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Central Ground Water Board

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

BONGAIGAON DISTRICT, ASSAM

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

AQUIFER MAPPING AND MANAGEMENT PLAN OF BONGAIGAON DISTRICT, ASSAM

ANNUAL ACTION PLAN, 2022-23

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CENTRAL GROUND WATER BOARD

North Eastern Region

Guwahati

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CHAPTER 1

1.0 Introduction

The vagaries of rainfall, inherent heterogeneity and unsustainable nature of aquifers, over exploitation of once copious aquifers, lack of regulation mechanism etc has a detrimental effect on ground water scenario of the Country in last decade or so. Thus, prompting the paradigm shift from **"Traditional Groundwater Development concept**" to **"Modern Groundwater Management concept**". Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plans. This leads to concept of Aquifer Mapping and Ground Water Management Plan. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. The proposed management plans will provide the "Road Map" for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. Thus the crux of NAQUIM is not merely mapping, but reaching the goal-that of ground water management through community participation.

1.1 Objective and Scope

The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization
- Quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

The groundwater management plan includes Ground Water recharge, conservation, harvesting, development options and other protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e, the aquifer map and management plan.

The main activities under NAQUIM are as follows:

a). Identifying the aquifer geometry

b). Aquifer characteristics and their yield potential

c). Quality of water occurring at various depths

d). Aquifer wise assessment of ground water resources

e). Preparation of aquifer maps and

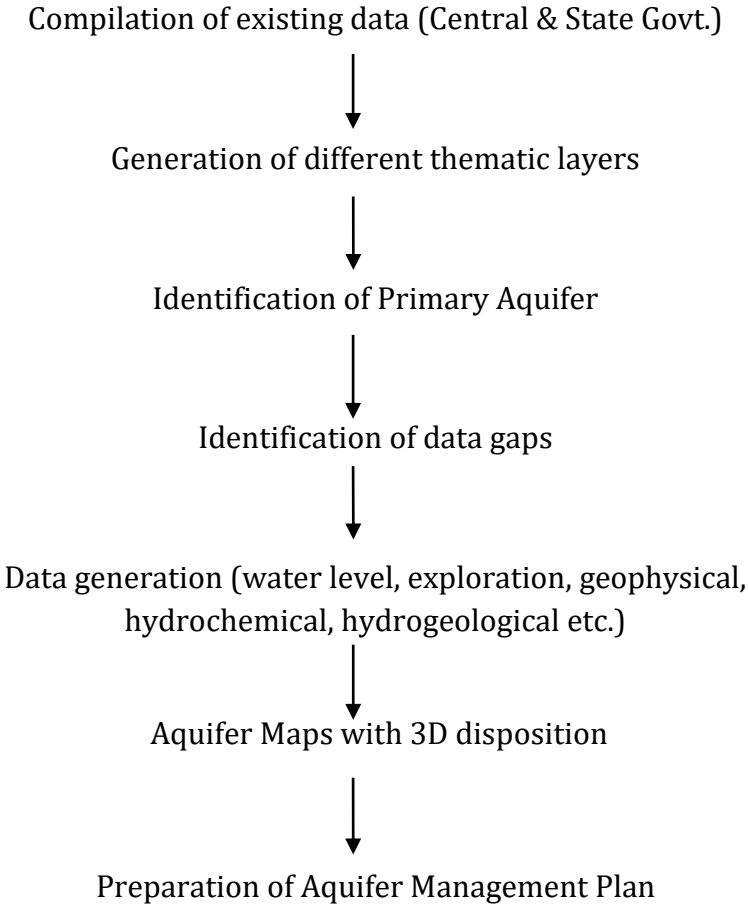
f). Formulate ground water management plan.

The demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a "Road Map" to systematically manage the ground water resources for equitable distribution across the spectrum.

1.2 Approach and Methodology

The ongoing activities of NAQUIM include hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilization for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:



1.3 Area Details

Study area is situated in eastern most part of Assam and on the southern bank of Brahmaputra . Bongaigaon district of Assam covers a geographical area of 1093 sq. km and lies between 26° 09′ 52″ and 26° 30′ 03″ N. Latitudes and 92° 22′ 47″ East longitudes. The district is bounded on the North by Chriang and North West by Kokrajhar district on the East by Barpeta district on the South west by Dhubri district. The Brahmaputra River flows through the southern boundary of the district. Bongaigaon has been subdivided into five

administrative development blocks namely Dangtol, Boitamari, Manikpur, Srijangram, Tappatary.

The study area is bound by survey of India toposh-etno:78J/02,83M/03,83M/04,83M/06,83M/07,83M/08,83I/11,83I/12,83I/14,83I/15,83I/16. Administrative map of the district is given in Figure **1.** As per 2011 census report total population of Bongaigaon district is 7,38,804. Blockwise area of the district is shown in Table 1.

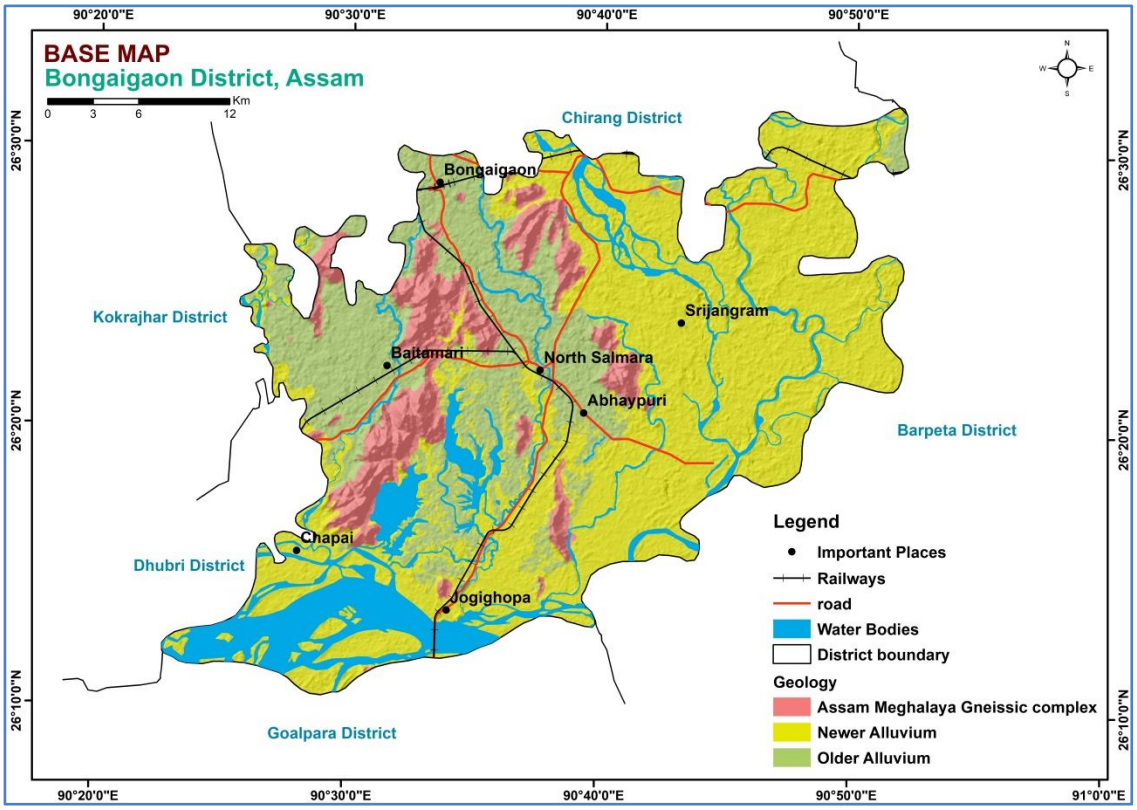


Fig.1.1: Base map of Bongaigaon district

Table 1.1: Block wise Area of Bongaigaon District, Assam

Sl. No.	Block	Area in (Hectare)
1	Manikpur	28038
2	Dangtol	24121
3	Boitamari	24080
4	Tapattary	14329
5	Srijangram	20317

1.4. Data Availability Adequacy and Data Gap analysis

1.4.1 Data Availability:

Central Ground Water Board has carried out exploratory drilling in the district and drilled 6 exploratory wells and 4 piezometer in alluvial formation and piedmont zone . In addition, ten numbers of permanent observation well station (NHNS) of Central Ground Water Board located in the district are being monitored for ground water regime and to assess the chemical quality of ground water.

1.4.2 Data Adequacy and Data Gap Analysis:

The available data of the Exploratory wells drilled by Central Ground Water Board, North-Eastern Region, Guwahati, ground water monitoring stations and ground water quality stations monitored by Central Ground Water Board were compiled and analysed for adequacy of the same for the aquifer mapping studies.

After taking into consideration, the available data of ground water exploration, geo-physical survey, ground water monitoring and ground water quality, the data adequacy has been compiled. The summarised details of required, existing and data gap of exploratory wells, ground water monitoring and ground water quality stations are given in table–2.

Table 1.2: Data adequacy and data gap analysis

Exploratory data			Geophysical data			GW monitoring data			GW quality data		
Req.	Exist.	Gap	Req.	Exis.	Gap	Req.	Exist.	Gap	Req.	Exis.	Gap
9	3	6	15	0	0	36	10	26	36	9	25

1.5 Rainfall - Climate

Climate of area is sub-tropical, humid and typical of Brahmaputra valley. Winter usually commences in November and continues upto February, followed by brief period of spring from March to April. Pre-monsoon shower appears in first-half of April, but regular monsoon sets in May and continues upto middle of October.

Annual rainfall in Bongaigaon district for the year 2022 is 1527mm there is a deviation of 42% from normal rainfall. Rainfall analysis has been done based on gridded IMD data for the study area. Based on percent deviation of monsoonal rainfall for a period of 10 years (2012-2022). The Rainfall Deviation (Rf_{dev}) which is expressed in percentage terms is calculated as below:

$$Rf_{dev} = \{(Rfi-RFn)/RFn\}*100$$

where, Rfi is current rainfall for a comparable period (in mm)

Rfn is the normal rainfall (at least 30 years average) for the same period (in mm).

Table 1.3: Classification of deviation of monsoonal rainfall from normal (2012-2022)

Deviation from Normal rainfall(%)	Category	Monsoonal rainfall year
+19 to-19	Normal	2013,2015,2017,2020
-20 to -59	Deficient	2011,2012,2014,2016,2018,2019,2021

According to IMD classification for percentage deviation of rainfall from normal rainfall during the period, it has been observed from that there has been deficit (-20% to 59%) monsoonal rainfall in 2022 (-42.6%). Monsoonal rainfall has been erratic in the observed period. There are few monsoon season where rainfall has been deficit. As agriculture is rainfall dependent in the study area deficit rainfall pattern creates impact on groundwater withdrawal for irrigation.

Table 1.4: Monthly Rainfall data of Bongaigaon district, 2022

MONTH	ACTUAL RAINFALL(mm)	NORMAL RAINFALL(mm)
JAN	13.8	36.1
FEB	68.65	56.2
MAR	20.47	103.8
APRIL	489.16	222.6
MAR	515.19	313
JUNE	1260.99	416.6
JULY	261.38	531.6
AUG	352.71	439.8
SEP	185.54	329.5
OCT	260.77	153.7
NOV	0	26.7
DEC	0.3184	19.8

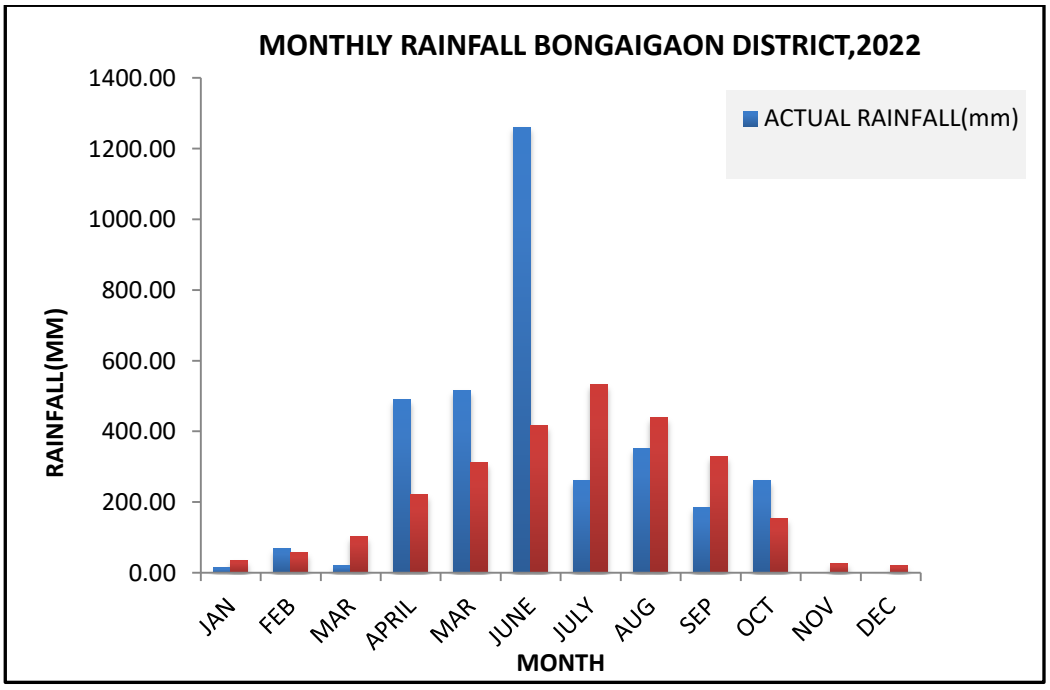


Fig. 1.2: Graph of monthly rainfall and normal rainfall Bongaigaon , 2022

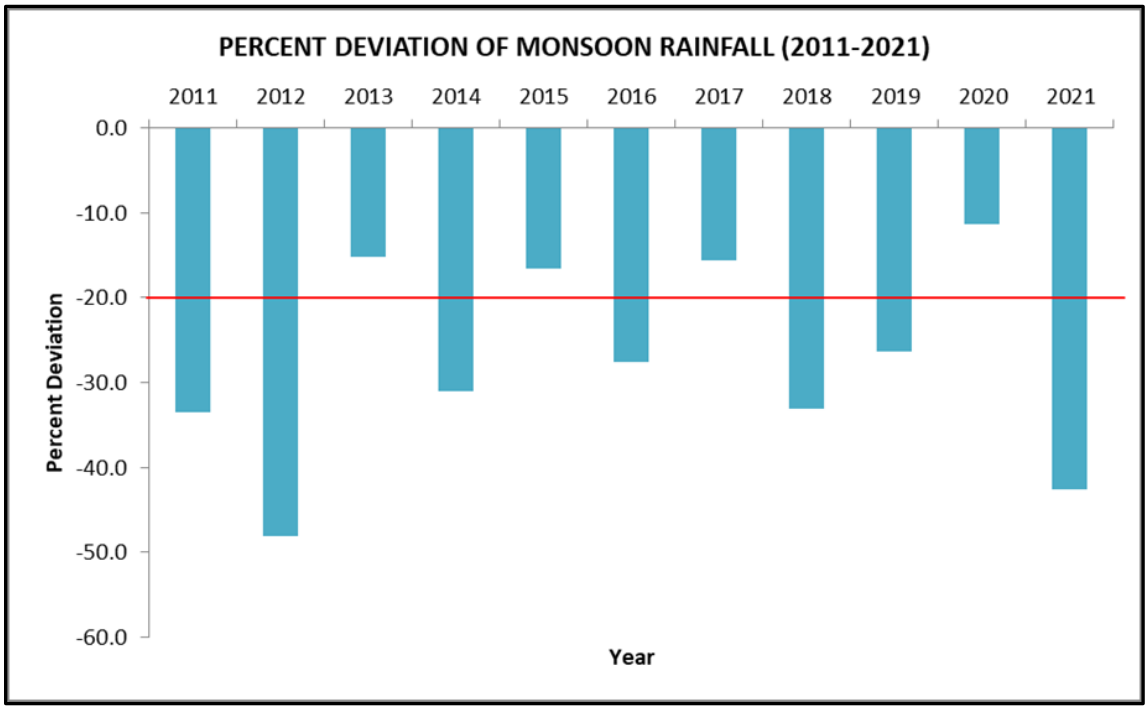


Fig. 1.3: Graph of Percentage deviation of monsoonal rainfall from normal (2011-2021)

1.6 Physiographic setup

Study area represents two distinct physiographic division viz. (a) flood plains of Brhamaputra River and (b) Denudational hills of Archean age. Bongaigaon district is a part of the northern extremity of the Shillong Plateau. The topography of the area is controlled mostly by the N-S to NE-SW trending hill ranges with intermittent valleys. The spatial disposition of the hillocks seems to be controlled by the structural lineaments and the major deformational events of the area. The highest elevation of the area is 510m above msl in Bhairab R.F (south of Mechpara) in the south- central part of the area while the lowest elevation is 33 m above msl in Brahmaputra River. Prominent hills located in the area are Bishwakarma Pahar, Mahadeo, Mahadeb, Bhairab, Bamungaon, Sonakhuli, Kakaijan, Phagkati, Lungai, Nakati and Bageswari.

The alluvial plain evolved during Quaternary period from the foreland depression between Himalayan orogenic belt and crystalline massif of shillong plateau. General elevation of alluvial plain varies from 33to 48 m above m.s.l. The general slope of the area is towards south.. The alluvial plains are marked by abandoned channels, meander cut-offs and water bodies locally called bil. Tamranga bil, Kanara bil, Bherbari bil, Dalani bil and Binabaja bil are the important bils located in the area.

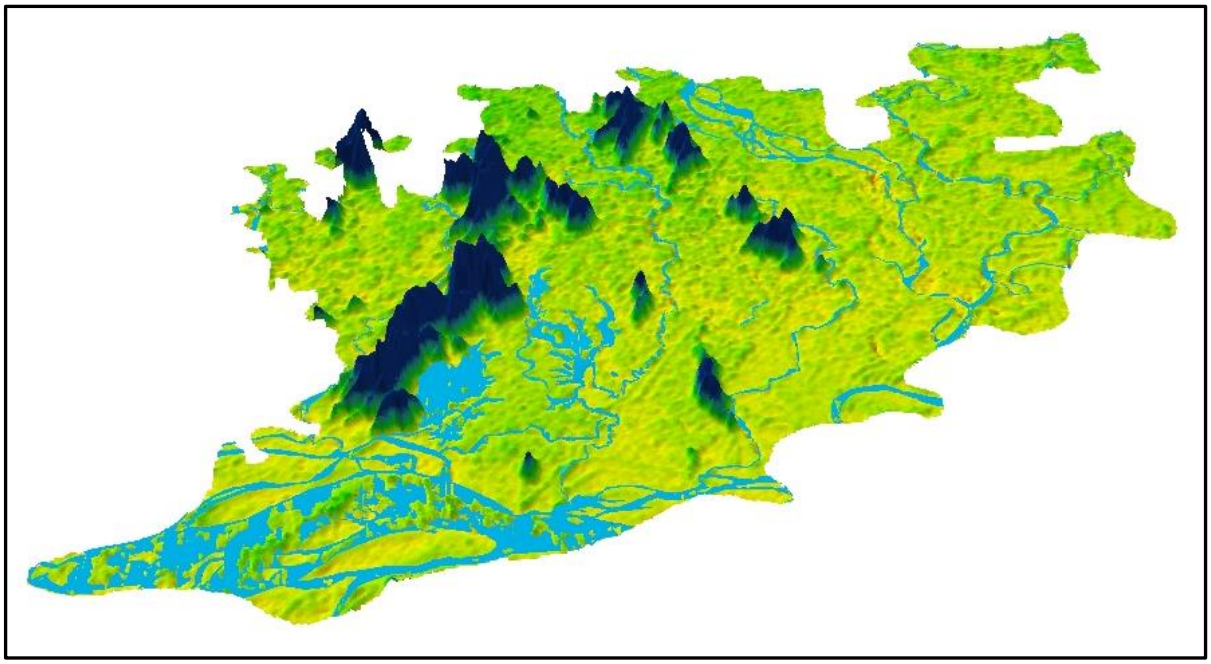


Fig. 1.4: Digital Elevation Map of Bongaigaon.

