केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

UDALGURI DISTRICT, ASSAM

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

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Ministry Of Water Resources, River Development & Ganga Rejuvenation

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AQUIFER MAPPING AND MANAGEMENT PLAN OF UDALGURI DISTRICT, ASSAM

ANNUAL ACTION PLAN, 2019-20

NORTH EASTERN REGION

उत्तरपूर्वीक्षेत्र

GUWAHATI

गुवाहाटी

October, 2021

AQUIFER MAPPING AND MANAGEMENT PLAN OF UDALGURI DISTRICT, ASSAM

ANNUAL ACTION PLAN, 2019-20

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Preface

Under National Aquifer Mapping and Management Plan (NAQUIM) program, Central Ground Water Board, North Eastern Region, Guwahati, Assam has carried out aquifer mapping and management plan in Udalguri district of Assam. The objective was to understand the aquifer system down to the depth of 300 meters, decipher the aquifer geometry, its characteristics, quantity and quality and to formulate a complete sustainable and effective management plan for ground water development.

A multi disciplinary approach of geology, geophysics, hydrology and chemistry was adopted to achieve the objectives of the study. A management plan was made with emphasis on irrigation for agriculture.

This report elaborates the different aquifer system prevailing in the study area, its characteristics and also provides the different scientific data which will help in proposing plans to achieve drinking water security, irrigation facilities etc. through sustainable ground water development.

The groundwater management plan was made with an emphasis in providing irrigation facilities through ground water development as agriculture is the main means of livelihood of the people in the district. To use the groundwater for irrigation purpose, a cropping plan has been designed for the district by using CROPWAT model developed by FAO.

The study of the Aquifer mapping and management plan of Udalguri district was carried out under the guidance and supervision of Shri. G L Meena, Ex. Regional Director, CGWB, NER, Guwahati, Shri Biplap Ray, HOO, CGWB, NER, Guwahati and Shri. Tapan Chakraborty, Nodal officer of NAQUIM, NER who has helped in all the aspects of technical inputs and report preparation.

I hope this report will help the stake holders, planners, policy makers, professionals, academicians and researchers dealing with water resources or ground water resources management.

Acknowledgement

I would like to acknowledge all the below mentioned for their help and support in all aspects related to this work.

At the outset, I would like to extend my heartfelt gratitude to Shri. G L Meena, Ex. Regional Director, CGWB, NER, Guwahati for his support and guidance during the course of study.

I render my sincere thanks to my supervisor Shri. TapanChakraborty, Nodal officer of NAQUIM, NER andShri. Biplab Ray, HOO, CGWB, NER, Guwahati for their support, technical input, encouragement during the year.

Sincere thanks to Dr. D.J.Khound, Scientist-B for the technical input and guidance in preparation of report.

I would like to thank all the officers and staff of the Regional Chemical laboratory, NER, Guwahati for analysing the ground water samples and providing the data. I thank all the Engineers and Drilling staff of CGWB, Division VII, Guwahati for their contribution in ground water exploratory drilling activities in the study area.

I would also like to thank State Government officials of Irrigation Department, Public Health Engineering Department, Statistical Department and Agricultural Department for providing the data and necessary information of the district.

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ABBREVIATION

AAP	Annual Action Plan
CGWB	Central Ground Water Board
NER	North Eastern Region
NAQUIM	National Aquifer Mapping and Management Plan
GL	Ground Level
GSI	Geological Survey of India
IMD	Indian Meteorological Department
LPM	Litres per minute
LPS	Litres per second
m	Metre
mbgl	Meters below ground level
MCM	Million Cubic Meter
Mm	Milli meter
mg/l	Milligram/litre
mamsl	Metre above mean sea level
Sq.km	Square Kilometre
µS/cm	Microsimens/centimetre
AMP	Aquifer Management Plan
AQM	Aquifer Mapping
BIS	Bureau of Indian Standards
BDL	Below detectable level
BCM	Billion Cubic Metres
DGM	Directorate of Geology and Mining
DTWL	Depth to water table
DW	Dug Well
BW	Bore well
EC	Electrical Conductivity
EW	Exploratory Well
GEC	Ground water Estimation Committee
Ha	Hectare
Ham	Hectare meter
Km	Kilometre
MP	Measuring Point
OW	Observation Well
°C	Degree Celsius
Ppm	Parts per million equivalents to mg/l
Pz	Piezometer
SWL	Static water level
TDS	Total dissolved solid
TW	Tube Well

EXECUTIVE SUMMARY

Aquifer Mapping studies and Management Plan has been carried out in Udalguri district, Assam under National Aquifer Mapping and Management Plan (NAQUIM) programme with an objective to know the different aquifer system prevailing in the study area, decipher the vertical and lateral extension of the aquifer down to the depth of 300 m, its characteristic, quantity as well as quality so as to bring a complete sustainable and effective aquifer management plan for ground water resources development in the district. This study has been done through multi-disciplinary approach so as to achieve the desired objectives.

The total coverage area of aquifer mapping and management plan is 2002 sq.km. Udalguri district is situated in the northern bank of the River Brahmaputra. The total geographical area of the district is 2,012 sq. km, which is 2.36% of the total geographical area of state. As per 2011 census, the total population of Udalguri is 8, 31,668 with density of population 413 per sq. km, which is higher than the state average of 398.

The district intersected by numerous hill streams in the northern parts of the district. The southern parts of the district are situated on the plains of the Brahmaputra Valley Zone. Major tributaries of the river Brahmaputra viz. Pachnoi, Dhansiri, Jiya Dhansiri, Mora Dhansiri, Noa, Kulsi, Dipila and Bornoi, which originate from the foothills of the Himalayan Range. The district falls under subtropical humid atmosphere, which is suitable for cultivation of a wide array of horticultural crops. In the foot hill with high elevation situation and in the medium land with high rainfall situation fruit crops like banana,pineapple and citrus, spices like ginger,turmeric, black pepper and vegetables (Kharif and Rabi) are grown in the district.The total cultivable land is 139647 hectares. Out of which 48.31% is rainfed and 51.69% or 72179 hectares is irrigated.

