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Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KOKRAJHAR DISTRICT, ASSAM

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

MINISTRY OF JAL SHAKTI

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GOVERNMENT OF INDIA

भारतसरकार

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

ANNUAL ACTION PLAN, 2022-23

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GUWAHATI

गुवाहाटी

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Introduction

1.0 Introduction

1.1 Objectives

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

1.2 Scope of the study

Kokrajhar district has vast groundwater and surface water resources. However, the agro based economy of the area has a less irrigation facility and low stage of ground water extraction. The water resources of the district can be judiciously used for sustainable economic growth. Sustainable management plan of groundwater extraction warrants study on the occurrence of groundwater, its quantity and quality. 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 and quantify the resources. 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, and State Groundwater Departments. All data were plotted in base map on GIS Platform (ArcGIS 10.3) using Projection category longitude/latitude (WGS 84). On the basis of available data, Data Gaps were identified.

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

Aquifer Map Preparation: It is a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. On the basis of integration of data generated from various studies of hydrogeology and geophysics, aquifers have been delineated and characterized in terms of quality and ground water potential. Various maps have been prepared to delineate the lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale.

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. 78F/14, 78F/15, 78F/16, 78J/1,78J/2, 78J/3, 78J/4, 78J/6. 78J/7 and 78J/8 bounded by 26° 6' 39.6" and 26° 52' 44.4" N Latitude and 89° 49' 51.6"and 90° 26' 31.2" E Longitude **covering an area of** 3270Sq.Km of Kokrajhar district of Assam. The base map of the district is shown in Fig.1.1.

Administrative set up of the study area:

Kokrajhar district is situated on the north bank of the river of Brahmaputra. The district has three sub- divisions, viz., Kokrajhar Sadar, Gossaigaon and Parbatjhora. Kokrajhar district comprises 5 revenue Circles with 1068 villages (Table 1.1). It has 5 Community Development Blocks within the district. The total area in the district is 3296Sq.Km.

Total population of the district is 8,87,142souls (as per 2011 census) with average population density of 269persons/sq.km. The decadal variation of population for 2001-2011 is 5.21% (Table 1.2).

Table 1.1: Administrative division of Kokrajhar district

No of Civil Subdivision	No of Blocks	No of Revenue Circles	No of Gram Panchayats	No of Villages (Inhabited)	Uninhabited Villages
3	11	5	0	1053	15

Data Source: Statistical Handbook-2021, Assam

Table 1.2: Block level geographical area (in sq.km) and population of Kokrajhar District

Sl.No	District	Blocks	No of Villages	Population
1	Kokrajhar	Kachugaon	239	194571
2	Kokrajhar	Gossaigaon	112	122132
3	Kokrajhar	Hatidhura (Part)	45	39184
4	Kokrajhar	Dotoma	172	144393
5	Kokrajhar	Kokrajhar	224	264220
6	Kokrajhar	Golakganj (Part)	8	3318
7	Kokrajhar	Rupsi (Part)	49	26961
8	Kokrajhar	Debitola (Part	143	52321
9	Kokrajhar	Mahamaya (Part)	35	32668
10	Kokrajhar	Bilasipara (Part)	4	4949
11	Kokrajhar	Chapar-Salkocha (Part)	37	20425
Total			**1068**	**887142**

Data Source: Census of India-2011

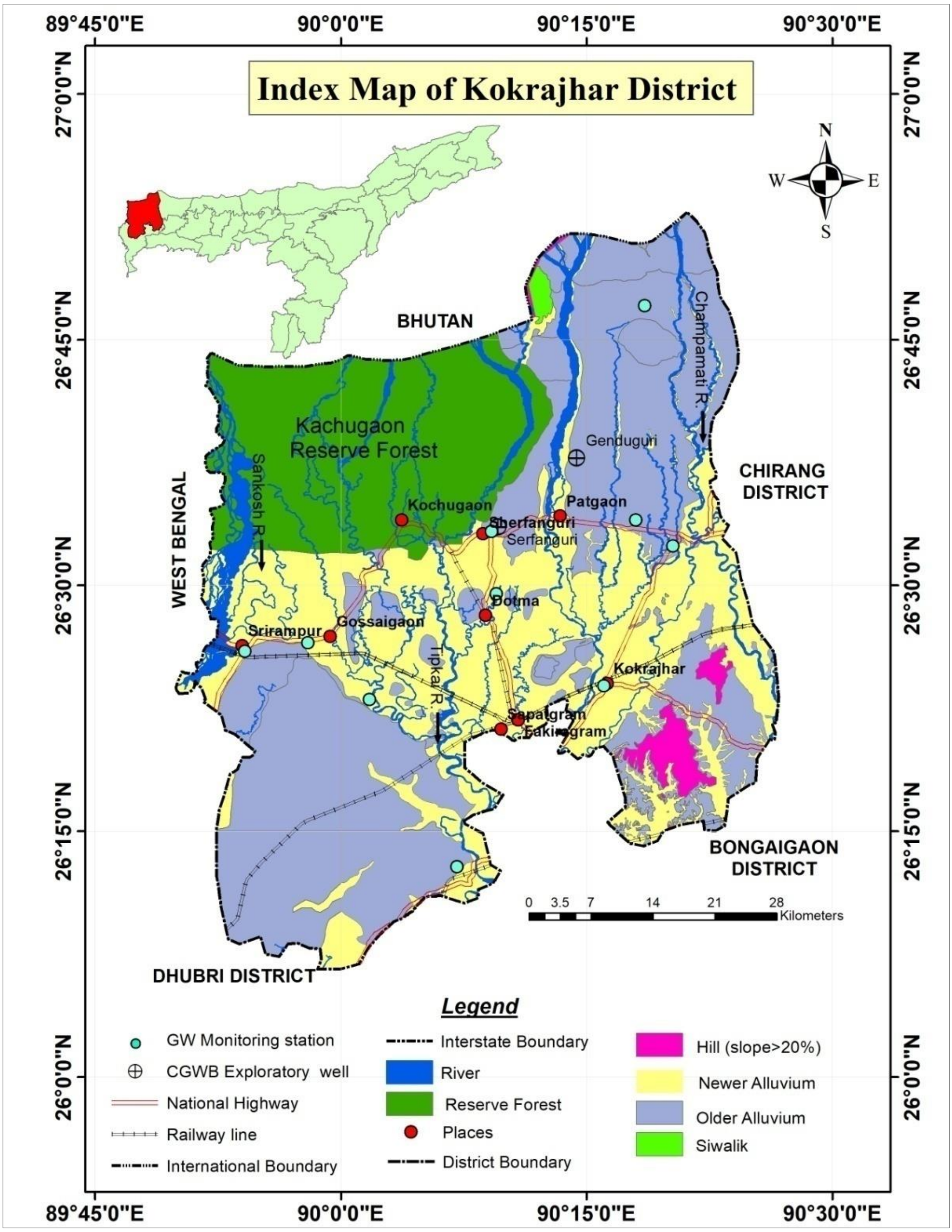

Fig.1. 1: Index Map of the study area

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

The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB. All data were plotted in base map on GIS Platform (ArcMap 10.5) using Projection category longitude/latitude (WGS 84).

The available data, data gap and data generation work is tabulated in Table: 1.3. The available data and data generation points are shown in Fig. 1.2 &Fig. 1.3.

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

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data	Tube well	2	9	nil	2	5 nos. of EW will be constructed through outsourcing
2	Geophysical data		Nil	6	6	6	
3	Groundwater level data	Dug well	10	30	54	64	
		Piezometer Aquifer-I	Nil	Nil	Nil	Nil	1 no. of Pz will be constructed through outsourcing
4	Groundwater quality data	Dugwell-Aquifer-I	10	20	26	36	
		Piezometer Aquifer-I	Nil	Nil	Nil	Nil	
5	Soil Infiltration Test		Nil	3	3	3	

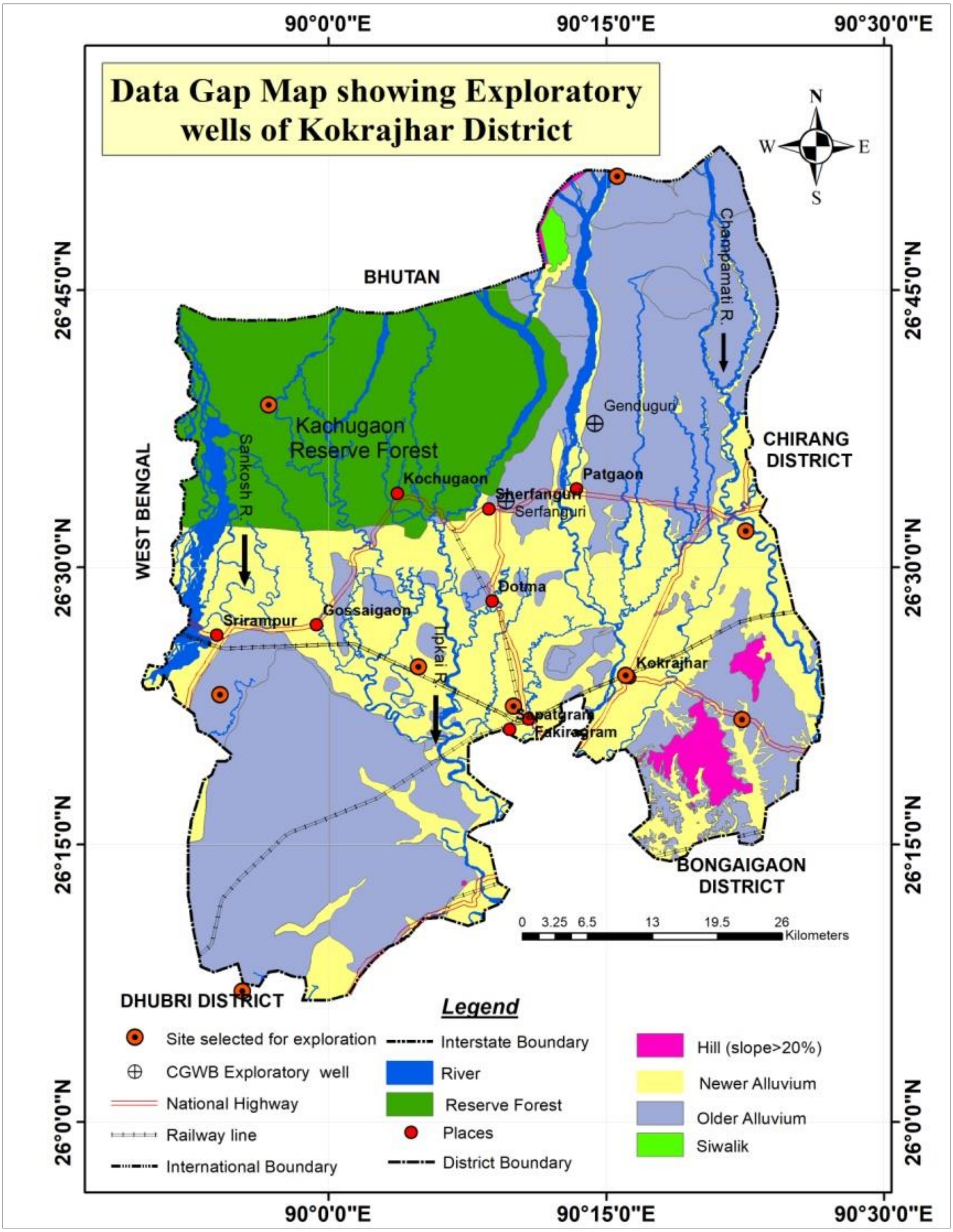

Fig.1. 2: Available data and data gap map of exploration in the study area

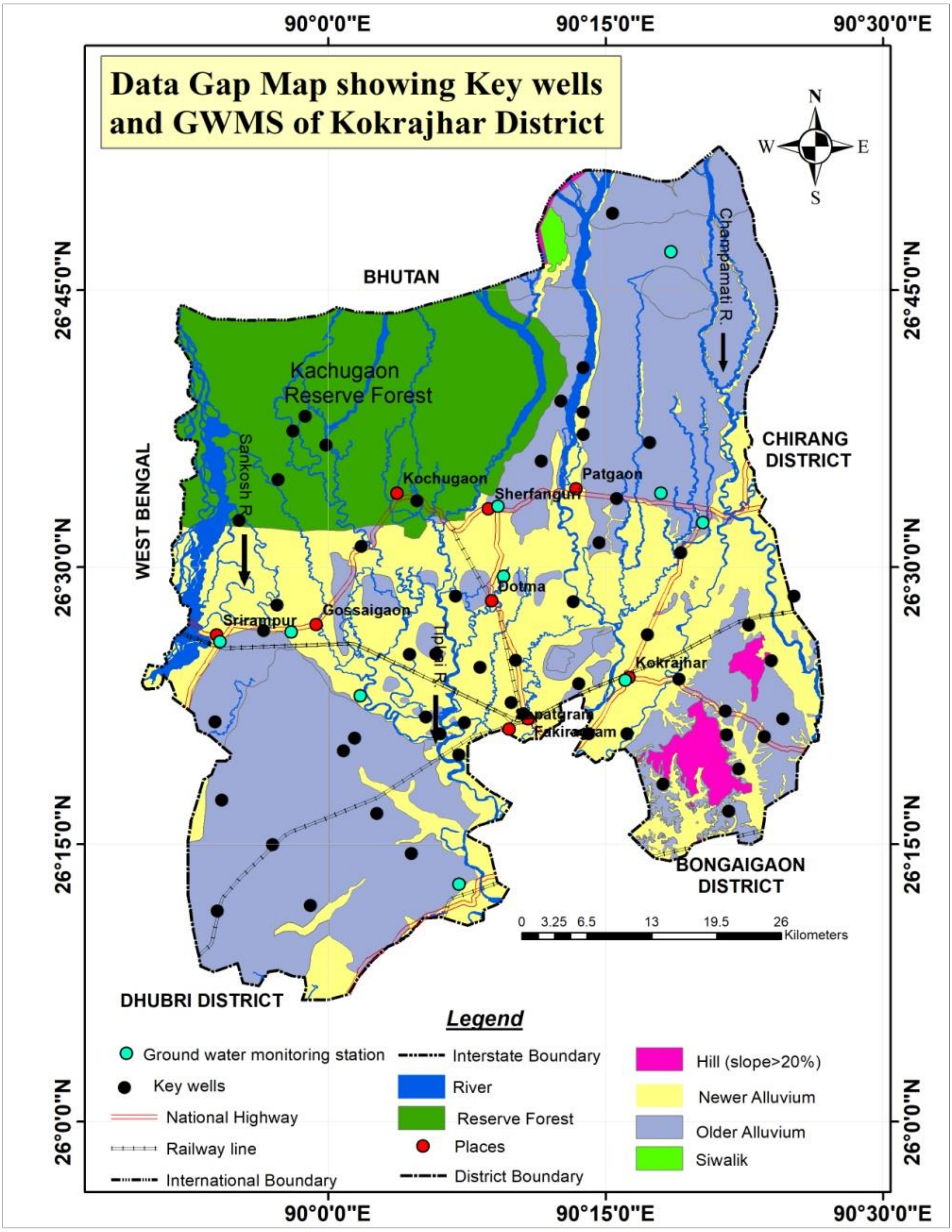

Fig.1. 3: Available data and data generation of ground water level monitoring in Kokrajhar district

1.6 Rainfall distribution

The average annual rainfall recorded from 2012 to 2021based on Indian Meteorological Department (IMD) data set is 3111mm.Rainfall during January to April contributes nearly 9.32 % to the total rainfall whereas the rainy season which commences from May and continues up to September contributes 86.26 %. October to December rainfall is 4.4%. December receives least rainfall and maximum rainfall occurs during June and July. (Table-1.4). The average monthly rainfall from 2012 to 2021 and also yearly rainfall distribution of Kokrajhar district are illustrated in Fig.1.4 and Fig. 1.5.

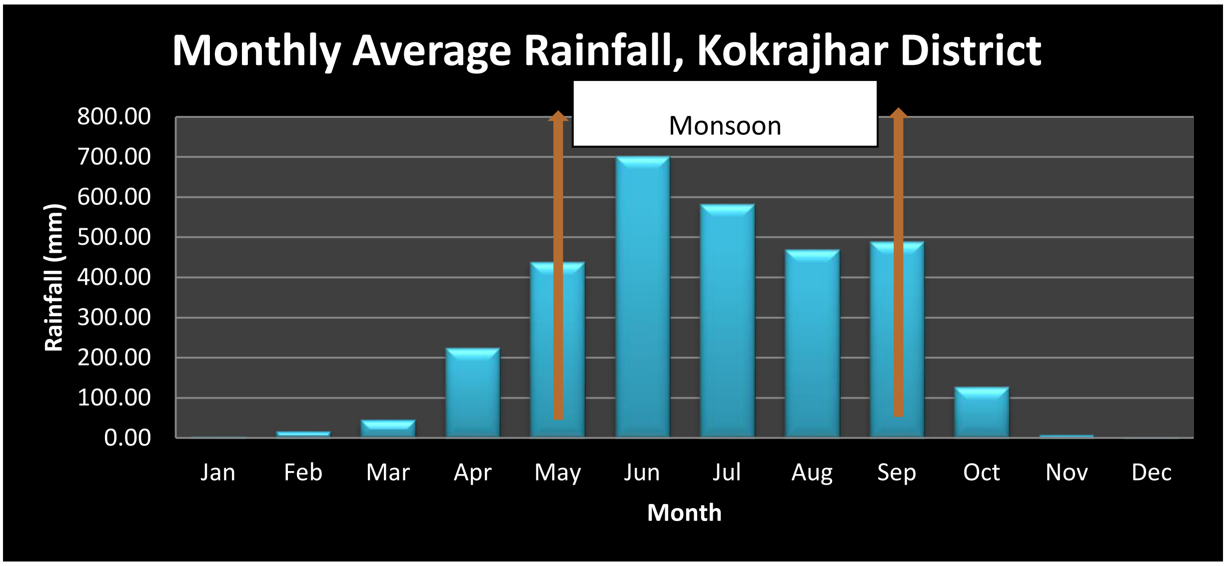

Fig.1. 4: Average monthly rainfall variations of Kokrajhar district

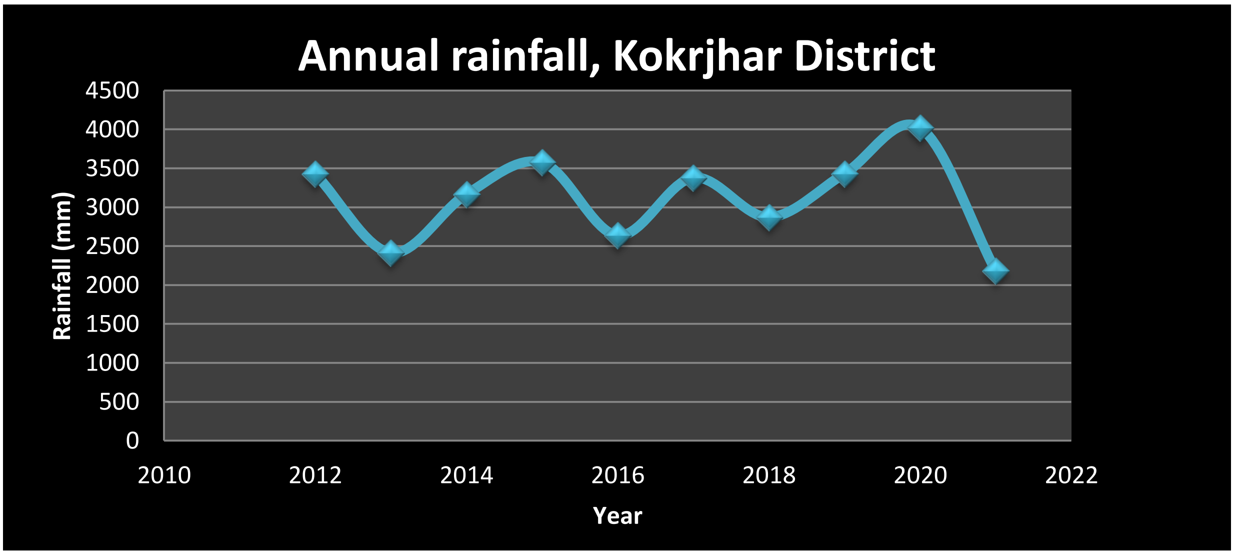

Fig.1. 5: Annual variation of rainfall as recorded I.M.D rain gauge stations of Kokrajhar district

Table 1.4: Rainfall distribution in Kokrajhar district, Assam

State / Dist	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Total
Kokrajhar	2012	3.07	21.62	1.58	270.72	207.37	1417.41	557.96	203.30	564.19	181.50	0.00	0.00	3428.72
Kokrajhar	2013	0.00	15.63	17.74	138.78	450.07	340.67	503.89	314.51	481.94	151.51	0.56	0.04	2415.34
Kokrajhar	2014	0.00	39.73	16.92	50.09	556.36	741.64	484.45	809.58	448.69	18.39	0.29	0.32	3166.46
Kokrajhar	2015	12.09	4.89	37.74	199.28	577.16	1033.46	405.35	967.19	291.87	13.91	20.21	11.51	3574.66
Kokrajhar	2016	8.83	0.91	90.53	336.90	415.00	594.60	649.75	135.33	279.72	125.96	0.00	0.06	2637.59
Kokrajhar	2017	0.04	28.12	79.27	424.38	305.67	486.22	397.76	776.02	615.01	262.19	5.53	0.01	3380.22
Kokrajhar	2018	0.00	14.06	76.85	253.22	517.82	489.02	532.98	293.35	623.33	49.56	13.52	8.66	2872.37
Kokrajhar	2019	0.07	25.20	42.55	220.49	566.16	450.75	1276.83	314.20	422.34	95.39	17.70	0.94	3432.62
Kokrajhar	2020	1.95	12.74	31.99	226.10	594.60	1015.08	666.10	398.97	936.79	119.74	15.83	0.88	4020.77
Kokrajhar	2021	11.86	2.14	62.04	122.24	198.87	455.56	351.01	483.86	237.09	253.82	3.23	0.24	2181.96

1.7 Temperature

The climate of the district is predominantly sub-tropical humid climate with heavy rainfall, hot summer and high humidity. The average temperature ranges from minimum 10^0C to maximum 35^0C throughout the year. The air is highly humid throughout the year. It is comparatively less during the months of February to April having 73 to 78 percentages. It is the highest during the period of May of September, when it ranges between 87 to 94 per cent.

