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Government of India
जल शक्ति मंत्रालय
Ministry of Jal Shakti
जल संसाधन,नदी विकास औरगंगासंरक्षण विभाग
Department of Water Resources, River Development & Ganga Rejuvenation
केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

जलभृत मानचित्रण और भूजल प्रबंधन योजना गोपालगंज जिला,बिहार

Aquifer Mapping and Ground Water Management Plan

Gopalganj District, Bihar

क्षेत्रीय कार्यालय
मध्य-पूर्वी क्षेत्र,पटना
Regional Office
Mid-Eastern Region, Patna

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Report on

जलभृत मानचित्रण और भूजल प्रबंधन योजना
गोपालगंज जिला,बिहार

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Gopalganj District, Bihar

AAP –2022-23

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CHAPTER 1

INTRODUCTION

The vagaries of rainfall, inherent heterogeneity of aquifer systems, over exploitation of once copious aquifers, lack of regulation mechanism etc. 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 implement table ground water management plans. This leads to concept of Aquifer Mapping and Ground Water Management Plan. 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 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 (National Aquifer Mapping) is not merely mapping, but reaching the goal-that of ground water management through community participation.

During XII five year plan (2012-17) National Aquifer Mapping (NAQUIM) study was initiated by CGWB to carry out detailed hydrogeological investigation. The Aquifer Mapping programme has been continued till 2023 to cover whole country. The present studies of Gopalganj district have been taken up in AAP 2018-19 as a part of NAQUIM Programme. The aquifer maps and management plans will be shared with the administration of Gopalganj district and other user agencies for its effective implementation.

1.1 Objective and Scope

The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization
- Quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

The groundwater management plan includes Ground Water recharge, conservation, harvesting, development options and other 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 main activities under NAQUIM are as follows:

a). Identifying the aquifer geometry

b). Aquifer characteristics and their yield potential

c). Quality of water occurring at various depths

d). Aquifer wise assessment of ground water resources

e). Preparation of aquifer maps and

f). Formulate ground water management plan.

The 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.

1.2 Approach and Methodology

The on-going activities of NAQUIM include hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilization for preparation of various thematic maps. The approach and methodology followed for Aquifermapping is as given below:

Compilation of existing data (Central & State Govt.)
↓
Generation of different thematic layer
↓
Identification of Primary Aquifer
↓
Identification of data gaps
↓
Data generation (water level, exploration, geophysical,
↓
Aquifer Maps with 3D disposition
↓
Preparation of Aquifer Management Plan
↓
Capacity building in all aspects of ground water through IEC Activities

1.3 Area Details

The district Gopalganj was taken for aquifer mapping study in AAP 2022-23. The district is spread over 2019 Sq. km of geographical area. Gopalganj district is situated in the north–western part of the Bihar state. It extends between N Latitude 26°12' & 26° 39' and E Longitude 83° 54' & 84° 55' covering parts of Survey of India Toposheets nos. 72 B/2, B/3, B/6, B/7, B/10, B/11 & B/15. This districts fall is the Indo- Gangetic plain covering parts of Gandak and Ghaghra sub-basin. It is bounded in the north by State of Uttar Pradesh & South by Uttar Pradesh state & Siwan district, east by Gandak and again west by Uttar Pradesh. Total population of the district is 2562012 (as per census of 2011) with rural population 2399207 and urban population 162805.

This district is divided in two subdivisions namely Gopalganj Sadar and Hathua having all together having 14 blocks namely –Baikunthpur, Barauli, Gopalganj, Kuchaikote, Manjha, Thawe, Sidhwaliya, Bhorey, Hathua, Kateya, Panchdewari, Phulwariya, Uchkagaon, Vijayipur.

Table 1: Administrative Divisions of Gopalganj District

Sub-division	No. of Blocks	Name of Blocks
Gopalganj	07	Baikunthpur, Barauli, Gopalganj, Kuchaikote, Manjha, Thawe, Sidhwaliya
Hathua	07	Bhorey, Hathua, Kateya, Panchdeori, Phulwariya, Uchkagaon, Vijaipur

The district boundaries, administrative divisions, major roads, rail, and rivers are shown in **Figure 1.**

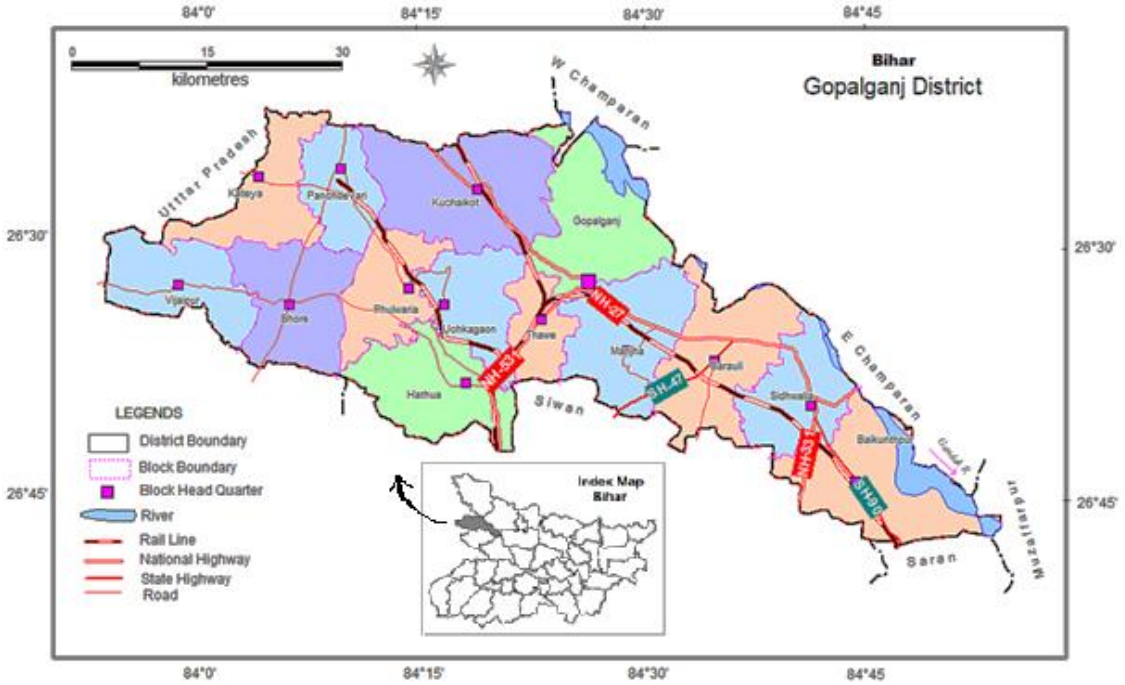

Figure 1:Administrative Map

Table 2: Demographic details

Block	Area(Sq.Km)	No. of Panchayat	No. of Village	Population		
				Rural	Urban	Total
Baikunthpur	204.08	22	120	217165	0	217165
Barauli	184.32	23	91	221999	41877	263876
Bhorey	130.41	17	172	178199	0	178199
Bijaipur	147.61	13	143	133038	0	133038
Gopalganj	195.48	16	72	152188	67339	219527
Hatwa	146.6	22	109	214648	7156	221804
Kataiya	126.14	11	53	110637	20193	130830
Kuchaikot	251.36	31	222	332041	0	332041
Manjha	141.46	20	111	199452	0	199452
Pachdeori	92.78	9	99	99933	0	99933
Phulwaria	95.5	12	106	130801	0	130801
Sidhwalia	120.12	13	50	141563	0	141563
Thawe	69.99	11	53	116106	0	116106
Uchkagaon	113.28	14	83	151437	26240	177677
Total	2019.13	234	1484	2399207	162805	2562012

Source-District Census Handbook - 2011

According to the 2011 census, Gopalganj district has a population of 2562012. The district has a population density of 1260 inhabitants per square kilometre. Its population growth rate over the decade 2001-2011 was 19.02%. The blockwise demographic details of Gopalganj district is given in detail in Table 1. The blockwise number of panchayats and villages is given in Fig. Siwan has a sex ratio of 1021 females for every 1000 males. Gopalganj ranks 1st in terms of sex-ratio (1,021) against the state's (918), and a literacy rate of 65.47%.

1.4 Physiographic Setup and Geomorphology

The entire district is underlain by flat alluvial formations of considerable thickness. The uniformity and flatness is quite often disturbed by marshy land, natural depression etc. Along rivers and stream courses, ravinous topography has developed. In the northern part around Rasauli the area is dotted with numerous physical manifestations like Ox-bow lakes, abandoned channels etc.

Flat alluvial formations of considerable thickness are very common in the entire district. The entire flat terrain has been divided into two main categories.

Alluvial Low Tracts: They are most commonly found in the immediate vicinity of river Gandak which is subjected to periodical submergence by flood water.

Diara Land: They are nothing but heap and sands, brought by rivers during flood and usually found in the bed of the river Gandak. There is a gradual slope from the north western to south eastern direction. The general slope varies between 70.69 mt MSL to 57.09 mt MSL. In general the surface gradient is about 0-11 m/km in the area.

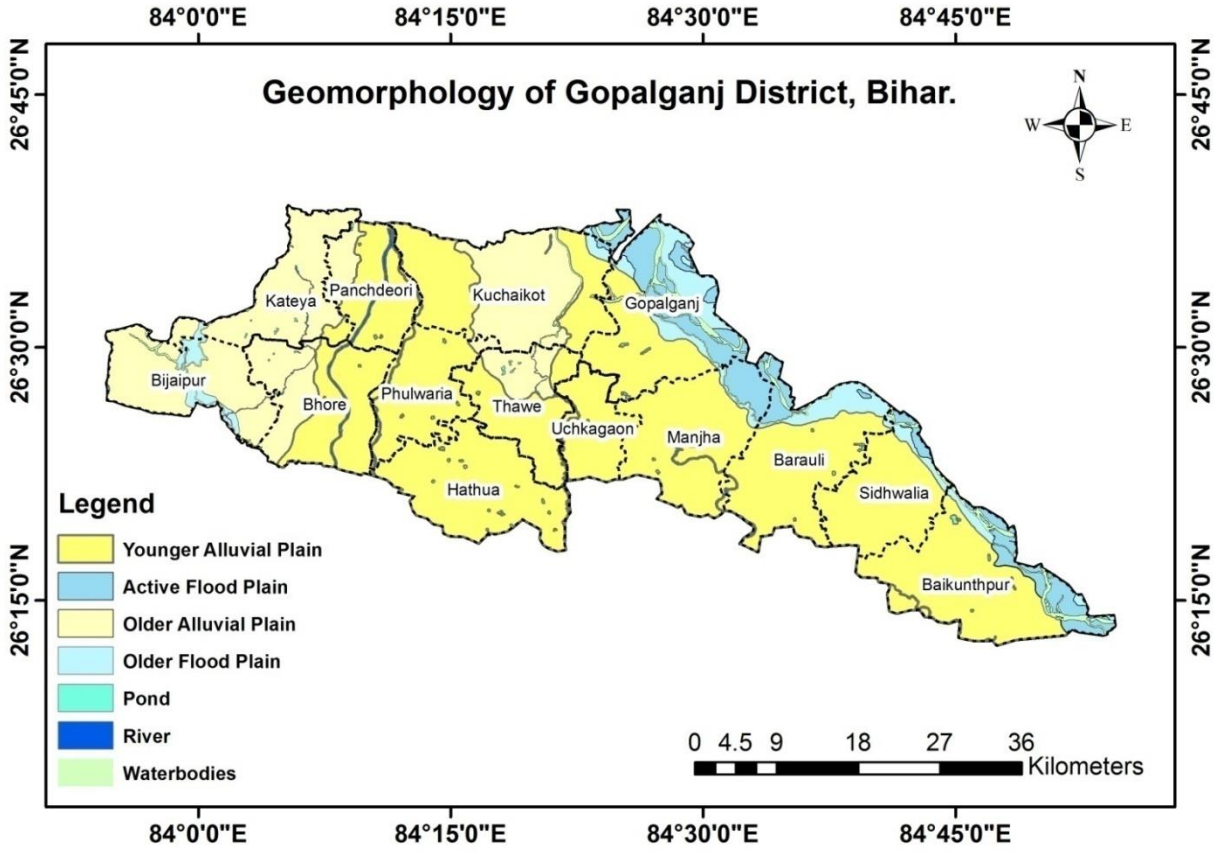

Figure 2: Geomorphology Map

1.4.1Rainfall-spatial and Temporal Distribution

The climate of Gopalganj district is semi-arid with very hot summer and equally cold winter season. The temperature varies from 25 to 34˚C. In the area monsoon sets in somewhere in June and lasts up to September. The average annual rainfall in Gopalganj district is about 1218 mm. Most of the rainfall receives from South West monsoon. Data reveals that there is a large variation in the rainfall over year to year. During monsoon surplus water is available for deep percolation to ground water.

Table 3: Rainfall Departure

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*	*R/F*	*%D*
2016	0	-100	0	-100	0	-100	0	-100	113	258	99.5	-36	257.1	-17	48.5	-84	327.9	49	19	-66	0	-100	0	-100
2017	2.1	-86	0	-100	10.6	51	7.5	-40	60.3	91	95.9	-38	379.9	23	178.9	-41	190.6	-14	4.5	-92	0	-100	0	-100
2018	0	-100	0	-100	0	-100	9.6	-23	69.1	119	51.1	-67	302	-3	348	14	60	-73	0	-100	0	-100	0	-100
2019	7.1	-33	14.3	40	3.3	-48	7.8	-35	1.8	-96	145.8	-1	611.1	82	126.7	-56	483.9	132	8.3	-83	0	-100	12.8	66
2020	6.5	-40	26.3	158	47.5	642	76.2	535	75.8	80	394	168	523.9	56	185.8	-35	445.9	114	0	-100	2.5	-38	0	-100

Source:-IMDCustomized Rainfall Information System (CRIS) (imd.gov.in)

1.4.2 Land Use

To know the spatial distribution of the 'land use Land Cover (10K): SIS-DP, a map obtains (on 20 April. 2023) from the website https://bhuvan-app1.nrsc.gov.in/ and given in Figure 5, to show the spatial distribution of LULC units. Based on the data presented in table a pie chart (In-sat) has also been prepared the data of land use has also been collected from District Irrigation Plan presented in table 4. The table inferred that the principal utilisation of land is under agriculture and almost evenly distributed in the district. It occupies nearly 70% of the area reported for LULC (2033 Sq. Km). Area under uncultivable land excluding fallow land includes 1.35% of the area and forest cover 0% of the area reported. Other major land utilisations are the lands put under non-agriculture use.

A Map from the 'Bhuvan' website has also been downloaded to observe the spatial distribution of land use land cover.

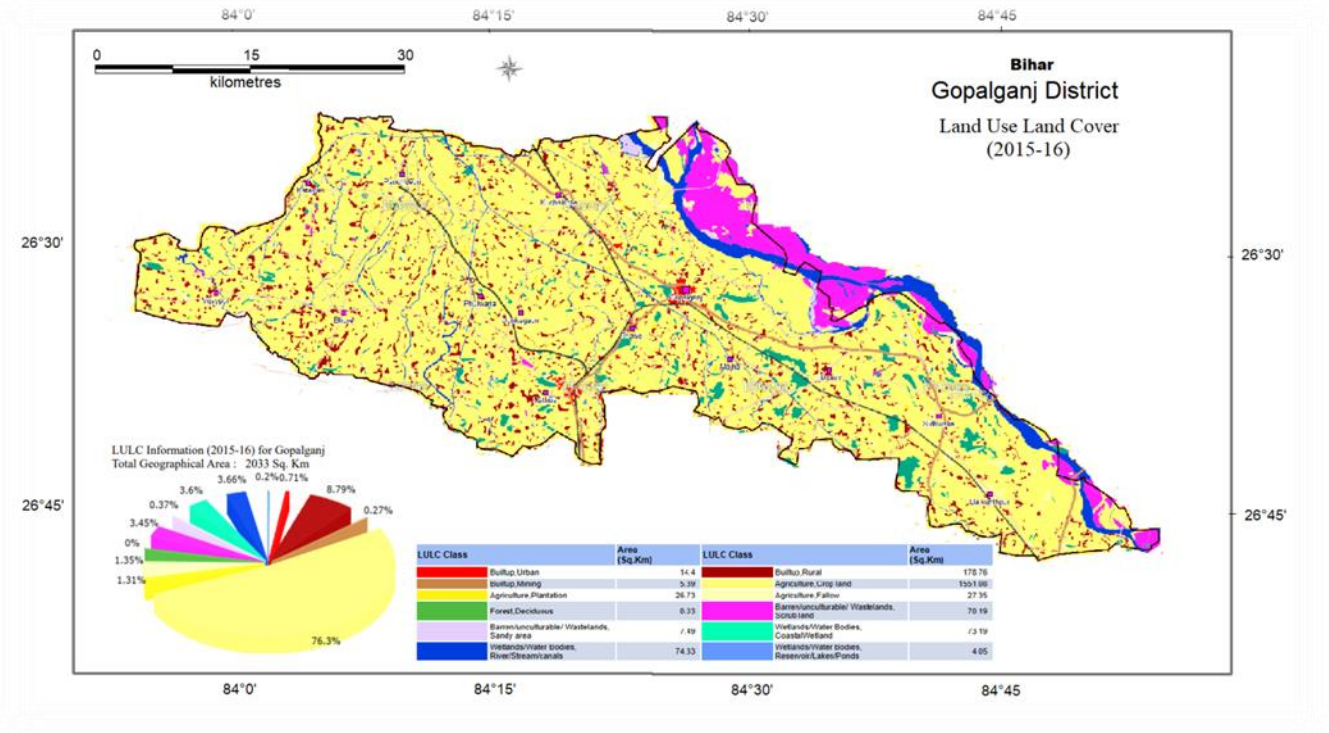

Figure 3: Land Use & Land Cover Map

Land use Statisticsof the district is given in**Table-4.**

Table 4: Land Use Statistics

Name of the Block	No. of Gram Panchayat	Total Geographical Area(ha)	Area under Forest(ha)	Area under Wasteland(ha)	Area under other uses(ha)
Baikunthpur	22	20408	0	1517	7363
Barauli	23	18432	0	2932	3445
Bhorey	17	13041	0	2285	3397
Bijaipur	13	14761	0	2025	1320
Gopalganj	16	19548	0	1679	8819
Hathua	22	1466	0	95	2354
Kateya	11	12614	0	502	1348
Kuchaikote	31	25136	0	723	5189
Manjha	20	14146	0	3905	4236
Panchdeori	9	9278	0	0	677
Phulwariya	12	955	0	0	2860
Sidhwaliya	13	12012	0	1313	1068
Thawe	11	6999	0	671	1488
Uchakagaon	14	11328	0	651	650
Total	234	201913	0	18298	44214

Source: District Irrigation Report

The above table and figure shows that forest cover is 0% , mainly land are used for agriculture purpose.

1.4.4 Soil

As per the U.S. Survey Staff (1975) the soil of the area is broadly divided into three groups based upon the diffluent conditions of pedogeny, climate and texture.