In the district, 35 key wells are established to monitor the water level, quality and its behavior periodically. Besides there are 12 ground water monitoring station in the district and 6 Exploratory well were monitored throughout the year. The occurrence and behaviour of ground water is controlled by climate, topography, geology of the district. Almost the entire district is occupied by unconsolidated quaternary alluvium. Ground water occurs in extensive aquifer down to explored depth of 300m and has a very good yield prospect. The shallow aquifer occurs under unconfined condition. Ground water from shallow aquifer is exploited through different types of ground water extraction structures such as dug wells and shallow tube wells/hand pump. It is constituted of a mixture of boulder, gravel, sand, silt and clay. The thickness of the aquifer varies from 15 to 40 m. The depth to water level in the major part of the district generally lies within 12 m bgl. The hydraulic gradient becomes gentler

towards south. The deeper aquifer occurs as semi-confined to confined condition. The drilled depth of exploratory wells tapping this aquifer ranges from 65 to 305 m bgl. The drilling discharges ranges from 28 m^3/hr to 216 m^3/hr.

The ground water quality is within permissible limit except for concentration of iron, which is found to be beyond permissible limit in deeper aquifer and in certain pockets of shallow aquifer. Dynamic Groundwater Resources of the district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). As per dynamic ground water resource of the district, net ground water availability is 63738 ham and stage of ground water extraction is 12.88%.Based on the stages of ground water extraction and long-term water level trend analysis the district can be categorized under safe category.

The major groundwater related issues found in the district are low stage of ground water extraction, irrigation practice by utilizing ground water (constructing tube well) is not practice in large scale by individual villagers due to small land holding, high cost for construction and running of a well compared to production outcome and high concentration of iron in groundwater from shallow and deeper Aquifer.

To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO (Food & Agriculture Organization) and ground water management plan is made based on the inputs from geological, hydrogeological, geophysical and hydrochemical studies with an emphasis in providing irrigation facilities through ground water development as agriculture is the main means of livelihood of the people living in the district.

CHAPTER 1.0

1.0 INTRODUCTION

Central Ground Water Board, North Eastern Region has carried out Aquifer mapping and management plan in Udalguri district, Assam during AAP 2019-20 covering an area of 2002 sq.km. Under National Aquifer Mapping and Management (NAQUIM) program, combination of geologic, geophysical, hydrologic and hydro chemical information is applied to characterize the quantity, quality and sustainability of ground water aquifers. Systematic aquifer mapping will improve the understanding of the geologic framework of aquifers, hydrogeologic characteristics, quality and also quantifying the available ground water resources potential and proposing plans appropriate to the scale of demand and the institutional arrangements for management. Aquifer mapping at the appropriate scale can help to prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development.

1.1 Objectives

The objectives of the study is to understand the aquifer systems down to 300 m depth, to define the aquifer geometry, type of aquifers, ground water regime behaviors, hydraulic characteristics and to establish groundwater quantity, quality and sustainability and also to estimate the dynamic resources accurately through a multidisciplinary scientific approach on 1:50,000 scale and finally formulate a complete, sustainable and effective management plan for ground water development in the district.

1.2 Scope of the Study

The activities of this Aquifer Mapping and management plan can be envisaged as follows:

1.2.1 Data Compilation & Data Gap Analysis

One of the important aspect of aquifer mapping program was the synthesis of the data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with new data set generated that broadly describe an aquifer system. The data were analyzed, examined, synthesized and interpreted from available sources. These sources were predominantly non computerized data, which was converted into computer based GIS data sets. On the basis of available data, data gaps were identified.

1.2.2 Data Generation

There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys to delineate the aquifer systems, to bring out the efficacy of various

geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological conditions.

1.2.3. Aquifer Map Preparation

On the basis of integration of data generated from various studies of hydrogeology, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out characterization of aquifers, providing spatial variation (lateral & vertical) in reference to aquifer extremities, quality, depth to water level, potential and vulnerability (quality & quantity).

1.2.4. Aquifer Management Plan Formulation

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

1.3 Approach and Methodology

Aquifer mapping has been carried out by adopting amulti-disciplinary approach:

(i) Exploratory drilling and construction of tube wells tapping various groups of aquifers.

(ii) Ground Water Regime monitoring by establishing monitoring wells tapping different aquifers at different depths for long term monitoring of water level and quality.

(iii) Pumping test/PYT of tube wells, soil infiltration test, slug tests for determination of ground water recharge scope, intensity and potentials and also to determine the characteristics and performances of existing aquifers at various depths.

(iv) Collection of various relevant technical data from the field in aquifer mapping area and also from the concerned State Govt. Agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data for final output.

(v) Preparations of a micro level mapping of existing aquifers, their potentials depth wise and sideways in 2D and 3D forms viewed from different angles by various GIS Layers.

(vi) Formulating a complete sustainable aquifer management plan for ground water development.

1.4 Location

Udalguri district is situated in the northern bank of the River Brahmaputra. The total geographical area of the district is 2,012 sq. km, which is 2.36% of the total geographical area of state. The district is bounded by Bhutan and Arunachal Pradesh in the North, Sonitpur district in the east, Darrang district in the south and Baksa district in the west. The district lies between 26°46’ and 26°77’ north latitude and 92°08’ and 95°15’ east longitude at an altitude of about 345’above the mean sea level (MSL). The district was formally inaugurated on June 14, 2004.

