केन्द्रीय भूमि जल बोर्ड

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भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

LAKHIMPUR DISTRICT
ASSAM

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

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Central Ground Water Board

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MINISTRY OF JAL SHAKTI

जल शक्ति मंत्रालय

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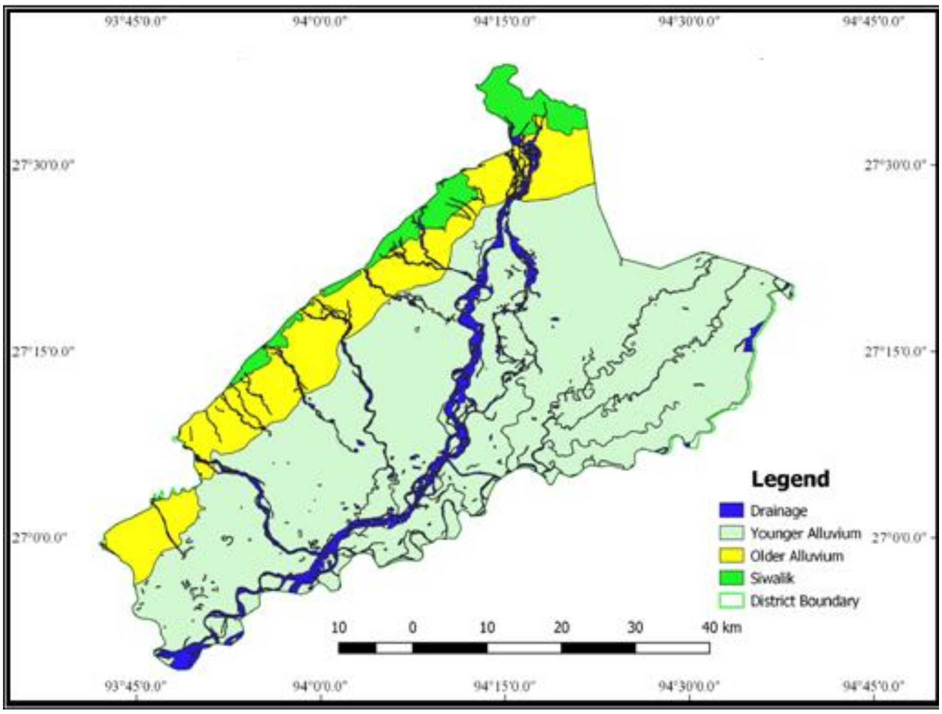
AQUIFER MAPPING REPORT OF LAKHIMPUR DISTRICT, ASSAM

(AAP 2018-19)



NORTH EASTERN REGION

उत्तर पूर्वी क्षेत्र

GUWAHATI

गुवाहाटी

CENTRAL GROUND WATER BOARD

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

MINISTRY OF JAL SHAKTI

GOVERNMENT OF INDIA

Report on

AQUIFER MAPPING REPORT OF LAKHIMPUR DISTRICT, ASSAM

(AAP 2018-19)

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INTRODUCTION

1.0 Introduction

1.1 Objectives: The objective of the study is to prepare aquifer map of the area in 1:50,000 scale, identify the groundwater contaminated area and prepare a groundwater management plan.

1.2 Scope of the study: The part of the Lakhimpur district has vast groundwater and surface water resources. However, the agro based economy of the area has no irrigation facility. Moreover, the groundwater of the area is contaminated with iron and arsenic which possesses serious health hazard to the general public. Proper hydrogeologic knowledge of the area can be helpful to prepare a sustainable management plan for groundwater utilization.

1.3. Approach and methodology: The approach is to identify the principal aquifers and to conceptualize the aquifer system. This will help to formulate an aquifer management plan. Finally the scientific knowledge will be disseminated to farmers, state government and stake holders. The methodology can be illustrated as follows:

Data compilation and data gap analysis: The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB, State Groundwater Departments. All data were plotted in base map on GIS Platform (MapInfo-11.0 using Projection category longitude/latitude (WGS 84). On the basis of available data, Data Gaps were identified.

Data Generation: Efforts were made to fill the data gaps by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, besides detailed hydrogeological surveys.

Aquifer Map Preparation: On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference aquifer extremities, quality, water level, potential and vulnerability (quality & quantity).

Aquifer Management Plan Formulation: Based on aquifer map and conceptual model a sustainable development plan of the aquifer is formulated

1.4 Area Details: The area chosen for aquifer mapping falls under Survey of India Toposheet No. 83 E/12 (part), 83 E/15 (part), 83 E/16, 83F/13 (part),83 I/2 (part), 83 I/3, 83I/4, 83I/6 , 83 I/7, 83I/8, 83I,11, 83I/12(part) and 83 J/1 bounded by $26^{0}48'00''$ and $27^{0}53'00''$ northern latitude and $93^{0}42'00''$ and $94^{0}20'00''$ east longitude

Administrative set up of the study area:

The district is divided into two sub divisions viz. North Lakhimpur and Dhakuakhana and seven revenue circles and nine civil blocks. Total population of the district is 10,42,137 souls (as per 2011 census) with average population density of 458 persons/sq.km.

Table 1.1 Administrative Division

No of Civil Sub Division	No of Blocks	No of Revenue Circles	No of Gram Panchayats	No of Villages (Inhabited)	No of Villages (Uninhabited)
2	9	7	81	1146	38

Data Source: Statistical Hand Book, Assam

Table 1.2 Block Level Geographical Area (in sq.km) and Population Lakhimpur District

Civil Sub Division	Blocks	No of Panchayat	No of Villages	Area (sq.km)	Population
North Lakhimpur Civil Subdivision:	Narayanpur	14	199	331.09	135641
	Kanubari	10	103	217.99	177974
	Bihpuria	4	62	125.79	54178
	Nowboicha	10	138	222.88	126986
	Boginadi	8	150	259.29	109900
	Lakhimpur	8	121	193.62	175289
	Telahi	6	102	184.36	75354
Dhakuakhana Civil Subdivision:	Ghilamara	9	110	259.38	100793
	Dhakuakhana	12	161	329.05	86022

#Data source: Census Handbook 2011

Lakhimpur is connected with the rest of the State by NH 52, by railways and also by flight service.

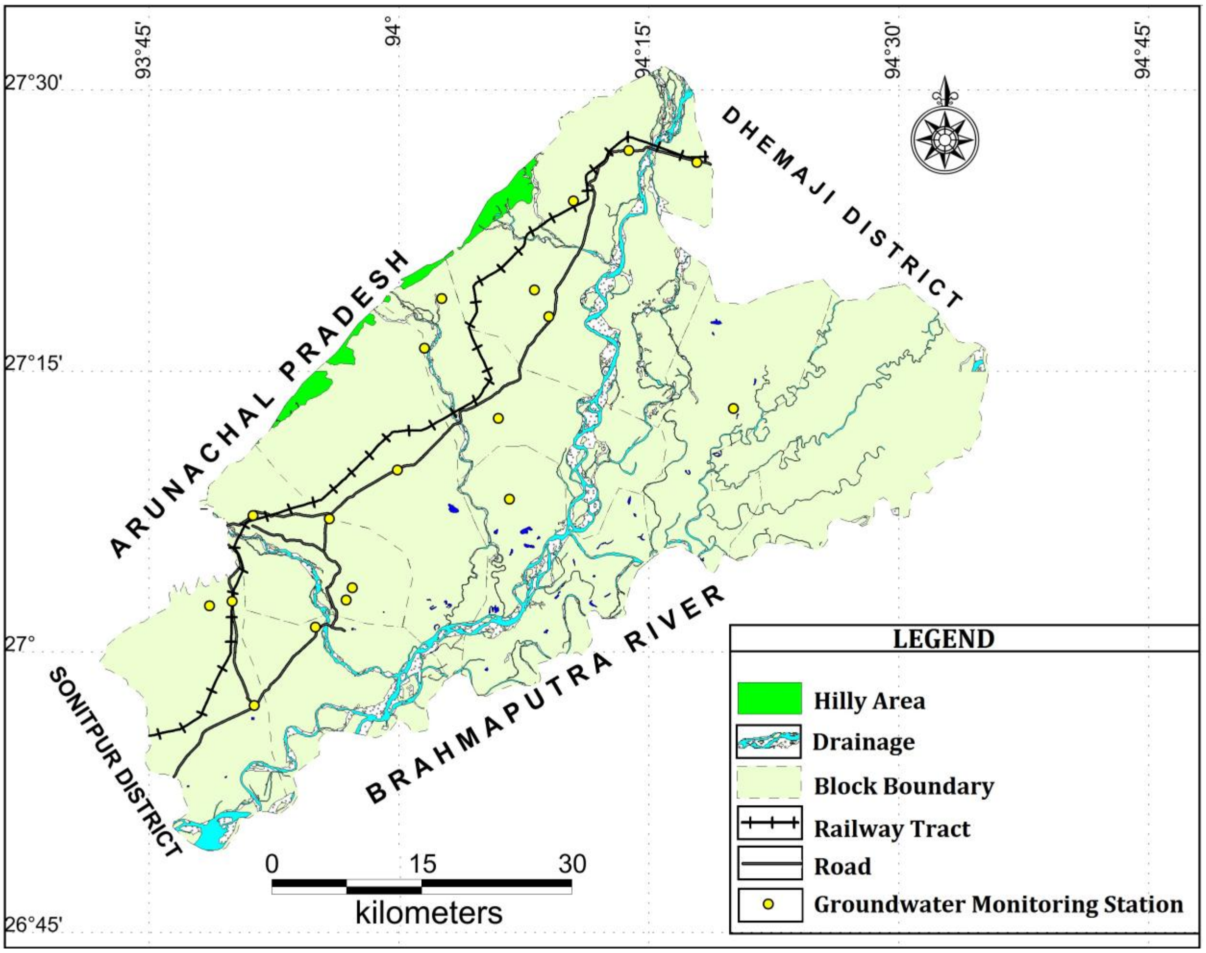


Fig.1.1: Index Map of the study area

1.5 Data availability, data adequacy, data gap analysis and data generation

The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB, State Groundwater Departments. All data were plotted in base map on GIS Platform (MapInfo-11.0 using Projection category longitude/latitude (WGS 84).

The available data, data gap and data generation work is tabulated in Table: 1.3

Table 1.3: Data availability, data gap and data generation in Lakhimpur district, Assam

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data		20	34	3	23	Maximum depth of well is 200 mbgl only.
2	Geophysical data		9	36	Nil	9	
3	Groundwater level data	Dug well	19	23	36	55	
		Piezometer Aquifer-I	Nil	2	Nil	2	
4	Groundwater quality data	Dugwell-Aquifer-I	19	23	15	34	
		Piezometer Aquifer-I	Nil	2	Nil	2	
5	Specific Yield		Nil	7	Nil	7	
6	Soil Infiltration Test		Nil	12	5	5	

The available data and data generation points are shown in following figures.

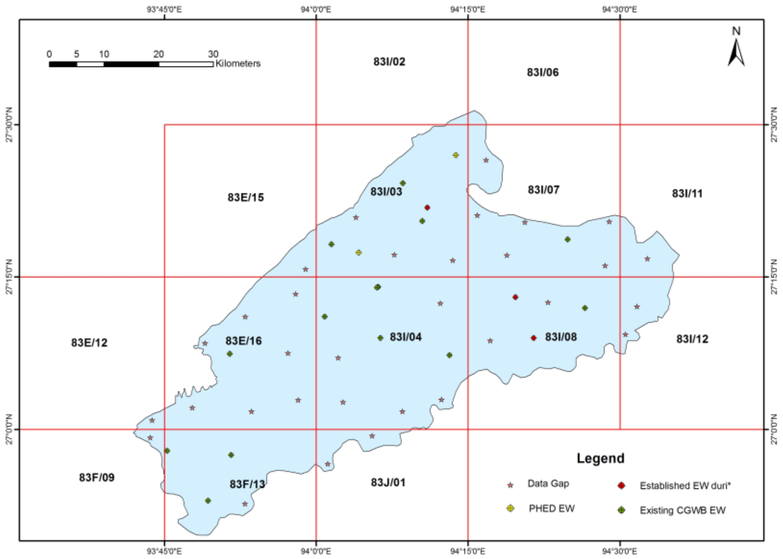


Fig. 1.2a: Available data and data generation of exploration in the study area

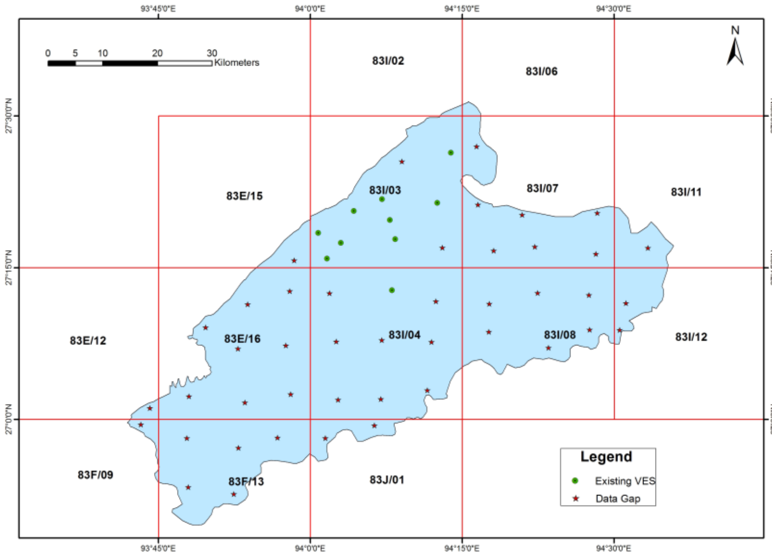


Fig. 1.2b: Available data and data generation of VES in the study area

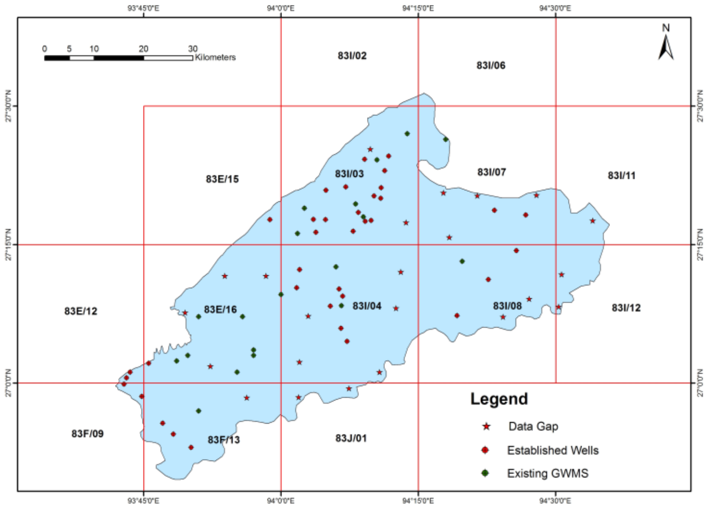


Fig. 1.2C: Available data and data generation of ground water level

1.6 Rainfall-spatial, temporal and secular distribution:

The area close to the foothills receives more rainfall than the area farther away from foothills. The Rainfall increasing trend of the district is NE direction. The average annual rainfall recorded from 2008 to 2018 in Hurmmuti TE is 2771.55 mm, IMD is 2897.3 mm, Regional Agriculture Research Station, Lakhimpur is 2876.08mm, Dijoo TE is 2979.8mm, Anand Tea Estate, is 33953.99 mm and Bordoibam TE is 4106.09mm.

Rainfall during January to April contributes nearly 13% to the total rainfall whereas the rainy season which commences from May and continues up to September contributes 81%. October to December rainfall makes up the rest. December receives least rainfall and maximum rainfall occurs during July.

The average monthly rainfall from 2008 to 2018 and also yearly rainfall distribution are illustrated in Fig.1.3

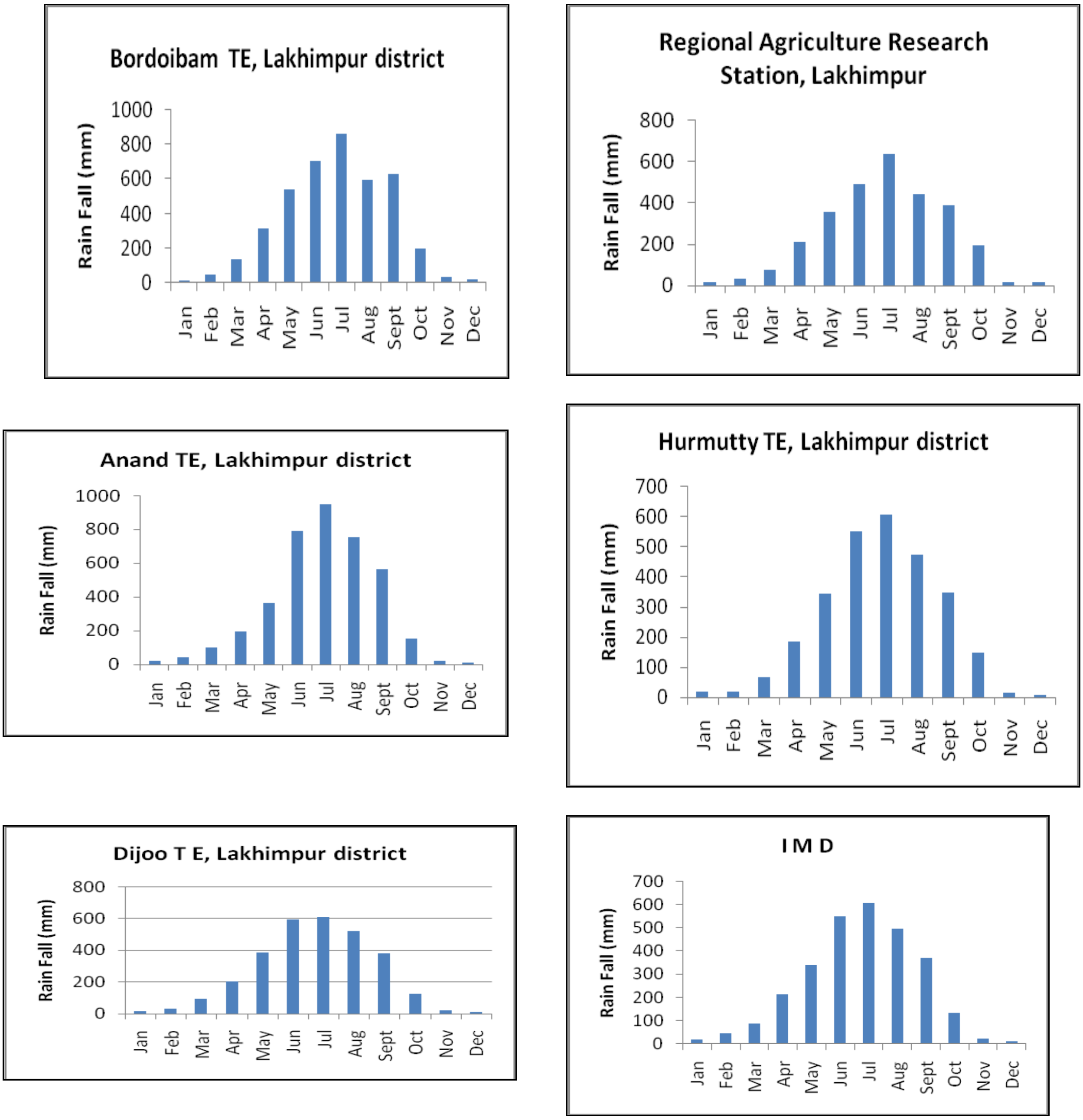
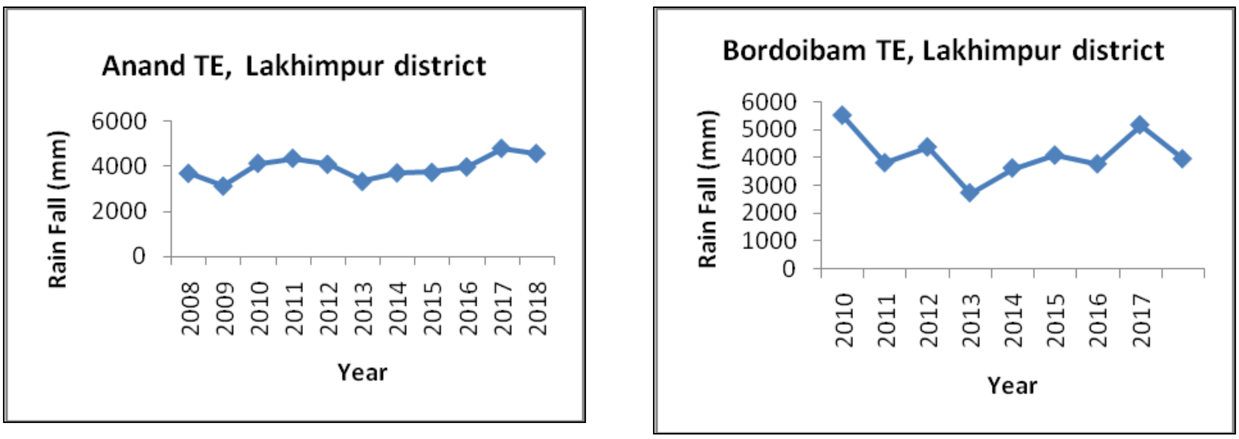
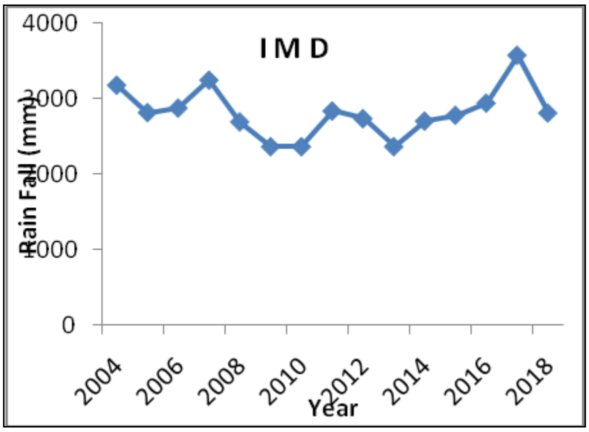
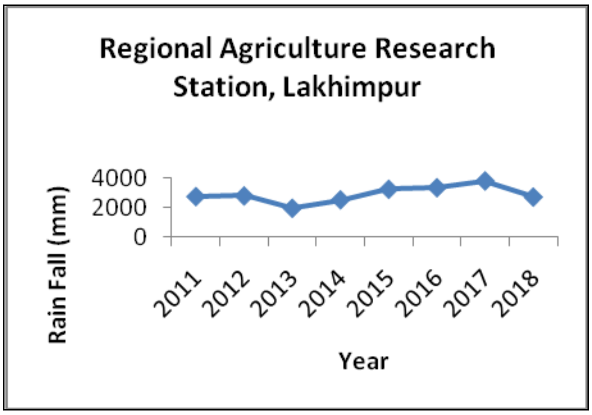
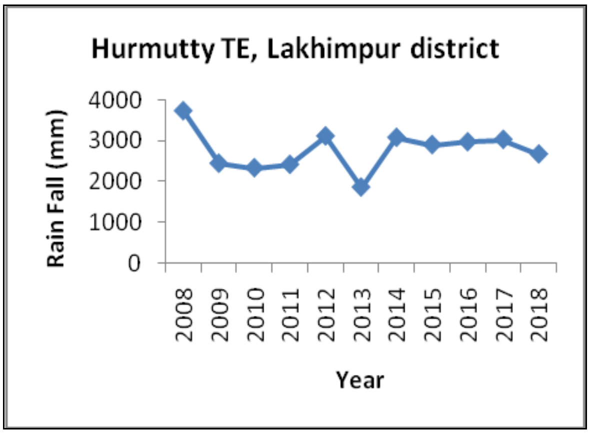


