केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

NATIONAL AQUIFER MAPPING

Parts of Bhojpur, Buxar, Patna, Bhagalpur and Kathihar Districts, Bihar

मध्य पूर्वी क्षेत्र, पटना

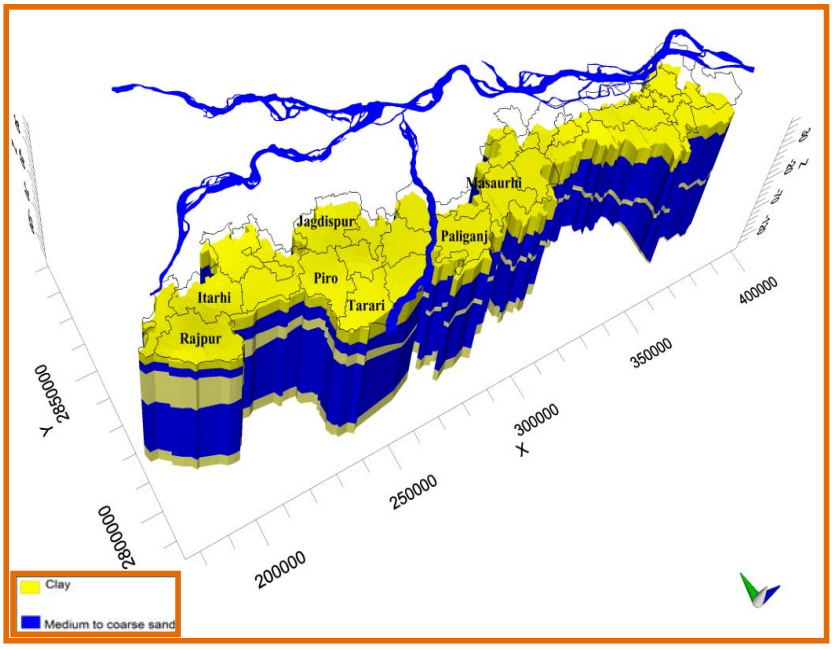
Mid-eastern Region, Patna

Report

on

Aquifer Mapping in parts of Bhojpur, Buxar, Patna, Bhagalpur & Katihar Districts, Bihar

(NAQUIM Phase - IV & V)
2016-17 & 2017-18



केंद्रीय भूमि जल बोर्ड

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मध्य पूर्वी क्षेत्र पटना

CENTRAL GROUND WATER BOARD
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION
GOVERNMENT OF INDIA
MID EASTERN REGION, PATNA

October 2018

Report
on

Aquifer Mapping in parts of Bhojpur, Buxar, Patna, Bhagalpur & Katihar Districts, Bihar

(NAQUIM Phase - IV & V)
2016-17 & 2017-18

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Aquifer Mapping in Parts of Bhojpur, Buxar, Patna, Bhagalpur and Katihar Districts, Bihar State (NAQUIM Phase IV & V Combined)

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Report on NAQUIM Phase IV & V in parts of Buxar, Bhojpur, Patna, Bhagalpur & Katihar, Bihar during 2016-17 & 2017-18

Executive Summary

Under the Phase IV & V of National Aquifer Mapping Programme (NAQUIM) in Bihar, a total of 39 blocks falling in parts of Bhagalpur, Katihar, Buxar, Bhojpur and Patna districts have been taken up for detailed hydrogeological survey and preparation of Aquifer Management plan. In the study, hydrogeological survey, ground water exploration study, geophysical investigations and groundwater quality studies have been undertaken and the data generated have been used in conjunction with the existing data available in the area in preparation of the aquifer maps and formulation of the aquifer management plan.

Detailed mapping of an aquifer encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale. The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale in general, in identified problematic areas.
- Quantification of ground water availability and assessment of its quality.
- Formulation of aquifer management plans to facilitate sustainable management of ground water resources through participatory management approach with active involvement of stakeholders.

a) In the field of Arsenic contamination in 1st aquifer in its upper most parts.
b) Important management challenge lays in the protection of the deeper aquifer from any possible threats of cross-contamination from 1st aquifer.
c) In the domain of Fluoride contamination in hard rock area of Bhagalpur district.
d) Conjunctive solution to prolonged seasonal water logging during June to October.

Area falling under Phase IV & V of NAQUIM in Bihar state covers the aquifers in the Ganga stem part and spreads over in parts of Buxar, Patna, Bhojpur, Katihar and Bhagalpur districts located on the northern and southern banks of the River Ganga. Study area spreads over 6,070 sq. km covering 39 administrative blocks.

The soil type is fine silty to coarse loamy. The Son River and its tributaries drain the western part of the area whereas; the River Ganga drains the eastern part of the area. The average altitude of the area varies from 41.3 to 96.7 m amsl in the western part, from 41 to 52.5 m amsl in middle part and from 15.4 to 161.4 m amsl in the eastern part of the area. The slope of the whole area varies from 0-1% to 2-4% on an average and the slope is towards River Ganga.

Geomophologically, the area is occupied by alluvial plain (shallow, moderate & deep) along with back swamp and deep flood plain area. In North bank of River Ganga, the area is

mostly Char / Diara land, lying within active flood plain of the River Ganga. The rainy season receives south-west monsoon and accounts for about 85-90% of the total rainfall. The area receives an average normal monsoon rainfall of about ~ 1,100 mm/year. Tals remain submerged into 1 to 3 m of water column from mid-June to mid-October during monsoon period. This water bodies act as indirect sources of ground water recharge. It is found that there is an absolute negative departure of last five years rainfall from normal rainfall in Bhojpur, Buxar and Patna districts.

Agriculture is the mainstay of the population in the area. The area falls in the Agro-climatic Zones II, IIIA & IIIB. The principal commercial agricultural products in crops in the area are rice, wheat, lentils, maize (corn), sugar cane and fruits. The principal source of assured irrigation is by Sone cannal system in parts of Bhojpur and Buxar districts and the tail end of Kosi canal system in parts of Katihar district. Ground water and surface water are other main sources of irrigation. The cropping intensity of the five districts varies from 120 to 140%. Irrigation through tube wells is upto 95% of the total irrigated area. Irrigation intensity varies from 42 (Bhagalpur) to 87% (Bhojpur). Dependency on ground water irrigation varies from 47 (Bhojpur) to 95% (Katihar) in the area.

The area forms a part of the Gangetic plain underlain by immensely thick alluvial deposits comprising sediments (sand, gravel and clay) of Quaternary age deposited un-conformably over the Pre-Cambrian basement. The alluvial deposits are characteristically divided into the Older and the Younger Alluvium. The Quaternary alluvium occupies more than 90% of the total geographical area of the study area. These alluviums have formed extensive and prolific aquifer systems in the area down to the explored depth of about 300 m bgl.

A total of 115 key wells have been set up to monitor depth to water levels during pre-monsoon and post-monsoon periods during 2016-17 & 2017-18 respectively. Lithological logs of 22 exploratory wells of CGWB have been considered for determination of aquifer characteristics. It is found that depth to water level varies from 5 to 8 m bgl during pre-monsoon and 2 to 5 m bgl during post-monsoon period in general. Water table during pre-monsoon period varies from 45 to 65 m amsl in Bhojpur-Buxar area, whereas in parts of Bhagalpur-Katihar area, it varies from 25 to 55 m amsl. Average depth of fluctuation of water level is 2 m. Total 55 VESs have been conducted. 70 water samples have been analyzed.

Mono aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area in parts of Katihar district. However, in Manihari block, 1st aquifer is found in the depth of 20-60 mbgl and 2nd aquifer is encountered at the depth of 94 m bgl and it is continued further.

In parts of Buxar and Bhojpur area, 1st aquifer occurs at the depth range of 16-80 m bgl while, 2nd aquifer is at the depth range of 90-260 m bgl. Ground water occurs under water table to semi-confined condition in 1st aquifer and in confined conditions in 2nd aquifer respectively. In parts of Buxar district, discharge of 1st aquifer varies from 30 to 50 cu.m/hr. In parts of Bhojpur district, discharge of 1st aquifer varies from 50 to 100 cu.m/hr. with

drawdown of 3-6 m. The discharge of 2nd aquifer varies from 138 to 175 cu.m/hr with drawdown of 5 to 7 m. Transmissivity ranges from 5073 to 5542 m^2 /day. In parts of Patna district, 1st aquifer occurs at the depth range of 58-120 mbgl, whereas 2nd aquifer lays at the depth range of 136-200 m bgl in Dulhin Bazar area. In parts of Belchi and Ghoswari area, 1st aquifer occurs at 20-70 m bgl, 2nd aquifer lays at 80-230 m bgl at Belchi area. Sometimes, 3rd aquifer system is also found at the depth range of 240 m to explored depth of 306 m bgl at Belchi and Ghoswari area.

In parts of south bank of Ganga River, single aquifer system is prevalent in the southern portion of Bhagalpur district adjoining Banka district at the depth of 25-75 m bgl. In Sabour block, 1st aquifer occurs at depth range of 66-97 m bgl. In north-eastern parts in Kahalgaon area, aquifer occurs at 79-131 m while in Pirpainty area, 1st aquifer occurs at 58-92 m bgl and 2nd aquifer occurs at 101-182 m bgl. Cumulative discharge of tube well is in the order of 50-75 cu.m/hr with drawdown of 17-22 m. Transmissivity is in the order of 111-209 m^2/day and storativity is 7.5×10^{-4} - 1.1×10^{-3} . Transmissivity at Rampur in Kahalgaon block is 4207.64 m^2/day . Specifically, in parts of Bhagalpur area, aquifer discharge and drawdown varies spatially as per the aquifer disposition as alluvium is thinner and underlain by hard rock in various locations.

In general, Ca-Mg-HCO_3 type ground water is found prevalent in the area which represents ground water is the resultant of direct rainfall recharge and its residential time is low. It is evident from USSL diagram that ground water is suitable for irrigation purposes, though medium to high salinity problems, particularly irrigation command area of Sone are conspicuous. Medium to high salinity hazards are also found in the study area. Out of 70 ground water samples, arsenic contamination of more than 10 ppb is found in 13 samples in parts of Bhagalpur and Katihar districts. Fluoride contamination in ground water in parts of hard rock area of Bhagalpur district is also found. Some salient points of the study are summarized below.

1) Arsenic above permissible limit in shallow aquifer in blocks under NAQUIM falling in Katihar and Bhagalpur districts.
2) Single aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 275 m bgl in parts of Katihar district. The thickness of clay layer is thickening in eastern part. Due to prolific nature of aquifer, arsenic contamination is restricted in shallow aquifer only.
3) Absence of potential aquifer below 100 m in Kahalgaon and Pirpainti block of Bhagalpur district.
4) Low ground water development in following NAQUIM areas is observed.

- Blocks under Bhojpur and Buxar districts
- Dulhin Bazaar and Paliganj in Patna district
- Kahalgaon and Pirpainti in Bhagalpur district
- Blocks in Katihar district

5) High and continuously increasing development of ground water is in Punpun, Fatuha and Sampatchak blocks of Patna district due to rapid urbanization in these areas. As per Ground Water Resource Estimation, 2013 Sampatchak is falling under 'Semi-critical' category.

The aquifer system in the entire study area may be summarized into the followings.

Buxar: Three aquifer zones exist in the area. 1st aquifer occurs at the depth range of 07-62 m bgl at Itarhi, Nawanagar & Keshath whereas at Rajpur, it occurs at 92-116 m bgl. Average thickness is 42 m. 2nd aquifer is at the depth range of 60-190 at Itarhi, Nawanagar & Keshath, whereas 2nd aquifer occurs at depth range of 122-262 m at Rajpur. Average thickness of 2nd aquifer is 110 m. In parts of Buxar district, discharge of 1st aquifer varies from 30 to 50 cu.m/hr. The discharge of 2nd aquifer varies from 100 to 200 cu.m/hr with draw down of 3 to 7 m. Transmissivity ranges from 1098 to 5187 m^2 /day.

Bhojpur: 1st aquifer occurs at the depth range of 30 -78 m bgl. Average thickness of 1st aquifer is 26 m. Maximum alluvium thickness (76 m) is found at Charpokhori. 2nd aquifer is at the depth range of 90-300 m bgl. Average thickness of 2nd aquifer is 110 m. In parts of Bhojpur district, discharge of 1st aquifer varies from 50 to 100 cu.m/hr. with draw down of 3-5 m. The discharge of 2nd aquifer varies from 100 to 200 cu.m/hr with drawdown of 4 to 10 m. Transmissivity ranges from 4769 to 5918 m^2 /day.

Patna: Top Aquitard Layer- The top aquitard layer is highly mixed and behaves like a low potential aquifer. The presence of silt in the top zones at places renders it semi-pervious in nature. This layer sustains the dug wells and shallow hand pumps in the area.

In parts of Patna area, 1st aquifer occurs at the depth range of 30-58 to 70-120 mbgl, whereas 2nd aquifer is at the depth range of 136-200 m bgl in Dulhin Bazar area. In parts of Belchi and Ghoswari area, 1st aquifer occurs at 20-70 m bgl, 2nd aquifer lays at 80-230 m bgl at Belchi area. Sometimes, 3rd aquifer system is found at the depth range of 240 to explored depth of 306 m bgl at Belchi and Ghoswari area. Pumping test data of Fatuha shows that discharge of tubewell is 188 cu.m/hr with drawdown of 5 m. Transmissivity is in the order of 10435 m^2 /day.

Bhagalpur: The geology of Bhagalpur is widely varying in nature and it has great impact on aquifer configuration of the area. Exploratory data reveal that single aquifer system (unconsolidated) is present upto 131 m depth in Kahalgaon area. Then, the hard rock is encountered. Aquifer thickness increases towards the Ganga River. In Pirpainti block, trap-basalt is encountered at the depth range of 68-73 (Jagdishpur, Laxmipur). Gondwana formation is encountered at depth of 101 m at Hardeochak, Lakshmipur). Granite gneiss is encountered at the depth range of 60 (Maheshmund), 73 (Coglong), 95 (Madarganj) - 128 (Harchandpur), 137(Ghogha). Alluvium thickness is a few m. In the western part, alluvium is directly laying on granite gneiss, while in the eastern part alluvium is resting on Gondwana formation (Damuda Series). Cumulative discharge of tube well is in the order of 20-50 cu.m/hr with drawdown of 11-20 m. Transmissivity is in the order of 111-209 m^2/day and

storativity is 7.5 x 10^{-4} - 1.1 x 10^{-3} . Transmissivity at Rampur in Kahalgaon block is 4207.64 m^2/day.

Katihar: Mono aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area. However, in Manihari block, aquifer is found in the depth of 20-60 mbgl and 2nd aquifer is encountered at the depth of 94 m bgl and it is continued further.

Management Plan for the entire Study Area

- ✓ **Bhagalpur district** - Supply of arsenic free ground water from deeper aquifer which is still to be explored in details. Filtered surface water supply is only possible mitigation measure.
- ✓ **Katihar district** - A mono aquifer system with thin layer of clay (~ 15 m) at the top. It is obvious that with more dewatering of the aquifer, vertical depth of arsenic contamination will be increased. Hence, regulation in dewatering of ground water from shallow depth should be prioritized.
- ✓ Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants may also be the reasonable mitigation measures.

Low ground water development

- ✓ All the blocks of Bhojpur, Buxar, Bhagalpur and Katihar districts.
- ✓ Dulhin bazar and Paliganj Blocks of Patna district.

Total 36,945 No. of shallow tube wells have been worked out to be constructed in the study area considering ground water development up to 70% Stage of Development (SOD).

High and Continuously Increasing Development of Ground Water in parts of Patna District

High and continuously increasing dewatering of ground water in Punpun, Fatuha and Sampatchak blocks of Patna district due to immense urbanization should be checked. Extraction from 1st aquifer should be regulated. Extraction from 1st aquifer should be stopped for supply of drinking water and extraction from arsenic free deeper aquifer should be started for water supply.

To avoid cross contamination of arsenic from 1st aquifer due to unregulated extraction from 2nd aquifer, care should be taken and discharge of 2nd aquifer should be limited within 50 m^3/hr. To avoid interference between deeper tube wells, 2 km gap between tube wells should be maintained. In no source (ground water) area, surface water may be utilized after proper filtration for water supply. In extreme situation, arsenic removal plants may be installed for filtration of arsenic contaminated ground water for water supply. In this case, care should be taken in treatment of sludge and its disposal. In urban area, roof top rain water harvesting should be amended.

Part -1
District wise (or part of a district) Technical Report
CHAPTER- 1

1. Introduction

There is a need for scientific planning in development of ground water under different hydrogeological situations and to evolve effective management practices with involvement of community for better ground water governance.

Aquifer mapping is a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. In National Aquifer Mapping Programme, mapping of the aquifer systems at scale of 1: 50,000 are considered necessary for planning its sustainable development and management. This will improve our understanding of aquifers, its charateristics over time and occurrence of natural and anthropogenic contaminants affecting potability. Results of the study contribute to implement various management interventions to acheive drinking water security, sustainability of precious ground water resources.

Under the Phase IV & V of National Aquifer Mapping Programme (NAQUIM) in Bihar, a total of 39 blocks falling in parts of Bhagalpur, Katihar, Buxar, Bhojpur and Patna districts have been taken up for detailed hydrogeological survey and preparation of Aquifer Management plan. In the study, hydrogeological survey, ground water exploration study, geophysical investigations and groundwater quality studies have been undertaken and the data generated have been used in conjunction with the existing data available in the area in preparation of the aquifer maps and formulation of the aquifer management plan.

1.1 Objective and Scope

Detailed mapping of an aquifer encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale. The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale in general in identified problematic areas.
- Quantification of ground water availability and assessment of its quality.
- Formulation of aquifer management plans to facilitate sustainable management of ground water resources through participatory management approach with active involvement of stakeholders.

a) In the field of Arsenic contamination in 1st aquifer in its upper most parts.
b) Important management challenge lays in the protection of the deeper aquifer from any possible threats of cross-contamination from 1st aquifer.
c) In the domain of Fluoride contamination in hard rock area of Bhagalpur district.
d) Conjunctive solution to prolonged seasonal water logging during June to October. Phase wise National Aquifer Mapping Area (NAQUIM) is given in Fig. 1.1.

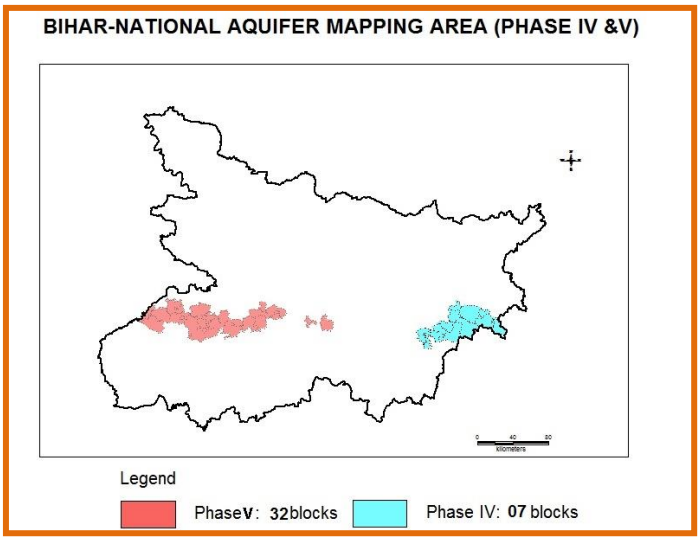


Fig. 1.1 Area covered under NAQUIM Phase IV & V

1.2 Approach and Methodology

The major activities involved in this process include compilation of existing data, identification of data gaps, and generation of data for filling data gaps and preparation of aquifer maps. 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 and land cover, geomorphology, geology, soil, hydrogeology etc. using various GIS and geo-scientific softwares. Data were collected from all concerned agencies for preparing the status of data gap. Greater attention was paid on activities that required generation of additional data to fill the identified gap. Once the maps are prepared, plans for sustainable management of ground water resources in the aquifers mapped shall be formulated and implemented through participatory approach involving all stakeholders. Mapping of the aquifer system at scale of 1: 50,000 is considered necessary for planning its sustainable development with participation of stakeholders.

1.3 Area Details

Area falling under phase IV & V of NAQUIM in Bihar State covers the aquifers in the Ganga stem part and spreads over in parts of Buxar, Patna, Bhojpur, Katihar and Bhagalpur districts located on the northern and southern banks of the River Ganga. Study area spreads over 6,070 sq km covering 39 administrative blocks. The area falls between N Latitudes 25.162^0 and 25.609^0 and E Longitudes 83.767^0 and 87.861^0 falling in Survey of India Toposheet No. 63O/14,15; 2C/2, 3, 6, 7, 8, 10, 11, 12,15 &16; 72G/2,3,6,7; 72G/11,15; 72O/3,4,6,7,8,10,11,15&16. The location of the study area is shown in Fig. 1.1. The population density of the study area is 793 persons per sq. km. The salient demographic details of the administrative blocks falling in the area are given in Table 1.1.

Table 1.1: Demographic details of the administrative blocks falling under NAQUIM area

District	*Block*	*Total area (sq.Km)*	*Rural Population*	*Urban Population*	*Total Population*
Katihar	Mansahi	78	84257	0	84257
	Barari	328	285381	0	285381
	Sameli	129	84486	0	84486
	Kursela	61	63928	0	63928
	Manihari	251	164778	26629	191407
	Amdabad	189	167398	0	167398
Bhagalpur	Gopalpur	132	17917	0	17917
	Pirpainti	351	53103	0	53103
	Ismailpur	83	8228	0	8228
	Sabour	115	24365	2374	26739
	Nathnagar	126	26916	906	27822
	Jagdishpur	110	23439	78376	101815
	Kahalgaon	336	63086	6690	69776
Buxar	Chaugain	55	48743	0	48743
	Kesath	31	33820	0	33820
	Dumraon	198	179064	53618	232682
	Chausa	108	103670	0	103670
	Itarhi	229	170629	0	170629
	Nawanagar	185	166534	0	166534
	Rajpur	274	213534	0	213534
Patna	Sampatchak`	65	106866	0	106866
	Dulhin Bazar	111	124966	0	124966
	Paliganj	238	244290	10614	254904
	Masaurhi	202	181413	59803	241216
	Dhanarua	186	211376	0	211376
	Punpun	127	138143	0	138143
	Fatuha	126	147047	50961	198008
	Daniawan	65	75086	0	75086
	Khusrupur	61	93773	15731	109504
	Belchi	69	66165	0	66165
	Ghoswari	140	74898	0	74898
Bhojpur	Agion	156	148373	0	148373
	Charpokhri	109	101363	0	101363
	Garhani	112	103262	0	103262
	Jagdishpur	258	231512	32447	263959
	Pirro	218	221126	33785	254911
	Sahar	127	110276	0	110276
	Sandesh	130	109712	0	109712
	Tarari	201	182631	0	182631

(As per census 2011)

1.4 Brief Description

Flexing of the Indian lithosphere in response to the compressive forces due to collision and thrust fold loading produced the Ganga plain foreland basin in Early Miocene. The basin expanded in the Mid-Miocene, and attained its present configuration in Late Quaternary.

The phase IV & V area of Bihar stretches from Buxar and Bhojpur in the west, Patna in the middle, to Bhagalpur and Katihar in the east covering parts of five districts and 39 blocks. The total area of 6,070 sq. km. is characterized by highly fertile alluvial plain. The soil type is fine silty to coarse loamy. The Son River and its tributaries drain the western part of the area whereas; the River Ganga drains the eastern part of the area. The average altitude of the area varies from 41.3 to 96.7 m amsl in the western part, from 41 to 52.5 m amsl in

middle part and from 15.4 to 161.4 m amsl in the eastern part of the area. The slope of the whole area varies from 0-1% to 2 - 4% on an average and it is towards River Ganga. Moderate dense forest to open forest exists occasionally in the study area. Non-forest area generally prevails in the area. Geomophologically, the area is occupied by alluvial plain (shallow, moderate & deep) along with back swamp and deep flood plain area. In North bank of River Ganga, the area is mostly Char / Diara land, lying within active flood plain of the River Ganga. Groundwater resource is not scarce here rather it occurs abundantly. The area is covered by Younger and Older Alluvium, underlain by Granitic rocks. As one moves towards Munger Hills, thickness of alluvium gradually decreases.

1.4.1 Data Availability

Central Ground Water Board has carried out systematic and reappraisal hydrogeological surveys, exploratory drilling under groundwater exploration programme and depth to water level monitoring under ground water regime monitoring etc. in Bihar state. The data available in the aquifer mapping area from the previous works of CGWB, Public Health Engineering Department, Govt. of Bihar, Minor Water Resource Department, Govt. of Bihar, etc have been compiled and data gap analysis has been carried out for working out the need for additional data generation in the study area. Though, the data generation through inhouse and outsourcing exploration drilling is in progress and this has been incorporated as far as possible.

1.4.2 Data Adequacy and Data Gap Analysis and Data Generation

As per the existing data availability on April 2017, data gap analysis has been carried out. On the basis of this data gap analysis, fresh data has been generated. Salient features of data generation for filling up the data gaps with regard to important components of aquifer maps are elaborated in following Tables (Table 1.2, 1.3, 1.4).

Table 1.2 Ground Water Monitoring Data Phase IV & V

State	*District*	*Block*	*Area (sq Km)*	*Requirement reworked considering homogeneity in aquifers*	*Data availbility*	*Data Gap*	*Data Generated*
Bihar	Katihar	Kursela	61	14	4	10	10
		Sameli	129				
		Amdabad	189				
		Barari	328				
		Manihari	251				
		Mansahi	78				
	Bhagalpur	Gopalpur	132	13	5	8	8
		Ismailpur	83				
		Jagdishpur	110				
		Nathnagar	126				
		Sabour	115				
		Kahalgaon	336				
		Pirpainty	351				

	Bhojpur	Charpokhri	109	18	1	17	17
		Garhani	112				
		Jagdishpur	258				
		Pirro	218				
		Tarari	201				
		Sahar	127				
		Agion	156				
		Sandesh	130				
	Buxar	Nawanagar	185	14	3	11	11
		Dumraon	198				
		Chaugain	55				
		Rajpur	274				
		Itarhi	229				
		Kesath	31				
		Chausa	108				
	Patna	Dulhin Bazar	111	12	4	8	8
		Punpun	127				
		Paliganj	238				
		Masaurhi	202				
		Dhanaura	186				
		Khusrupur	61				
		Daniyawan	65				
		Fatuha	126				
		Belchi	69				
		Sampatchak	65				
		Ghoswari	140				

Table 1.3 Ground Water Quality Data Phase IV-V

State	*District*	*Block*	*Area (sq km)*	*Requirement reworked considering homogeneity in aquifers*	*Data availbility*	*Data Gap*	*Data Generated*
Bihar	Katihar	Kursela	61	16	4	12	12
		Sameli	129				
		Amdabad	189				
		Barari	328				
		Manihari	251				
		Mansahi	78				
	Bhagalpur	Gopalpur	132	19	5	14	14
		Ismailpur	83				
		Jagdishpur	110				

		Nathnagar	126				
		Sabour	115				
		Kahalgaon	336				
		Pirpainty	351				
	Bhojpur	Charpokhri	109	26	1	25	25
		Garhani	112				
		Jagdishpur	258				
		Pirro	218				
		Tarari	201				
		Sahar	127				
		Agion	156				
		Sandesh	130				
	Buxar	Nawanagar	185	26	3	23	23
		Dumraon	198				
		Chaugain	55				
		Rajpur	274				
		Itarhi	229				
		Kesath	31				
		Chausa	108				
	Patna	Dulhin Bazar	111	32	4	28	28
		Punpun	127				
		Paliganj	238				
		Masaurhi	202				
		Dhanaura	186				
		Khusrupur	61				
		Daniyawan	65				
		Fatuha	126				
		Belchi	69				
		Sampatchak	65				
		Ghoswari	140				

Table 1.4 Exploration Data Phase IV & V

State	District	Block	Area(sq km)	Requirement reworked considering homogeneity in aquifers	Data availbility	Data Gap	Data Generated
Bihar	Katihar	Kursela	61	8	0	5	3
		Sameli	129				
		Amdabad	189				
		Barari	328				
		Manihari	251				
		Mansahi	78				

	Bhagalpur	Gopalpur	132	18	16	2	0
		Ismailpur	83				
		Jagdishpur	110				
		Nathnagar	126				
		Sabour	115				
		Kahalgaon	336				
		Pirpainty	351				
	Bhojpur	Charpokhri	109	8		8	4
		Garhani	112				
		Jagdishpur	258				
		Pirro	218				
		Tarari	201				
		Sahar	127				
		Agion	156				
		Sandesh	130				
	Buxar	Nawanagar	185	8		8	4
		Dumraon	198				
		Chaugain	55				
		Rajpur	274				
		Itarhi	229				
		Kesath	31				
		Chausa	108				
	Patna	Dulhin Bazar	111	7		7	2
		Punpun	127				
		Paliganj	238				
		Masaurhi	202				
		Dhanaura	186				
		Khusrupur	61				
		Daniyawan	65				
		Fatuha	126				
		Belchi	69				
		Sampatchak	65				
		Ghoswari	140				

Table 1.5 VES Data Phase IV & V

State	District	Block	Requirement reworked considering homogeneity in aquifers	Data availbility	Data Gap	Data Generated 2017-18
Bihar	Katihar	Kursela	41	5	36	
		Sameli				

		Amdabad				
		Barari				
		Manihari				
		Mansahi				
	Bhagalpur	Gopalpur	68	22	46	33
		Ismailpur				
		Jagdishpur				
		Nathnagar				
		Sabour				
		Kahalgaon				
		Pirpainty				
	Bhojpur	Charpokhri	55	29	26	
		Garhani				
		Jagdishpur				
		Pirro				
		Tarari				
		Sahar				
		Agion				
		Sandesh				
	Buxar	Nawanagar	60	19	41	13
		Dumraon				
		Chaugain				
		Rajpur				
		Itarhi				
		Kesath				
		Chausa				
	Patna	Dulhin Bazar	73	22	51	10
		Punpun				
		Paliganj				
		Masaurhi				
		Dhanaura				
		Khusrupur				
		Daniyawan				
		Fatuha				
		Belchi				
		Sampatchak				
		Ghoswari				

1.4.3 Rainfall-spatial and Temporal Distribution

Area experiences a tropical monsoon climate. The year may be divided into three seasons. The monsoon season intiates by mid June and continues till the end of September. There is slight rainfall in October but November and December are quite dry. The rainy season receives south-west monsoon and accounts for about 85-90% of the total rainfall. The area receives an average normal monsoon rainfall of about ~ 1,100 mm/year. The rainy days in a year are generally above fifty. In the western parts, normal rainfall varies from 880 mm (south-central part) to 1100 mm (north-easterrn border), wheras, in easrn parts, normal annual rainfall varies from 1200 to 1420 mm (in parts of Katihar district). Rainfall analysis pattern in parts of Bhagalpur and Katihar districts depicts that there is an absolute departure of last five years average rainfall from normal rainfall (Fig 1.2). The rainfall decreases generally from east to west (Fig 1.3).

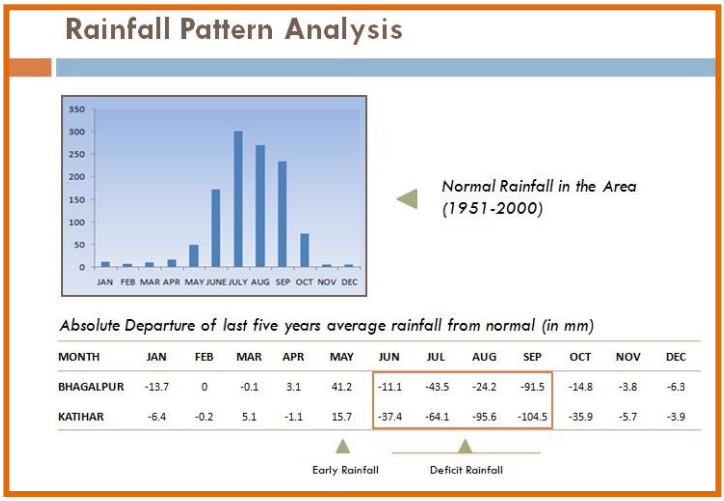


Fig.1.2. Rainfall analysis pattern in parts of Bhagalpur and Katihar districts

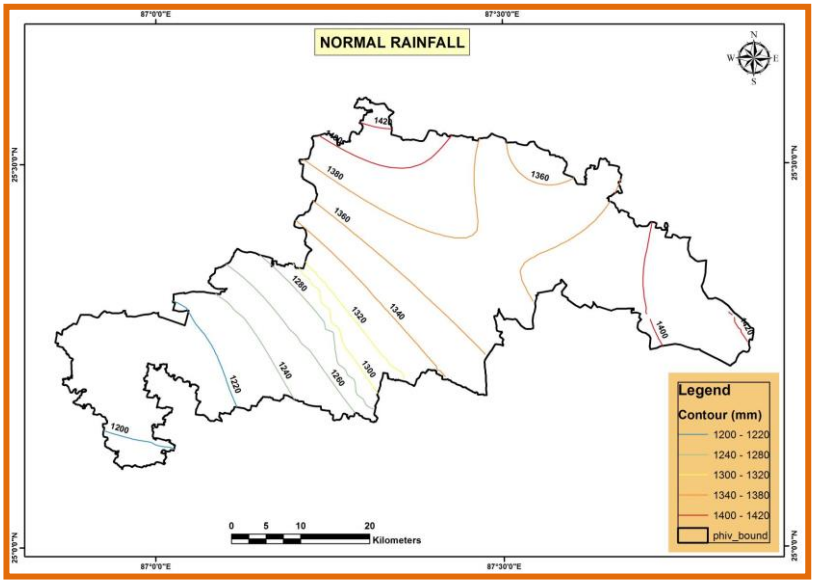


Fig.1.3. Map depicts normal rainfall distribution in Bhagalpur-Katihar area

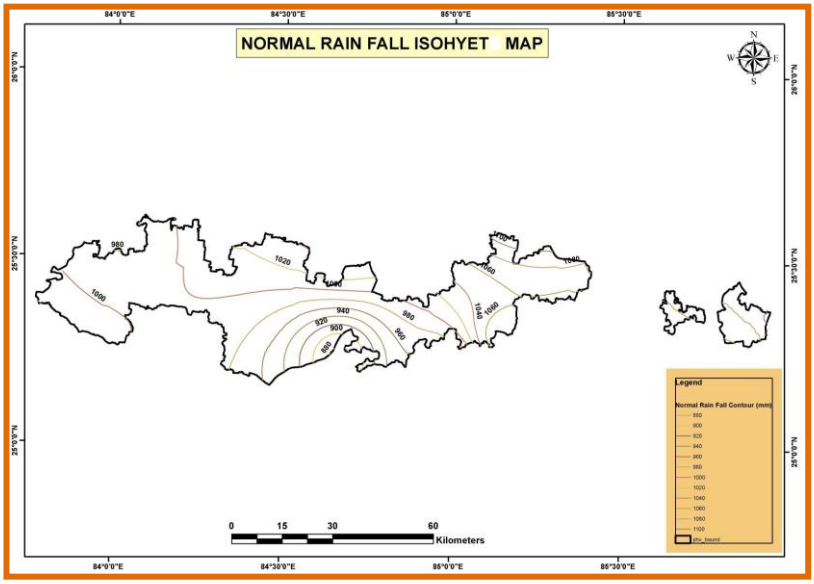


Fig.1.4 Map depicts normal rainfall distribution in Bhojpur-Buxar-Patna area

There may be three important variations from the normal in the monsoon rains. Firstly, the beginning of the rains may be delayed considerably over the area, secondly, there may be prolonged break or breaks lasting over the greater part of July and / or August and thirdly, the rains may end considerably earlier than usual. Consequences of the third variation are occasionally very serious and the success of the Kharif crop largely depends on the rainfall especially the Hathia rain.

In comparison to normal rainfall pattern, it is observed that the rainfall occurring during the period of March to May shows an increasing trend in Bhagalpur and Katihar districts. Rainfall during monsoon period has decreased in the last five years as compared to the normal rainfall.While in Bhojpur, Buxar and Patna districts; monsoon rainfall has drastically decreased in last five years as compared to the normal rainfall.

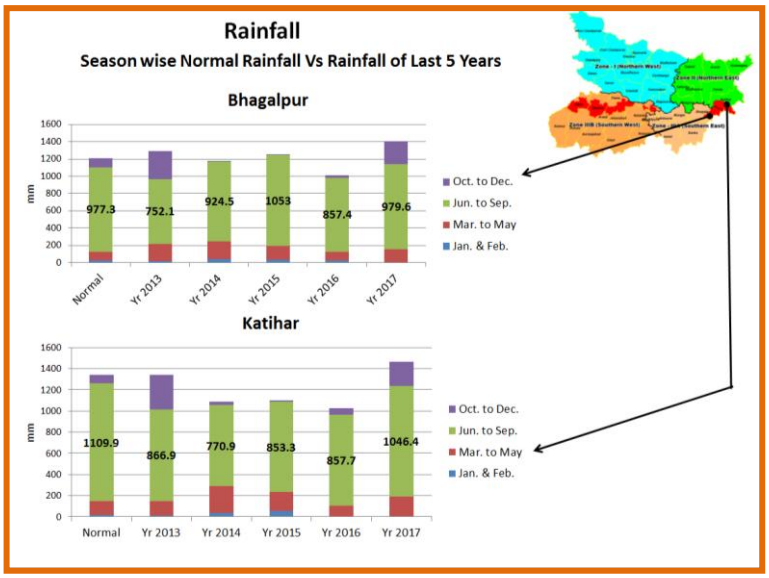


Fig.1.5 Season wise Normal Rainfall Vs Rainfall of Last 5 Years in Bhagalpur-Katihar area

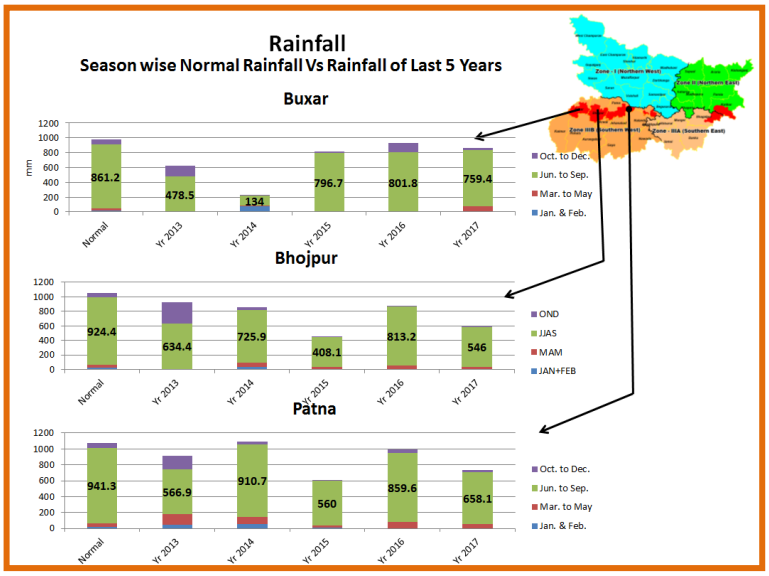


Fig.1.6 Season wise Normal Rainfall Vs Rainfall of Last 5 Years in Buxar-Bhojpur-Patna area

1.4.4 Physiographic setup

Area under NAQUIM Phase IV & V covers western and eastern part of Bihar State. The area comprises of fertile alluvial plains separated in two parts in north and south of River Ganga. The land in the northern bank of the River Ganga shows a general slope towards the south-east while for the part located on the southern flank of the Ganges, the general slope is towards north-east. Parts of Katihar district falls in the Kosi and Mahananda sub-basin. The Kosi River and the Mahananda River with their numerous tributaries like Pamar, Dhar, Kamla, Saura Nadi, Morabrandi Nadi, Fariyani Nadi and Nagar drain the district. The river Ganga passes through the southern border of the district in NW-SE direction. The other important rivers like the Kosi and the Mahananda pass through the district in N-S direction. Bhagalpur is on south of the river Ganga falls in the Badua- Koa Sub-Basin and the area to north of Ganga falls in the Baghmati - Kosi sub-basin. These two sub-basins are parts of Mid-Ganga basin in Bihar. The district is principally drained by the river Ganga, which enters the district at Sultanganj. The northern boundary of the district is marked by the river Kosi (Ghugri) known to be heavily laden with silt and sand.

Buxar district is part of the Upper Ganga sub-basin. The Ganga touches the district near Chausa. The river Ganga flows towards east parallel to the district boundary. The district is located in the Ganga basin in its central parts and the river Ganga forms the northern boundary of the district. The river Sone is the other major drainage flowing at the eastern boundary of the district.

1.4.5 Physiography/DEM

The elevation in the area ranges from 15.4 to 161.4 m above mean sea level (SRTM data with WGS 84 Spheroid). Broadly the area has flat topography (Fig 1.7). In general, the study area presents a vast flat terrain.

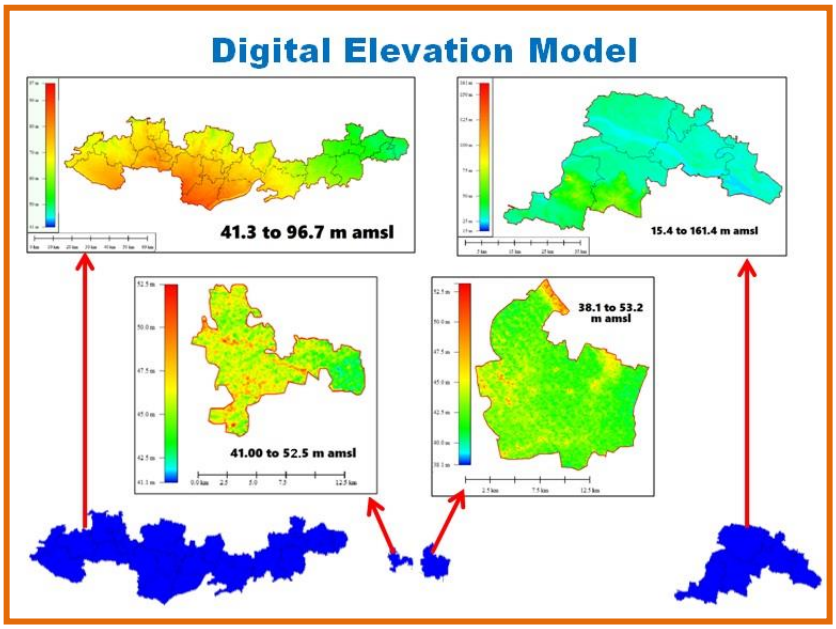


Fig.1.7 Digital Elevation Model of Study Area

1.4.6 Geomorphology

The study area forms the part of the Middle Ganga Plain and physiographically, it represents a monotonous flat topography. The geomorphology of the area has been carved out largely in Late Pleistocene-Holocene, when the Himalaya itself was tectonically more quiescent. Therefore, climate on the one hand and eustasy and related interglacial sea level fluctuations on the other seem to have played an important role.

The land surface for the part located on the northern bank of the River Gnaga shows a general slope towards the south-east while for the part located on the southern flank of the Ganges, the general slope is towards north-east. The area is drained by rivers Ganga, Gandak and their tributaries (Fig. 1.8). The west - east flow of the River Ganga forms the axial drainage of the area. The River Ganga forms the levee or upland all along its southern bank. In the south of the natural levee of the Ganga, there is a vast stretch of backwaters known as the Tal lands.

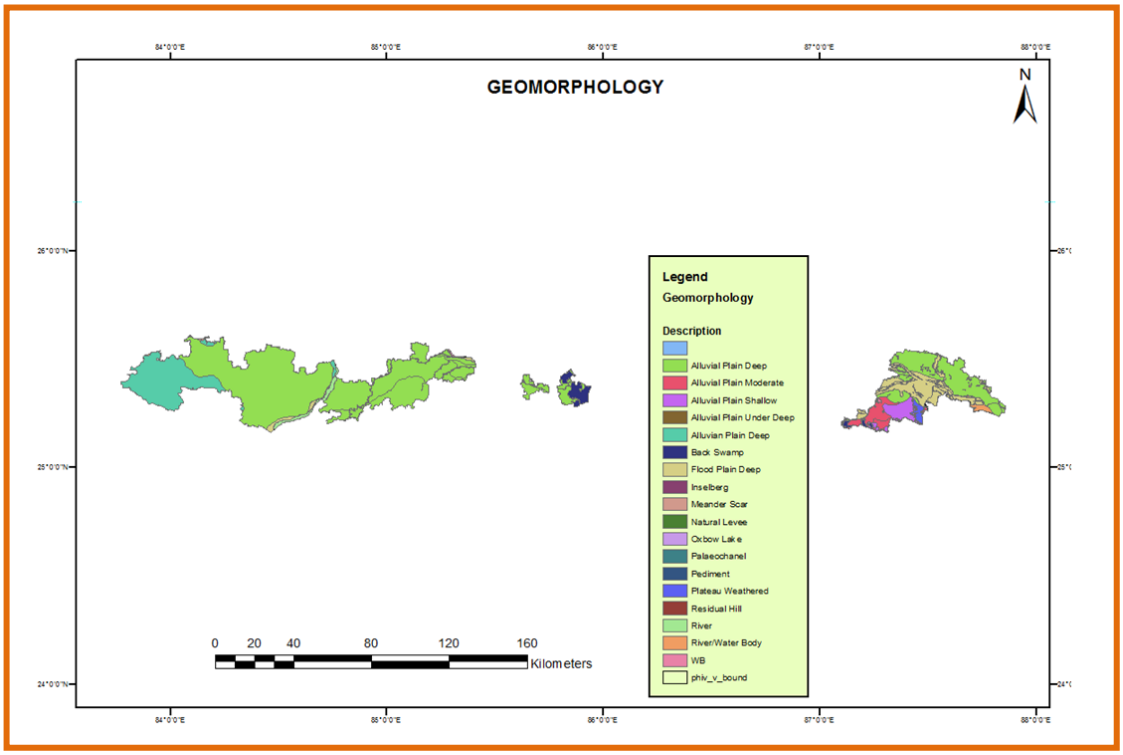


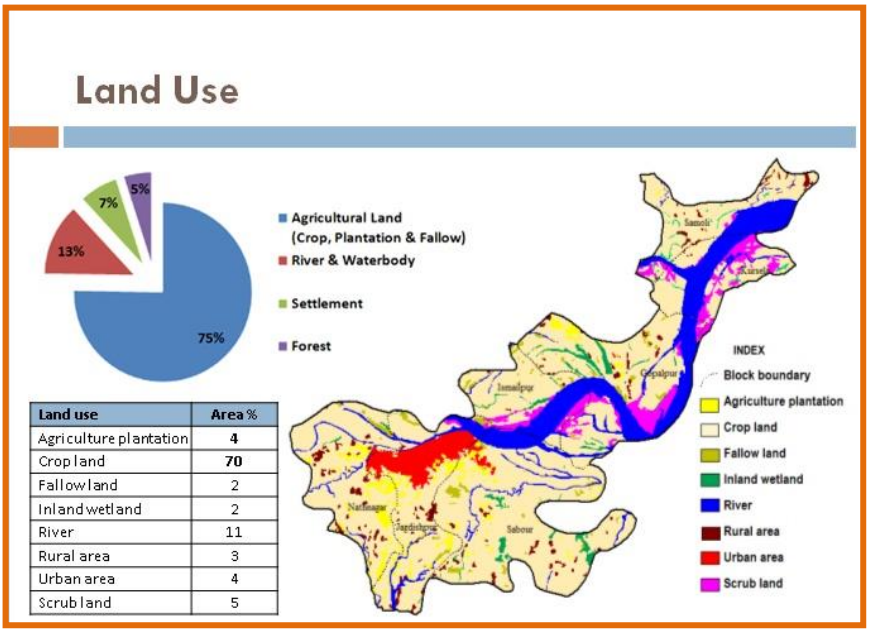
Fig.1.8 Geomorphological Map

The area is characterized by fertile flat land which is highly prone to floods during the monsoon season. The alluvium deposits covering the entire region are of Quaternary age.

The region is characterized by silt deposited from the river Ganges almost every year and is extremely fertile. The geomorphological map of the area (based on NRSA) is shown in (Fig. 1.8). In the western part, mostly deep alluvial plains exist. In middle part, largely back-swamp areas occupy in Ghoswari block, Patna district other than deep alluvial plain. While in eastern part, on northern bank, deep alluvial plain occurs, on the southern flank, deep flood plain along with moderate alluvial plains, back-swamp, shallow alluvial plain exist.

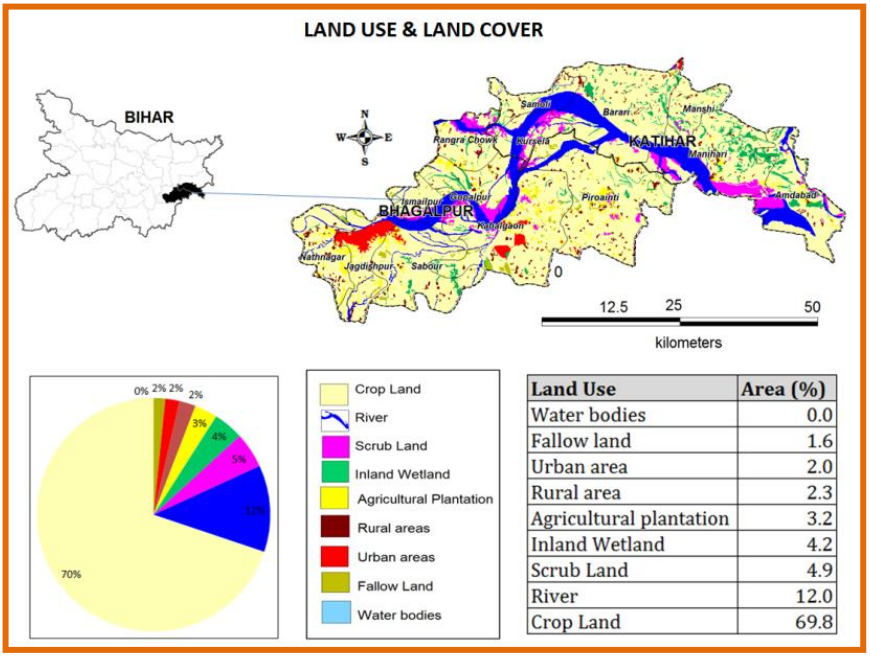
1.4.7 Land Use

Land use and land cover has direct linkage to the water demand of any area. The most reliable land use statistics are available from the reports of the Agriculture Department, Government of Bihar (2009), which provides district wise information. During the study, the landuse land cover map of the area falling under Phase IV & V has been prepared based on the NRSA data. The land use land cover map based on the NRSA data is produced as under in Fig. 1.9 a, 1.9 b, 1.9 c.



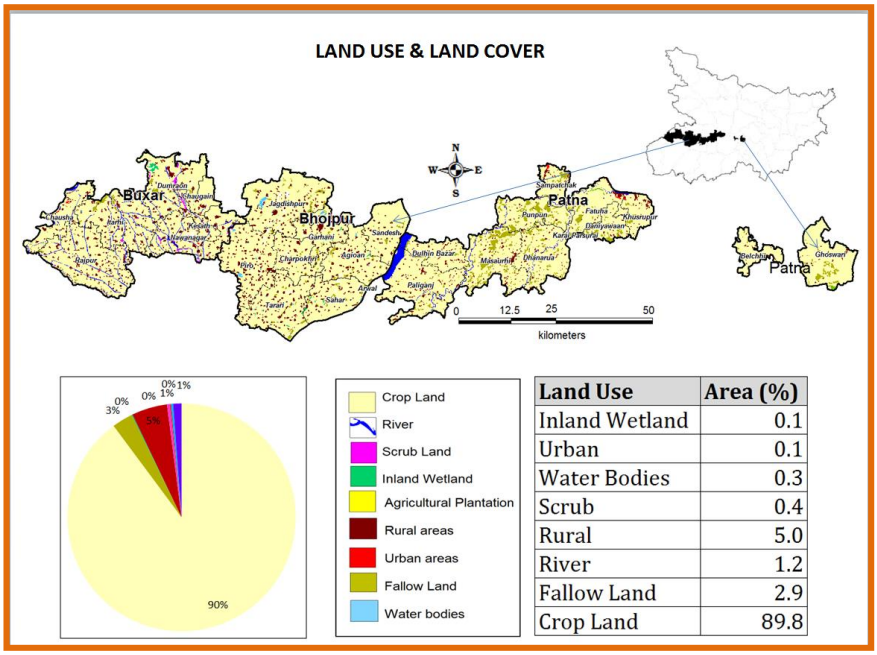
Land use	Area %
Agriculture plantation	4
Crop land	70
Fallow land	2
Inland wetland	2
River	11
Rural area	3
Urban area	4
Scrub land	5

Fig. 1.9 a Landuse & Landcover Map in parts of Bhagalpur and Katihar districts under Phase IV



Land Use	Area (%)
Water bodies	0.0
Fallow land	1.6
Urban area	2.0
Rural area	2.3
Agricultural plantation	3.2
Inland Wetland	4.2
Scrub Land	4.9
River	12.0
Crop Land	69.8

Fig. 1.9 b Landuse & Landcover Map in parts of Bhagalpur and Katihar districts under Phase V



Land Use	Area (%)
Inland Wetland	0.1
Urban	0.1
Water Bodies	0.3
Scrub	0.4
Rural	5.0
River	1.2
Fallow Land	2.9
Crop Land	89.8

Fig. 1.9 c Landuse & Landcover Map in parts of Buxar, Bhojpur, Patna districts

Out of the total geographical area of 12, 67,223 ha of Bhojpur, Buxar, Patna, Katihar and Bhagalpur districts, the net sown area is 7,78,893 ha constituting nearly 62% of the total geographical area. Landuse classification pattern in phase IV & V shows that 70-90% of the area is under crop land. The principal source of assured irrigation is by Sone cannal system in Bhojpur and Buxar and the tail end of Kosi canal system in Katihar. Ground water and surface water are main sources of irrigation. The cropping intensity of the five districts varies from 120 to 140% as depicted in Table 1.6.

Table 1.6 Block wise Gross Cropped area

District	Block	Block area	Gross cropped area	Net cropped area	Cropping intensity	Gross irrigated area	Irrigation intensity	Dependency on Ground water irrigation (%)
Bhojpur	Jagadishpur	258	242.36	200.85	120.66	211.98	87.46	47.17
Bhojpur	Garhani	112	105.21	87.19		92.02		
Bhojpur	Sandesh	130	122.12	101.2		106.81		
Bhojpur	Agiaon	156	146.54	121.45		128.17		
Bhojpur	Charpokhri	109	102.39	84.86		89.56		
Bhojpur	Pirro	218	204.78	169.71		179.11		
Bhojpur	Tarari	201	188.81	156.48		165.14		
Bhojpur	Sahar	127	119.3	98.87		104.34		
Bhagalpur	Pirpaiti	351	218.23	174.59	125	92.48	42.38	91.04
Bhagalpur	Gopalpur	132	82.07	65.66		34.78		
Bhagalpur	Kahalgaon	336	208.9	167.13		88.53		
Bhagalpur	Ismailpur	83	51.6	41.28		21.87		
Bhagalpur	Sabour	115	71.5	57.2		30.3		
Bhagalpur	Jagdishpur	110	68.39	54.71		28.98		
Bhagalpur	Nathnagar	126	78.34	62.67		33.2		
Patna	Dulhin	111	70.19	54.88	127.91	49.69	70.79	52.81

	bazaar							
Patna	Punpun	127	80.31	62.79		56.85		
Patna	Paliganj	238	150.5	117.66		106.54		
Patna	Masaurhi	202	127.74	99.87		90.43		
Patna	Dhanaura	186	117.62	91.96		83.27		
Patna	Khusrupur	61	38.57	30.16		27.31		
Patna	Daniyawan	65	41.1	32.14		29.1		
Patna	Fatuha	126	79.68	62.29		56.41		
Patna	Belchi	69	43.63	34.11		30.89		
Patna	Sampatchak	65	41.1	32.14		29.1		
Patna	Ghosawari	140	88.53	69.21		62.67		
Buxar	Chaugain	55	62.86	45.48		53.69		
Buxar	Chausa	108	123.43	89.3		105.42		
Buxar	Dumraon	198	226.28	163.72		193.27		
Buxar	Itahari	229	261.71	189.35	138.22	223.53	85.41	50.92
Buxar	Kesath	31	35.43	25.63		30.26		
Buxar	Nawanagar	185	211.43	152.97		180.58		
Buxar	Rajpur	274	313.14	226.56		267.45		
Katihar	Amdabad	189	166.83	118.81		109.63		
Katihar	Manihari	251	221.56	157.79		145.6		
Katihar	Manshahi	78	68.85	49.03		45.24		
Katihar	Barari	328	289.53	206.19	140.42	190.26	65.71	95.26
Katihar	Sameli	129	113.87	81.09		74.83		
Katihar	Kursela	61	53.85	38.35		35.38		

(Source: Agriculture Department, Govt. of Bihar)

Table 1.7 Land use pattern of distict under phase IV & V (in hectares)

Sl. No.			1	2	3	4	5
District			Patna	Bhojpur	Buxar	Katihar	Bhagalpur
Geographical area			317236	237339	166999	291349	254300
Forest area			56	0	0	1785	78
Land put to non-agriculture use	**Land area**		66012	30008	13008	41893	54305
	Water	**Perennial**	10332	2823	3230	12128	6564
		Temporary	2395	1409	1325	4075	9700
	Total		78739	34240	17563	58096	70569
Barren unculturable area			12369	6702	2180	22109	22403
Parmanent pastures and grazing land			110	71	23	128	630
Land under Misc. Tree crops and grooves not included in net area sown			1005	2021	750	11045	6709
Culturable waste land			760	617	651	640	2280
Fallow land	**Other fallow**		1560	2426	603	6066	4943
	Current fallow		65142	6410	7130	8782	21044
	Total		66702	8836	7733	14848	25987

(*Source: Bihar Statistical Hand Book, 2014*)

1.4.8 Soil

Areas under NAQUIM Phase IV & V are mainly divided into two physiographic regions, i) the alluvial plains in north of the River Ganga receiving sediments from the river originating in the Himalayas, ii) the alluvial plains in south of the River Ganga which receive sediments from the north bound rivers from Chotanagpur plateau.

The area in parts of Bhojpur district generally possesses alluvial soil. The soils are of poorly drained type. The area adjoining the rivers Ganga, Sone, Dharmawati, and Ganga consists of sandy loam, loamy sand and sand, whereas, the area away from the river channels consist of silty sand to sandy silt. The soils in general, are fine textured away from the river course and rivulets and coarse textured along their courses. The soils of coarse textured have got mixed with silt and fine sand due to the mixing of canal water being used perennially for irrigation.

There are mainly three types of soil found in parts of Buxar district.

a. Recent Alluvial Soil (Levee Soil) - It is found along the banks of the river Ganga. It is a new alluvial calcareous soil and white to light grey in colour. It is light in texture and has medium to high fertility. The pH varies between 6.6 and 7.5. Main crops are maize, sugarcane, wheat, gram and other Rabi crops.

b. Tal Soil (Kewal soil) - It is found in south of the levee soil. It is light to dark grey in colour and very fertile. Its water retention capacity is high. Its texture ranges from medium to heavy and pH varies between 7 and 8. This soil is suitable for Rabi crops i.e, wheat, gram, peas and barley etc.

c. Old Alluvium Soil - It is a combination of Kewal soil and clayey soil. According to textural analysis, clay is the dominant particle of this soil. It covers the central part of the district, which is free from floods. pH value ranges from 7 to 8.5. Its colour is reddish yellow to grey. The fertility of this soil is low to medium in upper layer, and medium to high in the lower layers. The content of Zinc is very poor in this soil and hence, it requires Zinc Sulphate to maintain its fertility. The main crops grown in this soil are paddy, wheat, gram and linseeds.

Soils in parts of Patna district are predominantly sandy loam with clay loam at places with low to medium nutrient status. It is generally alkaline with pH value ranging from 6.3 to 8.2. Soils are divided into three groups viz. (i) Recent alluvium (ii) Tal and (iii) Older alluvium. The soils are generally coarser in texture.

The soils in the Bhagalpur area are mainly derived from the older and newer alluvium. These alluvial plain soils are light grey to dark grey in colour, rather heavy and texturally fine in nature. The pH values range from neutral to acidic and the acidity of the soil gradually increases from north to south. The hilly soils are acidic with low nitrogen, medium to high potash.

The soils derived from older alluvium are mainly loamy in character with moderate to heavy texture and well drained. In low lands, these are poorly drained with heavy texture. Black soils found in Shahkund, Sonhaulia, and Sultanganj area. Sandy soils (Diara soils) derived from younger alluvium are light textured, well drained. These are moderate to highly fertile, calcareous soils and found along the banks/course of the river Ganga.

The area in parts of Katihar district represents flat topography with regional slope towards south. The areas towards north are at higher elevation. It gradually reduces towards south. The regional slope takes a tilt from west to east. The district has alluvial soil. The soil in the southern and western part of the district is sandy in nature. Overall, the soil in the district is non-calcareous and non-saline in nature and is a mixture of clay, sand and silt in varying proportions.

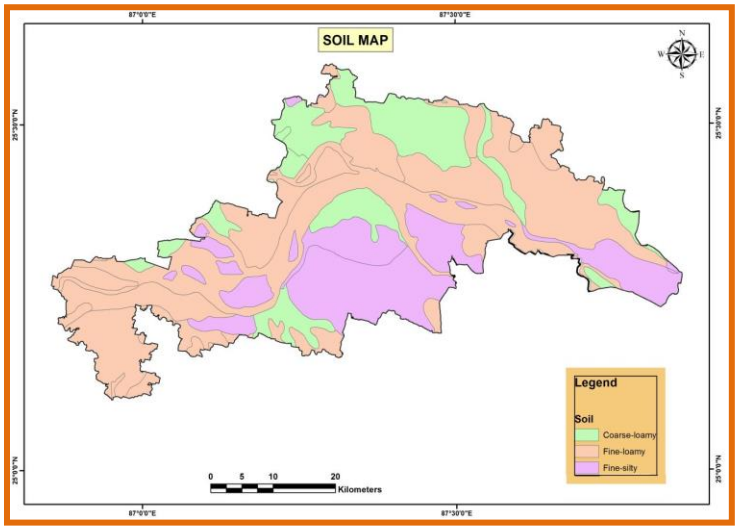


Fig. 1.10 Soil Map of parts of Bhagalpur & Katihar

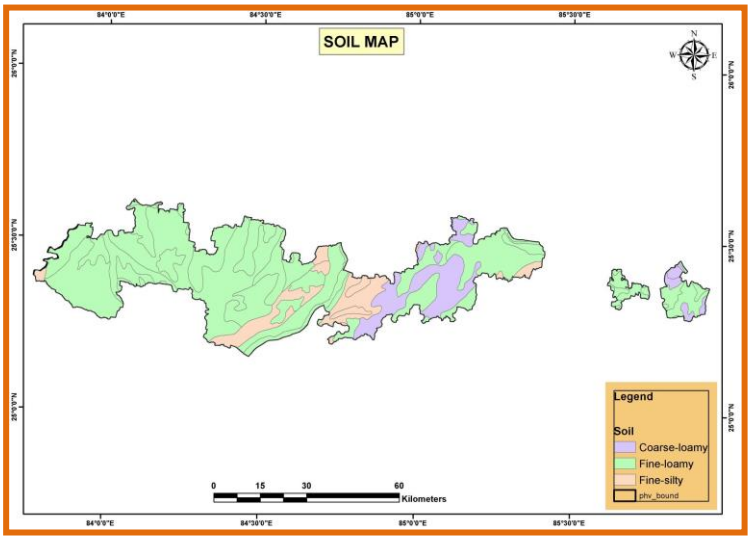


Fig. 1.11 Soil Map of parts of Buxar, Bhojpur & Patna

1.4.9 Hydrology and Drainage

West to east flowing Ganga River mainly drains the area. The part of the study area falling in Bhojpur and Buxar is drained by the River Ganga in north and in the east by the river Sone, in the west by the Karamnasa and River Ganga. The river Karmanasa delimits the district in the west and southwest. It debouches in the River Ganga near Chausa. The river Karmanasa is an important for irrigation in the western part of the district. There are many lift irrigation schemes and side channels to carry overflowing river water to the field. There is no

lake or spring in the district. However, there is a natural depression between Bhojpur- Kadim and Koliyadah which stores water in the rainy season.