(a) Entisols – These are younger alluvial soil, fringes near the bank of Gandak and the eastern bank of Ghaghra in the western part of the district. The entisols are generally a light, friable, loam with higher proportion of sand and silt. The maximum percent of clay is found to be up to 35%. They are often associated with calcareous nodules. The higher content of sand keeps the soil, except in the river bed, fairly drained and makes it suitable for autumn and rabi crops which do not need much water. These soils are most suitable for cultivation of high yielding crops like sugar cane and wheat.

(b) Inceptisols - There are locally known as Bangar and there calcareous alluvial soils occur mostly in the central part of the district. This forms the typical paddy land of Bihar. The clay and silt % ranges between 30-45%.

(c) Alfisols – These soils occur in patches around eastern part of the district. These are fairly matured soils subject to continuous leaching operation, leading to formation of calcareous nodules and ferruginous clay pans. Texturally there are well-drained reddish yellow silty sandy and clayey loams.

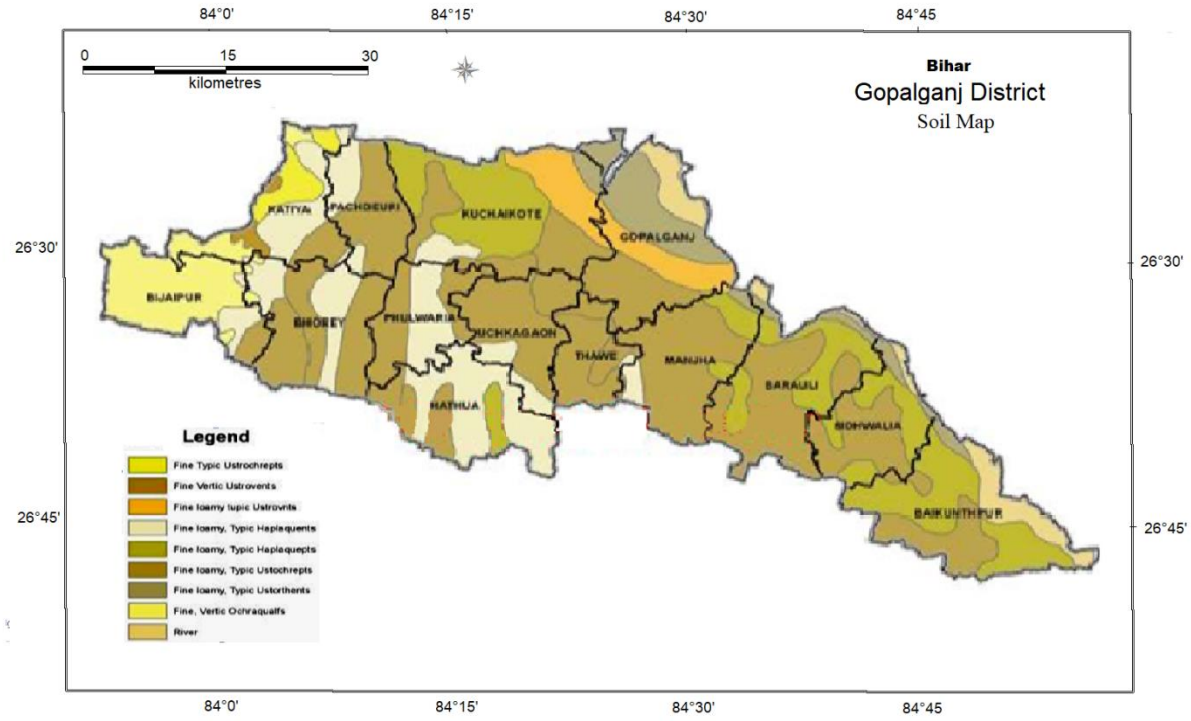

Figure 4: Soil Map

Source: District Irrigation Report

1.4.5 Hydrology and Drainage

The district is mainly drained by Gandak river that has taken the present course, which forms the eastern and north eastern boundary of the district. The Gandak river flows in a south easterly direction with an average gradient of 0.28 m/km. The river brings a lot of silt, which is deposited in the river bed resulting in oscillation of course.

Apart from this main rivers there are numerous ephemeral streams flowing in the district namely Jharbi, Dahe, Khanua, Ghoghli, Kedanjot, Sona etc. They all emerge near Gandak embankment which is locally known as Chaurs and Tal. In course of time these beds

get silted and their course start shifting. During the process of shifting of course there streams leave behind abandoned channels and a number of marques locally known as Chaus. These Chaus are also responsible for water logging in the area by spreading their span with the onset of monsoon and become localize during summer. Most of the ephemeral streams have their flow direction in north south.

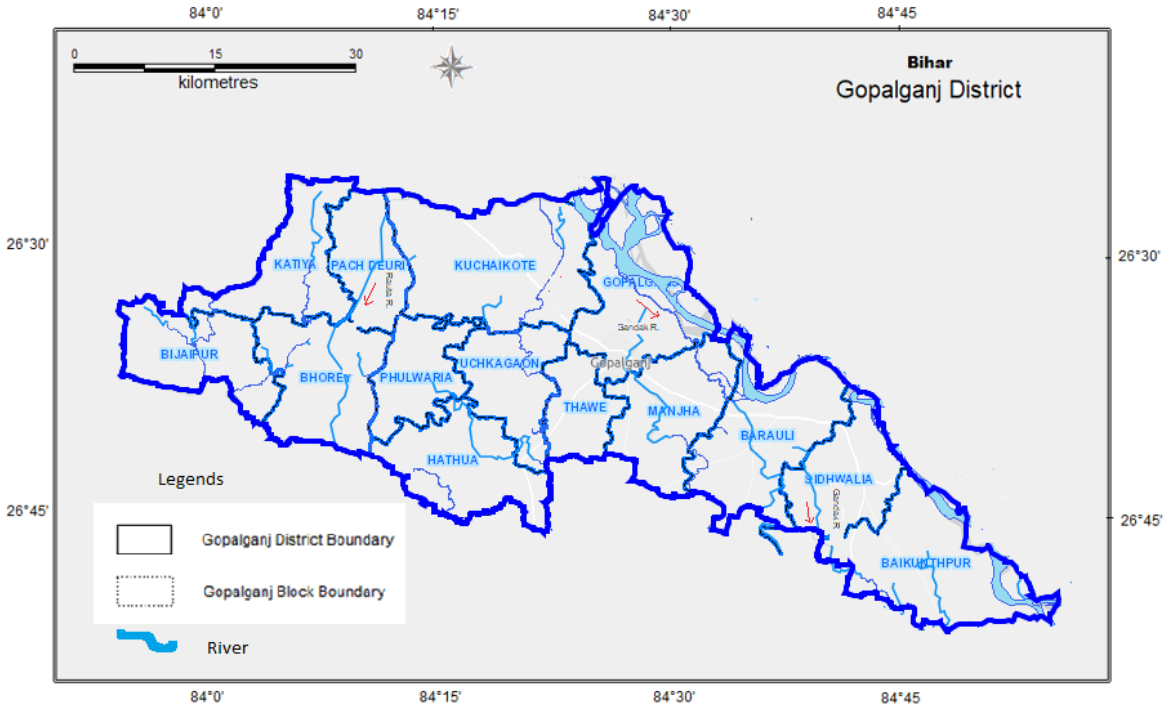

Figure 5: Drainage Map

1.4.6 Agriculture

Gopalganj district's economy is primarily based on agricultural production. There are three agricultural seasons in the district viz., Rabi, Kharif and summer. Rabi season starts in October or November and harvesting is done in March and April. The important crops are Rice, wheat, maize, mustard, toria, greengram and lentil etc. Kharif season starts in July and the harvesting is done in October or November. The millets, maize, arhar, rice and sugarcane etc. are the main crops of Kharif season. Summer crops occupy the fields from April to July.

Gopalganj district is part of Agro-climatic zone - I of Bihar. Fertile alluvial plain of the district coupled with favourable climate boosted agricultural activity. Rice is the main crop of Kharif season. Other Kharif crops are maize and potato grown in the district. Wheat is grown during Rabi season in the district. Other Rabi crops in the district are Pulses, Linseed, etc. Vegetables are also grown throughout the year. The cropping intensity of the district is 153%.

Table 5: Blockwise Agricultural details of Gopalganj district, Bihar

Name of the Block	No. of Gram Panchayat	Gross cropped	Net Sown Area(ha)	Area Sown more than once(ha)	Cropping Intensity
Baikunthpur	22	19073	11183	7890	170.56
Barauli	23	18707	11918	6789	156.96
Bhorey	17	14666	9670	4996	151.66
Bijaipur	13	13828	10810	3018	127.91
Gopalganj	16	13134	9133	4001	143.8
Hathua	22	18824	12329	6495	152.68
Kateya	11	16221	10638	5583	152.47
Kuchaikote	31	28516	18590	9926	153.39
Manjha	20	10292	5975	4317	172.25
Panchdeori	9	13151	8630	4521	152.387
Phulwariya	12	8960	6248	2712	143.4
Sidhwaliya	13	14797	9609	5188	153.98
Thawe	11	7797	4470	3327	174.42
Uchakagaon	14	13835	9876	3959	140.08
Total	234	211801	139079	72722	153

Source: District Irrigation Report

The above table shows that the cropping intensity of the district is about 153%. The rice, Sugarcane, Maize, Wheat, Potato etc. are the major crop of the district.

Table 6: Area under Crops in Gopalganj District for the Year Ending 2019-20

State/Crop/District	Season	Area (Hectare)	Production (Tonnes)	Yield (Tonnes/Hectare)
Bihar				
Arhar/Tur				
1.GOPALGANJ	Kharif	282	537	1.90
Total - Arhar/Tur		282.00	537	1.90
Maize				
1.GOPALGANJ	Autumn	5982	15650	2.62
	Rabi	4120	19702	4.78
	Summer	452	1344	2.97
	Total	10554	36696	3.48
Total - Maize		10554.00	36696	3.48
Masoor				
1.GOPALGANJ	Rabi	287	267	0.93
Total - Masoor		287.00	267	0.93
Moong(Green Gram)				
1.GOPALGANJ	Summer	506	104	0.21
Total - Moong(Green Gram)		506.00	104	0.21
Onion				
1.GOPALGANJ	Rabi	69	689	9.99
Total - Onion		69.00	689	9.99
Other Kharif pulses				
1.GOPALGANJ	Kharif	20	15	0.75
Total - Other Kharif pulses		20.00	15	0.75
Peas & beans (Pulses)				
1.GOPALGANJ	Rabi	442	460	1.04
Total - Peas & beans (Pulses)		442.00	460	1.04
Potato				
1.GOPALGANJ	Rabi	2900	31654	10.92
	Winter	476	6876	14.45
	Total	3376	38530	11.41
Total - Potato		3376.00	38530	11.41
Ragi				
1.GOPALGANJ	Kharif	3	3	1.00
Total - Ragi		3.00	3	1.00
Rapeseed &Mustard				
1.GOPALGANJ	Rabi	3040	4353	1.43
Total - Rapeseed &Mustard		3040.00	4353	1.43
Rice				
1.GOPALGANJ	Autumn	36424	73743	2.02
	Winter	27575	68788	2.49
	Total	63999	142531	2.23
Total - Rice		63999.00	142531	2.23
Sugarcane				
1.GOPALGANJ	Whole Year	16261	1078901	66.35
Total - Sugarcane		16261.00	1078901	66.35

Tobacco				
1.GOPALGANJ	Whole Year	211	371	1.76
Total - Tobacco		211.00	371	1.76
Urad				
1.GOPALGANJ	Kharif	52	47	0.90
Total - Urad		52.00	47	0.90
Wheat				
1.GOPALGANJ	Rabi	74868	218358	2.92
Total - Wheat		74868.00	218358	2.92

Source:APY1_Public (dac.gov.in)

Among all the crop production Sugarcane production is highest and it is the major product of Gopalganj district.

1.4.7 Irrigation

There are two major source of irrigation in the district – canal and tube well (ground water) for the year 2021-22. Canal in the district is a part of Gandak canal system. The Gopalganj district has good canal system, more or less all the blocks benefitted from the canal network.

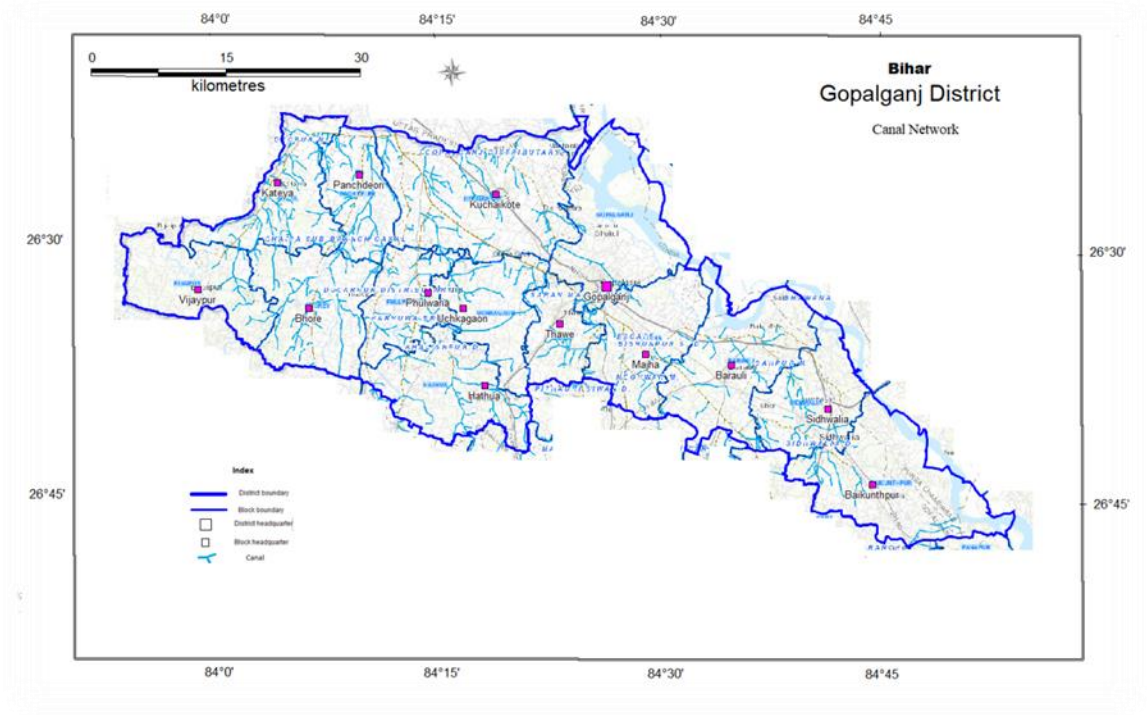

Figure 6: Canal Network

Tube wells are another source of groundwater withdrawal for irrigation in the district. During the year 2012-13(5th MI Census) tube wells are categorised based on their depth. Depth

of the shallow tube well is down to 35 m bgl, medium tube well is between 35 to 70 m bgl and deep tub well is more than 70 m bgl.

However, in the **table** the depth range of 35-40 m of 5th MI census data has been merged to create the depth range of 20-40 m. There is no well has been categorised within the depth range of 35-40 m during 5th MI census.

Table 7: Number of tube wells in 5th MI Census

SN	Block	5th MI Census				
		00-20	20-40	40-60	6070	>70
1	Baikunthpur	144	142	0	0	14
2	Barauli	189	475	0	0	0
3	Bhore	957	743	0	0	0
4	Bijaipur	319	1282	0	0	1
5	Gopalganj	2	1050	0	0	0
6	Hathua	385	1237	0	0	0
7	Katiya	603	771	0	0	0
8	Kuchaikote	993	1843	0	0	13
9	Manjha	87	496	0	0	0
10	Panchdewri	212	1075	0	0	0
11	Phulwariya	183	739	0	0	0
12	Sidhwaliya	70	943	0	0	0
13	Thawe	22	927	0	0	0
14	Uchkagaon	162	2206	0	0	0
	Total	4328	13929	0	0	28

The above table shows block wise no. of wells in 5th mi census, mostly tube well are drilled in 20-40 m range of depth, hence shallow aquifer is tapped for irrigation purpose. In Blocks like Baikunthpur, Bijaipur and Kuchaikote have tube well with depth more than 40 m.

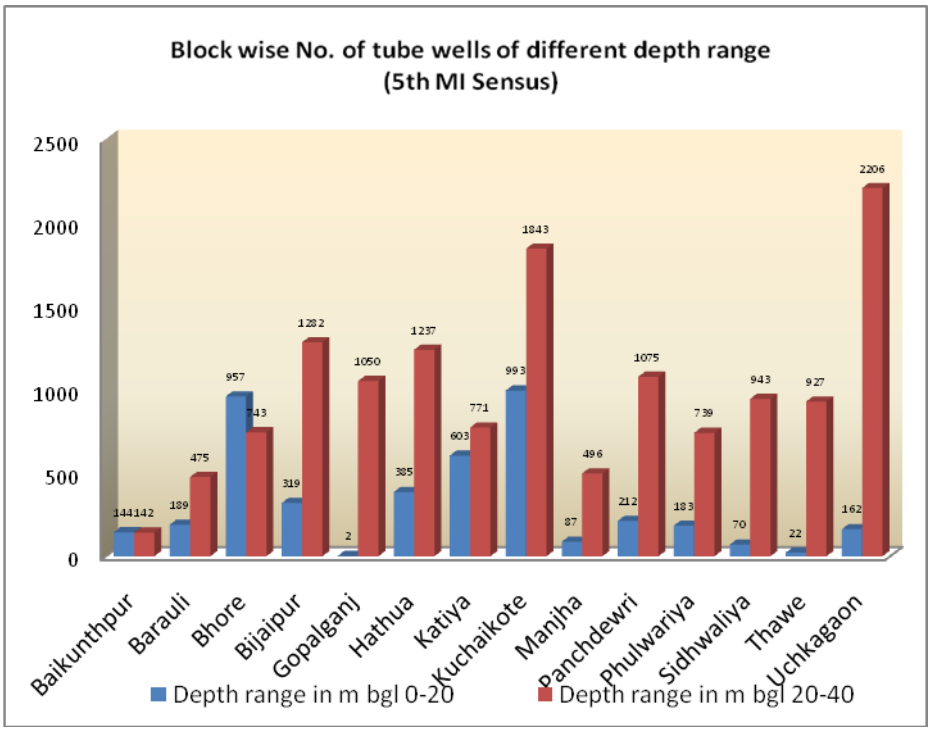

Figure 7: Block wise and depth wise Number of tube wells in 5th Minor Irrigation Census

Thus, there may be due the more dependency of canal for irrigational purpose and dependency on shallow potential aquifer.

1.4.8 Climate

The district of Gopalganj is known for its hot summers and severe winters. The summer season starts from the end of March with average temperature of about 25º C and maximum temperature of 38º C in the months of May and June. In winter season the temperature goes down to 4 - 5º C. Lowest temperature is reported from the end of December to January.

CHAPTER 2

2. DATA COLLECTION AND GENERATION

The primary Data such as water level, quality, geophysical data and exploration details available with CGWB has been collected and utilised as baseline data. The Central Ground Water Board has established a network of observation wells under National Hydrograph Network programme to study the behaviour of ground water level and quality of ground water in the district. To understand the sub–surface geology, identify the various water bearing horizons including their depth, thickness and compute the hydraulic characteristics such as transmissivity and storativity of the aquifers, exploratory drilling programme was carried out by Central Ground Water Board. For other inputs such as hydrometeorological, Landuse, cropping pattern etc. were collected from concerned state and central govt departments and compiled.