1.8Physiographic set up

Physiographically, the district can be divided into two units i) Northern alluvial region and 2) Southern swamps or flood plains of the river Brahmaputra. The northern alluvial part forms a flat land with heights of 40-300 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 form the main regional drainage. Its tributaries like Gangia, Laponi, Saumukha, Saralaganga and Lonyaetc originating from Northern Himalayan foothill have a steep slope and shallow braided channels for considerable distances. 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 beel and marshy land along the main river course.

The area is characterised by two different land forms, viz Inselbergs and alluvial plains. A large portion of the district is more or less plain and constitutes a part of the vast alluvial area formed by the Brahmaputra River. Hilly tracts of slope more than 20% are found in the northern border of the district with Bhutan and in the south eastern part occupied by inselbergs (Fig. 1.7). The inselbergs are Archean inliers in the form of disconnected and isolated hillocks. These hills are pre Cambrian complex and project abruptly amidst a blanket of alluvium. These inselbergs attain a maximum height of 472.4 above mean sea level in the east of Bidyapur (Fig. 1.6).

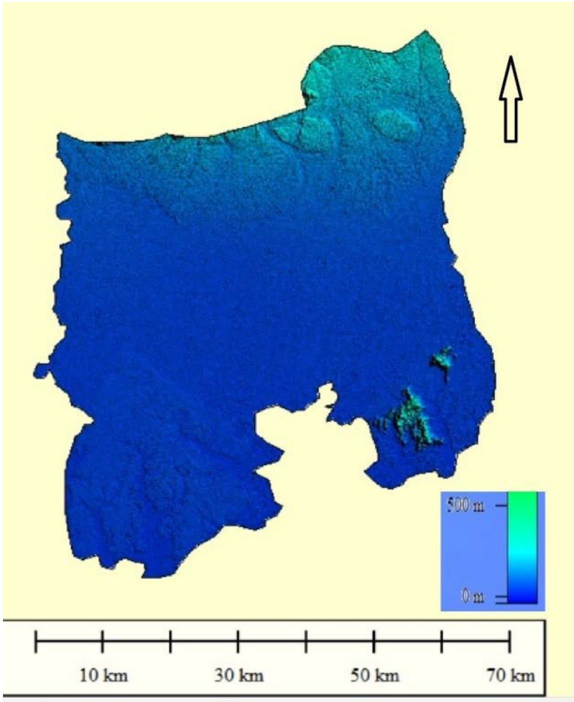

Fig.1. 6: 3D elevation map of Kokrajhar district

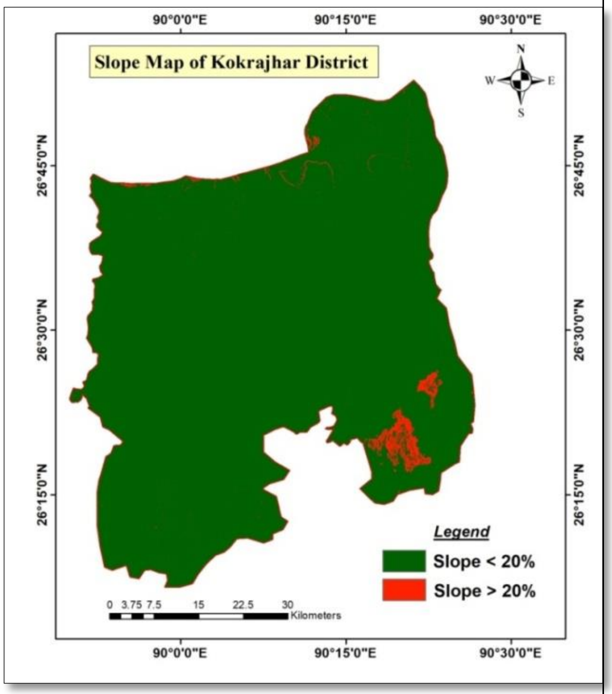

Fig.1. 7: Slope Map of Kokrajhar District, Assam

1.9Drainage and Morphometric Features

The area forms a part of the Brahmaputra Basin and falls in Manas Sub-basin.It is drained by River Saralbhanga, Champamati, Sankosh, Gongia, Gaurang, Tarang, Longa, rivers etc. These rivers are perennial and flow in north-south direction and almost all emerge from the Himalayan foothills of Bhutan in the north (Fig 1.8). These rivers meander and give rise to oxbow lakes along their courses. The drainage density is very high and the pattern is more or less parallel. A number of natural small lakes or beels are formed as a result of change of river courses.

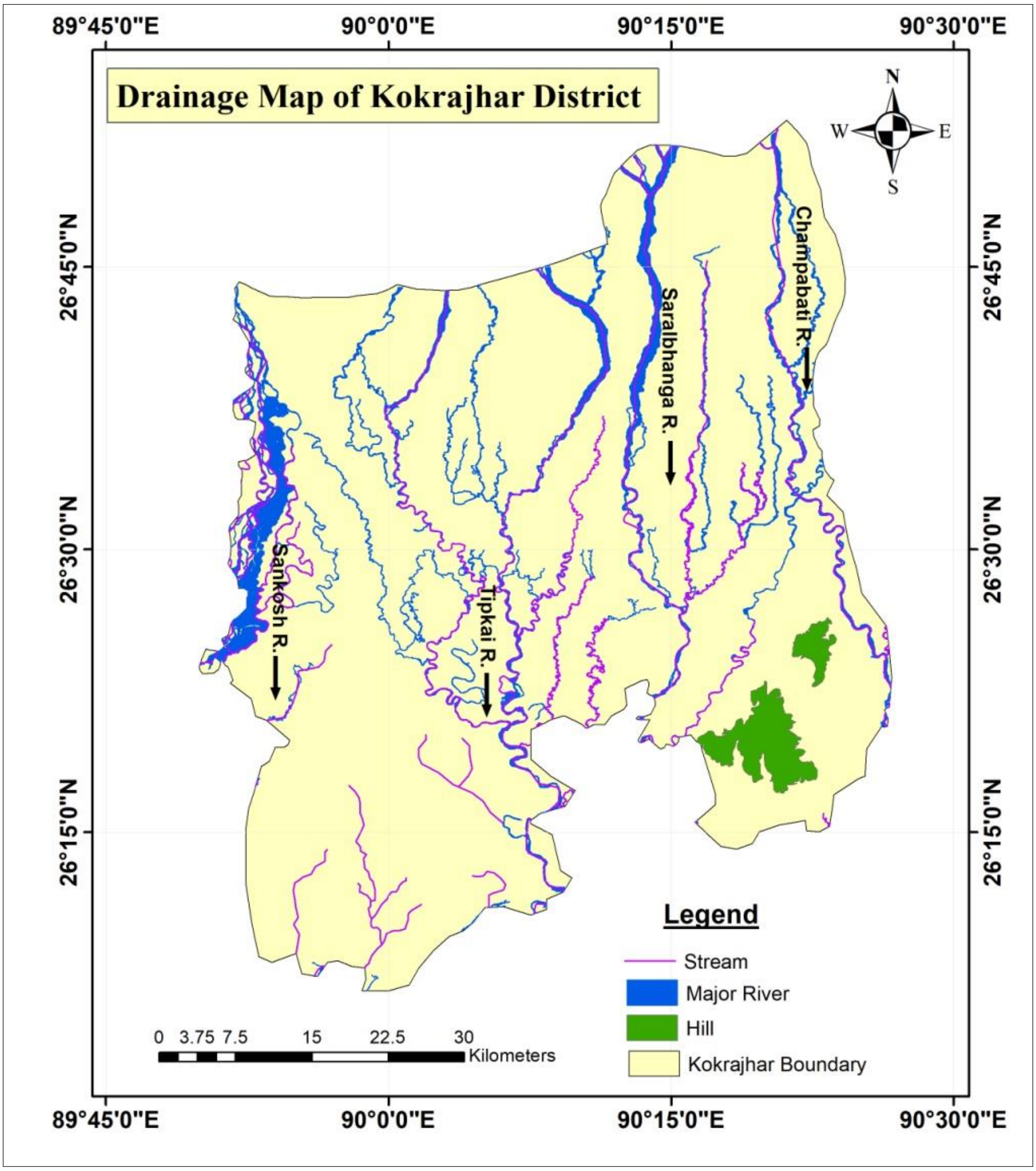

Fig.1. 8: Drainage Map of Kokrajhar District, Assam

1.10 Geology

The area of the district has evolved during the last two million years by alleviation of the foreland depression in between the comparatively younger mountain chain of the Himalayas on the north (in Bhutan) and block mountain chain of the Shillong plateau in the south. The numerous low hills called Inselbergs found scattered near Nandagiri and Kokragaon-Bidyapur are in fact the outlying portions of Shillong plateau and represent the oldest rocks. This metamorphic complex with intrusive granites and pegmatites are surrounded by extensive alluvium (Fig 1.9). The geological succession in the district is in Table 1.5.

Table 1.5: Geological Succession of Kokrajhar District, Assam

Group	Age	Formation	Lithology
Quaternary	Recent to Pleistocene	Newer/Low level Alluvium	Unconsolidated sands of various grades of texture, clay, silt, gravels with occasional pebbles.
		Older/ high level (Piedmont sediments) Alluvium	Sand, coarse to very coarse, clay, gravels and pebbles, boulders, cobbles, pebbles of quartzite, cherts embedded in gravel and sandy matrix.
Unconformity			
Archean	Archean	Metamorphic complex	Ortho and para gneisses, schists intruded by acidic (granitic) and basic intrusives

The geological formation of the district is described below.

a) Archean:

These formations mainly comprise biotite-hornblende gneiss, granulites, schist and bosses of intrusive granite and pegmatite. These have steep sloping with very sharp contact with the surrounding unconsolidated formation. These are called inselbergs.

b) Quaternary:

1) Piedmont plain- This zone occupies the entire northern part of the area running along the foothills of the Bhutan Himalayas. In immediate vicinity of the hills, boulders and cobbles of quartzite predominate in gravel and sandy matrix, the quantity and size reduce from north to south and the proportion of the sand increases south ward. The thickness of this formation ranges from a few metres to about 30 m.

2) High level/ older alluvium (Inselberg zone): It occurs as a broad platform with 20 to 30 metres scarp faces surrounded by low alluvium. The sediments have been deposited in between the erosional remnants of the Archean basement. These consist of unconsolidated reddish to brownish sand, coarse grained clay, silt, and irregularly distributed pebble, cobble beds.

3) Low level/ Newer Alluvium (flood plain): These are formed by the sediments brought down by the post Himalayan rivers and the present rivers during their periods of flood. It generally occurs at lower levels flanking the older alluvial formations. The sediments are light grey to light brown in colour, less compact and consist of sands of various grades, clay, silt, and pebbles, gravels. The granular deposits are mainly confined to the stream channels. The thickness of these deposits varies from 50 to 70 m.

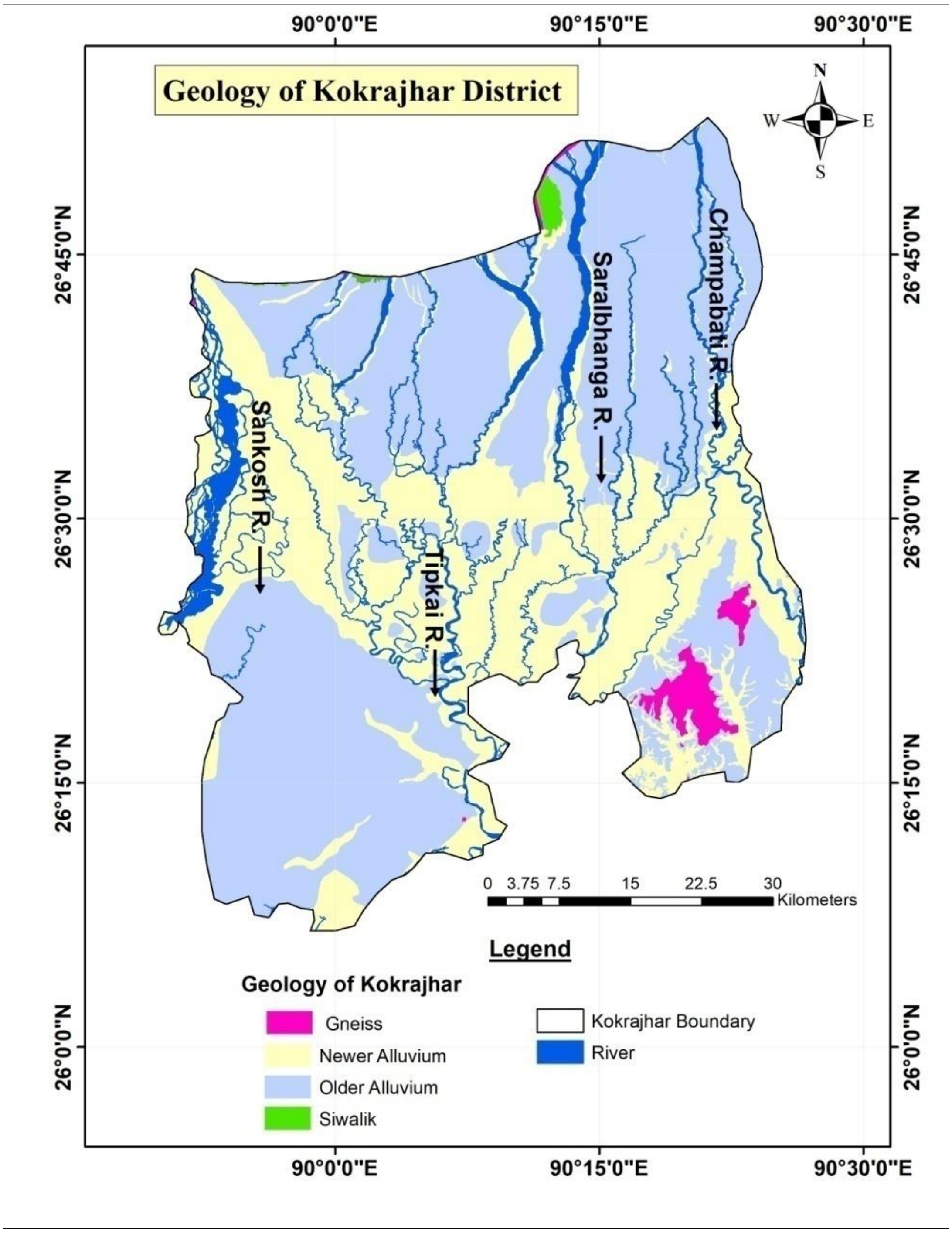

Fig.1. 9: Map showing Geology of Kokrajhar District

1.11Geomorphology

Geomorphologically, the area can be classified into six divisions: active flood plain, younger alluvial plain, older alluvial plain, piedmont alluvial plain, older flood plain and highly dissected structural hills and valleys (Fig 1.10). The piedmont plain forms the highest terrace of Quaternary landscape characterized by high relief with dense forest and thinly populated. The terraced alluvial plain covers the major part of the district.

The flood plain areas are restricted to flood plain of major river and its tributaries consisting of unconsolidated material like gravel, sand, silt and clay. Due to seasonal floods the different depositional environment like paleochannel, natural levees, back swamps wetlands and channel bars are common features of flood plain area. These areas are good for ground water development in shallow depth.

The major part of the district is occupied by younger and older alluvial plain. The elevation of the younger alluvial plain is slightly higher than the flood plain areas, consisting of gravel, sand, silt and clay. These areas are also good for ground water development in shallow depth.

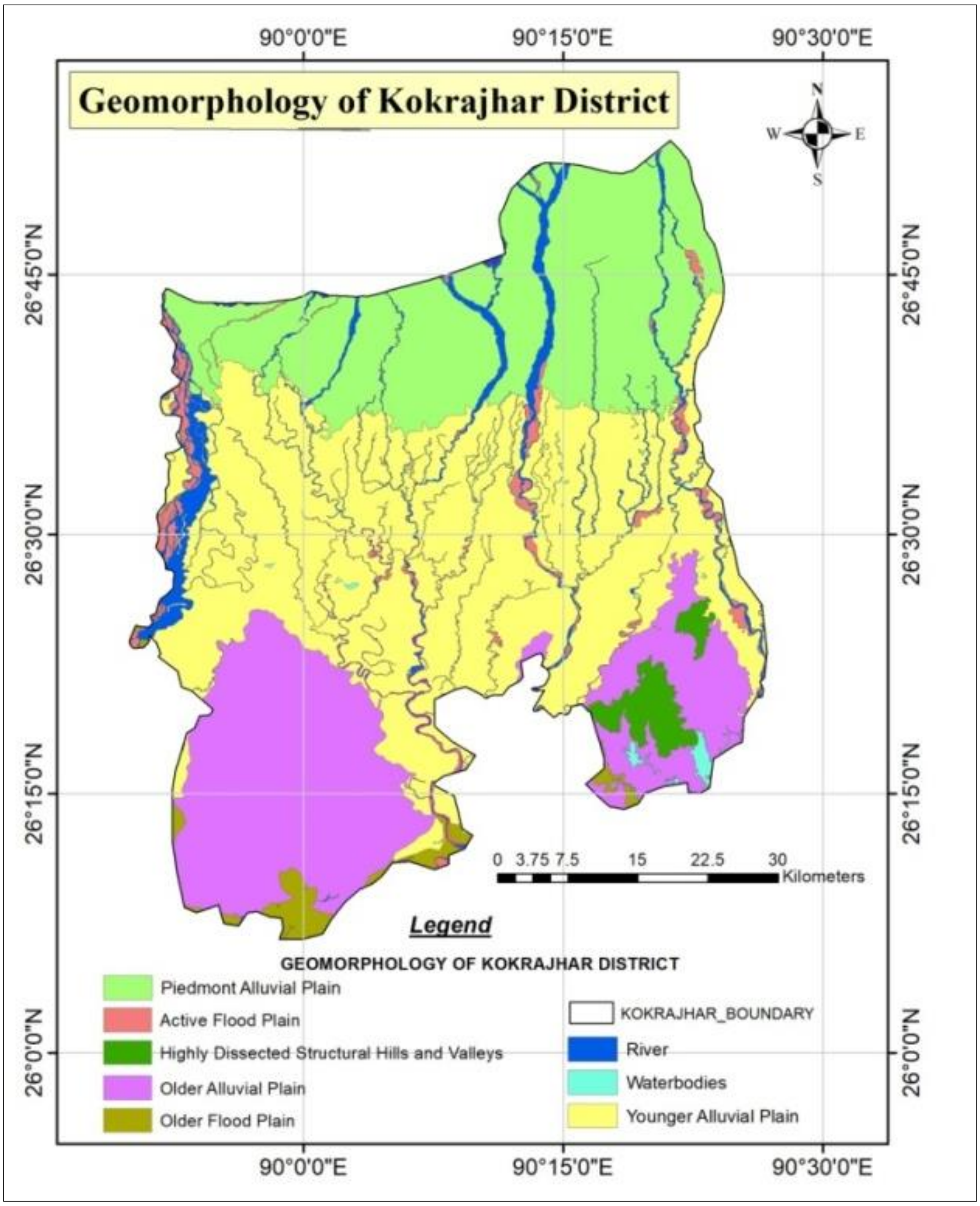

Fig.1. 10: Geomorphological Map of Kokrajhar District, Assam

1.12 Land use Pattern

The net sown area of the district is 95680ha which accounts for 29 percent of the total geographical area (329600ha) of the district & the land utilization pattern in the district is given in Table 1.6. The gross cropped area of the district is 149534ha with cropping intensity of 156 % percent. Out of the total cropped area, 149534 ha and that is36 percent are cropped more than once.

Forest area in the district accounts for 173465 ha i.e. 52.62 % of total Geographic area. Area under non-agricultural uses is 17897 ha. Barren and Uncultivable Land comes to be around 19539 ha. Grazing land of the district is around 12717 ha. Cultivable wasteland is around 3123 ha.

Thick vegetation covers are found in the northern and southern part of the district where reserve forests are located in the piedmont area. Built up area and agricultural land are mostly confined in the central part of the district. Bare areas of rock or soil with very sparse to no vegetation for the entire year are found in the flood plain of rivers (Fig.1.11)

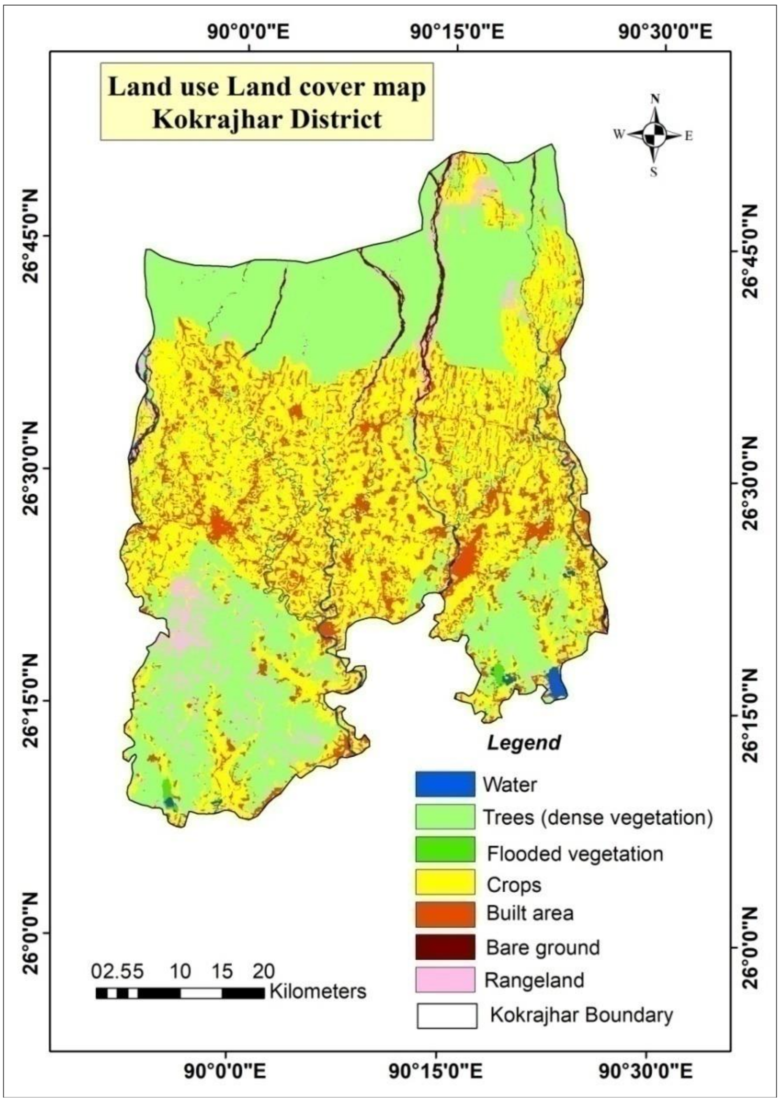

Fig.1. 11: Map showing Land Use and Land Cover, Kokrajhar District.

