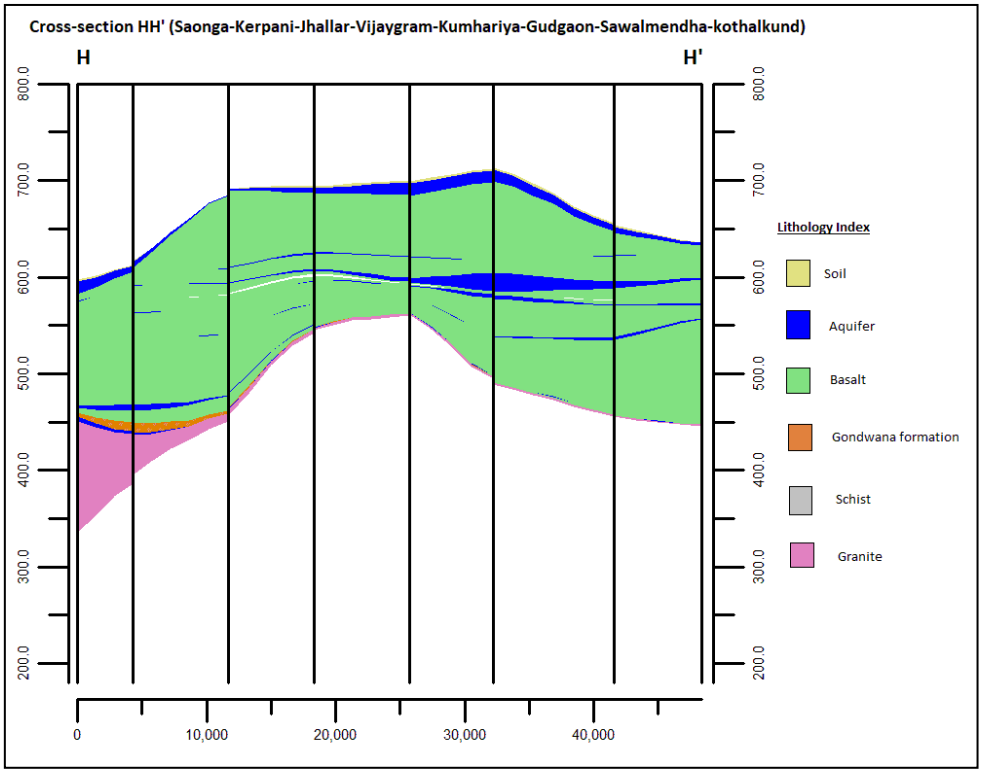

Fig. 4.2: Cross-section.

As the area is covered with hard Deccan trap basalt and Granitoid, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends

maximum up to the depth of 24m. The fractured /jointed basalt and Granitoids form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.4.1.**The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence.

Hydrogeological cross section H-H' (**Fig.4.2**) represents a section through the block Betul along north-south direction and data of 6 exploratory wells i.eSaonga, Kerpani, Jhallar, Vijaygram, Kumhariya, Gudgaon, Sawalmendha, Kothalkund has been utilised.

4.2.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block **(Fig.4.3)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt there is restricted depth of weathering (< 20 m) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Bhainsdehi, Gudgaon, Jhallar, Kothalkund nitrate concentration is 47mg/l, 49mg/l, 50mg/l and 85mg/l respectively which are above the permissible limit. At kerpani Fluoride concentration(2.95 mg/l) above permissible limit

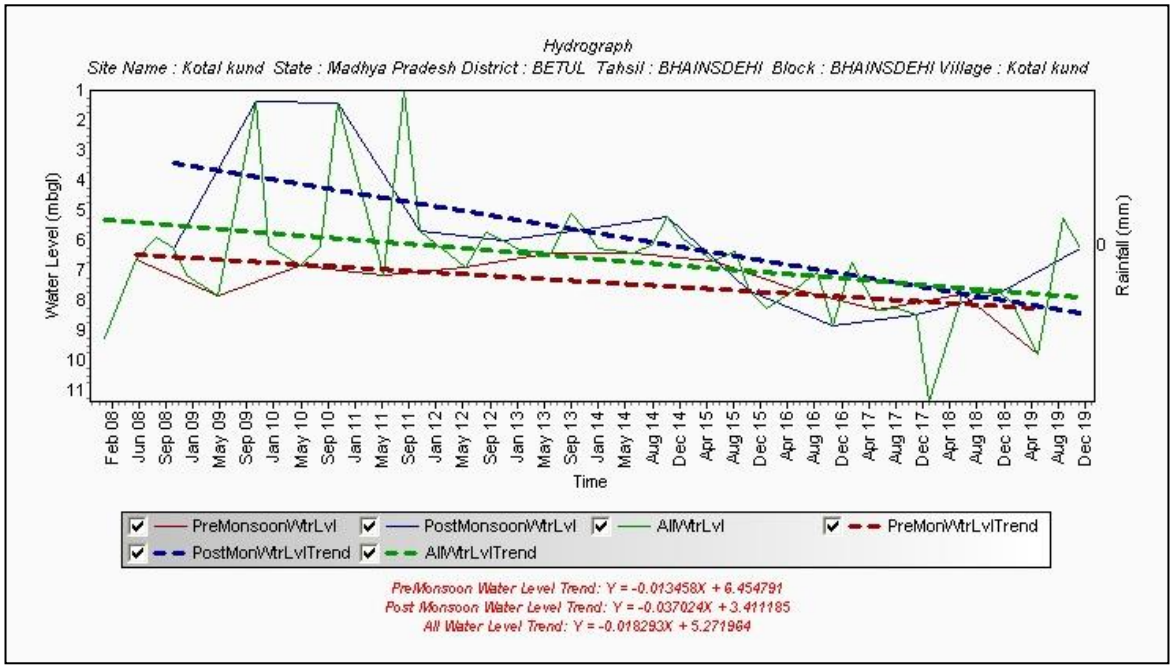

Fig.4.3: Hydrograph (2008-19), village- Kothalkund.

4.4 MANAGEMENT PLAN FOR BHAINSDEHI BLOCK		
Rainfall	meter	1.17226
Area	Sq Km	1257
Area suitable for recharge		1020
Average post-monsoon water level	Meter	4.3
Unsaturated zone		1.3
Average SP Yield	%	0.02
Sub-surface storage	MCM	26.520
Surface water required		35.27
Surface water (Run-off) available		358.71
Non-committed Run-off		107.61
Percolation tank		35
Recharge shaft/ Tube well		71
NB/ CD/ CP		247
No of Villages		142

Structures	Number	Cost in Crores
Percolation Tanks	35	7
NB/ CD/ CP	247	24.7
Recharge shaft/ Tube well	71	3.55
Renovation of Village Ponds	142	2.84

4.5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	131.270
Gross Draft		43.59
Stage of Development	**%**	10.788
Saving by Sprinkler in MCM	**MCM**	26.52
Additional recharge created by AR		157.79
After intervention of AR Structure Net GW AvL.		15.912
After intervention of AR Structure &utilisation of 60% of additional GW created.		62.344
Draft after sprinkler & additional area created for agriculture		39.51074213
Stage of Development W/O GW use for additional Area Irrigation		3978
Additional area irrigated by GW after intervention		6749.7975

5. AQUIFER MAPS AND MANAGEMENT PLAN OF BHIMPUR BLOCK

5.1 SALIENT INFORMATION			
Block	**Bhimpura**		
Area		Sq Km	1150
Population			1,50,924
Normal Rainfall(2005-14)		millimeter	1294.16
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	519.09
	Net sown area		406.23
	Area sown more than once		112.86
	Cropping intensity	%	128%
	Area under forest	Sq Km	346.97
	Area under Waste land		33.06
Data Utilised	Monitoring Wells for Water Level		Dw-0
	Monitoring Wells for Quality		Dw-0
Water level behaviour	Pre-monsoon WL	mbgl	8.66
	Post-monsoon WL		
	Pre-monsoon WL Trend	m /yr	-
	Post-monsoon WL Trend (m /yr)		-

5.2 AQUIFER DISPOSITION		
Major Aquifer	**Basalt / Gondwana Formations/Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Gondwana Formations/Granitoids	Jointed / Fractured Basalt/Gondwana Formations/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)		2.1 to >100
Weathered / Fractured rocks thickness (m)	up to 20	0.5 to 10
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	0.5 to 4.5 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

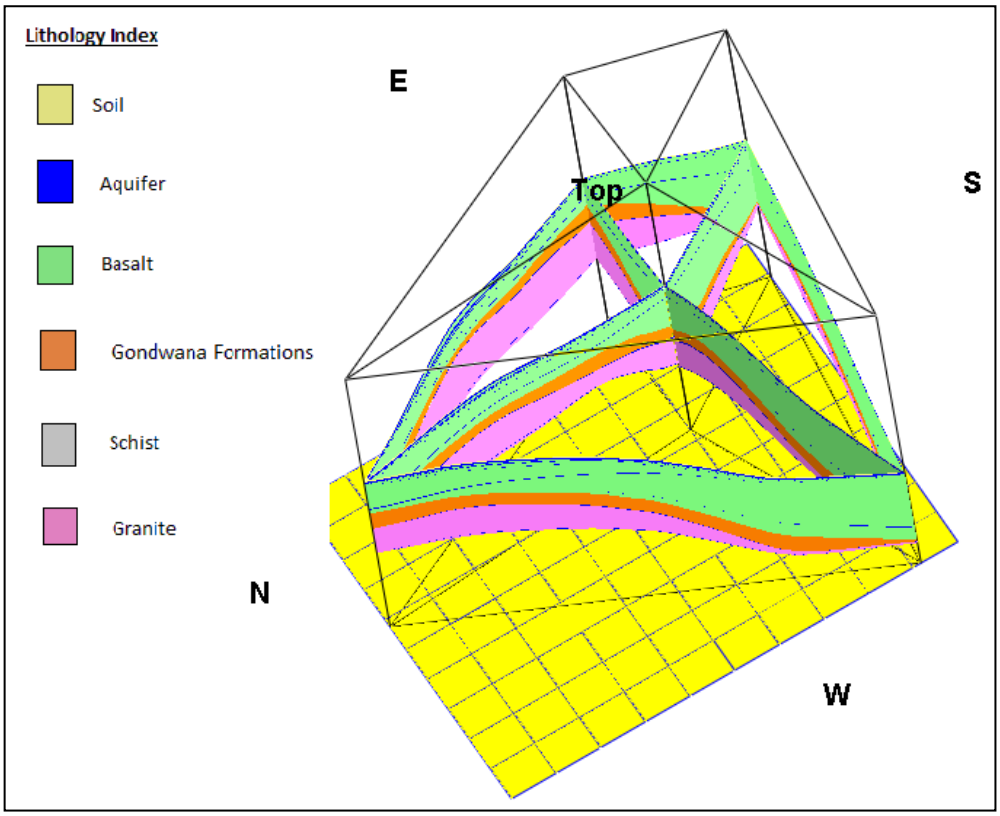

Fig. 5.1: Fence Diagram.

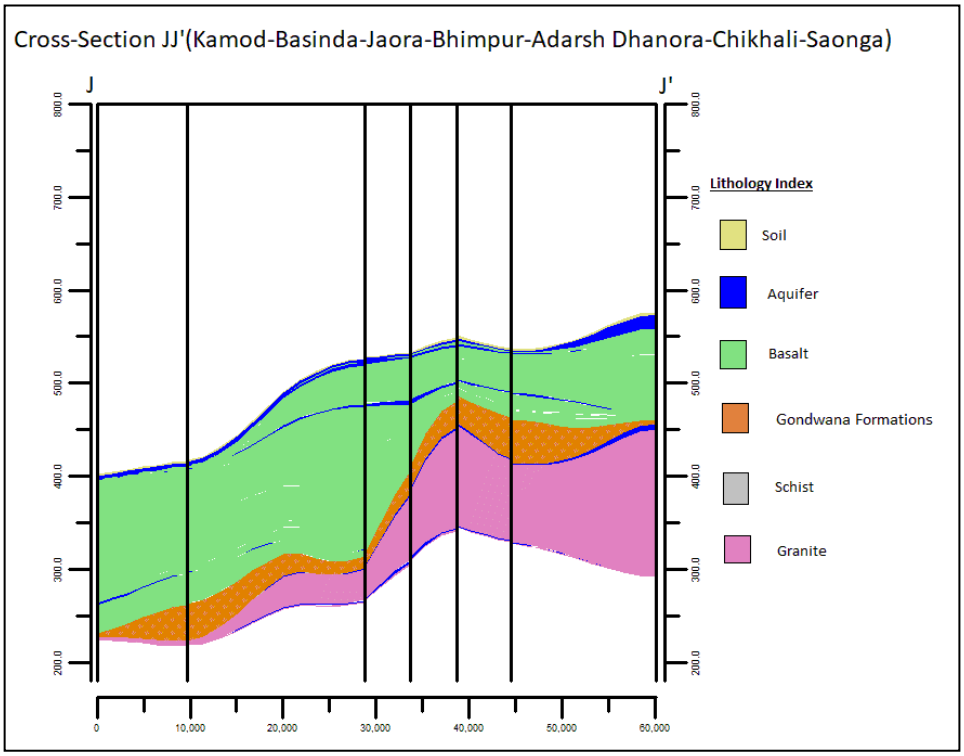

Fig. 5.2: Cross-Section.