1.7 Geomorphology

The present area of study forms part of the vast alluvial plains with gentle rolling topography of the Brahmaputra basin. It is bounded by Brahmaputra River in the south to the north the piedmont zone and to the southwest pediment inselberg complex. . Geomorphologically the district is subdivided into five geomorphic units: 1. Flood plain 2. Younger alluvial plain 3.Older alluvial plain 4. Pediment inselberg complex 5.Denudetional hills of gneissic complex.

Flood plain: Along river Brahmaputra and Manas thick piles of flood plain have been deposited due to river action, comprising different grades of sands, gravels, clays Abondoned channels, natural levees, channel bars are also observed in places.

Younger alluvial plain: Major parts of the district is underlain by younger alluvial plain, comprising different grades of sand, gravels, pebbles and silts. Old meanders, abondoned channels are also common in the unit.

Older alluvial plain: Northern and northwestern parts of the district is generally covered by older alluvial plain. These areas slightly at higher elevation then younger alluvial plain. The formation is mainly comprised of unconsolidated to semi-consolidated weathered limonitic clay, unsorted boulders, pebbles , gravels and sand .

Pediment Inselberg Complex: Pediment inselberg complex occurs in fringe areas of foothills, the thickness of pediment deposits varies from 5 to 15 metres. The degree of weathering is more in the valley then in the hill slopes.

Denudational hills of gneissic complex: Denudational hills of gneissic complex are found in the western part of the district. In northern and central part isolated denudational hills exist. These hills are mostly comprised of gneissic rocks and pegmatite occurs as intrusive

of varied nature. These rocks are deformed due to tectonic activities, resulting in development of fractures, fissures, cracks and lineaments.

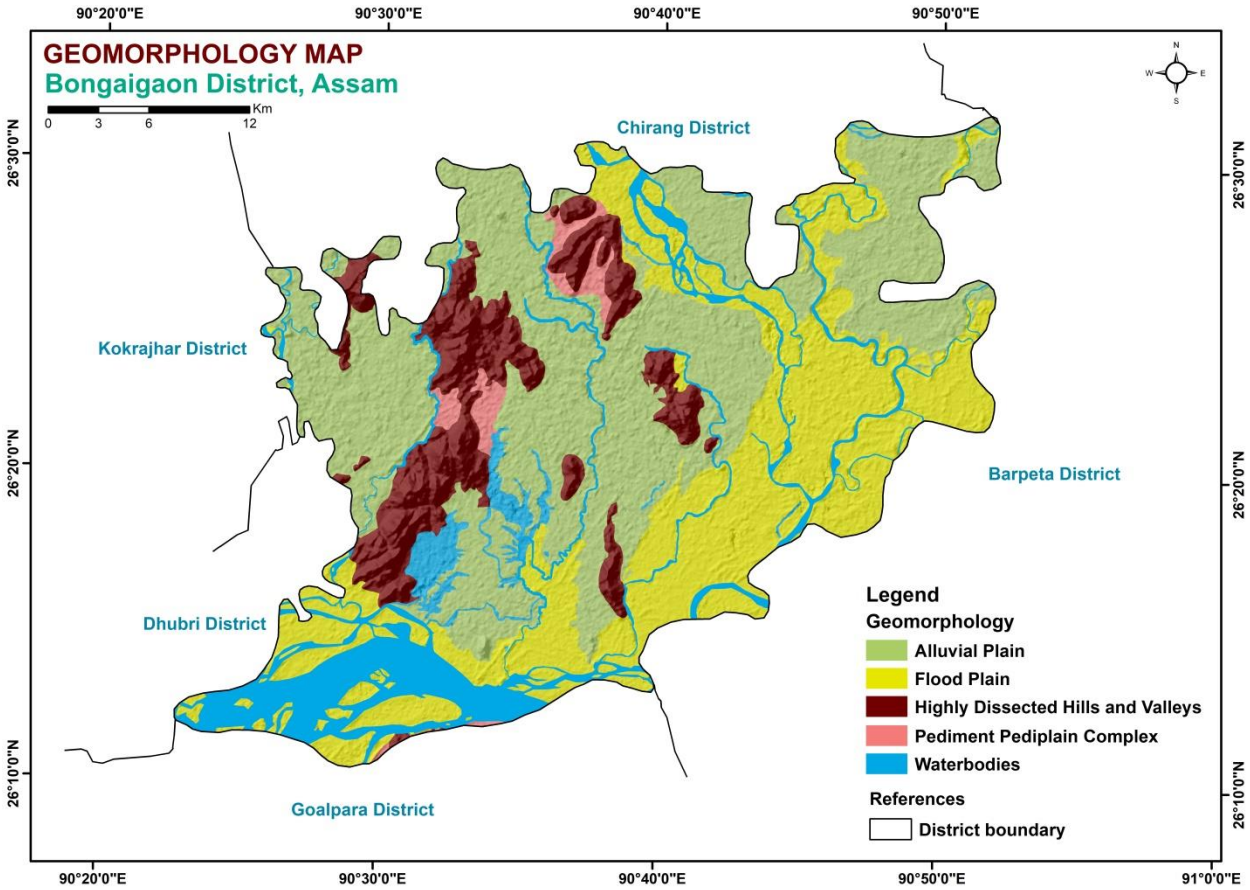


Fig.1.5: Geomorphology Map of Bongaigaon.

1.8 Land Use Pattern:

The greatest area under agriculture is in Manikpur block with 32,895 hectares of land as gross cropped area followed by Boitamari and Dangtol blocks. The least area under agriculture is in Tapattary block, but this may be due to the fact that it has the least geographical area as well. In terms of forest cover, Dangtol block has the highest area under forests with 2967 hectares or 14% of it's total geographical area, considerably more than the other blocks in the district

Table 1.5: Land Use Pattern in Bongaigaon District (in hectares)

Block	Total Geographical Area	Gross cropped Area	Net Sown Area	Area Sown more than once	Cropping Intensity	Area under Forest (Ha)	Area under Wasteland (Ha)	Area under other uses (Ha)
Manikpur	43369	32894	18905	7412	174%	313	2493	3046
Dangtol	70527	21656	12446	5412	174%	2967	1143	990
Boitamari	26950	27862	16013	7942	174%	379	2364	1269
Tapattary	52912	20594	11836	5218	174%	315	1501	1127
Srijangram	42723	14694	8445	4021	174%	227	1125	1499

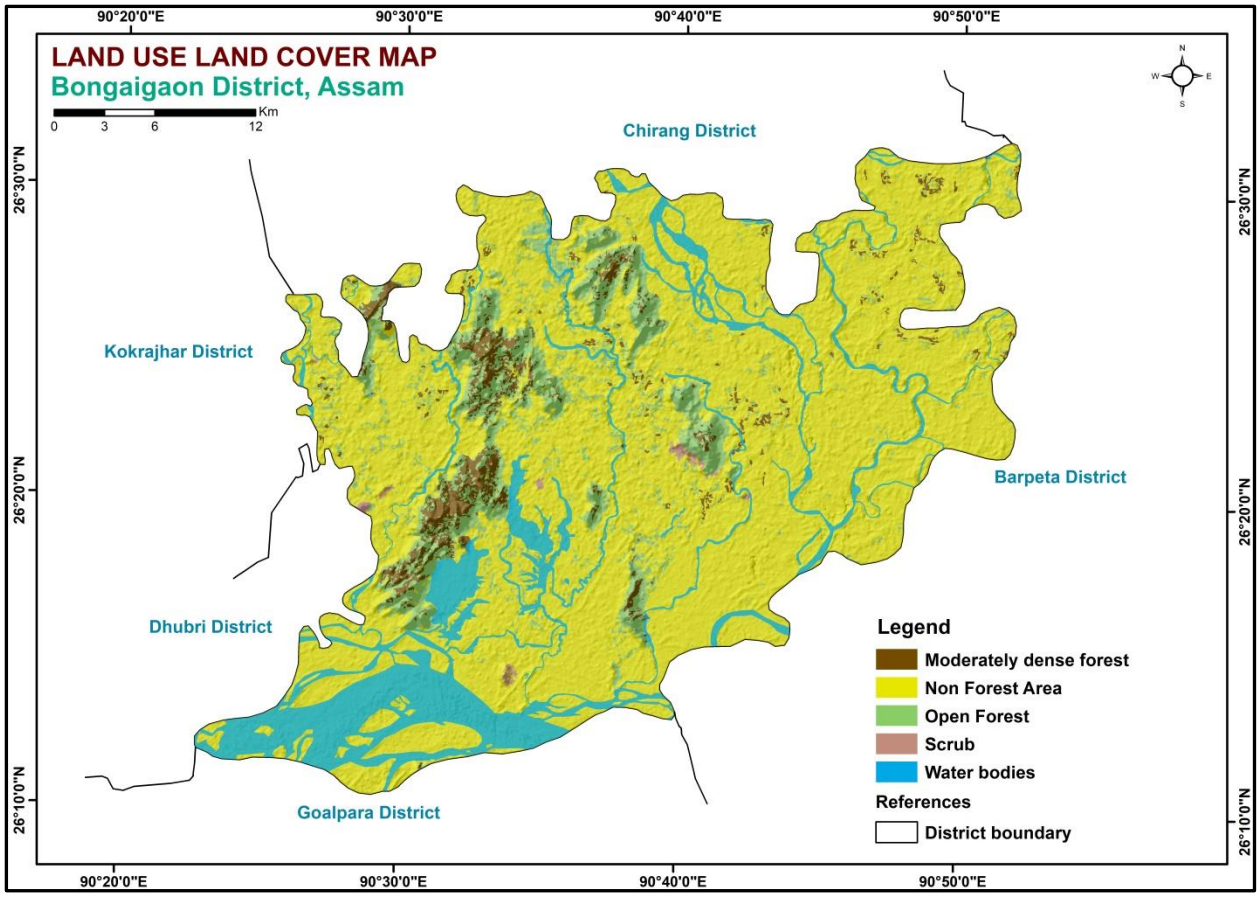


Fig. 1.6: Land Use Land Cover Map of Bongaigaon district.

1.9 Soil

Soils of the area are sandy to clayey loam type and greyish in colour. They are acidic in reaction with PH ranges from 4.6 to 5.9. Based on pedogenic and pedological characters, soils of this area may be classified into following classes a) Recent riverine alluvial soils (Antisol) b) Old riverine alluvial soils (Inceptisol) c) Old mountain valley alluvial soils (Alfisol) The predominantly soil of the district is clay loam which is covering an area of 255062 ha that is 76.59% of the total geographical area followed by clay soil with 8.78%, Sandy soil-by 7.60% and sandy loam soil-7.03%. Major areas of all AES and blocks are having clay loam soil, similarly clay, sandy and sandy loam soils are also found in all blocks. Large area under clay soil is present in two blocks namely Manikpur and Boitamari in comparison to other five blocks.

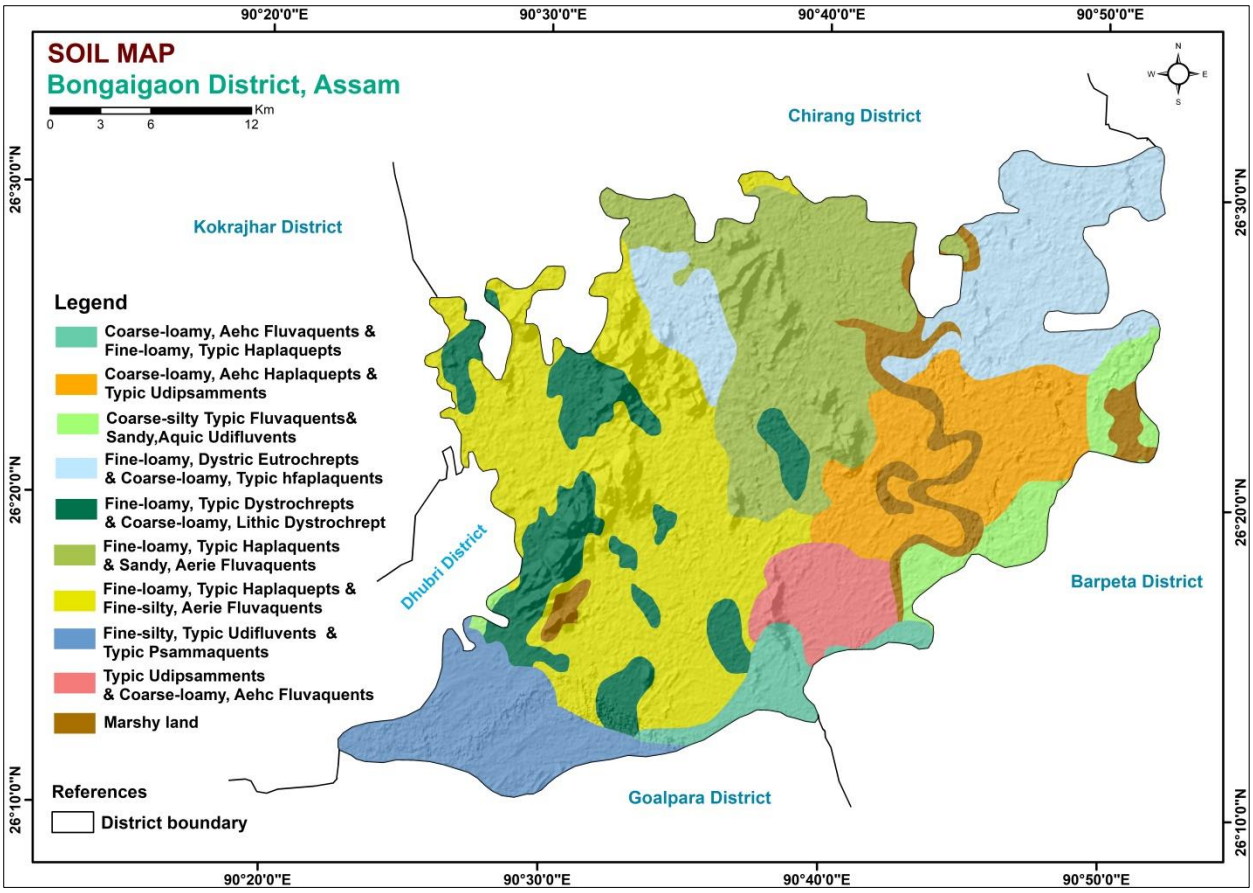


Fig.1. 7: Soil Map of Bongaigaon district

1.10 Hydrology and Drainage

The Manas River originates from the Bhutan Himalaya and flows in the north eastern part of the district. It flows in the northeast to southwest direction and meets Brahmaputra which forms the southern boundary of the district. The north-east to south-west direction of flow is also observed in Aie River, which is a third order tributary to the Manas River. The high degree of sinuosity, compression and deep incision observed along the course of the Manas River could be indicative of upliftment due to neotectonic activity. Champawati River originates in Chirang and flows northeast to south west direction and merges with Brahmaputra.

Kujia nadi flows through the central part of the area towards south and joins Kanara Bil. Tunia nadi flows from north to south and westward near Salbari and enters the adjacent sheet. The regional drainage pattern is observed to be structurally controlled. The sub- parallel drainage is manifested by the higher order streams while in some sub-basins.The 1 st and 2nd order streams also show sub parallel to dendritic drainage pattern.

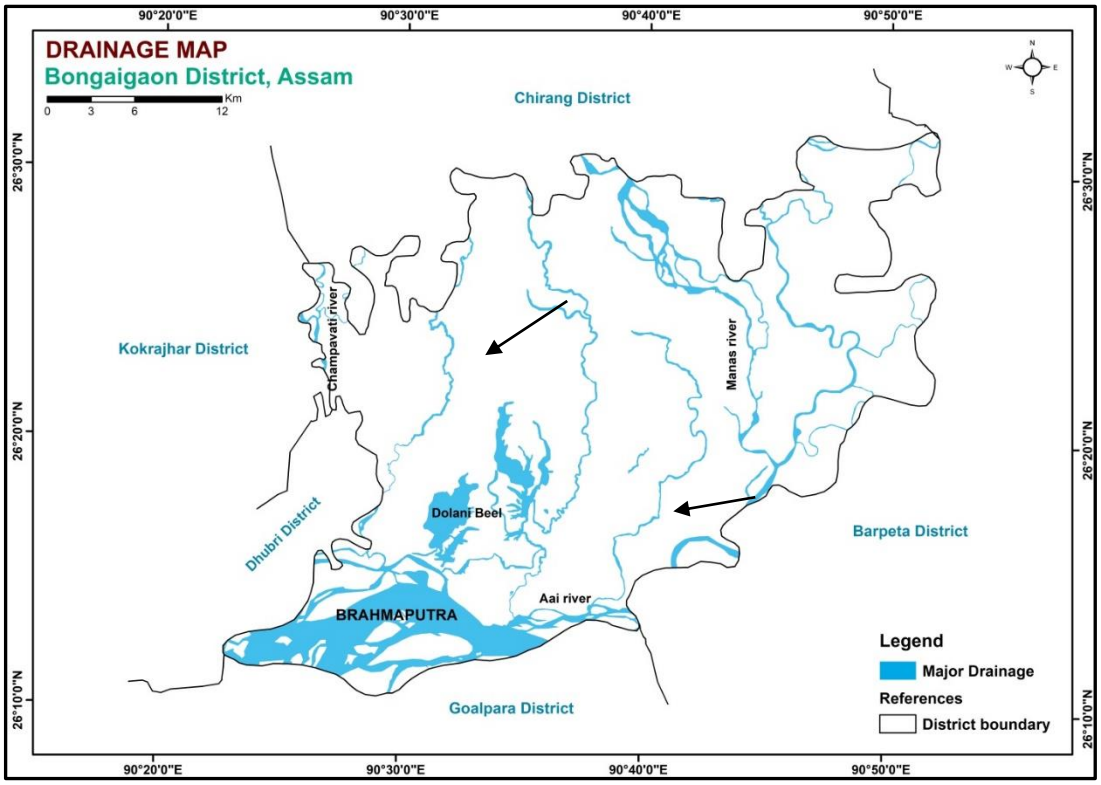


Fig.1.8: Drainage Map of Bongaigaon district

The lineaments are observed by linear ridges, streams and River course. The trends of lineaments are NE-SW, , NNW-SSE correlatable with Kopili lineament and E-W correlatable with Dauki lineament. At the place of crosscutting of lineaments, the E-W trending lineaments are discontinuous and this indicates E-W trending lineaments are earlier and other lineaments are later. The long axis of flood plain basins are NE-SW, NW-SE and N-S. This indicates the flood plain basins are structurally controlled. Drainage parallel lineaments are observed in Aie River, Kujia nadi.