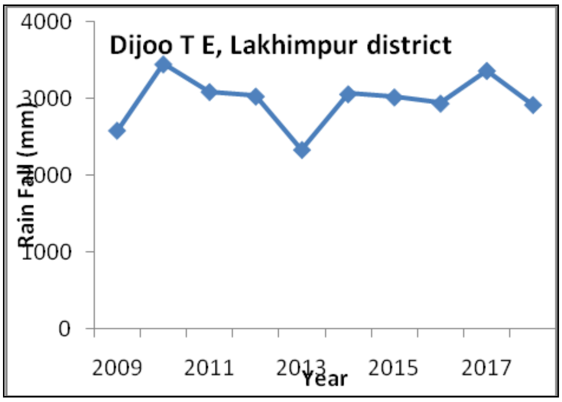
Fig.1.4: Annual variation of rainfall as recorded in six rain gauge stations of Lakhimpur district











1.7 Physiographic set up: Phisiographically the area can broadly be divided into three parts, i.e., the hilly tract, the foothill region and the extensive flood plain created by the river Brahmaputra and its tributaries in southern part. The hilly tracts comprise Siwalik sediments of lesser Himalayas. The southern limit of the sub-Himalaya is marked by Himalayan Frontal Fold (HFF).The HFF may be observed near Banderdewa and Harmuti tea garden, and further southward almost along Tarajuli-Pisola-Gorubandha track, where the Siwalik Hills terminate abruptly with steep slope and come in contact with Brahmaputra plain towards south (Singh 2007). The foothill region is characterised by older terrace deposit. Two terrace surfaces have been identified as the Harmuti and Joyhing surfaces that represent high and low level terraces. These terrace deposits are characterised by undulating surface comprising boulders, pebbles of quartzitic and gneissic rocks with fine sand, silt and clay act as matrix. The alluvial flood plain consists of younger and older alluvial deposits. It represents various sub-features, viz., palaeochannel, swampy/marshy land, river terraces, flood plains, point bars, channel bar and river channel. The average altitude in the central and southern flood plain varies from 80-85m above MSL with very gentle slope throughout. The 92m contour marks the northern limit of the flood plain area. The slope of the entire the district drops from northern and eastern corners towards south.

Fig. 1.6: Three dimensional view of the study area

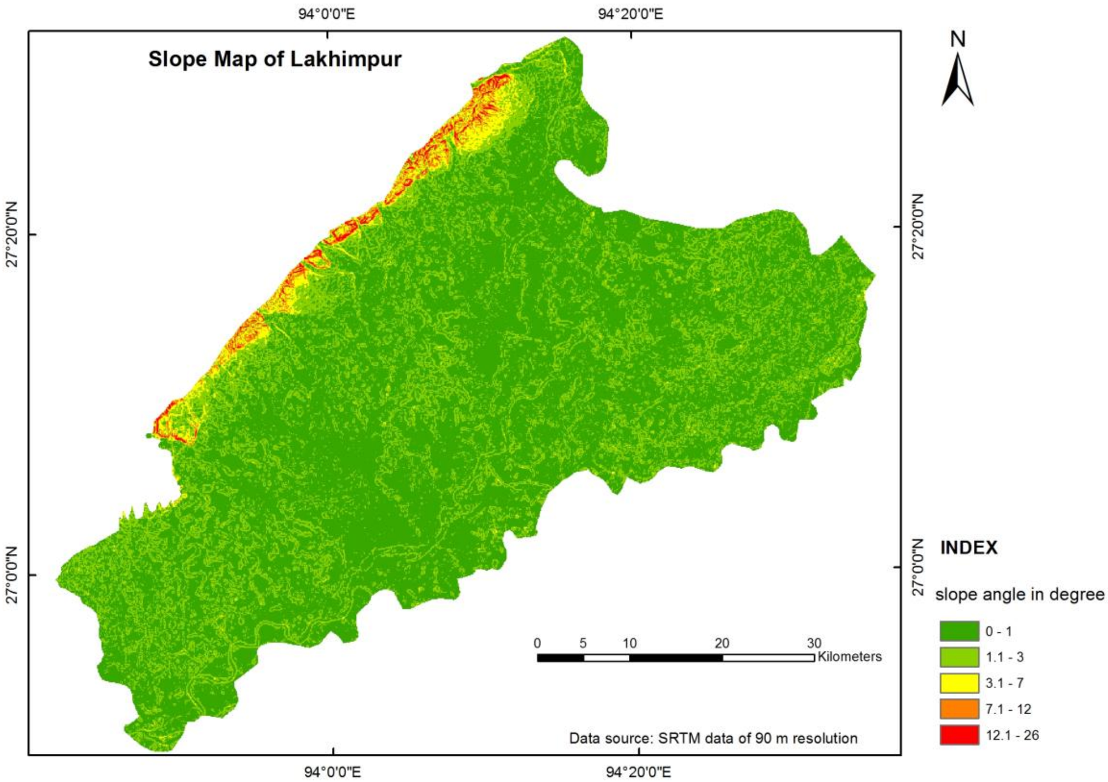


Fig.1.5: Slope map of the study area based on 90m resolution srtm data

1.8 Drainage and Morphometric Features

In the north bank the Brahmaputra River has several tributary systems. The Subansiri, Ranganadi, Dikrong, Shingora, Boginadi, Korha and Charikoria are major tributaries of the district. The Brahmaputra behaves as a braided channel near Dhemaji and further downstream. The Subansiri the largest tributary of river Brahmaputra is a Trans-Himalayan river originating from the Western part of Mount Pororu (5059 m) in the Tibetan Himalaya. The Subansiri is the largest tributary of the Brahmaputra. Its total length is 520 km and it drains a basin of 37,000 km^2. The river maintains an almost stable course but becomes unstable as soon as it enters into the alluvial plains of Assam. The average slope of the river bed from the foothills to Chauldhoaghat to the confluence of Ranga river being about 24cm/km (0.00024). The river banks from the foothills to Chauldhoaghat are composed mostly of sand, gravel and silt, beyond which they are composed almost exclusively of alluvial silt. The mean daily discharge of the Subansiri at Gerukamukh is 138842 m^3/sec (Goswami, 1997). The average annual sediment yield at Chauldhoaghat is 94.83 X 10^3 mtonnes (WAPCOS 1993).

Overall the drainage network of the area shows an anastomosing pattern. Collectively, the rivers after coming down from hills show a marked tendency to move towards south-westerly direction. This tendency may indicate influence of underlying fracture pattern or this may due to paleochannels of the Brahmaputra River. Individually, the rivers in the western part of the study area show dendritic drainage patterns and rivers of eastern part show parallel drainage pattern.

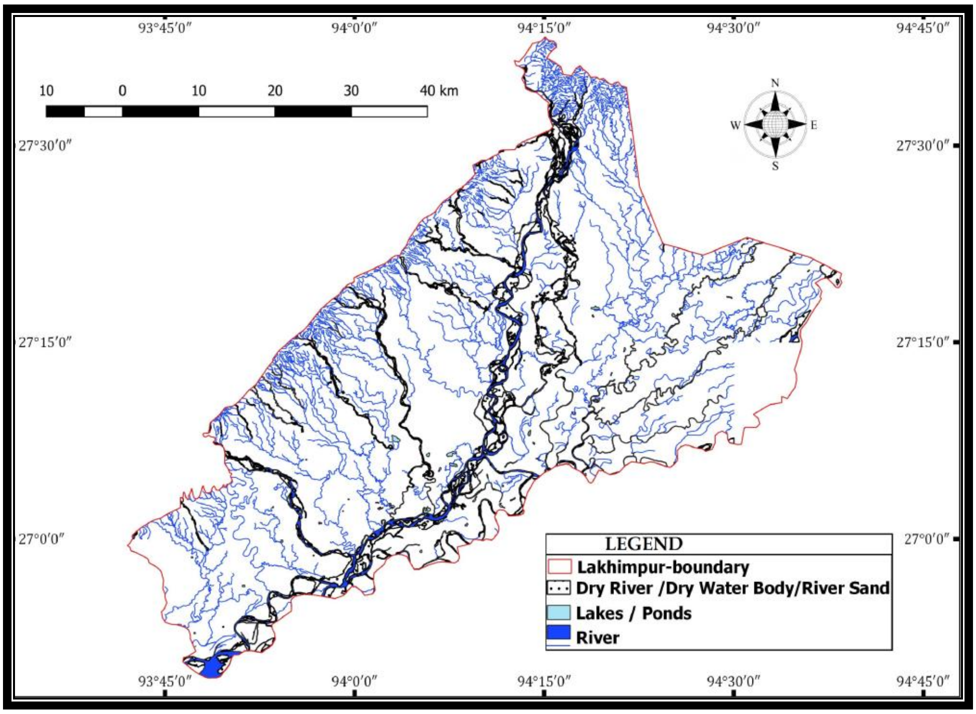


Fig. 1.6: Drainage Map of Lakhimpur District, Assam

1.9 Geology

The Lakhimpur district forms part of the Upper Assam Shelf. The northern boundary of the district is marked by Himalayan Frontal Fault (HFF).The Siwalik sediments crop out in the northern fringe area of the district bordering the Arunachal Himalayas where the HFF has passed through the district. Duara and Chatterjee (1972) have proposed the following geological succession of the area:

Age	Formation/Group	Lithology
Recent	Flood Plain	Sand, silt, clay with occasional pebbles, cobbles
Upper Pleistocene	Jayhing Surface	Pebbles, grit, coarse to fine sand, silt, silty clay with sand matrix
Pleistocene to Pliocene	Harmutty Surface	Boulders, cobbles and pebbles
	Unconformity	
Miocene	Siwalik Group	Sandstones, siltstones, mudstones, shales, conglomerates, etc.

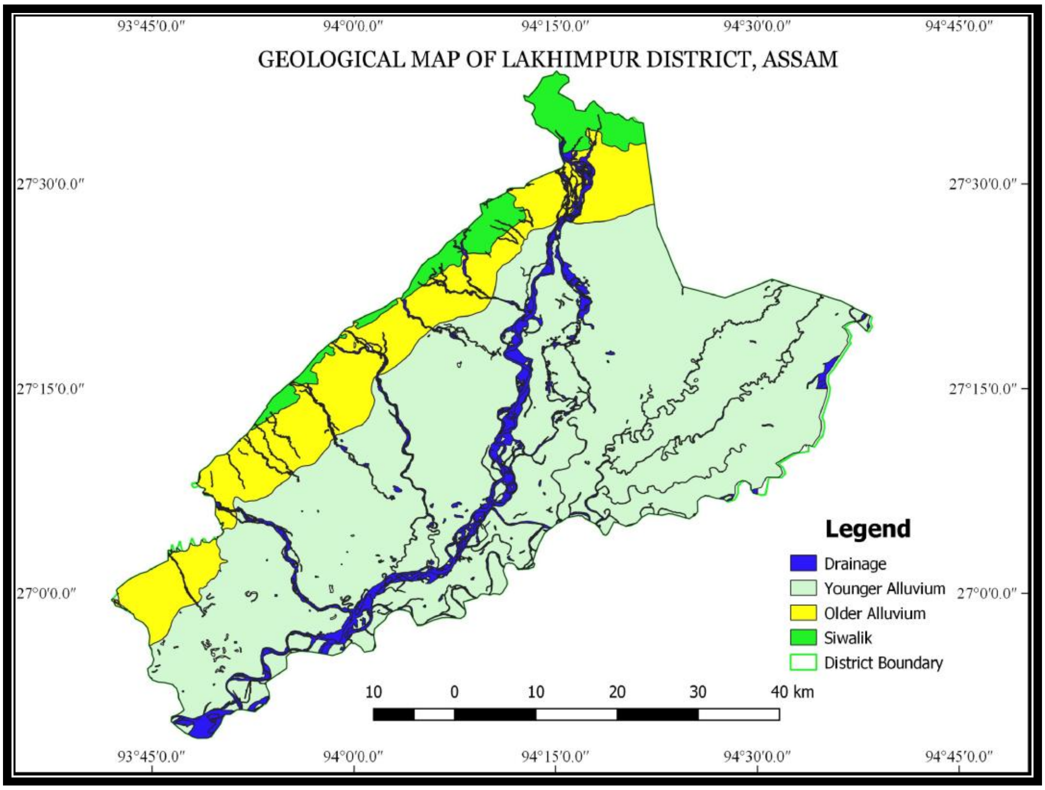


Fig. 1.7: Geological Map of Lakhimpur District, Assam

1.10 Geomorphology: Geomorphologically the area can be classified mainly into four divisions: structural hills, piedmont zone, alluvial plan and flood plain. Piedmont zone is in the north eastern part of the study area. The piedmont zone is gravel dominated while alluvial plain and the flood plain are mixture of sand and silt with varying proportions. The alluvial flood plain consists of younger and older alluvial deposits. It represents various sub-features, viz., palaeochannel, swampy/marshy land, river terraces, flood plains, point bars, channel bar and river channel (Fig. 1.8).

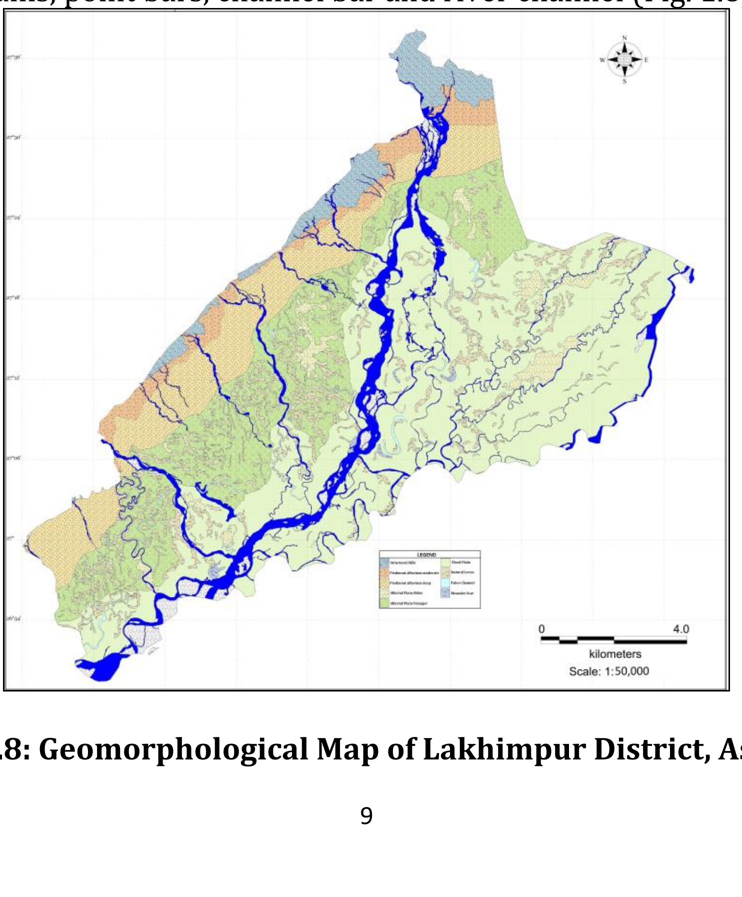


Fig. 1.8: Geomorphological Map of Lakhimpur District, Assam

1.11 Land use Pattern:

The net sown area of the district is 92171.16 ha which accounts for 43.41 percent of the geographical area of the district & the land utilization pattern in the district.

The gross cropped area of the district is 118561.32 ha with cropping intensity of 129 percent. Out of the total cropped area, 27234.30 ha and that 22.97 percent are used in more than once. The area under forest in the district is 13240.10 ha whereas the area under waste land is 4453.37 ha. However, the area used for other purposes is 5879.73. (Table 1.4).

As per 2011 census, only 8.76% of the district population lives in town area and as such more than 90% of the population live in the rural area. Out of the district total population 41.26% (4,29,995) are workers. Among the work force, 55.67% (2,39,377) are cultivators and 10.21 % are agricultural labourers. These statistics show that nearly 60% of the district population is dependent on agriculture.

The farmer of the district is habituated in production of rice and is evident from the land use pattern. Rice is produced three times as autumn rice, winter rice and summer rice. However, production of summer rice is generally preferred. Other cereal crops are wheat and maize. Pulse crops like arahar, gram, lentil, peas, etc., oil seeds like mustard, linseed, etc., rabi and kharif vegetables, jute, sugarcane and different horticulture crops are also produced in considerable quantities.

Table 1.4 Block wise Land Use Pattern in Lakhimpur District

Name of the Block	Total Geographical Area (Ha)	Area under Agriculture (Ha)				under Forest	Area under Waste Land	Area under Other Uses
		Cropped Area	Net Sown	Area Sown more than once	Cropping Intensity (%)			
Narayanpur	33109	21770	17730	4040	122.79%	500	1224	
Karunabari	21799	11703	3510	175	333.42%	357	1324	14.73
Bihpuria	12579	5555	5152	1625	107.82%	20	230	10
Nowboicha	22288	20069	16745	5550	119.85%	1288	398	1045
Boginadi	25929	18004	16367	1698	110.00%	0	10	245
North Lakhimpur	19362	18456	13799	2073	133.75%	848	395	763
Telahi	18436	17400	14400	10800	120.83%	9289	398	2505
Dhakuakhana	32905	214.32	148.16	67.3	144.66%	13.097	7.37	
Ghilamora	25938	5390	4320	1206	124.77%	925	467	1297
Total	212345	118561.32	92171.16	27234.30	129%	13240.1	4453.37	5879.73

Source: District Agriculture Officer, Dept. of Agriculture, Lakhimpur

1.12 Soil:

Red loamy soils are found in hilly slopes under high rainfall conditions. These are rich in organic matter and nitrogen but deficient in phosphate and potash. The soil occurring on very gently sloping piedmont plain are deep, well drained and coarse loamy and associated with deep, well drained, coarse silty soils. These soils are subjected to slight flooding. The new alluvial soils are found in the flood plain area and are subjected to occasional floods and consequently receive considerable silt deposit after flood recedes. The soils are admixtures of sand, silt and clay in varying proportions as such these are ideal for cultivation of winter crops like wheat, pulses, mustard, potato, etc. The soils are less acidic in reaction compared to older alluvial soils and moderately rich in plant nutrients (CGWB report 2005).

The older alluvial soils are developed at higher levels and are not subjected to flooding and agriculture is practiced on permanent basis. Sali paddy, sugarcane and tea plantation is suitable for these soils. The soils are comparatively more acidic than newer alluvial soils and hence are crop sensitive.