1.5 Administrative Set Up

The district headquarters of Udalguri district is Udalguri town. The district is divided into two sub-divisions: Udalguri and Bhergaon. These two sub-divisions are further divided into 9 revenue circles having a total of 800 Villages. Revenue Circle wise distribution of villages are as follows- Udalguri having 226 Villages, Mazbat having 138 Villages, Harsinga having 203 Villages , Kalaigaon (Part) having 77 Villages, Khoirabari (Part) having 84 Villages, Dalgaon (Part) having 46 Villages, Patharighat (Part) having 1 Village, Mangaldoi (Part) having 6 Villages and Dhekiajuli (Part) having 19 Villages. There are 3 Towns (2 statutory towns and 1 census towns) in this district, namely-- Kalaigaon Town Part (CT), Tangla (TC) and Udalguri (TC).The administrative map of the district is given in Fig 1.

1.6 Data Availability, Data Adequacy And Data Gap Analysis

Aquifer mapping and management plan is carried out through collaborative of different data. The required data on various attributes are collected from the available literatures of Central Ground Water Board, State Water Resources Department of Assam and various Central and State Government agencies. The data requirement, data availability and data gap analysis are presented in table 1.1.

Table1.1: Data availability and data gap analysis

SN	Theme	Type	Data available	Data gap	Data generation	Total
1	Borehole Lithology Data	Tube well	5	7	7	12
2	Geophysical data		Nil	10	Nil	Nil
3	Groundwater level data	Dug well (Shallow zone)	12	18	20	32
		Piezometer/OW (Deeper zone)	Nil	7	7	7
4	Groundwater quality data	Dug well (Shallow zone)	12	18	20	32
5	Soil Infiltration Test		Nil		3	3

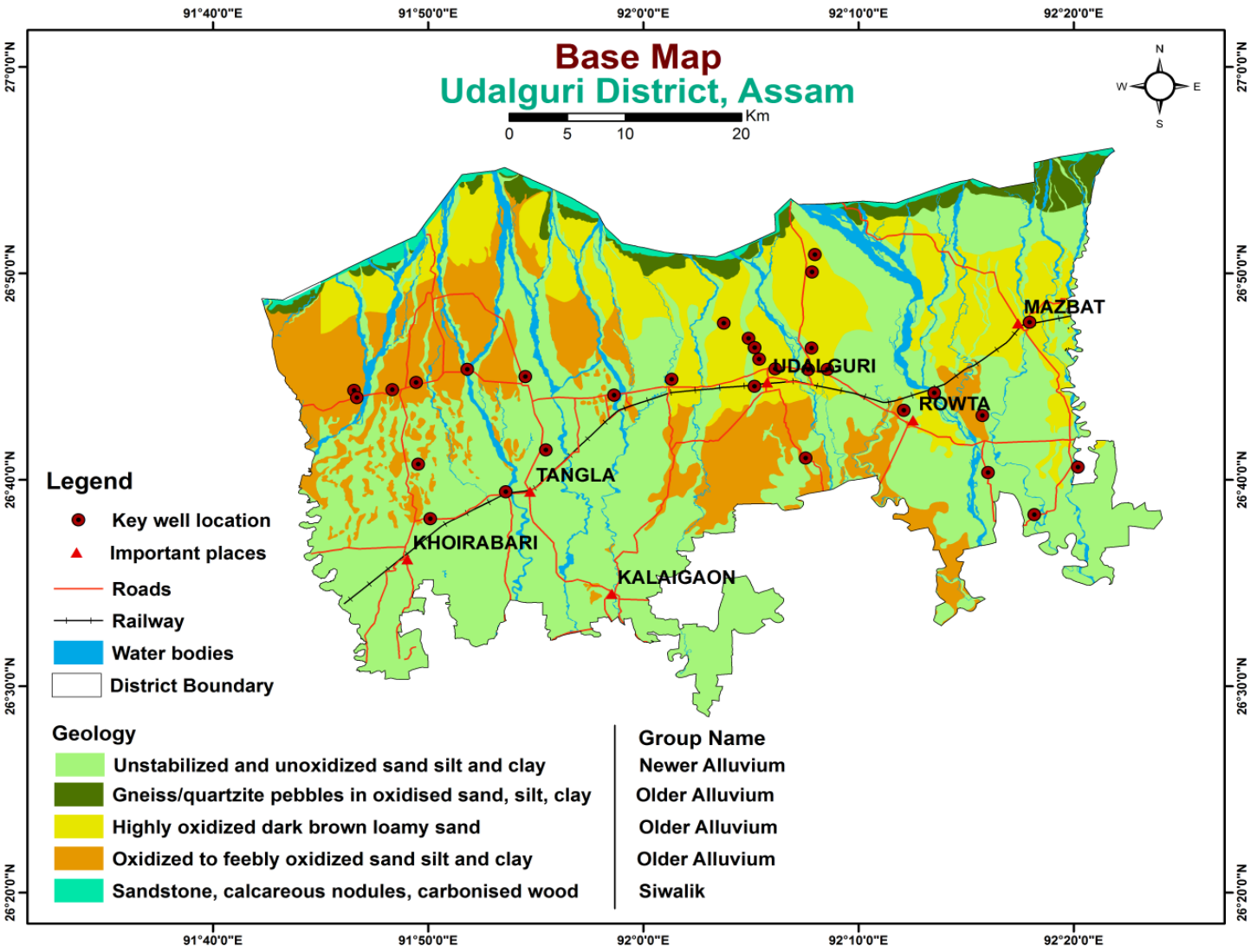


Fig. 1.0: Base map of the district

1.7 Demography

As per 2011 census, the total population of Udalguri is 8, 31,668 with density of population 413 per sq. km, which is higher than the state average of 398 and the decadal variation of population for 2001-2011 is 9.61%. The district is predominantly rural with 95.48 % of the total population in the district while the urban population is 4.52 % which is lower than the state average of 14.1 percent. The sex ratio in the district is 973 females per 1000 males, which is higher than the state average of 958. The total number of households in the district are 1, 68,717. Table 1.2 shows the distribution of population of the district.