The river Sone is the other major drainage flowing at the eastern boundary of the Bhojpur district. The river flows in northeast direction in a NE-SW trend and confluences with Ganga in the northeast corner of the Bhojpur district at Babura.

The study area in Patna district is drained by the mighty Ganga in the north, by the Sone in the West, and by the Punpun, Phalgu and their tributaries in the central part of the terrain.

The area in parts of Bhagalpur district is principally drained by the river Ganga, which enters the district at Sultanganj. The northern boundary of the district is marked by the river Kosi (Ghugri) known to be heavily laden with silt and sand. The river Ganga has two major tributaries joining from south; Badua and Koa. Apart from them, a number of ephemeral streams such as Gahra, Chanan, Kadwa, Gerua and Bhena from Chotanagpur plateau join the mighty River Ganga.

The numerous tributaries of Kosi and Mahananda River like Pamar, Dhar, Kamla, Saura Nadi, Morabrandi Nadi, Fariyani Nadi and Nagar drain the parts of Katihar district. The river Ganga passes through the southern border of district in NW-SE direction.

1.4.10 Agriculture

Agriculture is the mainstay of the population in the area. The eastern part (located on the northern and sothern banks of the River Ganga) of the area falling in Bhagalpur and Katihar districts fall in the Agroclimatic Zone II & IIIA while the central and western parts (located in south of the River Ganga) falls in the Agroclimatic Zone IIIB (Fig. 1.12). The cropping patterns of the Zone II and IIIA & IIIB are discussed under the head cropping patterns.

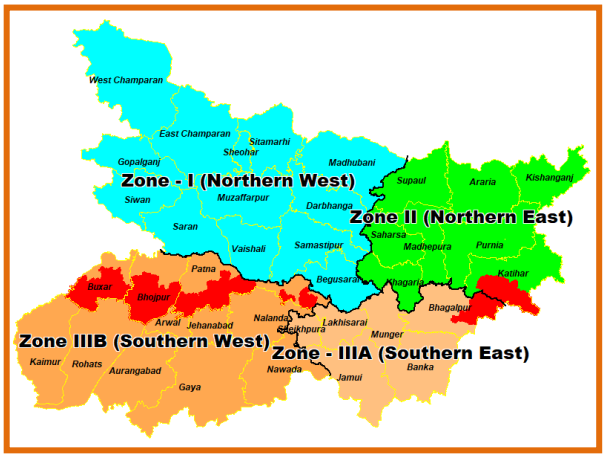


Fig. 1.12 Map of Bihar Agro climatic zones

Table 1.8 Agroclimatic Zones

Sl. No.	Districts	Agro-Climatic Zone	Soil	pH
1	Katihar	Zone II (Northern East)	Sandy loam, Clay loam	6.5–7.8

2	Bhagalpur	Zone IIIA (Southern East)	Sandy loam, Clay loam, loam, Clay	6.8–8.0
3	Buxar, Bhojpur, Patna	Zone IIIB (Southern West)	Sandy loam, Clay loam, loam, Clay	6.8–8.0

On different soil categories found in different agro-climatic zones, the farmers grow a variety of crops. The base of agriculture is its soil, with abundant water resources, particularly ground water.

The portion north of the Ganges River is rich in alluvial soil and lands are very fertile. The principal commercial agricultural products in crops in the area are rice, wheat, lentils, maize (corn), sugar cane and fruits like mangoes, bananas, jack-fruit, and litchis. In Bihar, there are two distinct having banana growing areas viz. old Vaishali region and new North-Eastern (Kosi) region. Though banana was introduced in the region during late '70s, the pace of adoption is very fast and nowadays, the area produces nearly two-third of total state's production.

The area lying in the north of river Ganga, the economy of the area is based mainly on agriculture. Inspite of higher yield per hectare, the per capita income of the people is the lowest in the area; this is because of execessive pressure of population on land, inequitable distribution of land, and less than optimum level of activities in the secondary and tertiary sectors of the economy.

The portion south of river Ganges is having combination of soils. These are patches of alluvial soil, sandy soil, clay soil and mix of any two which are very suitable for the particular types of crops. The Small Scale Industrial activities in the region are better in comparison to parts of North Bihar.

1.4.11 Irrigation

The main source of irrigation in parts of Patna, Bhagalpur and Katihar districts is ground water and it is done through tube wells (Fig. 1.13). Irrigation through tube wells is upto 95% of the total irrigated area. While in parts of Bhojpur, Buxar districts, canal irrigation dominates. Irrigation from ground water also plays key role and it varies from 41 to 44% of total irrigated area.

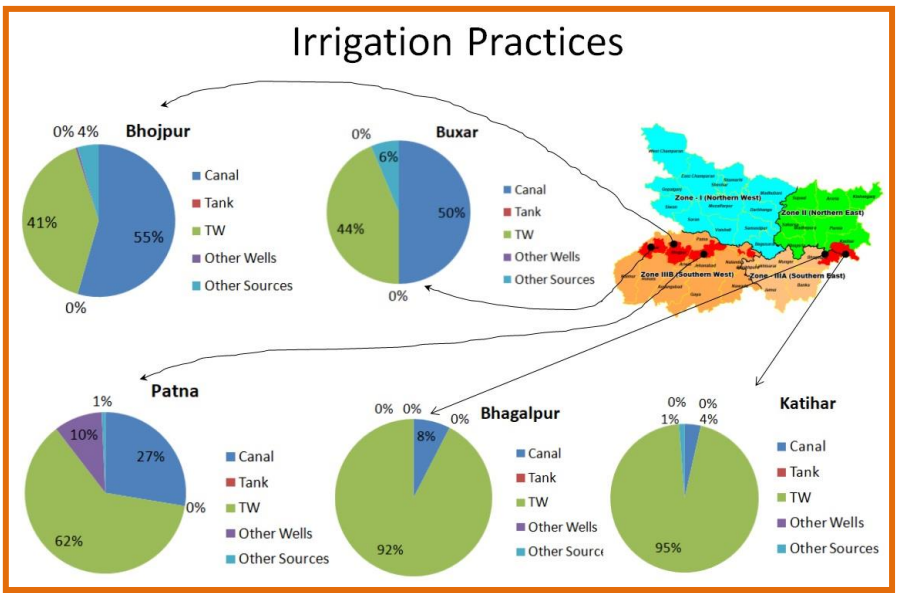


Fig.1.13 Irrigation practices in study area

1.4.12 Cropping pattern

The area falling in parts of Katihar district located to the north of the River Ganga falls under the Agroclimatic Zone II where following cropping sequence is practised.

Zone – II: Jute-Wheat, Jute-Potato, Jute-Kalai, Jute-Mustard, Rice- Wheat - Moong, Rice-Toria,

In Buxar, Bhojpur, Patna and Bhagalpur district, located to the south of the River Ganga, falling in Agroclimatic Zone III, the cropping sequence practised is the following.

Zone – III: Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai.

Table 1.9 Agroclimatic zones with cropping sequence

Sl. No.	Agro-climatic zone	Soil	Total Rainfall (mm)	Temperature (^{0}C)		Cropping sequence
				Max.	Min.	
1	Agro-climatic Zone II	Sandy loam, Clay loam	1200 – 1700	33.8	8.8	Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice – Wheat – Moong, Rice – Toria
2	Agro-climatic zone III	Sandy loam, Clay loam, loam, Clay	990 – 1240	37.1	7.8	Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai

1.4.13 Prevailing Water Conservation / Recharge Practices

A large part of the area remains seasonally water logged. In the northern part of the Ganga, these are locally known as Chaurs and remain seasonally water logged from July to February. In the south of the natural levee of the River Ganga, there is a vast stretch of backwaters known as the Tal lands. These Tals remain submerged into 1 to 3 m of water column from mid June to mid October during monsoon period. These water bodies act as indirect sources of ground water recharge in the area (Fig 1.14).

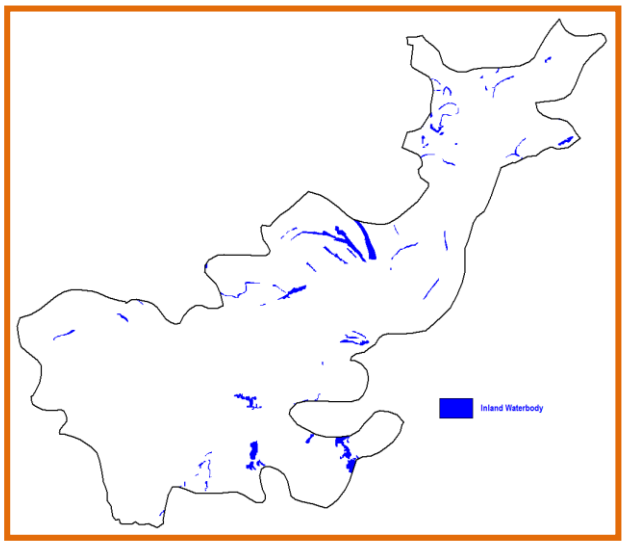


Fig.1.14 Inland water bodies with adjoining seasonally water logged areas in parts of Bhagalpur and Katihar districts

1.5 Climate

Climate records available from the IMD database indicate that the area enjoys a typical subtropical climate. The summer season in the area begins from the middle of March when hot westerly winds, locally called as *Loo*, begins to blow during the day. The months of April and May are hottest with peak summer temperatures shooting upto 44 - 45° C. Mean maximum temperature varies between 35 and 40 degree Celsius. During the hot weather period from March to May, there is continuous increase in heat and decrease in pressure which results in occasional dust storms of moderate to violent intensities ranging between 60 and 120 km per hour. The summer season continues up to mid June. The monsoon season intiates by the third week of June and continues till the end of September. From June to September, eastern and south-eastern wind starts blowing with onset of monsoon. There is slight rainfall in October but November and December are quite dry. The rainy season receives southwest monsoon and accounts for about 85-90% of the total rainfall. The area receives an average normal monsoon rainfall of about 1100 mm/year.The winter season begins from November month and lasts till the beginning of March. January is the coldest month when the temperature comes down to as low as 4 - 5˚ C. During early winter, wind generally blows from east to west but in December and January, direction of wind is from north and north-west which ultimately brings down the temperature in the area.

1.6 Geology

The area is located in the central axial part of Middle Ganga Plain occupying the central part of the Ganga Basin. The Ganga basin is an active foreland basin formed in response to the uplift of Himalaya due to collision of the Indian and the Asian plate. The Middle Ganga Plain lies between the Munger-Saharsa ridge in the east and Faizabad ridge in the west exhibiting an asymmetrical sediment wedge, with thickness varying from less than a meter in basin margin areas with Peninsular craton to more than 5 km near the Himalayan orogen. The area forms a part of the Gangetic plains underlain by immensely thick alluvial

deposits. Delineation of aquifer geometry based on the available data reveals the presence of a thick pile of alluvial sediments of Quaternary age comprising various grades of sand, silt, clay and sand, gravel which constitute the ground water repositories.

The sands brought and deposited by the River Ganga are grey, micaceous and rich in ferromagnesian minerals and occupy the topmost horizon along the course of the river upto a few kilometres south of it constituting the newer alluvium consisting of clay, kankars, fine to coarse grained sands, gravels and pebbles at depths.

The area forms a part of the Gangetic plain underlain by immensely thick alluvial deposits comprising sediments (sand, gravel and clay) of Quaternary age deposited unconformably over the Pre-Cambrian basement. The alluvial deposits are characteristically divided into Older (AL 03) and the Younger Alluvium (AL 01). The Quaternary alluvium occupies more than 90% of the total geographical area of the study area. These alluviums have formed extensive and prolific aquifer systems in the area down to the explored depth of about 300 m bgl.

1.6.1 Younger Alluvium

The Younger Alluvium is in general, light coloured and poor in calcareous matter. It contains lenticular beds of sand and gravel and peat beds. The geological map of the area is shown in the Fig. 1.15.

1.6.2 Older Alluvium

The Older Alluvium (called Bhangar in the Ganges valley) forms slightly elevated terraces, generally above the flood level. These are dark coloured and in general are rich in concretion and nodules of impure calcium carbonate known as ‘kankar’, of various shapes and sizes. The southern most part of Phase IV area is represented by rocky upland. Laterite and basalt comprise the lithology of the uplands.

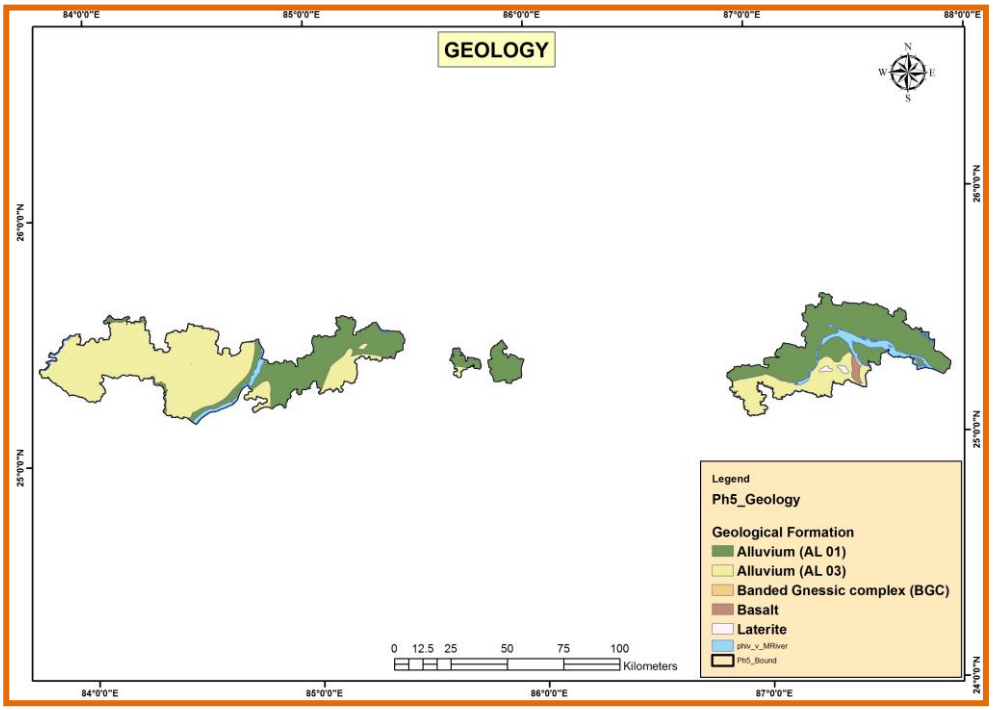


Fig. 1.15 Geological Map of the area (Source: GSI)

1.7 Sub surface lithological information

The area is underlain by immensely thick alluvial deposits. Assessment of the subsurface configuration of aquifer, based on the available data, reveals presence of a thick pile of alluvial sediments of Quaternary age comprising various grades of sand, silt and clay.

CHAPTER-II
DATA COLLECTION AND GENERATION

2.1 Hydrogeology

Available data indicate the presence of two aquifer systems up to ~300 mbgl. The deeper aquifer is made up of fine to medium grained sand often grading to gravelly sand at the bottom. The northern part of Ganga River is having thick clay layer at the bottom whereas southern part of the Ganga River is underlain by a Pre-Cambrian basement. In parts of Katihar district, mono-aquifer system upto the depth of 275 m has been encountered. A clay layer of ~ 15 m at the top has been found in Kursela, Katihar district.

2.1.1 (a) Water Level

Ground Water monitoring has been carried out at 115 (44+71) locations in the area during the year 2016-17 & 2017-18 respectively (Fig. 2.1, Annexure I). The depth to water level representing the phreatic aquifer has been prepared for pre and post monsoon season. The depth to water level map of the study area for the pre-and post-monsoon period is depicted as below (Fig. 2.2a & 2.2b).

2.1.1 Water Level, Pumping Tests

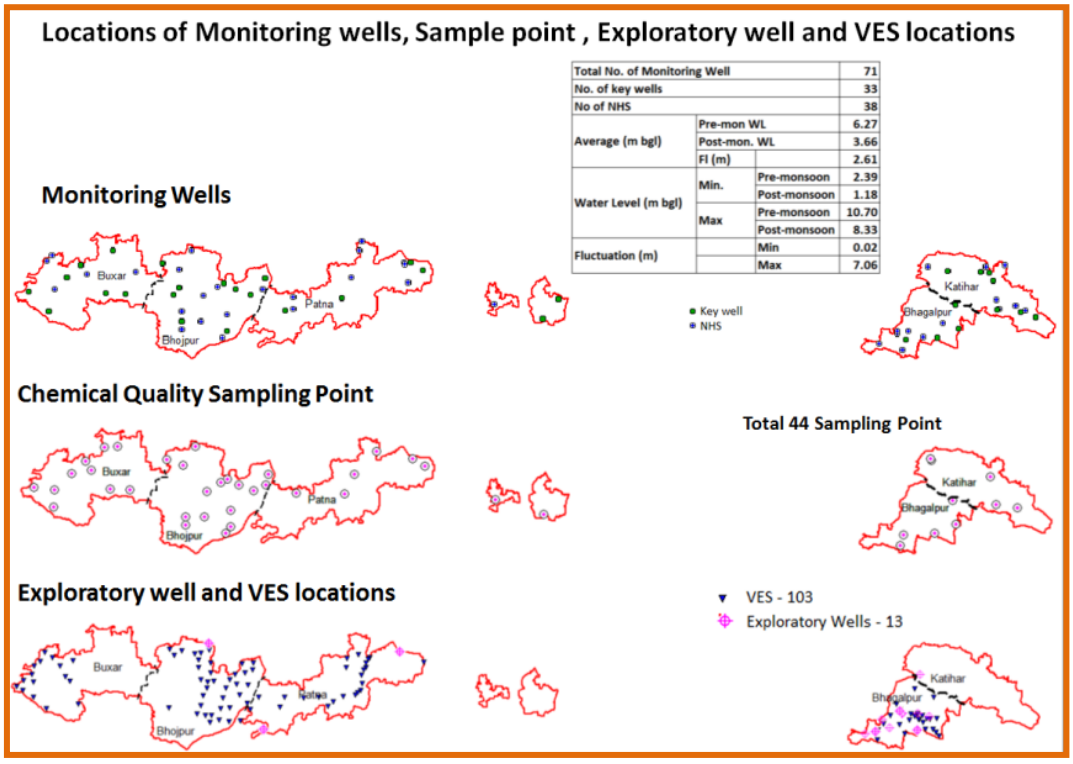


Fig. 2.1 Water level monitoring wells in the study area

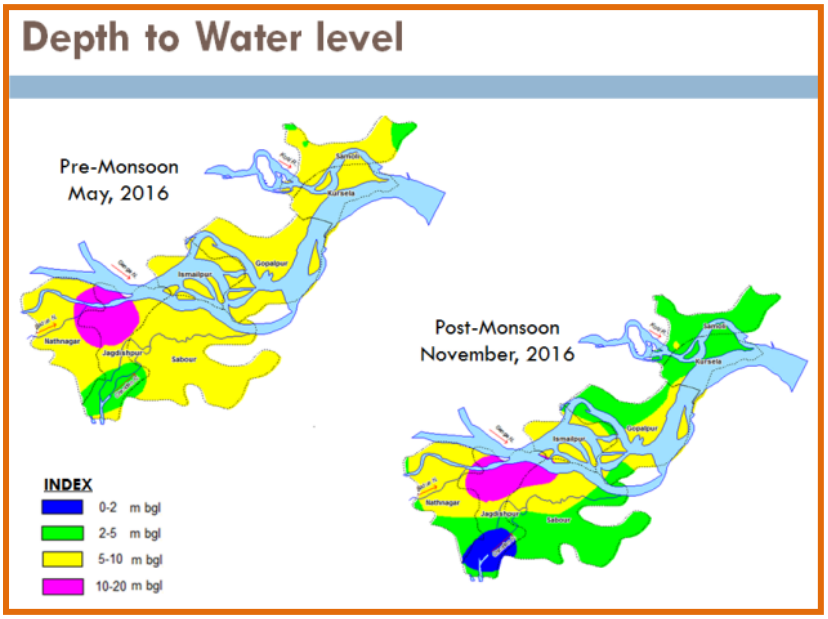


Fig. 2.2a Depth to water level map of pre- and post-monsoon

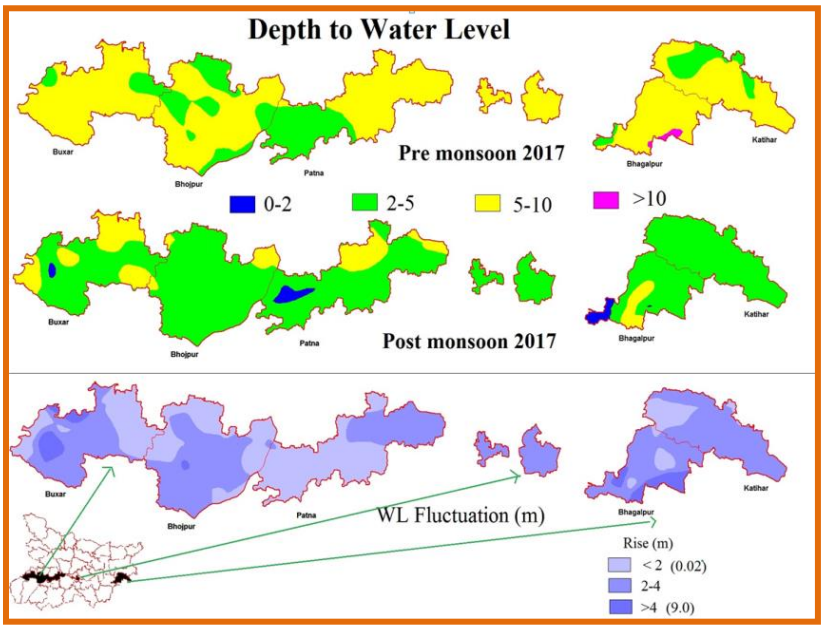


Fig. 2.2b Depth to water level map of pre- and post-monsoon

The depth to water level map of the area shows that majority of the area has water level of 5 – 10 m bgl in pre monsoon and 2 – 5 m bgl in post monsoon period respectively. In some parts, the water level is confined to 2 – 5 m bgl both in pre and post monsoon periods. The water level in few areas of Jagdishpur, Nathnagar blocks, Bhagalpur district recedes to more than 10 m bgl in pre and post monsson seasons during 2016 whereas, it recedes to more than 10 m bgl in Kahalgaon block, Bhagalpur district during pre monsoon 2017.

2.1.1 (b) Pumping Tests

Salient features of exploratory wells have been tabulated in Table 2.1. Discharge of tube wells vary from 12.9 to 188.72 m^3/hr with drawdown of 5.44 to 27.46 m. Transmissivity value ranges from 97 to 10,435 m^2/day.

Table 2.1 Salient features of CGWB exploratory wells

Location/ Block	Depth Drilled	Granular/ Zone/ fracture Tapped	Static Water level	Discharge	Draw Down	Specific Capacity	Trans-missivity	Conductivity	Storativity	Formation	Quality of water
	mbgl.	m.	m bgl	m^3/hr	m	m^3/hr./m	m^2/day	m/day			
2	3	5	6	7	8	9	10	11	13	14	15
Lakshmipur	294.06	094.00-097.00	6.53	52.4	19.52	2.68	209.52		1.1X10^{-3}	Alluvium	Potable
		107.00-114.00									
		143.00-149.00									
		164.00-170.00									
		172.00-183.00									
		201.00-203.00									
		206.00-210.00									
		212.00-218.00									
		270.00-274.00									
		277.00-285.00									
Hardeochak	202.57	051.00-057.00	6.28	60.65	17.67	3.43	111		4.00X10^{-3}	Alluvium	-do-
		061.00-063.00									
		064.00-068.00									
		069.96-075.45									
		075.45-083.97									
		090.89-097.37									
		098.37-102.82									
		104.33-108.39									
		114.45-131.37									
		143.49-146.55									
		162.00-167.58									
		169.68-175.73									
		178.23-194.90									
Rampur	141	079.00-086.00	13.78	14.3	11.16	1.2	4207.64		-	Alluvium	-do-
		091.00-093.00									
		095.00-097.00									
		099.00-									

		106.00									
		109.00-131.00									
Baijani	87.124	026.00-029.00	5.54	53.3	19.6	2.72	103.8		2.5x10^{-4}	Alluvium	-do-
		046.50-048.00									
		051.00-053.00									
		064.00-065.00									
		067.00-071.50									
		073.00-077.50									
		079.00-084.50									
Dhawa OW	73.89	025.50-030.50	3.12	62.41	16.16	3.86	97.87		7.5X10^{-4}	Alluvium	-do-
Kajrali		031.00-034.00									
		039.00-044.00									
		053.50-058.00									
		061.00-065.00									
Sainio (OW)	64.66	039.00-042.00	3.17	12.9	27.46	0.47			-	Alluvium	-d0
Mamlakhha (EW)	132	108-126	5.06	54	9.63	5.61	126		3.34X10^{-4}	Alluvium	
Pz-1	30	16-22									
Pz-2	132	112-124									
Fatuha Dak Bunglow	250.11	080.00-090.00	6.88	188.72	5.44		10435		2.29X10^{-3}	Alluvium	
		102.00-112.00									
		118.00-128.00									
		134.00-144.00									
		150.00-160.00									
Baijani	87.14	26-29,46-48,51-53,64-65.5,67-71.5,73-77,79-84.5	5.54	54.3	19.6	2.77	103.8	4.83	2.5x10-4		
Champanagar,	149.66	77-95,119-130,134-138,144-146	15.29	91.7	11	8.34	259.8	7.4			
Sandis Compound, Bhagalpur	163.27	27-32, 48-52, 88-106, 108-114, 138-142, 147-153	28.05	102.4	8.02	12.76	438.1	10.19			
Tilkakothi (Bhagalpur University)	122.99	66-95	7.58	102.4	10.42	9.83	402.5	13.88			
Teacher's Training College, Bhagalpur	144	26-29, 82-88, 94-97, 99-113, 130-140,	24.58	91.7	9.37	9.78	359.5	9.98			
Blind School, Bhagalpur	146	44-47, 54-57, 58.5-61.5, 79.5-83.5, 96.5-107.5, 110.5-116	22.5	104.9	12.05	8.71	447.6	15.17			
Jhowakothi, Bhagalpur	161.6	85-103.5, 134-137, 143-146, 149-151.5	21.92	68.04	8.41	8.09	303.7	11.25			

2.2 Hydrochemical

Quality of ground water is as much important as its quantity. Water quality in an area is a function of physical and chemical parameters that are greatly influenced by local geological formations and anthropogenic activities. Suitability of ground water for drinking and irrigational purpose is an important aspect for its safe and effective use. Ground water is also very important source of water for domestic and irrigation demand in the state of Bihar.

To study the groundwater chemistry of different aquifers present in the area, 44 ground water samples were collected in grid pattern during premonsoon period for analysis of major parameters (Annexure II). The water samples were collected and stored in 1 liter capacity clean plastic bottles. Before collection of samples, the bottles were properly washed. Prior to collecting the samples, the containers were rinsed by the water to be sampled.

These water samples were analysed in chemical laboratory of CGWB, MER, Patna. Besides these, available historical data of chemical analysis of ground water were also studied to have an understanding of ground water chemistry of the area. Analytical results of ground water samples are given in Annexure II.

2.2.1 Classification of Ground Water

In order to understand the chemical charactereistics of the groundwater in the study area, ground water samples were plotted in Piper trilinear diagram (Piper 1944), USSl, Durov and Box and Whisker Plot, Ludwig Langelier plots etc using Aquachem software. Five main ground water groups have been identified based on major ion concentrations. These are Mg-Na-HCO_3, Mg-Ca-HCO_3, and Ca-Mg- HCO3, Na-Mg HCO3 & Mg-HCO_3 (Fig. 2.5 & 2.6). About 24%water samples belong to Ca-Mg-HCO_3 type and about 18 % samples belong to Mg-Ca-HCO_3. Alkaline earths (Ca+Mg) exceed Alkalies (Na+K). In most of the samples weak acids (CO_3+HCO_3) exceeds strong acids (SO_4+Cl). In 9% water samples strong acids (SO_4+Cl) exceeds weak acids (CO_3+HCO_3).

The Ca–Mg-HCO_3 water is primarily a result of 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. A few of the samples are rich in Na-K which may be due to usage of fertilizers. The presence of low Cl & SO_4 indicates low residence time. Mixed $CaNaHCO_3$ water type express mineral dissolution and recharge of freshwater. NaCl water type suggest the mixing of high salinity water caused from surface contamination sources such as irrigation return flow, domestic westewater, and septic tank effluents, with existing water followed by ion exchange reactions. Summary of the physico-chemical parameters of groundwater samples are shown in Table 2.2.

Table 2.2 Summary of the physico-chemical parameters of groundwater samples

District	Block	pH	EC (microsiemens/cm)	TDS	F-	NO3-	TH(as CaCO3
Bhagalpur	Kahalgaon	7.1-7.3	784 - 1405	509.6- 913.25	0.21-0.74	8.12-67	290-480
Bhagalpur	Pirpainti	7.03-7.27	698-1065	453.7-692.75	0.11-0.23	1.29-52.6	354-425
Bhagalpur	Gopalpur	7.45-7.68	543-594	352.95-361	0.13-0.16	3.67-7.61	180-195
Bhagalpur	Ismailpur	7.23	567	368.55	0.11	6.71	260

Patna	Punpun	7.32	490	319	0.24	3.05	140
Patna	Dulhin Bazar	7.13	695	451.75	0.46	44	250
Patna	Masaurhi	7.49	896	582.4	0.03	13.3	380
Patna	Khusrupar	7.26	731	475.15	0	28.4	358
Patna	Fatua	7.17	616	400.4	0	35.5	295
Patna	Belchi	7.31	506	328.9	0.06	17.7	305
Patna	Sampatchak	7.34	482	313.3	0	42.6	325
Patna	Ghoswari	7.22-7.57	496-552	322.4-358.8	0.09	15.3-23.6	205-275
Bhojpur	Sandesh	7.86-8.08	555-1663	360.75-1080.95	0.2-0.46	12-151	220-665
Bhojpur	Agion	8.12	1076	699.4	0.6	94.1	516.6
Bhojpur	Sahar	7.99-8.15	572-623	371.8-404.95	0.38-0.52	6.3-52.3	165-300
Bhojpur	Jagdishpur	7.77-7.79	498-652	324-424	0.14-0.2	1.33-12.8	140-240
Bhojpur	Pirro	7.73-7.76	398-435	259-283	0.44-0.46	1.89-7.1	170-180
Bhojpur	Charpokhri	7.27-7.61	617-931	401-605	0.08-2.23	7.37-59.1	220-280
Bhojpur	Jagdishpur	7.94	841	547	0.78	38.99	455.1
Bhojpur	Tarari	7.3-7.4	1037-1522	674-989	0.1-0.33	66.4-264	230-480
Bhojpur	Garhani	7.73	557	362	0.35	7.09	344.4
Katihar	Amdabad	7.44-7.46	552-1215	359-790	0.13-0.15	8.87-19.7	260-315
Katihar	Barari	7.48-7.82	217.8-798	142-519	0.25-0.3	0.32-46.3	140-245
Katihar	Kursela	7.81	1012	658	0.33	10	435
Katihar	Sameli	7.45-7.77	758-786	493-510	0.26-0.29	27.5-52.5	280-335
Katihar	Manihari	7.35-7.98	224-1906	146-1239	0.17-0.26	3.54-74.4	100-475
Buxar	Chausa	7.12-7.82	503-1058	326.95-687.7	0.465-0.655	7.11-21.3	240-390
Buxar	Itarhi	7.67-7.74	497-1129	323.05-733.05	0.432-0.818	6.37-58.8	200-390
Buxar	Rajpur	7.4-7.67	433-861	281.45-559.65	0.805-0.901	2.59-51.7	195-315
Buxar	Nawanagar	7.55-7.68	557-991	320.65-644.15	0.476-0.88	28.5-28.9	265-380
Buxar	Kesath	7.46	632	410.8	0.496	2.35	270
Buxar	Buxar	7.78-8	394-625	254-1261.5	0.743-0.792	1.07-161	215-519
Buxar	Simri	7.85-8.05	484-640	314-409.5	0.11-0.221	1.27-23.8	160-320
Buxar	Dumraon	7.95-8.24	792- 825	514.8-536.25	0.71-0.95	4.05-18.5	200-305

2.2.2 Saturation Indices

To a great extent, the quality of groundwater depends upon mineral composition, mineral structure and the equilibrium that has occurred between water and rock (Robin, 2002). The chemistry of natural ground waters can be characterized by indicating the Saturation Index (SI) for a number of mineral phases. The Saturation Index is a number which indicates whether a solution is saturated, under saturated or over saturated with respect to a particular mineral phase.

In the present study, saturation indices with respect to calcite and dolomite are calculated using following equation.

$$SI = \log\left[\frac{IAP}{K_{SP}}\right]$$

Where, IAP is the relevant ion activity product of the dissociated chemical species in the solution, and K_{sp} is the equilibrium constant of the reaction considered at the sample temperature. It is obvious from the plot of saturation indices of calcite verses dolomite that most of the ground waters are supersaturated with respect to calcite and dolomite. In Katihar district 41% water samples have calcite saturation index value less than zero while 33% water samples have dolomite saturation index value less than zero. In Patna area, 55% water samples have calcite saturation index value less than zero while 22% water samples have dolomite saturation index value less than zero. Ground water of this type will dissolve calcite and/or dolomite if the ground water comes in contact with source rocks. In most of the samples from Buxar, Bhojpur and Bhagalpur areas, mineral saturation index value of calcite and dolomite is more than zero. If mineral saturation index is less than zero, mineral cannot precipitate from ground water. If saturation index is greater than zero, the mineral might precipitate but cannot dissolve.

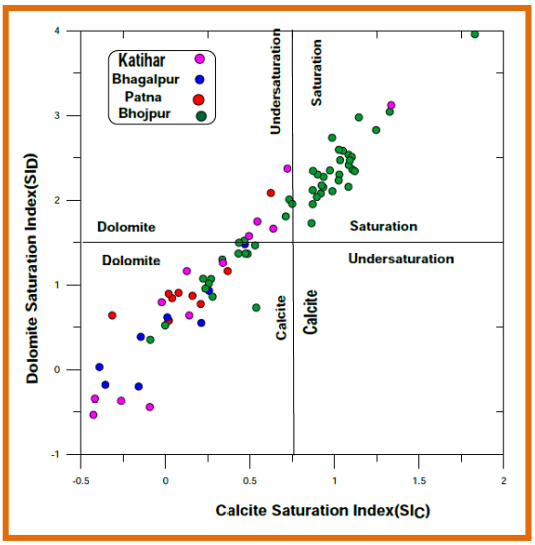


Fig.2.3 Chemical saturation index of Phase IV & V

2.2.3 Na–Cl Relationship

The Na–Cl relationship has often been used to identify the mechanisms for acquiring salinity. Fig. 2.4 (a-e) shows the value of Cl− as a function of Na+ in the groundwater samples. If halite dissolution is responsible for the sodium, the Na/Cl ratio is approximately one, whereas a ratio greater than one is typically interpretated as Na released from other sources. However, analytical data in 66% sample in Patna area, 17% water samples in Buxar area and 60% of water samples in Bhagalpur area have Na/Cl ratio greater than the expected 1:1, indicating that most of the Na+ is derived from other processes such as waste water. Usually waste water is enriched in Na+ relative to Cl−. The water samples of molar ratio greater than one indicates that ion exchange also contributing to enrichment of Na^+. The excess of Na can be attributed to silicate weathering from feldspar or due to anthropogenic activities like waste water. In Katihar area, most of the samples fall along the equilline in the Na+/Cl- plot, indicating common source of halite for both the ions.

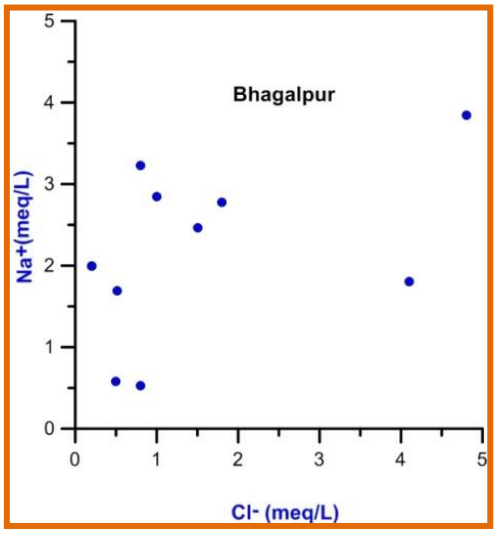


Fig. 2.4(a)

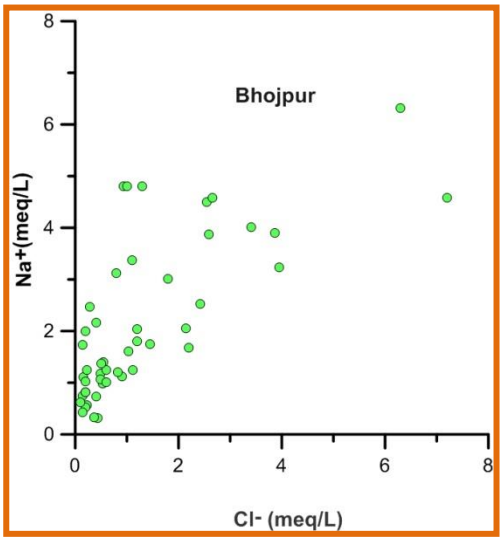


Fig. 2.4(b)

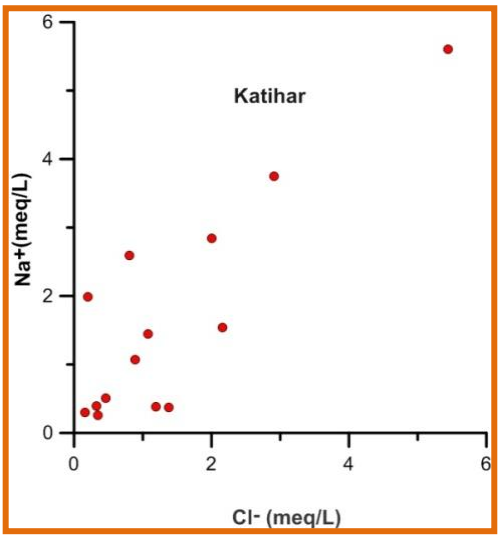


Fig.2.4(c)

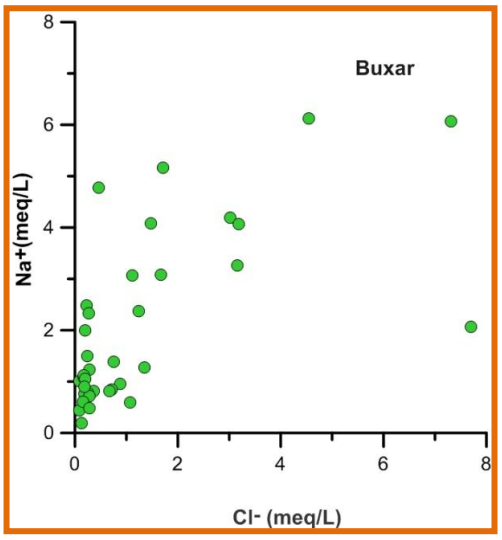


Fig. 2.4(d)

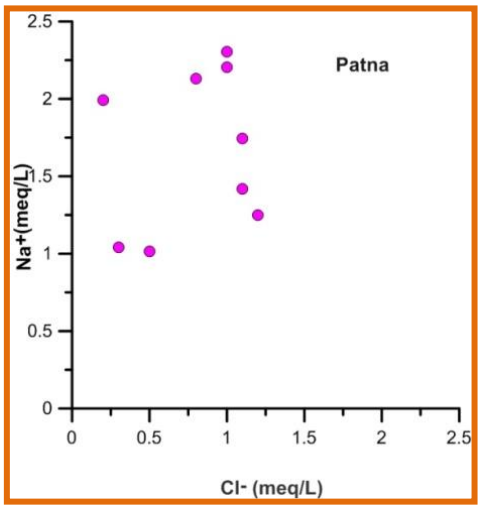


Fig. 2.4(e)

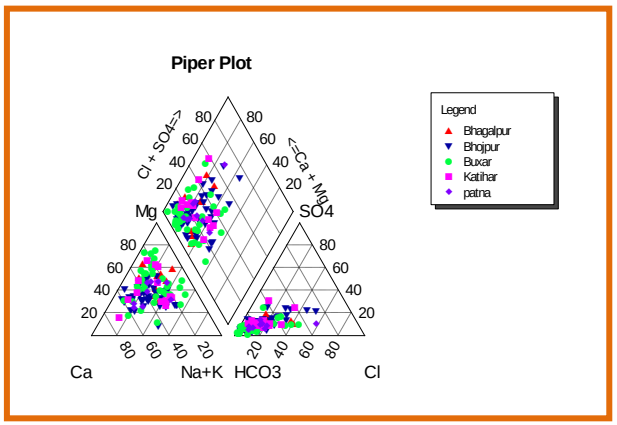


Fig. 2.5

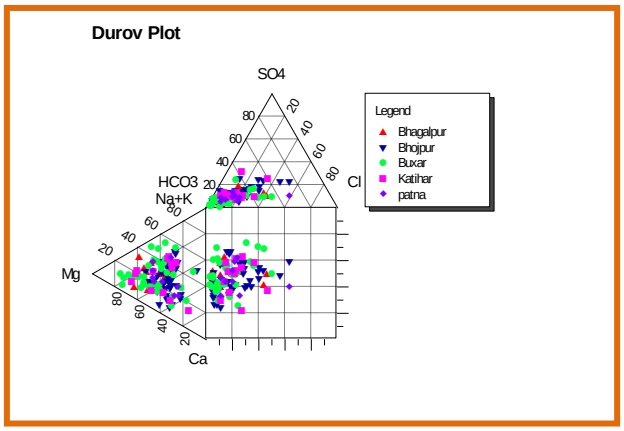


Fig.2.6 Durov Plot

2.2.4 USSL Diagram: The calculated value of SAR in the ground water of the study area ranges from 0.11–3.37. The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that most of the water samples fall in the category C1S1and C2S1 indicating low to medium salinity and low alkali water and it can be used for irrigation in most soil and crops (Fig. 2.7). However, about 18 % of the groundwater samples fall in the zone of C3S1 indicating high salinity and low alkali water.

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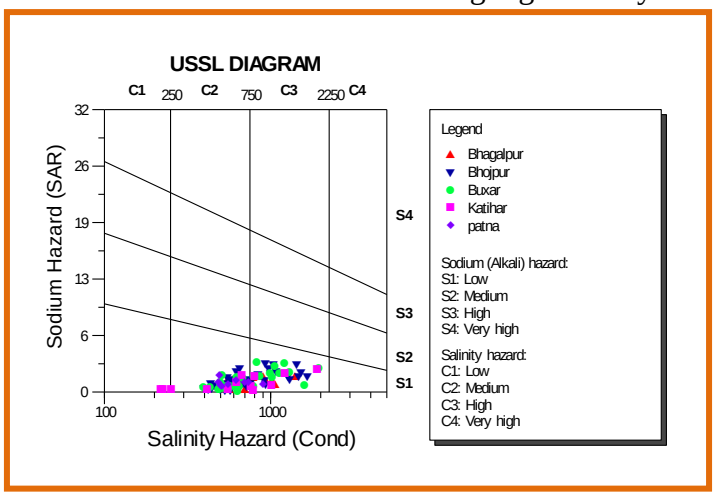


Fig.2.7 USSL Diagram

2.2.5 Box and Whisker Plot: Anion chemistry of the analyzed samples shows that bicarbonate and chloride are the dominant ions in most samples (Fig. 2.8). Concerning cationic chemistry it is evident that Na is dominant cation.

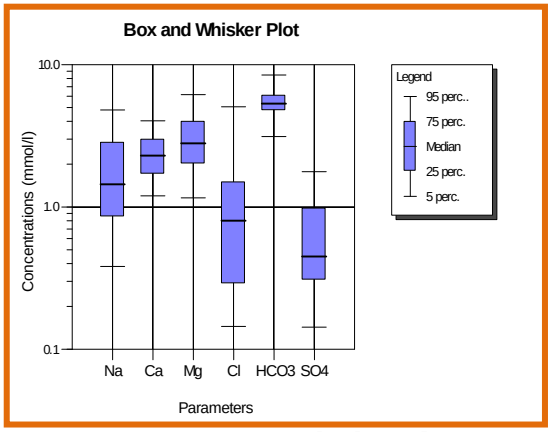


Fig.2.8 Box & Whisker Plot

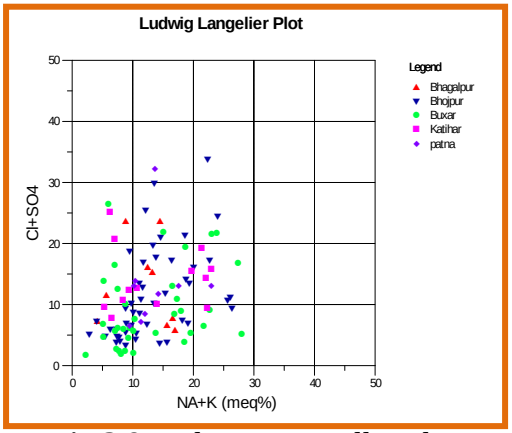


Fig.2.9 Ludwing Langeller Plot

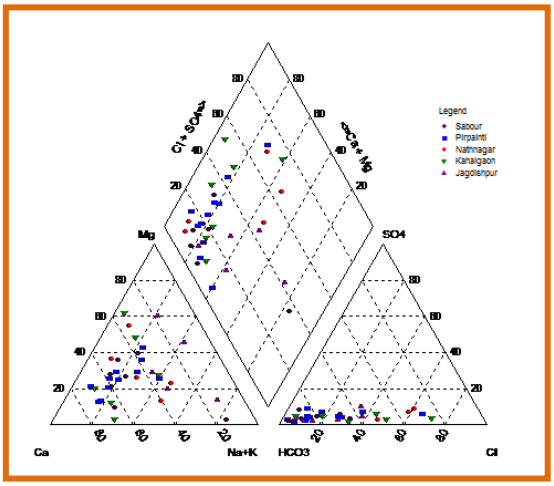
2.2.6 Hardness

Hardness is one of the most important properties of water. Hardness of water is demonstrated commonly by the amount of soap needed to produce lathers. Hardness of water is mainly due to the presence of calcium and magnesium ions in the water. Other cations such as iron, manganese, aluminum, zinc, strontium also react to the hardness but not significantly. The degree of hardness in water is commonly based on the classification given by Sawyer and Mc Carty, 1967 (Table 2.3).

Table 2.3 Total Hardness classification by Sawyer and Mc Carty, 1967

Total Hardness as $CaCO_3$ (mg/l)	Water Class
<75	Soft
75 – 150	Moderately hard
151-300	Hard
301-600	Very hard
>600	Extremely Hard

It is found that 23% water samples in parts of Bhojpur district, 54% water samples in parts of Bhagalpur district, 33% water samples in parts of Buxar district and 28% water samples in Katihar district, total hardness values are higher than desirable limit for drinking purposes of 300 mg/l. Therefore, ground water therefore, comes under the category of moderately hard to very hard.



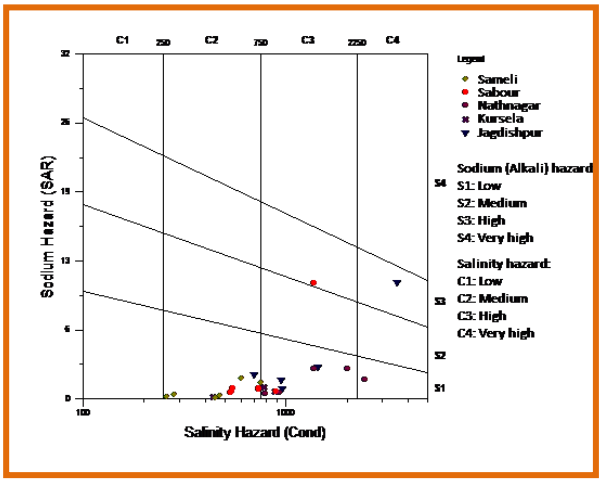


Fig.2.10 Piper plot in Bhagalpur and Katihar (2016-17) **Fig.2.11** USSL diagram in Bhagalpur and Katihar (2016-17)

On the basis of USSL diagram (Fig. 2.11), groundwater of the study area is suitable for irrigation purposes. The USSL diagram shows that the salinity problem in the area is moderate to high.

2.2.7 Ground water quality problem in the study area

The major issue of ground water quality problem in the study area is high arsenic content (>10 ppb) as reported by PHED, Govt. of Bihar and also revealed by the analysis of ground water samples by CGWB. Arsenic contamination of ground water is posing a serious challenge to the drinking water supply as the area is densely populated, and depends on

shallow aquifer for potable water. Out of 13 blocks in parts of Bhagalpur and Katihar districts in present study area, shallow aquifer is contaminated by high arsenic content in 11 blocks as reported by PHED, Govt. of Bihar. Distribution of arsenic samples collected and analysed by CGWB and PHED, Govt of Bihar is depicted in Fig.2.12. The contamination is confined within the top ~70 m of the unilithified Newer Alluvium of Holocene age in the flood plains of the Ganga River. Potential shallow aquifers are also tapped for irrigation and domestic water supply in rural and semi-urban areas. The detailed investigations reveal that the problem is widespread in 11 community development blocks in 2 districts in the study area (Table 2.4). Maximum arsenic concentration is found in the order of 83 ppb in Katihar district. Ironically, single aquifer system exists in parts of Katihar district as revealed by CGWB exploration programme upto the depth of 300 m bgl. Though, arsenic contamination is confined to ~70 m bgl as revealed by field study. Precaution should be taken in order to restrict dewatering of the aquifer so that depth of arsenic contamination should not extend downward futher.

Table 2.4 List of blocks, affected by high arsenic content

Sl No	District Name	Total no. of blocks	No. of blocks affected	Name of the blocks affected
1	Bhagalpur	7	5	1. Nathnagar
				2. Jagdishpur
				3. Kahalgaon
				4. Pirpainti
				5. Sabour
2	Katihar	6	6	1. Samoli
				2. Barari
				3. Kursela
				4. Manihari
				5. Amdabad
				6. Mansahi
Total		**13**	**11**	

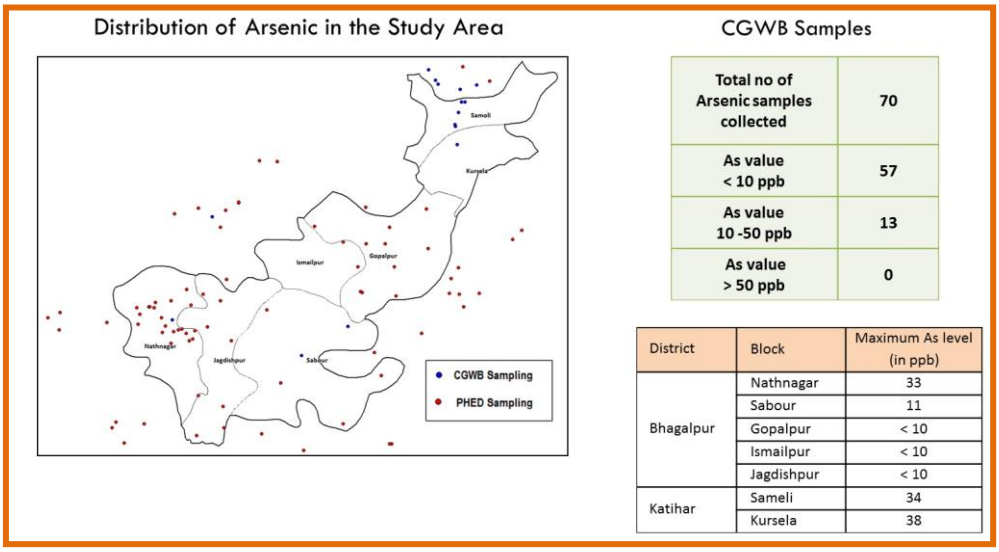


Fig.2.12 Distribution of Arsenic sample in parts of Bhagalpur and Katihar (Data source: CGWB & PHED, 2016-17)

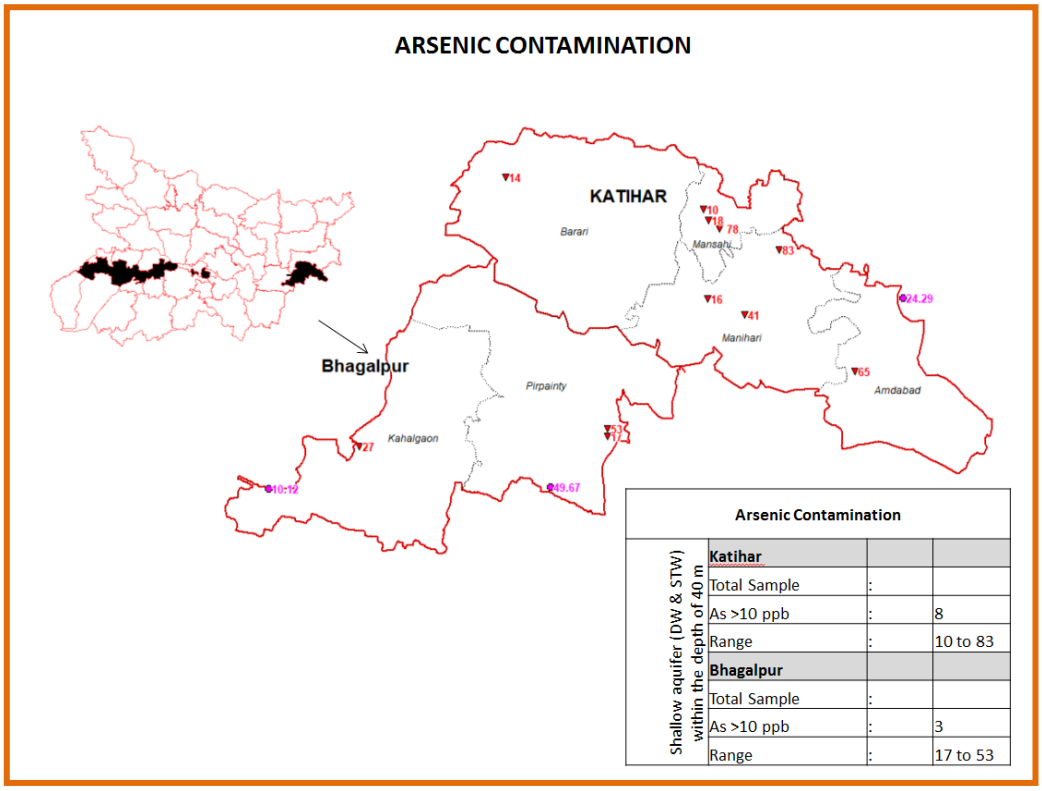


Fig.2.13 Location map of Arsenic samples above permissible limit (2017-18)

Fluoride Contamination in groundwater (>1.5 mg/l) has been reported from parts of Bhagalpur district in the study area. The names of the blocks from where the contamination has been reported are as under. Further exploration by CGWB is in process for identification of depth range of aquifer contaminated by Fluoride.

Table 2.5 Blocks affected with fluoride contamination

S.No	District	No. of Blocks from which Fluoride contamination reported (>1.5 mg/l)	Name of Block
1	Bhagalpur	5	1. Kahalgaon,
			2. Jagdishpur,
			3. Nathnagar,
			4. Pirpainti,
			5. Sabour,
Total	1	5	

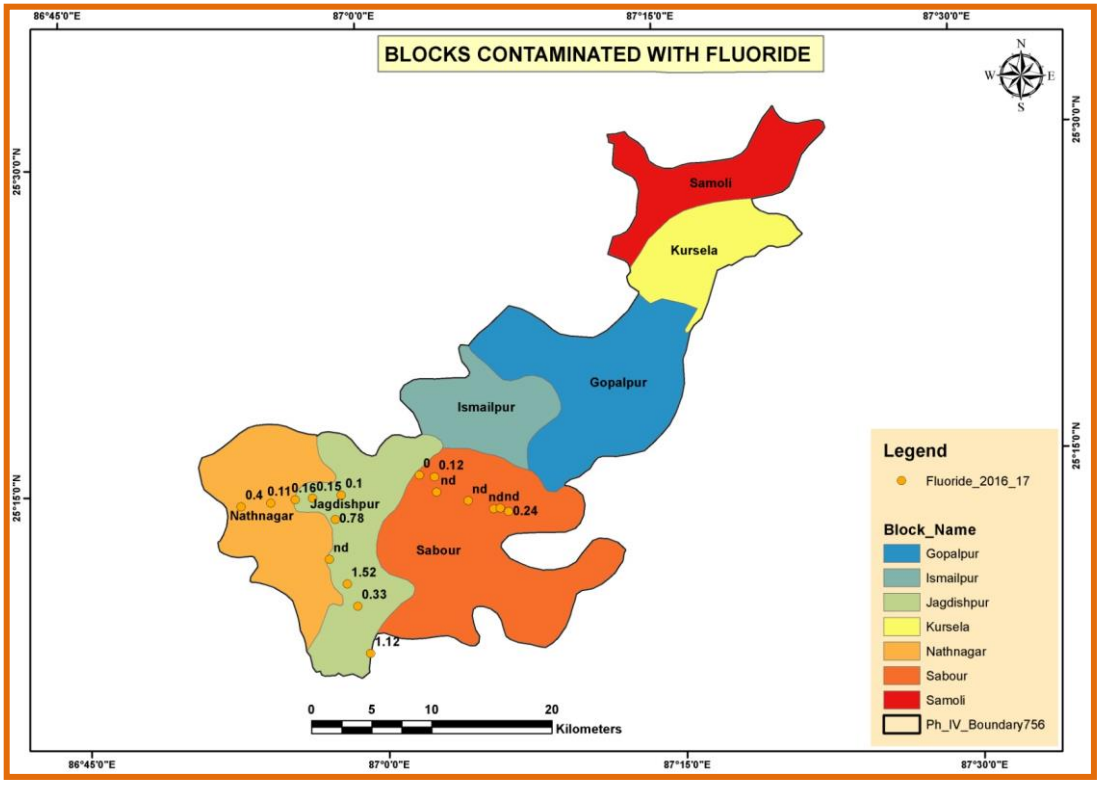


Fig.2.14 Flouride affected blocks in parts of Bhagalpur

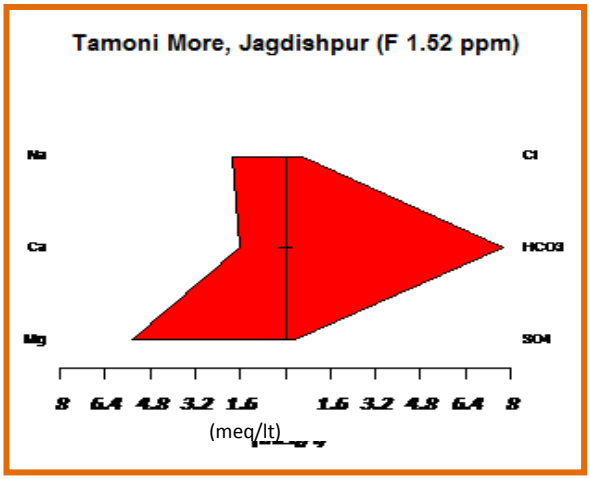


Fig.2.15 Stiff Diagram of ground water sample collected from Tamoni More, Jagdishpur having Fluoride concentration more than 1.5 ppm.

Sporadic occurrence of high nitrate (>45 mg/l) has also been revealed from shallow aquifer in parts of Bhojpur, Buxar, Bhagalpur and Katihar districts. This may be due to high use of fertilizers. Location of high nitrate sample collected from ground water has been depicted in Fig. 2.16.

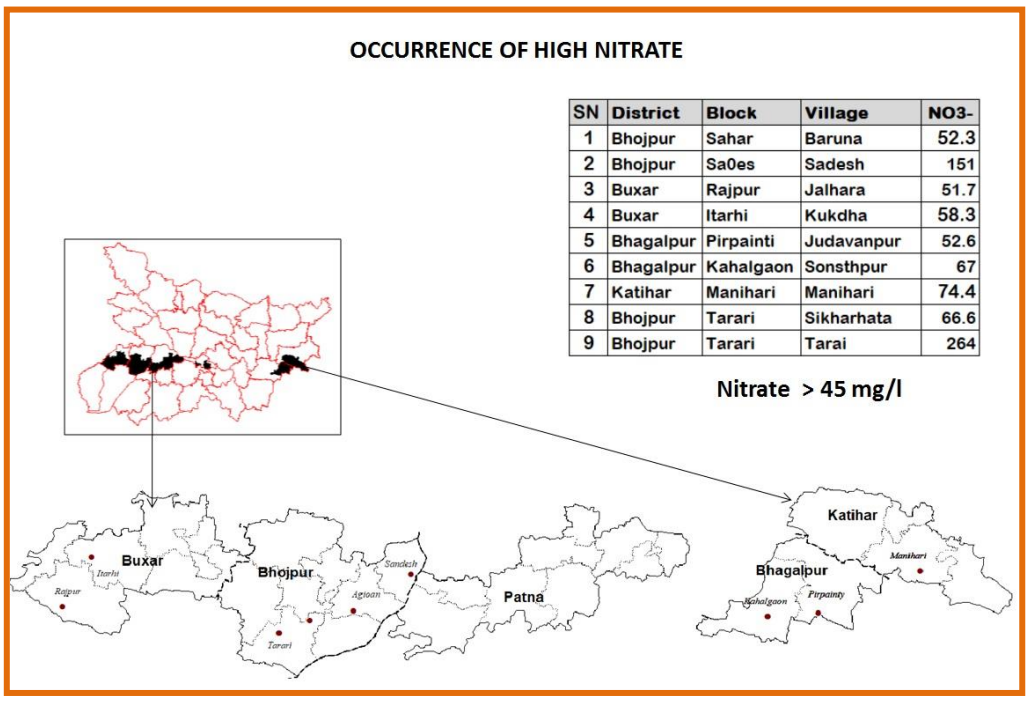


Fig. 2.16 Location of high nitrate sample collected from ground water

2.3 Geophysical Survey

The subsurface configuration of aquifer has been made based on available lithological logs of CGWB and State agencies along with interpreted records from VES survey. Several sections along different orientation have been prepared to depict aquifer geometry. The lithologs and the geophysical logs reveal the presence of a thick pile of alluvial sediments with alternating sequence of various grades of sand with clay and silt.