2.1 Data collection and Compilation:

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

i. *Hydro geological Data:* Water level data of 25 key wells and historical water level trend of monitoring wells were collected and compiled.
ii. *Hydro chemical Data*: To evaluate the quality of ground water, 22 samples were included which have been collected in the year 2022 from dug wells
iii. *Exploratory drilling:* Total 8 exploratory wells, located in and around Gopalganj district have been taken forthe present study.
iv. *Hydro meteorological Data:* Rainfall data for the study has been taken for the Indian meteorological Department.
v. *Land use and cropping pattern data:* The data of land use and cropping pattern obtained from the District Irrigation Plan.

2.2 Data Generation

The data has been generated and collected for various components as given below:

2.2.1 Ground water Monitoring Wells: Total 25 wells have been monitored to assess the ground water scenario of shallow aquifer (Aquifer-I) of the area. The depth of these dug well varies from 2.35 to 5.93mbgl.

2.2.2 Ground Water Exploration: Total8 exploratory well has been constructed in the district has been taken for study.

The area is underlain by thick deposits of quaternary alluvium deposited by the river Gandak and its tributaries flowing from. No basement has been encountered down to the explored depth of 205 m in exploratory drilling. Sub-surface lithology shows that there is alternating layers of sand and clay with some zones having sand and clay mixed with Kankar.

2.2.3 Ground Water Quality: To assess the quality of ground water, 22 samples were collected and analysed from dug wells representing Aquifer – I.

2.2.4 Thematic Layers: The following thematic layers were also generated which supported the primary database and provided precise information to assess the present ground water scenario and also to propose the future management plan.

1. Drainage
2. Geomorphology
3. Elevation
4. Land use
5. Geology & structure etc

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CHAPTER 3

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, 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 Geological set-up

The entire district consists a thick pile of unconsolidated sediments of Quaternary period varying in age from late pleistocene to recent. Geological Survey of India (GSI) has given classification of Quaternary alluvium based on topography, drainage and nature of alluvial deposits.

Startigraphic Succession
The general stratigraphic succession found in Gopalganj district is given below.

Table 8: Stratigraphic Succession of Gopalganj District

Geological Time	Formation	Lithology
Holocene to Recent	Diara Formation	Fine sand, silt, clays/fine sand
Middle to Late Holocene	Vaishali formation	Alternating layers of sand, silt and clays
Late Pleistocene	Hajipur Formation	Dark grey clay impregnated with caliche
Early Holocene	Mirganj/Gothini Formation	Clay associated with weathered fragments of hard rock

The Mirganj formation is the oldest formation exposed in the district. The formation mainly occupies palaeo levee areas and its age is Early Holocene. Hajipur formation consists of clay has age Late Pleistocene. Vaishali formation occupies the older flood plains of the district. The Diara formation is the youngest formation and it occupies the recent flood plain area.

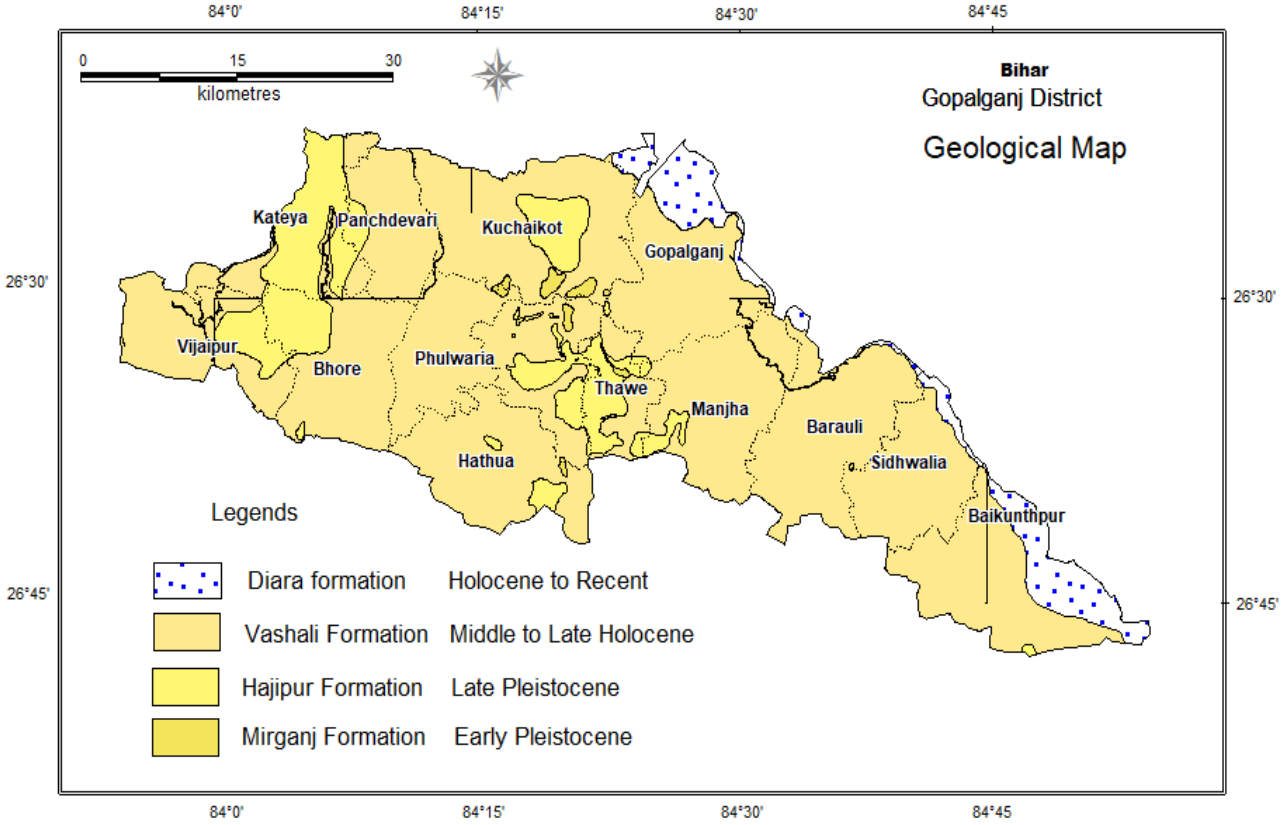

Figure 8: Geological Map

Source: DRM G.S.I.

3.2 Hydrogeology

The district forms a part of the vast alluvial terrain of Gandak and Ghaghra subbasins forming a part of Indo-Gangetic alluvium consisting of a thick pile of unconsolidated quaternary sediments. They are recent to sub-recent deposits underlain by erosional basement of Vindhyan formation of pre-cambrian age. The thickness of alluvium is still not yet confirmed through boreholes. These quaternary sediments consist of sequences of finer clastics like clay and silts with various grades of sand and gravel associated with Kankar. The Gangetic alluvial deposits can be sub-divided into two types viz. newer alluvium and older alluvium. The older alluvium of Pleistocene age in the area is rather dark in colour, occupies the higher ground and generally rich in kankar which are concretion of nodules of impure calcium carbonate ranging in size from small grains to 8 loose lumps whereas the newer alluvium of recent age occupying the lower grounds constitute a thick sequence of clay, silt and sand with occasional kankar.

The entire alluvial tract is exposed to fluvial action. Ground water occurs under unconfined conditions in the phreatic aquifer, which is generally disposed within 75 m below ground. Aquifers situated at deeper levels have ground water levels under confined condition.
A shallow tube well within the depth range of 20-40 m, tapping granular zone of 10-15 mbgl and 25- 30 mbgl respectively can yield as high as 75 m3 /hr. A well down to a depth of 70-100 meters tapping the aquifer of 50-80 m bgl can yield on an average of 180 m3 /hr discharge for nominal drawdown.The distance between two shallow tube wells should be 150 to 200 m and between two deep tube wells may be 500 to 600m for safe discharge.

The hydrogeological map of the district is shown in Figure 9.

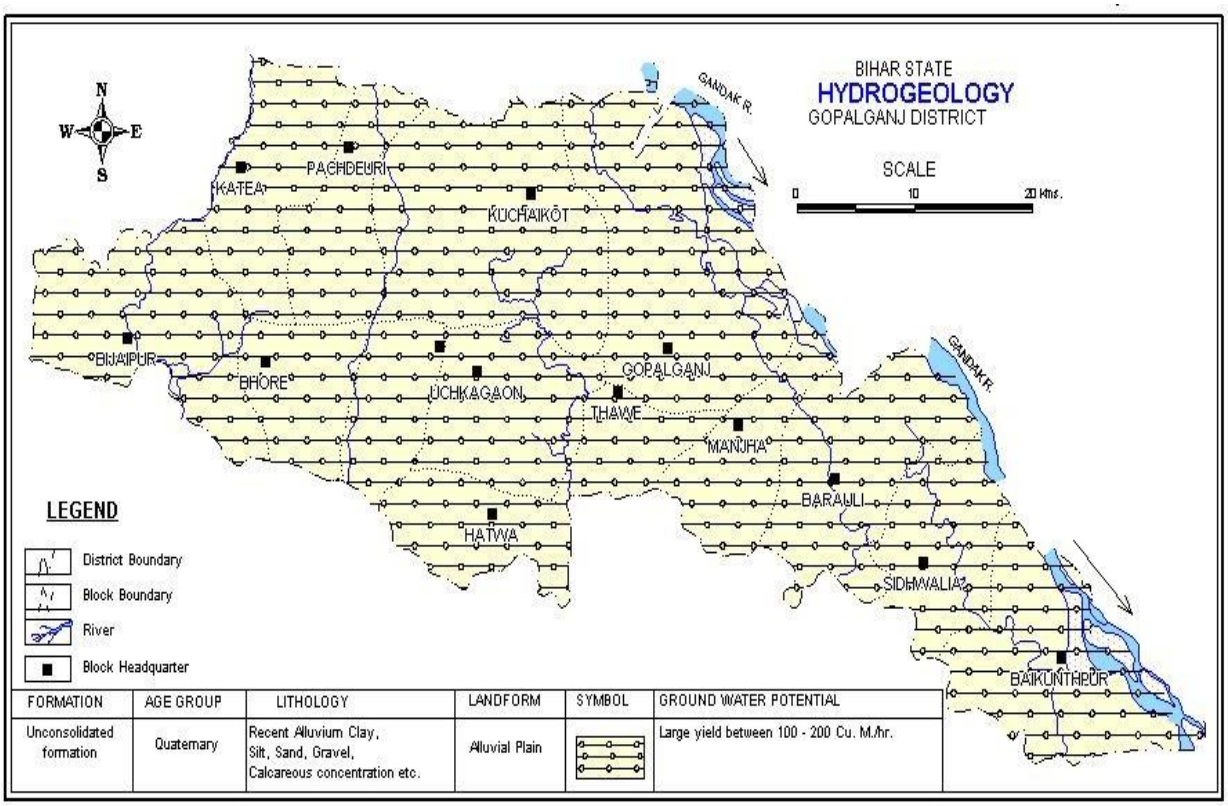

Figure 9: Hydrogeological map of the district

Source: Ground Water Information Booklet ,CGWB

3.2.1 Depth to Water Level

Based Maps are prepared in GIS environment, using Mapinfo™ and Vertical Mapper™ softwares by taking collected field data (NHS). Data interpolation is done through Natural Neighbour Interpolation method. The data then converted to delineate area in the classes of 0-2, 2-5 and 5-10 m bgl water level and for water level fluctuation 2 meter interval has been taken. Water Level data of pre-monsoon and post-monsoon has been given in Annexure –I and location is given in figure -10.

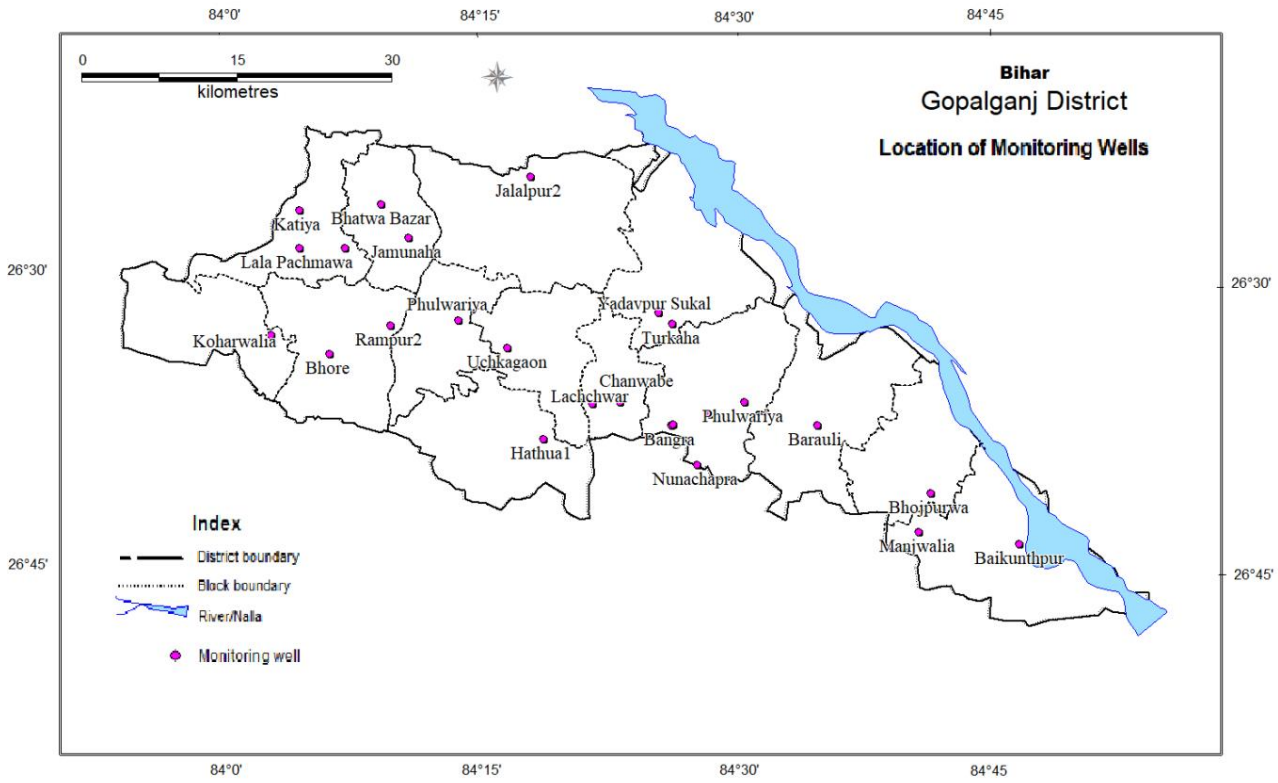

Figure 10: Monitoring Well Location of the district

Depth to water level – May 2022

During pre-monsoon period observed water level ranged from 2.35 to 5.93 m bgl. The average water level calculated to be 3.82 m bgl. Major part of the area is categorized under 2-5 m bgl water level. There are no well is categorised in shallowest water level categories of 0-2 m bgl. There are 03 wells located in Kuchaikote, Pachdeori and Kateya block where water level has been observed more than 5 m bgl.

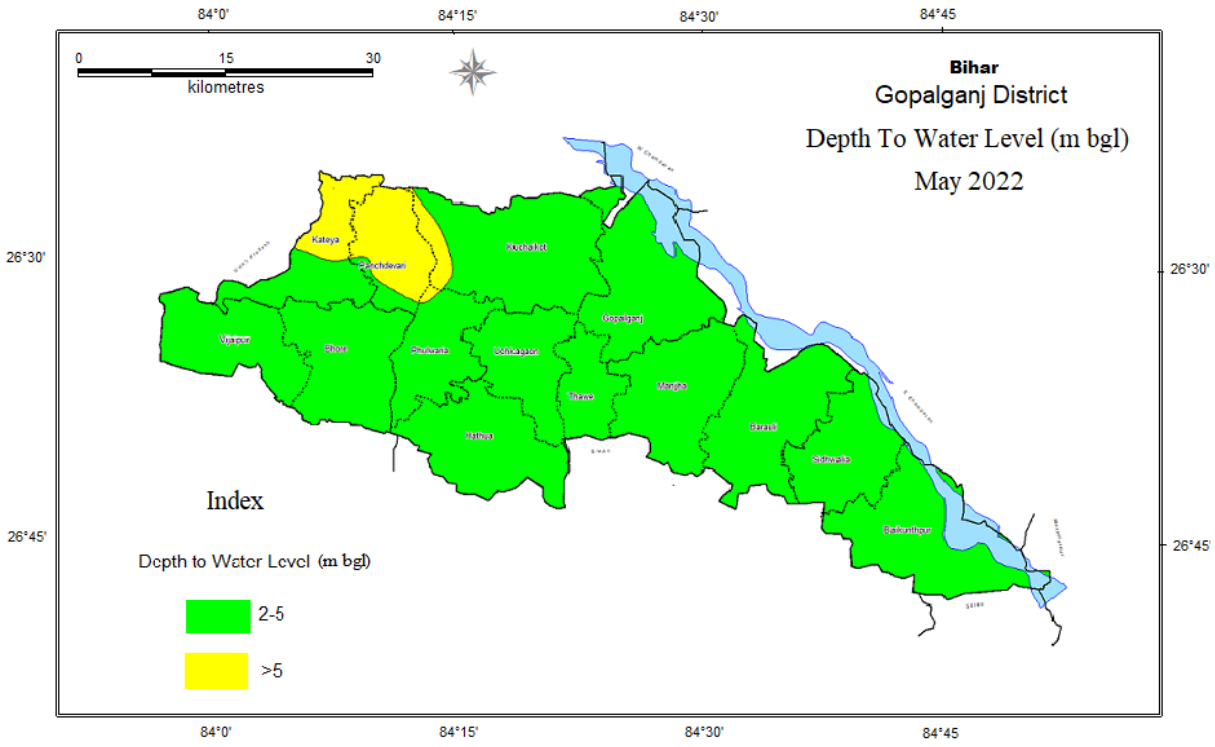

Figure 11:Depth to water level- May 2022

Depth to water level – November 2022

The water level monitored during month of November ranged from 1.3 to 4.03 m bgl. The Southern and western part of the district areas (60%) have shown category of 2 and 5 m bgl. Rest of the area (40%) of the district is categorized < 2 m bgl.

