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

Madhepura District
Bihar

मध्य पूर्वी क्षेत्र, पटना

Mid Eastern Region, Patna

Report on

NATIONAL AQUFER MAPPING AND MANAGEMENT PLAN

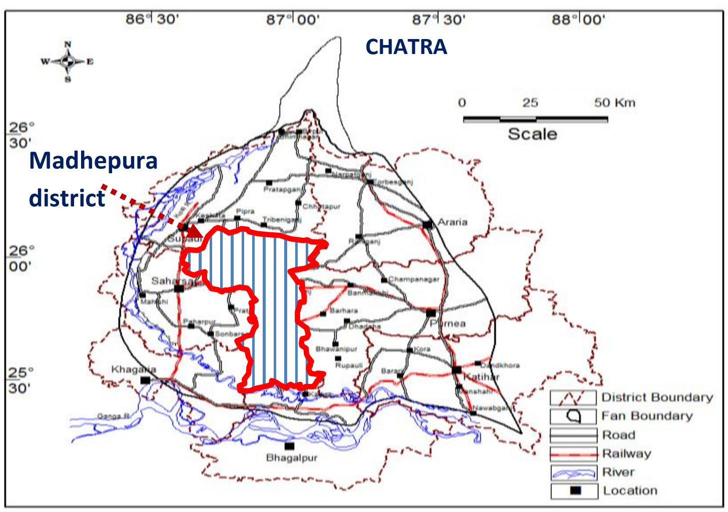
(NAQUIM) OF MADHEPURA DISTRICT,

(BIHAR)

(AAP: 2020-21)

Submitted by

Smt. Richa Gautam



Government of India

Ministry of Jal Shakti

Central Ground Water Board

Mid Eastern Region

Patna, Bihar

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Thanks to every person who directly or indirectly contributed in the final culmination of this report.

Smt. Richa Gautam (Scientist-B)

Central Ground Water Board
Northern Region,
Lucknow

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DISTRICT AT A GLANCE

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1.	**GENERAL INFORMATION**	
	I. Geographical Area (Sq. Km.)	1788
	Administrative Divisions	Madhepura,Uda Kishunganj 13 blocks, 170 panchayats and 434 revenue villages.
	II. Population (As per 2011 Census)	Total: 2,001,762 Rural: 1,913,301 Urban: 88,461
	III. Average Annual Rainfall (mm)	1231
2	**GEOMORPHOLOGY**	
	Major Physiographic Units	Younger Alluvium with Newer Flood Plains
	Major Drainages	Kosi Dhars
3	**LAND USE (area in sqkm)**	
	Forest Area	0
	Net Sown area	1020
	Total Cropped	2027
	Cultivable area	1455
4	**MAJOR SOIL TYPES**	Sandy loam, Loam, silty loam
5	**AREA UNDER PRINCIPAL CROPS**	Rice, wheat
6	**IRRIGATION BY DIFFERENT SOURCES** (Areas in sq km. 2011-12)	
	Dug wells	-
	Tube wells/Bore wells	480
	Tanks/ponds	-
	Canals	90
	Other Sources	-
	Net Irrigated Area	570
	Gross Irrigated Area	1400

7	**NUMBER OF GROUND WATER MONITERING WELLS OF CGWB (As on 31-03-2019)**	
	No. of Dug wells	17
	No. of Piezometers	Nil
8	**PREDOMINANT GEOLOGICAL FORMATIONS**	Quaternary Alluvium
9	**HYDROGEOLOGY**	
	Major water bearing formations	Sand zones in Quaternary Alluvium
	Pre-monsoon Depth to water level during 2019	2.96-6.12 m bgl
	Post-monsoon Depth to water level during 2019	1.48-3.54 m bgl
10	**GROUND WATER EXPLORATION BY CGWB (As on 31-03-2017)**	
	No. of well drilled (EW,OW, PZ, SH, Total)	9
	Depth Range (m)	100m
	Discharge (m/s)	-
	Storativity (s)	-
	Transmissitivity (m^2/day)	-
11	**Ground Water Quality**	Fresh and Portable

12	**DYNAMIC GROUND WATER RESOURCES (2020) IN**	
	Annual Replenishible Ground Water Resources	60872.35 Ham
	Net Annual Ground Water Draft	42988.44 Ham
	Projected Demand for Domestic and Industrial Uses up to 2025	17421.05 Ham

	Stage of Ground Water Development	70.62%
13	**GROUND WATER CONTROL AND REGULATION**	
	No. of OE Blocks	Nil
	No. of Critical Blocks	Nil
	No. of semi-critical Blocks **No. of safe Blocks**	7 6
14	**MAJOR GROUND WATER PROBLEMS AND ISSUES**	District forms part of Kosi mega fan and experiences seasonal flooding and water logging in many parts.

AQUIFER MAPPING AND MANAGEMENT PLAN OF MADHEPURA DISTRICT

By

Smt. Richa Gautam

Jr. Hydrogeologist, Scientist-B

1.0. Introduction

The National Project on Aquifer Management (NAQUIM) is an initiative of the Ministry of Jal Shakti, Government of India, for mapping and managing the entire aquifer systems in the country. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the portability of ground water.

Central Ground Water Board (CGWB), MER has carried out the Aquifer Mapping Programme in Madhepura District of Bihar, with the broad objective of preparing Block wise management plan for the district. The study integrates multiple disciplines and scientific approaches, including hydrogeology, geophysics, hydrochemistry, exploratory drilling and management approaches.

1.1. Objectives

The major objectives of Aquifer Mapping are-

i. To identify and map subsurface aquifer geometry at the micro level.
ii. To evaluate aquifer parameters, type of aquifers, ground water regime behaviors, Hydraulic characteristics and geochemistry of multi-layered aquifer systems on 1:50,000 scale.
iii. To quantify the available groundwater resources and to propose plans appropriate to the scale of demand and aquifer characteristics.
iv. Finalizing the approach and methodology on which National Aquifer mapping Programme of the entire country can be implemented.

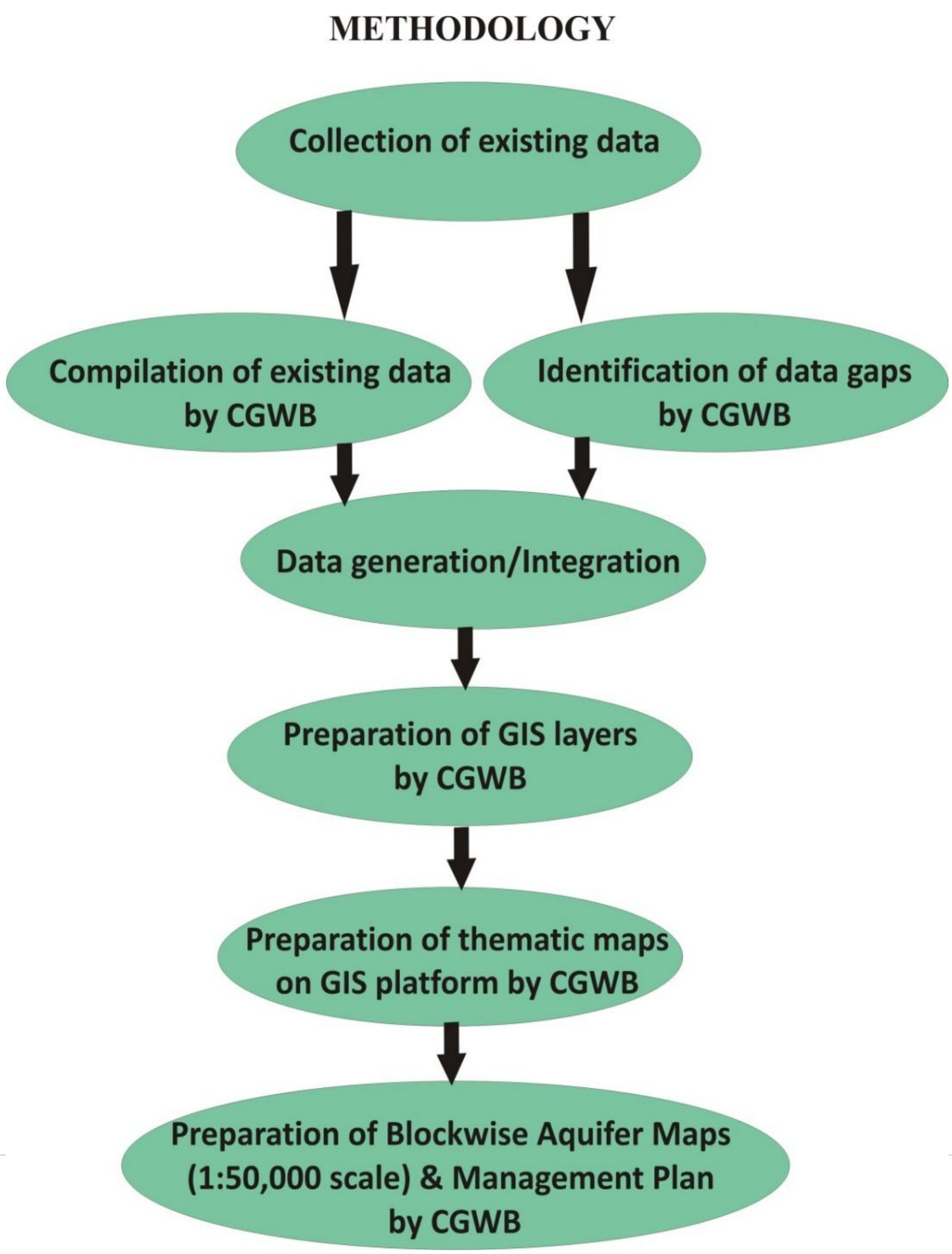
1.2. Scope of the Study

Systematic mapping of an aquifer in Madhepura district includes activities like collection and compilation of available information on aquifer system, demarcation of their extent and their characterization, analysis of data gap, generation of additional data for filling the identified data gap and finally preparation of aquifer maps at the desired scale. Results of these studies will contribute significantly to resource management which would help planners, policy makers and other stakeholders. Aquifer mapping studies would help to achieve drinking water security, improved irrigation facilities and sustainability in water resource development in the district as a whole

1.3. Approach and Methodology

The work plan for the aquifer mapping envisaged compilation, integration, validation and analysis of the existing database at one platform with a view to generate various thematic maps like land use/ land cover map, geomorphology map, geology, hydrogeology etc. using various GIS and geo-scientific computer software.

The major activities involved in this process include i) collection of data from various sources like CGWB records, State Government agencies and available literature/data on internet; ii)compilation of existing data; iii) identification of data gaps; iv) generation of data for filling data gaps and finally v) preparation of aquifer maps and Management Plan.The overall methodology for aquifer mapping is shown in the flow chart given below-



1.4. Location of the Study area

The study area forms North-eastern part of Bihar at latitude between 25°. 34 to 26°.07' and longitude between 86° .19' to 87°.07'. It is situated in the Plains of River Koshi. Madhepura district covers an area of 1,788 square kilometres. The district has 2 subdivisions - Madhepura and Uda Kishanganj. It is surrounded by Araria and Supaul district in the north, Khagaria and Bhagalpur district in the south, Purnia district in the east and Saharsa district in the West. Madhepura town is the administrative headquarters of this district. It is divided into 13 administrative blocks. Study area is bounded by Survey of India top sheet no.72J/12, 72K/9, 72K/10, 72K/13, 72K/14, 72K/11, 72J/16, 72N/4, 72O/1, 72O/2, 72K/15, 72O/3. The district has 2 sub-divisions - Madhepura and Uda Kishanganj, 13 blocks, 13 police stations, 170 panchayats and 434 revenue villages (Table 1, Fig 1).

Table 1: Administrative details of Madhepura district

Sl	*Sub Division*	*Blocks / Circles*	*Panchayat*	*Village*
1	Madhepura	Madhepura	17	49
2		Singheswar	13	27
3		Murliganj	17	45
4		Gamhariya	8	12
5		Ghelardh	9	16
6		Kumarkhand	21	71
7		Shankarpur	9	9
8	Uda Kishunganj	Chousa	13	43
9		Purani	9	31
10		Gwalpara	12	51
11		Bihariganj	12	22
12		Udakishunganj	16	44
13		Alamnagar	14	29
			170	449

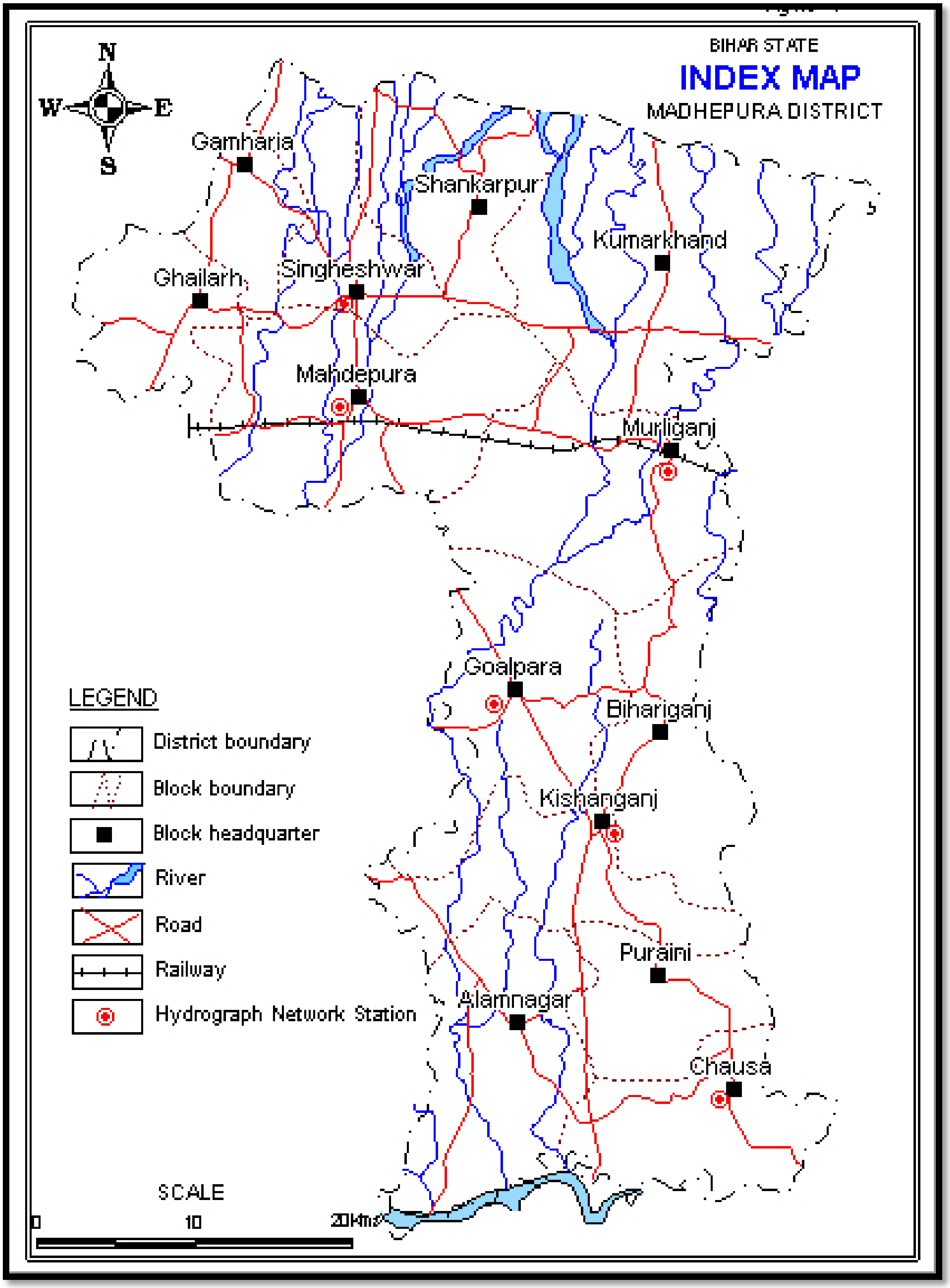


Figure 1: Administrative map of Madhepura district

1.5. Demography:

As per census of 2011 Madhepura had population of 2,001,762 of which male and female were 1,047,559 and 954,203 respectively (Table 1). There was change of 31.12 percent in the population compared to population as per 2001. The initial provisional data released by census India 2011 shows that density of Madhepura district for 2011 is 1,120 people per sq. km. Average literacy rate of Madhepura in 2011 were 52.25 compared to 36.07 of 2001. If things are looked out at gender wise, male and female literacy were 61.77 and 41.74 respectively. With regards to SexRatio in Madhepura it stood at 911 per 1000 male compared to 2001 census figure of 915. The average national sex ratio in India is 940 as per Census2011Directorate. Child sex ratio is 930 girls per 1000 boys compared to figure of 927 girls per 1000 boys of 2001 census.

Table 2: Demographic details of Madhepura district

Description	**2011**	**2001**
Actual Population	2,001,762	1,526,646
Male	1,047,559	797,180
Female	954,203	729,466
Population Growth	**31.12%**	**29.45%**
Area Sq. Km	1,788	1,788
Density/km2	**1,120**	**854**
Proportion to Bihar Population	1.92%	1.84%
Sex Ratio (Per 1000)	**911**	**915**
Average Literacy	**52.25**	**36.07**
Male Literacy	61.77	48.80
Female Literacy	41.74	22.11
Literates	**834,577**	**431,480**
Male Literates	517,666	305,330
Female Literates	316,911	126,150
Child Proportion (0-6 Age)	**20.21%**	**21.64%**

In total 88,461 people lives in urban areas whereas 95.58 % population i.e. 1, 913, 301 of the districts lives in rural areas of villages. Agriculture is the main livelihood of most of the population.

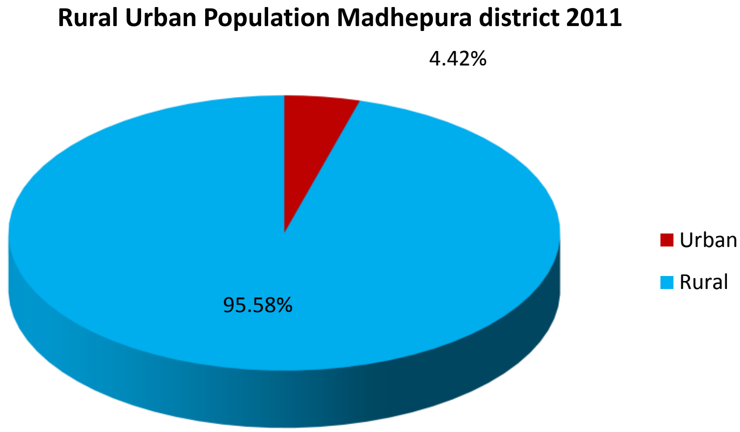


Figure 2: Pie diagram depicting the urban rural population in Madhepura district

1.6.Climate and Rainfall

The climatic condition of the area is generally humid and tropical. There are five groups of the climate condition on an average which prevail as winter (December to February), spring (February to April), summer (April to June), monsoon (June to September) and autumn (September to December). The maximum temperature of this district ranges from 35°C to 40°C and the minimum temperature varies from 7°C to 9°C. The month of April generally experiences hot wave due to dry wind. The month of May experiences wind from east with fall of temperature gradually and thereafter the SW monsoon wave starts. The month of January is having minimum temperature of 40°C and experiences cold wave due to NE monsoon due to western disturbances. The normal rainfall is 1231 mm. The rainfall during the SW monsoon i.e. months commencing from June to September, usually amounts to 80.85% of the total rainfall.