2.3.1 Location, number, analytical techniques

Electrical surface geophysical methods are used to detect changes in the electrical properties of the sub-surface. The electrical properties of soils and rocks are determined by water content, mineralogical clay content, salt content, porosity and the presence of metallic minerals. However, typically the resistivity of the water has a larger effect on the bulk resistivity than the soil or rock type. Variations in these electrical properties of soils and rocks, either vertically or horizontally, produce variations in the electrical signature measured by surface geophysical instrument. Surface geophysical resistivity surveys are usually designed to measure the electrical resistivity of sub-surface materials by making measurements at the earth surface. In Vertical Electrical Sounding (VES), the vertical (depth wise) variations in the resistivity of the sub-surface are measured. This is done by imposing an electrical field in the ground by a pair of electrodes at varying spacing expanding symmetrically from a central point, while measuring the surface expression of the resulting potential field with additional pair of electrodes at the appropriate spacing.

55 Surface electrical resistivity investigation (VES) were carried out by CGWB within the study area. The field data were interpreted with the help of empirical curves

(Master curves) based on curve matching technique and computer based software. The locations of the VES points are shown in the Fig. 2.17.

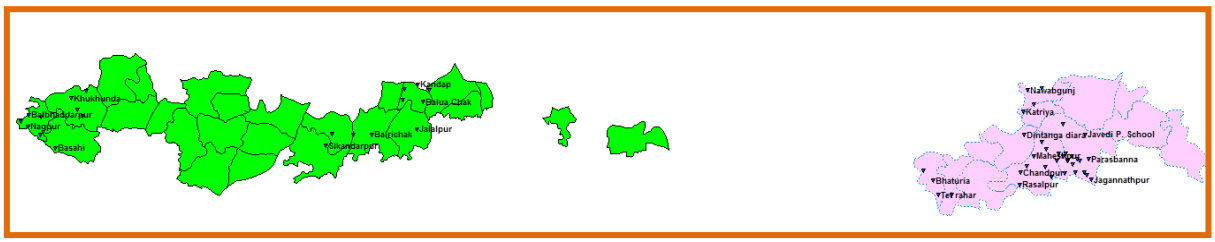


Fig. 2.17 Map showing the locations of VES points in the NAQUIM area

The location of the VES points is given below in Table 2.6.

Table 2.6 Locations of the VES conducted

District	Block	Village	Longitude	Latitude
Bhagalpur	Nathanagar	Tet rahar	86.94	25.16
Bhagalpur	Jagdishpur	Gonudham	86.98	25.16
Bhagalpur	Nathanagar	Bhaturia	86.92	25.21
Bhagalpur	Nathanagar	Ramchandra pur	86.88	25.24
Bhagalpur	Kahalgoan	Maheshpur	87.27	25.28
Bhagalpur	Pirpainthi	Lakarakol	87.34	25.27
Bhagalpur	Kahalgoan	Chandpur	87.22	25.23
Bhagalpur	Kahalgoan	Mathurapur	87.35	25.29
Bhagalpur	Kahalgoan	Rasalpur	87.21	25.20
Bhagalpur	Pirpainthi	Parasbanna	87.45	25.27
Bhagalpur	Pirpainthi	Banshichak	87.41	25.27
Bhagalpur	Pirpainti	Lakhmipur Rly. Station	87.37	25.29
Bhagalpur	Pirpainti	Rajganj	87.36	25.28
Bhagalpur	Pirpainti	In between Sadiput and Gobindpur	87.38	25.27
Bhagalpur	Pirpainti	Srirampur	87.40	25.26
Bhagalpur	Kahalgaon	Siyan	87.33	25.22
Bhagalpur	Pirpainti	Jagannathpur	87.46	25.21
Bhagalpur	Pirpainti	Barmasia	87.44	25.23
Bhagalpur	Pirpainti	Jhurkusia	87.45	25.22
Bhagalpur	Pirpainti	Gobindpur	87.38	25.27
Bhagalpur	Pirpainti	Panchrukhi	87.37	25.23
Bhagalpur	Pirpainti	Srinagar (Jagadishpur)	87.42	25.27
Bhagalpur	Pirpainti	Hiranand	87.39	25.28
Bhagalpur	Pirpainti	Durgapur M.School, Saguni	87.41	25.23
Bhagalpur	Pirpainti	Javedi P. School	87.44	25.35
Bhagalpur	Kahalgaon	choti Bariapur	87.31	25.31

Bhagalpur	Pirpainti	Ekchari Diyara (Flood Plane)	87.36	25.38
Bhagalpur	Kahalgaon	AntiChak (Primary Sub-Health)	87.29	25.33
Bhagalpur	Kahalgaon	Sadanandapur Baisa	87.30	25.25
Bhagalpur	Kahalgaon	Ramnagar	87.24	25.25
Bhojpur	Chausa	Balbhaddarpur	83.81	25.41
Bhojpur	Chausa	Mianpur	83.79	25.39
Bhojpur	Chausa	Nagpur	83.81	25.37
Bhojpur	Chausa	Sagram	83.85	25.40
Bhojpur	Chausa	Khiri	83.85	25.35
Bhojpur	Rajpur	Basahi	83.90	25.31
Bhojpur	Itarhi	Khukhunda	83.96	25.46
Bhojpur	Itarhi	Itarhi	84.01	25.48
Bhojpur	Itarhi	Barhana	83.98	25.42
Bhojpur	Itarhi	Indour	84.00	25.41
Patna	Pulwari Sharif	Kandap	85.15	25.50
Patna	Sampath chawk	Balua Chak	85.17	25.45
Patna	Sampath chawk	Palaki	85.19	25.49
Patna	Dhanarua	Jalalpur	85.15	25.37
Patna	Sampath chawk	Jolbigaha	85.10	25.46
Patna	Masaurhi	Bairichak	84.99	25.35
Patna	Dulhin Bazar	Bharatpura	84.85	25.35
Patna	Masaurhi	Ichipur	84.93	25.35
Patna	Sampath chawk	Rasilchak	85.10	25.49
Patna	Paligunj	Sikandarpur	84.83	25.31
Kathihar	Kursela	Katriya	87.23	25.42
Kathihar	Kursela	Dintanga diara	87.23	25.35
Kathihar	Samoli	Nawabgunj	87.24	25.48
Kathihar	Kursela	Tingaria	87.27	25.44
Kathihar	Samoli	Dumar	87.31	25.52

On the basis of interpreted results, geoelectrical sections have been prepared and vertical and horizontal disposition of granular zones of various grades are analysed within the investigated area (Fig.2.18-20).

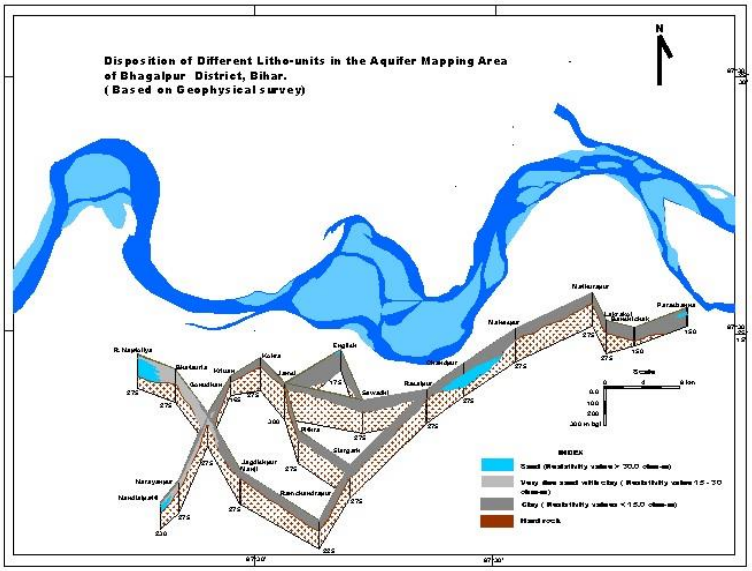


Fig. 2.18 Distribution of different litho-units in Bhagalpur District

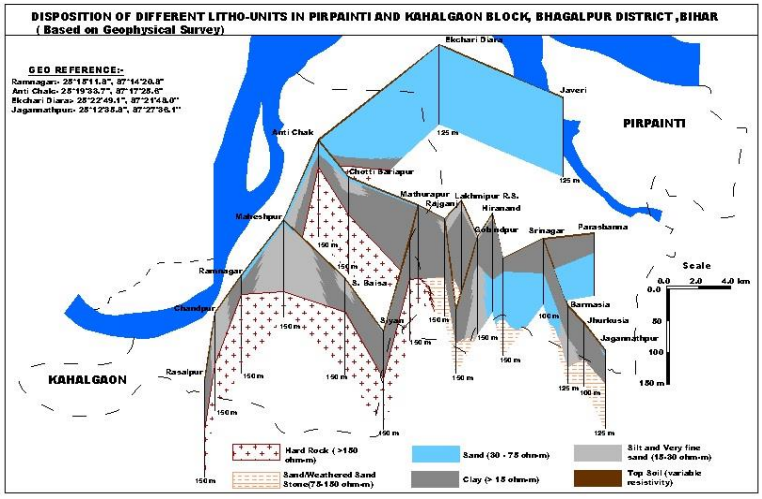


Fig. 2.19 Disposition of different litho-units in Kahalgaon and Pirpainti block of Bhagalpur district

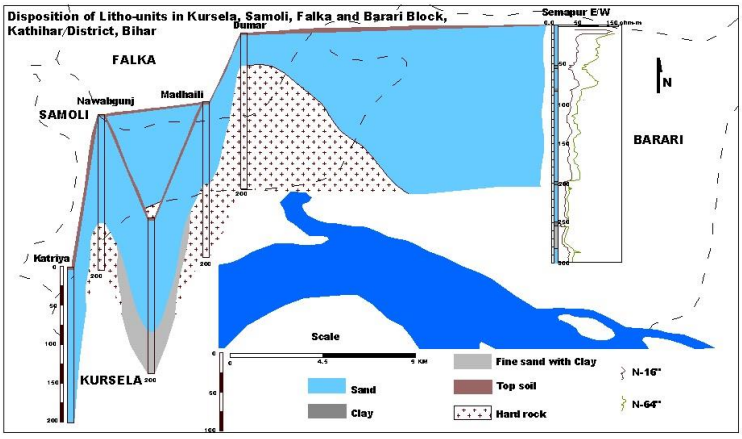


Fig.2.20 Disposition of litho-units in Kursela, Samoli, Falka and Barari block, Katihar district

2.4 Exploratory drilling-State, CGWB and private wells

Exploratory drilling has been conducted by CGWB up to the depth of 300 m bgl in the alluvium and 200 m bgl in hard rock areas to know the aquifer characteristics in the study area which has been shown in Fig. 2.21-2.22.

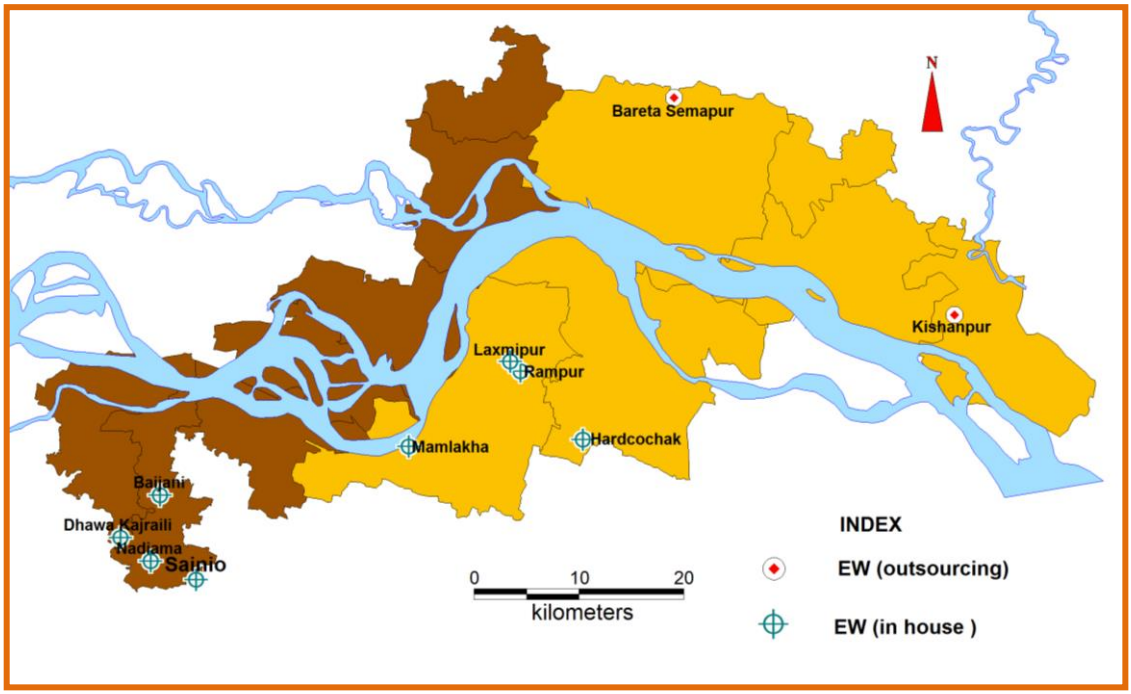


Fig. 2.21 Exploratory Wells of CGWB and Outsourcing Phase IV

Fig.2.22 Exploratory Well of CGWB and Outsourcing Phase V

CHAPTER-III
GENERATION OF AQUIFER MAP

3.1 Aquifer Disposition

The study area is covering the axial part of the Ganga Basin. The area is underlain by immensely thick alluvial deposits of Quaternary age comprising various grades of sand, silt and clay which constitutes the ground water repositories. 2D, 3D lithological sections and fence diagrams have been prepared to interprete the aquifer-disposition in the study area.

3.1.1 Aquifer Disposition in the Area

Thus, the detailed aquifer geometry on regional scale has been established in the study area. Principal aquifers in the area have been delineated by grouping the fine to medium sand, coarse sand and gravelly sand as aquifers. The sections reveal that the area is underlain by a two-tier aquifer system.

The clay layer of 10-20 m separates the 1st and 2nd aquifer in Buxar-Bhojpur area (Fig. 3.3, 3.5, 3.6). The formation at the top is clay mixed with kankar and fine sands and occassionaly with coarse sand. In the absence of any pure clay at the top, the shallow aquifer occurs under water table condition. However, aquifer around Sahar, the top clay layer is fairly thick and is under semi confined conditions. The depth of first aquifer in Bhojpur and Buxar area varies from 80 to 120 m bgl in general. Shallow private irrigation tubewells in the area tap the aquifer zone 20-60 m bgl. Average yield of the tube well varies from 30 to 95 m^3/hr with drawdown of 3 m. Transmissivity value of 1st aquifer in Itarhi block area is in the order of 3,653 m^2/day. From exploration data it has been found that the second aquifer varies from 120 to 250 m bgl. The yield of the second aquifer varies from 100 to 200 m^3/hr with drawdown of 4 to7 m. Transmissivity of the aquifer varies from 3653 to 15886 m^2/day; Storativity is in the order of $0.067x10^{-4}$.

In parts of Patna area, depth of 1st aquifer ranges from 35 to 90 m bgl (Fig. 3.1, 3.4). The thickness of 2nd aquifer varies from 100 to 150 m separated by clay layer of 20-22 m thick from the 1st aquifer. The depth of 2nd aquifer ranges from 80 to 230 m in Belchi area whereas in Ghoswari area, it ranges from 112 to 222 m bgl. The 3rd aquifer encountered ranges from 231 m downwards.

Single aquifer system is prevalent in the southern portion of Bhagalpur district adjoining Banka district at the depth of 25-75 m bgl (Fig. 3.2, 3.7, 3.8, 3.9, 3.10). In Sabour block, 1st aquifer occurs at depth range of 66-97 m bgl. In north-eastern parts in Kahalgaon area, aquifer occurs at 79-131 m while in Pirpainty area, 1st aquifer occurs at 58-92 m bgl and 2nd aquifer occurs at 101-182 m bgl. Cumulative discharge of tube well is in the order of 50-75 cu.m/hr with drawdown of 17-22 m. Specifically, in parts of Bhagalpur area, aquifer discharge and drawdown varies spatially as per the aquifer disposition as alluvium is thinner and underlain by hard rock in various locations.

Available data indicate the presence of two aquifer systems up to ~300 mbgl in general. However, in parts of Katihar district, mono-aquifer system upto the depth of 275 m has been encountered (Fig. 3.11-3.12). A clay layer of ~ 15 m at the top has been found in Kursela, Barari, and Amdabad area in Katihar district.

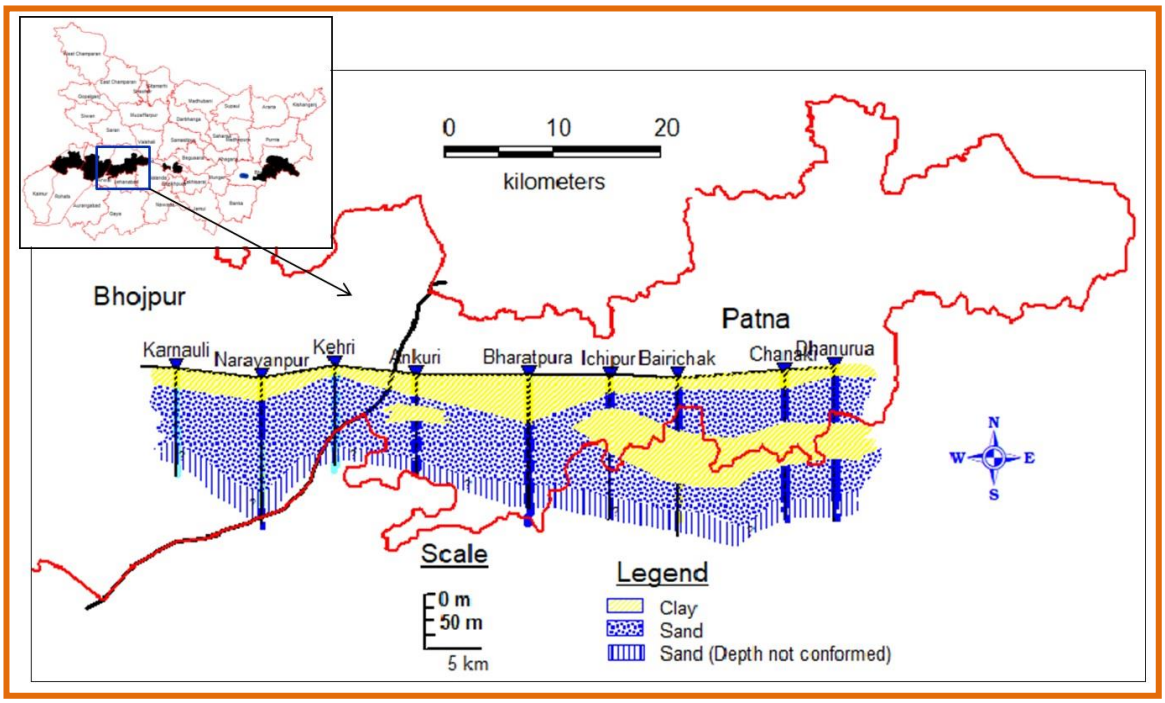


Fig.3.1 Lithological Section from Bhojpur to Patna

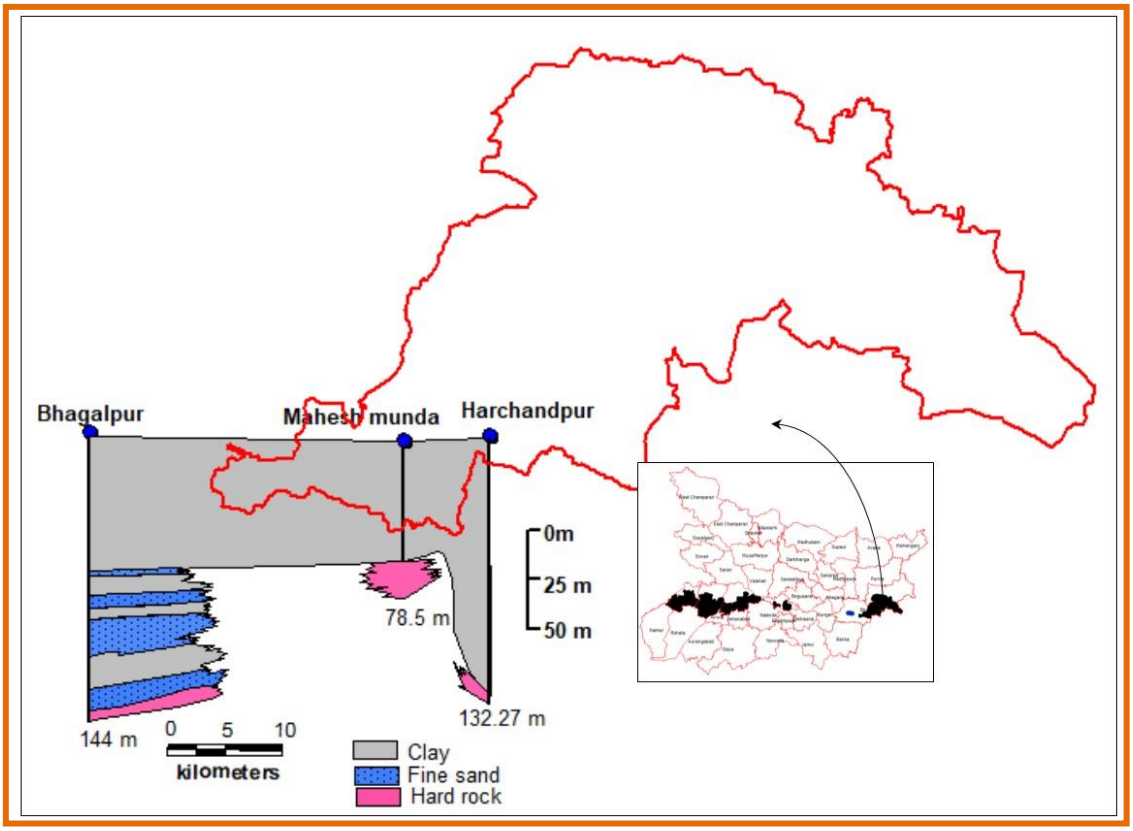


Fig.3.2 Lithological Section in Bhagalpur area

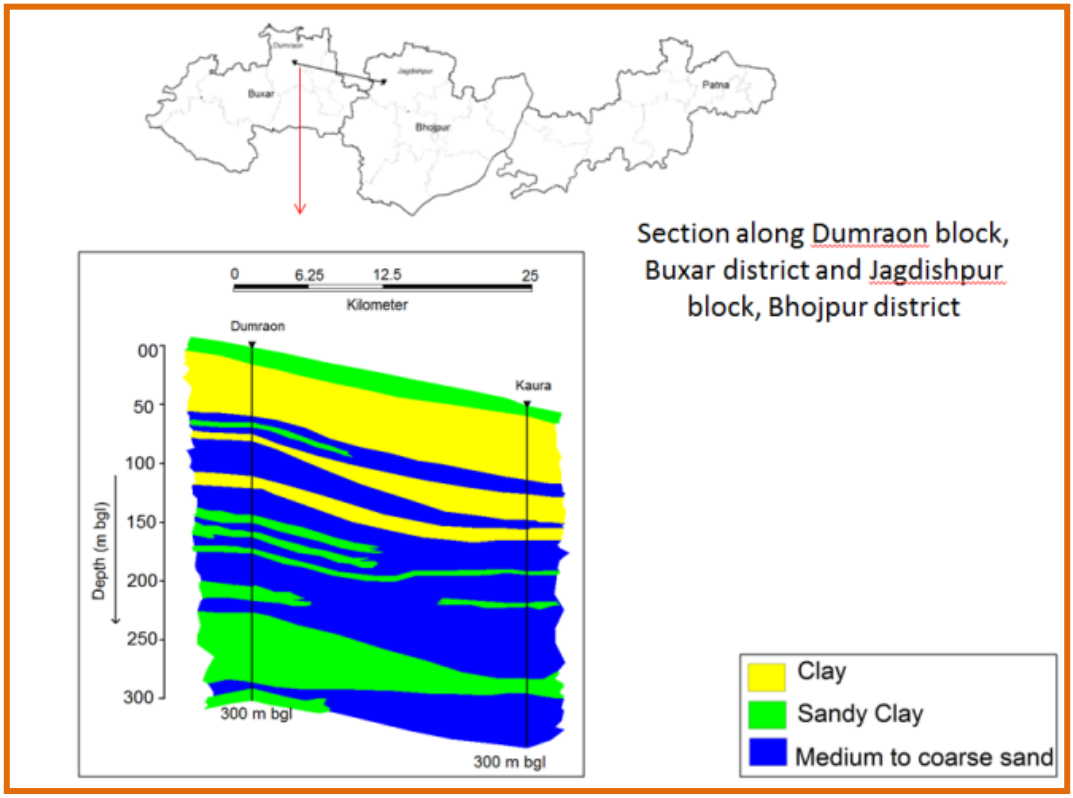


Fig. 3.3 Hydrogeological section Dumraon to Jagdishpur

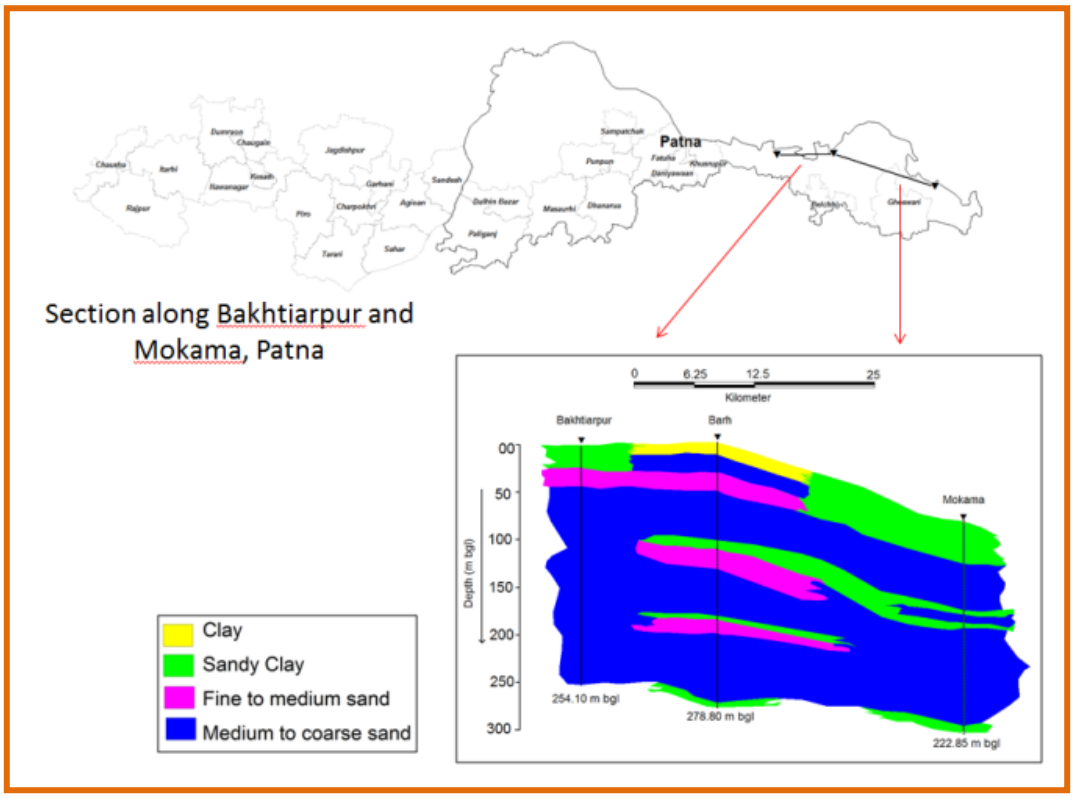


Fig. 3.4 Hydrogeological section from Bakhtiyarpur to Mokama

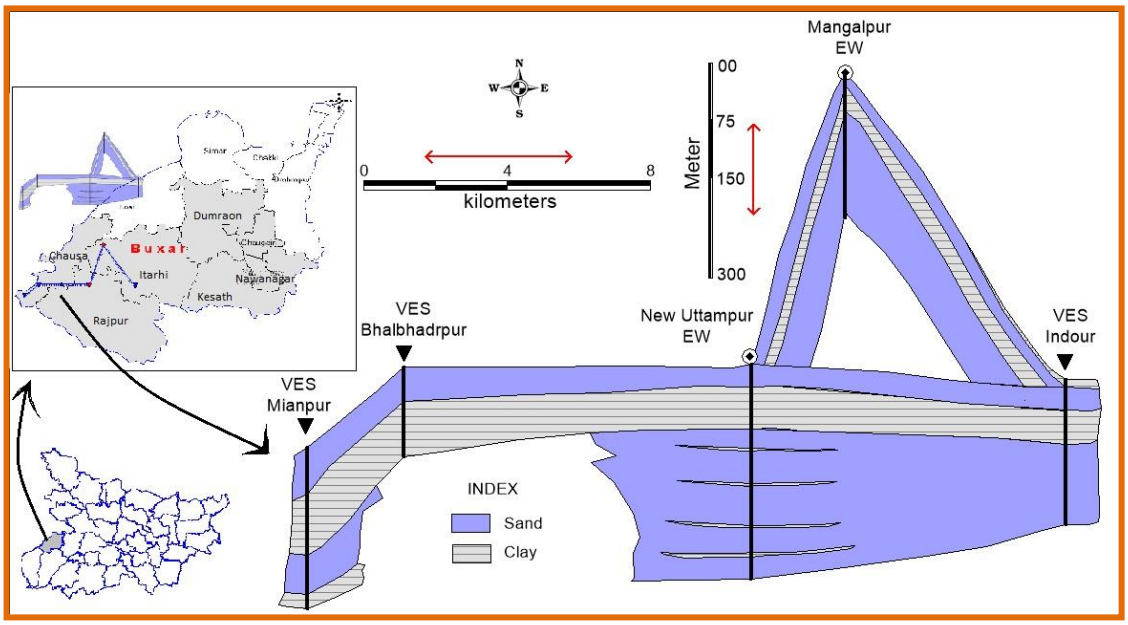


Fig. 3.5 Lithological section from Mainpur-Mangalpur to Indour

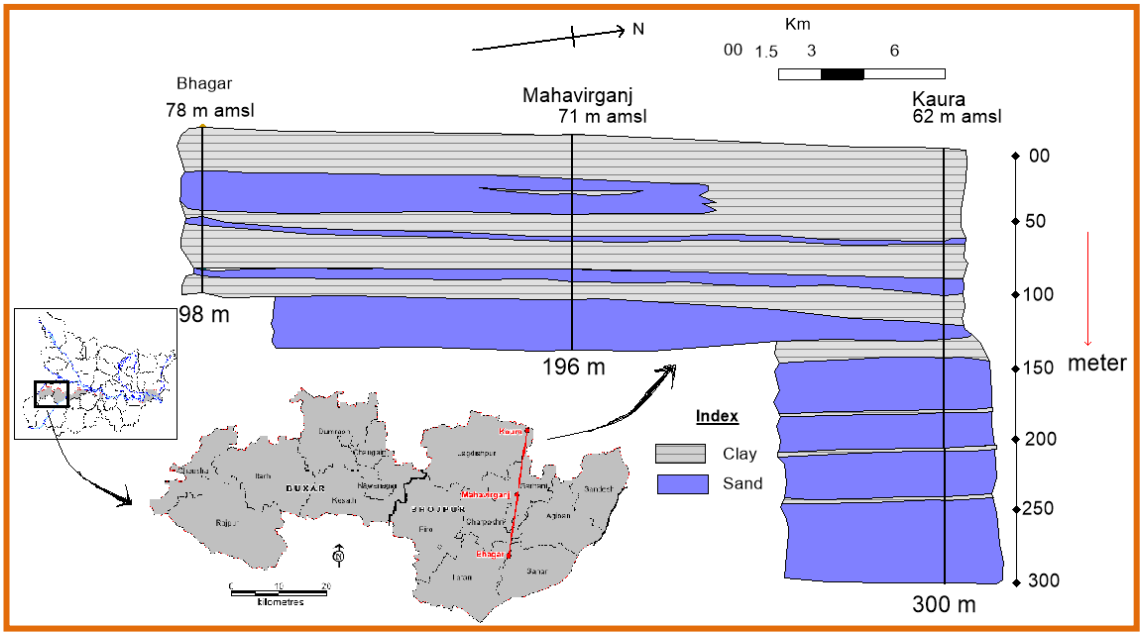


Fig. 3.6 Hydrogeological section from Bhagar to Kaura in Bhojpur

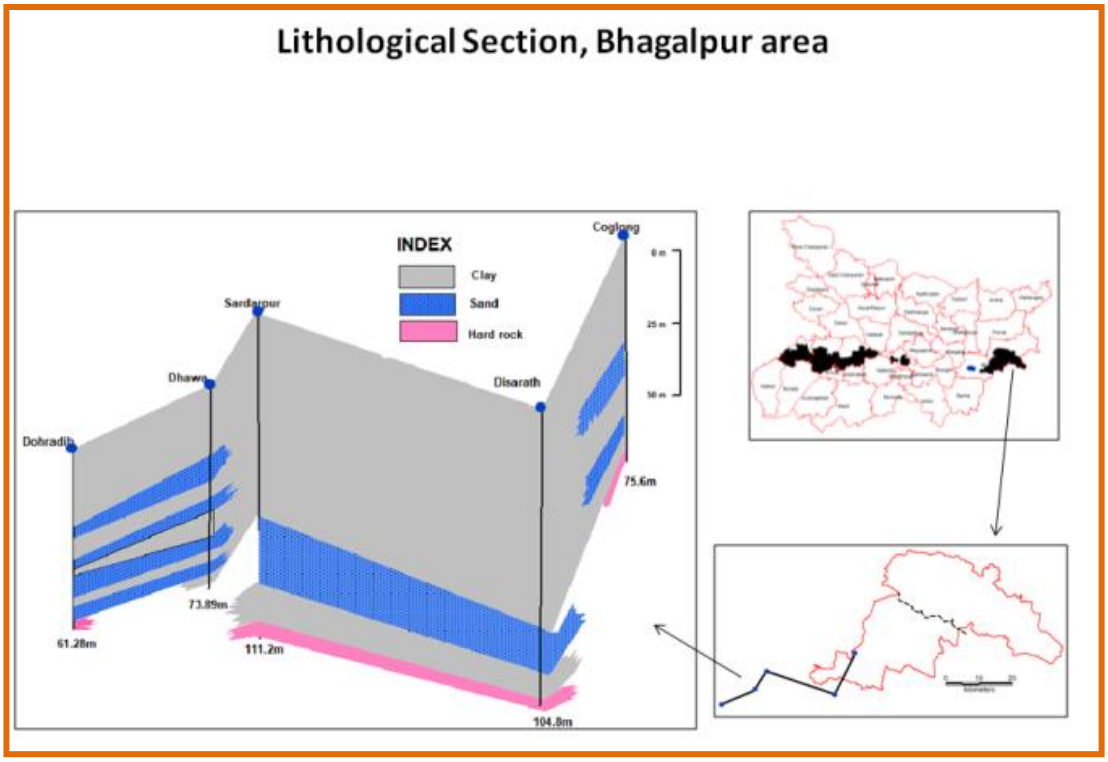


Fig. 3.7 Hydrogeological section from Dohradih to Coglong

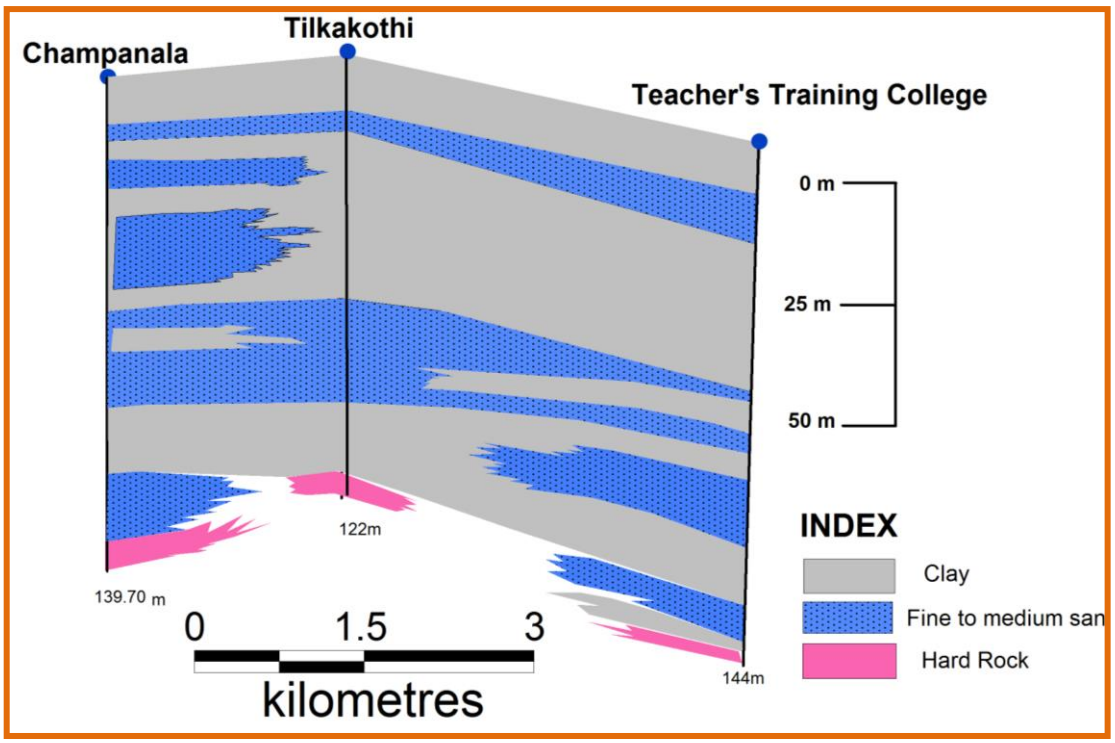


Fig. 3.8 Hydrogeological section of Champanala to Teacher's training college, Bhagalpur

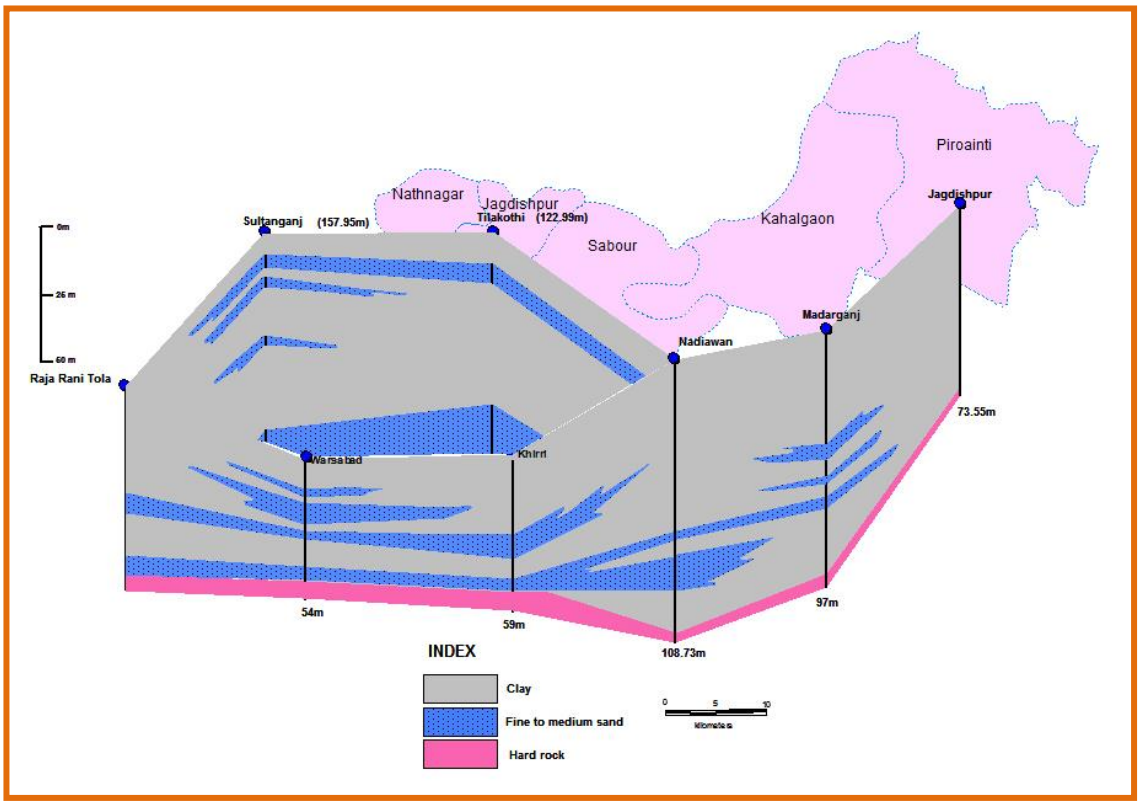


Fig. 3.9 Hydrogeological section from Sultanganj to Jagdishpur

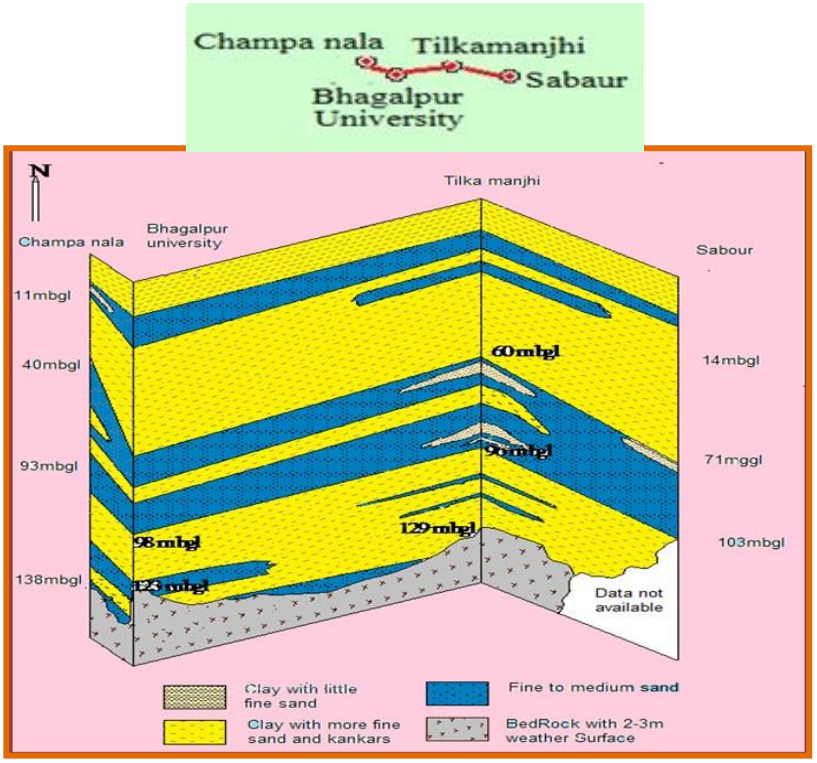


Fig. 3.10 Hydrogeological section from Champa Nala to Sabour

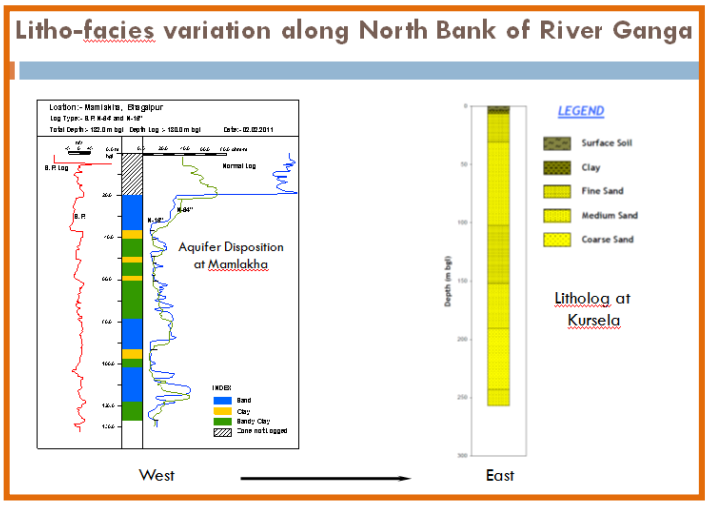


Fig.3.11 Lithofacies variation along North Bank of River Ganga in parts of Bhagalpur-Katihar

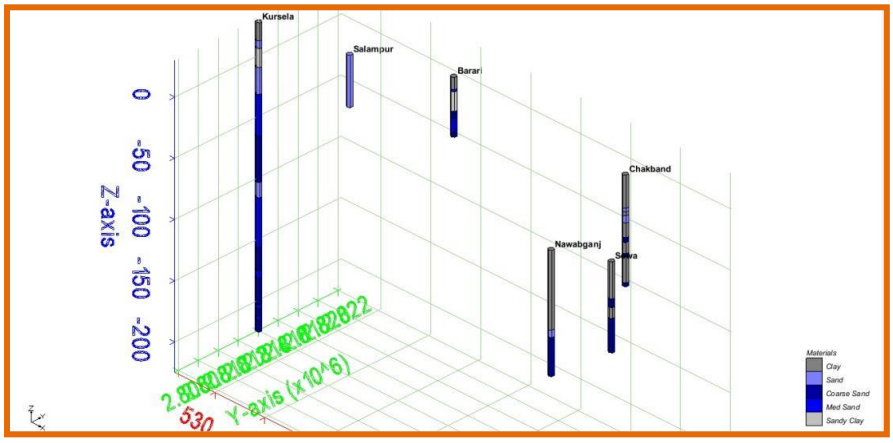


Fig.3.12 Lithological Log in Katihar area

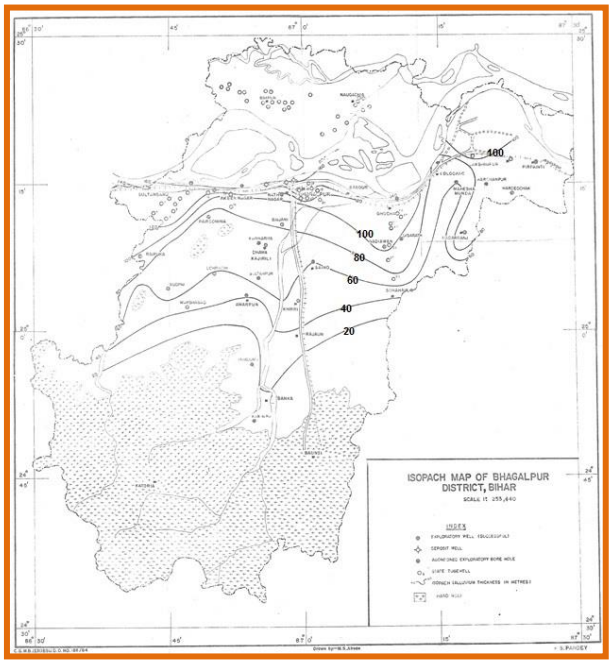


Fig.3.13 Isopach Map of Bhagalpur area

Table 3.1 Block wise Aquifer Characteristics

Ist Aquifer (Alluvium)										2nd Aquifer (Alluvium, Sandstone/Granite gneiss in Bhagalpur)				
District	Administrative Units	Area(sq km)	Depth Range (m bgl)		Thickness (m)	Discharge (m3/hr)	Drawdown (m)	Specific Capacity (m3/hr/m)	Transmissivity (m2/day)	Depth Range (m bgl)	Discharge (m3/hr)	Drawdown (m)	Transmissivity (m2/day)	Storativity
Bhagalpur	Nathnagar	126	25	44	19	20-50	11	-	100-600	53-65	92-102	6	260-438	$2.16x10^{-5}$ to $2.24x10^{-3}$
	Jagdishpur	110	26	53	27	20-50	11	-	100-600	88-153	100-200	9	5918	$2.16x10^{-5}$ to $2.24x10^{-3}$
	Sabour	115	66	97	31	20-50	3 to 6	-	100-600	80-140				
	Gopalpur	132	0	238	238	20-50	11 to 15	-	100-600					
	Ismailpur	83	0	238	238	20-50	11 to 15	-	100-600					
	Kahalgaon	335.84	79	131	52	14-37	6 to 11	1.2-5.96	126-4207					2.3-3.34 $x10^{-4}$
	Pirpainti	350.06	58	92	34	20-50	19.5	3.43	111 - 209.5	101-182,	50-75	17		0.4-1.0 $x10^{-3}$
Katihar	Amdabad	188.63	60	270	210	100 - 200								
	Barari	327.8	0	250	250	100 - 200								
	Manihari	250.12	20	60	40	100-200				94-				
	Sameli	129	42	148	106	100-200				-				
	Kursela	61	15	252	237	100-200				-				
	Mansahi	78.14	60	270	210	100 - 200								
Bhojpur	Charpokhri	109.31	38	114	76	50 - 100				126-292	100 - 200	4.23-9.91	4769 - 15886	0.067 x10-4
	Garhani	112.01	30	54	24	75-150				92-195	100-200			
	Jagdishpur	257.78	63	75	12	50-100		22.07		97-300	100-200	8.55	5918	
	Piro	218.39	63	75	12	50-100		22.07		97-300	100-200	8.55	5918	
	Tarari	200.98	36	61	25					84-				
	Sahar	127.29	32	68	22	50-100				88-186	100-200			
	Agioan	155.99	32	68	22	50-100				88-186	100-200			
	Sandesh	130.09	32	68	22	50-100				88-186	100-200			
Buxar	Nawanagar	184.5	7	42	35	30 - 50				60-80	75-125	7.04	1098 - 10980	
	Dumraon	197.99	59	172	92					190-226	130	4.56	5187	
	Chaugain	54.65	59	172	92					190-226	130	4.56	5187	
	Rajpur	274.34	92	116	24	30 - 50				122-262, 274-	100-200	4	8000	$1.8X10^{-5}$
	Itarhi	228.93	38	62	24					84-	175	3.4	3653	

	Kesath	30.79	19	25	6					56-200				
	Chausha	108.04	92	116	24					122-262, 274-	100-200	4	8000	1.8X 10^{-5}
Patna	Dulhin Bazar	110.68	58	128	70	30 - 50				136- 200	125 - 250	0.58-6.28	3786-19540	3.22x 10-6 - 7.7x10-2
	Punpun	126.75	30	62	32					94-232	188	5	10435	2.29 $X10^{-3}$
	Paliganj	237.75	58	128	70	30 - 50				136- 200	125 - 250	0.58-6.28	3786-19540	3.22x 10-6 - 7.7x10-2
	Masaurhi	202.43	58	128	70	30 - 50				136- 200	125 - 250	0.58-6.28	3786-19540	3.22x 10-6 - 7.7x10-2
	Dhanaura	185.55	58	128	70	30 - 50				136- 200	125 - 250	0.58-6.28	3786-19540	3.22x 10-6 - 7.7x10-2
	Khusrupur	61.39	30	62	32					94-232	188	5	10435	2.29 $X10^{-3}$
	Daniyawaan	65.1	30	62	32					94-232	188	5	10435	2.29 $X10^{-3}$
	Fathua	126.36	30	62	32					94-232	188	5	10435	2.29 $X10^{-3}$
	Belchhi	68.67	20	68	48					80-230	200	6	14770	3.22 $X10^{-6}$
	Sampatchak	65.35	30	62	32					94-232	188	5	10435	2.29 $X10^{-3}$
	Ghoswari	139.83	20	70	50					100-208, 240-296				

3.1.2 Aquifer Characterizations

Characterization of aquifer upto 300 m bgl in the study area has been arrived at by convergence of the observations from the study of the different lithological sections, fence diagrams, geoelectrical sections, sections based on elogs and overall lithological model of the area. All these figures reveal the presence of a thick pile of alluvial sediments with alternation of various grades of sand with clay and silt. The area is characterized by occurrence of fairly thick sands of various grades forming aquifers.

The perusals of the sections, fence diagram and lithological model indicate that there are mainly two principal aquifer systems below the top aquitard layer (water table aquifer) upto 300 m depth separated by clay and sandy clay layers. 3D view of the aquifer disposition has been prepared which provide a clear impression of the spatial variation of aquifer thickness in the area (Fig. 3.14 (a, b, c) & 3.15).

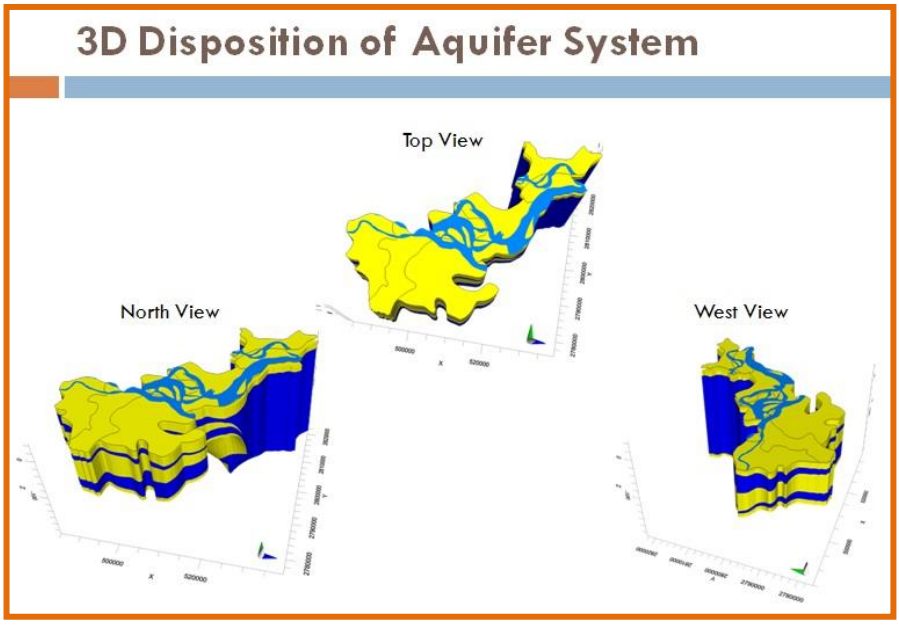


Fig. 3.14(a) 3D Disposition of Aquifer System in parts of Bhagalpur & Katihar districts

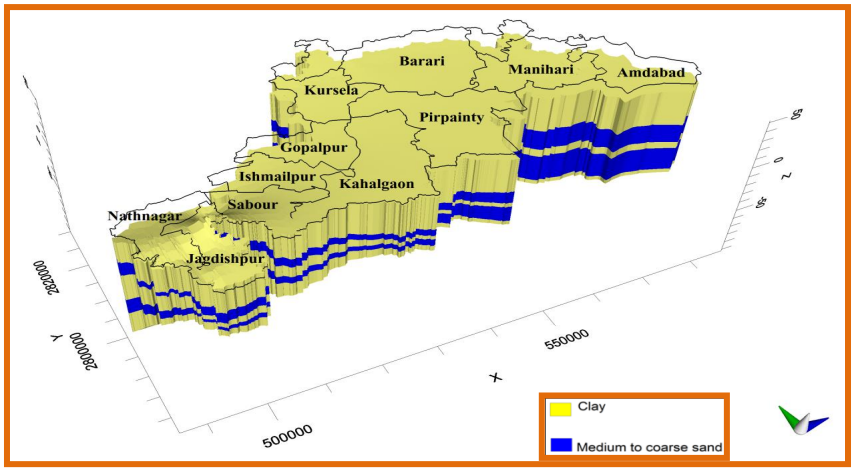


Fig.3.14(b) 3D view of aquifer disposition

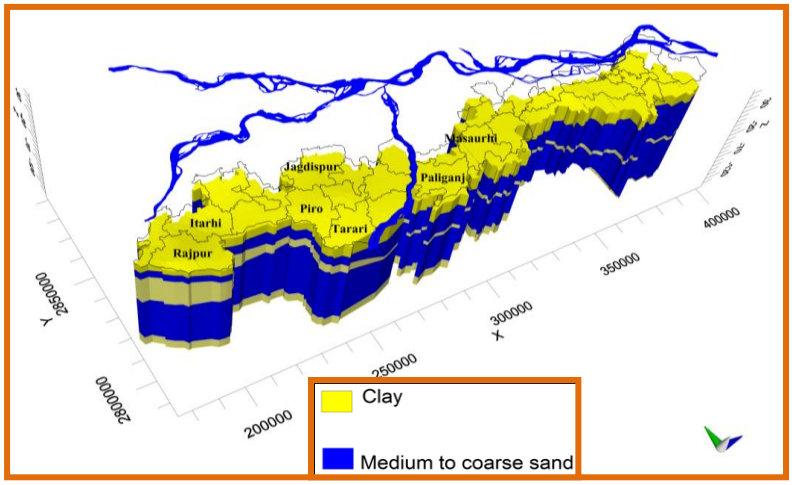


Fig. 3.14(c) 3D view of aquifer disposition

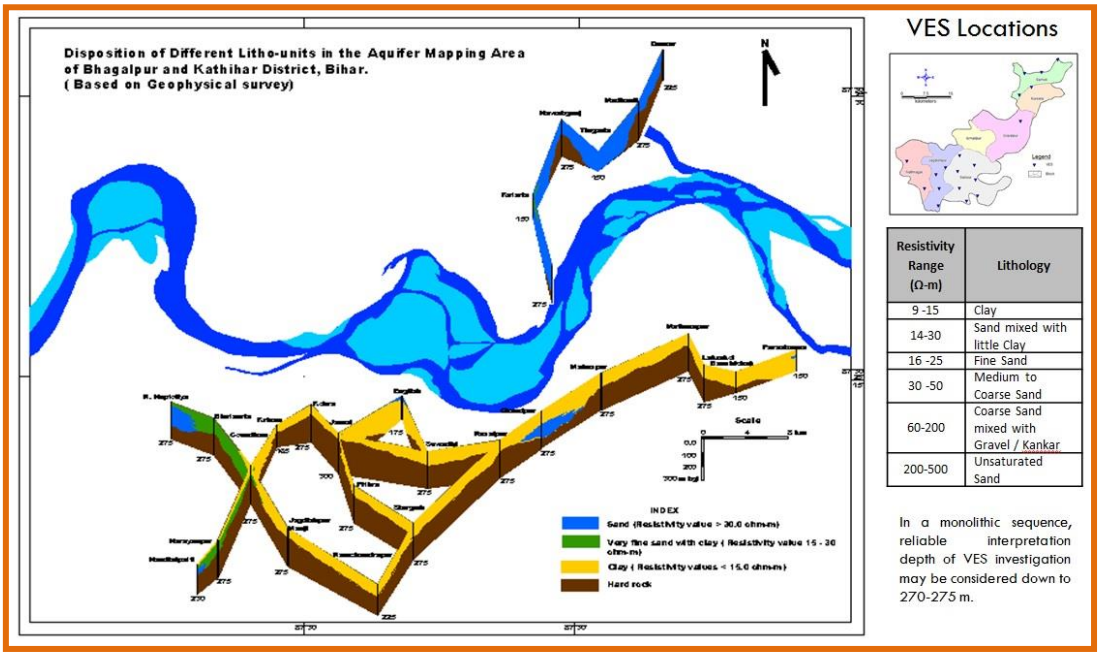


Fig. 3.15 Lithological section of Bhagalpur and Katihar based on Geophysical survey

3.1.3 Aquifer disposition and its hydraulic characteristics

Available data indicate the presence of two aquifer systems up to ~300 mbgl in general. However, in parts of Katihar district, mono-aquifer system upto the depth of 275 m has been encountered. A clay layer of ~ 15 m at the top has been found in Kursela area in Katihar district.

The aquifer system in the entire study area may be summarized into the followings.

Buxar: Three aquifer zones exist in the area. 1st aquifer occurs at the depth range of 07-62 m bgl at Itarhi, Nawanagar & Keshath whereas at Rajpur, it occurs at 92-116 m bgl. Average thickness is 42 m. 2nd aquifer is at the depth range of 60-190 at Itarhi, Nawanagar & Keshath, whereas 2nd aquifer occurs at depth range of 122-262 m at Rajpur. Average thickness of 2nd aquifer is 110 m. In parts of Buxar district, discharge of 1st aquifer varies from 30 to 50 cu.m/hr. The discharge of 2nd aquifer varies from 100 to 200 cu.m/hr withdraw down of 3 to 7 m. Transmissivity ranges from 1098 to 5187 m^2 /day.

Bhojpur: 1st aquifer occurs at the depth range of 30 -78 m bgl. Average thickness of 1st aquifer is 26 m. Maximum alluvium thickness (76 m) is found at Charpokhori. 2nd aquifer is at the depth range of 90-300 m bgl. Average thickness of 2nd aquifer is 110 m. In parts of Bhojpur district, discharge of 1st aquifer varies from 50 to 100 cu.m/hr. with draw down of 3-5 m. The discharge of 2nd aquifer varies from 100 to 200 cu.m/hr with drawdown of 4 to 10 m. Transmissivity ranges from 4769 to 5918 m^2 /day.

Patna: Top Aquitard Layer- The top aquitard layer is highly mixed and behaves like a low potential aquifer. The presence of silt in the top zones at places renders it semi-pervious in nature. This layer sustains the dug wells and shallow hand pumps in the area.

In parts of Patna area, 1st aquifer occurs at the depth range of 30-58 to 70-120 mbgl, whereas 2nd aquifer is at the depth range of 136-200 m bgl in Dulhin Bazar area. In parts of Belchi and Ghoswari area, 1st aquifer occurs at 20-70 m bgl, 2nd aquifer lays at 80-230 m bgl at Belchi area. Sometimes, 3rd aquifer system is found at the depth range of 240 to explored depth of 306 m bgl at Belchi and Ghoswari area. Pumping test data of Fatuha shows that discharge of tubewell is 188 cu.m/hr with drawdown of 5 m. Transmissivity is in the order of 10435 m^2 /day.

