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Department of Water Resources, River Development and Ganga Rejuvenation
जलसंसाधन, नदी विकास और गंगा संरक्षण विभाग
Central Ground Water Board
केंद्रीय भूजल बोर्ड

REPORT ON AQUIFER MAPPING AND MANAGEMENT PLAN OF NALBARI DISTRICT, ASSAM (AAP 2021-22)

North Eastern Region,
उत्तर पूर्वी क्षेत्र, गुवाहाटी
GUWAHATI
गुवाहाटी
JULY, 2022

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT
&
GANGA REJUVENATION
CENTRAL GROUND WATER BOARD

REPORT ON AQUIFER MAPPING AND MANAGEMENT PLAN OF NALBARI DISTRICT, ASSAM

(AAP 2021-22)

By
Bibhti Bhusan Sahoo
Scientist –B(Hg)

North Eastern Region
Guwahati
July 2022

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Chapter 1

Introduction

Central Ground Water Board, North Eastern Region has carried out Aquifer Mapping and Management plan in the district of under National Aquifer Mapping and Management (NAQUIM) program in the AAP 2021-2022. Systematic mapping is very much effective in building up our knowledge on the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers with periodic fluctuations and the occurrence of natural and anthropogenic contaminants in the groundwater and how they affect the whole system. Aquifer mapping at the appropriate scale can help to prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development.

1.1 Objectives

The objectives of this project are; to understand the aquifer systems up to 200 m depth, to demarcate the aquifer geometry, delineate type of aquifers, ground water regime behaviours, hydraulic characteristics and to establish groundwater quantity, quality, and sustainability, and to estimate the dynamic and static resources accurately through a multidisciplinary scientific approach on 1:50000 scale and finally formulate a complete, sustainable and effective management plan for ground water development.

1.1.1 Scope of the Study

district is blessed with many major rivers like the Brahmaputra River and its two tributaries Pagladia river and **Baralia** river; So, this district has vast Groundwater and surface water resources. Proper hydrogeological knowledge is required for the sustainable development of groundwater and systematic management plan for the ground water utilizations.

1.1.2 Approach and Methodology

The activities carried out for completion of the Aquifer Mapping and management plan can be envisaged as follows:

1.1.3 Data Compilation & Data Gap Analysis

Collection and synthesis of large volume of data is the foremost criteria during the specific studies carried out by Central Ground Water Board and various Government organizations with fresh generation of a new data to describe an aquifer system completely.

The data were assembled, analyzed, examined, synthesized and interpreted from available sources. These sources were predominantly non computerized data, which was converted into computer-based GIS data sets. On the basis of available data, data gaps were identified.

1.1.4 Data Generation

There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys to delineate multi aquifer system; to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.

1.1.5 Aquifer Map Preparation

After integration of all the collected data generated from various studies of hydrogeology, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared for the characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities, quality, water level, potential and vulnerability (quality & quantity).

1.1.6 Aquifer Management Plan Formulation

Aquifer Maps and ground water regime scenario is utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

1.2 Area details

Nalbari district is located in the south-central part of Assam and bounded by 26°N to 26.51°N Latitude and 91°E to 91.47°E Longitude. The district shares its northern and western boundaries with Baska and Barpeta districts respectively. Kamrup District marks the southern and eastern boundaries of the district. The geographical area of the district is 1009.57 sq km. Administratively the district is divided into three Civil Sub-Division, 7 nos. Revenue Circle, 7 nos. Community Development Blocks and 65 nos. Gaon Panchayats covering 471 villages. The entire area of the district is situated at the plans of the Brahmaputra Valley. The tributaries of the Brahmaputra, Nona, Buradia, Pagaldia, Borolia and Tihu are originated from the foothills of the Himalayas Range are wild in nature and have enormous contribution towards the agrarian economy of the district.

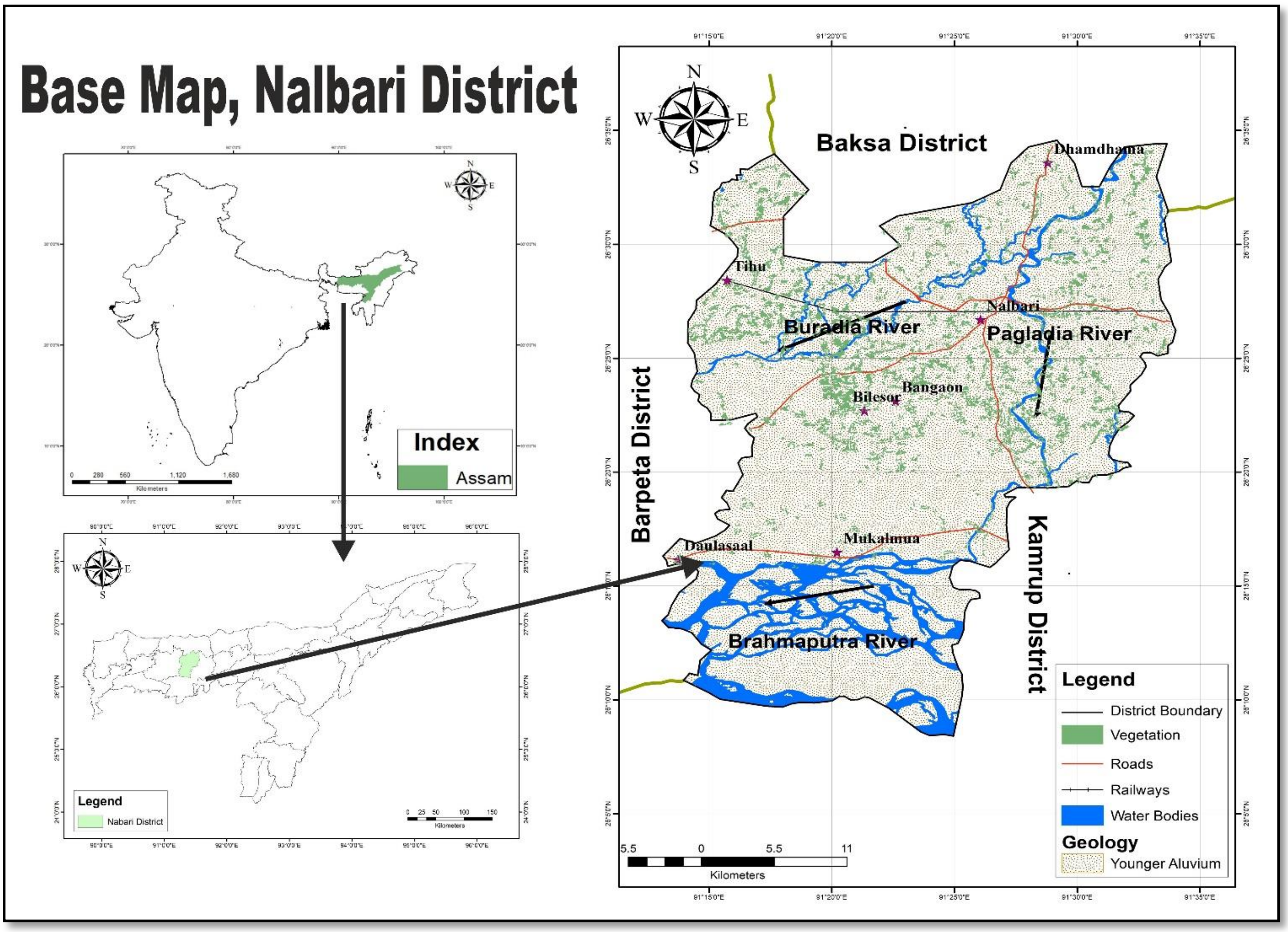

Fig.: 1.1 Base map of District.

1.3 Data availability, data adequacy and data gap analysis

Aquifer mapping and management plan is carried out through collaborative of different data. The required data on various attributes of the study are collected from the available literatures of Central Ground Water Board, State Departments of Assam and various Central and State Government agencies.

Table1.1 Data Availability and Data Gap Analysis in Aquifer Mapping Studies Area

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data	EW	09	10	Nil	9	Maximum depth of well is 304.6 mbgl only.
2	Geophysical data		Nil	10	8	8	
3	Groundwater level data	Dug well	3	8	14	17	
		Piezometer	2	5	Nil	2	
4	Groundwater quality data	HP/Dugwell	3	Nil	22	25	
6	Soil Infiltration Test		Nil	2	2	2	

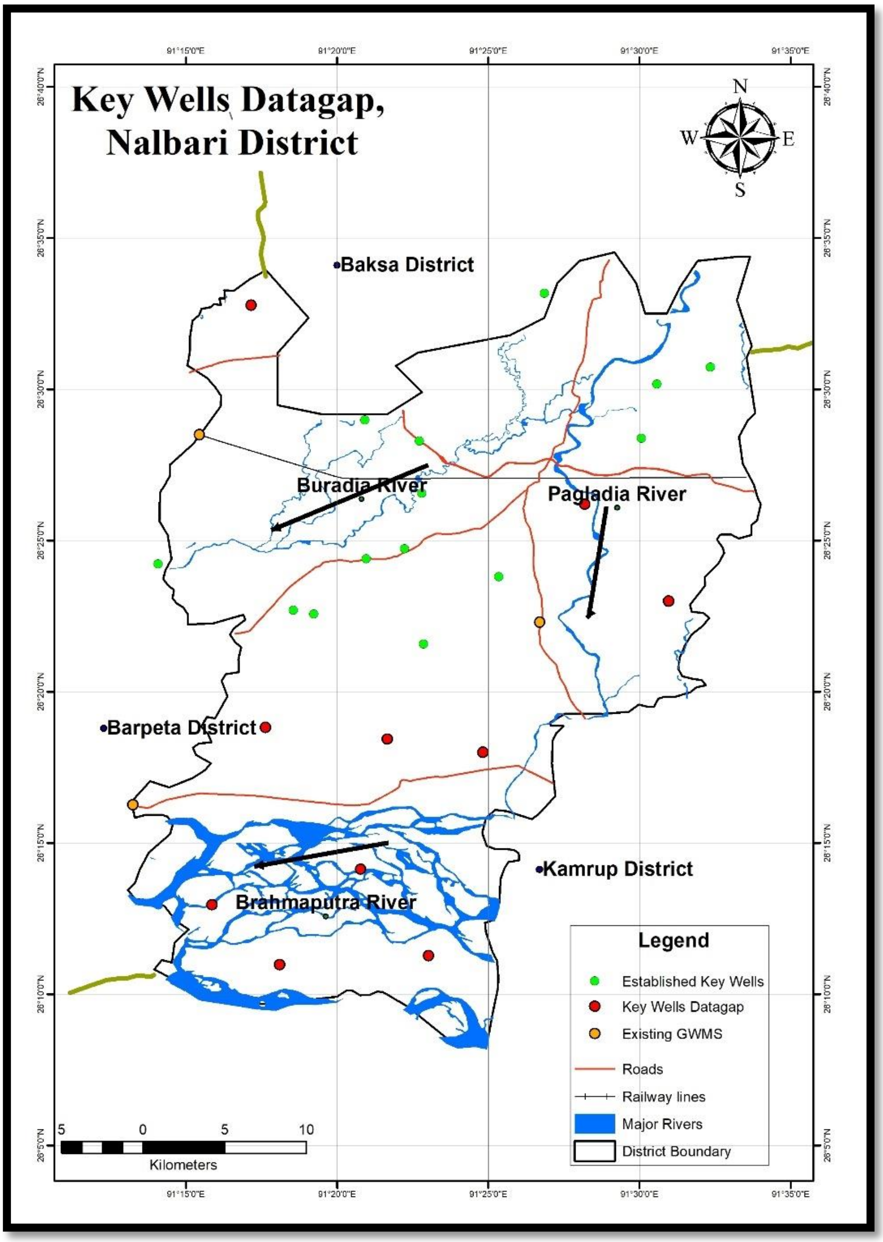

Fig. 1.2: Key Wells Data Gap, Nalbari District.

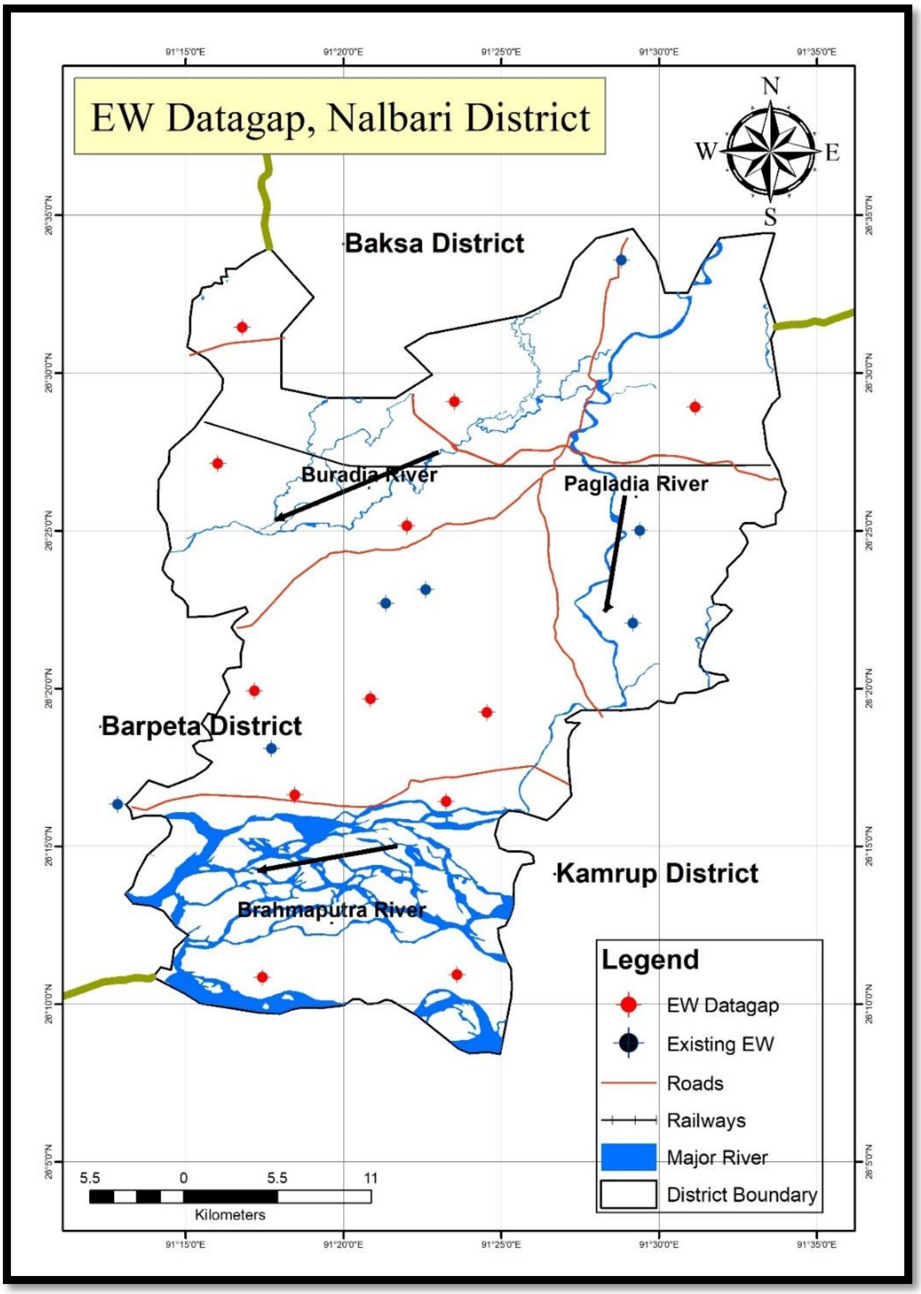

Fig.1. 3: EW Data Gap, Nalbari District

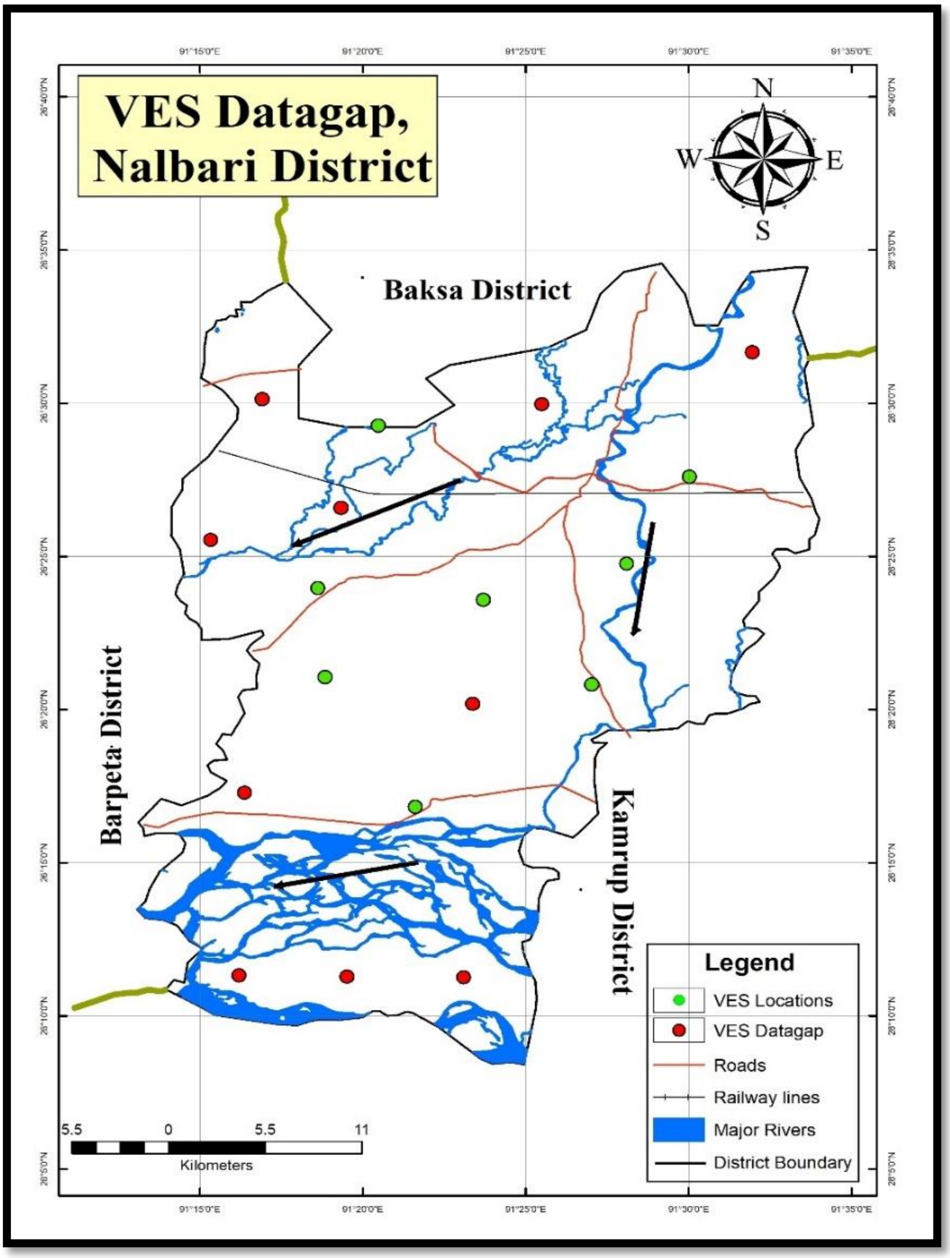

Fig. 1.4: VES Data Gap, Nalbari District

1.4 Demography

The total population of the district is 7,71,639 as per 2011 Census, out of which male population is 3,96,006and female population is 3,75,633. The scheduled caste population is 60,216 and scheduled tribe is 23,364. The population density is 733.5 persons per square kilometer.

Table.1.2. Demographic details of Nalbari district.

Name of the Blocks		TotalNHH*	TotalNM*	M	F
Barkhetri	Rural	38037	202196	103949	98247
	Urban	_	_	_	_
	Total	38037	202196	103949	98247
Pub	Urban	9604	44666	23140	21526
	Rural	22653	110160	56695	53465
	Total	32257	154826	79835	74991
Paschim	Rural	17835	87416	44887	42529
	Urban	6157	29461	14867	14594
	Total	23992	116877	59754	57123
Madhupur	Rural	10349	50934	26333	24601
	Urban	_	_	_	_
	Total	10349	50934	26333	24601
Borbhag	Rural	11080	55703	28608	27095
	Urban	845	4004	1985	2019
	Total	11925	59707	30593	29114
Barigog Banbhag	Rural	21410	105801	54106	51695
	Urban	_	_	_	_
	Total	21410	105801	54106	51695
Tihu	Rural	16237	76699	39099	37600
	Urban	1041	4599	2337	2262
	Total	17278	81298	41436	39862
Total		**155248**	**771639**	**396006**	**375633**

Source: Census of India, Nalbari, 2011 *M- Male, F- Female, NHH- No. of households, NM- No. of members

1.5 Communication

Nalbari is accessible by road via the NH.27 on the North end, while NH.427 connects it to the South. The Nalbari Train Station is located within the town center while the Guwahati International Airport's 60 km from town.

1.6 Climate and Hydrometeorology:

The district experiences a tropical humid climate with heavy rainfall and hot summer. The average temperature ranges from minimum 8^0 C to maximum 34^0 C throughout the year. The average humidity remains almost same with variation from 62% in winter to 87% in post monsoon period. The average annual rainfall of the district is 1904.4 mm.

Monthly rainfall pattern of the district for the year 2021 is illustrated graphically (Fig.1.5). The rainfall pattern of the district is uni-modal in nature. Peak rainfall is observed in the month of July and after that rainfall gradually recedes and reaches minimum in the month of December.