TABLE 1.2: Rural and urban population

Total/Rural/Urban	No. of households	Population	Male	Female
Total	1,68,717	8,31,668	4,21,617	4,10,051
Rural	1,60,404	7,94,094	4,02,442	3,91,652
Urban	8,313	37,574	19,175	18,399

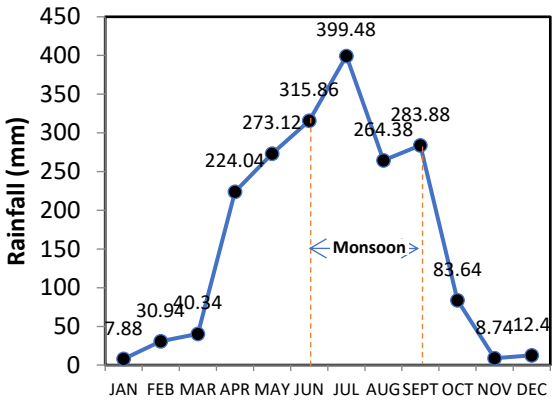
Source: Statistical Hand Book of Assam, Udalguri district

1.8: Communication

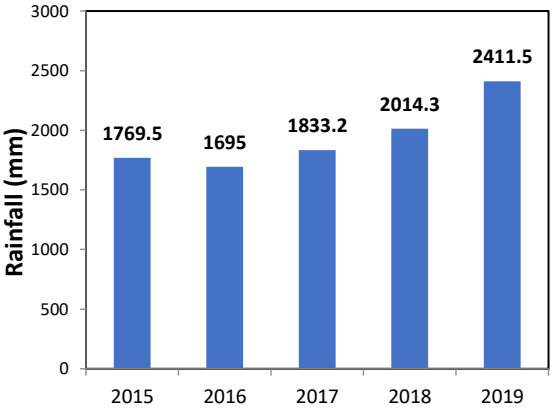
Since, the district is located at the centre of North Bank of the State, it is facilitating as a traffic corridor to the upper and northern districts of the state that are further extending to other N.E. states viz. Arunachal Pradesh and Nagaland. The district is well connected by road and rail. The national highway NH-52 passes through the district. North East Frontier Railways have its railway station at district head quarter i.e. at Udalguri. Dispur, the capital of Assam is at a distance of 140 km by roads from Udalguri town.

1.9: Climate

The district has a sub-tropical humid climate with semi-dry hot summer and cold winter. Agro-climatically, the district falls under the North Bank Plain Zone. During monsoon (May to Early September), heavy rainfall occurs due to south-west monsoon for which the district experiences flood.The temperature varies between Max 34.5 °C and Min 13.5 °C. Relative humidity ranges between 82% and 88%. The plot of 5 years average month wise rainfall data indicates that the monsoon rainfall pattern is bi-modal in nature. The first monsoon peak rainfall is observed in July and the second peak is in September (Fig.1.1(a)). The rainfall pattern observed dry during October to May with an average annual rainfall of 692 mm only while June to September was observed as wet period that received the average rainfall of 1273 mm. During last 5 years the annual rainfall varies from 1695mm to 2411.5mm while the normal annual rainfall in the district is 1957.8mm (Fig.1.1(b) & Table 1.3). Due to varied distribution of rainfall, the district suffers from heavy flood during wet period and moisture stress in the dry period.



(a)



(b)

Fig. 1.1(a): Average monthly RF distribution

Fig. 1.1(b): Yearly RF distribution

Table 1.3: Rainfall Distribution InUdalguri District, Assam

(Source: http://hydro.imd.gov.in/hydrometweb/(S(cwyf4555hfj0rz55cr2st4js))/DistrictRaifall.aspx)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2015	5.2	12	9.3	188.1	245.6	419.5	238.4	382.8	170.3	60.1	21.5	16.7
2016	33.7	3.9	40.8	413.1	285.3	156.3	342.7	97.4	231.9	75.9	2.9	11.1
2017	0.5	86.5	47	252.4	174.1	317.9	256.6	226.9	304.8	158.2	8.3	0
2018	0	3.1	71.6	59	265.6	338.4	502.2	325.2	355	63.8	7.4	23
2019	0	49.2	33	207.6	395	347.2	657.5	289.6	357.4	60.2	3.6	11.2

Table 1.4:Rainfall Data

Rainfall	**Normal RF (mm)**	**Normal rainy days (number)**
SW monsoon (June-Sep):	1273	55
NE Monsoon(Oct-Dec):	121.9	22
Winter (Jan- March)	88	
Summer (Apr-May)	488.8	21
Annual	1971.7	

Source: Agriculture Contingency Plan of UdalguriDistrict

1.10: Geomorphology

The district intersected by numerous hill streams in the northern parts of the district.Thesouthern parts of the district are situated on the plains of the Brahmaputra Valley Zone. The district forms a part of the vast alluvial plains of Brahmaputra River system.Geomorphologically, it is characterized by the different land forms resulting from a) denudation structural hill and b) alluvial plain. The low mounds/hillocks are covered by a thick lateritic mantle and these are occupied by evergreen mixed forests (Fig.1.2). The alluvial plains comprise of older and newer alluvium. The older alluvium occupies the piedmont zone towards the north of the district bordering Bhutan. The newer alluvium includes sand, gravel, pebble with silt and clay. The district is mostly plain with an area of 1969 sq. km (99.18%) with slope 0 to 20% (Fig.1.3).