Bhagalpur: The geology of Bhagalpur is widely varying in nature and it has great impact on aquifer configuration of the area. Exploratory data reveals that single aquifer system (unconsolidated) is present upto 131 m depth in Kahalgaon area. Then, hard rock is encountered. Aquifer thickness increases towards the Ganga River. In Pirpainti block, trap-basalt is encountered at the depth range of 68-73 (Jagdishpur, Laxmipur). Gondwana is encountered at depth of 101 m at Hardeochak, Lakshmipur). Granite gneiss is encountered at the depth range of 60 (Maheshmund), 73 (Coglong), 95 (Madarganj) - 128 (Harchandpur), 137(Ghogha). Alluvium thickness is a few m. In the western part, alluvium is directly laying on granite gneiss, while in the eastern part alluvium is resting on Gondwana formation (Damuda Series). Cumulative discharge of tube well is in the order of 20-50 cu.m/hr with drawdown of 11-20 m. Transmissivity is in the order of 111-209 m^2/day and storativity is 7.5 x 10^{-4} - 1.1 x 10^{-3} . Transmissivity at Rampur in Kahalgaon block is 4207.64 m^2/day.

Katihar: Mono aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area. However, in Manihari block, aquifer is found in the depth of 20-60 mbgl and 2nd aquifer is encountered at the depth of 94 m bgl and it is continued further.

CHAPTER-IV
GROUND WATER RESOURCES

4.1 Dynamic Ground Water Resources

The dynamic ground water resources of the 39 blocks of Katihar, Bhojpur, Buxar, Patna and Bhagalpur districts, as per the assessment made as on March 2013, is presented as under.

The average Stage of Ground Water Development (SOD) in the area is 47.49 % and all the blocks have been categorised under safe category on the basis of the status of ground water utilisation except Sampatchak is falling under 'Semi-critical' category. The SOD in the phase IV and V area varies from 8 to 88%.

Considering the nature of the aquifers in the study area, recommendations for increasing groundwater development upto 70% stage of development can be made. A total of 41416 no. additional shallow tube wells may be constructed in different blocks with available ground water resources. The numbers of additional shallow tube wells that has been recommended in different blocks considering the above criteria are as under (Table 4.1)

Table 4.1 Number of Additional Shallow Tube Wells

FEASIBLE NO. OF ADDITIONAL SHALLOW TUBEWELLS MAY BE CREATED									
Administrative Units	Net Annual Ground Water Availability (ham)	Existing Gross Ground Water Draft for All Uses (ham)	Net GW Availability for Future Irrigation Development (ham)	Existing Stage of Ground Water Development (%)	Agricultural land (ha)	No. of already existing STW's	STW command area (ha)	No. of Shallow Tubewells feasible	Additional no. of STW feasible Based on available GW Resource (nos.) upto 70% SOD
Kahalgaon	9196.119	2117.738	7559.339	23.03	21260	997	2.4	8858	3322
Pirpainti	9629.685	2186.725	7752.245	22.71	26410	1190	2.4	11004	3503
Amdabad	4662.369	3048.126	1916.019	65.38	10380	1236	2.4	4325	113
Barari	10720.773	4719.711	6492.833	44.02	25740	1894	2.4	10725	1465
Manihari	7517.169	597.0669	7238.199	7.94	13630	78	2.4	5679	2455
Mansahi	2999.3115	2511.746	686.0115	83.74	6054	1056	2.4	2522	0
Charpokhri	3901.84	1755	2325.25	44.98	9871	931	2.4	4112	697
Garhani	4347.099	1574.495	2944.199	36.22	9280	845	2.4	3866	1048
Jagdishpur	11399.238	5780.879	6276.508	50.71	22690	3118	2.4	9454	1570
Piro	8582.004	5290.008	3920.954	61.64	18920	2670	2.4	7883	512
Tarari	7408.629	4167.163	3610.789	56.25	18440	2254	2.4	7683	727
Sahar	4992.098	1100.373	4047.308	22.04	11990	538	2.4	4995	1710
Agioan	6103.026	2071.505	4268.986	33.94	14050	1100	2.4	5854	1571
Sandesh	5213.898	2379.006	3050.838	45.63	12160	1307	2.4	5066	907
Nawanagar	10804.383	2395.112	8679.143	22.17	2623	1197	2.4	1092	3445
Dumraon	7577.514	2789.161	5149.344	36.81	13610	1319	2.4	5670	1676
Chaugain	2316.222	1627.889	811.452	70.28	2192	861	2.4	913	0
Rajpur	12343.752	6171.982	6665.462	50	24910	3170	2.4	10379	1645
Itarhi	10773.675	5720.806	5484.945	53.1	19560	2814	2.4	8150	1213

Kesath	**1694.727**	**782.242**	**981.377**	**46.16**	**14460**	**410**	**2.4**	**6025**	**269**
Chausha	**5144.573**	**2301.425**	**3049.733**	**44.74**	**9587**	**1193**	**2.4**	**3994**	**866**
Dulhin Bazar	**4815.747**	**875.3764**	**4098.977**	**18.18**	**9261**	**415**	**2.4**	**3858**	**1919**
Punpun	**4102.173**	**3623.05**	**780.903**	**88.32**	**11130**	**2118**	**2.4**	**4637**	**0**
Paliganj	**11195.19**	**1028.627**	**10497.75**	**9.19**	**21450**	**358**	**2.4**	**8937**	**5236**
Masaurhi	**5687.136**	**3984.036**	**2369.986**	**70.05**	**17260**	**1878**	**2.4**	**7191**	**0**
Dhanaura	**4936.041**	**3081.543**	**2199.011**	**62.43**	**16290**	**1655**	**2.4**	**6787**	**287**
Khusrupur	**1581.228**	**943.9394**	**850.288**	**59.7**	**6125**	**435**	**2.4**	**2552**	**125**
Daniyawaan	**1778.589**	**1359.849**	**553.739**	**76.46**	**5869**	**805**	**2.4**	**2445**	**0**
Fathua	**3448.755**	**2527.213**	**1236.335**	**73.28**	**11650**	**1398**	**2.4**	**4854**	**0**
Belchhi	**1837.512**	**1086.483**	**864.672**	**59.13**	**6610**	**633**	**2.4**	**2754**	**153**
Sampatchak	**2522.772**	**2126.341**	**597.672**	**84.29**	**6039**	**1078**	**2.4**	**2516**	**0**
Ghoswari	**2536.947**	**1110.914**	**1549.007**	**43.79**	**16030**	**642**	**2.4**	**6679**	**511**
								Total	**36945**

Table 4.2 Additional TW Feasible based on Available GW Resource upto 70% SOD

District	**Administrative Units**	**Net Annual Ground Water Availability**	**Existing Gross Ground Water Draft for All Uses**	**Net GW Availability for Future Irrigation Development**	**Existing Stage of Ground Water Development**	**Agricultural land**	**No. of already existing STW's**	**TW command area**	**STW Unit Draft**	**No. of Tubewells possible based on land area**	**Additional no. of TW feasible Based on available GW Resource upto 70% SOD**
		(ham)	(ham)	(ham)	(%)	(ha)	(nos.)	(ha)	(ham)	(nos.)	(nos.)
Bhagalpur	Gopalpur	3775.08	1476.67	2440.25	39	9871	880	3	1.3	3290	896
	Ismailpur	2245.96	336.29	1960.88	15	4548	178	3	1.3	1516	950
	Jagdishpur	3009.92	1765.51	2271.04	59	6948	280	3	1.3	2316	262
	Nathnagar	3603.45	1660.63	2136.85	46	9630	951	3	1.3	3210	662
	Sabour	3262.29	1319.62	2114.22	40	9775	739	3	1.3	3258	741
Katihar	Kursela	2030.69	1057.50	1083.36	52	3668	424	3	1.9	1222	191
	Samili	4124.02	1425.56	2845.38	35	5419	574	3	1.9	1806	769
Total											**4471**

TW Command area considered as 3 ha
(Source: District Groundwater Resource, 2013, CGWB)

4.2 Static resource and extraction from unconfined aquifer

In the present exercise, attempt has been made to estimate the avaialability of the total ground water resource in the aquifers. In order to estimate the total availability of groundwater resource, a generalized 3D disposition of the aquifer has been made using Visual Modflow Flex package. To prepare the 3D disposition of the aquifers, a number of lithological logs available for the study area have been considered along with the results of the geophysical investigations made in the area. The generalized 3D disposition of the aquifer

represents the principal aquifer groups. A number of minor layers/clay intercalations recorded in the individual lithological logs have been subsumed into the dominant lithological layers immediatedly overlying/underlying it.

The avaialablity of the total ground water resource in 1st aquifer, considering an average specific yield of 10 %, has been worked out as 41.7 BCM. Thus, it can be surmised that the area is blessed with significant groundwater reserves which can be harnessed during the lean seasons. The distribution of the total groundwater resource has been apportioned block wise considering the variation in the thickness of the 1st aquifer in different blocks. The block wise estimated total ground water resource in 1st aquifer is as under (Table 4.3).

Table 4.3 Block wise estimated total resource in Aquifer I (Sp. Yield 0.1%)

District	Administrative Units	Area(sq km)	Sp.Yield (%)	Av. Thickness of Aquifer I (m)	Total Available GW Resources Aquifer I (MCM)
Bhagalpur	Nathnagar	126	0.1	19	239.4
Bhagalpur	Jagdishpur	110	0.1	27	297
Bhagalpur	Sabour	115	0.1	31	356.5
Bhagalpur	Gopalpur	132	0.1	238	3141.6
Bhagalpur	Ismailpur	83	0.1	238	1975.4
Bhagalpur	Pirpainti	350.06	0.1	52	1820.312
Bhagalpur	Kahalgaon	335.84	0.1	34	1141.856
Katihar	Amdabad	188.63	0.1	210	3961.23
Katihar	Barari	327.8	0.1	250	8195
Katihar	Manihari	250.12	0.1	40	1000.48
Katihar	Sameli	129	0.1	106	1367.4
Katihar	Kursela	61	0.1	237	1445.7
Katihar	Mansahi	78.14	0.1	210	1640.94
Bhojpur	Charpokhri	109.31	0.1	76	830.756
Bhojpur	Garhani	112.01	0.1	24	268.824
Bhojpur	Jagdishpur	257.78	0.1	12	309.336
Bhojpur	Piro	218.39	0.1	12	262.068
Bhojpur	Tarari	200.98	0.1	25	502.45
Bhojpur	Sahar	127.29	0.1	22	280.038
Bhojpur	Agioan	155.99	0.1	22	343.178
Bhojpur	Sandesh	130.09	0.1	22	286.198
Buxar	Nawanagar	184.5	0.1	35	645.75
Buxar	Dumraon	197.99	0.1	92	1821.508
Buxar	Chaugain	54.65	0.1	92	502.78
Buxar	Rajpur	274.34	0.1	24	658.416

Buxar	Itarhi	228.93	0.1	24	549.432
Buxar	Kesath	30.79	0.1	6	18.474
Buxar	Chausha	108.04	0.1	24	259.296
Patna	Dulhin Bazar	110.68	0.1	70	774.76
Patna	Punpun	126.75	0.1	32	405.6
Patna	Paliganj	237.75	0.1	70	1664.25
Patna	Masaurhi	202.43	0.1	70	1417.01
Patna	Dhanaura	185.55	0.1	70	1298.85
Patna	Khusrupur	61.39	0.1	32	196.448
Patna	Daniyawaan	65.1	0.1	32	208.32
Patna	Fathua	126.36	0.1	32	404.352
Patna	Belchhi	68.67	0.1	48	329.616
Patna	Sampatchak	65.35	0.1	32	209.12
Patna	Ghoswari	139.83	0.1	50	699.15
				Total	**41728.798**

CHAPTER-V
GROUND WATER RELATED ISSUES

5.1 Identification of Issues

In north bank of River Ganga, the area is mostly Char / Diara land, laying within active flood plain of the River Ganga. Groundwater resource is not scarce here rather occurs aplenty. In true sense, affluence is the main culprit.

On the other hand, in south bank of River Ganga, particularly in parts of Bhagalpur district, the area is buried pediplane sloping towards north. The area is covered by older alluvium, underlain by granitic rocks. As one moves towards Munger Hills, thickness of alluvium gradually decreases.

The most important groundwater issue in the study area is the arsenic contamination of groundwater affecting the upper part of the 1st aquifer. Detailed investigations carried out by CGWB have established that the 2nd aquifer, occurring below the 1st aquifer and separated from it by an aquitard layer, is free from arsenic contamination. Important management challenge is also there in the protection of the deeper 2nd aquifer from any possible threats of cross-contamination from 1st aquifer.

About 18 sq km area in the study area is represented by inland water bodies. These water bodies are mainly meander scars. During rainy season majority of them gets connected with main rivers. Due to their low water holding capacity, adjoining areas gets seasonally water logged during June to October.

In hard rock areas, fluoride contamination has been reported in fractured aquifers of 03 blocks in parts of Bhagalpur district.

5.2 Major Ground Water Issues

1) Arsenic above permissible limit in shallow aquifer in all blocks under NAQUIM falling in Katihar and Bhagalpur districts.
2) Single aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in parts of Katihar district. The thickness of clay layer is thickening in eastern part. Arsenic contamination is restricted to shallow depth only.
3) Absence of potential aquifer below 100 m in Kahalgaon and in major parts of Pirpainti block of Bhagalpur district.
4) Low ground water development in following study areas -
    - ❖ Blocks under Bhojpur and Buxar districts
    - ❖ Dulhin Bazaar and Paliganj in Patna district
    - ❖ Kahalgaon and Pirpainti in Bhagalpur district
    - ❖ Blocks in Katihar district
5) High and continuously increasing development of ground water is in Punpun, Fatuha and Sampatchak blocks of Patna district due to rapid urbanization in these areas. As per Ground Water Resources Estimation, 2013 Sampatchak is categorised as 'Semi-critical'.

CHAPTER-VI
MANAGEMENT STRATEGIES

6.1 Management Plan for the entire study area

6.1.1 Critical Concerns and Key Challenges

- ❖ Identification of contaminated as well as safe water sources & providing alternate safe drinking water source.
- ❖ Operation and maintenance of constructed treatment plant.

6.1.2 Steps and Intervention taken up

- ✓ Infected hand-pumps have to be identified and put into hold for further usages.
- ✓ Traditional water sources like dug wells should be converted into sanitary wells.
- ✓ Rain water harvesting should be adopted in quality problems areas. Dilution of arsenic contaminated ground water may yield better water.
- ✓ Surface water based scheme should be planned in no source quality problem areas.
- ✓ Safe aquifers explored should be used for piped water supply.

6.1.3 Mitigation Measures in Arsenic/Fluoride areas

The mitigation options are taken up on the basis of availability of water resources and hydrogeological conditions of the area which are as followings:-

6.1.3(a) Long-term Mitigation

Surface water Source:

- ✓ Multi village piped water supply scheme by using conventional treatment plant for arsenic & fluoride affected area in no source area.

Ground water Source:

- ✓ Piped water supply scheme from safe and sustainable ground water source.
- ✓ Solar based mini piped water supply scheme with treatment unit.

6.1.3(b) Short-term Mitigation

- Hand pump attachment treatment unit.
- Sanitary dug well with IM3 hand pump and with solar based pump.
- Adoption of Rainwater Harvesting technique.

6.1.4 Arsenic Contamination in parts of Bhagalpur and Katihar District

Bhagalpur district - Supply of arsenic free ground water from deeper aquifer which is still to be explored in details. Filtered surface water supply is only possible mitigation measures.

Katihar district – A single aquifer system prevails with thin layer of clay (~ 15 m) at top. It is obvious that due to more dewatering of the aquifer, depth of arsenic contamination will increase vertically. Filtered surface water supply and/or community based tube wells fitted with arsenic removal plants may be the reasonable mitigation measures.

6.1.5 Low ground water development

It has been observed that ground water development is low in blocks of Bhojpur, Buxar, Bhagalpur and Katihar districts in the study area. Dulhin bazar and Paliganj blocks of Patna district shows low ground water development. Additional 41416 no. feasible shallow tube wells have been worked out to be constructed based on available ground water resources (March 2013) considering upto70% Stage of Development.

6.1.6 High and continuously increasing development of ground water

High and continuously increasing development of ground water in Punpun, Fatuha and Sampatchak blocks of Patna district should be checked immediately. Extraction from 1st aquifer should be regulated. Extraction from 1st aquifer should be stopped for supply of drinking water. Water for drinking water purpose should be extracted from deeper aquifer only; in no source area where deeper aquifer is not available, surface water/arsenic filter should be used for domestic purpose. In urban area, roof top rain water harvesting should be amended.

6.1.7 Management Strategy for Seasonally Water-logged Areas

Tal lands are saucer shaped backwaters, occurring in south of the River Ganga upto Pirpainty in the east. These are from 1.5 to more than 4 kms in the breadth in Bhagalpur. These Tal lands are separated from the river Ganga in the north by a natural levee of varying breadth. Average depth of standing water column in inundated area is 0.5 – 1 m. 18 sq. km area is represented by inland water bodies; an additional area of 59 sq. km in adjoining locality gets seasonally water logged during June to October.

Tal lands remain inundated from July to the first week of October. Due to submergence in rainy season, kharif crops are not sown in Tal areas. Rabi cultivation is based on the residual moisture from submergence. Sowing of Rabi crops is delayed due to delay in drainage of submerged water which leads to loss of moisture during their maturity. Accelerated vertical recharge shaft filled with granular materials can be a viable solution in Tal areas. One recharge shaft of 7 m depth, filled with granular materials, can reclaim 1 ha land in 16 days.

6.1.8 Management Strategy for Arsenic Contaminated Areas

It is understood that in major parts of the study area, two aquifer systems exist. Sporadic arsenic contamination in upper part of the 1st aquifer (~70 m) is also prevalent in 11 blocks of Bhagalpur and Katihar districts. Obviously, deeper 2nd aquifer should be considered only for drinking water supply. It is also necessary to regulate pumping discharge of the 2nd aquifer to eliminate the chances of cross-contamination from the 1st aquifer. Study indicates that a discharge of 50 m^3/hr is the optimal discharge for this purpose. Well interference has also to be completely eliminated. For optimal discharge, a minimum spacing of 2 km is to be given. Deep tube wells should be constructed using proper cement sealing technique.

In areas particularly in parts of Katihar district, where single aquifer system exists, restriction on depth of construction of tube well is the only viable solution at present. The restriction may be continued till the deeper (> 300m) parts of the aquifer are explored and

alternative arsenic free groundwater source is found out. Conjunctive use may be encouraged in the area towards irrigational practices.

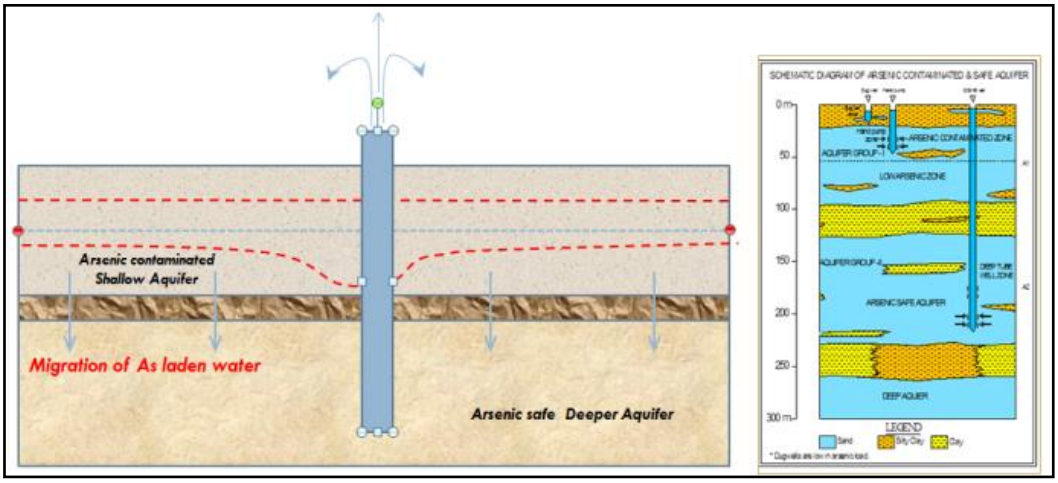


Fig. 6.1 Defensive mechanism of deeper aquifer

6.2 Proposed Design of Arsenic Free Wells

Development of the deeper aquifers should be made through properly designed wells which must be sealed from the overlying contaminated aquifers through cement sealing. The cement sealing is applied to a suitably thick intervening clay layer separating the arsenic contaminated aquifer from arsenic free aquifer. This cement seal prevents seepage of contaminated water through the annular space which is filled with gravels. A schematic design is presented as under (Fig. 6.2).

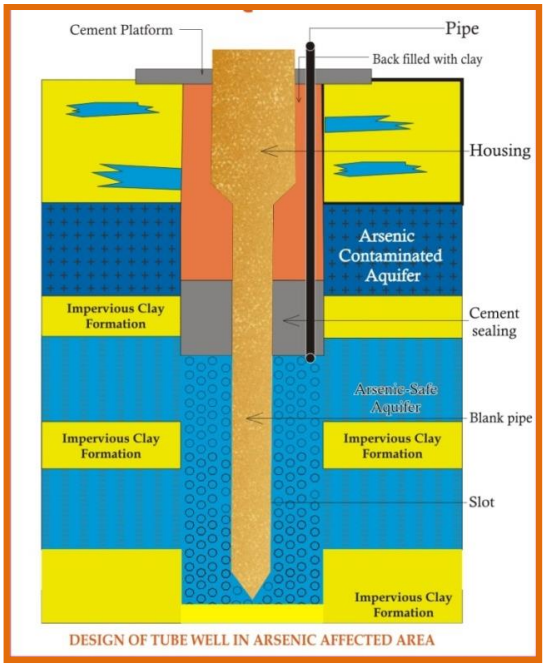


Fig. 6.2 Schematic design of tube well with cement seal for arsenic affected area

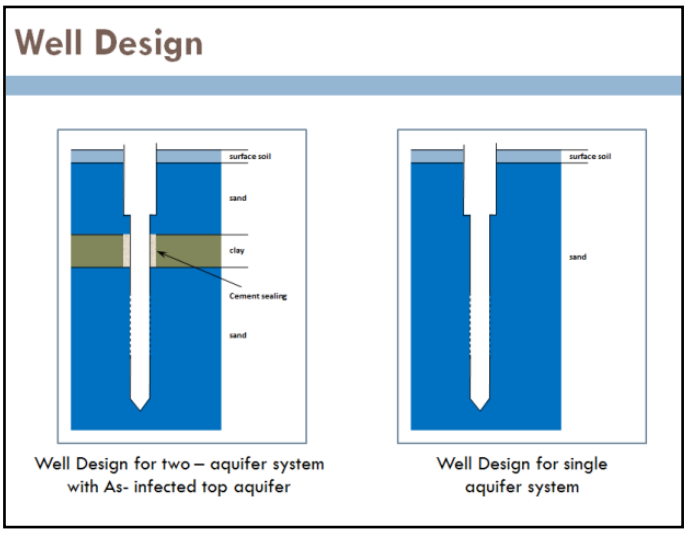


Fig. 6.3 Well-design using Cement-sealing Technique

6.2.1 Suggested Plan

- The 2nd aquifer should be considered only for drinking water supply.
- Maximum recommended discharge from 2nd Aquifer is 50 m^3/hr.
- Minimum spacing between wells should be 2 km.

6.3 Implementation plan and recommendation

The most important groundwater issue in the study area is the arsenic contamination of groundwater reported from the 11 out of the 13 blocks (source PHED, Govt. of Bihar) affecting the upper part of the 1st aquifer. Detialed investigations carried out by CGWB have established that the 2nd aquifer occurring below the 1st aquifer and separated from it by an aquitard layer is free from arsenic contamination. However, the most important management challenge in the area lies in protecting the deeper aquifers from the threats of cross-contamination. At the present level of our understanding of the arsenic contamination, prediction of the future arsenic concentrations is not possible. Studies have also cautioned over the development of the deeper aquifers. From the analysis, it has been observed that in order to minimize the effects of well interference, water supply schemes in the affected blocks should be designed for a maximum discharge of 50 m^3/hr only and the radial distance between two pumping schemes should be kept at a minimum of 2 km.

6.4 Requirement of deep tubewell schemes for piped water supply

Groundwater in the dug well zone has been found to contain low arsenic load and considering the 10 ppb as the limit, these have been found as safe in the study area. However, owing to the prevalence of the handpumps and the ease of drawing water from it, dugwells are sparingly being used. The other concern with the dug wells is the faecal contamination resulting in high bacteriological load. However, if the existing dug wells are revived and care is taken to protect them from sewage contamination, the dugwells can be an alternative source of water supply. The UNICEF model of converting the dugwells into sanitary wells is also recommended.

A detailed study involving experts from agriculture, soil science, agronomy, chemistry and hydrogeology is required to assess the impact of the use of the arsenic contaminated groundwater for irrigation.

Industrial demand for groundwater is on the rise as a number of water intensive industries are steadily coming up in the area. It is recommended that extraction for industrial uses should be allowed only from 1st aquifer and in no case from the 2nd aquifer.

For the 1st aquifer which is arsenic contaminated in its uppermost part, it is recommended to implement the use of solar photovoltaic groundwater pumping system with grounded tank for water storage developed for eastern India by the ICAR Research Complex for Eastern Region, Patna (Rahman and Bhatt, 2015). This technique has several advantages and the occurrence of shallow water level condition in the study area makes it more relevant. This model may also be tested for the reduction in the arsenic load upon surface storage before being fed for irrigation.

6.5 Management Strategy for Fluoride Contaminated Areas

Contamination is restricted in bore wells / hand pumps tapping fracture zones in hard rock area mainly. Dug wells tapping weathered zones in the vicinity of fracture zones also contain fluoride. Nalgonda Technique may be used in this regard for household-level filtering. Detailed exploration in fluoride affected areas will redefine fluoride free aquifers for further uses.

Annexure- I

Water level monitoring stations

S N	District	Block	Location	Longitude	Latitude	M.P	Dia	Depth (mbgl)	W.L (mbgl) May 2017	W.L (mbgl) Nov 2017
1	Katihar	Amdabad	Near goplapur chowk	87.78	25.31	0.70	1.50	8.10	6.58	2.96
2	Katihar	Amdabad	Balrampur	87.75	25.33	0.95	1.95	6.88	5.02	2.45
3	Katihar	Amdabad	Balua	87.78	25.31	1.37	0.97	8.16	4.34	1.56
4	Katihar	Amdabad	Navsariya	87.77	25.31	1.27	0.97	5.30	3.22	1.10
5	Katihar	Amdabad	Police station	87.79	25.30	0.80	0.97	7.70	5.47	3.90
6	Katihar	Amdabad	lalbathani	87.74	25.33	1.30	2.20	9.09	5.65	2.72
7	Katihar	Amdabad	nirpur	87.78	25.32	0.73	0.85	5.97	4.02	2.97
8	Katihar	Barari	Semapur	87.47	25.53	0.75	2.05	8.00	5.12	2.95
9	Katihar	Barari	Bantola terasi	87.44	25.51	0.87	1.87	6.03	5.68	3.63
10	Katihar	Barari	Nisara sibana	87.40	25.50	0.47	2.00	4.33	2.11	1.93
11	Katihar	Barari	Bari Bhejdhara colony	87.39	25.68	1.25	2.25	8.20	6.10	2.20
12	Katihar	Barari	Yadav toli	87.38	25.50	0.50	1.30	7.50	6.12	3.15
13	Katihar	Kursela	Kursela Block office	87.25	25.46	0.56	1.34	8.20	6.77	3.50
14	Katihar	Kursela	Kursela state compound	87.22	25.42	0.70	1.95	9.70	6.50	3.11
15	Katihar	Manihari	Haswar morh	87.64	25.36	1.28	0.97	6.12	4.77	2.82
16	Katihar	Manihari	Kumaripur	87.62	25.44	0.75	1.20	7.25	6.85	3.13
17	Katihar	Manihari	Nawabganj	87.63	25.37	0.50	2.50	7.50	6.07	2.51
18	Katihar	Manihari	Police station	87.44	25.48	1.34	1.60	9.14	6.15	3.90
19	Katihar	Manihari	Munjwar tal	87.63	25.34	0.60	2.30	8.60	6.37	3.55
20	Katihar	Mansahi	Marangi Ghasitola	87.57	25.51	0.70	1.10	5.80	4.91	1.86
21	Katihar	Mansahi	Aminnagar	87.57	25.47	1.00	2.20	7.00	5.70	2.20
22	Katihar	Mansahi	Marangi Chasitola	87.24	25.50	1.00	2.00	7.50	6.64	2.65
23	Katihar	Mansahi	Prathamik Vidyalaya naya tola	87.61	25.48	1.45	1.74	4.64	4.02	2.19
24	Katihar	Mansahi	basantpur imlitola	87.60	25.47	0.87	1.68	4.53	3,91	1.38
25	Katihar	Mansahi	basantpur	87.60	25.47	0.53	1.30	6.17	5.02	2.77
26	Katihar	Mansahi	Santola Phulhara	87.62	25.46	0.76	1.80	6.61	5.52	2.84
27	Katihar	Sameli	Sameli	87.70	25.35	1.60	2.00	6.40	5.60	2.85
28	Bhagalpur	Sabour	Sabour	87.05	25.23	0.85	2.10	4.00	3.56	1.78
29	Bhagalpur	Sabour	Mamalka	87.11	25.22	1.20	1.50	7.20	6.45	1.42
30	Bhagalpur	Kahalgaon	Ghoga	87.17	25.22	0.70	1.40	11.90	4.85	1.18
31	Bhagalpur	Kahalgaon	Saidpura	87.24	25.26	1.65	1.20	18.60	18.05	14.15
32	Bhagalpur	Kahalgaon	Dhanaura	87.26	25.19	1.15	1.80	10.20	9.80	5.89

33	Bhagalpur	Kahalgaon	Sonathpur	87.27	25.23	1.20	1.50	5.50	5.30	6.22
34	Bhagalpur	Pirpainti	Pirpainti	87.42	25.29	0.65	2.25	9.70	6.60	4.80
35	Bhagalpur	Pirpainti	Judavanpur	87.39	25.24	0.75	1.40	12.30	10.70	3.64
36	Bhagalpur	Pirpainti	Dubauli	87.48	25.27	1.00	1.80	10.30	7.84	3.88
37	Bhagalpur	Pirpainti	Parsurampur	87.47	25.35	1.10	2.10	6.70	5.20	2.45
38	Bhagalpur	Nathnagar	Champanagar	86.92	25.24	1.25	1.60	7.20	6.80	1.65
39	Bhagalpur	Jagdishpur	Jagdishpur	86.99	25.12	0.80	1.50	6.35	4.38	1.48
40	Bhagalpur	Jagdishpur	Sonauli	87.00	25.17	0.55	1.10	8.90	7.29	2.32
41	Bhagalpur	Gopalpur	Gopalpur	87.17	25.33	0.60	1.30	9.00	6.92	2.12
42	Bhagalpur	Gopalpur	Tia Danga Karai	87.20	25.30	1.10	1.80	7.65	7.05	1.95
43	Bhagalpur	Ismailpur	West Bihta Ismailpur	87.13	25.33	1.15	1.60	8.50	7.30	2.60
44	Bhagalpur	Nathnagar	Mohdipur	86.89	25.25	1.60	2.20	10.50	8.10	2.23
45	Patna	Dulhin Bazar	Bharatpura	84.86	25.34	0.50	1.50	5.75	3.20	1.48
46	Patna	Dulhin Bazar	Dulhin Bazar	84.86	25.38	0.91	0.90	5.90	4.65	4.43
47	Patna	Punpun	Deokoli	85.09	25.45	0.48	1.05	9.40	8.76	6.00
48	Patna	Paliganj	Imamganj(Muhammadpur)	84.56	25.35	0.28	0.70	7.18	3.94	2.34
49	Patna	Paliganj	Baliapakar	84.83	25.33	0.42	2.80	8.00	3.15	1.74
50	Patna	Masaurhi	Sharvan	85.05	25.38	0.53	2.00	7.28	5.51	5.45
51	Patna	Dhanrua	Nima	85.12	25.46	0.80	1.10	7.01	5.86	4.16
52	Patna	Khusrupur	Mustafapur	85.37	25.48	0.30	1.87	9.12	8.27	5.06
53	Patna	Daniyawan	Daniyawan	85.31	25.43	0.90	1.83	10.40	6.32	3.26
54	Patna	Fatuha	Fatuha	85.30	25.50	0.95	1.00	7.55	8.93	5.03
55	Patna	Fatua	Maksudpur	85.32	25.50	0.45	2.10	10.89	8.65	5.68
56	Patna	Belchi	Belchi	85.65	25.36	0.59	1.54	7.89	6.03	2.28
57	Patna	Sampatchak	Sampatchak	85.18	25.53	0.20	1.50	7.80	6.31	4.08
58	Patna	Ghoswari	Jhanki	85.84	25.31	0.76	1.76	7.21	5.15	3.01
59	Patna	Ghoswari	Gosai	85.90	25.37	0.59	1.14	8.50	6.51	3.86
60	Buxar	Chausa	Chausa	83.89	25.51	0.90	1.25	6.45	2.45	1.66
61	Buxar	Chausa	Nikrish	83.82	25.40				9.35	
62	Buxar	Itarhi	Purusottampur	84.02	25.41				10.00	
63	Buxar	Itarhi	Basudhar	84.05	25.46				6.34	
64	Buxar	Itarhi	Jalwasi	84.02	25.50				7.80	
65	Buxar	Itarhi	Kukdha	83.97	25.45				8.72	
66	Buxar	Rajpur	Rajpur	83.90	25.39	0.88	1.45	9.01	3.30	1.45
67	Buxar	Rajpur	Jalhara	83.90	25.33				7.58	
68	Buxar	Rajpur	Bahrutiya (Kedarganj)	84.04	25.29				9.00	
69	Buxar	Navanagar	Jitwadih (Jitwadehri)	84.20	25.39				8.87	
70	Buxar	Navanagar	Parmeshwar Tola	84.12	25.40				5.40	

71	Buxar	Kesath	Katkinar	84.12	25.40				6.20	
72	Buxar	Chausa	Chaugai	84.24	25.47				2.39	
73	Bhojpur	Sahar	Guljarpur	84.60	25.26	0.30	1.2	6.89	6.12	3.63
74	Bhojpur	Barhara	Baruna	84.60	25.32	0.67	1.8	5.3	4.39	8.12
75	Bhojpur	Sandesh	Kori	84.69	25.39	0.28	1.6	5.67	4.52	4.58
76	Bhojpur	Sandesh	Sandesh	84.74	25.41	0.56	1.34	5.78	4.84	3.12
77	Bhojpur	Agioan	Pauna	84.63	25.41	0.40	1.7	6.98	6.14	2.58
78	Bhojpur	Garhani	Garhani	84.56	25.42	0.50	1.00	6.50	5.50	3.22
79	Bhojpur	Sandesh	Nasratpur	84.75	25.45	0.73	1.9	8.45	7.73	6.77
80	Bhojpur	Jagdishpur	Jagadishpur1	84.41	25.48	0.44	1.10	6.10	6.10	2.66
81	Bhojpur	Jagdishpur	Bihiya	84.46	25.55	0.30	2.10	6.00	4.42	4.15
82	Bhojpur	Jagdishpur	Deotola	84.35	25.50	0.85	1.2	8.2	6.89	5.32
83	Bhojpur	Pirro	Keshwan	84.41	25.41	0.65	1.66	5.7	5.00	3.07
84	Bhojpur	Pirro	Basawan tola	84.39	25.39	0.8	1.2	5.2	3.78	2.14
85	Bhojpur	Tarari	Bhulkuwan	84.42	25.30	0.5	2.1	5.4	4.18	2.22
86	Bhojpur	Tarari	Sikarhata Khurd	84.42	25.27	0.8	1.2	6.4	4.23	2.24
87	Bhojpur	Tarari	Tarai	84.49	25.30	0.3	2.1	7.5	6.08	3.60
88	Bhojpur	Sahar	Dhawari	84.58	25.24	0.8	1	6.2	4.78	3.05
89	Bhojpur	Barhara	Barhara	84.51	25.39	0.3	1	6.2	4.70	2.52
90	Bhojpur	Charpokhari	Demhan	84.58	25.43	0.5	1.5	6.5	4.50	2.68

Annexure-II

Chemical analysis of groundwater sample of the study area (2016-17)

District	Block	Village	pH	EC (µs) /cm at 25°C	CO3-	HCO3-	Cl^-	F	SO_4^{2-}	NO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	PO4	SiO2
Bhagalpur	Nathnagar	Murharpur	7.85	789	nd	384	28	0.40	8	29.8	340	52	50	16	3.6	nd	6.4
Bhagalpur	Nathnagar	Mirza Pur	7.88	925	nd	519	21	0.11	11	35.5	440	102	44	24	3.7	nd	4.1
Bhagalpur	Nathnagar	Nath Nagar	7.66	2010	nd	299	301	0.16	50	38.5	415	94	43	128	63.8	nd	6.7
Bhagalpur	Nathnagar	Lalmatiya Chowk	7.62	1372	nd	342	181	0.15	15	0.5	300	90	18	109	21.3	nd	6.9
Bhagalpur	Nathnagar	Tatarpur	7.43	2440	nd	281	330	0.10	66	38.0	565	142	50	95	16.0	nd	3.8
Bhagalpur	Sabour	Rani Tola	7.74	1366	nd	543	163	0.00	23	39.6	120	40	5	270	22.4	nd	2.9
Bhagalpur	Sabour	Navtolia	7.8	738	nd	348	14	0.12	27	38.1	295	76	25	38	5.1	nd	6.2
Bhagalpur	Sabour	Farka	7.65	890	nd	281	64	nd	20	nd	315	84	25	25	1.0	0	4.5
Bhagalpur	Sabour	English Farka	7.87	536	nd	287	18	nd	9	nd	235	54	24	19	0.4	0.08	4.9
Bhagalpur	Sabour	Masaruh	7.79	738	nd	336	39	nd	16	15.5	275	54	34	33	6.8	nd	1.9
Bhagalpur	Sabour	Mamalkha	7.94	545	nd	293	7	nd	5	nd	185	64	6	28	4.6	0.04	7.8
Bhagalpur	Sabour	Shankarpur	7.8	541	nd	293	11	0.24	4	nd	205	60	13	19	4.3	nd	7.4
Bhagalpur	Kahalgaon	Panchak	7.7	662	nd	220	64	0.35	4	18.1	260	80	14	15	1.0	nd	4.7
Bhagalpur	Kahalgaon	Tolpora	7.57	1492	nd	165	284	0.24	19	35.0	400	64	32	79	10.3	nd	8.0
Bhagalpur	Kahalgaon	Shahpur	7.5	974	nd	214	110	nd	19	38.3	335	56	47	26	9.9	nd	5.5
Bhagalpur	Kahalgaon	Ammapur	7.87	597	nd	281	25	0.08	11	nd	210	70	8	27	3.9	nd	4.4
Bhagalpur	Kahalgaon	Pakkatalla	7.74	553	nd	281	11	0.27	11	12.9	185	70	2	31	8.4	2.13	4.6
Bhagalpur	Kahalgaon	Kahalgaon	7.73	701	nd	305	43	0.08	15	14.3	260	88	10	33	6.8	nd	5.7
Bhagalpur	Kahalgaon	Nandlalpr	7.76	929	nd	214	135	0.40	10	39.5	390	54	61	6	7.6	nd	6.2
Bhagalpur	Pirpainti	Badluganj	8.06	461	nd	195	18	0.00	8	29.6	195	60	11	9	0.9	nd	3.8
Bhagalpur	Pirpainti	Barahat	7.98	800	nd	317	71	0.31	17	38.4	335	112	13	33	1.5	nd	8.3
Bhagalpur	Pirpainti	Mirza Gaon	8.03	581	nd	183	71	0.15	19	37.8	235	60	20	20	3.8	nd	8.3
Bhagalpur	Pirpainti	Pyalapur	8.01	649	nd	244	60	0.61	12	13.2	265	72	20	28	5.0	nd	7.3
Bhagalpur	Pirpainti	Faizpur Bash	8.10	542	nd	238	32	0.38	17	17.7	215	64	13	18	6.9	nd	6.8
Bhagalpur	Pirpainti	Mirza Chowki	7.83	660	nd	110	152	0.47	19	0.0	235	56	23	40	0.9	nd	4.1
Bhagalpur	Pirpainti	Pakkariya	7.70	929	nd	488	21	0.35	8	40.2	355	72	42	53	8.1	nd	2.7
Bhagalpur	Pirpainti	Parasbanna	0.72	678	nd	342	7	nd	8	0.2	185	42	19	54	3.7	nd	15.3
Bhagalpur	Pirpainti	Pirpantti	7.91	634	nd	342	28	0.83	7	0.9	250	44	34	32	5.8	nd	3.9

Bhagalpur	Pirpainti	Pirpainti Bazar	7.84	697	nd	305	25	nd	13	33.1	275	76	20	22	3.1	nd	15.6
Bhagalpur	Pirpainti	Sadhu Mathiya	7.90	618	nd	262	18	0.06	23	nd	220	74	8	20	2.2	nd	3.4
Bhagalpur	Pirpainti	Lakshmipur	7.96	706	nd	226	82	0.78	32	15.8	185	46	17	70	8.0	nd	6.3
Bhagalpur	Jagdishpur	Dawood Uwad	7.74	962	nd	348	78	nd	10	40.1	285	62	31	67	4.3	nd	4.5
Bhagalpur	Jagdishpur	Tamoni Modh	8.14	973	nd	470	21	1.52	17	1.3	355	32	66	43	4.9	nd	1.6
Bhagalpur	Jagdishpur	Phulwariya	7.63	3580	nd	1098	418	0.33	73	42.4	435	82	55	518	64.9	nd	2.9
Bhagalpur	Jagdishpur	Nayachak Makhna	8.39	1447	9	689	74	1.12	16	nd	415	34	79	136	0.3	nd	0.0

(2017-18)

District	Block	Village	pH	EC (microsiemens/cm)	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH (as CaCO3	Ca2+(as $CaCO^3$)	Mg2+(as $CaCO^3$)	Na+	K+
Bhagalpur	Kahalgaon	Dhanaura	7.3	784	509.6	0.21	35.45	424.35	0	15.05	8.12	0	290	14	61.96	65.47	1.63
Bhagalpur	Kahalgaon	Sonsthpur	7.1	1405	913.25	0.74	170.16	350.55	0	55.59	67	0	480	80	68.04	88.3	3.27
Bhagalpur	Pirpainti	Judavanpur	7.03	1065	692.25	0.23	145.34	332.1	0	66.93	52.6	0	425	72	59.53	41.55	0.87
Bhagalpur	Pirpainti	Dubauli	7.17	942	612.3	0.38	53.17	393.6	0	87.6	38.1	0	377	46	63.74	56.7	1.44
Bhagalpur	Pirpainti	Parsurampur	7.27	698	453.7	0.11	17.72	356.7	0	24.17	1.29	0	354	44	59.25	13.25	2.75
Bhagalpur	Nathnagar	Champanagar	7.21	1022	664.3	0.18	63.81	375.15	0	68.28	87	0	402	42	72.15	63.9	4.78
Bhagalpur	Jagdispur	Sonauli	7.84	902	586.3	1.62	28.36	436.65	0	7.84	1.24	0	315	34	55.89	74.13	0.77
Bhagalpur	Gopalpur	Gopalpur	7.45	594	386.1	0.13	7.09	369	0	13.74	2.06	0	180	38	20.655	45.85	4.29
Bhagalpur	Gopalpur	Tia dangakarai	7.68	543	352.95	0.16	18.25	313.65	0	13.28	3.67	0	195	38	24.3	38.79	3.46
Bhagalpur	Ismailpur	Wast bihta Ismailpur	7.31	567	368.55	0.11	28.36	282.9	0	29.82	6.71	0	260	44	36.45	12.15	5.34
patna	Punpun	deokali	7.32	490	319	0.24	35.45	215.25	0	13	3.05	0	140	24	19.44	53	2.38
Patna	Dulhinbazar	dulhinbazar	7.13	695	451.75	0.46	202.06	190.65	0	48	44	0	250	66	20.65	42	1.5
Patna	Masurhi	Sharvan	7.49	896	582.4	0.03	39.0	365	0	51.3	13.3	0	380	64	52.8	40.12	6.9
Patna	Khusrupur	Mustafapur	7.26	731	475.15	0	28.4	358	0	20.9	19.6	0	345	68	42	49.01	0.87
Patna	Fatua	Maksudpur	7.17	616	400.4	0	35.5	295	0	26.9	20.3	0	290	40	45.6	50.72	2.5
Patna	Belchi	Belchi	7.31	506	328.9	0.06	17.7	305	0	12.6	7.9	0	245	64	20.4	23.3	4.7
Patna	Sampatchak	Sampatchak	7.34	482	313.3	0	42.6	325	0	33.6	6.9	0.03	125	14	21.6	28.73	3.5
Patna	Ghoswari	Jhanki	7.57	496	322.4	0	10.6	211	0	15.2	15.9	0	205	32	30	23.97	5.7

Patna	Ghoswari	Gosai	7.22	552	358.8	0.09	39.0	226	0	21.22	23.6	0	275	76	20.4	32.58	0.89
Bhojpur	Jagdishpur	Bihiyan	8.04	717	466.05	0.14	32.2	369	0	47.15	0	0	270	48	36.45	25.73	50.22
Bhojpur	Sandes	Nasratpur	8.02	677	440.05	0.37	36.4	289.05	0	45.43	41.6	0	290	60	34.02	36.95	1.58
Bhojpur	Sandes	Sandesh	7.86	1663	1080.95	0.2	255	319.8	0	171.52	151	0	665	112	93.55	105.46	14.65
Bhojpur	Sandes	Koeri	8.08	555	360.75	0.46	19.4	307.5	0	12.91	12	0	220	52	21.87	32.34	1.44
Bhojpur	Agiaon	Pauna	8.12	1076	699.4	0.6	94.1	516.6	0	24.72	0	0	340	50	58.32	105.46	1.07
Bhojpur	Sahar	Baruna	7.99	623	404.95	0.38	63.5	153.75	0	61.33	52.3	0	165	56	6.075	69.13	1.68
Bhojpur	Sahar	Guljarpur	8.15	572	371.8	0.52	12.7	313.65	0	11.58	0	0	300	68	31.59	7.51	1.25
Bhojpur	Sahar	Dhawri	8.14	615	399.75	0.72	39.6	319.8	0	13.23	6.3	0	260	52	31.59	28.53	0.85
Bhojpur	Jagdishpur	Deotola	7.79	652	424	0.22	28.36	307.5	ND	19.65	12.8	BDL	140	24	19.44	71.94	0.12
Bhojpur	Jagdishpur	Babhinav	7.77	498	324	0.14	14.18	295.2	ND	12.7	1.33	BDL	215	38	29.16	16.7	0.67
Bhojpur	Jagdishpur	Jagdishpur	7.77	560	364	0.2	21.27	319.8	ND	12.14	4.18	BDL	240	38	35.23	23.17	1.35
Bhojpur	Piro	Koshwar	7.73	435	283	0.46	21.27	227.55	ND	18.5	7.1	BDL	170	38	18.22	28.7	0.32
Bhojpur	Piro	Dhobighatwa More	7.76	398	259	0.44	3.54	239.85	ND	15.4	1.89	BDL	180	32	24.3	14.36	0
Bhojpur	Charpokhri	Pirro	7.27	931	605	0.23	33.27	344.4	ND	44.85	59.1	0.02	220	38	30.37	110.54	0
Bhojpur	Piro	Bhulkuan	7.37	550	358	0.37	14.18	282.9	ND	18.82	23	BDL	175	30	24.3	49.86	0
Bhojpur	Tarari	Sikharhata	7.4	1037	674	0.33	35.45	399.75	ND	48.97	66.6	BDL	230	42	30.37	110.54	1.82
Bhojpur	Tarari	Tarai	7.3	1522	989	0.1	46.08	369	ND	116.32	264	BDL	480	72	72.9	110.54	37.76
Bhojpur	Charpokhri	Mallaur	7.5	621	404	0.08	28.96	307.5	ND	20.29	21.7	BDL	280	42	42.52	27.6	0.26
Bhojpur	Charpokhri	Barhara	7.61	617	401	0.21	17.72	356.7	ND	10.61	7.37	BDL	255	50	31.59	31.42	0.12
Bhojpur	Jagdishpur	Grahani	7.94	841	547	0.78	38.99	455.1	ND	13.03	28.4	BDL	295	46	43.74	77.45	0.34
Bhojpur	Garhani	Dehman	7.73	557	362	0.35	7.09	344.4	ND	10.49	7.27	BDL	240	36	36.45	23.55	0.21
Katihar	Amdabad	Kishanpur	7.44	552	359	0.15	16.3	301.35	0	36.19	8.87	BDL	260	28	46.17	11.71	4.03
Katihar	Amdabad	Balrampur	7.46	1215	790	0.13	103	528.9	0	59.77	19.7	BDL	315	50	46.17	86.12	62.8
Katihar	Barari	Bari Behra	7.48	414	269	0.09	42.1	86.1	0	40.29	46.3	BDL	200	36	26.73	8.88	7.19
Katihar	Barari	Barari	7.64	217.9	142	0.25	11.5	98.4	0	40.47	1.05	BDL	140	46	6.07	9	2.46
Katihar	Barari	Yadavtoli	7.82	621	404	0.25	38.3	289.05	0	41.06	3.81	BDL	175	28	25.51	33.18	51.55

Katihar	Barari	Goharasthan	7.49	251	163	0.3	5.64	135.3	0	12.4	0.32	BDL	125	32	10.93	7	2.69
Katihar	Barari	Lakshmiipur	7.76	798	519	0.21	70.9	369	0	34.76	1.87	BDL	245	50	29.16	65.41	12.95
Katihar	Kursela	Kursela	7.81	1012	658	0.33	76.5	498.15	0	32.16	10	BDL	435	40	81.4	35.5	32
Katihar	Sameli	Dumaria	7.77	758	493	0.26	31.6	362.85	0	38.32	52.5	BDL	280	40	43.74	24.71	42.95
Katihar	Sameli	Dumaria	7.45	785	510	0.29	49	362.85	0	33.9	27.5	BDL	335	32	61.96	8.62	45.75
Katihar	Manihari	Manihari P.S.	7.98	1906	1239	0.26	193	615	0	71.63	74.4	BDL	475	90	60.75	128.9	57.1
Katihar	Manihari	Kunwaripur	7.39	668	434	0.28	28.36	362.85	0	28.8	1.49	BDL	180	38	20.65	59.71	11.4
Katihar	Mansahi	Tatrai Tola	7.53	224	146	0.17	12.2	123	0	10.7	3.54	BDL	100	22	10.93	6	5.44
Buxar	Chausa	Nikrish	7.12	1058	687.7	0.655	60.7	528.9	0	14.11	21.3	0	320	102	15.80	118.85	6.04
Buxar	Itarhi	Purusottampur	7.72	561	364.65	0.544	31.1	276.75	0	15.05	12.5	0	255	66	21.87	22	5.1
Buxar	Itarhi	Basudhar	7.74	497	323.05	0.616	8.4	289.05	0	16.22	6.37	0	200	56	14.58	34.29	1.21
Buxar	Itarhi	Jalwasi	7.74	569	369.85	0.432	12.7	307.05	0	16.22	32.8	0	230	72	12.15	18.65	13.75
Buxar	Itarhi	Kukdha	7.67	1129	733.85	0.818	107	412.05	0	83.96	58.3	0	390	50	64.40	96.25	18
Buxar	Rajpur	Jalhara	7.64	861	559.65	0.91	59.2	375.15	0	36.39	51.7	0	315	62	38.88	70.68	1.6
Buxar	Rajpur	Bahrutiya (Kedarganj)	7.4	433	281.45	0.805	9.08	227.55	0	12.44	2.59	0	195	40	23.08	17.96	0.56
Buxar	Navanagar	Jitwadih (Jitwadehri)	768	557	362.05	0.476	38.2	239.85	0	27.55	28.5	0	265	70	21.87	13.68	0.65
Buxar	Navanagar	Parmeshwar Tola	7.55	991	644.15	0.88	52.3	516.6	0	21.1	28.9	0	380	60	55.89	93.77	7.35
Buxar	Kesath	Katkinar	7.46	632	410.8	0.496	26.9	325.85	0	10.46	2.35	0	270	52	34.02	31.72	1.06
Buxar	Chausa	Chaugai	7.83	503	326.95	0.465	6.59	295.2	0	21.54	2.19	0	240	48	29.16	17.57	1.02
Buxar	Dumraon	Basauli	7.95	825	536.25	0.95	16.4	467.4	0	22.5	18.5	0	200	32	29.16	109.65	11.7
Buxar	Chausa	Chausa	7.82	1022	664.3	0	112	381.3	0	86.36	7.11	0	390	44	68.04	75.08	3.82
Buxar	Buxar	Churamanpur	7.98	625	406.25	0.743	7.99	369	0	14.14	14.6	0	215	24	37.66	57.09	1.85
Buxar	Buxar	Danikutia	8	394	256.1	0.793	9.74	264.45	0	16.74	1.07	0	210	30	32.8	16.68	0.64
Buxar	Buxar	Dudharchak	7.93	530	344.5	0	3.22	307.5	0	19.37	0.72	0	235	26	41.31	23.14	2.64
Buxar	Dumraon	Dumraon	8.24	792	514.8	0.71	39.4	424.35	0	15.17	4.05	0	305	50	43.74	70.42	1.47
Buxar	Rajpur	Rajpur	8.17	1210	786.5	1.19	161	442.8	0	52.02	6.25	0	360	16	77.76	140.79	0.81

Annexure II-A

Arsenic Analysis of Ground Water

SL. No.	District	Block	Village	Lingitude	Latitude	Source	As(ppm)
1	Bhagalpur	Kahalgaon	Ghoga	86.176	24.214	HP	BDL
2	Bhagalpur	Kahalgaon	Pakkaisharay	87.165	25.216	HP	BDL
3	Bhagalpur	Kahalgaon	Paramanandpur	87.167	25.219	HP	BDL
4	Bhagalpur	Kahalgaon	Ekchari	87.172	25.219	HP	BDL
5	Bhagalpur	Kahalgaon	Nadia Tola	87.182	25.221	HP	BDL
6	Bhagalpur	Kahalgaon	Kulkuliya	87.232	25.261	HP	BDL
7	Bhagalpur	Kahalgaon	Hasanpur	87.231	25.256	HP	BDL
8	Bhagalpur	Kahalgaon	Bhader	87.249	25.239	STW	BDL
9	Bhagalpur	Kahalgaon	Sadpura	87.242	25.252	HP	0.027
10	Bhagalpur	Kahalgaon	Dhanaura	87.263	25.256	HP	BDL
11	Bhagalpur	Kahalgaon	Dhanaura	87.257	25.191	STW	BDL
12	Bhagalpur	Kahalgaon	Seori	87.273	25.158	HP	BDL
13	Bhagalpur	Kahalgaon	Jalha	87.242	25.169	HP	BDL
14	Bhagalpur	Kahalgaon	Mahila	87.288	25.142	HP	BDL
15	Bhagalpur	Kahalgaon	Kalupur	87.215	25.137	HP	BDL
16	Bhagalpur	Kahalgaon	Sonathpur	86.923	25.241	HP	BDL
17	Bhagalpur	Kahalgaon	Nandlalpur	87.253	25.238	HP	BDL
18	Bhagalpur	Kahalgaon	Pratap Nagar	87.250	25.238	HP	BDL
19	Bhagalpur	Kahalgaon	Lattipur	87.246	25.265	HP	BDL
20	Bhagalpur	Kahalgaon	Siyarmari	87.264	25.296	HP	BDL
21	Bhagalpur	Pirpainti	Pirpainti	87.417	25.290	STW	BDL
22	Bhagalpur	Pirpainti	Mandangopali	87.420	25.322	HP	BDL
23	Bhagalpur	Pirpainti	Imamnagar	87.399	25.279	HP	BDL
24	Bhagalpur	Pirpainti	Dulduliya	87.394	25.304	HP	BDL

25	Bhagalpur	Pirpainti	Rifadpur	87.436	25.298	HP	BDL
26	Bhagalpur	Pirpainti	Judavanpur	87.409	25.246	STW	BDL
27	Bhagalpur	Pirpainti	Pachrukhi	87.461	25.277	HP	BDL
28	Bhagalpur	Pirpainti	Kaliprasad	87.371	25.236	HP	BDL
29	Bhagalpur	Pirpainti	Lachmipur	87.394	25.354	HP	BDL
30	Bhagalpur	Pirpainti	Mohanpur	87.374	25.282	HP	BDL
31	Bhagalpur	Pirpainti	Shamsirganj	87.450	25.336	STW	BDL
32	Bhagalpur	Pirpainti	Madhepura	87.446	25.255	HP	BDL
33	Bhagalpur	Pirpainti	Madhopur	87.366	25.339	HP	0.017
34	Bhagalpur	Pirpainti	Dubauli	87.473	25.303	HP	0.053
35	Bhagalpur	Pirpainti	Rashidpur	87.481	25.281	HP	BDL
36	Bhagalpur	Pirpainti	Manikpur	87.428	25.345	HP	BDL
37	Bhagalpur	Pirpainti	Khawaspur	87.445	25.317	HP	BDL
38	Bhagalpur	Pirpainti	Parsurampur	87.387	25.361	HP	BDL
39	Bhagalpur	Pirpainti	Gobindpur	87.519	25.324	HP	BDL
40	Bhagalpur	Pirpainti	Kalupur	87.488	25.362	HP	BDL
41	Bhagalpur	Nathnagar	Champanagar	86.921	25.238	HP	BDL
42	Bhagalpur	Nathnagar	Sitnabad	86.944	25.244	HP	BDL
43	Bhagalpur	Nathnagar	Serampur	86.955	25.249	HP	BDL
44	Bhagalpur	Nathnagar	Mathurapur	86.944	25.254	HP	BDL
45	Bhagalpur	Nathnagar	Jobra	86.927	25.244	HP	BDL
46	Bhagalpur	Jagdishpur	Jagdishpur	87.013	25.066	HP	BDL
47	Bhagalpur	Jagdishpur	Mobarakpur	86.961	25.081	HP	BDL
48	Bhagalpur	Jagdishpur	Saino	87.008	25.138	HP	BDL
49	Bhagalpur	Jagdishpur	Tekuni	87.009	25.110	HP	BDL
50	Bhagalpur	Jagdishpur	Mukhariya	87.010	25.076	HP	BDL
51	Bhagalpur	Jagdishpur	Sonauli	86.988	25.198	HP	BDL
52	Bhagalpur	Jagdishpur	Baijani	86.993	25.185	HP	BDL

53	Bhagalpur	Jagdishpur	Nima	86.969	25.176	HP	BDL
54	Bhagalpur	Jagdishpur	Samariya	86.964	25.189	HP	BDL
55	Bhagalpur	Jagdishpur	Fatepur	86.950	25.169	HP	BDL
56	Bhagalpur	Nathnagar	Basanthpur	86.892	25.231	HP	0.039
57	Bhagalpur	Nathnagar	Karanpur	86.908	25.242	HP	0.002
58	Bhagalpur	Nathnagar	Gosaindaspur	86.894	25.251	HP	0.035
59	Bhagalpur	Nathnagar	Mohdipur	86.924	25.260	HP	0.031
60	Bhagalpur	Nathnagar	Makandpur	86.878	25.250	HP	0.026

Annexure III

Summarised VES Results

District	Village	ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	ρ7	h1	h2	h2	h4	h5	h6
Bhagalpur	Tet rahar	32	10	681					1	95.6				
Bhagalpur	Gonudham	13	8	15	3323				1.9	16.8	64.3			
Bhagalpur	Bhaturia	16	4	11	170				2	1	83			
Bhagalpur	Ramchandra pur	8	15	54	2785				2	5	316			
Bhagalpur	Maheshpur	29	16	797 3					3.8	107				
Bhagalpur	Lakarakol	69	18	11	1838				1	10	97			
Bhagalpur	Chandpur	14	5	14	2755				1.8	1.4	129			
Bhagalpur	Mathurapur	24	12	216					1.7	114				
Bhagalpur	Rasalpur	14	5	10	148				3.2	11	69			
Bhagalpur	Parasbanna	25	14	63	0.05				2	32.4	67.6			
Bhagalpur	Banshichak	19	15	6	38	0.06			3.9	26.3	32.3	80.5		
Bhagalpur	Lakhmipur Rly. Station	447	23	14	10.5	124			0.62	3.08	18.4	155		
Bhagalpur	Rajganj	96	14.75	45	14.5	8.8	99.5		1	1	2.2	25	61.5	
Bhagalpur	In between Sadiput and Gobindpur	89.5	19	11	47.9				1	4.6	78.4			
Bhagalpur	Srirampur	37.5	9.5	32	9.5	33	141	1.8	1	1.3	2.7	17.5	74.5	10 3
Bhagalpur	Siyan	125	20	11	282				1	4	69.5			
Bhagalpur	Jagannathpur	23.6	8.1	29.6	2.3	10.5	48.5		1.8	1.4	4	6.2	53	
Bhagalpur	Barmasia	28.8	21.6	8.5	15	72			1.2	4	41.3	50		
Bhagalpur	Jhurkusia	12.2	32.2	8.8	59.5				3.6	3	60.5			
Bhagalpur	Gobindpur	25.1	14.9	6.2	24	581			1.1	18.9	23.6	188		
Bhagalpur	Panchrukhi	406	33.9	12.3	104				0.8	3.6	48.4			
Bhagalpur	Srinagar (Jagadishpur)	68.4	26.5	12	5.5	47.2			1.4	3.6	23.6	26		
Bhagalpur	Hiranand	69.6	19.2	13.4	7.7	30.1			1.2	4	17.1	74		
Bhagalpur	Durgapur M.School, Saguni	70	21	12.7	8.8	45.6			0.8	5.1	22	69.6		
Bhagalpur	Javedi P. School	64.5	265	53	148	1.5			0.8	4.7	64	97		
Bhagalpur	choti Bariapur	88	27	14	7.8	215			0.4	7.6	21	43.6		