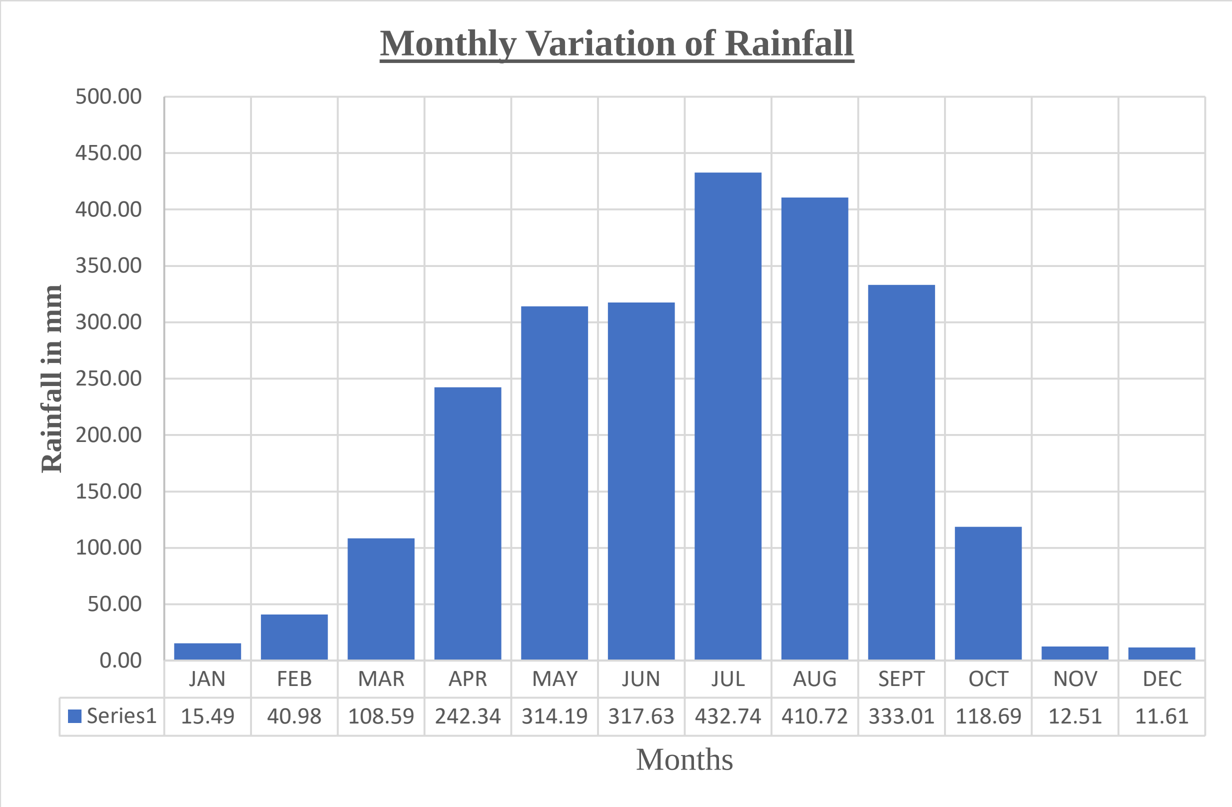

Fig. 1.5: Monthly variation of rainfall. (Source-IMD)

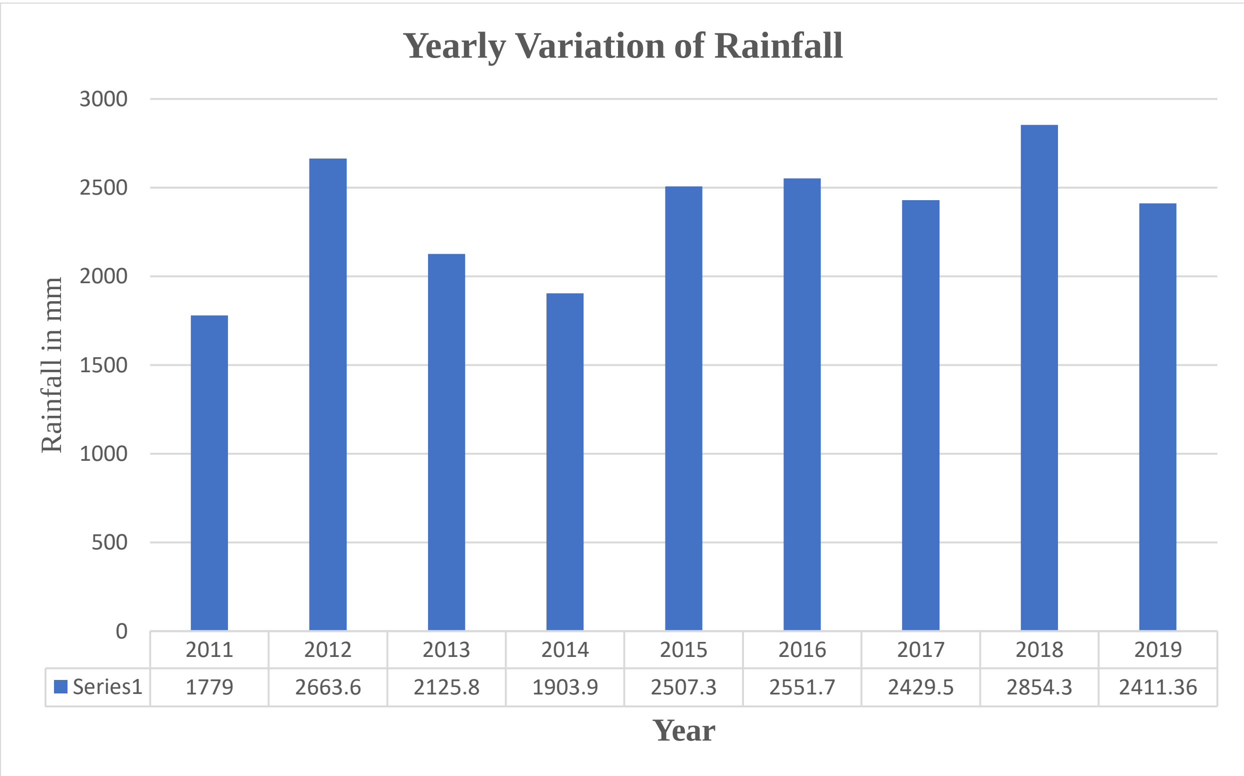

Fig. 1.6: Monthly and Yearly variation of rainfall. (Source-IMD)

1.7 Physiographic Setup

Physiographically, the district is divided into two units

(i) Northern alluvial region

(ii) Southern swamps or flood plains of the river Brahmaputra.

The northern alluvial part forms a flat land with heights of 120-140 m above MSL with a gentle slope towards south the river Brahmaputra. The regional gradient is from east to west which indicates the general flow direction of the Brahmaputra River.

The Brahmaputra River flows from east to west and from the main regional drainage. Its tributaries like Pagladia, Baralia etc. originating from Northern Himalayan foothill have a steep slope and shallow braided channels for considerable distances. They have coarse gravel and sandy beds and carry loads of silts and sand during flash flood. The elevation of land near the Brahmaputra is 5-10 m amsl and the flood water in the flood plain area is detained in low depression forming bil and marshy land along the main river course.

1.8 Drainage and Morphometry

The river Brahmaputra along with its tributaries like Pagladiya, Buradiya, Baralia etc. control the main drainage system of the district. The Buadiya and Pagladiya rivers flows from Northeast to southwest and Pagladiya north to south respectively. These two tributaries meet the Brahmaputra river in the southern part. The overall flowing trend of the Brahmaputra River is east to west.

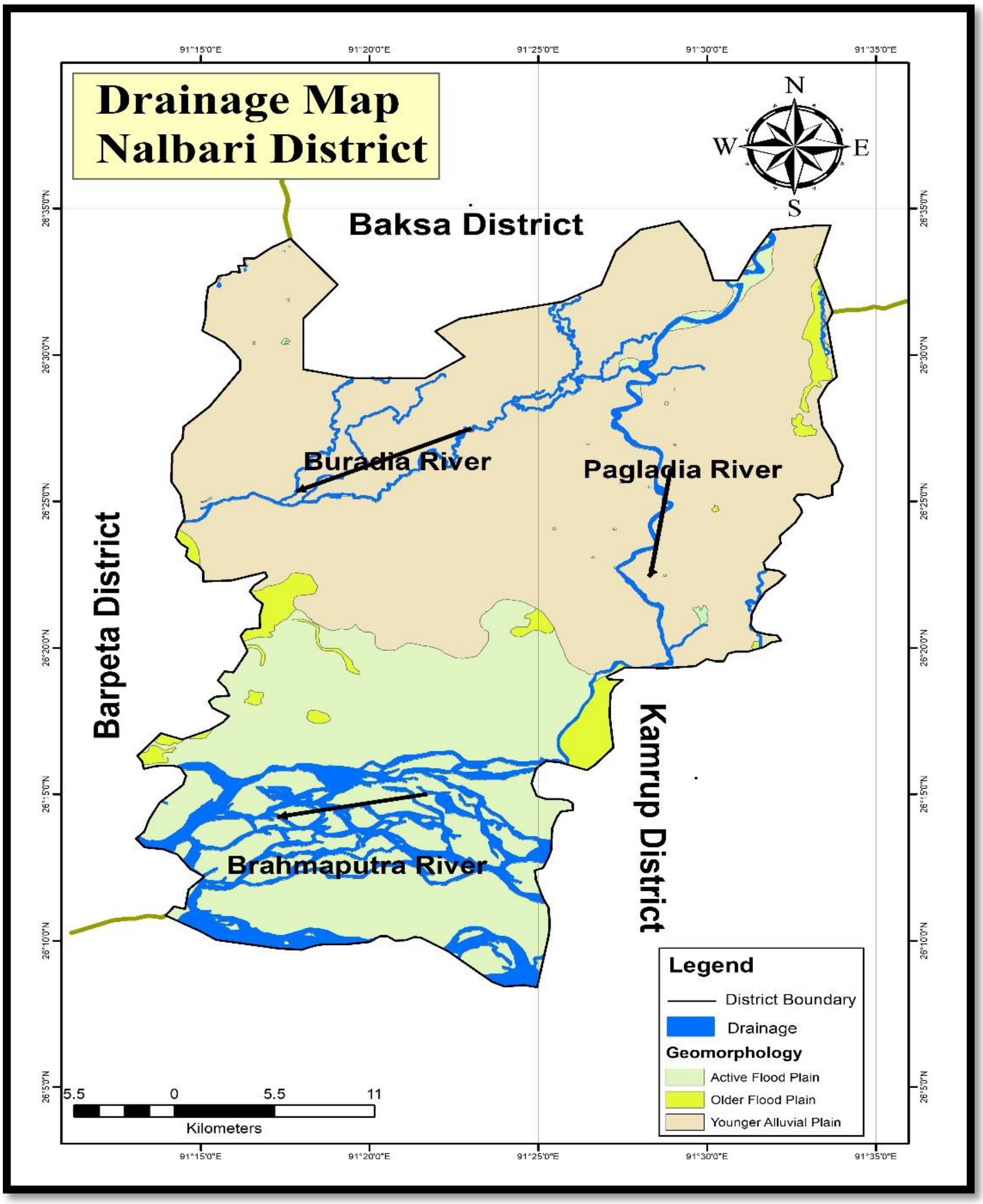

Fig. 1.7: Drainage Map, Nalbari District

1.9 Geology

Nalbari district forms part of the vast stretch of alluvial tract of the Brahmaputra valley with minor variation towards north and northeast. Geologically the entire area of Nalbari district is occupied by alluvial sediments of Quaternary age. The alluvium comprises unconsolidated sediments of clay, silt, sand. Gravel and boulders of quartz, feldspars etc. The younger alluvial cover deposited during the period comprises thick beds of clay, sand and gravel. The upper layer of the alluvial formation comprises clayey/sandy soil followed by coarse sand gravel beds at depth. This formation is a very good potential zone for ground water extraction.

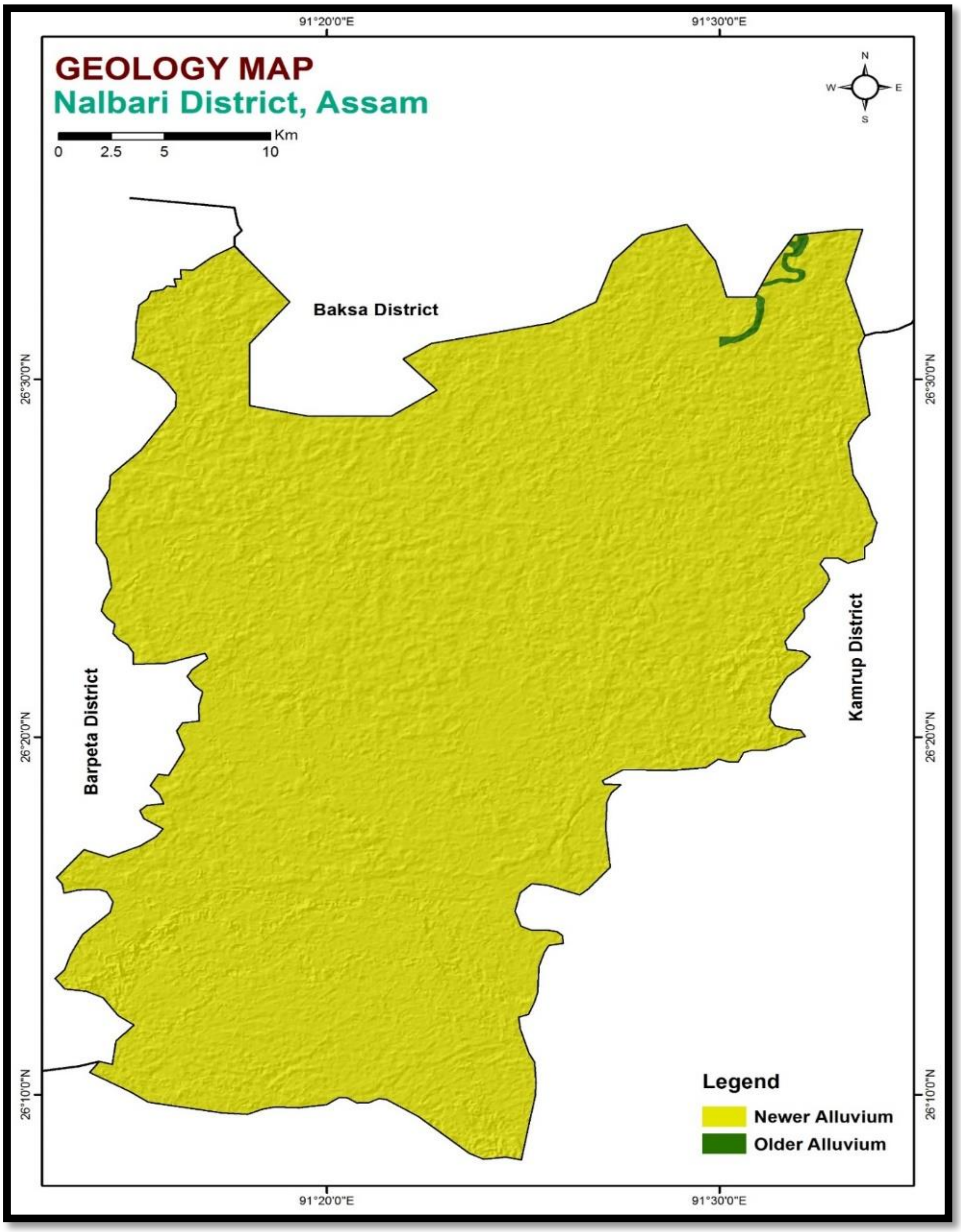

Fig. 1.9: Geology Map, Nalbari District, Assam.

1.10. Geomorphology

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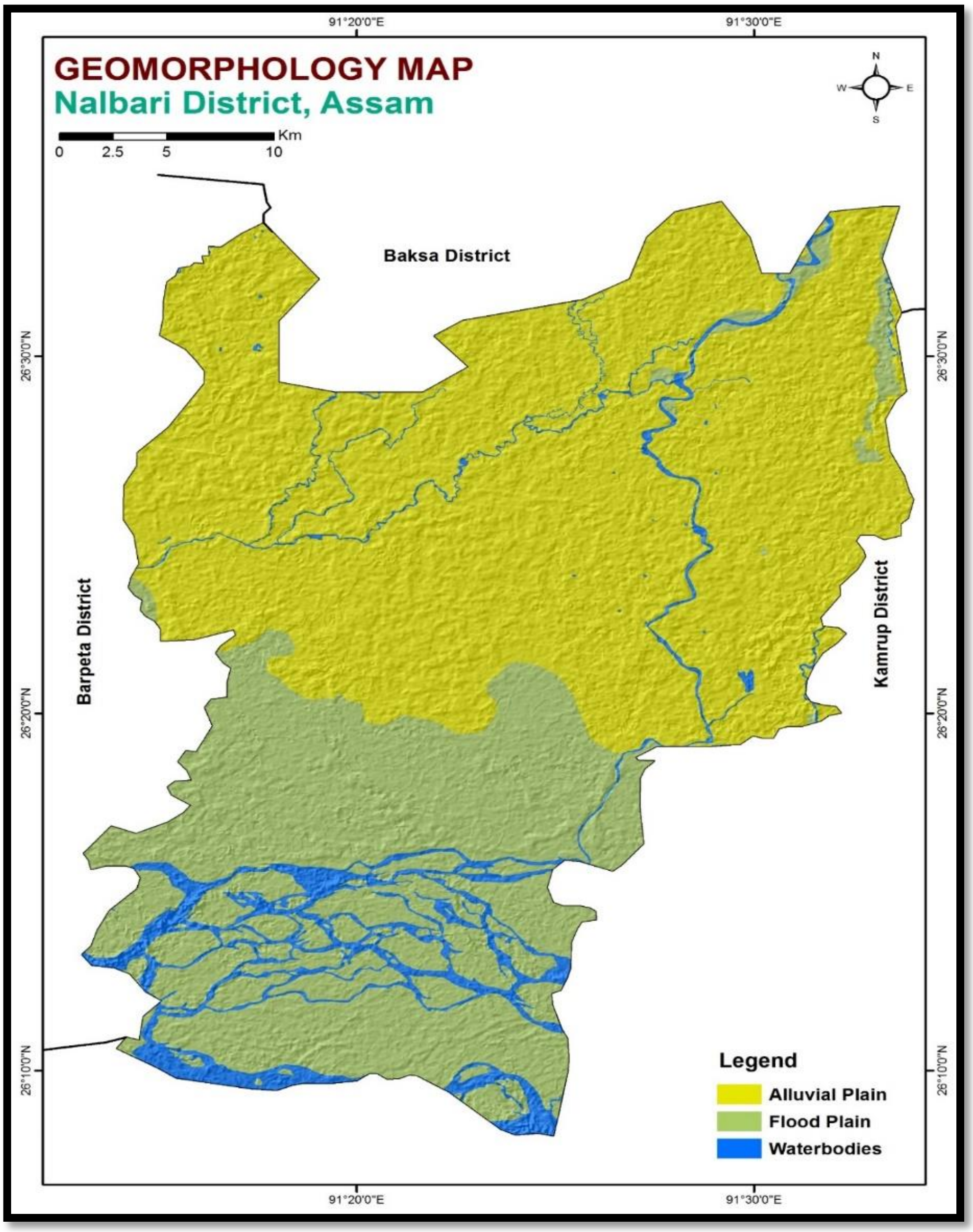

Fig. 1.10: Geomorphological Map, Nalbari District.

The elevation of land near the Brahmaputra is 5-10 m amsl and the flood water in the flood plain area is detained in low depression forming bil and marshy land along the main river course.

The flood plain and the alluvial plains only show gentle undulations at places. The elevation of the plains only ranges from 45 to 60 meters above mean sea level. In the southern and south-eastern parts, the elevation of the land and hill ranges varies from 40 to 50 meters mean sea level.