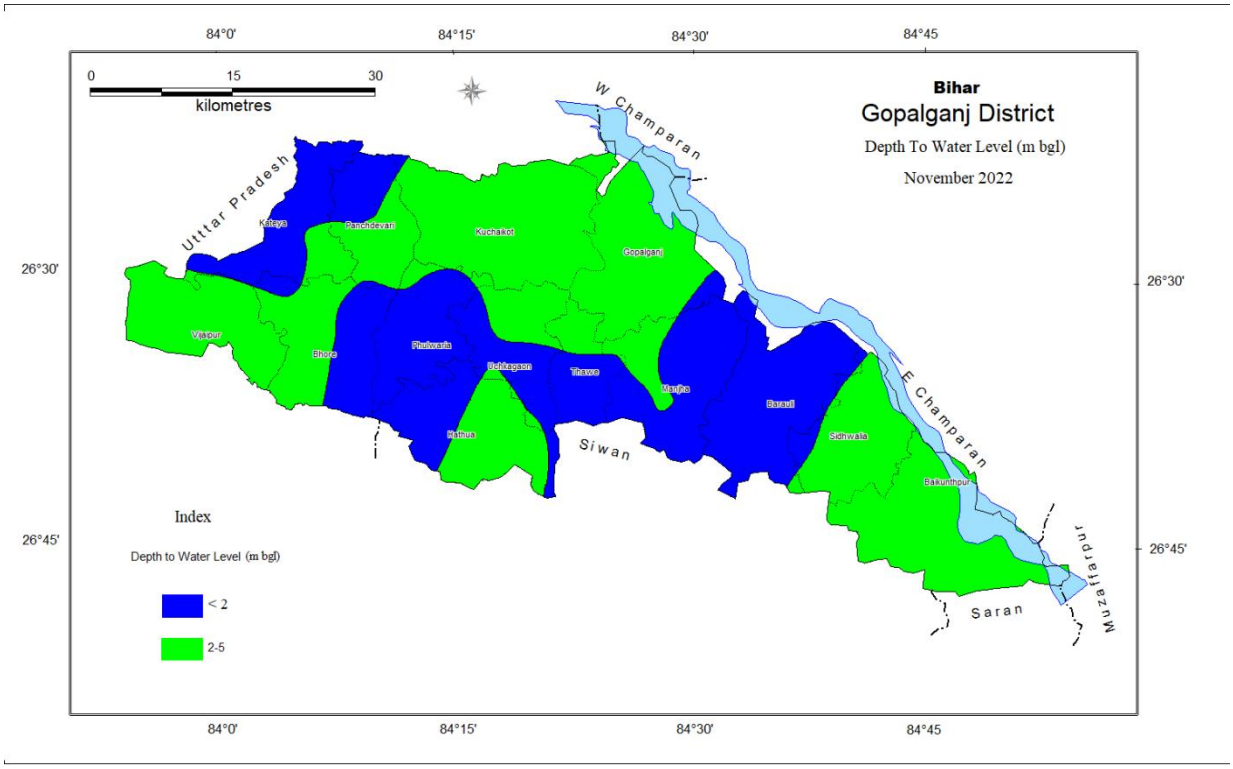

Figure 12:Depth to water level-November 2022

Monsoon fluctuation – November 2022 w.r.t. May 2022

Water level data monitored during Nov. 2022 has been compared with the water level data of May 2022 to know its monsoon fluctuation. The monsoon fluctuation of water level has been ranged from -0.34 to 2.91 m. About 87% area of the district has shown rise in water level up to 2 m. The area, in north-western about 7% area part of the district and a patch has been categorized more than 2 m rise. The area in northern part, about 6% area shown falls in water level as monsoon fluctuation.

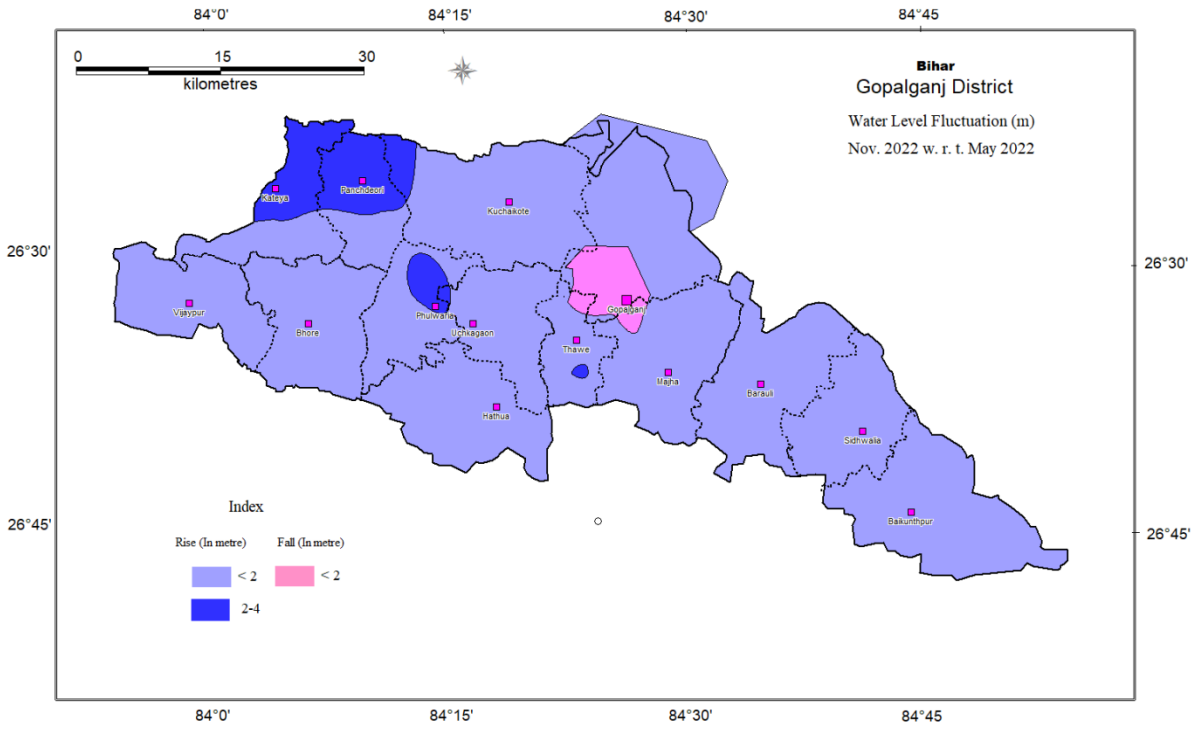

Figure 13:Water level Fluctuation November 2022 w.r.t. May 2022

Water Table contour

The water level w.r.t. mean sea level monitored during Nov. 2022 has been taken to prepare the water table contour map. The contour map reveals that ground water flow direction almost follow the topography of the area, gently sloped from NW to SE direction.

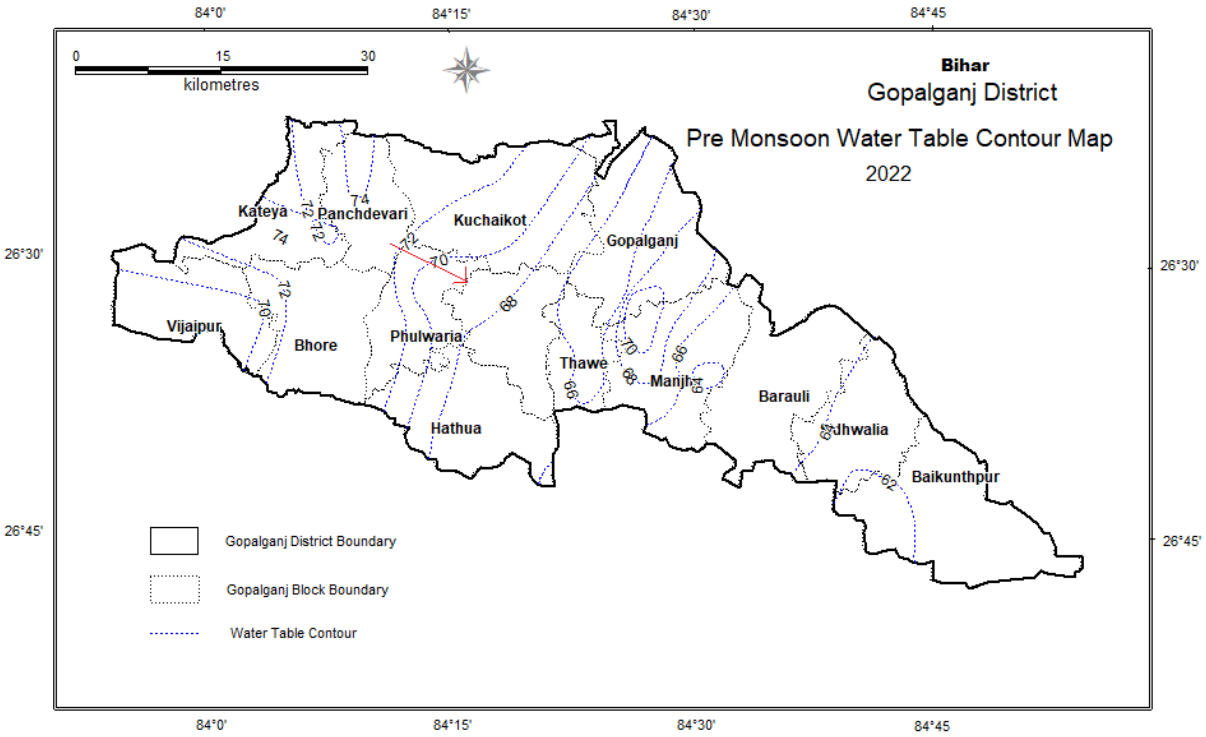

Figure 14:Water table Contour Map- May 2022

Hydrograph Analysis (Water level trend)

National Hydrograph Network Stations are being monitored four times in a year during the month of May, August, November and January. Last 10 years data has been taken for the trend analysis. Since, during the years 2020 and 2021 the monitoring work is badly affected by Covid -19 pandemic the trend has been analysed from the year 2010 to 2019. The water level trend of few wells viz. Barauli, Turkaha and Hathua in the district has been given below:

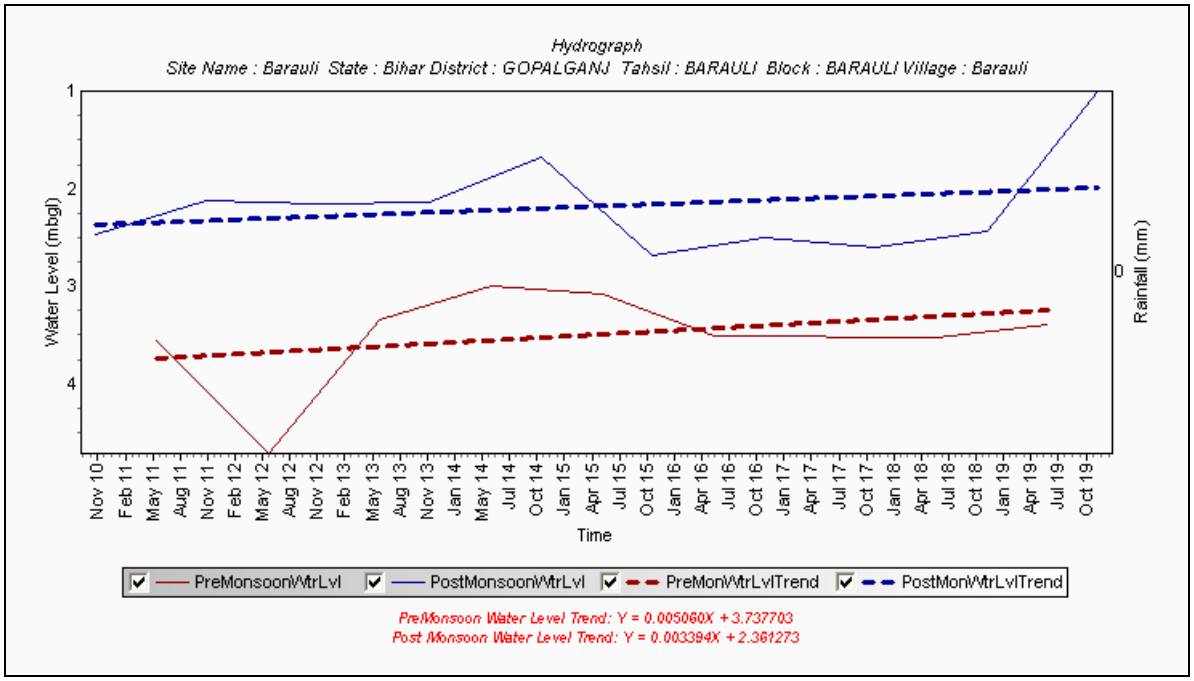

Figure 15: Water level trend at Barauli, Gopalganj district

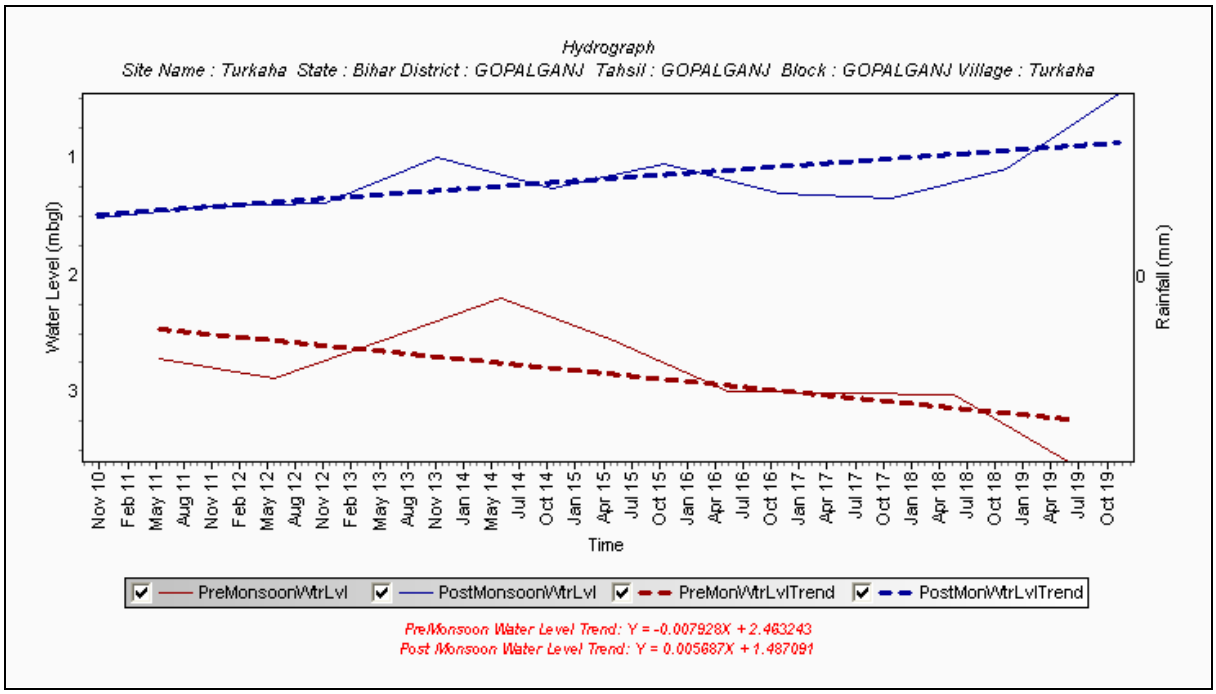

Figure 16: Water level trend at Turkaha, Gopalganj district

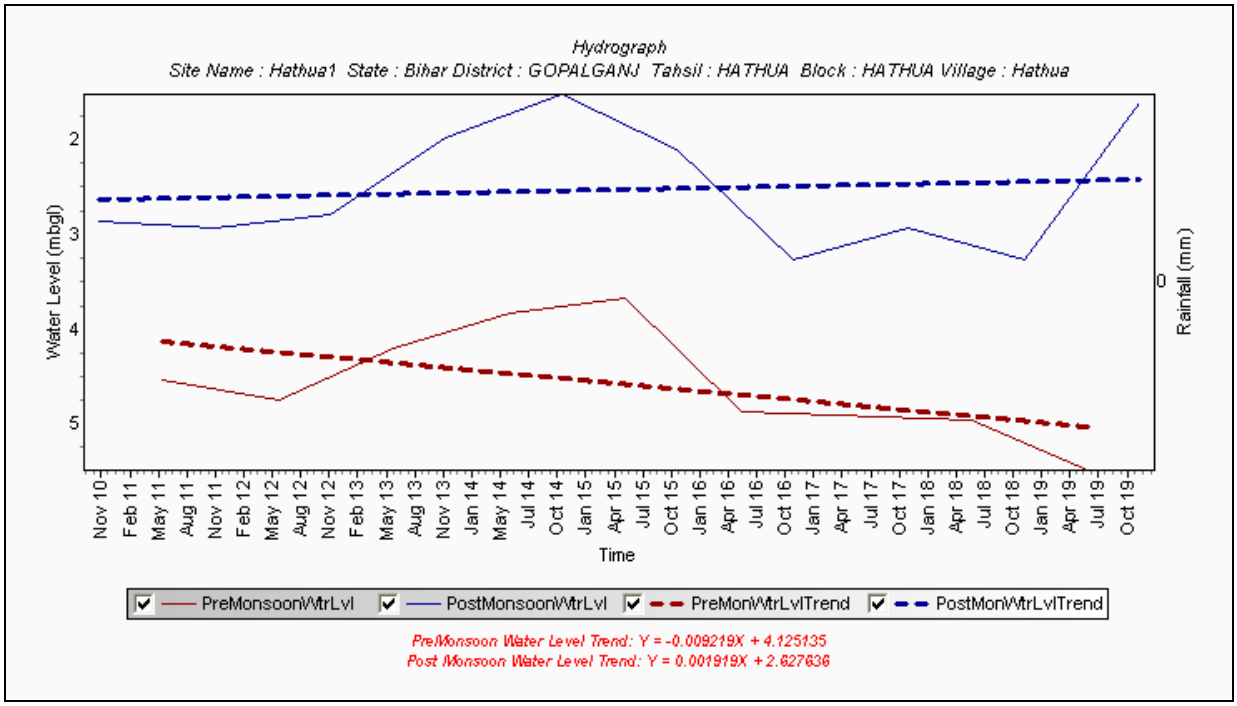

Figure 17: Water level trend at Hathua, Gopalganj district

3.3Ground Water Quality

Ground water quality and quantity are important parameters in quantifying utility of ground water for different purpose. It is most extensively used for domestic, industrial and irrigation purpose. The increasing industrialization and constant environment degradation is poorly affecting the water quality. The factors influencing the chemical quality of ground water are could be physical or chemical, topography of the area, microorganism growth, climatic conditions or maybe anthropogenic. A total of 22 samples were collected from Gopalganj district from various locations during Pre-Monsoon 2022 and were analyzed for basic parameters in the chemical lab of CGWB MER. All the samples were analyzed as per standard methods (APHA 2005) for the determination of pH, EC, CO_3^{2-}, HCO_3^-, Cl^-, F^-, NO_3^-, SO_4^{2-}, TH, Ca^{2+}, Mg^{2+}, Na^+ and K^+. Following observations were made from the analysis results **(Annexure II)**-

pH: It is one of the most important parameters while studying the water chemistry determining the alkaline/acidic nature of water on a scale range of 0-14. In the collected ground water samples, the pH value ranges from 6.57 to 7.1 with an average 6.85 indicating the ground water slightly acidic in few areas and almost within the limit of drinking water standards.

Electrical Conductivity (EC): It is a measure of the total mineralization in water and thus indicates its degree of salinity. It is influenced by the presence of dissolved cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe, Al^{3+} etc.) and anions (Cl^-. NO_3^-, PO_4^{3-}, SO_4^{2-} etc.). The electrical conductivity (EC) values range from 552-1948µS/cm with an average value of 968.22µS/cm. In all samples the EC value was well within permissible limit of 3000 µS/cm.

Total Hardness (TH): Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per litre.

Table 9:Hardness Classification of ground water sample of Gopalganj District

Hardness (mg/L)	Water Class	% Sample
0-75	Soft	0
75-150	Moderately hard	0
150-300	Hard	45.45
>300	Very hard	55.55

The TH in the district ranges from 190-745 mg/L, with an average value of 370.23 mg/L.