Table 1.5 Major soils in Lakhimpur District

Major Soils	Area ('000 ha)	Percent (%) of total
1. Sandy soil	33.97	16.19
2. Sandy loam	121.73	70.83
3. Other type of soil	40.37	15.18

Source: **Agriculture Contingency Plan for District: Lakhimpur**

1.13 Hydrology and surface water: Surface water bodies are mainly observed in the flood plain area where south and south western flowing rivers looses its gradient. Water logged and marshy lands are observed. Kawaimari beel, Chumani beel, Chakamara beel, etc. are some of the surface water bodies in the area. The area covered by the surface water bodies are shown in the following Table 1.6

Table: 1.6 Water bodies in Lakhimpur District

S. No.	Resources	Area (ha)
1	Ponds and tanks	1750
2	Reservoir fisheries	840
3	Derelict water bodies	4273
4	Beel fisheries	6499
Total		**13362**

Source : Statistical Hand Book of Assam, 2014

A number of rivers enter the area from northeast and northern direction. The Subansiri River, one of the principal tributary of the Brahmaputra flowing through Lower Subansiri district and enters the Lakhimpur district of Assam. All the major drainage, viz., the Kakoi, Bagi nadi debouches to river Subansiri in the south western part. Before debouching to Subansiri these streams create water logged and marshy condition in the southwest part of the toposheet. The Kawaimari Bill and the Bhimpara Bill are created by these two tributaries of Subansiri in the downstream. The drainage pattern of the area is dendritic. The Subansiri River is the main drainage entering in the area from north-western direction and flowing towards south-eastern direction to meet the Brahmaputra River.

Floods in the Lakhimpur of Assam which were triggered by heavy rainfall at the end of June to September in neighboring Arunachal Pradesh. The Subansiri, Ranganadi, Dikrong, are major tributaries flowing through the district, which originate from Arunchal Pradesh. Every year the district is affected by flood and people were suffering from a scarcity of food and pure drinking water at that time. Flood affected area of the district during 1998-2015 is given in the following Table

Table: 1.7 Flood affected area of Lakhimpur district

Hazard Severity	Area (ha)	Villages Affected (No.)
Very Low	77229	174
Low	37429	151
Moderate	20985	166
High	7269	97
Very High	1868	32
Total	144780	620

Source: National Remote Sensing centre

1.14 Agriculture

The major crops of Lakhimpur district are Paddy. Autumn paddy, winter paddy and summer paddy are the three main types of paddy are grown in the district. Winter paddy (Sali) is the most important crop in the district occupying 70.6 % followed by summer paddy (Boro) 25.4% and autumn paddy (Ahu) 4% of the total annual paddy area. Next to paddy, mustard, black gram and vegetables are the main agricultural produce. Among cash crops jute and cotton are the major crops grown in the district. Other cereal crops such as maize, wheat, small millets are having negligible area as compared to rice. Cereals, Coarse cereals, pulses, oil seeds, vegetables, Ginger, Turmeric, Chilies, potato, Banana and Assam Lemon are also produced in the district. There are nine numbers of tea gardens in the district.

Gross irrigated area in the district is 28219 ha and net irrigated area is 18532 ha.

Table 1.8 Block wise distribution of irrigated lands

Block	Irrigated (Area in Ha)		Rainfed (Area in Ha)	
	Gross Irrigated Area	Net Irrigated Area	Partially Irrigated/ Protective Irrigation	Un-irrigated or Totally Rainfed
Narayanpur	2409	1609	170	21004
Karunabari	6015	4240	2120	16300
Bihpuria	490	288	140	7258
Nowboicha	6450	3675	1400	13028
Boginadi	-	-	678	16180
North Lakhimpur	4750	3250	380	17200
Telahi	1440	1040	165	16128
Dhakuakhana	3140	2250	220	11000
Ghilamara	3525	2180	625	15000
Total	28219	18532	5898	133098

Source: District Agriculture officer, Department of Agriculture, Lakhimpur

Table 1.9 Block wise share of Surface and ground water irrigation

Name of Blocks	Existing Water availability (MCM)		Total (MCM)
	Surface water	Ground water	
Lakhimpur	8.2	10	18.2
Telahi	7.9	12	19.9
Boginadi	7.3	15	22.3
Nowboicha	6.2	13	19.2
Karunabari	8.2	16	24.2
Bihpuria	5.6	19	24.6
Narayanpur	6.6	17	23.6
Ghilamara	5.9	16	21.9
Dhakuakhana	8.5	17	25.5
Total	64.4 (32.3%)	135 (67.7%)	199.4

The total existing type of irrigation in the district is 8802. In surface irrigation category, canal based irrigation is a prominent source of irrigation in the district while in ground water category, the major source of irrigation is done by tube wells. Around 59.19% of the irrigation is mainly done by govt. canals while only 48.81% is done by govt. tube wells in the district. Boginadi block ranks first with 1340 govt. canals for the irrigation followed by Dhakuakhana with 1308 govt. canals. Among all blocks in the district, Nowboicha uses maximum govt. tube wells i.e. 900 as a source of irrigation followed by Narayanpur with 684 govt. tube wells.

Table 1.10 Block wise Existing type of Irrigation

Sources of Irrigation	**Surface Irrigation**		**Ground Water**					**Total**
	Canal based	**Tank/Ponds/Reservoirs**	**Tube Wells**		**Open wells**	**Bore well**		
	Govt. Canal	**Ponds**	**Govt.**	**Pvt.**	**Community/ Govt./ Pvt.**	**Govt.**	**Pvt.**	
Karunabari	Nil	Nil	468	Nil	Nil	Nil	Nil	**468**
North Lakhimpur	1030	Nil	496	Nil	Nil	Nil	Nil	**1526**
Nowboicha	650	Nil	900	Nil	Nil	Nil	Nil	**1550**
Boginadi	1340	Nil	144	Nil	Nil	Nil	Nil	**1484**
Narayanpur	680	Nil	684	Nil	Nil	Nil	Nil	**1364**
Bihpuria	Nil	Nil	504	Nil	Nil	Nil	Nil	**504**
Telahi	Nil	Nil	144	Nil	Nil	Nil	Nil	**144**
Ghilamora	202	Nil	108	Nil	Nil	Nil	Nil	**310**
Dhakuakhana	1308	Nil	144	Nil	Nil	Nil	Nil	**1452**
Total	**5210**	**-**	**3592**	**-**	**-**	**-**	**-**	**8802**

Source: Water Resource Department, Lakhimpur

CHAPTER 2.0

Data Collection and Generation

2.1 Data collection

Data collection includes collection of rainfall data from state government, litholog collection from state groundwater departments, compilation of CGWB's earlier survey data, exploration and geophysical data. Population data is collected from Census of India website. Agriculture data are taken from District Irrigation Plan, 2016-2020, Lakhimpur, Assam prepared by NABARD.

CGWB had constructed 18 exploratory wells in this area earlier and constructed 3 exploratory well during study period. Public Health Engineering Department, North Lakhimpur Division, Govt. of Assam had constructed number of tube wells in the area and the department (i.e., PHED, NLP Div) provided lithology and chemical analysis data. However, all the wells are not incorporated in the present study due to lack of coordinate data. Details of the wells are given in Table 2.4. Rainfall data was collected from Regional Agriculture Research Centre, Govt. of Assam, Lakhimpur, Anand Tea Garden, Pathalipam, Hurmoti TE, Dijoo TE, Bordoibam TE and Indian Meteorological Department.

2.2 Data Generation

2.2.1 Hydrogeological data: The entire study area is covered by regular monitoring of existing 19 GWMS and another 36 key wells have been established. All these wells are under monitoring after establishment (Table 2.1).

2.2.2 Soil Infiltration studies: Infiltration test

Salient features of the test sites are provided in **Table 2.2**. A perusal of the table shows that the test has been conducted only in barren land and the soil types encountered in the sites are sand admixtures. The infiltration test was conducted for 140 mins.

2.2.3 **Water Quality:** To understand the chemical quality of groundwater in the study area and its suitability for domestic, drinking and agricultural utilisation, and existing quality data of CGWB were collected. Water samples were collected from monitoring wells for detailed, iron, heavy metals and arsenic.

Table 2.1: GWMS and Key wells details

Sl No	Village	Lat	Long	Well Type	MP	RL	Depth	Aquifer group	Depth to water in mbgl				
									Apr,18	Aug,18	Nov,18	Jan,19	March, 19
1	Amguri	27.05	93.95	DUG	1	71	8	Unconsolidated (1st aquifer)	4.72	2.2	3	4.23	4.72
2	Basudeothan	27.22	94.33	DUG	1.1	76	6.41	Unconsolidated (1st aquifer)		1.97	2.5	3.95	4.41
3	Bhogpur Charali	27.05	93.83	DUG	1	74	4.77	Unconsolidated (1st aquifer)	1.87	0.82	1.34	1.62	1.59
4	Bihpuria	27.02	93.91	DUG	0.9	63	5.9	Unconsolidated (1st aquifer)	3.6		0.87	3.75	3.16
5	Borbil Tariyani	27.4	94.17	DUG	0.8	94	3.83	Unconsolidated (1st aquifer)	2.05		1.56	1.78	2.01
6	Dejoo	27.27	94.03	DUG	1	79	4.77	Unconsolidated (1st aquifer)	1.89	0.91	1.16	1.92	2.21
7	Dolanghat Chara	27.16	94	DUG	0.5	80	3.95	Unconsolidated (1st aquifer)	2.35	0.6	1.56	1.74	1.84
8	Harmoti	27.12	93.85	DUG	1	106	4.43	Unconsolidated (1st aquifer)	3.22	1.02	2.32	2.84	3.04
9	Islampur	27.06	93.95	DUG	0.9	71	7.58	Unconsolidated (1st aquifer)	4.84	2.45	3.09	4.36	4.9
10	Kadam	27.3	94.15	DUG	0.8	92	3.56	Unconsolidated (1st aquifer)	1.48	0.36	0.75	1.35	1.63
11	Koilamari	27.3	94.04	DUG	1	115	6.4	Unconsolidated (1st aquifer)	5.82	3.81	3.05	5.14	5.71
12	Laluk	27.12	93.93	DUG	0.9	74	4.25	Unconsolidated (1st aquifer)	1.96	0.23	0.98	1.57	1.78
13	Madhupur	27.04	93.81	DUG	0.9	75	4.24	Unconsolidated (1st aquifer)	1.38		0.55	0.86	0.66
14	Milanpur	27.44	94.3	DUG	0.8	95	5.1	Unconsolidated (1st aquifer)	3.49	0.83	1.33	2.28	3.23
15	Mori Dirgha	27.3	94.14	DUG	1.5	88	3.69	Unconsolidated (1st aquifer)		0.25	0.87	1.15	2.03
16	Narayanpur	26.95	93.85	DUG	1	80	5.85	Unconsolidated (1st aquifer)	3.34	0.2	1.11	2.84	3.38
17	North LakhimpurOld	27.21	94.10	DUG	1.1	109	3.64	Unconsolidated (1st aquifer)	1.75	0.9	1.63	2.01	
18	Panigaon	27.14	94.11	DUG	0.9	66	5.15	Unconsolidated (1st aquifer)		1.34	1.77	2.86	
19	Pathalipam	27.45	94.23	DUG	1	88	5.29	Unconsolidated (1st aquifer)	3.51	1.87	2.51	3.17	

Sl No	Village	Lat	Long	Well Type	MP	RL	Depth	Aquifer group	Depth to water in mbgl				
									June,18	Aug,18	Nov,18	Jan,19	March, 19
20	Naoboicha, 2 no Kawadanga	27.172	94.028	DUG	0.93	74	4	Unconsolidated (1st aquifer)	0.78	0.61	1.23	1.27	1.27
21	Borpukhuri	27.205	94.034	DUG	0.8	80	3.2	Unconsolidated (1st aquifer)	0.78	0.5	1.03	1.2	1.23
22	Kamalabaoria	27.17	94.106	DUG	0.89	71	4.96	Unconsolidated (1st aquifer)	2	1.47	2.19	2.87	3.19
23	Solalgaon	27.157	94.112	DUG	0.66	71	4.08	Unconsolidated (1st aquifer)	1.73	1.28	1.8	2.4	2.94
24	Dhenudharia	27.139	94.09	DUG	1.07	68	3.48	Unconsolidated (1st aquifer)	0.5	0.15	0.44	1.01	1.83
25	Kuhiarbari	27.099	94.109	DUG	1.03	70	4.7	Unconsolidated (1st aquifer)	1.9	0.99	2.11	2.69	3.4
26	11th Mile	27.076	94.12	DUG	1	67	4.94	Unconsolidated (1st aquifer)	2.06	0.46	2.5	2.86	3.74
27	Bardoibam	27.312	94.389	DUG	1.1	78	6.42	Unconsolidated (1st aquifer)	2.48	1.56		3.94	4.28
28	Batamari	27.304	94.446	DUG	1.1	69	5.43	Unconsolidated (1st aquifer)	3.09	1.12	2.44	3.02	3.28
29	Jamuguri	27.239	94.429	DUG	0.6	72	5.75	Unconsolidated (1st aquifer)	4.01	2.4	3.45	4.25	4.48
30	Jalbhari	27.187	94.378	DUG	1.03	81	5.34	Unconsolidated (1st aquifer)	3.29	1.22	3.02	3.79	3.87
31	Na Karabi	27.122	94.321	DUG	1.44	44	6.38	Unconsolidated (1st aquifer)	3.04		2.9	3.08	-1.44
32	Kakoi	27.274	94.131	DUG	1.04	147	4.4	Unconsolidated (1st aquifer)	0.71	0.71	1.22	1.62	1.81
33	Boginadi (Balijan)	27.384	94.189	DUG	0.97	74	4.17	Unconsolidated (1st aquifer)	1.58	1.58		1.63	2.14
34	Padumani	27.41	94.196	DUG	1.03	83	3.25	Unconsolidated (1st aquifer)	0.85	0.85	1.14	1.4	1.46
35	Kimin	27.295	93.98	DUG	0.7	148	7.4	Unconsolidated (1st aquifer)	5.35	3.44	4.5	5.88	6.5
36	Dighalia Majgaon	26.884	93.836	DUG	0.78	58	5.79	Unconsolidated (1st aquifer)	1.7	0.69	1.92	2.48	
37	Dhalpur (Dakua)	26.908	93.804	DUG	0.55	61	4.76	Unconsolidated (1st aquifer)	1.02	0.66	1.68	2.91	3.24
38	Ganakdalani	26.928	93.784	DUG	0.9	72	4.75	Unconsolidated (1st aquifer)	0.78	1.05	1.57	2.48	3

Sl No	Village	Lat	Long	Well Type	MP	RL	Depth	Aquifer group	Depth to water in mbgl				
									June,18	Aug,18	Nov,18	Jan,19	March, 19
39	Gobindapur	26.976	93.747	DUG	0.96	83	4.03	Unconsolidated (1st aquifer)	0.01	-0.02	0.75	1.4	2.04
40	Checha Rajgarh	27.01	93.718	DUG	0.79	101	9.26	Unconsolidated (1st aquifer)	6.86	2.69	2.63	4.97	6.71
41	Notchpur	26.998	93.714	DUG	0.8	94	11.6	Unconsolidated (1st aquifer)	8.55	4.18	3.82	6.28	8.26
42	Rajgharh	27.02	93.725	DUG	1.06	107	6.88	Unconsolidated (1st aquifer)	3.32	1.31	1.59	3.16	4.28
43	Durpang (Jotlibari)	27.036	93.759	DUG	0.97	108	5.54	Unconsolidated (1st aquifer)	4.11		4.03	4.59	5.16
44	Janakpur	27.295	94.081	DUG	0.97	99	5.17	Unconsolidated (1st aquifer)		0.23	1.26	2.37	3.79
45	Janambasti	27.296	94.059	DUG	0.88	86	4.04	Unconsolidated (1st aquifer)		0.8	1.67	2.08	2.06
46	Rangajan	27.272	94.063	DUG	0.74	89	4.96	Unconsolidated (1st aquifer)		0.54	1.35	2.01	3.54
47	Tariani Rajgarh	27.404	94.152	DUG	0.73	141	6.77	Unconsolidated (1st aquifer)				2.69	3.2
48	Siajuli station tinali	27.354	94.118	DUG	1.19	114	5.08	Unconsolidated (1st aquifer)		0.87	1.56	2.54	3.14
49	Sinatoli	27.348	94.082	DUG	1.06	96	4.86	Unconsolidated (1st aquifer)		1.07	1.62	2.18	2.71

Sl No	Village	Lat	Long	Well Type	MP	RL	Depth	Aquifer group	Depth to water in mbgl				
									June,18	Aug,18	Nov,18	Jan,19	March, 19
51	Gagaldubi Borkhelia	27.333	94.182	DUG	1.05	86	5.97	Unconsolidated (1st aquifer)		1.23	2.21	3.43	3.93
52	Dakhin Kulabali	27.338	94.169	DUG	0.95	81	4.76	Unconsolidated (1st aquifer)		0.4	1.18	1.79	1.91
53	1no Laimekuri	27.294	94.164	DUG	0.82	77	2.3	Unconsolidated (1st aquifer)		0.39	0.75	1.32	1.5
54	2no Laimekuri	27.292	94.153	DUG	0.47	**78**	3.67	Unconsolidated (1st aquifer)		0.72	1.03	1.38	1.58
55	Kadam Gohaigaon	27.308	94.141	DUG	0.87	82	3.66	Unconsolidated (1st aquifer)		0.73	0.71	0.78	1.03

Table 2.2: Summary of Infiltration Test

Site	Latitude	Longitude	RL (m)	Land use	Soil type	Infiltration rate (mm/hr)	Duration of test (min)	Total Quantum of water added in mm	IF = (7)/(9)*100)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Gossaichapori	27°13'02.5"N	94°19'38.6"E	70	Barren Land	Sandy soil	81	120	337	24.03561
Panigaon	27°08'15" N	94°06'38.2" E	71	Barren Land	Clay loam	6	120	202	2.97
Amguri	27°02'50.6" N	93°56'50" E	71	Barren Land	Sandy soil	24	140	237	10.1
Balijan (Saru Diju)	27°23'00" N	94°11'20.48" E	78	Barren Land	Sandy soil	42	120	253	16.6
Dholpur, Ganak Doloni	26°55'50" N	93°47'5.6" E	91	Barren Land	Sandy soil	81	130	150	24.03561

2.2.4 Geophysical survey: During AAP 2013-14, 10 VES survey was conducted with current electrodes spreading in the range of 200 and 500m in the area as part of data generation activity. The obtained VES data was plotted on double logarithmic graph sheet. The VES data was interpreted by using IP2WIN software technique. H, HK, K, Q type multilayered VES curves was obtained. The location details of these VES survey is shown in Table 2.3.

Table 2.3: Location details of VES survey points

SN	Name of the site	Latitude	Longitude	RL (mamsl)	Agency	VES/TEM	Depth of interpretation
1	Dejo Bijli basti	27.265	94.02722222	100	CGWB	VES	95
2	Kadamkacharigaon	27.29722222	94.13972222	99	CGWB	VES	259
3	Rajgarhgaon	27.34361111	94.07138889	116	CGWB	VES	139
4	Mari Dirgha	27.32861111	94.13083333	99	CGWB	VES	115
5	Dirgha Basti	27.36277778	94.11805556	111	CGWB	VES	68
6	Chawaldhoa	27.43944444	94.23138889	101	CGWB	VES	54
7	Bhimpara	27.35694444	94.20888889	96	CGWB	VES	250
8	Bali-chapori	27.29083333	94.05	105	CGWB	VES	172
9	Dhekiajuluy	27.30722222	94.01277778	118	CGWB	VES	141
10	N.Lakhimpur	27.5975	94.73777778		CGWB	VES	

2.2.5 **Exploratory Drilling:** During AAP 2018-19, three exploratory drilling was done in the area by CGWB. CGWB old drilling and Public Health Engineering Department, North Lakhimpur Division's old record were collected and examined. A list of wells constructed in the area was prepared incorporating location, well designs, etc.