Bhagalpur	Ekchari Diyara (Flood Plane)	51.5	15.3	212	28.7				3.3	16.4	14.4			
Bhagalpur	AntiChak (Primary Sub-Health)	15	10.2	31.6	6.8	29.3	3.9	434	1.2	1.3	2.7	5.6	11.6	24
Bhagalpur	Sadanandapur Baisa	23.3	16.1	6	1681				1.6	26.6	37			
Bhagalpur	Ramnagar	111	29	7.8	12147				0.8	5	26.8			
Bhojpur	Balbhaddarpur	43.5	25.2	190	7				1	17	30			
Bhojpur	Mianpur	10	5	15	10	25	3		1.2	5.5	57.5	85	55	
Bhojpur	Nagpur	3	143	6	28	103			4.5	5	19	22		
Bhojpur	Sagram	15.3	8	119					1	32				
Bhojpur	Khiri	11.3	7	22	10	49			1	7	35	54		
Bhojpur	Basahi	10.5	97.5	3					8	18				
Bhojpur	Khukhunda	10	3	9	6	113			1	4	22	26		
Bhojpur	Itarhi	8	7	40	8	25			3	11	17	120		
Bhojpur	Barhana	15	5	15	6	35			1	4	70	65		
Bhojpur	Indour	19.5	7	29	8	106			1.2	10	33	46		
Patna	Kandap	9.3	167	133	2.25				18.3	15.3	11.7			
Patna	Balua Chak	57.7	7.6	447	79	15.1			1.2	1.3	3	95.3		
Patna	Palaki	13	5.5	13	105				1	1.2	14			
Patna	Jalalpur	10	1.3	10	54	3			1	0.3	16	109		
Patna	Jolbigaha	6	40	3					9	64				
Patna	Bairichak	11	12	71	9				1	26	47			
Patna	Bharatpura	25	2	43	9	105			1	0.3	2	61		
Patna	Ichipur	8	71	9	56	3			1	0.3	25	23		
Patna	Rasilchak	6	13	55	3				6	17.5	105			
Patna	Sikandarpur	22.5	3	17	7	45.5			1	1	3	65		
Kathihar	Katriya	358	149	50					2	15.9				
Kathihar	Dintanga diara	210	47	136					3	94				
Kathihar	Nawabgunj	44	213	50	72	VH			1	0.5	18	120		
Kathihar	Tingaria	53	152	64	15				1	5	142			
Kathihar	Dumar	75	143	41	vh				1	17	24			

Annexure-IV

National Aquifer Mapping (NAM) Exploration Details

EW 1

- Location ; Rampur
- Co-ordinates ; 25°16'45" : 87°25'20"
- Total depth drilled (m bgl) ; 141.60
- Depth of construction (m bgl) ; 133.00
- Granular zone tapped (m) ; 79-86, 91-93 95-97 , 99-106 and 109-131

S N	Lithology	Depth Range (m bgl) *(from)*	*(to)*	Thickness (m)
1	**Clay:** grey with brownish tinge, plastic.	0.00	6.16	6.86
2	**Clay;** Brownish yellow, plastic.	6.86	37.15	30.29
3	**Clay:** brownish yellow mixed with reddish shale and quartz particles.	37.15	46.17	9.02
4	**Shale:** yellow to reddish mixed with quartz.	46.17	55.23	9.06
5	**Clay;** brownish yellow, plastic.	55.23	58.23	3.00
6	**Clay;** gray mixed with medium to fine sand composed of quartz, feldspar and shaly material.	58.23	79.95	21.72
7	**Sand:** gray, fine to medium, sub-rounded, composed of quartz and feldspar.	79.95	98.26	18.31
8	**Sand:** gray, fine to medium, sub-rounded, composed mostly of quartz .	98.26	101.26	3.00
9	**Sand:** gray, medium to coarse, sub-rounded, composed of quartz and feldspar.	101.26	107.39	6.13
10	**Sand:** gray, medium to coarse, sub-rounded, composed of quartz and feldspar mixed with reddish shaly material	107.39	122.72	15.33
11	**Sand:** gray, medium to coarse, sub-rounded, composed of quartz and feldspar mixed with little shaly material	122.72	131.83	3.12
12	**Crystalline (hard rock) :** garentiferrous biotite gneise, highly weathered consisting predominantly of quartz and feldspar grain	131.83	134.95	3.12
13	**Crystalline (hard rock) :** garentiferrous biotite gneiss, moderately weathered	134.95	140.90	5.95

EW 2

14	**Crystalline; (**core sample recovered)	140.90	141.60	0.70

- Location ; Hardeo chak
- Co-ordinates ; 25°13'40" : 87°23'30"
- Total depth drilled (m bgl) ; 202.57
- Depth of construction (m bgl) ; 159.59
- Granular zone tapped (m bgl) ; 51.00-57.00, 61.00-63.00, 64.00-68.00, 69.96-75.45, 76.45-83.97, 90 89-97.37, 8.37-102.82, 104.33-108.39, 14.45-131-37, 43.49-146.55, 62-167.58, 169.68-175.73, and 178.23-194.90
- Depth of Construction (OW) : 193.50 m bgl
- Granular zone tapped (m bgl) : 51.00-55.00, 64.00-68.00, 70.93-74.91, 78.00-82.88, 991 84-95.88, 9.88-103.53, 105.68-107.68, 15.61-130.54, 144.59-146.41 163.27-167.11, 170.00-175.00, and 179.87-192.10

S N	Lithology	Depth Range (m bgl) *(from)*	*(to)*	Thickness (m)
1	**Clay:** yellowish, plastic & sticky	0.00	12.91	12.91
2	**Clay:** yellowish brown, plastic, sticky mixed with ferruginous nodules	12.91	40.31	27.40

3	**Clay:**	yellowish, plastic & sticky	40.31	43.41	3.10
4	**Clay:**	yellowish grey, plastic, sticky & plastic mixed with fine sand.	43.41	52.51	9.10
5	**Sand:**	light grey, medium to fine, composed of sub-angular to sub-rounded colourless quartz and dirty white feldspar mixed with ferruginous nodules with little clay.	52.51	55.51	3.00
6	**Clay:**	Grey & yellow, plastic & sticky mixed with ferrugenous nodules.	55.51	58.51	3.00
7	**Sand:**	light grey, medium to fine, composed of sub-angular to rounded quartz and dirty white feldspar.	58.51	61.61	3.10
8	**Sand:**	light grey, coarse to medium, composed of white and colourlesss quartz, sub-angular to sub-rounded with very little clay.	61.61	67.71	6.10
9	**Sand:**	yellowish grey, medium to coarse, composed of sub-rounded to rounded colourless quartz and white feldspar	67.71	73.841	6.10
10	**Sand:**	yellowish grey, medium to very coarse, composed of yellowish white quartz and pink coloured feldspar with ferruginous nodules.	73.841	92.11	18.30
11	**Clay:**	yellowish brown mixed with medium to coarse sand composed of sub-rounded to colourless quartz and white feldspar.	92.11	95.11	3.00
12	**Clay:**	ash grey, plastic & sticky missed with medium to fine sand and small pieces of grey sandstone.	95.11	101.21	6.10
13	**Sand:**	ash grey, medium to fine, composed of grey, colourless, sub-rounded to rounded quartz and white feldspar mixed with clay.	101.21	110.41	9.20
14	**Sand:**	ash grey, very coarse to medium, composed of sub-rounded to rounded colourless grey quartz and white feldspar with a few ferruginous nodules and carbonaceous material.	110.41	134.81	24.40
15	**Sand:**	light ash gray, very coarse to medium, ub-angular to sun-rounded, colouless quartz and feldspar.	134.81	137.81	Contd.....
16	**Sand:**	greysih black, coarse to medium, sub-rounded to rounded, grey colourless quartz mixed with clay and carbonaceous material.	137.81	150.01	12.20
17	**Sand;**	blackish grey, fine to medium, sub-rounded to sub-angular quartz and white feldspar and particles of soft carbonaceous material mixed with grey coloured clay.	150.01	177.51	27.50
18	**Sand;**	ash grey, coarse to medium sub-rounded to rounded quartz & feldspar mixed with clay.	177.51	182.38	4.87
19	**Clay:**	blackish grey mixed with coarse to medium, sub-rounded to rounded quartz.	182.38	202.57	20.19

EW 3

Location ; Harchandpur
Co-ordinates ; 25°14’25” : 87°20’15”
Total depth drilled (m bgl) ; 131.27
Depth of construction (m bgl) ; Not constructed

S N		Lithology	Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Clay:**	reddish brown, sticky, plastic mixed with occasional ferruginous nodules.	0.00	17.89	17.89
2	**Clay:**	yellowish brown, sticky, plastic mixed with ferruginous nodules.	17.89	38.78	20.89
3	**Clay:**	yellowish brown, sticky, plastic mixed with ferruginous nodules and occasional kankar.	38.78	95.91	57.13

4	**Clay:**	Yellowish brown with highly weathered ash grey hornblende biotite with sub-angular pieces of white & pink feldspar, and sub-angular colourless, coarse, quartz & ferrugeneous nodules.	95.91	119.89	23.98
5	**Clay:**	yellowish brown mixed with angular to sun-angular white & pink feldspar, black biotite, sub-angular to sub-rounded, coarse quartz.	119.89	128.71	8.82
6	**Granite gneiss:**	grayish white weathered composed of pink & white feldspar, colourless quartz, black coloured biotite and grayish black hornblende.	128.71	131.52	2.80
7	**Core of granite gneiss**	recovered about 75% grayish white composed of orthoclase and plagioclase feldspar, colourless quartz, hornblende and garnet.	131.52	132.27	0.75

EW 4

Location ; Saino
Co-ordinates ; 25°06'40" : 87°00'40"
Total depth drilled (m bgl) ; 64.66
Depth of construction (m bgl) ; 61.50
Granular zone tapped (m bgl) ; 39.00-42.00, 44..00-47.00, and 50.00-60.00,
Depth of Construction (OW) : Not constructed

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Clay:**	grayish brown, sticky, semi-plastic, mixed with very fine sand & kankar	00.00	22.00	22.00
2	**Sand;**	grey, fine to medium, mixed with gravel and calcareous nodules.	22.00	30.00	8.00
3	**Clay:**	brown, sticky mixed with thin layers of silt and very fine sand	30.00	39.00	9.00
4	**Sand:**	grey, very fine to medium, intercalated with calcareous nodules.	39.00	42.50	3.50
5	**Clay:**	brownish grey, sticky, semi-plastic mixed with thin layer of silt.	42.50	44.00	1.50
6	**Sand:**	grey, fine to medium, qartzitic in nature, mixed with steaks of silt	44.00	47.50	3.50
7	**Clay:**	yellowish grey, sticky semi-plastic missed with silt.	47.50	50.00	2.50
8	**Sand:**	grey fine to medium, mixed with gravel thin layer of silt, gravels are mainly quartzitic with piece and little kankar.	50.00	60.00	10.00
9	**Granite gneiss:**	weathered on the top upto 2 m and rest is hard.	60.00	64.66	4.66

EW 5

Location ; Baijani
Co-ordinates ; 25°11'05" : 86°56'30"
Total depth drilled (m bgl) ; 86.82
Depth of construction (m bgl) ; 85.50
Granular zone tapped (m bgl) ; 26.00-29.00, 46.50-48.00, 51.00-53.00, 64.00-65.50, 67.00-71.50, 73.00-77.00, and, 79.00-84.50

Depth of Construction (OW) : 85.50 m bgl

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty Clay;**	brownish grey, semi-plastic, mixed with fine sand, silt & kankar.	00.00	25.50	25.50
2	**Sand;**	grey, fine	25.50	29.00	3.50
3	**Clay:**	brown, plastic intercalated with fine sand & kankar	29.00	34.00	5.00
4	**Clay;**	brown, sticky mixed with fine sand and little silt.	34.00	36.50	2.50
5	**Clay;**	brown, sticky, plastic mixed with little fine sand and kankar.	36.50	46.50	10.00
6	**Sand;**	fine to medium, grey, intercalated with kankar and little silt.	46.50	48.00	1.50
7	**Clay & Sand;**	fine sand mixed with brownish clay.	48.00	50.00	2.00
8	**Sand & Clay**	fine to medium sand mixed with brownish clay, semi-plastic and kankar.	50.00	55.00	5.00
9	**Clay;**	brown, sticky mixed with fine sand and little kankar.	55.00	57.00	2.00
10	**Clay & Sand:**	fine to medium sand, mixed with brownish clay & kankar.	57.00	59.50	2.50
11	**Clay:**	brownish, sticky, plastic mixed with kankar.	59.50	61.00	1.50
12	**Silt & Sand:**	silt mixed with fie sand and little brownish clay & kankar	61.00	64.00	3.00
13	**Sand:**	fine to medium, grey mixed with silt.	64.00	65.50	1.50
14	**Clay:**	brownish, semi-plastic mixed with silt and fine sand.	65.50	67.00	1.50
15	**Sand:**	fine to medium, brownish mixed with kankar.	67.00	71.50	4.50
	Clay;	brown, sticky, intercalated with fine sand kankar.	71.50	73.00	1.50
	Sand:	fine to medium, grey, micaceous.	73.00	74.00	1.00
	Sand & Silt:	medium sand, brown mixed with silt and clay	74.00	79.00	5.00
	Sand:	medium to coarse, well sorted, sub-rounded quartz, mica flex with occasional feldspar piece.	79.00	86.50	7.50
16	**Granite gneiss:** weathered at the top, pinkish feldspar and colourless quartz with mica (biotite) (core recovery 20%)		86.50	87.10	0.64

EW 6

Location ; Mahesh Munda
Co-ordinates ; 25°14'15" : 87°15'50"
Total depth drilled (m bgl) ; 78.50
Depth of construction (m bgl) ; Not constructed

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty Clay;**	Brownish, semi-plastic mixed with very fine sand.	0.00	13.00	13.00
2	**Sand:**	light brown, very fine, mixed with silt & kankar	13.00	17.00	4.00
3	**Clay;**	Brownish, sticky mixed with little silt.	17.00	21.00	4.00
4	**Sand:**	Light brown, very fine, mixed with calcareous nodules.	21.00	25.00	4.00
5	**Clay:**	brownish, sticky, plastic	25.00	28.00	3.00
6	**Sand:**	Very fine, light brown with silt and kankar.	28.00	31.00	3.00
7	**Clay:**	Brownish grey, sticky mixed with silt.	31.00	36.50	5.50
8	**Sand:**	light brown, very fine mixed with calcareous nodules.	36.50	39.00	2.50
9	**Clay:**	brownish, sticky, semi-plastic.	39.00	41.00	2.00

10	**Sand:**	light brown, fine, with sub-rounded quartz and pinkish feldspar.	41.00	44.00	3.00
11	**Clay:**	brownish, sticky, plastic.	44.00	50.00	6.00
12	**Sand:**	light brown, medium to coarse, sub-rounded quartz, colourless with weathered pinkish feldspar.	50.00	56.50	6.50
13	**Clay:**	brownish, sticky mixed with silt.	56.50	60.00	3.50
14	**Granite gneiss:**	weathered at the top, contact with quartzite hard and compact from 77 m bgl.	60.00	78.50	17.50

EW 7

Location ; Dhawa Kajaraili
Co-ordinates : 25°08'45" : 86°56'10"
Total depth drilled (m bgl) ; 73.89
Depth of construction (m bgl) ; 66.00
Granular zone tapped (m bgl) ; 25.50-30.50, 32.00-34.00, 39.00-42.00, 53.50-58.00, and 61.00-65.00

S N	Lithology		Depth Range (m bgl) *(from)*	*(to)*	Thickness (m)
1	**Silty Clay;**	grey, non-plastic, mixed with colourless quartz and little mica.	0.00	3.05	3.05
2	**Clay:**	yellwish grey, sticky, non-plastic with irregular calc. and ferruginous concreation.	3.05	25.60	22.55
3	**Sand:**	brown, fine to medium, angular to subangular, colourless angular quarts with pinkish feldspar and little silt.	25.60	30.50	4.90
4	**Clay:**	yellowish grey, sticky mixed with fine sand.	30.50	31.70	1.20
5	**Sand:**	brown, fine to medium, angular to subrounded, composed of colourless subrounded quartz, pinkish feldspar mixed with dark ferruginous concreation.	31.70	34.10	2.40
6	**Clay:**	yellow, sticky, semi-plastic with fine calcareous nodules.	34.10	39.00	4.90
7	**Sand:**	brown, fine with mica.	39.00	42.30	3.30
8	**Clay:**	yellowish grey, semi-plastic with irregular kankar.	42.30	53.50	11.20
9	**Sand:**	brown, fine with mica.	53.50	58.00	4.50
10	**Clay:**	yellowish grey, sticky, semi-plastic, mixed with kankar.	58.00	61.00	3.00
11	**Sand:**	brown medium to coarse, intercalated with colourless quartz and pink feldspar.	61.00	65.00	4.00
12	**Clay:**	yellow, sticky, non-plastic mixed with calcareous and ferruginous cincreation.	65.00	68.30	3.30
13	**Granite:**	weathered, greysih pink, coarse grained, milky and colourless quartz, red feldspar, hard granite from 73.20 m bgl, halo-crystalline, biotite**.**	68.30	73.89	5.59

EW 8

Location ; Ghogha
Co-ordinates : 25°10'00" : 87°10'00"
Total depth drilled (m bgl) ; 138.70
Depth of construction (m bgl) ; 138.50
Granular zone tapped (m bgl) : 108.50-113.50 and 125.30-137.00

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty Clay:**	Light to deep brown, sticky mixed with kankar in varying proportion and fine sand.	0.00	31.00	31.00
2	**Sand:**	Medium to coarse with some gravel.	31.00	34.40	3.40
3	**Clay:**	Grey, brown buff coloured, sticky, with occasional intercalations of sand, little gravel kankar and silt.	34.40	108.50	74.10
4	**Sand:**	Fine to very coarse, with little clay.	108.50	113.40	4.90
5	**Clay:**	Mottled brown and grey.	113.40	124.30	10.90
6	**Sand:**	very coarse, composed of quart, colloidal silica and little ferruginous material	124.30	137.10	12.80
7	**Granite Gneiss**		137.10	138.70	1.60

EW 9

Location ; Colgong
Co-ordinates : 25°15'00" : 86°48'00"
Total depth drilled (m bgl) ; 198.40

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty Clay:**	Brownish grey, soft with fine sand and kankar.	0.00	18.30	18.30
2	**Clay:**	Yellowish grey, soft, sticky clay with abundant kankar in varying proportion.	18.30	30.50	12.20
3	**Clay:**	Grey, soft, sticky	30.50	36.60	6.10
4	**Kankar & Gravel:**	Calcareous concreation with sub-angular to sub-rounded quartz, rosy feldspar.	36.60	39.60	3.00
5	**Clay & Kankar:**	Light brown, soft, sticky clay with abundant kankar.	39.60	45.70	6.10
6	**Gravel & Sand:**	Sub-rounded to angular, colourless quartz with coarse sand, ferruginous & micaceous and little silt.	45.70	49.70	2.00
7	**Clay:**	Grey sticky, very hard.	49.70	56.40	6.70
8	**Clay & Gravel**	Grey, brownish, sticky clay with gravel of mainly quartz.	56.40	57.90	1.50
9	**Clay:**	Light brown, soft sticky with medium sand.	57.90	60.90	3.00
10	**Sand & Gravel**	Coarse, ferruginous sand with gravel mainly composed of sub-rounded to rounded quartz and piece of sand stone chips.	60.90	72.80	11.90
11	**Granite Gneiss:**		72.80	74.80	2.80

EW 10

Location : Laxmipur
Co-ordinates : 25°17'18" : 87°22'30"
Total depth drilled (m bgl) ; 294.05
Depth of construction (m bgl) : 285.00
Granular zone tapped (m bgl) : 94.0-97.0, 107.0-114.0 142.0-150.0, 164.0-170.0, 172.0-183.0, 201.0-203.0, 206.0-210.0
Depth of Construction (OW) : 85.50 m bgl

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Clay:**	yellowish grey, plastic and sticky.	0.00	29.12	29.12
2	**Clay:**	yellowish grey, plastic and sticky mixed with little coarse sand and gravel.	29.12	39.08	9.96
3	**Clay:**	yellowish grey with brownish tinge, plastic and sticky.	39.08	56.66	17.58
4	**Clay:**	yellowish grey with brownish tinge, plastic and sticky mixed with fragments of basalt (weathered trap).	56.66	73.48	16.82
5	**Trap (basalt):**	grey to dark grey, weathered mixed with little clay which is dark grey in colour and plastic.	73.48	87.25	13.77
6	**Clay:**	carbonaceous, plastic and sticky.	87.25	91.25	4.0
7	**Clay:**	dark grey, plastic and sticky.	91.25	97.42	6.17
8	**Silt:**	grey to steel grey, sticky mixed with fine sand.	97.42	111.4	16.66
9	**Clay:**	ash grey to steel grey, plastic.	111.4	170.33	56.25
10	**Silt:**	ash grey, sticky mixed with fine sand except the depth range of 176.50-179.50 m	170.33	182.59	12.26
11	**Coal:**	ash grey to steel grey, very soft as if burnt, mixed with fine to medium sand, grey quartzitic in nature.	182.59	188.59	6.00
13	**Clay:**	dark grey to black, stick, plastic mixed with fine to medium sand, grey, quartzitic in nature.	188.59	197.59	9.00
15	**Coal:**	ash grey to steel grey, soft as if burnt mixed with very fine sand, and little amount of clay, grey, plastic in nature.	197.59	200.59	3.00
16	**Clay**	carbonaceous, steel grey to black, plastic, mixed with very fine sand	200.59	207.09	6.50
17	**Silt:**	carbonaceous, ash grey, sticky mixed with little fine sand.	207.09	234.82	27.73
18	**Clay**	carbonaceous, steel grey to black, plastic and sticky, mixed with little amount of silt.	234.82	241.01	6.19
19	**Clay:**	carbonaceous, grey to steel grey, plastic and sticky, mixed with silt.	241.01	250.73	9.72
20	**Sand:**	grey to steel grey, quartzitic in nature, medium to coarse mixed with sand and silt.	250.73	254.32	3.50
21	**Clay:**	grey to dark grey, plastic sticky mixed with little silt.	254.32	261.26	7.03
22	**Clay:**	ash grey, plastic sticky mixed with little amount of silt.	261.26	264.75	3.49
23	**Sand:**	ash grey to dark grey, medium to fine mixed with little amount of clay.	264.75	268.25	3.50
24	**Clay:**	dark grey to black, carbonaceous, plastic and sticky	268.25	283.26	15.01
25	**Silt:**	dark grey to steel grey, sticky, mixed with little amount of fine sand.	283.26	294.06	10.80

EW 11

Location : Jagdishpur
Co-ordinates : 25°16'45" : 87°25'20"
Total depth drilled (m bgl) ; 73.55
Depth of construction (m bgl) : Not constructed

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Clay:**	Yellowish grey, plastic and sticky.	0.00	10.13	10.13
2	**Clay:**	Yellowish grey, plastic mixed with little coarse sand.	10.13	19.37	9.24
3	**Clay:**	Yellowish grey, plastic & sticky.	19.37	40.84	21.47
4	**Sand:**	Grey, very coarse, mixed with little amount of gravel (quartzitic).	40.84	43.84	3.00
5	**Clay:**	Yellowish grey, plastic.	43.84	62.16	18.32
6	**Clay:**	Dark grey, plastic.	62.16	65.22	3.06
7	**Clay:**	Black, plastic, mixed with little amount of coarse sand.	65.22	68.28	3.06
8	**Trap rock (basalt)**	weathered (80 cm core was recovered) at 72.75-73.55 m.	68.28	73.55	2.27

EW 12

Location : Karhariya
Co-ordinates : 25°08'25" : 86°56'55"
Total depth drilled (m bgl) ; 80.44
Depth of construction (m bgl) : Not constructed

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty clay:**	Yellowish, semi-plastic, mixed with silt and fine sand.	0.00	27.00	27.00
2	**Sand & Gravel:**	Quartz, subangular to subrounde, well sorted mixed with fine sand.	27.00	31.50	4.50
3	**Silty clay:**	Yellowish grey mixed with clay, semi-plastic and fine sand, ferromagnesian material.	31.50	35.50	4.00
4	**Sand:**	Grey, fine to medium, mixed with little quartz and ferromagnesian material.	35.50	38.00	2.50
5	**Silty clay:**	Yellowish, grey, mixed with ferromagnesian material.	38.00	43.00	5.00
6	**Sand & Gravel**	Grey, fine, mixed with colourless, rounded to sub-angular quartz, well sorted.	43.00	46.50	3.50
7	**Clay:**	Yellowish sticky & plastic, intercalated with little silt.	46.50	52.00	5.50
8	**Sand & Silt:**	Grey, fine, mixed with sub-rounded quartz and silt, ferromagnesian material.	52.00	55.50	3.50
9	**Silty clay:**	Brownish grey, mixed with little quartz and fine sand.	55.50	58.50	3.00

10	**Gravel & sand:**	colourless, su-angular to sub-rounded quartz with fine sand, ferromagnesian material and little silt	58.50	64.00	5.50
11	**Clay:**	Yellowish grey, sticky, plastic, intercalated with fine sand and little quartz.	64.00	76.00	12.00
13	**Granite gneiss:**	Weathered, abundant quartz, pinkish feldspar, mica.	76.00	79.00	3.00
15	**Granite gneiss:**	Compact (core), contact of granitic gneiss and weathered qauartzite.	79.00	80.44	1.44

EW 13 Bhagalpur Urban Area

Location	:	Police Training Centre, Nathnagar
Co-ordinates	:	25°14'55" : 86°56'25"
Total depth drilled (m bgl)	;	146.66
Depth of construction (m bgl)	:	118.00
Granular zone tapped (m bgl)	:	72.00-115.00

SN	Lithology		Depth Range (m bgl) *(from)*	*(to)*	Thickness (m)
1	**Silty clay:**	grayish yellow, semi-plastic mixed with little fine sand and kankar	00.00	10.00	10.00
2	**Silt and sand:**	Yellowish grey, fine sand with silt and kankar.	10.00	36.00	26.00
3	**Clay:**	light brown, grey, sticky, plastic, intercalated of silt	36.00	56.00	20.00
4	**Sand and silt:**	Yellowish grey, fine sand mixed with silt.	56.00	62.00	6.00
5	**Clay:**	Yellowish grey, sticky, non-plastic with very fine sand and silt.	62.00	72.00	10.00
6	**Sand:**	Fine to medium, grey, sub-rounded to round well sorted, micaceous with some silt.	72.00	115.00	43.00
7	**Silt and sand**	Grayish yellow, fine sand, micaceous mixed with silt and carbonaceous materials.	115.00	136.00	21.00
8	**Granite gneiss:**	contact is weathered abundant quartzite, rounded to sub-angular, colourless quartz, and flesh red feldspar, biotite.	136.00	146.66	10.66

EW 14 Bhagalpur Urban Area

Location : Champanagar, Nathenagar
Co-ordinates : 25°14'58" : 86°56'45"
Total depth drilled (m bgl) ; 149.66
Depth of construction (m bgl) : 148.00
Granular zone tapped (m bgl) : 77.0-96.0, 119.0-130.0, 134.0-138.0, and 144.0-146.0

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty clay:**	Brownish, semi-plastic, intercalated with fine sand and some calcareous nodules.	0.0	19.0	19.0
2	**Sand:**	fine, grey, mixed with silt	19.0	30.0	11.0
3	**Clay:**	grayish, sticky, plastic with little silt and fine sand	30.0	77.0	47.0
4	**Sand;**	Fine, grey, intercalated with silt and kankar.	77.0	96.0	19.0
5	**Clay:**	Grayish, soft, sticky, non-plastic mixed with calcareous nodules.	96.0	119.0	23.0
6	**Sand:**	Fine, grey, micaceous, mixed with little silt and kankar.	119.0	130.0	11.0
7	**Clay:**	Brownish, soft, non-plastic, sticky.	130.0	134.0	4.0
8	**Sand:**	fine grey, micaceous, intercalated with silt and kankar in varying proportions	134.0	138.0	4.0
9	**Clay:**	Grayish, sticky, soft, non-plastic, mixed with silt.	138.0	144.0	6.0
10	**Sand:**	fine, grey, with silt and kankar	144.0	147.0	3.0
11	**Granite gneiss:** weathered towards top and contact with quartzite.		147.0	149.0	2.66

EW 15 Bhagalpur Urban Area

Location : Sandis Compound, Bhagalpur
Co-ordinates : 25°16'58" : 86°59'44"
Total depth drilled (m bgl) : 163.27
Depth of construction (m bgl) : 156.00
Granular zone tapped (m bgl) : 27.0-32.0, 48.0-52.0, 88.0-106.0, 108.0-114.0, 138.0-142.0 and 147.0-153.0

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty clay:**	Brownish grey, soft, sticky, mixed with calcareous nodules of varying sizes and shapes & silt.	0.00	16.00	16.00
2	**Sand and kankar:**	Fine, grey sand with abundant calcareous nodules (kankar) and little silt.	16.00	22.50	6.50
3	**Clay:**	Grayish sticky, plastic, with little fine sand.	22.50	27.50	5.00
4	**Sand:**	Fine to medium, grey to light brown, well sorted with abundant calcareous concretion and silt.	27.50	32.00	4.50
5	**Clay:**	Yellowish grey, sticky, semi-plastic mixed with kankar and silt.	32.00	48.00	16.00
6	**Sand:**	Fine to medium, grey, mixed with mica and calcareous nodules.	48.00	52.00	4.00
7	**Clay:**	Yellowish grey, soft, sticky, semi-plastic with intercalations of silt, fine sand and calcareous concretion	52.00	88.00	36.00

		(kankar).			
8	**Sand:**	Fine to medium, grey, micaceous, with calcareous nodules & carbonaceous materials.	88.00	106.00	18.00
9	**Clay:**	Grey, sticky, non-plastic with silt.	106.00	108.00	2.00
10	**Sand:**	Fine, grey, sticky, with kankar.	108.00	114.00	6.00
11	**Clay:**	Brownish grey, sticky with kankar.	114.00	132.00	18.00
13	**Sand:**	Fine, micaceous, grey with fine sand silt and kankar.	132.00	135.00	3.00
15	**Clay:**	Sticky, non-plastic, intercalated with fine sand, silt and kankar.	135.00	138.00	3.00
16	**Sand:**	Fine to medium, light brown, micaceous, mainly composed of quartz, well sorted with calcareous nodules.	138.00	142.00	4.00
17	**Clay:**	Grey, sticky, non-plastic with silt.	142.00	147.00	5.00
18	**Sand;**	Fine to medium, mainly composed of quartz well rounded..	147.00	153.00	6.00
19	**Cay & silt:**	Grey, sticky with silt, coarse grain of quartz, sub-rounded feldspar.	153.00	159.50	6.50
20	**Granite gneiss:**	weathered, sub-rounded quartz flesh red feldspar	159.50	163.27	3.77

EW 16 Bhagalpur Urban Area

Location	:	Tilkakothi (Bhagalpur University)
Co-ordinates	:	25°14’55” : 86°57’10”
Total depth drilled (m bgl)	:	122.99
Depth of construction (m bgl)	:	100.00
Granular zone tapped (m bgl)	:	66.00-95.00

SN		Lithology	Depth Range (m bgl) *(from)*	*(to)*	Thickness (m)
1	**Silty clay:**	Grayish black, sticky, non-plastic with ferrugenious and calcareous nodules and little sand	0.00	15.00	15.00
2	**Sand:**	Grey, fine to medium, micaceous, composed of quartz, sub-angular to sub-rounded with ferruginous materials.	15.00	21.00	6.00
3	**Clay:**	Yellowish grey, brown sticky, semi-plastic, mixed with sand, kankar and some ferruginous material.	21.00	68.00	47.00
4	**Sand:**	Fine to medium, mainly composed of quartz, micaceous, grey intercalated with little amount of clay, brownish and ferruginous material.	68.00	97.00	29.00
5	**Clay:**	Yellowish grey, sticky, semi-plastic, with ferruginous black materials.	97.00	108.00	11.00
6	**Sand and clay:**	Rounded to sub-rounded colorless quartz with yellowish grey clay, sticky,	108.00	116.00	8.00

		ferruginous materials and calcareous nodules, weathered flesh red feldspar.			
7	**Granite gneiss:**	weathered towards top, abundant biotite, flesh red feldspar and quartz	116.00	122.99	6.99

EW 17 Bhagalpur Urban Area

Location : Champanala, Nathnagar
Co-ordinates : 25°14'50" : 86°55'58"
Total depth drilled (m bgl) : 139.70
Depth of construction (m bgl) : 125.00
Granular zone tapped (m bgl) : 41.0-46.0, 67.0-71.50, 78.50-94.00, and 112.50-123.00

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty clay:**	Buff, yellowish, non-plastic mixed with abundant kankar and fine sand.	0.00	12.00	12.00
2	**Clay:**	Yellowish grey, sticky, non-plastic with silt.	12.00	14.00	2.00
3	**Sand & silt:**	fine sand, grey with silt and calcareous nodules (about 50%), ferruginous materials.	14.00	19.50	5.50
4	**Clay:**	Yellowish grey, sticky, non-plastic with fine sand and calcareous nodules.	19.50	25.00	5.50
5	**Sand & silt:**	Fine sand with silt and calcareous nodules.	25.00	32.00	7.00
6	**Clay**	Yellowish grey, sticky, non-plastic with silt and kankar.	32.00	41.00	9.00
	Sand:	Fine, grey, mainly composed of quartz, well rounded mixed with calcareous nodules.	41.00	61.00	20.00
	Clay:	Yellowish grey, sticky non-plastic with calcareous nodules.	61.00	67.00	6.00
	Sand:	Fine to medium, grey, composed of quartz, micaceous well sorted with kankar.	67.00	71.70	4.70
	Clay:	Yellowish grey, sticky, semi-plastic with silt.	71.70	78.80	7.10
	Sand:	Fine to medium, with calcareous nodules.	78.80	94.00	15.20
	Clay:	Brownish grey, sticky, non-plastic, with fine sand and kankar.	94.00	112.50	8.50
	Sand:	Fine to medium, grey, composed of quartz, micaceous and silt.	112.50	122.90	10.40
	Silt & sand:	silt, grey with fine sand and sub-rounded to rounded quartz, flesh red feldspar	122.90	131.00	9.90
	Granite gneiss: weathered towards top.		131.00	139.70	8.70

EW 18 Bhagalpur Urban Area

Location : Teacher's Training College, Bhagalpur
Co-ordinates : 25°14'30" : 86°59'20"
Total depth drilled (m bgl) : 144.00
Depth of construction (m bgl) : 143.00
Granular zone tapped (m bgl) : 26.0-29.0, 82.0-88.0, 94.0-97.0, 99.0-113.0, and 130.0-140.0

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Clay:**	Brownish, silty, semi-plastic, mixed with very fine sand.	0.00	15.00	15.00
2	**Silt & sand:**	Silt intercalated with fine sand, brownish grey and kankar.	15.00	20.00	5.00
3	**Silty clay:**	Brownish grey, intercalated with very fine sand.	20.00	26.00	6.00
4	**Sand & silt:**	Very fine sand with silt and calcareous nodules.	26.00	29.00	3.00
5	**Clay:**	Brownish grey, plastic, sticky intercalated with little silt.	29.00	38.00	9.00
6	**Silt & kankar:**	Brownish, silt mixed with calcareous nodules and little sand.	38.00	49.00	11.00
7	**Clay:**	Brownish grey, plastic mixed with silt.	49.00	70.00	21.00
8	**Sand & silt:**	Very fine sand, intercalated with silt, brownish grey.	70.00	72.00	2.00
9	**Clay:**	Brownish grey, sticky mixed with silt.	72.00	82.00	10.00
10	**Sand & kankar:**	Fine sand with abundant kankar in varying sizes and shapes.	82.00	88.00	6.00
11	**Silt:**	Browinish grey, mixed with clay, semi-plastic and little kankar.	88.00	94.00	6.00
13	**Sand & silt:**	Fine sand with silt, greyish and calcareous nodules.	94.00	97.50	3.50
15	**Silt:**	Grey mixed with clay and fine sand.	97.50	99.00	1.50
16	**Sand:**	Fine to medium, grey, micaceous, composed of quartz mixed with silt and calcareous nodules.	99.00	113.00	14.00
17	**Clay:**	Grey, sticky, mixed with silt and kankar.	113.00	123.00	10.00
18	**Silt & sand:**	Silt, grey with fine sand, micaceous and kankar.	123.00	126.00	3.00
19	**Clay:**	Grey, sticky, semi-plastic, with intercalations of silt.	126.00	130.00	4.00
20	**Sand:**	Fine to very fine, micaceous, grey with silt and kankar.	130.00	140.00	10.00
21	**Clay:**	Pinkish, sticky mixed with fine sand and kankar.	140.00	143.59	3.59
22	**Granite gneiss:**	weathered, sub-rounded quartz flesh red feldspar	143.59	144.00	0.41

EW 19 Bhagalpur Urban Area

Location : Blind School, Bhagalpur
Co-ordinates : 25°14'52" : 86°59'30"
Total depth drilled (m bgl) : 146.00
Depth of construction (m bgl) : 118.00
Granular zone tapped (m bgl) : 44.0-47.0, 54.0-57.0, 58.50-61.50, 79.50-83.50, 96.50-107.50 and 110.50-116.00

S N	Lithology		Depth Range (m bgl)		Thickness (m)
			(from)	*(to)*	
1	**Silty clay:**	Yellowish grey with very fine sand, micaceous and kankar of various shapes & sizes.	0.00	14.60	14.60
2	**Silt & sand:**	Yellowish grey silt with fine sand and abundant kankar.	14.60	23.50	8.90
3	**Silt & clay:**	Yellowish grey, sticky, non-plastic clay mixed with silt and kankar.	23.50	44.00	20.50
4	**Sand :**	Fine, grey, mainly composed of quartz, micaceous with kankar.	44.00	46.60	2.60
5	**Silt and clay:**	Yellowish grey, sticky clay with silt and fine sand, calcareous nodules.	46.60	54.0	7.40
6	**Sand:**	Fine to medium, grey, composed of quartz with kankar.	54.0	57.00	3.00
7	**Clay:**	Yellowish grey and light brown, sticky, semi-plastic intercalated with fine sand and calcareous nodules.	57.00	58.80	1.80

8	**Sand:**	Fine, grey, micaceous with little silt and kankar.	58.80	61.60	2.80
9	**Clay & silt:**	Yellowish grey, sticky, non-plastic mixed with fine and silt.	61.60	79.70	18.10
10	**Sand:**	Fine to medium, grey, sub-rounded to rounded, micaceous mixed with silt.	79.70	83.50	3.80
11	**Clay & silt:**	Yellowish grey, sticky semi-plastic, intercalated with silt and fine sand.	83.50	96.50	13.00
13	**Sand:**	Light brown, grey, fine, well sorted, composed of quartz, mixed with silt.	96.50	107.60	11.10
15	**Clay:**	Yellowish grey, sticky semi-plastic, mixed with fine sand.	107.60	110.70	3.10
16	**Sand:**	Fine to medium, grey, composed of quartz with little kankar.	110.70	116.00	5.30
17	**Silty clay:**	Yellowish grey, sticky, non-plastic mixed with medium sand and calcareous nodules.	116.00	140.00	24.00
18	**Granite gneiss:**	Contact of weathered quartzite and flesh red feldspar.	140.00	146.00	6.00

EW 20 Bhagalpur Urban Area

Location : Jhowakothi, Bhagalpur
Co-ordinates : 25°16'30" : 87°00'06"
Total depth drilled (m bgl) : 161.00
Depth of construction (m bgl) : 153.00
Granular zone tapped (m bgl) : 85.0-103.50, 134.0-137.0, 143.0-146.0, and 149.0-157.0,

S N	Lithology		Depth Range (m bgl) *(from)*	Depth Range (m bgl) *(to)*	Thickness (m)
1	**Silty clay:**	Brownish, non-plastic, mixed with calcareous nodules.	0.00	12.00	12.00
2	**Sand and silt:**	Fine to medium, grey, micaceous sand with silt and kankar.	12.00	18.00	6.00
3	**Clay:**	Grayish, sticky, non-plastic mixed with kankar and silt.	18.00	20.00	2.00
4	**Sand and silt:**	Fine, grey, micaceous composed of quartz, mixed with silt and kankar.	20.00	27.00	7.40
5	**Clay:**	Brownish, sticky, semiplastic, mixed with silt and fine sand.	27.00	39.00	11.60
6	**Sand:**	Fine to medium grey, micaceous, composed of quartz, well sorted intercalated with calcareous nodules.	39.00	45.70	6.70
7	**Clay:**	Brownish, sticky, non-plastic mixed with fine sand, silt & kankar.	45.70	85.30	39.60
8	**Sand:**	Grey, fine to medium, micaceous mixed with silt & calcareous nodules.	85.30	103.60	18.30
9	**Clay:**	grayish sticky, non-plastic mixed with fine sand & silt	103.60	134.00	30.40
10	**Sand:**	Fine to medium, grey, micaceous, composed of quartz, mixed with kankar.	134.00	137.00	3.00
11	**Clay:**	Grayish, sticky, semi-plastic, with kankar and silt.	137.00	143.00	6.00
13	**Sand:**	Fine to medium, grey, micaceous, mixed with silt and kankar.	143.00	146.00	3.00
15	**Clay:**	brownish, sticky, semi-plastic, mixed with calcareous nodules and ferruginous materials	146.00	149.00	3.00
16	**Sand:**	Fine to medium, grey, micaceous with silt.	149.00	151.50	2.50
17	**Clay:**	Brownish grey, sticky, semi-plastic mixed with kankar and silt.	151.50	156.70	5.20
	Granite gneiss: weathered towards top.		156.70	161.60	4.90

Annexure V

Dynamic Ground Water Resources of Blocks taken under Phase IV &V

District	Blocks	Recharge from rainfallMonsoon (ham)	Recharge from rainfall Non-Monsoon(ham)	Recharge from other sources Monsoon(ham)	Recharge from other sources Non-Monsoon(ham)	Total ground water recharge	Provision for natural discharge (ham)	Net ground water availibility(ham)	Existing Gross Ground Water Draft for irrigation(ham)	Existing Gross Ground Water Draft for Domestic Uses (ham)	Existing Gross Ground Water Draft for Industrial Uses(ham)	Existing Gross Ground Water Draft for All Uses(ham)	Provision for Domestic and Industrial Requirement for Next 25 years(ham)	Net GW Availability for Future Irrigation Development(ham)	Stage of Ground Water Development (%)
	Gopalpur	3315.68	600.81	130.68	147.36	4194.53	419.45	3775.08	1290.20	116.15	70.32	1476.67	44.63	2440.25	39.12
	Ismailpur	2068.14	374.75	24.73	27.89	2495.51	249.55	2245.96	263.10	57.18	16.01	336.29	21.98	1960.88	14.97
	Jagdishpur	2749.44	498.2	45.46	51.26	3344.36	334.44	3009.92	463.60	1081.74	220.17	1765.51	275.28	2271.04	58.66
	Kahalgaon	8399.64	1522.03	139.23	157.01	10217.91	1021.79	9196.12	1461.20	536.74	119.80	2117.74	175.58	7559.34	23.03
	Nathnagar	3153.36	571.39	131.17	147.91	4003.83	400.38	3603.45	1395.40	185.29	79.94	1660.63	71.20	2136.85	46.08
	Pirpainti	8755.3	1586.47	168.2	189.68	10699.65	1069.97	9629.69	1749.40	333.20	104.13	2186.73	128.04	7752.25	22.71
Bhagalpur	Sabour	2875	520.95	107.55	121.27	3624.77	362.48	3262.29	1084.10	166.47	69.05	1319.62	63.97	2114.22	40.45
	Agaiyon	3804.25	501.04	1398.98	1076.87	6781.14	678.11	6103.00	1747.40	225.46	98.64	2071.50	86.64	4268.99	33.94
	Charpokhri	1945.75	351.1	1013.33	797.02	4107.2	205.36	3901.84	1517.40	154.03	83.57	1755.00	59.19	2325.25	44.98
	Garhani	2731.68	359.78	986.97	751.68	4830.11	483.01	4347.10	1342.60	156.91	74.98	1574.49	60.30	2944.20	36.22
	Jagdishpur	6286.68	827.99	2928.6	2622.55	12665.82	1266.58	11399.24	4968.60	518.21	294.07	5780.88	154.13	6276.51	50.71
	Pirro	5326.04	701.47	1321.58	2186.47	9535.56	953.56	8582.00	4512.20	509.29	268.52	5290.01	148.85	3920.95	61.64
	Sahar	2973.88	408.86	1081.24	790.86	5254.84	262.74	4992.10	880.40	167.57	52.40	1100.37	64.39	4047.31	22.04
	Sandesh	3172.61	417.85	1230.6	972.16	5793.22	579.32	5213.90	2099.00	166.72	113.29	2379.01	64.06	3050.84	45.63
Bhojpur	Tarari	4901.46	645.55	398.08	2286.72	8231.81	823.18	7408.60	3691.20	277.52	198.44	4167.16	106.64	3610.79	56.25
Buxar	Rajpur	6206.52	822.64	3762.54	2923.63	13715.28	1371.53	12343.75	5553.3	324.28	293.9	6171.98	124.69	6665.46	50

	Chaungai	1236.37	163.87	490.97	682.37	2573.58	257.36	2316.22	1476.30	74.07	77.52	1627.89	28.47	811.45	70.28
	Chausa	2428.94	323.97	1515.6	1146.83	5415.34	270.77	5144.57	2034.30	157.54	109.59	2301.43	60.54	3049.73	44.74
	Dumraon	4479.23	593.69	1477.69	1868.85	8419.46	841.95	7577.51	2292.30	354.60	142.26	2789.16	135.87	5149.34	36.81
	Itarhi	5179.19	686.47	3019.28	3085.81	11970.75	1197.08	10773.68	5189.10	259.29	272.42	5720.81	99.63	5484.95	53.10
	Kesath	696.58	92.33	594.39	499.73	1883.03	188.3	1694.73	693.60	51.39	37.25	782.24	19.75	981.38	46.16
	Nawanagar	4174.03	553.24	3811.36	3466.24	12004.87	1200.49	10804.38	2028.00	253.06	114.05	2395.11	97.24	8679.14	22.17
	Amdabad	3518.52	989.74	315.91	356.24	5180.41	518.04	4662.37	2648.60	254.38	145.15	3048.13	97.75	1916.02	65.38
	Barari	9171.68	1719.97	479.55	540.77	11911.97	1191.2	10720.77	4061.30	433.66	224.75	4719.71	166.64	6492.83	44.02
	Kursela	1708.43	320.38	106.93	120.58	2256.32	225.63	2030.69	910.00	97.14	50.36	1057.50	37.33	1083.36	52.08
	Manihari	6998.23	1312.38	19.65	22.15	8352.41	835.24	7517.17	167.20	386.96	42.90	597.07	111.77	7238.20	7.94
	Mansahi	2181.15	410	266.03	299.99	3157.17	157.86	2999.31	2264.10	128.04	119.61	2511.75	49.20	686.01	83.74
Katihar	Samili	3599.84	675.08	144.44	162.88	4582.24	458.22	4124.00	1229.30	128.38	67.88	1425.56	49.34	2845.38	34.57
	Belchi	1551.05	222.08	102.05	166.5	2041.68	204.17	1837.51	934.20	100.54	51.74	1086.48	38.64	864.67	59.13
	Daniawan	1470.42	210.53	112.2	183.06	1976.21	197.62	1778.59	1181.00	114.10	64.75	1359.85	43.85	553.74	76.46
	Dhanarua	4191.02	600.07	263.49	429.91	5484.49	548.45	4936.04	2427.00	321.20	137.41	2885.61	124.00	2343.07	58.96
	Dulhinbazar	2499.94	357.94	760.36	1732.59	5350.83	535.08	4815.75	597.00	189.90	39.34	826.24	73.00	4135.23	17.19
	Fathua	2854.1	408.65	216.3	352.9	3831.95	383.2	3448.76	1939.20	301.86	120.67	2361.73	116.00	1358.10	69.19
	Ghoshwari	2105.57	452.21	99.2	161.85	2818.83	281.88	2536.95	871.80	113.81	49.28	1034.89	44.00	1604.86	41.06
	Khusrupur	1386.62	198.54	65.27	106.49	1756.92	175.69	1581.23	618.00	223.17	51.32	892.49	64.00	888.19	56.84
	Masuarhi	4572.3	654.66	462.35	629.73	6319.04	631.9	5687.14	2964.60	582.38	214.78	3761.76	141.00	2533.90	66.70
	Paliganj	5370.07	768.88	3168.42	3131.73	12439.1	1243.91	11195.19	508.20	425.65	52.35	986.21	149.00	10528.90	8.82
	Punpun	2862.91	409.91	616.46	668.69	4557.97	455.8	4102.17	3001.80	209.92	160.59	3372.31	81.00	848.64	85.78
Patna	Sampatchak	1476.06	211.34	423.96	691.72	2803.08	280.31	2522.77	1741.20	162.39	95.18	1998.77	63.00	691.23	80.10

BLOCK WISE
AQUIFER MAPS AND MANAGEMENT PLANS

Salient Information

Name of the Block and Area (in km^2)
AMDABAD (189 sq. km)

District/ State
Katihar/Bihar

Rainfall

The normal annual rainfall of Amdabad block is 708.6 mm (2016) of which 87.46% occurs during the monsoon season. The normal rainfall during monsoon season is 619.9 mm and during non monsoon season is 88.7 mm.

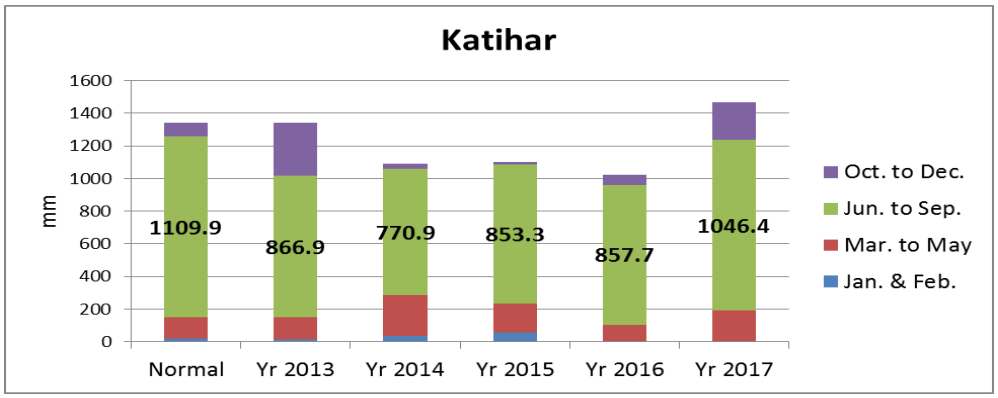


Fig 1 Season wise Normal Rainfall Vs Rainfall of Last 5 Years

Agriculture and irrigation

Block falls in the Agro-climatic Zone II. The cropping sequence followed in this zone is Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice- Wheat- Moong, Rice-Toria. The soils in this zone are sandy loam, clay loam. Soils are moderately acidic to neutral with a pH range of 6.5- 7.8. The variation of rainfall in this zone is from 1270 mm to 1700 mm with an average rainfall of 1450 mm, the temperature varies from 33.8 to 8.8˚C. Cropping intensity is 140.42 %. Irrigation intensity is 65.71%. Dependency of ground water irrigation is 95.26%.

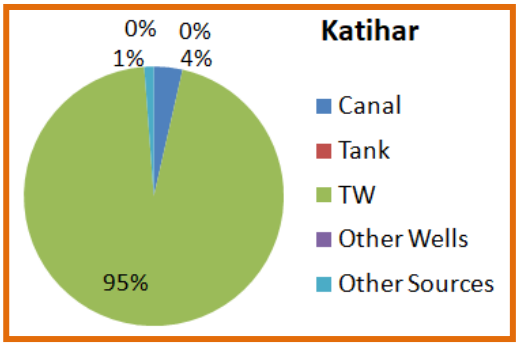


Fig 2 Irrigation Practices

Ground water resource availability and extraction

The dynamic ground water resource of Amdabad Block has been assessed as 46.62 MCM. The gross ground water draft for all uses stands at 30.48 MCM. The stage of ground water development is 65.38% (Annuexure I).

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Water level fluctuation is 2- 4 m in general. Ground water table is 25 - 30 m amsl in pre-monsoon period and 30 m amsl in post-monsoon period respectively. In general, ground water flow direction is towards south-east direction.

Aquifer disposition

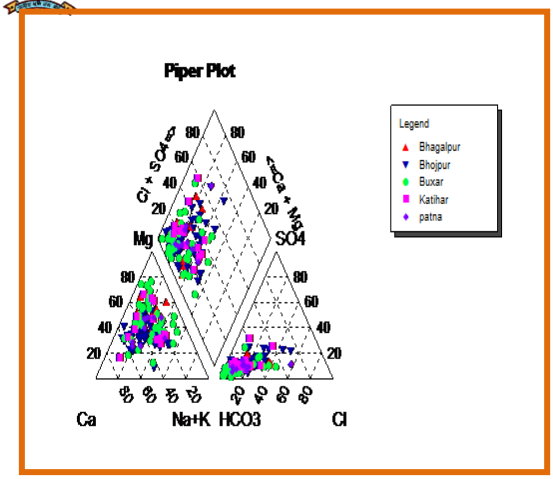
The area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the area. Average thickness of the aquifer is in the order of 210 m.The yield of aquifer is 100-200 m^3 /hr.

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 65.38 % and water level trend is not declining. Presently, 1236 STWs exist in the block. There is an ample scope for groundwater development in the block. An additional 113 STWs are feasible based on available GW Resource upto 70% SOD. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. Ground water exploration has revealed that the area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. It is obvious that with more irregular dewatering, vertical depth of arsenic contamination will increase. Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures. Regulation on dewatering must be imposed to control spreading of arsenic contamination.

Chemical quality of ground water and contamination

On the basis of Piper diagram, it is revealed that ground water of the block is mainly Ca-Mg-HCO3 type and it is the result of direct recharge of rainfall. As there is single aquifer exists, surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the long term solution. On the basis of USSL diagram, it is understood that it is suitable for irrigation. Salinity hazard is moderate to high.



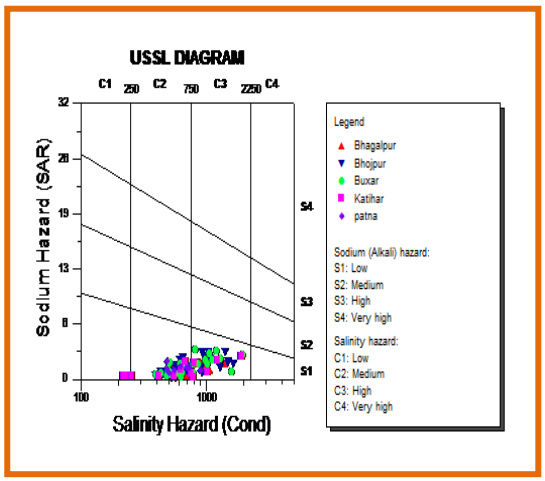


Fig 3 Piper Plot

Fig 4 USSL Diagram

1. Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

2. Demand side interventions

Extensive dewatering may increase the vertical depth of arsenic contamination. Shallow aquifer may be use for irrigation purpose. Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon (ham)	Recharge from rainfall Non-Monsoon(ham)	Recharge from other sources Monsoon(ham)	Recharge from other sources Non-Monsoon(ham)	Total ground water recharge	Provision for natural discharge (ham)	Net ground water availibility(ham)	Existing Gross Ground Water Draft for irrigation(ham)	Existing Gross Ground Water Draft for Domestic Uses (ham)	Existing Gross Ground Water Draft for Industrial Uses(ham)	Existing Gross Ground Water Draft for All Uses(ham)	Provision for Domestic and Industrial Requirement for Next 25 years(ham)	Net GW Availability for Future Irrigation Development(ham)	Stage of Ground Water Development (%)
Katihar	Amdabad	3519	989.7	315.9	356.24	5180.41	518	4662.37	2648.6	254.38	145.15	3048.13	97.75	1916.02	65.38

Annexure II

Chemical Analysis of Ground Water Samples

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Katihar	Amdabad	Kishanpur	7.44	552	359	0.15	16.3	301.35	0	36.19	8.87	BDL	260	28	46.17	11.71	4.03
Katihar	Amdabad	Balrampur	7.46	1215	790	0.13	103	528.9	0	59.77	19.7	BDL	315	50	46.17	86.12	62.8

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
MANIHARI (251 sq. km)
District/ State
Katihar/Bihar

Rainfall

The normal annual rainfall of Manihari block is 849.8 mm of which 80.46% occurs during the monsoon season. The normal rainfall during monsoon season is 805.6 mm and during non monsoon season is 94.7 mm.

Agriculture and irrigation

The Block falls in the Agro-climatic Zone II. The cropping sequence followed in this zone is jute-wheat, jute-potato, jute-kalai, jute-mustard, rice-wheat-moong, rice-toria. The soils in this zone are sandy loam, loam with pH in the range of 6.5 – 8.4. The variation of rainfall in this zone is from 1040 mm to 1450 mm and the temperature varies from 36.6 to 7.7˚C. Irrigation intensity is 65.71%. Cropping intensity is 140.42% and ground water dependency is 95.26%.

Ground water resource availability and extraction

The dynamic ground water resource of Manihari block has been assessed as 75.17 MCM. The gross ground water draft for all uses stands at 42.9 MCM. The stage of Development is 7.94% (Annuexure I).

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Water level fluctuation is 2- 4 m. Water table is 25 to 30 m amsl in premonsoon and 30 to 35 m amsl in post monsoon period respectively. Ground water flow direction is towards south-east.

Aquifer disposition

The area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the area. Average thickness of the aquifer is in the order of 210 m.The yield of aquifer is 100-200 m^3/hr.

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 7.94%. There is an ample scope for groundwater development in the block. Presently, 78 STWs exist in the block. There is an ample scope for groundwater development in the block. An additional

2455 STWs are feasible based on available GW Resource (nos.) upto 70% SOD. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. Ground water exploration has revealed that the area is bestowed with single aquifer system It is obvious that with more estensive dewatering, vertical depth of arsenic contamination will increase. Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures.

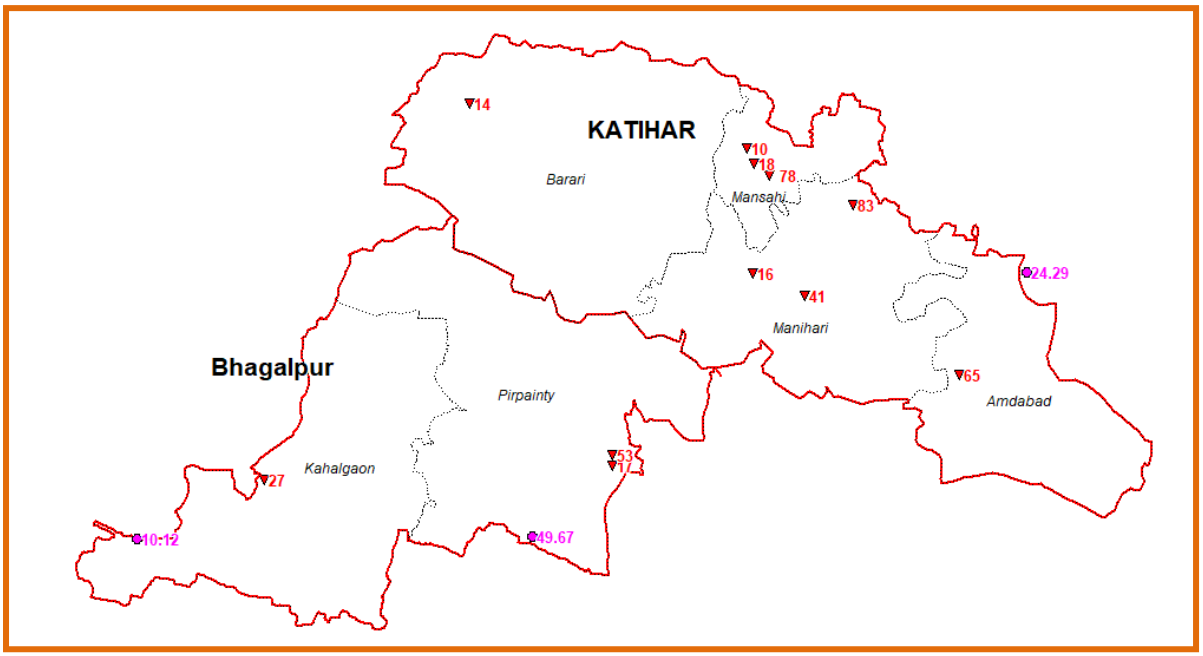


Fig 1 Arsenic contamination in shallow aquifer

Chemical quality of ground water and contamination

Mainly ground water is Ca-Mg-HCO3 type. On the basis of USSL diagram, it is suitable for irrigation, but salinity hazards are moderate to high.

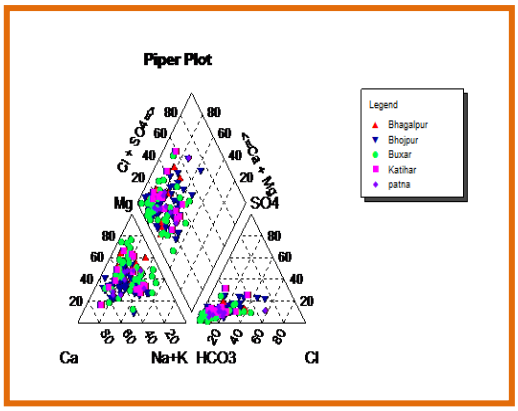


Fig 2 Piper Plot

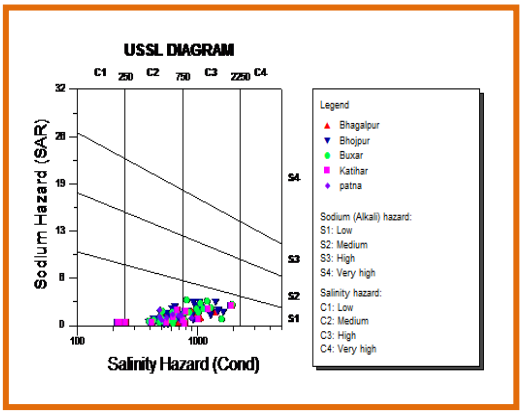


Fig 3 USSL diagram

Ground water resource enhancement

As the stage of groundwater development is very low and within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Extensive dewatering may increase the vertical depth of arsenic contamination. Shallow aquifer may be use for irrigation purpose. Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply.

Annexure I

Dynamic Ground Water Resources

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category:safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Katihar	Manihari	6998.23	1312.38	19.65	22.15	8352.41	835.24	7517.17	167.20	386.96	42.90	597.07	111.77	7238.20	7.94	Safe

Annexure II

Chemical Analysis of Ground Water Samples

District	Block	Village	pH	EC (µs) /cm at 25	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Katihar	Manihari	Manihari P.S.	7.98	1906	1239	0.26	193	615	0	71.63	74.4	BDL	475	90	60.75	128.9	57.1
Katihar	Manihari	Kunwaripur	7.39	668	434	0.28	28.36	362.85	0	28.8	1.49	BDL	180	38	20.65	59.71	11.4
Katihar	Manihari	Tatrai Tola	7.53	224	146	0.17	12.2	123	0	10.7	3.54	BDL	100	22	10.93	6	5.44

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Kursela (61 sq. km)
District/ State
Katihar/Bihar

Rainfall

The normal annual rainfall of Kursela block is 834.6 mm of which 95% occurs during the monsoon season. The normal rainfall during monsoon season is 792.2 mm and during non monsoon season is 42.4mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone II (Northern East). The cropping sequence followed in this zone is Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice – Wheat – Moong, and Rice – Toria. The soils in this zone are sandy loam, clay loam, with pH in the range of 6.8 – 7.8. The variation of rainfall in this zone is from 990 mm to 1240 mm and the temperature varies from 33.81 to 8.8˚C. Cropping intensity is 140.42% and dependency on ground water irrigation is 95%.