Nitrate

Nitrate contamination occurs in surface water and groundwater, leaching into the soil and from there into the water supply from various sources. Irrigation water containing fertilizers is a common culprit as are septic systems, wastewater treatment plants, milk industries and natural conditions. The nitrate concentration in the district ranges from 0.34-29 mg/L, with an average value of 5.17 mg/L. No samples collected from Gopalganj have shown high Nitrate value over its acceptable limit.

Chloride:

The concentration of chloride (Cl^-) controls the taste of the water and its maximum permissible limit is 250 mg/L by BIS, (10500- 2012). The chloride concentration in water samples collected from Gopalganj district varies between 7.1 and 269.8 mg/L (Avg. 62.29 mg/L). Out of 22 samples only 01 sample had chloride concentration greater than the permissible limit for drinking purpose.

Carbonates and Bicarbonates: In most of the water samples the concentration of carbonates (CO_3^{-2}) is almost nil. Concentration of bicarbonate (HCO_3^-) varies from a minimum of 219.6 mg/L to a maximum value of 616.1 mg/L, with an average value of 407.87 mg/L.

Sulphate

Sulphate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. High sulphate levels in drinking water results in gastro-intestinal disorders, and hence BIS (2012) has prescribed 200 mg/L as acceptable limit and 400 mg/L as permissible limit for sulphate in absence of alternate source for drinking and other domestic usage. The Sulphate concentration in water samples is well within permissible limit of 400 mg/L. Generally, the concentration of Sulphate in the district ranges from 12 to 99 mg/L with average values of 43.70 mg/L. In all sample sulphate concentration is well within permissible limit and is good for drinking as well as irrigational purposes.

Fluoride

Fluoride is found in all natural waters at some concentration. In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. The permissible limit for fluoride in drinking water as suggested by BIS (10500- 2012) is 1.5 mg/L. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis. In collected groundwater samples fluoride was found in the range of 0.51 to 1.06 mg/L, with an average value of 0.78 mg/L respectively. In all samples the concentration of fluoride was within the permissible limit of 1.5 mg/L.

Calcium and Magnesium ions

The dissolved solids like Calcium and Magnesium in ground water are essential to human nutrition and beneficial to the heart and nervous system of human beings respectively. Excess of Magnesium contributes to hardness of water. BIS, (10500- 2012) have suggested the acceptable/maximum permissible limits for Calcium and Magnesium in drinking water as 75/200 mg/L and 30/100 mg/L respectively.

In collected samples the concentration of calcium ranges between 22 to 250 mg/L, with an average value of 109.73 mg/L. The concentration of magnesium ranges from 9.72 to 100.84 mg/L, with an average value if 23.30 mg/L.

Sodium

Sodium concentration in the district ranges between 9.26 and 102 mg/l, with an average value of 41.06 mg/L. High concentration is harmful for those suffering from hypertension, cardiac and renal diseases.

Potassium

In the collected water samples the concentration of potassium was in the range of 3.16 and 13.2 mg/L, with an average value of 6.73 mg/L.

Suitability of groundwater towards Irrigation

The presence of sodium ions in irrigation water adversely affects the soil structure and its permeability by replacing calcium and magnesium in the soil. The United States Soil Laboratory (USSL) diagram explains the combined effect of sodium hazard and salinity hazard while classifying the irrigation water. This diagram classifies water samples into 16 categories based on its salinity and sodacity values. This diagram is plotted between sodium adsorption ratio value and electrical conductivity.

As can be seen from Figure 18, most of the samples were in the category of C3-S1 type, suggesting low sodium hazard and high salinity hazard, followed by C2-S1 type, indicating low sodium hazard and medium salinity hazard. No samples were found high salinity-high sodium hazard. Most of the samples in study area were found suitable for irrigation.

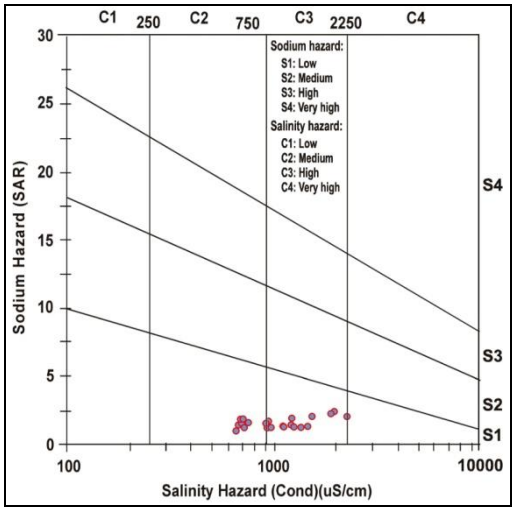

Figure 18: USSL diagram of samples collected from Gopalganj district

A Wilcox plot is given in Figure 19, which relates sodium percent with salinity. It can be seen that most of the samples were in the excellent to good and good to permissible category towards irrigation purpose. No samples were found in the permissible to doubtful category, doubtful to unsuitable category and unsuitable category.

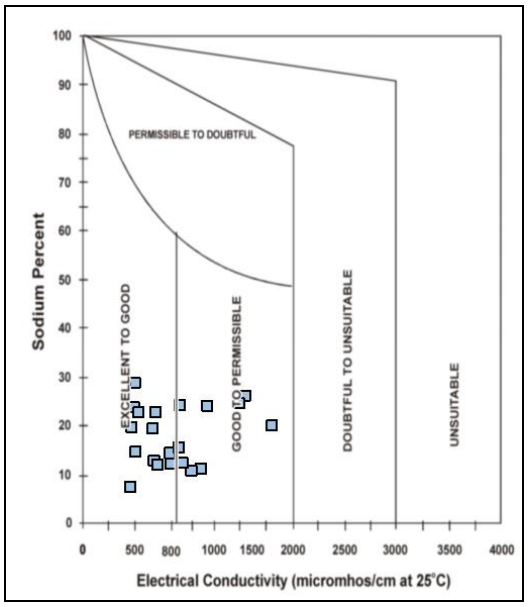

Figure 19: Wilcox plot of samples collected from Gopalganj district

In Table 10, a classification based on SAR value and % sodium value is given for water samples towards irrigation purpose.

Table 10: Classification of Groundwater Samples towards Irrigation purpose

Parameter	Range	Classification	% Of samples
SAR value	<10	Excellent	100
	10-18	Good	0
	18-26	Doubtful	0
	>26	Unsuitable	0
% Sodium	<20	Excellent	45.45
	20-40	Good	55.55
	40-60	Permissible	0
	60-80	Doubtful	0
	>80	Unsuitable	0

Hydrochemical Facies of Water

A modified piper diagram, Chadha's diagram was plotted to compare the ionic composition in the collected water samples.

The facies mapping using Chadha's diagram (Figure 20) suggests that the maximum ground water sample from Gopalganj district comes under the Ca^{2+}-Mg^{2+}-HCO_3^- type followed by Ca^{2+}-Mg^{2+}-Cl^-type. It was observed that the study area was dominated by HCO_3^-ions, and alkaline earth metals (Ca^{2+} and Mg^{2+}) dominating over alkali metals (Na^+ and K^+). The Ca - HCO_3 water results from dissolution of carbonate minerals and the origin of water is mainly due to rainfall-derived recharge, over decades to centuries, whereby surface water charged with atmospheric and biogenic CO_2 infiltrates into the subsurface

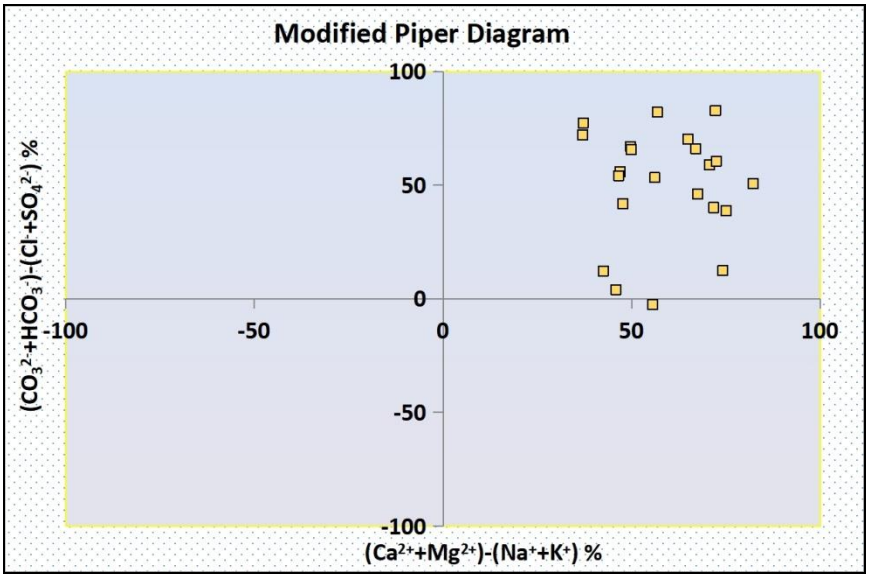

Figure 20:Chadha's plot of samples collected from Gopalganj district

The analytical result, its maximum, minimum and average value against the BIS Standards 2012 for drinking purpose has been shown in the table

Table 11: Chemical quality of phreatic aquifer

	Location	pH	EC(microsi-emens/cm)	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-
Range	Minimum	6.57	552	4	9.72	219.6	7.1	12	0.34	0.51
	Maximum	7.1	1948	130	70.5	616.1	269.8	99	29	1.06
BIS	*Acceptable limit*	*<6.5*	200	*75*	*30*	*200*	*250*	*200*	*NA*	*1*
	Permissible limit (in the absence of alternate source)	*>8.5*	600	*200*	*100*	*600*	*1000*	*400*	*45*	*1.5*

Value in mg/l

From the above table it can be inferred that in general, water is potable.

3.4 Geophysical Survey in Gopalganj District

In order to delineate aquifer geometry in Gopalganj district, TEM survey was carried out in AAP 2022-23. 14 soundings at 5 locations (Figure 21) in the south eastern part of the district were conducted using the instrument *Monex Geoscope*. The stations were placed in a straight line at an interval of 10.0 m. Coincident loop configuration was used to acquire the data. The size of the transmission and receiver loop was fixed at 40 x 40 m^2. Utmost care was taken to avoid sources of noise such as anthropogenic structures, buried cables, power source etc. The data interpretation was carried out using the software *IX1d*. Local hydrogeological conditions were kept in mind during inversion of data. The obtained results along withprinciple are discussed below.

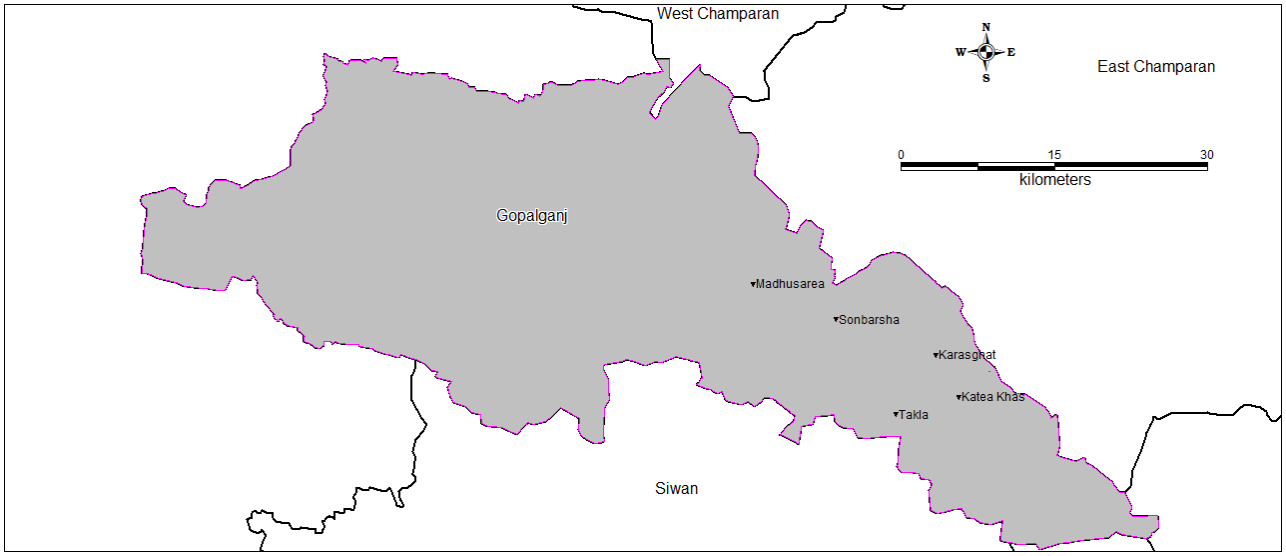

Figure 21: Map showing locations where geophysical survey was carried out in Gopalganj district

3.4.1 Principle

TEM is an electromagnetic method measuring in the time domain - in contrast to frequency domain methods - using artificial signals generated with particular transmitters. A current flowing in a transmitter loop is switched off abruptly. The collapsing electromagnetic field induces eddy currents in the conductive underground according to Maxwell's equations (Figure 22). This system of eddy currents produces a secondary magnetic field, whose propagation depends on the conductivity distribution in the subsurface.

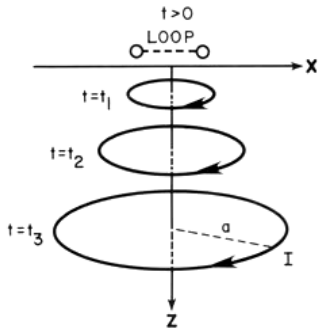

Figure 22: Propagation of currents in the underground Source.

The temporal change of the secondary field can be measured at the earth's surface: the magnetic components H_x, H_y, H_z as induced voltages in coils and the electrical horizontal components E_x, E_y directly as voltages between two electrodes (Figure 23). From the decaying induced voltage an apparent specific resistivity and an assigned depth as a function of time after switch off of the primary pulse can be calculated. The later the times are, the deeper the current system has penetrated. A great advantage of the method is the temporal separation between the strong primary field and the weak secondary field, allowing high amplification of the later.

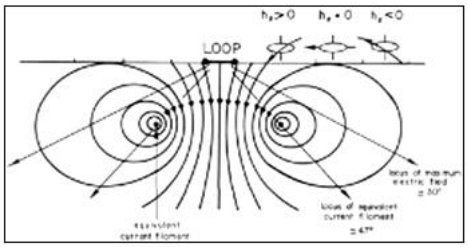

Figure 23: Field lines of the vertical magnetic dipole Source.

The quantity acquired is the voltage measured in the receiver coil as function of time after switching off the primary field. The calculation of an apparent specific resistivity, a much more descriptive quantity is possible. The values are plotted bi-logarithmically by convention; the quantities are normalized by the coil areas and the amperage of the transmitter current.

The quantitative interpretation of the data is conventionally accomplished with the help of one-dimensional models consisting of horizontal, infinitely extending homogeneous layers each with a different resistivity. The adjustment of measured data and model responses is usually performed using inversion methods.

3.4.2 Observations and Results

(a)

(b)

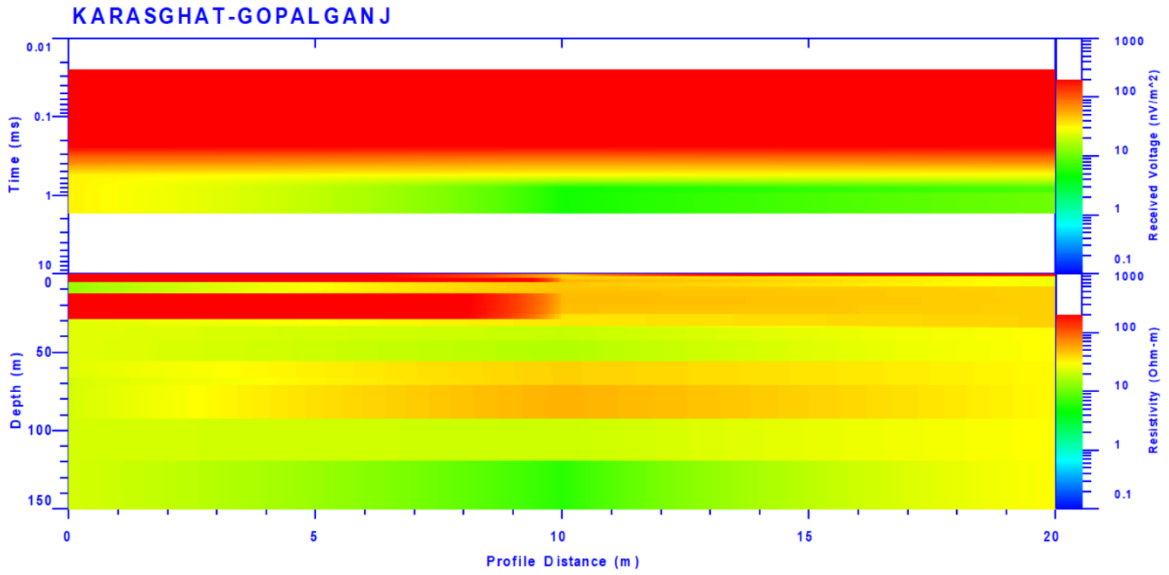

Figure 24: (a) Section showing Received voltage (nV/m^2) vs Time (ms) and (b) interpreted resistivity profile of Karasghat area, Gopalganj district, Bihar.