Table 1.6: Land Use Pattern in Kokrajhar District

Total Area and Classification of Area, 2020-21: ***(Area in Hectare)***

District	Reporting Area for land utilization	Forests	Not available for cultivation		Other Uncultivated Land excluding Fallow Land			Fallow Land		Net Area Sown	Total Cropped Area	Area Sown more than once
			Area under non-agricultural uses	Barren and Uncultivable Land	Permanent Pastures and other Grazing Land	Land under Misc. Trees groves not including in Net Area Sown	Cultivable Waste Land	Fallow Land other than Current Fallow	Current Fallow			
Kokrajhar	**329600**	**173465**	**17897**	**19539**	**12717**	**3046**	**3123**	**2654**	**1479**	**95680**	**149534**	**53854**

Source: Statistical Handbook, Assam-2021

1.13 Soil

The formation of the district has a wide range from Archean to Recent in age. These have undergone diversified podogenesis depending upon the composition of the parent material, paleo-geographical and climatic conditions shown in Fig.1.12.

The soils of the area are mainly alluvial in nature, which is composed of mixture of sand, clay and silt in varying proportions. The soils can be grouped into three zones.

1) The piedmont plain has soil sandy in nature, alkaline to slightly acidic. It is highly permeable and is covered by thick forest.

2) The floodplain has loamy (sandy silt loam to clayey loam or loamy clay) soil in nature. It is moderately permeable (highly permeable at places, particularly in recent flood plain areas developed by the present day streams where it contains more percentage of fine sand and silt). It is less acidic than piedmont plain soil.

3) High level alluvial soil or inselberg zone is comparatively more acidic in nature. It is composed of clay and laterite yellowish to reddish in colour.

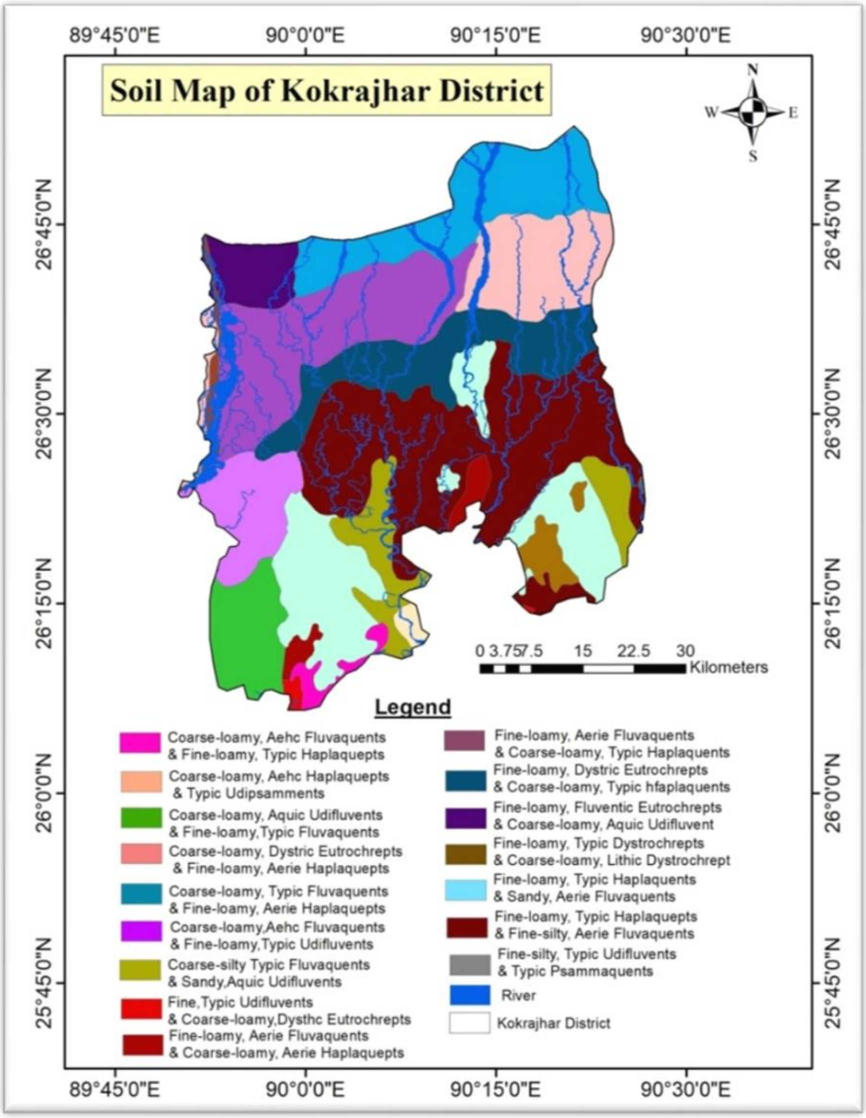

Fig.1. 12: Soil Map of Kokrajhar District, Assam

The soil of the district is good for cultivation of all types of crops. Comparatively, the areas of the recent flood plains are most suitable for winter crops such as rape, mustard and potato. The soil of the inselberg zone is favorable for the plantation.

1.14 Hydrology and surface water

Surface water bodies are mainly observed in the flood plain area where southward flowing rivers loses its gradient. Waterlogged and marshy lands are observed. The area covered by the surface water bodies are shown in the following Table 1.7.

Table 1.7: Water bodies in Kokrajhar District

Sl no	Water bodies	Area in ha
1	Ponds and tanks	1900.00
2	Paddy field/canal fisheries	395.00
3	Derelict water bodies	572.00
4	Beel fisheries	2066.00
5	River fisheries	2457.00
6	Eco hatchery	-
7	Magur hatchery	-
8	Forest Fisheries	208.00
Total		7598.00

Source: Statistical Handbook Assam 2021

1.15Agriculture

Agriculture is the main occupation of Kokrajhar district and contributes a major part in the district economy. Rice is the main crop grown in the district. The major crops of Kokrajhar district are paddy, jute, banana, pulses, potato and mustard. Under horticultural crops, cucumber, cauliflower, radish, tomato, banana, citrus, pineapple, jackfruit, areca nuts, coconut etc. are grown.

There are numbers of tea gardens in thedistrict. Three types of rice are grown in the district, viz., autumn rice or *ahu*, winter rice or*Sali*and summer rice or *boro*. Farmers are more dependent on winter rice.In the rabi season oilseed crops mainly mustard and rapseed are extensively grownin the district. Winter paddy is the most important crop in the district. Winter paddy occupies 80.4 % followed by summer paddy 14.03% and autumn paddy 5.56 % of the total annual paddy area.

Net irrigated area is 18703 ha. As the net sown area of the district is 151867ha, totally unirrigated or rain fed area of the district is found to be 133164ha.The net sown area accounts for 46 percent of the geographical area of the district.

Table 1.8: Season wise area covered and production of Rice in Kokrajhar district Area, Production and Yield of Rice, 2020-21:

District	**Season**	**Area (Hectare)**	**Production (Tonnes)**	**Yield (Tonnes/Hectare)**
Kokrajhar	Autumn	2964	6734.21	2.272
	Summer	7482	19692.6	2.632
	Winter	42860	129394	3.019
	Total	53306	155821	7.923

Source: Statistical Handbook Assam 2021

1.16 Irrigation

Agricultural activities in the district are predominantly rain fed as out of the total cropped area only 12.5 % area is under irrigation. Surface and ground water resources are used in the district for irrigation purposes. Source of water supply include major and medium irrigation canals, minor irrigation tank, diversion channels, rain water harvesting structures and ground water extraction structures. The government of India has formulated Pradhan Mantri Krishi Sinchaya Yojana (PMKSY) scheme with a vision of extending the coverage of 'Har Khet Ko Pani' in a focused manner. The scheme has a ground water component (PMKSY-HKKP-GW) which is for creating additional irrigation and aims in utilizing ground water resources for irrigation purpose in areas where groundwater is sufficiently available. It will also furthermore enhance the small and marginal farmer's income by providing assured irrigation facilities and thus bringing much desired rural prosperity.

Table 1.9: Irrigation potential created through irrigation scheme, 2020-21

Irrigation scheme	Major & medium irrigation scheme		Minor irrigation scheme					
Kokrajhar district	Surface flow	Total	Surface flow	Surface lift	Deep tube well	Shallow tube well	PMKSY HKKP Tube well	Total
Area(ha)	4960	4960	30732	4954	938	100	1680	38404

Source: Statistical Handbook Assam 2021

Table 1.10: Gross Area Irrigated under Govt. Irrigation Facilities, 2020-21

District	Irrigation scheme				Source		
	Surface lift	Surface flow	Ground water lift	Total	Canals	Tube wells	Total
Kokrajhar (ha)	585	33911	524	35020	34496	524	35020

Source: Statistical Handbook Assam 2021

Table 1.11: Sector wise Irrigation Potential Created, 2018-19 (Cumulative): (Area in Ha)

District	Irrigation potential created up to 31st March, 2021			
	Minor Irrigation	**Major/Medium Irrigation**	**PMKSY HKKP**	**Grand Total**
Kokrajhar	36724	4960	1680	43364

Source: Statistical Handbook Assam 2021

CHAPTER 2.0

2.0 Data Collection and Generation

2.1 Data collection

Data collection includes collection of rainfall data from IMD, litholog collection from state groundwater departments, compilation of CGWB’s earlier survey data and exploration data. Population data is collected from Census of India website. Agriculture data are taken from statistical handbook Assam 2021, District Irrigation Plan, 2016-2021, Kokrajhar, Assam prepared by NABARD.

CGWB had constructed 2 exploratory wells in this area earlier.Public Health Engineering Department and Irrigation department Govt. of Assam had constructed number of tube wells in the area and the department provided lithology data.

Rainfall data was collected from Indian Meteorological Department.

2.2 Data Generation

2.2.1 Hydrogeological data

The entire study area is covered by regular monitoring of existing 10GWMS and another 54 key wells have been established. All these wells are monitored duringestablishment (Table 2.1).

2.2.2 Exploratory Drilling

Two exploratory drilling and two observatory wells were drilled in the study area by CGWB and the details is shown in Table 2.2.Also, CGWB is planning to construct 5 exploratory wells and observation wells in the district through outsourcing.

2.2.3 Soil Infiltration studies:

Soil infiltration studies determine the infiltration capacity or infiltration rate of a soil. The infiltration rate is the amount of water per surface area and time unit which penetrates the soils. It provides a scientific approach of groundwater recharge, its suitability and the amount of water recharging in that area, and rainfall infiltration factor. The infiltration rate was determined by using double ring infiltrometers method. In the district two soil infiltration tests were conducted and the details of soil infiltration test are given in Table 2.1. Table 2.2 summarizes the test conducted in the district.

Table 2.1: Location and soil types details of Soil infiltration Test

Sl.No	Site	Location	Land Use	Soil Type	Latitude	Longitude
1	Bhadranpur L.P School	Next toBhadranpur L.P School	Open field	Fine Loam	26.612293	90.290099
2	Bhumka Pt I	Next to Private Residence	Open field	Fine Loam	26.384499	90.029750

Table 2.2: Result of Summary of Soil infiltration Test

Sl.No	Site	RL(m)	Infiltration rate(mm/hr)	Duration of test(min)
1	Bhadranpur L.P School	107	12	88
2	Bhumka Pt I	63.4	10	84

2.2.4 Water Quality

During pre-monsoon and post-monsoon 36nos of ground water samples were collected from dug well, hand pump and tube wells of the study area for chemical analysis of various parameters.

2.2.5 Geophysical survey

During AAP 2022-23, 7 numbers of VES survey was conducted with maximum current electrode separation of around 300m and 700 m using Schlumberger configuration. The results were correlated with the hydrogeological data of the boreholes located near the location of VES.The location details of these VES survey is shown in Table 2.3.

Table 2.3: GWMS and Key wells details

Sl.no	District	Village	Latitude	Longitude	Well establishment	Well type	RL (m amsl)	Measurement point (magl)	Diameter (m)	Depth(m)	WL (mbgl) Nov
1	Kokrajhar	Alangi Bazaar	26.562	90.260	Key well	DW	70.4	0.72	1.1	7.3	4.66
2	Kokrajhar	Anyajuli	26.318	90.370	Key well	DW	42	0.89	1.1	7.62	4.51
3	Kokrajhar	Athiabari	26.596	90.192	Key well	DW	74.7	0.78	0.75	5.88	2.53
4	Kokrajhar	Bagmara	26.474	90.115	Key well	DW	50.4	1	1.5	6.28	2.65
5	Kokrajhar	Ballamguri	26.466	89.954	Key well	DW	54.1	1.1	0.78	5.2	2.39
6	Kokrajhar	Basugaon	26.474	90.420	Key well	DW	58.4	0.89	0.7	8.8	3.03
7	Kokrajhar	Bengaldoba	26.347	90.393	Key well	DW	47.8	1.4	1	9.94	6.02
8	Kokrajhar	BhogAmguri	26.513	90.318	Key well	DW	55.6	1.05	1.12	4.6	5.09
9	Kokrajhar	Bhojighora	26.335	90.014	Key well	DW	52.8	0.88	1.8	8.1	4.56
10	Kokrajhar	Bhotgaon	26.350	90.235	Key well	DW	41	0.95	1.1	6.16	2.35
11	Kokrajhar	Bonorogaon	26.469	90.221	Key well	DW	55.3	0.86	1.1	4.58	2.17
12	Kokrajhar	Chilkikhata	26.278	90.044	Key well	DW	51.5	0.9	0.77	12.64	7.33
13	Kokrajhar	Chithila	26.410	90.137	Key well	DW	48.5	0.63	1.19	7.11	4.45
14	Kokrajhar	Daukibari	26.304	90.302	Key well	DW	39	0.74	0.8	6.86	2.26
15	Kokrajhar	Duligaon	26.242	90.075	Key well	DW	51.2	0.87	1.1	11.2	7.09
16	Kokrajhar	Fakiragram	26.368	90.176	Key well	DW	44.1	0.87	1	8.4	4.7
17	Kokrajhar	Fukangaon	26.448	90.379	Key well	DW	54.2	0.45	0.7	5.7	2.29
18	Kokrajhar	Gandabil	26.346	90.024	Key well	DW	51.6	0.76	1.1	9.46	6.93
19	Kokrajhar	Genduguri	26.620	90.230	Key well	DW	86	0.72	0.95	10.03	1.44
20	Kokrajhar	Gurufala	26.519	90.030	Key well	DW	55.2	0.59	0.6	5.2	3.24
21	Kokrajhar	Halghora Market	26.365	90.088	Key well	DW	45.2	0.85	1.05	6.6	3.54
22	Kokrajhar	Jaimary	26.522	90.244	Key well	DW	59.8	0.87	0.66	4.76	2.57
23	Kokrajhar	JogdoiMuslim	26.360	90.123	Key well	DW	41.2	1	0.9	5.97	3.72

Sl.no	**District**	**Village**	**Latitude**	**Longitude**	**Well establish ment**	**Well type**	**RL (m amsl)**	**Measurement point (magl)**	**Diameter (m)**	**Depth(m)**	**WL (mbgl) Nov**
		Para									
24	Kokrajhar	Kakrikhola	26.370	90.358	Key well	DW	51.5	1.4	1.5	7.67	4.2
25	Kokrajhar	Kashiabari	26.542	89.920	Key well	DW	64.9	0.82	0.77	4.4	2.51
26	Kokrajhar	Khalasi	26.640	90.230	Key well	DW	94	1.1	0.66	24	6.54
27	Kokrajhar	Khalasi 2	26.680	90.230	Key well	DW	113	1	1.02	>30	2.84
28	Kokrajhar	Khalisarimari	26.422	90.097	Key well	DW	47.3	0.66	0.17	5.71	2.19
29	Kokrajhar	Lalmati L.P. School	26.363	90.410	Key well	DW	50.1	0.82	0.97	8.74	4.06
30	Kokrajhar	Magurmari LP School	26.395	90.226	Key well	DW	54.2	1.1	1.05	10.48	5.76
31	Kokrajhar	MahamayaM andir	26.560	90.080	Key well	DW	57	0.56	0.65	4.48	2.54
32	Kokrajhar	Mandarpara	26.422	90.073	Key well	DW	47.3	0.8	0.77	6.4	2.69
33	Kokrajhar	Mauriagaon	26.349	90.359	Key well	DW	48.2	0.89	1.1	10.23	7.75
34	Kokrajhar	Modati FV	26.579	89.955	Key well	DW	67.2	0.88	1.6	4.73	2.22
35	Kokrajhar	Mornai Tea estate	26.361	89.898	Key well	DW	42.8	0.85	1	5.65	3.38
36	Kokrajhar	Mukhigaon	26.416	90.169	Key well	DW	47	1	1.9	7.54	2.48
37	Kokrajhar	Nayachara II	26.416	90.400	Key well	DW	49.7	0.89	0.64	5.92	5.11
38	Kokrajhar	Oxyguri FV	26.636	89.979	Key well	DW	75.5	0.83	1.09	7.68	2.21
39	Kokrajhar	Patgaon Market	26.650	90.210	Key well	DW	104	0.66	0.8	4.9	1.84
40	Kokrajhar	PratakhataPt II	26.378	90.165	Key well	DW	44.2	0.95	1.23	6.87	3.19
41	Kokrajhar	Raimona FV	26.623	89.969	Key well	DW	71.6	1	1.5	3.53	1.14
42	Kokrajhar	Rainadabri	26.350	90.269	Key well	DW	41	0.89	1.1	7.5	3.01

Sl.no	**District**	**Village**	**Latitude**	**Longitude**	**Well establish ment**	**Well type**	**RL (m amsl)**	**Measurement point (magl)**	**Diameter (m)**	**Depth(m)**	**WL (mbgl) Nov**
43	Kokrajhar	Ranipur	26.610	89.998	Key well	DW	69.6	0.78	0.8	5.2	1.54
44	Kokrajhar	Sapatgram	26.331	90.118	Key well	DW	43.8	1.84	0.6	4.85	2.08
45	Kokrajhar	Saralpara	26.819	90.256	Key well	DW	225.6	1.5	1.2	13.18	7.5
46	Kokrajhar	Sesapani	26.195	89.984	Key well	DW	32	0.86	1.2	12.7	8.26
47	Kokrajhar	Tintila	26.280	90.361	Key well	DW	45.6	0.8	0.6	11.98	8.22
48	Kokrajhar	Titaguri	26.439	90.288	Key well	DW	52.7	0.88	0.8	6.33	2.6
49	Kokrajhar	Uttar Charaikhola	26.399	90.316	Key well	DW	47.2	0.89	1.1	8.4	4.01
50	Kokrajhar	Basbari	26.190	89.900	Key well	DW	47.8	1	0.88	15	8.39
51	Kokrajhar	Monglajhora	26.250	89.950	Key well	DW	48	0.9	1	11	6.72
52	Kokrajhar	Chesapani	26.290	89.904	Key well	DW	43.4	0.8	1	6.09	3.73
53	Kokrajhar	BhumkaPt I	26.384	90.030	Key well	DW	44.4	0.86	0.76	5.85	2.75
54	Kokrajhar	Mandarpara	26.422	90.073	Key well	DW	45.5	0.8	0.77	6.4	2.69
55	Kokrajhar	Rupshi	26.118	89.923	NHNS	DW	25	0.9	1	7.5	2.27
56	Kokrajhar	Dotma	26.467	90.150	NHNS	DW	53.6	0.97	0.7	5.91	3.5
57	Kokrajhar	Gossaigaon	26.436	89.990	NHNS	DW	50	1.15			3.05
58	Kokrajhar	Kachugaon	26.566	90.072	NHNS	DW	61.7	1	0.65	6.6	2.32
59	Kokrajhar	Kokrajhar	26.398	90.268	NHNS	DW	48.5	1	1.16	7.7	3.79
60	Kokrajhar	Serfanguri	26.554	90.153	NHNS	DW	64.7	0.78	0.9	5.68	2.33
61	Kokrajhar	Ultapani	26.785	90.309	NHNS	DW	181.6	1	3.2	14.52	3.35
62	Kokrajhar	Amguri	26.540	90.338	NHNS	DW	60	0.89	1	7.4	5.25
63	Kokrajhar	Srirampur Forest Range	26.437	89.900	NHNS	DW	10	0.7	0.88	6.1	4.52
64	Kokrajhar	Bishmuri	26.561	90.292	NHNS	DW	71.8	0.85		5.93	3.39

*DW-Dug well

Table 2.4: Details of exploratory wells in Kokrajhar District, Assam

Sl No	Location	Toposheet No	Longitude	Latitude	Type of Well (DW/ BW/ TW)	Depth	Depth of construction (m)	Length of pipe	Source
1	Genduguri-EW	78J2	90°14’40	26°37’41	TW	106.00	98.50	Slotted pipe: 36 m Blank pipe: 62.50 m	CGWB
2	Serfanguri -EW	78J2	90°09’48	26°33’28	TW	61	58.50	Slotted pipe: 9 m Blank pipe: 19.50 m	CGWB

Table 2.5: Details of VES, Kokrajhar district

Sl. No.	District	Location	Coordinate		Depth of major Aquifer layers (m)		Thickness of Aquifer layer (m)	Resistivity Ohm m	Remark
1	Kokrajhar	Sesapani	26.4000	90.2240	0	3	3	669	Topsoil with pebbles
					3	17	14	1153	Sand with pebbles and boulders
					17	99	82	201	Sand with gravel
					Below 99			58	Sand with clay formation
2	Kokrajhar	Garjan II	26.4400	90.0440	0	3	3	2213	Topsoil with pebbles and boulders
					3	35	32	1708	Sand with pebbles and boulders
					Below 35			60	Sand with clay formation
3	Kokrajhar	Awjarguri	26.9853	90.3118	0	2.84	2.84	4268	Topsoil with boulders
					2.84	7.98	5.14	945	Sand with pebbles
					7.98	33.8	25.82	1934	Sand with pebbles and boulders
					33.8	63.6	29.8	74.7	Silty sand
					Below 63.6			16828	Consolidated formation

Sl. No.	District	Location	Coordinate		Depth of major Aquifer layers (m)		Thickness of Aquifer layer (m)	Resistivity Ohm m	Remark
4	Kokrajhar	Labanyapur-Ultapani	26.7781	90.3101	G.L.	0.9	0.9	1008	Topsoil with pebbles
					0.9	4.32	3.42	2382	Sand with pebbles and boulders
					4.32	20.81	16.49	3137	Sand with pebbles, cobbles and boulders
					20.81	45.62	24.81	2121	Sand with pebbles and boulders
					45.62	100	54.38	314.5	Sand
					Below 100			911.5	Sand with pebbles
5	Kokrajhar	Selekhaguri	26.6013	90.2540	G.L.	0.49	0.49	2780	Topsoil with boulders
					0.49	1.52	1.03	7026	Sand with pebbles cobbles and massive boulders
					1.52	2.87	1.35	468	Sand with pebbles
					2.87	34.5	31.6	2458	Sand with pebbles and boulders
					Below 34.5			512	Sand with pebbles
6	Kokrajhar	Jogendrapur	26.5806	89.9978	G.L.	1.98	1.98	263	Topsoil
					1.98	4.33	2.35	5092	Sand with pebbles and boulders
					4.33	47	42.7	804	Sand with pebbles and gravel
					Below 47			526	Sand with pebbles
7	Kokrajhar	Brbadha	26.3673	89.9332	G.L.	0.9	0.9	2184	Topsoil with boulders
					0.9	1.97	1.07	989	Sand with pebbles and cobbles
					1.97	4.33	2.36	196	Sand
					4.33	25.7	21.37	2342	Sand with pebbles and boulders
					25.7	112	86.3	379	Sand
					Below 112			35228	Consolidated formation

CHAPTER 3.0

Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

The aquifer system of the district is interpreted based – exploration data of Central Ground Water Board (CGWB) and State Govt. agencies in conjunction with geophysical data of CGWB. Lithologs of CGWB's exploratory well and shallow tube wells of PMKSY-HKKP-GW indicate that the subsurface is dominated by gravel, pebbles, sand, clay and boulders. Geophysical data also conforms the subsurface data derived from lithologs. Thus down to a depth of 134m, presence of one principal aquifer in the district, viz., alluvium of unconsolidated nature of Quaternary age is established. The Archean inselbergs are found in the southern eastern part of the district as structural hills with slope more than 20%. It mainly acts as a run-off zone.