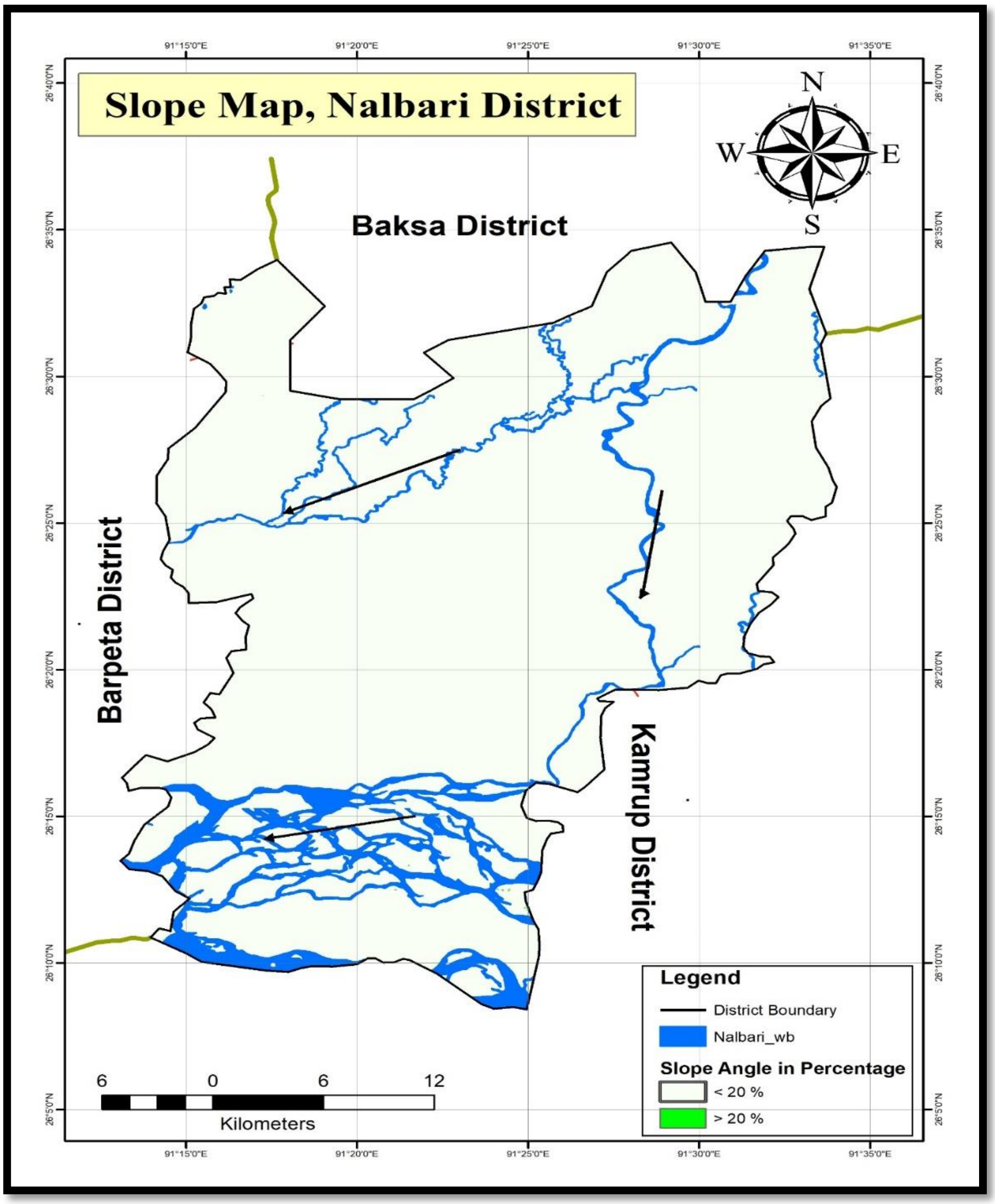

Fig.1.11: Slope Map, Nalbari District

1.11. Land use

Out of total geographical area of 1,00,957 hectares of land in Nalbari district, about 68.7% of the land is available for cultivation and 26.9 % is categorised as other non-cultivated land. Further, forest area is negligible in the Nalbari district. The following table shows the area of land put to different uses and their percentages to the total areas.

Table 1.3.: Land use statistics in Nalbari (2015)

Total geographical Area	: 1,00,957 ha
Area not available for cultivation	: 31,608 ha
Other cultivable land excluding fallow land	: 27,235 ha
Fallow land	: 4,373 ha
Net area sown	: 69349.46 ha
Area sown more than once	: 33881.54 ha
Gross Crop Area	: 103231 ha
Cropping intensity	: 148.86 %

Source: Agriculture inventory, Nalbari district 2015

1.12. Soil

The Soil condition of the district is a heterogeneous one. The Soil of the northern part of the district is clayey and loamy whereas middle part is loamy and sandy. The Soil of the southern part of the district is composed of sandy soil. Below table – 1.5 presents the block-wise soil profile of the district. Soil map of the area is given in Fig 9.

- 0-3% : - Level to very gentle sloping plain
- 3-8% : - gentle slopping plain
- 8-25%: - moderately sloping to moderately steeply sloping
- >25%: - steeply sloping to very steeply sloping

Table 1.4: Soil profile of Nalbari

Block	Soil Type		Area under different slope class (ha)			
	Major Soil Classes	**Area (ha)**	**0-3%**	**3-8%**	**8-25%**	**>25%**
Barbhag	Fine loamy to coarse loamy	6478	-	6478	--	--
	Fine loamy to sandy	314	314	-	--	--
	Total	**6792**	**314**	**6478**	--	--
Borigog Banbhag	Fine loamy to coarse loamy	2223	-	2223	--	--
	Fine loamy to sandy	13644	13644	-	--	--
	Total	**15867**	**13644**	**2223**	--	--
Barkhetri	Fine loamy to coarse loamy	3012	-	3012	--	--
	Fine loamy to coarse sandy	3730	3730	-	--	--
	Fine loamy to coarse loamy	26329	26329	-	--	--
	Total	**33071**	**30059**	**3012**	--	--
Madhupur	Fine loamy to coarse loamy	6239	--	6239	--	--
	Fine loamy to sandy	1147	1147	--	--	--
	Total	**7386**	**1147**	**6239**	--	--
Paschim	Fine loamy to coarse loamy	6102	--	6102	--	--
	Fine loamy to sandy	2555	2555	--	--	--
	Fine loamy to coarse loamy	3874	3874	--	--	--
	Marshy Land	1136	--	--	--	--
	Total	**13667**	**6429**	**6102**	--	--

Block	Soil Type		Area under different slope class (ha)			
	Major Soil Classes	**Area (ha)**	**0-3%**	**3-8%**	**8-25%**	**>25%**
Pub Nalbari	Fine loamy to coarse loamy	7247	--	7247	--	--
	Fine loamy to sandy	4702	4702	--	--	--
	Fine loamy to coarse loamy	939	939	--	--	--
	Total	**12888**	**5641**	**7247**	--	--
Tihu	Fine loamy to sandy	7374	7374	--	--	--
	Fine loamy to coarse loamy	3912	3912	--	--	--
	Total	**11286**	**11286**		--	--

Source: District Irrigation Plan, Nalbari, Assam.

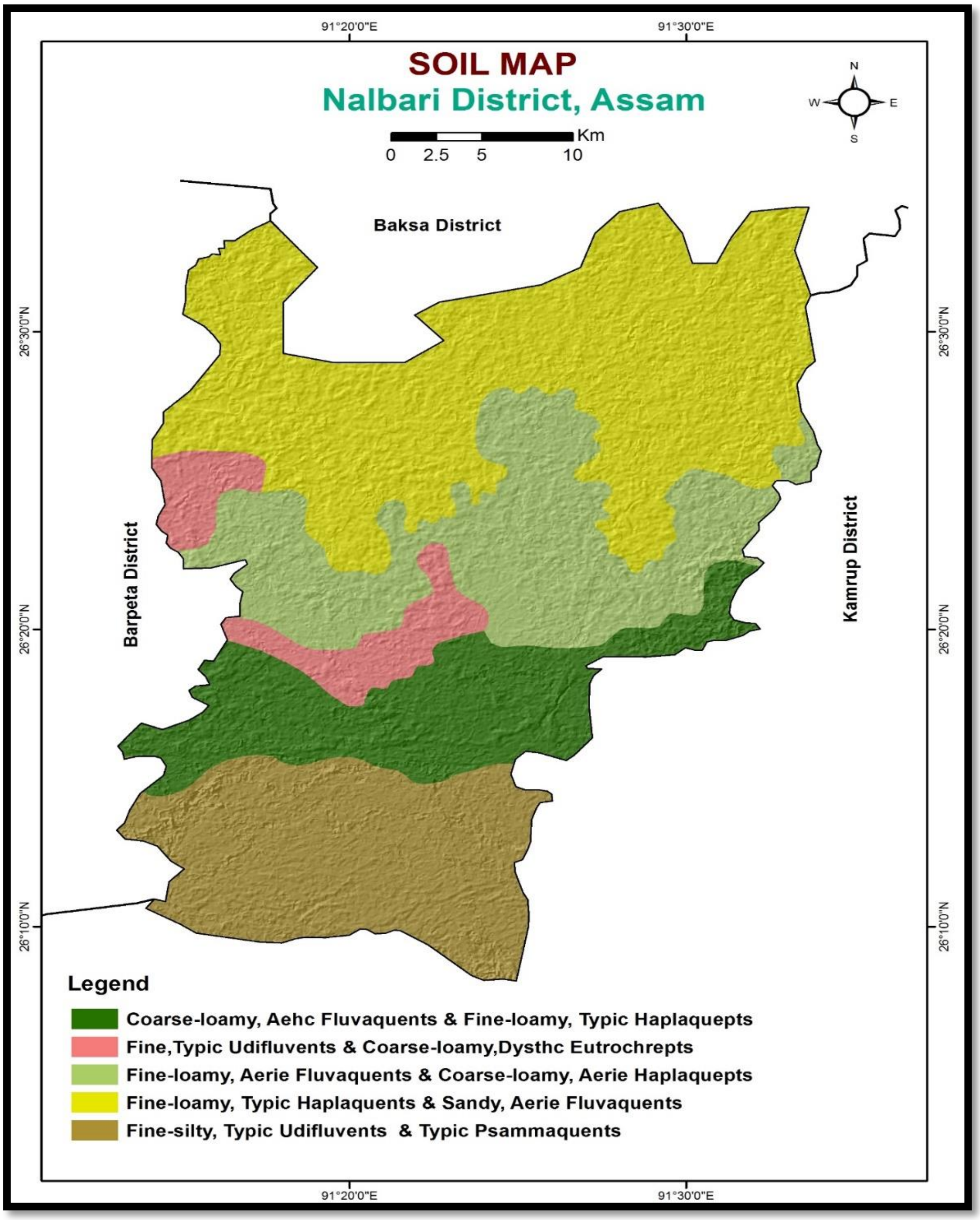

Fig.1.12: Soil Map, Nalbari District.

1.10 Agriculture & Irrigation

The district is predominantly a paddy growing area with other important crops like pulses, mustard, sugarcane, potato, vegetables and jute. Paddy is grown in low lands of the district which are suitable for rice cultivation. The sandy banks of the Brahmaputra River are suitable for vegetables and pulses. The red

It has been observed from records of Revenue department in the district that the Gross Cropped Area is 1,03,231 hectare out of which 43386 hectare and 12846 hectare i.e. around 42% and 12.4% of the area falls in Barkhetri and Borigog Banbhag Blocks respectively. Barkhetri and Borigog Banbhag Blocks also record for the maximum net sown area of 21575 hectare and 10883 hectares i.e. around 31.1% and 15.7% of the net sown area of the district. The cropping intensity in Barkhetri block is 201.1% which is highest among other blocks in the district. For rest of the blocks, the average cropping intensity is 148%. In the swampy and very low lands cultivation of jute is carried out. The average rainfall in the district although heavy is not uniform. The district receives about 90% of the total rainfall during monsoon. The rainfall is unevenly distributed and also varies annually from excess to shortage when farmers face wet or dry conditions. Irrigation has not been fully developed and is inadequate with no regular supply of water. So far, the extension of irrigational facilities in the district is mostly confined to a few rivers lift and flow irrigation schemes.

Table 1.5. Irrigation Based Classification of Nalbari district.

Name of the Block	Irrigated (Area in Ha)		Rainfed (Area in Ha)	
	Gross Irrigated Area	Net Irrigated Area	Partially Irrigated / Protective Irrigation	Un-Irrigated or Totally Rainfed
Barbhag	905	818.00	--	5189
Barkhetri	11728	6,256.00	--	31658
BorigogBanbhag	1390	794.00	--	11456
Madhupur	1085	746.00	--	5957
PaschimNalbari	1243	1,152.00	--	11541
Pub Nalbari	1082	914.00	--	10253
Tihu	1301	636.00	--	8443
Total	**18,734**	**11,316.00**	**--**	**84,497**

Source: Agriculture Department, Nalbari

1.11 Hydrology

The district has vast surface water resources. The Brahmaputra River along with its tributaries like Pagladiya, Buradiya, Baralia etc. carries enormous volume of water annually throughout the district. Besides these rivers there are numbers of tanks and ponds in the district which occupies nearly 8% of total geographical area of the district (Table 1.6).

Table: 1.6 Water bodies in Nalbari District

S. No.	Resources	Area (ha)
1	Ponds and tanks	3407.00
2	Derelict water bodies	3645.00
3	Beel fisheries	792.00
Total		**7844.00**

Source: Statistical Hand Book of Assam, 2021

Chapter 2

Data Collection and Generation

2.1 Data collection

Various data like rain fall data, hydrogeological data, exploration data are collected from previously existing data or newly generated or collected information in the AAP 2021-22.

2.1.1 Hydrogeological data

The entire study area is covered by 3 regular monitoring stations and 16 nos. of new key wells established for the purpose of the study during this AAP. Water level data were collected twice in November as Post-monsoon and in March for the Pre-monsoon period.

2.1.2 Exploration data

Central ground water board, North Eastern Region, Guwahati had undertaken exploration work in the district since 1980-81 and drilled 7 exploratory wells till date.

2.1.3 Meteorological Data

Meteorological data is collected from Tea Estates in the district and accessed free data of IMD.

2.1.4 Population and agriculture data

Population and groundwater dependency were collected from census 2011. All the data pertaining to agriculture were collected from District Irrigation Plan of Nalbari District for 2016-20 prepared by NABARD.

2.2 Data Generation

Data generation is important to fill up the gaps already existing in the district and this can be done after carefully observing the respective data gap maps. Generation of Water level data:16 nos. of key wells have been established to fill up the data gap.

Table 2.1. Key well location details.

Village	Latitude	Longitude	RL (mamsl)	Total depth of Pz/DW (mbgl)	Type (DW/Pz/Spring)	Aquifer group	Measuring point (magl)
Thankurchupa	26.57307	91.48506	62	4.2	DW	Alluvium	0.96
Danguapara	26.47137	91.37874	50	5.9	DW	Alluvium	0.95
Arikuchi	26.35443	91.44824	44	5	DW	Alluvium	0.80
Bihampur	26.41200	91.37045	45	5.5	DW	Alluvium	0.93
Koihati	26.37820	91.30919	41	6.5	DW	Alluvium	0.70
Chamata khata	26.40649	91.34936	43	5.6	DW	Alluvium	1.00
Parahkuchi	26.40366	91.23474	39	6	DW	Alluvium	1.63
Thakurbari	26.47483	91.26943	40	4.4	DW	Alluvium	0.93
Gobradal	26.48302	91.34855	48	5.7	DW	Alluvium	1.02
Pibalibari	26.37595	91.32051	42	4.75	DW	Alluvium	0.85
Daulasal	26.26944	91.22896	51	5.82	DW	Alluvium	1.05
Balizar	26.44262	91.38002	48	4.8	DW	Alluvium	1.20
Dalbari Kunia	26.51196	91.53902	56	4	DW	Alluvium	1.07
Malitara	26.47294	91.50105	54	8	DW	Alluvium	0.90
Sandakuchi	26.39650	91.42243	48	9.2	DW	Alluvium	0.60
Sagarkuchi	26.50274	91.50955	55	7	DW	Alluvium	0.75
Balua	26.35948	91.38097	45	7.2	DW	Alluvium	0.70
Dhamdhama	26.55275	91.44755	58	6.5	DW	Alluvium	0.81
Bartola	26.27266	91.31844	47	6	DW	Alluvium	0.90

Table 2.2. Water level measurement of key wells

Location	Depth-to-water level in mbgl	
	Nov-20	**Mar-21**
Arikuchi	1.6	2.16
Balizar	1.41	1.56
Balua	1.49	2.11
Bartola	2.42	3.31
Bihampur	1.87	2.77
Chamata khata	2.67	3.45
Dalbari Kunia	2.13	2.91
Danguapara	1.8	2.16
Daulasal	3.65	4.87
Dhamdhama	0.81	2.61
Gobradal	0.46	1.62
Koihati	1.51	2.41
Malitara	3.1	4.2
Parahkuchi	1.69	1.32
Pibalibari	1.35	2.08
Sagarkuchi	1.59	2.16
Sandakuchi	3.87	4.32
Thakurbari	1.44	1.21
Thankurchupa	1.14	2.65

2.3 Water Quality

To understand the chemical quality of groundwater in the study area and its suitability for domestic, drinking and agricultural utilization, and existing quality data of CGWB were collected. Water samples were collected from monitoring wells/ key wells for detailed analysis of iron, heavy metals and arsenic etc.

Table 2.3. Water quality data of samples collected during post-monsoon

Location	Type of sample	pH	EC	Turbidity (NTU)	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as CaCO3)	Cl-	SO_4^{-2}	NO_3^{-1}	F-	Ca^{+2}	Mg^{+2}	TH (as CaCO3)	Na	K	Fe	As (in ppb)
			(µs/cm) 25C	(in NTU)	(in mg/L)														
Salbari	HP	7.99	449.1	BDL	296.41	BDL	262.51	262.51	21.27	BDL	0.96	0.02	62.05	10.89	200	22.11	4.33	0.62	55.01
Borbhag	HP	8.09	508.9	BDL	335.87	BDL	299.14	299.14	28.36	BDL	2.67	0.02	32.03	52.17	295	3	5.05	0.4	0.81
Nalbarigaon	HP	7.92	375.1	BDL	247.57	BDL	207.57	207.57	17.73	BDL	3.23	0.06	26.02	24.26	165	20.79	2.27	0.4	15.07
Danguapara	DW	7.85	222.7	0.1	146.98	BDL	128.2	128.2	21.27	BDL	3.78	0.12	20.02	7.27	80	30.68	1.59	0.36	1.07
Gobradal	DW	7.69	424.2	BDL	279.97	BDL	244.2	244.2	21.27	BDL	34.06	0.16	36.03	24.25	190	23.73	3.98	1.4	43.44
Kaithalkuchi	HP	7.87	237.4	BDL	156.68	BDL	140.41	140.41	10.64	BDL	6.54	0.01	14.01	9.7	75	30.18	2.02	4.68	99.41
Haribhanga	HP	8.07	272.4	BDL	179.78	BDL	164.83	164.83	17.73	BDL	0.68	0.01	16.01	8.49	75	44.05	1.7	1.45	41.71
Thakurbari	DW	8.39	644.4	0.2	425.3	15	372.4	387.4	39	BDL	8.76	0.01	20.02	50.96	260	51.16	17.45	0.36	2.9
Parahkuchi	DW	8.15	292.2	0.1	192.85	BDL	170.94	170.94	21.27	BDL	0.9	0.02	14.01	14.56	95	37.61	3.53	0.31	9.3
Adabari	TW	8.09	397.2	BDL	262.15	BDL	213.67	213.67	31.91	BDL	BDL	0.01	22.02	36.4	205	13.73	5.89	0.26	2.64
Adabari	HP	7.6	253.9	BDL	167.57	BDL	97.68	97.68	21.27	0.01	5.35	0.01	20.02	14.55	110	5.64	1.06	0.45	6.69
Bartola	HP	7.88	222.8	BDL	147.05	BDL	140.41	140.41	14.18	BDL	1.84	0.02	22.02	15.77	120	10.94	4.19	0.45	0.29
Daulasal	DW	8.49	510.8	BDL	337.13	9	262.51	271.51	28.36	6.06	2.15	0.02	40.03	33.96	240	16.45	20.25	1.4	21.51
Gharathal	HP	8.01	309.1	BDL	204.01	BDL	140.41	140.41	31.91	BDL	0.33	0.02	30.02	20.62	160	4.47	4.65	0.4	3.94
Pibalibari	HP	7.9	381.4	BDL	251.72	BDL	189.25	189.25	31.91	BDL	0.09	0.02	26.02	29.11	185	10.53	9.05	0.49	1.07
Chamata khata	HP	7.63	162.1	0.1	106.99	BDL	103.78	103.78	14.18	BDL	0.12	0.05	18.01	10.91	90	7.04	3.05	0.4	0.03
Sondha	HP	7.78	532.1	BDL	351.19	BDL	244.2	244.2	35.45	18.66	2.05	0.02	26.02	47.32	260	14.24	6.11	0.5	6.03
Sandakuchi	HP	7.63	172.8	BDL	114.05	BDL	85.47	85.47	17.73	BDL	1.1	0.04	20.02	8.49	85	7.54	2.04	0.36	12.97
Niztapa	TW	8.29	387.1	BDL	255.49	BDL	256.4	256.4	14.18	BDL	1.84	0.02	20.02	38.83	210	15.02	8.97	0.36	0.55
Balitara	HP	7.96	219.4	BDL	144.8	BDL	115.99	115.99	10.64	BDL	11.85	0.49	26.02	9.7	105	9.35	2.12	0.4	4.73
Balitara	TW	8.08	233.7	0.3	154.24	BDL	158.73	158.73	67.36	BDL	0.36	0.09	26.02	40.04	230	4.86	2.75	3.43	69.05
Thankurchupa	DW	8.07	332.8	BDL	219.65	BDL	109.89	109.89	39	7.01	0.18	0.01	28.02	8.48	540	22.73	1.28	0.36	7.47
Malitara	DW	7.76	234.4	0.1	154.7	BDL	73.26	73.26	39	BDL	0.3	0.02	16.01	3.63	55	22.78	14.68	0.45	1.85
Dalbari Kunia	HP	7.89	248.4	BDL	163.94	BDL	128.2	128.2	24.82	BDL	3.76	0.02	24.02	10.91	105	19.11	5.72	0.5	1.46
Balua	HP	8.15	316.4	BDL	208.82	BDL	189.25	189.25	21.27	BDL	BDL	0.02	20.02	23.05	145	13.68	5.56	0.45	4.73
Balizar	HP	8.05	334.7	BDL	220.9	BDL	183.15	183.15	17.73	BDL	13.09	0.5	20.02	12.13	100	43.63	3.27	0.36	0.55
Bartola	TW	8.24	261.3	BDL	172.46	BDL	195.36	195.36	14.18	BDL	0.94	0.09	22.02	18.19	130	15.8	4.31	0.36	2.12