As the area is covered with hard Deccan trap basalt,Granitoid,Gondwana formations the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 20m. The fractured /jointed basalt, Granitoids, Gondwana formations form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.5.1.**The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence.

Hydrogeological cross section J-J' (**Fig.5.2**) represents a section through the block Bhimpur along north-south direction and data of 7exploratory wells i.eKamod, Basinda, Jaora, Bhimpur, AdarshDhanora, Chikhali, Saonga has been utilised.

5.3 GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES			
Dynamic Groundwater Resources 2017	Type of Rock formation	Archean Granite, Gondwana formations, Deccan trap Basalt	
	Recharge worthy area	Sq Km	978
	Command area		0
	Non-Command area		978
	Recharge From Rain Fall During Monsoon Season	MCM	93.6671
	Recharge From other sources During Monsoon Season		1.3771
	Recharge From Rain Fall During Non-Monsoon Season		1.0027
	Recharge From other sources During non-Monsoon Season		5.1931
	Total Recharge		101.24
	Annual Extractable Groundwater Recharge		96.178
	Existing Gross Ground Water Draft for Irrigation		28.7096
	Existing Gross Ground Water Draft for Industrial Water Supply		0.5504
	Existing Gross Ground Water Draft for Domestic Water Supply		3.1195
	Existing Gross Ground Water Draft for All Uses		32.3795
	Annual GW Allocation for Domestic Use as on 2025		4.2921
	Net Ground Water Availability for Future Irrigation Development		62.6259
	Stage of Ground Water Extraction	**%**	33.67%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	31.687
Static Resource Of Deep Aquifer			62.788

5.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block **(Fig.5.3)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt and granitoids, there is restricted depth of weathering in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground water quality	**Deep Aquifer:** At The location Saonga, the Nitrate concentration (55mg/l) of deeper aquifer is above permissible limit.
Increasing Stage of Ground water Extraction	Now the Stage of Extraction of the Block Betul is at Semi-Critical (79.1 %)

5.4 MANAGEMENT PLAN		
Rainfall	meter	1.29416
Area	Sq Km	1150
Area suitable for recharge		978
Average post-monsoon water level	Meter	3.84
Unsaturated zone		0.84
Average SP Yield	%	0.015
Sub-surface storage	MCM	12.323
Surface water required		16.39
Surface water (Run-off) available		379.71
Non-committed Run-off		113.91
Percolation tank		16
Recharge shaft/ Tube well		33
NB/ CD/ CP		115
No of Villages		155

Structures	Number	Cost in Crores
Percolation Tanks	60	16
NB/ CD/ CP	419	115
Recharge shaft/ Tube well	120	33
Renovation of Village Ponds	158	155

5. 5 DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	96.180
Gross Draft		32.38
Stage of Development	**%**	33.67
Saving by Sprinkler in MCM	**MCM**	4.9398
Additional recharge created by AR		12.3228
After intervention of AR Structure Net GW AvL.		108.5028
After intervention of AR Structure &utilisation of 60% of additional GW created.		7.39368
Draft after sprinkler & additional area created for agriculture		34.83388
Stage of Development W/O GW use for addidtional Area Irrigation		32.10413003
Additional area irrigated by GW after intervention		1848.42

6. AQUIFER MAPS AND MANAGEMENT PLAN OF CHICHOLI BLOCK

6.1 SALIENT INFORMATION			
Block	**Chicholi**		
Area		Sq Km	494
Population			77,513
Normal Rainfall(2005-14)		millimeter	1248.07
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	382.58
	Net sown area		232.2
	Area sown more than once		150.38
	Cropping intensity	%	165%
	Area under forest	Sq Km	87.41
	Area under Waste land		19.14
Data Utilised	Monitoring Wells for Water Level		Dw-6
	Monitoring Wells for Quality		Dw-6
Water level behaviour	Pre-monsoon WL	mbgl	9.17
	Post-monsoon WL		3.1
	Pre-monsoon WL Trend	m /yr	Rising 0.0075 to 0.0242 Falling 0.0105 to 0.0523
	Post-monsoon WL Trend		Falling 0.0056 to 0.0651

6.2 AQUIFER DISPOSITION		
Major Aquifer	**Basalt /Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Granitoids	Jointed / Fractured Basalt/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	3.1 to 9.17	4 to 42
Weathered / Fractured rocks thickness (m)	up to 24	0.5 to 9
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 5.3 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

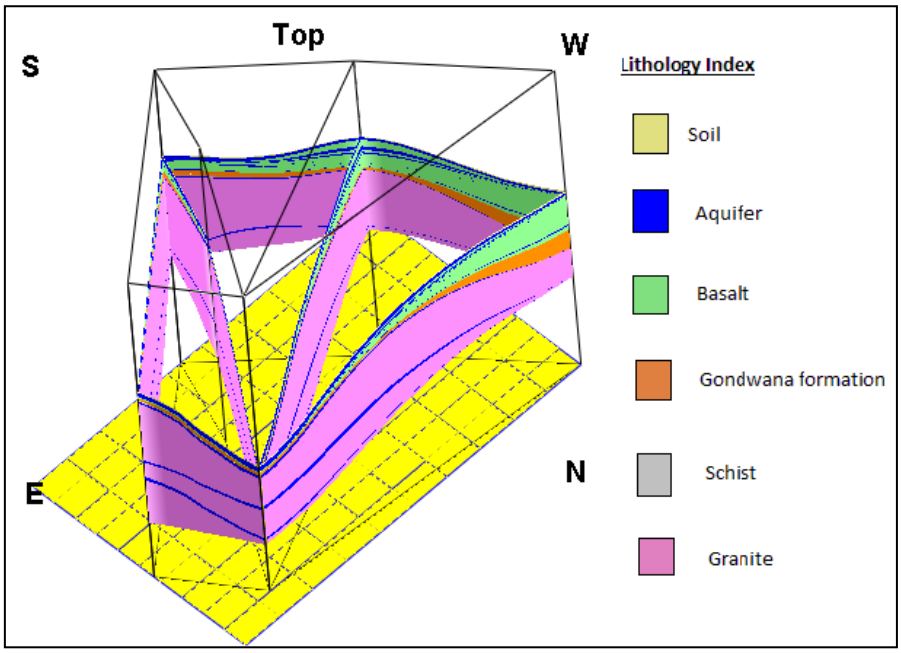

Fig. 6.1: Fence Diagram.

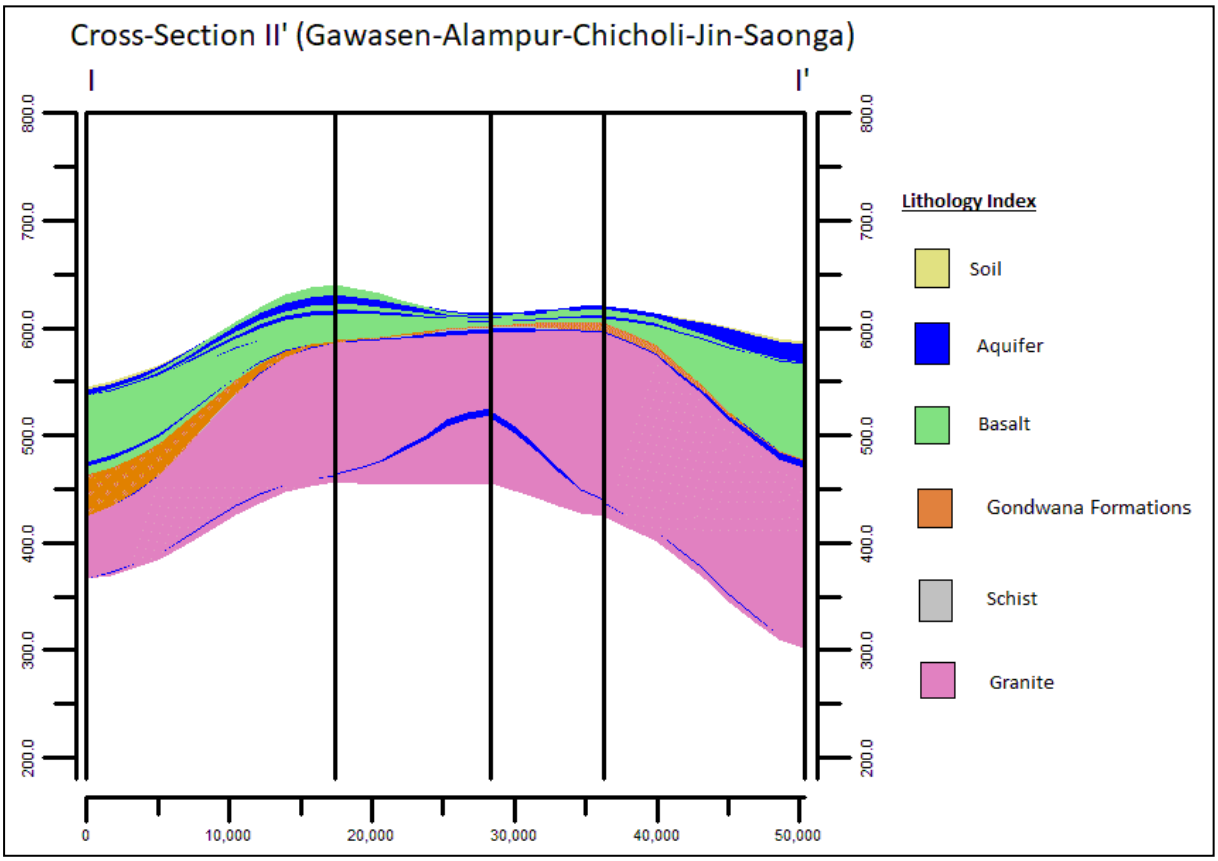

Fig.6.2: Cross-Section.

As the area is covered with hard Deccan trap basalt, Granitoid, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 24m. The fractured /jointed basalt, Granitoids form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.6.1.** The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence.

Hydrogeological cross section I-I' (**Fig.6.2**) represents a section through the block Chicholi along NW-SE direction and data of 5exploratory wells i.eGawasen, Alampur, Chicholi,Jin, Saonga has been utilised.

3. GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES			
Dynamic Groundwater Resources 2017	Type of Rock formation	Archaean Granite, Deccan trap Basalt	
	Recharge worthy area	Sq Km	398.5
	Command area		13.36
	Non-Command area		358.14
	Recharge From Rain Fall During Monsoon Season	MCM	52.78
	Recharge From other sources During Monsoon Season		2.08
	Recharge From Rain Fall During Non-Monsoon Season		5.95
	Recharge From other sources During non-Monsoon Season		6.37
	Total Recharge		67.18
	Annual Extractable Groundwater Recharge		63.82
	Existing Gross Ground Water Draft for Irrigation		36.8
	Existing Gross Ground Water Draft for Industrial Water Supply		0.339
	Existing Gross Ground Water Draft for Domestic Water Supply		1.921
	Existing Gross Ground Water Draft for All Uses		39.06
	Annual GW Allocation for Domestic Use as on 2025		2.01
	Net Ground Water Availability for Future Irrigation Development		24.671
	Stage of Ground Water Extraction	**%**	61.20%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	13.210
Static Resource Of Deep Aquifer			21.639

6.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block **(Fig.6.3 and 6.4)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt and granitoids, there is restricted depth of weathering in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Chirapatala, Gadha, Jogli, Khokharkheda, Pathakheda nitrate concentration are68mg/l, 54mg/l, 53mg/l, 75mg/l and 75 mg/l respectively which are above the permissible limit.
	Deep Aquifer: At location Jin, Neempani, malanjpur, the Nitrate Concentration are 155mg/l, 58mg/l and 78 mg/l respectively are above the permissible limit. At Chicholi the Fluoride conc. is 2.9mg/l which is also above the permissible limit

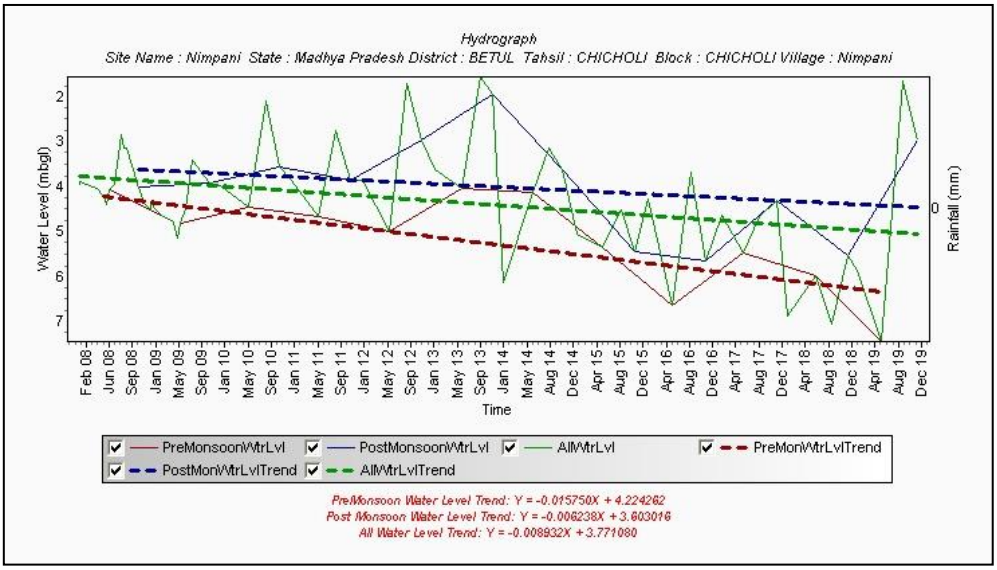

Fig.6.3: Hydrograph(2008-19),Village-Neempani.

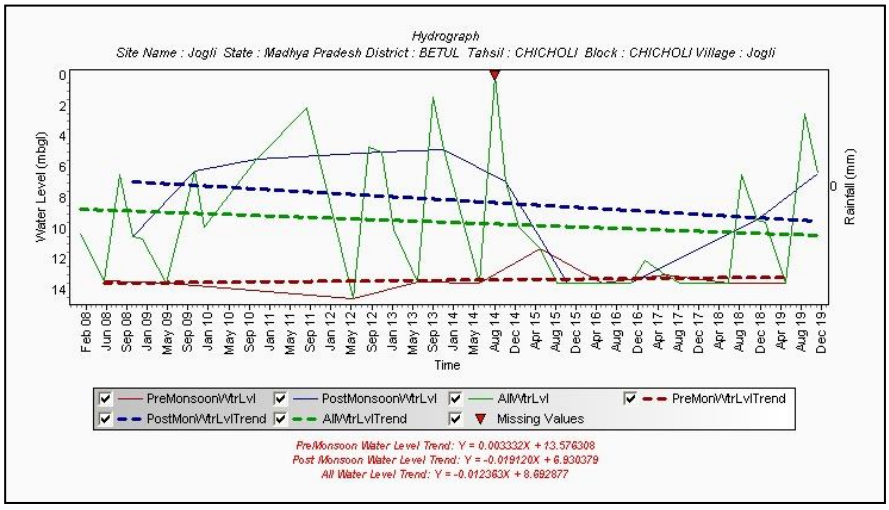

Fig.6.4: Hydrograph(2008-19),Village-Jogli.

6.4. MANAGEMENT PLAN		
Rainfall	meter	1.24807
Area	Sq Km	494
Area suitable for recharge		398.5
Average post-monsoon water level	Meter	4.65
Unsaturated zone		1.65
Average SP Yield	%	0.015
Sub-surface storage	MCM	9.863
Surface water required		13.12
Surface water (Run-off) available		149.21
Non-committed Run-off		44.76
Percolation tank		13
Recharge shaft/ Tube well		26
NB/ CD/ CP		92
No of Villages		80

Structures	Number	Cost in Crores
Percolation Tanks	13	2.6
NB/ CD/ CP	92	9.2
Recharge shaft/ Tube well	26	1.3
Renovation of Village Ponds	80	1.6

6.5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	63.82
Gross Draft		36.75
Stage of Development	**%**	57.58
Saving by Sprinkler in MCM	**MCM**	7.36
Additional recharge created by AR		9.862875
After intervention of AR Structure Net GW AvL.		73.682875
After intervention of AR Structure &utilisation of 60% of additional GW created.		5.917725
Draft after sprinkler & additional area created for agriculture		35.307725
Stage of Development W/O GW use for additional Area Irrigation		47.91849531
Additional area irrigated by GW after intervention		1479.43125

7. AQUIFER MAPS AND MANAGEMENT PLAN OF GHORADONGRI BLOCK

7.1 Salient Information			
Block	**Ghodadongri**		
Area		Sq Km	1300
Population			1,49,649
Normal Rainfall(2005-14)		millimeter	1203.06
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	400.94
	Net sown area		253.54
	Area sown more than once		147.4
	Cropping intensity	%	158%
	Area under forest	Sq Km	146.39
	Area under Waste land		24.55
Data Utilised	Monitoring Wells for Water Level		Dw-2
	Monitoring Wells for Quality		Dw-2
Water level behaviour	Pre-monsoon WL	mbgl	8.84
	Post-monsoon WL		1.93
	Pre-monsoon WL Trend	m/yr	Falling 0.0336 to 0.0474
	Post-monsoon WL Trend		Falling 0.0208 to 0.0306

7.2. AQUIFER DISPOSITION		
Major Aquifer	**Gondwana Formation/ Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Gondwana Formations/Granitoids	Jointed / Fractured Gondwana formation/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	1.93 to 8.84	10.49
Weathered / Fractured rocks thickness (m)	up to 12.2	0.5 to 3
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 0.8 lps
Transmissivity(m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

As the area is covered with hard Gondwana formation and Granitoidthe thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 12m. The fractured /jointed Gondwana formation and Granitoidform the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.7.1.** The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence.

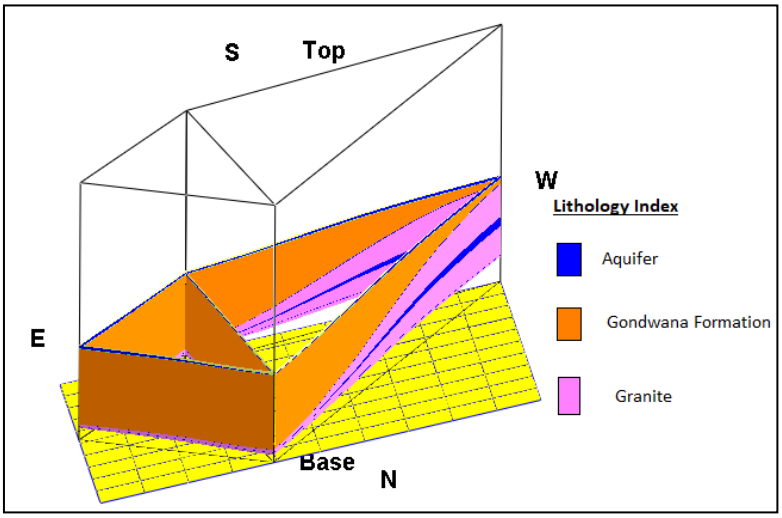

Fig.7.1: Fence Diagram.

6.3. GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES			
Dynamic Groundwater Resources 2017	Type of Rock formation	Gondwana Formation/ Granitoids	
	Recharge worthy area	Sq Km	1140
	Command area		15.6
	Non-Command area		1124.4
	Recharge From Rain Fall During Monsoon Season	MCM	90.9987
	Recharge From other sources During Monsoon Season		2.023
	Recharge From Rain Fall During Non-Monsoon Season		15.89
	Recharge From other sources During non-Monsoon Season		8.9976
	Total Recharge		117.9093
	Annual Extractable Groundwater Recharge		112.01
	Existing Gross Ground Water Draft for Irrigation		25.1653
	Existing Gross Ground Water Draft for Industrial Water Supply		0.5022
	Existing Gross Ground Water Draft for Domestic Water Supply		2.8456
	Existing Gross Ground Water Draft for All Uses		28.5131
	Annual GW Allocation for for Domestic Use as on 2025		3.8211
	Net Ground Water Availability for Future Irrigation Development		82.525
	Stage of Ground Water Extraction	**%**	25.46%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	34.200
Static Resource Of Deep Aquifer			35.340

6.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block **(Fig.6.3)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt and Granitoids there is restricted depth of weathering (< 20 m) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Ghoradongri nitrate concentration is 76mg/l which is above the permissible limit.

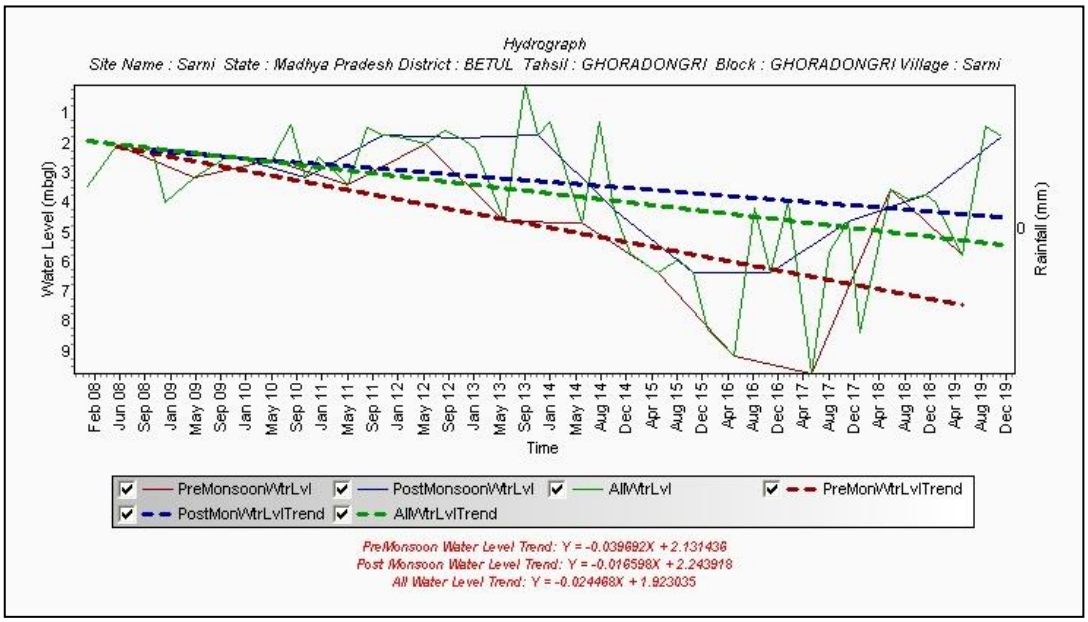

Fig.7.2: Hydrograph (2008-19), village- Sarni.