3.1.1 Geophysics and aquifer Characterization

The surface geophysical study was carried out during the AAP 2022-2023 in Kokrajhar district to assess the feasibility of exploratory tubewell at selected sites and to assess subsurface geology at particular places assumed to be the location of data gaps under aquifer mapping. Large numbers of buildings and constructions in the study area of Kokrajhar posed constraints resulting in limited spaces for resistivity surveys and only the current electrodes spread available was in the range of 300 m and 700 m. QHK,AKQ,AAK,KQ,HKH,QQH,HAKH and HKQ type VES curves were obtained. Taking into account the interpreted results as well as the apparent resistivities, inferences have been approximated to deeper depths in a few places.

Based on the analysis of interpreted data of geophysical studies, the study area consists of older alluvium and newer alluvium consisting of sand with cobbles, pebbles, boulders and clay. The aquifers are consisting of sands of various grades with gravel that are suitable for construction of both shallow and deep tube wells.

3.1.2Data Integration

Central Ground Water Board, North Eastern Region, Guwahati has drilled 2 exploratory wells and 7 nos of VES were carried out in the district. In addition, the litholog of the tube wells drilled by state govt departments are also used to delineate the aquifer section. The lithologs are dominated by sand and gravel, pebbles and boulders with fine to coarse grained sand matrix. Lithologic units of the district are grouped according to size of alluvial materials. The sand and gravels are grouped together into sand aquifer. Pebbles, cobbles and boulders are grouped together as a separate aquifer. Clay in the district occurs with sand, gravels and hence all clays are grouped into clay.

3.1.3Aquifer Disposition

To understand the disposition of aquifer, 2D and 3D sections are constructed using the lithologs of the exploratory wells, VES data and lithologs of state govt tube wells.

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

(a) a North - South section from Bongaon to Shimultapur in the flood plain formation parallel to the River Sankosh (Fig. 3.1).

(b) A North- South section showing sub surface aquifer disposition across the Piedmont older alluvial plain and younger alluvial plain (Fig. 3.2).

(c) An East - West section from Titaguri to Mallikapurshowing sub surface aquifer disposition in younger and older alluvial plain (Fig. 3.3).

Bongaon to Shimultapur:

This North South section along River Sankosh is a representative of the flood plain section. The top layer consisting silt and clay (topsoil) upto a depth of 2-7 m is observed throughout the section. A 15 m thick first clay layer is observed in the middle section at Khaksaguri where it thins out in the northern and southern part of the section. Apart from this clay layer, a second layer of clay nearly of 8 m thickness is consistently found at 27 m depths. A 7 m thick clay layer is observed in the southern section and it pinches out towards north. The first sand and gravel horizon of 20 m is encountered in the northern part upto a depth of 27m which pinches out into sand and clay horizon toward south. A second layer of sand and gravel horizon is encountered at a depth 30 m. The section is underlain by pebbles and gravels upto a depth of 43 m (Fig 3.1).

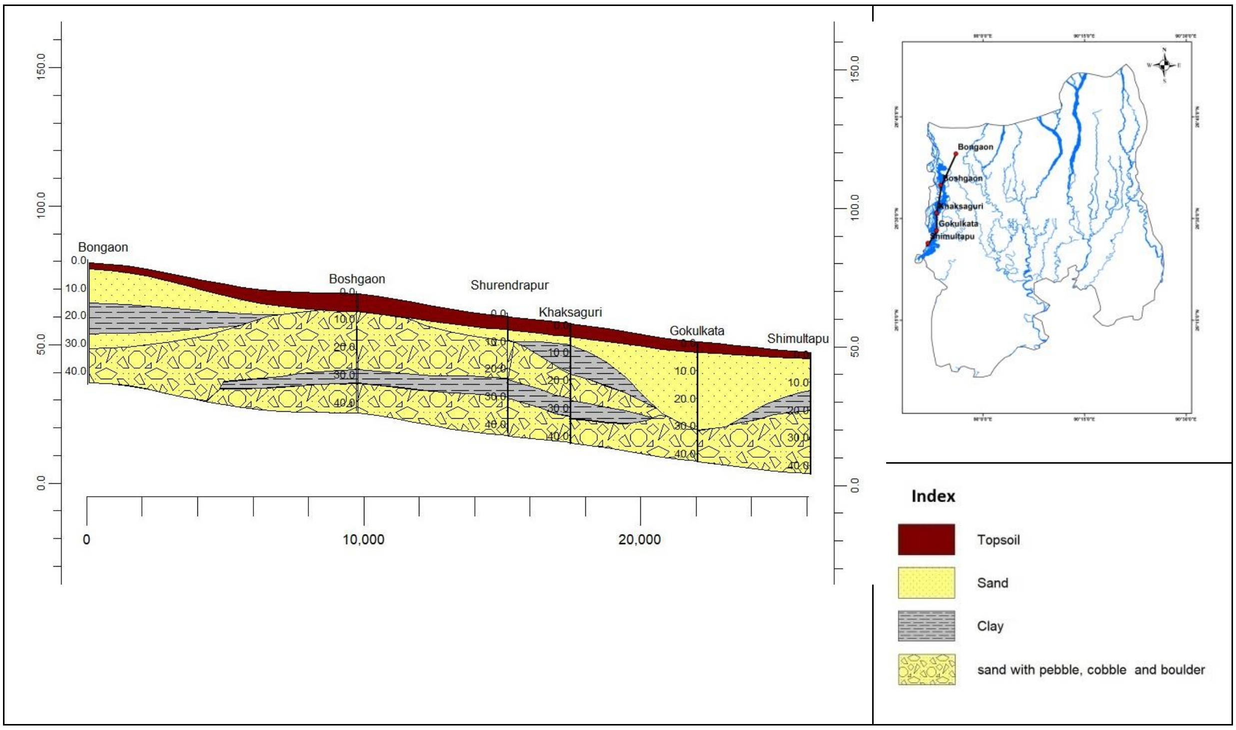

Fig.3. 1: North - South section showing sub surface aquifer disposition along the flood plain of RiverSankosh

Labanyapur to Sesapani:

The cobbles, pebbles and bouldery formation start immediately below the top soil at 2m depth and continue upto 45 m which is underlain by a sandy layer upto a depth of 100 m at Labanyapur in the north in the piedmont zone. Presence of thick layer of sand with cobbles, pebbles and boulders is prominent towards the south extending upto a depth of 106 m at Genderguriunderlying the surface soil which acts as an eminent aquifer. The sand layer reappears in the south at Sesapani (Fig 3.2).

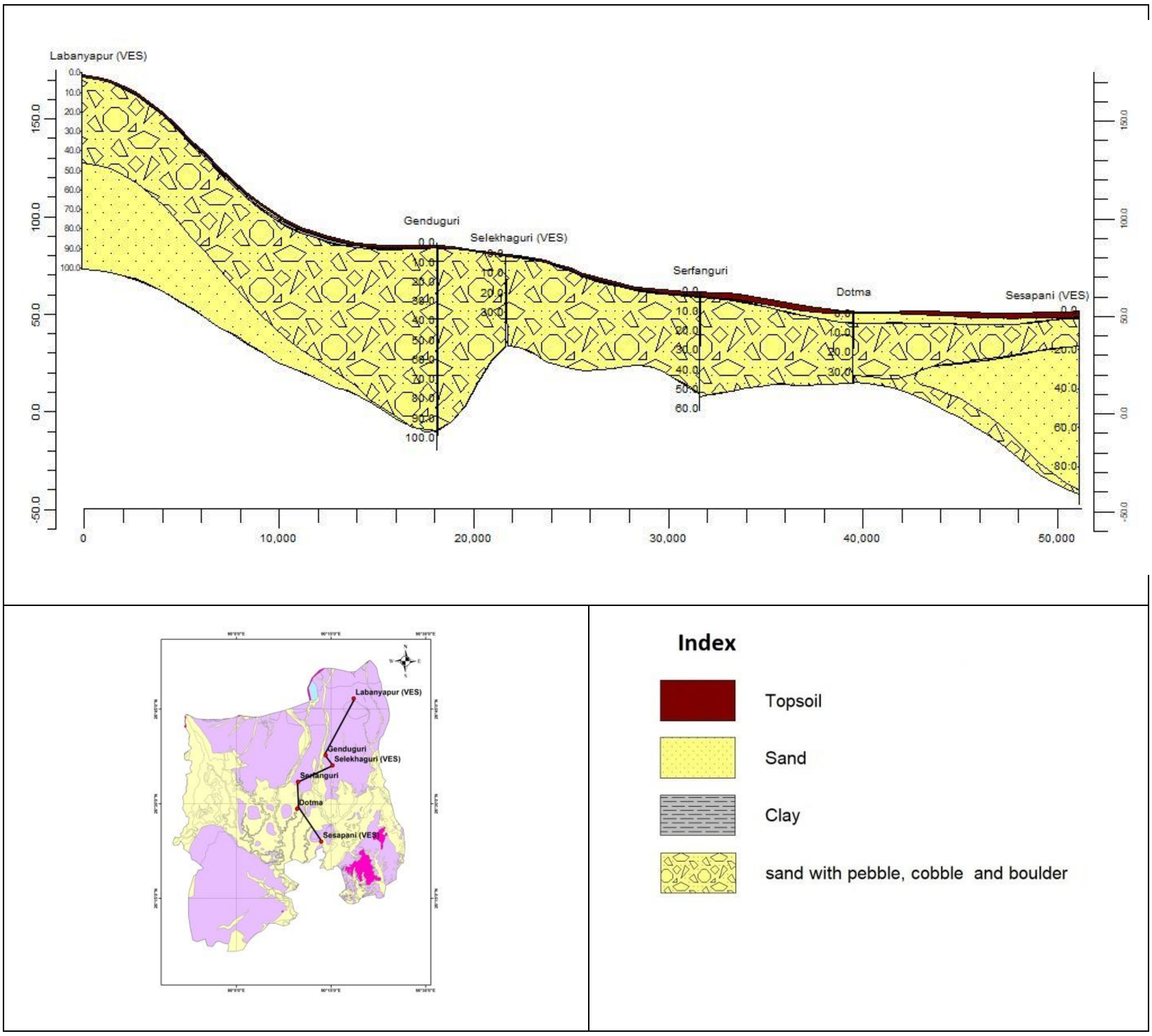

Fig.3. 2: North- South section showing sub surface aquifer disposition across the Piedmont older alluvial plain and younger alluvial plain.

Mallikapur to Titaguri:

The East-west section is a representative of the younger and older alluvial section. A clay layer of 9mthicknessis encountered just below the top soil at Mallikapur which pinches out and become insignificant towards east. The section is dominated by sand layer and cobbles, pebbles and bouldery formation down to a depth of 112m (Fig 3.3).

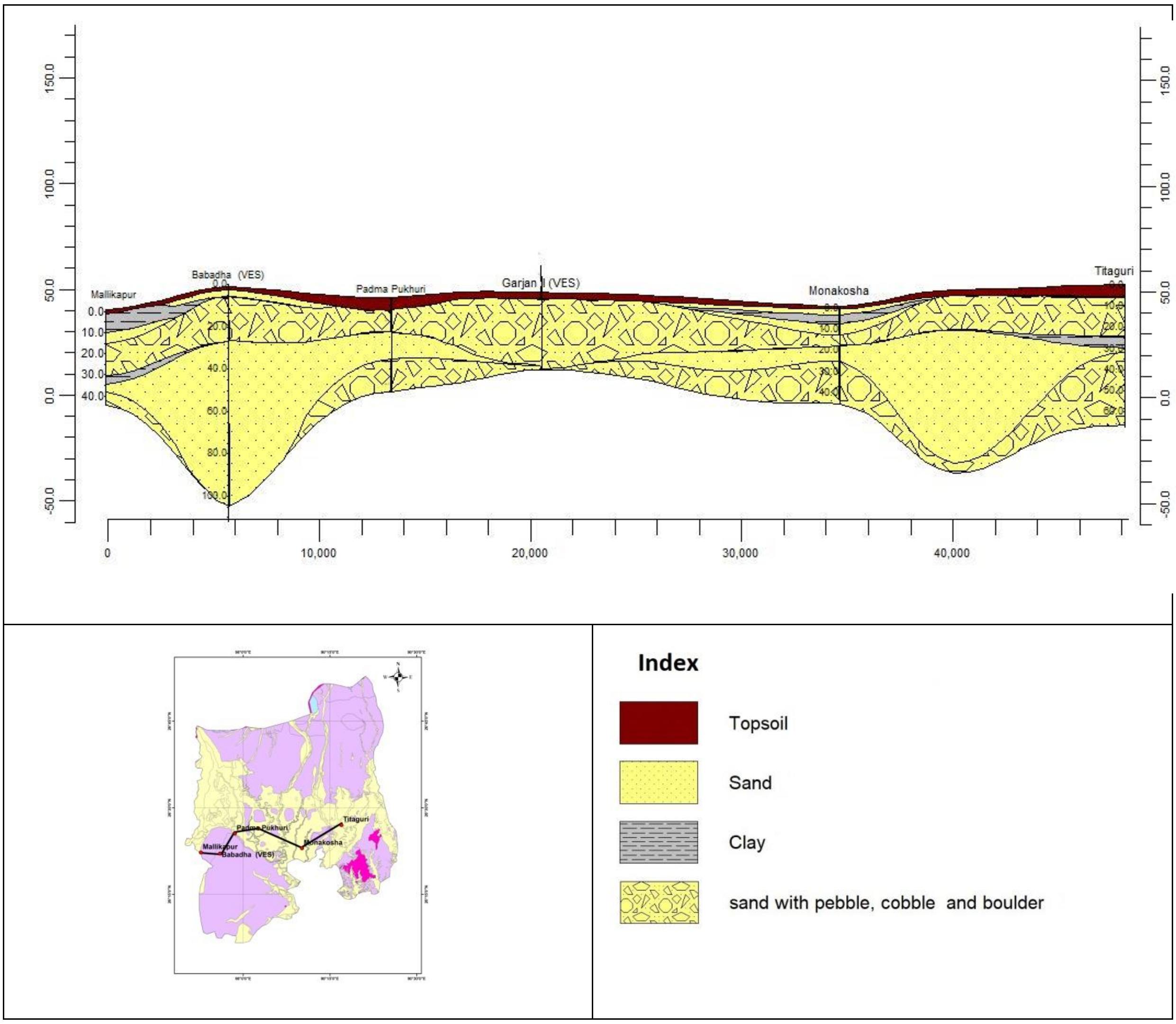

Fig.3. 3: A section showing sub surface aquifer disposition in younger and older alluvial plain.

3D Disposition of aquifer: The alluvial aquifer is sand and gravel dominated which is evident from the 3D fence diagram.

The fence diagram of the district indicates that the subsurface formation close to the piedmont alluvial is dominated by pebble, gravel and sand in the eastern part with an intervening clay layer extending toward west. The younger alluvial formation is dominated by sand and gravel formation extending towards the south into older alluvial plain where the clay layer reappears. The formation along the flood plain in the western part of the district is dominated by pebbles, gravels mixed with sand with intervening clay layer.

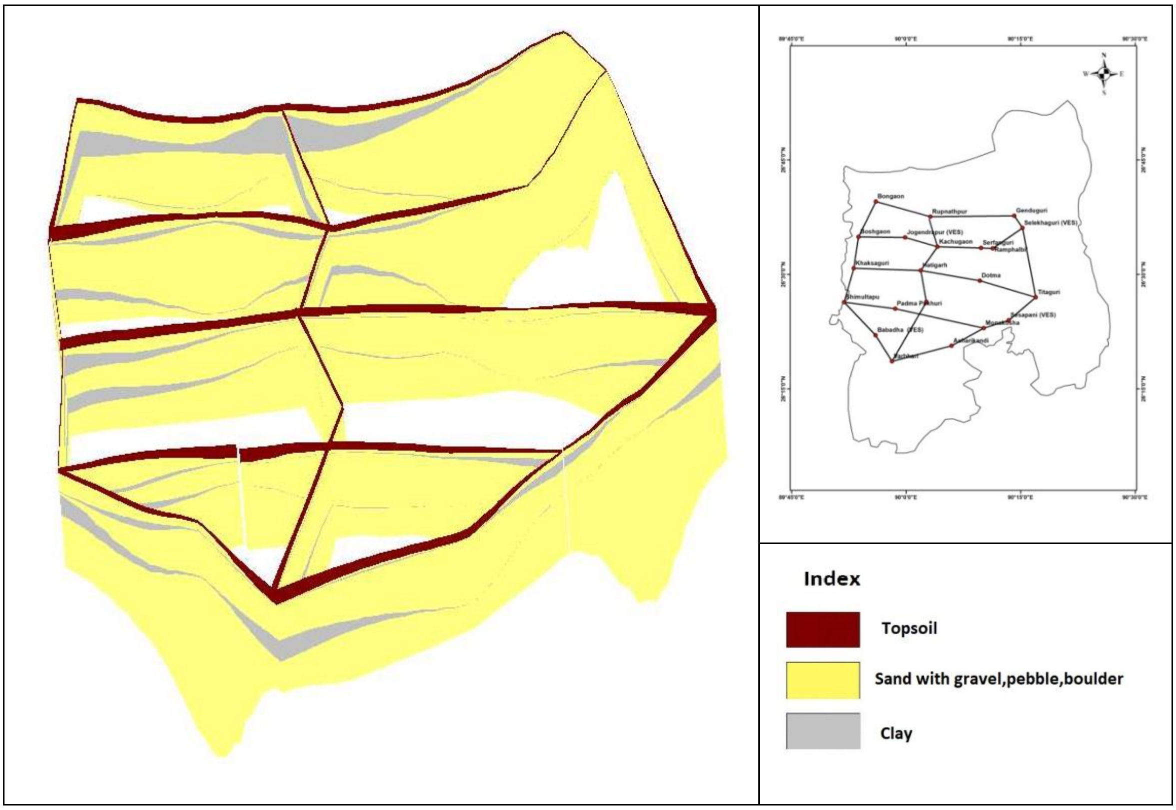

Fig.3. 4: Fence diagram showing the disposition of aquifer in the study area upto a depth of 45 m.

3.1.4 Aquifer Characteristics

Central Ground Water Board, North Eastern Region, Guwahati has drilled 2 exploratory wells in the district. The details of aquifer characteristics are given in Table 3.1.

Table 3.1: Table showing the aquifer properties of tube wells drilled in the district

Location	Depth (m)	Zone tapped (m)	SWL (mbgl)	Drawdown (m)	Transmissivity (m^2/day)	Storativity /S. Yield	Permeabil ty (m/day)	Discharge m3/hr
Genduguri	106	40-49, 58-70, 76-85, 91-97	1.48	5.12	101.98		2.84	35.6
Serfanguri	61	48-57	1.86	1.78	2218.5		246.5	38.1
Salakati	118	53-87, 94-111		9.66		305.4		6.78
Chaibari Tea garden	129.54	59-91, 96-111						13.86

Unconsolidated alluvial aquifer consists of older and younger alluvium. Younger alluvial aquifer is found towards north and centre part of the district. The older alluvial aquifer is found towards south. Previous studies have revealed the existence of two major granular formations in the district, which are as follows:

a) Shallow aquifer zone extending from 0-50 m below ground surface where the granular saturated zone thickness range between 27 to 45 metres with an average thickness of 35 metres.

b) Deep aquifer zone, extending from 50-140 m below land surface with granular zones occurring between 50-75m, 80-100 m, 105-110m, 115-140 m having a cumulative thickness of 70 m.

3.2Ground water level

To study ground water regime, depth to water level from 64 monitoring stations (Ground Water Monitoring Stations 10, newly established key wells54) were measured and monitored seasonallyin the month of November 2022 and March 2023. Seasonal variation in water level is discussed below.