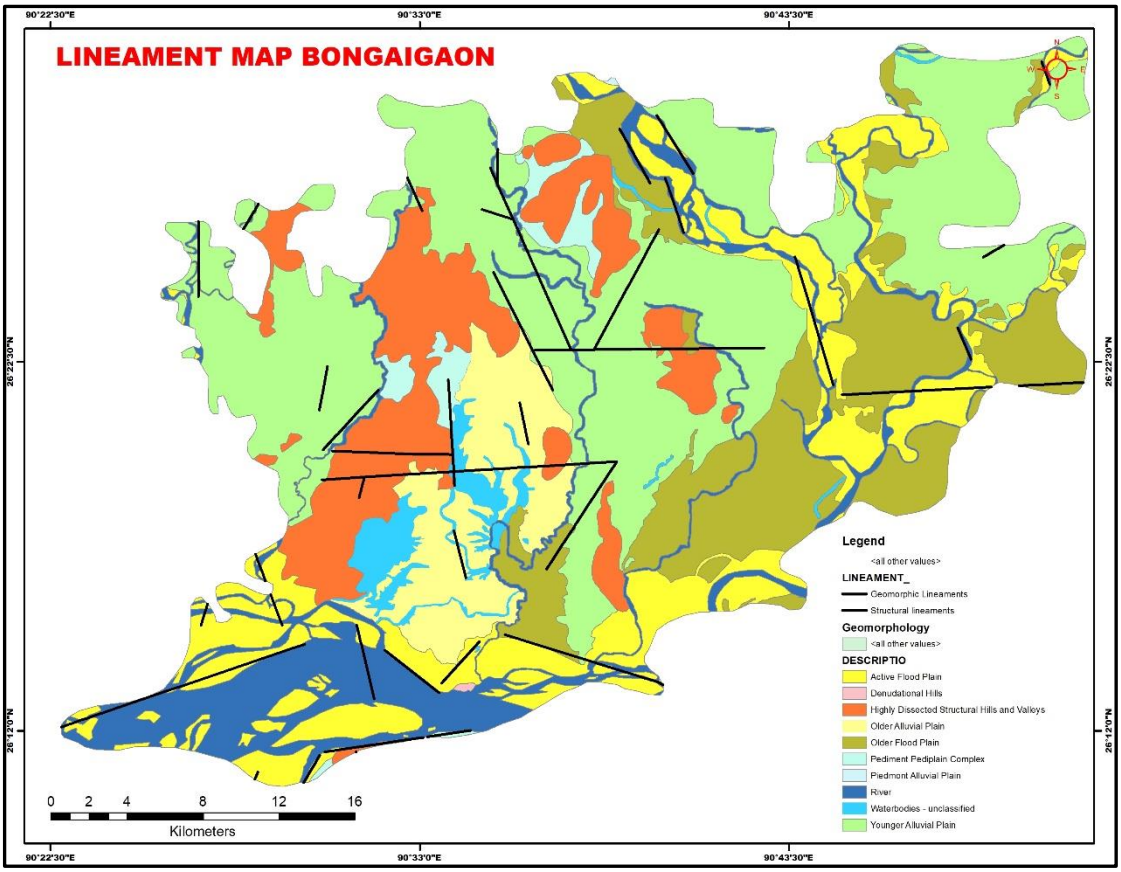


Fig.1.9: Lineament Map of Bongaigaon district.

1.11 Agriculture

The local population of the district mostly depends on agriculture for their sustenance. The agriculture activity of the area is solely dependent upon the monsoon rainfall. Paddy is the main crop of the district. Rice and pulses are other crops grown widely in Bongaigaon and its adjoining areas. Irrigational facilities are not adequate in this district. Most agriculture is rainfed, but this is not a very dependable source of irrigation.. Minor irrigation structures like surface water, tanks and ponds are the other source for irrigation. Available source wise acreage of agriculture production is given in table 5.

Table 1.6: Agriculture acreage and yield in Bongaigaon District (in hectares)

Rice									
Year	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**
Area (in hect.)	58846	70544	76156	77254	77409	77587	78070	74728	79342
Production (in tonnes)	93732	135347	154935	162958	105259	161327	148054	129091	153400
Average yield (in kg / hect.)	1617	1948	2065	2141	1380	2111	1925	1753	1963

Pulses									
Year	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**

Area (in hect.)	1055	688	1028	1099	1153	1865	1929	1779	1870
Production (in tonnes)	477	323	478	512	534	831	1105	996	1189
Average yield (in kg / hect.)	452	468	465	466	464	445	573	560	635
Rabi Pulses									
Year	**2007 -08**	**2008 -09**	**2009 -10**	**2010 -11**	**2011 -12**	**2012-13**	**2013-14**	**2014-15**	**2015 -16**
Area (in hect.)	1007	668	972	1034	1118	1825	1880	1730	1813
Production (in tonnes)	441	308	436	463	506	798	1063	949	1143
Average yield (in kg / hect.)	438	461	449	448	453	437	565	549	630
Oil Seeds									
Year	**2007 -08**	**2008 -09**	**2009 -10**	**2010 -11**	**2011 -12**	**2012-13**	**2013-14**	**2014-15(Pr)**	**2015 -16**
Area (in hect.)	858	846	1054	1198	2384	2502	2872	2794	
Production (in tonnes)	475	434	719	722	2324	2196	1799	1950	
Average yield (in kg / hect.)	552	514	682	603	975	877	626	698	

1.4.10 Irrigation

The district has net and gross cropped areas of 1,27,313 hectares and 1,88,692 hectares respectively, the net cropped area being 68 percent of the total geographical area. About 61,379 hectares out of the net cropped areas is put under multiple cropping with an average cropping intensity 148 percent as against 152.43 percent for the state. The crop wise irrigated and rain fed area sown in different seasons like kharif, rabi and summer.

The irrigation potential in the district is developed both from the surface and ground water sources. The irrigation department is responsible for creation of major, medium and minor irrigation schemes. The agriculture department has also created irrigation potential in different cultivable area by way of installation of shallow tube well schemes

Table 1.7: Irrigation structures in Bongaigaon (5th MI census)

Ground water				Surface water	
Dug Well	Shallow Tube well	Medium Tube Well	Deep Tube Well	Surface flow scheme	Surface lift irrigation
2	1454	0	11	2	379

Table 1.8: Source wise irrigation potential created and CCA of Bongaigaon district (in hectares)

In Use	Culturable Command Area	Potential Created	Potential Utilised	In Use	Culturable Command Area	Potential Created	Potential Utilised
2911	7359.5	8288.32	4627.08	95	2056.69	2714.99	431.2

1.12 Geology:

The area is part of foreland depression between younger Himalayan Mountains in the north and block mountains of shillong plateau in the south. The origin and development of the area is related to phases of uplifment due tectonic movement, glaciation and erosion of Himalaya and sinking with sedimentation.

The geological formation of the area can be describes as:

The Archean group of rocks comprising of biotite –hornblende gneiss, granulites, schist which are intruded by granite with pegmatites are trending NE-SW with moderate dip towards NW. They have very sharp contact with the unconsolidated formations.

The unconsolidated formation is divided into younger and older alluvium. Major parts of the district are underlain by younger alluvial plain, comprising different grades of sand, gravels, pebbles and silts. Old meanders, abandoned channels are also common in the unit.

The older alluvial plain is slightly at higher elevation then younger alluvial plain. The formation is mainly comprised of unconsolidated to semi-consolidated weathered limonitic clay, unsorted boulders, pebbles, gravels and sand.

Table 1.9: Stratigraphy of Bongaigaon

Age	Group	Formation	Lithology
Late Holocene		Barpeta Formation	Unoxidised grey loose sand, silt, clay with cobbles, pebbles and gravels.
Middle to late Holocene		Hauli Formation	Unoxidised grey coloured sand, silt, silty-clay, clay with cobbles, pebbles and gravels.
Late Pleistocene to Early Holocene		Sorbhog Formation	Moderately oxidized, pale- yellowish to dull brown sand, sandy-silt, silty-clay with gravels and pebbles
Middle to late Pleistocene		Chapar Formation	Brick- red color, highly oxidized semi consolidated, moderately sorted gravel, pebbles, sand, silt and clay.
Proterozoic		**Unconformity**	Granites, pegmatites and quartz veins. Secondary silicified zone.
Archean (?) to Early Proterozoic	Assam Meglaya Gneissic Complex		Biotite-gneiss/migmatite. Amphibolite, Mica-schist Banded Magnetite Quartzite (BMQ).

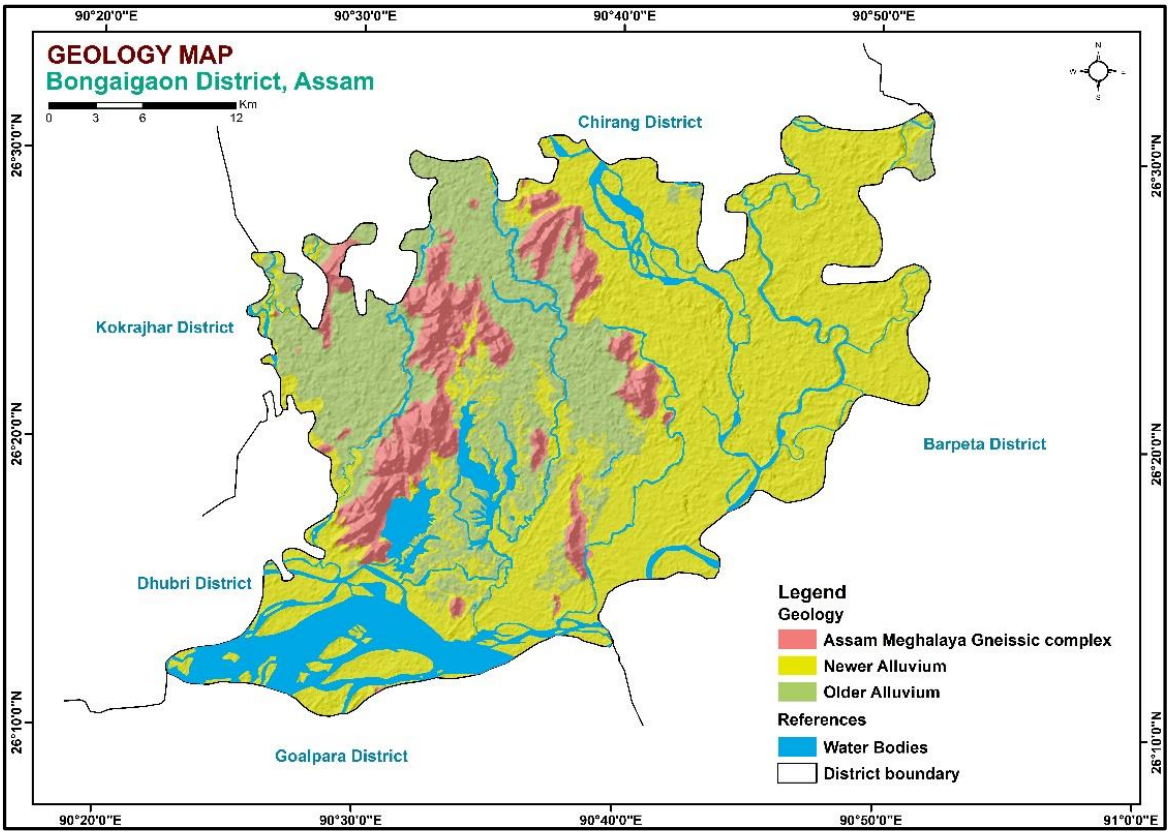


Fig. 1.10: Geology Map of Bongaigaon district

CHAPTER 2

2. Data collection

Data collection includes collection of rainfall data from state government, tea estates, compilation of CGWB's earlier survey data, exploration, and geophysical data. Population and agricultural data are collected from Census of India website.

2.1: Hydrogeological data

The entire study area is covered by regular monitoring of existing 9 GWMS (NHNS) and another 56 Key wells have been established. All these wells are monitored after establishment. Table 2.1 and figure (10) shows the details of monitoring well (GWMS) established in Bongaigaon district in AAP 2022-2023.

2.2 Water Quality

To assess the quality of ground water for drinking and irrigation purpose water samples were collected during pre and post monsoon season from 08 no of NHNS monitoring stations and 26 other sampling locations from dug wells and tube wells.

2.3: Geophysical survey

During AAP 2022-23, 06 no of geophysical survey had been conducted in Bongaigaon district.

Table 2.1: Location of VES survey in Bongaigaon district

Sl No.	Location	Longitude	Latitude
1	Aolaguri	90.775	26.417
2	Srijangram	90.718	26.388
3	Kabaitori	90.596	26.236
4	Mulagaon	90.542	26.452
5	Baraibukhur	90.576	26.334
6	Gerukapur	90.692	26.485

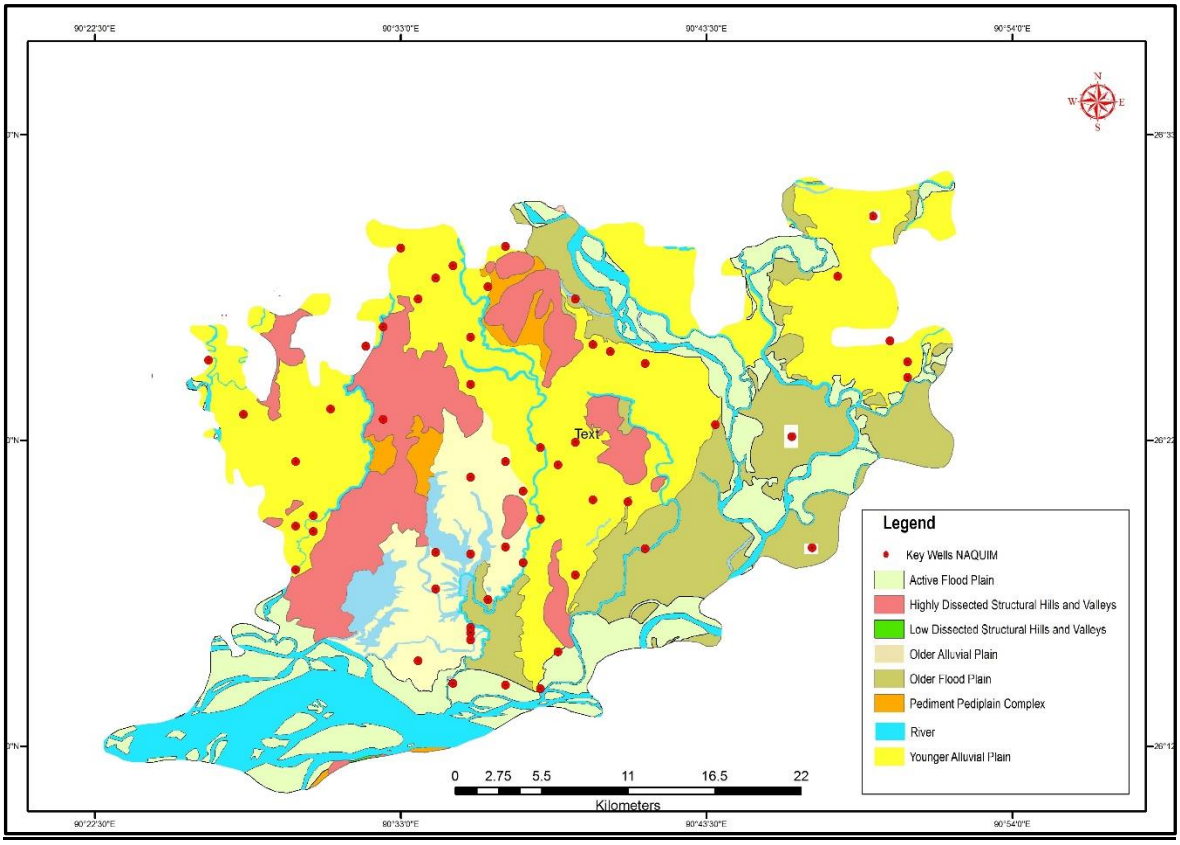
Table 2.2: Details of Key wells established in Bongaigaon district.

Location	Longitude	Latitude	M.P	Depth (mbmp)	Dia (m)	Type of well	Formation
North Salmara	90.63	26.371	0.59	7.2	1	DW	Younger Alluvium
Sarakola	90.65	26.456	0.93	4.5	0.7	DW	Younger Alluvium
Chaprakata	90.61	26.486	0.87	4.3	0.8	DW	Younger Alluvium
Kakijana	90.66	26.43	0.67	4.7	0.8	DW	Younger Alluvium
Borpara	90.56	26.456	0.5	7.5	0.8	DW	Consolidated
Mulagaon	90.54	26.44	0.87	9.3	1	DW	Consolidated
Mulagaon PHC	90.53	26.429	1	10.4	1.2	DW	Consolidated
Bansbari Pt II	90.51	26.393	0.77	8.09	2.1	DW	Younger Alluvium
Dhaknabari	90.5	26.323	0.74	7.3	0.7	DW	Younger Alluvium

Location	Longitude	Latitude	M.P	Depth (mbmp)	Dia (m)	Type of well	Formation
Boilamari	90.49	26.301	0.7	5.1	0.67	DW	Younger Alluvum
Talguri	90.49	26.326	1.02	7.3	2	DW	Younger Alluvium
Salbari	90.5	26.332	0.8	8.2	2	DW	Younger Alluvium
Borkhata	90.54	26.387	1.02	6.1	1	DW	Younger Alluvium
Durgapur	90.59	26.354	0.67	6.05	0.7	DW	Younger Alluvium
Ghilaguri	90.59	26.31	1.3	12.1	0.5	DW	Younger Alluvium
Sakumari	90.57	26.311	0.67	10.2	2	DW	Younger Alluvium
Chalantapara Pt II`	90.59	26.265	0.7	13.5	1	DW	Older Alluvium
Majgaon	90.59	26.407	0.56	5.4	1	DW	Older Alluvium
Kayapatty	90.58	26.236	0.97	8.7	0.7	DW	Younger Alluvium
Mohanpur PWSS	90.61	26.235	1	100	0.102	TW	Younger Alluvium
Pachania	90.63	26.233	0.67	5.2	0.7	DW	Consolidated
Malegarh Pt I	90.64	26.254	0.8	13.06	0.7	DW	Consolidated
Lalmati	90.65	26.298	1.2	9.15	2	DW	Consolidated
Amtola	90.65	26.374	0.8	6.42	1	DW	Younger Alluvium
Srijan-jan-gram(Borhola Pt II)	90.73	26.384	1	5.95	1	DW	Younger Alluvium
Hooramara	90.69	26.419	0.7	5.3	0.7	DW	Younger Alluvium
Kakoijana	90.67	26.426	0.98	5.45	0.7	DW	Younger Alluvium
Simalguri	90.5	26.488	0.8	7.72	1	DW	Younger Alluvium
Kinaborgaon	90.48	26.46	1.05	8.3	0.75	DW	Younger Alluvium
Kakragaon	90.45	26.446	0.8	15.5	0.9	DW	Younger Alluvium
Bijaygaon	90.42	26.445	0.8	6.2	1	DW	Younger Alluvium
Bilaspur PHED	90.41	26.412	1	100		TW	Younger Alluvium
Choraikonsra	90.44	26.421	0.9	8.5	0.7	DW	Younger Alluvium
Bidyapur	90.46	26.39	0.9	6.1	1	DW	Younger Alluvium
Jalakhata	90.49	26.363	0.5	5.5	0.7	DW	Younger Alluvium
Malipara	90.61	26.363	1.1	5.8	0.8	DW	Younger Alluvium
Jogipara	90.62	26.346	0.8	5.25	0.7	DW	Younger Alluvium
Choutaki	90.63	26.33	1.1	6.62	0.7	DW	Younger Alluvium
Nayagaon	90.62	26.305	0.7	7	1.2	DW	Younger Alluvium
Nayagaon	90.61	26.314	0.6	9	1	DW	Younger Alluvium
Bongaigaon	90.55	26.485	1.1	9.2	2.2	DW	Younger Alluvium
Deohati	90.64	26.361	1.2	7	0.7	DW	Younger Alluvium
Abhyapuri	90.66	26.341	0.5	6.65	0.9	DW	Younger Alluvium
Piradhara	90.69	26.313	0.4	100	0.102	TW	Older flood plain
Nuagaon	90.84	26.411	0.8	100		TW	Older flood plain
Jharbari	90.84	26.42	1.3	7.2	1	DW	Older flood plain
Chakihali	90.83	26.432	0.8	7.2	0.7	DW	Younger Alluvium

Location	Longitude	Latitude	M.P	Depth (mbmp)	Dia (m)	Type of well	Formation
Manikpur	90.8	26.469	1.1	7.3	0.9	DW	Younger Alluvium
Birjhora	90.58	26.475	0.8	7.2	0.7	DW	Younger Alluvium
Pakhrapara	90.57	26.468	0.9	5.2	0.7	DW	Younger Alluvium
Jhakuapara	90.6	26.463	0.8	6.3	0.8	DW	Younger Alluvium
Kashidoba	90.59	26.434	1	5.5	0.7	DW	Younger Alluvium
Katasbari PT-III	90.6	26.284	0.5	7.2	0.7	DW	Younger Alluvium
Chalantapara Pt -I	90.59	26.268	0.6	12.1	0.8	DW	Older Alluvium
Chalantapara	90.59	26.261	0.6	12.2	0.7	DW	Older Alluvium
Jogighopa	90.56	26.249	0.7	13.1	0.8	DW	Older Alluvium
Sakamura	90.57	26.29	0.62	12.5	1.2	DW	Older Alluvium
Borigaon PHED	90.68	26.34	0.5	100	0.102	DW	Younger Alluvium

Fig.2.1: Location of Key wells under NAQUIM, Bongaigaon district



2.4: Exploratory Drilling:

CGWB has drilled 06 no. of exploratory well for ground water investigation in Bongaigaon district. Under AAP 2022-23, 03 no. of new exploratory well has been drilled. The details of exploratory well are given in table 11

Table 2.3: Details of exploratory well in Bongaigaon district.