Table 2.4. Water quality data of samples collected during pre-monsoon

Location	Source	pH	EC	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as CaCO3)	Cl-	SO_4^{-2}	NO_3^{-1}	F-	Ca^{+2}	Mg^{+2}	TH (as CaCO3)	Na	K	Fe	As
			(μs/cm) 25C	(in mg/L)														(in μg/L)
Chamata khata	HP	7.75	139.10	91.81	BDL	79.36	79.36	56.72	3.42	0.91	BDL	24.02	16.98	130.00	8.64	4.00	3.73	6.12
Sandakuchi	HP	7.34	181.20	119.59	BDL	73.26	73.26	46.09	12.16	0.56	BDL	22.02	14.55	115.00	10.34	8.07	2.73	1.10
Balitara	TW	7.72	204.30	134.84	BDL	152.62	152.62	46.09	0.75	0.78	BDL	16.01	35.19	185.00	3.90	2.67	7.95	2.93
Balitara	HP	7.52	224.00	147.84	BDL	158.73	158.73	14.18	1.24	10.02	0.84	32.03	14.55	140.00	13.21	2.61	2.51	2.08
Bartola	HP	7.36	246.10	162.43	BDL	146.52	146.52	31.91	1.49	2.08	BDL	30.02	14.55	135.00	8.90	6.15	11.30	14.41
Malitara	DW	7.45	263.20	173.71	BDL	103.78	103.78	31.91	16.91	3.30	BDL	26.02	15.76	130.00	10.41	7.43	0.22	0.76
Adabari	HP	7.51	264.50	174.57	BDL	85.47	85.47	31.91	28.72	14.14	BDL	30.02	15.76	140.00	10.60	5.23	0.96	0.89
Dalbari Kunia	HP	7.44	273.60	180.58	BDL	109.89	109.89	31.91	19.16	8.83	BDL	30.02	8.48	110.00	20.42	8.14	5.43	2.01
Parahkuchi	DW	8.26	274.00	180.84	BDL	183.15	183.15	14.18	0.65	1.26	0.17	14.01	6.06	60.00	39.95	6.08	1.31	2.01
Kaithalkuchi	HP	8.16	274.90	181.43	BDL	177.04	177.04	10.64	8.69	11.69	BDL	10.01	12.13	75.00	26.00	9.16	11.66	35.80
Thankurchupa	DW	7.51	277.30	183.02	BDL	134.31	134.31	46.09	15.70	0.66	0.48	30.02	21.83	165.00	12.49	6.21	0.12	0.82
Haribhanga	HP	8.27	283.50	187.11	BDL	164.83	164.83	10.64	11.97	0.35	0.65	24.02	3.63	75.00	31.55	4.21	1.04	2.36
Gharathal	HP	8.41	285.40	188.36	12.00	140.41	152.41	56.72	6.45	0.95	BDL	40.03	25.47	205.00	14.20	6.01	1.15	1.10
Balua	HP	8.26	305.80	201.83	30.00	219.78	249.78	21.27	10.03	0.81	0.30	32.03	32.75	215.00	16.46	6.99	4.80	0.62
Gobradal	DW	8.22	313.80	207.11	BDL	183.15	183.15	14.18	49.07	0.24	0.07	20.02	10.91	95.00	47.01	7.59	11.63	46.26
Danguapara	DW	8.15	321.40	212.12	BDL	195.36	195.36	14.18	9.78	12.22	BDL	30.02	6.05	100.00	34.49	1.31	3.39	9.27
Niztapa	TW	8.36	324.40	214.10	12.00	225.88	237.88	7.09	17.30	0.64	0.50	42.03	29.11	225.00	8.63	3.12	5.09	4.98
Nalbarigaon	HP	8.12	369.50	243.87	BDL	225.88	225.88	21.27	10.02	10.88	BDL	26.02	21.83	155.00	21.21	8.56	1.18	0.76
Pibalibari	HP	8.34	384.50	253.77	15.00	225.88	240.88	31.91	14.48	0.83	BDL	44.04	20.61	195.00	26.90	11.45	0.75	0.82
Adabari	TW	8.39	407.20	268.75	12.00	164.83	176.83	46.09	19.02	0.62	BDL	50.04	19.39	205.00	15.50	7.49	4.92	3.87
Sondha	HP	7.60	416.00	274.56	BDL	225.88	225.88	46.09	31.28	1.84	BDL	48.04	30.32	245.00	19.72	6.81	8.15	19.97
Borbhag	HP	8.21	448.30	295.88	BDL	286.93	286.93	31.91	7.98	3.92	BDL	40.03	24.25	200.00	45.94	12.37	2.64	7.83
Salbari	HP	8.15	463.90	306.17	BDL	280.82	280.82	10.64	68.78	3.27	0.30	26.02	35.18	210.00	39.61	18.58	1.64	0.89
Daulasal	DW	8.40	503.30	332.18	15.00	299.14	314.14	24.82	24.84	0.90	0.08	62.05	26.67	265.00	18.60	30.04	0.43	2.08
Thakurbari	DW	8.19	625.80	413.03	BDL	384.61	384.61	39.00	0.21	0.08	0.12	28.02	35.18	215.00	51.45	8.94	0.14	5.21

2.4 Geophysical survey:

- A total 8 nos. of VES have been conducted (as per record) and all the interpreted results have been discussed.
- The thickness of the aquifers varies all over the district from 10-30 m.
- The maximum aquifer thickness is found to be respectively at Kardetola and Sapkata village of Nalbari district.
- The expected ground water bearing potential aquifers are in the depth ranges 6 to 110 mbgl.

Table 2.5. Electrical Resistivity (VES) carried out till date in Nalbari district.

Locations	Depth range (m)	Interpreted layer resistivity (ohm m)	Inferences
Arikuchi	G.L.-6.95	83.9	Topsoil with clay
	6.95-37.1	132	Sand formation
	37.1-58.8	56.7	Sandy clay
	>58.8	129	Sand and gravel
Bornadhi	G.L.-3.62	41.5	Topsoil with clay
	3.62-30.5	145	Sand formation
	30.5-91.3	108	Sand and gravel
	>91.3	96.5	Clayey sand
Bouragu	G.L.-2.65	29.3	Topsoil with clay
	2.65-58.6	68.2	Sandy Clay
	>58.6	99.9	Clayey sand
Gobradal	G.L.-0.818	51.6	Topsoil with clay
	0.818-11.4	27.8	Clay formation
	11.4-25.6	112	Sand formation
	25.6-78.6	68.1	Sandy clay
	>78.6	117	Sand formation
Jajiabari	G.L.-4.3	43.3	Topsoil with clay
	4.3-7.46	14.8	Clay formation
	7.46-68	184	Sand formation
	>68	89.2	Clayey sand
Kardetola	G.L.-1.25	46.9	Topsoil with clay
	1.25-7.35	15.6	Clay formation
	7.35-99.3	85.4	Clayey sand
	>99.3	151	Sand formation
Sapkata	G.L.-1.26	94	Topsoil with clay
	1.26-4.55	59.1	Sandy Clay
	4.55-44.7	125	Sand with gravel
	44.7-115	237	Sand formation
	>115	3.12	Clay formation
Thuikata	G.L.-0.474	68.9	Topsoil with clay
	0.474-2.85	32.5	Sandy Clay
	2.85-34.3	76.8	Clayey Sand
	>34.3	107	Sand formation

2.5 Exploratory Drilling

Central Ground Water Board, North Eastern Region, Guwahati had began exploration in the district since 1980-81 and drilled 9 exploratory wells/Piezometers combinely till date. During AAP 2021-22 no exploration work taken place in the Nalbari District. A list of wells constructed in the area was prepared incorporating location, well designs and the aquifer parameters etc. The depth range of the wells varies from 30.40 to 304.65 mbgl.

Table 2.6. Details of Ews/Ows/Pzs in Nalbari District, Assam

Long	Lat	Location	Tpye of well	Depth of Drilled (m)	Depth of constr. (m)	Zones / Fractured encountered upto 50 m	Zones / Fractured encountered upto 100 m	Zones / Fractured encountered upto 200 m	Static Water level (mbgl)	Discharge (m3/hr)	Draw Down (m)	T (m2/ day)	Specific Capacity (lpm/m)	Storage co-efficient	Formation
91.4861	26.368	Bijalighat-EW	EW	304.62	155.00	30-50	50-63,74-80	101-107, 137-152	2.28	162.10	8.80	2488.8	307.01	4.510-5	Alluvium
91.3750	26.335	Bongaon-EW	EW	301.69	143.00	41-50	50-53, 50-53, 63-71, 83-85	101-107, 116-125, 134-140	3.06	206.40	4.385	1396.9	784.49		Alluvium
91.5169	26.400	Ghagrapar-I-PZ	PZ	36.60											Alluvium
91.5181	26.417	Nankarvira-EW	EW	30.50	27.00	20.-26									Alluvium
91.4747	26.418	Balilecha-EW	EW	36.10	33.00	20-22			3.15	46.00					Alluvium
91.5000	26.785	Bogajuli-EW	EW	72.00	63.00	44-50	51-60		12.6	16.32	0.43	958	634.88		Alluvium
91.3336	26.201	Billeswar Dewalaya-EW	EW	109.00	105.00		60-66, 78-90, 92-100	100-103	2.73	20.00	0.29	98.86	1149.42		Alluvium
91.3856	26.317	Mugkuchi-EW	EW	202.00	171.00		67-79,81-93	107-121, 135-145, 165-168	3.01	81.06	0.51	2295	264.00		Alluvium
91.4253	26.289	Laharkata-EW	EW	195.00	173.00		80-86, 90-102	114-120, 140-152, 164-170	10.9	49.50	9.04	147	91.26	3.92*10-4	Alluvium

Chapter 3

Data Interpretation, Integration and Aquifer Mapping

3.1 Geophysical Exploration and Aquifer Characterization

Large numbers of constructions in the study area of Nalbari posed constraints resulting in limited spaces for resistivity surveys and only the current electrodes spread available was in the range of 500 m and 700 m. The VES observed can be located on **toposheets (**78N/07 and 78N/11**)** with the co-ordinates given along with results. KH, KQ, A, HKH, HK, HAK and HA type VES curves were obtained.

The result of VES survey has shown that the subsurface formation is sand and clay dominated and gravel occur as intercalations with sand.

3.2 Aquifer Dispositions.

The subsurface geology of Nalbari District is interpreted based on exploration data of CGWB. From the examination of this litholog it is observed that the northern and western most part of the district is mainly sand dominated which gradually occupied by clay layers while moving towards the eastern and southern part of the district. The maximum depth of well drilled up to 304.6 mbgl at the central part of the district in the Bongaon village which shows dominance of sand and gravel up to 200m and prominent clay layers are observed further up to 300m. The lithologs and the lithology identified in VES survey are used to understand 2D and 3D disposition of aquifer.

The drilled depth of CGWB's 8 exploratory well ranges from 50 to 304.6 mbgl Distribution of well as per drilling depth indicates that 50%wells are shallow wells wand rest 50% are deep wells. (Table 3.1).

Table 3.2. Distribution of EW based on drilled depth.

Depth	Within 50m	50- 100m	100-150	150-200	200-250	250-305	Total
No. of wells	0	2	2	0	1	2	10
% Of well	0	28	28	0	16	28	100

Plotting of EW locations in the geomorphologic map indicate that majority of wells were constructed younger alluvial plains. As per the geometry the aquifers have been classifies in to shallow and deeper aquifer on the basis of their depth of occurrences.

Top clay layer followed by mono aquifer with a thickness of 15 to 45 m occurs down to a depth of 50 m below ground level in most part of the district but in flood plain area, top clay layer is about exposing sand with occasional silt down to a depth of 50 m.

Zones extending below 50 m depth are considered deeper aquifer vertical as well as horizontal extension of the aquifer zone has been revealed by the exploratory drilling of Central Ground Water Board. Central Ground Water Board drilled seven tube wells at Daulasaal, Belsor, Bongaon, Kathalbari, Chamarkuchi, Bijalighat, Damdama. Lithological logs of the boreholes are given Appendix-I and hydrogeological data is given in table-2.8. Lithological sections and Panel diagram prepared on the basis of lithological logs of deep tube wells. It is seen that in the northern part of the district, we can get mainly aquifer system.

The lithologs of drilling data and the lithology identified in VES survey are used to understand 2D and 3D disposition of aquifer.

A. 2D dispositions of aquifer

Three sections are prepared to visualize the aquifer disposition

(i) An East-West section from Bijalighat to Daulasaal in the Younger alluvial plain. (Fig. 3.1).

(ii) A Northeast - Southwest section from Chamarkuchi to Daulasaal in the younger alluvial plains (Fig. 3.2).

(iii) A North – South section from Gobradal to Kathalbari in the younger alluvial plains (Fig. 3.3).

In the alluvial plains sand formation is dominated and the thickness of sand formation is decreasing towards south and the clay is dominated to the southern part near Kathalbari area. Presence of sand and gravelly sand formation with a very good thickness around 100 m in the central part of the district and the thickness decreases towards Bijalighat in the east and Kathalbari in south found to be 30m to 40 metres in thickness. Greyish Sand mixed with boulders and pebbles marked a good thickness of horizon.

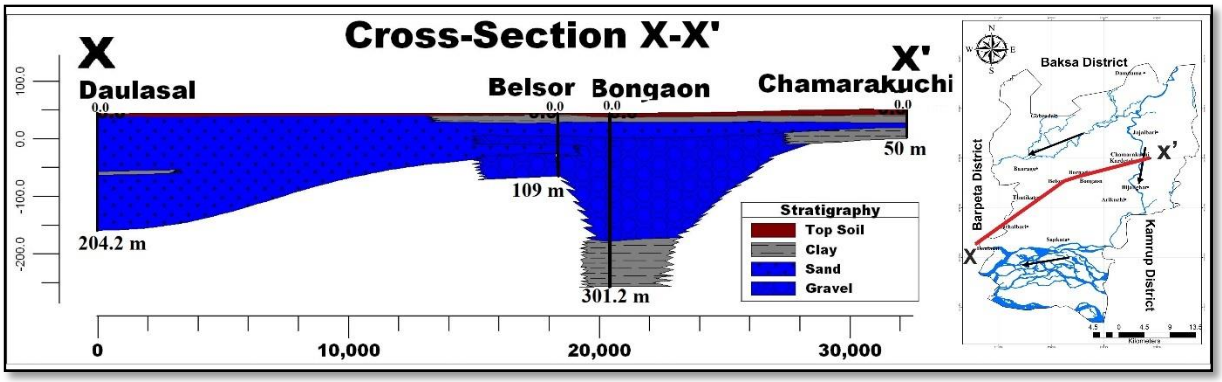

Fig.3.1: 2D disposition along *Northeast - Southwest direction*.

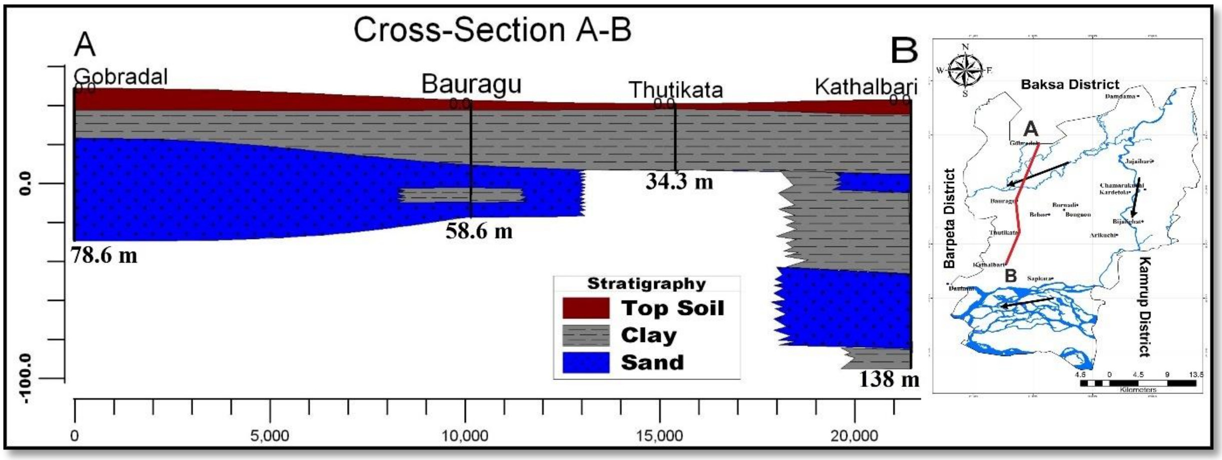

Fig.3.2: 2D disposition along *North – South* direction.

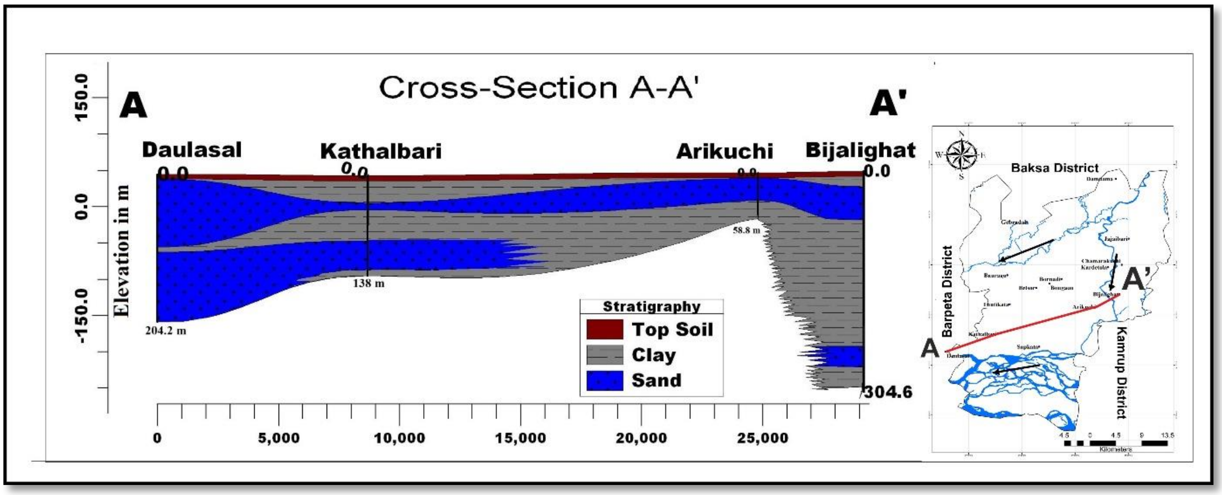

Fig.3.3: 2D disposition along East-West direction.

The East to West directions the wells has been constructed in the younger alluvial pains. Sandy formations are clearly dominated central portions of the district and decreases towards other parts. The thickness of clay zone are more than 150 m in the eastern and southern boarder.Apart from the clay horizon sand and sand with gravel zones are present in the middle position which demarcate the aquifer system. Maximum depth of the well is 304.6 metres in the Bijalighat Exploratory well.

The well found in the flood plain has very good thickness of sandy formations throughout the entire depth of well separated by clay layers. Good thickness of sand is present sandwiched between two clay layers in the central part but their horizontal extension makes this zone unconfined. Overall scenario shows that the system is mono-aquifer system with very fine clay layers.

Sub-surface geology and ground water conditions are described in chapter 01. It shows that aquifer in the area can be classified into two groups; i.e.

i) Shallow Aquifer – Depth ranges up to 50m bgl.

ii) Deeper Aquifer – Depth range below 50m bgl.

I) Shallow aquifer system

Shallow aquifer system is considered to be within 50 m below ground level. Within this depth total thickness of aquifer ranging from 35 to 40 m in the younger alluvium and depth range of aquifer is up to 50m towards the western past in the Daulasaal area which falls in the active flood plain area. The aquifer geometry of younger alluvium is similar of flood plain deposits. However, in older alluvium thickness of aquifer is less due to lack of wells the geometry couldn't be identified. Ground water structures contains in flood plain, younger and older alluvium in shallow aquifer zones can give yield varies from 40 to 120 m^3/hr for economic draw down.

II) Deeper Aquifer System:

Deeper aquifer system in the depth ranges 50 to more than 200 m possess multiple sand and gravel layers with in a aquifer having cumulative thickness of more than 70 m. These tube wells are giving yield of 20 to 162 m^3/hr; irrespective of flood plain, older and younger alluvium.

B. 3D disposition of aquifer

The aquifer disposition of the area in the 3D block diagram indicates presence of single aquifer system with multiple zones separated by clay layers.

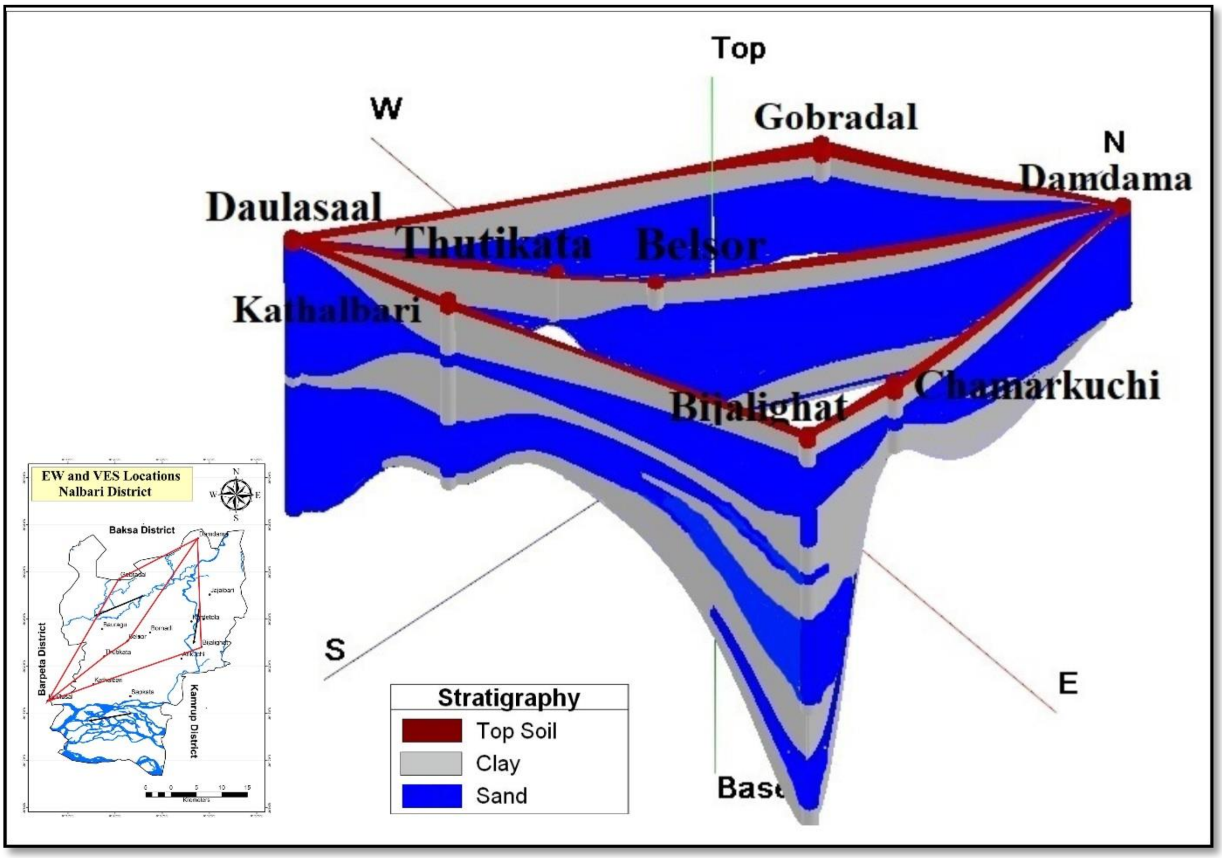

Fig.3.4: 3D disposition of aquifer in the study area.