During Pre-Monsoon i.e. on March 2023, only two key wells (about 3.3%) show depth-to-water level of less than 2m bgl, 62.7 % wells i.e. 37 key wells show water level in the range from 2 to 5 mbgl, 30.5% (around 18) key wells have water level in the range of 5 to 10 mbgl and 3.3% (2) key wells have water level more than 10mbgl. Minimum water level of 1.36 mbgl at Raimona FV and maximum water level recorded is 14.41 mbgl at Bagribari (Fig. 3.5)

During post-monsoon, i.e., on November 2022, depth to water level data of Kokrajhar district ranges from a minimum of 1.14 m bgl at Raimona to maximum 8.39mbgl at Basbari. 6 % of key wells (4 numbers) show water level less than 2mbgl, 70 % (45) wells record water level of 2 to 5 mbgl and only in 23.43 % (15) key well water level is above 5mbgl (Fig. 3.6).

Fluctuation of water level in pre and post monsoon water level, difference ranges from 0.0 to 2.0 m in 87.27% (48 wells) of the key wells, 2.0 to 4.0 m in 10.9% (6) wells and only in one well (Khalasi) water level fluctuation above 4 m is observed in the monitored wells of the district. Minimum fluctuation of 0.04 m and maximum of 4.66 m is recorded in Jamairy and Khalasi respectively (Fig. 3.7).

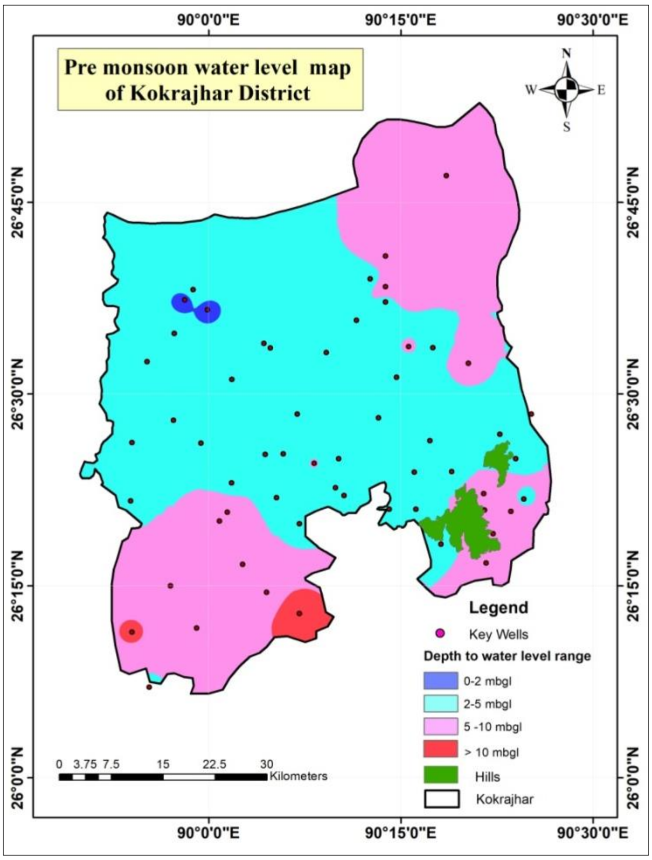

Fig.3. 5: Pre-monsoon depth to water level map of the study area

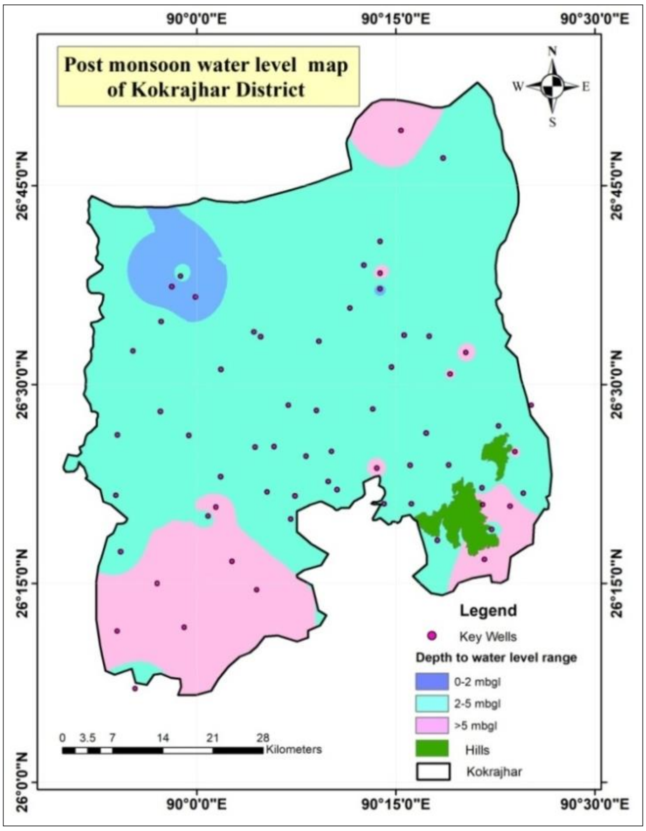

Fig.3. 6: Post-monsoon depth to water level map of the study area

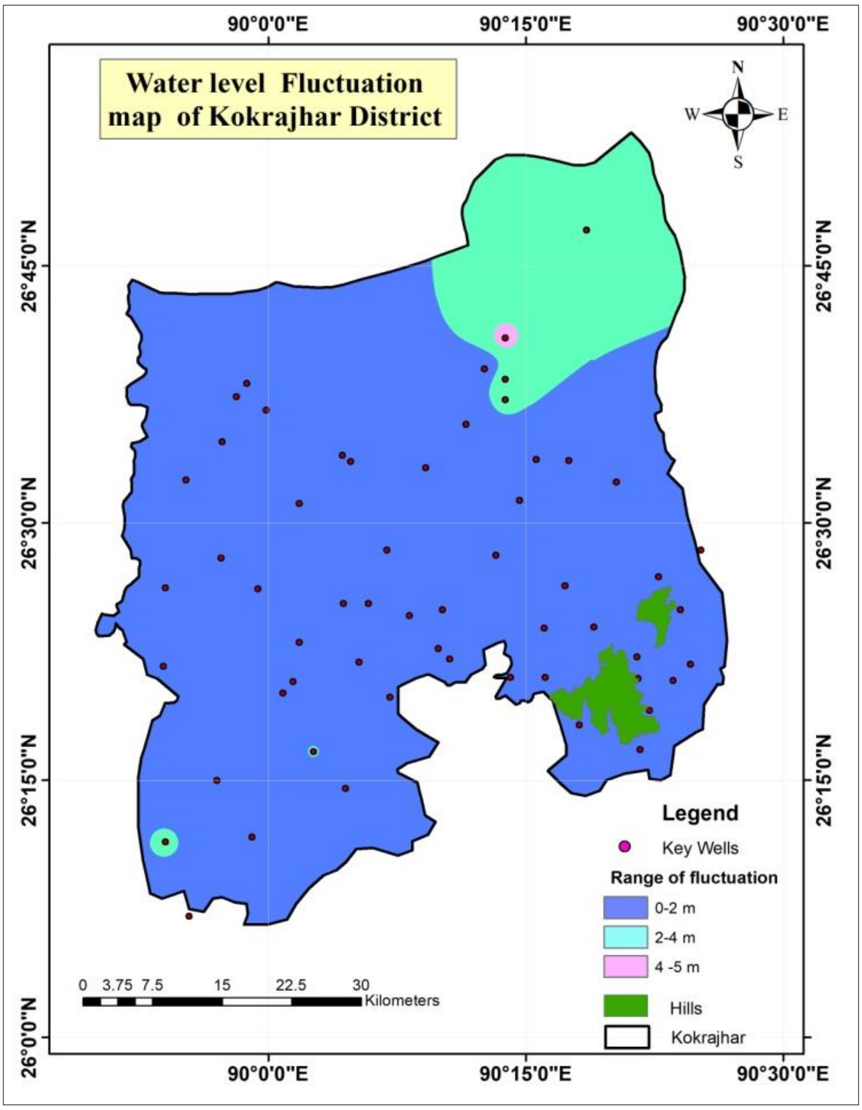

Fig.3. 7: Water level fluctuation map of the study area

3.3 Ground Water Movement

The water table contour of the phreatic aquifer has been prepared based on water level data with respect to the elevation of ground water monitoring stations from mean sea level (Fig.3.8). The contour map shows that water table contour of the district varies from 200m to 40m. The ground water flow direction is from the higher elevation from the piedmont area in northeastern side towards the alluvial plain in the southern side of the district. The piedmont area acts as a recharge zone with a steep gradient and the alluvial plain towards the south acts as a discharge zone.

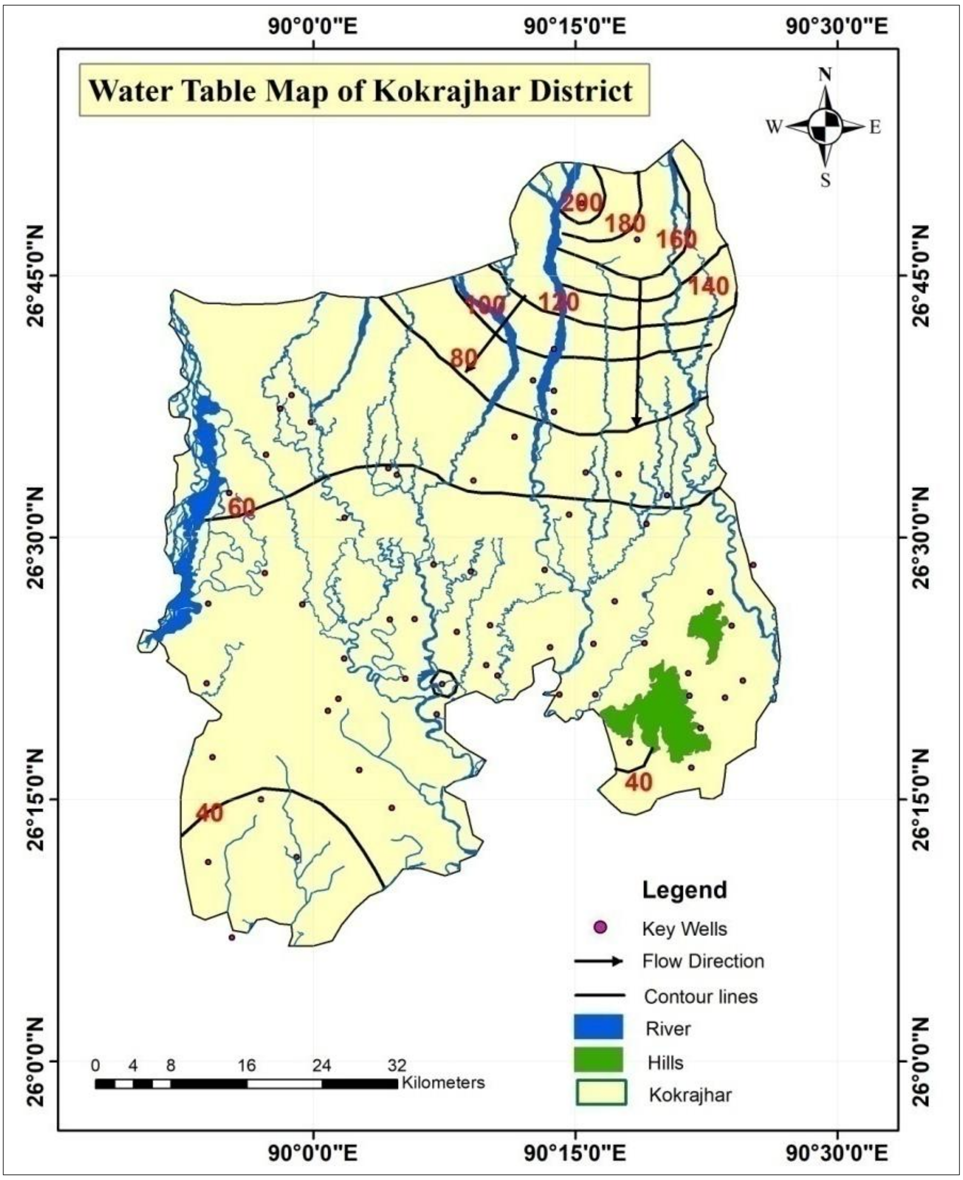

Fig.3. 8: Water table contour map of the study area

3.4 Hydrochemistry

In order to study the chemical quality, water samples from representative dug well, and handpumps/tube wells were collected during the course of field work during pre-monsoon and post monsoon studies. Chemical analysis of ground water samples is carried out by regional chemical laboratory of Central Ground Water Board, North Eastern Region, Guwahati. The parameters analyzed are pH, EC, Turbidity, TDS, CO3, Cl, SO4, Na, K, HCO3, NO3, F, Ca, Mg, TH and Fe. The details of chemical analysis of the pre-monsoon and post monsoon are given in the Annexure-I and Annexture-II respectively.

3.4.1 Ground water quality

For water quality analysis, samples were collected from different sources of dug wells and handpumps/tube wells. A total of 35 number of ground water samples during the pre-monsoon and 36 samples from post-monsoon were collected to determine the range of concentration of different chemical constituent present in the samples (Table 3.2).It is deciphered that all of the chemical parameters from both pre-monsoon and post-monsoon are within the permissible limit for all uses except for Iron concentration in few patches of the district.

Table 3.2. Pre-monsoon and Post-monsoon ground water chemical quality of Kokrajhar district

Parameter	Unit	Pre- Monsoon				Post-Monsoon			
		Dug well	Hand Pump	Tube Well	Place	Dug Well	Hand Pump	Tube Well	Place
pH		5.38-7.96	5.66-6.30	6.36-6.63		5.53-7.78	5.84-6.71	6.2-6.54	
EC (µs/cm) 25C		30.36-328.1	56.69-73.37	62.62-228.2		49.03-478.8	54.25-137.8	39.12-323	
Turbidity (NTU)		BDL-0.46	BDL-0.19	0.21-0.21		BDL-0.24	BDL-0.03	BDL-0.35	
TDS	mg/L	20.04-216.55	39.40-48.42	41.33-150.61		32.36-316	30.81-90.95	21.07-213	
CO3-2	mg/L	BDL-12	BDL-BDL	BDL-BDL		BDL-BDL	BDL-BDL	BDL-BDL	
HCO3-1	mg/L	6.10-164.83	30.52-42.73	48.84-85.47		12.21-189.25	24.42-78.36	30.52-67.15	
Cl-	mg/L	3.55-49.63	10.64-10.64	10.63-24.82		3.54-67.36	7.09-24.82	3.54-35.45	
SO4-2	mg/L	0.13-27.28	2.07-18.32	4.46-20.80		0.61-22.45	1.3-10.13	0.28-16.93	
NO3-1	mg/L	0.05-32.9	BDL-1.83	BDL-36.82		0.37-46.93	6.26-11.89	0.05-43.32	
F-	mg/L	0.01-0.34	0.04-0.05	0.05-0.06		0-0.48	0.01-0.03	0.01-0.04	
Ca+2	mg/L	2.00-42.03	12.01-14.01	10.01-30.02		2-58.05	4-12.01	4-26.02	
Mg+2	mg/L	1.20-15.76	1.21-3.63	2.42-15.77		1.2-9.69	1.2-6.06	1.21-7.27	
TH (as CaCO3)	mg/L	20-135	40-45	40-95		15-170	15-55	15-95	
Na	mg/L	0.03-35.68	5.47-6.11	3.07-15.45		1.7-48.9	1.7-8.99	3.9-26.9	
K	mg/L	0.27-24.64	0.68-2.91	0.68-8.34		0.7-36.6	1.04-2.4	0.8-10.43	
Fe	mg/L	0.08-8.739	0.53-6.20	0.31-1.35	Fukangaon DW, Nayachara DW, Baruah Para HP, Pokalagi TW, Fe is more than permissible limit	0.1-17.31	0.17- 0.33	0.17-2.25	Nayachara DW and Pokalagi TW, Fe is more than permissible limit
U	ppb	BDL-0.44	0.07-0.17	BDL-0.12		BDL-0.85	BDL-0.12	BDL-0.07	
As	ppb					BDL-0.19	0.30-0.53	BDL	

Pre-monsoon pH value collected from various wells were found to vary ranging from 5.35 at Kakrikhola to 7.96 at Oxiguri (Dug wells), 5.66 at Baruah Para to 6.30 at Bhadranpur (Hand Pump) and 6.36 at Pokalagi PHED to 6.63 at Ultapani PHED (TW) and the same for Post-monsoon varies from 5.53at Anyajuli to 7.78 at Oxiguri (Dug wells), 5.84 at Baruah Para to6.25 at Bhadranpur (Hand Pump). From tube wells, pH value ranges from 6.42 at Ultapani to 6.5 at Pokalagi.

In almost all of the samples collected during the pre-monsoon season, the iron concentrations are found to be within the permissible limit excepts in few places like Fukangaon DW (1.724 mg/L), Nayachara DW (8.74 mg/L), Baruah Para HP, (6.20 mg/L) and Pokalagi TW (1.35 mg/L) . Post-monsoon iron concentration ranges from 0.1mg/L at Ultapani to 17.31mg/l at Nayachara. Location at Pokalagi TW shows iron concentration more than BIS permissible limit of 1mg/L. In general, most of the samples have iron concentration within the permissible limit. Iron concentration map for both pre-monsoon and post-monsoon are shown in Fig 3.9 and Fig 3.10 respectively.

In both pre-monsoon and post monsoon samples, fluoride concentration is within permissible limit in all the samples. Electrical conductivity of all the samples are also within the BIS permissible limit of 1000μS/cm in both Pre-monsoon and post-monsoon ranging from 30.36 to 328.1 μS/cm and39.12 to 478 μS/cm respectively.

For remaining parameters such as Ca, Mg, Cl, SO_4, TDS and hardness as $CaCO_3$, it is observed that in both pre-monsoon and post-monsoon, groundwater samples are within permissible limit. So, ground water of Kokrajhar district is potable for other constituent except iron and low pH (**Annexure-I & Annexure-II**).

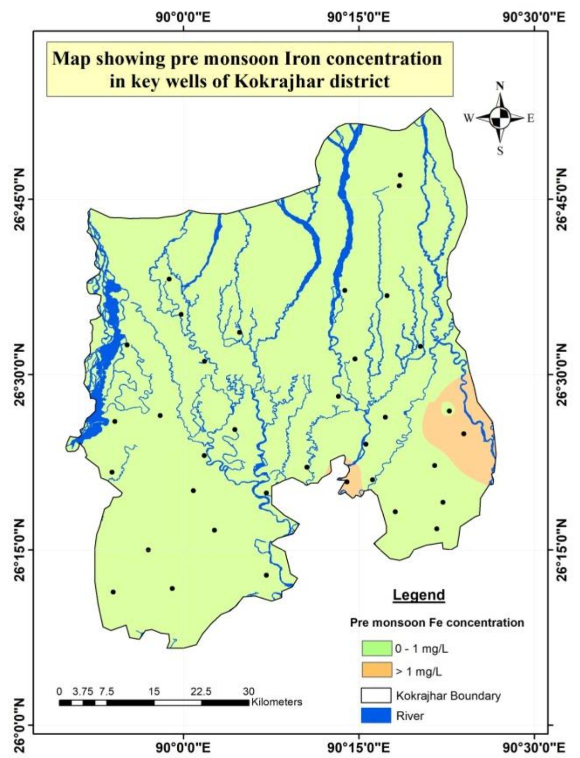

Fig.3.9: Pre monsoon Iron concentration map of Kokrajhar District

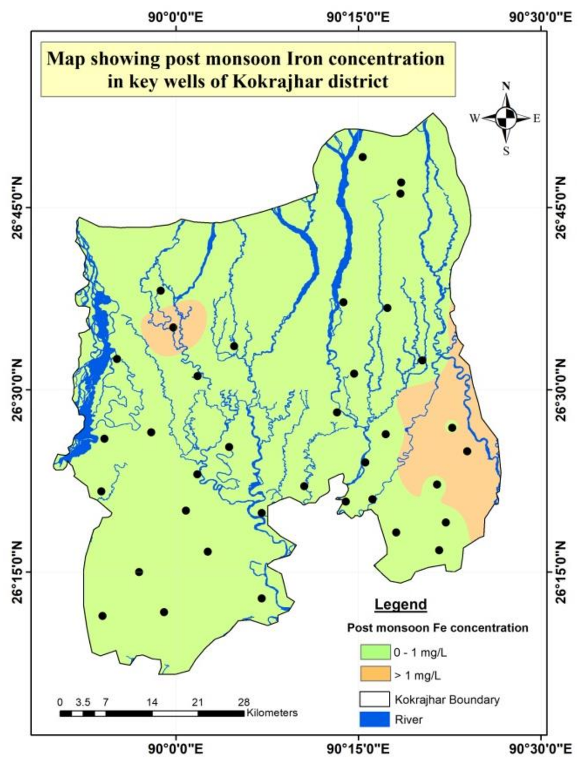

Fig.3.10: Post monsoon Iron concentration map of Kokrajhar District

3.4.2 Hydro-geochemical Facies

A Piper diagram is a graphical representation of water chemistry that is commonly used to display the geochemical characteristics of groundwater samples. The diagram is divided into four quadrants, with the upper left and lower right representing the cations and anions that dominate the water chemistry, respectively.

Fig.3.11 shows calcium dominance in the cation quadrant, which means that calcium is the most abundant cation present in the water sample in both the seasons however in the pre monsoon, dominance of Magnesium has been observed in some location. Meanwhile, in the anion quadrant, bicarbonate and carbonate are dominant, which means that these two anions are the most abundant in the water.