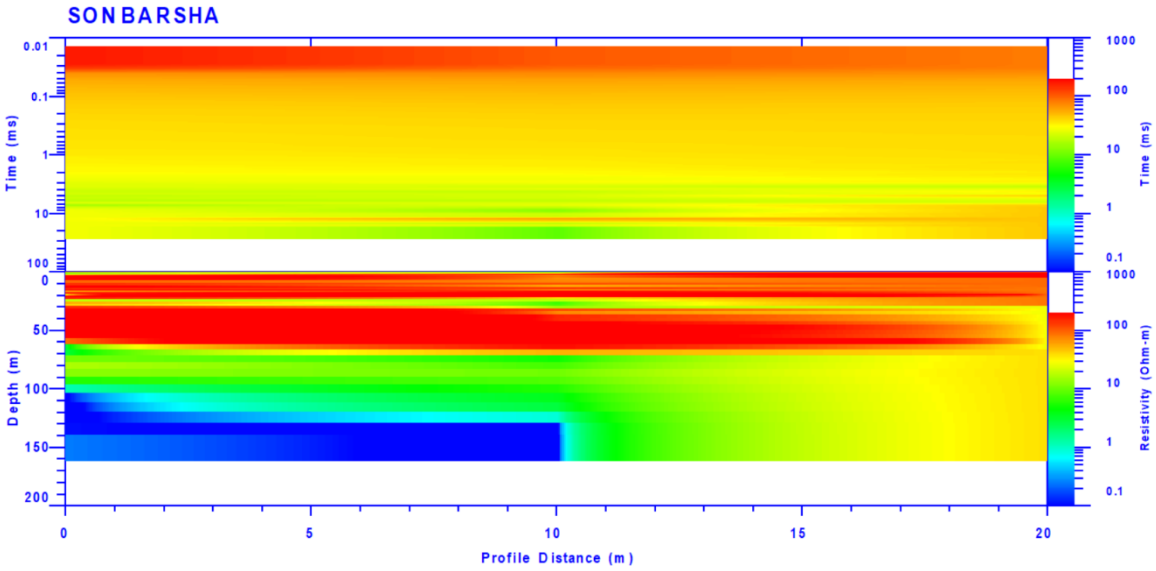

Figure 25: Interpreted Resistivity profile of Sonbarsha area, Gopalganj

Table 12: Interpreted results of TEM survey in Gopalganj District, Bihar

Location	Coordinates		Resistivity (ohm-m)							Depth (m)					
	Longitudes	Latitudes	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	d_1	d_2	d_3	d_4	d_5	d_6
Katea Khas	84.71139	26.33892	102.05	2.3335	162.33	31.564				0.12143	0.75391	17.952			
	84.71136	26.339	80.683	0.64828	56.895	27.822	0.41151			0.0995	0.35944	44.133	362.33		
	84.71136	26.33908	323.86	9.8175	77.286	29.648				0.10188	1.4489	15.252			
Madhusarea	84.50939	26.43792	169.29	1.1521	89.955	32.945	0.2436			0.0674	0.17876	31.909	483.34		
	84.50947	26.438	1.893	16.442	171.48	34.637				0.0525	0.427	18.049			
	84.5095	26.43808	1.6427	51.657	94.131	34.132				0.0374	0.3016	22.044			
Sonbarsha	84.59092	26.40692	124.55	6.833	38.041	18.512	59.515	29.843	4.1995	0.0668	0.20133	0.71632	1.568	16.606	174.55
	84.59083	26.40692	103.12	1.6373	121.89	29.66	3.6401	0.0356		0.11796	0.30643	15.978	186.61	343.58	
	84.59075	26.40697	1.484	12.673	85.255	32.424	72.482			0.089	0.3763	13.42	232.81		
Takla	84.64972	26.32372	185.86	4.6929	96.681	24.001	1.3678			0.0974	0.57308	15.601	208.4		
	84.64981	26.32369	2.0808	19.66	75.78	25.122	12.8			0.0828	0.21191	12.592	185.23		
Karasghat	84.68908	26.37572	5.7245	67.621	25.702					0.0944	18.922				
	84.68917	26.37569	70.166	48.003	23.468	2.3955				1.751	23.743	114			
	84.68928	26.37569	4.3206	218.95	28.766	85.717				0.0657	9.0166	104.42			

CHAPTER 4

GENERATION OF AQUIFER MAP

4.1 Aquifer Disposition

As per the Annual Action Plan the Central Ground Water Board has been generating depth wise data through groundwater exploration, geophysical survey, drilling and also collecting from other agency etc. The tube wells, drilled by Central Ground Water Board as well as Production Well drilled by Bihar State Authorities also included here These data are further will be analysed in order to refine sub-surface disposition for the preparation of aquifer maps.

By taking 8 exploratory well data following panel diagram and sections has been prepared.

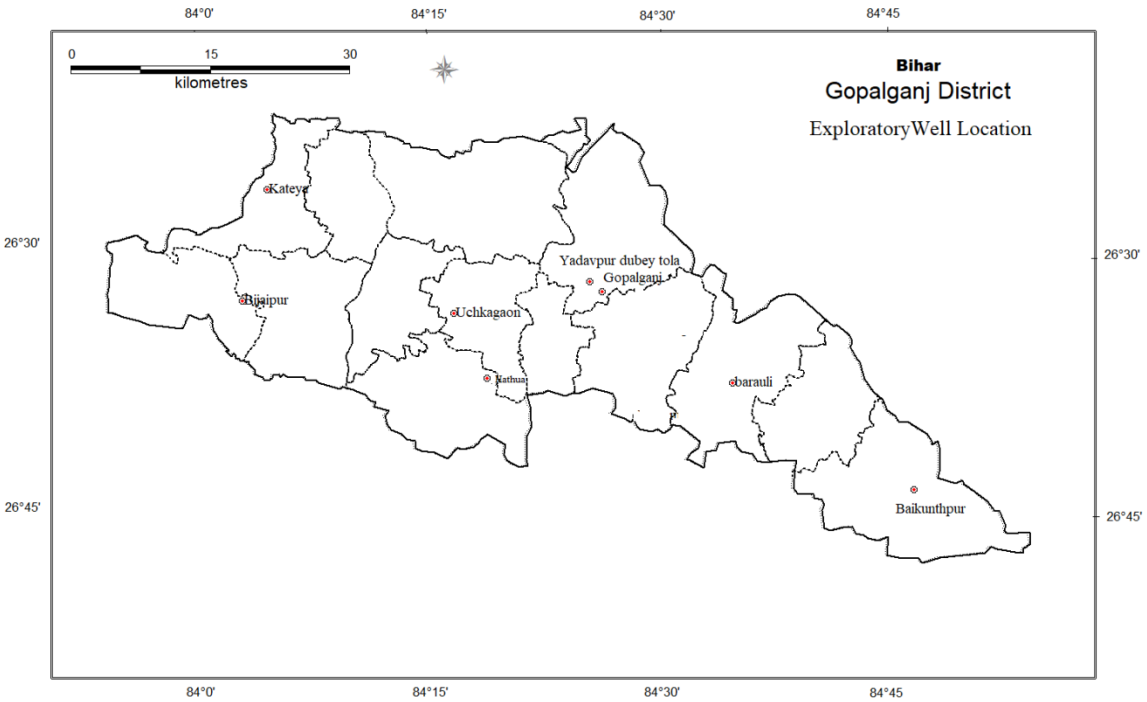

Figure 26:Location of exploratory well

The 2D- panel diagram and sections shows that the sediments vary in texture and thickness both laterally and vertically. The clay and Kankar bed often occur as lenses. There are intercalations of sand & clay found throughout the panel diagram and sections.

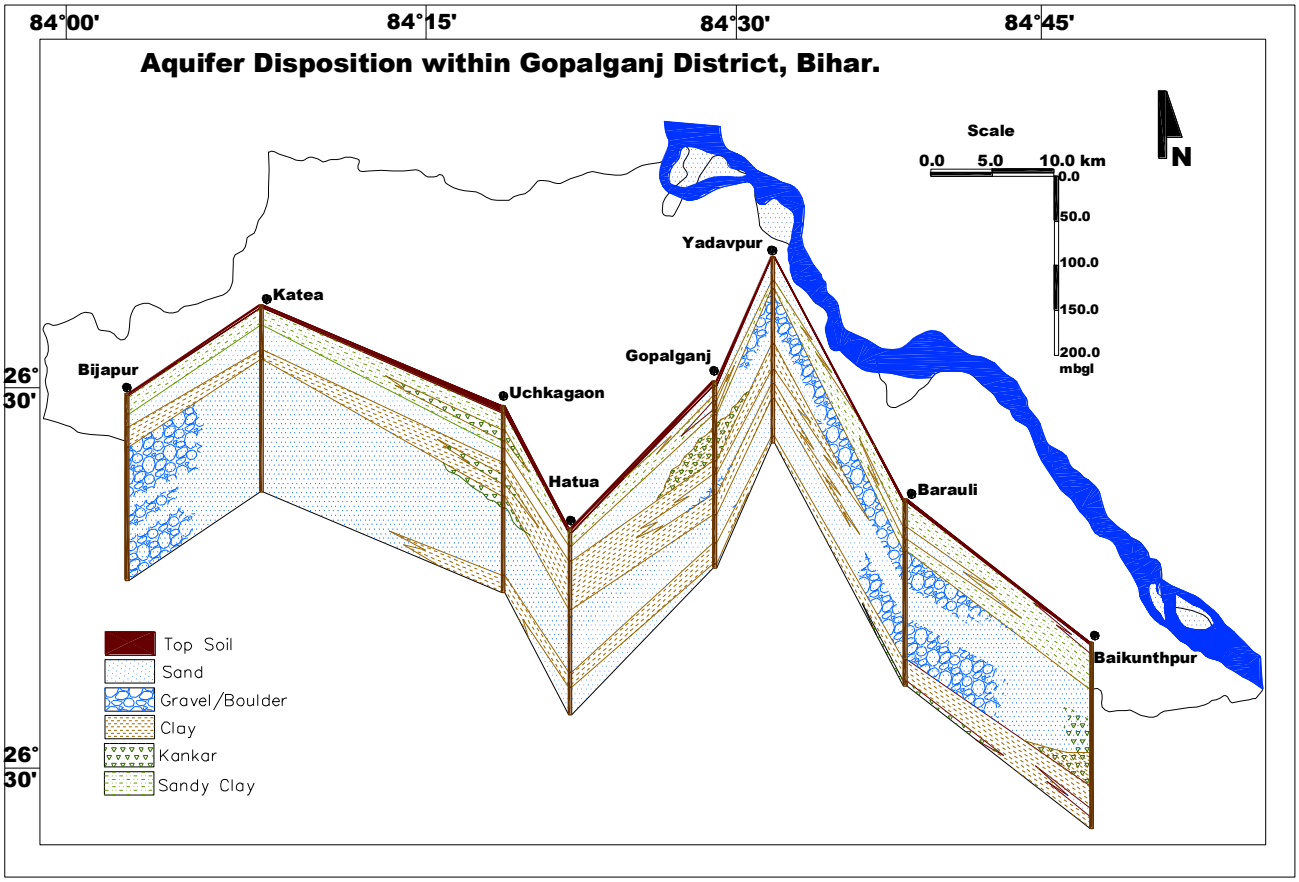

Figure 27: Panel diagram showing Aquifer Dispostion in Gopalganj District

The study of panel diagram and section shows that thick layer of clay mixed with sand found as topmost layer in Bijaipur, Kateya and continued upto Gopalganj. However thickness of clay mixed with sand bed decreases as we move from west to east. Second layer of clay found and it also continued upto Gopalganj , towards Barauli the clay layer pinches out. The thickness of 2nd clay layer varies 20-50 m at places. The grain size of sand vary from fine to coarse. There are lensoid deposits of gravel found in exploratory wells at Bijaipur, Yadavpur and Barauli locations also lenses of Kankar found in Uchkagaon, Gopalganj and Baikunthpur locations. So two aquifers found as shown in sections and the 2nd aquifer is more extensive and homogeneous throughout the district. However when we move towards south-eastern (Barauli-Baikunthpur) part of district the aquifer may be considered as single

aquifer system.

The 1st aquifer is characterized to be unconfined, whereas the 2nd aquifer is characterized as semi confined to confined aquifer.

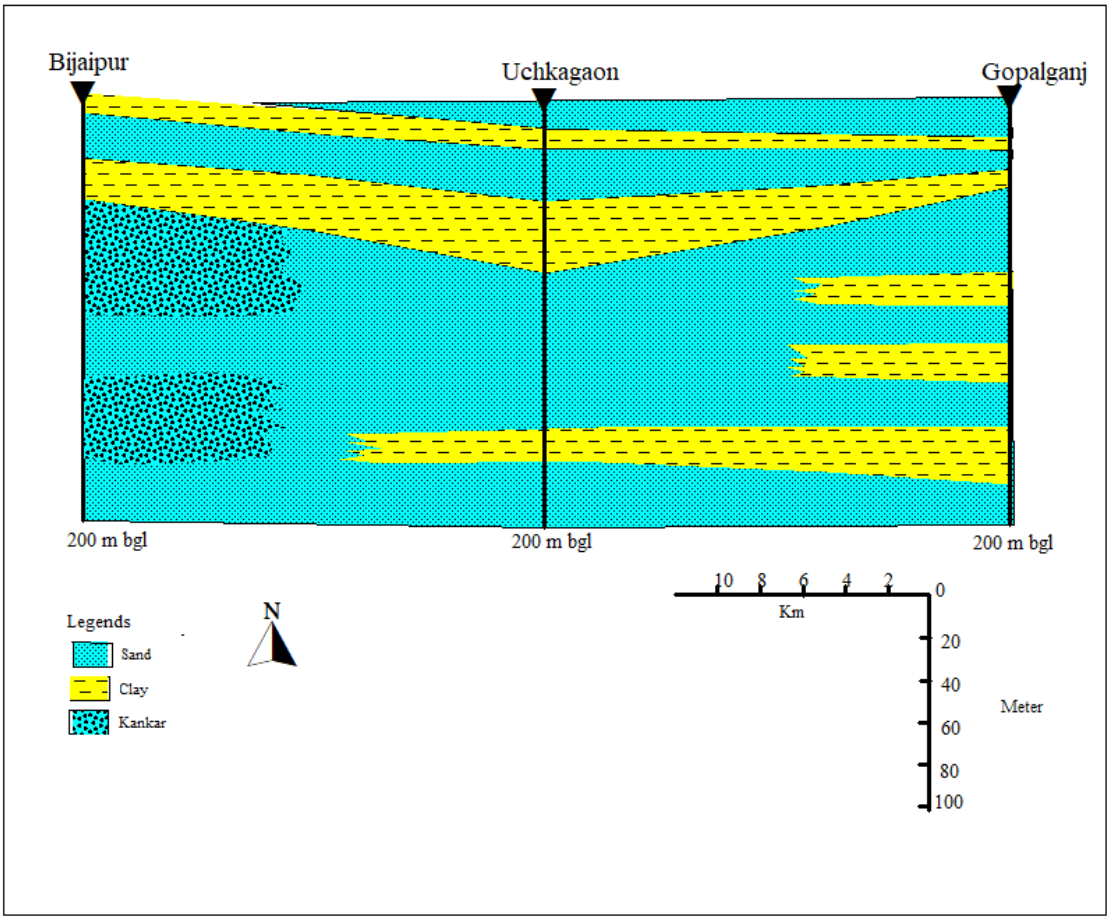

Figure 28: Cross Sections showing Aquifer Disposition of Gopalganj District

The cross sections are drawn to decipher aquifer disposition of Gopalganj district in detailed manner. The 1stcross section is taken along east-west direction. It shows that number of clay lenses increases as we move away from bijaipur towards east. The 1st clay layer is thinner as compare to the 2nd clay layer. Lensoid deposits of kankar found in the 2nd aquifer at Bijaipur location. The 2nd aquifer is more thick and extensive. The 1st aquifer may be characterized as unconfined, whereas the 2nd aquifer may be characterized as semi confined to confined aquifer.

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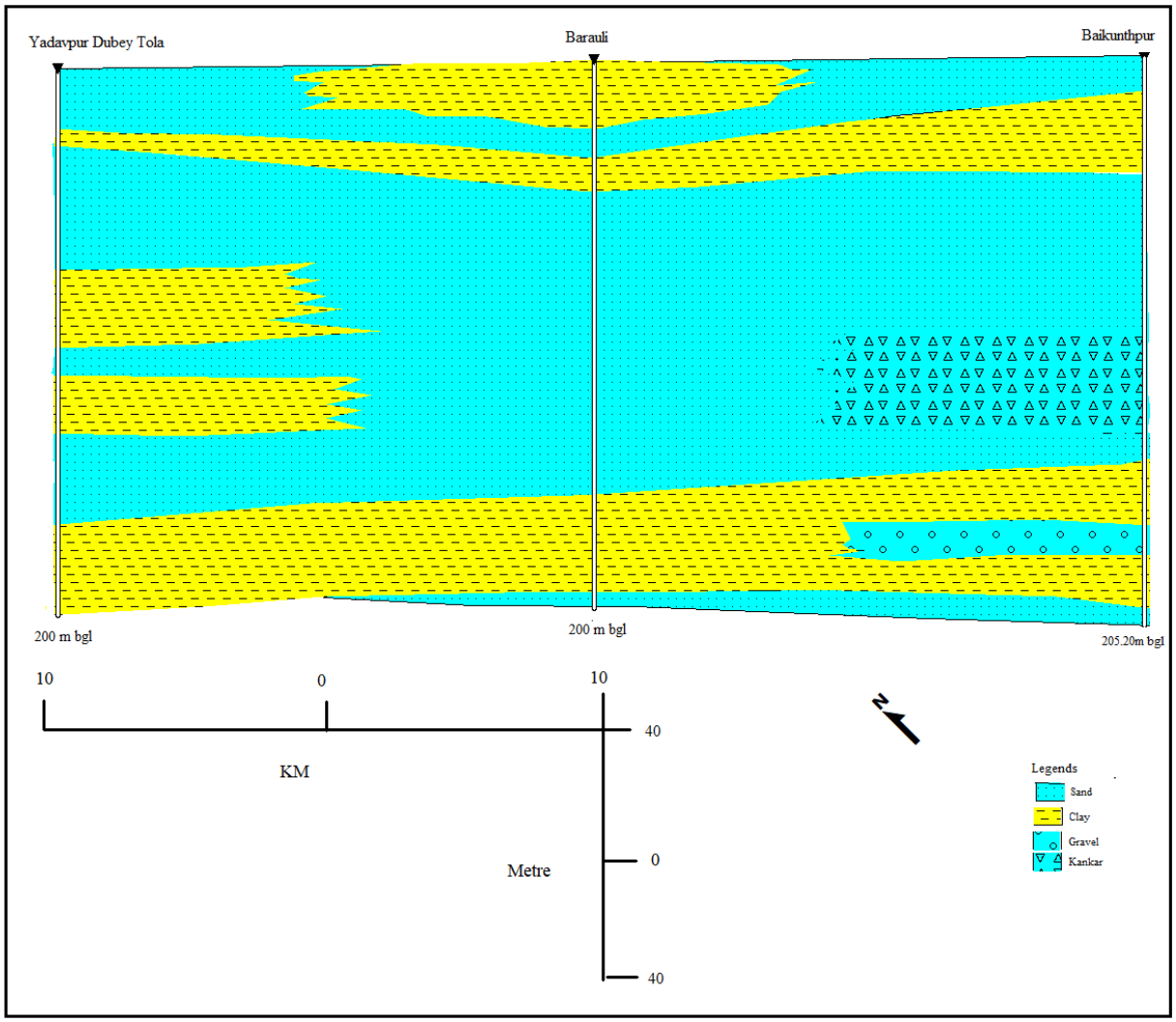

Figure 29: Cross Sections showing Aquifer Disposition of Gopalganj District

This 2nd cross section is taken along NW-SE direction. It shows that number of clay lenses increases as we move toward Gopalganj similar to the 1st section and the clay layer pinch out as we move toward west. The 1st clay layer is thinner as compare to the 2ndprominent clay layer. Lensoid deposits of kankar found in the 2nd aquifer at Baikunthpur location. At Baikunthpur a small gravel lense is also found of ~10 m thickness at about 180 m depth. The 2nd aquifer is more thick and extensive. The 1st aquifer may be characterized as unconfined, whereas the 2nd aquifer may be characterized as semi confined to confined aquifer.

4.1.1 Aquifer Characteristics

The district is mainly drained by the river Gandak and its tributaries. Under exploratory program of CGWB, 8 Nos. exploratory wells and 10 Nos. observation wells were constructed to decipher the aquifer geometry and hydrological regime. The exploratory drilling is confined to a depth of 200 m . Aquifer test data results indicate that yield of the wells vary between 168 m^3/hr to 215 m^3/hr for a drawdown of 6 m to 11 m. The review of bore hole data indicates presence of 3 to 5 granular zones between the depth of 28 to 68 m and 133 to 190 m. below ground level. The aquifer test results indicate that the transmissivity values ranges from 1100 to 2200 m^2/day and storativity ranges between 2.4 X 10^{-3} to 4.8 X 10^{-4}. The piezometric level ranges between 1 m to 5 m below ground.