Ground water resource availability and extraction

The dynamic ground water resource of Kursela block has been assessed as 20.30 MCM. The gross ground water draft for all uses stands at 10.57 MCM. The stage of Development is 52.08 %.

Water level behaviour

The depth to water level varies from 5 to 8 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 6 mbgl.

Aquifer disposition

The area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area.Thickness of the aquifer is 237 m in general.

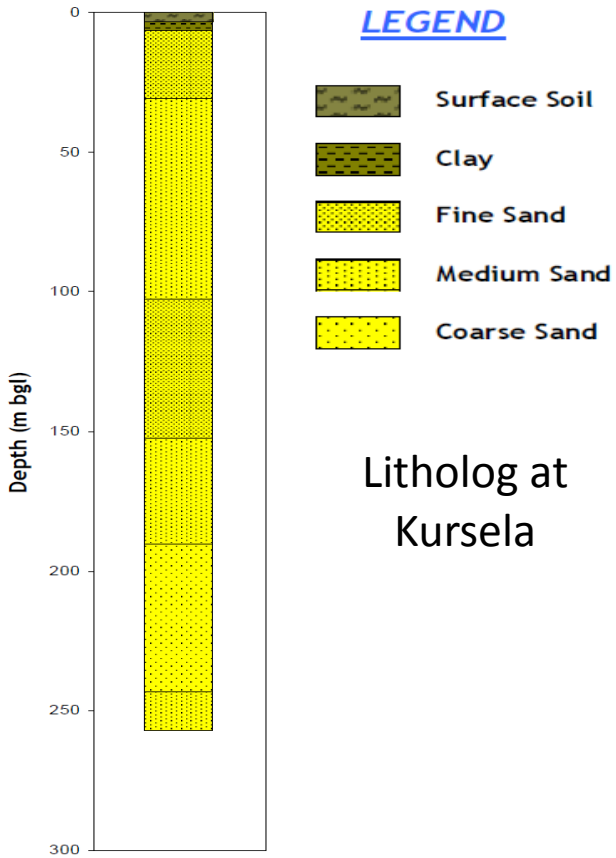


Fig 1 Litholog of Kursela (CGWB)

Ground water resource, extraction, contamination and other issues

Sufficient scope exists for groundwater development in the block. An additional 191 STWs are feasible based on available GW Resource considering upto 70% SOD. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. Ground water exploration has revealed that the area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. It is obvious that with more irregular dewatering, vertical depth of arsenic contamination will increase. Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures.

Chemical quality of ground water and contamination

On the basis of USSL diagram, it is understood that ground water is suitable for irrigation, but salinity hazards is moderate to high.

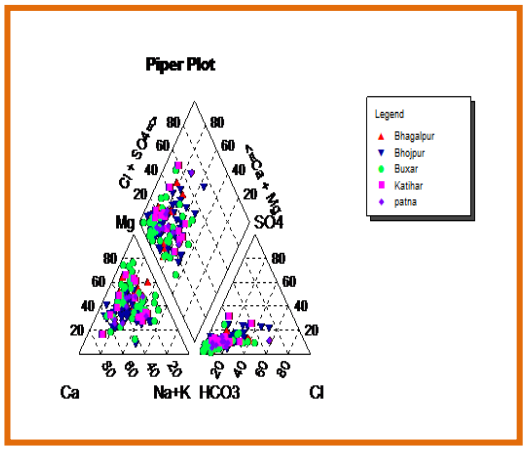


Fig 2 Piper plot

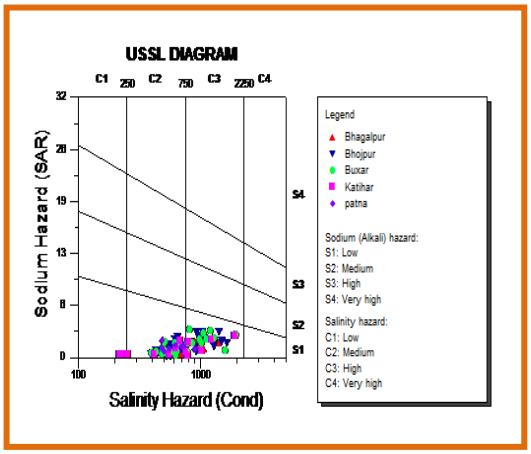


Fig 3 USSL diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Regulation may be imposed on dewatering of the single aquifer as arsenic contamination will spread vertically depending on draft of ground water. Artificial recharge to augment ground water resource may be thought as it will dilute arsenic contamination.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category:safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	52.08	Safe
Katihar	Kursela	1708.43	320.38	106.93	120.58	2256.32	225.63	2030.69	910.00	97.14	50.36	1057.50	37.33	1083.36		

Annexure II

Chemical Analysis of Groundwater Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Katihar	Kursela	Kursela	7.81	1012	658	0.33	76.5	498.15	0	32.16	10	BDL	435	40	81.4	35.5	32

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
MANSAHI (177 sq. km)
District/ State
Katihari/Bihar

Rainfall

The normal annual rainfall of Mansahi block is 1104.9 mm of which 80.46% occurs during the monsoon season. The normal rainfall during monsoon season is 889.05 mm and during non monsoon season is 213.35 mm.

Agriculture and irrigation

The Block falls in the Agro-climatic Zone II. The cropping sequence followed in this zone is Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice – Wheat – Moong, and Rice – Toria. The soils in this zone are sandy loam, loam with pH in the range of 6.5 – 8.4. The variation of rainfall in this zone is from 1040 mm to 1450 mm and the temperature varies from 36.6 to 7.7˚C.

Ground water resource availability and extraction

The dynamic ground water resource of Mansahi block has been assessed as 29.99 MCM. The gross ground water draft for all uses stands at 25.11 MCM. The stage of Development is 83.74% (Annuexure I).

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Water table varies from 30 to 35 m amsl in premonsoon period. Ground water flow direction is towards south east.

Aquifer dsposition

The area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area.Thickness of the aquifer is 210 m.

Ground water resource, extraction, contamination and other issues

Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. Ground water exploration has revealed that the area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. It is obvious that with more estensive dewatering, vertical depth of arsenic contamination will increase. Surface water supply with

filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures.

Chemical quality of ground water and contamination

On the basis of Piper diagram ground water of the block is potable and on the basis of USSL diagram it is suitable for irrigation.

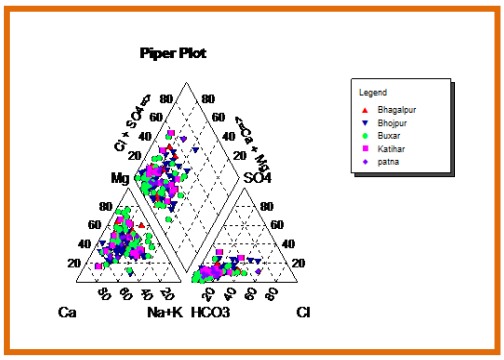


Fig 1 Piper Plot

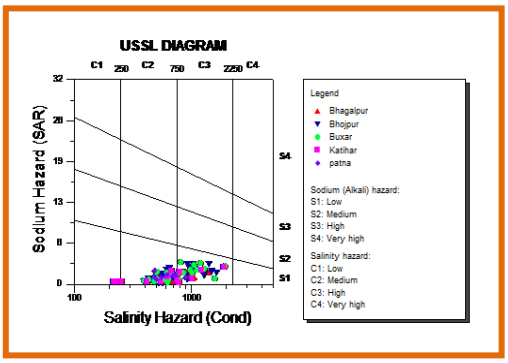


Fig 2 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is high, the need for artificial recharge may be thought and it may dilute arsenic contamination.

Demand side interventions

In view of the issue of arsenic contamination, it is recommended to use arsenic filter for domestic requirement. Necessary regulations to enforce to restrict dewatering for arsenic contamination depth wise.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Katihar	Mansahi	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
		2181.15	410	266.03	299.99	3157.17	157.86	2999.31	2264.10	128.04	119.61	2511.75	49.20	686.01	83.74	

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Katihar	Mansahi	Tarari Tola	7.53	224	146	0.17	12.2	123	0	10.7	3.54	BDL	100	22	10.93	6	5.44

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Barari (328 sq. km)

District/ State
Katihari/Bihar

Rainfall

The normal annual rainfall of Barari block is 810.8 mm of which 87.7% occurs during the monsoon season. The normal rainfall during monsoon season is 711.4 mm and during non monsoon season is 99.4 mm.

Agriculture and Irrigation

The Block falls in the Agro-climatic Zone II. The cropping sequence followed in this zone is Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice – Wheat – Moong, and Rice – Toria. The soils in this zone are sandy loam, loam with pH in the range of 6.5 – 8.4. The variation of rainfall in this zone is from 1040 mm to 1450 mm and the temperature varies from 36.6 to 7.7˚C. Cropping intensity is 140.42% and irrigation intensity is 65.71%. Ground water dependency for irrigation is 95.26%.

Ground water resource availability and extraction

The dynamic ground water resource of Barari block has been assessed as 107.70 MCM. The gross ground water draft for all uses stands at 47.19 MCM. The stage of Development is 44.02% (Annuexure I). 1894 STWs exist in the block and an additional 1465 STWs may be constructed with available ground water resource in the block.

Water level behaviour

The depth to water level varies from 2 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Water level fluctuation is 2 – 4 m. Premonsoon water table varies from 30 to 35 m amsl.

Aquifer Disposition

The area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area. Average thickness of aquifer is 250 m in general.

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 44.02% and water level trend is not declining in nature.Sufficient scope exists for groundwater development in the block. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in

shallow depth. Ground water exploration has revealed that the area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. Ground water regulation is needed to restrict dewatering otherwise arsenic contamination will increase vertically. Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures.

Chemical quality of ground water and contamination

On the basis of USSL diagram, it is inferred that ground water is suitable for irrigation, but salinity hazard is moderate to high.

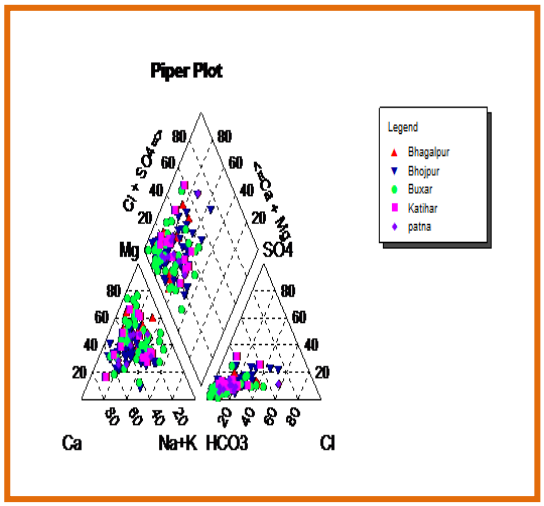


Fig 1 Piper Plot

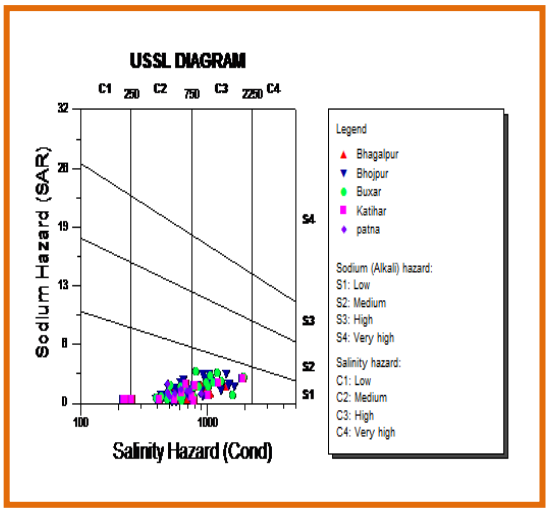


Fig 2 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limits and there is no water level decline found in the area, the need for artificial recharge is not felt.

Demand side interventions

Extensive dewatering may increase the vertical depth of arsenic contamination. Shallow aquifer may also be used for irrigation purpose. Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply. Artificial recharge may be thought to dilute arsenic contamination as well as to augment ground water resources.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Katihar	Barari	9171.68	1719.97	479.55	540.77	11911.97	1191.2	10720.77	4061.30	433.66	224.75	4719.71	166.64	6492.83	44.02	Safe

Annexure II

Chemical analysis of ground water samples

District	Block	Village	pH	EC(microsiemens/cm)	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Katihar	Barari	Bari Behra	7.48	414	269	0.09	42.1	86.1	0	40.29	46.3	BDL	200	36	26.73	8.88	7.19
Katihar	Barari	Barari	7.64	217.9	142	0.25	11.5	98.4	0	40.47	1.05	BDL	140	46	6.07	9	2.46
Katihar	Barari	Yadavtoli	7.82	621	404	0.25	38.3	289.05	0	41.06	3.81	BDL	175	28	25.51	33.18	51.55
Katihar	Barari	Goharasthan	7.49	251	163	0.3	5.64	135.3	0	12.4	0.32	BDL	125	32	10.93	7	2.69
Katihar	Barari	Lakshmipur	7.76	798	519	0.21	70.9	369	0	34.76	1.87	BDL	245	50	29.16	65.41	12.95

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
SAMELI (129 sq. km)

District/ State
Katihar/Bihar

Rainfall

The normal annual rainfall of Begusarai district is 814.44 mm of which 80.46% occurs during the monsoon season. The normal rainfall during monsoon season is 706.74 mm and during non monsoon season is 107.7 mm.

Agriculture and Irrigation

The Block falls in the Agro-climatic Zone II. The cropping sequence followed in this zone is Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice – Wheat – Moong, and Rice – Toria. The soils in this zone are sandy loam, loam with pH in the range of 6.5 – 8.4. The variation of rainfall in this zone is from 1040 mm to 1450 mm and the temperature varies from 36.6 to 7.7˚C. Cropping intensity is 140.42%.

Ground water resource availability and extraction

The dynamic ground water resource of Samili Block has been assessed as 41.24 MCM. The gross ground water draft for all uses stands at 14.25 MCM. The stage of Development is 34.57% (Annuexure I). Ground water dependency for irrigation is 95%. An additional 769 STWs may be constructed with available ground water resource in the block.

Water level behaviour

The depth to water level varies from 5 to 7 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from and 2 to 4 mbgl in some.

Aquifer disposition

The area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl in most of the study area. The section depicting the aquifer disposition is shown below (Fig. 1). Average thickness of aquifer is 106 m.

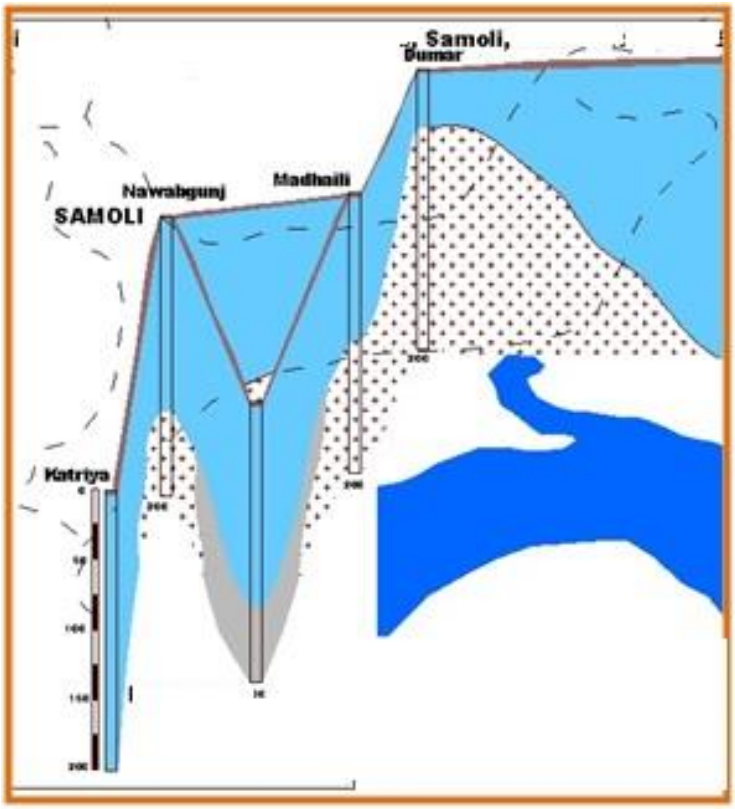


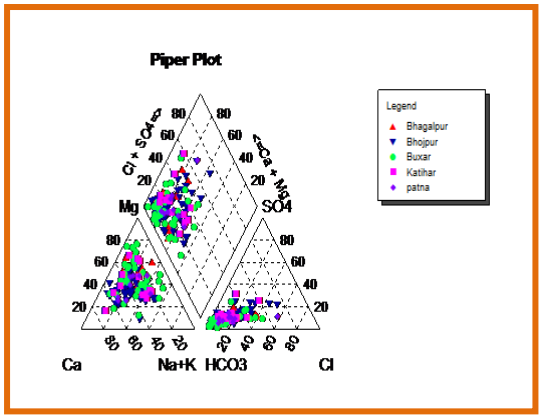
Fig 1 Lithological section

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 34.57% and water level trend is not declining. There is scope exists for groundwater development in the block. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. Ground water exploration has revealed that the area is bestowed with mono-aquifer system with thin layer of clay (~ 15 m) at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. It is obvious that with more estensive dewatering, vertical depth of arsenic contamination will increase. Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures.

Chemical quality of ground water and contamination

On the basis of Piper diagram ground water of the block is potable and on the basis of USSL diagram it is suitable for irrigation.



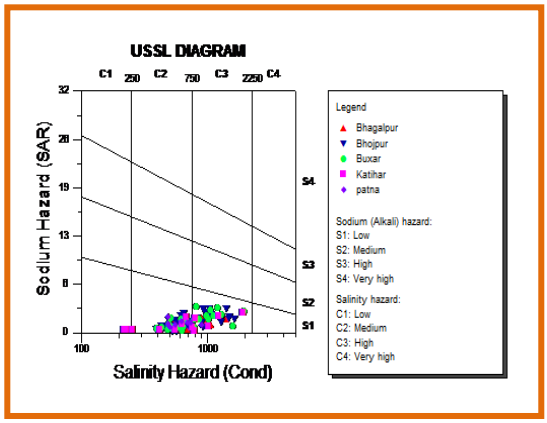


Fig 2 Piper Plot

Fig 3 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limits and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Extensive dewatering may increase the vertical depth of arsenic contamination. Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply. Artificial recharge may be thought to dilute arsenic contamination as well as to augment ground water resources.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category:safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Katihar	Samili	3599.84	675.08	144.44	162.88	4582.24	458.22	4124.00	1229.30	128.38	67.88	1425.56	49.34	2845.38	34.57	Safe

Annexure II

Chemical analysis of ground water samples

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Katihar	Sameli	Dumaria	7.77	758	493	0.26	31.6	362.85	0	38.32	52.5	BDL	280	40	43.74	24.71	42.95
Katihar	Sameli	Dumaria	7.45	785	510	0.29	49	362.85	0	33.9	27.5	BDL	335	32	61.96	8.62	45.75

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Gopalpur (132 sq. km)

District/ State
Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Bhagalpur district is 903.5 mm of which 79.5% occurs during the monsoon season. The normal rainfall during monsoon season is 718.8 mm and during non monsoon season is 184.7 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone II. The cropping sequence followed in this zone is Jute – Wheat, Jute – Potato, Jute – Kalai, Jute – Mustard, Rice – Wheat – Moong, and Rice – Toria. The soils in this zone are sandy loam, loam with pH in the range of 6.5 – 8.4. The variation of rainfall in this zone is from 1040 mm to 1450 mm and the temperature varies from 36.6 to 7.7˚C. Cropping intensity is 125% and ground water dependency for irrigation is 92%.

Ground water resource availability and extraction

The dynamic ground water resource of Gopalpur block has been assessed as 37.75 MCM. The gross ground water draft for all uses stands at 14.76 MCM. The stage of Development is 39.12% (Annuexure I). An additional 896 STWs may be constructed with the available ground water resource considering SOD up to 70% from shallow aquifer.

Water level behaviour

The depth to water level varies from 5 to 8 mbgl during pre-monsoon period. In post monsoon season, the depth to water level varies from 2 to 5 mbgl.

Aquifer disposition

The area is bestowed with mono-aquifer system with thin layer of clay at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl (Fig 1). Average thickness of single aquifer is 238 m.

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 39.12% and water level trend is not declining. There is an ample scope for groundwater development in the block. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth.

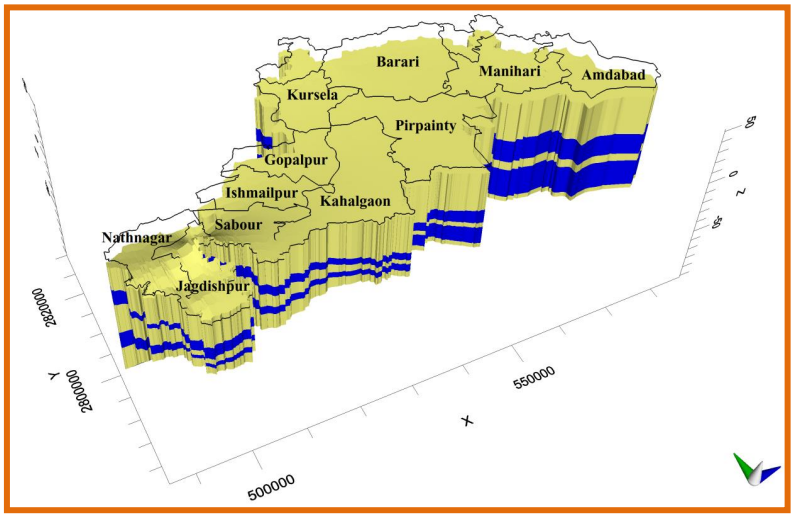


Fig 1 3D Disposition of Aquifer System

Chemical quality of ground water and contamination

Arsenic has been reported from Gopalpur. Arsenic occurs more than the permissible limit of 0.01 mg/L. Arsenic occurs sporadically in hand pumps and it largely depends on the depth of the hand pump. In dug wells arsenic concentration is reported as below detection limit (BDL).

On the basis of Piper diagram, it can be said that ground water of the block is Ca-Mg-HCO3 type. USSL diagram indicates that ground water is fit for irrigation.

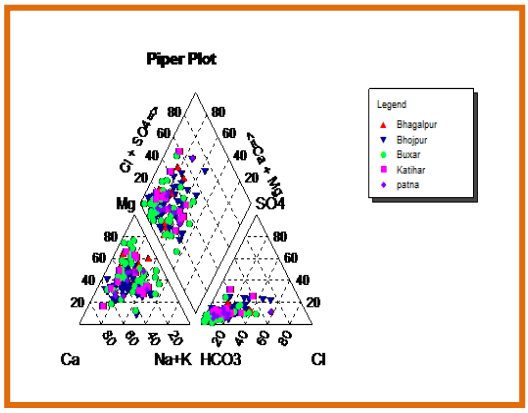


Fig 2 Piper Diagram

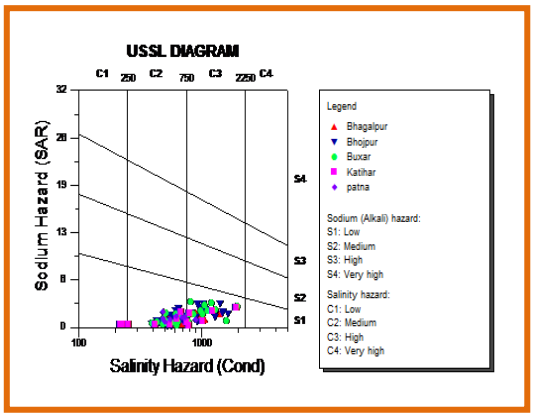


Fig 3 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area. Artificial recharge to ground water may be thought to dilute arsenic contamination in shallow aquifer.

Demand side interventions

Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply from shallow aquifer.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category:safe/semi-critical/critical/over-exploited.
Bhagalpur	Gopalpur	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		Safe
		3315.68	600.81	130.68	147.36	4194.53	419.45	3775.08	1290.20	116.15	70.32	1476.67	44.63	2440.25	39.12	

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhagalpur	Gopalpur	Gopalpur	7.45	594	386.1	0.13	7.09	369	0	13.74	2.06	0	180	38	20.655	45.85	4.29
Bhagalpur	Gopalpur	Tia dangakarai	7.68	543	352.95	0.16	18.25	313.65	0	13.28	3.67	0	195	38	24.3	38.79	3.46

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
ISMAILPUR (83 sq. km)

District/ State
Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Ismailpur block is 848.8 mm of which 82.13% occurs during the monsoon season. The normal rainfall during monsoon season is 697.2 mm and during non monsoon season is 151.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic zone IIIA. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. The soils in this zone are Sandy loam, Clay loam, loam, Clay with pH in the range of 6.8–8.0. The variation of rainfall in this zone is from 990 – 1240 mm and the temperature varies from 37.1-7.8. Cropping intensity is 125% and ground water dependency for irrigation is 92%.

Ground water resource availability and extraction

The dynamic ground water resource of Ismailpur block has been assessed as 22.45 MCM. The gross ground water draft for all uses stands at 3.36 MCM. The stage of Development is 14.97% (Annuexure I).

Water level behaviour

The depth to water level varies from 5 to 7 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl and in northern parts it is less than 2 mbgl.

Aquifer disposition

The area is bestowed with mono-aquifer system with thin layer of clay at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. Average thickness of single aquifer is 238 m (Fig 1).

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 14.97% and water level trend is not declining. There is an ample scope for groundwater development in the block. Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. The area is bestowed with mono-aquifer system with thin layer of clay at the top and sand sequence of varying grade is continuing down to the depth of 300 m bgl. It is

obvious that with more estensive dewatering, vertical depth of arsenic contamination will increase. Surface water supply with filtration and/or community based tube wells fitted with arsenic removal plants should be the reasonable mitigation measures.

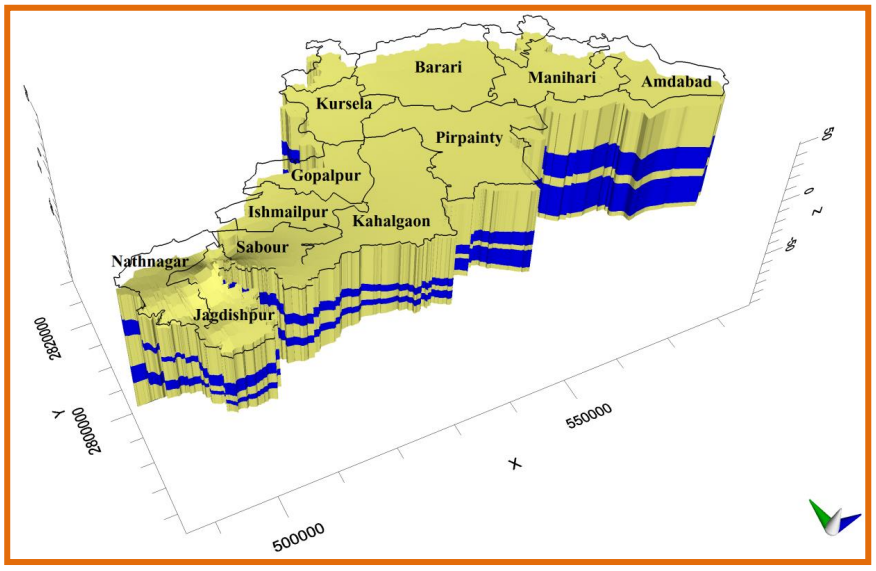


Fig 1 3D Disposition of Aquifer System

Chemical quality of ground water and contamination

Arsenic has been reported from Ismailpur. Arsenic occurs sporadically in hand pumps and it largely depends on the depth of the hand pump and from which formation it taps water. In dug wells arsenic concentration is reported as below detection limit (BDL**).**

On the basis of Piper diagram, it can be said that ground water of the block is mainly Ca-Mg-HCO3 type and USSL diagram indicates that ground water is suitable for irrigation.

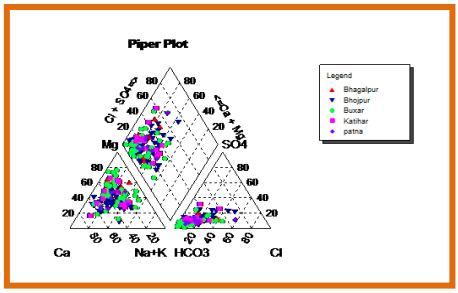


Fig 2 Piper Plot

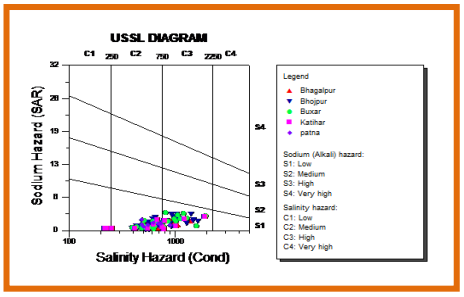


Fig 3 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no water level decline in the area, the need for artificial recharge is felt.

Demand side interventions

Extensive dewatering may increase the vertical depth of arsenic contamination. Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply. Artificial recharge to ground water may dilute arsenic contaminated ground water and also augment ground water resources.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhagalpur	Ismailpur	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		Safe
		2068.14	374.75	24.73	27.89	2495.51	249.55	2245.96	263.10	57.18	16.01	336.29	21.98	1960.88	14.97	

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3 -	CO32-	SO42-	NO3-	PO43 -	TH	Ca2+	Mg2+	Na+	K+
Bhagalpur	Ismailpur	Wast bihta Ismailp ur	7.31	567	368.5 5	0.11	28.36	282.9	0	29.82	6.71	0	260	44	36.45	12.15	5.34

Block wise
Aquifer Maps and Management plans

1. Salient Information

Name of the Block and Area (in km^2)
JAGDISHPUR (110 sq. km)

District/ State
Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Jagdishpur block is 842 mm of which 83.75% occurs during the monsoon season. The normal rainfall during monsoon season is 705.2 mm and during non monsoon season is 136.8 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic zone IIIA. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. The soils in this zone are Sandy loam, Clay loam, loam, Clay with pH in the range of 6.8–8.0. The variation of rainfall in this zone is from 990 – 1240 mm.

Ground water resource availability and extraction

The dynamic ground water resource of Jagdishpur block has been assessed as 30.09 MCM. The gross ground water draft for all uses stands at 17.65 MCM. The stage of Development is 58.66% Annuexure I.

Water level behaviour

The depth to water level varies from 4 to 6 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 5 mbgl except in central part where it is between 2 to 5 mbgl.

Aquifer Disposition

Two-aquifer sysytem prevails in the area (Fig.1, 4). On the northern part of the block, the thickness of first aquifer varies from 15 to 20 m bgl and separated by 48-62 m thick clay layer from the second aquifer. Depth of second aquifer varies from 70-80 to 97-140 m bgl, underlain by granite gneiss. Two aquifer system has also been found in southern part of the block overlain by 22 to 25 m thick clay layer, second aquifer is of 15 to 20 m thick upto depth of 60 -80 m bgl underlain by granite gneiss. The yield of 1st aquifer varies from 50 to 100 m^3 /hr where as the yield of 2nd aquifer varies from 100 to 200 m^3 /hr with 9 m drawdown. Cumulative transmissivity is in the order of 5918 m^2 /day.

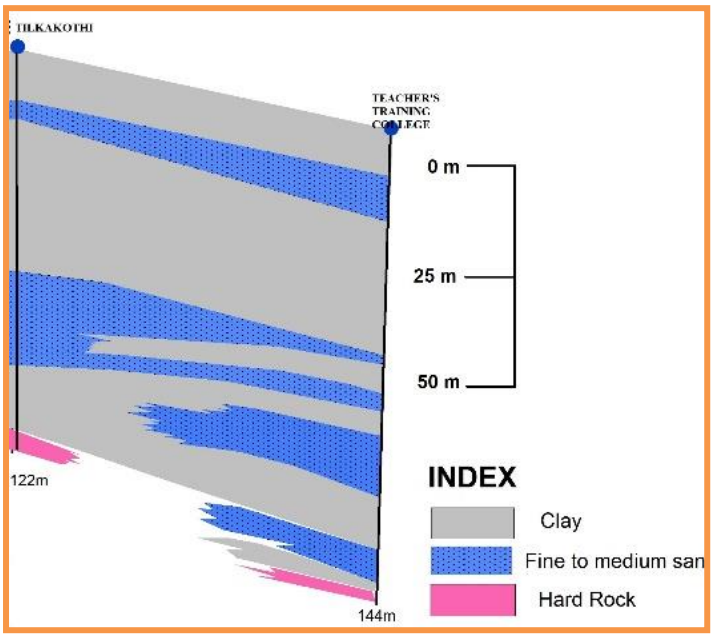


Fig 1 Lithological Section

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 58.66% and water level trend is not declining. There is an ample scope for groundwater development in the block. Arsenic contamination (>10 ppb) of groundwater has been reported from 1st aquifer in shallow depth. Ground water exploration has revealed that the area is bestowed with two aquifer system. 2nd aquifer should be used for pipe water supply.

Chemical quality of ground water and contamination

Arsenic occurs sporadically in hand pumps. In dug wells arsenic concentration is reported as below detection limit (BDL).

On the basis of USSL diagram, it can be said that ground water is fit for irrigation.

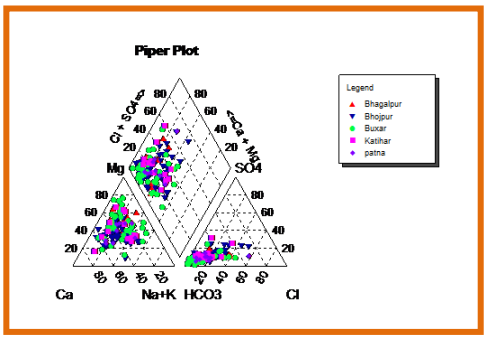


Fig 2 Piper plot

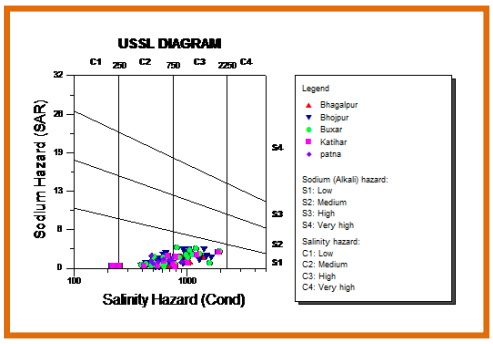


Fig 3 USSl diagram

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no water level decline in the area. Still, artificial recharge to ground water may be thought to augment ground water resources as well as to dilute arsenic contamination.

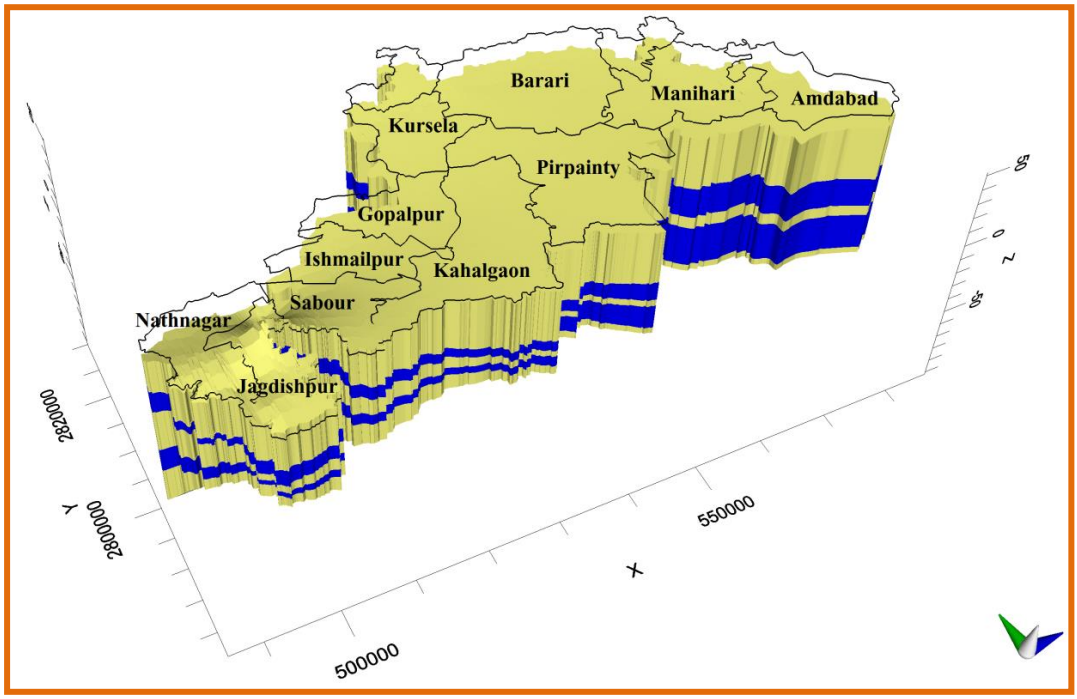


Fig 4 3D Disposition of Aquifer System

Demand side interventions

Deeper aquifer may be strictly used for drinking water supply. Filtration and/or community based tube wells fitted with arsenic removal plants can also be used for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhagalpur	Jagdishpur	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		Safe
		2749.44	498.2	45.46	51.26	3344.36	334.44	3009.92	463.60	1081.74	220.17	1765.51	275.28	2271.04	58.66	

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F^-	Cl^-	HCO^{3-}	CO_3^{2-}	$SO4^{2-}$	NO^{3-}	PO_4^{3-}	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
Bhagalpur	Jagdispur	Sonauli	7.84	902	586.3	1.62	28.36	436.65	0	7.84	1.24	0	315	34	55.89	74.13	0.77

Block wise
Aquifer Maps and Management plans

1. Salient Information

Name of the Block and Area (in km^2)
Kahalgaon (241 sq. km)

District/ State
Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Kahalgaon block is 839.1mm of which 88.09% occurs during the monsoon season. The normal rainfall during monsoon season is 739.2 mm and during non monsoon season is 99.9 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic zone IIIA. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. The soils in this zone are Sandy loam, Clay loam, loam, Clay with pH in the range of 6.8–8.0. The variation of rainfall in this zone is from 990 – 1240 mm and the temperature varies from 37.1-7.8. Cropping intensity is 125% and irrigation intensity is 42.38%. Ground water dependency for irrigation is 91.04%.

Ground water resource availability and extraction

The dynamic ground water resource of Kahalgaon block has been assessed as 91.96 MCM. The gross ground water draft for all uses stands at 21.17 MCM. The stage of Development is 23.03% (Annuexure I).

Water level behaviour

The depth to water level varies from 5 to 18 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 5 to 9 mbgl. Water level fluctuation is of 2-4 m. Water table varies from 35 to 55 m amsl and flow direction is towards north side.

Aquifer Disposition

Shallow aquifer in Kahalgaon occurs within 132 m bgl (Fig 1). After that no potential aquifer has been encountered. Alluvium thickness is about 50 m and underlain by hard rock. Alluvium thickness increases toward northern part of the block near River Ganga. The yield of tube well is 14 – 37 m^3 /hr with drawdown of 6-11 m. Transmissivity varies from 126 to 4207 m^2 /day.

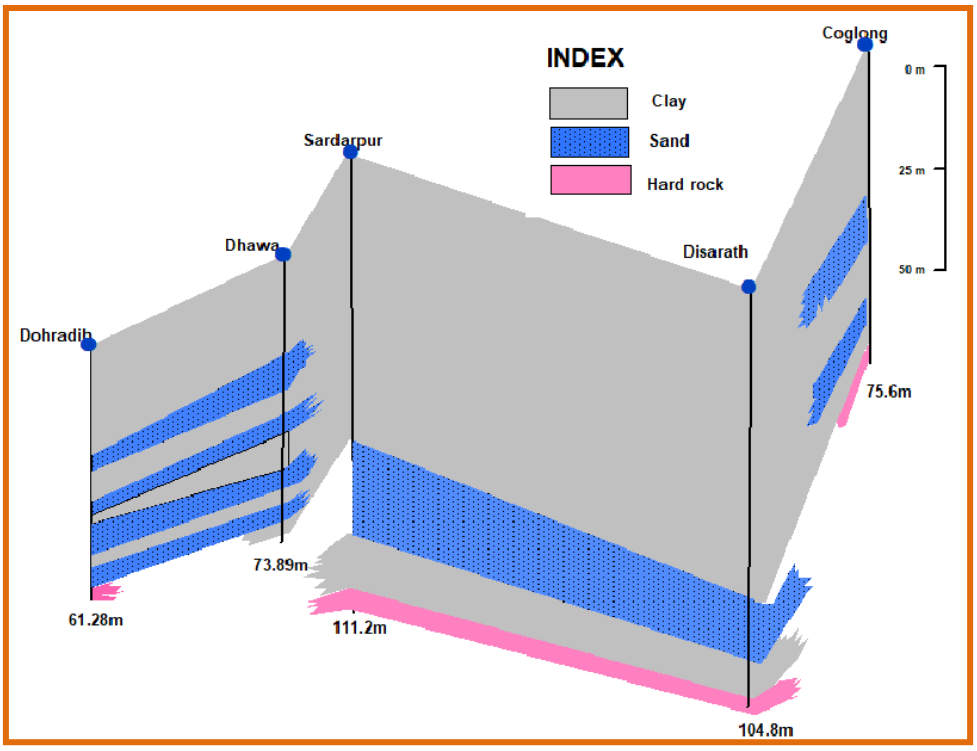


Fig.1 Lithological section

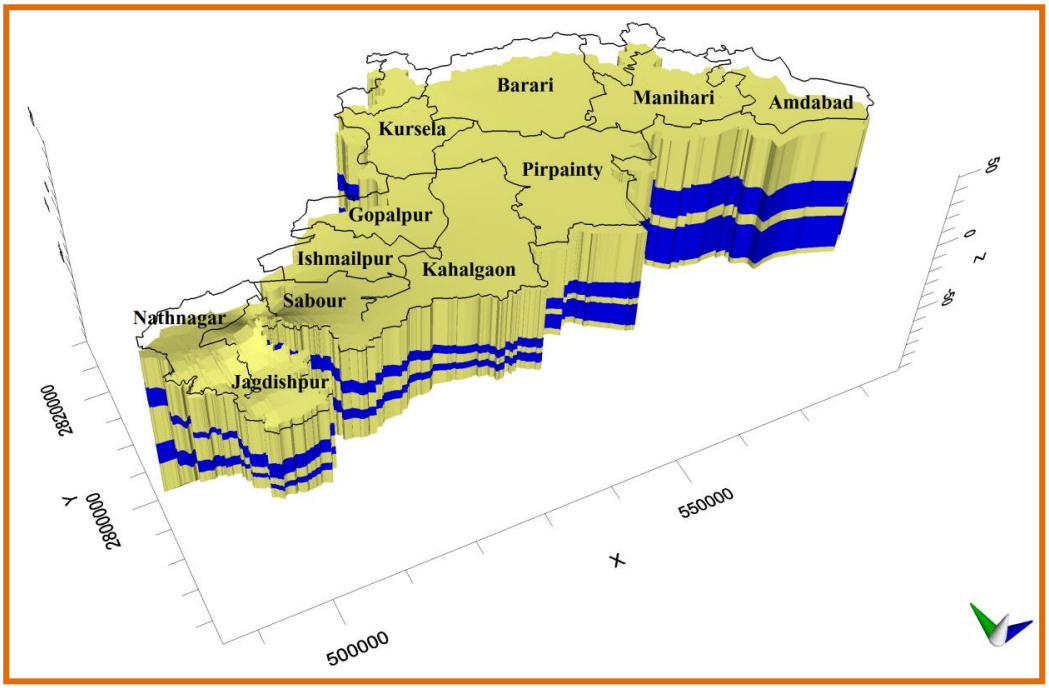


Fig 2 3D Disposion of Aquifer system

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 23.03% and water level trend is not declining. 1190 STWs exist there. An additional 3322 STWs are feasible with available ground water resources.

Chemical quality of ground water and contamination

Arsenic occurs sporadically in hand pumps and it largely depends on the depth of the hand pump from which formation it taps water. In dug wells, arsenic concentration is reported as below detection limit (BDL). Arsenic contamination in shallow aquifer may be diluted with the aid of artificial recharge and it will augment ground water resource also.

Ground water resource enhancement

As the stage of groundwater development is within the safe limits and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply otherwise surface water supply after filtration may be long term solution of pipe water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhagalpur	Kahalgaon	8399.64	1522.03	139.23	157.01	10217.91	1021.79	9196.12	1461.20	536.74	119.80	2117.74	175.58	7559.34	23.03	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F^-	Cl^-	HCO^{3-}	CO_3^{2-}	$SO4^{2-}$	NO^{3-}	PO_4^{3-}	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
Bhagalpur	Kahalgaon	Dhanaura	7.3	784	509.6	0.21	35.45	424.35	0	15.05	8.12	0	290	14	61.96	65.47	1.63
Bhagalpur	Kahalgaon	Sonsthpur	7.1	1405	913.25	0.74	170.16	350.55	0	55.59	67	0	480	80	68.04	88.3	3.27

Block wise
Aquifer Maps and Management plans

1. Salient Information

Name of the Block and Area (in km^2)

NATHNAGAR (241 sq. km)

District/ State

Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Nathnagar block is 987.9 mm of which 87.03% occurs during the monsoon season. The normal rainfall during monsoon season is 860.1 mm and during non monsoon season is 127.8 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIA. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The variation of rainfall in this zone is from 990 mm to 1240 mm and the temperature varies from 37.1 to 7.8˚C.

Ground water resource availability and extraction

The dynamic ground water resource of Nathnagar block has been assessed as 36.03 MCM. The gross ground water draft for all uses stands at 16.6 MCM. The stage of Development is 46.08% (Annuexure I). An additional 662 STWs are feasible for construction with available ground water resources.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 6 mbgl.

Aquifer Disposition

The block is bestowed with two-aquifer sysytem (Fig.1, 2). On the northern part of the block, the thickness of 1st aquifer varies from 15 to 20 m bgl and separated by 48-62 m thick clay layer from the 2nd aquifer. The yield of tube well varies from 20 to 50 m^3 /hr with 11-15 m drawdown. Depth of second aquifer varies from 70-80 to 97 -140 m bgl, underlain by granite gneiss. Two aquifer system has also been found in southern part of the block overlain by 22 to 25 m thick claylayer, second aquifer is of 15 to 20 m thick upto depth of 60 - 80 m bgl underlain by granite gneiss. The yield of 2nd aquifer is in order of 100 m^3 /hr with 6 m drawdown.

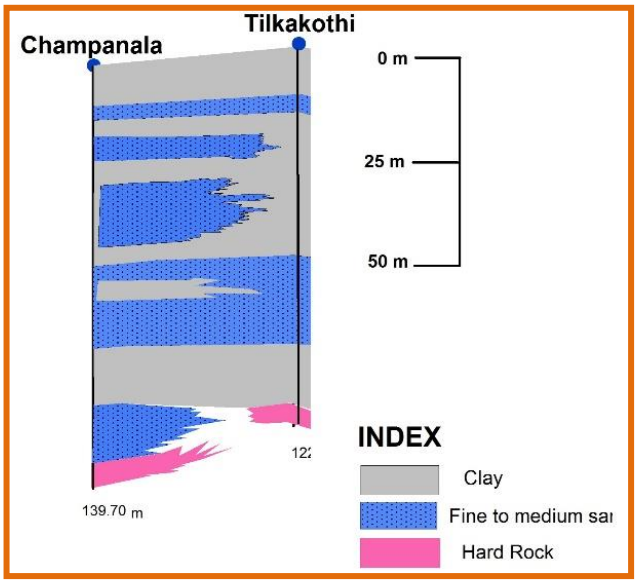


Fig 1 Litholgical Section

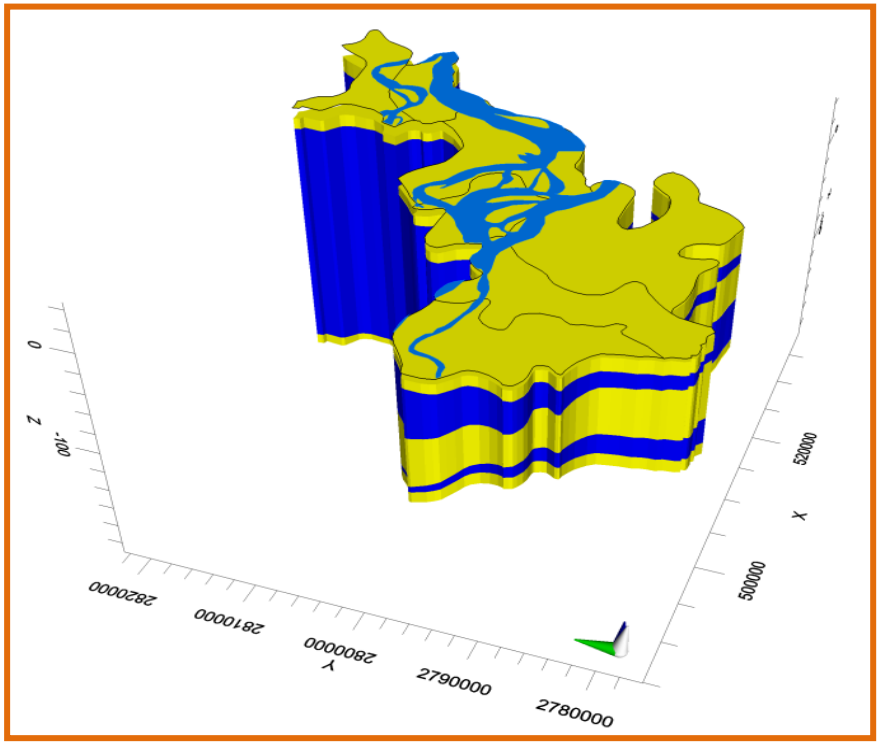


Fig 2 3D Disposition of two aquifer system

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 46.08% and water level trend is not declining. There is scope for groundwater development in the block. Arsenic

contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. 2nd aquifer should be utilized for pipe water supply.

Chemical quality of ground water and contamination

Arsenic occurs sporadically in hand pumps and it largely depends on the depth of the hand pump from which formation it taps water. In dug wells, arsenic concentration is reported as below detection limit (BDL).

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no water level decline in the area. Artificial recharge to ground water will be effective in feasible location to dilute arsenic contamination and also augment ground water resources.

Demand side interventions

In view of the issue of arsenic contamination, it is recommended to use the 2nd aquifer solely for meeting the drinking water supply requirement. Necessary regulations to enforce this recommendation in the arsenic affected blocks may be made so as to keep the 2nd aqufer safe from arsenic contamination.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhagalpur	Nathnagar	3153.36	571.39	131.17	147.91	4003.83	400.38	3603.45	1395.40	185.29	79.94	1660.63	71.20	2136.85	46.08	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F^-	Cl^-	HCO^{3-}	CO_3^{2-}	$SO4^{2-}$	NO^{3-}	PO_4^{3-}	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
Bhagalpur	Nathnagar	Champanagar	7.21	1022	664.3	0.18	63.81	375.15	0	68.28	87	0	402	42	72.15	63.9	4.78

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
PIRPAINTI (351 sq. km)
District/ State
Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Pirpainti block is 960 mm of which 84.07% occurs during the monsoon season. The normal rainfall during monsoon season is 852 mm and during non monsoon season is 108 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIA. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The variation of rainfall in this zone is from 990 mm to 1240 mm and the temperature varies from 37.1 to 7.8˚C.

Ground water resource availability and extraction

The dynamic ground water resource of Pirpainti block has been assessed as 96.29 MCM. The gross ground water draft for all uses stands at 21.86 MCM. The stage of Development is 22.71 % (Annuexure I). 997 STWs exist in the block. An additional 3503 STWs are feasible for construction with available ground water resources.

Water level behaviour

The depth to water level varies from 6 to 10 mbgl during pre-monsoon season except for very few areas where it goes to 12 mbgl. In post monsoon season, the depth to water level varies from 5 to 10 mbgl.

Aquifer disposition

Shallow aquifer in Pirpainty block occurs within 132 m bgl (Fig.1, 2). After that no potential aquifer has been encountered. However, in Pirpainty block, trap-basalt is encountered at the depth range of 68-73 (Jagdishpur, Laxmipur). Gondwana formation has also been encountered at Lakshmipur and Hardeochak.

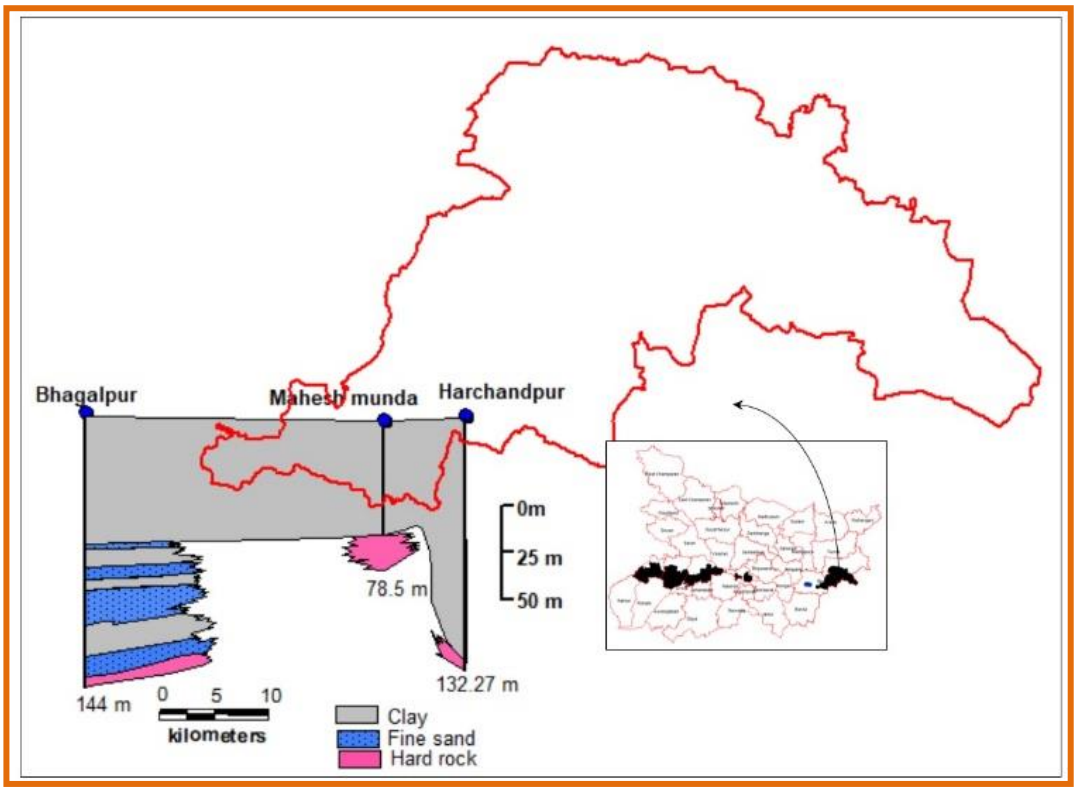


Fig 1 Lithological Section

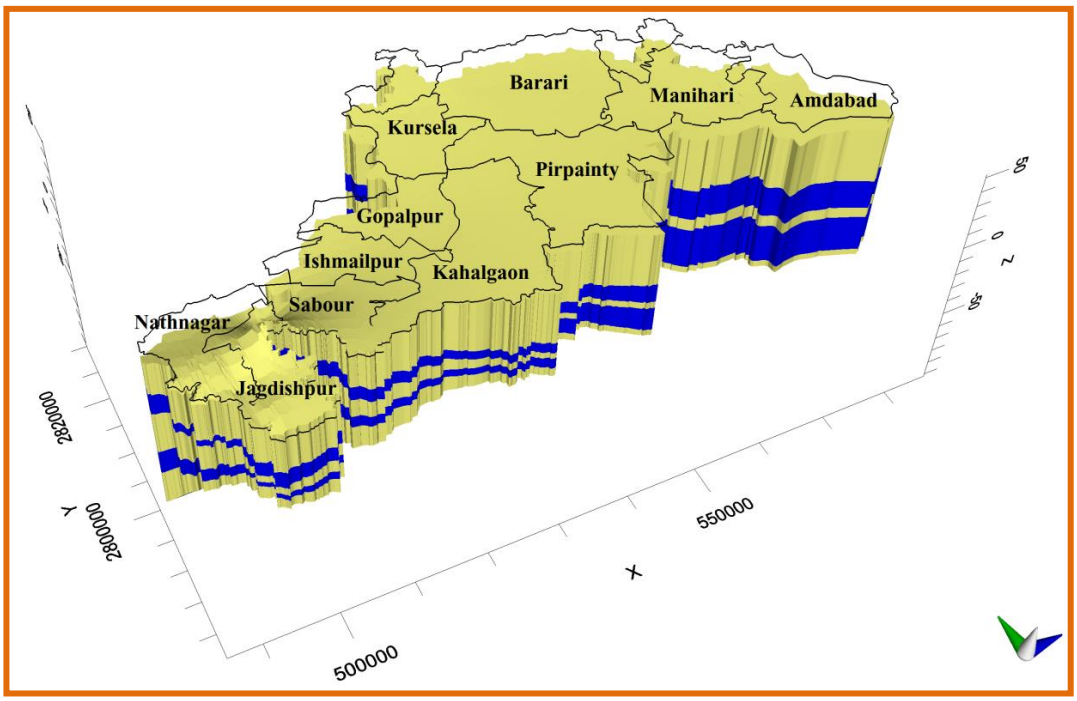


Fig 2 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 22.71% and water level trend is not declining in nature. There is scope for groundwater development in the block.

Arsenic contamination (>10 ppb) of groundwater has been reported from the aquifer in shallow depth. 2nd aquifer should be utilized for pipe water supply.

Chemical quality of ground water and contamination

Arsenic occurs sporadically in shallow aquifer and shallow hand pumps are the abstraction structures. In dug wells, arsenic concentration is reported as below detection limit (BDL).

Ground water resource enhancement

Artificial recharge to ground water may be encouraged in suitable condition to augment ground water resources as well as to dilute arsenic contaminated water.

Demand side interventions

Deeper aquifer may be strictly used for drinking water supply. Filtration and/or community based tube wells fitted with arsenic removal plants can be used for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhagalpur	Pirpainti	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	22.71	Safe
		8755.3	1586.47	168.2	189.68	10699.65	1069.97	9629.69	1749.40	333.20	104.13	2186.73	128.04	7752.25		

Annexure II

Chemical Analysis of Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhagalpur	**Pirpainti**	**Dubauli**	**7.17**	**942**	**612.3**	**0.38**	**53.17**	**393.6**	**0**	**87.6**	**38.1**	**0**	**377**	**46**	**63.74**	**56.7**	**1.44**
Bhagalpur	**Pirpainti**	**Parsurampur**	**7.27**	**698**	**453.7**	**0.11**	**17.72**	**356.7**	**0**	**24.17**	**1.29**	**0**	**354**	**44**	**59.25**	**13.25**	**2.75**

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Sabour (115 sq. km)

District/ State
Bhagalpur/Bihar

Rainfall

The normal annual rainfall of Sabour block is 810.9 mm of which 84.07% occurs during the monsoon season. The normal rainfall during monsoon season is 681.8 mm and during non monsoon season is 129.1 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIA. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The variation of rainfall in this zone is from 990 mm to 1240 mm and the temperature varies from 37.1 to 7.8˚C. Cropping intensity is 125% and ground water dependency for irrigation is 92%.

Ground water resource availability and extraction

The dynamic ground water resource of Sabour block has been assessed as 32.62 MCM. The gross ground water draft for all uses stands at 13.19 MCM. The stage of Development is 40.45 % (Annuexure I).

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 6 mbgl in general.

Aquifer Disposition

The block is bestowed with two-aquifer sysytem (Fig.1, 2). On the northern part of the block first aquifer varies from 15 to 20 m bgl and separated by 48-62 m thick clay layer from the second aquifer. The average thickness of 1st aquifer is 30 m. The yield of shallow tube well varies from 20 to 50 m^3 /hr with drawdown of 3-6 m. Depth of second aquifer varies from 70-80 to 97 -140 m bgl, underlain by granite gneiss. Two aquifer system has been found in southern part of the block overlain by 22 to 25 m thick clay layer, second aquifer is of 15 to 20 m thick upto depth of 60 – 80 m bgl underlain by granite gneiss.

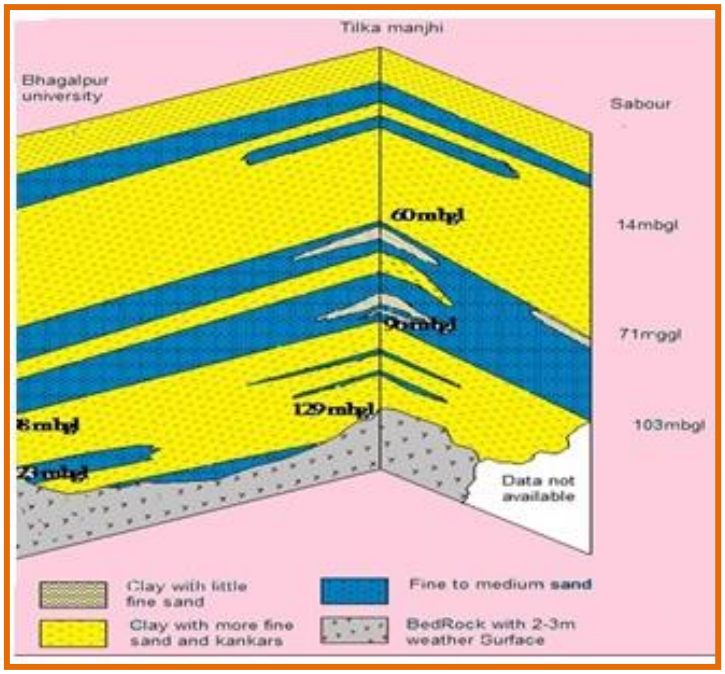


Fig 1 Lithological section

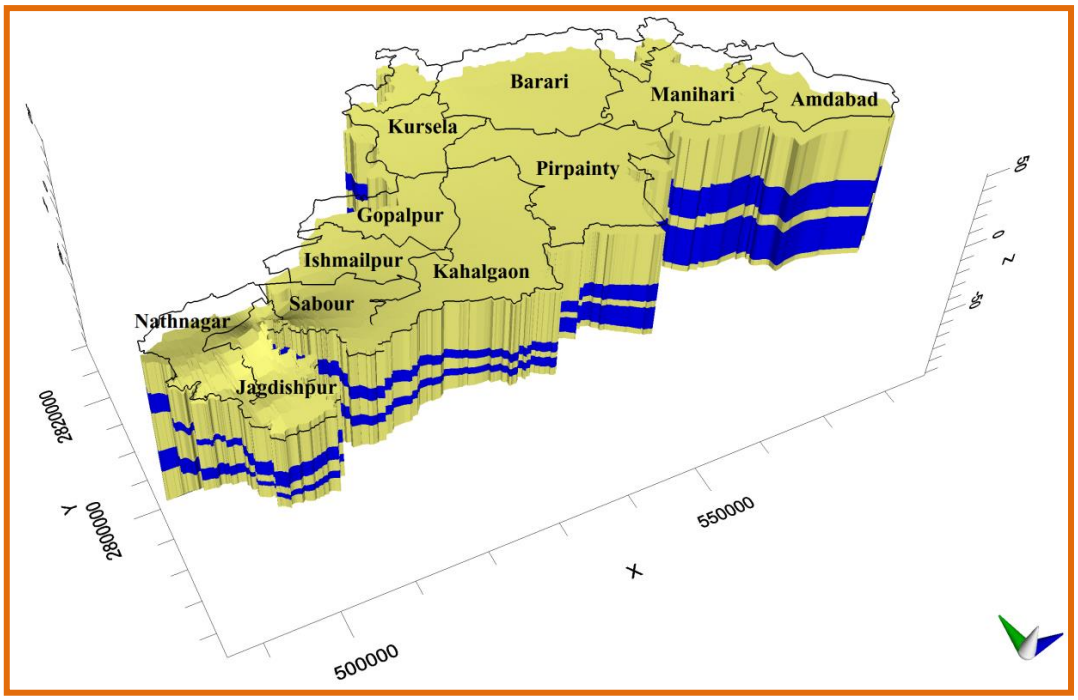


Fig 2 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 40.45%. Thus, sufficient scope exists for groundwater development in the block. Arsenic contamination of groundwater has been reported from the 1st aquifer in the younger alluvial belt upto the depth of ~60 m. Ground water exploration has revealed that the 2nd aquifer which is encountered below the clay layer separating the 1st and 2nd aquifer is safe from arsenic contamination. The 2nd aquifer is thus recommended for community drinking water supply. Even in the 1st

aquifer, the concentration of arsenic below the depth of 60 m has been found within the permissible limit; however, these are vulnerable to contamination with further groundwater development as they are part of the same contaminated aquifer. It is therefore, recommended to develop the groundwater from the lower parts of the 1st aquifer only through hand-pumps. Energized extraction should be discouraged as this would accelerate the vertical mixing with the arsenic contaminated layers.