Table 2.4: Details of exploratory wells in the study area

Sl No	District	Location	Block	Toposheet No	Long	Lat	Type of Well (DW/ BW/ TW)	Depth	Depth of construction (m)	Source
1	**Lakhimp**	Rajgarh nepali	Boginadi	83I/3	94.1428	27.404	TW	125.00	93.00	CGWB
2		Diju	Lakhimpur	83I/3	94.025	27.304	TW	142.70	48.00	CGWB
3		Bahadur chok-	Telahi	83I/4	94.2194	27.122	TW	24.00		CGWB
4		Panigaon	Telahi	83I/4	94.1056	27.150	TW	200.00	155.00	CGWB
5		Merbit Harmoty	Kanubari	83E/16	93.8575	27.124	TW	117.50	116.50	CGWB
6		Jalukata	Narayanpur	83F/13	93.8597	26.958	TW	200.35	156.00	CGWB
7		Rajgarh Bangali	Lakhimpur	83I/8	92.4	26.742	TW	137.00	136.00	CGWB
8		Jorabari	Narayanpur	83F/13	93.8217	26.883	TW	28.70	28.00	CGWB
9		Kowadanga	Nowboicha	83I/4	94.0139	27.185	TW	50.00	48.00	CGWB
10		Lakhimpur H.S.School	Lakhimpur	83I/8	94.101667	27.233	TW	33.00	33.00	CGWB
12		Dhakuwakhana	Dhakuwakhana	83I/4	94.4428	27.199	TW	200.00	172.00	CGWB
13		Ghilamara-	Ghilamara	83I/7	94.4139	27.312	TW	135.00	135.00	CGWB
14		Kadam Kachari	Boginadi	83I/3	94.1747	27.342	TW	57.00	57.00	CGWB

Sl No	District	Location	Block	Toposheet No	Long	Lat	Type of Well (DW/ BW/ TW)	Depth	Depth of construction (m)	Source
15	Lakhimpur	Laluk	Nowboicha	83E/16	93.9320	27.125	TW	55.30	54.00	CGWB
16		Rajgarh Rampur	Nowboicha	83E/16	93.9790	27.242	TW	109.20	107.50	CGWB
17		Balijan	Ghilamara	83I/4	94.2510	27.148	TW	200.70	125.00	CGWB
18		Simalguri	Narayanpur	83F/13	93.7542	26.965	TW	78.00	69.00	CGWB
19		Boginadi	Boginadi		94.183	27.364	TW	30.5	21	CGWB
20		Gossaichapori	Ghilamara		94.328	27.217	TW	89	78	CGWB
21		Sonari Chapori	Ghilamara		94.358	27.15	TW	126.3	98	CGWB
22		Tarajan Mahari Camp	Baginadi	83I/6	94.32	27.49	TW	59.5		CGWB
23		Barala Miri Gaon	Baginadi	83I/6	94.32	27.52	TW	61.5		CGWB
24		Anand Tea Garden	Boginadi		94.23	27.45	TW	100	NA	PHED
25		Gereki Gaon	Ghilamara		94.383		TW	103	NA	irrigation
26		Lilabari	Lakhimpur		94.07	27.29	TW	150.9	NA	PHED
27		Phulbari	Nowboicha		93.95	27.21	TW	117	NA	Irrigation
28		Gusaipukhuri	Kanubari		93.99	27.06	TW	115	NA	PHED
29		Kadam Kachari	Boginadi	83I/3	94.1747	27.342	TW	38	NA	PHED
30		Dhemagarh	Nowboicha		93.92	27.21	TW	71.74	NA	PHED
31		Borbali	Kanubari		93.86	27.04	TW	79.7	NA	PHED
		Lakhimpur HS School	Lakhimpur		94.1	27.23	TW	33.00	33.00	CGWB

CHAPTER 3.0

Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

3.1.1 Geophyscis and aquifer Characterization: The interpreted results of VES curves has shown that top soil has resistivity value within 500 Ohm m being approximately 5m thick comprises clays with boulders of compact nature. The layer below the top soil in the depth range of 5m and 50m with resistivity in the range of 100 Ohm m and 250 Ohm m is indicative of saturated formation comprising sands, clays with pebbles etc. The consecutive layer below 50m and 250m with resistivity more than 150 Ohm m is indicative of the probably the saturated formation comprising pebbles with sands and clays occasionally with boulders. Comparatively lesser resistivity within 70-80 Ohm m is indicative of clays predominance intercalated with thin bands of sands etc. The summary result of resistivity survey is shown in Table: 3.1

Table 3.1: Summary result of VES study

Resistivity section	Resistivity value Ωm	Depth (mbgl)	Inferred Lithology
	500	0 to 5mbgl	Top soil: clays with boulders of compact nature
	100 to 250	5 to 50mbgl	Saturated formation : Sands, clays with pebbles etc.
	>150	50 to below 250mbgl	Saturated formation: Pebbles with sands and clays occasionally with boulders
	70-80	clays predominant; intercalated with thin bands of sands	

The result of VES survey has shown that the subsurface formation is sand or gravel dominated and clay occur as intercalations with sand. Moreover, saturated formation is extended below 250m.

Central Ground Water Board, North Eastern Region, Guwahati has drilled 21 exploratory wells in the district. Public Health Engineering Department has also drilled number of wells in the area. From the examination of this litholog it is observed that down to a maximum explored depth of 200 m the sequence is dominated by gravel, sand, clay and boulders. The lithologs and the lithology identified in VES survey are used to understand 2D and 3D disposition of aquifer.

2D disposition: Two sections are constructed to visualize the aquifer disposition

(a) a north east-south west section from Rajgarh Nepali gaon to Simalguri in the piedmont zone (Fig. 3.2)

(b) a north west to south east section from Phulbari to Panigaon, i.e., from piedmont to flood plain (Fig. 3.3).

In the piedmont zone sediments deposited in high energy conditions as coarser grain materials are dominated in sub surface formation. One gravelly formation are encountered and identified in the VES and in drilling. Resistivity value of the first zone ranges from 319 to 352Ωm and perusal of litholog of Rajgarh Nepali Gaon EW shows that the zone is dominantly gravelly mixed with sand. Resistivity value ranges from 537 to 7447 Ωm indicating coarseness of the sub surface formation materials. Highest value of resistivity is found close to the foothill area, i.e., Dejoo and Dhekiajulu (Jhumi Basti) area. Five clay layers are encountered in the piedmont zone. However, except the second clay layer other clay layers are not laterally continuous in the section. The clay layer thickness is maximum near Rajgarh Gaon (53m).

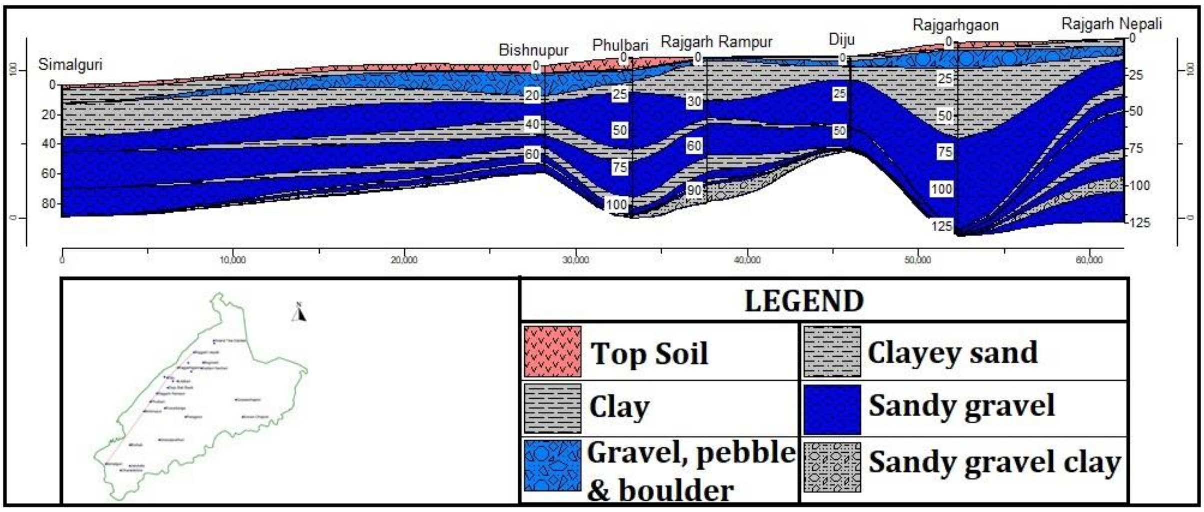
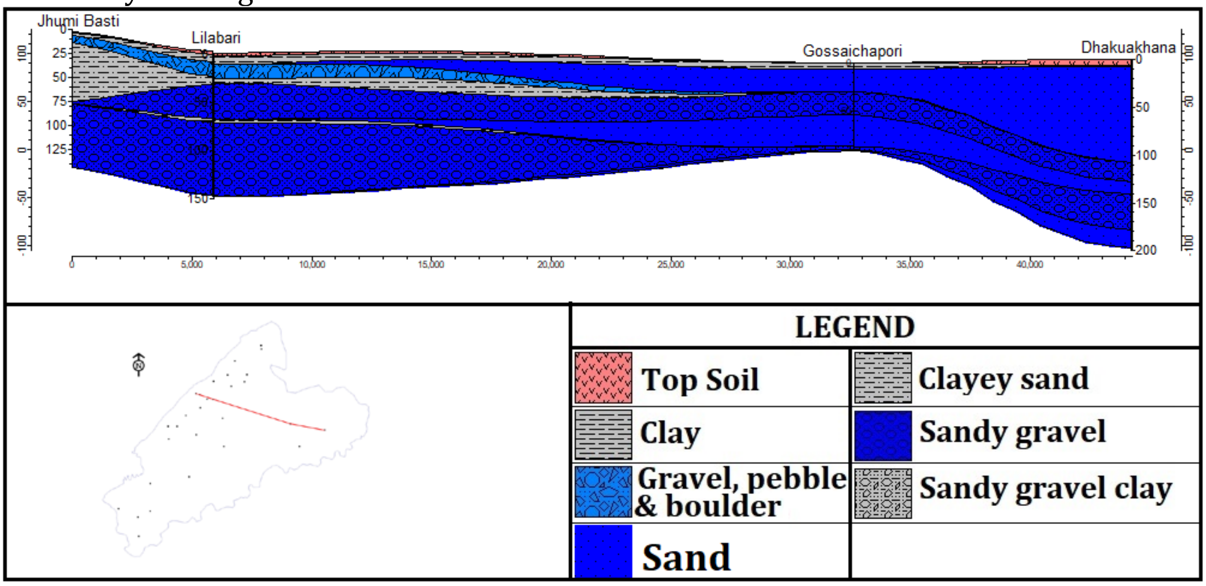


Fig.3.2: Section showing aquifer disposition along piedmont zone

The significant feature of the section from piedmont to flood plain is the dominance of the fine grained unit of the unconsolidated aquifer. Three gravel layers are encountered in the area. The first gravel/pebble and boulder layer appears in the section in lens shaped manner and pinch out further southeast. The second gravelly layer maintains almost uniform thickness throughout the section. The third gravelly layer has maximum thickness in the piedmont zone, however, its thickness considerably reduced towards southeast, i. e, towards the flood plain. Three sand layers are found to emerge in the section and generally sand thickness increases towards the flood plain. The maximum thickness of this gravel and sand layers are found in Lilabari well and Dhakuakhana EW respectively. Top and intermediate clay layers in the piedmont zone are totally missing in the Dhakuakhana EW.



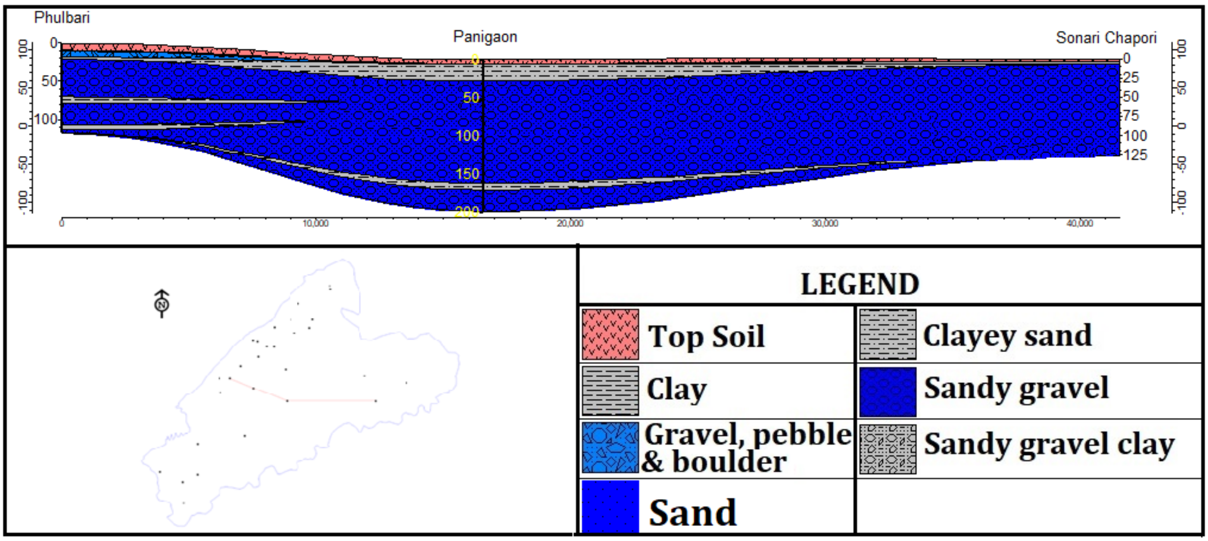


Fig. 3.3: Section showing aquifer disposition normal to piedmont zone, i.e., towards flood plain

Resistivity value of the clay layers ranges from 37 to 127 Ωm. The first clay layer is encountered at Simalguri at 2 to 35, at Rajgarh Rampur surface to 32 m and at Rajgarh gaon 19 to 72 m also thin clay and sand layer alternately encountered within a depth range of 54 to 64m corroborating the result of VES study in the NAQUIM area.

3D disposition of aquifer: Presence of clay layers in the piedmont zone as evident in the 3D block diagram is indicative of multi aquifer system. However, their lateral continuity is not observed towards the flood plain. Moreover, the resistivity value of clay layers indicates mixing of sand and gravels. As a whole the aquifer of the district can be termed as mono-aquifer with localized exception.

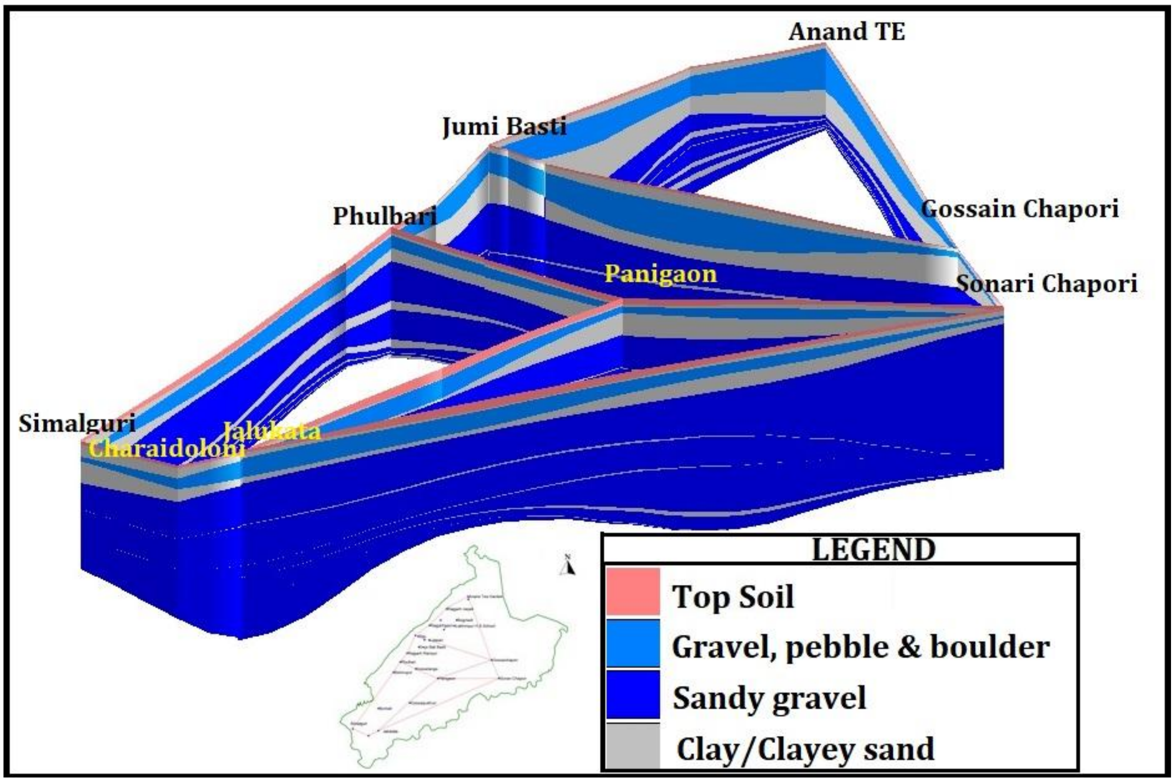


Fig. 3.4: 3D disposition of aquifer in the study area

Table 3.2: Aquifer parameters

S N	Location	Block	Long	Lat	Type of Well	Depth (m)	SWL (mbgl)	Discharge (m³/hr)	Draw Down (m)	T (m2/ day	Specific Capacity	Source
1	Rajgarh nepali	Boginadi	94.14	27.40	TW	125	6.00	38.00	12.4	171.03	50.95	CGWB
2	Dejoo	Lakhimpur	94.03	27.30	TW	142.7	1.45	43.90	16.78	91	48.67	CGWB
4	Panigaon	Telahi	94.10	27.15	TW	200	2.50	76.00	2.00	8055	633.33	CGWB
5	Merbit Harmoty	Kanubari	93.85	27.12	TW	117.5	0.65	54.00	2.90	1386	310.34	CGWB
6	Jalukata	Narayanpur	93.85	26.95	TW	200.35	1.00	54.28	1.60	9541	567.4	CGWB
7	Jorabari	Narayanpur	93.82	26.88	TW	28.70	2.40	51	6.3	981.7	136.19	CGWB
8	Dhakuwakhana-I	Dhakuwakhana	94.10	27.23	TW	200.00	2.22	51.36	0.28	8621	3057	CGWB
9	Ghilamara	Ghilamara	94.41	27.31	TW	135.00	2.34	43.20	4.41	36.07	163.27	CGWB
10	Laluk	Nowboicha	93.93	27.13	TW	55.30	2.24	47.50				CGWB
11	Rajgarh Rampur	Nowboicha	93.98	27.24	TW	109.20	9.32	54.92	11.4	4.70	653.81	CGWB
12	Balijan	Ghilamara	94.25	27.15	TW	200.70	2.85	23.00	5.6			CGWB
13	Simalguri	Narayanpur	93.75	26.97	TW	78.00		35.64			373.67	CGWB
14	Boginadi	Boginadi	94.18	27.36	TW	30.5	4.1	7.16		54.89		CGWB
15	Gossaichapori	Ghilamara	94.33	27.22	TW	89	4.17	12.5				CGWB
16	Sonari Chapori	Ghilamara	94.36	27.15	TW	126.3	4.21	12.5		95.75		CGWB
17	Tarajan Mahari Camp	Baginadi	94.32	27.49	TW	59.5	1.25	12.43	2.08	9831	358.5	CGWB
18	Barala Miri Gaon	Baginadi	94.32	27.52	TW	61.5	2.62	13.5	0.855	3883.2	947.36	CGWB

3.1.2 Ground water level

To study ground water regime, depth to water level from 55 monitoring stations (GWMS 19, Key well 36) are measured seasonally (Fig. 3.5). Block wise variation of water level can be discussed as below.

Pre-monsoon depth-to-water level of the key wells in Narayanpur Block is 0.66 to 8.26 mbgl, Kanubari Block 1.78 to 4.9 mbgl, Bihpuria 3.16m bgl, Nowboicha block is 1.23 to 1.84 mbgl , Baginadi Block 1.03 to 3.99 mbgl, Lakhimpur block depth-to-water level varies from 1.83 to 5.71mbgl, Telahi Block 3.35 to 3.74 mbgl, Dhakuakhana Block 4.41 mbgl. Post-monsoon (November 2018) water level data of Narayanpur Block is 0.55 to 4.03 mbgl, Kanubari Block 0.98 to 3.09 mbgl, Bihpuria 1.74m bgl, Nowboicha block is 1.03 to 1.56mbgl , Baginadi Block 0.75 to 2.51 mbgl, Lakhimpur block 0.44 to 3.05 mbgl, Telahi Block 1.77 to 2.50 mbgl, Dhakuakhana Block 2.50 mbgl and in Ghilamara Block 4.28m bgl.

Block wise Fluctuation of water level pre- and post monsoon water level difference ranges from in Narayanpur Block is 0.11 to 4.23 mbgl, Kanubari Block 0.8 to 1.81 mbgl, Nowboicha block is 0.20 to 0.28 mbgl , Baginadi Block 0.28 to 1.48 mbgl, Lakhimpur block depth-to-water level varies from 1.39 to 2.66mbgl, Telahi Block 1.24 to 1.58 mbgl. The piedmont area water level fluctuation is more than alluvial plain.

3.1.3 Ground Water Movement

The water table contour has been prepared based on water level of ground water monitoring stations (Fig.3.7). The ground water flow direction is from the higher elevation in northwestern towards the plain area. The highest water table is 140 m above mean sea level in the piedmont zone area while lowest contour is 80m towards south in the flood plain. The entire piedmont zone forms the recharge zone for the entire area.