The exploratory drilling indicates presence of prolific aquifers down to 150 m having 3 to 5 granular zones which can be taped for construction of shallow as well as deep tubewell for ground water development in the area.

Table 13: Exploration data of Gopalganj district

Sl.No.	Location/ Block	Depth Drilled	Granular/ Zone/ fracture Tapped	Static Water level	Discharge	Drawdown	Specific Capacity	Trans-missivity	Storativity	Year
		mbgl.	m.	m. bgl.	m^3/hr.	m.	m^3/hr./m.	m^2/day		
1	**GOPAL-GANJ/ Gopalganj sadar** $26^0$28'50" $84^0$26'45"	201	040.00-049.00 065.00-083.00 097.00-104.00 108.00-114.00 114.50-147.50	3.87	194.64	9.68	20.1	1127	$4.80X10^{-4}$	1990
	OW	152.7								
2	**BARAULI/ BARAULI/** $26^0$25'00" $84^0$37'40"	200	052.00-064.00 085.00-097.00 099.00-105.00 111.00-117.00 123.00-135.00	3.05	200.3	5.61	35.7	2392	$2.40X10^{-3}$	1990
	OW	156.1	141.00-147.00							
3	**YADAVPUR Gopalganj Sadar** $26^0$33'65" $84^0$31'50"	200	031.00-043.00 046.00-058.00 104.00-107.00	4.17	211.44	5.77	36.64	1836	$4.30X10^{-4}$	1991
	OW	113.65								

4	**HATHUA/ Hathua** $26^0$22'20" $84^0$19'10"	201	086.00-098.00 107.00-119.00	4.79	208.2	11.21	18.57	1284.52	$1.25X10^{-4}$	1991
	OW	125.63								
5	**UCHKA-GAON/ Uchkagaon** $26^0$27'15" $84^0$17'25"	200	041.00-047.00 061.00-067.00 098.00-104.00 110.00-122.00 145.00-148.00	1.08	208.7	9.7	21.68	1899	$4.3X10^{-4}$	1991
	OW	153								
6	**KATEA/ Katea** $26^0$36'00" $84^0$07'40"	202	056.00-062.00 072.00-078.00 084.00-090.00 102.00-108.00 120.00-132.00	2.36	215	9.91	21.69	2210	$3.01X10^{-4}$	1991
	OW	140.77								
7	**BIJAIPUR** $26^0$30'30" $84^0$00'45"	200	048.00-060.00 072.00-084.00 090.00-096.00 132.00-138.00	3.84	200.3	8.62	23.2	1472	$3.3X10^{-3}$	1991
	OW1	144.2								
	OW2	31.4								
8	**BAIKUNTH-PUR/ Baikunthpur** $26^0$00'26' $84^0$44'54"	205	065.00-074.00 086.00-092.00 099.00-105.00 117.00-123.00 126.00-138.00	3.02	84.2	18.9	4.45	1788	$2.30x10^{-3}$	1992
	OW1	144.3								
	OW2	16.2								

CHAPTER 5

5. GROUND WATER RESOURCES

Rainfall is the principal source of water to recharge ground water. Major part of the total annualrecharge takes place during monsoon period. Besides rainfall, seepage from canal, return flow from irrigation *etc*. also recharge the ground water. On the other hand, besides base flow of ground water and evapotranspiration, ground water extraction carried out for its drinking, domestic, irrigation and industrial purposes.

Thus the methodology for ground water resources estimation is based on the principle of water balance as given below –

Inflow – Outflow = Change in Storage (of an aquifer)

The equation can be further elaborated as

$$\Delta S = RRF+RSTR+RC+RSWI+RGWI+RTP+RWCS \pm VF \pm LF - GE - T - E - B$$

Where,

ΔS – Change is storage, RRF – Rainfall recharge, RSTR- Recharge from stream channels, RC – Recharge from canals, RSWI – Recharge from surface water irrigation, RGWI- Recharge from ground water irrigation, RTP- Recharge from Tanks & Ponds, RWCS – Recharge from water conservation structures, VF – Vertical flow across the aquifer system, LF- Lateral flow along the aquifer system (through flow), GE-Ground Water Extraction, T-Transpiration, E- Evaporation, B-Base flow

The recharge and extraction of ground water is calculated from the above equation. Stage of development (SOD) is the ratio of ground water recharge and its extraction calculated in percentage.Roughly, stage of development up to 70% is considered as safe.

The assessment of ground water includes assessment of dynamic and in-storage ground water resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect impacts of ground water mining. Such resources may not be replenish able annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

5.1 Dynamic Ground Water Resources

The dynamic Ground Water Resources has been assessed by CGWB, Mid-Eastern Region, Patna in association with Minor Water Resources Department, Government of Bihar based on GEC, Methodology 2015. The summarized detail of Annually Replenish able or Dynamic Ground Water Resources of Gopalganj district is in **Table below**

Table 14: Net ground water availability (GWRE - 2022)

Block	Ground Water Recharge (Ham)				Total Annual Ground Water Recharge (Ham)	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
	Recharge from Rainfall Monsoon Season	Recharge from Other Sources Monsoon Season	Recharge from Rainfall Non Monsoon	Recharge from Other Sources Non Monsoon Season			
Baikunthpur	3877.33	1700.97	143.90	1067.68	6789.88	446.72	6343.16
Barauli	3400.56	3029.09	129.97	1619.27	8178.89	817.90	7360.99
Bhore	2692.49	3500.36	91.95	2270.54	8555.34	855.54	7699.80
Bijaipur	4522.55	1089.14	137.83	579.03	6328.55	632.86	5695.69
Gopalganj	3292.12	2084.45	103.37	1709.98	7189.92	719.00	6470.92
Hathua	2483.80	3367.39	88.94	1935.20	7875.33	787.54	7087.79
Katiya	4685.02	3341.51	177.23	2577.07	10780.83	858.59	9922.24
Kuchaikote	3121.54	2041.49	99.74	1440.25	6703.02	670.30	6032.72
Manjha	2121.35	1275.39	65.41	1258.11	4720.26	472.02	4248.24
Panchdewri	1917.95	2543.88	67.34	1533.65	6062.82	606.29	5456.53
Phulwariya	2154.05	2107.01	84.69	1127.40	5473.15	547.32	4925.83
Sidhwaliya	1353.90	1245.23	49.35	778.82	3427.30	342.73	3084.57
Thawe	2542.11	1272.14	79.87	1015.76	4909.88	490.99	4418.89
Uchkagaon	3415.05	1412.64	104.08	975.87	5907.64	590.75	5316.88
Total	41579.82	30010.69	1423.67	19888.63	92902.81	8838.55	84064.25

Table 15: Assessment of Dynamic Ground Water Resources (2022)

Block	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-Exploited/Critical/Semi critical/Safe/Saline)
Baikunthpur	6343.16	3545.16	5.00	676.92	4227.08	735.47	2057.53	66.64	safe
Barauli	7360.99	2855.89	0.00	915.77	3771.65	994.96	3510.15	51.24	safe
Bhore	7699.80	4603.59	0.00	555.46	5159.07	603.50	4500.16	67.00	safe
Bijaipur	5695.69	1701.47	13.50	582.33	2297.31	632.69	3348.02	40.33	safe
Gopalganj	6470.92	3793.01	0.00	707.32	4500.32	768.48	1909.44	69.55	safe
Hathua	7087.79	2282.67	0.00	452.77	2735.44	491.92	5420.31	38.59	safe
Katiya	9922.24	4852.09	5.00	1035.0	5892.10	1124.51	3940.63	59.38	safe
Kuchaikote	6032.72	2777.83	0.00	621.71	3399.54	675.48	2579.41	56.35	safe
Manjha	4248.24	1818.70	0.00	407.72	2226.42	442.98	1986.56	52.41	safe
Panchdewri	5456.53	2054.94	0.00	311.50	2366.45	338.44	4026.36	43.37	safe
Phulwariya	4925.83	990.87	333.60	441.27	1765.74	479.43	3121.93	35.85	safe
Sidhwaliya	3084.57	1130.80	1.00	361.91	1493.72	393.21	1559.55	48.43	safe
Thawe	4418.89	2155.73	2.00	612.26	2769.99	665.21	1595.95	62.69	safe
Uchkagaon	5316.88	2726.15	0.00	414.69	3140.84	450.56	2140.17	59.07	safe
Total	84064.25	37288.91	360.10	8096.6	45745.6	8796.84	41696.17	54.42	Safe

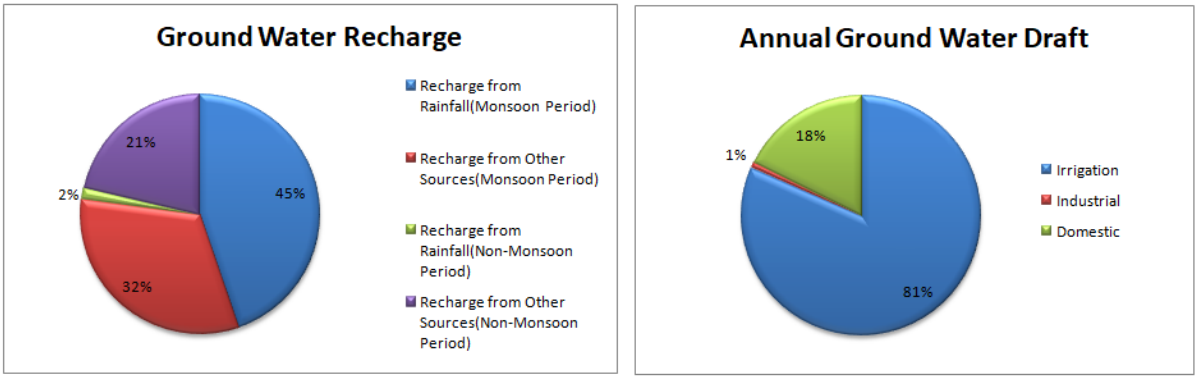

Figure 30: Percentage of Ground water Recharge and Ground Water Draft

As per the Ground Water Resource Assessment – 2022, Stage of Ground Water Extraction of ground water resources of the district is 54% only. Block wise calculated Stage of Groundwater Extraction is ranged from 35.85% (Sidhwalia) to 69.55 % (Harthua). So all 14 blocks fall under safe category.

About 50 % blocks have the stage of ground water development is around 60% and approaching to the safe limit of 70%. It indicates the dependency on ground water to fulfil the domestic, industrial and irrigation need. Therefore, ample scope existed in the district for the further development of ground water up to the safe limit of the Stage of Groundwater Extraction of 70%.

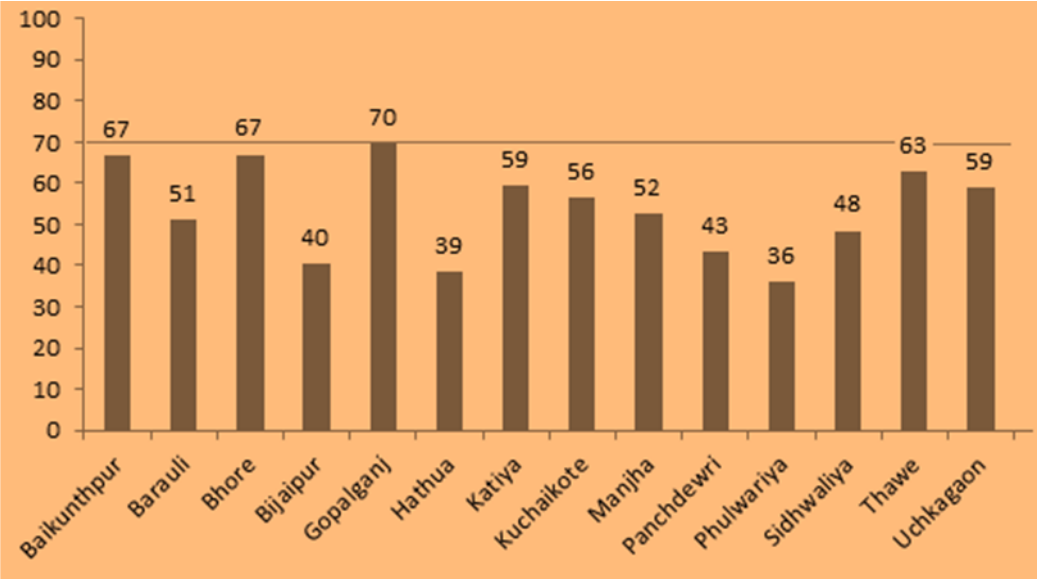

Figure 31: Block-wise stage of groundwater extraction in Gopalganj district, Bihar

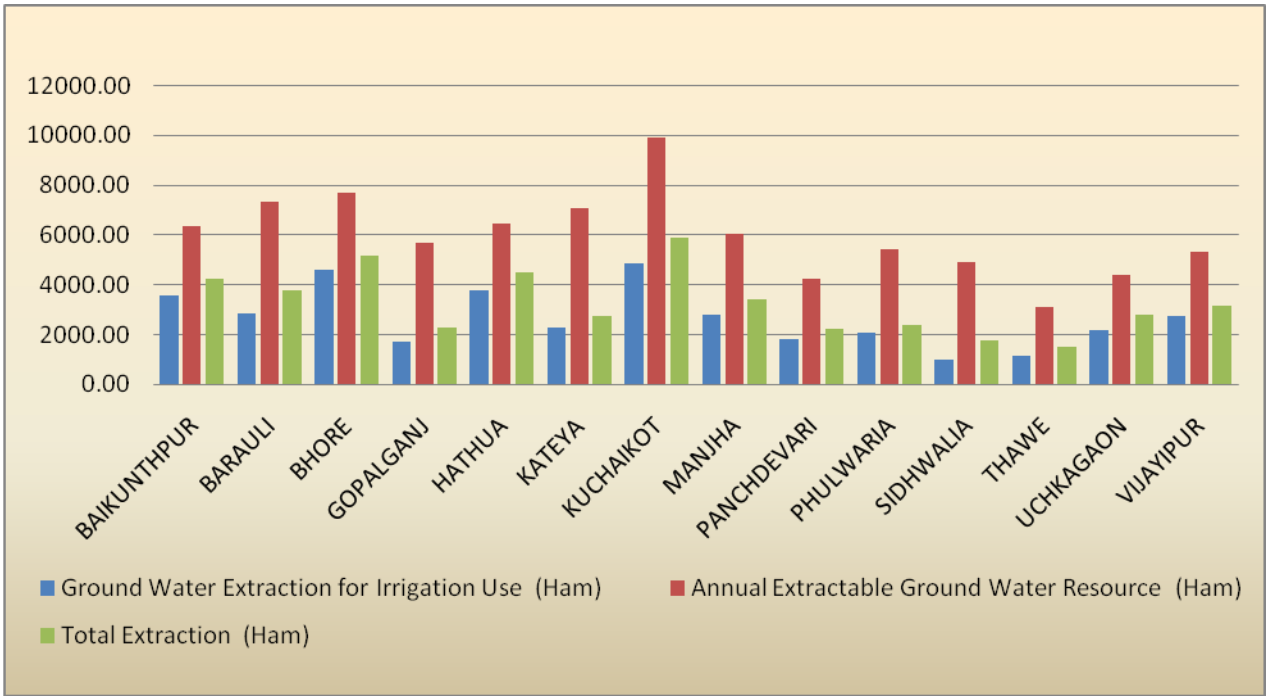

Figure 32:Blockwise Net Resources vis-a-vis Gross Draft

CHAPTER 6

6. GROUND WATER RELATED ISSUES

Gopalganj district falls in north-west region of Bihar have agrarian based economy. Total geographical area is 2019 sq km out of which cultivable area is 1390 sq km. Gopalganj is the administrative headquarter of the district. Economy of this district mainly relies on the agriculture. Geologically the district is characterised by the alluvium having alternating layers of sand and clay which favours the possibility of surface water irrigation as well as from ground water. As Gopalganj district is situated in alluvial plain of Gandak river. One of the objectives of this study is to prepare management plan after identifying ground water related issues in terms of its quantity and quality. Quality of ground water of Gopalganj district, in general, has been found suitable for domestic and irrigation purposes. The issues related quantity of ground water has been discussed below:

6.1Major Ground Water Issues

The major issues identified are:

1. As per the Ground water Resources assessment 2022 Stage of ground water extraction is 54.42% only. Stage of ground water extraction in majority of block is around 50%. It indicates that ample scope exists for the further development of ground water safely.
1. The MI census data and fence diagram prepared indicates that in general, there is an occurence of productive aquifer after down to 25 m depth. Hence the number of irrigational tube well is maximum within the depth range of 20-40 m bgl. Hence this productive zone may be kept under regular monitoring to know its behaviour in time and space.
2. The long term water level trend shows that at places it is in declining trend. Hence there is need of artificial recharge..
3. There is water logging problem found in parts of Gopalganj district especially north-western parts. i.e. Kateya , Pachdeori and in south –eastern parts i.e. Barauli, Sidhwalia
4. As per the previous record, in general, ground water is suitable for irrigation and domestic purpose

CHAPTER 7

7. MANAGEMENT STRATEGIES

7.1 Ground Water Development

Development of groundwater potential in the area has to be viewed against the backdrop of a predominant agrarian economy. The aquifer system present in the district is highly potential. As per Ground Water Resources Assessment 2022, the stage of ground water extraction in the district is 54%. There is still lot of scope for further development of ground water.

North western and eastern parts of Gopalganj district are generally waterlogged. The direction of groundwater flow in the district is from NW to SE, it is recommended that the heavy duty tube wells should extensively be constructed in the north-western and eastern parts of the district comprising Barauli, Gopalganj, Kateya, Panchdevari, Phulwaria and Sidhwalia blocks. It will act both as perennial sources of water supply and also to some extent eliminate the water logging problem in the affected areas.

A shallow tube well within the depth range of 20-40 m, tapping granular zone of 10-15 mbgl and 25- 30 mbgl respectively can yield as high as 75 m3 /hr. A well assembly of 76 mm diameter or 102 mm diameter with 6 to 12 m of slotted pipes can be used for construction of tube wells. Medium tube wells can be constructed by tapping potential aquifer present in the depth range of 50-100 m bgl. A well down to a depth of 70-100 meters tapping the aquifer of 50-80 m bgl can yield on an average of 180 m3 /hr discharge for nominal drawdown. The slot size should be recommended as per the grain size. For medium to coarse-grained sand the slot opening may be 1/16". The distance between two shallow tube wells should be 150 to 200 m and between two deep tube wells may be 500 to 600m for safe discharge.

Table 16: Proposed Well Assembly in Gopalganj District for Well Construction (CGWB District Report, 1992)

Sl.No	**Discharge m3/hr**	**Proposed depth of well**	**Proposed Well Assembly**		**H.P. of Motor**
			Dia of the pipe	**Length of the pipe (m)**	
1	150	100	306 mm Housing 153 mm Slotted pipe 153 mm Blank pipe	25 24 51	22
2	200	150	357 mm Housing 204 mm Slotted pipe 204 mm Blank pipe	30 30 90	35

Possibility of construction of additional shallow tube wells On the basis of Dynamic Ground Water Resources Assessment - 2022, additional number of shallow tube well for alluvium area for each block has been calculated within the safe limit of the Stage of extractionup to 70% by considering unit draft for each tube well 1.95 ha m. Out of 14 blocks 7 blocks are taken based on stage of ground water development and as per the calculation, a total of 3889 number of tube wells can be constructed to fulfil the future demand of ground water. The block wise additional number of tube well is given in table below.

