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जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

AQUIFER MAPPING REPORT

Parts of Lakhimpur District, Assam

उत्तरी पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

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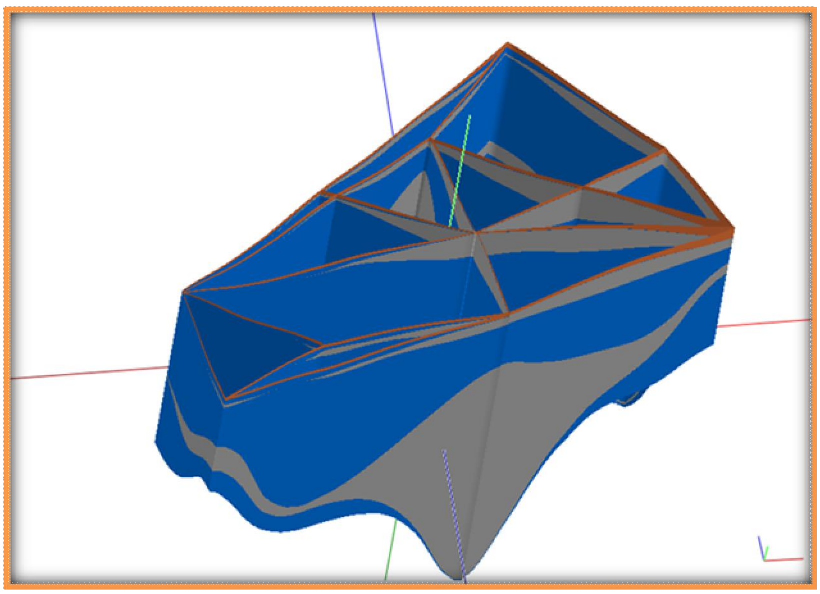
Govt. of India
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation

AQUIFER MAPPING IN PARTS OF LAKHIMPUR DISTRICT OF ASSAM
(AAP 2013-14)



State Unit Office
Naharlagun
November 2015

AQUIFER MAPPING IN PART OF LAKHIMPUR OF ASSAM
AAP 2013-14

CONTENTS

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 are hazardous to the health of the common people. 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-6.5 using Projection category longitude/latitude (Indian for Pakistan, India, Bangladesh, Nepal projection). 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 I/3, 83I/6 and 83 I/10 bounded by 27˚ 15ʹ and 27˚ 45ʹNorth Latitudes and 94˚ and 94˚ 45ʹ East longitudes covering an area of 1000 sq. km (Fig.1).

Table 1.1: Administrative set up of the study area

State	District	Block	Circle	Panchayat
Assam	Lakhimpur	Nowboicha	NA	1
		Lakhimpur	NA	6
		Boginadi	NA	11

NA: Data not available

Table 1.2: Population of the study area as per 2011 census

District	Block	No. of villages	Population	Geographical area (Hectre)
Lakhimpur Assam	Nowboicha	6	5841	895.14
	Lakhimpur	37	40300	6347.49
	Boginadi	109	77804	16760.36

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

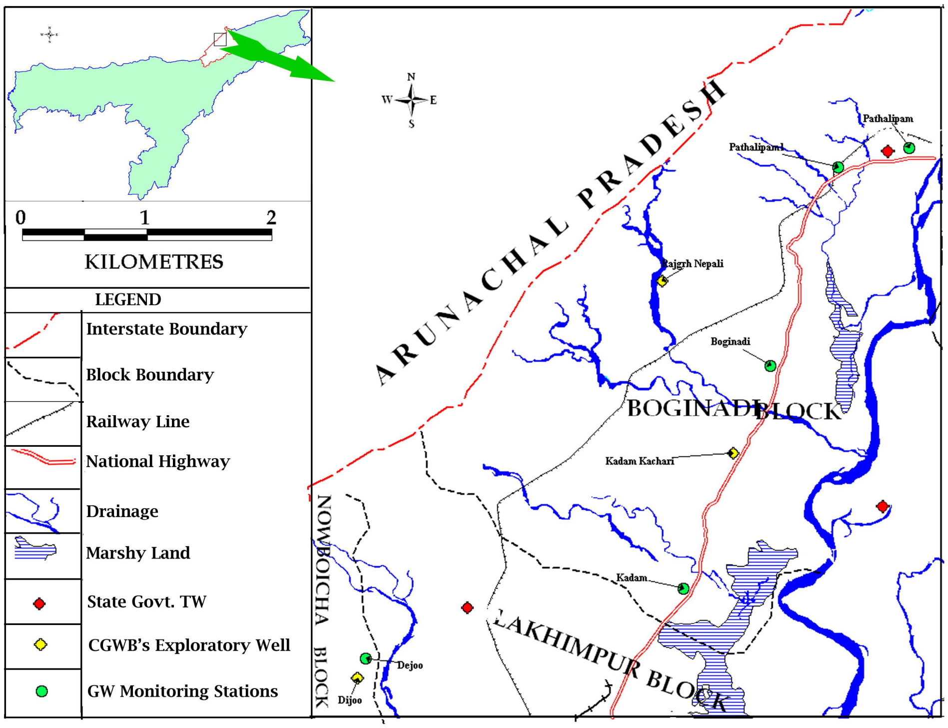


Fig.1.1: Index Map of the study area

1.3 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 as well as State Groundwater Departments. All data were plotted in base map on GIS Platform (MapInfo-6.5 using Projection category longitude/latitude (Indian for Pakistan, India, Bangladesh, Nepal projection).

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		7	3	Nil	10	Maximum depth of well is 125mbgl only.
2	Geophysical data		Nil	17	10	17	
3	Groundwater level data	Dug well	10	10	15	25	
		Piezometer Aquifer-I	Nil	2	Nil	2	
4	Groundwater quality data	Dugwell-Aquifer-I	10	8	7	15	
		Piezometer Aquifer-I	Nil	2	Nil	2	
5	Specific Yield		Nil	7	Nil	7	
6	Soil Infiltration Test		Nil	12	1	12	

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

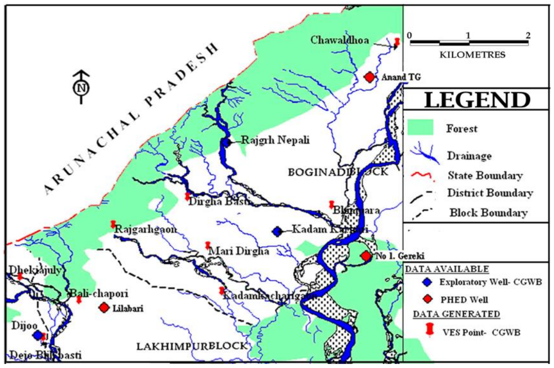


Fig. 1.2a: Available data and data generation of exploration and VES in the study area

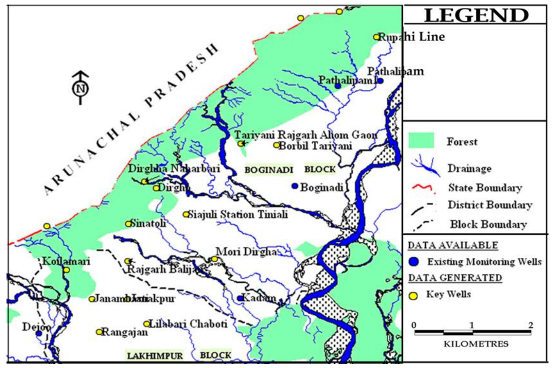


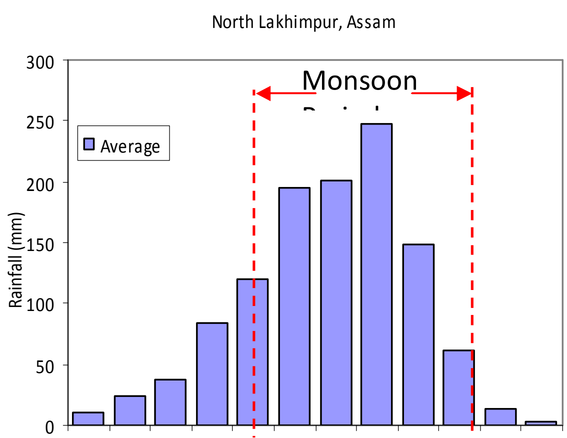
Fig. 1.2b: Available data and data generation of ground water level and quality monitoring

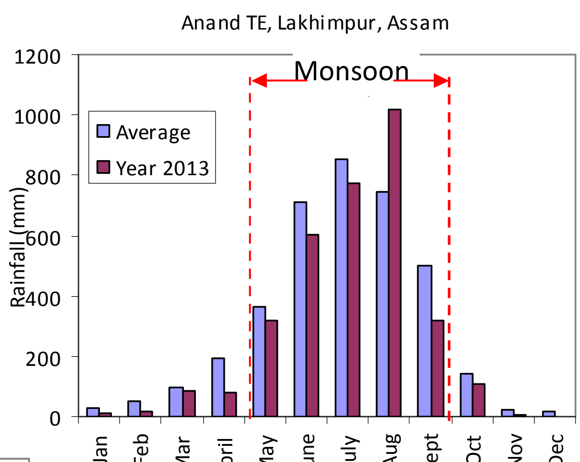
1.4 Rainfall-spatial, temporal and secular distribution:

The area close to the foothills receives more rainfall than the area farther away from foothills. The average annual rainfall recorded in Anand Tea Estate, Lakhimpur District, Assam is 3733.93mm whereas the rain gauge station located in North Lakimpur, Assam which is away from foothill area recorded average annual rainfall of 1536mm. Average monthly rainfall and yearly rainfall variations are graphically illustrated in Fig. 2.1. Based on IMD data set from 2004 to 2013 the average annual rainfall of the district found out to be 2837.97mm.

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 and monthly rainfall during 2013 and also yearly rainfall distribution are illustrated in Fig.





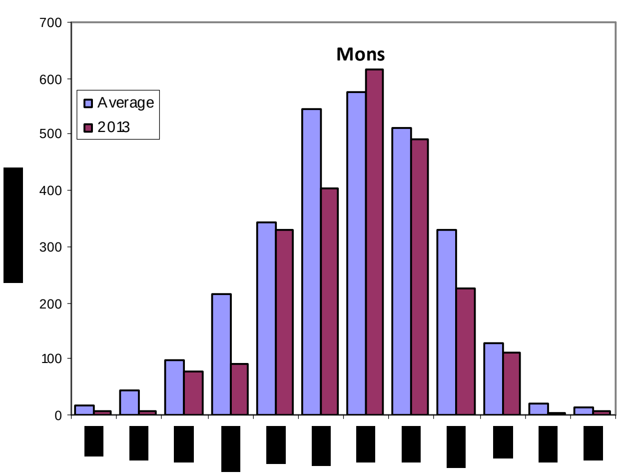
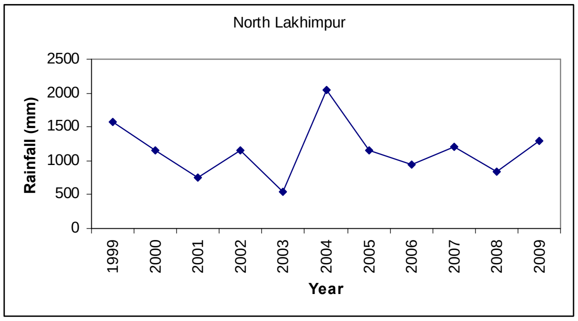
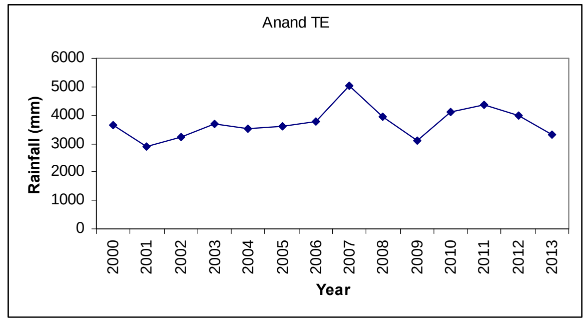