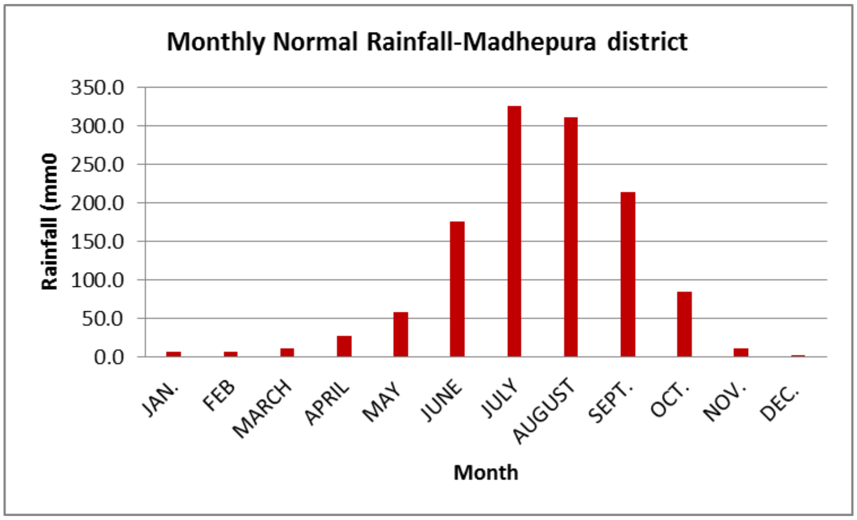


Figure 3 : Rainfall variation over the year of Madhepura

The month of July usually is the month of maximum rainfall which is about 32.6% of total rainfall in the area the months of November and December are generally having scanty to free rain period. The district has also rainfall during winter due to north-eastern monsoongenerally having scanty to free rain period. The district has also rainfall during winter due to north-eastern monsoon.

1.7.Drainage

The Madhepura district is located at the north-eastern parts of Bihar state, which is situated in the middle parts of Ganga Basin. The district falls in the Kosi Sub-basin. Originating at an altitude of ~7000 m amsl in the Tibet Himalayas, the Kosi River form an important northern tributary of the Ganga. The Kosi is the third largest Himalayan River, after the Indus and the Brahmputra. The river has remained dynamic from historic parts and as such few palaeochannels of the river are traced in the district. Mis-fit channels (locally known as *Dhars)*, mosly occupying the palaeochannels of Kosi, flow across the district in anorth-south fashion. The rivers possess significant drainage during monsoon. The Kosi River has formed a megafan of ~13,000 km2 in Bihar state. The Madhepura district is situated at the south- eastern parts of the megafan (Fig.3). The district is regularly visited by the flood water of Kosi. The flood of the year 2008 owing to breach of eastern embankment at Kusaha, was devastating in nature. This created havoc with large-scale inundation and devastation in Supaul, Saharsa and Madhepura districts, causing huge property and life loss along with the loss in agriculture.

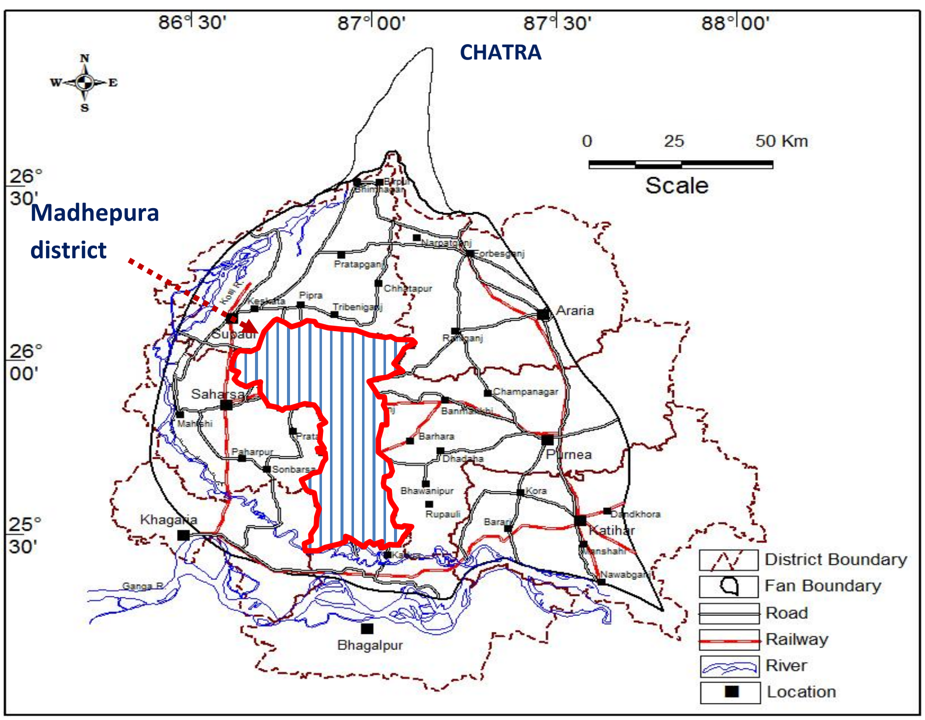


Figure 4: Basin/ Sub basin map of Madhepura district

1.8.Land use/ Land Cover

The total geographical area (TGA) of Madhepura is 1.8 lakh hectare. The largest block of the district is Kumarkhand which comprises of a TGA of 25,134 hectare i.e. about 13.92 percent of the TGA of the district. Murliganj, Madhepura, Alamnagar and Kishanganj are the other large blocks of the district which comprise of 10.92 percent, 10.24 percent, 9.82 percent and 8.95 percent of the total geographical area respectively. Gamharia is the smallest block of the district which comprise of 6,416 hectare i.e. around 3.55 percent of total geographical area of the district. It has been observed from agriculture department's records that the Gross Cropped Area of the district is 1,81,016 hectare and the Net Sown Area is 1,53,420 hectare. Kumarkhand and Murliganj both occupies around 29.8 percent of the Gross Cropped Area of the district. This is followed by Madhepura and Gwalpara where both equally occupy 19 percent of the gross cropped area each. Singheshwar block contributes in the gross cropped area to the extent of 8 percent which is further followed by Bihariganj and Chausa block both of which contributes to the extent of 13.4 percent in gross cropped area of the district.

Table 3: Land use pattern of Madhepura district (Area Ha)

S.no.	Block	Total Geographical Area	Gross cropped	Net Sown Area	Area Sown More Than Once	Cropping Intensity	Area under forest	Area under wasteland	Area under other uses
1	Alamnagr	17745	11287	5869	5418	192	0	0	5418
2	Bihariganj	10657	12715	11734	982	108	0	0	982
3	Chausa	13700	11529	8765	2764	132	0	0	2764
4	Gamharia	6416	7125	6356	769	112	0	228	540
5	Ghailarh	9169	6793	6588	205	103	0	0	205
6	Gwalpara	11462	15576	14364	1212	108	0	0	1212
7	Kishanganj	16163	10555	8515	2039	124	0	0	2039
8	Kumarkhand	25134	29497	26486	3011	111	0	870	2140
9	Madhepura	18496	18766	15354	3412	122	0	0	3412
10	Murliganj	19 726	24425	21422	3003	114	0	32	2972
11	Puraini	8910	7775	6768	1007	115	0	0	1007
12	Shankarpur	10379	10559	8480	2079	125	0	0	2079
13	Singheshwar	12586	14412	12717	1695	113	0	128	1567
	Total	180642	181016	153420	27596	118	0	1258	26337

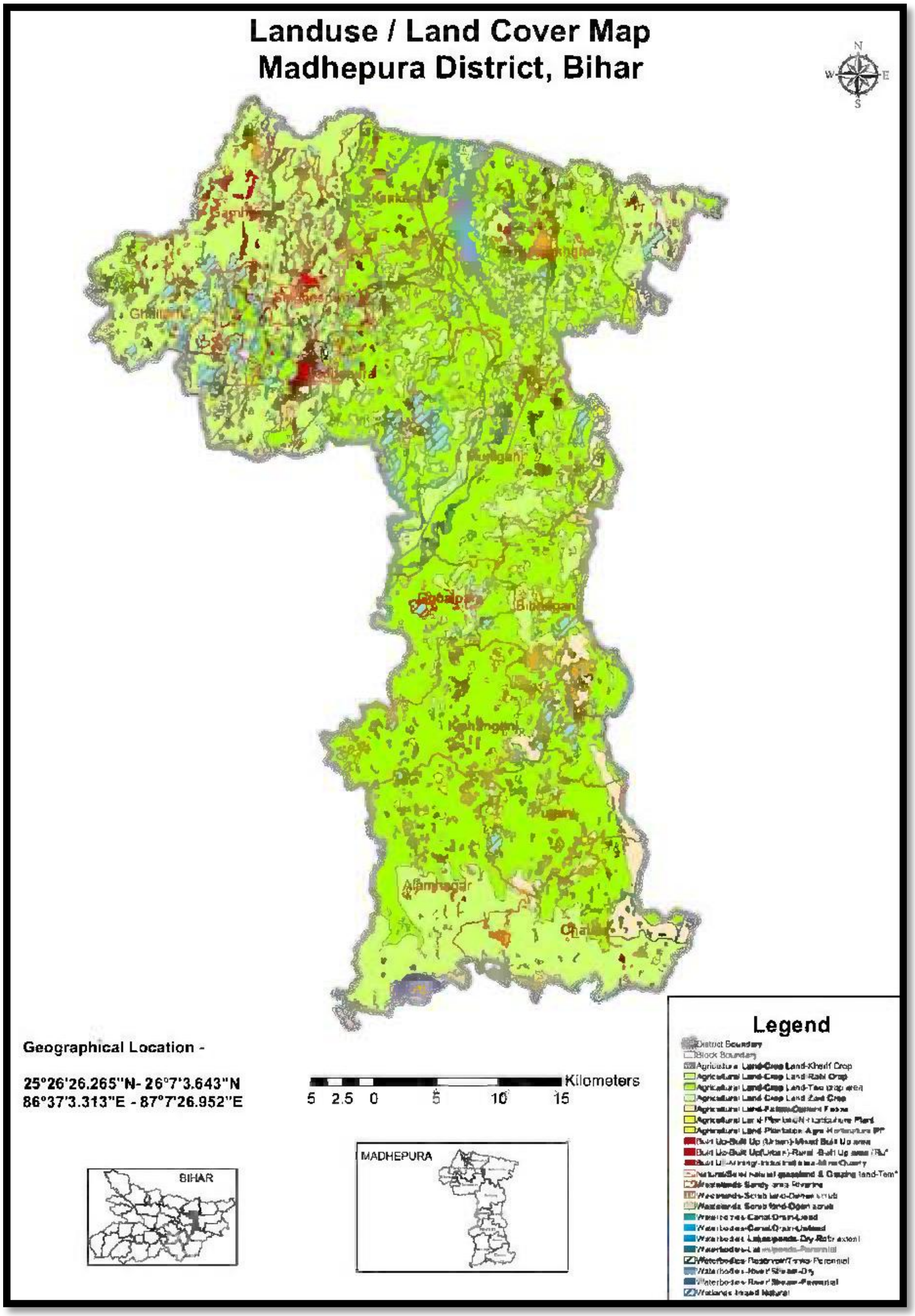


Figure 5 : LULC Map of Madhepura

1.9.Agriculture

Agriculture is the main occupation of the people of the district. The ravaging Kosi has been considerably tamed and Kosi project has helped in changing the cropping pattern. The principal crops are paddy, jute, maize and wheat. The district is growing jute and maize in large quantities. Both bhadai and aghani paddy are grown. Marua and oil-seeds continue to be grown. Cultivation of sugar-cane has increased considerably. Main Horticulture crops are Mango, Banana, Guava, Coconut and Litchi. Each C.D. Block has one seed multiplication farm. Coconut Development Board owned by Central Govt. is functioning in this district. In order to represent comprehensive picture, crops have been categorized into various groups such as Cereals, Coarse cereals, pulses etc as indicated in table 2.1. Further, block wise analysis of status of irrigation of various crop groups have been done to reflect a broad picture of the various blocks of the district. It is imperative from the table 2.1 that total irrigated area in the district is 1.39 lakh hectare. Out of this, the maximum extent of irrigated area is in Kharif season (61,405 ha) followed by Rabi season (49,433 ha). Though the irrigated area in Kharif is larger than the irrigated area in rabi seasons, the percentage of irrigated area to total area (of the season) is less in Kharif itself as the total area under cultivation in Kharif is around 0.85 lakh hectare. It implies that the extent of irrigation during kharif is near about 72 percent only while the same during Rabi season is 93 percent. Out of the total area under cultivation in the district, 40.9 percent area (69,379 ha) is covered by cereals crop during Kharif season, 18 percent (30,572 ha) during Rabi season and 1 percent (1,629 ha) during summer season. Coarse cereals occupy a total of 24.3 percent (41,185 ha) of the gross cropped area (5.1 percent i.e. 8,668 ha during Kharif, 10.6 percent i.e. 18,037 ha during Rabi and 8.5 percent i.e. 14,481 ha during summer season) which is mostly irrigated (21.24 percent irrigated and 3.01 percent rainfed). In case of Pulses, it occupies 11.1 percent (18,868 ha) of the gross cropped area of the district. During Kharif season, 0.8 percent of the gross cropped area of the district is covered by pulses while the same during Rabi and summer are 1 percent and 9.4 percent respectively. The area under Oilseed is limited to the tune of 2 percent (3,314 ha) of the gross cropped area of the district. Most of the pulses are cultivated during Rabi season. Fiber crop also occupies a significant position in the gross cropped area of the district.

Table 4 : Area wise , crop wise irrigation status

Crop Type	Kharif Area (Ha)		Rabi Area (Ha)		Summer Area (Ha)	
	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed
Cereals	55952	427	676	895.3	1530	99.14
Coarse Cereals	4405	4263.1	17966	71.06	13697	784.3
Pulses	18.29	1300.2	243.46	1374	563.5	15369
Oil Seeds	552.5	65.53	1548	1148	0	0
Fibre	20.49	4222.7	0	0	0	0
Any other Crops	457	114.12	0	0	0	0
Horticulture & Plantation (Annual)					12316	6719

1.10.Cropping pattern

Agriculture is an integral part of economy of the district. It provides direct employment to more than 70 percent of the population of the district. Wheat, Maize, Gram, Pea, Masoor, Khesari, Rape & Mustard, Tulsi, Sunflower, Kusum, Chili, Garlic &Sugarcane are the major crops grown in the district. Over the years there has been a shift from subsistence farming to crop diversification in the district as the area under commercial crops like fruits and vegetables has increased substantially. Since, Land is an inelastic resource in the district, the production and productivity of the crops can be increased by irrigation, use of high yielding varieties, bio fertilizers etc. Higher production and productivity of major crops ensure higher returns to the farmers. As per Department of Agriculture, Madhepura, during Kharif season, the production of agricultural crops under irrigated and rain fed conditions have been observed to be 16 lakh Qtl and 4.0 lakh Qtl respectively. It is noteworthy, that the productivity of agricultural crops increases remarkably when cultivated in irrigated conditions as the productivity of Kharif crops in irrigated conditions is 2600 Kg per ha compared total productivity of 1700 Kg per ha in rain fed conditions. The cost of cultivation of irrigated Kharif crop is Rs 26,500 per ha as compared to Rs, 19,000 per ha for rain fed crops The difference in the cultivation cost arises because of capital expenditure in constructing irrigation assets as well as recurring expenses on power, diesel etc. During Rabi season, the production of agricultural crops under irrigated and rain fed conditions have been observed to be 13.6 lakh Qtl and 0.6 lakh Qtl respectively. The productivity of agricultural crops cultivated in irrigated conditions is 2750 Kg per ha and in rain fed conditions is 1680 Kg per ha. The significant increase in productivity is observed for agricultural crops which are irrigated because of better growth of agricultural crops in irrigated conditions. The cost of cultivation of irrigated Rabi crop is Rs 27600 per ha as compared to Rs 18,750 per ha for rain fed crops.

Table 5: Production and productivity of major crops

Irrigated Cultivation					**Rain fed Cultivation**			
Season	Production (lakh Qt)	Yield (Kg/Ha)	Coc (Rs./Ha)	Area (Ha)	Prodution (lakh Qt)	Yield (Kg/Ha)	Coc (Rs.Ha)	Area (Ha)
Kharif	16	2600	26500	61405	4.0	1700	19000	23392
Rabi	13.6	2750	29050	49433	0.6	1680	19000	3489
Summer	3.7	2340	27600	15790	1.9	1150	18750	16252

1.11.Irrigation practice

Madhepura is one of the districts which due to various reasons in the past did without much of artificial irrigation facilities. The need of a systematic irrigation had not been felt before as the rainfall was generally ample and soil in most parts retained moisture, and the large number of rivers, rivulets and marshes assured facility of water. Still after independence, considerable attention has been paid to the provision of irrigation facility in the district by means of flood control measures as well as irrigation channels, etc. The gigantic Kosi project has resulted in extension of irrigation facilities in the district. In addition to this various irrigation facilities have been provided in the district through a number of medium and minor irrigation schemes, surface percolation wells, open borings with strainer, rahat pumps, low lift pumps and hand pumps. The agricultural activities in the district is carried out under both irrigated and rainfed system. Out of the gross cropped area of 1.8 lakh ha, the extent of irrigated land is 1.27 lakh ha, i.e. 70% of total cropped area. Considering the block-wise data, percentage of gross irrigated land to gross cropped area is maximum in Ghailarh block (91.1%), followed by Gamharia block (90.1%). The same is least in Shankarpur (53%). A total of 6241.09 ha of area is under rain fed cultivation. The area under partial irrigation has been reported to be 6241.09 ha across all the blocks the district.

Table 6: Irrigation based classification

Block	Gross Irrigated Area (Ha)	Net Irrigated Area (Ha)	Partially Irrigated	Un-irrigated /Rainfed (Ha)
Alamnagar	8142	4234	119.71	1515
Bihariganj	10460	9652	520.41	1562
Chausa	6780	5155	192.79	3418
Gamharia	6419	5731	166.19	459
Ghailarh	6191	6004	226.57	357
Gwalpara	12247	11294	513.92	2557
Kisanganj	8249	6655	248.17	1612
KumarKhand	18594	16696	817.22	8973
Madhepura	11976	9799	1029.49	4526
Murliganj	16845	14774	1047.35	5600
Puraini	5037	4385	179.77	2203
Shankarpur	5606	4502	633.97	3344
Sigheshwar	10090	8903	545.53	3268
Total	126636	107784	6241.09	39394

1.12.Geomorphology

The district is forming a small segment of North Ganga Plain in Bihar within Kosi sub-basin. It has a general gentle slope from north to south along which the Kosi submits its course together with its tributaries. The land elevation of the district varies within 54m and 35 m amsl, with the average slope at ~1:4210.Geomorphologically, the district is a part of the Kosi mega fan. A number of old channel beds of Kosi are traceable in Madhepura district. The river Kosi is one of the tributaries of Ganga in the north Bihar having its own several tributaries in the fan deposits whose apical part lies in the kingdom of Nepal near Chatra. The shifting of Kosi River has taken place since pre-historic times due to the heavy sedimentation deposits brought by the river from upland of Himalaya. Number of small channels occupies the abandoned channels of Kosi. Those include Tillash, Chillouni etc known as *Dhars*. The flow of tributaries is tectonically controlled in the N-S direction. The paleao channels i.e.Kosi *Dhars* are ephemeral drainage channels during the monsoon exhibiting characteristically meandering pattern. These channels are conspicuous characterized by a network of shallow interlaced stream in the flat terrain.The Kosi river carries enormous heavy load of silt and sand during flood of monsoon, ultimately which are left over on the plain area after recession of flood. These cause shifting of the channels of Kosi *Dhars* and in the low lying areas of *Chaurs* forming the pools of stagnant water and low marshy lands causing thereby the area under water logging. Though the major river Kosi has made the regional architecture of the district, numerous interconnected minor rivers participate in carving out features of the plains by reworking and redistributing the sediments deposited by the river Kosi. These small streams (basically groundwater fed) with clayey beds mostly follow the old channels and traverse the district Madhepura in a north-southfashion.