6.4. MANAGEMENT PLAN		
Rainfall	meter	1.20306
Area	Sq Km	1300
Area suitable for recharge		1140
Average post-monsoon water level	Meter	4.79
Unsaturated zone		1.79
Average SP Yield	%	0.015
Sub-surface storage	MCM	30.609
Surface water required		40.71
Surface water (Run-off) available		411.45
Non-committed Run-off		123.43
Percolation tank		41
Recharge shaft/ Tube well		81
NB/ CD/ CP		285
No of Villages		172

Structures	Number	Cost in Crores
Percolation Tanks	41	8.2
NB/ CD/ CP	285	28.5
Recharge shaft/ Tube well	81	4.05
Renovation of Village Ponds	172	3.44

6.5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	112.013
Gross Draft		37.176
Stage of Development	**%**	33.19
Saving by Sprinkler in MCM	**MCM**	5.033
Additional recharge created by AR		30.609
After intervention of AR Structure Net GW AvL.		142.622
After intervention of AR Structure &utilisation of 60% of additional GW created.		18.3654
Draft after sprinkler & additional area created for agriculture		50.5084
Stage of Development W/O GW use for additional Area Irrigation		35.41417173
Additional area irrigated by GW after intervention		4591.35

8.AQUIFER MAPS AND MANAGEMENT PLAN OF MULTAI BLOCK

8.1 SALIENT INFORMATION			
Block	**Multai**		
Area		Sq Km	1081
Population			1,26,080
Normal Rainfall(2005-14)		millimeter	1108.36
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	882.52
	Net sown area		607.31
	Area sown more than once		275.21
	Cropping intensity	%	145%
	Area under forest	Sq Km	13.95
	Area under Waste land		3.29
Data Utilised	Monitoring Wells for Water Level		Dw-5
	Monitoring Wells for Quality		Dw-5
Water level behaviour	Pre-monsoon WL	mbgl	8.70
	Post-monsoon WL		3.45
	Pre-monsoon WL Trend	m /yr	Rising 0.0089 to 0.0351 Falling 0.0036 to 0.007
	Post-monsoon WL Trend		Rising 0.0049 Falling 0.0024 to 1.119

8.2 AQUIFER DISPOSITION		
Major Aquifer	**Deccan trap Basalt**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt	Jointed / Fractured Basalt
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)		12 to 36
Weathered / Fractured rocks thickness (m)	up to 25	0.5 to 12
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	0.1 to 14 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

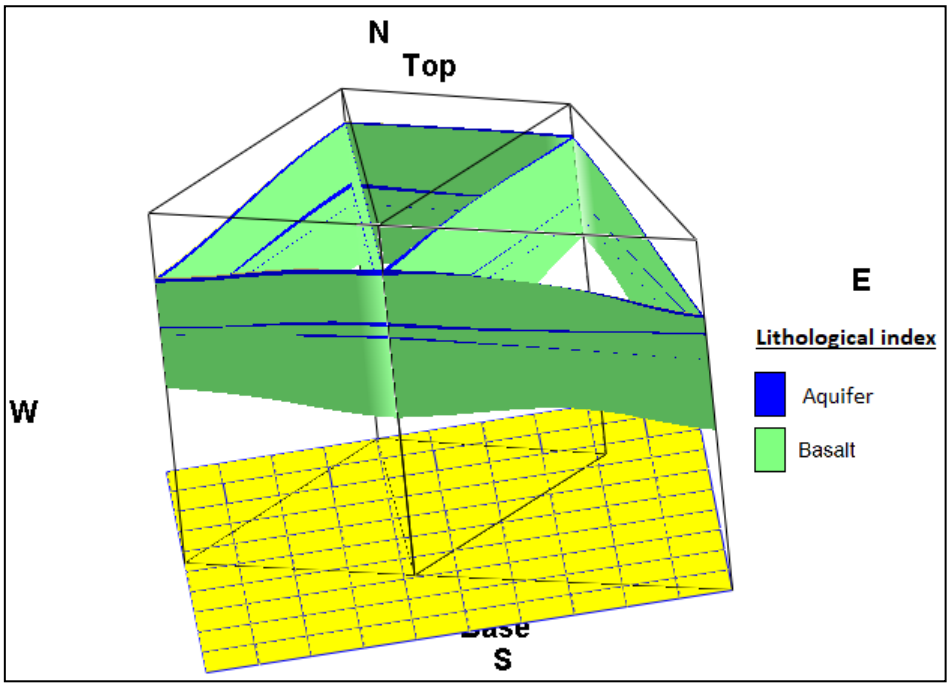

Fig.8.1: Fence Diagram.

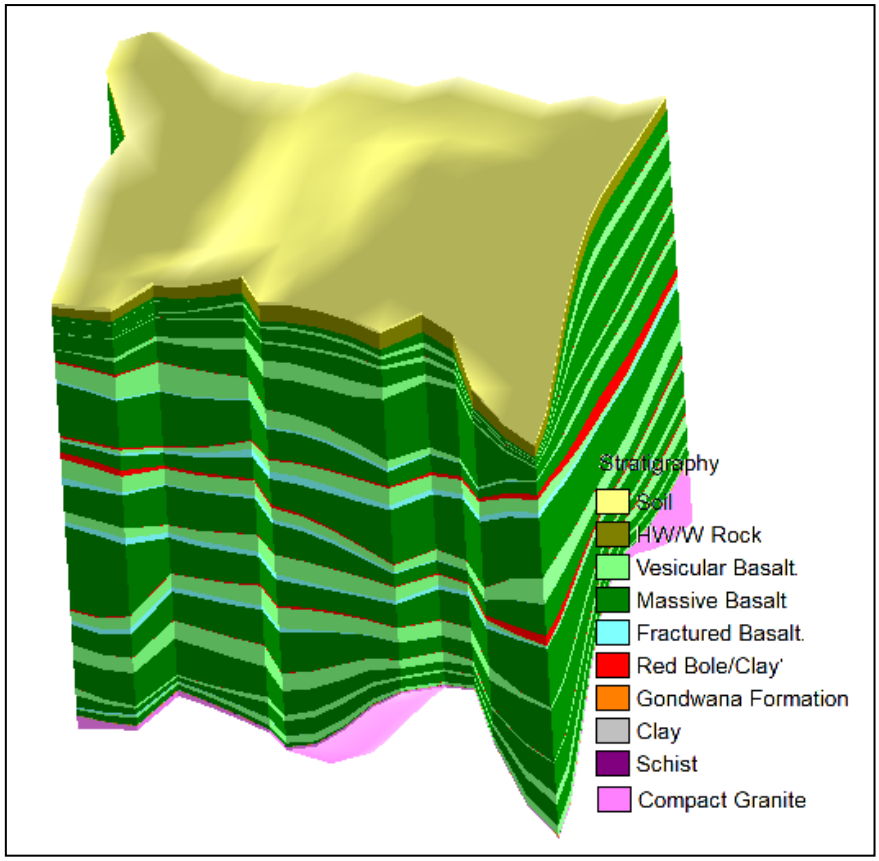

Fig.8.2:3D Model.

As the area is covered with hard rock Deccan trap Basalt, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 25 m. The fractured /jointed basalt form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.8.1**and 3-D representation is presented in **Fig. 8.2**. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

Hydrogeological cross section J-J' (**Fig.8.3**) represents a section through the block Multai along nearly E-W direction and data of 6 exploratory wells i.eSaikheda, Jualkheda, Sandiya, Chandora, Dhauva, Khambarahas been utilised.

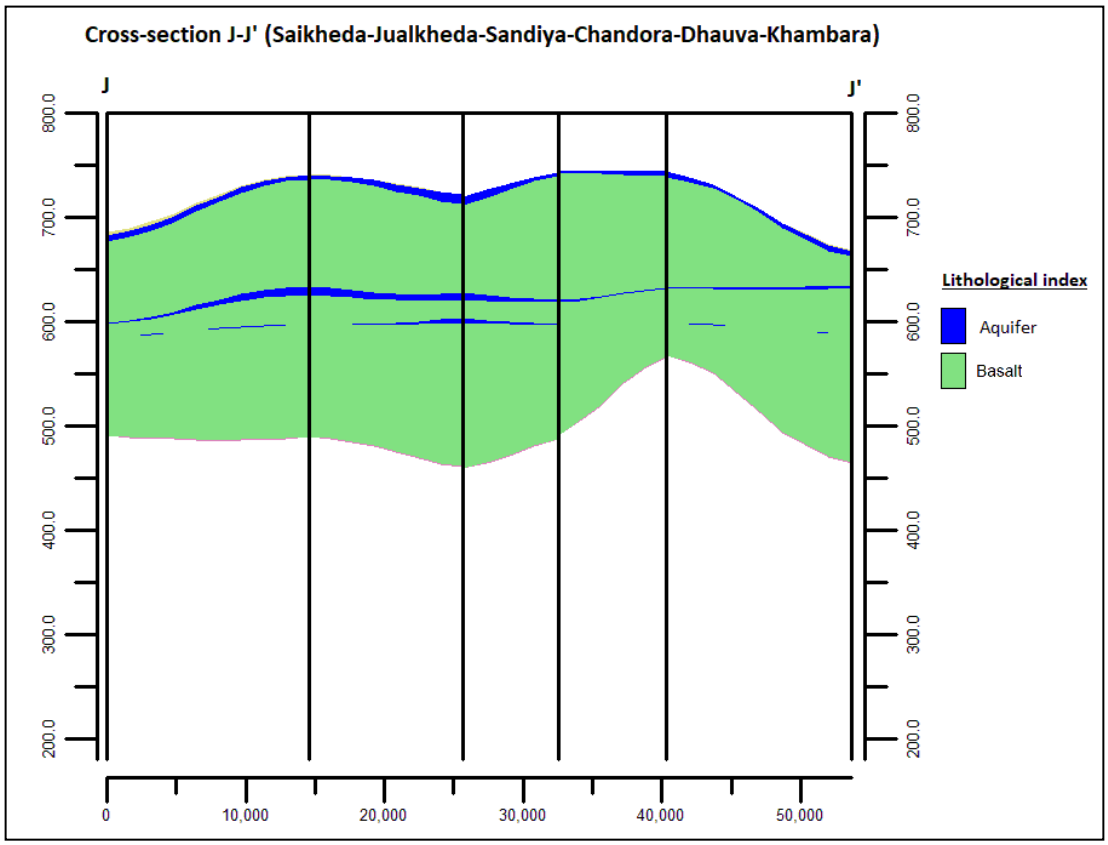

Fig.8.3: Cross-Section.

8.3 GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES			
Dynamic Groundwater Resources 2017	Type of Rock formation	Deccan trap Basalt	
	Recharge worthy area	Sq Km	871
	Command area		39.07
	Non-Command area		831.93
	Recharge From Rain Fall During Monsoon Season	MCM	107.27
	Recharge From other sources During Monsoon Season		9.82
	Recharge From Rain Fall During Non-Monsoon Season		16.45
	Recharge From other sources During non-Monsoon Season		31.33
	Total Recharge		164.87
	Annual Extractable Groundwater Recharge		155.877
	Existing Gross Ground Water Draft for Irrigation		125.8
	Existing Gross Ground Water Draft for Industrial Water Supply		0.606
	Existing Gross Ground Water Draft for Domestic Water Supply		3.434
	Existing Gross Ground Water Draft for All Uses		129.84
	Annual GW Allocation for Domestic Use as on 2025		3.59
	Net Ground Water Availability for Future Irrigation Development		25.881
	Stage of Ground Water Extraction	**%**	83.30%
	Category		**SEMI-CRITICAL**
Static Resource Of Shallow Aquifer		MCM	35.537
Static Resource Of Deep Aquifer			63.322

8.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block **(Fig.8.4)**
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt there is restricted depth of weathering in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Junapani, Multai, Sasundra the nitrate concentration in the shallow aquifer is 85mg/l, 52 mg/l and 51 mg/l respectively which are above the permissible limit.
	Deep Aquifer: At The location Sandiya Fluoride concentration is 2.74mg/l which is above permissible limit.
Increasing Stage of Ground water Extraction	Now the Stage of Extraction of the Block Multai is at Semi-Critical (83.30 %)

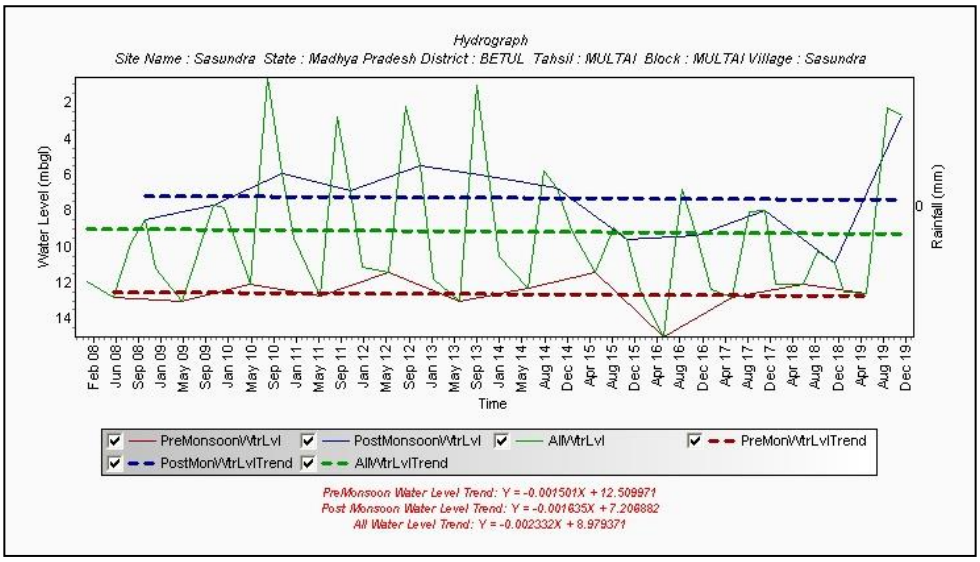

Fig.8.4: Hydrograph (2008-19), village Sasundra.