Fig.1.3: Average monthly rainfall (a) North Lakhimpur, (b) Anand Tea Garden, Pathalipam and (C)IMD Station, Lilabari, North Lakhimpur, Assam



(a)



(b)

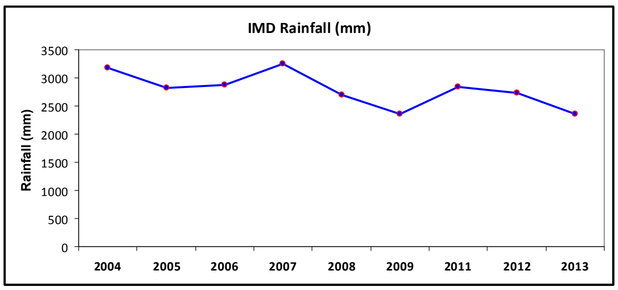


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Fig.1.4: Annual variation of rainfall as recorded in three raingauge stations (a) North Lakhimpur, Agriculture Dept, (b) Anand Tea Garden, Pathalipam and (c) IMD station, Lilabari, North Lakhimpur, Assam

1.5 Physiographic set up: Phisiographically the area can broadly be divided into three parts, i.e., the hilly tract, the piedmont and flood plain. The hilly tracts are characterized by low to moderate relief hills and corrugated landform and comprise of Siwalik sediments of lesser Himalayas. The slope of the area drops from northeast to southwest.

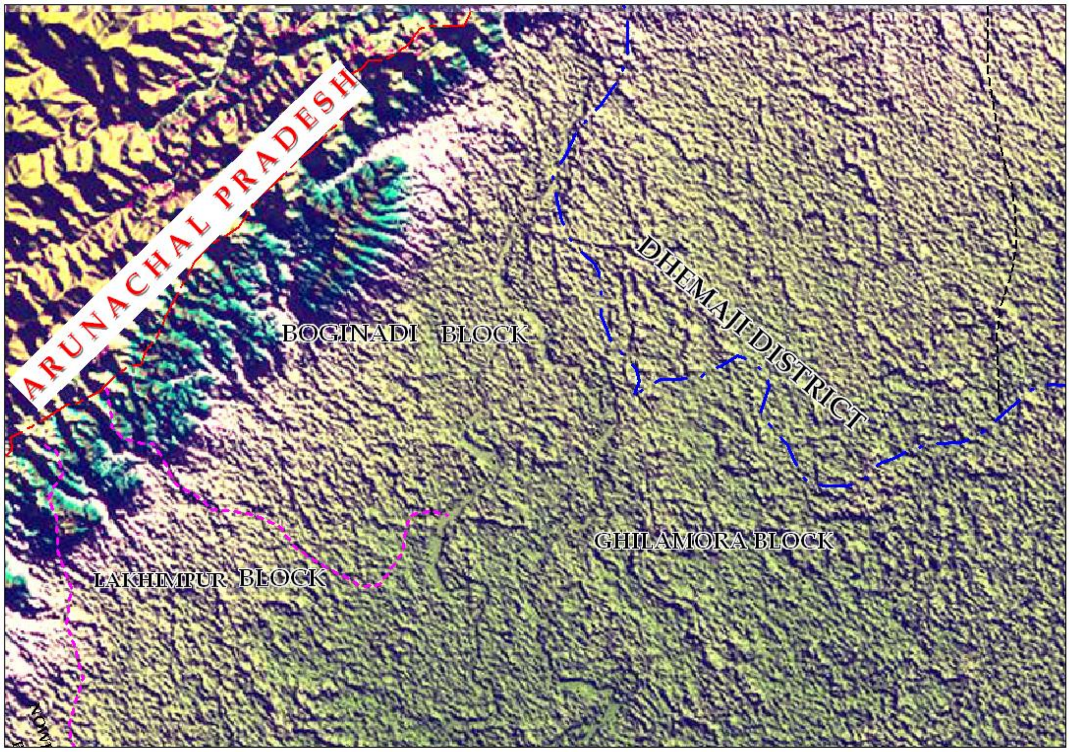

Fig.1.5: Digital Elevation Model of the study area based on 90m resolution srtm data.

1.6 Geomorphology: Geomorphologically the area can be classified mainly into four divisions: structural hills, piedmont zone, alluvial plain 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. 1.6).

1.7 **Land use Pattern:** Land use pattern of the villages in different blocks are given in the following table (Table: 1.4)

Table 1.4: Land use pattern of the study area under Lakhimpur district, Assam (Source:Census 2011)

Block	Area (in Hectares)										
	Total Geographical Area	Forest	Area under Non-Agricultural Uses	Barren & Un-cultivable Land	Permanent Pastures and Other Grazing Land	Land Under Miscellaneous Tree Crops etc.	Culturable Waste Land	Fallows Land other than Current Fallows	Current Fallows	Net Area Sown	Net Cultivale
Boginadi	16760.36	1150.87	1642.33	988.17	127.27	2894	5557.61	631.09	318.31	2116.73	11645.01
Nowboicha	895.14	11.39	213.42	1.83	1.46	0	0	0	667.04	667.04	1335.54
Lakhimpur	6347.49	4	861.25	68	138.58	124	135.22	0	33	4077.52	4508.32

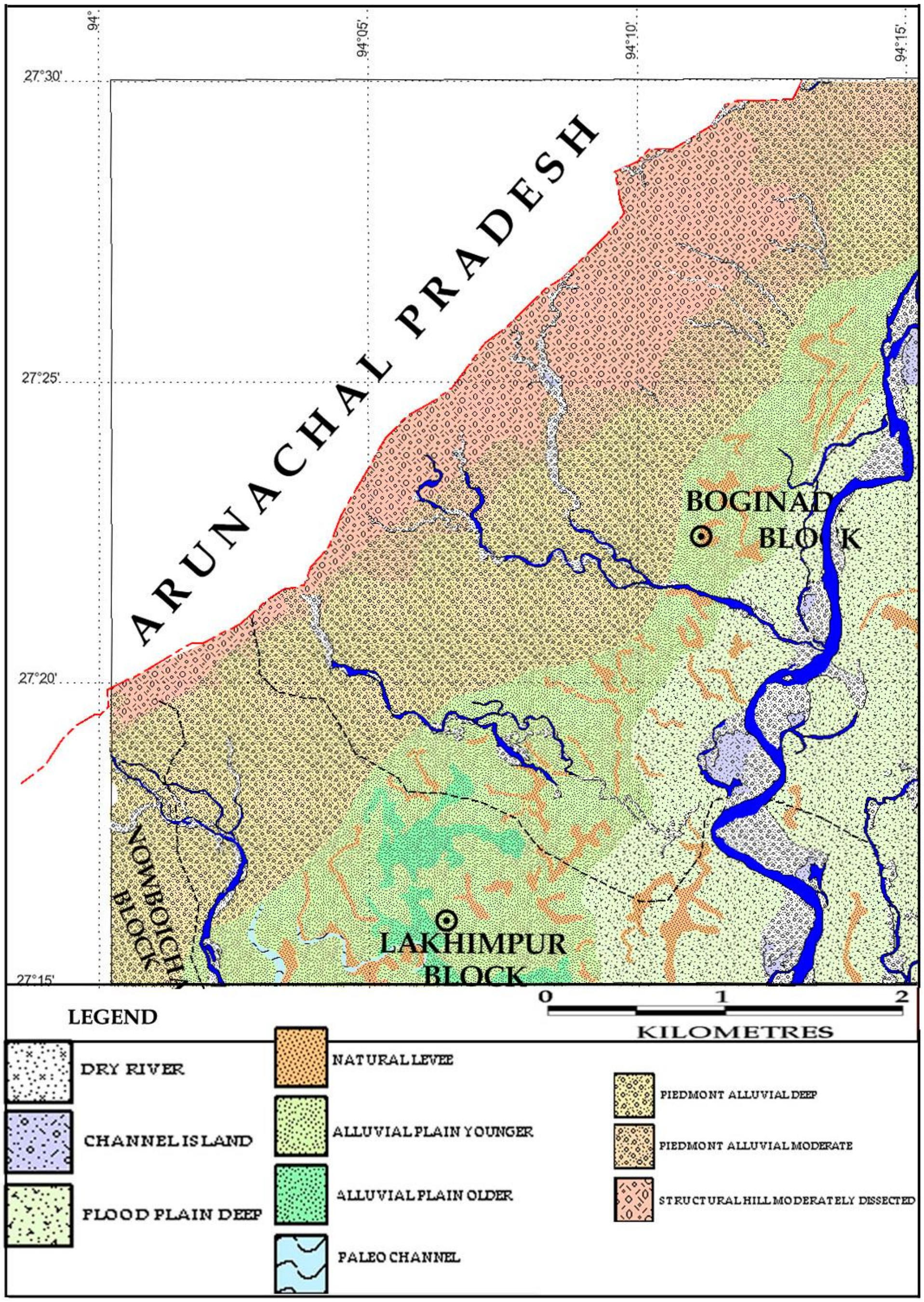

Fig. 1.6: Geomorphological Map of the study area, Lakhimpur District, Assam

1.8 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.

1.9 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 bill, Chumani bil, Chakamara bil, etc. are some of the surface water bodies in the area.

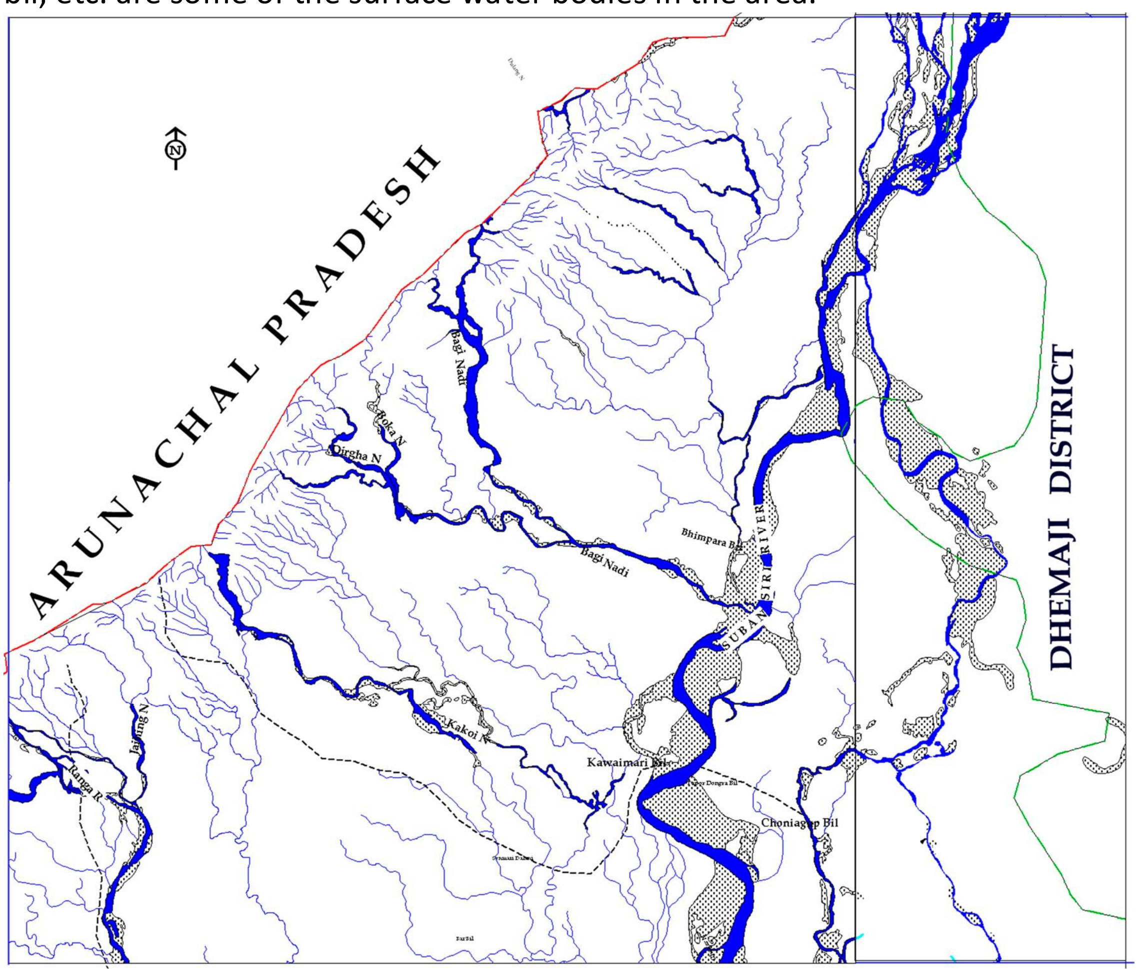

Fig. 1 7: Drainage map of the study area, Lakhimpur district, Assam

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 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.