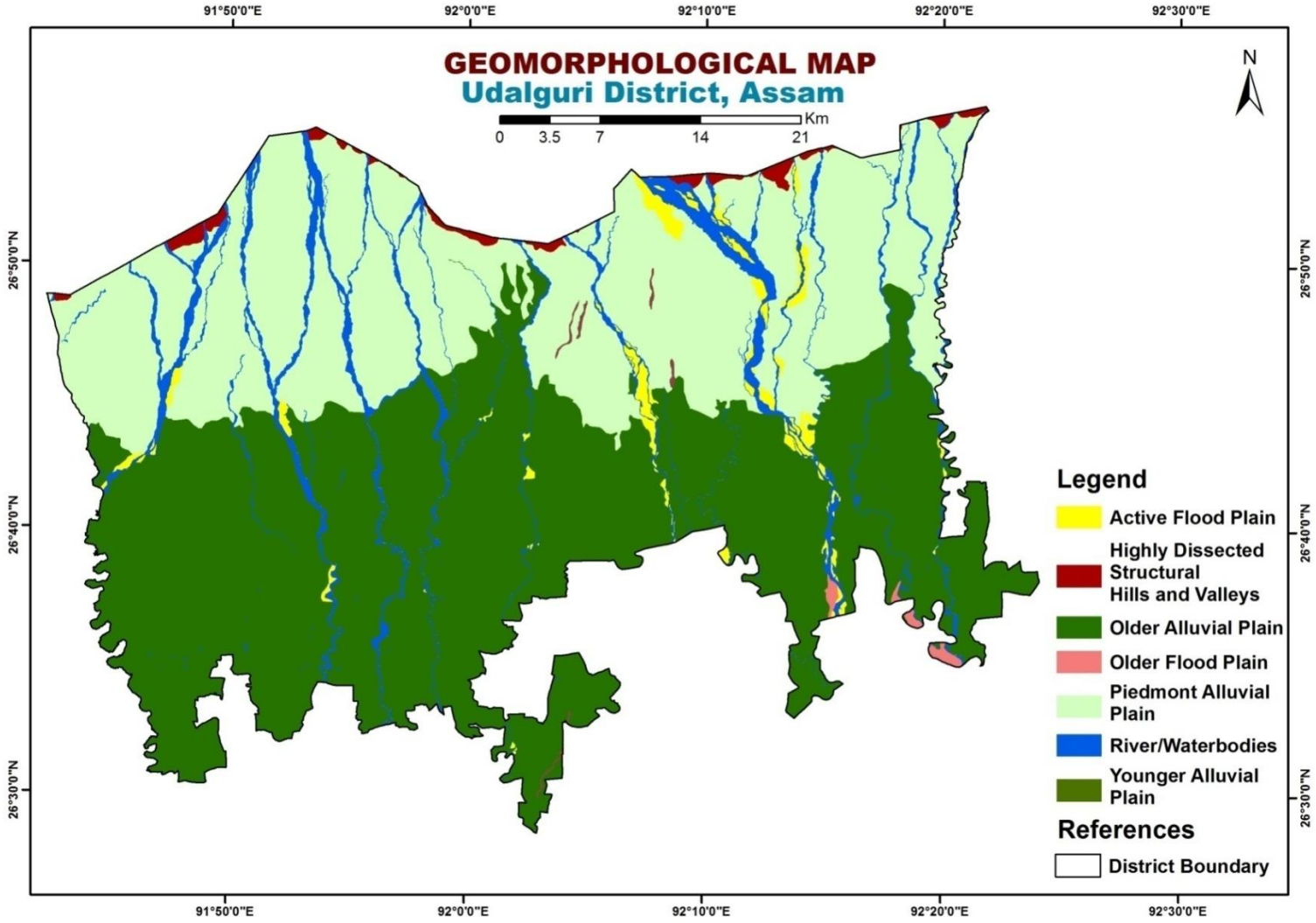


Fig.1.2: Geomorphological map

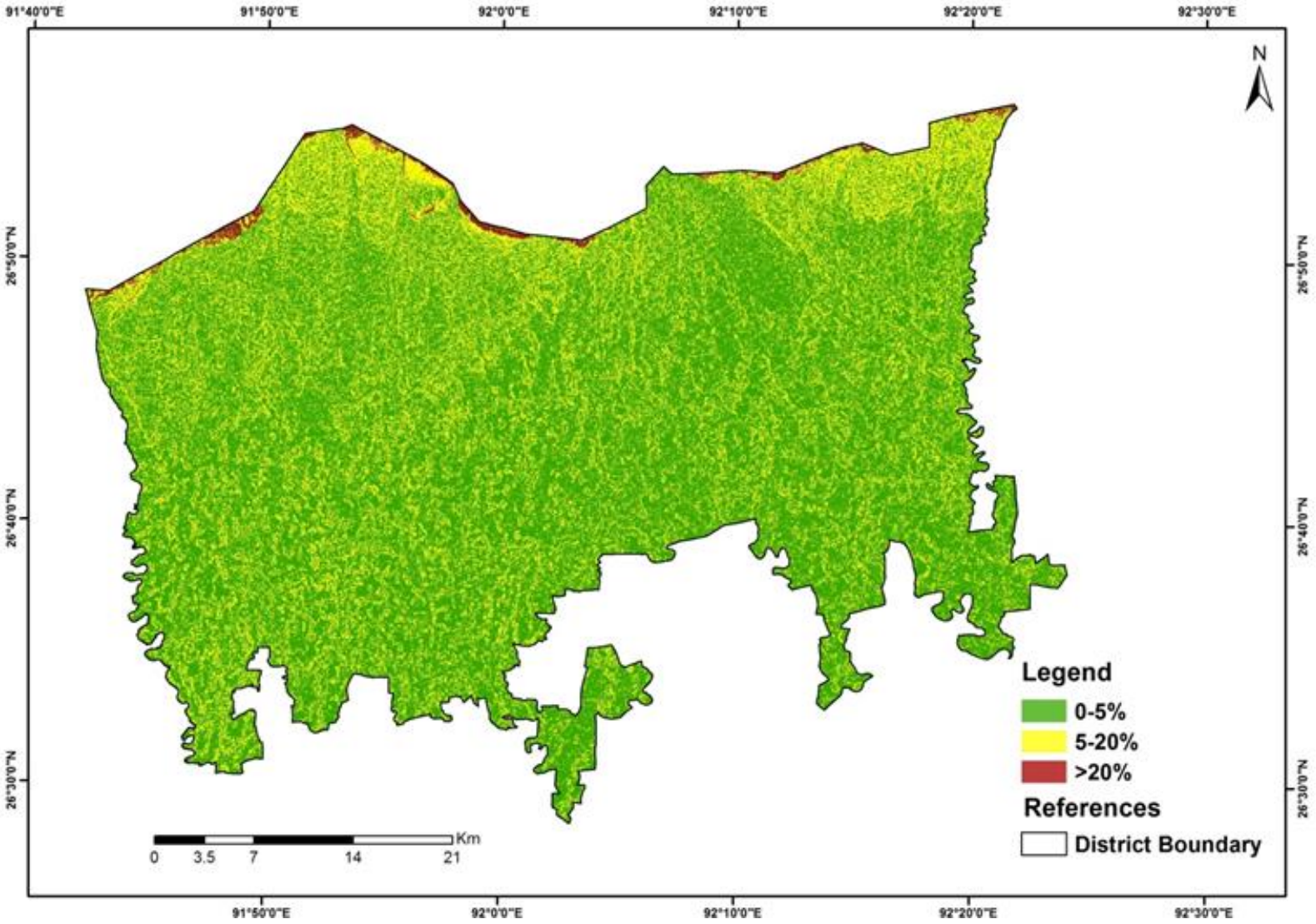


Fig.1.3: Slope Map, Udalguri District, Assam

1.11 Land Use

Land utilization statistics provide detailed information of the land use pattern in the district. Based on the land utilization, the total area is divided into various types of landforms such as forest, cultivable land, fallows lands, crops area etc. which in turn reflects the degree of development of agricultural activities and cultivation potential. The Land use map is shown in fig 1.4. The land utilization statistics of the Udalguri district is shown in the following table1.4.

Table 1.4: Land Use Pattern

Land Classifications	Area in hectares
A. Geographical area	201200
B. Reporting area	201200
1. Forests (classed &unclassed)	21996
2. Area not available for cultivation (i) Area under non-agricultural uses	
a. Barren and uncultivable lands	-
b. Water logged land	104
c. Social Forestry	133
d. Land under still water	6355
e. Other land	24589
TOTAL (i) = (a to e)	31181
(ii) Barren and unculturable lands	14536
TOTAL = Col. i& ii	45717
3. Other uncultivable lands a. Permanent pastures and other grazing lands	5301
b. Land under Misc. tree crops &grooves etc	8507
c. Cultivable wastelands	3625
TOTAL = (a+b+c)	17433
4. Fallow lands	
a. Fallow lands other than current fallows	109
b. Current fallows	42
TOTAL = (a+b)	151
5. Net area sown	**115903**
6. Area sown more than once	42198
7. Total Cropped area	158101

Source: Directorate of Economics & Statistics, Govt. of Assam.

1.12 Soil

Accordingly to the National Bureau of soil survey and land use planning, Jorhat Regional Centre in association with the Department of Agriculture, Assam, the soil of the district is moistly deep well drained, coarse loamy skeletal soils occurring on very gently sloping piedmont plain having loamy surface with moderate to severe erosion & slightly