4. MANAGEMENT PLAN FOR AMLA BLOCK		
Rainfall	meter	1.10836
Area	Sq Km	1081
Area suitable for recharge		871
Average post-monsoon water level	Meter	3.55
Unsaturated zone		0.55
Average SP Yield	%	0.02
Sub-surface storage	MCM	9.581
Surface water required		12.74
Surface water (Run-off) available		289.61
Non-committed Run-off		86.88
Percolation tank		13
Recharge shaft/ Tube well		25
NB/ CD/ CP		89
No of Villages		139

Structures	**Number**	**Cost in Crores**
Percolation Tanks	13	2.6
NB/ CD/ CP	89	8.9
Recharge shaft/ Tube well	25	1.25
Renovation of Village Ponds	139	2.78

5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	155.877
Gross Draft		129.84
Stage of Development	**%**	83.3
Saving by Sprinkler in MCM	**MCM**	25.16
Additional recharge created by AR		23.12505
After intervention of AR Structure Net GW AvL.		179.00205
After intervention of AR Structure &utilisation of 60% of additional GW created.		13.87503
Draft after sprinkler & additional area created for agriculture		118.55503
Stage of Development W/O GW use for addidtional Area Irrigation		66.23110182
Additional area irrigated by GW after intervention		3468.7575

9. AQUIFER MAPS AND MANAGEMENT PLAN OF PRABHAT PATTAN BLOCK

9.1. SALIENT INFORMATION			
Block	**PrabhatPattan**		
Area		Sq Km	1133
Population			1,31,022
Normal Rainfall(2005-14)		millimeter	978.03
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	773.62
	Net sown area		567.71
	Area sown more than once		205.91
	Cropping intensity	%	136%
	Area under forest	Sq Km	58.98
	Area under Waste land		66.58
Data Utilised	Monitoring Wells for Water Level		Dw-2
	Monitoring Wells for Quality		Dw-2
Water level behaviour	Pre-monsoon WL	mbgl	13.1
	Post-monsoon WL		3.17
	Pre-monsoon WL Trend ()	m /yr	Falling 0.0331 to 0.0619
	Post-monsoon WL Trend (m /yr)		Falling 0.0129 to 0.0586

2. AQUIFER DISPOSITION		
Major Aquifer	**Deccan trap Basalt**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt	Jointed / Fractured Basalt
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	3.17 to 13.1	46 to 81
Weathered / Fractured rocks thickness (m)	up to 16	0.5 to 12
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	0.1 to 25 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

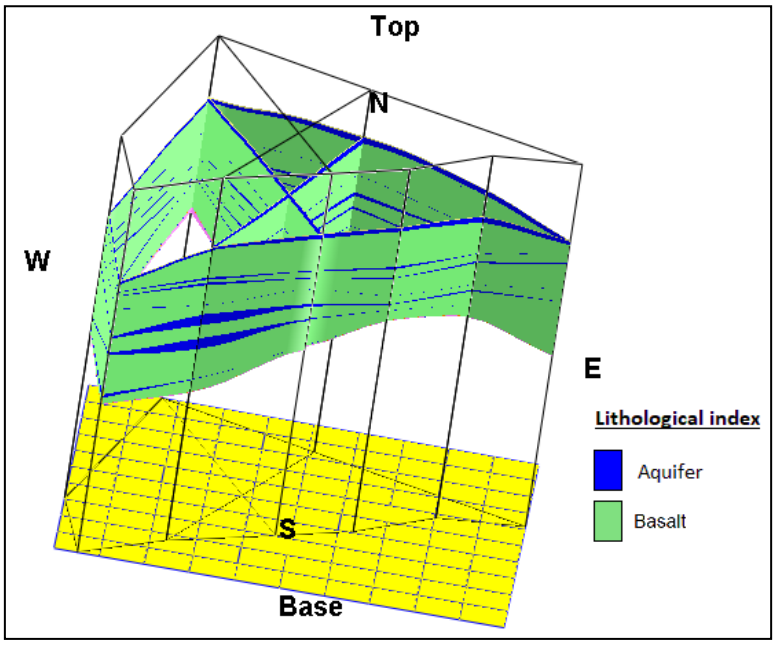

Fig.9.1: Fence Diagram.

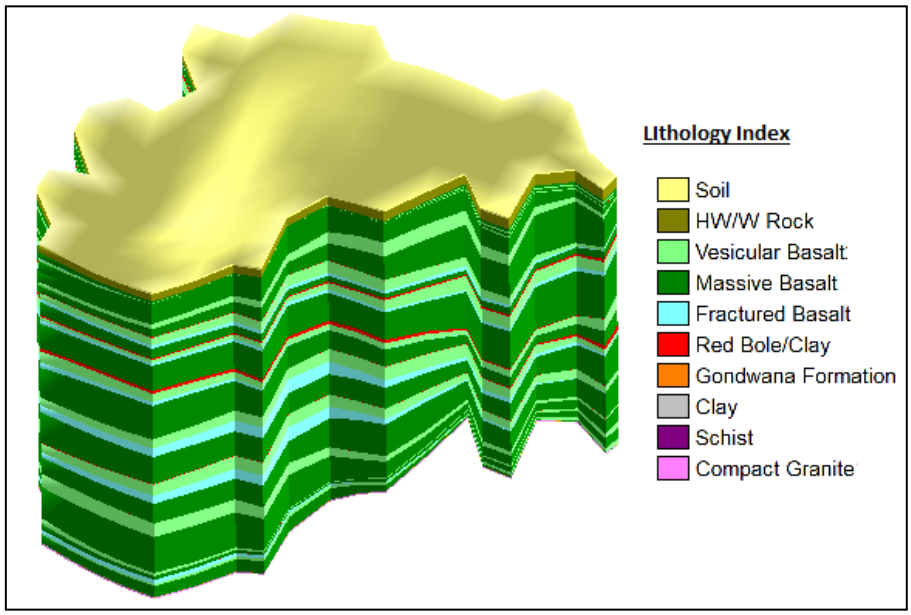

Fig.9.2: 3D Diagram.

As the area is covered with hard rock Deccan trap Basalt, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 16m. The fractured /jointed basalt form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.9.1**and 3-D representation is presented in **Fig. 9.2**. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

Hydrogeological cross section K-K' (**Fig.9.3**) represents a section through the block PrabhatPattanand data of 6 exploratory wells i.eSaikheda, Jualkheda, Sandiya, Chandora, Dhauva, Khambarahas been utilised.

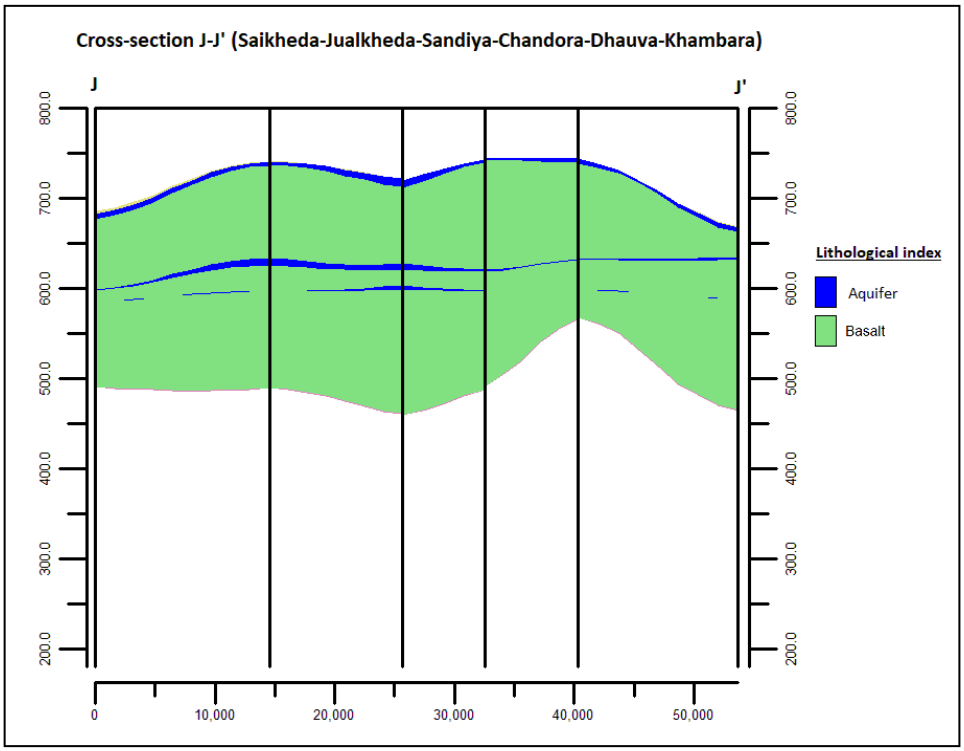

Fig.9.3: Cross-Section.

3. GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES			
Dynamic Groundwater Resources 2017	Type of Rock formation	Deccan trap Basalt	
	Recharge worthy area	Sq Km	1066
	Command area		33.26
	Non-Command area		1032.74
	Recharge From Rain Fall During Monsoon Season	MCM	105.86
	Recharge From other sources During Monsoon Season		5.27
	Recharge From Rain Fall During Non-Monsoon Season		17.66
	Recharge From other sources During non-Monsoon Season		18.31
	Total Recharge		147.1
	Annual Extractable Groundwater Recharge		139.002
	Existing Gross Ground Water Draft for Irrigation		83.6
	Existing Gross Ground Water Draft for Industrial Water Supply		0.6
	Existing Gross Ground Water Draft for Domestic Water Supply		3.4
	Existing Gross Ground Water Draft for All Uses		87.6
	Annual GW Allocation for Domestic Use as on 2025		3.552
	Net Ground Water Availability for Future Irrigation Development		51.25
	Stage of Ground Water Extraction	**%**	63.02%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	38.536
Static Resource Of Deep Aquifer			69.183

Ground Water Related Issues	
Declining water level	Declining water level observed both in pre and post-monsoon in major part of the block
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt there is restricted depth of weathering (< 20 m) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Masod the nitrate concentration in the shallow aquifer is 52mg/l which is above the permissible limit.

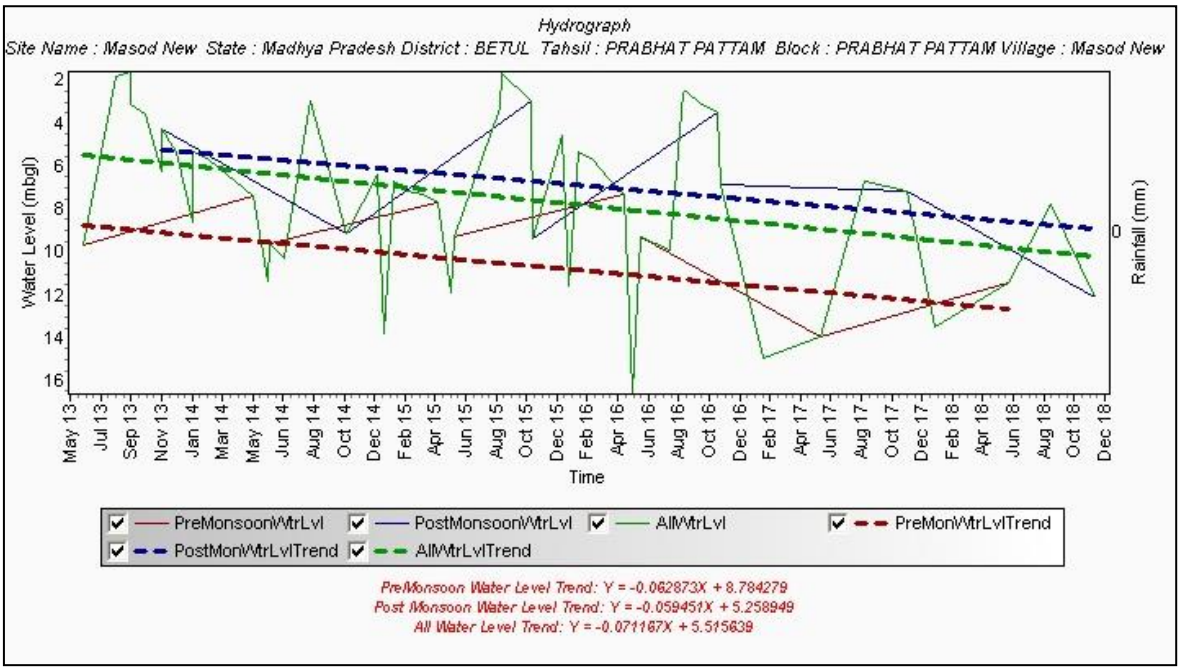

Fig.9.4: Hydrograph (2013-18), Village Masod.