Overall the drainage network of the area shows an anastomising 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 paleo-channels 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.

1.10 Agriculture

In the study area paddy is the principal crops. The agriculture is rain fed. Majority of the population dependent on cultivation. Paddy is the dominant crop, however, double cropping pattern is not observed in this part mainly due to lack of irrigation facility. There are two big tea gardens in the area.

In the Boginadi block of Lakhimpur district only 50 hectres is irrigated by source and 2hectres of land of No. 2 Bhangabil village is irrigated by surface water. The rest of the cultivable land of the study area does not have any irrigation scheme (Table 1.4).

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 and agricultural data is collected from Census of India website.

CGWB had constructed 3 exploratory wells in this area. 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 2.5. Rainfall data was collected from Agriculture Department, Govt. of Assam, Lakhimpur, Anand Tea Garden, Pathalipam and Indian Meteorological Department. CGWB has 5 groundwater monitoring station in the area and these monitoring stations were regularly monitored (Table 2.1 and 2.2).

2.2 Data Generation

2.2.1 Hydrogeological data: The entire study area is covered by regular monitoring of existing GWMS and another 12 key wells have been established. All these wells are under monitoring after establishment.

Water level data:

Table 2.1: Key wells location details

Name of Village/Site	Latitude	Longitude	Establishment date	RL (ma msl)	Total depth of Pz/Dw (mbgl)	Type (DW/Pz/Spring)	Aquifer group	Measurement point (magl)	Source/ Agency
Dejoo	27.27	94.03	NHS Well	100	3.18	DW	Unconsolidated (1st aquifer)	0.87	CGWB
Janakpur	27.30	94.08	23/05/2013	99	4.3	DW		0.97	CGWB
Janambasti	27.30	94.06	23/05/2013	86	3.16	DW		0.88	CGWB
Lilabari Chaboti	27.28	94.09	22/11/2013	83	3.76	DW		1	CGWB
Tariyani Rajgarh Ahom Gaon	27.40	94.15	24/05/2013	141	5.88	DW		0.73	CGWB
Borbil Tariyani	27.40	94.17	24/05/2013	97	3.01	DW		0.82	CGWB
Siajuli Station Tiniali	27.35	94.12	24/05/2013	114	4.05	DW		1.03	CGWB
Dirghha Naharbari Forest Camp	27.38	94.09	24/05/2013	128	4.44	DW		1.12	CGWB
Dirgha	27.37	94.10	24/05/2013	108	2.46	DW		0.84	CGWB
Mori Dirgha	27.32	94.14	24/05/2013	88	2.49	DW		1.47	CGWB
Sinatoli	27.35	94.08	22/11/2013	96	3.8	DW		1.06	CGWB
Rajgarh Balijan	27.32	94.08	22/11/2013	86	3.95	DW		0.9	CGWB
Boginadi	27.37	94.19	NHNS Well	82	2.98	DW		0.95	CGWB
Kadam	27.30	94.15	NHNS Well	92	3.56	DW		0.75	CGWB
Pathalipam	27.45	94.22	NHNS Well	104	9.01	DW		0.99	CGWB

Pathalipam1	27.44	94.21	NHNS Well	111	6.22	DW		0.96	CGWB
Rupahi Line	27.48	94.24	23/11/2013	102	8.63	DW		0.86	CGWB

Table 2.2: Water level measurement of key wells

Name	Date of measurement (dd/mm/yyyy)	Depth of water level in mbgl	Name	Date of measurement (dd/mm/yyyy)	Depth of water level in mbgl
Dejoo	30/08/2013	0.83	Sinatoli	22/11/2013	1.85
	2/1/2014	1.99		20/1/2014	2.76
	11/3/2014	2.22		10/3/2014	2.94
	8/1/2015	1.88		30/01/2015	2.52
	5/3/2015	2.01		10/3/2015	2.94
	23/08/2015	1.2		19/08/2015	NA
	11/3/2015	1.51		19/11/2015	1.79
Janakpur	23/05/2013	1.56	Rajgarh Balijan	22/11/2013	1.29
	22/11/2013	1.14		20/1/2014	2.83
	11/3/2014	2.32		30/08/2014	0.7
	30/08/2014	0.26		10/11/2014	1.96
	10/11/2014	1.99		30/01/2015	2.93
	30/01/2015			10/3/2015	3.33
	10/3/2015	3.25		19/08/2015	NA
	19/08/2014	-0.07		19/11/2015	2.03
	19/11/2015		Boginadi	27/08/2013	0.66
Koilamari 6No. Line	23/05/2013	5.25		2/11/2013	1.7
	22/11/2013	4.48		9/1/2014	2.48
	21/01/2014	5.73		10/3/2014	2.92
	11/3/2014	6.48		28/8/2014	0.56
	30/08/2014	2.35		1/11/2014	1.52
	10/11/2014	3.89		8/1/2015	2.45
	30/01/2015	5.18		5/3/2015	2.92
	10/3/2015	5.92		20/08/2015	0.31
	19/08/2015	3.68		19/11/2015	1.75
	1/9/2015	4.28	Kadam	6/3/2013	1.96
	1/10/2015	2.94		27/08/2013	0.75
	19/11/2015	4.28		9/11/2013	0.88
Rangajan	23/05/2013	1.18		7/1/2014	1.64
	22/11/2013	2.7		10/3/2014	1.75
	21/01/2014	3.02		22/8/2014	0.36
	11/3/2014	2.1		1/11/2014	1.14
	30/08/2014	2.06		8/1/2015	1.65
	10/11/2014	3.32		7/3/2015	1.88
	30/01/2015	3.36		20/08/2015	0.35
	10/3/2015	2.49		19/11/2015	1.34
	19/08/2015	2.05	Pathalipam	6/3/2013	3.47
	19/11/2015	2.14		30/08/2013	1.93
Janambasti	23/05/2013	1.28		2/11/2013	2.79
	22/11/2013	2.02		7/1/2014	3.2
	21/01/2014	1.92		10/3/2014	3.44
	10/3/2014	2.5		28/8/2014	1.44
	30/08/2014	1.2		1/11/2014	2.51
	10/11/2014	1.99		8/1/2015	3.26
	30/01/2015	2.25		7/3/2015	3.51
	10/3/2015	1.92		20/08/2015	1.27
	19/08/2015	1.09		19/11/2015	2.75
	19/11/2015	2.02	Pathalipam1	6/3/2013	5.5

Name	Date of measurement (dd/mm/yyyy)	Depth of water level in mbgl
Lilabari Chaboti	22/11/2013	0.9
	21/01/2014	2.91
	10/3/2014	3.53
	30/08/2014	0.63
	10/11/2014	1.06
	30/01/2015	2.64
	10/3/2015	2.9
	19/08/2015	0.53
	19/11/2015	0.93
Tariyani Rajgarh Ahom Gaon	23/05/2013	4.88
	23/11/2013	3.52
	22/01/2014	NA
	10/3/2014	5.52
	31/08/2014	0.41
	10/11/2014	3.71
	30/01/2015	4.9
	10/3/2015	5.78
	22/8/15	1.07
	19/11/2015	3.05
	23/05/2013	1.52
Borbil Tariyani	23/11/2013	1.84
	22/01/2014	NA
	10/3/2014	1.83
	31/08/2014	0.32
	10/11/2014	2.62
	30/01/2015	2.12
	10/3/2015	1.92
	22/8/15	0.94
	19/11/2015	1.6
Siajuli Station Tiniali	23/05/2013	2.6
	23/11/2013	2.3
	/1/2014	
	10/3/2014	
	31/08/2014	1.07
	10/11/2014	1.59
	30/01/2015	3.17
	10/3/2015	3.75
	19/08/2015	0.95
	19/11/2015	1.99
Dirghha Naharbari Forest Camp	23/05/2013	1.08
	22/11/2013	2.63
	20/1/2014	3.66
	10/3/2014	3.72
	31/08/2014	NA
	10/11/2014	
	30/01/2015	2.89
	10/3/2015	3.66
	19/08/2015	NA
	19/11/2015	

Name	Date of measurement (dd/mm/yyyy)	Depth of water level in mbgl
Pathalipam1	27/08/2013	3.29
	2/11/2013	3.95
	7/1/2014	5.09
	10/3/2014	5.75
	28/8/2014	2.74
	1/11/2014	3.8
	8/1/2015	
	7/3/2015	5.72
	20/08/2015	3.04
	19/11/2015	4.16
Rupahi Line	23/11/2013	3.25
	21/1/2014	
	9/3/2014	8.31
	31/08/2014	2.32
	10/11/2014	3.92
	31/1/2015	7.15
	9/3/2015	8.21
	22/08/2015	2.3
	19/11/2015	4
Dirgha	23/05/2013	0.03
	22/11/2013	1.05
	20/1/2014	1.42
	10/3/2014	1.98
	31/08/2014	0.12
	10/11/2014	2.79
	30/01/2015	1.52
	10/3/2015	1.8
	19/08/2015	-0.13
	19/11/2015	0.88
Mori Dirgha	23/05/2013	0.26
	22/11/2013	0.9
	20/1/2014	1.15
	10/3/2014	1.8
	30/08/2014	0.33
	10/11/2014	0.12
	8/1/2015	1.71
	10/3/2015	1.15
	19/08/2015	0.3
	19/11/2015	0.9

2.2.2 Soil Infiltration studies: **Salient features of the test sites are provided in Table 4.1. A perusal of the table shows that the test has been conducted only in barren land and the soil type encountered in the sites are sand admixtures. The infiltration test was conducted for 145 mins.**

Table 2.3: Salient features of the test sites

Site	Location	Land use	Soil type	Latitude	Longitude
Dejoo	In the field of 110/107 Grant Tea Garden LP School	Barren Land	Sandy soil	27° 16' 16.5"N	94° 01'31.5"E