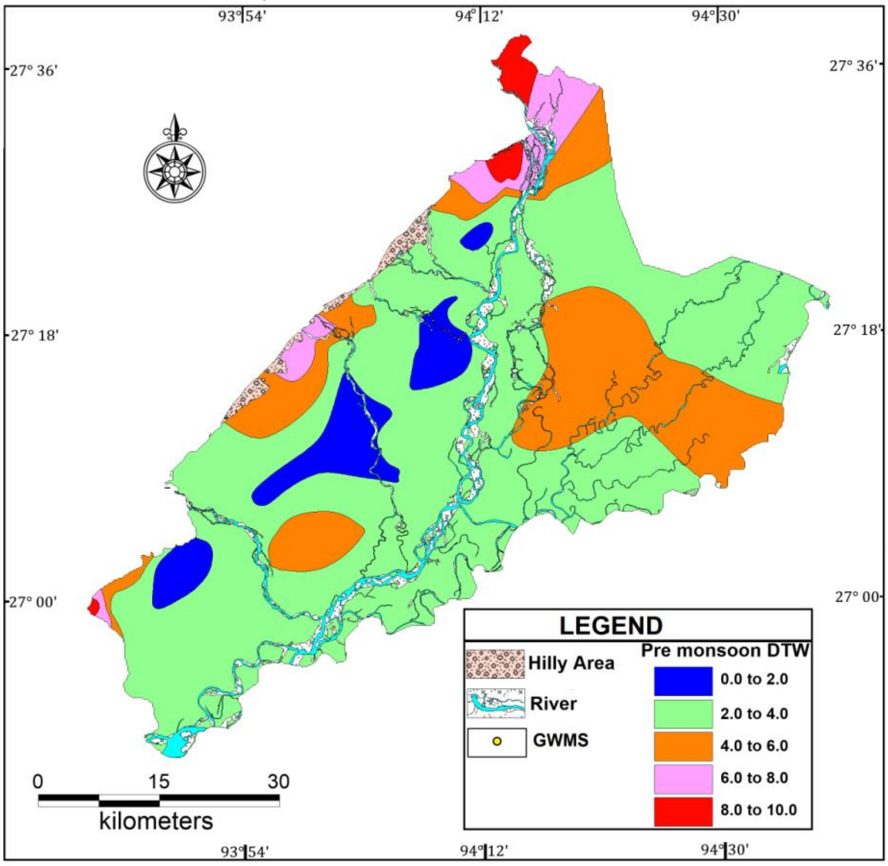


Fig. 3.5: Pre-monsoon DTW level contour of the study area

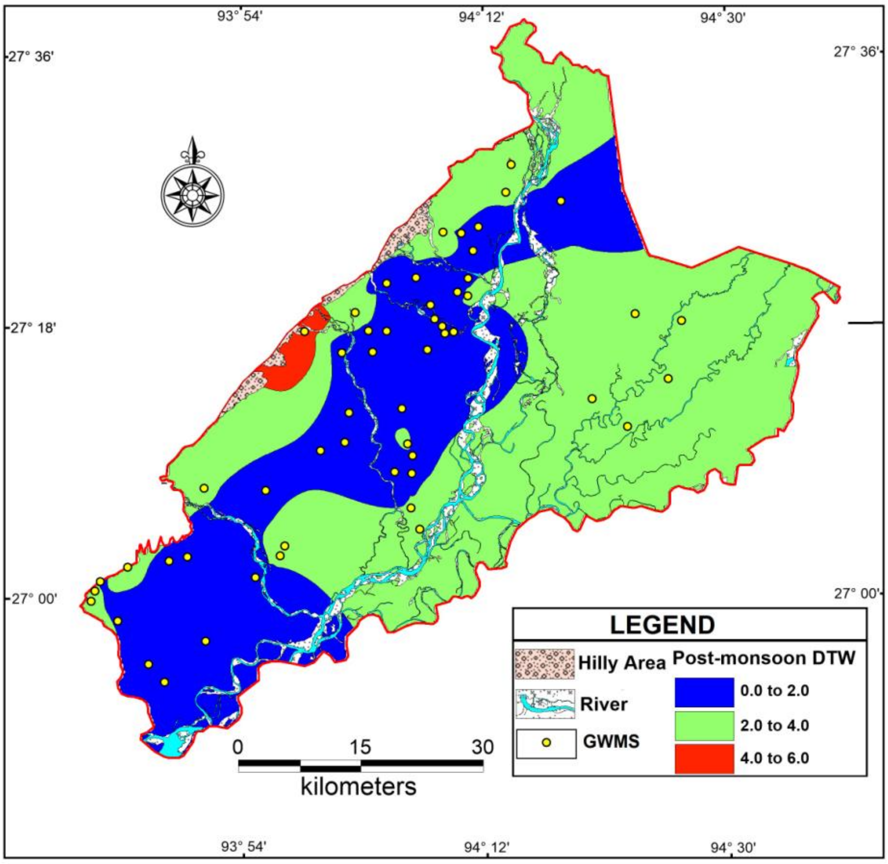


Fig. 3.6: Post-monsoon DTW contour of the study area

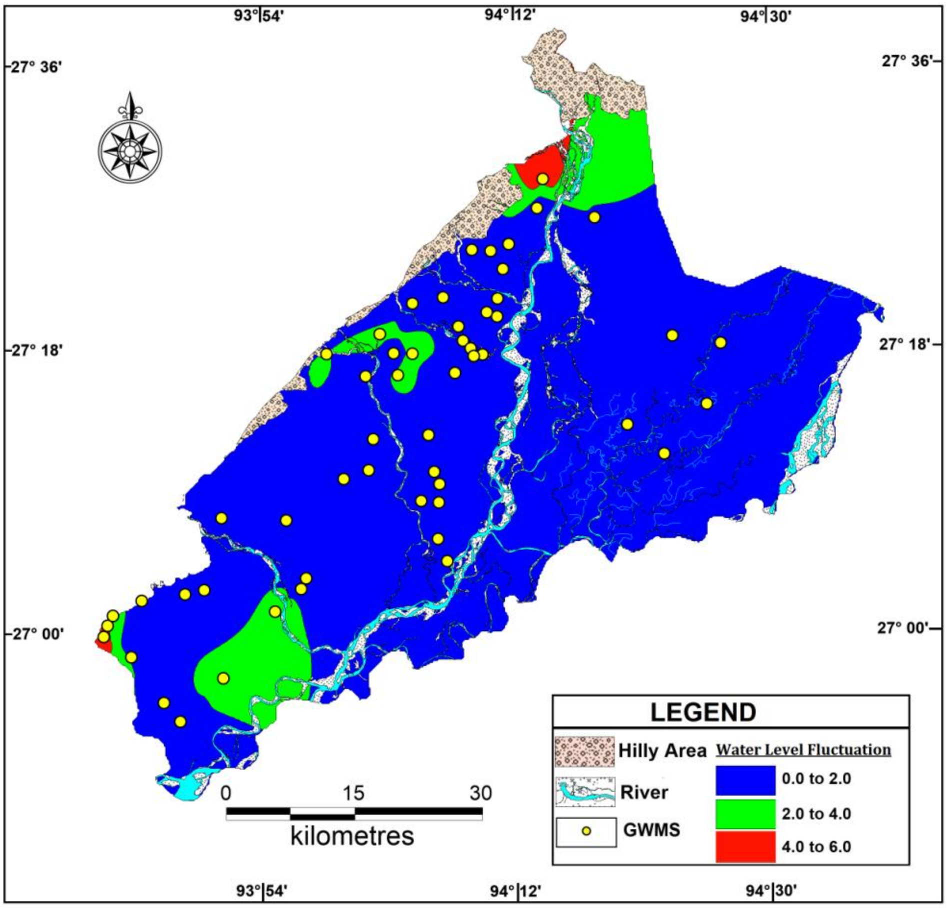


Fig. 3.6: Water Level Fluctuation map of the study area

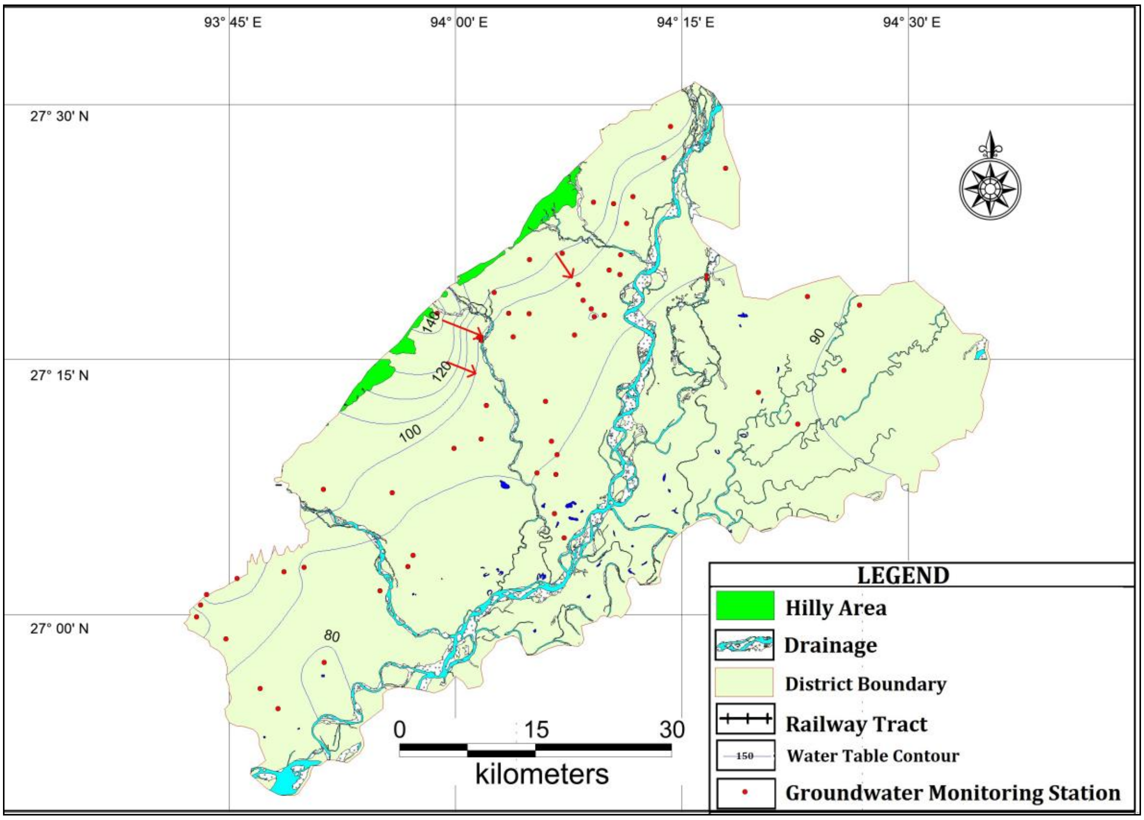


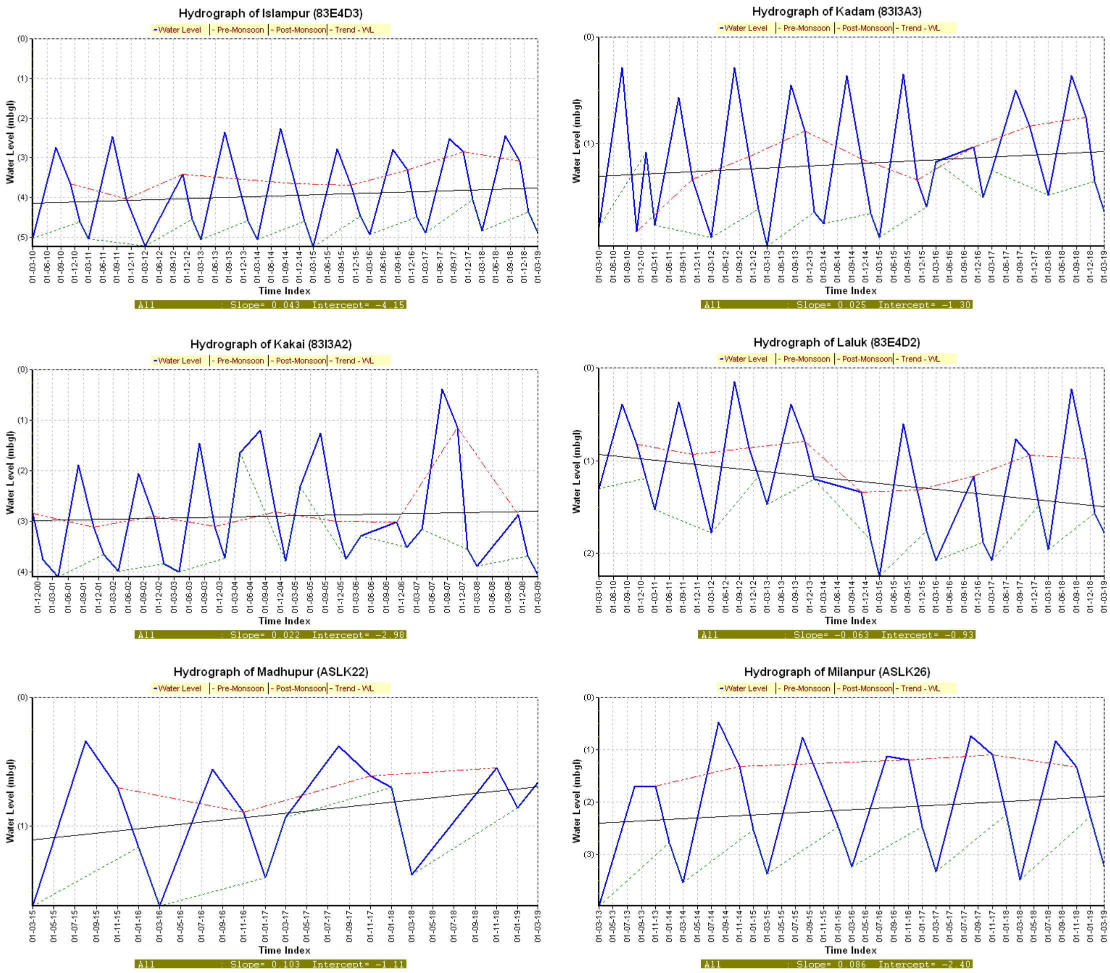
Fig. 3.7: Water table contour of the study area

3.1.3 Water level trend analysis

For analysis of long-term behavior of ground water level, data from Ground Water Monitoring Stations (GWMS) are utilized. Historical depth-to-water level data (in m bgl) are plotted as individual hydrographs and are given in Figure 3.8 and Table 3.3 shows the overall trend of water levels in GWMS wells.

Table 3.3 Trend of Water levels in GWMS Wells

SN	Locality/Name	No. of years	Water Level Trend	
			Post-monsoon	Pre-monsoon
1	Islampur	9	Rise	Rise
2	Kadam	9	Rise	Rise
3	Kakoi	9	Rise	Rise
4	Laluk	9	Fall	Fall
5	Madhupur	5	Fall	Fall
6	Milanpur	6	Rise	Fall
7	Moridirgh	3	Rise	Fall
8	N.Lakhimpur (old)	9	Rise	Fall
9	Naoboisa	9	Rise	Fall
10	Narayanpur	9	Rise	Fall
11	Panigaon	9	Rise	Fall
12	Pathalipam	9	Rise	Fall
13	Pathalipam II	4	Rise	Fall



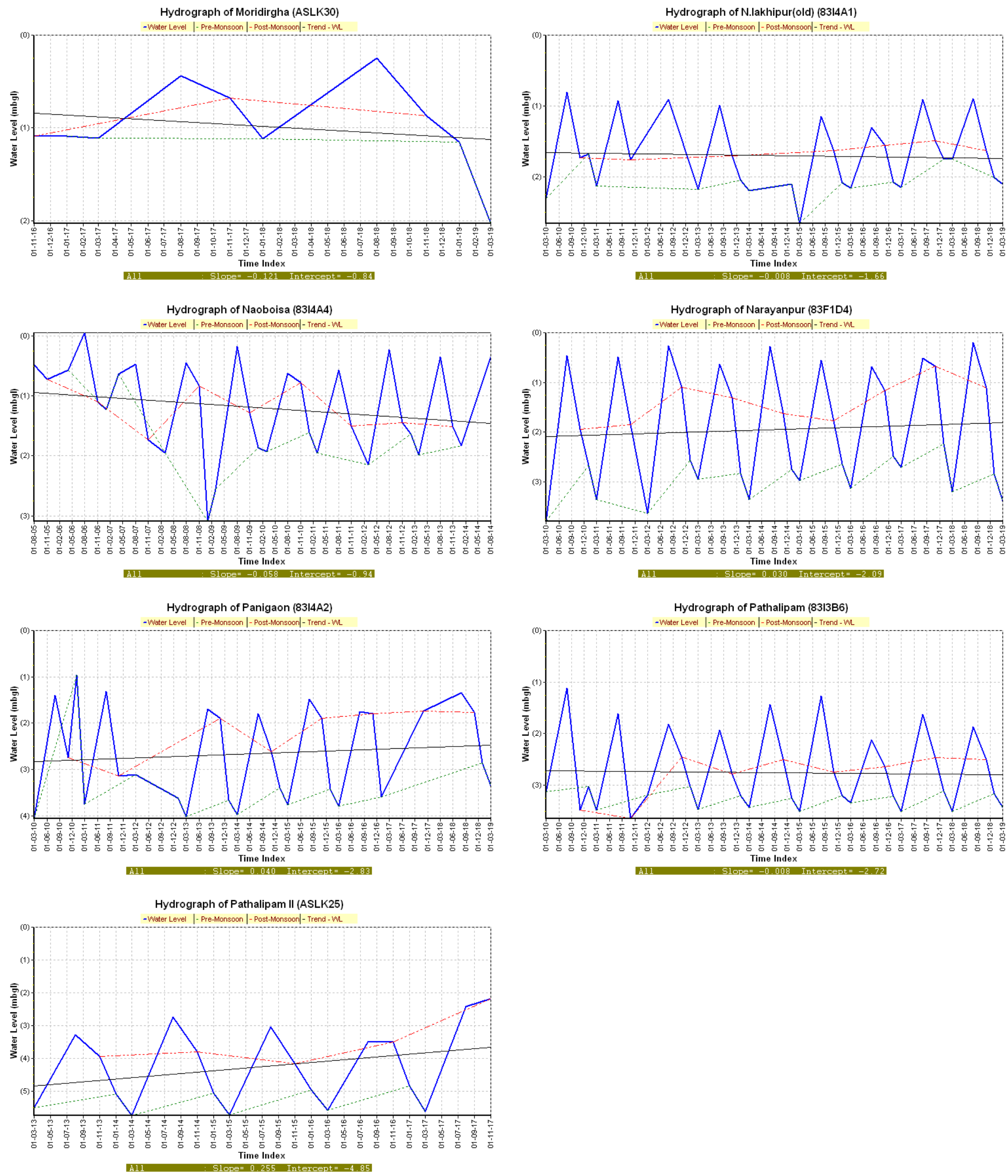


Fig.3.8: Hydrograph of GWMS wells

3.1.4 Ground water quality

Chemical analysis of ground water samples are carried out by regional chemical laboratory of Central Ground Water Board, North Eastern Region, Guwahati. Water quality data is also collected from Public Health Engineering Department, North Lakhimpur Division.

Pre-monsoon pH value ranges from 6.9 to 8.39 and in the post-monsoon pH value ranges from 7.58 to 8.25 indicating wide variation in pH. Pre-monsoon iron concentration ranges from 0.11 to 14.91mg/l. In post monsoon water samples iron concentration is ranges from 0.002 to 13.1mg/l. In general most of the samples Iron concentration is within limit, except Bhogpur 1.13 mg/l, Dakhin Kulabali 3.48 mg/l, Dhenudharia 5.86 mg/l, Gagaldubi 14.92mg/l, Gergaria 10.28 mg/l, Janakpur 1.56 mg/l, Kuhiarbari 2.97 mg/l, Moridirgha 4.36 mg/l, No 2 Laimekuri 2.98 mg/l in Pre monsoon. In post monsoon the Iron concentration is more than permissible limit are Checha Rajgarh 12.7mg/l, Gagaldubi 13.3 mg/l, Kadam Gohaigaon 5.52 mg/l, Moridirgha 4.69 mg/l, No 1 Laimekuri 13.1 mg/l, No.2 Laimekuri 1.53 and Padumani 2.17 mg/l. It is observed that in both pre- and post-monsoon groundwater samples concentration of Ca, Mg, Cl, SO_4, TDS and hardness as $CaCO_3$ are within desirable limit. Concentration range of different chemical elements in ground water during pre- and post monsoon in the study area is given in **Table 3.4**.

Arsenic in groundwater: PHED, North Lakhimpur Division carried out water testing in its laboratory. 54 ground water samples collected from tara pump, shallow hand pump, hand tube well were analyised and results shows that arsenic concentration ranges from 52.5 to 583.1ppb. The Ghilamar Division of PHED also analyzed 11 water samples and reported arsenic concentration ranges from 52.5 ppb to 269.1 ppb.

During aquifer mapping pre and post monsoon ground water samples were collected and analyzed in NABL accredited Regional Chemical Laboratory of Central Ground water Board, Guwahati. Arsenic above permissible limit is found only in two post monsoon samples. The analyzed result shows that only two sources viz., one hand pump and one Tara pump of No 1 Laimekuri village under Boginadi Block is above the permissible limit of arsenic.