District	Location	Tpye of well	Topo sheet	Depth of Drilled (mbgl)	Depth of constr. (mbgl)	Source
Bongaigaon	Gerukabari-EW	EW	**78J/11**	81.25	63	CGWB
Bongaigaon	Kalbari-EW	EW	**78J/11**	100.50	92	CGWB
Bongaigaon	Kalbari -OW	OW	**78J/11**	100.50	92	CGWB
Bongaigaon	Chalantpara -EW	EW	**78J/12**	100.50	84	CGWB
Bongaigaon	Chalantapara-OW	OW	**78J/12**	100.50	84	CGWB
Bongaigaon	Aolaguri-EW	EW	**78J/12**	94.6	94	CGWB
Bongaigaon	Aolaguri-OW	EW	**78J/11**	90	80	CGWB
Bongaigaon	Srijangram -EW	EW	**78J/11**	32.3	32	CGWB
Bongaigaon	Bagulamari EW	EW		30.6	30	CGWB
Bongaigaon	Pachania	EW	**78J/11**	156.16		State Agency
Bongaigaon	Jogighopa	EW	**78J/11**	165.5		State Agency
Bongaigaon	Boitamari	EW	**78J/11**	125.87		State Agency
Bongaigaon	Abhyapuri	OW	**78J/11**	125.5		State Agency

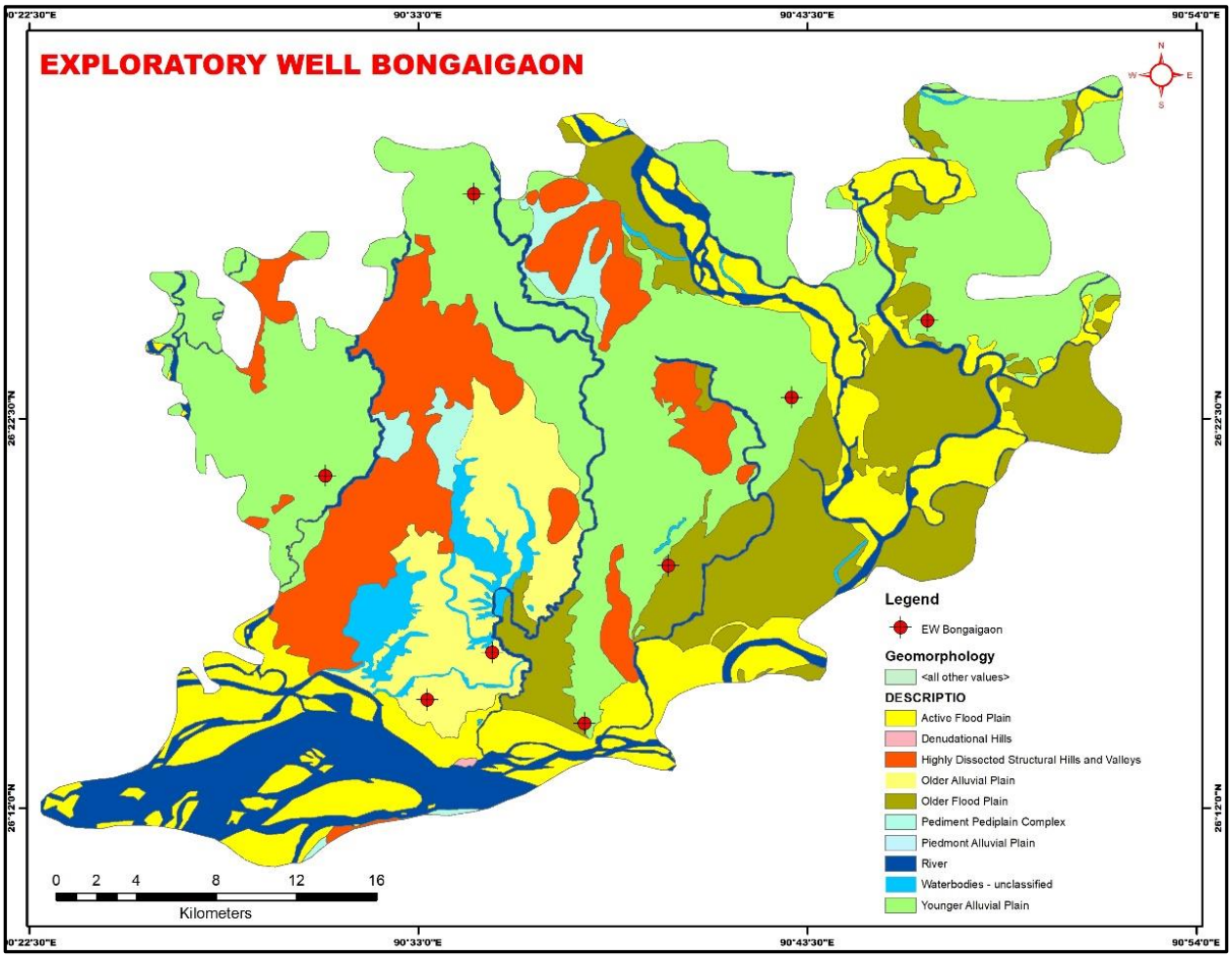


Fig. 2.2: Exploratory wells Bongaigaon district

CHAPTER 3

3. Data Interpretation, Integration and Aquifer Mapping

3.1Data Interpretation

3.1.1Geophysical Exploration and Aquifer Characterization –

Geophysical studies have been conducted in Bongaigaon district. To unearth the subsurface information systematic geophysical studies such as vertical electric sounding (VES), survey is being conducted by CGWB.

3.1.2 Aquifer disposition

Aquifer disposition has been interpreted based on data collected from the tube wells by state agencies and exploratory drilling by central Ground Water Board. It has been observed that the aquifer disposition changes from north to south of the district. In the north eastern and northern fringe of the district exploratory tube wells drilled down to the depth of 100 m shows mono aquifer system. The granular zones comprising of fine to coarse sand associated with gravels occurs at the depth varying from 10 to 100m exploratory tube wells drilled in the younger alluvium at Gerukabari, Aolaguri, Bongaigaon refinery shows the dominance of coarse sand and gravel zones .

Exploratory wells drilled at Abhyapuri, Pachania, Jogighopa,Boitamari reveals that the thickness of first granular zone increases from east to west, i.e., from Boitamari towards Jogighopa and south to north i.e ., from Jogighopa towards Abhyapuri. The second granular zone occurs at depth ranging from 30 to 62 m and comprises medium to coarse sand with occasional gravel. The thickness of aquifer varies from 30 to 85 m with the explored depth of 165 m. The first and second granular zones are separated by a clay bed of 1 to 11 m thickness.

Bed rock topography is highly irregular in Bongaigaon district. The sub-surface geology of inselberg zone was studied with the help of the lithological logs of the exploratory drilled by CGWB at Boitamari, Pachania, Jogighopa and Abhyapuri down to the depth of 142,165,151 and 91 m respectively. The boreholes at Jogighopa and Pachania though ar located in the inselberg, the bedrock was not encountered down to the depth of 165m.

In the northern part of the district along the flood plain zone exploratory wells drilled at Abhyapuri and Bongaigaon refinery township bedrock was encountered at the depth of 140 to 145 m.

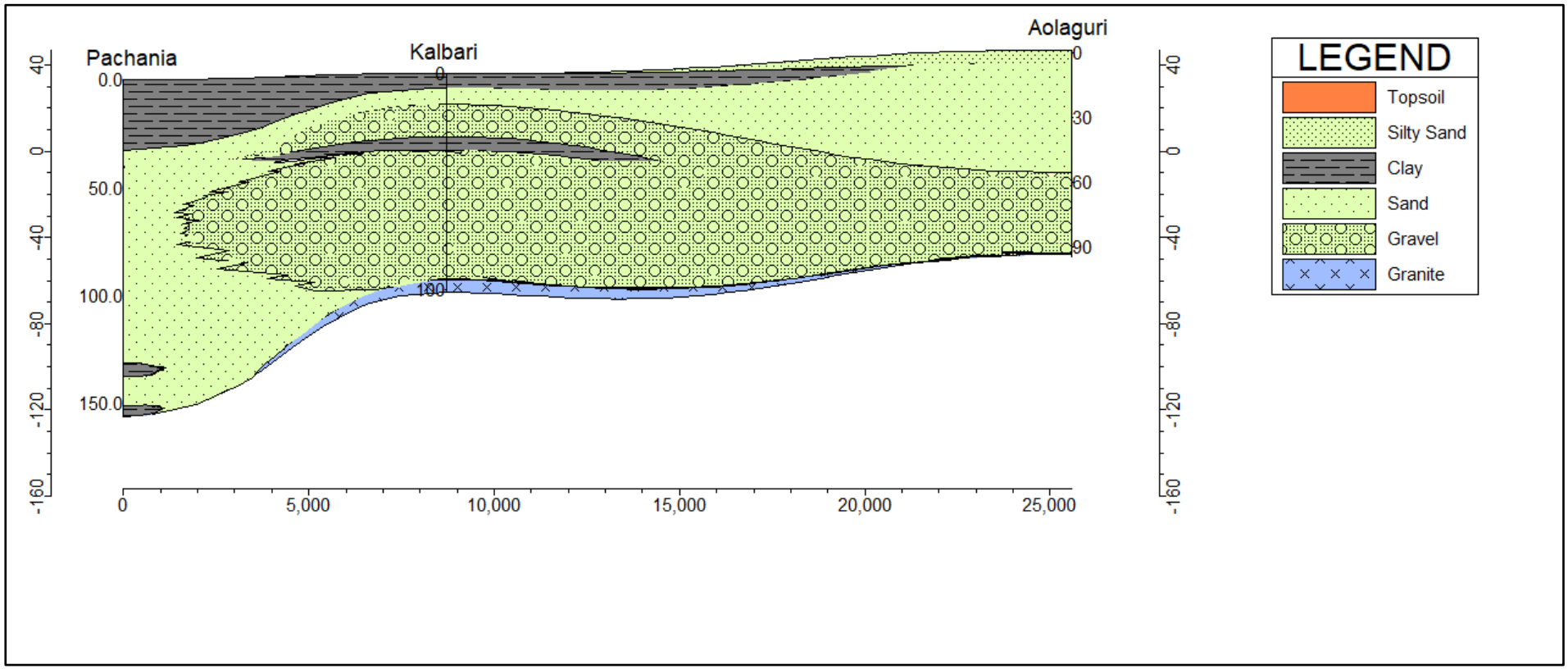


Fig.3.1: Section showing Aquifer disposition along Northeast to Southeast in Bongaigaon district.

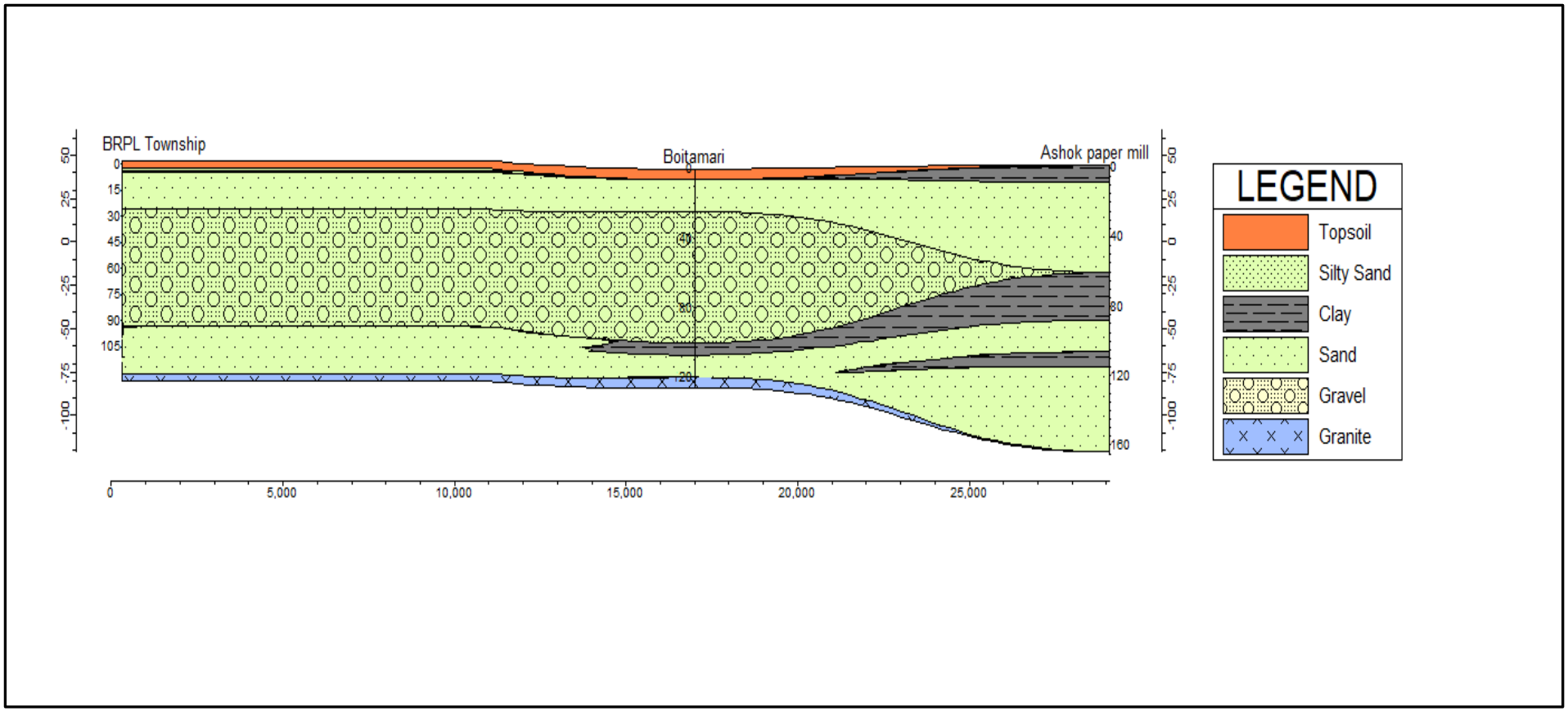


Fig. 3.2: 2D disposition of aquifer along Northwest to Southwest in Bongaigaon district.

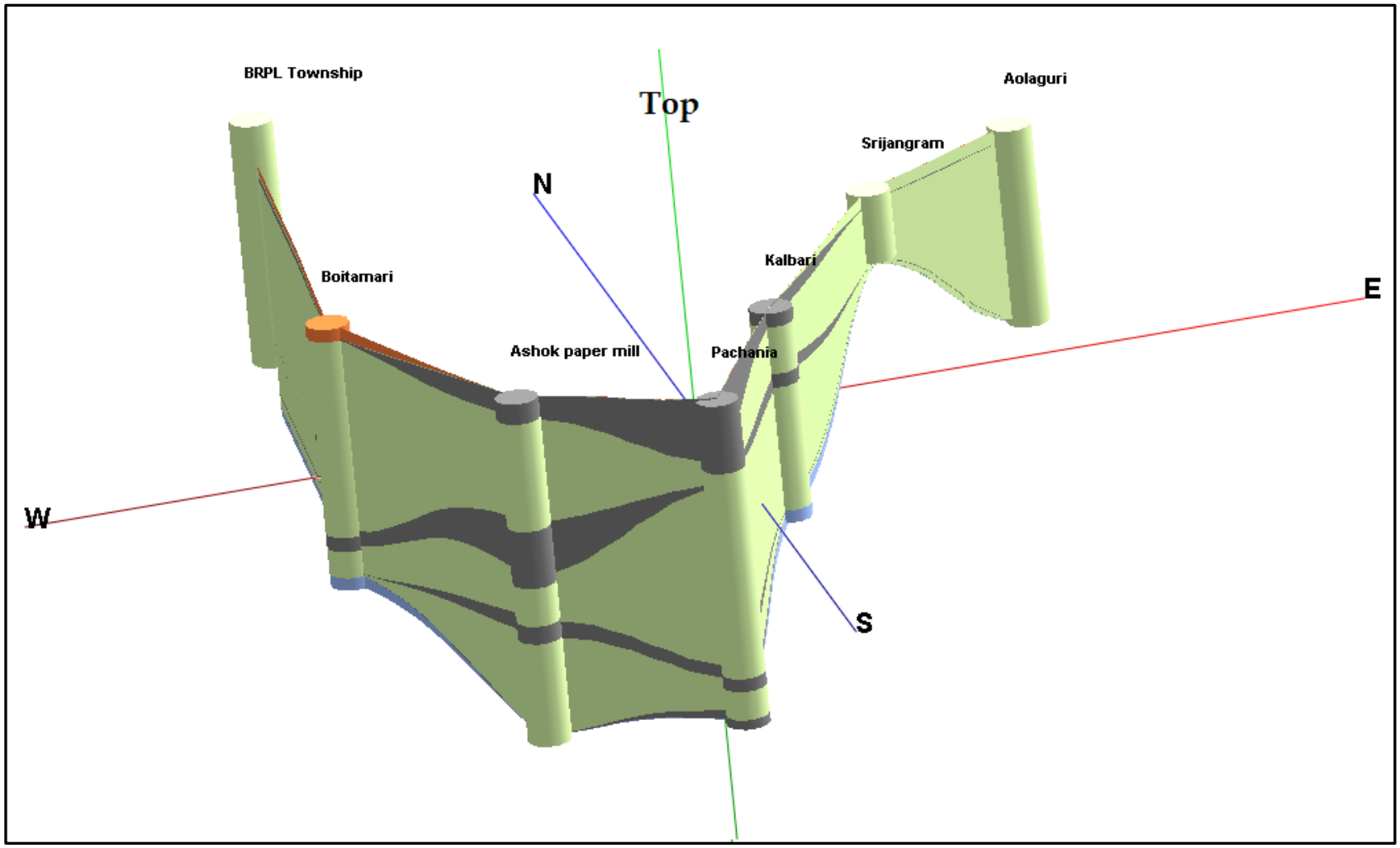


Fig. 3.3: 3D disposition of aquifer in Bongaigaon district.