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 existing quality data of CGWB were collected. Water samples were collected from monitoring wells for detailed, iron, heavy metals and arsenic. However, heavy metal and arsenic analysis data are yet to be received**.**

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 2.5: 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 2013-14, there was no exploratory drilling in the area. 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 2.6: Details of exploratory wells in the study area

Village/ Location	Taluka/ Block	District	Toposheet No.	Lat	Long	Type of well (DW/BW/TW)	Depth (m)	Dia (mm)	Source/ Agency
Dejoo	Nowboicha	Lakhimpur	83I/3	27.27	94.02	TW	60	41.0mX304.8mm 19.0mX203.4mm	CGWB
Rajgarh Nepali Gaon	Boginadi		83I/3	27.55	95.42	TW	93	50.5mX304.8mm 13.0mX152.4mm 30.0mX152.4mm	CGWB
Kadam Kachari			83I/3	27.34	94.17	TW	57	254.0mmX32.0m 152.4 mmX25.0m	CGWB
Anand TG			83I/3	27.45	94.23	TW	100	NA	PHED, N. Lakhimpur
Gereki Gaon			83I/3	27.13	93.73	TW	103	NA	
Lilabari	Lakhimpur		83I/3	27.29	94.07	TW	150.9	NA	

CHAPTER 3.0
Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

Geophyscis and aquifer Characterization: The interpreted results of VES curves has shown that top soil has resistivity value within 500 Ohm 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 three exploratory wells in the area. Public Health Engineering Department has also drilled number of wells in the area. However, only three lithologs are included in this study after proper verification. From the examination of this litholog it is observed that down to a maximum explored depth of 150.9m 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 Anand Tea Garden at Pathalipam to Dhekiajuli in the piedmont zone (Fig. 3.2)

(b) a north west to south east section from Dhekijuli to No.1 Gereki Gaon, 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. Two gravelly formations 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 Dhekiajuli area. Two clay layers are encountered in the piedmont zone. The first layer is thin and occasionally found in the section. The second layer is lense shaped that is pinched out towards North West and thin out toward north east.

The significant feature of the section from piedmont to flood plain is the dominance of the fine grained unit of the unconsolidated aquifer. The first gravel layer appears in the section in lense shaped manner and pinch out further southeast. Both these gravel zones are intermittently found throughout the area. The maximum thickness of this gravel layer is found in Lilabari well and missing at Kadam Kachari Gaon. Another gravelly layer is found at a depth of nearly 40m depth. The second gravelly layer is also found in the northeastern extremity of the area. In between these coarser grain aquifer units a sand dominated unit is found. The second gravel layer is separated from the upper sandy zone by a 5m thick clayey layer north east-south west. The clay layer thickness is maximum near Kadam Kachari and in the section it intermittently appears.

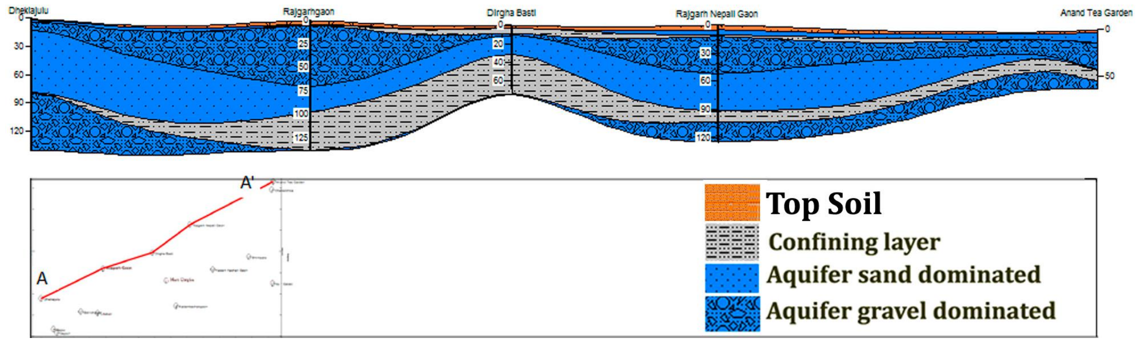

Fig.3.2: Section showing aquifer disposition along piedmont zone

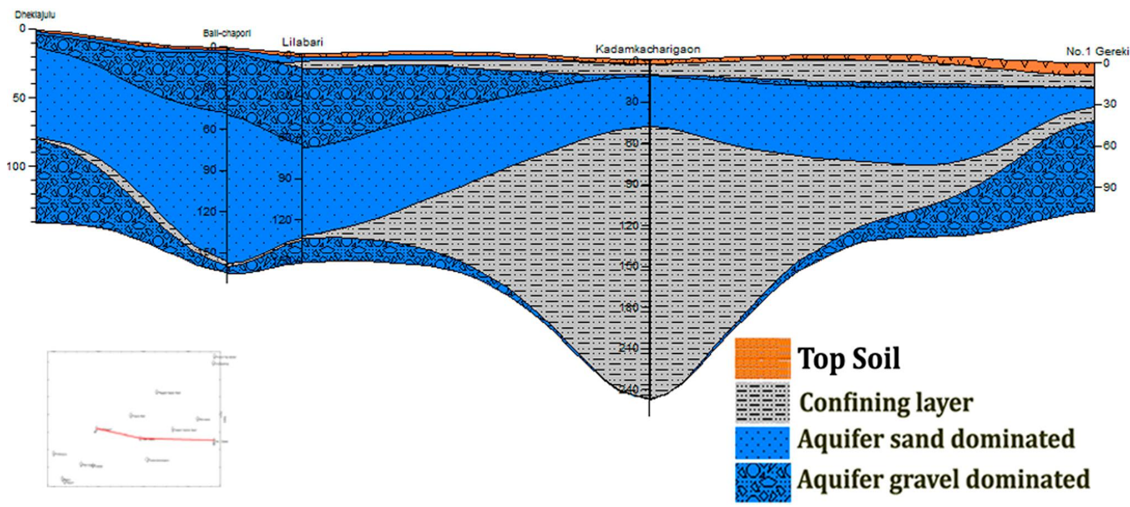

Fig. 3.3 Section showing aquifer disposition normal to piedmont zone, i.e., towards flood plain

Resistivity value of this clay layer ranges from 37 to 127 Ωm indicating facies change towards northeast of the area. Below 50m one clay layer of 1m thickness is encountered at Rajgarh Nepali Gaon and at Anand Tea Garden 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: The aquifer disposition of the area in the 3D block diagram indicates existence of a single aquifer in the area. The confining layers are not continuous throughout the area.

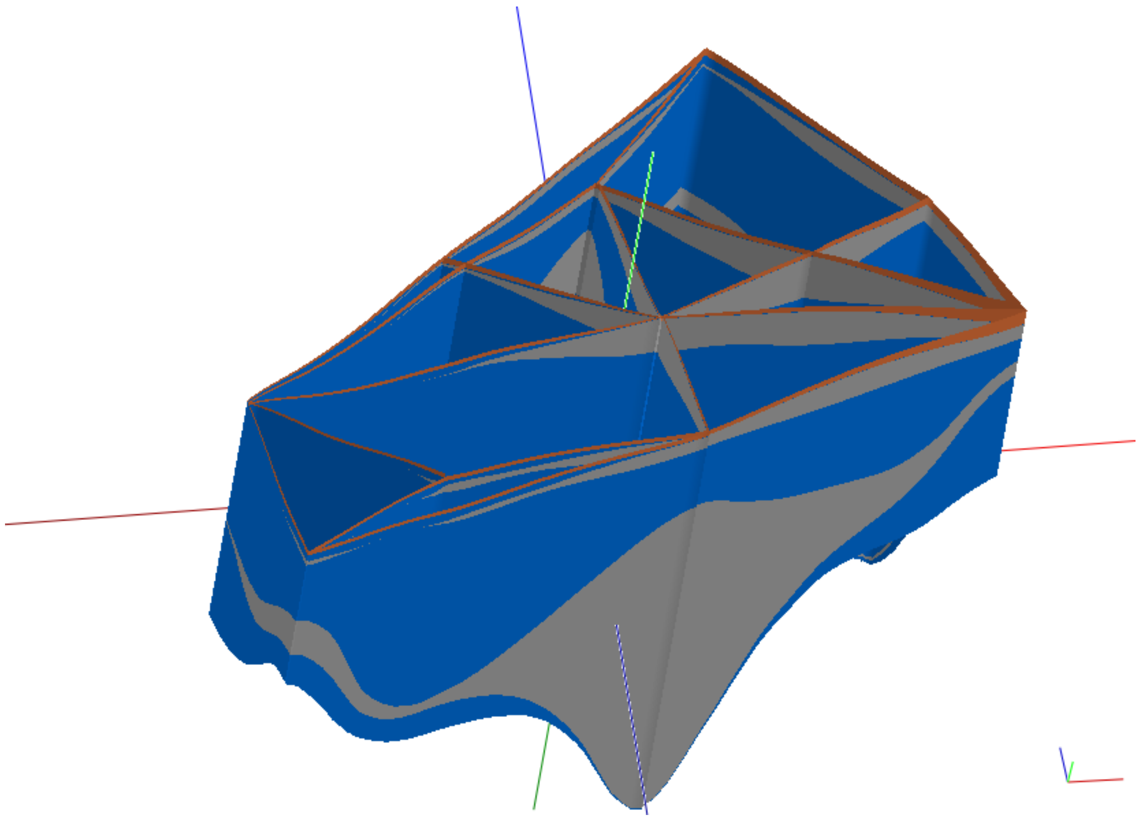

Fig. 3.4: 3D disposition of aquifer in the study area

Table 3.2: Aquifer parameters

Village/ Location	Taluka/ Block	Lat	Long	Type of well (DW/BW/TW)	Depth (m)	Draw down (m)	Transmissivity (m^2/day)	Storativity/ S.Yield	Specific Capacity (lpm/m of dd)	Source/ Agency
Dejoo	Nowboicha	27.27	94.02	TW	60	16.776	90.99	NA	43.6	CGWB
Rajgarh Nepali Gaon	Boginadi	27.55	95.42	TW	93	12.43	171.653	NA	NA	CGWB
Kadam Kachari		27.34	94.17	TW	57	23.43	3.88	NA	NA	CGWB
Anand Tea Garden		27.45	94.23	TW	100	NA	NA	NA	NA	PHED
Gereki Gaon		27.13	93.73	TW	103	NA	NA	NA	NA	PHED
Lilabari	Lakhimpur	27.29	94.07	TW	150.9	NA	NA	NA	NA	PHED

Ground water level

To study ground water regime, depth to water level from 15 monitoring stations are measured seasonally (Map 8). Block wise variation of water level can be discussed as below. Pre-monsoon depth-to-water level of the key wells in Nowboicha block is 1.26 mbgl and in Lakhimpur block depth-to-water level varies from 1.08 to 5.39mbgl. In Boginadi block water level varies between 0.03 to 5.5 mbgl. Pre-monsoon depth-to-water level contour is prepared (Fig. 3.5). In 2014 the monsoon water level of Lakhimpur block varies between to 0.26 to 2.35 mbgl and in Boginadi block water level varies between 0.12 to 2.74mbgl. In Nowboicha block monsoon water level is 0.83mbgl. Post-monsoon (November 2013) water level data of Nowboicha block 1.38mbgl. Depth to water level in Lakhimpur block varies between 1.28 to 2.70 mbgl and for Boginadi block DTW varies from 0.88 to 3.95mbgl (Fig. 3.6).

Fluctuation of water level in the piedmont zone ranges from -0.06 to 5.06 m bgl while in alluvial plain pre- and post monsoon water level difference ranges from -0.6 t0 2.63mbgl. The water level fluctuation in the alluvial plain is generally within 3.0m.