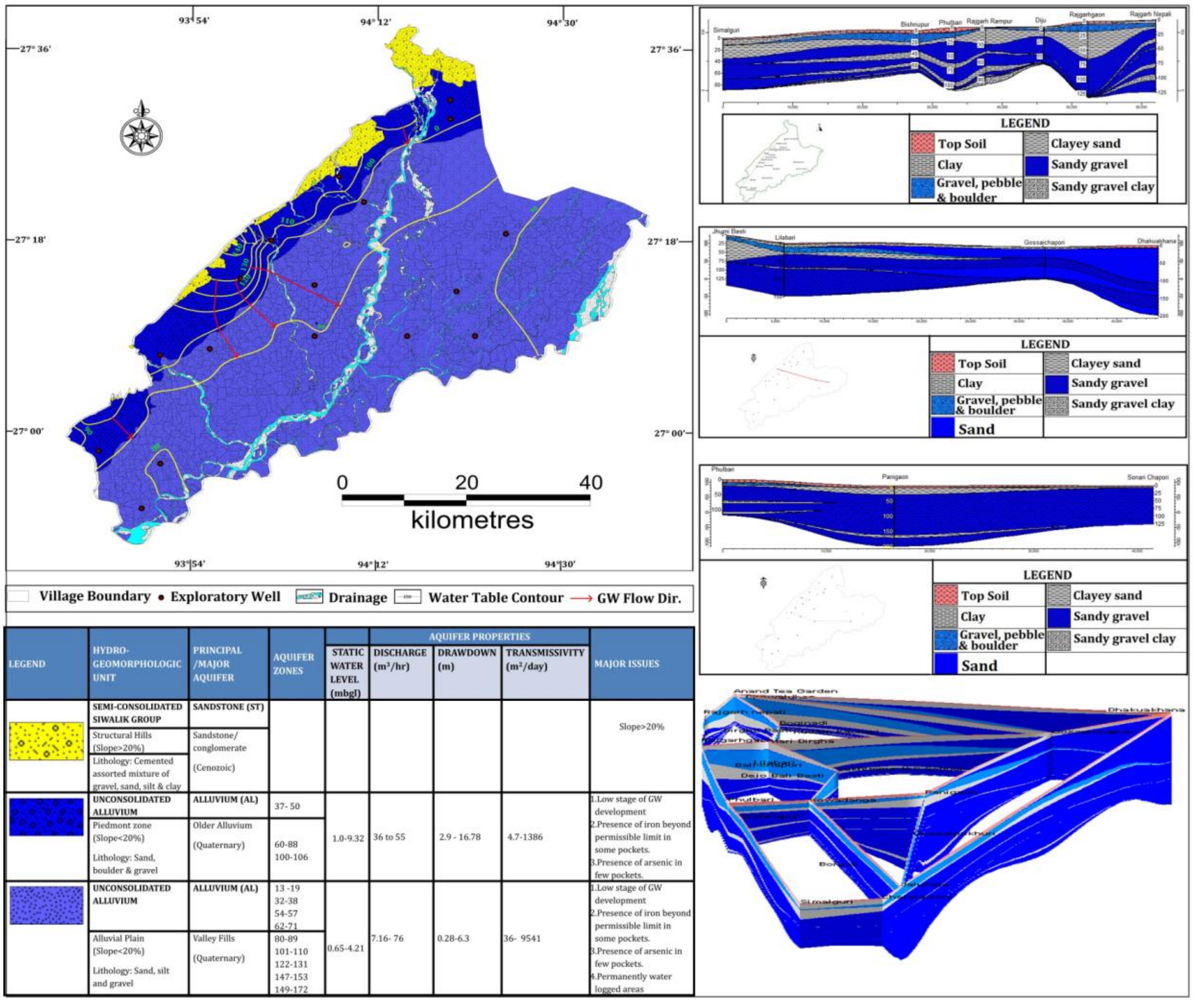
Aquifer map: Two principal aquifers are found in the district, viz., Tertiary Siwalik and the Quaternary alluvium. The Tertiary Siwalik aquifer is found in the northeast part of the district. The Siwalik rocks are found as structural hills and slope is more than 20%.

The Quaternary alluvial aquifer is found in the foothill of Siwalik and extends up to the north bank of river Brahmaputra in the south. The aquifer in the piedmont zone is composed of older alluvial deposits sand, pebble, cobble and boulder and is mixed in varying proportions whereas the flood plain aquifer is mainly composed of different grades of sand with little gravel. The piedmont zone extends over 8-10km from the foothill, and is followed by younger flood plain area.

The alluvial aquifer can be divided into two, viz, shallow and deeper, based on the subsurface geology deciphered from drilling and prevailing ground water conditions.

Shallow aquifers: The water bearing horizons occur within 30-50mbgl is considered to constitute shallow aquifer system. Ground water in this aquifer occurs under unconfined to semi-confined conditions. The aquifer materials comprise sands of different grades with varying proportions of gravels. The grain size of the aquifer materials is found to decrease towards the southern part of the district. The top-confining layer is consisted of clay with interlayer sand and its thickness is varying from nearly 1m to 29m. The lower confining layer is 3m to 12 m thick and is not regionally extensive.

Deeper Aquifers: In the deeper aquifers, ground water occurs under semi-confined to confined conditions. The upper confining layer is generally 3 to nearly 12m thick and is not regionally extensive. The aquifer materials are composed of sands and gravels of different size grade. In this district, CGWB, NER had explored the subsurface down to the depth of 200m in Dhakuakhana, Panigaon and Jalukata areas. The cumulative thickness of the granular zones in the deeper aquifer varies from 60 to 150m. There is a clear distinction of grain size of aquifer materials in the northern, southern and western part of the district. Presence of multi aquifer system in the western part of the district around Dholpur, Narayanpur is deciphered from lithologs. The confining layers are not persistent.



LEGEND	HYDRO-GEOMORPHOLOGIC UNIT	PRINCIPAL /MAJOR AQUIFER	AQUIFER ZONES	AQUIFER PROPERTIES: STATIC WATER LEVEL (mbgl)	DISCHARGE (m^3/hr)	DRAWDOWN (m)	TRANSMISSIVITY (m^2/day)	MAJOR ISSUES
	SEMI-CONSOLIDATED SIWALIK GROUP	SANDSTONE (ST)						Slope>20%
	Structural Hills (Slope>20%) Lithology: Cemented assorted mixture of gravel, sand, silt & clay	Sandstone/ conglomerate (Cenozoic)						
	UNCONSOLIDATED ALLUVIUM	ALLUVIUM (AL)	37- 50	1.0-9.32	36 to 55	2.9 - 16.78	4.7-1386	1.Low stage of GW development 2.Presence of iron beyond permissible limit in some pockets. 3.Presence of arsenic in few pockets.
	Piedmont zone (Slope<20%) Lithology: Sand, boulder & gravel	Older Alluvium (Quaternary)	60-88 100-106					
	UNCONSOLIDATED ALLUVIUM	ALLUVIUM (AL)	13 -19 32-38 54-57 62-71	0.65-4.21	7.16- 76	0.28-6.3	36- 9541	1.Low stage of GW development 2.Presence of iron beyond permissible limit in some pockets. 3.Presence of arsenic in few pockets. 4.Permanently water logged areas
	Alluvial Plain (Slope<20%) Lithology: Sand, silt and gravel	Valley Fills (Quaternary)	80-89 101-110 122-131 147-153 149-172					

Fig. 3.9 Aquifer map of the study area

Table: 3.4 a. Concentration range of chemical constituents in groundwater (Pre Monsoon)

Block wise Pre monsoon Chemical Quality data of Lakhimpur district, Assam

Block	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS (mgL^{-1})	CO_3^{-2} (mgL^{-1})	HCO_3^- (mgL^{-1})	TA (as $CaCO_3$) (mgL^{-1})	Cl- (mgL^{-1})	SO_4 (mgL^{-1})	NO_3^- (mgL^{-1})	F^- (mgL^{-1})	Ca^{+2} (mgL^{-1})	Mg^{+2} (mgL^{-1})	TH (as $CaCO_3$) (mgL^{-1})	Na (mgL^{-1})	K (mgL^{-1})	Fe (mgL^{-1})
Karunabari	6.99 - 8.39	170.1 - 795.1	0 - 0.2	101 - 422.7	0 - 30	85.06 - 175.14	85.06 - 195.14	17.72 - 120.53	5.36 - 38.97	0.07 - 10.24	0.09 - 0.84	22.01 - 74.05	7.26 - 14.53	90 - 245	7.71 - 43.69	1.24 - 25.68	0.11 - 0.16
North Lakhimpur	7.44 - 8.19	80.62 - 339.2	0	41.42 - 184.1	0	40.032 - 150.12	40.032 - 150.12	10.63 - 67.35	7.04 - 27.59	0.82 - 1.72	0.11 - 0.55	6 - 40.03	1.2 - 19.39	35 - 180	5.96 - 18.1	2.31 - 5.08	0.14 - 5.86
Nowboicha	8.17	175.2	0	94.06	0	70.056	70.056	42.54	22.1	0.66	0.25	14.01	13.3	90	13.6	7.48	0.09
Boginadi	7.21- 8.32	106.1- 856.4	0	55.03 - 445.9	0 - 50	30.02 - 115.1	30.02 - 350.28	14.18 - 113.44	2.74 - 63.33	0.54 - 9.06	0.07 - 1	14.01 - 30.02	1.2 - 37.59	50 - 285	1.27 - 55.05	1.13 - 36.72	0.11 - 14.91
Narayanpur	7.87 - 8.87	79.17 - 376.6	0 - 0.6	41.75 - 202.4	0- 30	45.03 - 160.14	45.03 - 160.14	24.81 - 42.54	1.99 - 26.41	0.43 - 1.55	0.18 - 0.49	10.01 - 56.04	8.46 - 13.32	59.99 - 180	8.04 - 18.97	2.84 - 7.73	0.08 - 1.39
Bihpuria	8.35	213.4	0	113	10	0.008	10.008	42.54	4.54	13.8	0.43	34.03	2.41	95	2.12	2.07	0.46
Telahi	8.11 - 8.06	190.2 - 201.7	0	102.1 - 109	0	75.06 - 115.09	75.06 - 115.09	35.45 - 49.63	5.22 - 31.07	0.59 - 0.74	0.32 - 0.39	26.02 - 28.02	9.69 - 10.90	105 - 115	14.43 - 16.64	1.31 - 2.87	0.91 - 2.97
Dhakuakhana	8.6	367.9	0	191.5	70	90.128	160.13	7.09	29.4	1.46	0.3	50.04	2.4	135	28.9	10.5	0

Table: 3.4 b. Concentration range of chemical constituents in groundwater (Post Monsoon)

Block wise Post monsoon Chemical Quality data of Lakhimpur district, Assam

Block	**pH**	**EC (µs/cm) 25C**	**Turbidity (NTU)**	**TDS (mgL^{-1})**	**CO_3^{-2} (mgL^{-1})**	**HCO_3^- (mgL^{-1})**	**TA (as $CaCO_3$) (mgL^{-1})**	**Cl- (mgL^{-1})**	**SO_4^{-2} (mgL^{-1})**	**NO_3^- (mgL^{-1})**	**F^- (mgL^{-1})**	**Ca^{+2} (mgL^{-1})**	**Mg^{+2} (mgL^{-1})**	**TH (as $CaCO_3$) (mgL^{-1})**	**Na (mgL^{-1})**	**K (mgL^{-1})**	**Fe (mgL^{-1})**
Karunabari	7.58 - 8.25	207.3 - 480.8	0 - 0.3	113.7 - 262.9	0	85.06 - 185.14	85.06 - 185.14	31.9 - 85.0	39.3 - 55.4	0 - 0.88	0.27 - 0.31	20.01 - 28.02	13.33 - 30.32	110 - 195	13.36 - 34.14	4.01 - 21.34	0.03 - 0.10
North Lakhimpur	7.25 - 8.64	72.94 - 565.9	0 - 0.4	39.85 - 309.7	0- 40	45.03 - 185.16	45.03 - 205.16	24.81 - 85.08	6.8 - 110.2	0	0.09 - 0.31	12.0 - 26.02	2.41 - 42.46	50 - 240	9.6 - 60.44	5.39 - 29.36	0.03 - 0.1
Nowboicha	7.64	196.9	0	108.4	0	80.064	80.064	49.63	16.29	0	0.19	16.0128	9.7	80	8.54	33.43	0.0733
Boginadi	7.40 - 8.18	134.3 - 874	0 - 0.4	73.57 - 479.4	0	65.05 - 330.26	65.05 - 330.26	24.81 - 124.07	8.01 - 118.5	0 - 5.66	0.06 - 1	18.01 - 28.02	6.05 - 47.31	75 - 265	1.53 - 60.5	2.45 - 59.5	0.50 - 13.1
Narayanpur	7.09 - 8.37	92.13 - 444.3	0 - 0.2	50.44 - 247.4	0- 20	80.06 - 195.17	80.06 - 215.2	28.36 - 38.99	11.39 - 38.88	0	0.12 - 0.82	4.0 - 24.01	18.2 - 32.75	85 - 195	7.38 - 28.4	3.56 - 18.6	0.07- 0.21
Bihpuria	7.75	131.8	0	72.55	0	75.06	75.06	28.36	11.59	0	0.26	16.01	14.5	100	4.23	4.68	0.27
Telahi	7.99	252.4	0.5	138.6	0	120.1	120.1	35.45	25.77	0	0.43	26.0208	19.4	145	7.56	7.08	0.336
Dhakuakhana	8.19	292.2	0	159.4	0	135.11	135.11	31.905	28.829	0	0.28	22.0176	24.261	155	6.01	4.99	0.0203

CHAPTER 4.0
Ground water Resources

The computation of ground water resources available in the district has been done using GEC 2015 methodology. The dynamic resource estimation presented here is taken from 2017 dynamic groundwater resources of Assam where resource was estimated district wise due to paucity of block-wise data. In the present report the same calculation is used and the resource is proportionately divided among blocks based on their geographical areas.

Data and assumptions used in the assessment: Following data and assumptions are used in the assessment:

1) Rainfall recharge has been computed by both RIF and WLF methods. In RIF method, rainfall infiltration factor has been taken as 0.22 for major aquifer like valley fill. In WLF method, specific yield has been taken as 0.16.
2) IMD rainfall data is considered for 2017 groundwater resource calculation.
3) Water level data has been considered for 2016. Water level fluctuation based on data of March (Pre monsoon) and November (post monsoon) has been considered since deepest water levels are recorded during the month of March.

The average pre- and post-monsoon water level of Lakhimpur district is 3.036mbgl and 1.743mbgl.

4) The population figures were collected from Census, 2011and projected to 2017. The per capita domestic requirement for the rural population has been considered as 70 lpcd and for urban population, it is 135 lpcd.
5) The dependency on ground water resource for domestic and industrial water supply in rural areas is considered as 90% and for urban areas, the dependency is 50%.
6) In order to calculate the canal seepage, the data on length of the drainage channels are taken from the Irrigation Department, Govt. of Assam. The factor for return flow from surface water irrigation has been taken as 0.50 (paddy) and 0.30 (non-paddy) and for Ground water irrigation it has been taken as 0.45 (paddy) and 0.25 (non-paddy). Recharge from tanks and ponds are calculated based on the norms suggested in GEC'2015.
7) Recharge from water conservation structure has been taken as nil.

The total replenishable ground water resources available in the study area have been computed using the average water level fluctuations in observation wells and specific yield of aquifers. These have been normalised using normal rainfall data to eliminate variations in recharge due to excess or deficit rainfall. The monsoon recharge arrived at is then compared with the recharge computed using rainfall infiltration method. In cases where the difference between the two is more than 20 percent, the recharge is computed using ad hoc method.

4.1 Recharge: The aquifers of the study area are recharged through a) infiltration of rainfall on the outcrop b) seepage from the tanks and ponds c) subsurface inflow across the up dip margin. The area experiences south-east monsoon. Monsoon rainfall contributes approximately 81 percent of total rainfall (May, June, July, August, September) while share of post and pre monsoon rainfall are approximately 13 and 6 percent each.

Previous records show that the rainfall occurs almost in every month of a year. The month November to December has the minimum number of rainy days in any year and the period May to September has maximum number of rainy days.

The monsoon recharge of the 227700 hectre of recharge worthy area from rainfall is 90950.92 ham while non-monsoon recharge is 27460.03ham. Recharge from other sources during monsoon is 513.78 ham and during non-monsoon is 1292.40 ham. Total ground water recharge is 120217.12 ham.

4.2 Ground Water Extraction: The ground water extraction of unconsolidated aquifer is created by natural discharge like seepages and draft created by human interference, viz., (a) withdrawals for irrigation and industry and (b) public-supply wells.

In the district natural discharge is 6656.32 of the total groundwater recharge, i.e., 120217.12 ham. Total irrigation extraction created is 3044.16ham, for industry 36.90 ham and extraction for domestic uses is 2424.44 ham. Total groundwater extraction for all uses is only 5505.50 ham.

The water trend analysis shows that there is no significant change in the water level for both post-monsoon periods.

4.3 Allocation of resources up to 2025: The net ground water resource is allocated for domestic and industrial and irrigation sector. 2763.82ham of resource is allocated for domestic while 107715.92ham resource is available for future use.

4.4 Stage of Ground Water Extraction: The area has very little irrigation facilities. Similarly industrial development in the area is practically nil. Groundwater is mainly utilized for domestic purposes. However, Public Health Engineering & Water Supply Department has supplied water mainly through surface water sources. The stage of groundwater extraction in the district is 4.85%.

CHAPTER 5.0

Groundwater Related Issues

Identification of issues: The main groundwater issue in this area is vulnerability issue. The vulnerable areas generally include areas vulnerable to water logging and polluted areas.

5.1 Area vulnerable to water logging: Permanently water logged areas are identified by preparing depth-to-water level contour for both pre- and post-monsoon seasons. The permanently water logged areas are those which are water logged both in pre- and post-monsoon seasons. The pre-monsoon depth-to-water level varies from 0.66 to 1.91mbgl whereas the post monsoon depth-to-water level varies from 0.55 to 1.56mbgl. The water level fluctuation varies from 0.04 to 1.39m. Permanently water logged areas are found in Narayanpur, Karunabari, Nowboicha, North Lakhimpur and Boginadi. The post monsoon depth-to-water level in Narayanpur, Madhupur, Bhogpur in Narayanpur Block, Dolohat, Borpukhuri, Kawadanga in Nowboich Block , Moridirgha, Milanpur, Kadam, Borbil Toriyani, Kakoi, Bogindi Balijan Padumani in Boginadi Block, Laluk in Kanubari Block and Rangajan, Janambasti, Janakpur, Dhenudhari of Lakhimpur Block shows water logging condition. The water logged areas are roughly parallel to piedmont zone. Water logged areas are found in the alluvial plain, flood plain and gently sloping piedmont zone. In the water logged areas high iron concentration is observed.

5.2 Area vulnerable to arsenic pollution: Public Health Engineering Department, Lakhimpur Division, Govt. of Assam reported that in July, 2014 they identified 54 villages as Arsenic affected village. They collected water samples from Hand pump and Tara pump of these villages and analyzed in their own Laboratory. The ranges of Arsenic in these shallow tubewells are 52.5 ppb to 583.1 ppb. (Annexure1). The Ghilamara Division of PHED also analyzed 11 water sample and reported Arsenic ranges from 52.5 ppb to 269.1 ppb. (Annexure2).

In the present study water samples were collected from shallow aquifer in pre- and post-monsoon seasons. During pre-monsoon 25 samples and post monsoon 34 samples were collected from dug well, hand pump and tara pump. The samples were analyzed in the Regional Chemical Laboratory, Central Ground water Board, Guwahati. The analyzed result confirms presence of arsenic in the district. It is interesting to note that arsenic is below detectable limit nearly 75% of pre-monsoon and nearly 60% of post-monsoon samples. In pre-monsoon samples arsenic concentration varies from 0.05 to 1.3 (ppb or mg/l) while in post-monsoon samples it varies from 0.07 to 8.96mg/l. (Table 5.1a & 5.1b)

Those sampling points are plotted in the vulnerability map where arsenic concentration is above BDL but within the acceptable limit (Fig. 5.1). It is observed that majority of sample points are clustered in water logged areas. It is also observed that general trend of arsenic distribution in the district is its affinity to associate with iron.