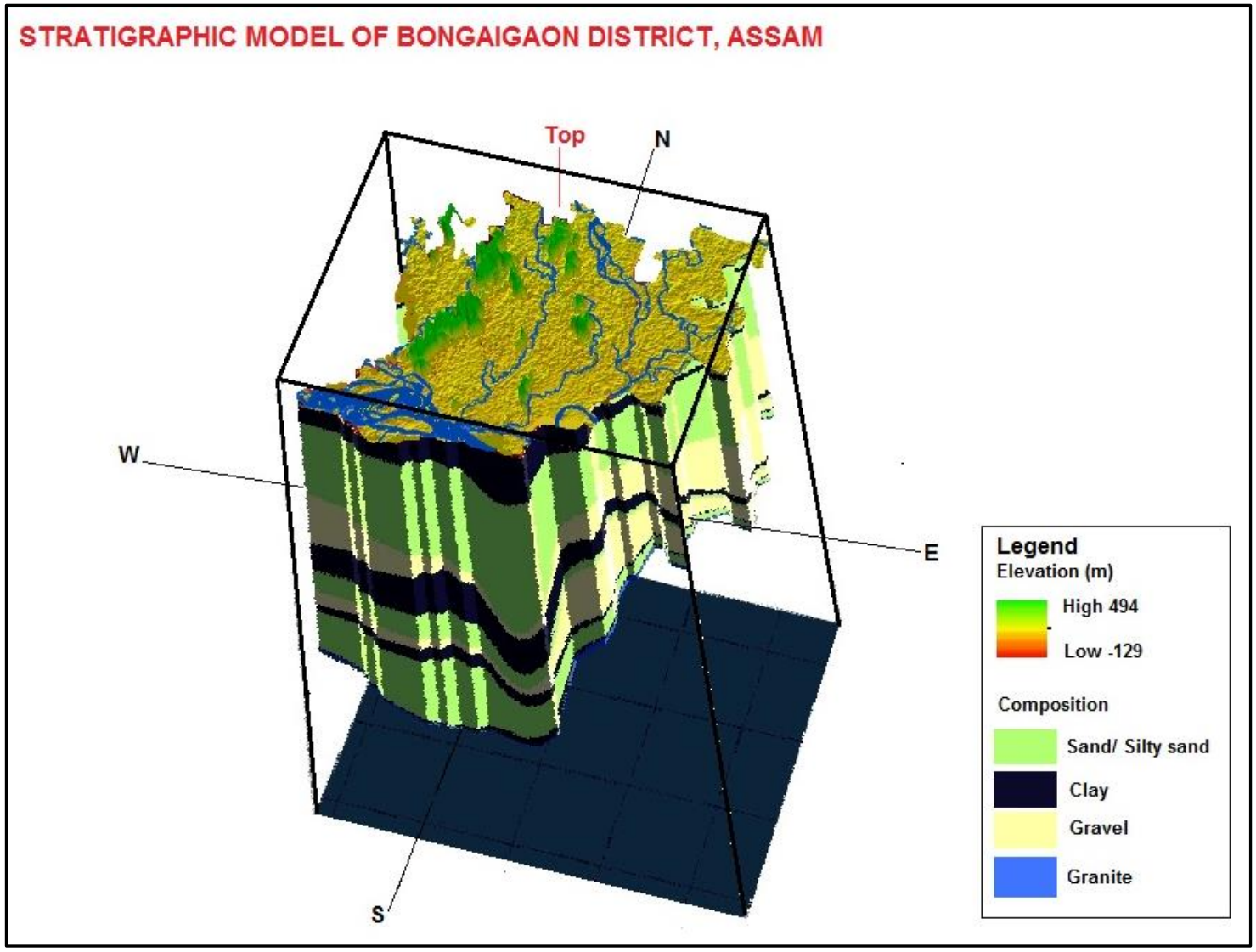


Fig. 3.4: Stratigraphic model of aquifer disposition along Bongaigaon district.

3.1.3 Aquifer Characteristics

Unconsolidated rocks covering the flood plain and younger alluvium in the northern part of the district depicts thick extensive aquifer system , comprising of different grades of sand, gravels ,pebbles and boulders within the depth range of 6m to 100 m. Tubewells tapping the granular zone in the northern part of Aie river basin are high yielding, the yield ranges from 46.54 m^3/hr at Gerukabari to a maximum of 156m^3/hr at BRPL township for a drawdown of 146m to 20.75 m. Transmissivity varies from 2110 m^2/day to 4300 m^2/day .Groundwater occurs under water table or unconfined condition.

Aquifer system in the younger alluvium formation towards southern part of the district at Abhyapuri, Pachania and kalbari are generally two aquifer system separated by thin clay layers. The yield of aquifer ranges from 43.62 m^3/hr at kalbari to 136.38 m^3/hr for a drawdown of 2.50 m to 4 m. The aquifers are in semi confined to confined condition with storativity of 1.09X 10^{-2} at Pachania to 5.4X 10^{-4} at Kalbari. Transmissivity value ranges from 1032 m^2/day to 6779 m^2/day.

Multiple aquifer system has been observed in the older alluvium (Chapar formation) at the fringe area of hard rock at Jogighopa down to depth of 165.23 m. The yield of tubewells constructed at older alluvium ranges from 42.5 m^3/hr at Jogighopa to 43.53 m^3/hr at Chalantapara for a drawdown of 2.72m to 4.90 m. Transmissivity value ranges from 47.5 m2/day to 7417 m^2/day.

Table 3.1: Aquifer characteristics of exploratory wells at Bongaigaon

District	Location	Longitude	Latitude	Depth of Drilled (mbgl)	Depth of con-str. (mbgl)	Zones encoun-tered	Static Water level (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permea-bility (m/day)	Storage co-efficient (S) (lpm/m)
Bongaigaon	Kalbari (Abha-yapuri)-EW	90.662	26.309	100.50	92.00	41-53,59-71,77-89	3.50	43.62	2.50	1036.5		$5.4*10^{-4}$
Bongaigaon	M.G.College (Chalantapara)-EW	90.583	26.270	100.50	84.00	33-48,72-81	7.05	42.5	4.90	47.54		
Bongaigaon	Gerukabari-EW	90.575	26.476	81.25	63.00	33-54	3.03	46.54	1.46	4758	176	
Bongaigaon	Jogighopa	90.554	26.2486	165.23		41.27-53.81,91.26-103.87,117.13-129.72,136.48-146.92	6.02	43.83	2.72	7416		$8.75*10^{-2}$
Bongaigaon	Pachania	90.6249	26.238	156.16		33.52-45.24, 73.20-98.91, 125.61-131.50,143.70-150.10	4.53	90.15	5.65	6779		$1.09*10^{-2}$
Bongaigaon	Abhyapuri	90.664	26.281	145.00		22.38-27.43,39.62-51.81,57.91-73.14	3.34	136.38	4			

Ground water level of Shallow Aquifer zone:

CGWB has established 09 no of groundwater monitoring stations in the district. During AAP 2022-23 as a part of NAQUIM 59 key wells were established to monitor pre and post monsoon ground water level in phreatic aquifer. Water level of NHNS wells are summarized in table 3.2. Details of key wells, pre and post monsoon data along with seasonal fluctuations is attached in Annexure (I)

Table 3.2: Pre & Post Monsoon DTWL and fluctuation data of NHNS monitored wells

NHNS well	Pre monsoon DTWL(mbgl)	Post monsoon DTWL(mbgl)	Fluctuation
Abhyapuri	4.10	3.36	0.74
Boitamari	5.10	2.72	2.38
Bongaigaon New	2.80	2.17	0.63
Chalantapara	9.10	8.50	0.6
Chaprakata	3.12	2.63	0.49
Chaprakata (Dankinamari)	3.05	2.56	0.49
Majgaon	4.12	2.92	1.9
Manikpur	3.16	2.72	0.44
North Salmara	5.00	3.07	1.93

Based on the pre & post monsoon depth to water level data collected from monitoring of the key wells, DTWL maps have been drawn and shown in Fig 3.5 & 3.6

Groundwater condition in the district are described under three distinct hydrogeological units namely (i) consolidated conditions (inselberg zone) (ii) Unconsolidated formations (terraced flood plains) (iii) Unconsolidated formations (older alluvium condition).

Weathered mantle of the crystalline rocks occurring as inselbergs form another hydrogeological unit. In the fringe area of the foot hills, the thickness of the weathered mantle varies from 4 to 10 m. Groundwater occurs under water table condition and move along joints and fractures. The water level in varies from 3mbgl to 5 mbgl in pre-monsoon and in 2mbgl to 4 mbgl in post monsoon with and fluctuation of 1 m.

Groundwater occurs both water table and semi-confined conditions. In the vicinity of rivers, where sand and silt occurs thin veener or pockets above clay beds, perched water table conditions are noticed. In the flood plain area groundwater varies from 2mbgl to 5 mbgl in pre –monsoon and 1mbgl to 4 mbgl in post monsoon with an fluctuation of 0.94 m. In general, depth to water level increases from Aie river levee to central flood plain.

Depth to water table in older alluvial plain (Chapar formation) generally varies from 5.5 mbgl to 10.1 mbgl in pre –monsoon. The older formation consists of admixtures of sand of all grades and gravel intervened by lenticular clay and sandy clay. These formations are capped by poorly permeable lateritic clay. Generally deeper water level has been noticed in older alluvial plain namely in Chalantapara, Kheragaon, Uparkarya.. The annual fluctuation is > 1 m.

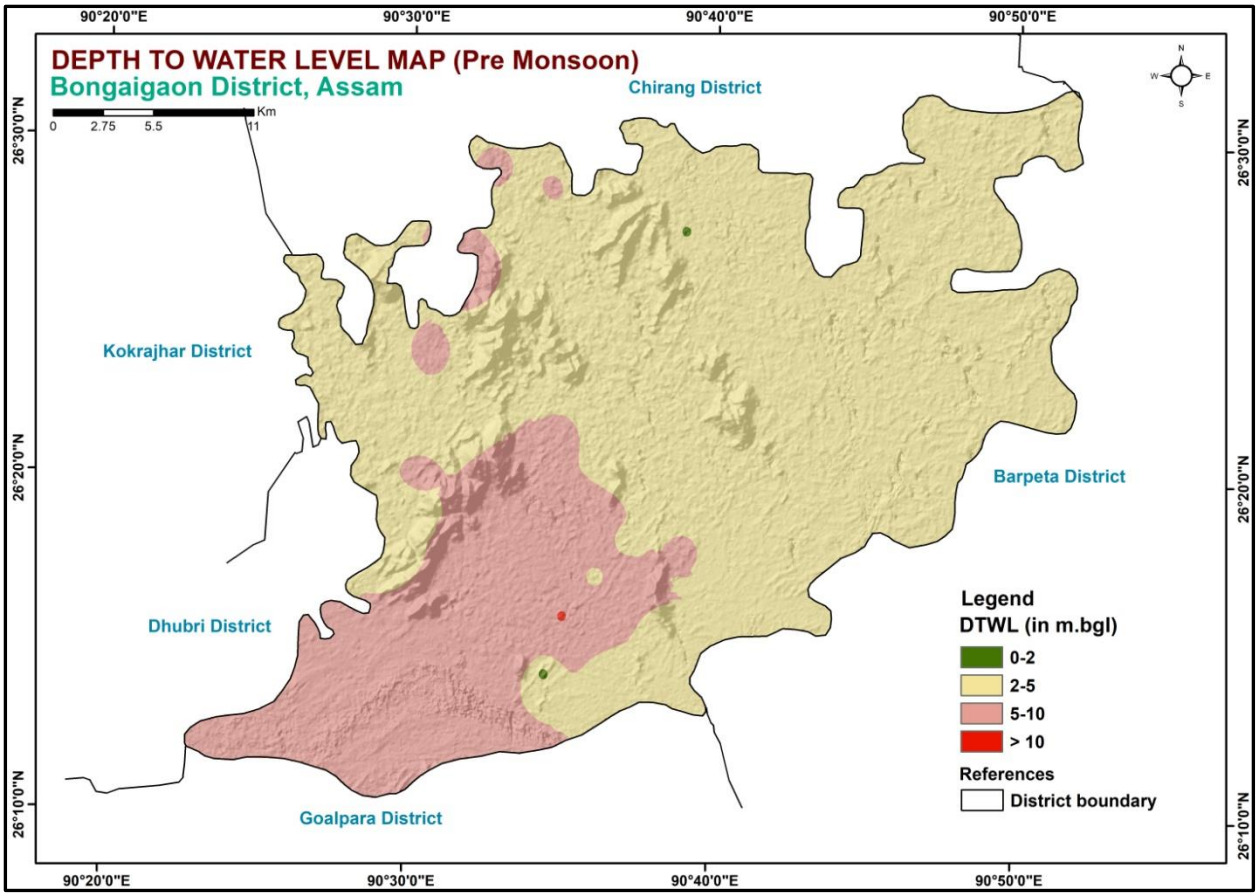


Fig. 3.5: - Pre monsoon DTWL map of Bongaigaon district.

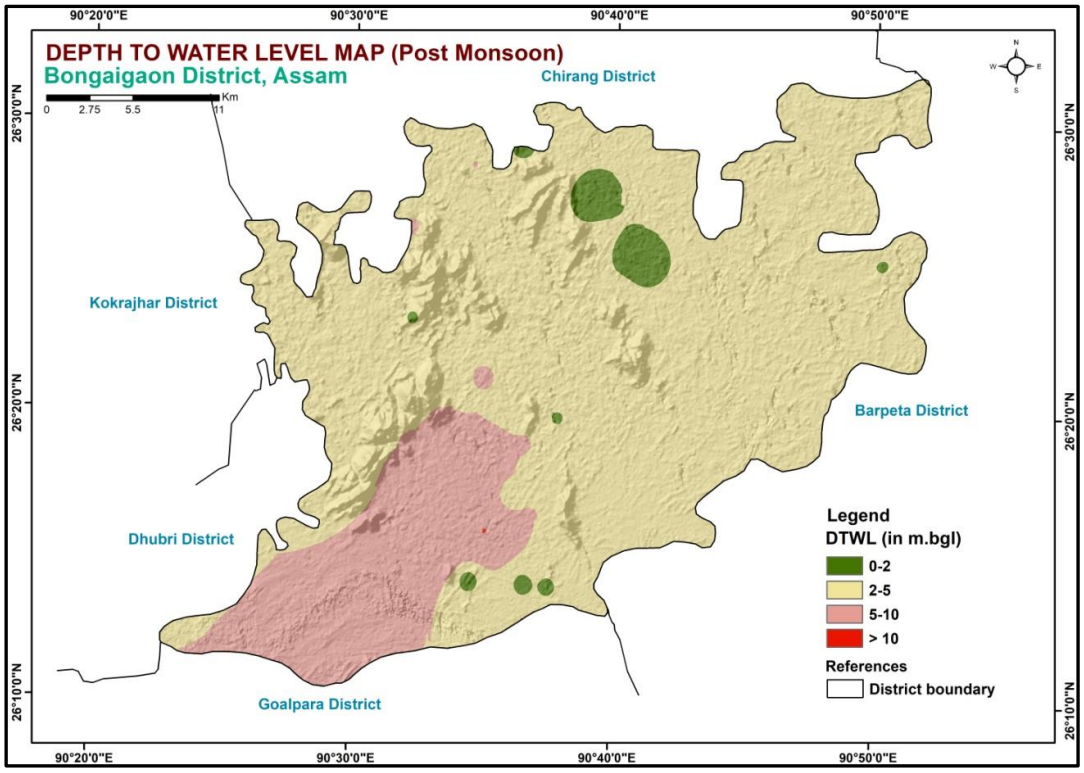


Fig. 3.6: Post monsoon DTWL map of Bongaigaon district

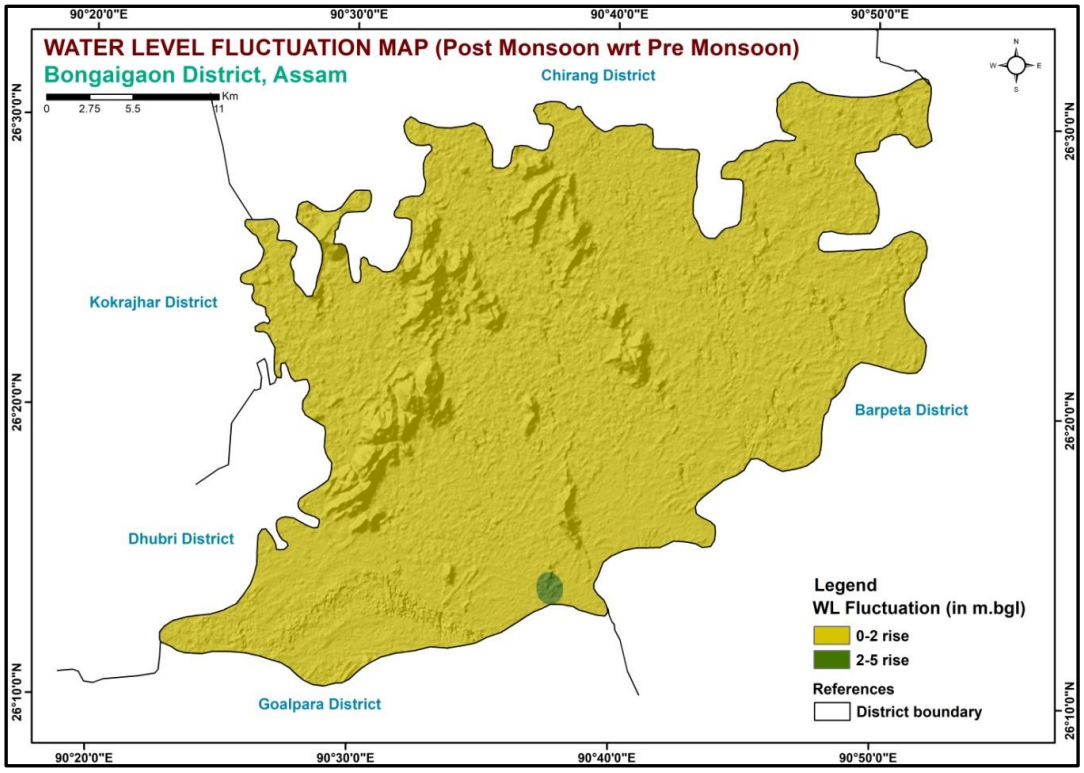


Fig 3.7: Water level fluctuation map of Bongaigaon district

Ground Water Movement

The water table contour has been prepared based on the water level of ground water monitoring stations with respect to its elevation above mean sea level. Regional ground water flow conforms to the general elevation of the district gently sloping towards the south. The general direction of groundwater flow is from higher elevation in the north to lower elevation in the south with local variation due to presence of denudational hills. In the western part of the district flow is towards the west, hydraulic gradients also varies due to difference of elevation in the fringe areas of the denudational hills and it is generally estimated to be 0.90 m/Km for plain areas and 1.40 m/Km in the northern parts.