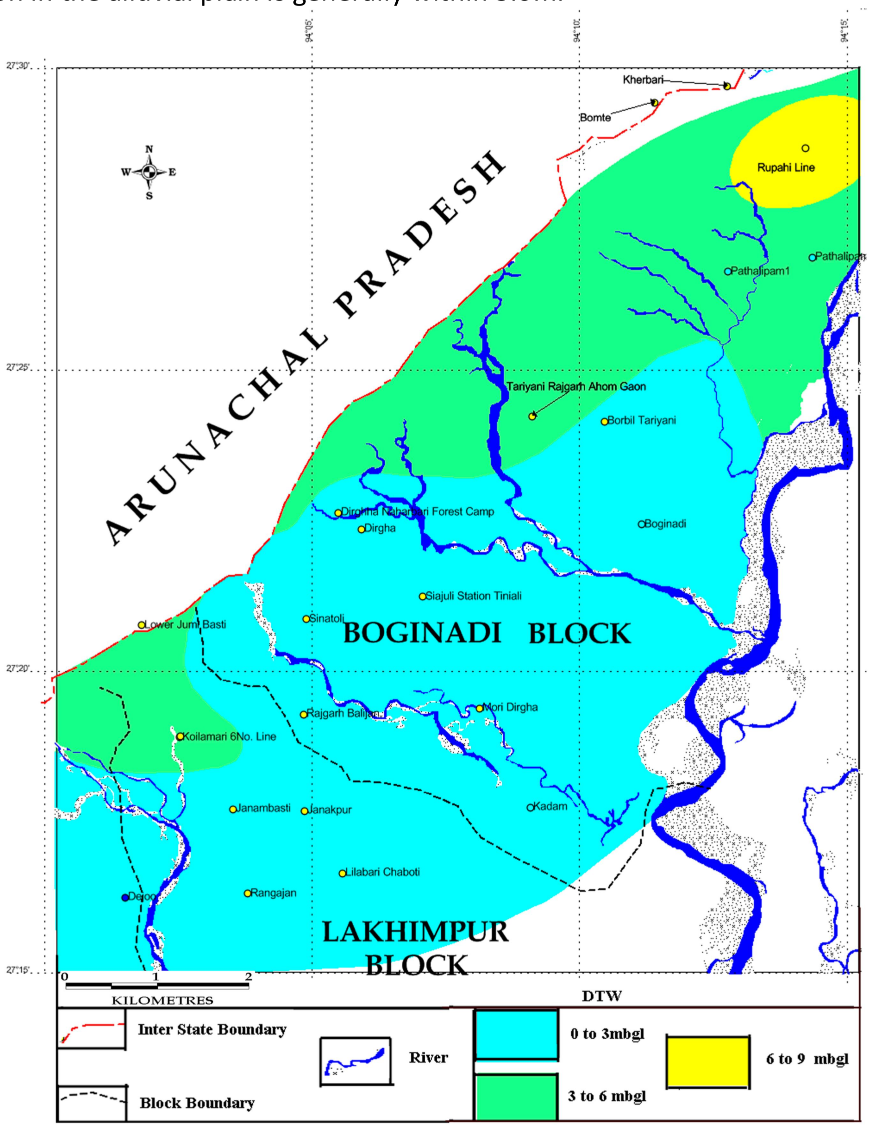

Fig. 3.5: Pre-monsoon DTW level contour of the study area

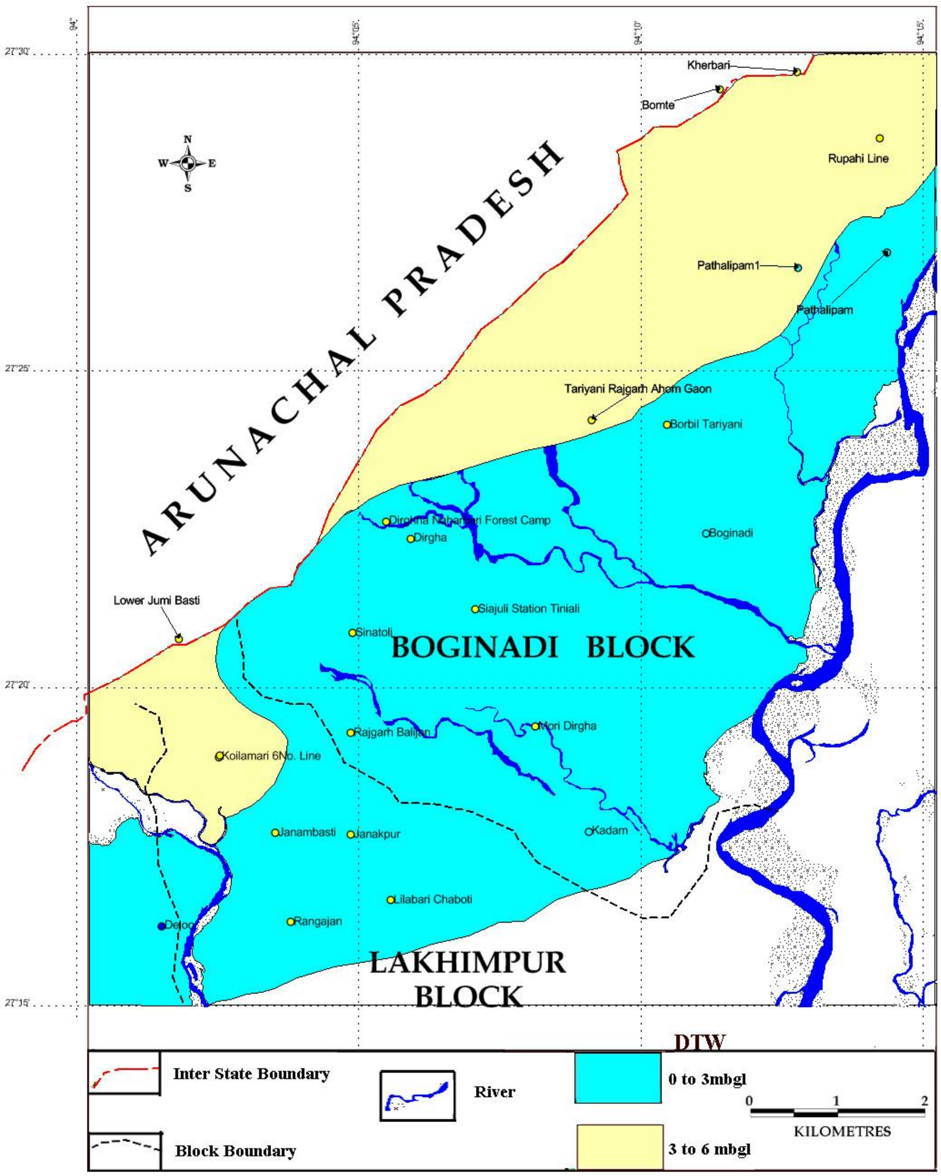

Fig. 3.6: Post-monsoon DTW contour of the study area

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 190 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.

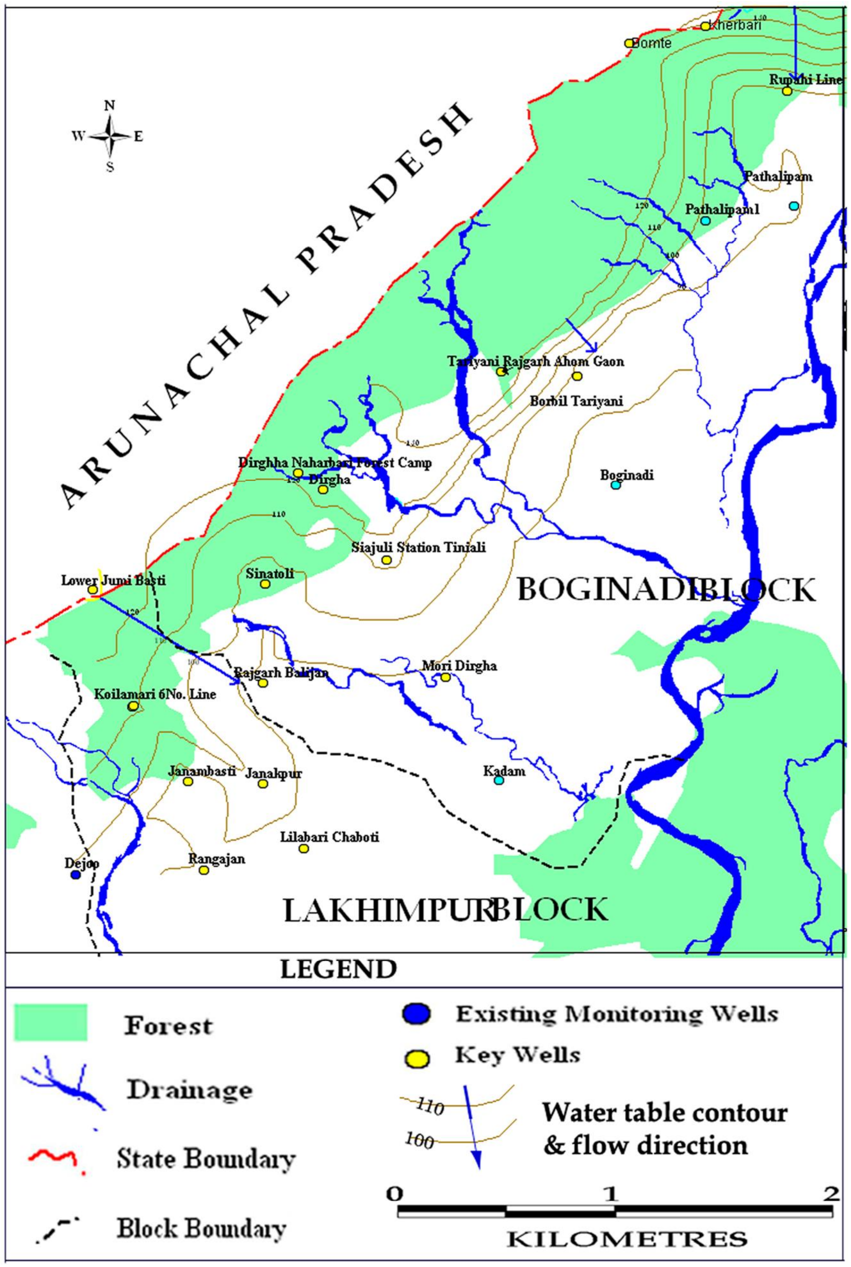

Fig. 3.7: Water table contour of the study area

Water level trend analysis

For analysis of long-term behaviour 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 2.3.3 and 2.3.4. Table 2.3.2 shows the overall trend of water levels in GWMS wells.