The 2nd Aquifer is recommended only for extraction for drinking water supply.

Chemical quality of ground water and Arsenic contamination:

Sabour block has been reported to be containing arsenic more than the permissible limit of 0.01 mg/L. Arsenic occurs sporadically in hand pumps and it largely depends on the depth of the hand pump and from which formation it taps water. In dug wells, arsenic concentration is reported as below detection limit (BDL).

Flouride

Flouride contamination has been reported from the block more then permissible limit of 1.5 mg/L. Contamination is restricted in bore wells / hand pumps tapping fracture zones mainly. Dug wells tapping weathered zones in the vicinity of fracture zones sometimes contain fluoride. Community awareness and use of village level fluoride removal plant may be practiced. Nalgonda Technique may be used in this regard for household-level filtering.

Ground water resource enhancement

In suitable position, artificial recharge to ground water may be encouraged to augment ground water.

Demand side interventions

In view of the issue of arsenic contamination, it is recommended to use the 2nd aquifer solely for meeting the drinking water supply requirement. Necessary regulations to enforce this recommendation in the arsenic affected blocks may be made so as to keep the 2nd aqufer safe from arsenic contamination.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhagalpur	Sabour	2875	520.95	107.55	121.27	3624.77	362.48	3262.29	1084.10	166.47	69.05	1319.62	63.97	2114.22	40.45	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC (µs) /cm at 25°C	F	Cl^-	HCO3-	CO3-	SO_4^{2-}	NO_3^-	PO4	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+
Bhagalpur	Sabour	Rani Tola	7.74	1366	0	163	543	nd	23	39.6	nd	120	40	5	270	22.4
Bhagalpur	Sabour	Navtolia	7.8	738	0.12	14	348	nd	27	38.1	nd	295	76	25	38	5.1
Bhagalpur	Sabour	Farka	7.65	890	nd	64	281	nd	20	nd	0	315	84	25	25	1
Bhagalpur	Sabour	English Farka	7.87	536	nd	18	287	nd	9	nd	0.08	235	54	24	19	0.4
Bhagalpur	Sabour	Masaruh	7.79	738	nd	39	336	nd	16	15.5	nd	275	54	34	33	6.8
Bhagalpur	Sabour	Mamalkha	7.94	545	nd	7	293	nd	5	nd	0.04	185	64	6	28	4.6
Bhagalpur	Sabour	Shankarpur	7.8	541	0.24	11	293	nd	4	nd	nd	205	60	13	19	4.3

Block wise
Aquifer Maps and Management plans

Salient Information

Name of the Block and Area (in km^2)

AGIOAN (156 sq. km)

District/ State

Bhojpur/Bihar

Rainfall

The normal annual rainfall of Agioan block is 727.1 mm of which 84.88% occurs during the monsoon season. The normal rainfall during monsoon season is 617.2 mm and during non monsoon season is 109.9 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are Sandy loam, Clay loam, loam, Clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells. Cropping intensity is 120.66% and irrigation intensity is 87.46%. Ground water dependency for irrigation is 47.17%.

Ground water resource availability and extraction

The dynamic ground water resource of Agioan block has been assessed as 61.03 MCM. The gross ground water draft for all uses stands at 20.71 MCM. The stage of Development is 33.94 % (Annuexure I). 1571 STWs are feasible for construction with available ground water resources considering upto 70% of SOD.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 6 mbgl in some parts and in some parts 2 to 5 mbgl. Water level fluctuation is 2 m in general. Ground water table varies from 60 to 65 m amsl in premonsoon period and 65 to 70 m amsl during post monsoon period. Ground water flow direction is towards northern side.

Aquifer disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer systems have been reported with fining upward sequence from medium to fine sand (Fig 1). 1st aquifer ranges from 32 to 68 m bgl and is composed of fine sand. The average thickness of 1st aquifer is 22 m. 2nd aquifer ranges from 88 to 186 m bgl upto the explored depth of 200 m bgl

with intercalation of thick clay layers. The average thickness of 2nd aquifer is 44 m in general. Deeper aquifer is under confined condition. The top layer (within 32 m bgl) is an aquitard, which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps.

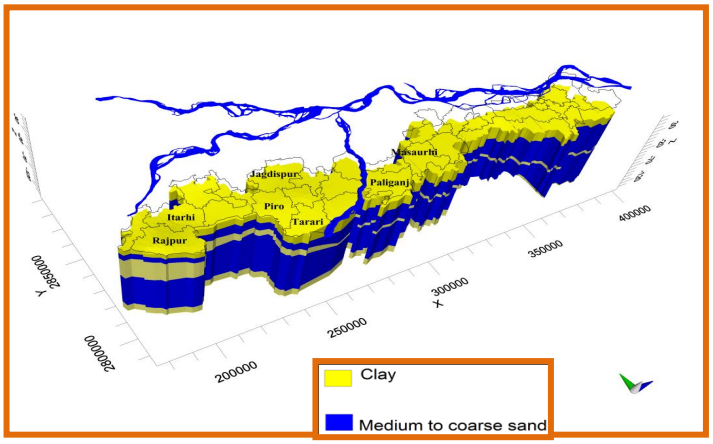


Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 33.94% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer must be used for drinking water supply.

Chemical quality of ground water and contamination

On the basis of Piper diagram, it can be said that ground water of the block is Ca-Mg-HCO_3 type and potable. On the basis of USSL diagram, it is inferred that it is suitable for irrigation.

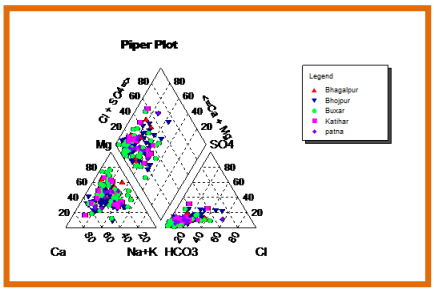


Fig 2 Piper plot

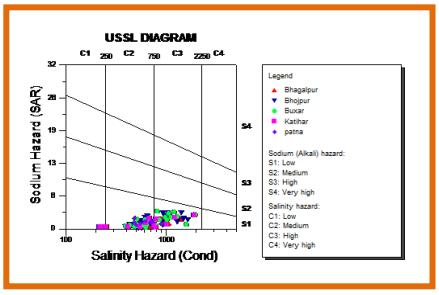


Fig 3 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Shallow aquifer may be utilised for irrigation purpose and deeper aquifer should be used for drinking water supply.

Annexure I

Dynamic Ground Water Resources Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhojpur	Agioan	3804.25	501.04	1398.98	1076.87	6781.14	678.11	6103.00	1747.40	225.46	98.64	2071.50	86.64	4268.99	33.94	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Agiaon	Pauna	8.12	1076	699.4	0.6	94.1	516.6	0	24.72	0	0	340	50	58.32	105.46	1.07

Block wise
Aquifer Maps and Management plans

Salient Information

Name of the Block and Area (in km^2)

CHARPOKHRI (109 sq. km)

District/ State

Bhojpur/Bihar

Rainfall

The normal annual rainfall of Charpokhri block is 1000 mm of which 92.84% occurs during the monsoon season. The normal rainfall during monsoon season is 928.4 mm and during non monsoon season is 71.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells. Dependency of ground water irrigation in the block is 47.17%.

Ground water resource availability and extraction

The dynamic ground water resource of Charpokhri block has been assessed as 39.01 MCM. The gross ground water draft for all uses stands at 17.55 MCM. The stage of Development is 44.98 % (Annuexure I). 697 STWs are feasible for construction with available ground water resources considering upto 70% SOD.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in some parts and in some parts 5 to 10 mbgl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer systems have been reported (Fig 1). 1st aquifer ranges from 38 to 114 m bgl while 2nd aquifer ranges from 126 to 292 m bgl. The top layer (within 30 m bgl) is an aquitard, which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps.

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 44.98% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer must be strictly for drinking water supply.

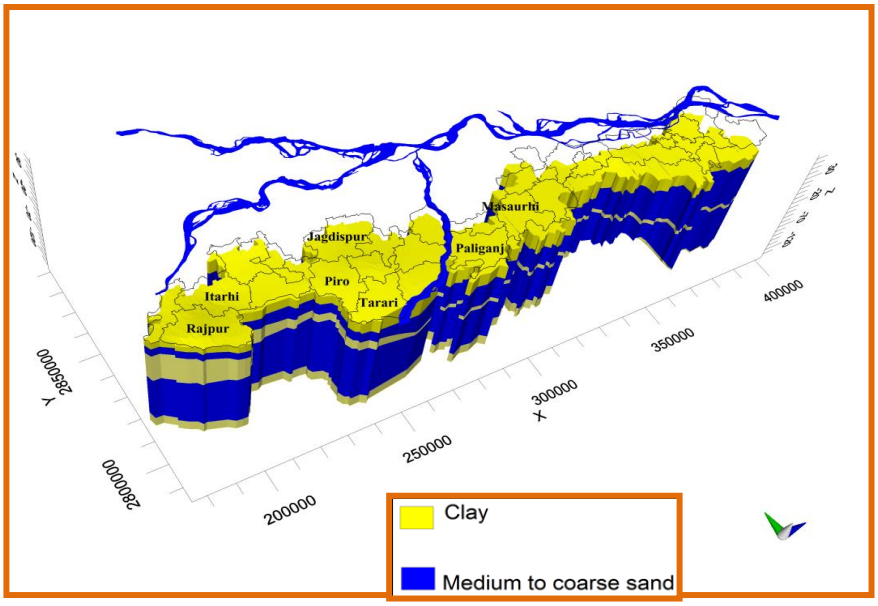


Fig 1 3D Disposition of Aquifer System

Chemical quality of ground water and contamination

Ground water of the block is potable is suitable for irrigation, though salinity hazards is moderate to high in nature.

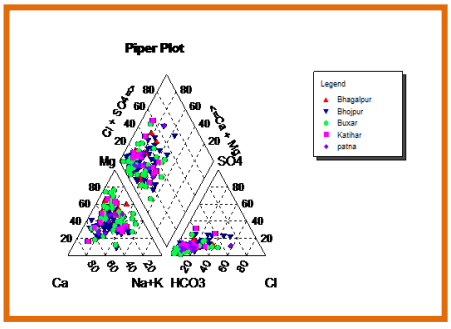


Fig 2 Piper plot

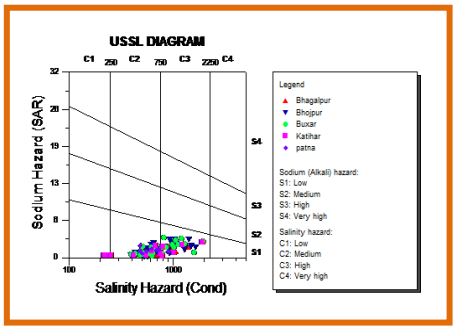


Fig 3 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limits and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Shallow aquifer may be utilised for irrigation purpose and deeper aquifer must be utilized for drinking water supply.

Annexure I

timationDynamic Ground Water Resource Es

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Charpokhri	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	44.98	Safe
		1945.75	351.1	1013.33	797.02	4107.2	205.36	3901.84	1517.40	154.03	83.57	1755.00	59.19	2325.25		

Annexure II

Analysis of Ground Water Sample Chemical

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Charpokhri	Pirro	7.27	931	605	0.23	33.27	344.4	ND	44.85	59.1	0.02	220	38	30.37	110.54	0
Bhojpur	Charpokhri	Mallaur	7.5	621	404	0.08	28.96	307.5	ND	20.29	21.7	BDL	280	42	42.52	27.6	0.26
Bhojpur	Charpokhri	Barhara	7.61	617	401	0.21	17.72	356.7	ND	10.61	7.37	BDL	255	50	31.59	31.42	0.12

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
GARHANI (112 sq. km)

District/ State
Bhojpur/Bihar

Rainfall

The normal annual rainfall of Garhani block is 1173.58 mm of which 82.72% occurs during the monsoon season. The normal rainfall during monsoon season is 970.75 mm and during non monsoon season is 202.83 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells. Dependency of ground water irrigation is 47.17%.

Ground water resource availability and extraction

The dynamic ground water resource of Garhani block has been assessed as 43.47 MCM. The gross ground water draft for all uses stands at 15.74 MCM. The stage of Development is 36.22 % (Annuexure I). 1048 STWs may be constructed with available ground water resources.

Water level behaviour

The depth to water level varies from 4 to 7 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most parts. Premonsoon water table varies from 60 to 65 m amsl and flow direction is towards NNE.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers in the block. Two aquifer systems have been found (Fig 1, 4). 1st aquifer ranges from 30 to 54 m bgl whiere as 2nd aquifer starts from 90 m onwards down to explored depth of 200 m with intercalation of thick clay layers. The top layer (within 30 m bgl) is an aquitard, which is mixed with high percentage of sand, silt and kankars. It supports construction of dug wells and shallow hand pumps.

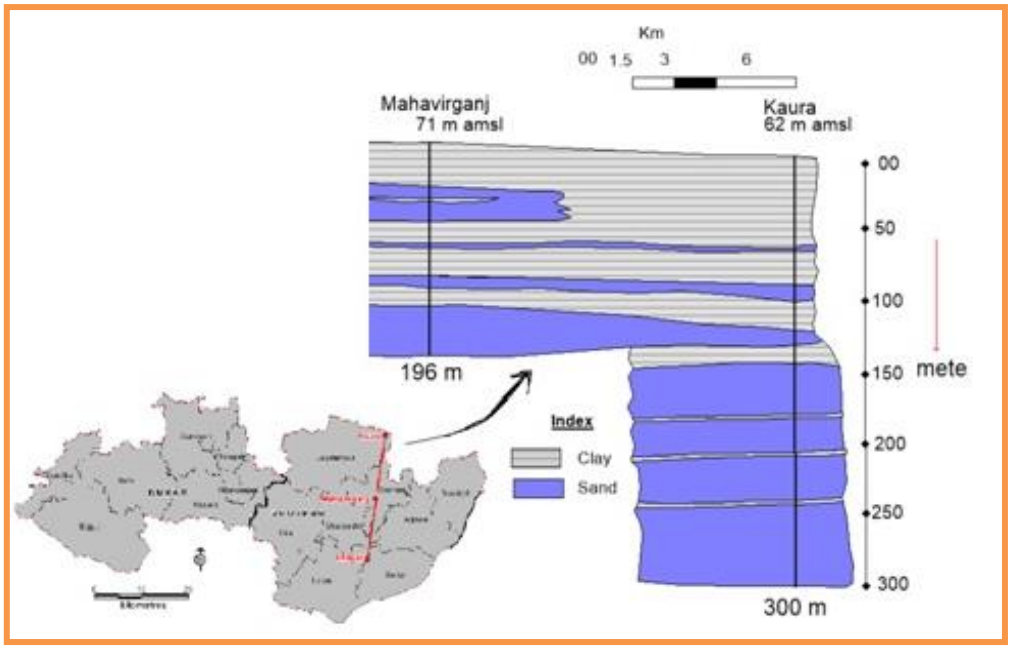


Fig 1 Lithological section at Mahavirganj-Kaura, Bhojpur

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 33.94% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer must be used for drinking water supply.

Chemical quality of ground water and contamination

On the basis of Piper diagram, it is said that ground water of the block is mainly Ca-Mg-HCO_3 type and potable and on the basis of USSL diagram, it is inferred that it is suitable for irrigation.

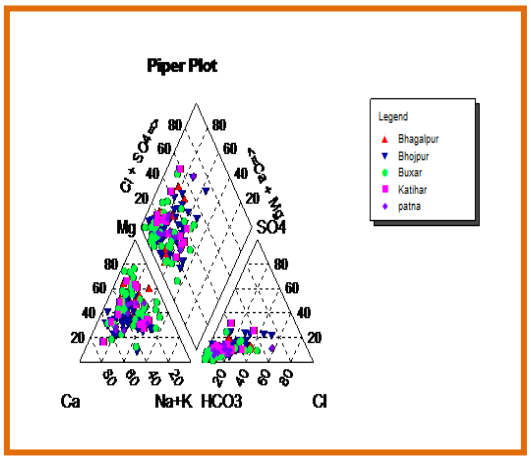


Fig 2 Piper plot

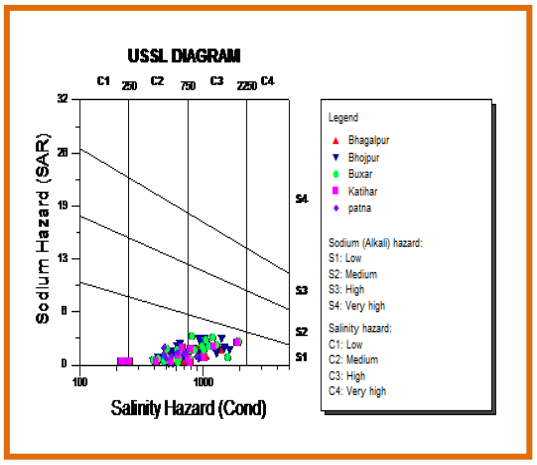


Fig 3 USSL Diagram

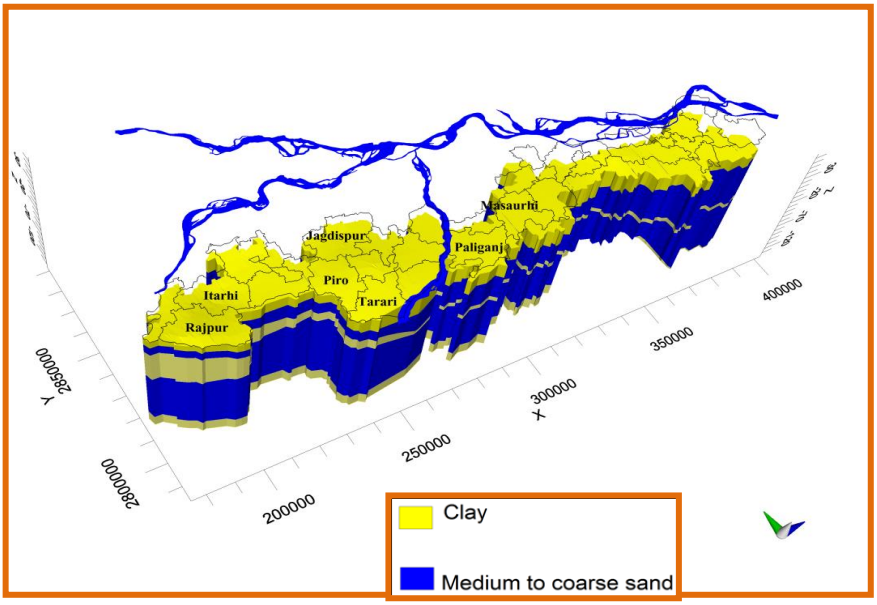


Fig 4 3D Disposition of Aquifer System

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

For sustainable development, ground water from shallow aquifer may be utilised for irrigation purpose and deeper aquifer must be used for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhojpur	Garhani	2731.68	359.78	986.97	751.68	4830.11	483.01	4347.10	1342.60	156.91	74.98	1574.49	60.30	2944.20	36.22	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Garhani	Dehman	7.73	557	362	0.35	7.09	344.4	ND	10.49	7.27	BDL	240	36	36.45	23.55	0.21

Block wise
Aquifer Maps and Management plans

Salient Information

Name of the Block and Area (in km^2)

JAGDISHPUR (258 sq. km)

District/ State

Bhojpur/Bihar

Rainfall

The normal annual rainfall of Jagdishpur block is 899 mm of which 91.9% occurs during the monsoon season. The normal rainfall during monsoon season is 826.2 mm and during non monsoon season is 72.8 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells. Cropping intensity is 120.66% and irrigation intensity is 87.46%. Dependency of ground water irrigation is 47.17%.

Ground water resource availability and extraction

The dynamic ground water resource of Jagdishpurr block has been assessed as 113.99 MCM. The gross ground water draft for all uses stands at 57.8 MCM. The stage of Development is 50.71 % shown in Annuexure I. 1570 STWs are feasible for construction with available ground water potential considering upto 70% SOD.

Water level behaviour

The depth to water level varies from 5 to 8 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. In general, water table varies from 60 to 65 m amsl during pre-monsoon period while from 65 to 70 m amsl during post monsoon period.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer systems has been reported upto explored depth of 300 m (Fig 1, 2, 3). 1st aquifer ranges from 63 to 75 mbgl while 2nd aquifer ranges from 97 to 300 m bgl with intercalation of thick clay laters.

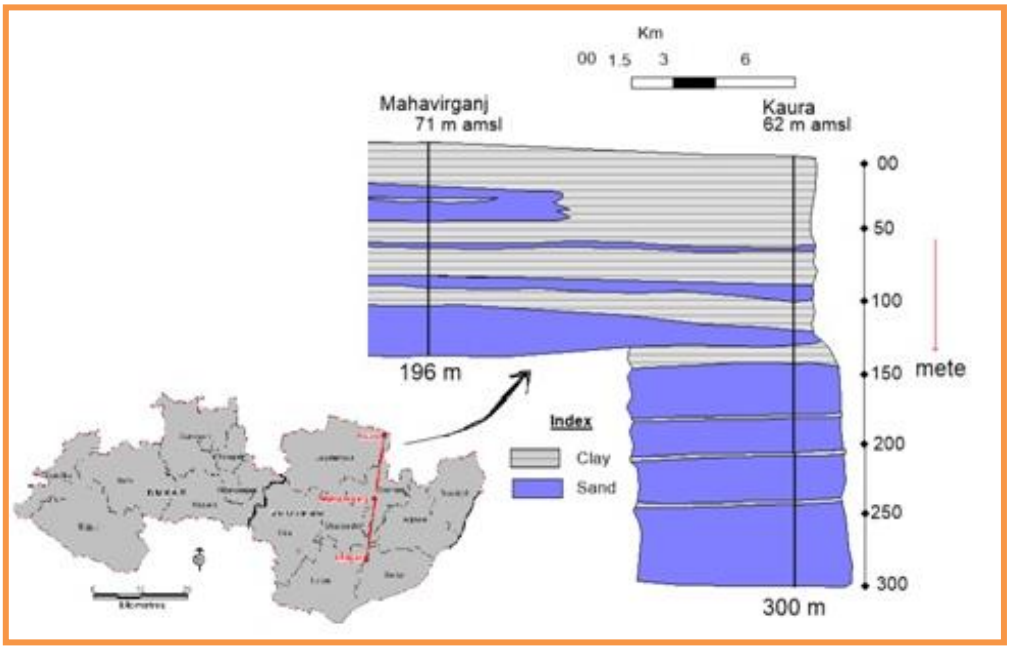


Fig 1 Lithological section of Mahavirganj to Kausa area

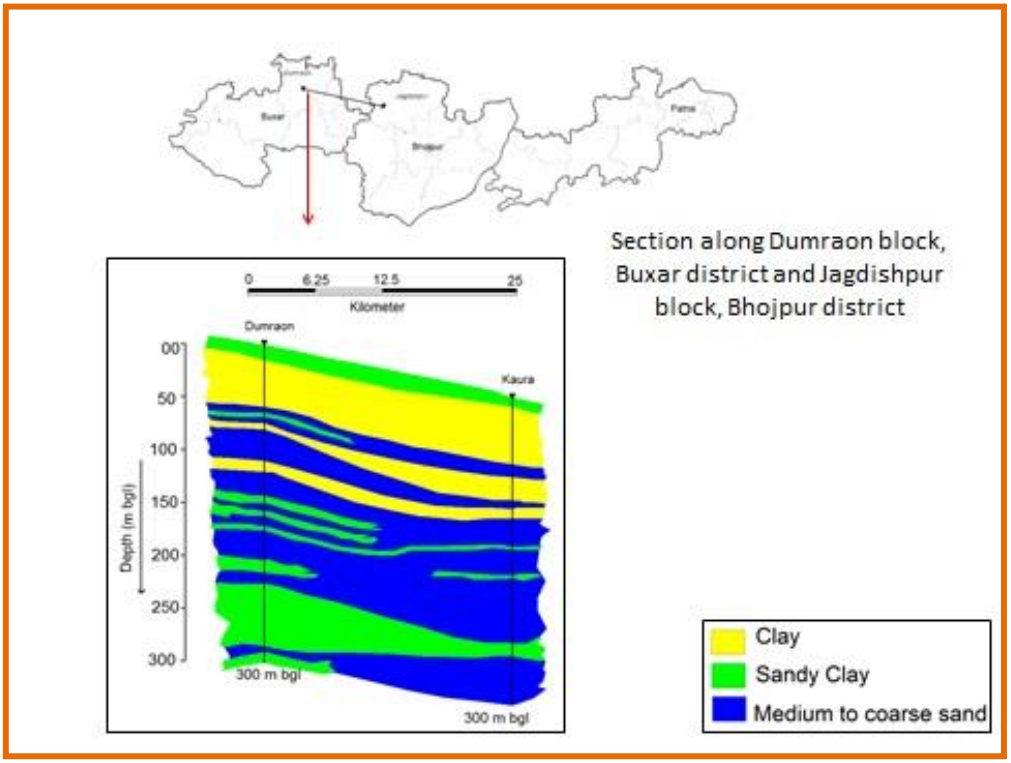


Fig 2 Lithological section of Dumraon to Kaura area

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 50.71% and water level trend is not declining. There is sufficient scope for groundwater development exists in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds

during stream flow are the other source of natural recharge for ground water resource enhancement. Shallow aquifer may be developed for drinking and domestic purposes. However, deeper aquifer is preferable for pipe water supply.

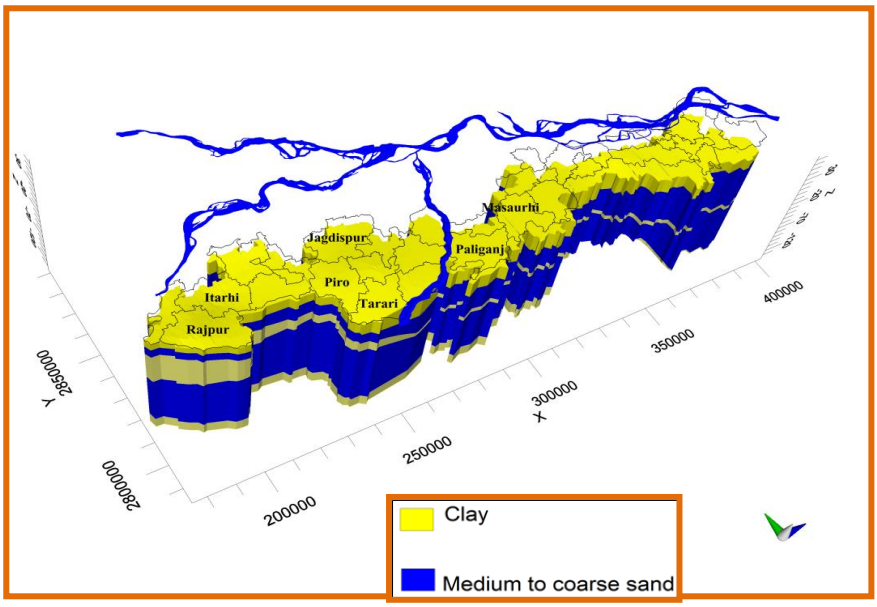


Fig 3 3D Disposition of Aquifer System

Chemical quality of ground water and contamination

Ground water is potable and good for irrigation use. Salinity hazards are moderate to high interpreted from USSL diagram.

Ground water resource enhancemnt

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

For sustainable development, ground water from shallow aquifer may be utilised for irrigation purpose and deeper aquifer may be utilized for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Jagdishpur	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	50.71	Safe
		6286.68	827.99	2928.6	2622.55	12665.82	1266.58	11399.24	4968.60	518.21	294.07	5780.88	154.13	6276.51		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Jagdishpur	Deotola	7.79	652	424	0.22	28.36	307.5	ND	19.65	12.8	BDL	140	24	19.44	71.94	0.12
Bhojpur	Jagdishpur	Babhinav	7.77	498	324	0.14	14.18	295.2	ND	12.7	1.33	BDL	215	38	29.16	16.7	0.67
Bhojpur	Jagdishpur	Jagdishpur	7.77	560	364	0.2	21.27	319.8	ND	12.14	4.18	BDL	240	38	35.23	23.17	1.35

Block wise
Aquifer Maps and Management plans

Salient Information

Name of the Block and Area (in km^2)

PIRRO (218 sq. km)

District/ State

Bhojpur/Bihar

Rainfall

The normal annual rainfall of Pirro block is 695.1 mm of which 88.26% occurs during the monsoon season. The normal rainfall during monsoon season is 613.5 mm and during non monsoon season is 81.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Pirro block has been assessed as 85.82 MCM. The gross ground water draft for all uses stands at 52.9 MCM. The stage of Development is 61.64 % depicted in Annuexure I.

Water level behaviour

The depth to water level varies from 5 to 8 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer systems has been reported upto explored depth of 300 m. 1st aquifer ranges from 63 to 75 mbgl while 2nd aquifer ranges from 97 to 300 m bgl with intercalation of thick clay laters (Fig 1).

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 36.22% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater

irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer must be strictly for drinking water supply.

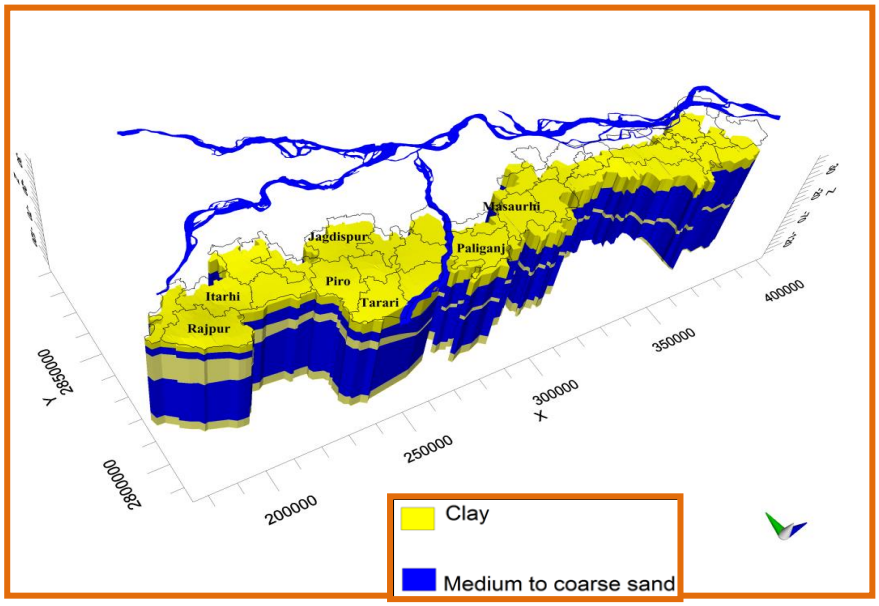


Fig 1 3D Disposition of Aquifer System

Chemical quality of ground water and contamination

On the basis of Piper diagram ground water of the block is potable and on the basis of USSL diagram it is suitable for irrigation.

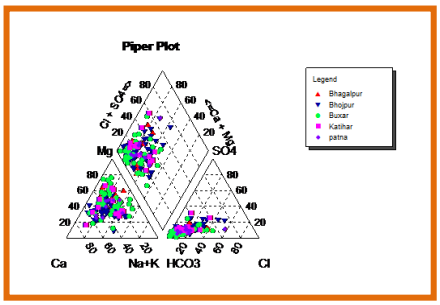


Fig 2 Piper plot

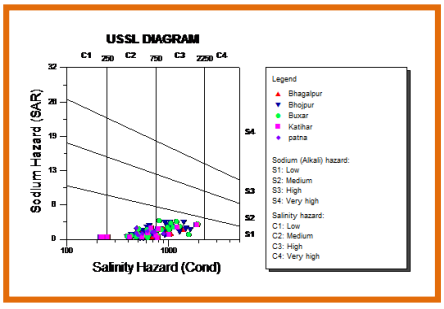


Fig 3 USSL Diagram

Ground water resource enhancement

Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement.

Demand side interventions

In view of the issue of arsenic contamination, it is recommended to use the 2nd aquifer solely for meeting the drinking water supply requirement. Necessary regulations to enforce this recommendation in the arsenic affected blocks may be made so as to keep the 2nd aqufer safe from arsenic contamination.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Pirro	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	61.64	Safe
		5326.04	701.47	1321.58	2186.47	9535.56	953.56	8582.00	4512.20	509.29	268.52	5290.01	148.85	3920.95		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Piro	Bhulkuan	7.37	550	358	0.37	14.18	282.9	ND	18.82	23	BDL	175	30	24.3	49.86	0

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
SAHAR (127 sq. km)

District/ State
Bhojpur/Bihar
Rainfall

The normal annual rainfall of Sahar block is 869.8 mm of which 87.74% occurs during the monsoon season. The normal rainfall during monsoon season is 763.2 mm and during non-monsoon season is 106.6 mm.

Agriculture and irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Jamalpur block has been assessed as 49.92 MCM. The gross ground water draft for all uses stands at 11 MCM. The stage of Development is 22.04 % depicted in Annuexure I. 1710 STWs are feasible for construction with available ground water resources considering upto 70% SOD.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer systems have been reported with fining upward sequence from medium to fine sand (Fig 1). 1st aquifer ranges from 32 to 68 m bgl and is composed of fine sand. The average thickness of 1st aquifer is 22 m. 2nd aquifer ranges from 88 to 186 m bgl upto the explored depth of 200 m bgl with intercalation of thick clay layers. The average thickness of 2nd aquifer is 44 m in general. Deeper aquifer is under confined condition. The top layer (within 32 m bgl) is an aquitard, which

is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps.

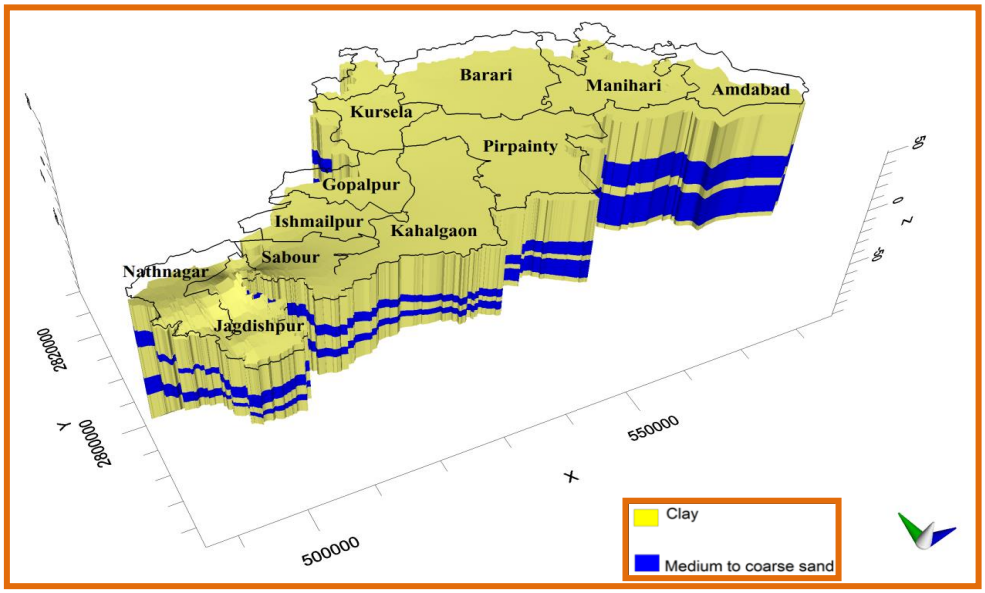


Fig 1 3D Disposition of aquifer system

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 36.22% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer should be utilized for drinking water supply.

Chemical quality of ground water and contamination

On the basis of Piper diagram, it is inferred that ground water of the block is mainly Ca-Mg-HCO_3 type. Ground water is good and potable. On the basis of USSL diagram, it is said that it is suitable for irrigation though salinity hazards are moderate to high in nature.

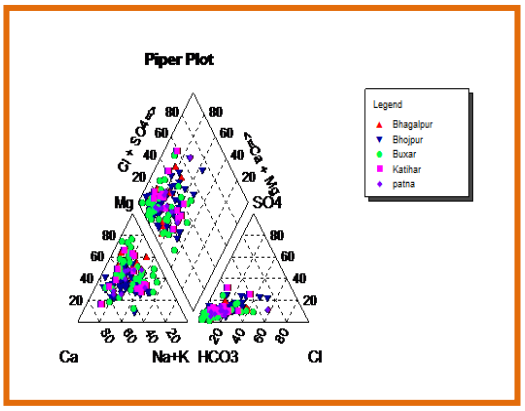


Fig 2 Piper plot

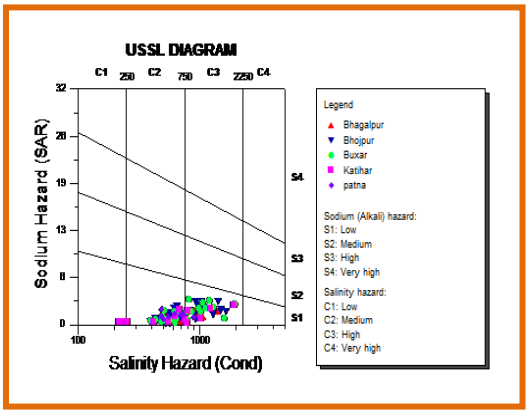


Fig 3 USSL diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe category and there is no water level decline in the area, the need for artificial recharge is not felt.

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Demand side interventions

For sustainable ground water development from shallow aquifer, additional STWs are feasible for irrigation purpose and deeper aquifer must be utilized for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Sahar	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	22.04	Safe
		2973.88	408.86	1081.24	790.86	5254.84	262.74	4992.10	880.40	167.57	52.40	1100.37	64.39	4047.31		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Sahar	Baruna	7.99	623	404.95	0.38	63.5	153.75	0	61.33	52.3		165	56	6.075	69.13	1.68
Bhojpur	Sahar	Guljarpur	8.15	572	371.8	0.52	12.7	313.65	0	11.58	0		300	68	31.59	7.51	1.25
Bhojpur	Sahar	Dhawri	8.14	615	399.75	0.72	39.6	319.8	0	13.23	6.3		260	52	31.59	28.53	0.85

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Sandesh (130 sq. km)

District/ State
Bhojpur/Bihar

Rainfall

The normal annual rainfall of Sandesh block is 760 mm of which 78.94% occurs during the monsoon season. The normal rainfall during monsoon season is 600 mm and during non monsoon season is 160 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Sandesh block has been assessed as 52.13 MCM. The gross ground water draft for all uses stands at 23.79 MCM. The stage of development is 45.63 % depicted in Annuexure I. 907 STWs are feasible for construction with available ground water resources in the block.

Water level behaviour

The depth to water level varies from 5 to 7 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 6 mbgl in most of the parts and in some parts 5 to 10 mbgl.

Aquifer disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer systems have been reported with fining upward sequence from medium to fine sand (Fig 1). 1st aquifer ranges from 32 to 68 m bgl and is composed of fine sand. The average thickness of 1st aquifer is 22 m. 2nd aquifer ranges from 88 to 186 m bgl upto the explored depth of 200 m bgl with intercalation of thick clay layers. The average thickness of 2nd aquifer is 44 m in general.

Deeper aquifer is under confined condition. The top layer (within 32 m bgl) is an aquitard, which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps.

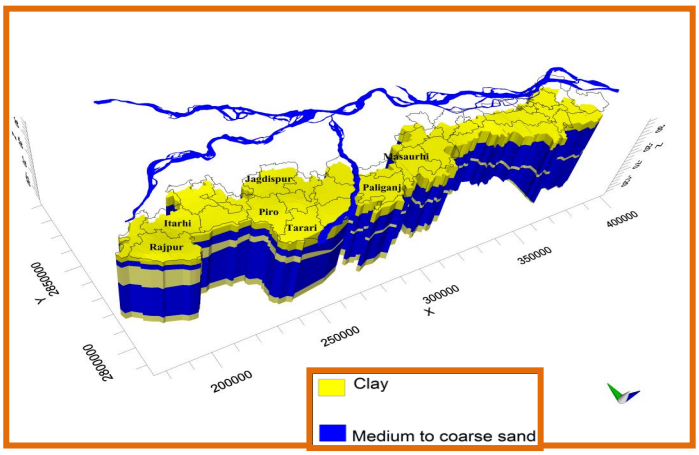

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the Block is 45.63% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer should be restricted for drinking water supply.

Chemical quality of ground water and contamination

Ground water of the block is good and potable. USSL diagram shows that it is suitable for irrigation, though salnity hazards are moderate to high in the area.

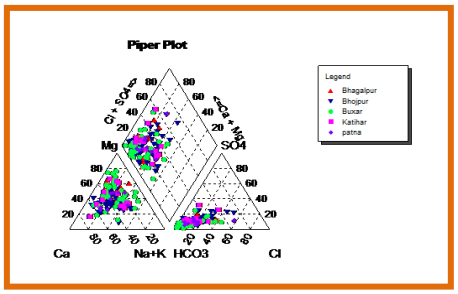

Fig 2 Piper plot

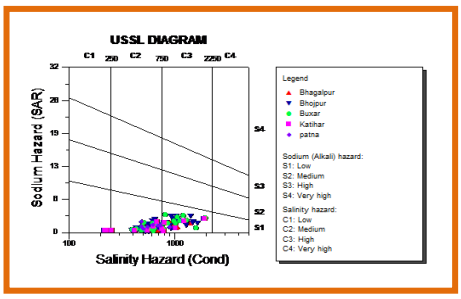

Fig 3 USSL Diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe category and there is no water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

For sustainable development, ground water from shallow aquifer may be utilised for irrigation purpose and deeper aquifer should be utilized for drinking water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhojpur	Sandesh	3172.61	417.85	1230.6	972.16	5793.22	579.32	5213.90	2099.00	166.72	113.29	2379.01	64.06	3050.84	45.63	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Sandes	Nasratpur	8.02	677	440.05	0.37	36.4	289.05	0	45.43	41.6		290	60	34.02	36.95	1.58
Bhojpur	Sandes	Sandesh	7.86	1663	1080.95	0.2	255	319.8	0	171.52	151		665	112	93.55	105.46	14.65
Bhojpur	Sandes	Koeri	8.08	555	360.75	0.46	19.4	307.5	0	12.91	12		220	52	21.87	32.34	1.44

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
TARARI (201 sq. km)

District/ State
Bhojpur/Bihar

Rainfall

The normal annual rainfall of Tarari district is 706.6 mm of which 96.03% occurs during the monsoon season. The normal rainfall during monsoon season is 679 mm and during non monsoon season is 27.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. The Arah branch canal feeds the area. The irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Tarari block has been assessed as 74.08 MCM. The gross ground water draft for all uses stands at 41.67 MCM. The stage of Development is 56.25 % depicted in Annuexure I. 727 STWs are feasible with available ground water resources considering up to 70% SOD.

Water level behaviour

The depth to water level varies from 4 to 7 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most parts.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers on the block. Two aquifer system has been reported (Fig. 1), mainly a total of 100-120 m thick aquifer upto depth of 300 m with fining upward sequence from very coarse sand to medium to fine sand. Deeper aquifers are under confined condition. The top layer (within 38 m bgl) is an aquitard, which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps. 1st aquifer ranges from 38 to 62 m bgl and fine to medium sand is the main aquifer materials. 2nd

aquifer ranges from 84 m onwards upto the explored depth of 100 m bgl with intercalation of clay layers.

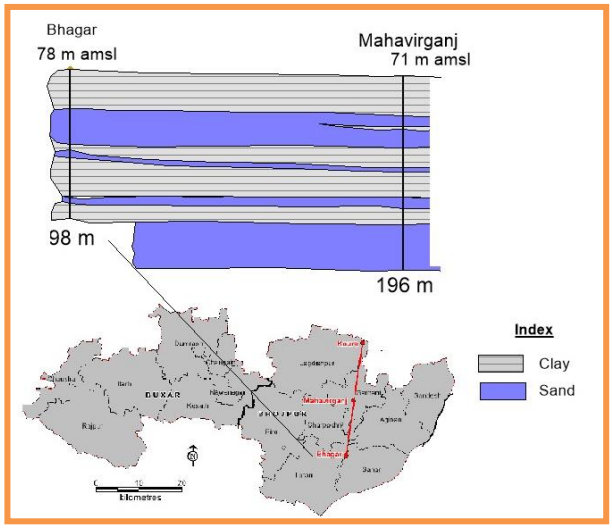

Fig. 1 Lithological disposition from Bhangar to Mahavirganj

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 56.25% and water level trend is not declining. Shallow Tube Well (STW) is the main abstraction structure for irrigation purposes. No contamination is found in ground water of two aquifers.

Chemical quality of ground water and contamination

On the basis of Piper diagram, it can be said that ground water is of Ca-Mg-HCO3 type. USSL diagram shows that ground water is suitable for irrigation though salinity hazards are moderate to high.

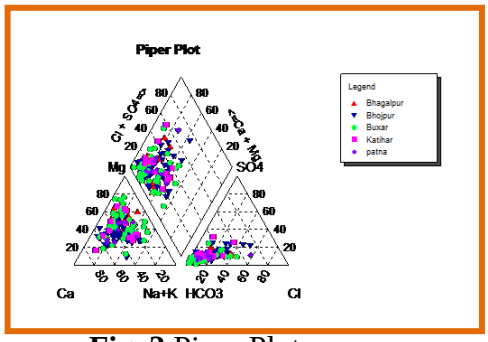

Fig. 2 Piper Plot

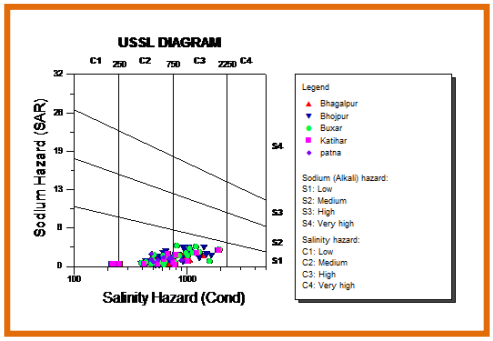

Fig. 3USSL diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

For sustainable ground water shallow aquifer must be utilised for irrigation purpose and deeper aquifer must be strictly for drinking water supply. Recharge of ground water for resource must be done on priority basis.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Tarari	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	56.25	Safe
		4901.46	645.55	398.08	2286.72	8231.81	823.18	7408.60	3691.20	277.52	198.44	4167.16	106.64	3610.79		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Bhojpur	Tarari	Sikharhata	7.4	1037	674	0.33	35.45	399.75	ND	48.97	66.6	BDL	230	42	30.37	110.54	1.82
Bhojpur	Tarari	Tarai	7.3	1522	989	0.1	46.08	369	ND	116.32	264	BDL	480	72	72.9	110.54	37.76

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Chaugain (55 sq. km)
District/ State
Buxar/Bihar

Rainfall

The normal annual rainfall of Chaugain block is 739.4 mm of which 92.101% occurs during the monsoon season. The normal rainfall during monsoon season is 681 mm and during non monsoon season is 58.4 mm.

Agriculture and irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water resource availability and extraction

The dynamic ground water resource of Chaugain block has been assessed as 23.16 MCM. The gross ground water draft for all uses stands at 16.27 MCM. The stage of Development is 70.28 % depicted in Annuexure I. Cropping intensity is 138.22% and irrigation intensity is 85.41%. Dependency of ground water irrigation is 50.92%. 861 STWs already exist in the block; no additional STW is feasible for construction with available ground water resource.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most parts and in few parts 5 to 10 mbgl.

Aquifer disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand as aquifers (Fig.1, 2). The sections reveal that the area is underlain by a two-tier aquifer system. The clay layer of 12-15 m separates the 1st and 2nd aquifer. The formation at the top is clay mixed with kankar and fine sands. In the absence of any pure clay at the top, the shallow aquifer occurs under water table condition. The depth of 1st aquifer in the area varies from 59 to 172 m bgl in general. Shallow private irrigation tubewells in the area tap the aquifer zone 20-60 m bgl. Average yield of the tube well varies from 30 to 95 m^3/hr with draw down of 3

m. 2nd aquifer ranges from 190 to 226 m bgl. Aquifer materials are composed of fine to medium sands.

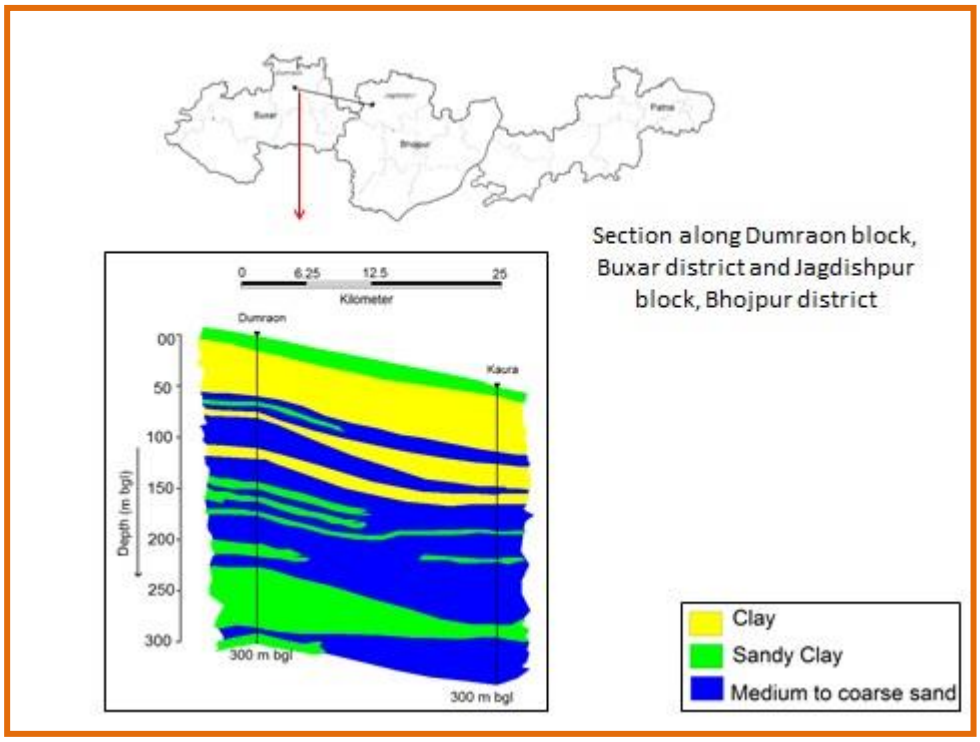

Fig 1 Lithological section frojm Dumraon to Kaura, Buxar & Bhojpur districts

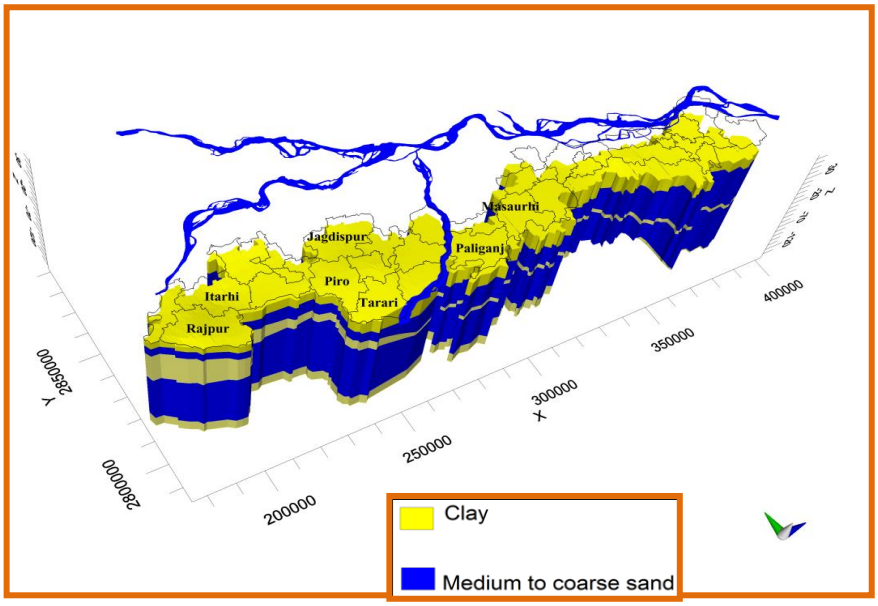

Fig 2 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 70.28%. High withdrawal of ground water has been observed in the block. Artificial recharge structures like contour bund and recharge ponds can also be constructed to augment the ground water resources. No additional STW is feasible for construction with available ground water resources.

Chemical quality of ground water and contamination

On the basis of Piper diagram, it is inferred that ground water of the block is Ca-Mg-HCO3 type in general. Ground water is good and potable in nature. USSL diagram shows that it is suitable for irrigation.

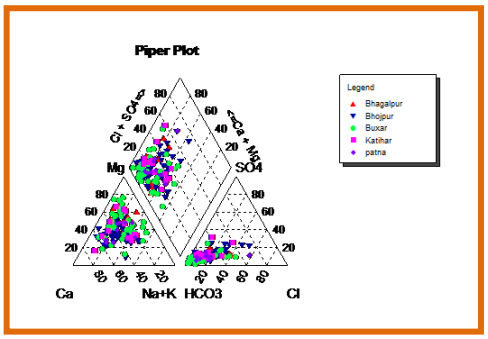

Fig 3 Piper Plot

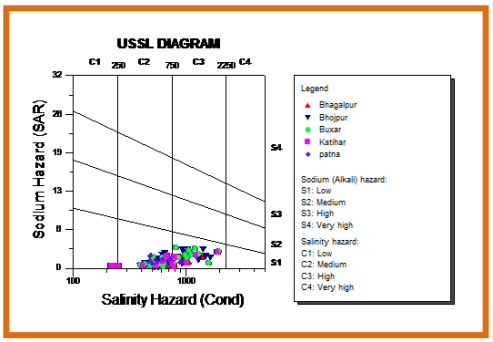

Fig 4 USSL diagram

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

Artificial recharge to ground water may be thought of in suitable condition to augment ground water resources. To avoid possibility of arsenic contamination in 1st aquifer, 2nd aquifer may strictly be targeted for pipe water supply scheme for safe ground water.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhojpur	Chaungain	1236.37	163.87	490.97	682.37	2573.58	257.36	2316.22	1476.30	74.07	77.52	1627.89	28.47	811.45	70.28	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Chaugain	Chaugain	7.83	503	326.95	0.465	6.59	295.2	0	21.54	2.19	0	240	48	29.16	17.57	1.02

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
Chausa (108 sq. km)

District/ State
Buxar/Bihar

Rainfall

The normal annual rainfall of Chausa block is 564.6 mm of which 84.6% occurs during the monsoon season. The normal rainfall during monsoon season is 477.8 mm and during non monsoon season is 86.8 mm

Agriculture and irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C. Cropping intensity is 138.22% and irrigation intensity is 85.41%. Dependency of ground water irrigation is 50.92%.

Ground water resource availability and extraction

The dynamic ground water resource of Tarari block has been assessed as 51.44 MCM. The gross ground water draft for all uses stands at 23.01 MCM. The stage of development is 44.74 % shown in Annuexure I. 1193 STWs tapping 1st aquifer exist in the block for irrigation purpose. An additional 866 STWs are feasible for construction with available ground water resources.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most of the parts. Premonsoon ground water table varies from 60 to 65 m amsl and its flow direction is towards north.

Aquifer disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand, coarse sand and gravel as aquifer (Fig.1). The sections reveal that the area is underlain by a two-tier aquifer system. The clay layer of 8 - 50 m separates the 1st and 2nd aquifer.

The formation at the top is clay mixed with kankar and fine sands and occassionaly with coarse sand. In the absence of any pure clay at the top, the shallow aquifer occurs under

water table condition. The depth of first aquifer area varies from 92 to 116 m bgl in general. Shallow private irrigation tubewells in the area tap the aquifer zone 20-60 m bgl. Average yield of the tube well varies from 30 to 95 m^3/hr with draw down of 3 m. The extensive 2nd aquifer is found ranging from 122 to 262 m.

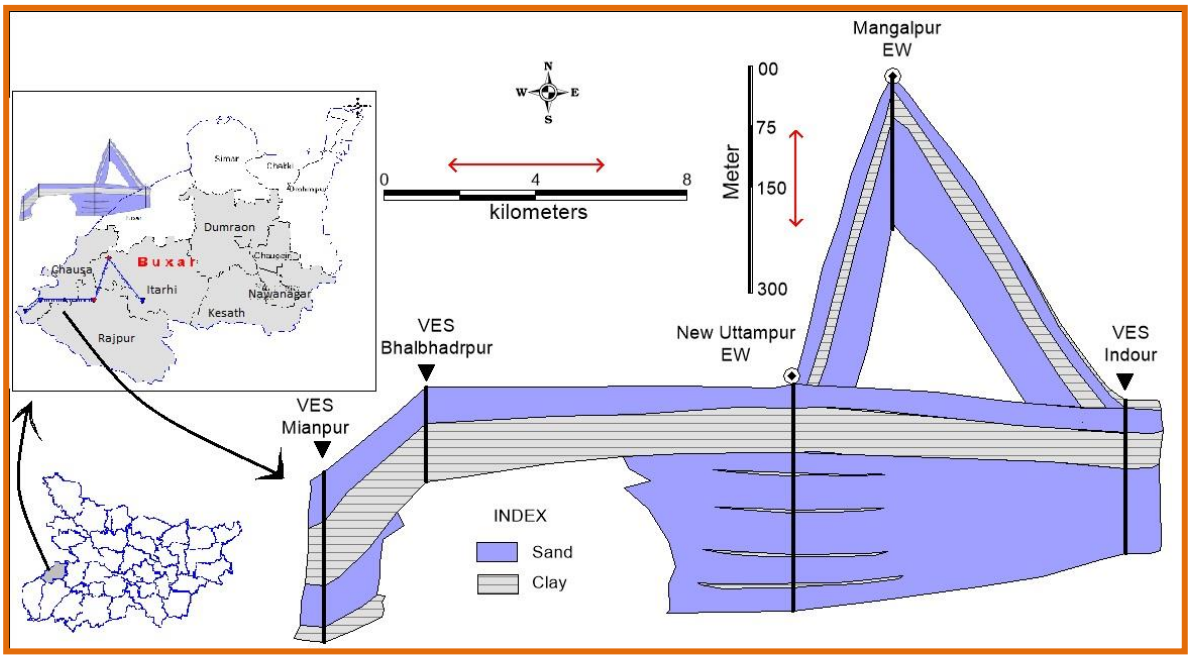

Fig 1 Lithological section in parts of Chausa block, Buxar

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 44.74% and water level trend is not declining in nature. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer should be used for pipe water supply to avoid arsenic contamination in future.

Chemical quality of ground water and contamination

In general, ground water is good and potable in nature. Ground water from 1st aquifer is being used for domestic and irrigation purposes. No arsenic contamination is reported from this block. But, as a precautionary measure, only 2nd aquifer may be used for pipe water supply.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

In view of the issue of sporadic arsenic contamination in neighbouring blocks, it is recommended to utilize 2nd aquifer only for meeting drinking water supply requirement.

Annexure I

Dynamic Groundwater Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Bhojpur	Chausa	2428.94	323.97	1515.6	1146.83	5415.34	270.77	5144.57	2034.30	157.54	109.59	2301.43	60.54	3049.73	44.74	Safe

Annexure II

Chemical Analysis of Groundwater sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Chausa	Chausa	7.82	1022	664.3	0	112	381.3	0	86.36	7.11		390	44	68.04	75.08	3.82

Block wise
Aquifer Maps and Management plans

Salient Information

Name of the Block and Area (in km^2)

DUMRAON (198 sq. km)

District/ State

Buxar/Bihar

Rainfall

The normal annual rainfall of Dumraon block is 717.6 mm of which 84.58% occurs during the monsoon season. The normal rainfall during monsoon season is 607 mm and during non monsoon season is 110.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected distributaries and minors of Sone canal irrigation system. The irrigation from ground water is mainly through the shallow tube wells. Cropping intensity is 138.22% and irrigation intensity is 85.41%. Dependency of ground water irrigation is 50.92%.

Ground water resource availability and extraction

The dynamic ground water resource of Dumraon block has been assessed as 75.77 MCM. The gross ground water draft for all uses stands at 27.89 MCM. The stage of development is 36.81% depicted in Annuexure I. 1319 STWs tapping shallow aquifer exist in the block. An additional 1676 STWs are feasible with available ground water resources in the block.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Premonsoon water table varies from 60 to 65 m amsl and ground water flow is towards north.

Aquifer Disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand as aquifers (Fig.1). The sections reveal that the area is underlain by a two-tier aquifer system. The clay layer of 12-15 m separates the 1st and 2nd aquifer. The formation at the top is clay mixed with kankar and fine sands. In the absence of any pure clay at the top, the shallow

aquifer occurs under water table condition. The depth of 1st aquifer in the area varies from 59 to 172 m bgl in general. Shallow private irrigation tubewells in the area tap the aquifer zone 20-60 m bgl. Average yield of the tube well varies from 30 to 95 m^3/hr with draw down of 3 m. 2nd aquifer ranges from 190 to 226 m bgl. Aquifer materials are composed of fine to medium sands.