3.3 Ground water level

CGWB, NER has 03 nos. of groundwater monitoring stations in the district. During NAQUIM study 16 nos. of key wells were established covering most of the blocks of the district. During AAP 2021-22, water level of the GWMS was measured three times in a groundwater year. The key wells were established in November, 2021 and the water levels of the key wells were monitored during November 2021 and March 2022. Water level data of the district were summarized in Table 3.3.

Table 3.3. Pre- and Post-monsoon depth-to-water level and fluctuation of water level

SN	Locations	Pre-monsoon DTW (mbgl)	Post-monsoon DTW (mbgl)	Fluctuation(m)
1	Thankurchupa	2.65	1.14	1.51
2	Danguapara	2.16	1.8	0.36
3	Arikuchi	2.16	1.6	0.56
4	Bihampur	2.77	1.87	0.9
5	Koihati	2.41	1.51	0.9
6	Chamata khata	3.45	2.67	0.78
7	Parahkuchi	1.32	1.69	0.37
8	Thakurbari	1.21	1.44	0.23
9	Gobradal	1.62	0.46	1.16
10	Pibalibari	2.08	1.35	0.73

11	Daulasal	4.87	3.65	1.22
12	Balizar	1.56	1.41	0.15
13	Dalbari Kunia	2.91	3.1	0.19
14	Malitara	4.2	2.13	2.07
15	Sandakuchi	4.32	3.87	0.45
16	Sagarkuchi	2.16	1.59	0.57
17	Balua	2.11	1.49	0.62
18	Dhamdhama	2.61	0.81	1.8
19	Bartola	3.31	2.42	0.89

The pre-monsoon water level in the younger alluvium varies from 1.21 to 4.87 mbgl. The north-west part of the district water level is found under 2.0 mbgl which show a water logging condition. This area falls in the flood plain of Buradia River which flow towards south from the north.

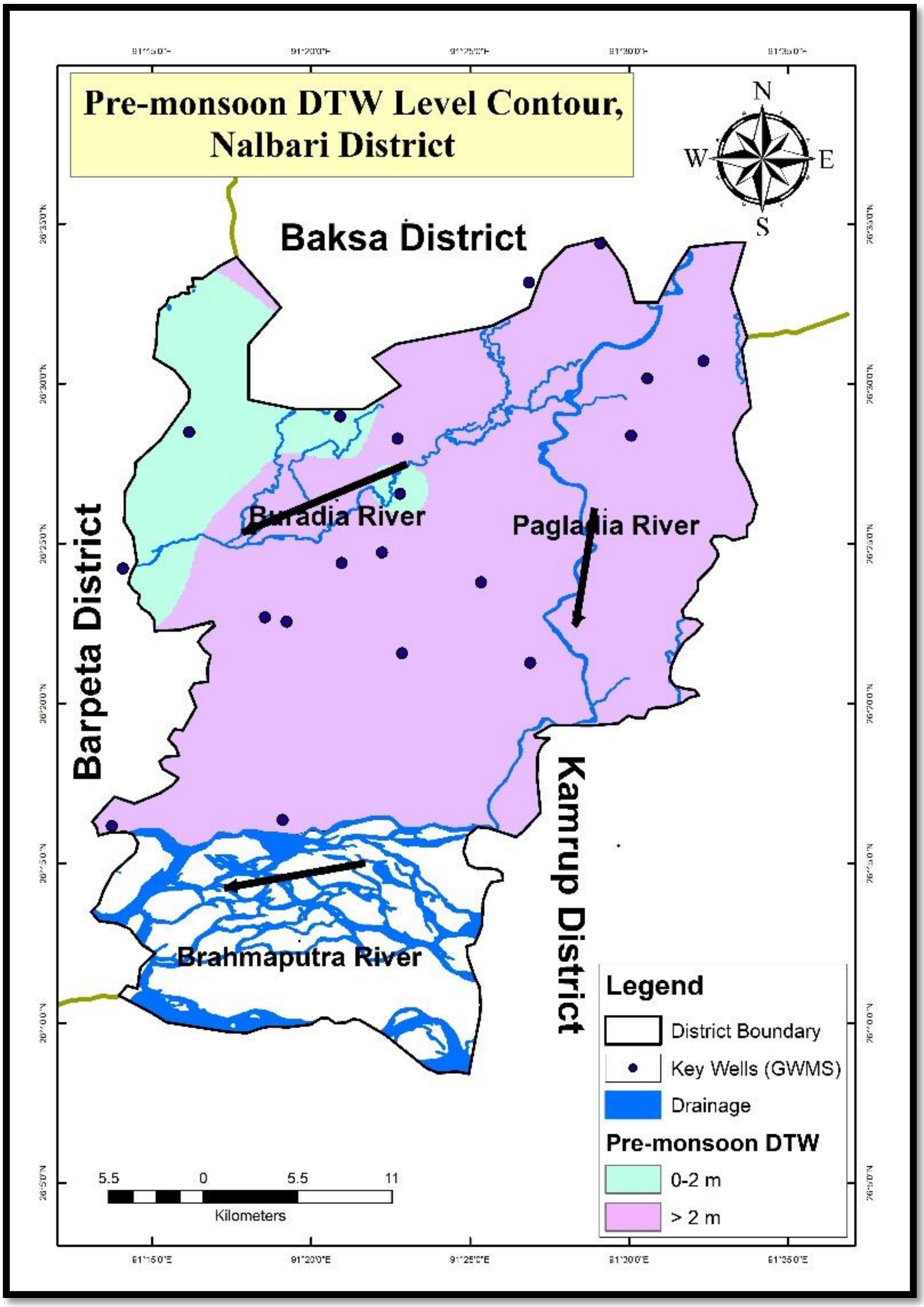

Fig. 3.5: Pre-monsoon DTW level contour Nalbari District, Assam

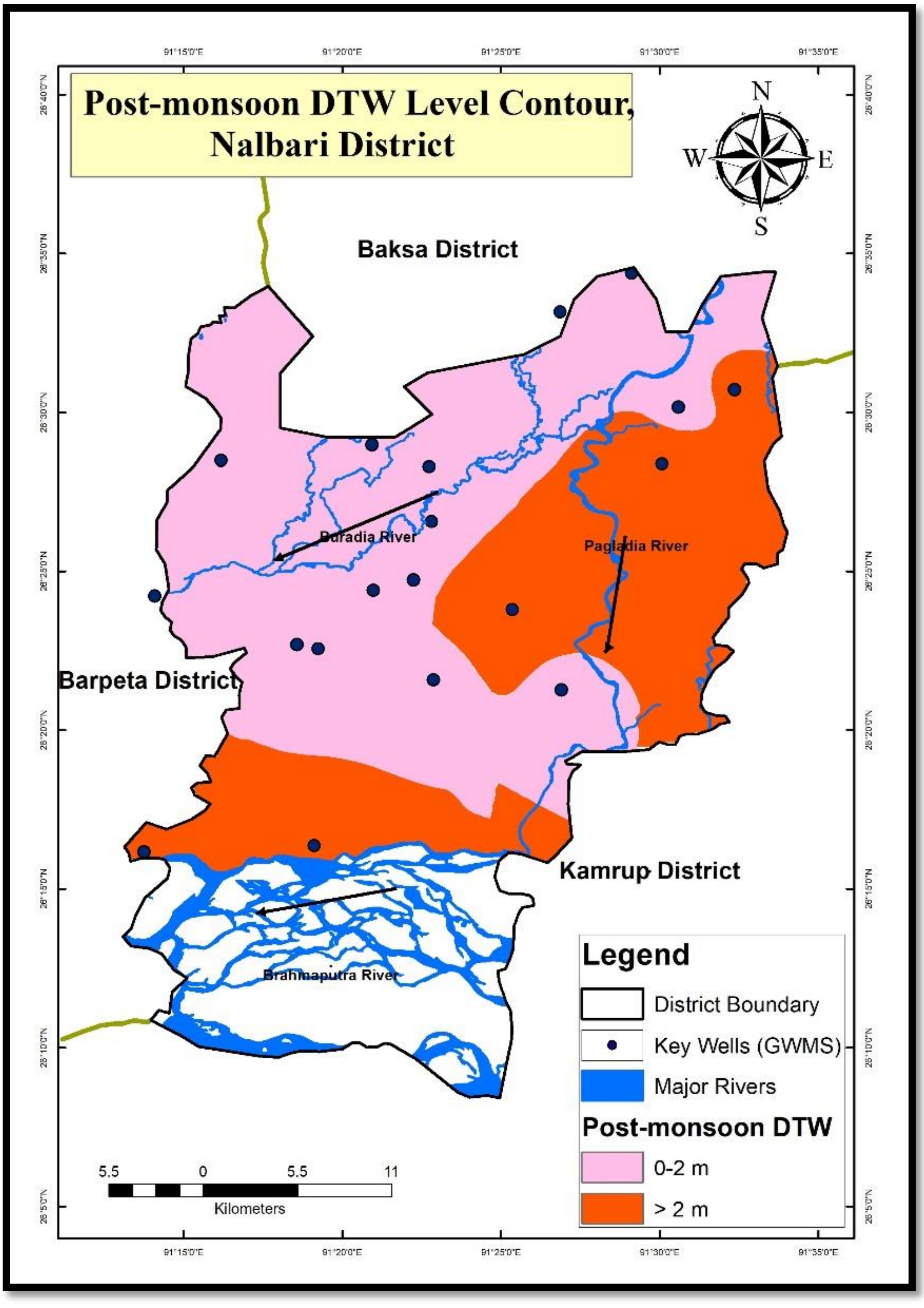

Fig.3.6: Post-monsoon DTW level contour of Nalbari District, Assam

The post-monsoon water level in the younger and older alluvium varies from 0.46 to 3.87 mbgl. The western part of the district shows water level with in 2.0mbgl where as in the eastern and southern flood plain part show water level more than 2.0 mbgl.

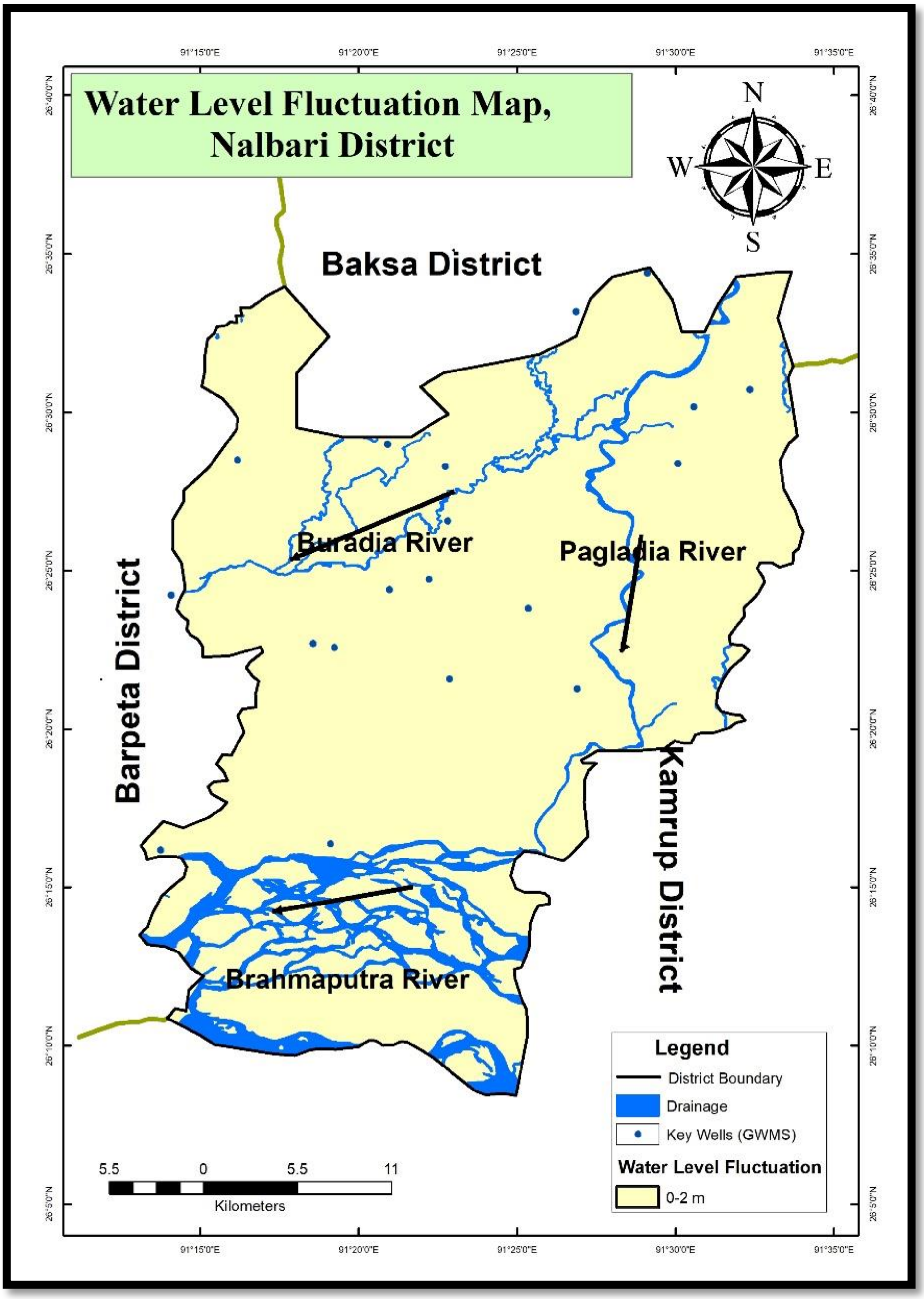

Fig.: 3.7. Water level fluctuation of Nalbari District, Assam

Fluctuation of water level in the younger alluvium varies from 0.15 to 2.17 mbgl. The minimum fluctuation is seen Balizar area where the maximum water level fluctuation is seen in Dalbari Kunia area. (Fig 3.7)

3.3.1 Ground Water Movement

The water table contour of phreatic aquifer has been prepared based on water level data with respect to elevation of ground water monitoring stations from mean sea level (Fig. 3.8). The contour map shows that water table contour of Nalbari district varies from 37.68 m to 59.35 m above mean sea level (Fig.3.8). In general groundwater movement is towards south, i.e., toward the river Brahmaputra and conforms to the general topography of the district. The

Buradiya river, the Pagladia river and other tributaries of the Brahmaputra are effluent in nature i.e., they receive ground water.

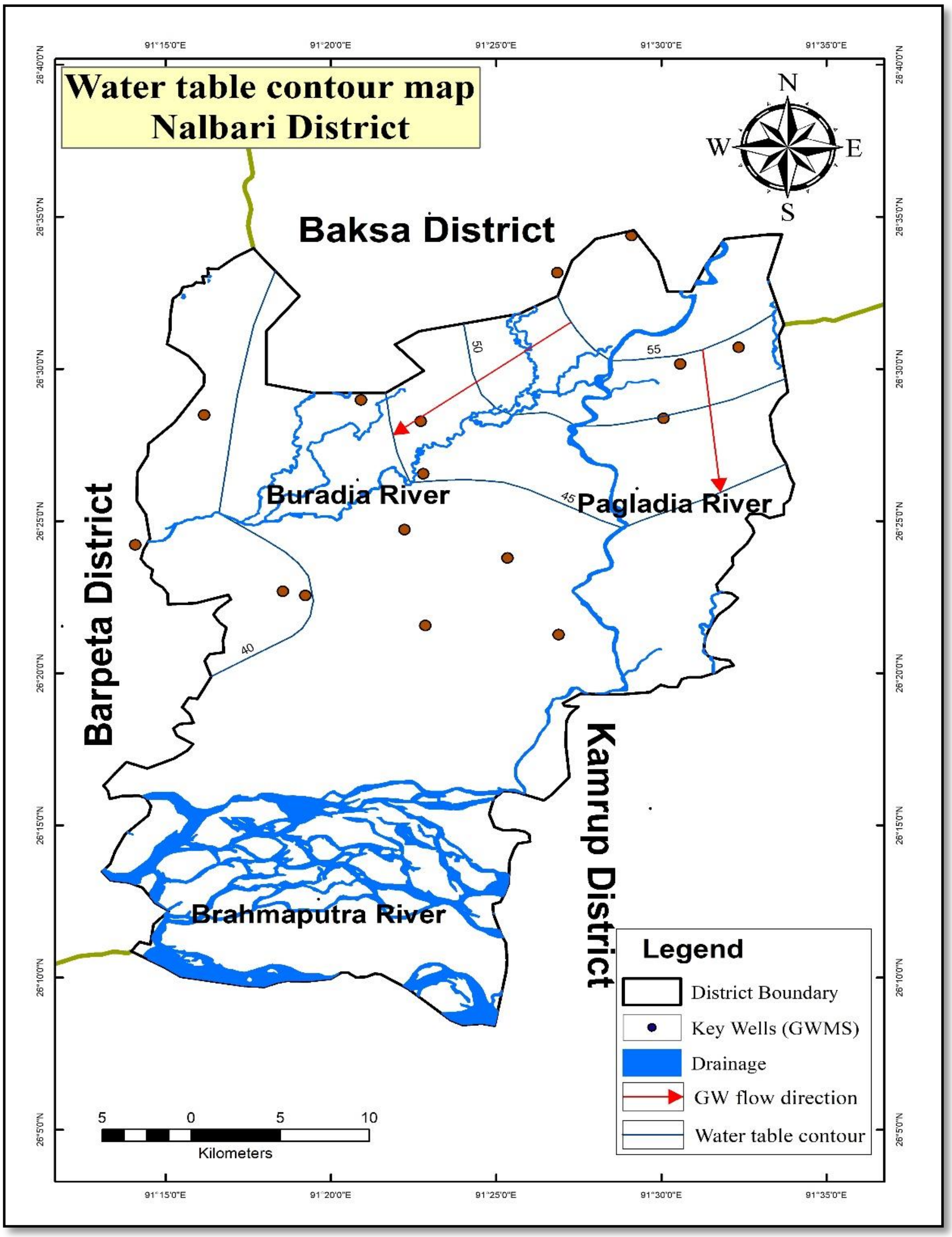

Fig. 3.8: Water table contour of Nalbari District, Assam

3.3.2 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 shown in Fig.: 3.9 and Table 3.4.