Table 3.3 Trend of Water levels in GWMS Wells

SN	Well No	Locality/Name	No. of years	Water Level Trend	
				Post-monsoon	Pre-monsoon
1	ASDM16	Kadam	9	Fall	Fall
2	ASDM17	Boginadi	7	Rise	Fall
3	ASDM15	Pathalipam	8	Rise	Fall

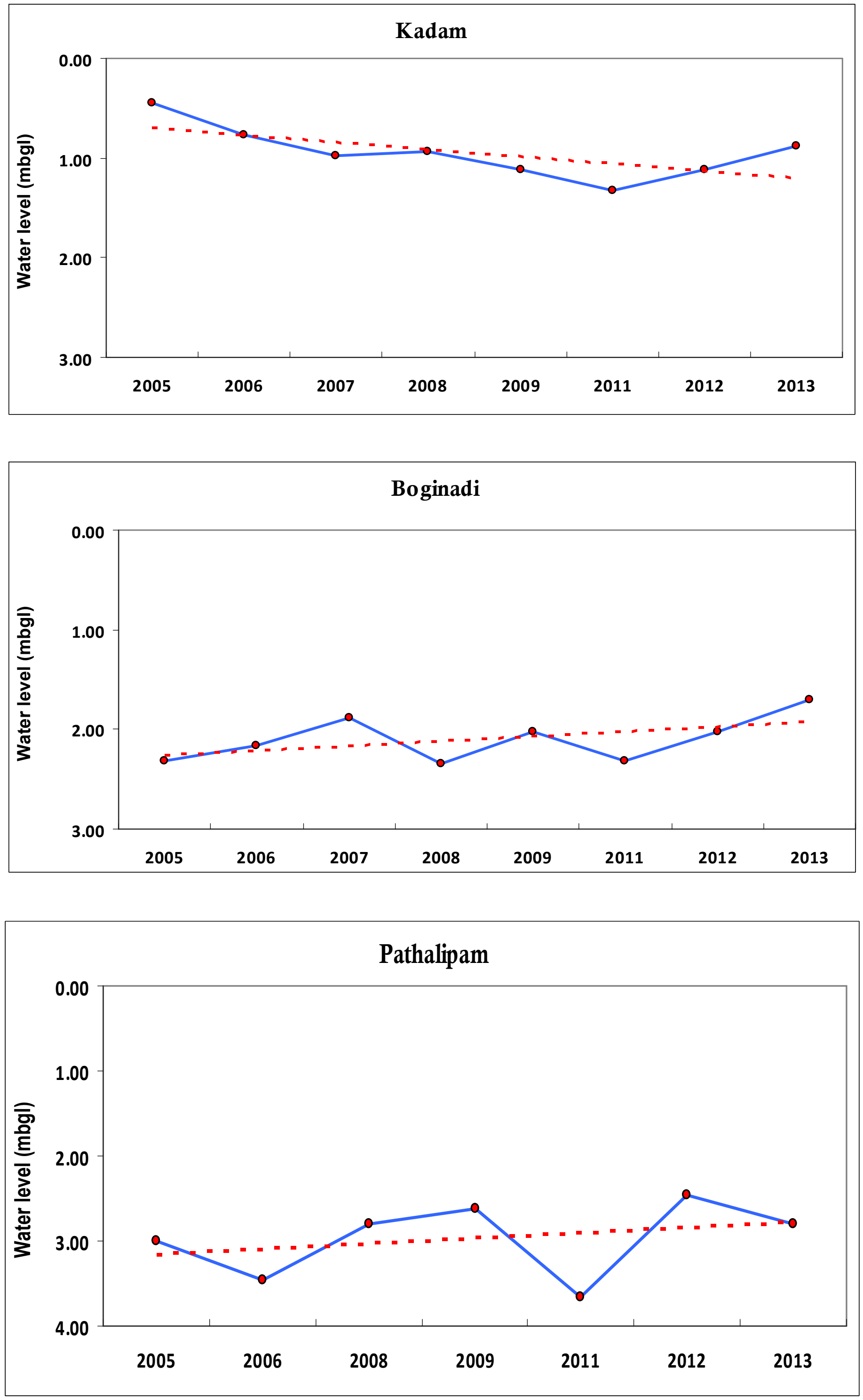

Fig.3.8: Post –monsoon Hydrograph of GWMS wells

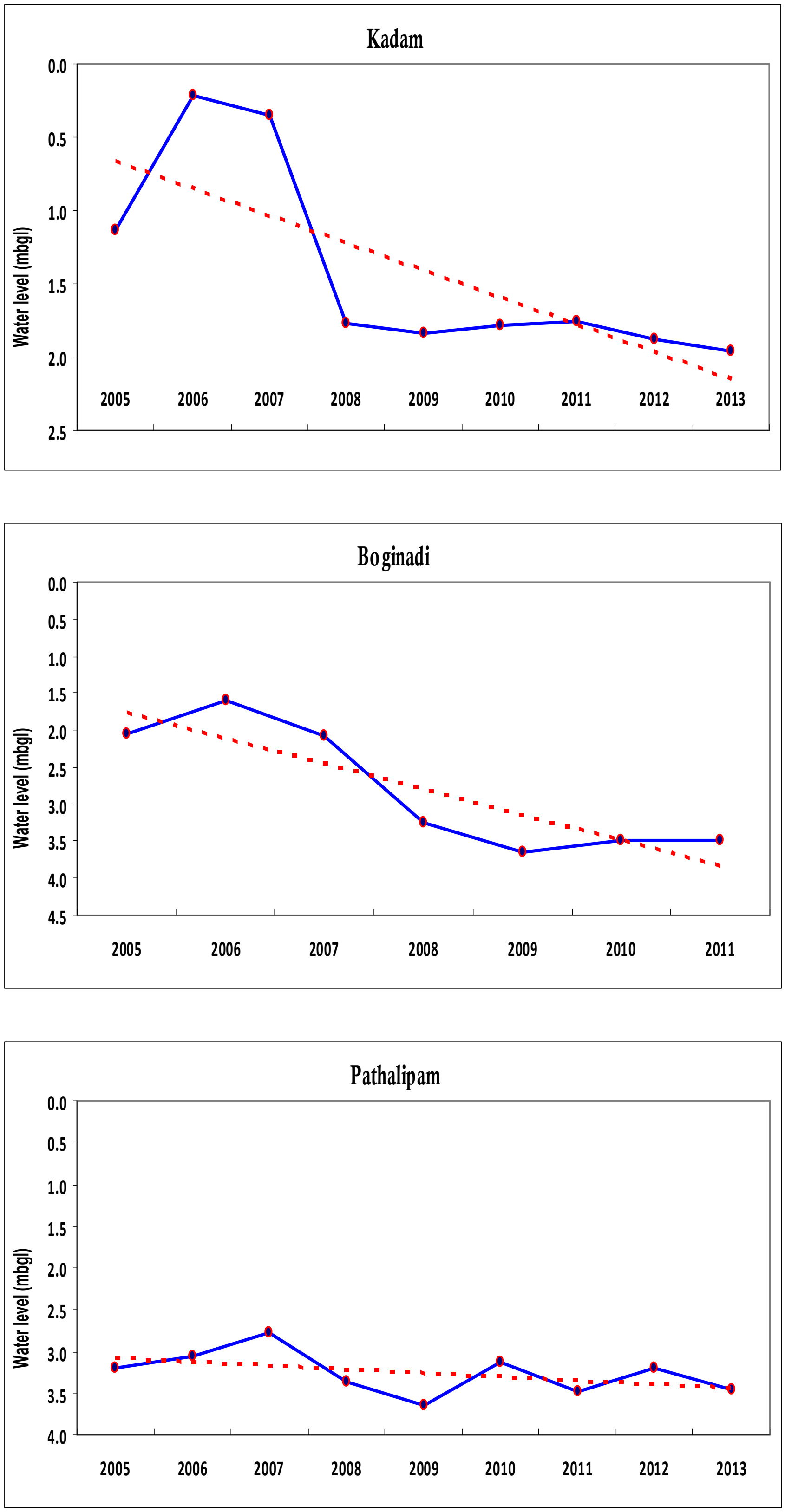

Fig.3.9: Pre-monsoon Hydrograph of GWMS wells

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 7.2 to 8.4 and in the post-monsoon pH value ranges from 6.3 to 8.0 indicating wide variation in pH. Pre-monsoon water sample mostly alkaline while post-monsoon samples are mostly acidic in nature. Pre-monsoon pH value increases the chance of bacterial contamination. Pre-monsoon iron concentration range in Lakhimpur block is 0.38 to 1.32mg/l and in Boginadi block the value is 0.33 to 3.31mg/l. Pre and post monsoon iron concentration in Nowboicha block is 5.65mg/l and 0.53mg/l. In post monsoon water samples also iron concentration is above permissible limit. In Lakhimpur block its value ranges from 0.46 to 0.56mg/l while in Boginadi block iron occurs within 0.44 to 3.43mg/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. Block wise concentration range of different chemical elements in ground water during pre- and post monsoon in the study area is given in Table 3.4.

Table 3.4: Block-wise concentration range of chemical constituents in groundwater

Elements	Pre-monsoon			Post-monsoon		
	Nowboicha	Lakhimpur	Boginadi	Nowboicha	Lakhimpur	Boginadi
pH	7.9	8.1-8.2	7.3-8.3	6.8	7.1	6.5-8
EC	256.7	128-221	59.4-356.3	161	129-162	64.8-402
	conc. In mg/l					
TDS	122.5	67.5-117	27.7-166.8	85.6	68.7-86.3	46-128
TH	208	102-146	60-76	80	60-76	46-128
Ca	32	24-12.8	9.6-32	27.2	18.4-19.2	11.2-44
Mg	36	10.1-27.6	7.8-17.5	6.6	4.47-4.66	2.72-10.68
Na	10	5.7-16.3	1-10.5	5.7	5.05-7.2	0.64-18.2
K	8.9	0.8-2.8	0.9-3.4	2.99	1.53-3.25	1.01-10.96
HCO3	36	56-88	28-108	62	62-78	42-122
SO4	1.3	3.18-9.45	0.99-4.28	5.69	2.71-8.04	1.46-27.31
NO3	2.4	0.4-2.2	0.4-1.2	18.8	18.6-23.1	1.2-26.4

Arsenic in groundwater: PHED, North Lakhimpur Division carried out water testing in its laboratory and present data set is provided for Boginadi block. 51 ground water samples collected from tara pump, shallow hand pump, hand tube well were analysied and results shows that arsenic concentration ranges from 52.5 to 583.1ppb. Out of 51 sampled sources only 9 sampled sources have arsenic within acceptable limit.

Aquifer Map: The aquifer map of the area is prepared and it clearly shows that the piedmont area is extending in northeast-southwest direction and is gravel dominated. The alluvial plain area is sand dominated. Water logged areas are found in the flood plain and alluvial plain area. The aquifer map is shown in Fig. 3.10.