Table 5.1 a Results of Pre-monsoon groundwater samples analyzed by Regional Chemical Laboratory, CGWB, NER, Guwahati

Location	Latitude	Longitude	Type of sample (TW or DW)	Date of collection	Arsenic (in ppb or µg/L)
Bhogpur	27.05	93.83	DW	12.03.2019	BDL
Rajgarh	27.02	93.73	DW	12.03.2019	BDL
Checha Rajgarh	27.01	93.72	DW	2.03.2019	BDL
Gobindapur	26.976	93.75	DW	2.03.2019	BDL

Location	Latitude	Longitude	Type of sample (TW or DW)	Date of collection	Arsenic (in ppb or µg/L)
Ganakdoloni	26.928	93.78	DW	12.03.2019	BDL
Amguri	27.05	93.95	DW	12.03.2019	BDL
Laluk	27.12	93.93	DW	12.03.2019	BDL
Harmoti	27.12	93.85	DW	12.03.2019	1.05
Barpukhuri	27.205	94.03	DW	13.03.2019	BDL
Dijoo	27.27	94.03	DW	13.03.2019	BDL
Panigaon	27.13	94.11	DW	13.03.2019	BDL
Kuhiarbari	27.099	94.11	DW	13.03.2019	0.05
Dhenudharia	27.139	94.09	DW	13.03.2019	0.05
Jalbhari	27.187	94.428	DW	14.03.2019	1.3
Janakpur	27.295	94.08	DW	15.03.2019	BDL
Koilamari	27.32	94.044	DW	15.03.2019	BDL
Sinatoli	27.348	94.081	DW	15.03.2019	BDL
Moridirgha	27.32	94.136	DW	15.03.2019	BDL
Dakhin Kulabali	27.337	94.169	DW	15.03.2019	0.05
Gagaldubi Barkhelia	27.333	94.181	DW	15.03.2019	BDL
Gagaldubi	27.35	94.179	TP	15.03.2019	BDL
Gergeria	27.352	94.182	TP	15.03.2019	0.55
Gergeria	27.352	94.182	DW	15.03.2019	BDL
Pathalipam	27.447	94.23	DW	16.03.2019	BDL
No 2 Laimekuri	27.292	94.153	DW	16.03.2019	BDL

Table 5.1 b Results of post monsoon groundwater samples analyzed by Regional Chemical Laboratory, CGWB, NER, Guwahati

Location	Latitude	Longitude	Type of sample (TW or DW)	Date of collection	Arsenic (in ppb or µg/L)
Biphuria	27.02	93.92	DW	12.04.2018	4.955
Laluk	27.12	93.93	DW	15.04.2018	4.73
Pathalipam	27.45	94.23	DW	09.04.2018	4.955
Amguri	27.05	93.95	DW	12.04.2018	4.955
Bhogpur	27.05	93.83	DW	12.04.2018	6.191
Bhogpur	27.05	93.83	DW	02.11.2018	BDL
Rajgarh	27.02	93.73	DW	02.11.2018	BDL
Checha Rajgarh	27.01	93.72	DW	02.11.2018	BDL
Gobindapur	26.98	93.75	DW	02.11.2018	0.071
Ganakdoloni	26.93	93.78	DW	02.11.2018	0.273
Dighalia Majgaon	26.88	93.84	DW	02.11.2018	BDL
Amguri	27.05	93.95	DW	05.11.2018	BDL
Laluk	27.12	93.93	DW	05.11.2018	0.071
Harmoti	27.12	93.85	DW	05.11.2018	BDL
Barpukhuri	27.21	94.03	DW	05.11.2018	BDL
Dijoo	27.27	94.03	DW	05.11.2018	BDL
Rangajan	27.27	94.06	DW	06.11.2018	BDL
Koilamari	27.32	94.044	DW	06.11.2018	BDL
Janakpur	27.3	94.08	DW	06.11.2018	BDL
Kamalboria	27.17	94.11	DW	08.11.2018	BDL

Location	Latitude	Longitude	Type of sample (TW or DW)	Date of collection	Arsenic (in ppb or µg/L)
Kuhiarbari	27.1	94.11	DW	08.11.2018	BDL
Dhenudharia	27.14	94.09	DW	08.11.2018	BDL
No 2 Laimekuri	27.29	94.153	DW	10.11.2018	BDL
No 1 Laimekuri	27.29	94.164	DW	10.11.2018	BDL
Kadam Gohaigaon	27.31	94.14	DW	10.11.2018	8.96
Moridirgha	27.32	94.136	DW	10.11.2018	3
Cinatoli	27.35	94.081	DW	10.11.2018	BDL
Gergeria	27.35	94.182	DW	10.11.2018	BDL
Gagaldubi	27.35	94.179	TP	10.11.2018	7.646
Gagaldubi Barkhelia	27.33	94.182	TP	10.11.2018	4.616
Dakhin Kulabali	27.34	94.169	DW	11.11.2018	BDL
Gagaldubi Barkhelia	27.33	94.181	DW	11.11.2018	BDL
Padumani	27.41	94.196	DW	11.11.2018	BDL
Pathalipam	27.45	94.23	DW	11.11.2018	BDL
Milanpur	27.44	94.298	DW	11.11.2018	BDL
Jalbhari	27.19	94.429	DW	13.11.2018	BDL
Boginadi	27.22	94.328	EW	31.10.2018	7.141

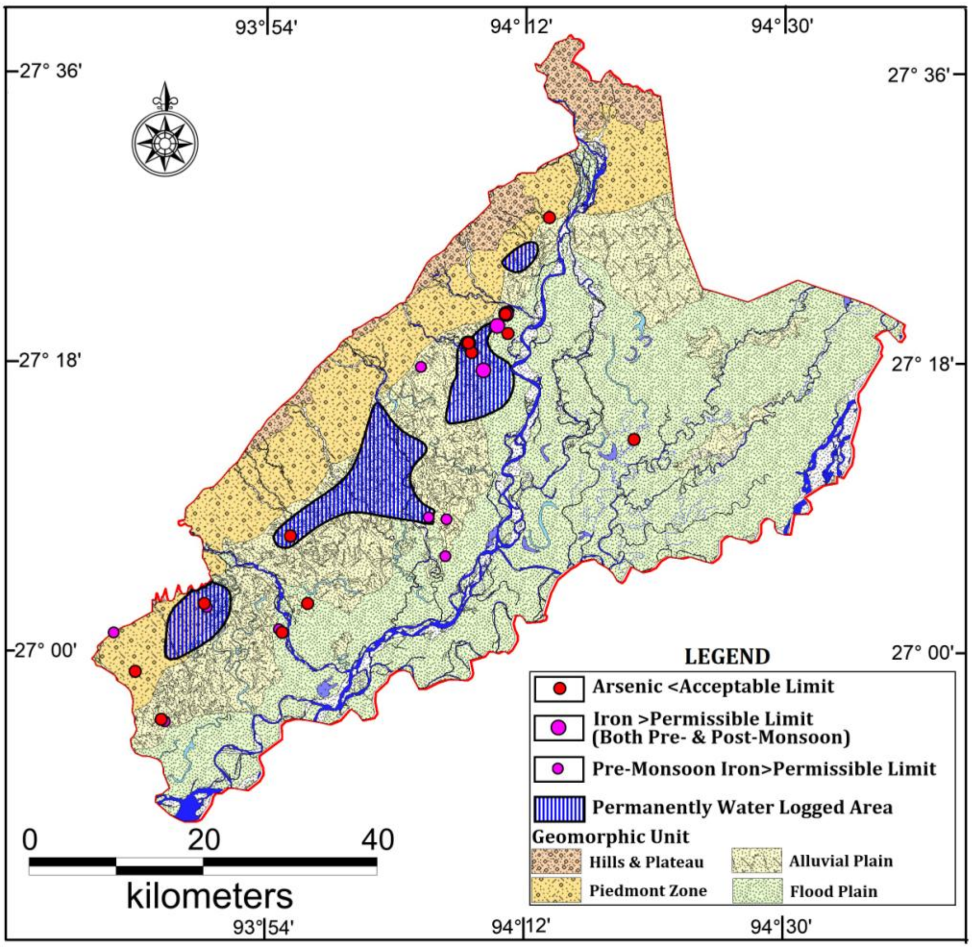


Fig. 5.1: Vulnerability map of Lakhimpur District

5.3 Future demand scenario and stress aspects of the aquifer

Domestic Water Supply Demand: Future demand of water in the area will mainly come from domestic sector. Public Health Engineering Department supplies water using both surface and ground water sources. The dependency on ground water is only 92.82% as per 2011 census.

As per GEC 2017 the current ground water extraction in domestic sector is 2424.4 ham. Water demand in this sector is calculated by projecting the population to 2025 and allocating 60lpcd water. The ground water demand is found to be 2763.82ham up to 2025.

5.4 Future demand for agriculture:

The area has saucer shaped topography. In the northern part there is Arunachal Himalayas and towards south the Brahmaputra River. The Brahmaputra River bed is elevated after 1950's great earthquake. Water logging problem of the area can be related with this changing physiography.

As a result during monsoon season, the increase surface run-off in the form of increased discharge of hilly rivers flow to this part of land and immediately losses its velocity due to sudden fall of slope and as such agriculture field and human settlement area is inundated. The flood water remains in the land for longer period if Brahmaputra River is also flowing at a higher level.

The rainfed agriculture is badly affected by longer flood period. In this context irrigation should aim to bring the entire net sown area under assured irrigation.

As vast part of the land area is under water logging condition, large or medium surface irrigation scheme is not advisable. Therefore, groundwater based irrigation scheme coupled with small scale surface water irrigation may be adopted.

Future demand of water for agriculture is estimated in the present analysis by projecting the cropping intensity to 200%. As per data provided by Dept. of Agriculture, Lakhimpur, the cultivated area is 133098ha while irrigated area is only 18532ha. The present analysis estimated water requirement in agriculture to increase the cropping intensity to 200% by providing assured irrigation in agricultural field. The whole calculation for projection of cropping intensity to 200% is carried out by use of Cropwat 8.0 software of FAO.

The major crops of Lakhimpur district are Paddy. Autumn paddy, winter paddy and summer paddy are the three main types of paddy are grown in the district. Winter paddy (Sali) is the most important crop in the district occupying 70.6 % followed by summer paddy (Boro) 25.4% and autumn paddy (Ahu) 4% of the total annual paddy area. The common cropping sequence next to paddy, mustard, black gram and vegetables are the main agricultural produce. Among cash crops jute and cotton are the major crops grown in the district. Other cereal crops such as maize, wheat, small millets are having negligible area as compared to rice. Cereals, Coarse cereals, pulses, oil seeds, vegetables, Ginger, Turmeric, Chilies, potato, Banana and Assam Lemon are also produced in the district. The present season wise cropping pattern of Lakhimpur district is shown in Table 5.2.

Table 5.2: Season wise cropping pattern of Lakhimpur district

(Source: Agriculture Contingency Plan for District: Lakhimpur)

SN	Main Crop	Sowing season					
		Kharif		Summer		Rabi	
		Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
1	Paddy	June to July	June to July		-	-	-
2	Rapseed Mustard		-		-	October to November	-
3	Potato		-		-	December	-
4	Ginger		-	March to April	-	-	-
5	Turmeric			March to April			

The Net irrigated area is 18532 ha. The total un irrigated area of the district is 133098 ha. Present minor irrigation schemes are using surface water sources only. Present irrigation from ground water sources is almost nil. Hence, there is ample scope for ground water extraction for irrigation purpose which will bring prosperity to the society and help the district in achieving self-reliance on food grain. To use groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO (Food & Agricultural Organisation). CROPWAT 8.0 for Windows is a computer program for the calculation of crop water demand/requirements and irrigation demand/requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. FAO defined water requirements of various crops as the depth (or amount) of water needed to meet the water loss through evapotranspiration. The crop water need can be calculated using the following formula.

ETcrop = ETo * Kc

Where: ETcrop = Crop water need (mm/unit time)

ETo = Reference crop evapotranspiration (mm/unit time) [Influence of climate]

Kc = Crop factor [Influence of crop type and growth stage]

5.5 CALCULATION OF REFERENCE EVAPOTRANSPIRATION (ETo): The FAO Penman-Monteith method is the recommended method for determining reference crop evapotranspiration (ETo). In this method ETo of reference crop is calculated by utilizing climatic data of Tezpur, FAO's climatic station using ClimWat 2.0 software (Table 5.3).

Table 5.3: Month wise evapo-transpiration determined by Cropwat 8.0 from climatic data

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	$MJ/m^2/day$	mm/day
January	11.4	23.7	100	26	8.7	15.4	2.04
February	13.7	25.4	81	61	8.1	16.9	2.58

March	17.1	29	65	95	8.7	20.1	3.86
April	20.2	30.3	67	130	8.3	21.5	4.65
May	22.5	30.3	88	95	6.9	20.2	4.11
June	24.7	31.6	93	61	5.6	18.5	3.92
July	25.3	32.1	90	26	5.3	18	3.92
August	25.4	32.2	91	26	5.7	17.9	3.89
September	24.7	31.7	96	26	6.1	17.1	3.66
October	21.8	30.2	94	26	7.7	17.1	3.36
November	16.5	27.6	100	35	8.8	15.9	2.65
December	12.4	24.7	100	35	9.1	15.1	2.08
Average	19.6	29.1	89	53	7.4	17.8	3.39

Irrigation requirement: Etc - Effective Rainfall

Effective rainfall is defined as the portion of the rainfall which is available to the root zone. Run-off and deep percolation of rainfall are not effective for crop. Effective rain fall is calculated by empirical method provided by USDA soil conservation service where

Effective rainfall= (rainfall*(125-0.2*3*rainfall))/125 for P<=250/3mm

P_{eff}=125/3+0.1P for P>250/3mm .

The effective rainfall for different months for Lakhimpur district as calculated by Cropwat 8.0 is shown in Table 5.4:

Table 5.4: Effective rainfall estimated by Crowat 8.0

	Rain	Eff rain
	mm	mm
January	22.5	21.7
February	43.4	40.4
March	98.7	83.1
April	193.8	133.7
May	362.5	161.3
June	789.7	204
July	948.1	219.8
August	752.8	200.3
September	562.1	181.2
October	150.9	114.5
November	21.4	20.7
December	8.1	8
Total	3954	1388.5

5.6 Cropping Plan: During Kharif season, paddy is cultivated in 133098 ha land. After Kharif crops were grown major portion of this area remains fallow during Rabi season. The intention of the proposed plan is to bring this fallow land under assured irrigation during Rabi season which will help to increase gross cropped area to 266196 ha and thereby increase cropping intensity up to 200%. This can be achieved by growing potato, mustard and rabi vegetables in rice and maize fallow with the support of irrigation. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in tabular form (Table 5.5)

Table 5.5: Cropping pattern, proposed cropping pattern, intended cropping intensity

Cropping pattern (s)				
Pulse-Rice-Potato	Present Cultivated area	Area to be cultivated	Area to be cultivated (ha)	Irrigation requirement (ha m)
Rice-Wheat-Vegetables	(ha)	(%)		
Rice-Pulses				
Rice-Millet				
Rice-Rapseed Mustard				
	1	2 (= % of 1)	3	4
Rice (main crop)	133098		133098	23148.41
Pulses		10	26619.6	870.73
Potato		5	13309.8	689.98
Maize		5	13309.8	1180.05
Oilseed		10	26619.6	4392.23
Vegetables		10	26619.6	1638.17
Millet		10	26619.6	102.49
		50		
Net cultivated area	133098	266196	133098	
Gross cultivated area (Paddy/+Maize/+Wheat+Pulses+ Millet)	133098		266196	
Total irrigation requirement With 70% irrigation efficiency				32022.06
Gross irrigation water requirement				45745.8
Cropping intensity			200% (Intended)	

Table 5.6: Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Rice	0	0	0	0	48.4	95.8	0	0	0	0	0	0
2. Rice	0	0	0	0	0	0	98	0	0	0	14.2	0
3. Rice	0	0	0	0	0	0	146.9	0	0	0.8	31	0
4. Rice	0	0	0	0	0	0	146.8	0	0	1.3	48.3	3.6
5. Rice	0	0	0	0	0	0	48.9	98	0	1.3	50.4	17.3
6. Pulses	0	0	0	0	0	0	0	1.2	0	0.5	27.6	0
7. Pulses	0.5	0	0	0	0	0	0	0	1.2	0	48.5	40.1
8. MAIZE (Grain)	37.8	33.6	1.7	0	0	0	0	0	0	0	3.6	13.4
9. Mustard	30.1	22.4	5.9	0	0	0	0	0	0	0	22.8	35.4
10. Mustard	30.1	22.4	5.9	0	0	0	0	0	0	0	15.5	32.8
11. Small Vegetables	35	14.5	0	0	0	0	0	0	0	0	25.1	33.7
12. Small Vegetables	33.8	24	0	0	0	0	0	0	0	0	6.8	27.6
13. Small Vegetables	0	7.2	0.3	0	0	0	0	0	0	0	0	0
14. MILLET	0.3	0.9	5.6	0	0	0	0	0	0	0	0	0
15. MILLET	0	0	0.9	0	0	0	0	0	0	0	0	0
16. Potato	23	33.9	18.7	0	0	0	0	0	0	0	0	10.8
Net scheme irr.req.												
in mm/day	0.3	0.3	0.1	0	0.2	0.3	1.3	0.5	0	0	0.7	0.4
in mm/month	9.2	7.6	1.9	0	4.8	9.6	39.2	14.8	0	0.4	21.4	11.6
in l/s/h	0.03	0.03	0.01	0	0.02	0.04	0.15	0.06	0	0	0.08	0.04
Irrigated area	36	38	37	0	10	10	40	20	2	35	73	56
(% of total area)												
Irr.req. for actual area (l/s/h)	0.1	0.08	0.02	0	0.18	0.37	0.37	0.28	0	0	0.11	0.08

Table 5.7: Actual monthly water requirement for different crops in Lakhimpur district, Assam

Actual monthly water requirement for different crops in mid low land area of Lakhimpur district, Assam															
Crop	Net sown area (Ha)	Area (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total IWR (Ham)
1. Rice		10	0	0	0	0	1288.39	2550.16	0	0	0	0	0	0	3838.55
2. Rice		10	0	0	0	0	0	0	2608.72	0	0	0	378.00	0	2986.72
3. Rice		5	0	0	0	0	0	0	1955.21	0	0	10.65	412.60	0	2378.46
4. Rice		10	0	0	0	0	0	0	3907.76	0	0	34.61	1285.72	95.83	5323.92
5. Rice		15	0	0	0	0	0	0	1952.55	3913.08	0	51.91	2012.44	690.78	8620.76
6. Pulses		5	0	0	0	0	0	0	0	15.972	0	6.65	367.35	0	389.98
7. Pulses	133098	2	2.66	0	0	0	0	0	0	0	6.39	0	258.21	213.49	480.75
8. MAIZE (Grain)		5	503.11	447.21	22.63	0	0	0	0	0	0	0	28.749	178.35	1180.05
9. Mustard		5	400.63	298.14	78.53	0	0	0	0	0	0	0	303.46	471.17	1551.92
10. Mustard		10	801.25	596.28	157.06	0	0	0	0	0	0	0	412.60	873.12	2840.31
11. Small Vegetables		2	186.34	77.20	0	0	0	0	0	0	0	0	133.63	179.42	576.58
12. Small Vegetables		4	359.90	255.55	0	0	0	0	0	0	0	0	72.405	293.88	981.73
13. Small Vegetables		4	0	76.66	3.194	0	0	0	0	0	0	0	0	0	79.86
14. MILLET		5	3.99	11.98	74.53	0	0	0	0	0	0	0	0	0	90.51
15. MILLET		5	0	0	11.98	0	0	0	0	0	0	0	0	0	11.98
16. Potato		3	183.68	270.72	149.33	0	0	0	0	0	0	0	0	86.2475	689.98
Total irrigation requirement With 70% irrigation efficiency		100	2441.55	2033.74	497.25	0	1288.39	2550.16	10424.24	3929.05	6.39	103.81	5665.18	3082.28	32022.06
Gross irr. Requirement (HAM)			**3487.93**	**2905.34**	**710.36**	**0**	**1840.56**	**3643.08**	**14891.76**	**5612.93**	**9.13**	**148.31**	**8093.12**	**4403.26**	**45745.78**

Annexure 1: List of Arsenic affected villages, Lakhimpur district, Assam (PHED) North Lakhimpur Division, PHED (Mitigation activities taken against Arsenic affected Habitations), July,2014