Table 4.3. Trend of Water levels in GWMS Wells

SN	Well No	Locality/Name	No. of years	Water Level Trend	
				Slope	Remark
1	78N3B4	Arikuchi	10	0.003	Rise
2	78N3B3	Tihu	10	-0.019	Fall
3	ASBP14	Daulasaal	9	-0.062	Fall

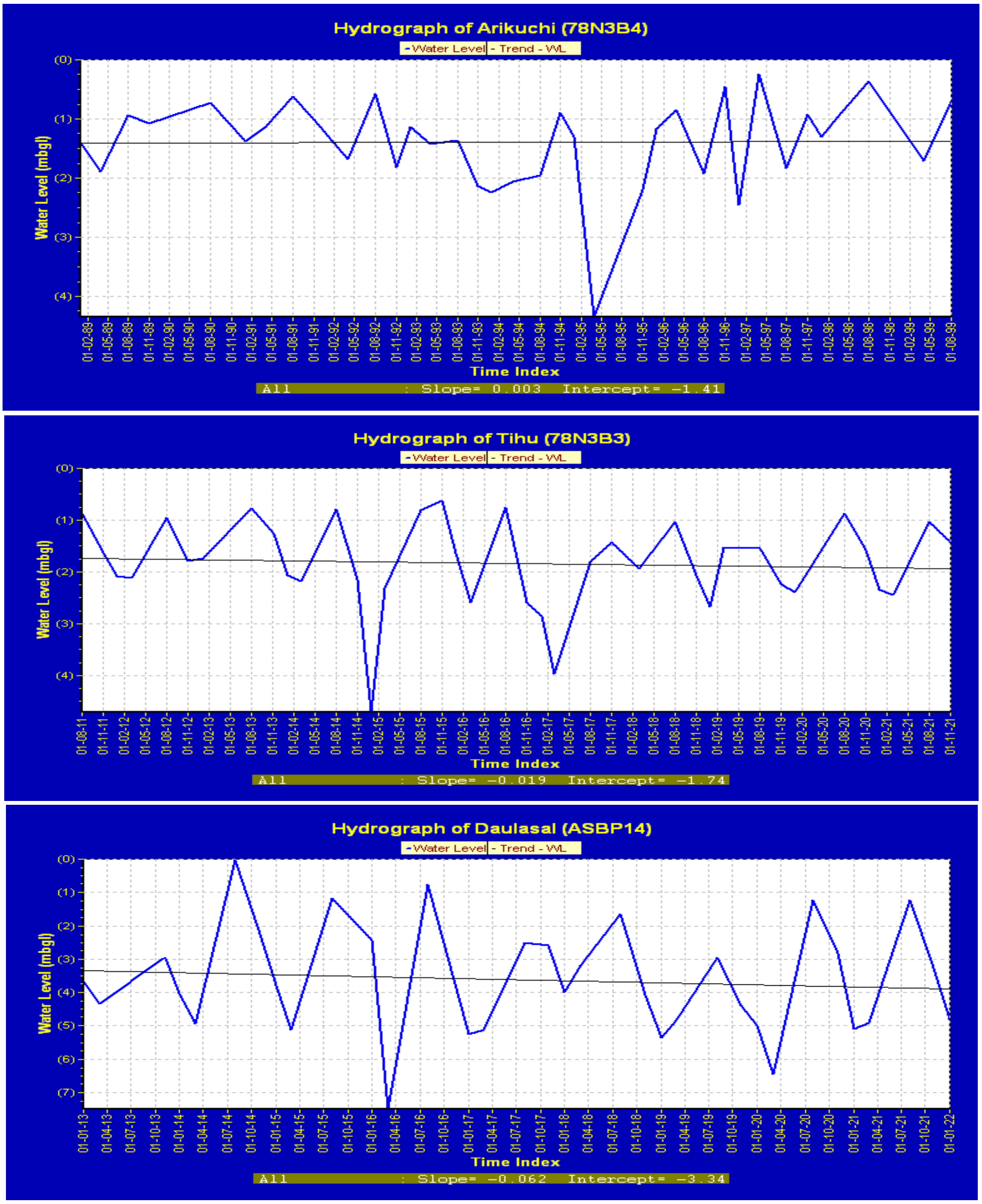

Fig. 3.9: Hydrograph of Ground Water Monitoring Stations in Nalbari District, Assam

3.4 Ground water quality

To study the ground water quality of Nalbari district chemical analysis of collected ground water samples were carried out in the NABL accredited regional chemical laboratory of Central Ground Water Board, North Eastern Region, Guwahati. From the entire district 27 samples have been collected in the Pre-monsoon of which 7 from dug well, 16 from hand pump and 4 from deep tube well whereas 25 samples in the post-monsoon out of which 7 samples were from dug wells and 15 samples from hand pump of 20-30m depth and 3 from 120-130 m tube well. The chemical analysis data during Pre-monsoon and Post-monsoon season are given in the Table 2.5 and Table 2.6 respectively. Summary of the analyzed data are given below in the table 4.1 and 4.5. Table 3.2 – Summarized chemical quality of water samples collected during post-monsoon.

Table 4.1– Summarized chemical quality of water samples collected during Pre-monsoon.

Sl. No.	Chemical constituents and other parameters	Unit	Maximum	Minimum
1	pH		8.49	7.60
2	EC	(µs/cm) 25°C	644.40	162.10
3	Turbidity	NTU	0.1	BDL
4	TDS	mg/l	425.30	106.99
5	CO3-2		15.0	BDL
6	HCO3-1		384.61	73.26
7	TA (as CaCO3)		384.61	73.26
8	Cl-		56.72	7.09
9	SO4-2		68.78	0.21
10	NO3-1		14.14	0.08
11	F-		0.07	BDL
12	Ca+2		62.05	10.01
13	Mg+2		35.19	3.63
14	TH (as CaCO3)		540	55
15	Na		51.45	3.90
16	K		30.04	1.31
17	Fe		11.66	0.12
18	U	µg/l	NA	NA
19	As		99.41	0.03

Table 4.2– Summarized chemical quality of water samples collected during post-monsoon.

Sl. No.	Chemical constituents and other parameters	Unit	Maximum	Minimum
1	pH		8.41	7.34
2	EC	(µs/cm) 25°C	625.80	139.10
3	Turbidity	NTU	0.20	BDL
4	TDS	mg/l	413.03	91.81
5	CO3-2		30.0	BDL
6	HCO3-1		384.61	73.26
7	TA (as CaCO3)		384.61	73.26
8	Cl-		56.72	7.09
9	SO4-2		68.78	0.21

10	NO3-1		14.14	0.08
11	F-		0.84	BDL
12	Ca+2		62.05	10.01
13	Mg+2		35.19	3.63
14	TH (as CaCO3)		265	60
15	Na		51.45	3.90
16	K		30.04	1.31
17	Fe		11.66	0.12
18	U	**µg/l**	NA	NA
19	As		46.258	0.619

Table 4.3 – Summarized chemical quality of water samples collected during Pre-monsoon.

Type of Structure	**No. of Sample analysed**	**Conc. Of Iron(mg/l)**		**pH value**		**As (µg/l)**	
		< 1	**> 1**	**<7**	**>7 to < 8.5**	**<10**	**>10**
Dug wells	7	5	2	0	7	5	2
Hand Pump	16	14	2	0	16	11	5
Tube Well	4	3	1	0	4	3	1

Table 4.4 – Summarized chemical quality of water samples collected during post-monsoon.

Type of Structure	**No. of Sample analysed**	**Conc. Of Iron(mg/l)**		**pH value**		**As (µg/l)**	
		< 1	**> 1**	**<7**	**>7 to < 8.5**	**<10**	**>10**
Dug wells	7	5	2	0	7	5	2
Hand Pump	15	2	13	0	15	12	3
Tube Well	3	0	3	0	3	3	0

3.4.1 Ground water quality of Dug wells and hand pump

A total of 23 samples in Pre-monsoon and 22 samples were collected from dug wells and hand pumps during post monsoon. The range is given in the table 3.1 and 3.2 respectively.

From the analyzed data it can be known that all the samples from dug wells and hand pump both during pre-monsoon and post monsoon have pH value ranges from 7 to 8.5. This show the nature of the groundwater in the dug wells and hand pumps in both seasons are slightly alkaline. The concentration of iron in 19 dug wells and hand pumps in premonsoon and 7 dug wells and hand pumps in postmonsoon are found to be with in the permissible limit (<1.0 mg/l by WHO), 2 dugwells and 2 hand pumps in pre-monsoon and 2 dug wells, 13 hand pump in post-monsoon shows iron conc. beyond the permissible limit (i.e > 1 mg/l). The concentration of Arsenic in 16 dug wells and hand pumps in premonsoon and 17 dug wells and hand pumps combinedly in post monsoon are found to be with in the permissible limit (<10 μg/l by WHO), 2 dugwells and 5 hand pumps in pre-monsoon and 2 dug wells, 3 hand pump in post-monsoon shows Arsenic conc. beyond the permissible limit (i.e > 10 μg/l). Apart from these parameters all the parameters analyzed are within the permissible limit.

3.4.2 Ground Water quality assessment

Various chemical diagrams like Piper diagram, Wilcox diagram are prepared by using the Aquachem software to assess the quality of ground water of Nalbari district.

A. Piper Diagram

Piper trilinear diagram is an effective graphical procedure to segregate the analytical data to understand the sources of the dissolved constituent in water. In chemical equilibrium cations and anions are present in the water. The analyzed pre monsoon and post monsoon sample falls under the magnesium bicarbonate type, few samples fall under mixed type origin and only one samples in the sodium bicarbonate type. From the plot in the cation triangle, we can see most of the samples from pre monsoon and post monsoon are falling under no dominant type and magnesium type whereas few post monsoon samples are under magnesium and potassium type. In the anion triangle all the pre-monsoon and post monsoon samples are falling under bicarbonate to no dominant type. By the extrapolation of cations and anions in to the diamond field represents the hydro-chemical facies of groundwater samples. The facies reflect the response of chemical processes operation within the lithologic framework and flow pattern.

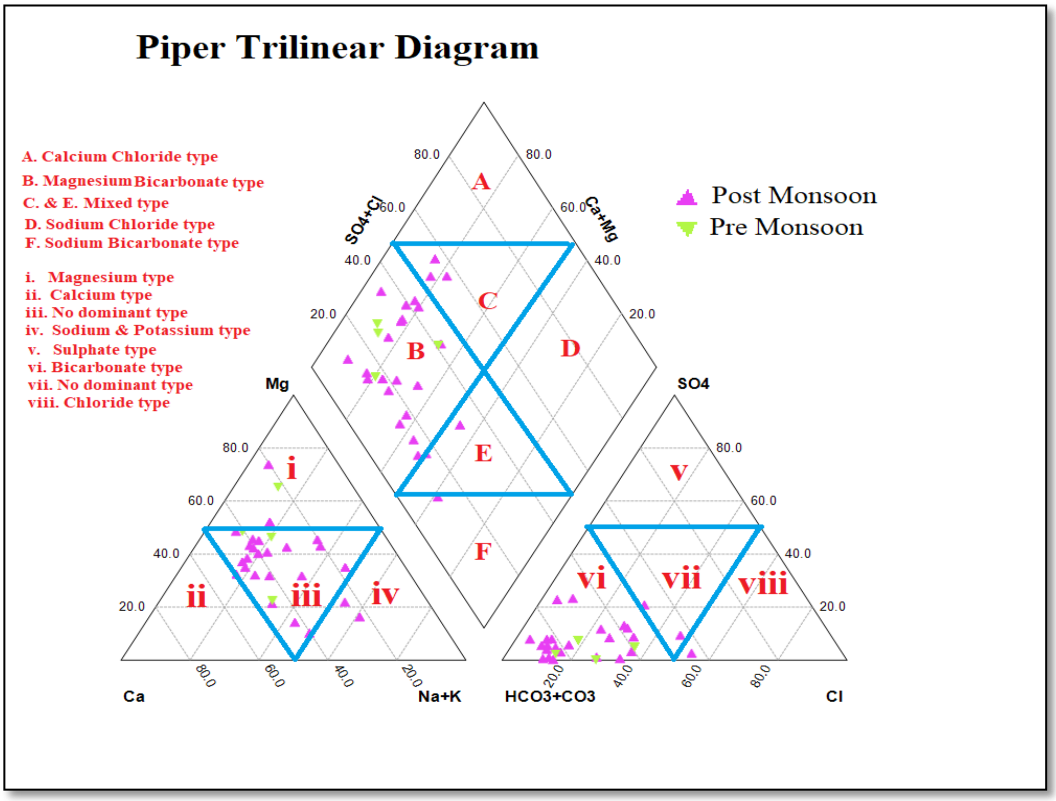

Fig.3.10: Piper trilinear Diagram

B. Wilcox diagram

According to Wilcox diagram (US Salinity Laboratory's diagram) in Fig.: 3.11, salinity and alkalinity hazard class of water samples were determined. The result shows that a majority of the ground water samples possess low salinity with low sodium (C1–S1) and (C2-S1) field. Samples falling under (C1–S1) field shows that this water can be used directly for irrigation purpose. However, water samples falling in medium salinity and low sodium class (C2-S1) should be treated before using for irrigation purposes.

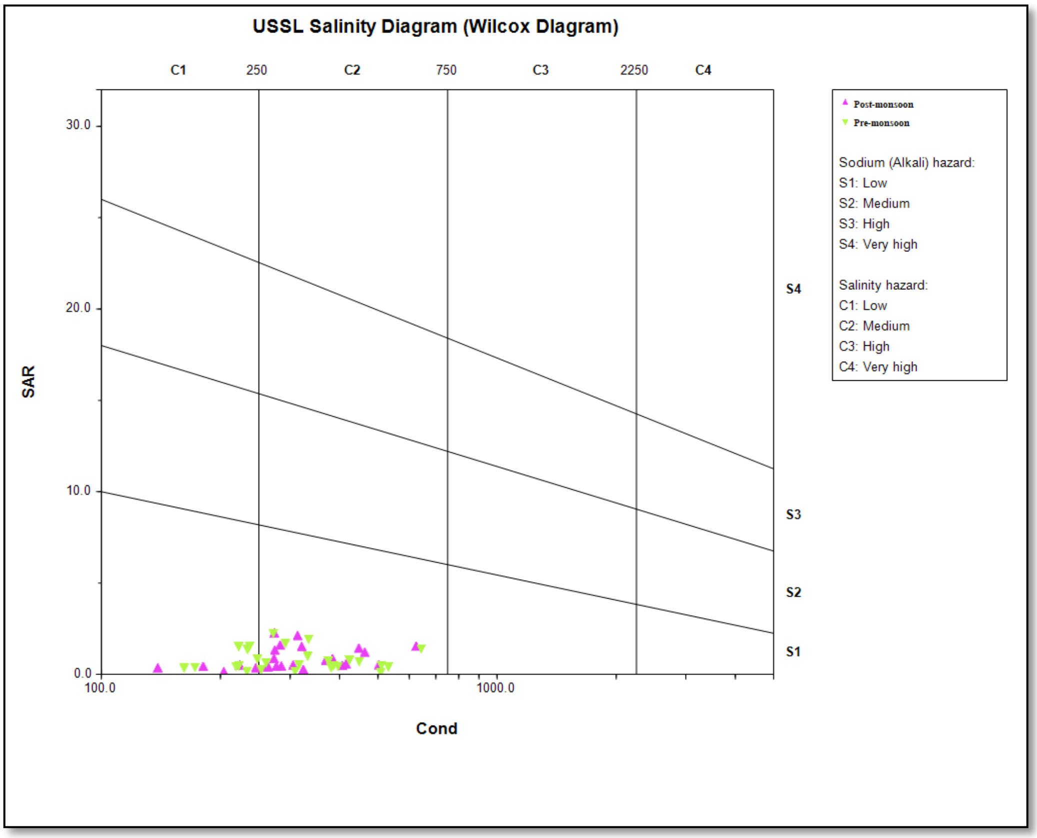

Fig. 3.11: Wilcox Diagram, Wilcox, L.V. (1955)

3.4.3 Ground water quality assessment for irrigation

To study the groundwater quality for irrigation 25 samples in the pre-monsoon and 25 samples in the post monsoon have been collected from the entire district respectively. Various parameters like Alkalinity hazard or Sodium Absorption ratio (SAR), Magnesium Hazard (MH), Residual Sodium carbonate (RSC), Permeability Index (PI), Kelly ratio have been calculated from the analyzed chemical components.

a. Alkalinity Hazard (SAR)

Sodium Absorption ration is calculated to determine the alkalinity index for the classification of the groundwater. In the pre-monsoon season the SAR value ranges from 1.25meq/L to 3.84meq/L whereas in the post monsoon season the value ranges from 2.93meq/L to 6.51meq/L. From the plot given below we can see all the samples from pre-monsoon and post-monsoon falls below 10meq/l which means the ground water is in the excellent quality for irrigation. Only the water samples collected from Thakurbari, Tihu shows the SAR value between 10-12 meq/L slight higher than the permissible limit. So this water can be treated before using for irrigation.

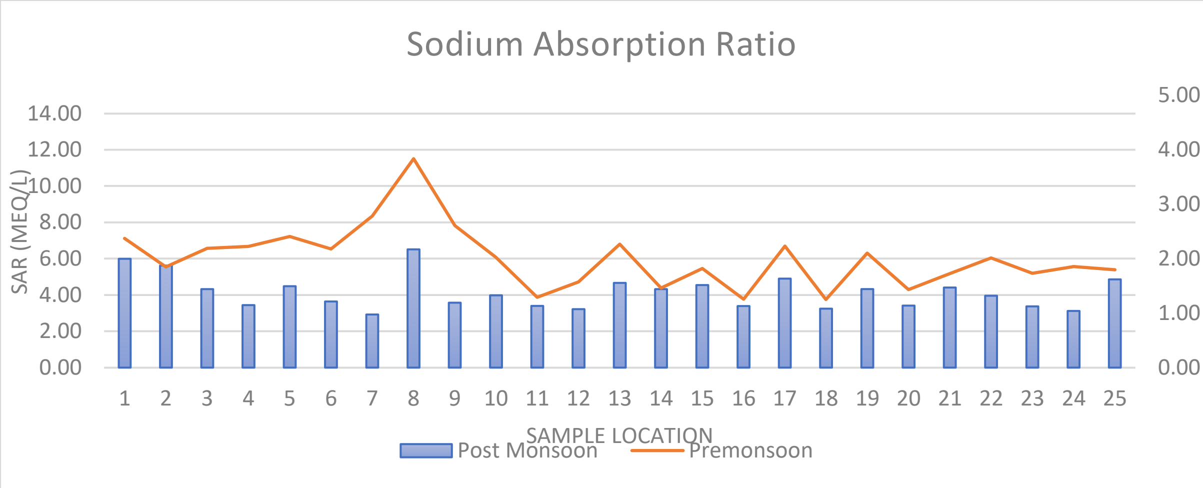

Fig. 3.12: Sodium Absorption Ratio Diagram,

b. Salinity Hazard

Electric conductivity values represent the saline conditions of the groundwater. Above plotted Wilcox diagram clearly indicates that the EC values of the collected samples are within 750µS/cm i.e with in the field of C2. Majority of samples are within the C1 field which makes them very good in terms of quality water for irrigation and Samples falling in C2 filed are good for irrigation (Wilcox, L.V. (1955)).

c. Residual Sodium carbonate

RSC index of irrigation water or soil used to indicate the alkalinity hazard for soil. Both from the pre monsoon and post monsoon the RSC value ranges from -1.40 to 2.01 maximum. From the diagram it clearly indicates that all the samples except Thakurbari and parahkuchi are falling below 1.25meq/L which makes them best suitable for irrigation. Water from the Thakurbari, Tihu area to be treated before using from irrigation directly.

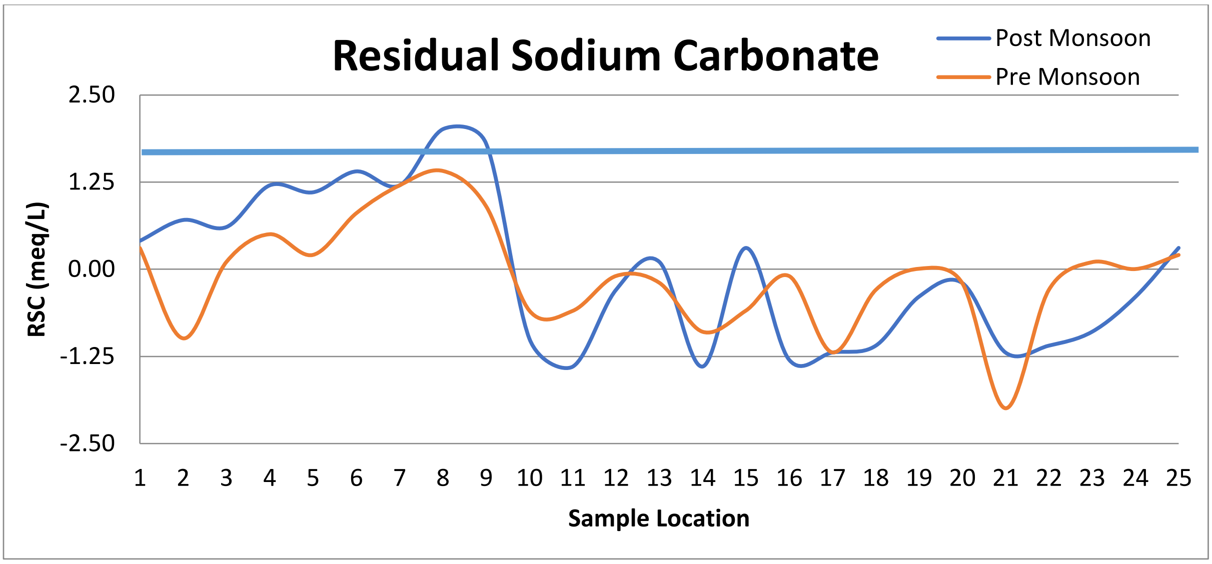

Fig. 3.13: Residual Sodium Carbonate diagram

d. Kelly Ratio

This ratio is calculated from considering sodium ion concentration against calcium and magnesium ion concentration. It is an important parameter in determining the quality of irrigation water. KR value less than 1meq/L is considered to be excellent for irrigation purpose. From the diagram it is clearly indicated that the KR value of all the samples from premonsoon and post monsoon are under 1 meq/L which makes the water suitable for irrigation. Only samples from Haribhanga and Parahkuchi are slightly higher Kr which can be treated before using for irrigation purpose.