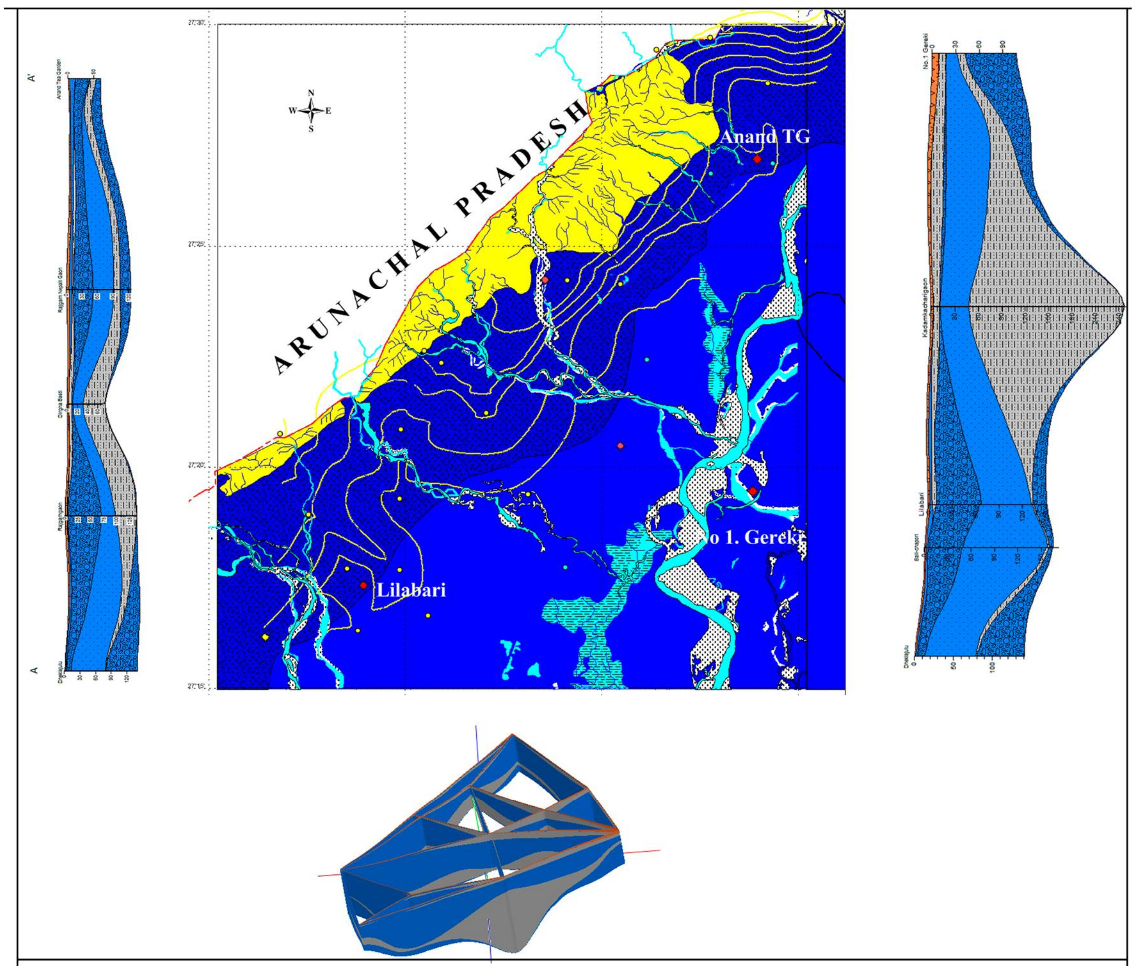

Fig. 3.10: Aquifer map of the study area

CHAPTER 4.0
Ground water Resources

The computation of ground water resources available in the district has been done using GEC 1997 methodology. The dynamic resource estimation presented here is taken from 2013 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 0.20 for Indo-Gangetic plains and inland area and 0.08 where clayey contents are more. In WLF method, specific yield has been taken as 0.20 for coarse grained sandy alluvium and 0.08 for silty alluvium following the norms recommended by GEC'97.

   Rainfall data is taken from IMD. The rainfall of Lakhimpur district is 2859.3mm.

2) Water level data has been considered for 2012. 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.

3) The population figures were collected from Census, 2011and projected to 2013. The per capita domestic requirement for the rural population has been considered as 60 lpcd and for urban population, it is 135 lpcd.
4) 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%.
5) 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'97.
6) 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.

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 updip 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 227700hectre of recharge worthy area is 73775ham while non-monsoon recharge is 37980ham. Recharge from other sources during monsoon is 5975 ham and during non-monsoon is 987ham. Total ground water recharge is 106845ham.

Draft: The draft 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 considered to be 10% of the total groundwater recharge, i.e., 11872ham. Total irrigation draft created is 14992ham. There is no major industry in the area. Draft for domestic uses is 2242ham. Total groundwater draft for all uses is only 17234ham.

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

Allocation of resources up to 2025: The net ground water resource is allocated for domestic and industrial and irrigation sector. 2783ham of resource is allocated for domestic and industrial purposes while 89070ham resource is allocated for irrigation.

Stage of groundwater development: 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 development in the district is 16%.

Block wise dynamic ground water resource: As mentioned earlier, due to paucity of block level irrigation data, ground water uses for domestic purpose and rainfall data, the resource estimation is carried out district wise. However, in the present study the total district resource is divided block wise based on geographical area of block. In doing so, it is assumed that all other hydrogeological, climatic conditions and draft are same for the entire district. Salient features of this approximation is shown in Table 4.1

Table 4.1: Recharge and net GW availability

Block	Recharge from rainfall during monsoon	Recharge from other source during monsoon	Recharge from rainfall during non-monsoon	Recharge from other source during non-monsoon	Total GW Recharge	Provision for natural discharges	Net Annual GW availability
	Unit in ham						
Nowboicha	7228.576	585.4387	3721.333	96.70762	11632.06	1163.206	10468.85
Lakhimpur	6131.221	488.2538	3156.405	82.02664	9857.906	985.7906	8872.116
Boginadi	8217.391	665.5224	4230.383	109.9365	13223.23	1322.323	11900.91

Table 4.2: Block wise draft, resource allocation up to 2025 and stage of GW development

Block	Net Annual GW availability	Existing gross GW draft for irrigation	Existing gross GW draft for domestic and industrial water supply	Existing gross GW draft for all uses	Provision for domestic and industrial requirement supply to 2025	Net GW availability for future irrigation development	Stage of GW development
Nowboicha	10468.85	1468.93	219.67	1688.61	272.68	8727.20	16.12
Lakhimpu	8872.11	1245.9	186.32	1432.2	231.29	7402.34	16.14

r		4		7			
Boginadi	11900.9 1	1669.8 9	249.72	1919.6 0	309.98	9921.01	16.12

Static resource: The static groundwater resource of the district has been calculated for the base year 2009. Here also the administrative district has been considered as the assessment unit due to paucity of block-wise data. Hilly areas having slope more than 20% are deleted from the total area to get the area suitable for recharge.) The average thickness of saturated unconfined aquifer below ground level as obtained from dug wells / bore wells in the district has been considered.

The Pre-monsoon (month of March) Water Level from Monitoring Wells of CGWB in Lakhimpur district has been considered as the maximum depth below ground level up to which the zone of water level fluctuation occurs. Since the north eastern states receives pre-monsoon showers, which commences from the first week of April, resulting in rise in water levels in the phreatic zones, the deepest water levels are recorded during the month of March. Specific yield value of 0.20 is considered for the district.

(e) Finally the Static Ground Water Resource is computed from the data as obtained:

$$Y = A^* (Z_1 - Z_2)^* Sy$$

Where, Y = Static ground water resources,

A = Area of ground water assessment unit

Z_1 = Thickness of saturated unconfined aquifer below ground level

Z_2 = Pre-monsoon water level

Sy = Specific yield of the unconfined aquifer

Table 4.3: Salient information of static resource of Lakhimpur district, Assam

Name of the assessment unit	Type of rock formation	Total Geographical Area Ha	Assessment Area Ha	Bottom of the unconfined aquifer (m)	Average Pre-monsoon Water Level (m)	Thickness of the saturated zone of the un-confined aquifer below WLF zone (m) [(5)-(6)]	Volume of Saturated zone of the unconfined aquifer below WLF zone (ham)
1	2	3	4	5	6	7	8
Lakhimpur District	Alluvium	227700	227700	15	2.91	12.09	2752893

Static/In-storage Ground Water Resources (ham): Volume of saturated zone X specific yield

= 2752893X0.2=550578.6ham

Extraction from unconfined aquifer/deeper aquifer: As mentioned earlier that groundwater in this area is utilized mainly for drinking or domestic purposes. Public Health Engineering Department water supply projects are mainly based on groundwater.

Table 4.4: Public water supply scenario in the study area

Block	Total number of Public Water Supply Scheme	Source
Nowboicha	13	Deep Tube Well
Lakhimpur	20	Deep Tube Well
Boginadi	24	Deep Tube Well

PHED tube well depth is within 100m. However, earlier PHED drilled tube well down to a depth 150m also. Besides the public water supply scheme rural population utilize dug wells for drinking and domestic water purposes. Dug well depth is generally more towards piedmont zone. Dug well depth in this area is generally within 10m. In the alluvial plain area dug well depth 3 to 7m.

CHAPTER 5.0

Groundwater Related Issues

The main issues related to ground water in the area include vulnerability to water logging and arsenic pollution.

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 (Fig. 5.1).

Area vulnerable to water logging: Water logged areas are observed in the southwestern part of toposheet no. 83I/3 and southern part of toposheet no. 83I/10. The post monsoon depth-to-water level varies from 0.67 to 2.0. 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.

Area vulnerable to arsenic pollution: During the survey samples were collected from shallow aquifer. However, as the analytical results are yet to be received, vulnerability map of the area has been prepared based on CGWB's earlier data as well as data obtained from PHED, North Lakhimpur Division.

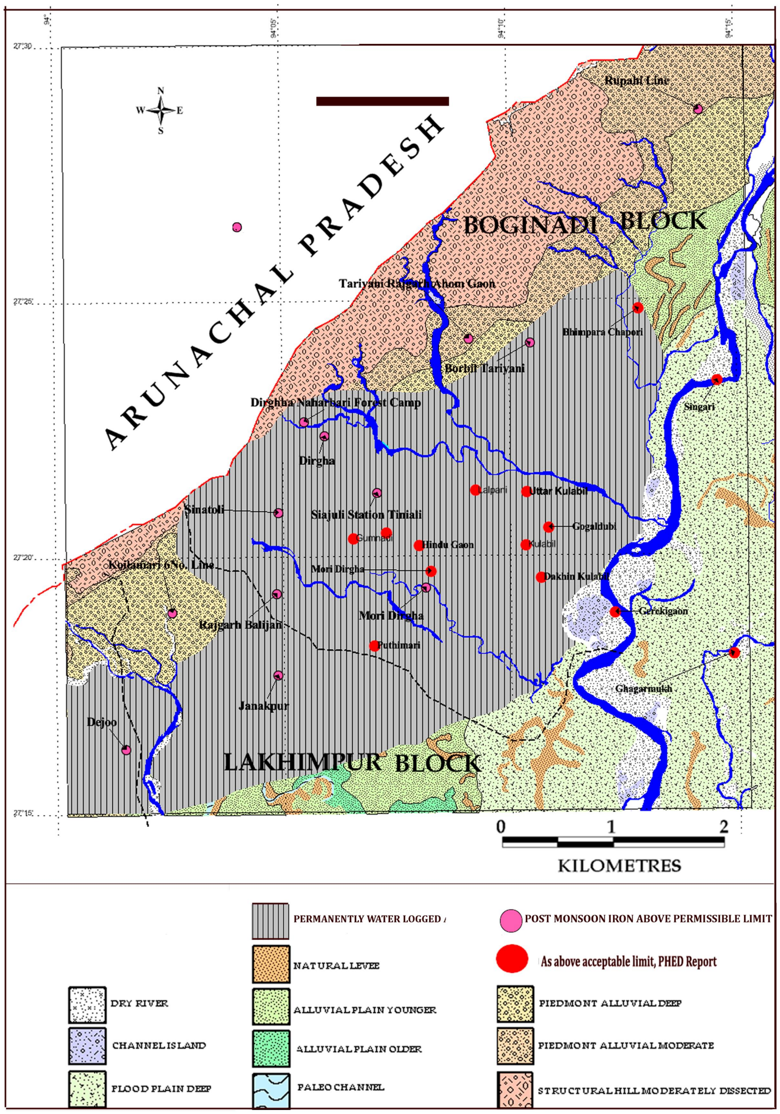

Fig. 5.1: Vulnerability map of the study area

Future demand: Future demand of ground water is analyzed for domestic, drinking and irrigation purposes

Domestic and drinking purpose: The drinking and domestic requirement is worked out for projected block population where requirement has been considered as 60 litre per person per day. The block wise requirement up to 2030 is worked out and tabulated (Table)

Table 5.1: Projected population and water demand for domestic purpose of the area

Block	**Block Population 2011**	**% Decadal population growth**	**Projected Population**			**Projected Water Demand considering per person water need of 60litre per day (ham)**		
			2013	**2025**	**2030**	2013	**2025**	**2030**

Boginadi	107330	17.06	110992	129303	138458	66.5952	77.5818	83.0748
Nowboicha	126716		131040	152657	163466	78.624	91.5942	98.0796
Lakhimpur	114964		118887	138499	148306	71.3322	83.0994	88.9836

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 to this changing physiography.