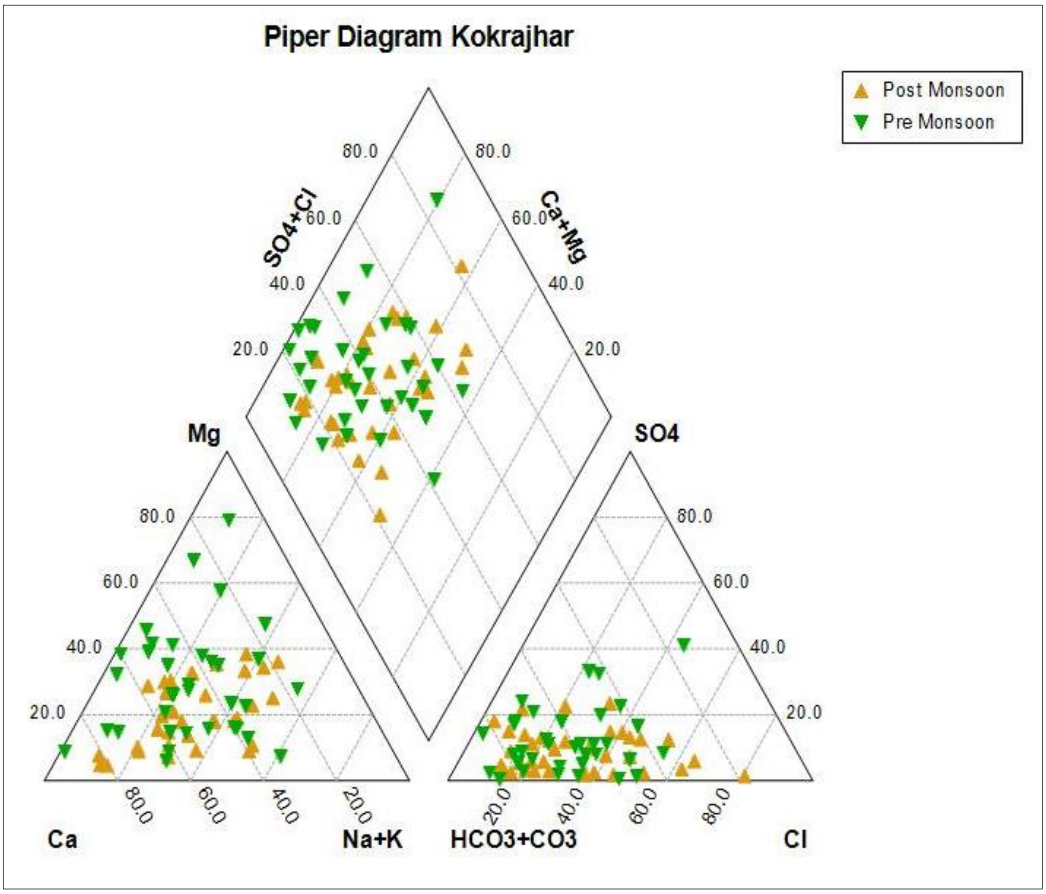

Fig.3. 11: Piper plot of chemical analysis of ground water samples

3.4.3 Groundwater Quality for Irrigation

In the study area, a total number of 35ground water samples from dugwells and handpump/tubewells were analyzed for pre-monsoon (March 2023) and 36 samples for post-monsoon (Nov 2022) covering the entire region of Kokrajhar district. The overall irrigational water quality of the collected samples from the district is assessed by using water quality indices such as Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), Permeability Index (PI), Sodium Percentage (Na%), Kelly Ratio (KR) and USSL salinity diagram. These indices were calculated by using Aquachem 10.0 and MS excel softwares.

3.4.3.a Sodium Absorption Ratio (SAR):

It is the ratio of sodium ion with respect to calcium ion and magnesium ion in ground water determined by the following formula. If the SAR value is within 0 to 10meq/L then the water is considered Excellent, 10 to 18 meq/L is considered Good, 18 to 26 meq/L is considered Fair and beyond 26 meq/L, the water is considered Poor for Irrigation. From risk point of view, > 18meq/L is considered medium to high risk.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} meq/L$$

It is evident from Fig 3.4.3.a that the SAR value of all the samples in the district are within excellent category (<10) suggesting no risk in terms of irrigation. Analysis from the US Salinity plot of SAR vs Electrical Conductivity (Wilcox Plot) also supports the above statement (Fig.3.4.3.a').

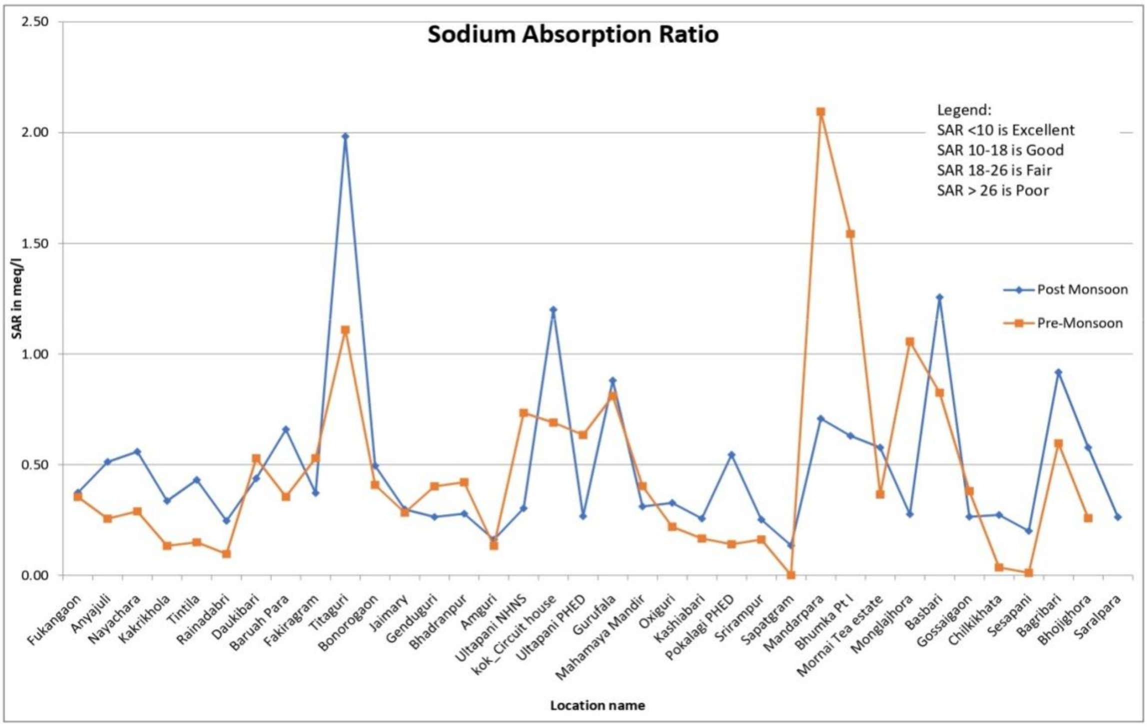

Fig. 3.4.3. a: Sodium Absorption Ratio

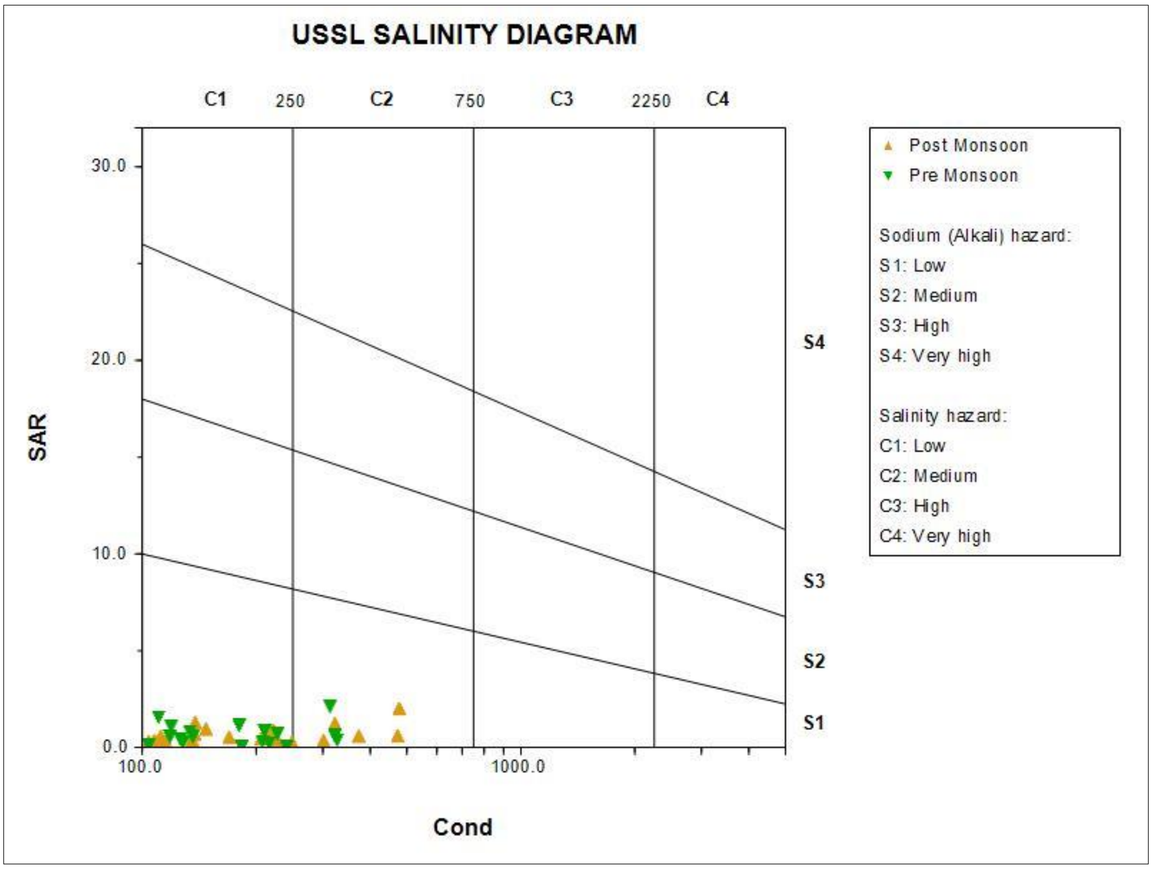

Fig.3.4.3.a': USSL Salinity diagram

Most of the samples in both the seasons fall in the C1S1 zone which represents low salinity and is characterized by the dominance of sodium and chloride ions in the water. This region is typically associated with good quality irrigation water.

C2S1 represents low to medium salinity and is characterized by the dominance of calcium and sulfate ions in the water. This region is also associated with good quality irrigation water, but may require some management practices, such as leaching or the use of soil amendments, to prevent the buildup of salts over time.

3.4.3.b Magnesium Hazard (MH)

This gives us an idea about the Magnesium content in respect to total divalent cations in irrigation water. Mg:Ca below 50% is considered suitable for irrigation.

$$MH\% = \frac{Mg^{2+}}{(Ca^{2+}+Mg^{2+})} * 100 \text{ meq/L}$$

Fig 3.4.3.b shows that except few, most samples of both pre-monsoon and post-monsoon shows MH % less than 50%. During pre-monsoon, groundwater samples from Fukangaon, Anyajuli, Bhumka pt I, Tintila, Bagribari, Daukibari, Genduguri, Mahamaya mandir and Pokalagi shows MH% more than 50 % but accounts only 26% of the total samples and

75%shows that the MH is less than 50%. If we look at the Post- monsoon curve, except Fukangaon, Anyajuli, Bhumka pt I and Bagribari other locations shows that the MH% is <50. Therefore, it can be said that the overall water of study area is suitable for irrigation.

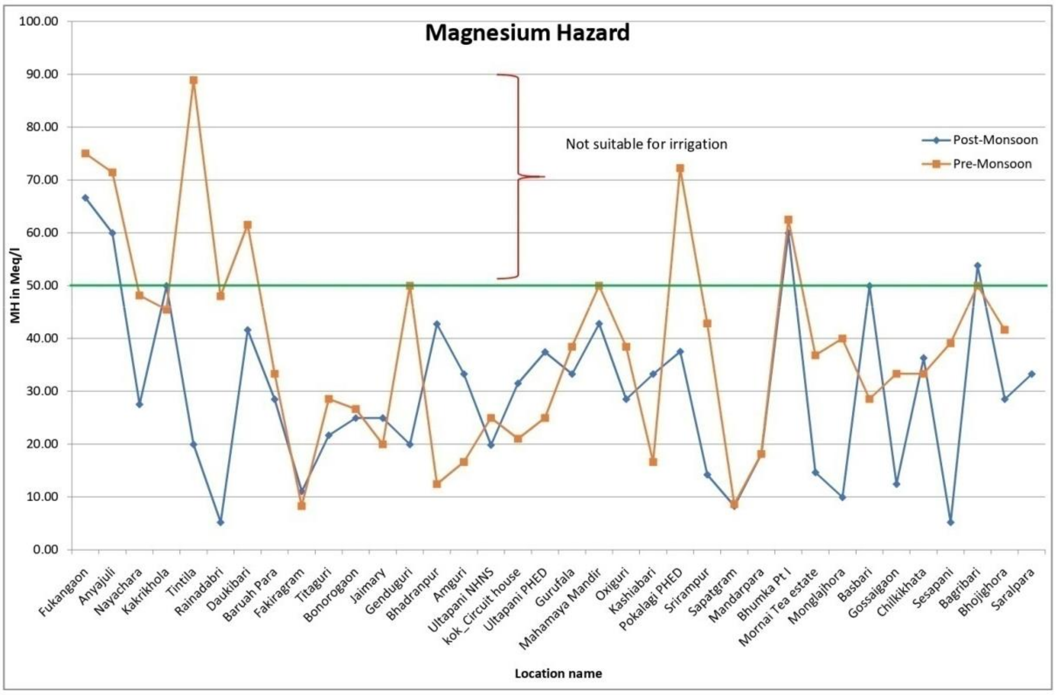

Fig. 3.4.3. b: Magnesium Hazard

3.4.3.c Residual Sodium Carbonate (RSC)

This indices is used to indicate the alkalinity hazard in irrigation water. It can be calculated by the following formula.

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

If RSC value is less than 1.25 meq/L then it is considered excellent with no risk, 1.25to 2.5 meq/L is Good with low risk and more than 2.5meq/L RSC value is considered Poor quality with High Risk factor.

All the samples show RSC value less than 2.5meq/L. Hence the area is safe from any residual sodium carbonate hazard and is suitable for irrigation.

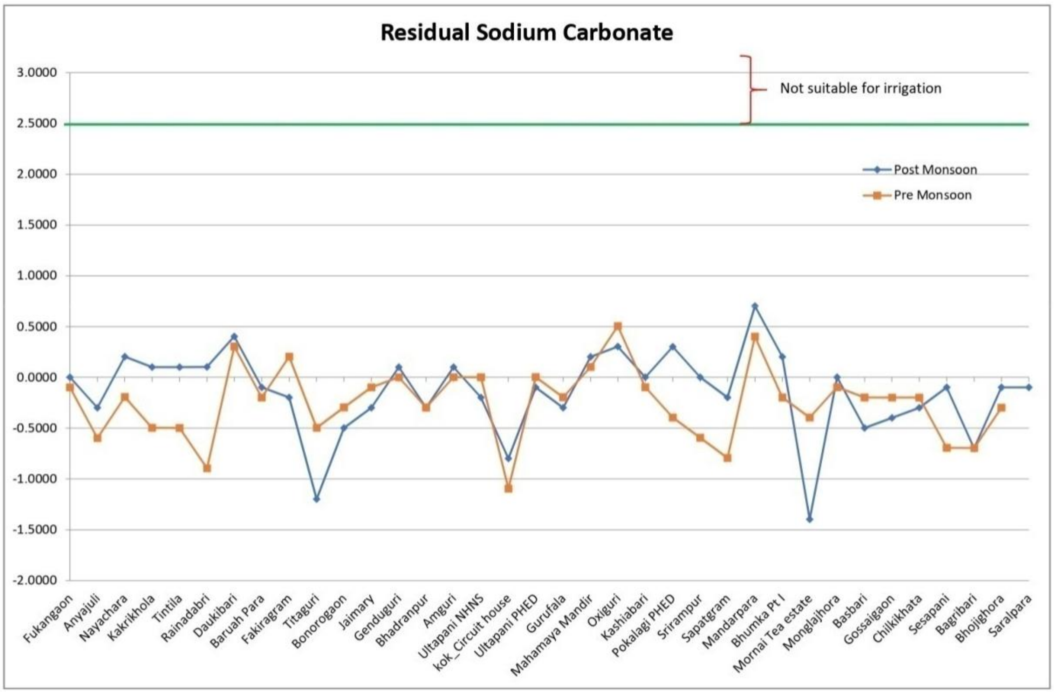

Fig. 3.4.3. c: Residual Sodium Carbonate

3.4.3.d Permeability Index (PI)

The permeability Index determines the suitability of irrigation with respect to permeability. It can be calculated by using the following formula.

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \times 100 \text{ meq/L}$$

PI can be categorized in three classes: class I (> 75%, suitable), class II (25–75%, good) and class III (< 25%, unsuitable). The water that comes under class I and II is recommended for irrigation.

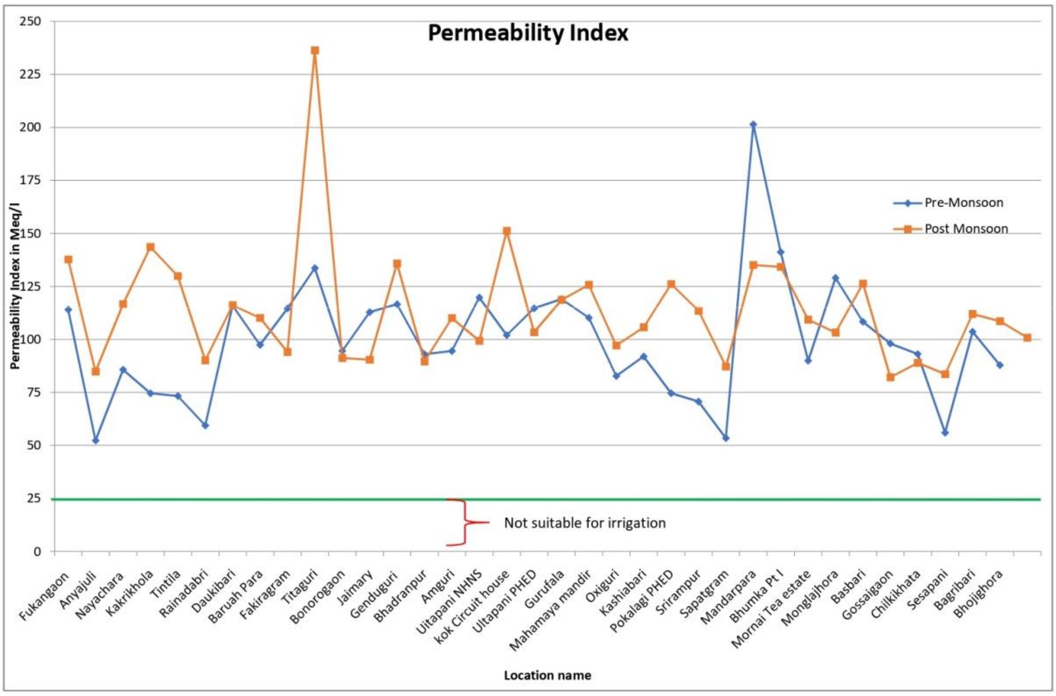

Fig. 3.4.3. d: Permeability Index

3.4.3.e Sodium Percentage (Na%):

It is amount of monovalent cations with respect to total cations. All the ion concentrations are expressed in meq/L. Na% less than 40 is considered good for irrigation. Sodium percentage within 40 to 60 % is poor and 60- 80 % is considered doubtful and more than 80 % becomes unsuitable for irrigation.

$$Na\% = \frac{Na^{+}+K^{+}}{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}} \times 100 \text{ meq/L}$$

The Na% Index of pre-monsoon divulge about 37.1% of the groundwater falls in Excellent category for irrigation, 42.9% falls in Good category and around 20% falls in Poor category. However, In post-monsoon, 16.67% of the groundwater falls in the excellent category for irrigation, 61.11% falls in Good category, and 19.4% falls in the Poor category (Fig 3.5.4.e).

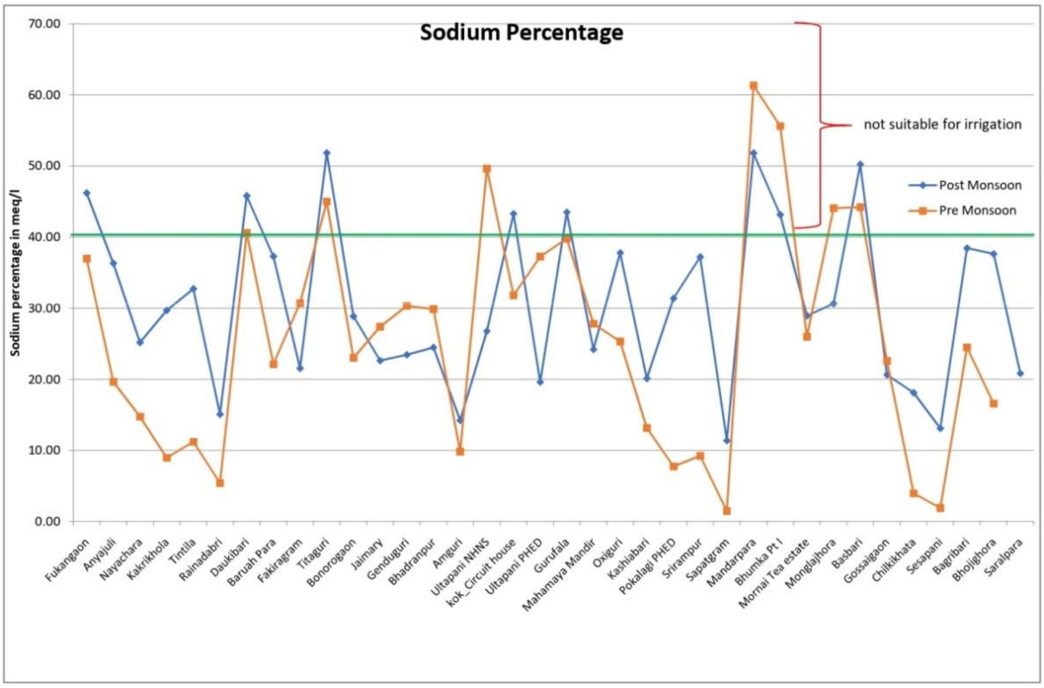

Fig. 3.4.3. e: Sodium Percentage

3.4.3.f Kelly Ratio (KR):

It is the ratio of sodium cation with respect to divalent cations, Ca^{2+} and Mg^{2+}. It can be calculated using the following formula

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} meq/L$$

If KR value is <1 meq/L, then water is suitable for irrigation and if KR value is >1meq/L then the water is considered as unsuitable for irrigation. Except Mandarpara and Bhumka Pt I from the pre-monsoon show KR more than one. However, their post-monsoon KR value is within suitable conditions. So the Kelleys's ratio of groundwater in the district renders suitability of the water for irrigation.