flooding associated with moderately deep well drained coarse loamy soils.The soil map is shown in fig 1.5. The soil can broadly be classified into the following groups:

Red Loamy soil: These are found in the northern border of the district. This soil type develops in the hill slopes under high rainfall condition. This soil is characterized by low nitrogen, low phosphate and medium to high potash. PH is acidic.

Lateritic Soil: The lateritic soils are the product of high leaching and found in hilly region. Soil PH is acidic due to intensive leaching of bases and formation of clay minerals and ferric hydroxides. The lateritic soils are characterized by brick red to brownish red color and poor plant nutrient.

New Alluvial Soil: The new alluvial soils are found in the flood plain area and are subjected to occasional floods and consequently receive considerable silt deposit after the flood recedes. These are yellow to yellowish grey in color and are admixtures of sand, silt and clay in varying proportions. Mineral weathering and geo-chemical changes are nominal. But incipient changes in the top layer have been noticed due to biological activity. Soil PH is feebly alkaline and moderately rich in plant nutrient.

Older Alluvial Soil: It develops at higher levels and practically unaltered alluvium representing a broad spectrum of sand, silt and humus rich clay depending on landform. The soils are comparatively more acidic than the newer alluvial soil and hence more crop sensitive.

The major part of the soils of the district is acidic in nature. The organic matter content of soil is medium to high. The available N is medium and available P and K is low to medium.

1.13: Agriculture

Agriculture is the main stays of livelihood of the people in the district. The importance of agriculture in the life of the people is reflected in the population which is predominantly rural. The dominating role of agriculture has bearing even upon the socio-economic, cultural and religious life of the people and manifests itself in the form of festival, rites and beliefs.