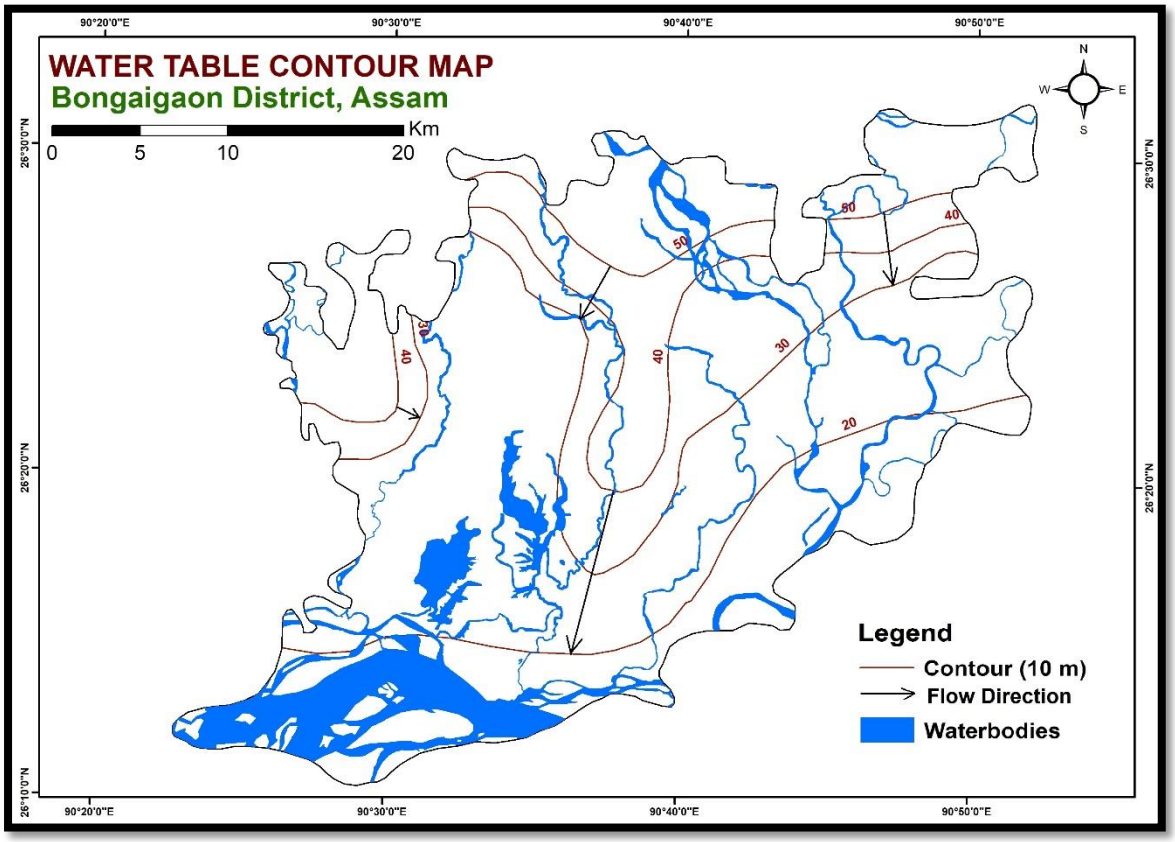


Fig. 3.8: Water table contour map of Bongaigaon district

3.5 Ground water quality

Ground water samples were collected during pre and post monsoon field season .A total of 27 samples were collected during post monsoon period and 25 samples were collected during pre-monsoon period. Chemical analysis of ground water samples is carried out by regional chemical laboratory of Central Ground Water Board, North Eastern Region, Guwahati. Samples were analyzed for the parameters like pH, EC, Turbidity, TDS, CO3, Cl, SO4, Na, K, HCO3, NO3, F, Ca, Mg, As and Fe. Chemical analysis of groundwater samples for pre and post monsoon are summarized in Annexure III and IV.

pH:

pH is an important parameter in evaluating the acid–base balance of water. It is also the indicator of acidic or alkaline condition of water status. WHO has recommended maximum permissible limit of pH from 6.5 to 8.5. Values of pH range of water samples collected range from 7.03-8.47(pre-monsoon) and 6.1 -8.35 (post-monsoon) .The over-all value indicate that water from study area is within the suitable and desired range.

Electrical Conductivity (EC):

Generally, the amount of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) actually measures the ionic process of a solution that enables it to transmit current. According to WHO standards, EC value should not exceeded 400 µS/cm. The current investigation indicated that EC value range from 15-731.2 µS/cm with an average value of 239 µS/cm. 90% of samples falls within the permissible limit. These results clearly indicate that in the study area indicate few samples were considerably ionized and higher ionic concentration activity.

Total Dissolved Solids(TDS):

According to BIS specification TDS up to 500 mg/l is the highest desirable and up to 2000 mg/l is maximum permissible. In the study area the TDS value varies between a minimum of 10.22 mg/l and a maximum of 486 mg/l, indicating that most of the groundwater samples lies within the maximum required acceptance limit.

Calcium and magnesium (Ca and Mg):

Calcium and magnesium are the most abundant elements in the natural surface and groundwater and exist mainly as bicarbonates and to a lesser degree in the form of sulfate and chloride. Ca^{2+} concentrations are varying from 4 to 138 mg/l . The desirable limit of calcium concentration for drinking water is specified as 75 mg/l (BIS, 2012) . A few water samples collected during post-monsoon shows calcium value above desirable limit..

Magnesium content is varying from 2.42 to 72.80 mg/l. The maximum permissible limit of Mg^{2+} concentration of drinking water is specified as 100 mg/l (BIS.2012) .All the samples are within the maximum permissible limit.

3.5.1 : Hydrogeochemical facies

Piper diagram was created for ground water samples analysed during pre and post –monsoon period. Based on plotting of data on piper plot it has been observed that during pre-monsoon period there are four water types (fig 21). Majority of the samples (72%) are plotted in Ca-HCO3 type . 14% in Ca-Mg-Cl type field and rest in Ca-Na-HCO3 type field. Alkaline earth and weak acid (CaMgHCO3) type are the domimant facies.

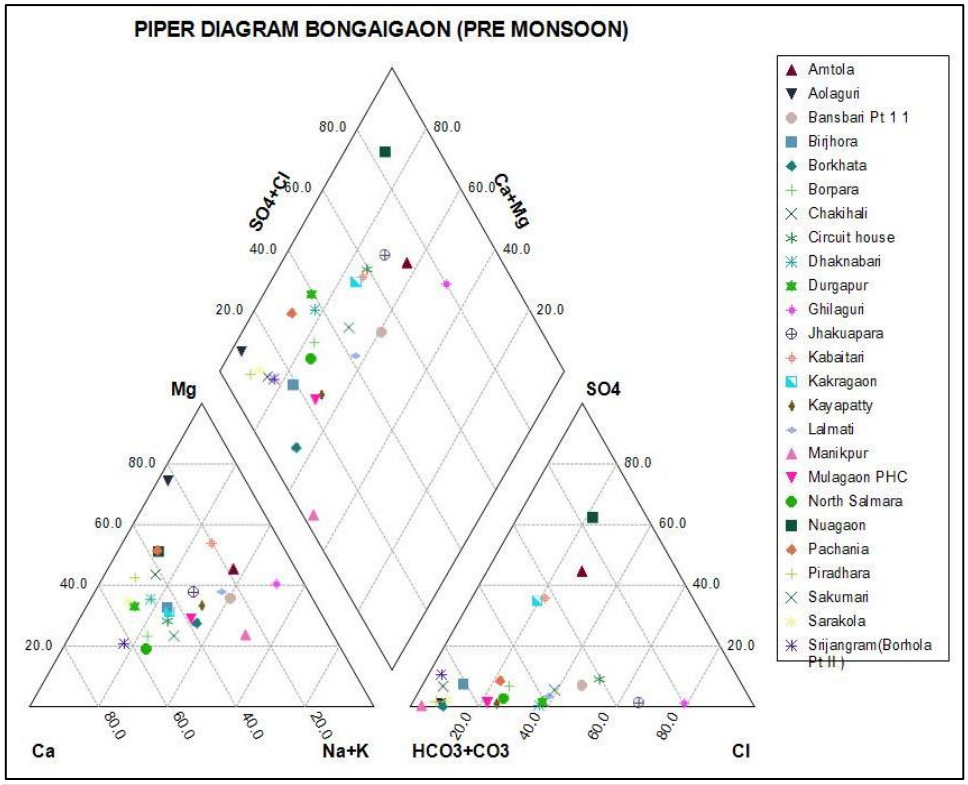


Fig. 3.9: Piper plot of pre-monsoon groundwater samples.

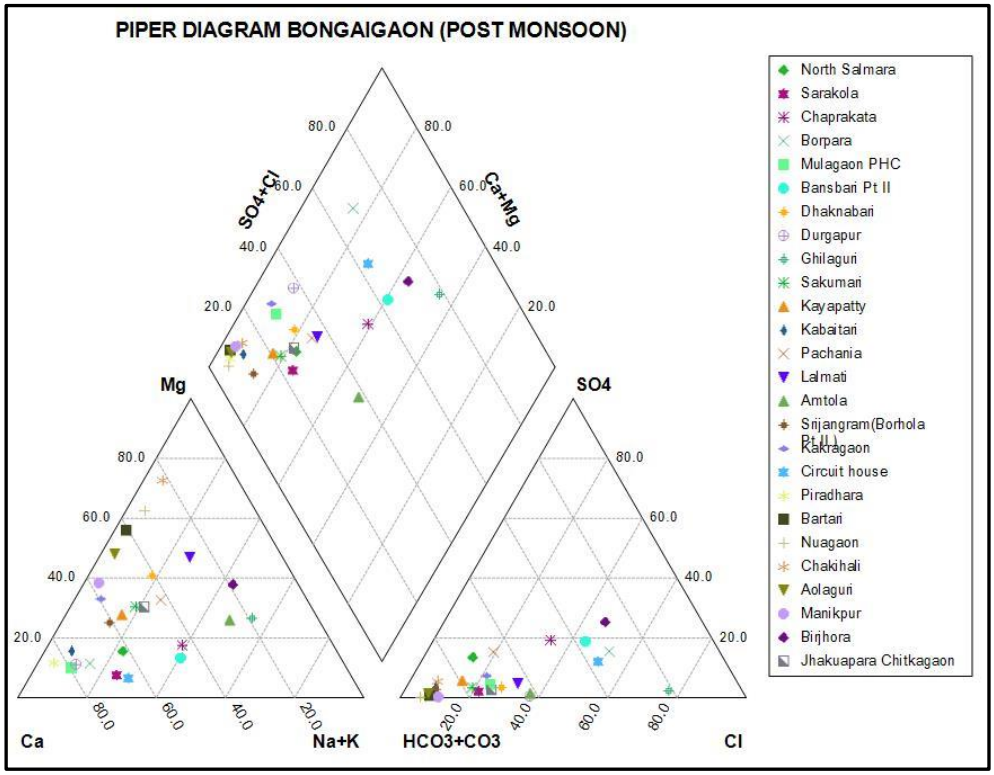


Fig. 3.10: Piper plot of post-monsoon groundwater samples

In post monsoon sample majority of the sample belongs to Ca^{2+} - Mg^{2+}-HCO^{3-} type facies(fig:22). About 52% of sample falls in no dominant type in cation field and almost 92% of sample falls in bicarbonate type in anion triangle.

3.5.2 Irrigation water suitability Indices:

Sodium Percent (Na%)

The sodium in irrigation waters is usually denoted as percent of sodium. Na% is a common parameter to assess its suitability for irrigational purposes. The sodium percent (Na%) values was obtained by using the following equation:

Na%=Na+×100/[Ca2++Mg2++Na++K+]Na%=Na+×100/[Ca2++Mg2++Na++K+]

where all ionic concentrations are expressed in meq/l. Based on analysis of percent and total concentration shows that 83 % of the groundwater samples fall in the field of good category and 17% of groundwater samples falls in permissible for irrigation category.

Sodium Adsorption Ratio:

Sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation, because sodium concentration can reduce the soil permeability and soil structure (Todd 1980). SAR is a measure of alkali/sodium hazard to crops and it was estimated by the following formula:

$$SAR=Na/\ [(Ca+Mg)/2]^{0.5}$$

The calculated values of SAR in the study area vary between 0.08 and 2.83. The SAR values of all the samples are found within the range of excellent. The water is suitable for irrigation.

USSL Diagram

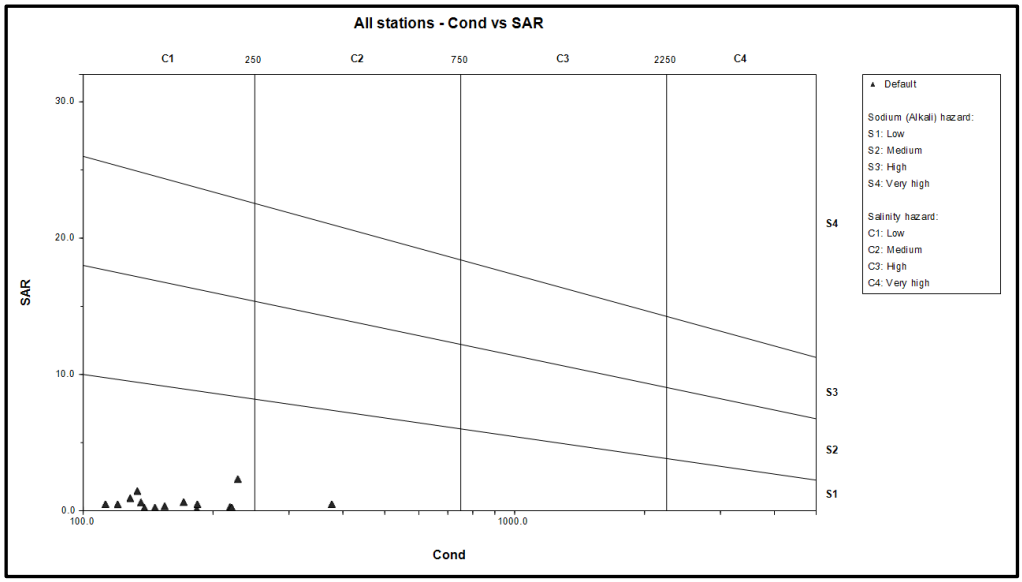


Fig. 3.11: USSL salinity plot of pre-monsoon groundwater samples

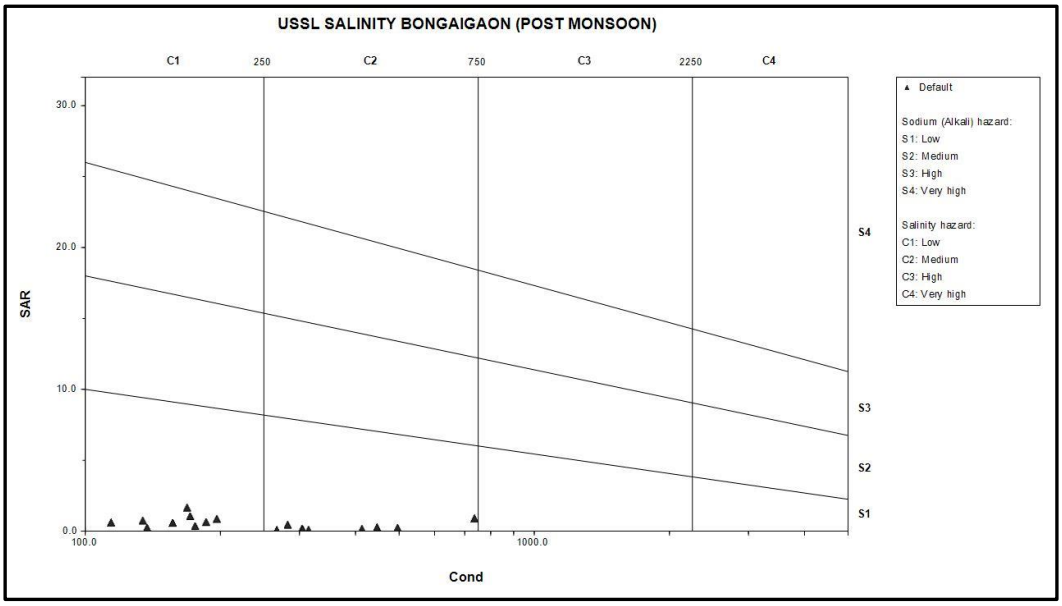
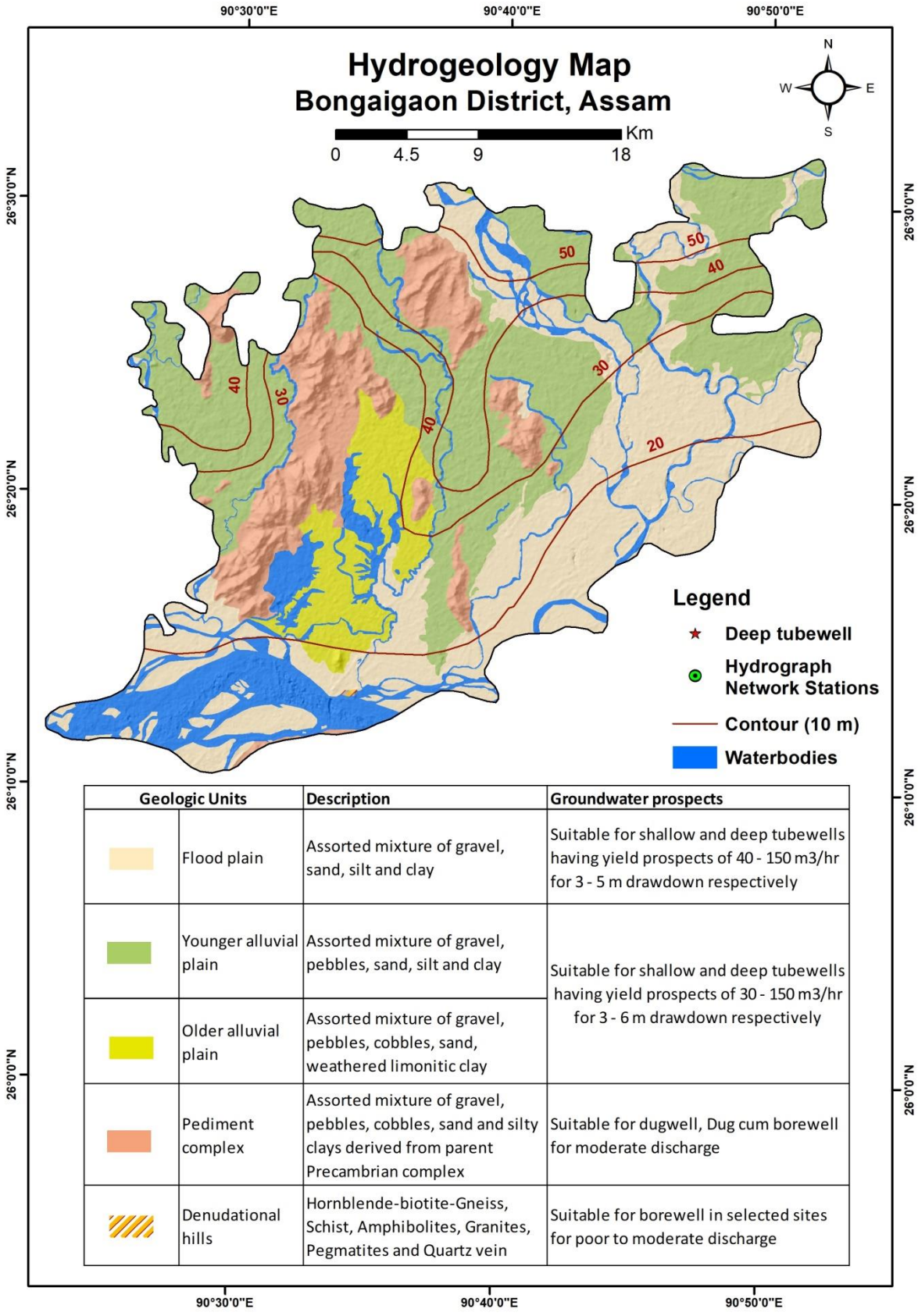


Fig. 3.12: USSL salinity plot of post-monsoon groundwater samples

The US Salinity Laboratory diagram (USSL) can be used to evaluate the suitability of irrigation water based on alkalinity and salinity. The vertical ordinates are SAR and %Na respectively, and the horizontal ordinates of them are both electric conductivity (EC). In pre-monsoon groundwater samples 23 samples falls under C1S1 and one in C2S1. The groundwater samples are suitable for irrigation purpose. Salinity and soudim percentage is low in the water samples.