As a result, during monsoon season, increase in surface run-off commensurate with increase discharge of hilly rivers debauch to this part of land and immediately losing their velocity due to sudden fall of slope resulting in inundation of agriculture land as well as human settlement.

Rain fed agriculture is badly affected due to longer residence period of flood. Flood water badly affects the paddy cultivation. Whenever flood causes havoc in agriculture, the farmer losses can be compensated through rabi cultivation. In this context, entire net sown area needs to be brought under assured irrigation. Assured irrigation bring about a change in cropping pattern, conversely a change in cropping pattern is always associated with increase in 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 has to be adopted.

Since the area has shallow water level condition, the total depth of water required to raise a crop over a unit area (∆) is considered as 1.2m

Table 5.2: Block wise water requirement for winter paddy cultivation through irrigation

Block	Irrigated Area	Un irrigated Area	Total Area	60% of net sown area bring under paddy cultivation and irrigation	∆ in m	Water requirement for 60% of net sown area (ham)
Nowboicha	100	15981.7	16081.7	9589.02	1.2	11506.82
Boginadi	52	2962.25	3014.25	1777.35		2132.82
Lakhimpur	152	12280.36	12432.4	7368.22		8841.864
Total water requirement						**22482.0** Ham

Table 5.3: Block wise water requirement for rabi crops other than paddy through irrigation

Block	**Total Area**	**∆ in m**	**Base period for crops other than Rice**	**Water requirement for 40% of net sown area (ham)**
Nowboicha	6392.68	0.3	100days	1917.804
Boginadi	1184.9			355.47
Lakhimpur	4912.14			1473.642
Total water requirement				3747 **Ham**

Stress Aspects of aquifer: Stress aspects of aquifer are discussed comparing water demand in various sectors and supply.

Table 5.4: Total water requirement for the area

Block Name	Drinking water requirement up to 2025 Ham	Water requirement to bring 60% of net sown area under irrigation for paddy cultivation Ham	Water requirement to bring 40% of net sown area under irrigation for non-paddy cultivation Ham	Water allocated for drinking and domestic purposes up to 2025 Ham	Water allocated for irrigation up to 2025 Ham
Nowboicha	77.5818	11506.82	2557.072	272.68	8727.20
Boginadi	91.5942	2132.82	473.96	231.29	7402.34
Lakhimpur	83.0994	8841.864	1964.856	309.98	9921.01

Supply and demand gap: It is observed that drinking water allocation is sufficient to meet the future demand and it will not give additional stress on the aquifer. However, if entire net sown area is bring under irrigation then allocated water for irrigation will not be sufficient to meet the future demand.

Table 5.5: Supply and demand gap in drinking water sector

Block Name	Drinking water demand up to 2025 Ham	Water allocated for drinking and domestic purposes up to 2025 Ham	Gap between supply and demand Ham
Nowboicha	77.5818	272.68	195
Boginadi	91.5942	231.29	132.29
Lakhimpur	83.0994	309.98	227

Table 5.6: Supply and demand gap in irrigation

Block Name	Total irrigation demand Ham	Water allocated for irrigation up to 2025 Ham	60% of the allocated water for irrigation available for use	Gap between supply and demand Ham
Nowboicha	14063.89	8727.20	5236	(-) 8827.892
Boginadi	2606.78	7402.34	4441	(+) 1834.22
Lakhimpur	10806.72	9921.01	5953	(-) 4853.72

CHAPTER 6.0

Management Strategy

The aquifer in the study area represents a single or mono aquifer system. 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 materials 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 is mainly found in the north eastern part of toposheet no 83I/3 covering the area of Pathalipam, Assam. 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: Sustainable management plan of groundwater of this area can be formulated considering the geomorphologic, hydrogeologic, hydrochemical characters of the aquifer and also the water demand (Table 6.1).

Assessment of water demand in irrigation sector shows that there is a 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. Since the major part of the area is under shallow water table condition, lowering of water level within 5m will unlikely to affect the sustainability of the aquifer.

The additional water available after lowering water level by 2m is shown in Table

Block	Geographical Area Ha	WL fluctuation m	Sp. Yield	Additional Water Available Ham
Boginadi	25362.25	2	0.2	10144.9
Nowboicha	22347.03	3.5	0.2	8938.812
Lakhimpur	18923.47	2	0.2	7569.388

Additional irrigation water is not required for Boginadi block and in Lakhimpur block also 1m lowering of water level is sufficient to meet irrigation demand.

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 10hrs a day for 150days of a year then a tube well having discharge will create a draft of 0.06MCM.

Therefore with available resource and to create a draft of 0.06MCM, 2605 numbers of tube wells can be constructed in the area. Block wise break up is given below (Table 6.3).

Table 6.3: Block wise tube well construction

Block	Resource allocated for irrigation (ham)	60% of allocated resource (ham)	No of TW
Nowboicha	8727.2	5236.32	873
Lakhimpur	7402.34	4441.404	740
Boginadi	9921.01	5952.606	992
Total	26050.55	15630.33	2605

However, based on total net sown area and total unirrigated status of the land is worked out. Therefore, the required numbers of tube wells are worked out and shown in Table 6.1.

Table 6.1: Numbers tube well required for irrigation

Block Name	Total irrigation demand Ham	No. of TW required with $Q=40m^3/hr$ for 10 hrs pumping hrs for 150days Probable Unit Draft to be created =0.06MCM
Nowboicha	14063.89	2344
Lakhimpur	2606.78	434
Boginadi	10806.72	1801
Total	**4605.6**	**4580**

Sustainable management plan should take care to increase recharge of rain water artificially. Increase recharge will fill the aquifer as well as lower surface run-off and soil erosion.

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 utilized to separate the arsenic occurrence 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. 6.1.

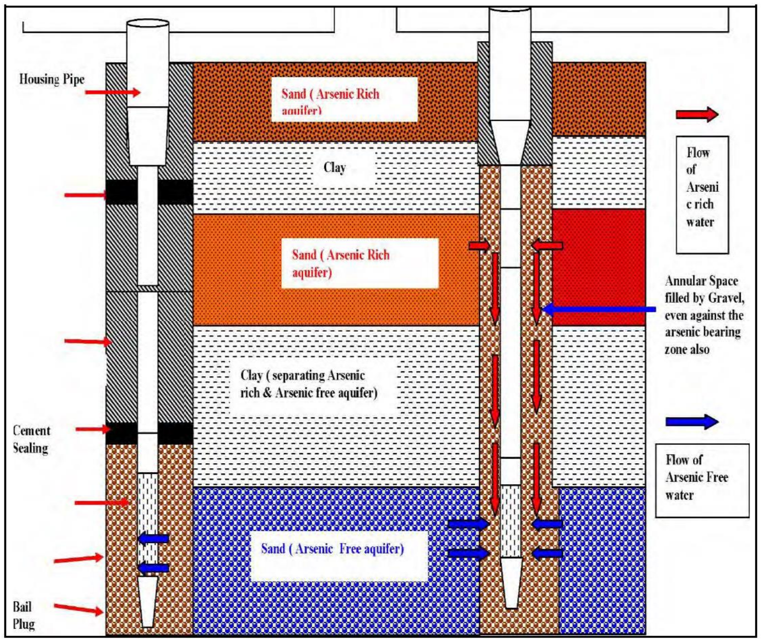

Fig.6.1: Tube-well design of a deep tube well tapping safe deeper aquifer
(Source: Concept note on geogenic contamination of groundwater in India)

Aquifer wise availability of unsaturated zone: Aquifer wise availability of unsaturated zone is found out from the area enclosed by 3.0mbgl post monsoon water level contour (Manual of Artificial Recharge: CGWB, 2007). The area is found to be 72.41sq.km. However, the groundwater monitoring stations are not uniformly spread out in the area due to lack of dug wells. The area can be further extended after establishing representative monitoring stations.

The marked area belongs to 1st aquifer, i.e., phreatic unconsolidated aquifer. Volume of sub-surface storage space available for recharge= Area (3m WL contour)X Specific yield

$=110.89X0.2=22.178m^3$

Considering recharge efficiency of individual recharge structure 70%, surface water required to recharge the unsaturated storage space is

= (Sub-surface volumeX100)/recharge efficiency

= (22.178X100)/0.7 m^3 or $1552.46m^3$

The area identified for recharge is piedmont zone. However, long term post and pre-monsoon water level trend do not show significant change in water level. Moreover, ground water development in the area is only 16%. A major part of the area is under shallow water table and water logging conditions. As such there is every possibility that artificial recharge in the piedmont area may increase water logged area. Therefore artificial recharge is not recommended for the area.

6.3 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 convenyance 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 hectre 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.

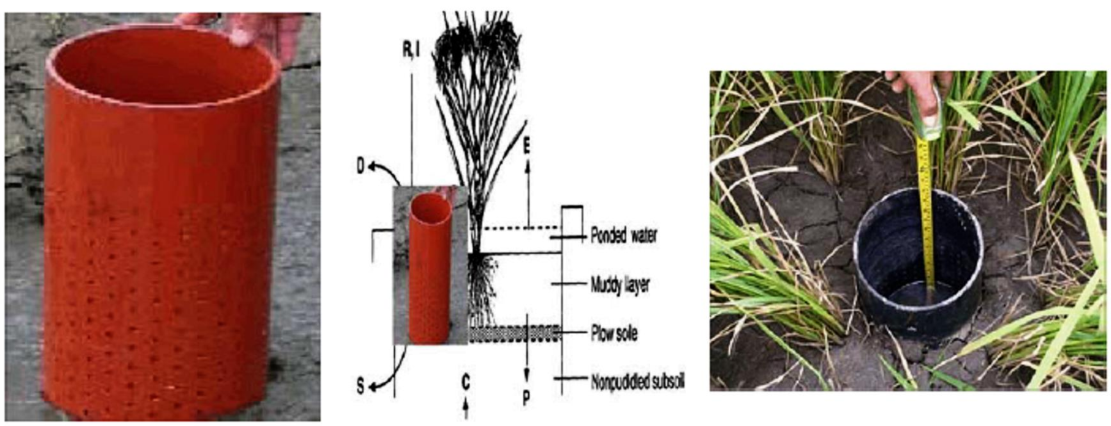

Fig. 6.2: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface (Kulkarni, 2011)

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

Block	**Paddy cultivated area (as per Agriculture Census 2010-11) (ha) (From Table: 5.2)**	**40% reduction of water for land leveling by the use laser land leveler**	**Approximate saving of water ham**
Nowboicha	9589.02		767.1216
Boginadi	1777.35		142.188
Lakhimpur	7368.22		589.4576
Total water saving			1498.77

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 80% dependency on groundwater (Table 5.4).

Irrigation:

Barring Boginadi block other two blocks irrigation water requirement is more than the allotted dynamic groundwater resource for irrigation. In Nowboicha block gap between supply and demand is 8828ham and in Lakhimpur block the gap is 4854ham. For water level fluctuation of 3.5m in Nowboicha block, 15671ham water can be withdrawn and in Lakhimpur block water level fluctuation of 2.0m will release 12681ham water.

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.