1.13.Soil

Soil of the area constitutes part of large inland deltaic deposits of huge granular silt-sand grade, transported by river Kosi. The estimated probable load of silty-sand with clay is about 25 MCM/year. The soil of the area is Younger Alluvium deposited by Kosi River. The area, generally inundated by flood of Kosi, possesses the soil of sandy loam to sandy deposits. Elsewhere, the soil is of heavier texture. The soils association types-Recent alluvium, non-calcareous, non-saline is overlying the entire area, mostly high to medium textured, acidic to neutral and generally yellowish to white to light grey in color.

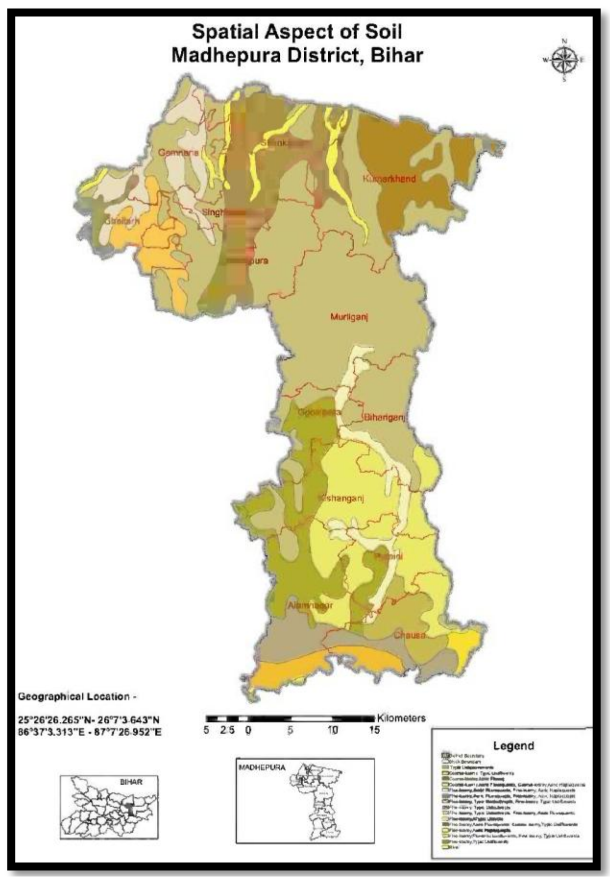


Figure 6 : Map of Soil profile of Madhepura

1.14.Geological setup

The kosi basin covering parts of Madhepura district has been geologically mapped by GSI (Operation Bihar, Patna). The entire Madhepura district is a part of Kosi alluvium fan, consisting of a thick pile of unconsolidated quaternary alluvium sediments of Holocene age which are multicyclic sequence of fine to coarse sand with silt in varying proportions with occasional clay, Kankars, and pebbles.The quaternary alluvium sediments of the area have been classified into three geological units. The classification is based mainly on the difference between the natures of the sediments, Degree of oxidation, Color, Compaction, Peologenic character (soil profile). Their relative chronology is based on the principle that successive older units occupy successive higher elevation. The three units have been given informal stratigraphic names and status as follows:-

Table 7: Morphostratigraphy and lithostratigraphy covering Eastern Kosi Basin (Madhepura district)

Morphostratigraphy	Lithology	Lithostratigraphy	Age
Diara Plain: Aeolian sand and sand splays (present Meander Belt)	over lapping alternation of light yellow to grey fine to medium sand with occasional silt and clay , pedigenesis yet to start . Channel bars, point dunes, recent ripples and sand splays present.	Diara formation	Present day
Kosi Terrace (older meander belt)	Alternative sequence of light yellow fine sand and silt with partings of silt and sandy silt	Kosi formation	Holocene (unclassified sediments)
Purnea surface	a) Fan facies – within the kosi purnea fan this constitute formation mainly light brownish yellow sand of various size , increasing towards depth with occurrence of pebbles with parting of fine sand & silt. b) flood plain facies – yellow silt and yellowish grey clay with rock fragments in the outer margin of kosi fan	Purnea formation	Holocene (unclassified sediments)

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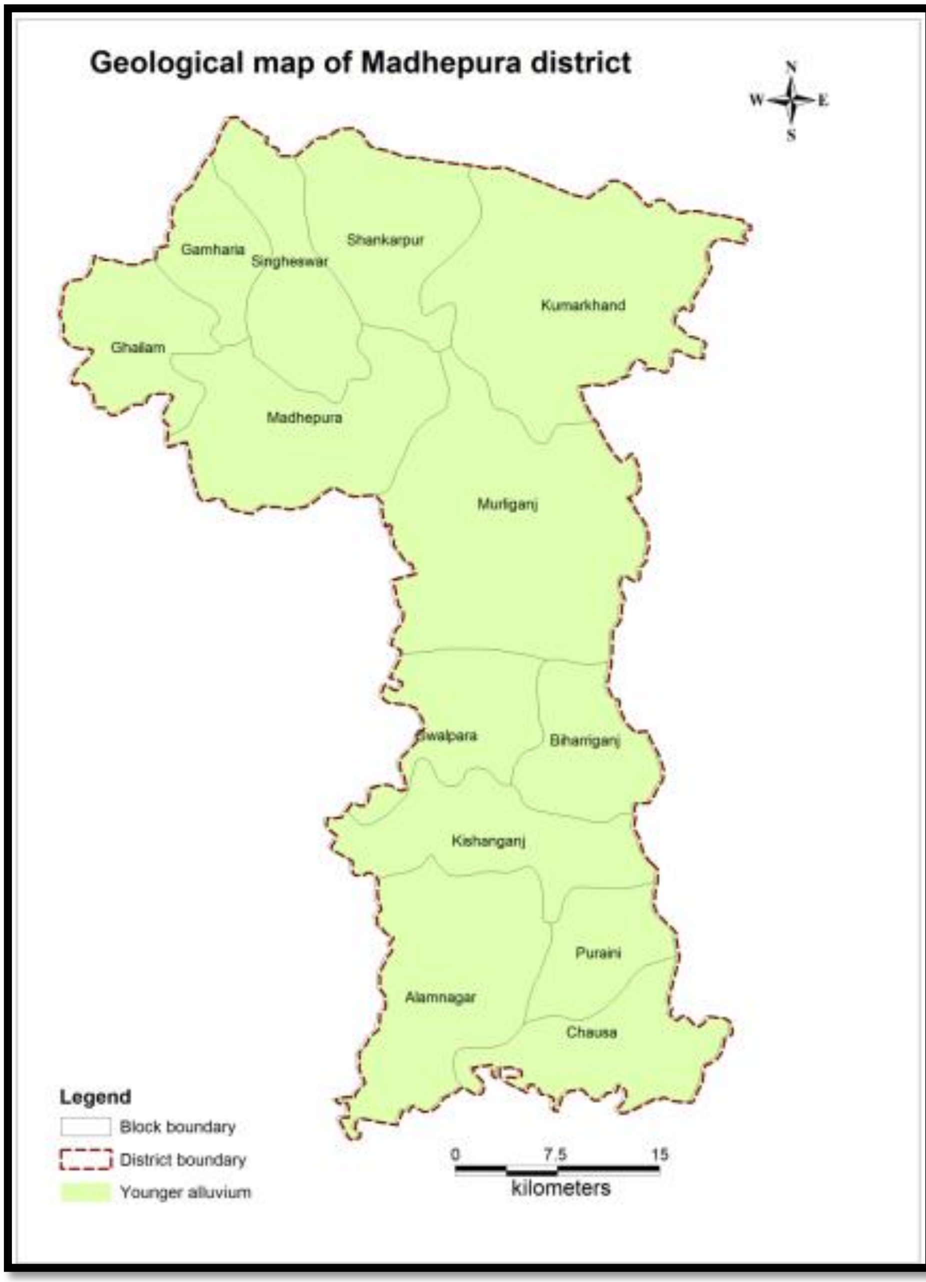


Figure 7: Geological setup of Madhepura district

1.15. Data Availability

The data pertaining to various attributes of ground water were collected from available literatures of Central Ground Water Board, State Departments and other agencies. The compiled data were plotted on 1:50,000 scale map and data gap analysis carried out for ascertaining additional requirement of Hydrogeological, Hydrological, Hydro chemical and Geophysical studies. The summarized details presenting the data availability, data requirement, data adequacy, data gap analysis and data generation is shown in table 1.15 given below:

Table-8: Data Requirement, Data Adequacy, Data Gap Analysis & Data Generation

S. No.	Parameters	Data Requirement	Data Availability	Data Gap	Data Generation
1	Rainfall data	IMD Meteorological stations spread over the project area	Data available	No	Nil
2	Soil	Soil Map and soil infiltration rate	Soil Map available	Soil Infiltration test	Soil infiltration rate across study area
3	Land Use/ Land cover	Land Use/Land cover pattern	Land Use/ Land cover Map available	Nil	District irrigation plan Madhepura 2016-2020
4	Geomorphology	Digitized geomorphological map	Geomorphological Map available	yes	yes
5	Geophysics	Geophysical data in each quadrant	Insufficient data	yes	Data to be generated
6	Exploration Data	EW in each quadrant	Exploration data of only Urban area available	Data Gap in whole area	Block wise Data to be generated
7	Aquifer Parameters	Aquifer parameters in all the quadrants	Not available	Data Gap in whole area	Data to be generated
8	Recharge parameters	Recharge parameters for different types of soil and aquifer types based on field studies	Available in Ground water Resources Estimation	Nil	Nil
9	Discharge Parameters (Draft data)	Discharge Parameters of different Ground Water abstraction structures	Available in Resources Estimation	Nil	Nil
10	Geology	All the data/maps on 1:50,000 scale. Hard and soft copy	Geological Map available	Nil	Generated on GIS platform

2.0. DATA COLLECTION AND GENERATION

2.1. Hydrogeology

The area comprises of one of most prolific aquifer system in the Gangetic alluvium of north Bihar. The Quaternary-Recent unconsolidated sediments (Fig 6) consisting of sand, gravels, pebbles constitutes the potential aquifer and having huge dynamic ground water resources extending down to hundreds of meter below the subsurface (Fig 6). At places a thin veneer of clay with 3–6 m thick is seen overlying the granular zones. The area may be treated as single aquifer system down to 100 m bgl depth.The shallow aquifer with depth of 50 m bgl is reported to yield about 150 m^3/hr with meager drawdown of less than 2.0 m, inferring thereby the presence of highly potential aquifer. The water table contour drawn with the key wells data of water level during the Conjunctive Use Study in the area indicates that the hydraulic gradient varies from 0.8 to 0.25 m/km. The overall gradient is from north to south.

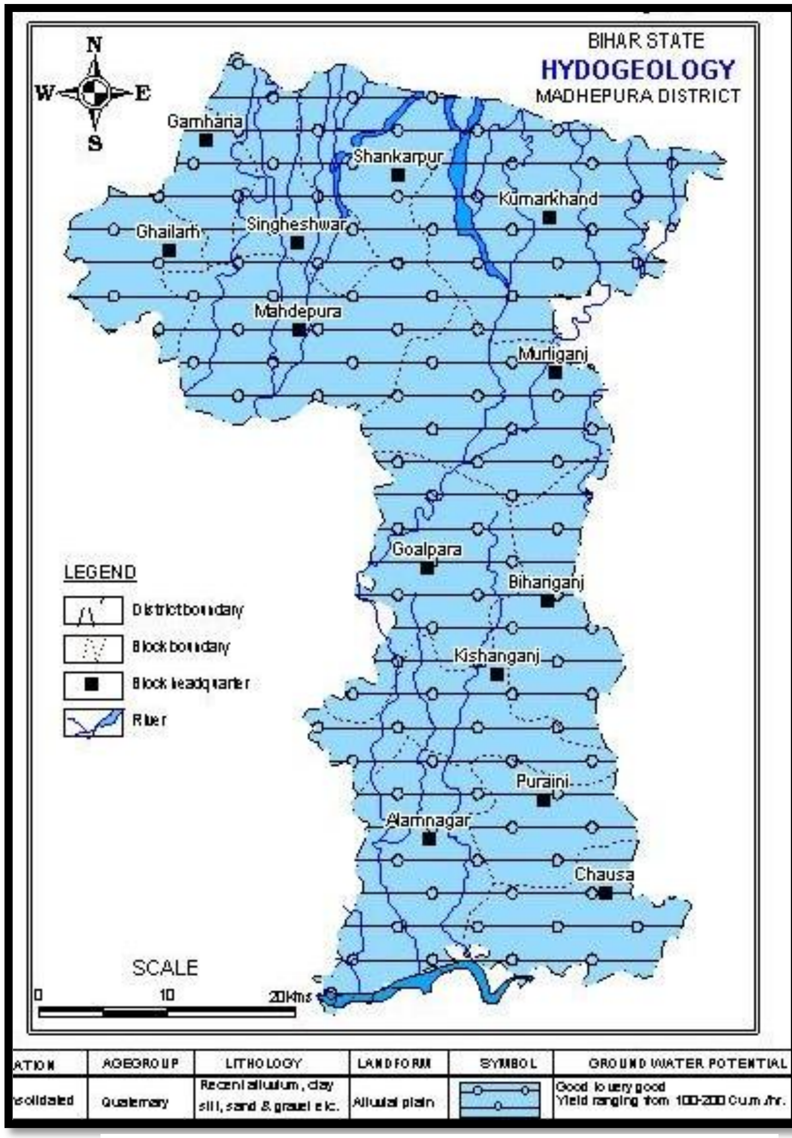


Figure 8 : Hydrogeology Map of Madhepura

2.2.Depth to water level Pre-monsoon (May 2019)

Ground water dynamics is used to decipher the spatial and temporal change in ground water level. It also significantly aids in dynamic ground water resource calculation. In order to determine the ambient ground water regime key wells were established in several part of the district. Pre and post monsoon data were collected and analyzed. Depth to water level varied from 2 to 10 m during pre-monsoon, 2019 (figure 7.3). Generally entire area has identified with shallow water level ranges from 2 to 5 m bgl. Whereas small patches of south western and north western parts shows the slightly deeper water level ranges from 5 to 10 m bgl.

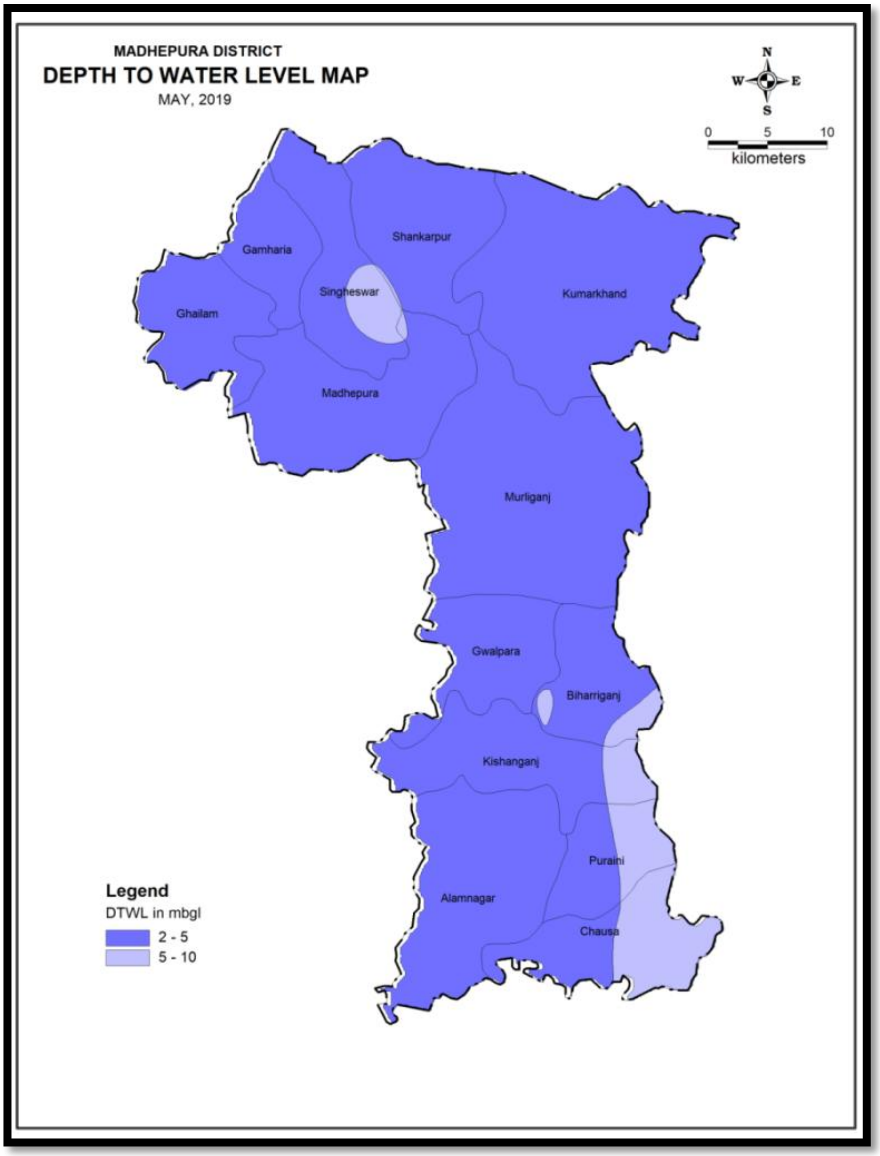


Figure 9: Pre monsoon depth to water level map of Madhepura district

2.3. Depth to water level Post-monsoon (November 2019)

The post monsoon data of the district revels that the ground water become shallower due to increase in storage of the phreatic aquifer in response to ground water recharge. The change in storage can be evidently reveals in post monsoon map. Major portion of the district has water level ranges 2 to 5 m bgl whereas in north eastern realm and north western realm show water level less than 2 m bgl.

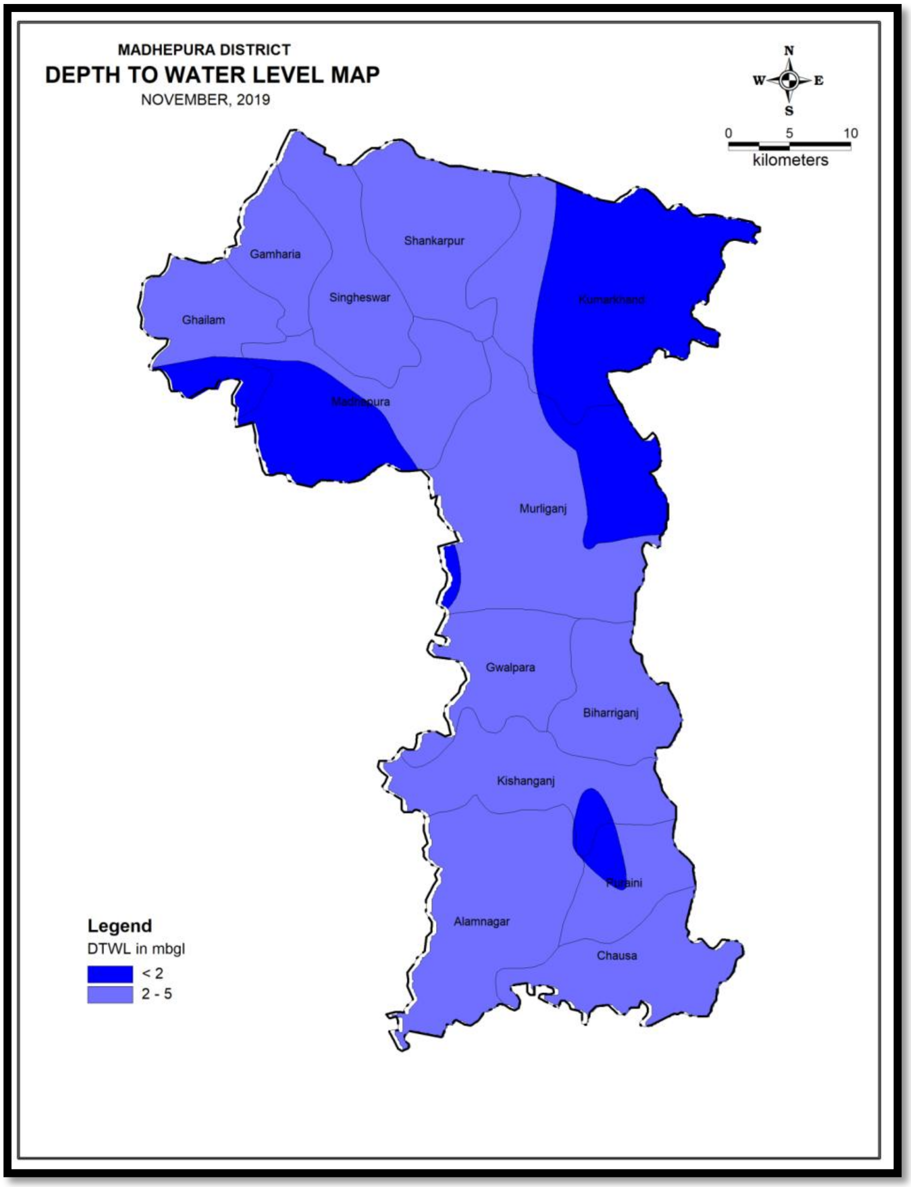


Figure 10: Post monsoon depth to water level map of Madhepura

2.4.Seasonal fluctuation in Ground water level

Seasonal fluctuation map of the study area for the period of May, 2019 to Nov, 2019 were taken into consideration which reflects the overall rise of the ground water ranges from 0 m to 02 m whereas south eastern part and central part of the area shows rise in ground water ranges from 02 to 04 m.