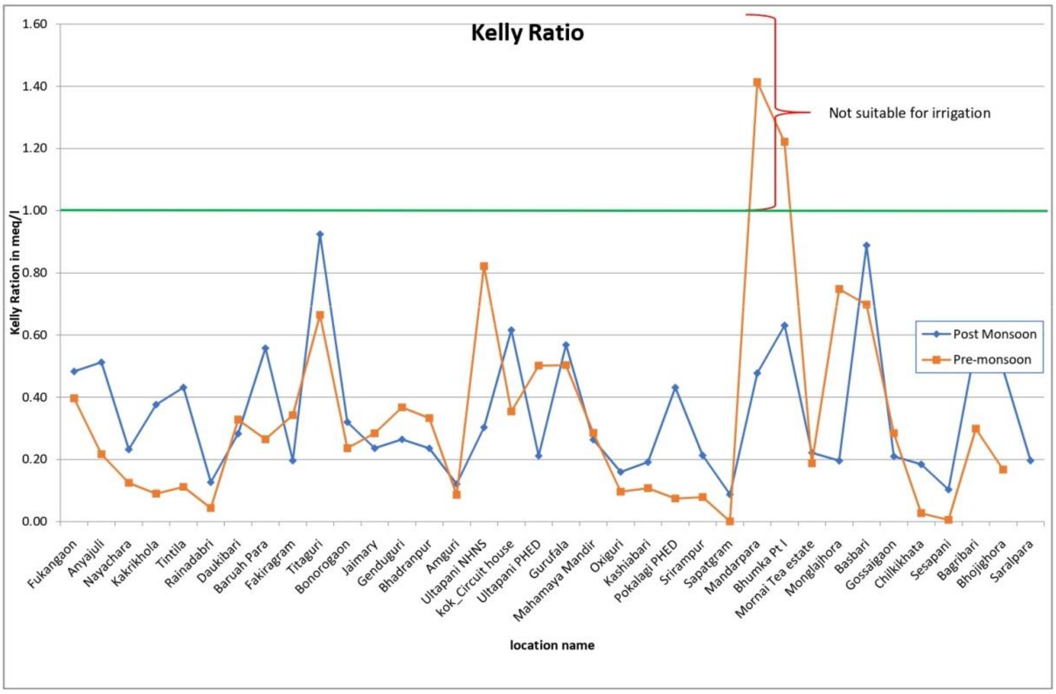

Fig. 3.4.3. f: Kelly Ratio

CHAPTER 4.0

Ground Water Resources

The computation of ground water resources available in the district has been done using GEC 2015 methodology. The dynamic resource estimation is done district wise due to paucity of block-wise data.

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

1) Rainfall recharge has been computed by both RIF and WLF methods. In RIF method, rainfall infiltration factor has been taken as 0.22 for major aquifer like valley fill. In WLF method, specific yield has been taken as 0.12 for younger alluvium as per the norm recommended by GEC'2015.

2) Last five years rainfall data is considered for groundwater resource calculation.

3) Water level data has been considered for 2018-21. 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 Kokrajhar district is 4.7 mbgl and 3.7 mbgl.

4) The population figures were collected from Census, 2011 and projected to 2022. The per capita domestic requirement for the rural population has been considered as 55 lpcd and for urban population, it is 135 lpcd.

5) The dependency on ground water resource for domestic water supply in rural areas is considered as 91%.

6) In order to calculate the canal seepage, the data on length of the drainage channels are taken from the Irrigation Department, Govt. of Assam. The factor for return flow from surface water irrigation has been taken as 0.50 (paddy) and 0.30 (non-paddy) and for Ground water irrigation it has been taken as 0.45 (paddy) and 0.25 (non-paddy). Recharge from tanks and ponds are calculated based on the norms suggested in GEC'2015.

7) Recharge from water conservation structure has been taken as nil.

The total replenishable ground water resources available in the study area have been computed using the average water level fluctuations in observation wells and specific yield of aquifers. These have been normalised using normal rainfall data to eliminate variations in recharge due to excess or deficit rainfall. The monsoon recharge arrived at is then compared with the recharge computed using rainfall infiltration method.

4.1 Ground Water Resources of Kokrajhar District

Kokrajhar has a Total Geographic area of 3296 sq.km. of which Hilly area having slope less than 20% is 25.70 sq.km. Hence, area taken up for Aquifer Mapping was 3270.30 sq.km which is the total rechargeable area. Further the district divided into command, Non

Command and poor quality areas. Kokrajhar has a command area of 3460 ha and non-command 323570 ha and no poor-quality area. Resource assessment for only Non-Command area is done.

Table 4.1: Total geographical area, recharge worthy area of Kokrajhar district

Assessment Unit	*Total Geographical Area (ha)	*Hilly Area (ha)	*Total Recharge Worthy Area (ha)			
			*Command	*Non Command	*Poor Quality	Total
Kokrajhar	327030	2570	3460	323570	0	327030

4.2 Recharge

The aquifers of the study area are recharged through a) infiltration of rainfall on the outcrop, b) seepage from the tanks and ponds, c) subsurface inflow across the up dip margin d) recharge from surface water irrigation and ground water irrigation. The area experiences south-east monsoon. Monsoon rainfall contributes approximately 86.3 percent of total rainfall (May, June, July, August, September) while share of post and pre monsoon rainfall are approximately 9.3 and 4.4 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.

4.2.1 Recharge from Rainfall:

Seasonal i.e., monsoon and non-monsoon, ground water recharge is estimated both by rainfall infiltration and water table fluctuation or water balance method for monsoon season and by rainfall infiltration method for non-monsoon season as per guidelines. The monsoon recharge computed by WLF method is normalized for the current year rainfall.

Table 4.2: Recharge from rainfall

District	Rainfall Recharge(Ham)			
Kokrajhar	Command	Non Command	Poor Quality	Total
	1889.24	149678	0	151567

4.2.2 Recharge from other sources:

Recharge from other sources means recharge through return flow from tanks and ponds, canals, water conservation structures, surface and ground water irrigation. Recharge from water conservation structure and pipeline is zero for Kokrajhar.

Table 4.3: Recharge from other sources

Recharge from other sources										
District	Tanks &Ponds		Canal		Ground water irrigation		Surface water irrigation			Total
	Non Command	Total	Command	Total	Non Command	Total	Com mand	Non Command	Total	
Kokrajhar	2852.38	2852.38	225.82	225.82	2852.38	2852.38	3240	97.2	3337.2	7469.54

Total ground water recharge from all sources is 159037 ham.

4.3Ground Water Extraction

The ground water extraction of unconsolidated aquifer is created by natural discharge like seepages and draft created by human interference, viz., (a) irrigation, (b) drinking or domestic purposes and (c) industrial purpose.

In the district natural discharge is 15,903.65 ham. Total irrigation extraction created is 6,338.64 ham, for industry 0 ham and extraction for domestic uses is 1,713.36 ham. Total groundwater extraction for all uses is only 23334.02 ham.

Table 4.4: Groundwater extraction

District	Domestic	Industrial	Irrigation	Extraction from all source
Kokrajhar	1,713.36 Ham	0 Ham	6,338.64 Ham	8,052.00 Ham

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

4.4 Annual ground water recharge:

Annual ground water recharge is the sum-total of monsoon and non-monsoon recharge. An allowance is kept for Environmental Flow (un-accounted natural discharge as per GEC'97) in the non-monsoon season by deducting 5% of total annual ground water recharge, where WLF method is employed to compute rainfall recharge during monsoon season and 10% of total annual ground water recharges where RIF method is employed before getting the annual extractable ground water resource.

Table 4.5: Annual extractable ground water resources

District	**Annual Ground water Recharge (ham)**	**Environmental Flows (ham)**	**Annual Extractable Ground water Resource (ham)**
Kokrajhar	1,58,888.09	15,903.65	1,42,984.44

4.5 Allocation of resources up to 2025

The net ground water resource is allocated for domestic and industrial and irrigation sector. 1,750.73 ham of resource is allocated for domestic use in future. Annual extractable ground water resource for the district is 1,42,984.44 (ham). Net ground water availability for future use is 1,34,895.07 ham.

4.6 Stage of Ground Water Extraction

Industrial development in the area is practically less. Groundwater is mainly utilized for domestic and irrigation purposes. However, Public Health Engineering & Water Supply Department has supplied water mainly through surface water sources. The stage of groundwater extraction in the district is 5.63 %.

Table 4.6: Ground water resources of Kokrajhar district as on March 2022.

PARAMETER	VALUES
Total geographical area (Ha)	329600
Recharge worthy area (Ha)	327030
Rainfall Recharge (monsoon) (Ham)	111438
Rainfall Recharge (non-monsoon) (Ham)	42129.05
Annual Recharge from Other Sources (monsoon) (Ham)	5542.63
Annual Recharge from Other Sources (non- monsoon) (Ham)	1926.91
Annual G. W. Recharge (Ham)	1,58,888.09
Ecological Flow (Ham)	15,903.65
Total Natural discharge (Ham)	15,903.65
Annual extractable Ground Water Resource (Ham)	1,42,984.44
Current annual gross G.W. Extraction for domestic use (Ham)	1,713.36
Current annual gross G.W. Extraction for irrigation (Ham)	6,338.64
Current annual gross G.W. Extraction for industrial use (Ham)	0
Current annual gross G.W. Extraction for All uses (Ham)	8,052.00
Annual G.W. Allocation for Domestic water supply as on 2025 (Ham)	1,750.73
Net Annual G.W. availability for future use (Ham)	1,34,895.07
Stage of GW Extraction (in %)	5.63
Quantity Categorisation for Future GW extraction (Safe/Semi-Critical /Critical /Over Exploited)	Safe

4.7 Potential resource:

Shallow water table areas: Potential resource due to shallow water table areas was estimated from aquifer area where depth-to-water level was within 5 mbgl. The area within depth-to-water level of 5 mbgl is 3066 sq.km which is 70 % of total area of the district. The potential resource of shallow water table areas is 31228.32 ham.

4.8 Static resource:

The administrative district has been considered as the assessment unit. 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 DWs / bore wells in the district has been considered up to a depth of 40 metres.

The pre-monsoon (month of March) water level from monitoring wells of CGWB in Kokrajhar 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.

Finally the static ground water resource is computed from the data as obtained:

$$Y = A^* (Z1 - Z2)^* Sy$$

Where, Y = Static ground water resources,

A = Area of ground water assessment unit

Z1 = Thickness of saturated unconfined aquifer below ground level

Z2 = Pre-monsoon water level

Sy = Specific yield of the unconfined aquifer

Table 4.7: Salient information of static resource of Kokrajhar district, Assam

Type of rock formation	Alluvium
Total Geographical Area (Ha)	329600
Assessment Area (Ha)	327030
Bottom of the unconfined aquifer (m)	40
Average Pre- monsoon Water Level (m)	4.7
Thickness of the saturated zone of the un-confined aquifer below WLF zone (m)	35.3
Specific yield	0.12
Volume of Saturated zone of the unconfined aquifer below WLF zone (ham)	13,87,250.52

CHAPTER 5.0

Groundwater Related Issues

Identification of issues: The main groundwater issues identified in the area are-low stage of groundwater extraction, vulnerable areas under water logging and flood as well as high iron concentration.

5.1 Low stage of groundwater extraction

Compared to vast dynamic groundwater resource of Kokrajhar district, groundwater extraction for domestic, irrigation and industrial purposes is low. Vast tract of agricultural land remain fallow after harvesting of paddy only due to lack of irrigation facility. The stage of groundwater extraction is only 5.63 %.

5.2Area vulnerable to water logging

Water logged areas are identified by preparing depth-to-water level contour for both pre and post monsoon seasons. The permanently water logged areas are those which are water logged both in both the seasons in the range of 0-2 mbgl.

Permanently water logged areas are found in Raimona and Ranipur key well area where depth to water level is 0-2 mbgl throughout the year. Water logged areas are found in the alluvial plain and flood plain.

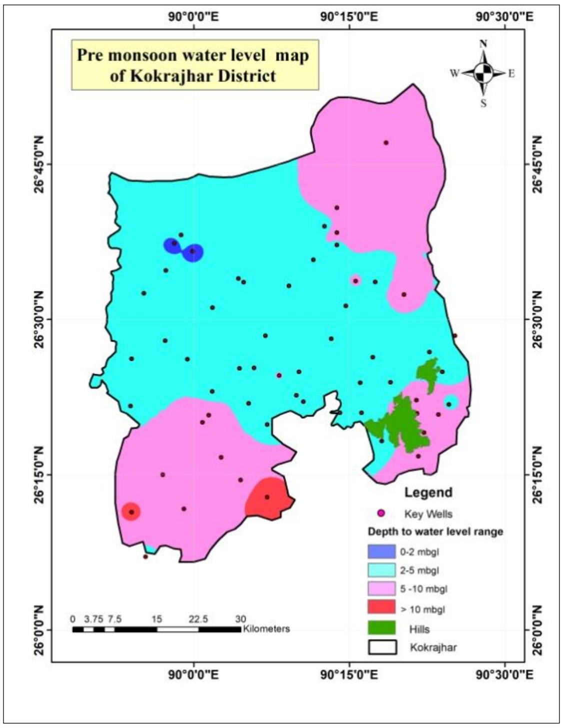

Fig.5. 1: Depth to water level map (Mar-23) of Kokrajhar district

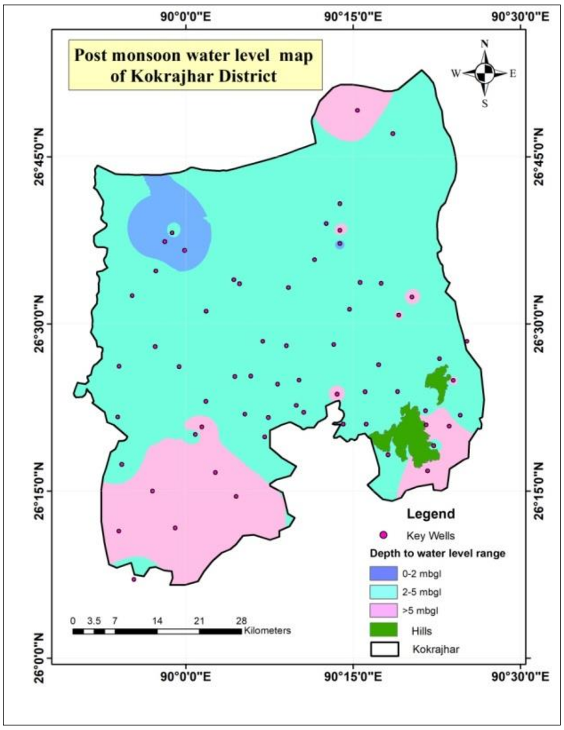

Fig.5. 2: Depth to water level map (Nov-22) of Kokrajhar district

5.2 Water Quality Issue

In most of the samples of Dug wells and hand pumps/tubewells, except iron, other chemical parameters are within permissible limit.

High concentration of Iron has been reported in few locations in the district. High concentration of Iron in drinking water can cause various health issues like diabetes, hemochromatosis, stomach problems, and nausea. It can also harm skin cells as such water does not rinse off the soap residue from the body, it also gives water an unpleasant metallic taste and stains the pipes, bathroom fixtures etc. Locations from Fukangaon dug well, Nayachara dug well, Baruah Para hand pump and Pokalagi tube well shows iron concentrations more than 1mg/L in pre-monsoon. However, in post-monsoon, the concentration of iron of more than 1mg/L is found only in Nayachara and Pokalagi. It is therefore necessary to filter the iron before any human consumption or domestic use especially in area infested with iron.

CHAPTER 6.0

Management Strategies

The groundwater management involves the optimum utilization of sub-surface water based on geological, hydrological, economic, ecological and legal consideration for the welfare and benefit of the society. The main objective of Groundwater management is to utilize the available ground water resources to fulfil human needs and also to boost economy of an area without hampering the interest of future generation. That objective can be achieved by finding out the demand of various sectors and adjusting the demand with available resource.

As per dynamic ground water resources 2021-2022, the annual extractable groundwater of Kokrajhar district is 142984.44ham. The current annual groundwater extraction accounts for 8052ham and the stage of ground water extraction is only 5.63%. The district is having balance net groundwater availability for future irrigation use in the tune of 134895ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 80937 ham of groundwater resources is available in the district for future irrigation uses. Hence, there is ample scope for ground water development for irrigation purpose which will help the district in achieving self-reliance on food grain.

According to Agricultural census, 2015-2016, the district has a net sown area of 91296ha and grossed cropped area of 106089 ha with a cropping intensity of116.20%. The net sown area included field crops as well as horticulture and plantation crops. Cropping intensity is calculated generally from field crops, which are of short duration whereas horticulture (like citrus, banana, pineapple) and plantation crops like spices are long duration crops.

According to Agricultural census, 2015-2016, the land under cultivation during the Kharif season is 63868ha. After growing and harvesting the Kharif crops, the land remains fallow and uncultivated during the Rabi season. The intention of this plan is to utilized and brings this fallow land of 63868ha under assured irrigation during Rabi season which will help to increase the gross cropped area to 12,7736ha and thereby increase the cropping intensity upto 200%. Since the stage of groundwater extraction is only 5.63%, this area of 63868ha can easily be covered by constructing groundwater-based irrigation projects. In rice fallow, pulses, potato, mustard and rabi vegetables can be grown with the support of irrigation.

To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO. Suitable cropping plan was prepared and the cropping pattern, proposed cropping pattern, targeted increase in cropping intensity was shown in tabular form (Table 6. 1). Crop wise and month wise precipitation deficit has also been estimated using the same software after giving necessary meteorological, soil data and crop plan inputs and the same has been shown in the table 6.2. Crop wise and month wise Irrigation Water Requirement (IWR) in ham has been further calculated in Table 6.3.

Table 6.1: Cropping pattern, proposed cropping pattern and intended cropping intensity

Cropping pattern (s)				
	Present Cultivated area(**ha**)	Area to be cultivated (%)	Area to be cultivated (**ha**)	Irrigation requirement (**ham**)
Winter Rice-Winter Vegetables-Summer Vegetables-Pulses--Potato-Oilseed				
Cultivated Area	**63868**			
	1	2 (= % of 1)	3	4
Winter Rice	63868	100	63868	9883.57
Potato		15	9580	2249.14
Pulses		15	9580	1633.50
Oil Seed		25	15967	2201.42
Winter Vegetables		10	6387	1078.87
Winter Wheat		20	12774	3617.44
MAIZE (Grain)		15	9580	2040.01
				22703.95
Net cultivated area	63868	100		22703.95
Gross cultivated area (Paddy/+Wheat+Pulses)			127736	
Total irrigation requirement				**22703.95**
70% irrigation efficiency				**32434**

Table 6.2: Precipitation deficiency (mm) in Kokrajhar district,Assam

Precipitation deficit	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Winter Rice	0	0	0	0	49.6	98	0	0	0	0	0	0
Winter Rice	0	0	0	0	49	98	0	0	0	6.3	0	0
Winter Rice	0	0	0	0	0	147.6	0	0	0	0	0	0
Winter Rice	0	0	0	0	0	49.1	98	0	0	6	17.4	0
Potato	62.1	43.4	0	0	0	0	0	0	0	0	35.4	68
Potato	63.4	76.4	39	0	0	0	0	0	0	0	23.8	45.1
Pulses	62	19	0	0	0	0	0	0	0	4.7	23.6	63.3
Pulses	47.5	0.9	0	0	0	0	0	0	0	0	38.3	69.5
Pulses	63.9	51.4	0	0	0	0	0	0	0	0	18.7	48.7
Soybean	33.4	0	0	0	0	0	0	0	0	2.4	35	69.5
Soybean	44.6	0	0	0	0	0	0	0	0	0	25.1	68.9
Soybean	14.6	0	0	0	0	0	0	0	0	1.3	51	69
Small Vegetables	49.1	72.4	36.2	0	0	0	0	0	0	0	0	30
Small Vegetables	46.3	0	0	0	0	0	0	0	0	0	42.1	61.7
Winter Wheat	41.8	58.9	76.8	42.1	0	0	0	0	0	0	34.2	43.2
Winter Wheat	40.3	57	73.7	38.6	0	0	0	0	0	0	17.3	42.4
MAIZE (Grain)	58.5	82.5	44.3	0	0	0	0	0	0	0	3.7	23.9

Table 6.3: Actual monthly water requirement (Ham) for different crops

Crops	Area %	Jan IWR	Feb IWR	Mar IWR	Apr IWR	May IWR	Jun IWR	Jul IWR	Aug IWR	Sep IWR	Oct IWR	Nov IWR	Dec IWR	Total IWR	Total
Winter Rice	25	0	0	0	0	791.96	1564.76	0	0	0	0	0	0	2356.73	9883.57
Winter Rice	25	0	0	0	0	782.38	1564.77	0	0	0	100.59	0	0	2447.74	
Winter Rice	25	0	0	0	0	0	2356.73	0	0	0	0	0	0	2356.73	
Winter Rice	25	0	0	0	0	0	783.98	1564.77	0	0	95.80	277.83	0	2722.38	
Potato	5	198.31	138.59	0	0	0	0	0	0	0	0	113.05	217.15	667.10	2249.14
Potato	10	404.93	487.96	249.09	0	0	0	0	0	0	0	152.008	288.05	1582.04	
Pulses	5	197.99	60.68	0	0	0	0	0	0	0	15.009	75.37	202.15	551.20	1633.50
Pulses	5	151.69	2.87	0	0	0	0	0	0	0	0	122.31	221.95	498.83	
Pulses	5	204.07	164.15	0	0	0	0	0	0	0	0	59.72	155.53	583.47	
Soybean	5	106.67	0	0	0	0	0	0	0	0	7.66	111.78	221.96	448.07	2201.42
Soybean	10	284.88	0	0	0	0	0	0	0	0	0	160.32	440.09	885.29	
Soybean	10	93.26	0	0	0	0	0	0	0	0	8.30	325.76	440.74	868.06	
Small Vegetables	5	156.82	231.23	115.62	0	0	0	0	0	0	0	0	95.81	599.48	1078.87
Small Vegetables	5	147.88	0	0	0	0	0	0	0	0	0	134.46	197.06	479.40	
Winter Wheat f.f.	10	267.01	376.24	490.58	268.93	0	0	0	0	0	0	218.46	275.95	1897.18	3617.44
Winter Wheat f.f.	10	257.43	364.11	470.79	246.57	0	0	0	0	0	0	110.51	270.85	1720.26	
Maize (Grain)	15	560.55	790.52	424.48	0	0	0	0	0	0	0	35.45	229.009	2040	2040
Total	200						Total Irrigation Requirement								**22703.95**

Based on available groundwater resources and subsurface condition, the approximate numbers of tube wells that can be constructed in the district is worked out. Groundwater draft is calculated for well discharge of $37 m^3/hr$. If the well is allowed to run 8 hours a day for 120 days of a year then a tube well having a discharge will create a draft of 3.5ham. To meet irrigation demand of 32434ham area, 8960 numbers of shallow tube wells can be constructed to cover an unirrigated area of 127736ha area. The current total extraction of ground water in Kokrajhar district is 8052ham resulting in a stage of groundwater development of 5.63%. In extracting additional requirement of 32434ham, stage of groundwater development in Kokrajhar will increase from 5.63% to 28.31%.