4. MANAGEMENT PLAN		
Rainfall	meter	0.97803
Area	Sq Km	1133
Area suitable for recharge		1066
Average post-monsoon water level	Meter	4.79
Unsaturated zone		1.79
Average SP Yield	%	0.015
Sub-surface storage	MCM	28.622
Surface water required		38.07
Surface water (Run-off) available		312.77
Non-committed Run-off		93.83
Percolation tank		38
Recharge shaft/ Tube well		76
NB/ CD/ CP		266
No of Villages		128

Structures	Number	Cost in Crores
Percolation Tanks	38	7.6
NB/ CD/ CP	266	26.6
Recharge shaft/ Tube well	76	3.8
Renovation of Village Ponds	128	2.56

5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	139.002
Gross Draft		87.6
Stage of Development	**%**	63.02
Saving by Sprinkler in MCM	**MCM**	16.72
Additional recharge created by AR		28.6221
After intervention of AR Structure Net GW AvL.		167.6241
After intervention of AR Structure &utilisation of 60% of additional GW created.		17.17326
Draft after sprinkler & additional area created for agriculture		88.05326
Stage of Development W/O GW use for additional Area Irrigation		52.53019106
Additional area irrigated by GW after intervention		4293.315

10. AQUIFER MAPS AND MANAGEMENT PLAN OF SHAHPUR BLOCK

10.1 Salient Information			
Block	**Shahpur**		
Area		Sq Km	505
Population			1,13,306
Normal Rainfall(2005-14)		millimeter	1254.81
Land use and Agriculture	Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize, Kodokutki
	Gross cropped area	Sq Km	336.14
	Net sown area		225.85
	Area sown more than once		110.29
	Cropping intensity	%	149%
	Area under forest	Sq Km	112.92
	Area under Waste land		11.22
Data Utilised	Monitoring Wells for Water Level		Dw-2
	Monitoring Wells for Quality		Dw-2
Water level behaviour	Pre-monsoon WL	mbgl	9.87
	Post-monsoon WL		3.34
	Pre-monsoon WL Trend (m /yr)	m /yr	Rising 0.0015 to 0.0046
	Post-monsoon WL Trend (m /yr)		Falling 0.0129 to 0.0585

10.2. AQUIFER DISPOSITION		
Major Aquifer	**Gondwana Formation/ Granitoids**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Gondwana Formations/Granitoids	Jointed / Fractured Gondwana formation/Granitoids
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)		3.25 to 12.64
Weathered / Fractured rocks thickness (m)	up to 18	0.5 to 6
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 0.6 lps
Transmissivity (m^2/day)	-	5 to 80 m^2/day
Specific Yield/ Storativity (Sy/S)	-	$1.0x10^{-4}$ to $5.5x10^{-5}$

As the area is covered with hard Gondwana formation and Granitoid the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 16m. The fractured /jointed Gondwana Formation and Granitoids form the deeper aquifer. The fence diagram indicating the disposition of various aquifers is presented in **Fig.10.1.** The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence.

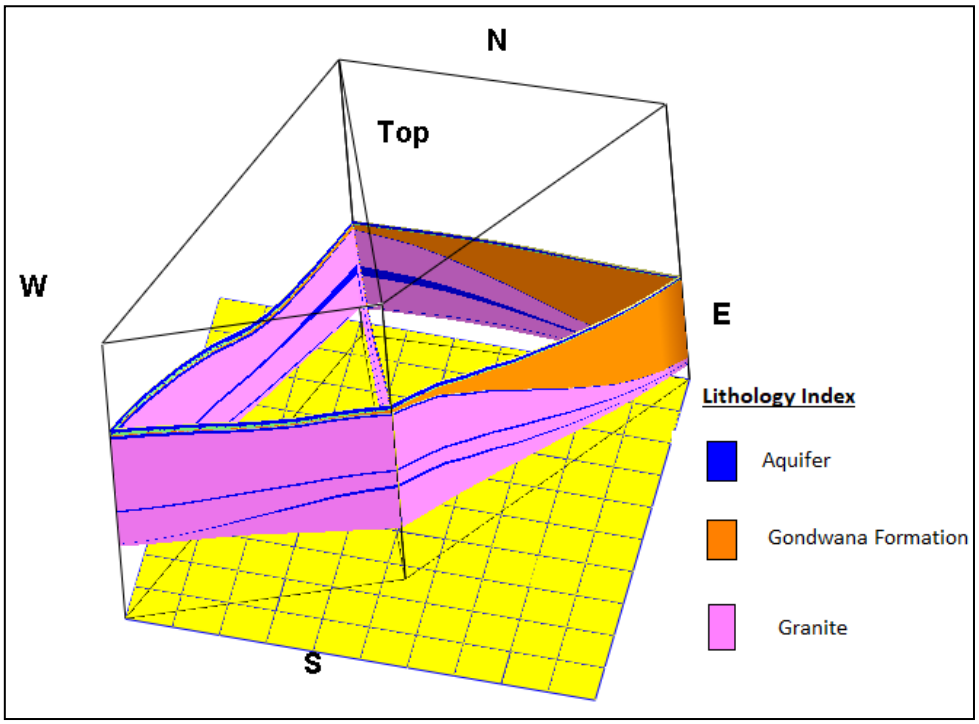

Fig. 10.1: Fence Diagram.

10.3. Ground water resource, extraction, contamination and other issues			
Dynamic Groundwater Resources 2017	Type of Rock formation	Gondwana Formation/ Granitoids	
	Recharge worthy area	Sq Km	445
	Command area		12.62
	Non-Command area		432.38
	Recharge From Rain Fall During Monsoon Season	MCM	48.61
	Recharge From other sources During Monsoon Season		2.5
	Recharge From Rain Fall During Non-Monsoon Season		7.51
	Recharge From other sources During non-Monsoon Season		8.42
	Total Recharge		67.04
	Annual Extractable Groundwater Recharge		63.34
	Existing Gross Ground Water Draft for Irrigation		38.65
	Existing Gross Ground Water Draft for Industrial Water Supply		0.411
	Existing Gross Ground Water Draft for Domestic Water Supply		2.329
	Existing Gross Ground Water Draft for All Uses		41.39
	Annual GW Allocation for Domestic Use as on 2025		2.44
	Net Ground Water Availability for Future Irrigation Development		21.843
	Stage of Ground Water Extraction	**%**	65.34%
	Category		**SAFE**
Static Resource Of Shallow Aquifer		MCM	21.160
Static Resource Of Deep Aquifer			20.648

10.3.1 Ground Water Related Issues	
Declining water level	Declining water level observed in some part of the block
Low Ground Water Potential / Limited Aquifer Thickness / Low Sustainability and High runoff	As the block is covered with hard Deccan trap basalt there is restricted depth of weathering (< 20 m) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers is limited.
Inferior Ground Water quality	**Shallow Aquifer:** At the location Shapur the nitrate concentration in the shallow aquifer is 55 mg/l which is above the permissible limit.

10.4. MANAGEMENT PLAN		
Rainfall	meter	1.25481
Area	Sq Km	505
Area suitable for recharge		445
Average post-monsoon water level	Meter	3.65
Unsaturated zone		0.65
Average SP Yield	%	0.015
Sub-surface storage	MCM	4.339
Surface water required		5.77
Surface water (Run-off) available		167.52
Non-committed Run-off		50.26
Percolation tank		6
Recharge shaft/ Tube well		12
NB/ CD/ CP		40
No of Villages		131

Structures	Number	Cost in Crores
Percolation Tanks	6	1.2
NB/ CD/ CP	40	4
Recharge shaft/ Tube well	12	0.6
Renovation of Village Ponds	131	2.62

10.5. DEMAND SIDE INTERVENTIONS		
Net GW Availability	**MCM**	63.344
Gross Draft		41.39
Stage of Development	**%**	65.34
Saving by Sprinkler in MCM	**MCM**	7.73
Additional recharge created by AR		4.33875
After intervention of AR Structure Net GW AvL.		67.68275
After intervention of AR Structure &utilisation of 60% of additional GW created.		2.60325
Draft after sprinkler & additional area created for agriculture		36.26325
Stage of Development W/O GW use for additional Area Irrigation		53.57827511
Additional area irrigated by GW after intervention		650.8125

SUM UP & RECOMMENDATIONS

- A thorough study was carried out based on data gap analysis, data generated in-house; data acquired from State Govt. departments and GIS maps prepared for various themes. All the available data was brought on GIS platform and an integrated approach was adopted for preparation of aquifer maps and aquifer management plans of Betul district.
- The study area is spanning over 10043 sq.km, out of which 1478.50 sq.km is hilly area and area suitable for recharge is 8564.50 sq.km.
- The major rivers flowing in the district are the Tapi River, the Ganjal River (a tributary of the Tapti River), the Morand River and the Tawa River (tributaries of the Narmada River).
- Main geological units of the area are Deccan traps, Gondwana formations, Archaeans. Deccan traps comprising basaltic lava flows and most extensive rocks in the district.
- The pre-monsoon depth to water levels during May 2019 ranged between 2.45 to 19.7 mbgl and the post-monsoon depth to water levels during Nov. 2019 ranged between 0.44 to 7.53 mbgl.
- About 60.72% of monitoring wells of the district are showing high fluctuation range (pre-monsoon WL & post-monsoon WL) indicating aquifer storage capacity of the district is not good.
- For Shallow aquifers the electrical conductivity of ground water ranged between 265 to 1388 µS/cm at 25°C, pH ranged in between 7.25 to 8.10, fluoride concentration was ranged in between 0.05 to 1.35 mg/l, nitrate concentration ranged in between 27 to 161 mg/l. Total hardness ranged in between 126 to 610 mg/l.
- For deep aquifers the electrical conductivity of ground water ranged between 112 to1543 µS/cm at 25°C,pH ranged in between 6.95 to 8.30, fluoride concentration was ranged in between 0.26 to 4.84 mg/l, nitrate concentration ranged in between 1 to 155 mg/l. Total hardness ranged in between 45 to 540 mg/l.
- During monsoon season recharge from rainfall contributes maximum component (87832.29 ham) and recharge from other sources is 4914.79 ham, whereas during non-monsoon season, recharge from rainfall is 15543.34 ham and the recharge from othe r sources is 17950.96 ham.
- The net dynamic ground water resource available is 119671.78 ham. The annual gross draft for all uses is estimated as 69852.02 ham with irrigation sector being the major consumer having a draft of 65506.60 ham, resulting the stage of ground water development to be 58.37 % as a whole for district. The Betul district falls under safe category.
- There are 2 Semi critical blocks out of 10 Blocks (79.1 & 83.3 % Stage of Development in Betul and Multai respectively).
- On the basis of the exploratory bore wells drilled by CGWB, NCR under its NAQUIM program, it has been observed that the yield varies from meagre to 25 lps.
- As per the Management plan prepared under NAQUIM of all the Block of Betul District, a total number of 258 Percolation Tanks, 515 Recharge Shafts/Tube wells and 1504Nala Bunds/Check Dams/Cement Plugs have been proposed and financial expenditure is expected to be Rs285.73 Crores in Betul District for sustainable development and management of ground water resources.