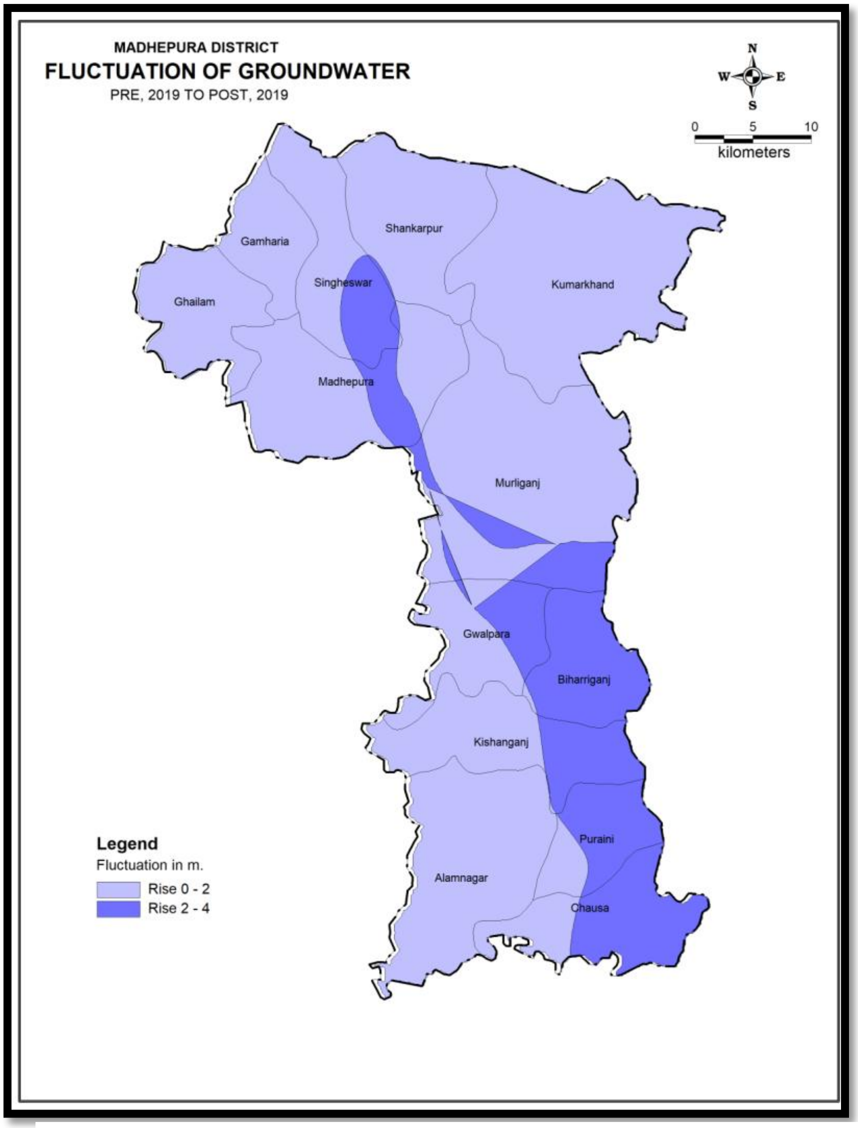


Figure 11: Water level fluctuation map of Madhepura district

2.5. Long Term Water Level Trend (2010-2020)

Decadal fluctuation of the area was analyzed in order to determine the ambient ground water regime. In hydrograph, water level verses year has been plotted. The general trend of majority of hydrographs show rising trend of wells over the district. The rate of rise of the ground water level is about 0.01 to 0.1 m/ year.

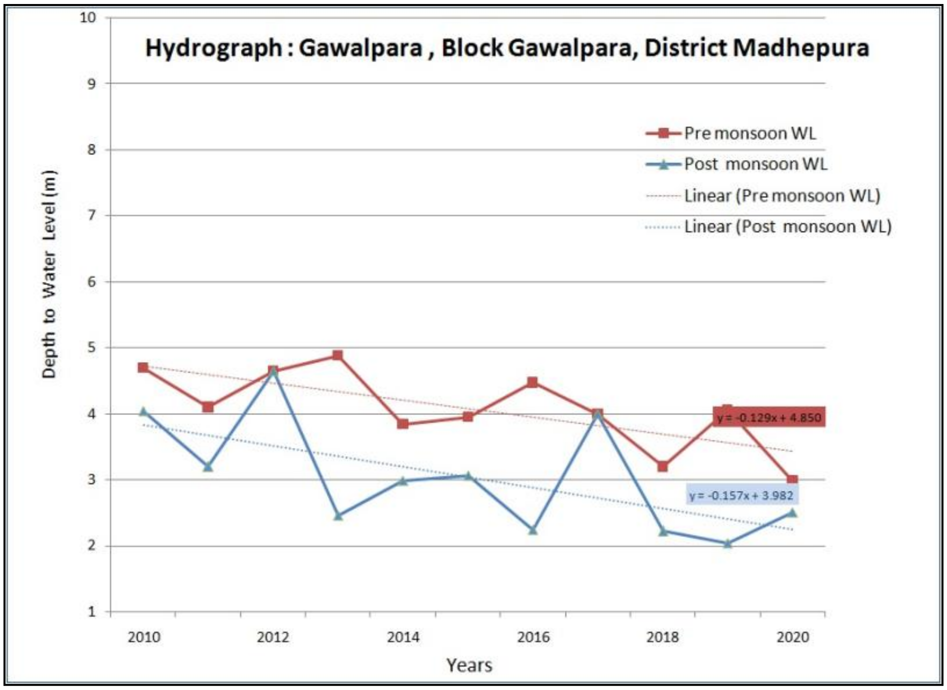


Figure 12: Hydrograph Gawalpara block

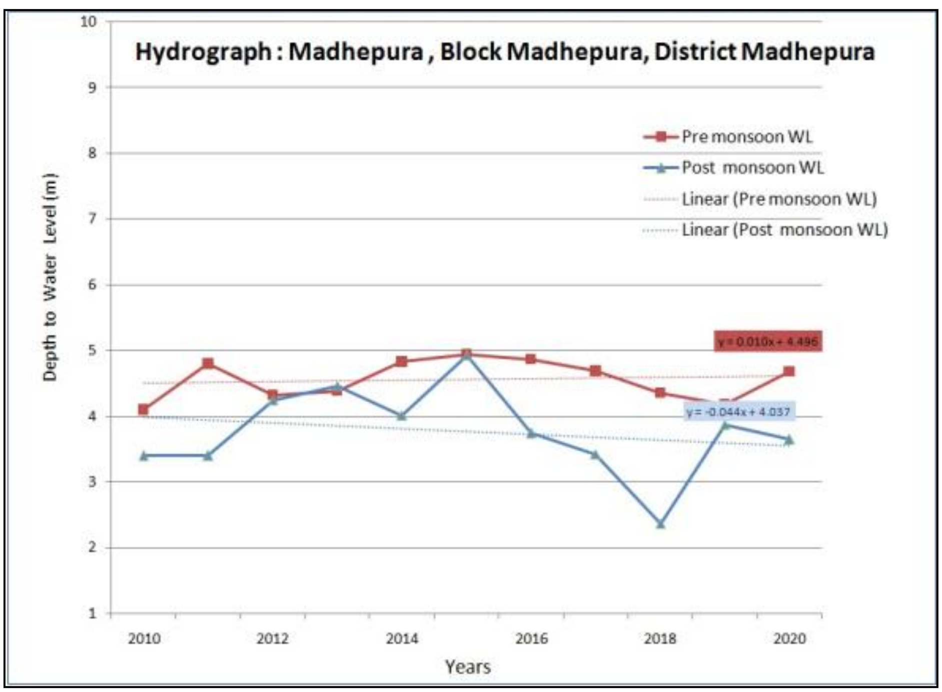


Figure 13: Hydrograph Madhepura block

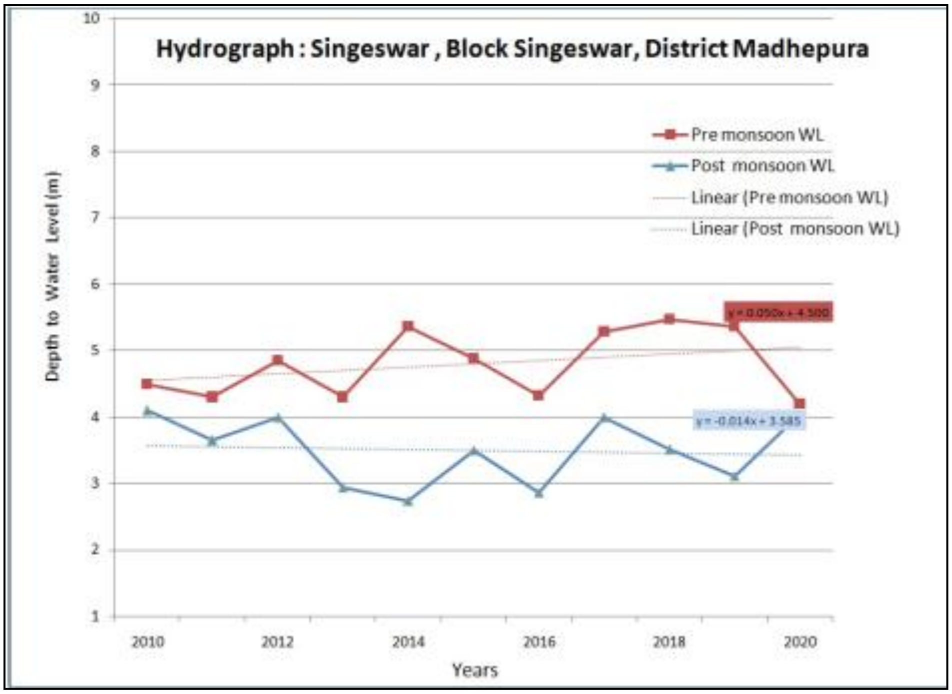


Figure 14: Hydrograph Singeswar block

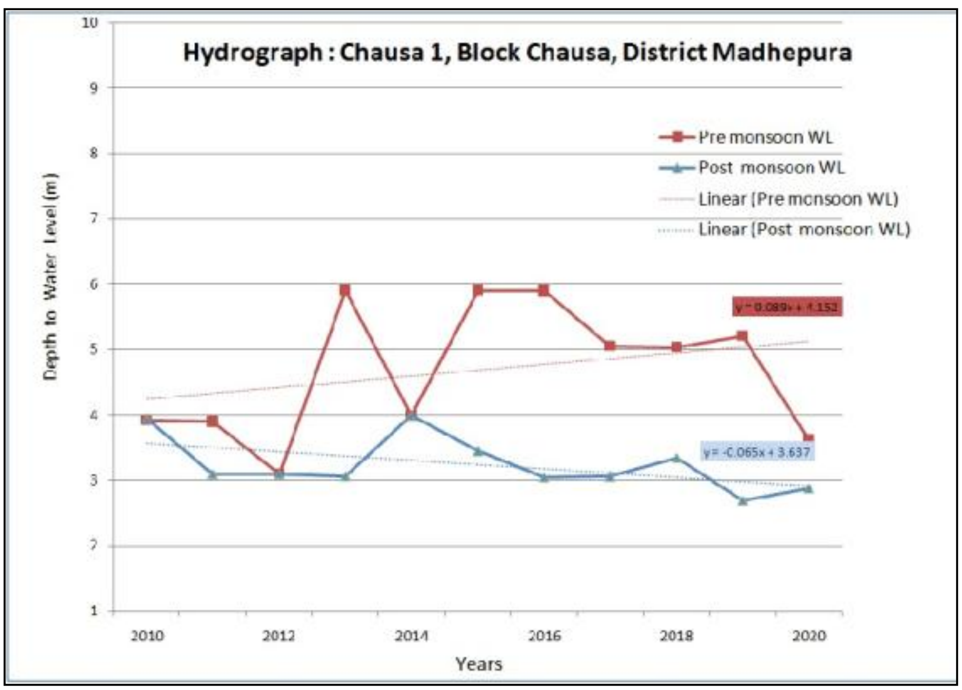


Figure 15: Hydrograph Chausa block

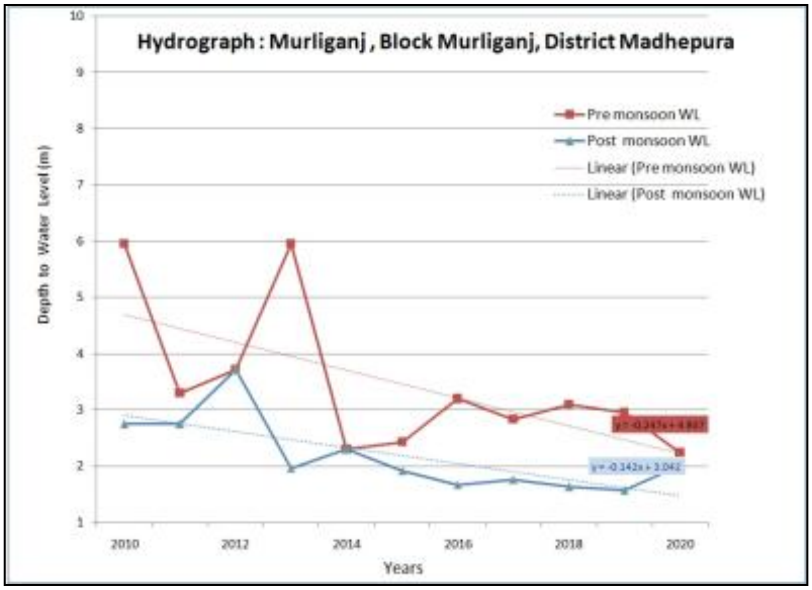


Figure 16: Hydrograph Murliganj block

2.6.Hydrochemistry

Water demands are constantly increasing due to population growth, intense agriculture, urbanization and industrial activities. Anthropogenic and natural pollution pollute the water resources. In order to determine the suitability of water for various uses water quality assessment is indispensable. The chemical quality of the water samples collected from the national hydrograph stations during May 2019 by CGWB,MER are within the permissible limit (BIS 2012). The result of ground water analysis are given in Table 9**.**

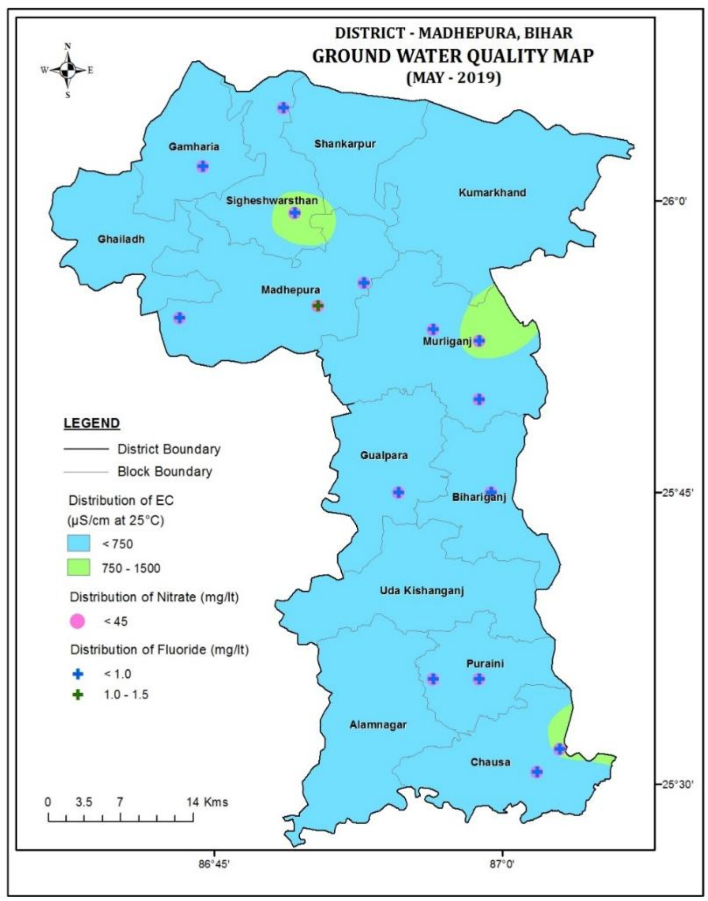


Figure 17: Chemical Quality Map of Madhepura District

2.6.1.Results of Basic constituents

i.pH Value:

pH is a measure of the hydrogen ion concentration of a solution. It shows how acidic or basic water is. pH in most part of the study area is within the acceptable/desirablelimit of BIS (6.5-8.5 mg/l) and is neutral to moderately alkaline in nature.

ii.Electrical Conductivity

Electrical conductivity (EC) for groundwater is the ability of 1 cm^3 water to conduct an electric current at 25˚C. It's a measure of total mineralization in water, indicating salinity of groundwater. EC of ground water in area is generally within thepermissiblelimits of BIS i.e. < 3000 µS/cm at 25^oC.

iii.Total Hardness as $CaCO_{3:}$

High concentration of carbonates, bicarbonates of calcium and magnesium, in ground water causes hardness. Hardness concentration in most part of the study area is within thepermissiblelimit of BIS (200-600 mg/l) ranging in between 110-490 mg/l.

iv. Carbonates (CO_3) and Bicarbonates (HCO_3):

Bicarbonates associated with carbonates effect the alkalinity of groundwater. The concentration of carbonates (CO3) ranges from 0-42 mg/l while the concentration of Bicarbonates (HCO_3) in all the samples is below 600 mg/l which is considered to be safe (BIS-2012) for domestic and irrigation.

v.Calcium (Ca):

Presence of calcium contributes to the hardness of water. Calcium concentration is within theacceptable/permissiblelimit of BIS (0-200 mg/l) in the study area ranging in between 16-70 mg/l.

vi.Magnesium (Mg):

Excess of magnesium contributes to the hardness of water. Magnesium concentration in the study area is within theacceptable/permissiblelimit of BIS (0-100 mg/l) ranging in between 2.40-78.85 mg/l.

vii.Sodium (Na) and Potassium (K):

No standard desirable limits for Sodium and Potassium concentration in the drinking water have been given. However, in the study area the values of Na ranges in between 10.63-80.48 mg/l and K values ranges in between 2.38-63.79 mg/l.

viii.Fluoride (F):

Higher concentration fluoride intake causes different types of diseases like fluorosis, primarily dental and skeletal fluorosis. Fluoride concentration in the study area is within theacceptablelimit of BIS (0-1.0 mg/l) ranging in between 0.5-1.1 mg/l.

ix.Nitrate (NO_3) and Sulphate (SO_4):

Nitrate and Sulphate concentration in most part of the district is below detection limit (BDL).Samples show concentration within theacceptablelimit of BIS (45 mg/l) for nitrate ranges from 0.04-12.47and 12.93-73.51mg/l for sulphate. High sulphate levels in drinking water results in gastro-intestinal disorders.

x.Chloride

Chloride concentration is within theacceptable/desirablelimit of BIS (0-250 mg/l) in all part of the study area ranging in between 35.45-138.25 mg/l.