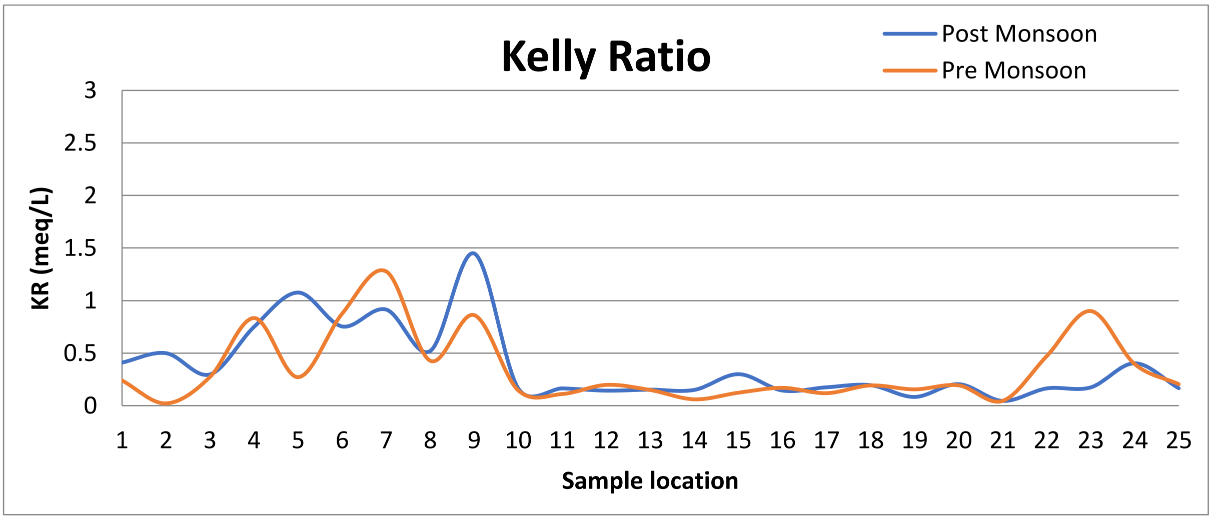

Fig. 3.14: Kelly ratio Diagram

From all the calculated parameters from the analyzed data it is clearly indicated that all the samples Nalbari district are suitable for the irrigation purposes. A tabular summary is given below for all the parameters and their classification for irrigation suitability.

Table 3.5. Classification of ground water for irrigation suitability.

Parameters	**Range**	**Classification**	**Pre monsoon (No. samples)**	**Post monsoon (No. samples)**
Total Dissolved Solid (TDS) (mg/L)	<1000	Non-saline	27	25
	1000-3000	Slightly saline	NA	NA
	3000-10000	Moderately saline	NA	NA
	>10000	Very saline	NA	NA
Salinity Hazard (EC) (µS/cm)	<250	Excellent	9	5
	250-750	Good	18	20
	750-2000	Permissible	NA	NA
	2000-3000	Doubtful	NA	NA
	>3000	Unsuitable	NA	NA
Alkalinity Hazard (SAR)	<10	Excellent	27	25
	10-18	Good	NA	NA
	18-26	Doubtful	NA	NA
	>26	Unsuitable	NA	NA
Kelly's Index (KI)	<1	Suitable	24	23
	>1	Unsuitable	1	2
Residual Sodium Carbonate (RSC)	<1.25	Suitable	24	22
	1.25-2.5	Marginally suitable	1	3
	>2.5	Unsuitable	Na	NA

3.4.4 Iron and Arsenic

Iron is detected in all most all the samples from the Nalbari districts which is more than the permissible limit set by WHO i.e., 1mg/l. Similarly, few samples have detected with Arsenic concentration more than the permissible limit i.e., 10ppb. Maps reflecting the concentrations of Fe and As are given in the Fig. no. : 3.5 to 3.8.

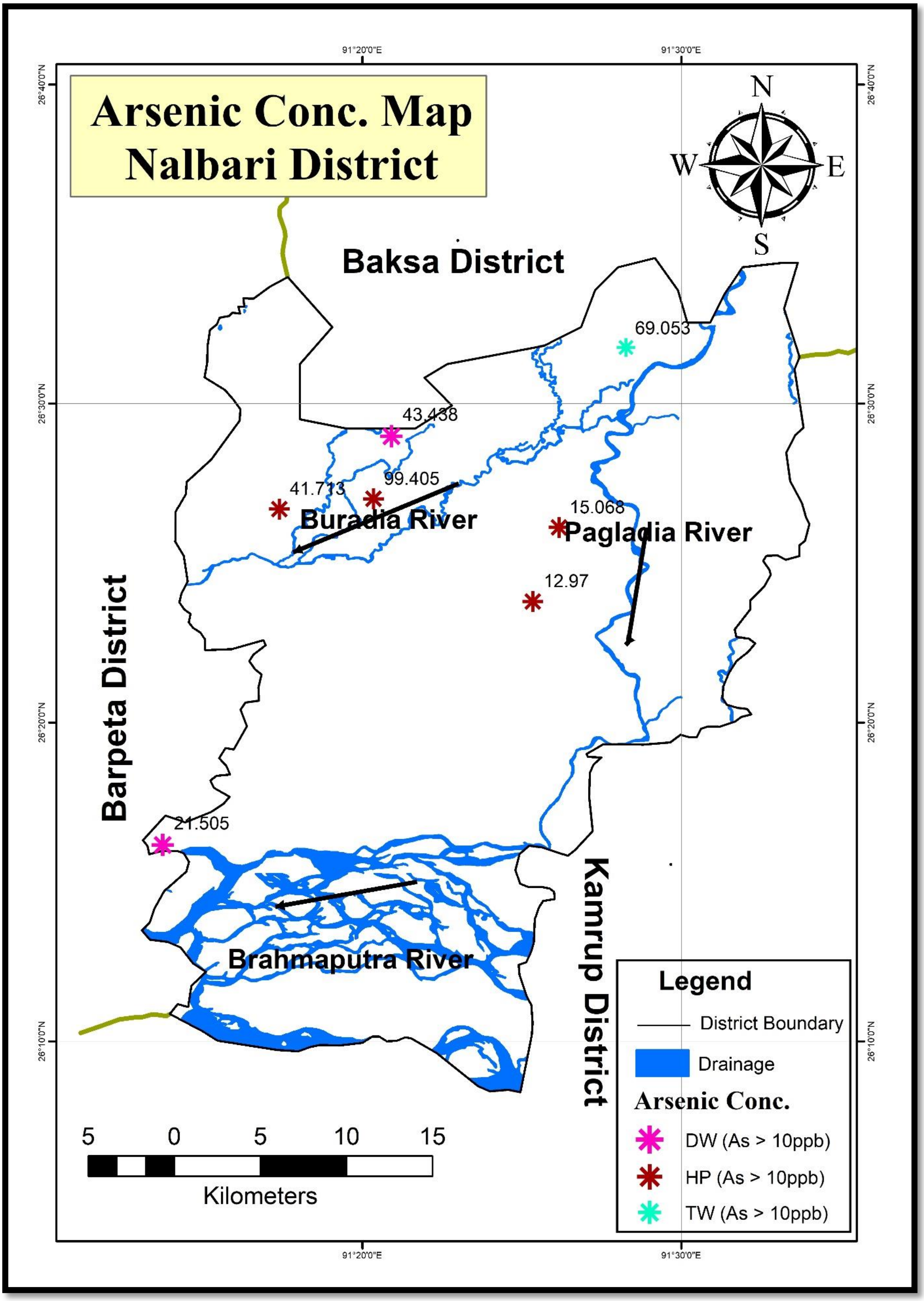

Fig.3.15: Pre-monsoon As Conc. Map

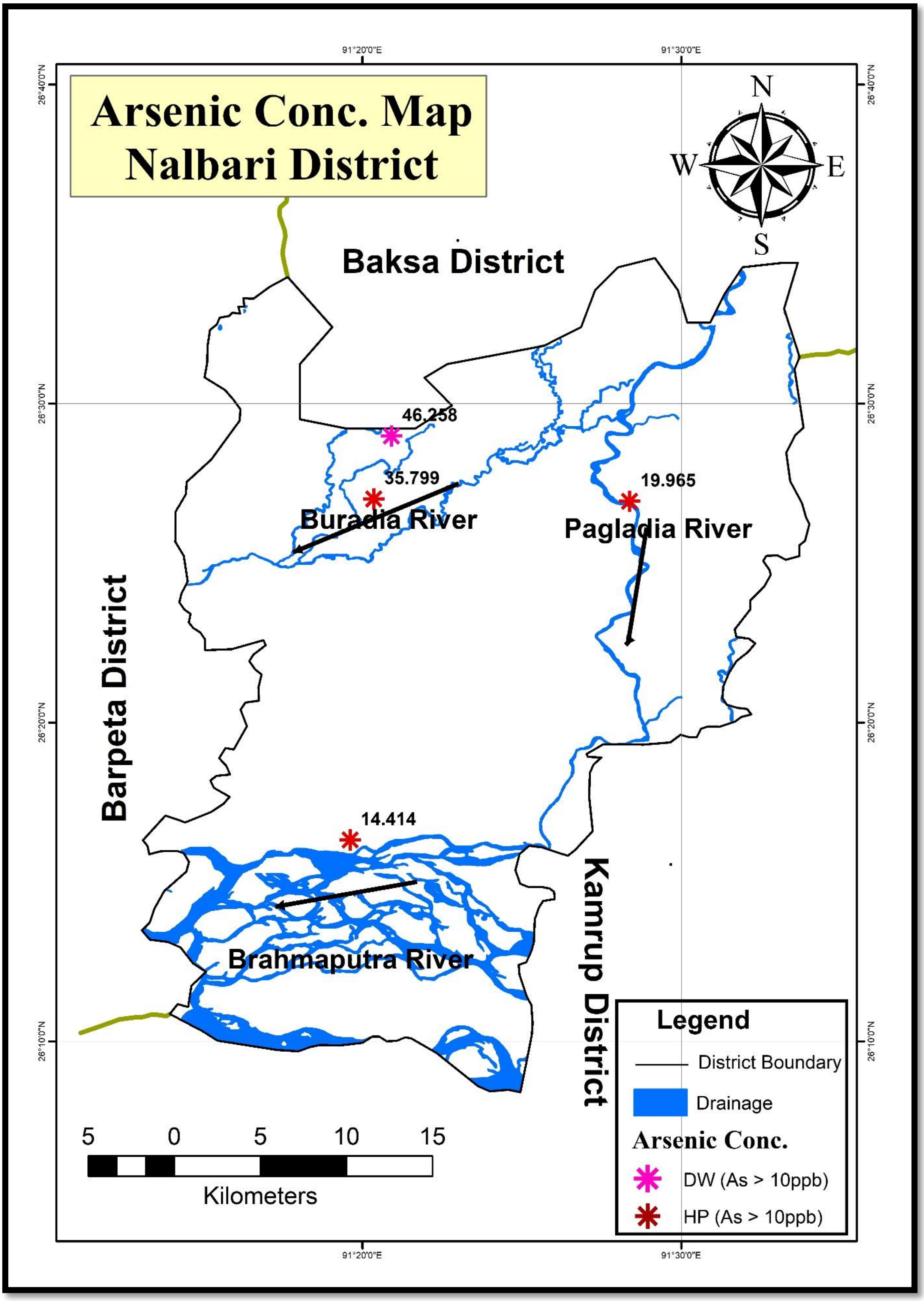

Fig. 3.16: Post-monsoon As Conc. Map

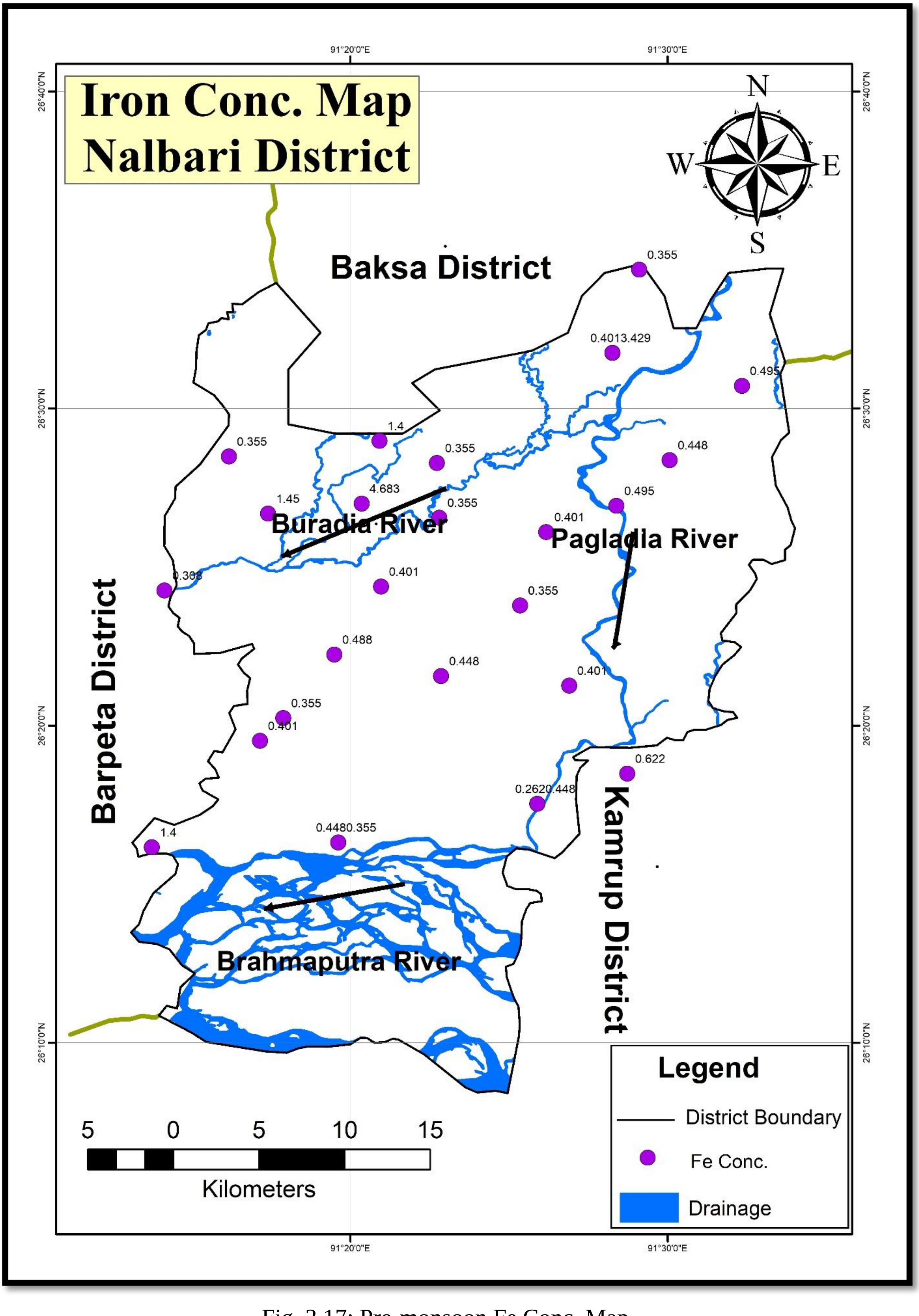

Fig. 3.17: Pre-monsoon Fe Conc. Map

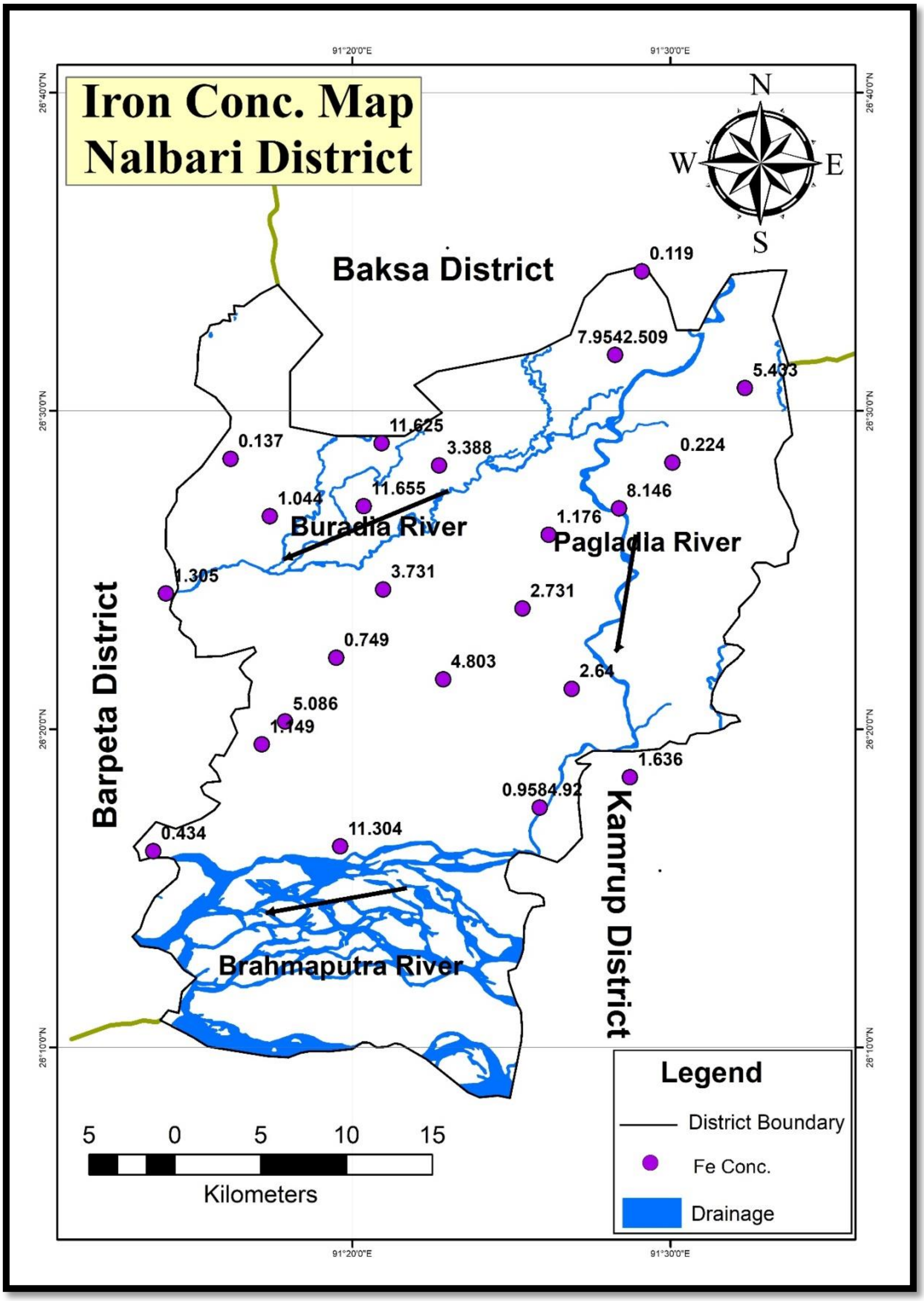

Fig.3.18: Post-monsoon Fe Conc. Map

Chapter 4

Ground water Resources

The rechargeable area of Nalbari district with slope ≤20% is identified by downloading 30m resolution DEM of Shuttle Radar Topography Mission (SRTM) from http://earthexplorer.com. The rechargeable area is found to be 103630 ha. As block boundary is not available, it was not possible to carry out block wise resource calculation. Here district wise resource calculation is presented. The computation of ground water resources available in the district has been done using GEC 2015 methodology.

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. Rainfall infiltration factor of 22% for valley fill as per norms is taken for calculation. In WLF method, specific yield has been taken as 0.16 for valley fill deposit following the norms recommended by GEC'2015. The rainfall of Nalbari district is 2,357.10 mm.
2) Water level data has been considered for 2019-20. Water level fluctuation based on data of March (Pre monsoon) and November (post monsoon) has been considered. The average pre- and post-monsoon water level of Nalbari district is 2.98 mbgl and 2.25 mbgl. The average water level fluctuation is 0.73 m.
3) The population figures s were collected from Census, 2011 and projected to 2020. The per capita domestic requirement is considered as 60 lpcd.
4) Recharge from other sources includes recharge from minor surface and ground water irrigation.

4.1 Recharge

The aquifers of the study area are recharged by rainfall. The area experiences south-east monsoon. Monsoon rainfall contributes approximately 74 percent of total rainfall (June, July, August, September) while share of post and pre monsoon rainfall are approximately 26 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 June to September has maximum number of rainy days.

The monsoon recharge of the 103630 ha of recharge worthy area is 30289.99 ham while non-monsoon recharge is 12700.87 ham. Recharge from other sources is 2808.07 ham. Total ground water recharge is 45798.93 ham.

4.2 Extraction

The agriculture in the area is partly rainfed and mostly irrigated. 84.05% of the total extracted ground water is used for irrigation purpose. i.e., 7,153.44 ham. Total industrial extraction is 5.55 ham. So, ground water is extracted for domestic use is 1351.94. Total groundwater extraction of Nalbari district is 8510.92 ham

4.3 Allocation of resources up to 2025

The net ground water resource is allocated for domestic use 1458.79 ham. Net available resource for future use is 300085.5 ham. Stage of groundwater development: Groundwater is mainly utilized for irrigation purposes followed by domestic purpose. The stage of groundwater extraction in the district is 21.99%.

Table 5.1: Net groundwater availability, existing extraction and stage of extraction for the year 2020.

Recharge worthy area Ha	Total annual GW recharge Ham	Environmental flow Ham	Annual extractable GW resource Ham (2-3)	Existing gross GW extraction for all uses Ham	Stage of GW extraction [(5/4) *100%]
1	2	3	4	5	6
103036	45798.9	4579.9	38703.31	8510.92	21.99 %

4.4 Potential resource

(i) Shallow water table areas: Potential resource due to shallow water table areas was estimated from aquifer area where depth-to-water level was within 5mbgl. The area within depth-to-water level 0f 5mbgl is 3293 sq.km which is 87% of total area of the district. The potential resource of shallow water table areas is 43074.66ham.

(ii) Flood prone area: As per GWRE 2020, the flood prone area of the district is 74345 ha and it is considered that flood water remained in the area for at least 15days. Potential resource in flood prone area is 3122.49ham.

(iii) Total potential resource of Tinsukia district is 46197.15ham.

4.5 Static resource

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 Nalbari 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 0.12 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 5.2: Salient information of static resource of Tinsukia district, Assam

Type of rock formation	Alluvium
Total Geographical Area (Ha)	104644
Assessment Area (Ha)	103630
Bottom of the unconfined aquifer (m)	50
Average Pre- monsoon Water Level (m)	3.9 4
Thickness of the saturated zone of the un-confined aquifer below WLF zone (m)	46.06
Volume of Saturated zone of the unconfined aquifer below WLF zone (ham)	4772990.5

5.2. Static/In-storage Ground Water Resources (ham):

Volume of saturated zone * specific yield = 4772990.5 X 0.12

= 572578.86 ham.