- In Betul district, the main ground water issues are Decline in the water level, Limited Ground Water Potential / Limited Aquifer Thickness / Sustainability, Deeper Water Levels particularly in deeper aquifers, Inferior Ground Water Quality both in shallow and deep aquifers and Increasing Stage of ground water extraction

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ANNEXURE-I: Details of Ground Water Exploration

S. No.	Location	Block	Type of well	Year of construction	Depth Drilled	Thickness of weathering (m)	Aquifer	Zone	SWL (mbgl)	Discharge (lps)
1	AdarshDhanora	Bhimpur	EW	2018-19	200	6.1	Weathered/ fractured Basalt	12.2-15.25, 67.1-70.1	22.75	1.5
2	Amla	Amla	EW	2008-09	250.1	15			10	0.22
3	Athner	Athner	EW	2005-06	250	19	Fractured & Jointed granitic gneiss	158-164,231-233	10.28	16
4	Barai	Multai	EW		147.3		Weathered Vesicular Basalt	12-16,37-46	12.3	2.5
5	Basinda	Bhimpur	EW	2018-19	200	6	Weathered Basalt/Sandstone	3.05-6.1, 152-154	>100	Meagre
6	Betul sadar	Betul	EW	2005-06	305	24.3	Fractured & Jointed granitic gneiss	54.9-59, 115-122, 296-300	13.7	4.26
7	Betul sadar	Betul	OW	2005-06	134.2	27.4	Fractured & Jointed granitic gneiss	21.4-27.4, 117-122	13.52	
8	Bhainsdehi	Bhainsdehi	EW	2008-09	189.7	21	Fractured/ Jointed Basalt	45-55, 134-140, 154-159	112.8	12
9	Bhainsdehi	Bhainsdehi	OW1	2008-09	154	21	Fractured/Jointed Basalt	43-53, 140-146	112.7	
10	Bhainsdehi	Bhainsdehi	OW2	2008-09	146.1	24	Fractured/Jointed Basalt	46-55, 135-140	111.95	
11	Bhimpur	Bhimpur	EW	2006-07	201	12	Gondwana sandstone /fractured granite/Fractured basalt	54-64, 70-85,192-198	2.01	3
12	Bhimpur	Bhimpur	OW1	2006-07	98.6	11	Fractured basalt	54-64	3.87	
13	Bhimpur	Bhimpur	OW2	2006-07	202	8	fractured granite/Fractured basalt	56-65, 192-195	1.53	
14	Bhujaliaghat	Betul	EW	2006-07	269	19	Fractured Amphibolite	19.0-24.0,24.0-37.0	19.72	3.28
15	Bhujaliaghat	Betul	OW	2006-07	49.8	16	Fractured Granite	16.0-25.0,40.0-44.0	26.17	0.22
16	Birolijhilpa	PrabhatPattan	EW	2018-19	155	12.2	fractured Basalt	79.3-82, 122-128		

17	Bisnoor	PrabhatPatan	EW	2018-19	201.3	6.1				Megare
18	Bordehi	Amla	EW	2018-19	200	6	Basalt/ Gabbro	80.3-83.3	10.54	2.38
19	BotharPathar	Multai	EW	2018-19	202.3	4	Basalt			
20	Chakora	PrabhatPatan	EW	2018-19	201.3	6	Basalt	183-192.15		
21	Chandora	Multai	EW	2008-09	274.5	4	Weathered/Vescicular Basalt	33.5-39.5	22.5	0.75
22	Chandu	Bhimpur	EW	2018-19	200.2	2.5	Basalt	58.90-68.10	55.85	1.76
23	Chicholi	Chicholi	EW	2005-06	263	17	Fractured & Jointed granitic gneiss	15-17,64-73, 153-158,258-263	36.18	5.3
24	Chicholi	Chicholi	OW	2005-06	263	20	Fractured & Jointed granitic gneiss	17-20, 159-165, 159-165, 256-263	36.1	
25	Chikhali	Bhimpur	EW	2018-19	200.1	1.9	Basalt	43-44.6		
26	Dahuva	Multai	EW	2018-19	204.7	12.2	Basalt	21.8-24.9,83.7-86.8	11.99	0.1
27	Dedhpani	Bhainsdehi	EW	2008-09	134.2	6	Fractured Basalt	125-134.2	87.22	11
28	Dedhpani	Bhainsdehi	OW1	2008-09	146.4	6	Fractured Basalt	130-136	87.53	1.2
29	Dedhpani	Bhainsdehi	OW2	2008-09	134.1	6	Fractured Basalt	128-134.10	87.45	2.75
30	Dhamangaon	Bhainsdehi	EW	2008-09	266.6	10	Fractured Basalt	10.0-14.0	12.5	0.25
31	Gawasen	Chicholi	EW	2018-19	178.9	8.1	Basalt	36.6-39.65,72.1-75.2		
32	Gudgaon	Bhainsdehi	EW	2008-09	256.2	15	Fractured/ Jointed Basalt	150-153	100	0.75
33	Hirapur	Shahpur	EW	2018-19	200	7.5	Gondwana sandstone	25.4-28.4	12.38	0.6
34	Jaora	Athner	EW	2006-07	305	12	Weathered Vesicular Basalt	30-36	24.9	0.22
35	Jhallar	Bhainsdehi	EW	2007-08	275.5	3.1	Fractured basalt	25.4-37.6	7.49	0.22
36	Jholi	Ghodadongri	EW	2018-19	198.25	12.2	Gondwana Sandstone	35.3-38.4	10.49	0.8
37	Jin	Chicholi	EW	2005-06	300.1	14	Fractured Basalt/Basic Intrusive/Sandstone	23.0-26.0,36.0-45.0,216.5-219.0	4.1	0.75

38	Jualkheda	Multai	EW	2007-08	256.4	4	Fractured/weathered basalt	41-45, 107-117,	36.1	1.18
39	Kantawadi	Shahpur	EW	2018-19	130	18	Granite	18-21,70.15-73.2, 131.15-134.2		
40	Kantawadi	Shahpur	OW	2018-19	103.7	21.35	Granite	15.05-18.3, 48.8-54, 82.35-85.4		
41	Kerpani	Bhainsdehi	EW	2007-08	190.6	3	Fractured basalt	144-158, 173-190	75	15
42	Kerpani	Bhainsdehi	OW	2007-08	158.6	3	Fractured/weathered basalt	149-158.6		
43	Khamapur	Bhimpur	EW	2018-19	91.5	6.1	Basalt			
44	Khambara	P.Pattan	EW	2018-19	203.3	6.1	Basalt	25.4-28.4	80.72	0.1
45	Khedi	Betul	EW	2005-06	298	6	Fractured Basalt/Granite/Marble	13.2-19.2,135.2-140.0,152.0-159.6	50	0.75
46	Khumariya	Bhainsdehi	EW	2005-06	164.7	15.3	Weathered Vescicular Basalt	3.0-18.3	49.7	
47	kolgaon	Betul	EW	2006-07	286.7	3	Fractured basalt	85-94,152-160,115-125,204-214	30.52	1.8
48	KothalKund	Bhainsdehi	EW	2018-19	185	1	fractured Basalt	53-55, 130-132		
49	Kvk Betul	Betul	EW	2018-19	152.5	9.15	fractured Basalt	06-9.15		
50	Malanjpur	Chicholi	EW	2006-07	305	18	Fractured & Jointed granitic gneiss	217-220	19.2	0.5
51	Mangona Kurd	P.Pattan	EW	2018-19	200	9.15	Basalt	116.9-119.9	41.39	0.2
52	Masod	P.Pattan	EW	2008-09	274.5	4	Weathered/Vescicular Basalt	67.0-73.0	46.62	0.75
53	Multai	Multai	EW	2005-06	304.51	3	Fractured basalt/Gondwana Sandstone	Dry	Dry	Dry
54	Nanda	Bhimpur	EW	2018-19	200	6	Sandstone/Granite	160.4-163.4	23.11	0.5
55	Neempani	Chicholi	EW	2005-06	305	17	Fractured & Jointed granitic gneiss	12-17,152-156,178-186	7.92	5.36
56	Neempani	Chicholi	OW	2005-06	152.2	20	Fractured & Jointed granitic gneiss	16-20	7.7	
57	Pathakheda	Chicholi	EW	2006-07	292.7	24	Fractured basalt/Gondwana Sandstone	58-67,118-125,289-292.8	41.9	3.28
58	Pathakheda	Chicholi	OW	2006-07	79	24	Fractured basalt/Gondwana	58-67, 67-79	31.23	

							Sandstone			
59	Pawarjhanda	Shahpur	EW	2018-19	200	6.1	Granite	139-142.1	12.64	0.1
60	PrabhatPattan	PrabhatPattan	EW	2007-08	112	16	Fractured basalt	82-88, 102-112		25
61	PrabhatPattan	PrabhatPattan	OW	2007-08	109.8	10	Fractured basalt	6-10, 80-90, 105-109.8		
62	Ratamati	Betul	EW	2005-06	293	31	Jointed & fractured granite			
63	Remli	Amla	EW	2018-19	200	14	Basalt/Granite	95.5-98.6	32.02	1.02
64	Saikheda	Multai	EW	2007-08	186	25	fractured Basalt	9-25, 125-131		14
65	Saikheda	Multai	OW	2007-08	164.7	25	fractured Basalt	9-25, 125-132		
66	Sakadehi	Betul	EW	2005-06	268	30	Fractured & Jointed granitic gneiss	12-15,27-30	13.5	3.28
67	Sandiya	Multai	EW	2007-08	274.5	16	fractured Basalt	88-97, 112-118,146-152		10
68	Sandiya	Multai	OW1	2007-08	158.6	6	fractured Basalt	97-104, 104-115, 146-158.6		
69	Sandiya	Multai	OW2	2007-08	158.6	6	fractured Basalt	97-102, 146-150		
70	Saonga	Bhimpur	EW	2005-06	293	7	Fractured Basalt/Granite	13.0-20.0,118.0-125.0	10.25	2.45
71	Sasundra	Multai	EW	2005-06	209.6	6	Vesicular basalt	157.60-166.90	34.5	2.36
72	Sataldehi	Godadongari	EW	2018-19	200	8				
73	Sawalmendha	Bhainsdehi	EW	2018-19	200.8	8.5	Fractured/Jointed Basalt	57.3-63.4, 120-124.4	12.36	24
74	Sawalmendha	Bhainsdehi	OW	2018-19		10	Fractured/Jointed Basalt	63-66		
75	Shahpur	Shahpur	EW	2005-06	304.51	20	Gondwana sandstone	48-56	11.7	1.8
76	Surgaon	Betul	EW	2005-06	305	15.2	Fractured & Jointed granitic gneiss	112-118	29.5	1.18
77	Thana	Athner	EW	2018-19	200					
78	Vijaygram	Bhainsdehi	EW	2018-19	57.95	12.2	Basalt	7.90-9.10	21.5	0.7

ANNEXURE-II: Water Level Details of Shallow Aquifer

BLOCK_NAME	VILLAGE_NAME	Pre-monsoon WL	Post-Monsoon WL	Fluctuation
AMLA	Amla	6.87	2.3	4.57
AMLA	Amla(S)	7.92	2.02	5.9
ATHNER	Gujarmaal	13.1	4	9.1
ATHNER	Athner	3.8	2.4	1.4
BETUL	Betul	11.5	0.84	10.66
BETUL	Kolgaon	9.5	2.6	6.9
BETUL	Khedi	19.7	5.92	13.78
BHAINSDEHI	Sanwal Medha	5.57	1.79	3.78
BHAINSDEHI	Kotal kund	9.77	6.25	3.52
BHAINSDEHI	Gudagaon	11.16	2.26	8.9
BHAINSDEHI	Bhainsdehi	14	3.35	10.65
BHAINSDEHI	Jhallar	13.06	0.44	12.62
CHICHOLI	Chirapatala	10	3.8	6.2
CHICHOLI	Pathakhera	4.8	1.25	3.55
CHICHOLI	Jogli	13.53	6.38	7.15
CHICHOLI	Khokharkheda	5.1	1.3	3.8
CHICHOLI	Gadha	14.14	2.9	11.24
CHICHOLI	Nimpani	7.45	2.95	4.5
GHORADONGRI	Ghoradongri	11.93	2.1	9.83
GHORADONGRI	Sarni	5.75	1.75	4
MULTAI	Multai	2.45	1.15	1.3
MULTAI	Junapani	14.35	3.45	10.9
MULTAI	Sasundra	12.6	2.7	9.9
MULTAI	Kapasia	2.8	2.4	0.4
MULTAI	Ghatpiparia	11.33	7.53	3.8
PRABHAT PATTAM	Pattan	13.1	1.15	11.95
SHAHPUR	Bhonra	8.66	1.66	7
SHAHPUR	Shahpur	11.07	5.02	6.05

ANNEXURE-III: Pre-monsoon Trend (2009-18)

BLOCK_NAME	VILLAGE_NAME	TREND(m/yr)
Amla	Amla(d)	0.019594
Amla	Amla(S)	0.024054
Athner	Athner	-0.01951
Athner	Athner	-0.027766
Betul	Kolgaon	0.020473
Betul	Thapa	0.003049
Betul	Khedi	-0.002674
Betul	Betul	0.020439
Bhainsdehi	Kotal kund	-0.005828
Bhainsdehi	Sanwal Medha	-0.026205
Bhainsdehi	Gudagaon	0.014611
Bhainsdehi	Bhainsdehi	0.006199
Bhainsdehi	Jhallar	0.055467
Chicholi	Jogli	0.007507
Chicholi	Chincholi	0.01594
Chicholi	Pathakhera	-0.052368
Chicholi	Nimpani	-0.010517
Chicholi	Chirapatala	-0.019023
Chicholi	Khokharkheda	0.024264
Ghoradongri	Sarni	-0.047469
Ghoradongri	Ghoradongri	-0.033603
Multai	Junapani	0.008923
Multai	Multai	0.020477
Multai	Kapasia	0.035175
Multai	Sasundra	-0.003697
Multai	Ghatpiparia	-0.007007
Prabhat pattam	Masod	-0.000318
Prabhat pattam	Masod New	-0.061947
Prabhat pattam	Pattan	-0.033157
Shahpur	Shahpur	0.004695
Shahpur	Bhonra	0.00153