Table 9: Chemical Quality Results of Madhepura District																
S.No.	**Block**	**Location**	**pH**	**EC**	**TDS**	**TH**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**CO_3^{2-}**	**HCO_3^{-}**	**Cl^{-}**	**SO_4^{2-}**	**NO_3^{-}**	**F^{-}**
				(μs/cm)	**mg/L**											
1	Chausa	Abhiyatola, Basaitha	8.3	769.7	500.305	305	64.05	35.163107	41.72	11.06	21	293.03424	38.995	69.3309	0.6323	0.5
2	Singheshwar	Barhari	8.52	336.9	218.985	160	30.02	20.616505	44.94	6.97	6	177.04152	67.355	29.5828	1.4919	0.73
3	Madhepura	Bhimpura	8.3	557.9	362.635	290	50.04	40.024272	25.96	4.84	15	280.82448	53.175	43.0201	0.5018	1.2
4	Chausa	Chausa 1	8.41	540.5	351.325	275	36.03	44.885437	14.98	3.74	15	183.1464	35.45	48.9525	8.9041	0.61
5	Chausa	Ganeshpur	8.53	333.3	216.645	190	30.02	27.898058	52.2	11.27	27	183.1464	85.08	29.0742	0.0487	1
6	Murliganj	Gaushala Chowk	8.48	474.6	308.49	190	38.03	23.039806	24.88	27.29	15	170.93664	56.72	46.645	4.1154	0.64
7	Alamnagar	Gwalpura	8.3	485.6	315.64	110	40.03	2.407767	62.29	11.23	6	213.6708	53.175	22.2952	0.9475	0.5
8	Murliganj	Hathkora Bazar	8.39	534.5	347.425	175	38.03	19.399029	76.81	6.14	12	250.30008	67.355	16.6597	2.5293	1.1
9	Singheshwar	Jiwachhapur	8.03	342.1	222.365	280	16.01	58.24466	17.98	12.46	0	164.83176	88.625	48.1268	12.4757	1
10	Bihariganj	Kusthan	8.46	551.3	358.345	210	36.03	29.108738	31.05	63.79	18	225.88056	53.175	52.852	3.6529	0.64
11	Madhepura	Madhepura	8.13	870.3	565.695	490	66.05	78.851456	12.73	2.38	0	256.40496	138.255	73.5129	10.8051	0.56
12	Murliganj	Murliganj	8.41	762.3	495.495	280	44.04	41.240777	80.48	14.92	42	341.87328	70.9	53.2481	1.6988	0.48
13	Murliganj	Rajuri Rajni Goth	8.35	509.7	331.305	315	40.03	52.165049	19.47	7	24	201.46104	53.175	46.4962	5.5264	0.64
14	Murliganj	Rampur	8.45	158.3	102.895	150	20.02	24.262136	10.63	2.83	9	103.78296	38.995	12.932	0.7491	0.75
15	Singheshwar	Singheswar	8.52	775.5	504.075	260	70.06	20.597087	74.69	31.72	18	354.08304	88.625	50.952	6.7152	0.62
16	Madhepura	Surajganj	7.84	248.1	161.265	330	28.02	63.093204	15.44	3.61	0	134.30736	138.255	31.3255	1.2666	0.46

2.6.2. Hill piper diagram

Hill piper diagram is commonly and popularly used to plot the ions in triangle. The cations are plotted in the left triangle whereas the anions are plotted in right triangle. The cations and anions are projected onto diamond shape field which is often used to determine the facies of ground water. As shown in figure 23 Cationic facies does not show dominance of any cation except few sample show dominance of Na + K type facies. On the other hand anionic facies represents the HCO3+CO3type of water sample. However cumulative plot of ions on to the diamond shape field reflects major ground water samples are of Ca, Mg, and HCO3 type.

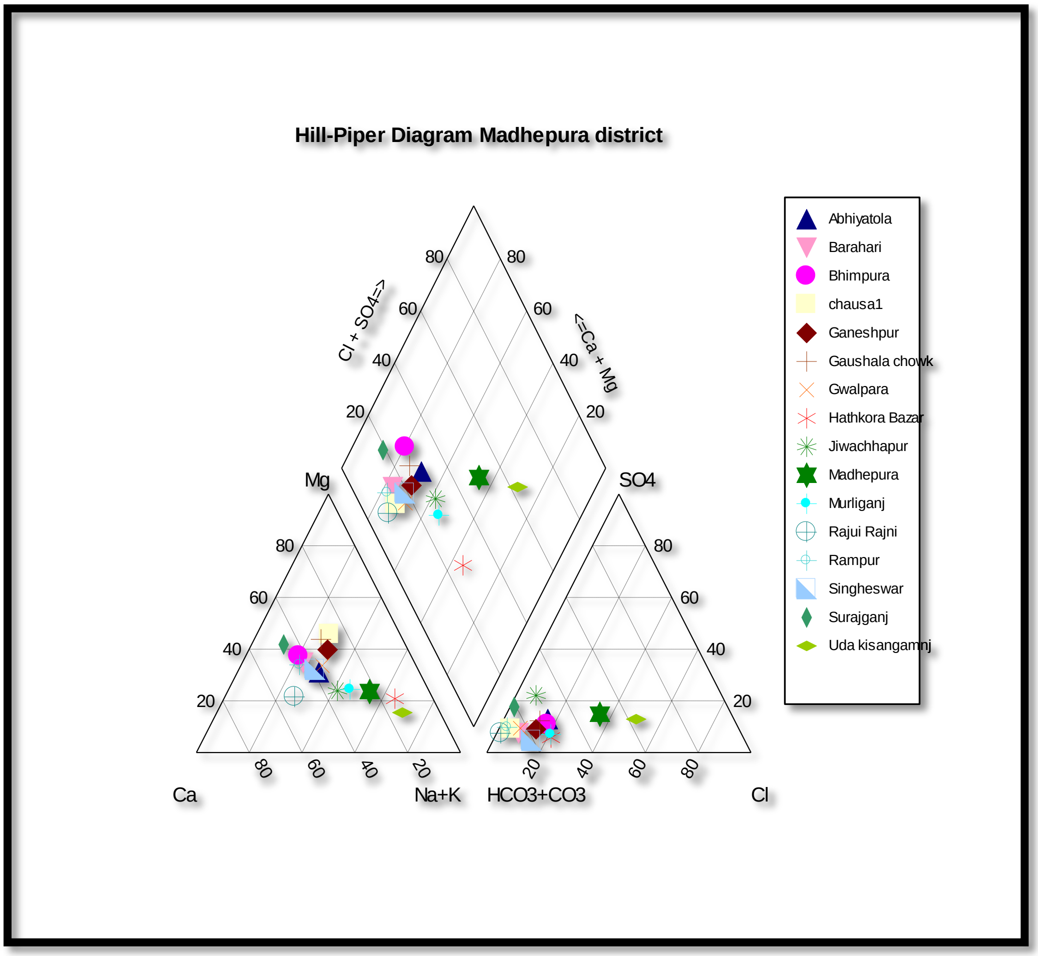


Figure 18: Hill Piper Diagram

2.6.3Schoeller diagram

Schoeller diagram is mainly used to represent the ionic concentration of the various constituents available in the ground water. This diagram helps to interpret the several ionic constituents in ground water samples. The major ionic constituents of the ground water samples of the Madhepura district is represented in order of decreasing constituents as Ca, Mg,Na,HCO3,SO4,Cl.

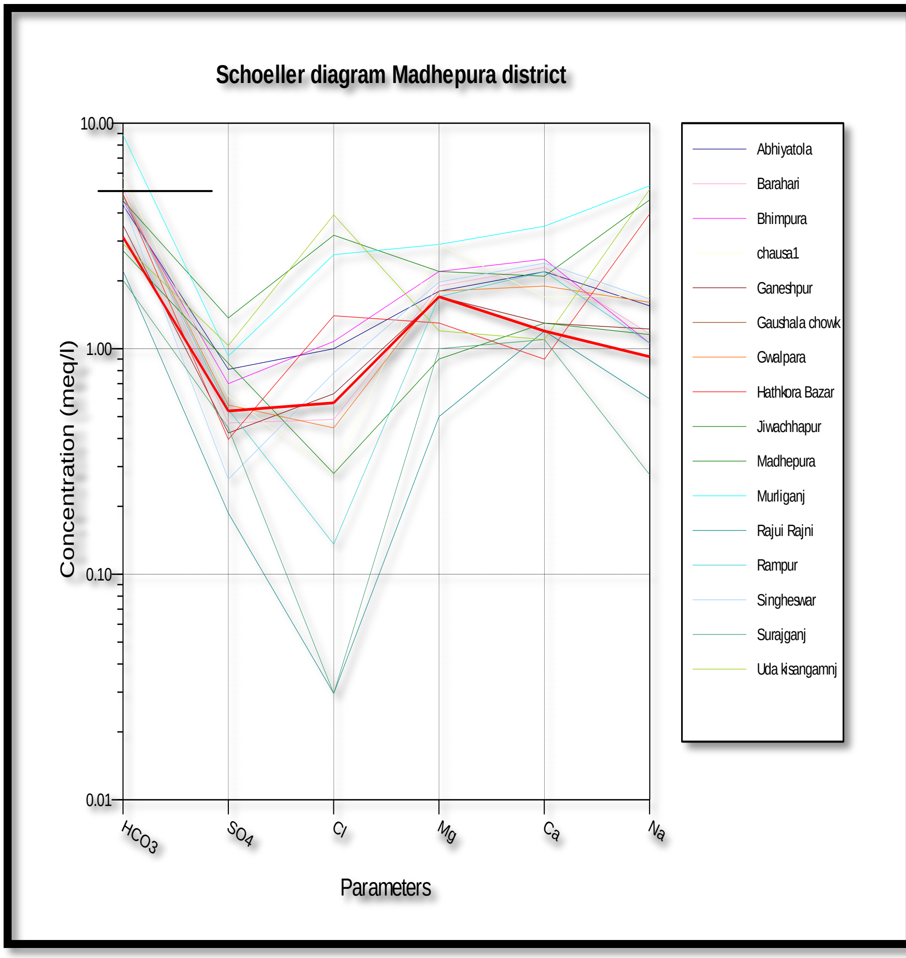


Figure 19: Schoeller diagram

2.6.4. Suitability of Ground Water for Irrigation Purpose

Ground water used for irrigation is an important factor in productivity of crop, its yield and crop quality. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. The Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are the most important quality criteria. Which influence the water quality and its suitability for irrigation. The quality of groundwater based on EC and SAR is discussed in Table10.

Table 10: Quality of groundwater based on EC and SAR

Type of Water	Classification	No of Samples	Samples percent	Activities required
Low Saline< 250 mg/l	Excellent	2	12.5	1) Good for all crops 2).little likelihood of development of salinity
Medium Saline 250–750 mg/l	Good	11	68.75	1) Plants with moderate salt tolerance 2) No special practices for salinity control required. 3) Moderate amount of leaching occurs
Highly Saline 750 –2250 mg/l	Permissible	3	18.75	1) Cannot be used on soils with restricted drainage. Even with adequate drainage, 2) special management for salinity control may be required 3) Plants with good salt tolerance should be selected
Very Highly saline>2250 mg/l	Doubtful	0	0	1) Not suitable for irrigation under ordinary condition. 2) soils must be permeable, drainage must be adequate, irrigation 3) water must be applied in excess to provide considerable leaching 4) very salt tolerant crops should be selected
		16	100	

2.6.5. Sodium Percent (Na %):

Sodium in irrigation waters is usually denoted as percent of sodium. According to Wilcox (1955), in all natural waters Na% is a common parameter to assess its suitability for irrigation purpose. The sodium percent (Na %) values were obtained by using the following equation:

$Na\% = [Na^{+} + K^{+}] \times 100 / [Ca2^{++} Mg2^{++} Na^{+} + K^{+}]$ all ionic concentrations are expressed in meq/l.

Low sodium (alkali) water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium sodium water will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity especially under low leaching conditions. This water can be used on coarse textured or organic soils with good permeability

Table 11:Classification of water based on sodium percent

Na%			
Water Class	**Range**	**No of Samples**	**% samples**
Excellent	< 20	2	12.5
Good	20 - 40	9	56.25
Medium	40 - 60	3	18.75
Bad	60 - 80	2	12.5
Very Bad	**> 80**	0	0

2.6.6. Sodium Adsorption Ratio (SAR):

High concentration of sodium in water produces undesirable effects of changing soil properties and reducing soil permeability and thus reduces the supply of water needed for crops. It is calculated from the ratio of sodium to calcium and magnesium by following formula:

$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+})/2]^{0.5}$ where all ionic concentrations are expressed in meq/l.

Cumulative effect of salinity and sodium hazard in the study area can be study by plotting sodium-absorption ratio and electrical conductivity data on US Salinity diagram (USSL, 1954). Sodium Percent (Na %). The sodium in irrigation waters is usually denoted as percent

Table 12 Classification of water based on SAR

SAR			
Water Class	**Range**	**No of Samples**	**% samples**
Excellent	<10	16	100
Good	10 to 18	0	0
Medium	18 to 26	0	0
Bad	>26	0	0

2.6.7. Residual Sodium Carbonate (RSC):

Residual Sodium Carbonate (RSC) has been used to determine the harmful effect of carbonate and bicarbonate on the quality of water for agricultural purpose and is estimated by the formula.

$RSC = (HCO_3^{-} + CO_3^{-}) - (Ca^{2+} + Mg^{2+})$

Where all ionic concentrations are expressed in meq/L . According to the RSC classification for irrigation purposes, the water samples with values greater than 2.5 meq/l are unsuitable for irrigation.

Table 13 Classification of water based on Residual Sodium Carbonate

RSC (meq/l)			
Range	**No of Samples**	**% samples**	
< 1.25	14	87.5	
1.25 - 2.0	0	0	
2.0 - 2.5	0	0	
2.5 - 3.0	2	12.5	
> 3.0	**0**	0	

Table 14 Statistical data of ground water for irrigation purpose and major parameters

Suitability of water for irrigation purpose							
	S S P%	**SAR**	**RSC**	**%Na**	**K I**	**Mg^{+2}**	**P I**
Average	33.06785	1.571823	0.774293	34.23733	0.623841	48.64699	73.57018
Min	11.60402	0.26902	-0.16275	11.83185	0.131273	29.40835	55.34829
Max	68.89883	4.751113	2.87302	69.91844	2.215313	63.03964	100.0011
SD	16.21554	1.312626	0.868121	16.36194	0.591139	8.193319	12.17867
Skewness	1.191684	1.46055	1.580055	1.077131	1.984194	-0.30603	0.876567
Kurtosis	0.681778	1.023555	2.139427	0.404578	3.246539	0.951817	0.149395

2.6.8US salinity diagram:

In this diagram the data of EC verses SAR are plotted and diagram is separated by several class depending on increasing value of EC as C1,C2, C3,C4 and SAR as S1,S2,S3,S4. Usually higher EC and SAR value samples are not suitable for irrigation purpose. The data of the district fall under the category of C2S1, C1S1and C3S1. Moreover the US salinity diagram reveals that the ground water samples are suitable for irrigation use.

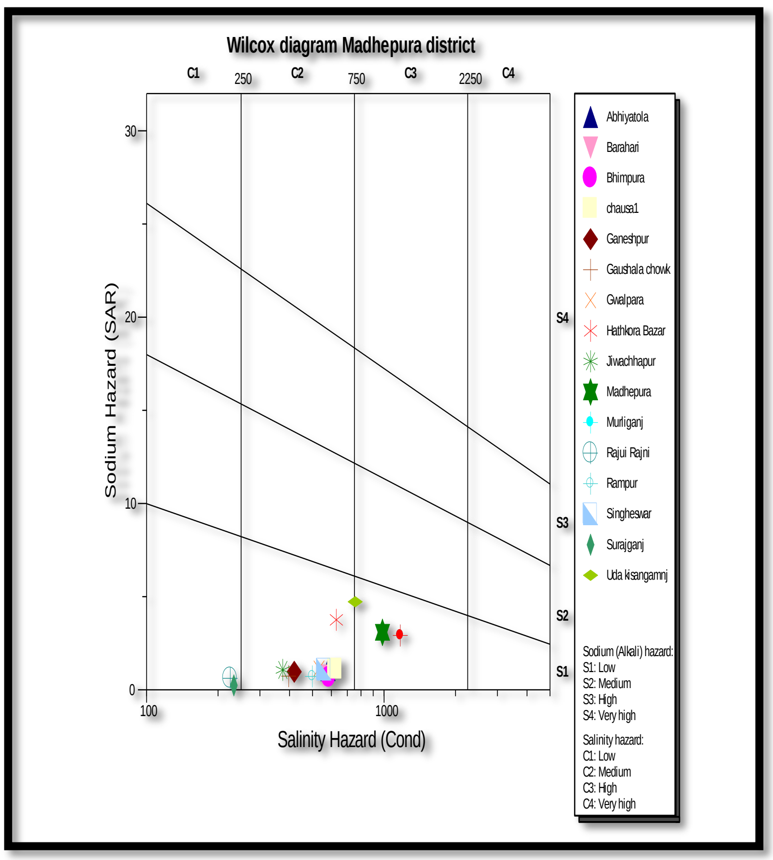


Figure 20: US Salinity Diagram

2.7.Exploration:

The exploratory drilling at Baldev Laxmi High School, Murliganj, Madhepura has been carried out down to the depth of 252.50 m bgl. After completion of 252.50 m drilling, well has been collapsed therefore geophysical drilling could not been carried out. The lithological log has been prepared is given below. In the entire drilling, only sand zone has been encountered.