In post-monsoon groundwater samples 18 samples falls in C1S1 and 8 samples falls in C2S1 i.e of low SAR and medium salinity.



Geologic Units		Description	Groundwater prospects
	Flood plain	Assorted mixture of gravel, sand, silt and clay	Suitable for shallow and deep tubewells having yield prospects of 40 - 150 m3/hr for 3 - 5 m drawdown respectively
	Younger alluvial plain	Assorted mixture of gravel, pebbles, sand, silt and clay	Suitable for shallow and deep tubewells having yield prospects of 30 - 150 m3/hr for 3 - 6 m drawdown respectively
	Older alluvial plain	Assorted mixture of gravel, pebbles, cobbles, sand, weathered limonitic clay	
	Pediment complex	Assorted mixture of gravel, pebbles, cobbles, sand and silty clays derived from parent Precambrian complex	Suitable for dugwell, Dug cum borewell for moderate discharge
	Denudational hills	Hornblende-biotite-Gneiss, Schist, Amphibolites, Granites, Pegmatites and Quartz vein	Suitable for borewell in selected sites for poor to moderate discharge

Fig. 3.13: Hydrogeological map of Bongaigaon district

CHAPTER 4.0

Ground water Resources

The rechargeable area of the district is found to be 99730 ha. As block boundary is not available, it was not possible to carry out block wise resource calculation. Here district wise resource calculation is presented.

The computation of ground water resources available in the district has been done using GEC 2015 methodology.

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

1) Rainfall recharge has been computed by both RIF and WLF methods. Rainfall infiltration factor of 22% for valley fill as per norms is taken for calculation. In WLF method, specific yield has been taken as 0.16 for valley fill deposit following the norms recommended by GEC'2015. The rainfall of Bongaigaon district is 1672 mm.
2) Water level data has been considered for 2021-22. Water level fluctuation based on data of March (Pre monsoon) and November (post monsoon) have been considered. The average pre- and post-monsoon water level of Bongaigaon district is 4.36 mbgl and 3.19 mbgl.
3) The population figures were collected from Census, 2011 and projected to 2022. The per capita domestic requirement is considered as 60 lpcd.
4) Recharge from other sources includes recharge from minor surface and ground water irrigation.

Recharge: The aquifers of the study area are recharged by rainfall. The area experiences south-east monsoon. Monsoon rainfall contributes approximately 70 percent of total rainfall (June, July, August, September) while share of post and pre monsoon rainfall are approximately 30 percent each.

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

The monsoon recharge of the 99370 ha of recharge worthy area is 33285.82 ham while non-monsoon recharge is 12847.54 ham. Recharge from other sources is 4804.64 ham. Total ground water recharge is 50938 ham.

Extraction: The agriculture in the area generally rainfed. 20% of cropped area has irrigation facilities and groundwater irrigation is nearly 50% of total irrigation. Total groundwater extraction for irrigation purpose is 10155 ham. Total industrial extraction is 1.53 ham and total domestic extraction is 1634.40 ham. Total groundwater extraction of Bongaigaon district is 11909.56 ham.

Allocation of resources up to 2025: The net ground water resource is allocated for domestic use 1780.70 ham. Net available resource for future use is 33840.38 ham.

Stage of groundwater development: Groundwater is mainly utilized for domestic purposes. The stage of groundwater extraction in the district is 25.76%.

Table 4.1: shows the net groundwater availability, existing draft and stage of development for the year 2022.

Recharge worthy area Ha	Total annual GW recharge Ham	Environmental flow Ham	Annual extractable GW resource Ham (2-3)	Existing gross GW extraction for all uses Ham	Stage of GW extraction [(5/4)*100%]
1	2	3	4	5	6
99730	51598	5159.80	45778.20	11791.52	25.74

Extraction from unconfined aquifer/deeper aquifer: Groundwater in the district is utilized for (a) irrigation, (b) drinking or domestic purposes and (c) industrial purpose.

Potential resource:

(i) Shallow water table areas: Potential resource due to shallow water table areas was estimated from aquifer area where depth-to-water level was within 5mbgl. The area within depth-to-water level of 5mbgl is 59967.66 Ha which is 60 % of total area of the district. The potential resource of shallow water table areas is 7234.83 ham.

(ii) Flood prone area: As per GWRE 2020, the flood prone area of the district is 41605 ha and it is considered that flood water remained in the area for at least 30 days. Potential resource in flood prone area is 1797.34 ham.

(iii) Total potential resource of Bongaigaon district is 9032.17 ham.

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

The Pre-monsoon (month of March) Water Level from Monitoring Wells of CGWB in Bongaigaon district has been considered as the maximum depth below ground level up to which the zone of water level fluctuation occurs. Since the north eastern states receives pre-monsoon showers, which commences from the first week of April, resulting in rise in water levels in the phreatic zones, the deepest water levels are recorded during the month of March. Specific yield value of 0.12 is considered for the district.

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

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

Where, Y = Static ground water resources,

A = Area of ground water assessment unit

Z_1 = Thickness of saturated unconfined aquifer below ground level

Z_2 = Pre-monsoon water level

Sy = Specific yield of the unconfined aquifer

Table 3.2: Salient information of static resource of Bongaigaon district, Assam

Type of rock formation	Alluvium
Total Geographical Area (Ha)	109300
Assessment Area (Ha)	99730
Bottom of the unconfined aquifer (m)	50
Average Pre- monsoon Water Level (m)	4.36
Thickness of the saturated zone of the un-confined aquifer below WLF zone (m) [(5)-(6)]	45.64
Volume of Saturated zone of the unconfined aquifer below WLF zone (ham)	4551677.2

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

= 4551677.2 X 0.12= 546201.26 ham

5. Ground Water Related Issues

The main groundwater issues in the study area include areas vulnerable to water logging as well as prone to water logging conditions along with high Iron concentration in ground water above the WHO permissible limit.

5.1 Low stage of ground water development:

As per ground water resource estimation 2021, the stage of ground water extraction is just 25.76 % .Due to lack of irrigation vast tract of agriculture land remain fallow. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice. Irrigation scheme has been developed under PMKSY-HKKP scheme.

5.2 High Iron Concentration:

Quality analysis of groundwater samples collected from dug wells and tubewells during pre and post monsoon shows presence of high iron(Fe) concentration above permissible limit (>0.3mg/l) (fig 25) as per BIS IS 10500:2012 drinking water standard.

5.3 Water logging:

Water logged area is mainly observed in the flood plain zone of Brahmaputr, Manas and Aie river mostly in the northeastern, eastern and south eastern part . Depth to ground water level in these areas is below 2 mbgl. High rainfall and and inundation by flood along with low stage of ground water development also results in water logging in the area. Such area has pre monsoon depth to water level of 2-3m.

CHAPTER 6.0

Management Strategy

6.1: Management strategies for agriculture

The groundwater regime of Bongaigaon district is influenced by lithological variation and geomorphologic set up. The district can be divided into two slope classes, viz., slope >20% and slope <=20%. Areas with slope more than 20% are found in northern and western extremities of the central part of the district. Geomorphologically, these areas include structural hills in southern-central, western-central and central part in pockets. Areas with slope less or equal to 20% slope include alluvial plain and flood plain. Water logged areas are found in alluvial plain.

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

- Stage of groundwater development in the district is 25.76 % leaving vast scope for groundwater development.
- Irrigated area is still 20 % only and requires boasting for agricultural purpose.

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

Table 6.1: Cropping pattern of un-irrigated areas of Bongaigaon district

SN	Crop	Planting date	Area (%)	Actual area (ha)
1	Winter Rice	10-May	10	1976
2	Winter Rice	25-May	20	3951
3	Winter Rice	10-Jun	25	4939
4	Winter Rice	20-Jun	25	4939
5	Winter Rice	10-Jul	10	1976
6	Winter Rice	15-Aug	10	1976
7	Maize	20-Feb	10	1975.6
8	Pulse	20-Nov	10	1975.6
9	Pulse	10-Dec	10	1975.6
10	Oil seed	15-Oct	10	1975.6
11	Oil seed	10-Nov	10	1975.6
12	Winter Vegetables	10-Oct	5	987.8

13	Winter Vegetables	10-Nov	5	987.8
14	Winter Vegetables	30-Nov	5	987.8
15	Summer Vegetables	10-Mar	5	987.8
16	Summer Vegetables	20-Mar	5	987.8
17	Summer Vegetables	30-Mar	5	987.8
18	Potato	10-Nov	10	1975.6
19	Wheat	15-Nov	10	1975.6

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

As per information, Net sown area of the district is 94908 ha and out of which 14389 ha only is under irrigation (District Irrigation Plan 2016-20). It is observed that un-irrigated area associated with kharif paddy (winter rice) is 19756 ha which is sown during summer time from May-July. For further utilization of groundwater seeing the vast scope for ground water development in the area, other crops like maize, pulses, rapeseed, potato, winter vegetables will be used in the 100% of the area of kharif paddy with in area of 19756 ha.

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

Table 3.2: Water requirement for un-irrigated areas of Bongaigaon district

Cropping pattern (s)				
Early Summer Rice-Late Winter Rice	Present Cultivated area	Area to be cultivated	Area to be cultivated (**ha**)	Irrigation requirement (**ham**)
Summer vegetables- Late Winter Rice	(**ha**)	(**%**)		
Pulses-Late Winter Rice-Potato/Vegetables/Wheat				
Net cultivated area	**19756**			
	1	2 (= % of 1)	3	4
Rice (main crop)	19756		19756	
Winter Rice (main crop)	19756	100	19756	2861
Potato		10	1976	476
Pulses		20	3951	743
Mustard		20	3951	1106
Winter vegetables		15	2963	477
Summer vegetables		15	2963	115
Wheat		10	1976	558
Maize		10	1976	134

Gross cultivated area (Paddy/+Maize/+Wheat+Pulses+Vegetables)			**39512**	6470
Total irrigation requirement (70% irrigation efficiency)				**9243**
Cropping intensity			**200% (Intended)**	

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

Table 6.3: Precipitation deficiency

Sr. no.	**Precipitation deficit**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	Rice	0	0	0	57.9	98	0	0	0	0	0	0	0
2	Rice	0	0	0	0	197.2	0	0	0	3.1	0	0	0
3	Rice	0	0	0	0	49.6	98	0	0	0	0	0	0
4	Rice	0	0	0	0	48.4	97.5	0	0	0	0	0	0
5	Rice	0	0	0	0	0	48.9	98	0	0	2.5	8.7	0
6	Rice	0	0	0	0	0	0	49	98	0	5.7	65.2	23.1
7	Maize (Grain)	0	2.9	17	47.8	0	0	0	0	0	0	0	0
8	Pulses	61.1	70.1	7.1	0	0	0	0	0	0	0	9.4	34.7
9	Pulses	44.3	78.1	54.7	0	0	0	0	0	0	0	0	16.7
10	Mustard	46.9	59.4	68.5	22.6	0	0	0	0	0	0	40.4	53
11	Mustard	46.9	59.4	68.5	22.6	0	3.1	0	0	0	0	21.1	47.2
12	Small Vegetables	20	0	0	0	0	0	0	0	0	2.3	51.6	62.1
13	Small Vegetables	56.2	26.9	0	0	0	0	0	0	0	0	34.2	53.2
14	Small Vegetables	53.1	69.2	8.7	0	0	0	0	0	0	0	1.7	43.6
15	Small Vegetables	0	0	33	23.7	0	6.9	0	0	0	0	0	0
16	Small Vegetables	0	0	16.8	9.8	0	6.9	0	0	0	0	0	0
17	Small Vegetables	0	0	6.3	5.7	0	0	7	0	0	0	0	0
18	Potato	61.6	74.3	36.9	0	0	0	0	0	0	0	23.8	44.4
19	Winter Wheat f.f.	40.9	57.7	74.4	39.2	0	0	2	0	0	0	25.7	42.7

Table 6.4: Actual monthly water requirement for different crops in Unirrigated Areas of Bongaigaon district, Assam

Actual monthly water requirement for different crops in Flood Prone Areas of Bongaigaon district, Assam															
Crop	**Net sown area**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Cropwise Total IWR (Ham)**	Total crop-wise IWR (Ham)
Winter Rice	1975.6	0	0	0	114.39	193.61	0	0	0	0	0	0	0	307.99	2861.36
Winter Rice	3951.2	0	0	0	0	779.18	0	0	0	12.25	0	0	0	791.43	
Winter Rice	4939	0	0	0	0	244.97	484.02	0	0	0	0	0	0	728.99	
Winter Rice	4939	0	0	0	0	239.05	481.55	0	0	0	0	0	0	720.60	
Winter Rice	1975.6	0	0	0	0	0	96.60	193.61	0	0	4.939	17.19	0	312.34	
Winter Rice	1975.6	0	0	0	0	0	0	96.80	193.61	0	11.26	128.81	45.63	476.11	
Maize	1975.6	0	5.73	33.59	94.43	0	0	0	0	0	0	0	0	133.75	133.75
Pulse	1975.6	120.71	138.49	14.027	0	0	0	0	0	0	0	18.57	68.55	360.35	743.22
Pulse	1975.6	87.52	154.29	108.07	0	0	0	0	0	0	0	0	32.99	382.87	
Oil seed	1975.6	92.66	117.35	135.32	44.65	0	0	0	0	0	0	79.81	104.71	574.50	1105.54
Oil seed	1975.6	92.66	117.35	135.32	44.65	0	6.12	0	0	0	0	41.69	93.24	531.04	
Winter Vege-tables	987.8	19.76	0	0	0	0	0	0	0	0	2.27	50.97	61.34	134.34	476.91
Winter Vege-tables	987.8	55.51	26.57	0	0	0	0	0	0	0	0	33.78	52.55	168.42	
Winter Veg-etables	987.8	52.45	68.36	8.59386	0	0	0	0	0	0	0	1.67926	43.07	174.15	
Summer Vegetables	987.8	0	0	32.5974	23.4108	0	6.81582	0	0	0	0	0	0	62.82408	114.68
Summer Vegetables	987.8	0	0	16.59504	9.68044	0	6.81582	0	0	0	0	0	0	33.0913	
Summer Vegetables	987.8	0	0	6.22314	5.63	0	0	6.91	0	0	0	0	0	18.77	
Potato	1975.6	121.7	146.79	72.89	0	0	0	0	0	0	0	47.02	87.72	476.12	476.12
Wheat	1975.6	80.80	113.991	146.98	77.44	0	3.95	0	0	0	0	50.77	84.36	558.30	558.30
Month wise IWR (Ham)	39512	723.76	888.92	710.22	414.2	1456.80	1085.88	297.32	193.61	12.25	18.47	470.29	674.17	6946.01	6469.89

Total unirrigated area of the district is 31032 ha and out of which 19756 ha is kharif paddy. Total water requirement to bring the un-irrigated area of the district and water availability for future use are summarized in Table: 6.5

Table 6.4: Summarised results of water requirement to bring the un-irrigated area of Bongaigaon district, Assam

Area	Net Cultivated area (Ha)	Irrigation water requirement (Ham)	Water allocated for future use (Ham)
Kharif paddy	19756	9243	33840

Discharge of the tube wells constructed by CGWB tapping 20 to 40m depth of the older alluvial aquifer varies from 30 to 35 m^3/hr. If the well is allowed to run 8 hrs a day for 120 days then a tube well having discharge of 30 m^3/hr will extract 2.88 ham groundwater annually.

Total numbers of shallow tube wells require to construct in the district to fulfil the irrigation requirement of 9243 ham, is found to be 2247 nos. On the other hand consideration of safe distance of 200 m permits to construct 4949 nos.

Extraction of 9243 ham of groundwater will increase the stage of groundwater extraction to 46 %. Potential resource of the district is 9032.17 ham.

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

6.2 Demand side management

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

Water use efficiency should be high in all sectors particularly in the irrigation sector. Loss in irrigation water will increase water logged area.

Irrigation efficiency can be increased by

- reducing convenience loss
- improving water application efficiency

Following demand side interventions will increase water use efficiency

- Use of water efficient irrigation method: Drip and sprinkler irrigation methods are very useful in saving water. Both of them save conveyance losses and improve water application efficiency by applying water near the root-zone of the plant. Drip irrigation can increase crop yield per hectare and also saves water up to 70% than conventional irrigation.
- Water loss through supply canals can be minimized by proper lining in the canals.

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

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

Following recommendations are suggested:

- Water distribution mechanism should minimize water loss by using lining distribution canals. Locally available materials are to be preferred as these materials are cheap and eco-friendly.
- Conservation of rain water in the up dip of cultivated field. During rabi season the conserved water can be drained to paddy field through gravity.
- In some pockets iron content is very high. The sources of iron pollution in deeper aquifer can be attributed to geogenic origin. It needs removal before human consumption.
- Rain water harvesting in the technique collection and storage of rainwater at surface or in sub-surface aquifer, before it is lost as surface runoff further aggravating water logging condition. Therefore, existing and abandoned dug wells may be utilized as recharge structure after cleaning and desilting the same.