Chapter 5

Groundwater Related Issues

5.1 Identification of issues

The main groundwater issues identified in the area are-low stage of groundwater extraction, around 100 sq. km areas under water logging conditions, high iron concentration, higher conc. of arsenic in some locations.

5.2 Low stage of groundwater extraction

Compared to vast dynamic groundwater resource of Nalbari district, groundwater extraction for domestic, irrigation and industrial purposes is low. Vast tract of agricultural land remains fallow after harvesting of paddy only due to lack of irrigation facility. The stage of groundwater extraction is only 21.99 %.

5.3 Water logged area

Water logged areas are observed mostly in north-western side of the district in the Tihu block. Over all post monsoon depth-to-water level varies from 0.46 -3.87 whereas pre-monsoon depth-to water level varies from 1.21 – 4.87 mbgl. Water logged area is 10500 ha. Water logged areas are found in the younger alluvial plain. Occurrence of water logging conditions in the region is due to high rainfall, shallow water level and a meagre ground water draft in vast flood plain of the Buradia river. Generally, it is observed that water logged areas of the district does not coincide with the flood prone areas.

5.4 Area vulnerable to arsenic pollution

Arsenic is detected in some groundwater samples. In most of the samples arsenic concentration is within permissible limit. During pre-monsoon in some dugwells like Gobradal, Daulasaal, in some hand pumps likeHaribhanga, Kaithalkuchi, Nalbarigaon, Chandakuchi, and in one tube well of PHED, Balitara the As conc. is above permissible limit i.e., >10ppb as per WHO standard. Similarly, during post monsoon 4 hand pumps i.e., in Kaithalkuchi, Chanda, Bartola and Gobradal the concentration is higher and above permissible limit. In most cases arsenic present in water logged areas.

5.5 Area vulnerable to iron pollution

In a vast number of samples iron is detected throughout the district. Fe content more than 1mg/l is not acceptable for drinking purpose. Iron content in ground water, above permissible limit is found in 5 samples (2 DWs, 2HPs, and 1 TW) out of 27 at different locations of the districts during pre-monsoon and the concentration varies from 1.4 to 4.68 mg/l. During post monsoon Iron conc. in ground water is above permissible limit is found in 19 samples (2 DWs, 14 HPs, and 3 TW) out of 25 at different locations of the districts the concentration varies from 1.04 to 11.66 mg/l.

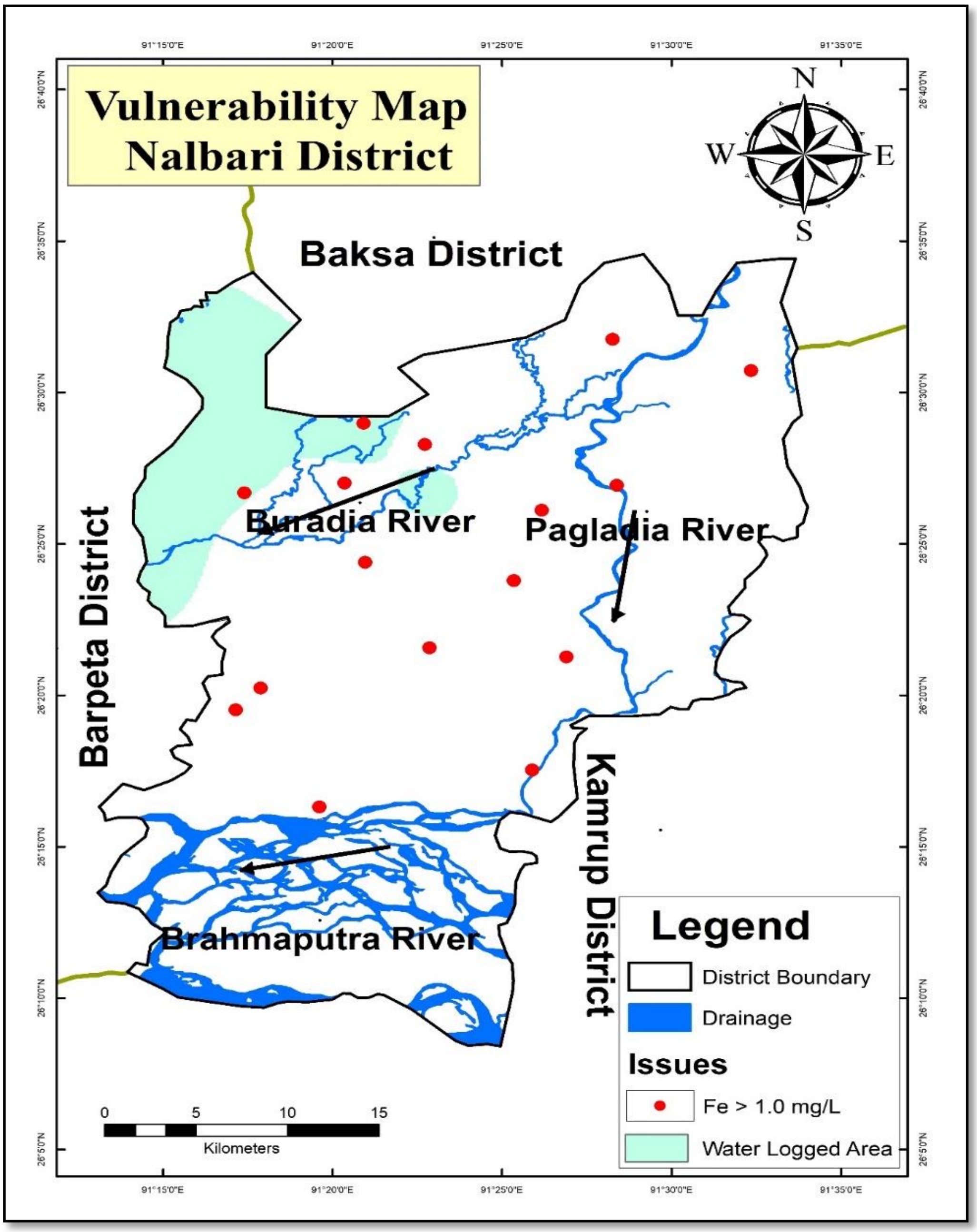

Fig. 5.1: Vulnerability map of Nalbari district, Assam.

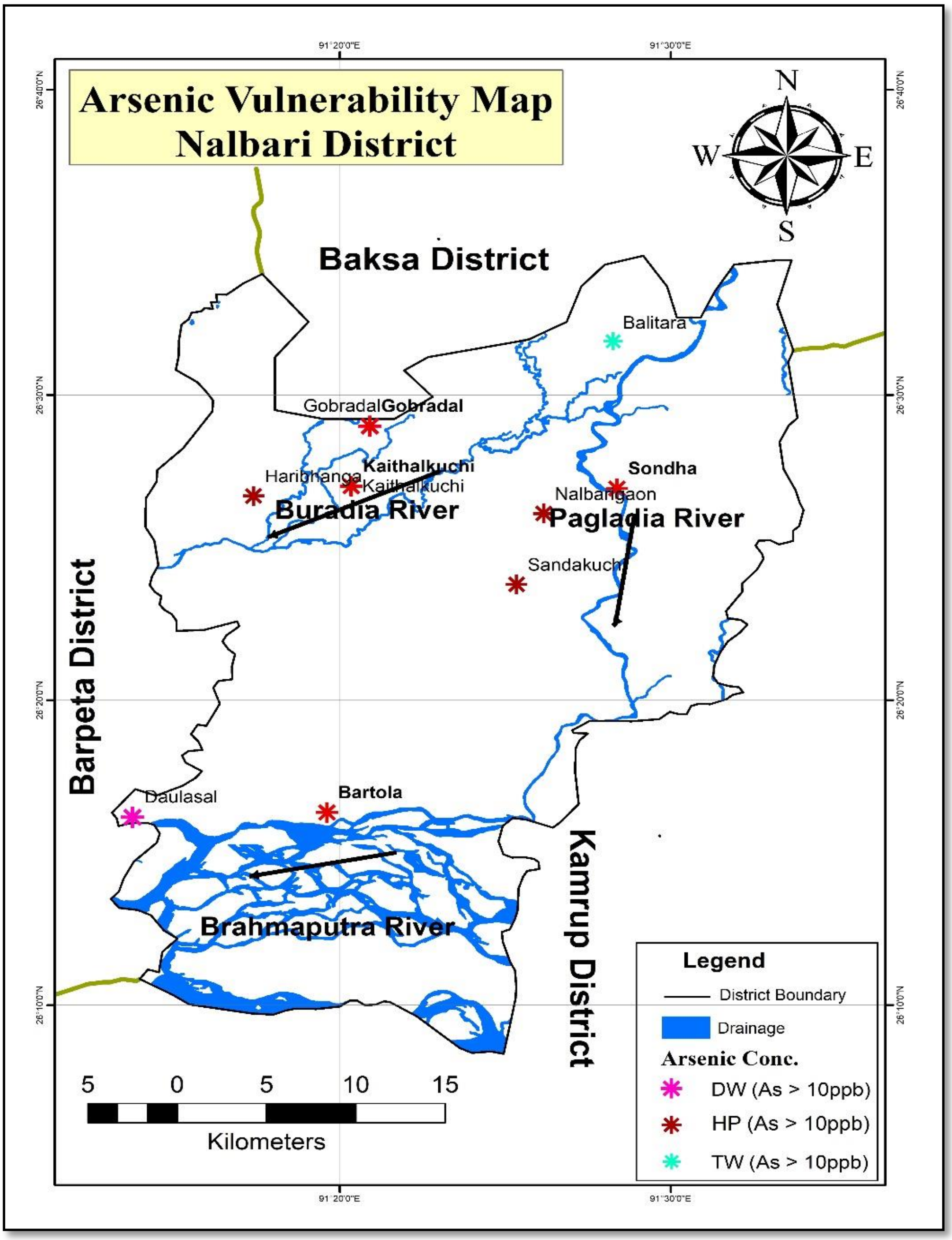

Fig. 5.2: Arsenic Vulnerability map of Nalbari district, Assam.

Chapter 6

Management Strategy

The groundwater regime of Nalbari district is influenced by lithological variation and geomorphologic set up. The district can be divided into two slope classes, viz., slope >20% and slope <=20%. Areas with slope more than 20% are found is less than 10% of the entire district and is unevenly distributed throughout the district. Geomorphologically the district is comprised of younger alluvium, flood plains and major drainage of river the Brahmaputra. Water logged areas are found in younger alluvial plain.

Sustainable Management Plan of Resource: Some important points have to be taken into consideration during preparation of aquifer management plan.

- Stage of groundwater extraction in the district is just 21.99 % leaving vast scope for further groundwater development. Irrigated area is still in nascent stage of 18% only and requires increment for agricultural purpose.
- Groundwater quality data indicates that aquifer contains iron of high concentration in some pockets.

6.1 Management of resources for agricultural sector:

The crop water requirement for unirrigated area of the district is estimated based on soil condition, flooding and geomorphic classification and the estimation is carried out in accordance to the suggestion of Assam Agriculture University. AAU has identified characteristics cropping sequence for different geomorphologic conditions. The cropping pattern suitable for flood prone area is shown below.

Table 6.5. Cropping pattern of un-irrigated areas of Nalbari district from CROPWAT 8.0

Sl. No.	Crop	Planting date	Harvest date	Area (%)	Gross sown area (Ha)	Area / Crop
1	Rice	05-Jun	02-Oct	12.5	14394.25	57577
2	Rice	15-Jun	12-Oct	12.5	14394.25	
3	Rice	20-Jun	17-Oct	12.5	14394.25	
4	Rice	27-Jun	24-Oct	12.5	14394.25	
5	Pulses	20-Oct	06-Feb	5	5757.7	11515.4
6	Pulses	25-Oct	11-Feb	5	5757.7	
7	Potato	14-Oct	20-Feb	5	5757.7	11515.4
8	Potato	05-Nov	14-Mar	5	5757.7	
9	Mustard	10-Nov	24-Mar	5	5757.7	11515.4
10	Mustard	25-Nov	08-Apr	5	5757.7	
11	Small Vegetables	10-Oct	12-Jan	5	5757.7	11515.4
12	Small Vegetables	22-Oct	24-Jan	5	5757.7	
13	Small Vegetables	09-Dec	13-Mar	5	5757.7	11515.4
14	Small Vegetables	18-Dec	23-Mar	5	5757.7	

The water demand of agricultural sector to provide assured irrigation potentiality to un-irrigated areas will be calculated using Cropwat 8.0 software of FAO. AAU suggested cropping sequence can be followed which will provide water logging affected people assured irrigation facility.

As per information, Net sown area of the district is 69349 ha and out of which 18734 ha only is under irrigation (District Irrigation Plan 2016-21). It is observed that un-irrigated area associated with kharif paddy (winter rice) is 57577 ha (source: agricencus:2015-16) which is sown during summer time from June-July. For further utilization of groundwater seeing the vast scope for ground water development in the area. Entire area of kharif paddy will be used for other crops like winter vegetables, summer vegetables, potato, pulse and mustard.

A management plan has been prepared for un-irrigated crop land based on cropping pattern suggested by Assam Agriculture University (Table 6.2)

Table 6.6. Water requirement for un-irrigated areas of Nalbari district

Cropping pattern (s)				
Winter Paddy - Winter vegetables - Potato - Pulses - Potato - Mustard - Pulses - Summer vegetables	Present Cultivated area	Area to be cultivated	Area to be cultivated	Irrigation requirement
	(Ha)	**(%)**	**(Ha)**	**(Ham)**
Cultivated Area	**57577**			
	1	2 (= % of 1)	3	4
Rice (main crop)	57577	100	57577	9594
Mustard	0	20	11515.4	1612
Pulses	0	20	11515.4	2143
Potato	0	20	11515.4	1841
Winter Vegetable	0	20	11515.4	1472
Summer Vegetable	0	20	11515.4	1836
Total	**57577**		**115154**	**18497**
Net cultivated area	**57577**		**57577**	
Gross cultivated area (Rice+Pulses+Mustard+Potato+Winter Veg+Summer Veg)	**57577**		**115154**	
Total irrigation requirement (70% irrigation efficiency)				**26424**
Cropping intensity	**100**		**200% (Intended)**	

Sowing season of winter rice is October-November and can be harvested during summer season. Winter rice sowing month is fixed as June-July depending upon cessation of flood water from the crop land. If flood water retains in paddy field during July and August then the winter rice may not be cultivated, instead other crops like vegetables, wheat, pulses and potato can be cultivated with assured irrigation facilities provided by construction of tube wells.

Table 6.3: Precipitation deficiency

Precipitation Deficit (mm)													
Sr. No	**Crop**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	Rice	0	0	0	0	147.1	52.1	0	0	0	6.2	0	0
2	Rice	0	0	0	0	49.1	98	0	0	0	7.1	0	0
3	Rice	0	0	0	0	48.5	98	0	0	0	1.8	0	0
4	Rice	0	0	0	0	1.9	138	0	0	0	11.8	0	0
5	Pulses	51	4.3	0	0	0	0	0	0	0	1.3	23.5	59.1
6	Pulses	55.8	10.1	0	0	0	0	0	0	0	0	18.1	56.7
7	Potato	57.1	31.2	0	0	0	0	0	0	0	0	29.4	59
8	Potato	58.7	57.2	18.5	0	0	0	0	0	0	0	17.1	44
9	Mustard	45.9	44.6	15.9	0	0	0	0	0	0	0	13.3	41.6
10	Mustard	45.8	47.2	32.3	0	0	0	0	0	0	0	3.5	29.6
11	Small Vegetables	19.1	0	0	0	0	0	0	0	0	6.5	44.4	54.5
12	Small Vegetables	38.5	0	0	0	0	0	0	0	0	2	37	53.6
13	Small Vegetables	46.9	56	23.2	0	0	0	0	0	0	0	0	28.5
14	Small Vegetables	42.1	55.8	49.2	0	0	0	0	0	0	0	0	17.2

Table 6.4: Actual monthly requirement (Ham) for different crops for unirrigated area

Irrigation water requirement (in Ham) for different crops in Sivasagar district, Assam																	
Sr. No.	**CROP**	**Area (%)**	**Gross cultivated area (Ha)**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**TOTAL IWR**	**Ham/ crop**
1	Rice	12.5	14394.25	0	0	0	0	2117	750	0	0	0	89	0	0	2957	9594
2	Rice	12.5	14394.25	0	0	0	0	707	1411	0	49	0	102	0	0	2269	
3	Rice	12.5	14394.25	0	0	0	0	698	1411	0	49	0	26	0	0	2183	
4	Rice	12.5	14394.25	0	0	0	0	27	1986	0	2	0	170	0	0	2186	
5	Pulses	10	5757.7	294	25	0	0	0	0	0	0	0	7	135	340	801	1612
6	Pulses	5	5757.7	321	58	0	0	0	0	0	0	0	0	104	326	810	
7	Potato	5	5757.7	329	180	0	0	0	0	0	0	0	0	169	340	1017	2143
8	Potato	5	5757.7	338	329	107	0	0	0	0	0	0	0	98	253	1126	
9	Mustard	5	5757.7	264	257	92	0	0	0	0	0	0	0	77	240	929	1841
10	Mustard	5	5757.7	264	272	186	0	0	0	0	0	0	0	20	170	912	
11	Small Vegetables	5	5757.7	110	0	0	0	0	0	0	0	0	37	256	314	717	1472
12	Small Vegetables	5	5757.7	222	0	0	0	0	0	0	0	0	12	213	309	755	
13	Small Vegetables	5	5757.7	270	322	134	0	0	0	0	0	0	0	0	164	890	1836
14	Small Vegetables	5	5757.7	242	321	283	0	0	0	0	0	0	0	0	99	946	
		100	5757.7	2654	1764	801	0	3550	5558	0	100	0	444	1073	2555	18497	18497
Gross irr. Requirement with 70% irr. Efficiency (Ham)				3791	2520	1144	0	5071	7939	0	142	0	634	1532	3650	26424	

Total unirrigated area of the district is 82223 ha and out of which 57577 ha is kharif paddy. Total water requirement to bring the un-irrigated area of the district and water availability for future use are summarized in Table: 6.5

Table 6.5: Summarised results of water requirement to bring the un-irrigated area of Nalbari district, Assam

Area	Net Cultivated area (Ha)	Irrigation water requirement (Ham)	Water allocated for future use (Ham)
Kharif Paddy	57577	26424	30085.54

No. of days requiring irrigation has been determined on the basis of precipitation deficit in respective months, summarised in Table 6.6

Table 6.6 Rainfall deficit and Irrigation requirement in the months of Nov-Dec and Jan-March

Month Interval	Rainfall deficit (in mm)	Irrigation Requirement (in ham)
Nov- Dec	630.1	5182.76
Jan -March	906.4	7455.40

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

Discharge of the tube wells constructed by CGWB tapping 15 to 35m of the sub unit 1 of the older alluvial aquifer varies from 19.70 to 150 m3/hr. It is expected that tube wells of 50m depth tapping 15 to 30m of granular zones of the sub unit 1 of the alluvial aquifer can yield 15 to 60 m3/hr. If the well is allowed to run 8 hrs a day for 150 days a year, then a tube well having discharge of 30 m3/hr will extract 3.6 ham groundwater annually.

Total numbers of shallow tube wells require to construct in the district to fulfil the irrigation requirement of 26424 ham, is found to be 7340 nos.

Extraction of 26424 ham of groundwater will increase the stage of groundwater extraction to 87.83%. Potential resource of the district is 30085.54 ham. But this can lead to a semi critical stage of ground water extraction to the district. To prevent this situation the irrigation water required for kharif to be used from surface water irrigation only. This means a volume of 12638.12 Ham of water can be groundwater can be saved from extraction during kharif for paddy cultivation. This volume can be managed by using the surface water irrigation. After saving of 12638.12 Ham volume of water the stage of extraction will be increased up to 45.82 % from the current 21.99%.

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.

6.2 Demand side management

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

- reducing convenience loss
- improving water application efficiency

Following demand side interventions will increase water use efficiency

- 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.
- Water loss through supply canals can be minimized by proper lining in the canals.
- 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.

Therefore, groundwater resource of the district is sufficient to meet drinking water demand and also irrigation and other industrial demands under different condition.

Following recommendations are suggested

- 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.
- 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.
- In some pockets iron content is very high. The sources of iron pollution in deeper aquifer can be attributed to geogenic origin. It needs removal before human consumption.

- Rain water harvesting in the technique collection and storage of rainwater at surface or in sub-surface aquifer, before it is lost as surface runoff further aggravating water logging condition. Therefore, existing and abandoned dug wells may be utilized as recharge structure after cleaning and desilting the same.

6.3 Groundwater Quality

CGWB has confirmed the occurrences of arsenic and iron in the groundwater. However, it is observed that arsenic is detected only from shallow aquifer within 50 m depth. Earlier CGWB has drilled few wells with depth more than 50m up to 304.65m at different locations. Chemical sample from those deep tube wells have no signature of As. This indicates that the deeper wells are free from Arsenic contaminations. Therefore, tube wells can be constructed down to a depth of 100 m tapping lower 50m granular zones. From the 2D disposition of aquifer diagram of those particular areas where As is detected, 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. In arsenic affected areas, surface water bodies like river, lakes, ponds/tanks should be used for drinking purpose (after suitable treatment/ filtering). If surface water sources are not available then groundwater can be extracted.

As a remedy to iron contaminations in most of the locations around the district, iron removal plants (compact/ traditional) are should be installed before supplying water.