Depth range		**Thickness (m)**	**Litholog**
From	*To*		
0.0	6.00	6	Top soil : brownish, clayey
6.0	27.0	21	Sand : medium, Greyish & black
27.0	30.0	3	Sand : coarse,, Greyish & black
30.0	63.0	33	Sand :, fine to medium, Greyish & black
63.0	84.0	21	Sand : fine to medium, Greyish & black
84.0	90.0	6	Sand : medium to coarse, Greyish & black
90.0	120.0	30	Sand : medium to coarse with gravel, Greyish & black
120.0	153.0	33	Sand : medium to coarse, Greyish & black
153.0	192.0	39	Sand : fine to medium, Greyish & black
192.0	204.0	12	Sand : coarse, and gravel, Greyish & black
204.0	252.0	48	Sand : fine to medium, Greyish & black

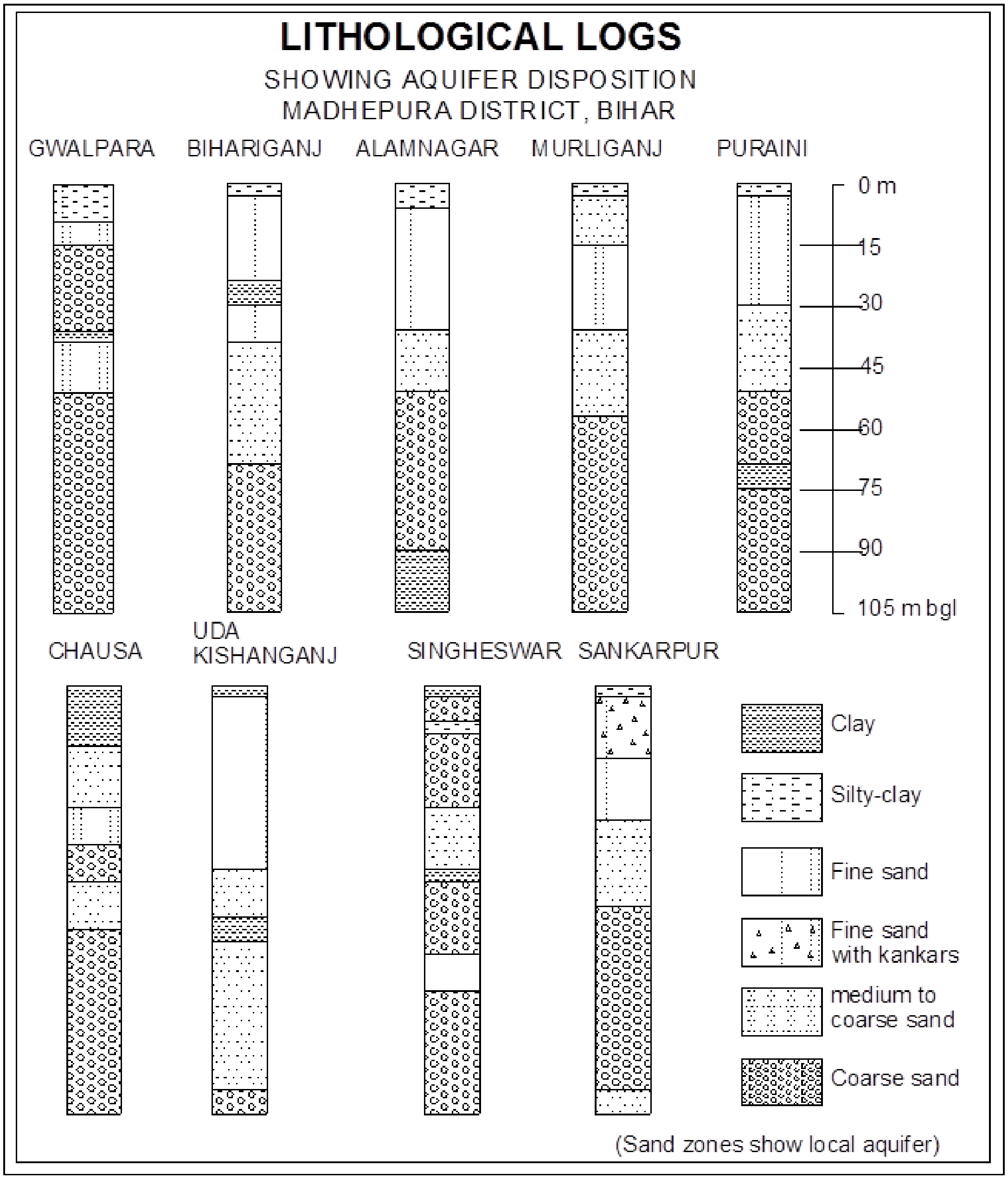


Figure 21: Lithological logs of bore holes in Madhepura district depicting the potential sand zones down to 100 m depth

3.0. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1.Aquifer Disposition

The area of the entire district forms a part of the Kosi alluvial fan (Eastern part of the Kosi River). The Kosi Fan is a body of river deposits whose surface approximates a segment of a cone that radiates down slope from the point where the river leaves the mountain. Deposition is caused by changes in the hydraulic geometry of flow resulting from the sudden reduction in channel slope. As the deposition proceeds the course of principal channel is shifted many times and the abandoned channels get covered up with the heterogeneous material. During the growth of alluvial fan the sediments are carried farther out into plain so that they overlap the sediments deposited earlier. The sediments in the area are of recent age and constitute of fine to coarse grained sands with silt. The various grades of sand occurring in the alluvial sediments form excellent and prolific aquifers in the area. The gradation of the sediments are in aerial distribution and alternation of silt, fine-sand and coarse - sand layers. Therhythmic cycle of deposition with general finess towards top clearly indicates the ever changing environments of deposition in the riverine regime of the kosi and its tributaries in recent to sub-recent times. The coarse, medium and fine sand indicate the changing velocities of the fluid medium depositing these sediments. The coarser clastics represents channel deposits,while finer sediments were deposited in the flood plains. In this complex depositional history, the different riverine environments have over lapped each other in space and time with the ever shifting course of the Kosi and its tributaries.

3.2. Occurrence andGround Water Flow

Oflate, theemphasishas been laid onthe role of ground water for irrigation, particularly for the benefits of small and marginal farmers due to its cost- benefits ratio. As such study of occurrence and movement of groundwater and evaluation of resource potential form the basic components for an in-depth study of this vital resource.

a)<u>Occurrence</u>: The geological set up of the area controls the occurrence and movement of ground water in the area. Ground water occurs in the pore space of the unconsolidated alluvial material in the zone of saturation in the near surface aquifers (shallow aquifer) under water table or unconfined conditions. The details of deeper aquifers are not known because the area has not been explored. Ground water within the shallow aquifer in the entire district occurs under unconfined conditions. This aquifer is composed of sand of different grades,silt andoccasionally silty clay; pebbles are also met in the area. These granular aquifers are loosely cemented. Maximum saturation is observed after the monsoon. The upper level of the zone of saturation is the water table rise during and after monsoon, due to heavy recharge of percolating rain water, flood water of Kosi, the water recedes but not appreciably due to factors like lack of precipitation, flood recession and evapotranspiration. The entire Madhepura district is suitable for high yielding deep as well as shallow tube wells.

b)<u>Flow of ground water</u>: An aquifer is a dynamic storage and under normal conditions transmits the water like a pipe line at a slower pace from areas of recharge to those of discharge in response to hydraulic gradient. However,the flow is appreciably restricted by friction. Water table elevations map has been prepared for pre-monsoon (May) and post-monsoon (Nov) for the year 1991 to reveal the nature , flow and disposition of water table in different season and the influence and behavior of river and canal system on the water table.A critical study of water table contour map indicates that it is in conformity with the topographical gradient which is not steep and the general direction of ground water flow is from N-S with hydraulic gradient of 0.33m/km and 0.16m/km in the northern and southern parts respectively. Further from the map it can be seen that the elevation of the flow line is ranging from (northern portion) 46m to 30m (southern portion)above mean sea levelduring the post- monsoon period. The widely spaced flow lines are also indicative of permeable nature of the phreatic aquifer materials.The water table behavior along the Kosi dhars at Kumarkhand , Madhepura, Murliganj sites has been studied and it has been found that the Kosi dhars are influent in nature in the upper reaches. The shallow water table condition is prevailing in Madhepura district due to the continuous recharge through Tilabeh, Kosi dhars at the upper reaches and through unlined canal system. Thelow-lying area in the south eastern part of the district which is in the fact the old kosi dhar bed is now swampy and water logged. It is inferred that the water table is intersecting the land surface causing seepage which in turn is causing water logging.

3.3. 3-D lithological and Aquifer Model

The 3-D lithological and aquifer model of the complete aquifer mapping area depicts the presence of a thick pile of alluvial sediments like clay, silt, sand of various grades and occasionally gravel. Kankar is interspersed with clay at different depths is common in parts of the district. In order to prepare three dimensional disposition of aquifer system of the district, bore holes data were taken from district Report of Madhepura District. The perusal of model revels that lateral as well as vertical variation in texture and composition of clastic sediments due to change in depositional environment .The top most unsaturated area are mainly silty clay in nature that often impede the natural ground water recharge. Model of the study area reveals that the single aquifer system is in existence in the area. However a thin clay layer also encounters at depth of 30 to 50m but it is not spread over the entire district. The water bearing zone occurs at 35m depth at few places and 55 to 95 m depth. Due to thin veneer of clay layer and not existed in entire district, ground water occurs under phreatic condition and fluctuation is mainly caused by change in atmospheric condition.

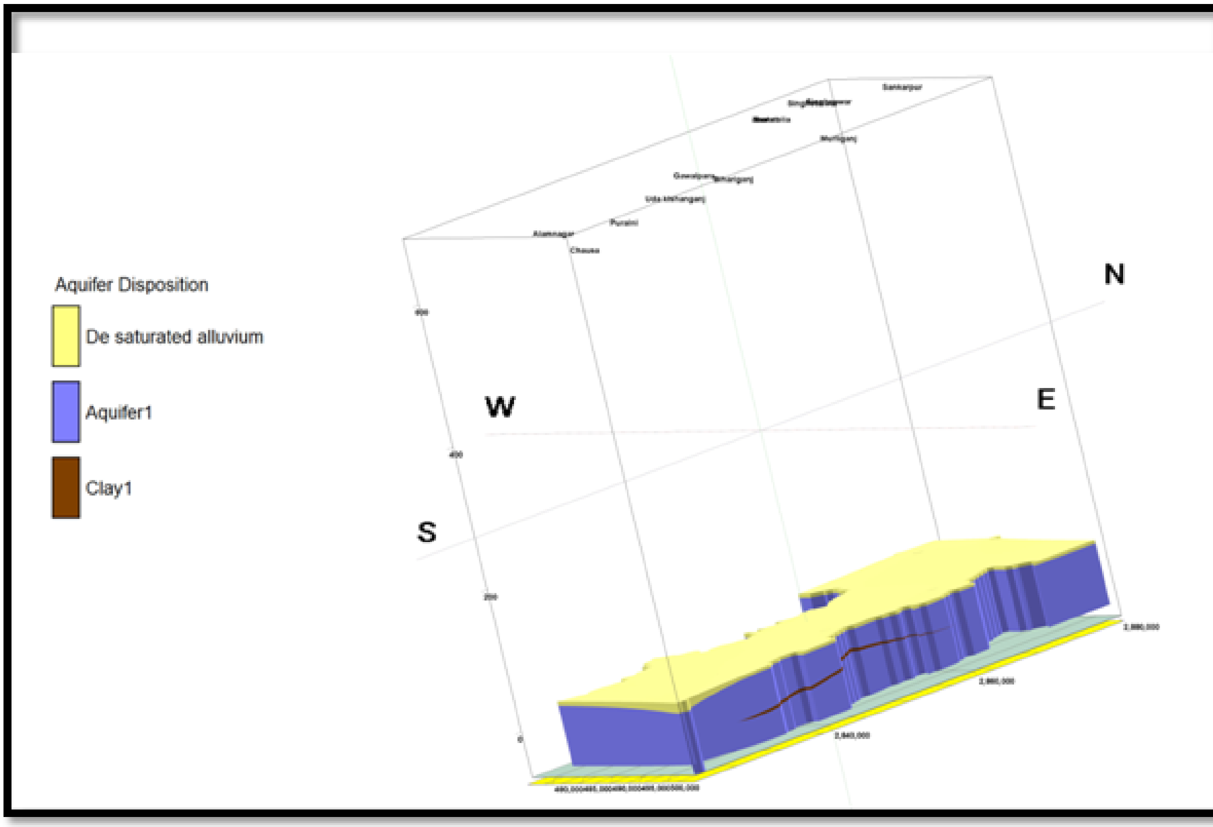


Figure 22: 3-D lithological and Aquifer Model

3.4. Fence Diagram:

The fence diagram was also formulated from lithology which also indicates that the clay thickness is slightly increasing from north to south and central portion of the district.

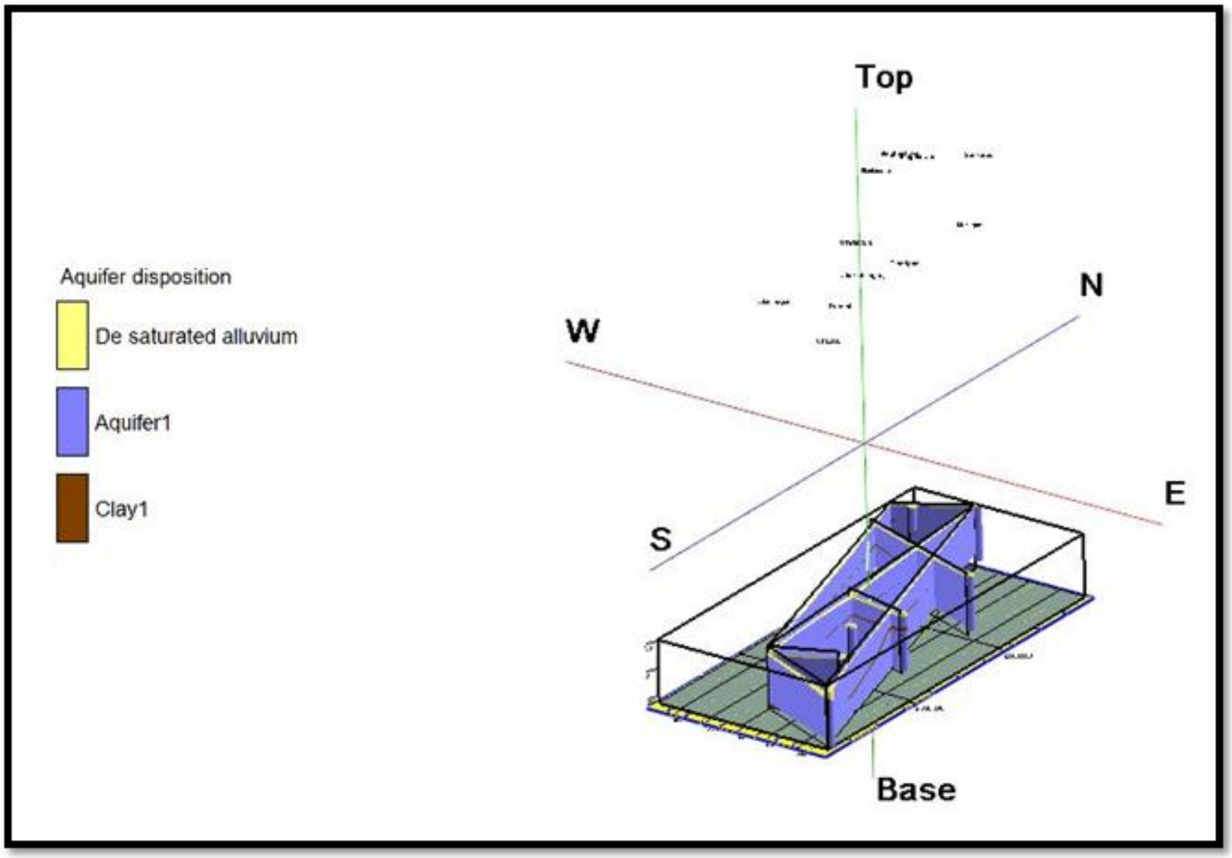
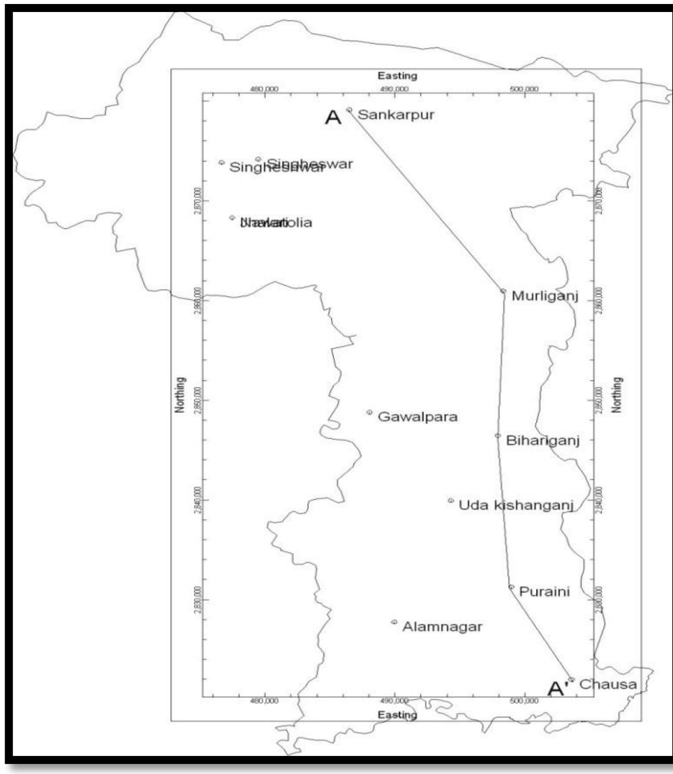


Figure 23: Fence Diagram

3.5. 2D-Cross Section Model

A cross section along AA’ from Sankarpur, Morlaiganj, Bihariganj, Puraini, Chausa were prepared with the aid of bore holes data which also apparently display that the clay layers is being thicken near central part of the district whereas in north and south ambits pinching can be seen through the cross section.



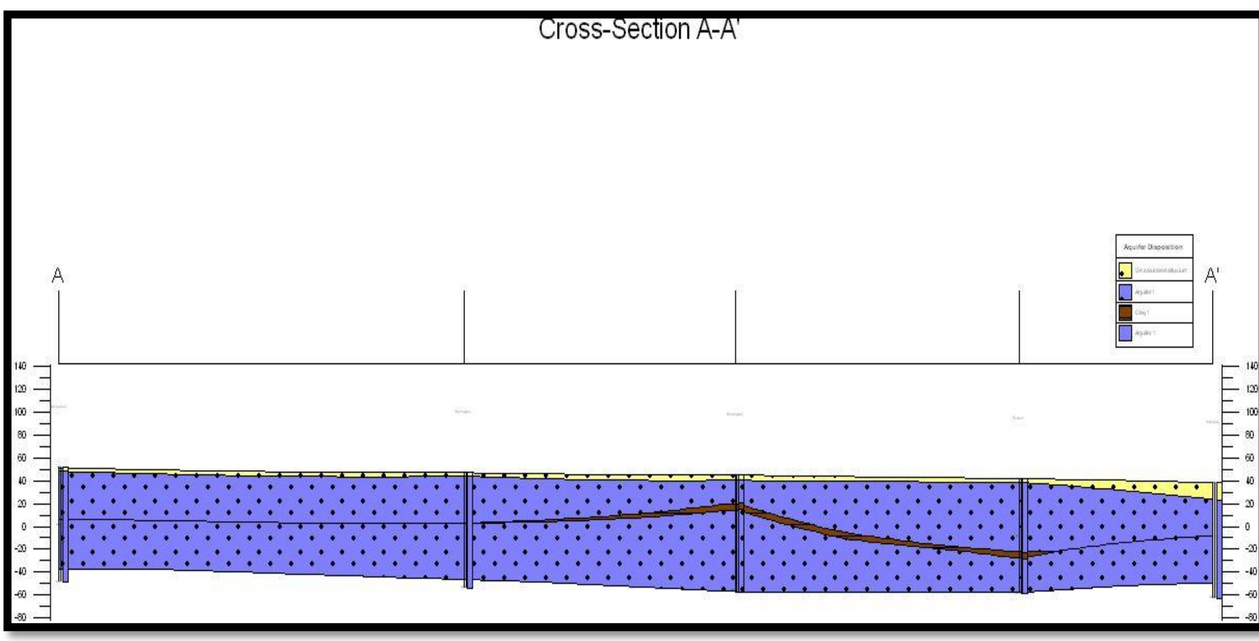


Figure 24 : 2-D lithological cross section along A-A’

4.0 Ground water resources

Ground water resources have been computed jointly by Central Ground Water Board and Ground Water Department, Govt. of U.P. as on 31st March 2020 according to the methodology recommended by the Ground Water Estimation Committee constituted by Government of India (GEC 2015).

4.1 Dynamic Ground Water Resources

The assessment of total availability of ground water resources encompasses two component namely Dynamic and In-storage resources. The in-storage resources include In-storage unconfined and In-storage confined resources. For unconfined aquifer in-storage resources are computed based on specific yield of the aquifer and for confined aquifer based on the storativity of the confined aquifer. On the basis of Ground Water Estimation Committee (2015) methodology, Central Ground Water Board and Ground Water Department, Government of U.P. has jointly estimated Dynamic Ground Water Resources of Uttar Pradesh in 830 assessment units (820 blocks and 10 Urban areas) for the base year 2019-20 (As on March- 2020).