ANNEXURE I

Details of wells established for ground water monitoring under NAQUIM, Bongaigaon district

Location	Longitude	Latitude	M.P	Depth (mbmp)	Dia(m)	Type of well	Formation	W.L(mbgl) (Nov)	W.L(mbgl) (Feb)	Fluctuation
North Salmara	90.63	26.371	0.59	7.2	1	DW	Younger Alluvium	3.95	4.8	0.85
Sarakola	90.65	26.456	0.93	4.5	0.7	DW	Younger Alluvium	1.47	1.97	0.5
Chaprakata	90.61	26.486	0.87	4.3	0.8	DW	Younger Alluvium	1.53	2.23	0.7
Kakijana	90.66	26.43	0.67	4.7	0.8	DW	Younger Alluvium	2.42	2.75	0.33
Borpara	90.56	26.456	0.5	7.5	0.8	DW	Consolidated Formation	3.17	3.71	0.54
Mulagaon	90.54	26.44	0.87	9.3	1	DW	Consolidated Formation	5.14	5.78	0.64
Mulagaon PHC	90.53	26.429	1	10.4	1.2	DW	Consolidated Formation	5.18	5.52	0.34
Bansbari Pt II	90.51	26.393	0.77	8.09	2.1	DW	Younger Alluvium	4.83	5.58	0.75
Dhaknabari	90.5	26.323	0.74	7.3	0.7	DW	Younger Alluvium	3.86	4.18	0.32
Boilamari	90.49	26.301	0.7	5.1	0.67	DW	Younger Alluvium	3.25	3.75	0.5
Talguri	90.49	26.326	1.02	7.3	2	DW	Younger Alluvium	4.18	4.83	0.65
Salbari	90.5	26.332	0.8	8.2	2	DW	Younger Alluvium	5	5.65	0.65
Borkhata	90.54	26.387	1.02	6.1	1	DW	Younger Alluvium	1.88	2.83	0.95
Durgapur	90.59	26.354	0.67	6.05	0.7	DW	Younger Alluvium	5.38	5.78	0.4
Ghilaguri	90.59	26.31	1.3	12.1	0.5	DW	Younger Alluvium	5.9	6.2	0.3
Sakumari	90.57	26.311	0.67	10.2	2	DW	Younger Alluvium	5.73	6.7	0.97
Chalantapara Pt II`	90.59	26.265	0.7	13.5	1	DW	Older Alluvium	10.28	10.53	0.25
Majgaon	90.59	26.407	0.56	5.4	1	DW	Older Alluvium	2.14	3.34	1.2
Kayapatty	90.58	26.236	0.97	8.7	0.7	DW	Younger Alluvium	0.83	1.7	0.87
Mohanpur PWSS	90.61	26.235	1	100	0.102	TW	Younger Alluvium	1.4	2.1	0.7

Location	Longitude	Latitude	M.P	Depth (mbmp)	Dia(m)	Type of well	Formation	W.L(mbgl) (Nov)	W.L(mbgl) (Feb)	Fluctuation
Pachania	90.63	26.233	0.67	5.2	0.7	DW	Consolidated formation	1.73	4.43	2.7
Malegarh Pt I	90.64	26.254	0.8	13.06	0.7	DW	Consolidated formation	2.7	4.1	1.4
Lalmati	90.65	26.298	1.2	9.15	2	DW	Consolidated formation	4.2	5.37	1.17
Amtola	90.65	26.374	0.8	6.42	1	DW	Younger Alluvium	3.7	4.26	0.56
Srijangram(Borhola Pt II)	90.73	26.384	1	5.95	1	DW	Younger Alluvium	4.25	4.97	0.72
Hooramara	90.69	26.419	0.7	5.3	0.7	DW	Younger Alluvium	1.6	2.27	0.67
Kakoijana	90.67	26.426	0.98	5.45	0.7	DW	Younger Alluvium	1.72	2.67	0.95
Simalguri	90.5	26.488	0.8	7.72	1	DW	Younger Alluvium	3.9	5.05	1.15
Kinaborgaon	90.48	26.46	1.05	8.3	0.75	DW	Younger Alluvium	4.21	5.07	0.86
Kakragaon	90.45	26.446	0.8	15.5	0.9	DW	Younger Alluvium	2.3	3.36	1.06
Bijaygaon	90.42	26.445	0.8	6.2	1	DW	Younger Alluvium	3.1	3.96	0.86
Bilaspur PHED	90.41	26.412	1	100		TW	Younger Alluvium	3.4	4.34	0.94
Choraikonsra	90.44	26.421	0.9	8.5	0.7	DW	Younger Alluvium	4.4	5.05	0.65
Bidyapur	90.46	26.39	0.9	6.1	1	DW	Younger Alluvium	2.5	3.88	1.38
Jalakhata	90.49	26.363	0.5	5.5	0.7	DW	Younger Alluvium	2.55	3.15	0.6
Malipara	90.61	26.363	1.1	5.8	0.8	DW	Younger Alluvium	2.32	2.86	0.54
Jogipara	90.62	26.346	0.8	5.25	0.7	DW	Younger Alluvium	2.4	2.96	0.56
Choutaki	90.63	26.33	1.1	6.62	0.7	DW	Younger Alluvium	1.8	2.35	0.55
Nayagaon	90.62	26.305	0.7	7	1.2	DW	Younger Alluvium	3.31	4.27	0.96
Nayagaon	90.61	26.314	0.6	9	1	DW	Younger Alluvium	5.45	6.56	1.11
Bongaigaon	90.55	26.485	1.1	9.2	2.2	DW	Younger Alluvium	4.5	5.29	0.79
Deohati	90.64	26.361	1.2	7	0.7	DW	Younger Alluvium	2.82	3.81	0.99
Abhyapuri	90.66	26.341	0.5	6.65	0.9	DW	Younger Alluvium	2.85	3.73	0.88
Piradhara	90.69	26.313	0.4	100	0.102	TW	Older flood plain	3.08	3.94	0.86
Nuagaon	90.84	26.411	0.8	100		TW	Older flood plain	2.68	3.33	0.65
Jharbari	90.84	26.42	1.3	7.2	1	DW	Older flood plain	1.85	2.55	0.7

Location	Longitude	Latitude	M.P	Depth (mbmp)	Dia(m)	Type of well	Formation	W.L(mbgl) (Nov)	W.L(mbgl) (Feb)	Fluctuation
Chakihali	90.83	26.432	0.8	7.2	0.7	DW	Younger Alluvium	2.5	3.16	0.66
Manikpur	90.8	26.469	1.1	7.3	0.9	DW	Younger Alluvium	2.2	2.7	0.5
Birjhora	90.58	26.475	0.8	7.2	0.7	DW	Younger Alluvium	5.12	5.55	0.43
Pakhrapara	90.57	26.468	0.9	5.2	0.7	DW	Younger Alluvium	2.6	3.9	1.3
Jhakuapara	90.6	26.463	0.8	6.3	0.8	DW	Younger Alluvium	4.3	4.55	0.25
Kashidoba	90.59	26.434	1	5.5	0.7	DW	Younger Alluvium	2.3	2.62	0.32
Katasbari PT-III	90.6	26.284	0.5	7.2	0.7	DW	Younger Alluvium	3.6	4.47	0.87
Chalantapara Pt -I	90.59	26.268	0.6	12.1	0.8	DW	Older Alluvium	7.9	8.47	0.57
Chalantapara	90.59	26.261	0.6	12.2	0.7	DW	Older Alluvium	8.7	9.16	0.46
Jogighopa	90.56	26.249	0.7	13.1	0.8	DW	Older Alluvium	8.4	9.31	0.91
Sakamura	90.57	26.29	0.62	12.5	1.2	DW	Older Alluvium	7.36	7.83	0.47
Borigaon PHED	90.68	26.34	0.5	100	0.102	DW	Younger Alluvium	3.26	3.86	0.6

ANNEXURE II

DETAILS OF GROUND WATER EXPLORATORY WELL IN BONGAIGAON DISTRICT

District	Location	Longitude	Latitude	Depth of Drilled (mbgl)	Depth of con-str. (mbgl)	Zones encoun-tered	Static Water level (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permea-bility (m/day)	Storage co-efficient (S) (lpm/m)
Bongaigaon	Kalbari (Abha-yapuri)-EW	90.662	26.309	100.50	92.00	41-53,59-71,77-89	3.50	43.62	2.50	1036.5		$5.4*10^{-4}$
Bongaigaon	M.G.College (Chalantapara)-EW	90.583	26.270	100.50	84.00	33-48,72-81	7.05	42.5	4.90	47.54		
Bongaigaon	Gerukabari-EW	90.575	26.476	81.25	63.00	33-54	3.03	46.54	1.46	4758	176	
Bongaigaon	Jogighopa	90.554	26.2486	165.23		41.27-53.81,91.26-103.87,117.13 - 129.72,136.48 -146.92	6.02	43.83	2.72	7416		$8.75*10^{-2}$
Bongaigaon	Pachania	90.6249	26.238	156.16		33.52-45.24, 73.20-98.91, 125.61-131.50,143.70 -150.10	4.53	90.15	5.65	6779		$1.09*10^{-2}$
Bongaigaon	Abhyapuri	90.664	26.281	145.00		22.38-27.43,39.62-51.81,57.91-73.14	3.34	136.38	4			

ANNEXURE III

CHEMICAL ANALYSIS DATA OF PRE-MONSOON GROUND WATER SAMPLES, BONGAIGAON DISTRICT.

Location	Unit	pH (lab)	El. Cond.	Turbidity (NTU)	TDS	CO3	HCO3	Measured Alkalinity	Cl	SO4	NO3	F	Ca	Mg	Measured Hardness	Na	K
Amtola	mg/L	7.41	19.25	0.04	12.71	0	18.31	18.31	10.64	23.02	4.03	0.0	4.0	6.1	35.0	5.6	6.2
Aolaguri	mg/L	8.23	183.6	0.11	121.18	12	616.59	628.59	35.45	5.73	0.22	0.1	54.0	108.0	580.0	5.5	5.3
Bansbari Pt 1 1	mg/L	7.658	86.35	0.04	56.99	0	42.73	42.73	24.82	4.96	17.34	0.0	8.0	7.3	50.0	9.9	9.9
Birjhora	mg/L	8.23	171.2	0.02	112.99	12	268.61	280.61	24.82	20.91	3.51	0.0	56.0	25.5	245.0	22.2	21.7
Borkhata	mg/L	8.283	128.7	0.06	84.94	0	170.94	170.94	10.64	0.00	0.21	0.4	22.0	9.7	95.0	20.0	5.9
Borpara	mg/L	7.39	120.4	0.06	79.46	0	97.68	97.68	21.27	7.61	1.05	0.1	28.0	7.3	100.0	10.4	5.3
Chakihali	mg/L	8.47	377.4	0.2	249.08	18	293.03	311.03	14.18	19.49	3.56	0.0	48.0	30.3	245.0	16.6	5.5
Circuit house	mg/L	7.55	136.3	0.03	89.96	0	48.84	48.84	35.45	8.52	38.51	0.0	26.0	9.7	105.0	13.9	5.3
Dhaknabari	mg/L	7.312	29.62	0.17	19.55	0	30.52	30.52	10.64	0.14	1.49	0.0	8.0	3.6	35.0	2.3	1.9
Durgapur	mg/L	7.189	63.25	0.3	41.75	0	48.84	48.84	17.73	0.98	5.18	0.0	16.0	6.1	65.0	4.2	1.2

Location	Unit	pH (lab)	El. Cond.	Turbidity (NTU)	TDS	CO3	HCO3	Measured Alkalinity	Cl	SO4	NO3	F	Ca	Mg	Measured Hardness	Na	K
Ghilaguri	mg/L	7.03	133.7	0.06	88.24	0	24.42	24.42	56.72	0.97	32.90	0.0	4.0	12.1	60.0	25.3	6.8
Jhakuapara	mg/L	8.06	112.8	0.14	74.45	0	48.84	48.84	56.72	1.41	2.97	0.1	16.0	10.9	85.0	9.8	10.3
Kabaitari	mg/L	7.41	28.88	0.11	19.06	0	36.63	36.63	10.64	23.97	1.03	0.0	6.0	9.7	55.0	5.4	6.0
Kakragaon	mg/L	7.78	41.45	0.09	27.36	0	42.73	42.73	10.64	25.69	0.00	0.0	14.0	6.1	60.0	5.6	6.2
Kayapatty	mg/L	7.507	29.1	0.73	19.21	0	36.63	36.63	7.09	0.36	2.81	0.0	6.0	3.6	30.0	5.1	3.2
Lalmati	mg/L	7.67	66.29	0.25	43.75	0	54.94	54.94	21.27	2.50	6.36	0.0	8.0	7.3	50.0	9.9	6.1
Manikpur	mg/L	8.37	228.6	0.49	150.88	99	500.60	599.60	14.18	0.99	6.88	0.1	54.0	30.3	260.0	85.3	66.8
Mulagaon PHC	mg/L	7.441	33.25	0.1	21.95	0	42.73	42.73	7.09	0.49	4.17	0.0	8.0	3.6	35.0	5.4	4.1
North Salmara	mg/L	7.461	154.7	0.08	102.10	0	67.15	67.15	14.18	1.90	2.22	0.1	18.0	3.6	60.0	5.5	5.9
Nuagaon	mg/L	8.42	221.2	0.09	145.99	0	30.52	30.52	24.82	94.77	1.72	0.1	26.0	21.8	155.0	6.6	5.5
Pachania	mg/L	7.95	146.9	0.09	96.95	0	134.31	134.31	24.82	12.70	1.06	0.1	26.0	21.8	155.0	6.1	5.5
Piradhara	mg/L	8.47	219.1	0.06	144.61	18	293.03	311.03	14.18	4.62	1.56	0.1	52.0	27.9	245.0	8.6	5.4
Sakumari	mg/L	7.303	49.23	0.05	32.49	0	42.73	42.73	17.73	3.23	3.13	0.0	12.0	3.6	45.0	5.4	6.2
Sarakola	mg/L	8.011	138.9	0.11	91.67	0	170.94	170.94	10.64	3.35	1.45	0.2	34.0	13.3	140.0	5.2	5.2

Location	Unit	pH (lab)	El. Cond.	Turbidity (NTU)	TDS	CO3	HCO3	Measured Alkalinity	Cl	SO4	NO3	F	Ca	Mg	Measured Hardness	Na	K
Srijangram(Borhola Pt II)	mg/L	8.36	184.2	0.08	121.57	9	244.20	253.20	7.09	25.35	4.32	0.3	54.0	10.9	180.0	14.2	5.1

ANNEXURE IV

CHEMICAL ANALYSIS DATA OF POST_MONSOON GROUND WATER SAMPLES

Location	Unit	pH (lab)	El. Cond.	Tur-bidity (NTU)	TDS	CO3	HCO3	Meas-ured Alka-linity	Cl	SO4	NO3	F	Ca	Mg	Measured Hardness	Na	K	Fe
North Salmara	mg/L	7.009	80.31	0.05	53.00	0	61.05	61.05	7.09	8.90	2.10	0.08	16.01	2.42	50	5.35	2.43	0.366
Sarakola	mg/L	7.263	156.8	0.11	103.49	0	128.20	128.20	21.27	2.64	12.56	0.11	36.03	2.41	100	13.09	3.73	2.659
Chaprakata	mg/L	6.531	134.5	0.04	88.77	0	67.15	67.15	28.36	21.56	6.74	0.06	20.02	4.84	70	13.85	11.22	0.149
Borpara	mg/L	5.643	137.5	0.1	90.75	0	18.31	18.31	17.73	6.93	42.20	0.02	26.02	2.41	75	4.4	3.17	0.293
Mulagaon PHC	mg/L	6.904	57.05	0.29	37.65	0	36.63	36.63	7.09	1.74	10.57	0.07	16.01	1.21	45	1.75	1.24	1.06
Bansbari Pt II	mg/L	6.565	114.3	0.05	75.44	0	30.52	30.52	21.27	12.09	18.82	0.04	14.01	2.42	45	9.01	8.77	0.025
Dhaknabari	mg/L	6.467	33.84	0.09	22.33	0	30.52	30.52	7.09	1.18	3.19	0.03	6.00	3.64	30	2.23	1.54	0.203
Borkhata	mg/L	7.328	171.5	1.3	113.19	0	158.73	158.73	17.73		9.44	0.41	32.03	3.63	95	23.22	1.81	0.605
Durgapur	mg/L	7.239	57.54	0.06	37.98	0	30.52	30.52	10.64	0.14	1.10	0.06	14.01	1.21	40	2.08	0.49	0.078
Ghilaguri	mg/L	6.195	168.8	0.03	111.41	0	30.52	30.52	63.81	2.54	29.73	0.02	10.01	8.49	60	29.05	6.77	0.043
Sakumari	mg/L	6.895	41.86	0	27.63	0	48.84	48.84	7.09	1.62	2.05	0.05	10.01	3.64	40	3.51	1.38	0.078
Kayapatty	mg/L	7.818	736.8	0.05	486.29	0	665.43	665.43	74.45	36.87	5.65	0.2	154.12	46.04	575	48.22	6.06	0.549
Kabaitari	mg/L	7.939	447.2	0.02	295.15	0	433.45	433.45	24.82	13.22	0.23	0.09	118.09	14.51	355	10.52	5.89	0.061
Pachania	mg/L	7.125	186.1	0.07	122.83	0	122.10	122.10	21.27	22.13	0.00	0.09	26.02	12.12	115	15.33	4.21	1.099
Lalmati	mg/L	6.682	72.27	0	47.70	0	61.05	61.05	17.73	3.48	4.07	0.03	8.01	8.49	55	7.96	1.88	0.061
Amtola	mg/L	6.37	15.48	0.04	10.22	0	30.52	30.52	10.64	0.49	0.95	0.02	4.00	2.43	20	6.63	3.41	0.096
Srijan-jan-gram(Borhola Pt II)	mg/L	7.816	282.8	0.07	186.65	0	299.14	299.14	17.73	7.29	0.04	0.33	68.05	16.96	240	15.17	4.94	0.185

Location	Unit	pH (lab)	El. Cond.	Tur-bidity (NTU)	TDS	CO3	HCO3	Meas-ured Alka-linity	Cl	SO4	NO3	F	Ca	Mg	Measured Hardness	Na	K	Fe
Kakragaon	mg/L	7.037	72.28	0.04	47.70	0	61.05	61.05	10.64	4.90	0.28	0.03	18.01	6.06	70	2.13	0.87	0.167
Circuit house	mg/L	6.544	91.25	0.02	60.23	0	30.52	30.52	24.82	7.84	14.11	0.1	20.02	1.20	55	8.15	3.57	0.043
Piradhara	mg/L	7.023	413.8	0.11	273.11	0	457.87	457.87	21.27	0.59	7.25	0.24	130.10	10.86	370	6.08	4.02	10.855
Bartari	mg/L	8.23	314.7	0.03	207.70	12	305.24	317.24	17.73	1.78	0.08	0.23	48.04	40.03	285	2.77	3.34	1.493
Nuagaon	mg/L	8.35	304.4	0.04	200.90	15	366.29	381.29	14.18	0.29	0.68	0.36	42.03	49.74	310	6.15	3.96	0.043
Chakihali	mg/L	8.26	496.9	0.03	327.95	15	482.29	497.29	28.36	25.19	2.47	0.18	42.03	84.93	455	10.22	4.1	0.384
Aolaguri	mg/L	8.33	305.3	0.01	201.50	15	335.77	350.77	17.73	4.25	0.06	0.2	58.05	35.17	290	3.79	3.46	0.774
Manikpur	mg/L	8.22	267.4	0.04	176.48	12	268.61	280.61	21.27	0.27	2.89	0.22	60.05	24.24	250	2.11	5.57	0.167
Birjhora	mg/L	6.22	196.6	0.02	129.76	0	54.94	54.94	53.18	38.75	9.78	0.03	12.01	14.56	90	18.35	22.81	0.132
Jhakuapara Chitkagaon	mg/L	7.17	175.9	0.01	116.09	0	140.4122	140.4122	28.36	3.8643	6.1454	0.19	32.03	12.12	130	8.96	12.6	0.849