Udalguri district falls under subtropical humid atmosphere, which is suitable for cultivation of a wide array of horticultural crops. In the foot hill with high elevation situation and in the medium land with high rainfall situation fruit crops like banana,pineapple and citrus, spices like ginger,turmeric, black pepper and vegetables (kharif and rabi) are grown in the district.

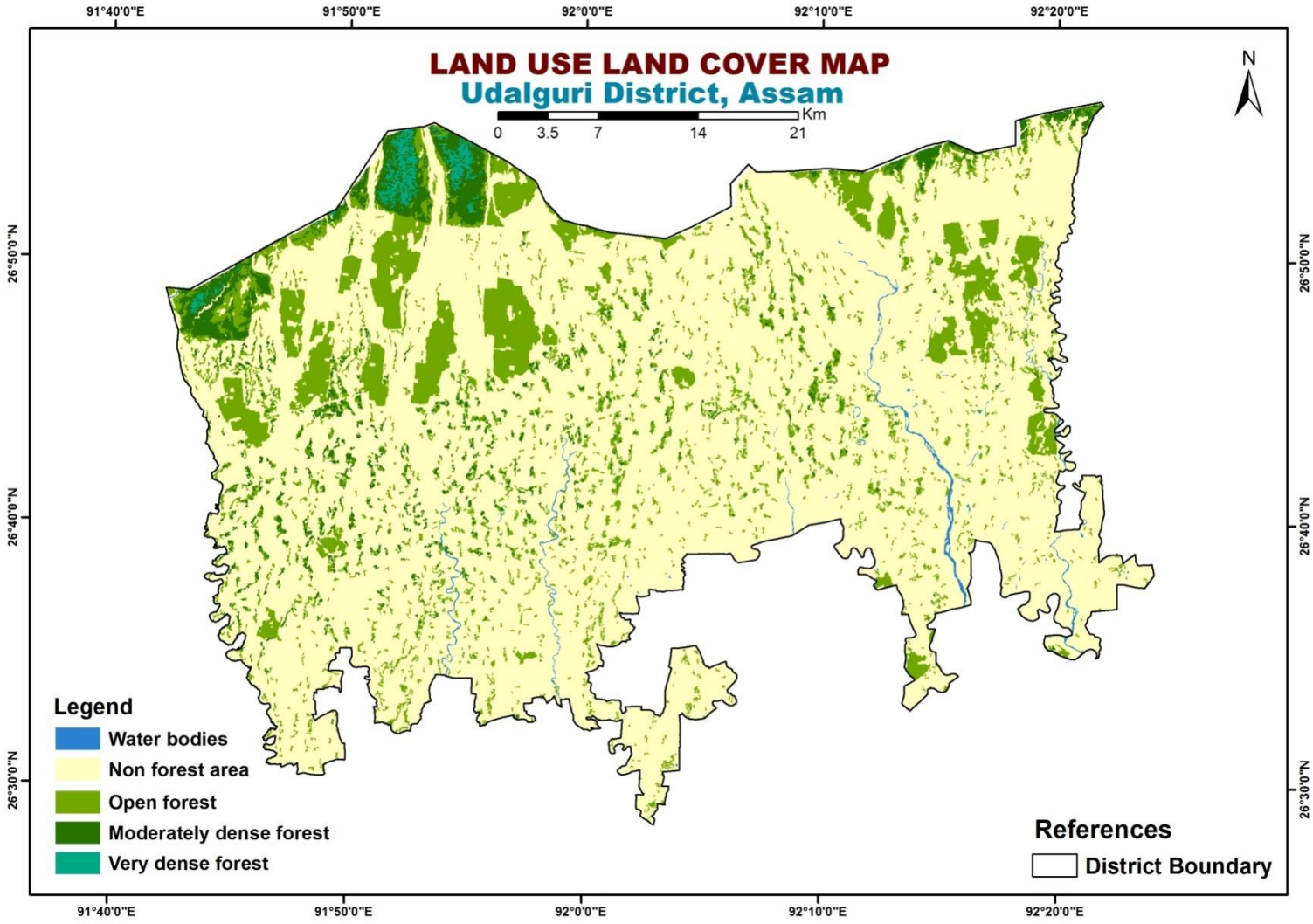


Fig.1.4: Land use map

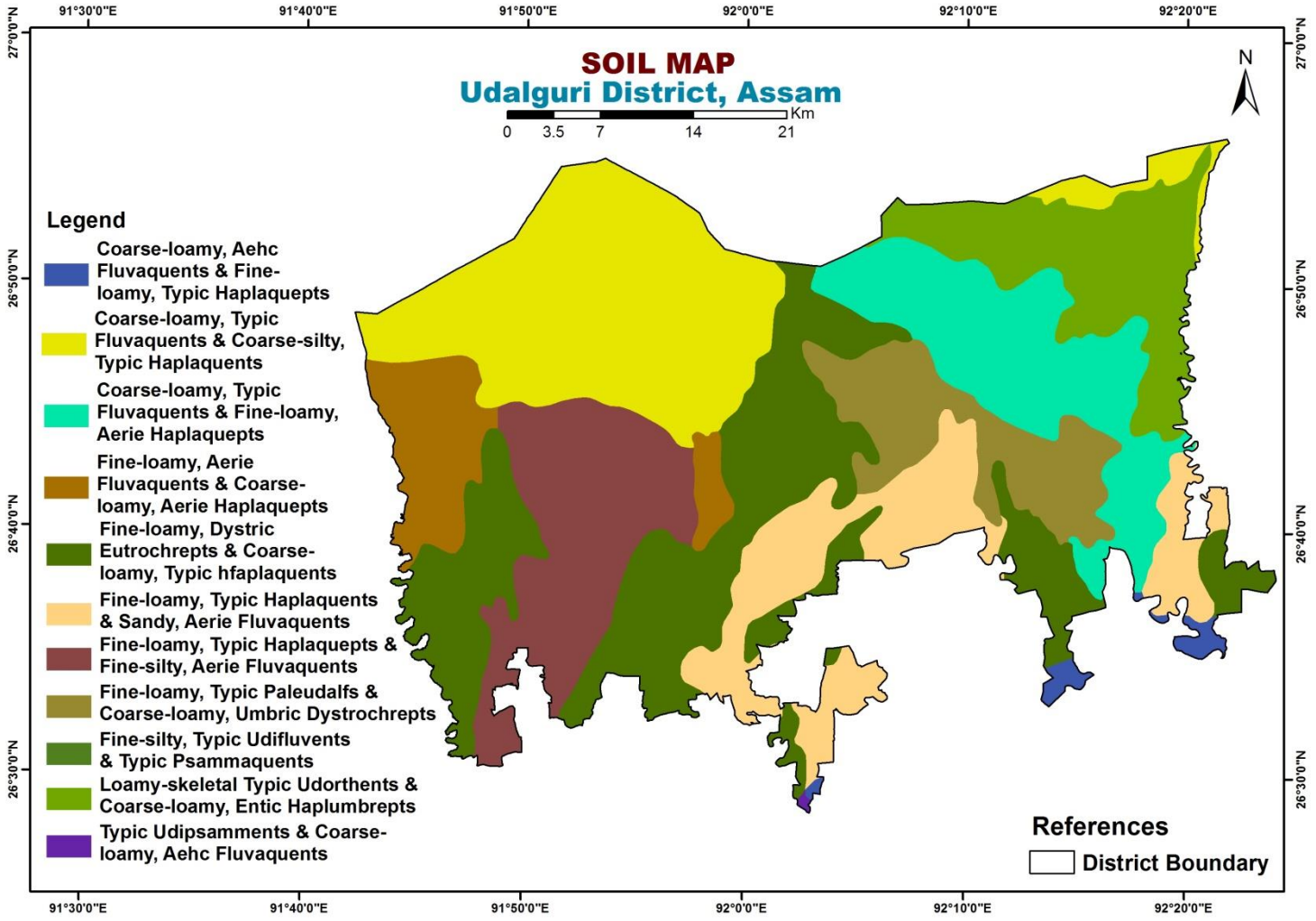


Fig.1.5: Soil map of Udalguri District

Table 1.5: Crop Wise Status of Irrigated andRainfed Area

SN	Crop Type	Irrigated	Un-irrigated	Total
1	Autumn or pre-kharif paddy	40	442	482
2	Summer paddy	2365	4050	6451
3	Kharif or winter paddy	11895	53418	65314
4	Total pulses	21	657	678
5	Total oilseeds	34	1643	1677
6	All vegetables	154	4835	7989
Total		14509	65045	82591

(Source: https://agcensus.dacnet.nic.in/DistCharacteristic.aspx)

As per Agriculture Census 2015-16, the net irrigated area of the district is 18116 ha (Source: https://agcensus.dacnet.nic.in/DL/disttabledisplay4.aspx). Paddy is the major crops in the district, viz., autumn, summer and winter paddy. Paddy cropped area is 72,211 ha and irrigated area under paddy is 14300ha which means 80% area is under rainfed condition (Table 1.5).

1.13.1: Production and Productivity of Major Crops

Agriculture is the main occupation in the district and contributes a major parts of district economy which however is a subsistence type. Sali (winter) paddy is the main crop in the district under rainfed condition Jute, banana, potato, vegetables, pineapple, turmeric, ginger etc. are also important crops. The district is surplus in production of oilseeds, fruits and spices while it is measurably deficit in pulses, milk, meat, egg and fish production. There are scope for horticultural crops, plantation crops, animal husbandry and sericulture in the district.