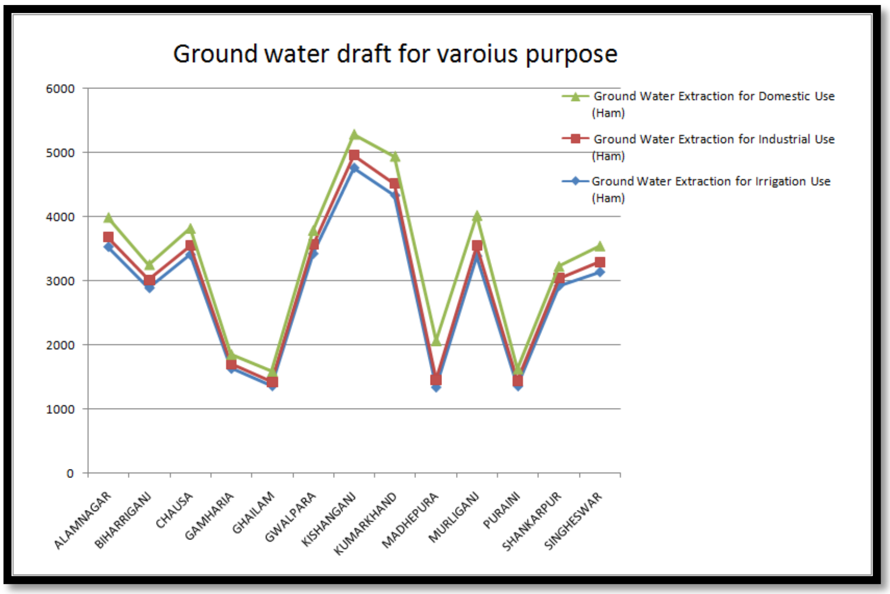


Figure 25 : Ground Water Draft for Various Purposes

Table15: Dynamic Ground Water Resource-2020

Assessment Unit Name	Total Area of Assessment Unit (Ha)	Recharge Worthy Area(Ha)	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources-Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources-Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	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)	Stage of Ground Water Extraction (%)	Category
Alamnagar	17120	17120	3891.2	675.09	500.45	661.58	5728.32	572.83	5155.49	3532.5	153.00	302.18	3987.68	77.35	semi critical
Biharriganj	10568	10568	3127.72	550.75	308.92	539.36	4526.75	226.33	4300.42	2892.5	126.00	233.50	3252	75.62	semi critical
Chausa	13665	13665	3860.28	827.36	399.46	770.81	5857.91	292.89	5565.02	3410	144.00	263.06	3817.06	68.59	safe
Gamharia	7655	7655	1739.9	314.66	223.77	308.84	2587.17	258.72	2328.45	1637.5	72.00	142.17	1851.67	79.52	semi critical
Ghailam	9177	9177	2085.84	265.3	268.26	260.7	2880.1	288.01	2592.09	1367.5	63.00	158.18	1588.69	61.29	safe
Gwalpara	11668	11668	2952.16	670.38	341.08	638.41	4602.03	230.1	4371.93	3425	144.00	217.11	3786.11	86.60	semi critical
Kishanganj	14869	14869	3824.76	1024.98	434.65	950.23	6234.62	311.73	5922.89	4760	198.00	325.88	5283.88	89.21	semi critical
Kumarkhand	24709	24709	5616.1	825.13	722.29	811.52	7975.04	797.5	7177.54	4332.5	189.00	419.72	4941.22	68.84	safe
Madhepura	18995	18995	4317.37	259.55	555.26	254.71	5386.89	538.69	4848.2	1347.5	108.00	611.23	2066.73	42.63	safe
Murliganj	19745	19745	4487.83	2618.19	577.19	828.8	8512.01	851.2	7660.81	3390	162.00	468.09	4020.09	52.48	safe
Puraini	8698	8698	1976.96	515.47	254.26	370.97	3117.66	311.76	2805.9	1365	81.00	179.92	1625.92	57.95	safe
Shankarpur	10858	10858	2467.91	893.25	317.4	657.45	4336.01	433.61	3902.4	2925	117.00	183.00	3225	82.64	semi critical
Singheswar	11113	11113	2525.87	1093.17	324.86	768.55	4712.45	471.24	4241.21	3140	153.00	249.39	3542.39	83.52	semi critical

4.2. Ground water availability and draft

Perusal of Figure26reveals that net ground water availability verses ground water abstraction for all purpose. The net ground water availability is substantially higher than the ground water recharge. It reflects rate of ground water abstraction is lower than the ground water resources. And other important reason for high net ground water availability is area under study comprises of one of themost prolific aquifer system i.e. unconsolidated quaternary alluvium.

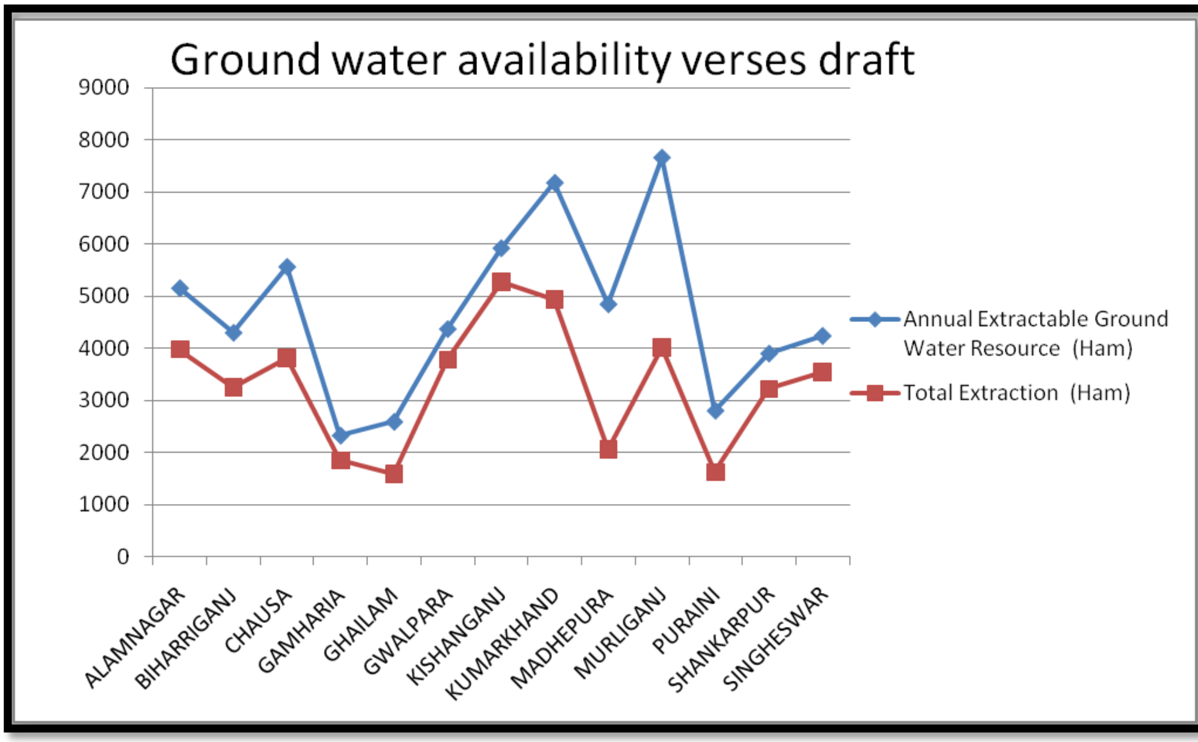


Figure 26: Ground water availability verses draft

4.3. Ground water recharge from different source

Perusal of Figure 27 reveals that ground water recharge from different sources. The monsoon recharge particularly from rainfall is exorbitantly higher than the other sources of recharge because area under study comprises of one of the most prolific aquifer system i.e. unconsolidated quaternary alluvium.

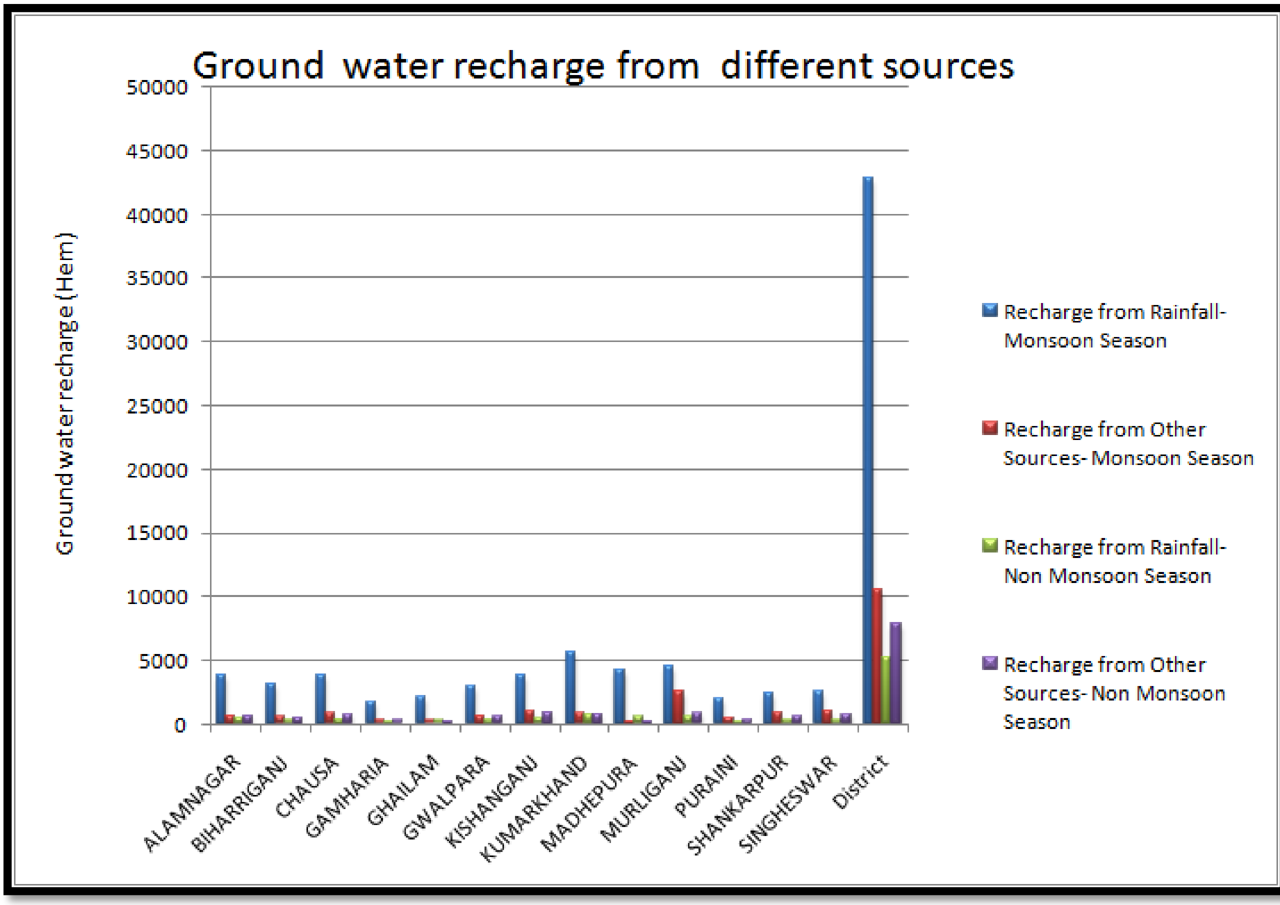


Figure 27: Ground water recharge from different sources

4.4. Monsoon verses Non-Monsoon Ground water Recharge

Perusal of Figure 28 reveals thatcolumn diagram of ground water recharge from monsoon period and non-monsoonperiod. The recharge data reveals that the contribution of ground water recharge from monsoon period is about to 80 % of total ground water recharge whereas non monsoon recharge contributes merely 20 %of total ground water recharge.

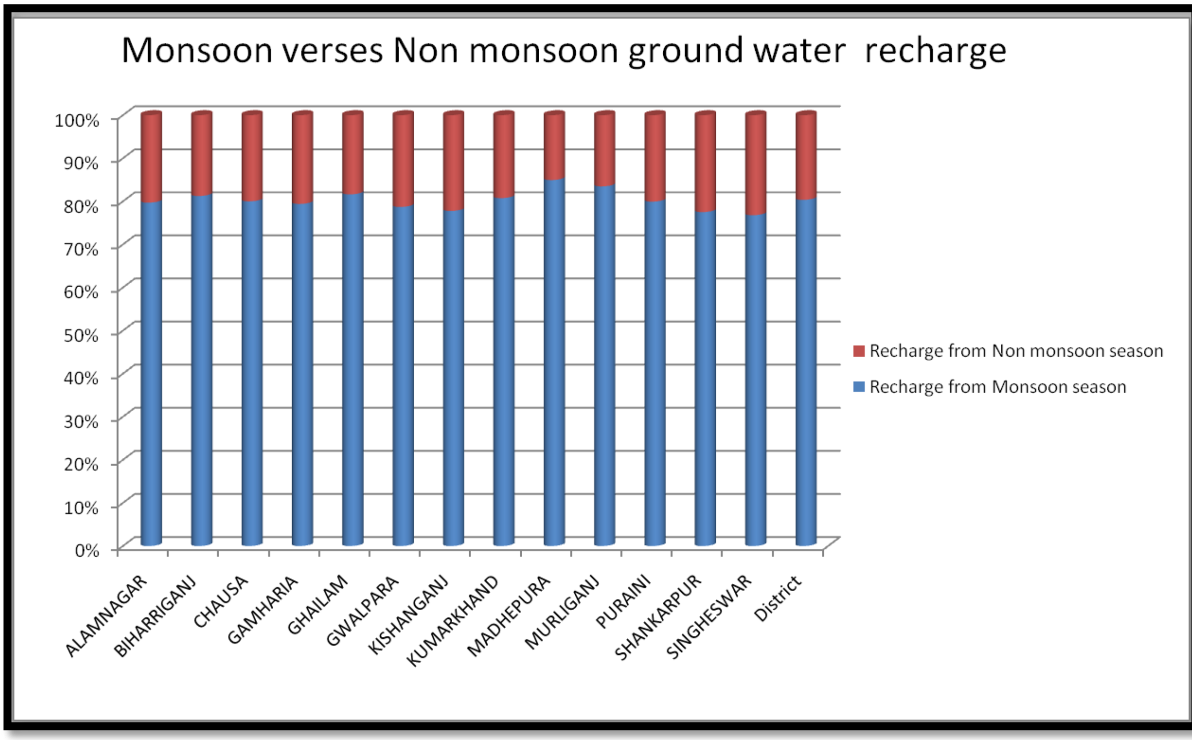


Figure 28: Monsoon verses Non-Monsoon Ground water Recharge

5.0. GROUND WATER RELATED ISSUES& PROBLEMS

Identification of issues related to groundwater in the study area are basically focused on the aspect of quality, quantity and sustainability. The major issue of the district is seasonal flooding and water logging. As per earlier records of CGWB, iron contamination has been reported in shallow tube wells in some pockets. In the case of quantity, 6 blocks of the district comes under safe category and rest are comes under semi-critical category as per GWRE-2020. Major groundwater issues in the district are detailed below:

1. Seasonal flooding and water logging: The district forms part of Kosi mega fan and experiences seasonal flooding and water logging in many parts. The river enters into plains of north Bihar, the velocity of flow is dropped leading to reduction of sediment carrying capacity. Thus sediments deposited into river beds, resulting into rise of river bed and bank erosion. The mouth of the channels also gets choked causing shift in river courses. This further contributed to the rise in the river water level, which ultimately leads to overtopping and breaches of banks and flooding in the basin area. This potentially arrest agriculture activities and crop productivity. Water logging in vast flood plains of Kosi persists till October and this delays agriculture activities during Rabi season. Flooding and water logging coupled with demographic pressure put farmers to go for subsistence crops rather than value crops in many parts of the district.

2. Irrigation demand for groundwater: Irrigation in the district is mainly dependent on groundwater. From agriculture statistics, and minor irrigation census data it can be observed that about 88% of the district's irrigation needs are catered by groundwater. As such no major ground water issues have been observed in the study area.

3.The area is receiving exorbitantly high normal rainfall of 1231mm. Moreover the high temperature leads to increase the rate of the evaporation and evapo-transpiration but it's not much significant in area having abundant streams and streamlets. The aquifer is prolific and has vast aerial extension. Ground water level of the area is shallowoccursup to depth of 5 mbgl. The study of hydrographs reflect that majority of hydrographs are showing rising trends whereas few Hydrographs show almost flat trend. Shallow water level condition often leads to adverse effect on deep root plants and hinders the plant growth and ultimately affects the crop quality as well as crop yield.

4.Riverine Erosion: There are two factors of this hazard (1) the harmonic natural erosion due to channel oscillation in the meander belt and (11) the disharmonic erosion due to sudden high discharge in the channel resulting in the uncontrolled erosion and channel avulsion. From the geomorphic and tectonic consideration and also from the field observation of channels pattern and micro-relief features, it is evident that the Madhepura district is prone to the second type of riverine erosion.

5.Earth Quake: The Kosi basin area is susceptible to earth quake to its tectonic from work. The area was rocked by severe tremor on 15th January 1934.In recent time ,i.e. on 21st Aug'1988 the was again rudely shall-waived by the ominous rumbling from deep below due to severe earth quake caused considerable damage of life and property. Even the GroundWater started oozing from the depression caused by this earth quake whose epicenter was located near Dharm town in Nepal, which is about 50 Km.

6.0. MANAGEMENT STRATEGIES

As per the resource evaluation (GRE 2020) the average utilization of ground water in the district is 70.62%.Alamnagar , Biharriganj, Gwalpara,Kishanganj, Shankarpur,Singheswar blocks in the district comes under semi-critical whereasChausa, Ghailarh, Kumarkhand, Madhepura, Murliganj, Puraini blocks comes under safe category.

Ground Water Management Options

6.1. Supply side Interventions

- Canal lining will improve the water use efficiency of canal water but recharge to ground water from canal seepage will be reduced. So, canal lining is not advisable except in the heavy filling patches, where canal seepage is more than the ground water use and the seepage water is converting the adjacent land to sodic lands. Even in the canal command areas the existing canals are losing their utility and storage capacity for agriculture purposes due to siltation as well as improper management. Through desiltation and proper management, canals can be efficiently used for irrigation purposes. Thus the stress on ground water can be minimize
- Construction of nala bunds
- Revival and renovation of ponds
- On farm activities like laser levelling, bench terracing, construction of farm ponds, plantation of forests etc.

6.2. Demand side Interventions

i. ***Management of Surface water resources***

- Surface water resources like canal and ponds/tanks should be used to meet the specified demand in a given area especially for irrigation purposes.
- The area irrigated by ground water structures is 80 % while irrigation through canal and ponds is only 20%. There is urgent need to increase the surface water irrigation to reduce the stress on ground water along with intervention practices.

ii. ***Change in irrigation practices***

- More area can be brought under agriculture through judicious use of ground water and advance irrigation techniques.

- Lowering of full supply level of irrigation channels. If the full supply level of irrigation channel is reduced, there will be lesser seepage loss from embankment. The effective head between full supply level and field will also reduce and therefore chances of wastage of water are avoided.
- There is urgent need to promote piped and pressurized irrigation practices which can save 25 to 70% of water use in the agriculture.
- Quality of production and increase in productivity can be gained by adopting drip and sprinkler irrigation system.

iii. *Diversification of cropping pattern*

- Area with high water table may be allowed only for Kharif irrigation and during Rabi the cultivators may irrigate from dug wells and tube wells.
- Cultivation of new crops in nontraditional seasons and regions.
- Encouraging horticulture crops on uneven field.

iv. *On Farm Practices*

Laser leveling has been found very effective ensuring saving of 10 to 30% of applied irrigation. This technique is well known for achieving higher levels of accuracy in land levelling and offers great potential for water savings and higher grain yields. Other on- farm activities like contour bunding , water harvesting structures, diversification of cropping pattern will help to capture and hold rainfall before it can runoff, thereby less consumption of water.