Table 17: Additional Nos. of STW feasible based on GW availability

Assessment Unit Name	Total Annual Ground Water (Ham) Recharge	Annual Extractable Ground Water Resource (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Stage of Ground Water Extraction (%)	Category	Projected SOD (%)	GW draft at Projected SOD	Additional Resource Available	Unit Draft of STW	Additional Nos. of STW feasible based on GW availability
Barauli	8178.89	7360.99	3771.65	994.96	51.24	safe	70	5152.693	1213.337	1.95	622
Gopalganj	6328.55	5695.69	2297.31	632.69	40.33	safe	70	3986.983	1076.017	1.95	552
Kateya	7875.33	7087.79	2735.44	491.92	38.59	safe	70	4961.453	1634.417	1.95	838
Panchdevari	4720.26	4248.24	2226.42	442.98	52.41	safe	70	2973.768	831.492	1.95	426
Phulwaria	6062.82	5456.53	2366.45	338.44	43.37	safe	70	3819.571	1298.519	1.95	666
Sidhwalia	5473.15	4925.83	1765.74	479.43	35.85	safe	70	3448.081	998.319	1.95	512
Thawe	3427.3	3084.57	1493.72	393.21	48.43	safe	70	2159.199	532.161	1.95	273

7.2 Water Conservation and Artificial Recharge

Although, all the 14 blocks are in safe category the artificial recharge should be encouraged to arrest the decline of ground water level caused by the increasing demand of ground water.

By considering entire non-monsoon rainfall as committed, excess monsoon rainfall can be safely harnessed to replenish groundwater table without affecting surface water resource. For the present calculation for artificial recharge, 60% of the normal monsoon rainfall for identified feasible areas is considered as available non- committed surface runoff.

Table 18: Identified Area, Computed Storage Volume and Source Water availability for Artificial Recharge

Area	Area Identified for AR	Volume of Desaturated zone	Source Water Requirement	Total Surplus Runoff available
(sq.km.)	(sq.km.)	(MCM)	(MCM)	(MCM)
2019.13	1112.82	55.20	85.01	1404.56

Considering hydrogeological and geomorphological set up and relative groundwater potentialities in the district, various types of artificial recharge/conservation structure has been recommended. Actual numbers of structures implementable may vary significantly based on scale of implementation. Based on available literature and previous experiences, unit cost of structures is also worked out. Block wise no are given in Table 16. Suitable area for artificial recharge has been identified where the post monsoon (2022) water level is more than 3 m bgl.

A general norm has been followed for the computation of number and type of recharge structures. Thus the type and number of recharge structures suggested are given below:

Nala Bunding	Lateral Recharge Shaft	Recharge Shaft	Injection Well in Village Tank	Percolation Tank	De-siltation of existing tank/pond/talab
2	13	26	64	1	48

In this map the tentative location for 1. De-siltation of existing tank/pond/talab and 2. Nalabund 3. Injection Well 4. Perlocation Tank in Village Tank has been shown. During the preparation of map, area affected by seasonal flood, lithology and areas where depth to water level is more than 3m have been considered.

As the number of recharge structures is primarily based on the availability of source water hence, it may vary as per actual field condition.

The number and type of the recharge structure is based on the published report on "Master Plan to Artificial Recharge".

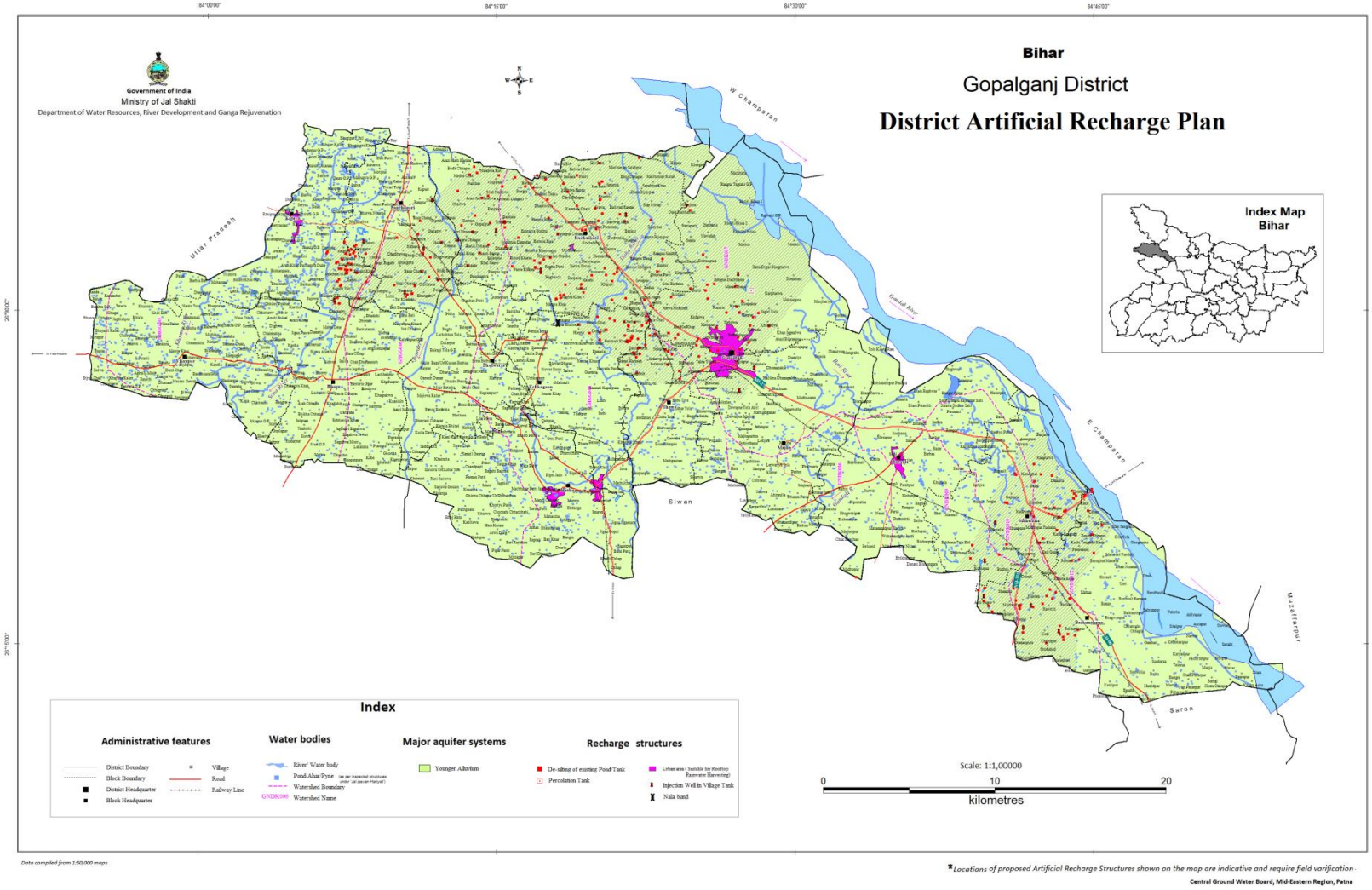

Figure 33: District Artificial Recharge Plan

Annexure I

SN	Location	Latitude	Longitude	May_22	Nov_22	Fluctuation	Altitude	May_22amsl	Nov_22 amsl
				m bgl		m	m amsl	m amsl	
1	Manjwalia	26.2869	84.6864	3.78	3.48	0.3	65.2	61.42	61.72
2	Barauli	26.3792	84.5875	2.9	2.1	0.8	68	65.1	65.9
3	Bhojpurwa	26.3206	84.6978	3.84	3.35	0.49	66	62.16	62.65
4	Bhore	26.4417	84.1125	4.39	2.95	1.44	78	73.61	75.05
5	Rampur2	26.4661	84.1725	2.35	1.75	0.6	76.3	73.95	74.55
6	Turkaha	26.4678	84.4467	3.06	3.29	-0.23	74.7	71.64	71.41
7	YadavpurSukal	26.4775	84.4333	3.23	3.57	-0.34	68	64.77	64.43
8	Hathua1	26.3672	84.3211	3.71	2.9	0.81	70	66.29	67.1
9	Jamunaha	26.5425	84.1897	5.93	4.03	1.9	78.7	72.77	74.67
10	Katiya	26.5667	84.0833	5.32	2.41	2.91	77	71.68	74.59
11	Lala Pachmawa	26.5333	84.0833	3.99	2.24	1.75	78	74.01	75.76
12	Misirbatha1	26.5333	84.1281	4.8	3.46	1.34	76.7	71.9	73.24
13	Jalalpur2	26.5961	84.3089	3.7	3.2	0.5	75.8	72.1	72.6
14	Bangra	26.3792	84.4458	3.64	2.1	1.54	71	67.36	68.9
15	BangraDeoria	26.3806	84.4472	3.68	2.42	1.26	71.8	68.12	69.38
16	Chanwabe	26.4000	84.3958	3.87	1.8	2.07	69	65.13	67.2
17	Lachchwar	26.3981	84.3689	3.32	1.88	1.44	70.3	66.98	68.42
18	Manjhwa1	26.3889	84.4831	3.39	2.8	0.59	71.2	67.81	68.4
19	Nunachapra	26.3450	84.4706	3.11	1.3	1.81	68.7	65.59	67.4
20	Phulwariya	26.4000	84.5167	3.22	1.52	1.7	67	63.78	65.48
21	Koharwalia	26.4580	84.0560	3.22	2.98	0.24	72.9	69.68	69.92
22	Bhatwa Bazar	26.5716	84.1631	5.12	2.4	2.72	79.2	74.08	76.8
23	Baikunthpur	26.2759	84.7840	3.73	2.7	1.03	66.1	62.37	63.4
24	Uchkagaon	26.4466	84.2856	4.29	2.6	1.69	72.3	68.01	69.7
25	Phulwariya	26.4705	84.2380	3.98	1.82	2.16	73	69.02	71.18

Annexure II

Result of Chemical Analysis of Ground Water (2022-23)

No	Block	Location	pH	EC(µS/cm @25°C)	F^-	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}	NO_3^-	PO_4^{3-}	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
1	Kateya	Kateya	7.03	552	1	17.75	250.1	0	40.34	0.42	0	250	76	15	9	3
2	Kateya	Lalpachmah	7.07	567	0.9	28.4	244	0	20	0.55	0	200	62	11	24	3
3	Bijaipur	Bijaipur	6.79	588	0.7	39.05	219.6	0	18	5.74	0	190	46	18	28	5
4	Bhore	Bhore	6.74	1948	0.9	269.8	561.2	0	99	29	0	745	250	29	90	13
5	Bhore	MishirBatra	6.84	1246	0.6	117.15	408.7	0	92	25	0	525	188	13	33	5
6	Hathua	Hathua	6.95	786	0.7	24.85	341.6	0	36	1.23	0	300	98	13	20	6
7	Thawe	Lacchawar	6.98	798	1	21.3	372.1	0	29	0.92	0	275	94	10	40	4
8	Barauli	Barauli	6.76	775	0.8	14.2	402.6	0	12	0.58	0	285	90	15	34	4
9	Manjha	Phulwaria/I	7.07	581	0.9	7.1	305	0	21	0.71	0	195	54	15	39	4
10	Manjha	Bishmbarap	7.1	598	0.9	10.65	292.8	0	23	0.76	0	200	54	16	40	4
11	Manjha	Manjha	6.86	1154	0.7	71	481.9	0	71	2.44	0.11	495	148	30	28	8
12	Kuchaikot	Jalalpur	6.7	1685	1.1	191.7	549	0	78	25	0	580	170	38	102	10
13	Kuchaikot	Police Thana	6.87	635	0.8	21.3	317.2	0	23	0.86	0	235	72	13	33	5
14	Gopalganj	Yadavpur	6.86	822	0.8	24.85	396.5	0	43	1.04	0	350	114	16	23	5
15	Gopalganj	Gopalganj	6.7	1309	1	74.55	616.1	0	36	2.38	0	470	22	101	72	10
16	Sidhawalia	Sidhawalia	6.72	941	0.7	39.05	402.6	0	64	7.47	0	380	126	16	29	8
17	Mohammadpur	Bhojpurwa	6.75	1032	0.6	35.5	530.7	0	25	0.79	0	415	120	28	35	9
18	Baikunthpur	Deokoli	6.8	1040	0.5	53.25	488	0	42	6.9	0	380	104	29	58	10
19	Unchkagaon	Kuchaikolt-	6.95	606	0.7	17.75	305	0	25	0.34	0	250	74	16	19	6
20	Phulwaria	Phulwaria	6.57	950	0.6	17.75	530.7	0	15	0.6	0	405	138	15	27	5
21	Panchdeuari	Panchdeuari	6.87	1622	0.8	213	506.3	0	79	0.59	0	575	184	28	92	11
22	Baikunthpur	Baikunthpur	6.73	1066	0.5	60.35	451.4	0	70	0.43	0	445	130	29	28	10
		Minimum	6.57	552	0.51	7.1	219.6	0	12	0.34	0	190	4	9.72	5.14	1.17
		Maximum	7.1	1948	1.06	269.8	616.1	0	99	29	0.11	745	130	70.5	157	40.5

Annexure III

Lithological Logs

Location	:	Gopalganj	Gopalganj
Coordinate	:	26.4678	84.4467

Depth Range (m)		Thickness (m)	Litholog
From	To		
0	6.7	6.7	Soil
6.7	12.87	6.17	Sand
12.87	18.97	6.1	Sand
18.97	24.97	6	Clay
24.97	34.12	9.15	Sand & Kankar
34.12	40.27	6.15	Clay
40.27	49.56	9.29	Sand & Kankar
49.56	65.01	15.45	Sand
65.01	83.46	18.45	Sand & Kankar
83.46	86.61	3.15	Clay
86.61	98.75	12.14	Clay & Kankar
98.75	104.9	6.15	Sand & Kankar
104.9	108.4	3.5	Clay & Kankar
108.4	114.2	5.8	Sandstone Chips
114.2	135.65	21.45	Clay
135.65	141.8	6.15	Sandy Clay
141.8	150.95	9.15	Sand
150.95	157.2	6.25	Sand
157.2	193	35.8	Clay
193	201	8	Sand & Kankar

Location	:	Bijaipur	Gopalganj
Coordinate	:	26.4678	84.4467

Depth Range (m)		Thickness (m)	Litholog
From	To		
0	7	7	Clay
7	13.5	6.5	Sand
13.5	16.6	3.1	Clay
16.6	28.8	12.2	Gravel
28.8	47.1	18.3	Clay
47.1	98.9	51.8	Gravel
98.9	129.4	30.5	Sand
129.4	172	42.6	Gravel
172	200	28	Sand

Location	:	Kateya	Gopalganj
Coordinate	:	26.5667	84.0833

Depth Range (m)		Thickness (m)	Litholog
From	To		
0	16.7	16.7	Clay
16.7	19.7	3	Clay
19.7	31.9	12.2	Sand
31.9	47.2	15.3	Sand
47.2	56.4	9.2	Sand
56.4	62.5	6.1	Sand
62.5	71.5	9	Sand
71.5	90	18.5	Sand
90	99	9	Sand
99	111.3	12.3	Sand
111.3	117.4	6.1	Sand
117.4	135.7	18.3	Sand
135.7	157.1	21.4	Sand
157.1	184.5	27.4	Sand
184.5	202.8	18.3	Sand

Location	:	Uchkagaon	Gopalganj
Coordinate	:	26.4466	84.2856

Depth Range (m)		Thickness (m)	Litholog
From	To		
0	12.7	12.7	Sand
12.7	21.9	9.2	Clay
21.9	31	9.1	Kankar
31	37.1	6.1	Clay
37.1	46.3	9.2	Sand
46.3	52.4	6.1	Clay
52.4	55.4	3	Sand
55.4	61.4	6	Clay
61.4	67.6	6.2	Gravel
67.6	79.8	12.2	Clay
79.8	92	12.2	Kankar
92	98.9	6.9	Sand
98.9	128.9	30	Gravel
128.9	146.9	18	Sand
146.9	156.1	9.2	Gravel
156.1	168.3	12.2	Clay

168.3	177.3	9	Gravel
177.3	180.5	3.2	Clay
180.5	200	19.5	Sand

Location	:	Yadavpur dubey tola	Gopalganj
Coordinate	:	26.4678	84.4467

Depth Range (m)		**Thickness**	**Litholog**
From	To	(m)	
0	9.7	9.7	Sand
9.7	15.8	6.1	Sand
15.8	24.9	9.1	Sand
24.9	28	3.1	Clay
28	40.1	12.1	Sand
40.1	58.4	18.3	Sand
58.4	76.7	18.3	Sand
76.7	92	15.3	Clay
92	104.2	12.2	Clay
104.2	107.3	3.1	Sand
107.3	113.4	6.1	Sand
113.4	134.7	21.3	Clay
134.7	153	18.3	Sand
153	168.3	15.3	Sand
168.3	200	31.7	Clay

Location	:	Barauli	Gopalganj
Coordinate	:	26.3792	84.5875

Depth Range (m)		**Thickness**	**Litholog**
From	To	(m)	
0	18.9	18.9	Clay
18.9	25.2	6.3	Clay
25.2	37.5	12.3	Sand
37.5	49.8	12.3	Clay
49.8	65.25	15.45	Sand
65.25	83.7	18.45	Sand
83.7	105.15	21.45	Sand
105.15	120.6	15.45	Sand
120.6	148.2	27.6	Sand
148.2	151.35	3.15	Sand
151.35	160.65	9.3	Sand With Chips
160.65	197	36.35	Clay
197	200	3	Kankar

Location	:	Hathua	Gopalganj
Coordinate	:	26.3625	84.3042

Depth Range (m)		Thickness (m)	Litholog
From	To		
0	6	6	Surface Soil
6	18	12	Clay with kankar
18	31	13	Sand
31	55	24	Fine Sand
55	79.8	24.8	Clay with kankar
79.8	85.9	6.1	Fine Sand
85.9	104.2	18.3	Coarse Sand
104.2	107.3	3.1	Fine Sand
107.3	119.5	12.2	Coarse Sand
119.5	134.7	15.2	Clay
134.7	168.3	33.6	Fine Sand
168.3	201	32.7	Coarse Sand

Location	:	Baikunthpur	Gopalganj
Coordinate	:	26.2758	84.7839

Depth Range (m)		Thickness (m)	Litholog
From	To		
0	13.1	13.1	Sand
13.1	46.6	33.5	Clay
46.6	52.7	6.1	Sand
52.7	80.2	27.5	Sand
80.2	107.6	27.4	Sand
107.6	138.1	30.5	Kankar
138.1	144.2	6.1	Sand
144.2	154	9.8	Clay
154	171.7	17.7	Clay
171.7	180.8	9.1	Gravel
180.8	199.1	18.3	Clay
199.1	205.2	6.1	Sand

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Disclaimer

The Report has been prepared based on the available data, observations from fields and discussion with the local farmers. Additional data, incorporated in future, may change the understanding of hydrogeological scenario of the area.