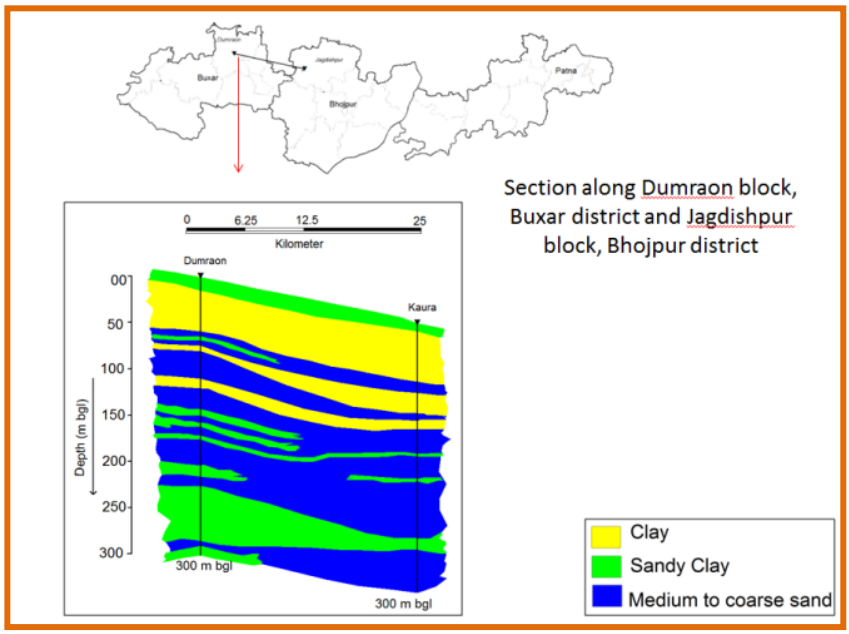

Fig 1 Lithological section along Dumraon block, Buxar and Jagdishpur block, Bhojpur

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 36.81% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. In view of arsenic contamination in neighbouring blocks, 2nd aquifer may be used for pipe water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

In view of the issue of sporadic arsenic contamination in neighbouring blocks, it is recommended to utilize 2nd aquifer only for meeting drinking water supply requirement.

Dynamic Ground Water Resource Estimation

Annexure I

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Dumraon	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	36.81	Safe
		4479.23	593.69	1477.69	1868.85	8419.46	841.95	7577.51	2292.30	354.60	142.26	2789.16	135.87	5149.34		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Dumraon	Basauli	7.95	825	536.25	0.95	16.4	467.4	0	22.5	18.5	0	200	32	29.16	109.65	11.7

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
ITARHI (229 sq. km)

District/ State
Buxar/Bihar

Rainfall

The normal annual rainfall of Itarhi block is 826.1 mm of which 77.87% occurs during the monsoon season. The normal rainfall during monsoon season is 643.3 mm and during non monsoon season is 182.8 mm.

Agriculture and irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected distributaries and minors of Sone canal system. Irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Itarhi block has been assessed as 107.73 MCM. The gross ground water draft for all uses stands at 57.2 MCM. The stage of Development is 53.1 % shown in Annuexure I. 2814 STWs already exist in the block tapping shallow aquifer for irrigation purposes. Still, an additional 1213 STWs are feasible for construction with available ground water resources.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most of the parts.

Aquifer disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand, coarse sand and gravel as aquifers (Fig.1). The sections reveal that the area is underlain by a two-tier aquifer system. The clay layer of 8-12 m separates the 1st and 2nd aquifer. The formation at the top is clay mixed with kankar and fine sands. The depth of first aquifer in the area varies from 14 to 74 m bgl with intercalation of thick clay layer of 10 m from 24 to 34 m bgl. Shallow private irrigation tubewells in the area tap the aquifer zone 20-60 m bgl.

Average yield of the tube well varies from 30 to 95 m^3/hr withdraw down of 3 m. 2nd aquifer occurs 82 m onwards upto the explored depth of 200 m with intercalation of clay layers.

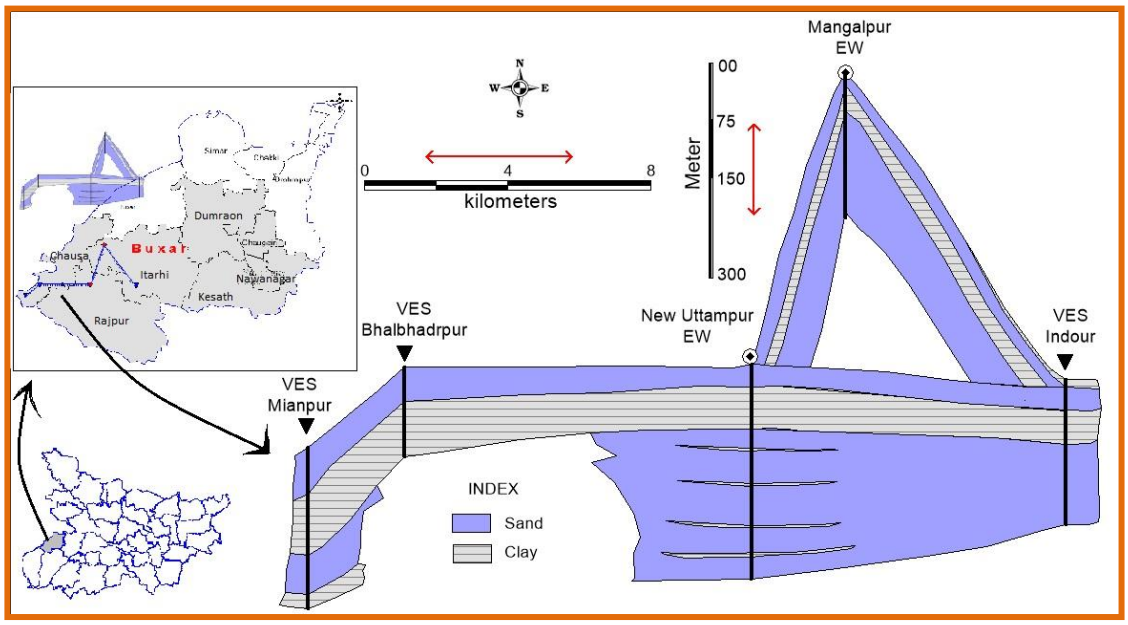

Fig 1 Lithological section

Ground water resource, extraction, contamination and other issues

The overall stage of groundwater development in the block is 53.1% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Shallow aquifer must be utilised for irrigation purpose and deeper aquifer must be strictly for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

In view of the issue of sporadic arsenic contamination in neighbouring blocks, it is recommended to utilize 2nd aquifer only for meeting drinking water supply requirement.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Buxar	Itarhi	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	53.10	Safe
		5179.19	686.47	3019.28	3085.81	11970.75	1197.08	10773.68	5189.10	259.29	272.42	5720.81	99.63	5484.95		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Itarhi	Purusottampur	7.72	561	364.65	0.544	31.1	276.75	0	15.05	12.5	0	255	66	21.87	22	5.1
Buxar	Itarhi	Basudhar	7.74	497	323.05	0.616	8.4	289.05	0	16.22	6.37	0	200	56	14.58	34.29	1.21
Buxar	Itarhi	Jalwasi	7.74	569	369.85	0.432	12.7	307.05	0	16.22	32.8	0	230	72	12.15	18.65	13.75
Buxar	Itarhi	Kukdha	7.67	1129	733.85	0.818	107	412.05	0	83.96	58.3	0	390	50	64.40	96.25	18

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
KESATH (31 sq. km)

District/ State
Buxar/Bihar
Rainfall

The normal annual rainfall of Munger district is 859.9 mm of which 94.23% occurs during the monsoon season. The normal rainfall during monsoon season is 810.3 mm and during non monsoon season is 49.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected by distributaries and minors of Sone canal system. Irrigation from the ground water is mainly through the shallow tube wells. Dependency of ground water irrigation is 50.92%.

Ground water resource availability and extraction

The dynamic ground water resource of Kesath block has been assessed as 16.94 MCM. The gross ground water draft for all uses stands at 7.82 MCM. The stage of development is 46.16 % shown in Annuexure I. 410 STWs tapping shallow aquifer exist in the block for irrigation purpose. An additional 269 STWs are feasible for construction with available ground water resources in the block.

Water level behaviour

The depth to water level varies from 5 to 8 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl.

Aquifer Disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand, fine sand as aquifer. The area is underlain by a two-tier aquifer system (Fig 1). There is a prominent clay layer ranging from 26 to 44 m. 1st aquifer is restricted to 26 m bgl. 2nd aquifer ranges from 56 m onwards down to explored depth of 200 m with intercalation of thick clay layers. Aquifers are composed of fine to medium sand. Shallow private irrigation

tubewells in the area tap the aquifer zone 20-60 m bgl. Average yield of the tube well varies from 30 to 95 m^3/hr withdraw down of 3 m.

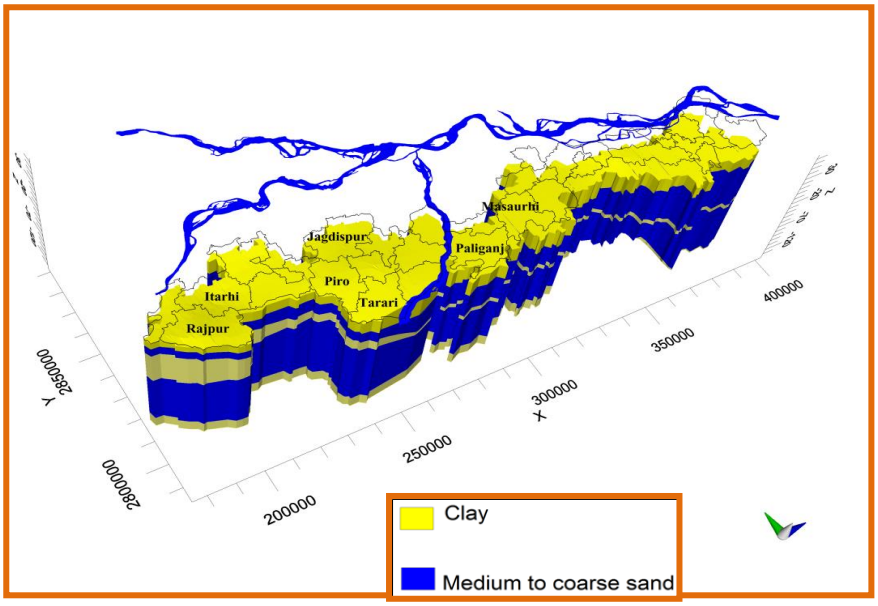

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 46.16% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

In view of the issue of sporadic arsenic contamination in neighbouring blocks, it is recommended to utilize 2nd aquifer only for meeting drinking water supply requirement.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Buxar	Kesath	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	46.16	Safe
		696.58	92.33	594.39	499.73	1883.03	188.3	1694.73	693.60	51.39	37.25	782.24	19.75	981.38		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Kesath	Katkinar	7.46	632	410.8	0.496	26.9	325.85	0	10.46	2.35	0	270	52	34.02	31.72	1.06

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
NAWANAGAR (185 sq. km)

District/ State
Buxar/Bihar

Rainfall

The normal annual rainfall of Nawanagr block is 768.6 mm of which 94.01% occurs during the monsoon season. The normal rainfall during monsoon season is 722.6 mm and during non monsoon season is 46 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected distributaries and minors of Sone canal system. Irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Nawanagari block has been assessed as 108.04 MCM. The gross ground water draft for all uses stands at 23.95 MCM. The stage of development is 22.17 % depicted in Annuexure I. 1197 STWs already exist in the block. An additional 3445 STWs are feasible for construction with available ground water resources in the block.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl.

Aquifer Disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand, coarse sand as aquifer. The area is underlain by a two-tier aquifer system (Fig 1). The clay layer of 15-20 m separates the 1st and 2nd aquifer. The formation at the top is clay mixed with kankar and medium sands and occassionaly with coarse sand. In the absence of any pure clay at the top, the shallow aquifer occurs under water table condition. The depth of first aquifer area varies from 07 to 42 m bgl in general. Shallow private irrigation tubewells in the

area tap the aquifer zone 20-60 m bgl. Average yield of the tube well varies from 30 to 95 m^3/hr with drawdown of 3 m. 2^{nd} aquifer ranges from 60 to 80 m.

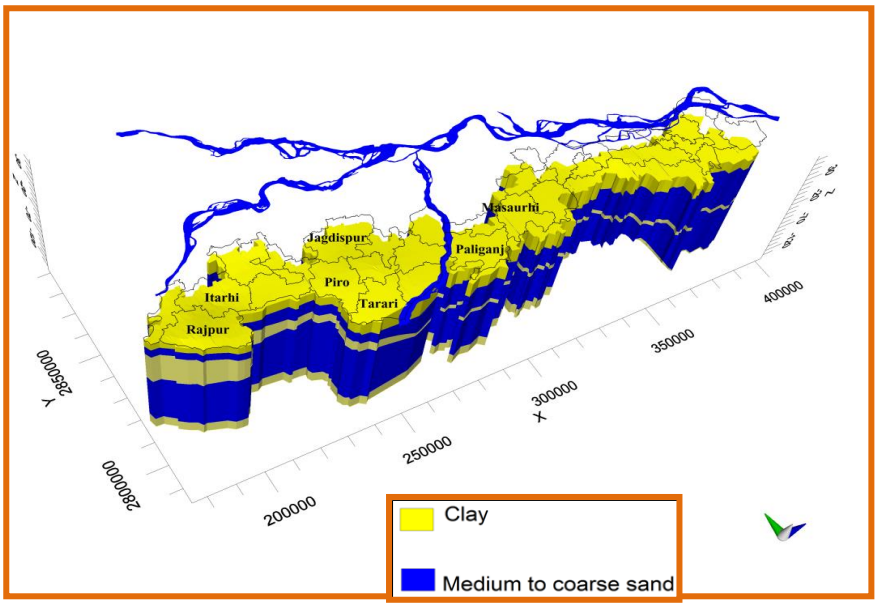

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the Block is 22.17% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used strictly for drinking water supply in view of arsenic contamination in neighbouring blocks.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

In view of the issue of sporadic arsenic contamination in neighbouring blocks, it is recommended to utilize 2^{nd} aquifer only for meeting drinking water supply requirement.

Annexure I

ound Water Resource EstimationDynamic Gr

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Buxar	Nawanagar	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	22.17	Safe
		4174.03	553.24	3811.36	3466.24	12004.87	1200.49	10804.38	2028.00	253.06	114.05	2395.11	97.24	8679.14		

nnexure IIA

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Navanagar	Jitwadih (Jitwadehri)	768	557	362.05	0.476	38.2	239.85	0	27.55	28.5	0	265	70	21.87	13.68	0.65
Buxar	Navanagar	Parmeshwar Tola	7.55	991	644.15	0.88	52.3	516.6	0	21.1	28.9	0	380	60	55.89	93.77	7.35

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
RAJPUR (274 sq. km)

District/ State
Buxar/Bihar

Rainfall

The normal annual rainfall of Rajpur block is 788 mm of which 88% occurs during the monsoon season. The normal rainfall during monsoon season is 693.1 mm and during non monsoon season is 94.9 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

The area is developed with well-connected distributaries and minors of Sone canal system. Irrigation from the ground water is mainly through the shallow tube wells.

Ground water resource availability and extraction

The dynamic ground water resource of Rajpur block has been assessed as 123.43 MCM. The gross ground water draft for all uses stands at 61.71 MCM. The stage of development is 50% shown in Annuexure I.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most of the parts. 3170 STWs tapping shallow aquifer already exist in the block for irrigation. A few deep irrigation TWs also exist. An additional 1645 STWs are also feasible in the block with available ground water resources.

Aquifer Disposition

Principal aquifers in the area have been delineated by grouping the fine to medium sand, coarse sand as aquifers (Fig.57). The sections reveal that the area is underlain by a two-aquifer system. The formation at the top is clay mixed with kankar and coarse sands. The shallow aquifer occurs under water table condition. The depth of first aquifer in the area varies from 92 to 116 m bgl in general. Average yield of the tube well varies from 30 to 95

m^3/hr withdraw down of 3 m. 2nd aquifer ranges from 122 m to 262 m. 3rd aquifer is encountered from 274 m onwards.

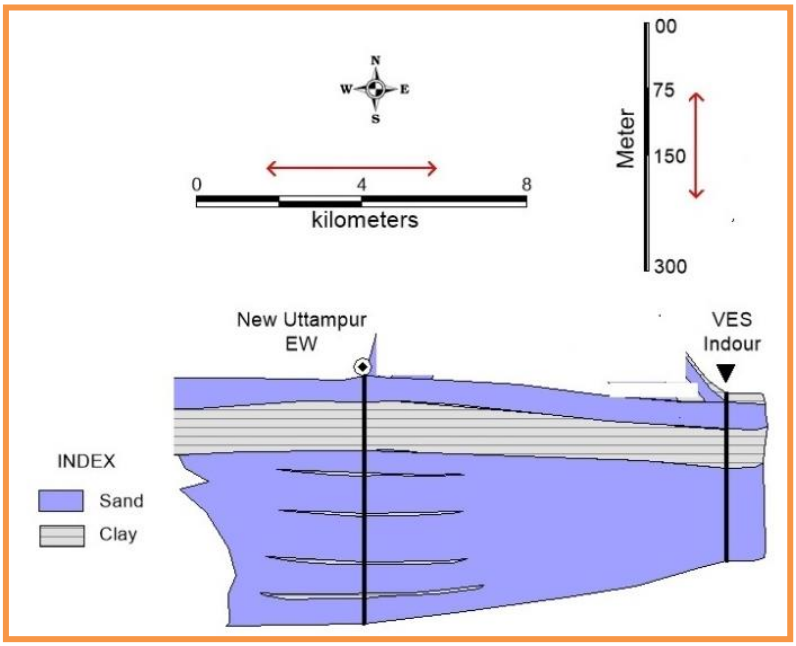

Fig 1 Lithological section in Rajpur block

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 50% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side interventions

2nd aquifer may be used for meeting drinking water supply requirement.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Bhojpur	Rajpur	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		Safe
		6206.52	822.64	3762.54	2923.63	13715.28	1371.53	12343.75	5553.30	324.28	293.90	6171.98	124.69	6665.46	50.00	

Annexure II

Chemical Analysis of Groundwater Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Buxar	Rajpur	Jalhara	7.64	861	559.65	0.91	59.2	375.15	0	36.39	51.7	0	315	62	38.88	70.68	1.6
Buxar	Rajpur	Bahrutiya (Kedarganj)	7.4	433	281.45	0.805	9.08	227.55	0	12.44	2.59	0	195	40	23.08	17.96	0.56

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
BELCHI (69 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Belchi block is 1335.7 mm of which 81.26% occurs during the monsoon season. The normal rainfall during monsoon season is 1085.5 mm and during non monsoon season is 250.2 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water is the principal source of irrigation. 153 STWs are feasible for construction with available ground water resources considering up to 70% of SOD.

Ground water resource availability and extraction

The dynamic ground water resource of Belchi block has been assessed as 18.37 MCM. The gross ground water draft for all uses stands at 10.85 MCM. The stage of Development is 59.13 % depicted in Annuexure I.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Water level fluctuation is in the order of 2- 4 m.

Aquifer Disposition

The top aquitard layer of ~20 m thickness is highly mixed and behaves like a low potential aquifer (Fig 1). The presence of silt in the top zones at places renders it semi-pervious in nature. This layer sustains the dug wells and shallow hand pumps in the area. Depth of 1st aquifer ranges from 60 to 65 m bgl. The thickness of 2nd aquifer varies from 140 to 150 m separated by clay layer of 10-15 m thick from the 1st aquifer. The depth of 2nd aquifer ranges from 80 to 230 m in Belchi area. Third aquifer is encountered below 250 bgl.

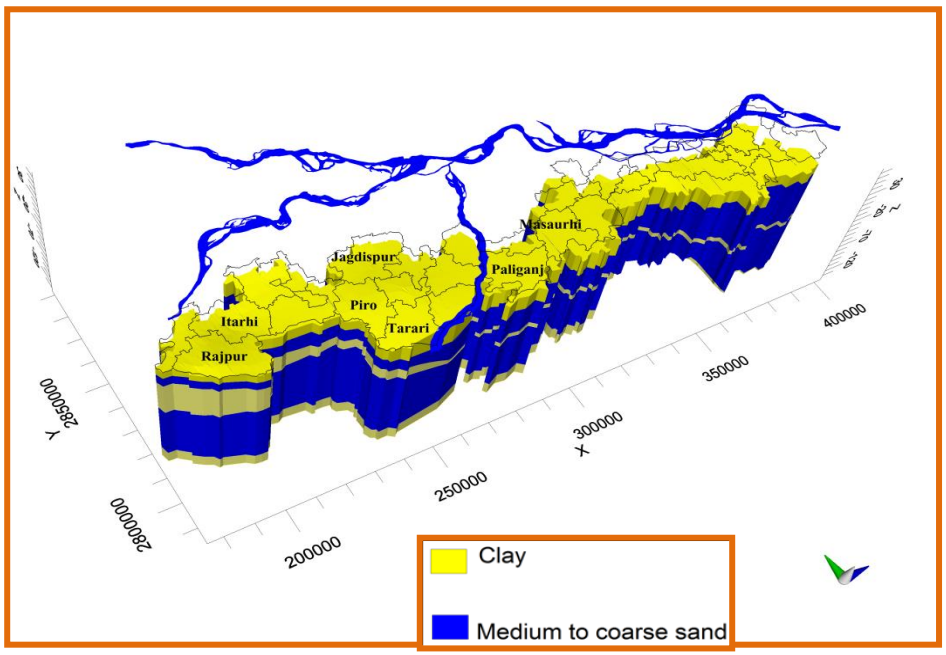

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

There is scope for groundwater development in the block. Deeper aquifer may be utilized for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

The stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, still, artificial recharge may be encouraged to augment ground water resources in suitable condition.

Demand side intervention

2nd aquifer may be used for meeting drinking water supply requirement.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Buxar	Belchi	1551.05	222.08	102.05	166.5	2041.68	204.17	1837.51	934.20	100.54	51.74	1086.48	38.64	864.67	59.13	Safe

Annexure II

Chemical analysis of Groundwater sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Belchi	Belchi	7.31	506	328.9	0.06	17.7	305	0	12.6	7.9	0	245	64	20.4	23.3	4.7

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
DANIAWAN (65 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Daniawan block is 807.1 mm of which 86.54% occurs during the monsoon season. The normal rainfall during monsoon season is 698.5 mm and during non monsoon season is 108.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water is the principal source of irrigation. Dependency of ground water irrigation is 52.81%.

Ground water resource availability and extraction

The dynamic ground water resource of Daniawan block has been assessed as 17.78 MCM. The gross ground water draft for all uses stands at 13.59 MCM. The stage of development is 76.46 % Annuexure I. 805 STWs already exist in the block for irrigation purpose.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Premonsoon watertable varies from 45 to 50 m amsl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers in the block. Clay of about 30 m occupies at the top in the block. The top layer (within 30 m bgl) is an aquitard in nature which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps. Two aquifer systems has been reported, mainly a total of 150-165 m thick aquifer upto explored depth of 250 m bgl. The deeper aquifer is separated by a major clay zone (within 62 to 94 m bgl). Deeper aquifer is under semi confined to confined condition.

The cumulative yield of tube well is 188.72 m^3 /day. Transmissivity is in the order of 10435 m^2 /day.

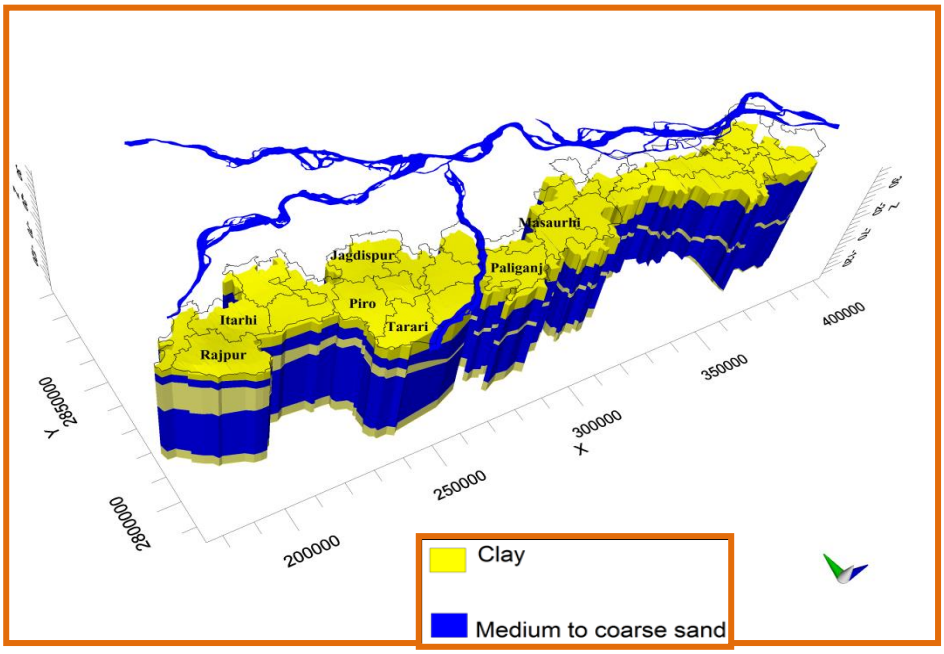

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 76.46%. High ground water draft has been observed from the block. Artificial recharge structures like recharge ponds etc can also be constructed to augment the ground water resource.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

High ground water draft has been observed from the block. Artificial recharge structures like recharge-ponds with shaft etc can also be constructed to augment the ground water recharge in suitable condition. Rainfall is the primary source of ground water. Return flow from irrigation, recharge through infiltration of river side alluvium augments ground water resource.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. Small and marginal farmers can opt for shallow tube wells for irrigation, while farmers' co-operative may construct high discharge tube wells for meeting irrigation needs.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Buxar	Daniawan	1470.42	210.53	112.2	183.06	1976.21	197.62	1778.59	1181.00	114.10	64.75	1359.85	43.85	553.74	76.46	Safe

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
DHANAURA (186 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Dhanaura block is 628.7 mm of which 95.29% occurs during the monsoon season. The normal rainfall during monsoon season is 599.1 mm and during non monsoon season is 29.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops sown are paddy, wheat, sugarcane, potato and vegetables. Crops are growing in all the four seasons namely Bhadai, Ahgani, Rabi and Garma seasons in a year. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water resource availability and extraction

The dynamic ground water resource of Dhanaura block has been assessed as 49.36 MCM. The gross ground water draft for all uses stands at 28.85 MCM. The stage of development is 58.96 % depicted in Annuexure I. 1655 STWs already exist in the block; an additional 287 STWs are feasible for construction for irrigation purposes in the block.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 3 to 7 mbgl.

Aquifer Disposition

The area is underlain by Quaternary alluvial formation comprising various grades of clay, silt, sand with occasional and gravel. Two aquifer systems have been encountered in the block (Fig 1). The first aquifer having thickness of about 70 m within the depth range of 58 to 128 m is underlain by 45 - 58 m thick clay layer. The second aquifer is continued from depth of 136 to 200 m separated by 8 m thick clay layer. Aquifer lithology comprises of various grades of medium to coarse sand and upward coarsening occurs. Cumulative discharge of tube well varies from 125 to 250 m^3 /hr with ~ 6 m drawdown.

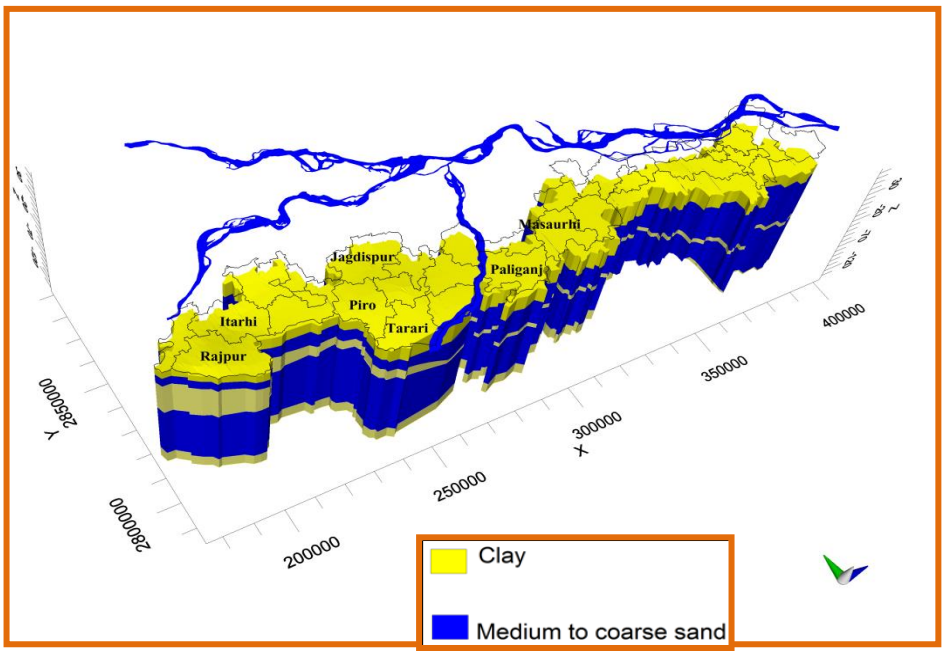

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 58.96% and water level trend is not declining. There is scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

Rainfall is the primary source of ground water recharge besides which return flow from ground water irrigation, direct infiltration from river bed during stream flow are the other source of recharge for ground water resource enhancement.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. Small and marginal farmers can opt for shallow tube wells for irrigation, while farmers' co-operative can opt for high discharge tube wells for meeting irrigation needs.

Annexure 1

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Buxar	Dhanarua	4191.02	600.07	263.49	429.91	5484.49	548.45	4936.04	2427.00	321.20	137.41	2885.61	124.00	2343.07	58.96	Safe

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
DULHIN BAZAR (201 sq. km)

District/ State
Patna /Bihar

Rainfall

The normal annual rainfall of Dulhin Bazar block is 1108.5 mm of which 89.73% occurs during the monsoon season. The normal rainfall during monsoon season is 994.7 mm and during non monsoon season is 113.8 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water is the principal source of irrigation. 415 STWs already exist for irrigation purpose in this block.

Ground water resource availability and extraction

The dynamic ground water resource of Dulhin Bazar block has been assessed as 48.15 MCM. The gross ground water draft for all uses stands at 8.26 MCM. The stage of development is 17.19 % shown in Annuexure I. An additional 1919 STWs are feasible for irrigation purpose with available ground water resources.

Water level behaviour

The depth to water level varies from 2 to 5 mbgl during pre-monsoon season in most of the area. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most of the parts and in few parts; it is 0 to 2 mbgl.

Aquifer Disposition

The area is underlain by Quaternary alluvial formation comprising various grades of clay, silt, sand with occasional and gravel. Two aquifer systems have been encountered in Dulhin bazar block (Fig 1). The first aquifer having thickness of about 70 m within the depth range of 58 to 128 m is underlain by 45 - 58 m thick clay layer. The second aquifer is continued from depth of 136 to 200 m separated by 8 m thick clay layer. Aquifer lithology comprises of various grades of medium to coarse sand and upward coarsening occurs.

Cumulative discharge of tube well varies from 125 to 250 m^3 /hr with ~ 6 m drawdown. Transmissivity varies from 4000 to 19500 m^2 /day.

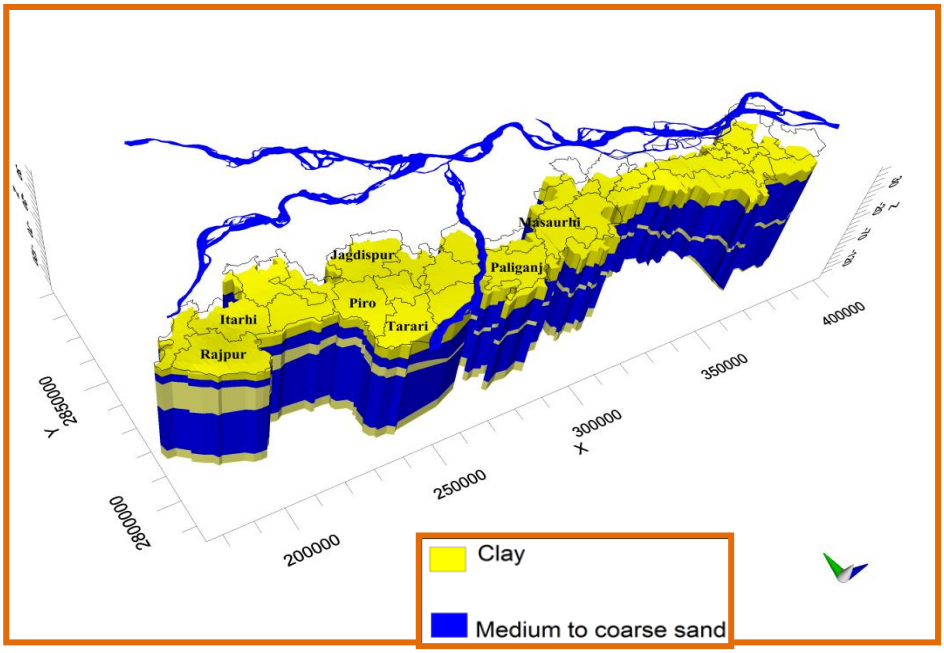

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 17.19% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. Small and marginal farmers can opt for shallow tube wells for irrigation, while farmers' co-operative can opt for high discharge tube wells for meeting irrigation needs.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Buxar	Dulhinbazar	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	17.19	Safe
		2499.94	357.94	760.36	1732.59	5350.83	535.08	4815.75	597.00	189.90	39.34	826.24	73.00	4135.23		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Dulhinbazar	dulhinbazar	7.13	695	451.75	0.46	202.06	190.65	0	48	44	0	250	66	20.65	42	1.5

Block wise
Aquifer Maps and Management plans

Salient Information

Name of the Block and Area (in km^2)

FATUHA (126 sq. km)

District/ State

Patna/Bihar

Rainfall

The normal annual rainfall of Fatuha block is 723.8 mm of which 78.22% occurs during the monsoon season. The normal rainfall during monsoon season is 566.2 mm and during non monsoon season is 157.6 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water is the principal source of irrigation. Dependency of ground water irrigation is 52.81%.

Ground water resource availability and extraction

The dynamic ground water resource of Fatuha block has been assessed as 34.48 MCM. The gross ground water draft for all uses stands at 23.61 MCM. The stage of development is 69.19 % shown in Annuexure I. 1398 STWs already exist in the block.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers in the block (Fig 1). Clay of about 30 m occupies at the top in the block. The top layer (within 30 m bgl) is an aquitard in nature which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps. Two aquifer systems has been reported, mainly a total of 150-165 m thick aquifer upto explored depth of 250 m bgl. The deeper aquifer is separated by a major clay zone (within 62 to 94 m bgl). Deeper aquifer is under semi confined to confined condition.

The cumulative yield of tube well is 188.72 m^3 /day. Transmissivity is in the order of 10435 m^2 /day.

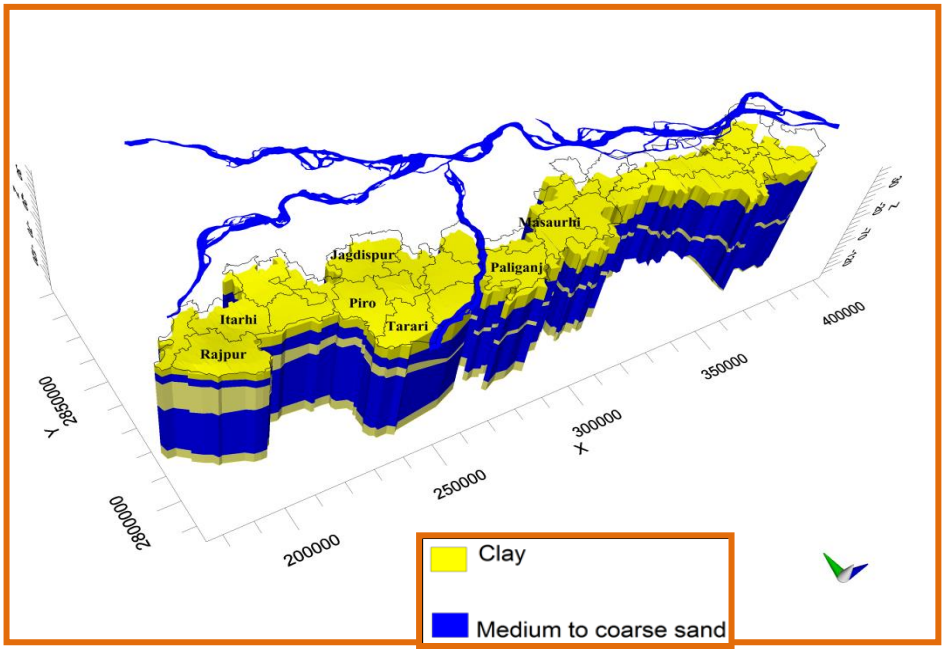

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 66.7 % and water level trend is not declining. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the artificial recharge may be encouraged to augment ground water resources.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. 2nd aquifer should be targeted for pipe water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Buxar	Fathua	2854.1	408.65	216.3	352.9	3831.95	383.2	3448.76	1939.20	301.86	120.67	2361.73	116.00	1358.10	69.19	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25˚C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Fatua	Maksudpur	7.17	616	400.4	0	35.5	295	0	26.9	20.3	0	290	40	45.6	50.72	2.5

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
GHOSWARI (140 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Ghoswari block is 1078.8 mm of which 88.3% occurs during the monsoon season. The normal rainfall during monsoon season is 953 mm and during non monsoon season is 125.8 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water is the principal source of irrigation. 642 STWs already exist for irrigation in the block.

Ground water resource availability and extraction

The dynamic ground water resource of Tarari block has been assessed as 25.36 MCM. The gross ground water draft for all uses stands at 10.34 MCM. The stage of Development is 41.06 % depicted in Annuexure I. An additional 511 STWs are feasible with available ground water resources fro irrigation purposes only.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in the block.

Aquifer Disposition

The top aquitard layer of 20 m thickness is highly mixed and behaves like a low potential aquifer (Fig 1). The presence of silt in the top zones at places renders it semi-pervious in nature. This layer sustains the dug wells and shallow hand pumps in the area. Depth of 1st aquifer ranges from 20 to 70 m bgl. The thickness of 2nd aquifer varies from 100 to 208 m separated by clay layer of 08 - 10 m thick from the 1st aquifer.

The 3rd aquifer encountered ranges from 240 to 296 m bgl within the explored depth of 310 m bgl.

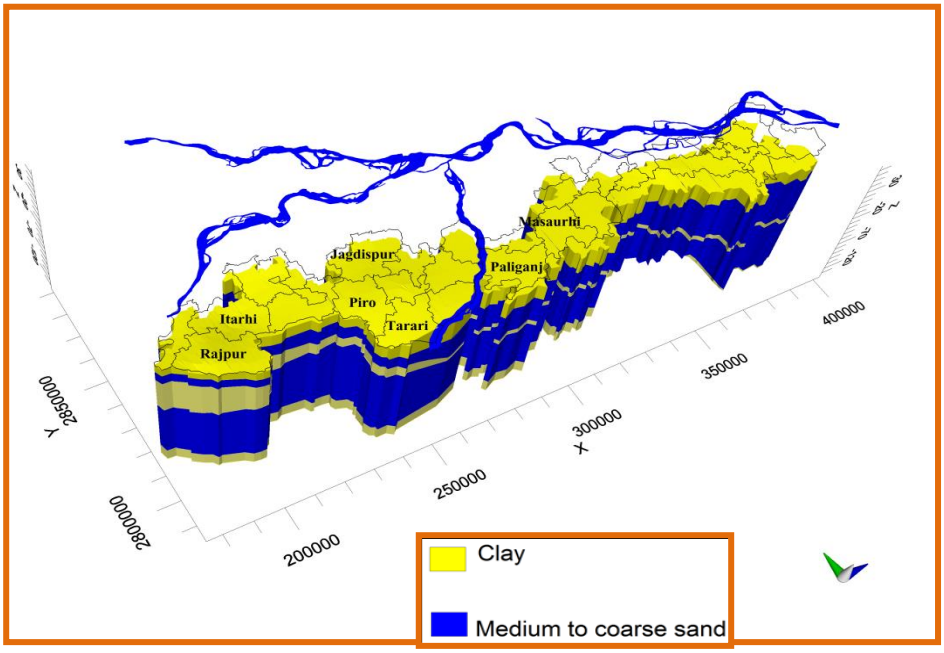

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 41.06 % and water level trend is not declining. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the artificial recharge with recharge shafts may be encouraged to augment ground water resources.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. 2nd aquifer should be targeted for pipe water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Buxar	Ghoshwari	2105.57	452.21	99.2	161.85	2818.83	281.88	2536.95	871.80	113.81	49.28	1034.89	44.00	1604.86	41.06	Safe

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Ghoswari	Jhanki	7.57	496	322.4	0	10.6	211	0	15.2	15.9	0	205	32	30	23.97	5.7
Patna	Ghoswari	Gosai	7.22	552	358.8	0.09	39.0	226	0	21.22	23.6	0	275	76	20.4	32.58	0.89

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
KHUSRUPUR (61 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Khusrupur block is 1155.1 mm of which 82.42% occurs during the monsoon season. The normal rainfall during monsoon season is 952.1 mm and during non monsoon season is 203 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Cropping intensity is 127.91% and irrigation intensity is 70.79%. Dependency on ground water irrigation is 52.81%. 435 STWs already exist for irrigation purposes in the block and an additional 125 STWs are feasible with available ground water resources.

Ground water resource availability and extraction

The dynamic ground water resource of Khusrupur block has been assessed as 15.81 MCM. The gross ground water draft for all uses stands at 8.92 MCM. The stage of development is 56.84 % depicted in Annuexure I.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl. Premonsoon water table varies from 45 to 50 m amsl and flow direction is towards east.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers in the block. Clay of about 30 m occupies at the top in the block (Fig 1). The top layer (within 30 m bgl) is an aquitard in nature which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps. Two aquifer systems has been reported, mainly a total of 150-165 m thick aquifer upto explored depth of 250 m bgl. The deeper aquifer is separated by a major clay zone (within 62 to 94 m bgl). Deeper aquifer is under semi confined to confined condition. The cumulative yield of tube well is 188.72 m^3 /day. Transmissivity is in the order of 10,435 m^2 /day.

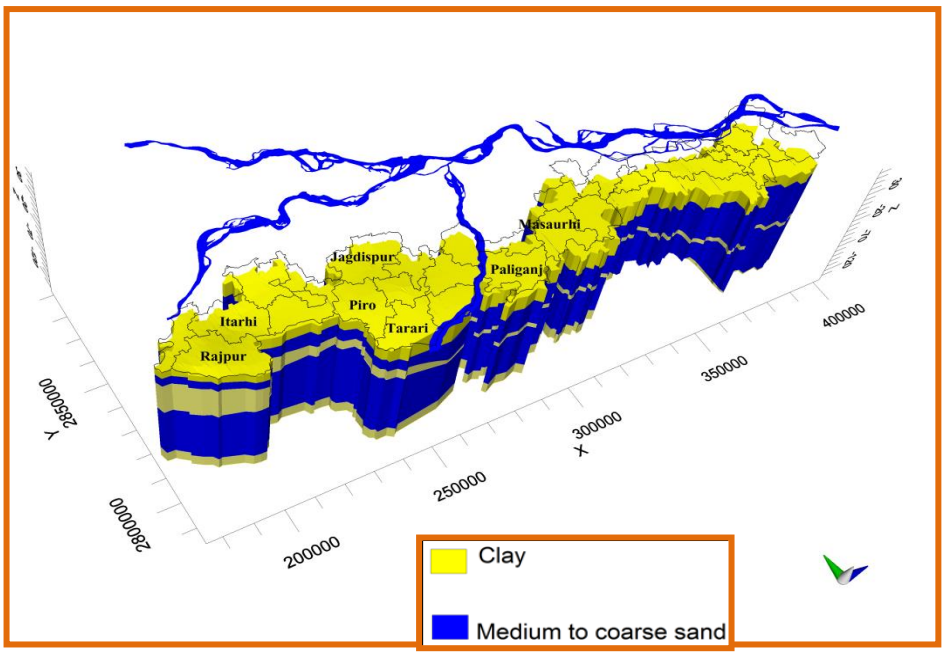

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 56.84 % and water level trend is not declining. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the artificial recharge at suitable locality may be encouraged to augment ground water resources.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. 2nd aquifer should be targeted for pipe water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
Patna	Khusrupur	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	56.84	Safe
		1386.62	198.54	65.27	106.49	1756.92	175.69	1581.23	618.00	223.17	51.32	892.49	64.00	888.19		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Khusrupur	Mustafapur	7.26	731	475.15	0	28.4	358	0	20.9	19.6	0	345	68	42	49.01	0.87

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
MASAURHI (202 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Masaurhi block is 1036.8 mm of which 93.84% occurs during the monsoon season. The normal rainfall during monsoon season is 973 mm and during non monsoon season is 63.8 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water is the principal source of irrigation.

Ground water resource availability and extraction

The dynamic ground water resource of Masaurhi block has been assessed as 56.87 MCM. The gross ground water draft for all uses stands at 37.61 MCM. The stage of development is 66.7 % depicted in Annuexure I. 1878 STWs already exist for irrigation purposes in the block. No additional STW is feasible with available ground water resources.

Water level behaviour

The depth to water level varies from 5 to 8 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most of the parts.

Aquifer Disposition

The area is underlain by Quaternary alluvial formation comprising various grades of clay, silt, sand with occasional and gravel. Two aquifer systems have been encountered in the block (Fig 1). The first aquifer having thickness of about 70 m within the depth range of 58 to 128 m is underlain by 45 - 58 m thick clay layer. The second aquifer is continued from depth of 136 to 200 m separated by 8 m thick clay layer. Aquifer lithology comprises of various grades of medium to coarse sand and upward coarsening occurs. Cumulative discharge of tube well varies from 125 to 250 m^3 /hr with ~ 6 m drawdown.

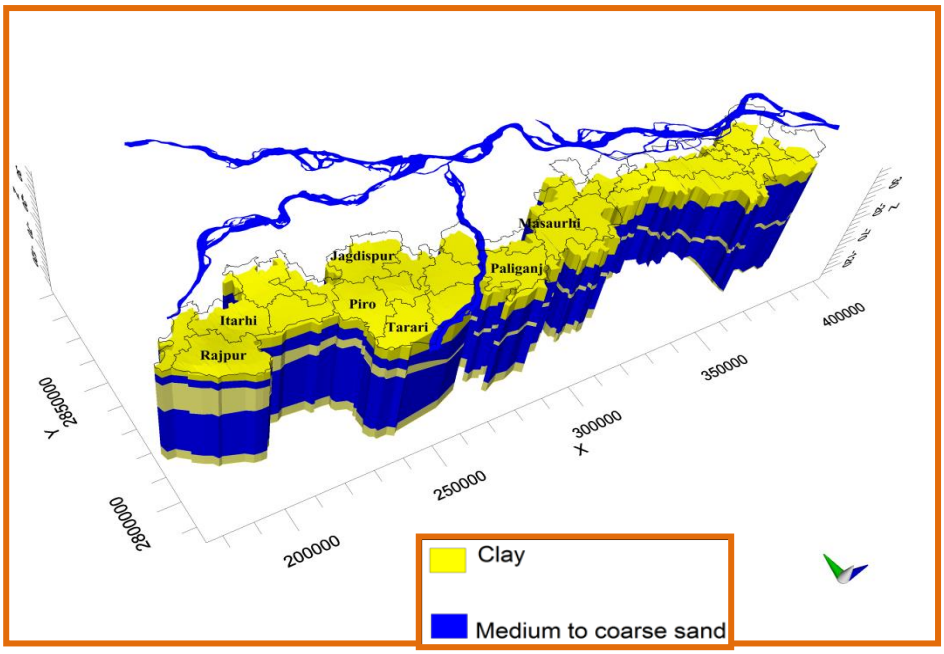

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 66.7 % and water level trend is not declining. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the artificial recharge in suitable locality may be encouraged to augment ground water resources.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. 2nd aquifer should be targeted for pipe water supply.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Patna	Masuarhi	4572.3	654.66	462.35	629.73	6319.04	631.9	5687.14	2964.60	582.38	214.78	3761.76	141.00	2533.90	66.70	Safe

Annexure II

Chemical Analysis of Water Samples

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Masurhi	Sharvan	7.49	896	582.4	0.03	39.0	365	0	51.3	13.3	0	380	64	52.8	40.12	6.9

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
PALIGANJ (238 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Paliganj block is 871 mm of which 88.01% occurs during the monsoon season. The normal rainfall during monsoon season is 766.6 mm and during non monsoon season is 104.4 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Ground water resource availability and extraction

The dynamic ground water resource of Tarari block has been assessed as 111.95 MCM. The gross ground water draft for all uses stands at 9.86 MCM. The stage of Development is 8.82% shown in Annuexure I. An additional 5236 STWs are feasible in the block with available ground water resources.

Water level behaviour

The depth to water level varies from 2 to 5 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most parts.

Aquifer Disposition

The area is underlain by Quaternary alluvial formation comprising various grades of clay, silt, sand with occasional and gravel. Two aquifer systems have been encountered in the block (Fig 1). The first aquifer having thickness of about 70 m within the depth range of 58 to 128 m is underlain by 45 - 58 m thick clay layer. The second aquifer is continued from depth of 136 to 200 m separated by 8 m thick clay layer. Aquifer lithology comprises of various grades of medium to coarse sand and upward coarsening occurs. Cumulative discharge of tube well varies from 125 to 250 m^3 /hr with ~ 6 m drawdown. Transmissivity varies from 4000 to 19500 m^2 /day.

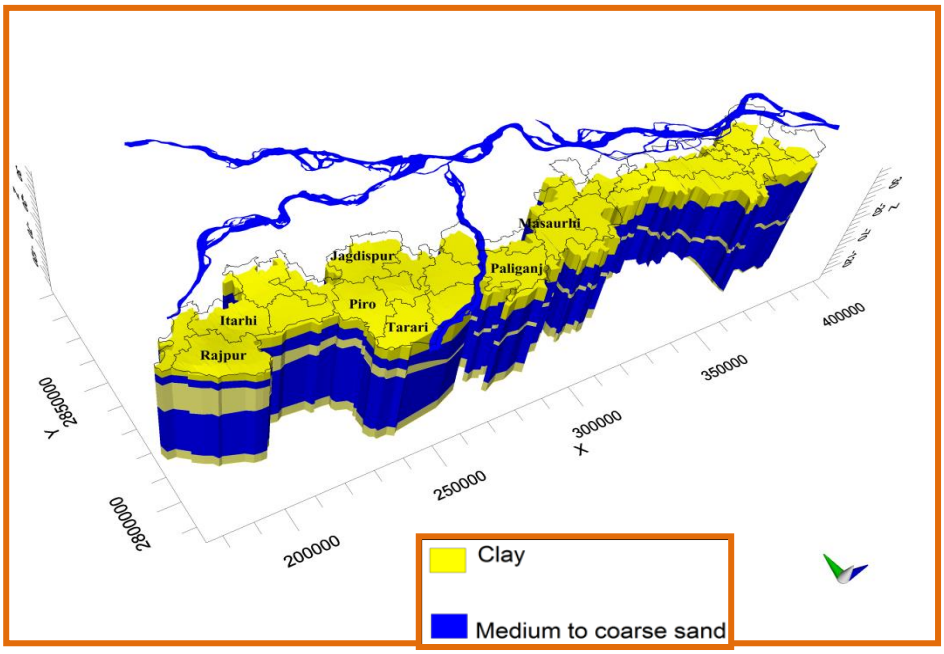

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 8.82% and water level trend is not declining. There is an ample scope for groundwater development in the block. Rainfall is the primary source of groundwater recharge besides which return flow from groundwater irrigation, seapage from canal, ponds, tanks and direct infiltration from river beds during stream flow are the other source of recharge for ground water resource enhancement. Deeper aquifer may be used for drinking water supply.

Chemical quality of ground water and contamination

Ground water is good and potable in nature. USSL diagram shows that salinity hazard is moderate to high.

Ground water resource enhancement

As the stage of groundwater development is within the safe limit and there is no long-term water level decline in the area, the need for artificial recharge is not felt.

Demand side interventions

Demand for ground water can be met through both shallow and deep tube wells. Small and marginal farmers can opt for shallow tube wells for irrigation, while farmers' co-operative can opt for high discharge tube wells for meeting irrigation needs.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Patna	Paliganj	5370.07	768.88	3168.42	3131.73	12439.1	1243.91	11195.19	508.20	425.65	52.35	986.21	149.00	10528.90	8.82	Safe

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
PUNPUN (127 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Punpun block is 1114 mm of which 91% occurs during the monsoon season. The normal rainfall during monsoon season is 1013.8 mm and during non monsoon season is 100.2 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are Sandy loam, Clay loam, loam, Clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Cropping intensity is 127.91% and irrigation intensity is 70.79%. Dependency on ground water irrigation is 52.81%.

Ground water resource availability and extraction

The dynamic ground water resource of Punpun block has been assessed as 41.02 MCM. The gross ground water draft for all uses stands at 33.72 MCM. The stage of development is 85.78 % depicted in Annuexure I.2118 STWs already exist for irrigation. No additional STW is feasible with available ground water resources.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 2 to 5 mbgl in most parts and in few parts; it is from 5 to 10 mbgl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers in the block (Fig 1). Clay of about 30 m occupies at the top in the block. The top layer (within 30 m bgl) is an aquitard in nature which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps. Two aquifer systems has been reported, mainly a total of 150-165 m thick aquifer upto explored depth of 250 m bgl. The deeper aquifer is separated by a major clay zone (within 62 to 94 m bgl). Deeper aquifer is under semi confined to confined condition.

The cumulative yield of tube well is 188.72 m^3 /day. Transmissivity is in the order of 10435 m^2 /day.

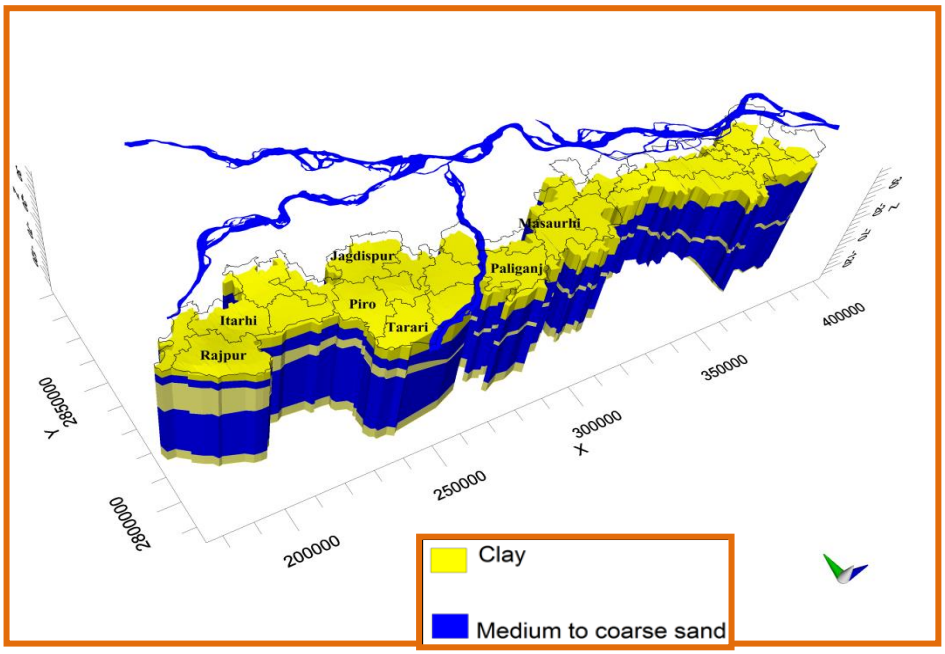

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 80.1%. High ground water draft has been observed in the block. Artificial recharge structure like recharge ponds with recharge shafts may be constructed to augment the ground water resource.

Chemical quality of ground water and contamination

Ground water, in general, is good and potable in nature. It is good for irrigation also. But, pipe water supply should be made from deeper aquifer only.

Ground water resource enhancement

High ground water draft has been observed in the block. Artificial recharge structure like recharge ponds with recharge shafts may be constructed to augment the ground water resource.

Demand side interventions

High and continuously increasing development of ground water in this block should be checked. Extraction from 1st aquifer should be regulated. Water supply for drinking water purpose should be extracted from deeper aquifer only. In urban area, roof top rain water harvesting should be amended.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category: safe/semi-critical/critical/over-exploited.
		(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)		
Patna	Punpun	2862.91	409.91	616.46	668.69	4557.97	455.8	4102.17	3001.80	209.92	160.59	3372.31	81.00	848.64	85.78	Safe

Block wise
Aquifer Maps and Management plans

Salient Information
Name of the Block and Area (in km^2)
SAMPATCHAK (65 sq. km)

District/ State
Patna/Bihar

Rainfall

The normal annual rainfall of Sampatchak block is 635.6 mm of which 82.66% occurs during the monsoon season. The normal rainfall during monsoon season is 525.4 mm and during non monsoon season is 110.2 mm.

Agriculture and Irrigation

The block falls in the Agro-climatic Zone IIIB. The cropping sequence followed in this zone is Rice – Wheat, Rice – Gram, Rice – Lentil, Rice – Rai. Principal crops grown are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. The soils in this zone are sandy loam, clay loam, loam, clay with pH in the range of 6.8 – 8.0. The temperature varies from 37.1 to 7.8˚C.

Cropping intensity is 127.91% and irrigation intensity is 70.79%. Dependency of gound water irrigation is 52.81%.

Ground water resource availability and extraction

The dynamic ground water resource of Sampatchak block has been assessed as 25.22 MCM. The gross ground water draft for all uses stands at 19.98 MCM. The stage of development is 80.1% depicted in Annuexure I. 1078 STWs already exist for irrigation in the block. No additional STW is feasible in the block.

Water level behaviour

The depth to water level varies from 5 to 10 mbgl during pre-monsoon season. In post monsoon season, the depth to water level varies from 4 to 6 m bgl.

Aquifer Disposition

Quaternary alluvium deposit marks the potential aquifers in the block (Fig 1). Clay of about 30 m occupies at the top in the block. The top layer (within 30 m bgl) is an aquitard in nature which is mixed with high percentage of sand, silt and kankars. It supports dug wells and shallow hand pumps. Two aquifer systems has been reported, mainly a total of 150-165 m thick aquifer upto explored depth of 250 m bgl. The deeper aquifer is separated by a major clay zone (within 62 to 94 m bgl). Deeper aquifer is under semi confined to confined condition.

The cumulative yield of tube well is 188.72 m^3 /day. Transmissivity is in the order of 10435 m^2 /day.

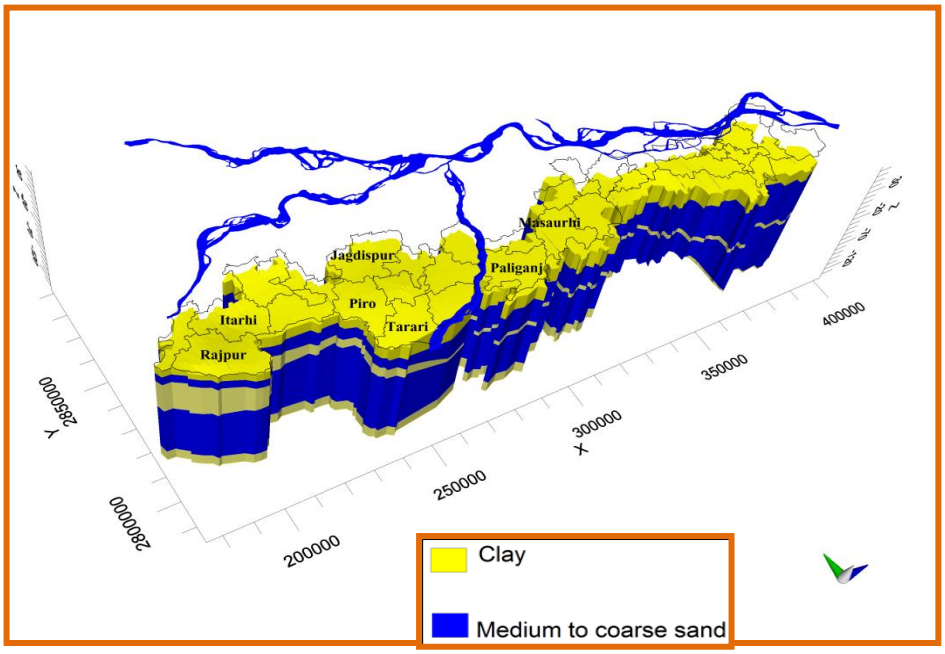

Fig 1 3D Disposition of Aquifer System

Ground water resource, extraction, contamination and other issues

The stage of groundwater development in the block is 80.1%. High ground water draft has been observed in the block. Artificial recharge structure like recharge ponds with recharge shafts may be constructed to augment the ground water resource.

Chemical quality of ground water and contamination

Ground water, in general, is good and potable in nature. It is good for irrigation also. But, pipe water supply should be made from deeper aquifer only.

Ground water resource enhancement

High ground water draft has been observed in the block. Artificial recharge structure like recharge ponds with recharge shafts may be constructed to augment the ground water resource.

Demand side interventions

High and continuously increasing development of ground water in Sampatchak block should be checked. Extraction from 1st aquifer should be regulated. Water supply for drinking water purpose should be extracted from deeper aquifer only. In urban area, roof top rain water harvesting should be amended.

Annexure I

Dynamic Ground Water Resource Estimation

District	Blocks	Recharge from rainfallMonsoon	Recharge from rainfall Non-Monsoon	Recharge from other sources Monsoon	Recharge from other sources Non-Monsoon	Total ground water recharge	Provision for natural discharge	Net ground water availibility	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for Domestic Uses	Existing Gross Ground Water Draft for Industrial Uses	Existing Gross Ground Water Draft for All Uses	Provision for Domestic and Industrial Requirement for Next 25 years	Net GW Availability for Future Irrigation Development	Stage of Ground Water Development (%)	Category:safe/semi-critical/critical/over-exploited.
Patna	Sampatchak	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	(ham)	80.10	Safe
		1476.06	211.34	423.96	691.72	2803.08	280.31	2522.77	1741.20	162.39	95.18	1998.77	63.00	691.23		

Annexure II

Chemical Analysis of Ground Water Sample

District	Block	Village	pH	EC(µs/cm) at 25°C	TDS	F-	Cl-	HCO3-	CO32-	SO42-	NO3-	PO43-	TH	Ca2+	Mg2+	Na+	K+
Patna	Sampatchak	Sampatchak	7.34	482	313.3	0	42.6	325	0	33.6	6.9	0.03	125	14	21.6	28.73	3.5

Block Details end