Table16: Block wise unit Draft

	Block	Draft For Irrigation (from Resource) Ham	Net Irrigated Area (From Statistical Diary) Ha	Unit Draft
1	Alamnagar	3532.5	8142	0.43
2	Biharriganj	2892.5	10460	0.28
3	Chausa	3410	6780	0.50
4	Gamharia	1637.5	6419	0.26
5	Ghailarh	1367.5	6191	0.22
6	Gwalpara	3425	12247	0.28
7	Kishanganj	4760	8249	0.58
8	Kumarkhand	4332.5	18594	0.23
9	Madhepura	1347.5	11976	0.11
10	Murliganj	3390	16845	0.20
11	Puraini	1365	5037	0.27
12	Shankarpur	2925	5606	0.52
13	Singheswar	3140	10090	0.31

Table17: Projected Stage of Development (%) After Interventions

Block	CDs (Nos)	NBs (Nos)	Str Dev (Km)	Ponds (Nos)	On-farm (ha)	Water Use EfficiencyWUE (ha)	Rech frm Str MCM	Saving from Str MCM	Saving frm On-farm & WUE MCM	Total Rech MCM	Total Saving MCM	Present Stage of Ground Water Development (%)	Projected Stage of Development (%) After Interventions
Alamnagar	2	2	2	2	587	587	0.11	0.11	1.53	0.11	1.64	77.35	74.02
Biharriganj	1	1	1	1	1173	1173	0.07	0.07	1.95	0.07	2.01	75.62	70.83
Chausa	1	1	1	1	877	877	0.09	0.09	2.65	0.09	2.73	68.59	63.58
Gamharia	1	1	1	1	636	636	0.05	0.05	0.97	0.05	1.02	79.52	74.98
Ghailarh	1	1	1	1	659	659	0.06	0.06	0.87	0.06	0.93	61.29	57.57
Gwalpara	1	1	1	1	1436	1436	0.07	0.07	2.41	0.07	2.48	86.60	80.78
Kishanganj	1	1	1	1	852	852	0.09	0.09	2.95	0.09	3.04	89.21	83.94
Kumarkhand	2	2	2	2	2649	2649	0.16	0.16	3.70	0.16	3.86	68.84	63.33
Madhepura	2	2	2	2	1535	1535	0.12	0.12	1.04	0.12	1.16	42.63	40.14
Murliganj	2	2	2	2	2142	2142	0.13	0.13	2.59	0.13	2.71	52.48	48.85
Puraini	1	1	1	1	677	677	0.06	0.06	1.10	0.06	1.16	57.95	53.72
Shankarpur	1	1	1	1	848	848	0.07	0.07	2.65	0.07	2.72	82.64	75.53
Singheswar	1	1	1	1	1272	1272	0.07	0.07	2.37	0.07	2.45	83.52	77.63
Total	18	18	18	18	15342	15342	1	1	27	1	28	71	67

Table 18: Projected Stage of Development (%) After Interventions

Blocks	Area	Net Annual Ground Water Avail-ability (MCM)	Existing Gross Ground Water Draft for All Uses (MCM)	Present Stage of Ground Water Development (%)	TOT RECH through interventions (MCM)	Tot GW Saving through interventions (MCM)	Projected Net GW Availability (MCM)	Projected Gross GW Draft (MCM)	Projected Stage of Development After Interventions
Alamnagar	171.2	51.55	39.88	77.35	0.11	1.64	51.66	38.24	**74.02**
Biharriganj	105.68	43.00	32.52	75.62	0.07	2.01	43.07	30.51	**70.83**
Chausa	136.65	55.65	38.17	68.59	0.09	2.73	55.74	35.44	**63.58**
Gamharia	76.55	23.28	18.52	79.52	0.05	1.02	23.33	17.50	**74.98**
Ghailarh	91.77	25.92	15.89	61.29	0.06	0.93	25.98	14.96	**57.57**
Gwalpara	116.68	43.72	37.86	86.60	0.07	2.48	43.79	35.38	**80.78**
Kishanganj	148.69	59.23	52.84	89.21	0.09	3.04	59.32	49.80	**83.94**
Kumarkhand	247.09	71.78	49.41	68.84	0.16	3.86	71.93	45.55	**63.33**
Madhepura	189.95	48.48	20.67	42.63	0.12	1.16	48.60	19.51	**40.14**
Murliganj	197.45	76.61	40.20	52.48	0.13	2.71	76.73	37.49	**48.85**
Puraini	86.98	28.06	16.26	57.95	0.06	1.16	28.11	15.10	**53.72**
Shankarpur	108.58	39.02	32.25	82.64	0.07	2.72	39.09	29.53	**75.53**
Singheswar	111.13	42.41	35.42	83.52	0.07	2.45	42.48	32.98	**77.63**
Total	1788.4	608.72	429.88	70.62	1.14	27.92	609.86	401.96	**65.91**

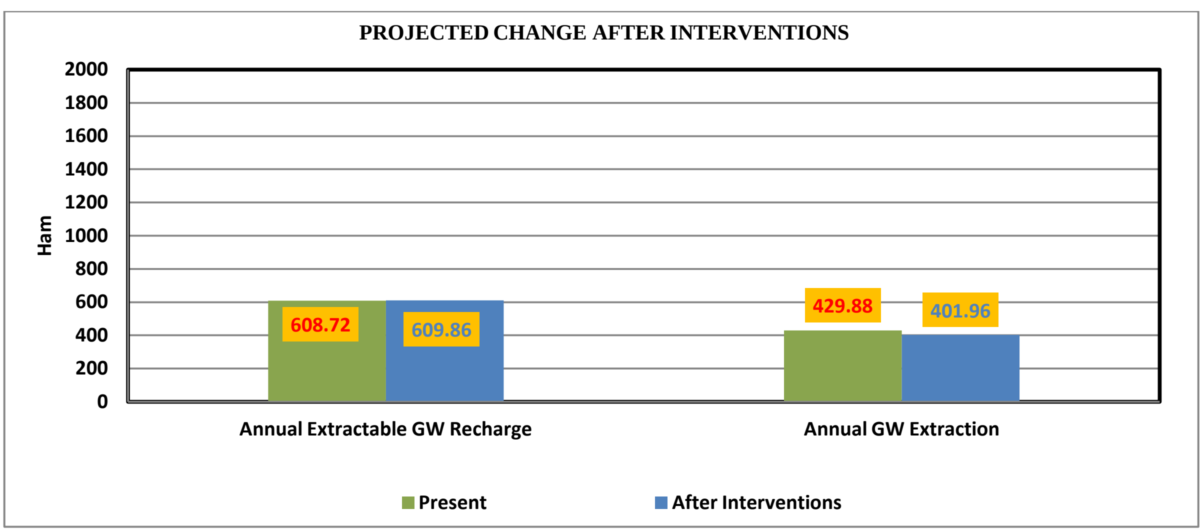


Figure29: projected change after interventions

	Annual Extractable GW Recharge	Annual GW Extraction
Present	608.72	429.88
After Interventions	609.86	401.96

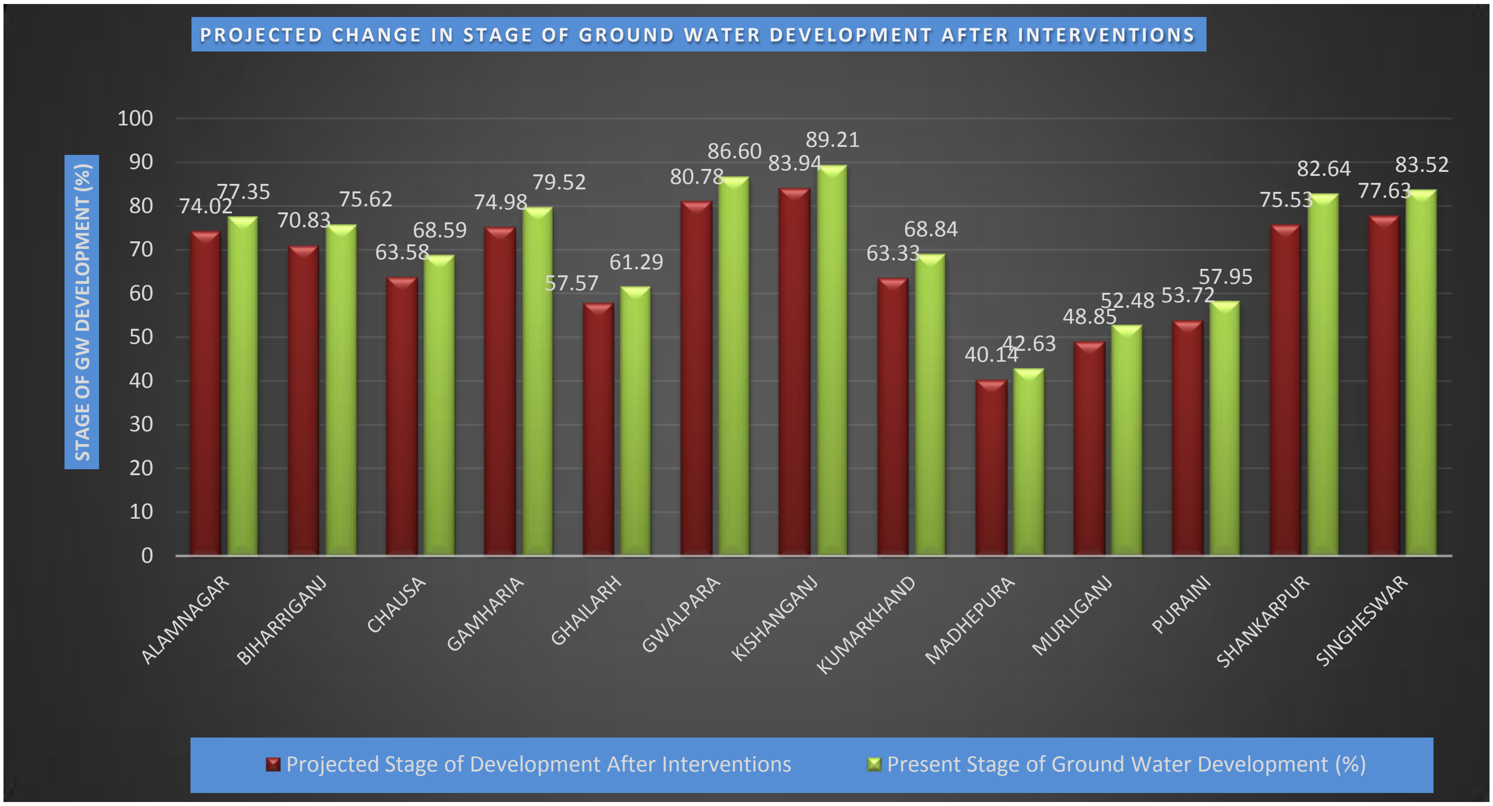


Figure30: projected change in stage of ground water development after intervention

7.0. RECOMMENDATION

Flood hazard

Flood hazard is the global phenomena, it can be completely eradicated but, can be minimized. After taming the Kosi River and its tributaries (Kosi dhars) through embankments the effect of flood have been minimized. But still the flood is there which requires proper attention to minimized to mitigate the suffering of the people. The remedial measures to be taken are given below:-

1. Due to the continuous siltation of the beds of Kosi river and its tributary continuous are making the beds shallower and shallower, almost to the ground level, in turn making the river influent, it the de-siltation of the river bed is carried out in a planned way, and regularly, the river channels will become deep and allow more volume of water to flow through it. Ultimately it might change the influent condition of the river to effluent condition. It will minimize the inundation as well as water logging (Singh, 1989).
2. Series of fishing pond can be constructed in existing water logged area by excavating 100 X 100 X 6 m. size of earth material. The idea behind it is that the ponds constructed 6 m. Deep will create void space in the Sub-surface locally. In turn the hydraulic gradient of water table will become concentric towards pond and consequently the adjoining aquifer will be de-watered. Hence the water table shall be lowered to some extent and consequently water logging will be minimized.
3. All the rivulets has to be widened and deepened and finally at the confluence of its major river should be provide with proportionate sluice gate. The excavated material should not be kept as an embankment which may serve as a cultivated land. All the small rivers or rivulets (Kosi dhars) are having the small catchment area which does not require embankment for its discharge, only desilting of the bed is sufficient. For low lying around Udakishanganj parts of alamnagar, should made to avoid water logging by constructing of channels and discharge the excess water into the rivers.

Soil erosion

This is a seasonal phenomenon caused by the absence of the absence of protective green cover on uncompact soil aided by the absence of binding clay in the matrix. The sandy cover of the completely aggraded meander scroll areas in the domain of Kosi fan (Madhepura district is located on Kosi fan) and sandy bar area of the diara plain in Ganga Kosi and other active river channels are seasonally particularly from March to May end. Soil erosion by surface run off during monsoon is largely arrested by the traditional layout of agricultural land. Creation of green belts through social forestry is the only practical means to prevent Aeolian transport of the zonal and a zonal alluvial of the area.

Siltation

Earlier, the entire basin was prone to the problem of siltation as the Kosi and its various en-branches used to carry a log of silt that was deposited on the ground during the floods. The channel thus used to choke up due to rise of channel bed result in channel aggradation. This problem has been overcome after the construction of the Kosi-barrage and embankments on the Kosi dhars. But the problem of siltation has posed a serious threat to the canal network of designed capacity of the canal due to rise in the canal bed. This also diminishes the productivity of land as a considerable amount of sand is deposited on the ground carried by the canal water. This problem may be solved by constructing siltation tank at various stages.

Agriculture and Irrigation

Agriculture the main occupation of the district depends mainly on the availability of the quantity of water required in proper time. Rain fall has been the main source of water. Rainfall is not a dependable source of water and irrigation facilities are essential. So, far the older irrigational facilities are concerned there were bunds, tanks, well etc. The Tilabeb River and several Kosi dhars were bonded up and water was lifted by the contraption-known as Kartins (Palm-tree trunks hollowed out). Water was led from the reservoirs formed by damming up of the raised for irrigational purposes. Such wells did not last long due to a sandy soil. Contraption like Karting, Sewing basket etc. Were used these temporary irrigational provisions have from time to time been very heavily damaged and in some cases fully destroyed by the ravages of Kosi and its tributaries.These temporary arrangements had continued to be built up till the Kosi project were built and the network of canals provided for irrigation.There are many high patches of lands on which the will have no control within the command area and such lands can be irrigated only by lifting the water either from tube wells or perennial Kosi dhars.

There are many chaurs in the district which can be used for irrigation if proper drainage system is developed. Since the people within the embankments were liable to flood and inundations, they could not have thought of irrigational facilities, but when embankments have been constructed and there is no heavy flood as used to be experienced before, tube wells are being constructed for irrigating the agricultural fields .

Drought

Owing to the construction of barrage in Nepal, the discharge of water through distributary canals, is regulated in such a way that the water is mostly utilized within Nepal and streams remain almost dry with meager amount of water during summer, water made available in the India is inadequate for the vast population. Added to this, as and when monsoon fails the drought like situation prevails putting the people of the area into great difficulties.

- There exists further scope for development of groundwater for irrigation purposes without disturbing the groundwater regime in the district. Tube wells should be installed keeping the safe operating distance of 200 m.
- Energisation of all the tube wells should be made for increasing the cropping intensity.
- Chemical quality of groundwater has been observed to be in general suitable for drinking and irrigation purpose. In areas where high iron concentration is present, domestic water supply should be made after proper treatment of groundwater. Alternate deeper aquifers, free from iron may also be found for the purpose.
- The district is backward industrially. The water based industry may be promoted for utilizing the resources in a planned manner.
- There is data gap in the study area. Aquifer wise ground water exploration is recommended in all the blocks to ascertain characteristics of each aquifer
- Abandoned river channels, Ox-bow lakes and excavations should be converted into rain water conservation tanks instead of garbage dumping ground.
- Ground water flow modeling study of the Aquifer system is recommended for future prediction of ground water scenario of Madhepura district.

Annexure 1

Depth to water level data pre- and post- monsoon and Key wells data

S.NO.	BLOCK	LOCATION	LATITUDE	LOGITUDE	May,19	Nov,19
1	Chausa	Abhiyatola	25.531	87.050	6.12	3.54
2	Chausa	Chausa1	25.513	87.033	5.21	2.69
3	Puraini	Ganeshpur	25.593	86.981	4.06	1.48
4	Madhepura	Bhimpura	25.909	86.835	4.09	2.07
5	Madhepura	Hatkora bazar	25.929	86.875	4	2.02
6	Madhepura	Madhepura	25.929	86.875	4.18	3.87
7	Madhepura	Surajganj	25.905	86.720	3.1	1.6
8	Alamnagar	Gaushala Chowk	25.593	86.938	3.38	2.72
9	Murliganj	Murliganj	25.883	86.983	2.96	1.57
10	Murliganj	Rajui Rajni	25.827	86.977	3.86	1.98
11	Murliganj	Rampur	25.889	86.937	4.29	2.76
12	Shankarpur	Barahari	26.080	86.807	3.48	2.38
13	Gamharia	Jiwachhapur	26.030	86.736	4.07	3
14	Singheswar	Singheswar	25.992	86.817	5.36	3.11
15	Gwalpara	Gwalpara	25.754	86.906	4.06	2.04
16	Biharriganj	Kusthan	25.749	86.990	4.61	2.5
17	Biharriganj	Uda Kishanganj	25.681	86.949	5.04	3.03

Annexure 2

Lithological logs of bore holes in Madhepura district depicting the potential sand zones down to 100 m depth

(***Source: Hydrogeology and Ground water resource of Madhepura District , Bihar, Eastern Region Calcutta, March 1994)***

LITHOLOGY	DEPTH (m)	THICKNESS (m)
silty clay	0-6	6
fine sand	6-35	29
medium-coarse sand	35-50	15
coarse sand	50-88	38
clay	88-103	15
Murliganj		
LITHOLOGY	**DEPTH (m)**	**THICKNESS (m)**
silty clay	0-3	3
medium - coarse sand	3-15	12
fine sand	15-34.5	19.5
medium - coarse sand	34.5-55.5	21
coarse sand	55.5-100.5	45
Puraini		
LITHOLOGY	**DEPTH (m)**	**THICKNESS (m)**
silty clay	0-3	3
fine sand	3-28	25
medium-coarse sand	28-47.5	19.5
coarse sand	47.5-64	16.5
clay	64-70	6
coarse sand	70-100	30
Chausa		
LITHOLOGY	**DEPTH (m)**	**THICKNESS (m)**
clay	0-15	15
medium - coarse sand	15-30	15
fine sand	30-39	9
coarse sand	39-48	9
medium - coarse sand	48-58	10
coarse sand	58-101	43

Uda Kishanganj		
LITHOLOGY	**DEPTH (m)**	**THICKNESS (m)**
clay	0-4	4
fine sand	4-45	41
medium - coarse sand	45-56	11
clay	56-62	6
medium - coarse sand	62-97	35
coarse sand	97-103	6
Singheswar		
LITHOLOGY	**DEPTH (m)**	**THICKNESS (m)**
clay	0-3	3
coarse sand	3-9	6
silty clay	9-12	3
coarse sand	12-28.5	16.5
medium-coarse sand	28.5-43.5	15
clay	43.5-46.5	3
coarse sand	46.5-63	16.5
fine sand	63-72	9
coarse sand	72-100.5	28.5
Sankarpur		
LITHOLOGY	**DEPTH (m)**	**THICKNESS (m)**
silty clay	0-3	3
fine sand with kankars	3-17	14
fine sand	17-31	14
medium -coarse sand	31-52	21
coarse sand	52-94	42
medium -coarse sand	94-100	6