S N	Name of Habitation	Name of Village	Name of GP	Type of Sources installed prior to detection of Arsenic		Quantum of Arsenic found in source in ppb	Type of Sources installed for mitigation purpose		Quantum of Arsenic found in source in ppb by AAP	Functionality status of Source
				Type	No		Type	No		
1	Adibasi Chuk	No2 Dakhin Rupahi	Chauldhowa	SHP	1	72.2	RW		1.00	Functional
								2	1.00	Functional
2	Ahot Guri	No1 Karkani	Bhimpara	TP	1	193.5	RW		1.00	Functional
								2	1.00	Functional
3	Bhereki Chuk	Monipara	Thowthani	TP	1	81	RW	1	1.00	Functional
4	Bhimpara Chapori	Bhimpara Chapori	Bhimpara	TP	1	243	RW		2.00	Functional
									0.00	Functional
									2.00	Functional
								4	1.00	Functional
5	Bihdia	Bihdia	Boginadi	TP	1	140.2	RW		12.00	Functional
								2	11.00	Functional
6	Borkhelia	Bihdia	Boginadi	TP	1	187	RW		2.00	Functional
								2	1.00	Functional
7	Cheijan Kachari	Cheijan Kachari	Kadam	HTW	1	583.1	RW	1	10.00	Functional
8	Dakhin Hazong Chuk	No 5 Katori Chapori	Chauldhowa	SHP	1	211	RW		13.00	Functional
								2	11.00	Functional
9	Dakhin Kulabali	Dakhin Kulabali	Thowthani	TP	1	186.4	RW		1.00	Functional
									14.00	Functional
								3	0.00	Functional
10	Gagaldubi No 1	Gagaldubi No 1	Boginadi	TP	1	93	RW		2.00	Functional
								2	1.00	Functional
11	Garh Chuk	Pratapgarh	Thowthani	TP	1	285.7	RW		13.00	Functional
								2	0.00	Functional
12	Gergeria	No 2 Boginadi	Boginadi	SHP	1	142	RW		0.00	Functional
								2	3.00	Functional
13	Garh Chuk	Na Gaon Pathar	Na Kadam	TP	1	285.7	RW	2	20.00	Functional
14	Golukpur	Tenghakhat	Bhimpara	SHP	1	168.6	RW	1	10.00	Functional
15	Hatimora Chapori NC	Hatimora Chapori NC	Bhimpara	SHP	1	216.8	RW	2	10.00	Functional
16	Hindu gaon	Hindu gaon	Thowthani	SHP	1	187.7	RW		10.00	Functional
								2	20.00	Functional

S N	Name of Habitation	Name of Village	Name of GP	Type of Sources installed prior to detection of Arsenic		Quantum of Arsenic found in source in ppb	Type of Sources installed for mitigation purpose		Quantum of Arsenic found in source in ppb by AAP	Functionality status of Source
				Type	No		Type	No		
17	Kadam Gohai Gaon	Laimekuri	Kadam	SHP	1	554.6	RW	2	1.00	Functional
18	Kakoi Gumnodi	Gumnodi	Thowthani	TP	1	181	RW	1	10.00	Functional
19	Kalipam	2 No Ghagor Mukh	Bhimpara	TP	1	139.1	RW	2	13.00	Functional
									14.00	Functional
20	KataotiChapori No 2	Kataoti Chapori No 2	Chauldhowa	TP	1	246.3	RW	2	12.00	Functional
									10.00	Functional
21	Kathalguri (Milanpur)	Kathalguri	Chauldhowa	TP	1	122.9	RW	2	1.00	Functional
						52.5	RW		3.00	Functional
22	Kuchiamari	Bodhakora Kuchiamari	Na Kadam	SHP	1	454.1	RW	2	21.00	Functional
23	Kulabali Chutia Chuk	Dakhin Kulabali	Thowthani	SHP	1	139.5	RW	1	2.00	Functional
24	Kulabali Hindu	Dakhin Kulabali	Thowthani	TP	1	427.2	RW	2	21.00	Functional
									1.00	Functional
25	Lamu Azarguri	Tipukial	Na Kadam	SHP	1	156	RW	1	10.00	Functional
26	Madhya Joradhara	Thowthani	Thowthani	SHP	1	108.9	RW	1	21.00	Functional
27	Moridirgha	Moridirgha	Thowthani	SHP	1	182	RW	1	31.00	Functional
28	Namoni Dorge (Ajarguri)	Dorge gaon	Bhimpara	TP	1	306.4	RW	1	1.00	Functional
29	No1 Boginadi	No1 Boginadi	Boginadi	TP	1	205.1	RW	3	12.00	Functional
									12.00	Functional
									13.00	Functional
30	No1 Lalpani	No1 Lalpani	Thowthani	TP	1	115	RW	2	12.00	Functional
									13.00	Functional
31	No 2 Puthimari	No 2 Puthimari	Kadam	SHP	1	138.5	RW	1	12.00	Functional
32	No2 Lalpani	No2 Lalpani	Thowthani	HTW	1	53.2	RW	1	0.00	Functional
33	No 4 Branchpur Boro	No 5 Kataoti Chapori	Chauldhowa	HTW	1	52.8	RW	2	10.00	Functional
									12.00	Functional
34	No 5 Kataoti Chapori	No 5 Kataoti Chapori	Chauldhowa	HTW	1	52.5	RW	2	13.00	Functional
									1.00	Functional
35	Singari	Bhimpara Chapori	Bhimpara	SHP	1	245	RW	2	10.00	Functional
									1.00	Functional

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				Type	No		Type	No		
35	Singari	Bhimpara Chapori	Bhimpara	SHP	1	245	RW		10.00	Functional
								2	1.00	Functional
36	Tengakhat	Tengakhat	Bhimpara	SHP	1	78.5	RW		12.00	Functional
								2	13.00	Functional
37	Tini Gharaia	No 1 Gereki	Bhimpara	TP	1	137.7	RW	3	12.00	Functional
							RW		12.00	Functional
							RW		13.00	Functional
38	Tipukial	Tipukial	Na Kadam	HTW	1	172.9	RW	1	2.00	Functional
39	Urium Guri	Urium Guri	Chauldhowa	SHP	1	155.3	RW		2.00	Functional
								2	1.00	Functional
40	Urium Guri jorhatia	Urium Guri jorhatia	Chauldhowa	SHP	1	132.2	RW		10.00	Functional
									1.00	Functional
								3	2.00	Functional
41	Uttar Kulabali	Uttar Kulabali	Boginadi	HTW	1	240	RW	4	10.00	Functional
									10.00	Functional
									12.00	Functional
									13.00	Functional
42	Bhereki Chuk	Moinapara	Thowthani	HTW	1	54.7		1	12.00	Functional
43	Badati Alimur	Badati Alimur	Badati Jamuguri	HTW	1	72.2	RW		12.00	Functional
									1.00	Functional
								3	10.00	Functional
44	Dakaya Chuburi	Bihpuria gaon	Bihpuria	HTW	1	54.1	RW		1.00	Functional
45	Kachikata Bagan Pachim Chuburi	Kachikata Bagan Grant	Bihpuria	SHP	1	104.9	RW		10.00	Functional
								2	1.00	Functional
46	Kachikata Bagan Pub Chuburi	Kachikata Bagan Grant	Bihpuria	TP	1	121.7	RW	2	10 12	Functional
47	Kachikata Bagan	Kachikata Bagan Grant	Bihpuria	SHP	1	108.4	RW	2	12.00	Functional
48	Kachikata Bagan Miri Deuri	Kachikata Bagan Grant	Bihpuria	TP	1	61.4 & 105.80	RW		20.00	Functional
									1.00	Functional
								3	21.00	Functional

S N	Name of Habitation	Name of Village	Name of GP	Type of Sources installed prior to detection of Arsenic		Quantum of Arsenic found in source in ppb	Type of Sources installed for mitigation purpose		Quantum of Arsenic found in source in ppb by AAP	Functionality status of Source
				Type	No		Type	No		
49	Kalwani Bottom Chuk	Kalwani Bottom Chuk	Badati Jamuguri	TP	1	242.5	RW		13.00	Functional
								2	12.00	Functional
50	Kalwan iNC	Kalwan iNC	Badati Jamuguri	HTW	1	152.4	RW		12.00	Functional
								2	13.00	Functional
51	Pabhamukh Bhekeli	Pabhamukh Bhekeli	Badati Jamuguri	TP	1	62	RW		12.00	Functional
								2	12.00	Functional
52	Ligiramukh Chanong	Ligiramukh	Luhit Khabalu	SHP	1	236.3	RW		1.00	Functional
								2	10.00	Functional
53	Kambong	Kambong	Luhit Khabalu	TP	1	476.4	RW		1.00	Functional
									12.00	Functional
									12.00	Functional
54	Dambukial	Dagharia Chelek	Luhit Khabalu	SHP	1	66.8	RW	1	12.00	Functional

Annexure 2: Mitigation activities taken against Arsenic affected Habitations, Ghilamara Division, Lakhimpur district, Assam (PHED) North Lakhimpur Division, PHED (Mitigation activities taken against Arsenic affected Habitations), July,2014

SN	Name of Habitation	Name of Village	Name of GP	Type of Sources installed prior to detection of Arsenic		Quantum of Arsenic found in source in ppb	Type of Sources installed for mitigation purpose		Quantum of Arsenic found in source in ppb by AAP	Functionality status of Source
				Type	No		Type	No		
1	Ujani Bebejia	Bebejia Gaon	Mornoi	TP	1	52.5	RW	2	Sample collected & sent to Gogamukh SDLL	Functional
2	Bagariguri Pathar	Bagariguri Pathar	Borkhamukh	HTW	1	146.3	RW	1		
3	Bahguri	Bahguri	Borkhamukh	HTW	1	150.9	RW	2		
				HTW	1	269.1				
4	Doley Chuk	No 2 Borkhamukh NC	Borkhamukh	HTW	1	107.6	RW	2		
5	Maghua Chuk	Maghua Chuk NC	Borkhamukh	HTW	1	250.3	RW	2		
6	No 1 Borkhamukh NC	No 1 Borkhamukh NC	Borkhamukh	HTW	1	87.3	RW	2		
7	No 2 Borkhamukh NC	No 2 Borkhamukh NC	Borkhamukh	HTW	1	74.2	RW	2		
8	Patir Chuk	Obhata Champora NC	Borkhamukh	HTW	1	110.7	RW	3		
9	Taid Chuk	No 1 Borkhamukh NC	Borkhamukh	HTW	1	61.5	RW	4		
10	Towa Chuk	No 1 Borkhamukh NC	Borkhamukh	HTW	1	103.1	RW	3		
11	Kathar Bari	Dulia Pera Bhari	Pachim Dhakuakhana	HTW	1	58	RW	1		

CHAPTER 6.0

Management Strategy

The aquifer system in the study area is a mono or single aquifer type. From the panel diagram it is clear that bouldery or gravelly bed is present all along the foothills from south west to north east direction of the study area while the aquifer material become finer towards the flood plain. The variation of lithology and geomorphic set up of the study area has also influenced the ground water regime. In the piedmont slope pre-monsoon water level is deeper and difference of pre and post monsoon water level is high and this area. In the piedmont zone water level fluctuation is less compared to piedmont slope while flood plain area is characterized by water logged condition.

Based on the hydrogeomorphic set up in mind the area can broadly be classified into three zones. The characteristic feature of these zones are enumerated in the following table (Table 6.1)

Table6.1: Division of study area based on geomorphology and its characteristic features

Zone	Geomorphology	Lithology	Chemical Quality	WL condition	Population density
Zone-I	Alluvial plain and flood plain	Sand, silt dominated with occasional gravel	High Fe and also arsenic	Shallow water level/ water logged	High
Zone-II	Piedmont	Gravel, pebbles, boulder with little sand and clay	Arsenic nil or within acceptable limit	Post monsoon water level is generally 3 to 4 mbgl	Sparse to medium
Zone-III	Piedmont slope and highly dissected structural hills	Gravel, pebbles, boulder with little sand and clay	As not reported and Fe is within acceptable limit	Deeper pre-monsoon WL, WL fluctuation is high	Sparse

Sustainable Management Plan of Resource: It is observed that there is a huge gap between irrigation water available and irrigation demand. The gap can be minimized by lowering the post-monsoon water level from present nearly 2mbgl to 4mbgl.

Based on available groundwater resource and subsurface condition, the approximate numbers of tube wells that can be constructed in the area is worked out.

Groundwater draft is calculated for well discharge of $40m^3/hr$. If the well is allowed to run 8 hrs a day for 120 days of a year then a tube well having discharge will create a draft of 0384 MCM or 3.84 ham. To meet irrigation demand of 45745.78 ham, 11913 numbers of shallow TW can be constructed. About 33275 number of shallow tube wells can be constructed, considering 200m spacing between two shallow tube well in the unirrigated area of 1330.98 sq km area

Drilling: In the northern part of the district percussion rig is useful as bouldery formation is encountered in the area. Combination rig is more useful. Private party use odex drilling technology in this area. Although the drilling rate is fast, non-use of slotted pipe reduces the life of the well and also the yield. Direct Rotary Rig is useful for drilling in the rest Flood plain area down to depth of 200 m. A tube well tapping 15 to 30m granular zone can expected to yield 45 to 80m3 /hr

Shallow Tube wells can be designed within a depth of 50m. Tube wells can be constructed by using 8// dia. Housing pipe down to 30 m. A tube well tapping 12m granular zone can expected to yield 20 to 40m3 /hr.

The pump test data of CGWB has indicated that the drawdown of the tube wells is 10 to 16m in the area where bouldery formation is dominant and in the flood plain area 2 to 5m.

Arsenic pollution: PHED Lakhimpur Division has recorded occurrence of arsenic in the groundwater. However, it is observed that arsenic is detected in shallow hand pump, dug well or tara pump. Therefore, arsenic detection is restricted most probably to 30m depth. Therefore tube wells can be constructed down to a depth of 50m tapping lower 20m granular zones. From the 2D and 3D disposition of aquifer diagram it is observed that clay or sandy clay layers are present in many areas. These confining layers can be utilize to separate the arsenic occurance zone by adopting proper well construction technique.

Deep tube well in the flood plain and arsenic affected areas may be constructed by proper cement sealing and clay filling as shown in Fig.

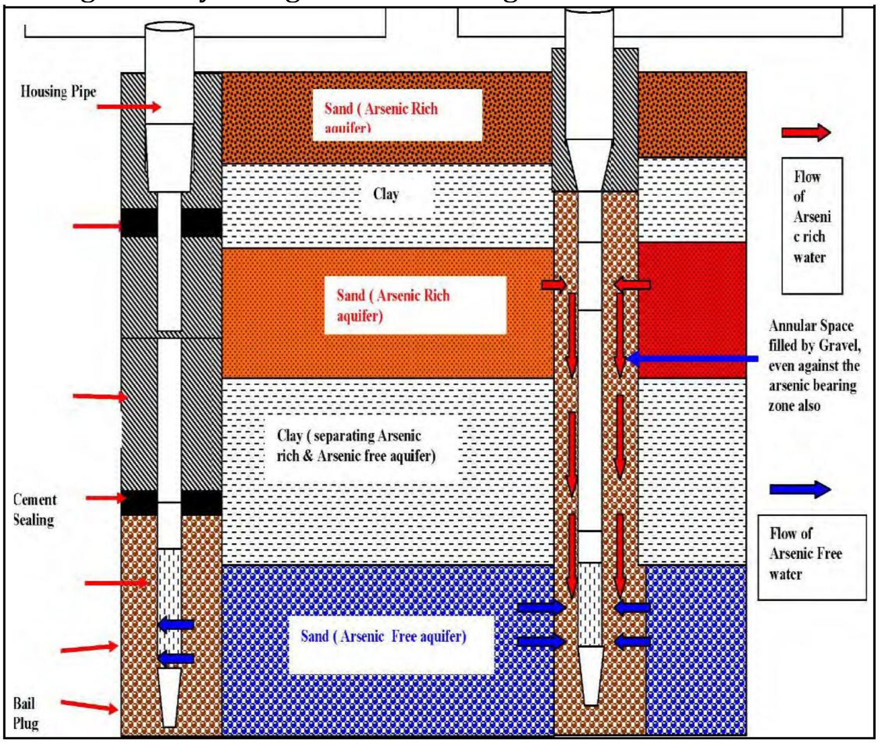

Fig.6.1: Tube-well design of a deep tube well tapping safe deeper aquifer
(Source: Concept note on geogenic contamination of groundwater in India)

Aquifer wise availability of unsaturated zone: The post-monsoon water level of Lakhimpur district ranges from 0.2 to 4.49mbgl. Since permanent water logging is one of the major issues in the district and post-monsoon water level generally varies within 4.0mbgl, unsaturated zone below 3mbgl is not estimated,

Demand side management: Demand side management implies sustainable management of water. In irrigation and in drinking water supply also sufficient quantity of water loss occurs.

The general slope of the area is towards southeast. The slope is greater near piedmont zone than in the flood plain. Therefore water logging condition is observed in the flood plain, alluvial plain or in the gently sloping piedmont zone. Therefore water use efficiency should be high in all sectors particularly in the irrigation sector. Loss in irrigation water will increase water logged area.

Irrigation efficiency can be increased by

(i) reducing convenience loss
(ii) improving water application efficiency

Following demand side interventions will increase water use efficiency

1) Use of water efficient irrigation method: Drip and sprinkler irrigation methods are very useful in saving water. Both of them save conveyance losses and improve water application efficiency by applying water near the root-zone of the plant. Drip systems convey water in small quantities through drippers/micro-tubes while sprinklers are pressurized systems where a fountain or spray of water is released by the sprinkler connected by pipes, resulting in foliar irrigation. Drip irrigation can increase crop yield per hectare and also saves water up to 70% than conventional irrigation.
2) Water loss through supply canals can be minimized by proper lining in the canals.
3) Adopting water saving rice irrigation: In this method instead of submerging the paddy field for longer duration, the rice field have to provide water through irrigation only after a certain number of days when the ponded water disappears. This technology is known as alternate wetting and drying (AWD) irrigation. With the optimal management, this technology reduces the amount of water required by about 25% without reduction in yields.

   International Rice Research Institute (IRRI) has developed a simple tool to help farmers make decisions on when to irrigate. They found that when field water level recedes to 15 cm below the soil surface, soil water tension in the root zone is always <10 kPa, ensuring good yield. Thus a practical way to implement safe AWD is to monitor the depth of ponded water using a field water tube/ pipe This tube can be made of plastic pipe or bamboo 30 cm long and 15 cm or more in diameter and having perforations on all sides (Fig. 6.2). After transplanting, farmers would keep the field submerged for about 2 weeks to suppress weed growth. The tube is then inserted into the soil by leaving 10 cm above the soil surface. Soil inside the tube is then taken out.

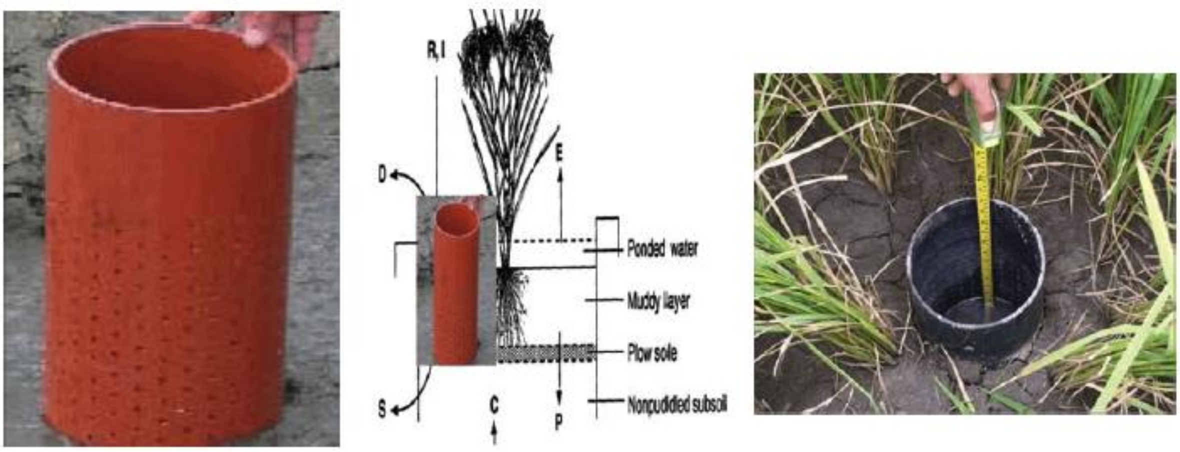

Fig. 6.2: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface (Kulkarni, 2011)

4) Reduce losses of water during leveling: As per Food Agriculture Organization, 200mm of water per hectre is required to level the rice field by traditional method. However, use of laser land leveler help in fine leveling of rice field by eliminating unnecessary depression and elevated contour. It saves 40 to 50% water. A uniformly leveled field allows uniform spreading of irrigated water. It is reported that in Punjab 100% use of laser land leveler in the existing cropping pattern (rice-wheat) can prevent 19cm groundwater draft in entire state (Aggarwal, et. al., 2010)

Approximate Water saving through use of Laser Land Leveler in the rice cultivated area of the district

District	**Present Paddy cultivated area**	**40% reduction of water for land leveling by the use laser land leveler**	**Approximate saving of water ham**
Lakhimpur	133098		532.39
Total water saving			532.39

Stress aspect future demand: Numerical modelling and aquifer simulation study could not be done due to paucity of various data, it was not possible to test a model under different stress conditions.

However, stress aspects of aquifer are analyized for different situations.

Stress on aquifer due to drinking water supply: The population of the study area has been projected based on 2011 census data up to 2025. Based on this projected population drinking water demand of the area is calculated.

There will surplus of supply in domestic and industrial demand considering groundwater 83% dependency on groundwater

Irrigation:

The additional withdrawal of water may not adversely affect the ground water regime of the area as major portion of the area is under shallow water table condition. The piedmont area in all the blocks can be recharged as mentioned earlier.

Following recommendations are suggested

1) Water distribution mechanism should minimize water loss by using lining distribution canals. Locally available materials are to be preferred as these materials are cheap and eco-friendly.
2) Conservation of rain water in the up dip of cultivated field. During rabi season the conserved water can be drained to paddy field through gravity.