ANNEXURE-IV: Post-monsoon Trend (2009-18)

BLOCK_NAME	VILLAGE_NAME	TREND(m/yr)
Amla	Amla(d)	-0.003647
Amla	Amla(S)	0.003348
Amla	Amla	-0.010552
Athner	Athner	-0.027931
Athner	Athner	-0.014149
Betul	Kolgaon	0.006734
Betul	Thapa	-0.035661
Betul	Betul	-0.018398
Bhainsdehi	Kotal kund	-0.062989
Bhainsdehi	Sanwal Medha	-0.01426
Bhainsdehi	Gudagaon	0.003584
Bhainsdehi	Bhainsdehi	-0.174108
Bhainsdehi	Bhainsdehi	-0.029147
Bhainsdehi	Jhallar	0.000012
Chicholi	Jogli	-0.065413
Chicholi	Chincholi	-0.040585
Chicholi	Pathakhera	-0.030801
Chicholi	Nimpani	-0.018796
Chicholi	Chirapatala	-0.005652
Chicholi	Khokharkheda	-0.019794
Ghoradongri	Sarni	-0.030668
Ghoradongri	Ghoradongri	-0.020884
Multai	Junapani	0.004913
Multai	Multai	-0.002424
Multai	Multai	-1.119175
Multai	Kapasia	-0.030129
Multai	Sasundra	-0.03414
Multai	Ghatpiparia	-0.006159
Prabhat pattam	Masod New	-0.058597
Prabhat pattam	Pattan	-0.01294
Shahpur	Shahpur	-0.018544
Shahpur	Bhonra	-0.032105

Annexure-V: Ground Water Quality Data of Aquifer-I (Shallow Aquifer)

S. No.	District	Block	Location	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	Total Hardness	Ca	Mg	Na	K
				@ 25°C	µS/cm at 25°C	mg/l												
1	Betul	Athner	Athner1	7.98	1388	0	447	135	12	110	0.25	BDL	22	425	104	40	104	13.1
2	Betul	Betul	Betul1	7.68	1367	0	306	222	18	67	0.50	BDL	15	610	178	40	25	2.3
3	Betul	Bhainsdehi	Bhainsdehi1	7.27	587	0	141	67	28	47	0.30	0.2	29	210	62	13	32	0.3
4	Betul	Shahpur	Bhonra	7.32	912	0	423	30	18	27	0.60	BDL	47	340	102	21	45	1.0
5	Betul	Chicholi	Chirapatala	7.39	1288	0	472	120	15	68	0.15	BDL	51	510	150	33	52	0.4
6	Betul	Chicholi	Gadha	7.87	712	0	263	27	12	54	0.20	BDL	26	245	64	21	38	0.2
7	Betul	Multai	Ghatpiparia	7.63	1068	0	269	87	26	161	0.15	BDL	27	490	162	21	14	0.2
8	Betul	Ghoradongri	Ghoradongri	7.48	1199	0	462	87	14	76	0.50	0.2	30	429	152	12	72	0.9
9	Betul	Bhainsdehi	Gudagaon	7.87	612	0	207	50	12	49	0.85	BDL	14	177	38	20	57	0.3
10	Betul	Athner	Gujarmaal	7.97	723	0	298	15	28	42	0.20	BDL	19	313	79	28	18	0.4
11	Betul	Bhainsdehi	Jhallar	7.72	498	0	164	20	12	50	0.30	BDL	28	126	36	9	48	0.5
12	Betul	Chicholi	Jogli	8.10	786	0	237	74	25	53	1.35	BDL	16	222	63	16	71	4.9
13	Betul	Multai	Junapani	7.52	789	0	316	20	10	85	0.20	BDL	33	328	99	20	22	0.6
14	Betul	Multai	Kapasia	7.73	712	0	279	35	12	28	0.10	BDL	35	247	65	21	35	6.6

S. No.	District	Block	Location	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	Total Hardness	Ca	Mg	Na	K
				@ 25°C	µS/cm at 25°C	mg/l												
15	Betul	Betul	Khedi	7.82	1011	0	340	111	5	42	0.55	BDL	0	419	129	23	32	2.1
16	Betul	Chicholi	Khokharkheda	7.25	586	0	176	27	8	75	0.20	BDL	32	227	63	17	18	0.4
17	Betul	Betul	Kolgaon	7.87	789	0	340	30	16	39	0.05	BDL	23	278	71	25	50	2.1
18	Betul	Bhainsdehi	Kotal Kund	7.57	938	0	383	27	12	84	0.15	0.1	28	343	99	23	52	0.5
19	Betul	Prabhat Pattam	Masod New	7.25	856	0	158	139	18	52	0.65	BDL	42	394	105	32	12	0.3
20	Betul	Multai	Multaidw	7.52	844	0	358	22	14	52	0.50	BDL	25	308	83	25	42	2.4
21	Betul	Chicholi	Nimpani	7.82	265	0	134	15	5	40	0.50	BDL	29	126	30	12	20	1.3
22	Betul	Chicholi	Pathakhera	7.85	888	0	358	17	18	75	0.40	0.1	34	359	83	37	29	2.1
23	Betul	Prabhat Pattam	Pattan	7.73	456	0	134	47	6	32	0.70	BDL	22	192	42	21	10	0.7
24	Betul	Bhainsdehi	Sanwal Medha	7.52	868	0	413	12	13	38	0.30	BDL	19	293	83	21	58	0.8
25	Betul	Ghoradongri	Sarni	7.84	896	0	395	25	26	40	0.15	BDL	24	298	71	29	64	0.7
26	Betul	Multai	Sasundra	7.87	725	0	286	7	36	51	0.10	0.1	32	258	63	25	37	1.1
27	Betul	Shahpur	Shahpur	7.42	942	0	371	40	12	55	0.50	BDL	29	364	91	33	35	2.3

Annexure-VI: Ground Water Quality Data of Aquifer-II (Deeper Aquifer)

S. No.	Location	longitude	latitude		pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	Total Hardness	Ca	Mg	Na	K
					@ 25°C	µS/cm at 25°C	mg/l										
1	Athner	77.9067	21.625	EW	7.4	713	0	311	21	28	35	0.72	315	82	13	20	0.1
2	Athner	77.9067	21.625	OW	7.2	697	0	299	21	25	31	0.52	300	76	27	21	0.2
3	Sadar	77.88389	21.89722	EW	7.1	1543	0	214	305	100	151	0.49	540	204	7	117	5.8
4	Surgaon	77.89722	21.83139	EW	7.3	888	0	18	74	200	60	1.37	170	64	2	105	2.2
5	Neempani	77.875	22.075	EW	7.03	600	0	256	7	18	58	1.23	255	54	29	20	2.4
6	Chicholi	77.6756	22.015	EW	8.3	970	0	177	124	72	32	2.3	195	36	7.3	135	17
7	Chicholi	77.6756	22.015	OW	8.1	926	0	140	121	135	1.7	2.9	130	38	21	125	4.4
8	Bhainsdehi	77.62981	21.644	EW	7.1	567	0	140	85	10	37	0.31	120	34	9	75	1
9	Bhainsdehi	77.62981	21.644	OW1	7.2	528	0	79	35.5	20	12	2.95	45	6	7.3	51	0.8
10	Bhainsdehi	77.62981	21.644	OE2	7.2	379	0	85	64	14	15	0.5	90	20	10	46	0.6
11	Dedhpani	77.5555	21.5107	EW	7	265	0	98	21	3	22	0.46	120	30	11	6	0.2
12	Dedhpani	77.5555	21.5107	OW1	7.1	287	0	110	25	3	17	0.38	55	16	4	41	0.5
13	Dedhpani	77.5555	21.5107	OW2	7.1	112	0	112	28	5	19	0.41	62	18	9	22	0.2
14	Chandora	78.275	21.78055	EW	7.52	625	0	250	60	15	9	0.38	210	68	10	48	0.8
15	Masod	78.1218	21.601	EW	7.52	722	0	195	60	15	9	0.4	210	68	10	44	0.8
16	Dhamangaon	77.7575	21.5933	EW	7.52	725	0	197	54	22	16	0.45	220	52	10	42	0.8
17	Bujhaliaghat	77.88611	21.91084	EW	7.2	887	0	311	89		47	0.26	375	132	23	32	2.9
18	Bujhaliaghat	77.88611	21.91084	OW	7.2	709	0	189	74	40	48	1.37	250	80	12	36	15.5
19	Pathakheda	77.5528	22.1294	EW	6.95	540	0	171	39		29	0.3	105	38	2	78	4.3
20	Sandiya	78.225	21.73889	EW	7.28	423	0	171	39	10	2	2.74	55	10	7	89	0.9
21	Sandiya	78.225	21.73889	OW	7.23	420	0	146	46	15	6	1.36	70	18	6	65	0.9
22	Saikheda	78.09861	21.775	EW	7.19	710	0	384	21	10	4	0.46	300	84	22	28	0.4
23	Jhallar	77.75	21.728	EW	7.64	720	0	305	35.5	35	14	1.12	190	28	29.2	70	12.5
24	Kerpani	77.75	21.7949	EW	7.92	328	0	79	35.5	20	12	2.95	45	6	7.3	51	0.8
25	Jualkheda	78.2219	21.8386	EW	7.52	625	0	250	60	15	9	0.38	210	68	10	48	0.8

S. No.	Location	longitude	latitude		pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	Total Hardness	Ca	Mg	Na	K
					@ 25°C	µS/cm at 25°C	mg/l										
26	PrabhatnPattan	78.2664	21.6494	EW	7.94	435	0	171	39	20	2	0.46	90	22	9	59	0.5
27	PrabhatnPattan	78.2664	21.6494	OW	7.83	609	0	153	89	30	24	0.97	90	16	12	98	2.5
28	Kolgaon	77.89889	21.76833	EW	7.3	901	0	171	156	0	32	4.25	115	42	2	158	0.9
29	Gawasen	77.4772	22.1818	EW	7.39	466	0	133	59	10	29	0.49	175	46	15	26	1.2
30	Gawasen	77.4772	22.1818	OW	7.43	453	0	133	57	9	26	0.67	170	42	16	24	1.5
31	Chikhli	77.62055	21.89028	EW	7.59	450	0	108	67	17	19	0.50	140	16	24	36	3.7
32	Mendha Chhindwada	77.867	21.533	EW	7.27	387	0	175	15	13	8	0.42	110	22	13	35	2.8
33	Mendha Chhindwada	77.867	21.533	OW	8.19	354	0	151	17	16	7	0.51	100	24	10	33	2.5
34	Saonga	77.75834	21.8325	EW	8.12	611		92	110	25	55	1.9	145	44	9	74	11.7
35	Khedi	77.8083	21.8606	EW	7.55	688	0	281	35	18	1	2.53	190	48	17	60	2
36	Jin	77.6967	21.9458	EW	7.31	1244	0	250	121	70	155	0.27	445	106	19	66	0.1
37	Bhimpur	77.5417	21.9167	EW	7.6	617	0	79	74	86	44	4.84	110	24	12	91	0.8
38	Jaora	77.51811	21.8783	EW	7.2	456	0	122	43		69	1.52	65	20	4	78	1.1
39	Malanjpur	77.7314	22.025	EW	7.42	1400	0	122	227	170	78	0.97	330	100	19	156	12.2
40	Amla	78.1307	21.9239	EW	7.52	1332	0	293	199	154	18	0.6	300	80	24	166	14
41	Sawalmendha	77.6992	21.509	EW	7.56	574	0	305	21	5	2	0.39	210	44	24	35	0.5
42	Sawalmendha	77.6992	21.509	OW	7.55	583	0	292	28	3	3	0.37	225	60	18	30	0.7
43	Gudgaon	77.7097	21.593	EW	7.15	634	0	287	43	28	2	0.47	200	46	21	53	4

Here, all parameters are expressed in mg/L except pH, EC (µS/cm @ 25°C).