Domestic and drinking purpose: The drinking and domestic requirement is worked out for projected district population and requirement is considered as 55litre per person per day. The district requirement up to 2025 is worked out and tabulated as below:

Table 6.4: Kokrajhar population and GW demand projected to 2025

District	Decadal Growth rate 2011-2022	Population as per 2011 Census	Dependency on Ground Water Projected	Ground Water Demand considering per person water need of 55 litre per day (Ham) 2011	
				2022	2025
Kokrajhar	5.2	887142	91%	1713.36	1750.73

Demand side management: Demand side management implies sustainable management of water. In irrigation as well as in drinking water supply sufficient quantity of water is lost

The general slope of the area is towards South. The slope is greater in piedmont area of northern part of the district than in the flood plain. Therefore water logging condition is observed in the flood plain, alluvial plain area. Therefore water use efficiency should be high in all sectors particularly in the irrigation sector. Loss in irrigation water will increase water logged area.

Irrigation efficiency can be increased by

(i) reducing convenience loss

(ii) improving water application efficiency

Following demand side interventions will increase water use efficiency

1) Use of water efficient irrigation method: Drip and sprinkler irrigation methods are very useful in saving water. Both of them save conveyance losses and improve water application efficiency by applying water near the root-zone of the plant. Drip systems convey water in small quantities through drippers/micro-tubes while sprinklers are pressurized systems where a fountain or spray of water is released by the sprinkler connected by pipes, resulting in foliar irrigation. Drip irrigation can increase crop yield per hectare and also saves water up to 70% than conventional irrigation.

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

3) Adopting water saving rice irrigation: In this method instead of submerging the paddy field for longer duration, the rice field have to provide water through irrigation only after a certain number of days when the ponded water disappears. This technology is known as alternate wetting and drying (AWD) irrigation. With the optimal management, this technology reduces the amount of water required by about 25% without reduction in yields.

International Rice Research Institute (IRRI) has developed a simple tool to help farmers make decisions on when to irrigate. They found that when field water level recedes to 15 cm below the soil surface, soil water tension in the root zone is always <10 kPa, ensuring good yield. Thus a practical way to implement safe AWD is to monitor the depth of ponded water using a field water tube/ pipe This tube can be made of plastic pipe or bamboo 30 cm long and 15 cm or more in diameter and having perforations on all sides (Fig. 6.1). 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.

4) Reduce losses of water during leveling: As per Food Agriculture Organization, 200mm of water per hectare 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).

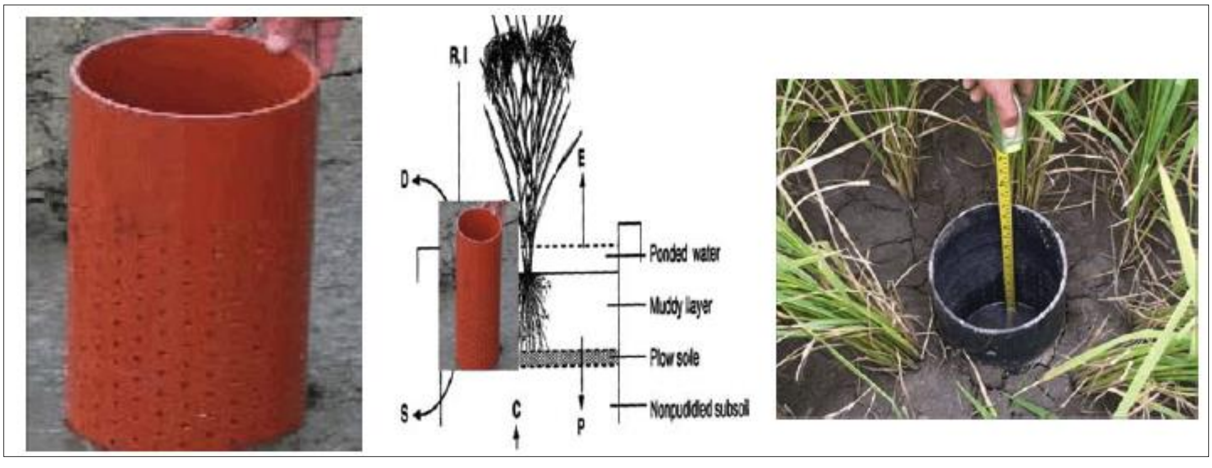

Fig.6. 1: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface (Kulkarni, 2011)

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

District	Present Paddy cultivated area	40% reduction of water for land leveling by the use laser land leveler	Approximate saving of water (ham)
Kokrajhar	63868		2554.72
Total water saving			2554.72

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.

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.

Irrigation: The additional withdrawal of water may not adversely affect the ground water regime of the area as major portion of the area is under shallow water table condition.

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.

Water Quality Management:

Except iron, the overall quality of ground water in Kokrajhar district is potable for drinking and other domestic and irrigation use.

Iron:

Presence of iron and manganese promotes the growth of bacteria in water. These bacteria harness energy for growth from the chemical reaction that occurs when iron and manganese mix with dissolved oxygen. Presence of iron in ground water is mainly geo-genic and it originates from the underlying rock formation. As water infiltrates into the aquifer, it dissolves some iron and accumulates in aquifer.

Since iron occurs naturally in nature, it cannot be removed in situ. There are several methods by which iron can be removed. Iron filters/iron removal plants are to be installed in order to remove iron from ground water.

1. **Iron removal by ion exchange**: Resins such as polystyrene-type gel resin in water softeners can remove iron from water by the process of ion exchange if the water is not exposed to oxygen.
2. **Iron removal by filtration**: Iron (and Manganese) can be easily removed from water by the process of gravity and pressure filtration after oxidation with air (aeration), chlorine or potassium permanganate.

Annexure I: Concentration range of chemical constituents in groundwater (pre monsoon)

Location	Lat	Long	Source	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	U from Fluorimeter
Fukangaon	26.4478	90.379	DUG	5.451	42.54	0.46	28.08	0	18.31464	18.31464	7.09	5.8893	4.2004	0.02	2.0016	3.639806	20	3.64	2.97	1.72	0.1475
Anyajuli	26.318	90.37	DUG	5.439	43.97	0.04	29.02	0	6.10488	6.10488	10.635	13.2929	9.0432	0.02	4.0032	6.066019	35	3.48	0.77	0.306	0.0198
Nayachara	26.4157	90.3995	DUG	6.259	208.3	0.27	137.48	0	152.622	152.622	10.635	3.0875	0.0529	0.11	28.0224	15.76311	135	7.72	5.11	8.739	BDL
Kakrikhola	26.3702	90.358	DUG	5.376	30.36	0.02	20.04	0	36.62928	36.62928	14.18	4.1131	0.9648	0.02	12.0096	6.062136	55	2.27	0.37	0.306	0.0726
Tintila	26.28	90.361	DUG	5.569	32.2	0.03	21.25	0	24.41952	24.41952	7.09	14.1254	3.3311	0.02	2.0016	9.707767	45	2.31	0.51	0.455	0.0483
Rainadabri	26.35	90.2694	DUG	6.867	104.4	BDL	68.90	0	97.67808	97.67808	7.09	27.2819	0.3174	0.07	26.0208	14.55049	125	2.5	1.33	0.082	0.0922
Daukibari	26.3043	90.302	DUG	6.175	136.4	0.22	90.02	0	97.67808	97.67808	17.725	14.1198	0.1064	0.03	10.008	9.703883	65	9.79	18.01	0.903	0.1733
Baruah Para	26.34677	90.23309	HP	5.664	73.37	0.19	48.42	0	42.73416	42.73416	10.635	2.0652	0	0.04	12.0096	3.634951	45	5.47	0.68	6.201	0.0692
Fakiragram	26.368	90.176	DUG	7.038	118.7	0.01	78.34	0	85.46832	85.46832	10.635	7.6243	1.7635	0.06	22.0176	1.202913	60	9.42	4.74	0.231	0.2221
Titaguri	26.43917	90.28778	DUG	6.046	180.9	0.09	119.39	0	54.94392	54.94392	35.45	17.7292	32.9154	0.01	20.016	4.84466	70	21.34	8.4	0.306	0.156
Bonorogaon	26.469	90.221	DUG	6.385	126.5	0.1	83.49	0	73.25856	73.25856	24.815	7.5994	0.5357	0.13	22.0176	4.843689	75	8.13	3.69	0.754	0.2253
Jaimary	26.5222	90.2445	DUG	6.135	35.69	0.01	23.56	0	24.41952	24.41952	7.09	3.2282	4.6132	0.04	8.0064	1.209709	25	3.26	1.82	0.381	0.1487
Genduguri	26.62	90.23	DUG	6.248	45.61	0	30.10	0	36.62928	36.62928	7.09	4.7858	1.3643	0.04	6.0048	3.637864	30	5.06	1.59	0.306	0.1991
Bhadranpur	26.6124	90.29	HP	6.298	59.69	BDL	39.40	0	30.5244	30.5244	10.635	18.3227	1.8326	0.05	14.0112	1.206796	40	6.11	2.91	0.53	0.1746
Amguri	26.54028	90.33778	DUG	6.947	80.6	BDL	53.20	0	73.25856	73.25856	7.09	0.1314	1.2967	0.06	20.016	2.417476	60	2.37	1.08	0.381	0.2879
Uitapani NHNS	26.7846	90.309	DUG	6.186	34.33	BDL	22.66	0	24.41952	24.41952	10.635	4.1453	4.3136	0.02	6.0048	1.21068	20	7.54	2.57	0.455	BDL
kok Circuit house	26.40049	90.25991	TW	6.425	228.2	BDL	150.61	0	48.83904	48.83904	24.815	20.7987	36.8176	0.06	30.024	4.839806	95	15.45	8.34	0.306	0.1229
Ultapani PHED	26.76911	90.30782	TW	6.63	62.62	BDL	41.33	0	48.83904	48.83904	10.635	11.3065	2.4097	0.06	12.0096	2.421359	40	9.21	2.89	0.53	BDL
Gurufala	26.519	90.03	DUG	6.179	133.9	0.01	88.37	0	67.15368	67.15368	24.815	10.532	20.7871	0.09	16.0128	6.060194	65	15.01	8.01	0.604	0.1298
Mahamaya mandir	26.56	90.08	DUG	6.28	68.24	0.05	45.04	0	67.15368	67.15368	10.635	4.6569	1.3224	0.03	10.008	6.063107	50	6.54	3.92	0.53	BDL
Oxiguri	26.63607	89.97947	DUG	7.964	216.9	0	143.15	12	164.8318	176.8318	3.545	25.1656	5.8145	0.34	32.0256	12.12039	130	5.74	24.64	0.381	0.4358
Kashiabari	26.5423	89.9198	DUG	7.075	92.06	0.07	60.76	0	67.15368	67.15368	7.09	5.2629	0.3047	0.09	20.016	2.417476	60	2.96	2.07	0.455	0.0058
Pokalagi PHED	26.58574	89.99684	TW	6.362	88.87	0.21	58.65	0	85.46832	85.46832	10.635	4.4597	0	0.05	10.008	15.77184	90	3.07	0.68	1.351	0.0528
Srirampur	26.433	89.9024	DUG	6.729	99.38	0	65.59	0	91.5732	91.5732	7.09	16.7245	3.0184	0.09	24.0192	10.91068	105	3.81	1.86	0.53	0.0782

Location	Lat	Long	Source	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	U from Fluorimeter
Sapatgram	26.331	90.118	DUG	7.092	241.4	0.17	159.32	0	91.5732	91.5732	7.09	17.6617	3.0918	0.14	42.0336	2.406796	115	0.03	1.29	0.555	0.3336
Mandarpara	26.42151	90.07329	DUG	6.62	314.2	0.09	207.37	0	91.5732	91.5732	28.36	13.8004	16.3062	0.05	18.0144	2.418447	55	35.68	7.41	0.268	BDL
Bhumka Pt I	26.38425	90.02968	DUG	6.051	110.8	0.05	73.13	0	36.62928	36.62928	31.905	6.4472	1.0409	0.03	6.0048	6.065049	40	22.42	1.03	0.388	BDL
Mornai Tea estate	26.3607	89.8983	DUG	6.64	328.1	0.09	216.55	0	91.5732	91.5732	10.635	22.5705	23.8245	0.08	24.0192	8.483495	95	8.18	12.12	0.483	0.0474
Monglajhora	26.25	89.95	DUG	6.656	119.6	0.16	78.94	0	54.94392	54.94392	28.36	0.3447	9.4608	0.03	12.0096	4.848544	50	17.16	1.57	0.34	BDL
Basbari	26.19	89.9	DUG	6.076	211.1	0.14	139.33	0	30.5244	30.5244	17.725	3.1032	18.9487	0.02	10.008	2.42233	35	11.21	2.6	0.292	BDL
Gossaigaon	26.44167	89.96667	DUG	6.488	81.51	0.12	53.80	0	42.73416	42.73416	14.18	2.6654	3.2526	0.03	12.0096	3.634951	45	5.87	0.27	0.292	BDL
Chilkikhata	26.278	90.044	DUG	6.595	35.81	0.08	23.63	0	42.73416	42.73416	10.635	0.8596	0.4275	0.02	12.0096	3.634951	45	0.56	0.5	0.268	BDL
Sesapani	26.195	89.984	DUG	7.315	183.6	0.06	121.18	0	97.67808	97.67808	14.18	2.6068	4.8115	0.04	28.0224	10.90874	115	0.28	1.27	0.411	BDL
Bagribari	26.214	90.118	DUG	6.631	323.3	0.13	213.38	0	79.36344	79.36344	49.63	1.4863	8.1181	0.02	20.016	12.12621	100	13.72	2	0.364	BDL
Bhojighora	26.3345	90.014	DUG	6.44	128.5	0.12	84.81	0	54.94392	54.94392	17.725	0.8777	10.4505	0.01	14.0112	6.061165	60	4.6	1.49	0.555	BDL

Annexure II: Concentration range of chemical constituents in groundwater (post monsoon)

Location	Lat	Long	Source	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	As (in ppb)
Fukangaon	26.4478	90.379	DUG	5.69	56.47	BDL	37.27	BDL	18.31	18.31	10.64	2.16	21.21	0.02	2.00	2.43	15	3.33	4.4	0.214	0.186
Anyajuli	26.318	90.37	DUG	5.53	83.44	BDL	55.07	BDL	12.21	12.21	31.91	0.61	15.93	0.01	4.00	3.64	25	5.89	1.13	0.260	BDL
Nayachara	26.4157	90.3995	DUG	6.66	374.3	0.14	247.04	BDL	189.25	189.25	28.36	5.67	4.99	0.2	42.03	9.69	145	15.48	11.84	17.314	1.682
Kakrikhola	26.3702	90.358	DUG	6	49.03	0.08	32.36	BDL	30.52	30.52	10.64	0.61	1.66	0.02	4.00	2.43	20	3.46	0.72	0.329	BDL
Tintila	26.28	90.361	DUG	6.15	91.18	BDL	60.18	BDL	36.63	36.63	17.73	0.80	6.63	0.01	8.01	1.21	25	4.96	1.08	0.352	BDL
Rainadabri	26.35	90.2694	DUG	7.14	249.3	BDL	164.54	BDL	122.10	122.10	10.64	5.17	5.00	0.06	36.03	1.20	95	5.53	3.79	0.283	BDL
Daukibari	26.3043	90.302	DUG	6.4	206.8	BDL	136.49	BDL	97.68	97.68	14.18	11.74	4.49	0.05	14.01	6.06	60	7.8	26.33	0.101	0.53
Baruah Para	26.34677	90.23309	HP	5.84	137.8	BDL	90.95	BDL	36.63	36.63	24.82	1.33	6.89	0.01	10.01	2.42	35	8.99	1.05	0.169	0.53
Fakiragram	26.368	90.176	DUG	6.77	227.4	BDL	150.08	BDL	97.68	97.68	21.27	10.80	25.14	0.06	32.03	2.41	90	8.12	5.52	0.283	BDL
Titaguri	26.43917	90.28778	DUG	6.28	478.8	0.01	316.01	BDL	67.15	67.15	63.81	19.17	46.93	0.02	36.03	6.05	115	48.9	13.65	0.283	BDL
Bonorogaon	26.469	90.221	DUG	6.26	170.2	BDL	112.33	BDL	42.73	42.73	28.36	10.09	9.52	0.15	18.01	3.63	60	8.83	4.02	0.260	BDL
Jaimary	26.5222	90.2445	DUG	6.36	107.7	0.1	71.08	BDL	30.52	30.52	10.64	4.01	22.13	0.02	12.01	2.42	40	4.34	1.77	0.169	BDL
Genduguri	26.62	90.23	DUG	6.34	65.72	BDL	43.38	BDL	36.63	36.63	7.09	5.20	10.98	0.02	8.01	1.21	25	3.04	0.82	0.329	BDL
Bhadranpur	26.6124	90.29	HP	6.25	83.26	0.04	54.95	BDL	24.42	24.42	10.64	10.13	11.89	0.03	8.01	3.64	35	3.81	2.4	0.329	0.302
Amguri	26.54028	90.33778	DUG	6.73	95.23	0.19	62.85	BDL	61.05	61.05	7.09	1.33	9.88	0.01	12.01	3.63	45	2.5	1.58	0.237	BDL
Ultapani NHNS	26.7846	90.309	DUG	6.08	61.24	0.05	40.42	BDL	18.31	18.31	10.64	4.27	14.74	BDL	8.01	1.20	20	3.48	1.22	0.101	BDL
kok_Circuit house	26.40049	90.25991	TW	6.51	323.7	0.12	213.64	BDL	67.15	67.15	35.45	16.93	42.32	0.04	26.02	7.27	95	26.98	10.43	0.169	BDL
Ultapani PHED	26.76911	90.30782	TW	6.42	92.32	0.09	60.93	BDL	42.73	42.73	3.54	10.49	9.75	0.02	10.01	3.64	40	3.9	1.02	0.237	BDL
Gurufala	26.519	90.03	DUG	6.16	222.7	0.05	146.98	BDL	54.94	54.94	24.82	13.09	34.20	0.06	16.01	4.85	60	15.68	9.44	0.191	BDL
Mahamaya Mandir	26.56	90.08	DUG	6.49	91.28	0.06	60.24	BDL	54.94	54.94	7.09	2.94	4.36	0.02	8.01	3.64	35	4.24	1.53	0.517	BDL
Oxiguri	26.63607	89.97947	DUG	7.78	302.1	0.02	199.39	BDL	146.52	146.52	10.64	22.45	16.16	0.48	30.02	7.27	105	7.71	36.68	0.329	BDL
Kashiabari	26.5423	89.9198	DUG	6.62	109.2	0.12	72.07	BDL	54.94	54.94	10.64	3.37	6.10	0.03	12.01	3.63	45	3.96	2.13	0.302	BDL
Pokalagi PHED	26.58574	89.99684	TW	6.54	112.3	BDL	74.12	0	67.15	67.15	10.64	3.94	0.05	0.04	10.01	3.64	40	7.94	0.82	2.249	BDL
Srirampur	26.433	89.9024	DUG	6.395	109.2	0.12	72.07	BDL	42.73	42.73	7.09	6.37	2.03	0.02	12.01	1.21	35	3.43	10.37	0.710	BDL
Sapatgram	26.331	90.118	DUG	7.06	134.3	BDL	88.64	BDL	61.05	61.05	7.09	9.10	8.14	0.13	22.02	1.20	60	2.41	1.93	0.329	BDL

Location	Lat	Long	Source	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	As (in ppb)
Mandarpara	26.42151	90.07329	DUG	6.86	221	BDL	145.86	BDL	109.89	109.89	10.64	9.67	6.63	0.09	18.01	2.42	55	12.08	25.67	0.759	BDL
Bhumka Pt I	26.38425	90.02968	DUG	5.83	78.9	0.04	52.07	BDL	42.73	42.73	10.64	6.34	0.37	0.02	4.00	3.64	25	7.25	2.5	0.376	BDL
Mornai Tea estate	26.3607	89.8983	DUG	6.77	474.2	BDL	312.97	BDL	122.10	122.10	3.54	21.91	28.39	0.19	58.05	6.04	170	17.31	24.64	0.423	BDL
Monglajhora	26.25	89.95	DUG	6.41	104.4	0.11	68.90	BDL	61.05	61.05	10.64	1.71	6.98	0.01	18.01	1.20	50	4.5	9.61	0.734	BDL
Basbari	26.19	89.9	DUG	5.99	138.4	0.17	91.34	BDL	30.52	30.52	39.00	4.63	14.37	BDL	10.01	6.06	50	20.43	4.72	0.423	BDL
Gossaigaon	26.44167	89.96667	DUG	6.26	54.64	0.12	36.06	BDL	24.42	24.42	10.64	2.65	5.41	0.01	14.01	1.21	40	3.86	1.57	0.470	BDL
Chilkikhata	26.278	90.044	DUG	6.41	77	0.14	50.82	BDL	48.84	48.84	10.64	1.38	4.64	0.01	14.01	4.85	55	4.66	1.59	0.423	BDL
Sesapani	26.195	89.984	DUG	7.08	137.3	0.16	90.62	BDL	109.89	109.89	10.64	3.23	7.54	0.03	36.03	1.20	95	4.5	3.55	0.686	BDL
Bagribari	26.214	90.118	DUG	6.04	147.8	0.12	97.55	BDL	36.63	36.63	39.00	2.71	17.74	BDL	12.01	8.49	65	17.02	2.8	0.565	BDL
Bhojighora	26.3345	90.014	DUG	6.05	92.21	0.16	60.86	BDL	36.63	36.63	14.18	1.11	25.01	0.01	10.01	2.42	35	7.86	3.15	0.541	0.302
Saralpara	26.81930	90.25630	DUG	6.25	115.7	0.24	76.36	BDL	48.84	48.84	10.64	15.14	20.24	0.03	12.01	3.63	45	4.06	2.35	0.306	BDL