Paddy is the principal crop grown in the district and autumn paddy, winter paddy and summer paddy are the main types of paddy grown in the district. After paddy, wheat, green gram, mustard, black gram and vegetables are the agricultural product. Among cash crops, jute and sugarcane are the major crops grown in the district. Rice is of key importance to the district's economy and the people of the district. Almost 52% of the gross cropped area is under rice cultivation. Winter paddy is the most important crop in the district occupying 64.81 % followed by autumn paddy 29.89% and summer paddy 5.30% of the total annual paddy area.

1.14: Irrigation

In Udalguri district, the mighty river Brahmaputra flows along the southern part from east to west. Subansiri, Ranganodi, Dikrong, Shingora, Boginodi, Korha and Charikoria are the major tributaries of the district. The district has shallow ground water level and plenty of natural water bodies along with perennial streams, ponds and tanks which can easily be harnessed for water resource management like irrigation except in foothills. The unused swampy areas prevailed in the district may be utilized for fish farming. Irrigation management can be mainly done through shallow tube well, lift, flow and canals.

Table 1.6: Irrigation Based Classification

Name of Block	Irrigated (Area in Ha)		Rainfed(Area in ha)
	Gross Irrigated area	Net Irrigated area	Un- Irrigated or Totalrainfed
Bhergaon	20522	16418	24955
Udalguri	17186	13749	7769
Kalaigaon	4033	3226	13751
Mazbat	6673	5338	15957
Rowta	330	264	21965
Khoirabari	7924	6339	18571
Barchola	238	190	5359
Pub Mangaldai	173	138	4201
Bechimari	514	411	6337
DalgaonSialmari	1094	876	4673
Total	58687	46949	123538

Source: District Agriculture Officer, Udalguri

The gross irrigated area in the district was 58687 hectares andnetirrigated area is 46949 hectares respectively. The total area under rainfed is 123538 hectares.

Table 1.7: Status Of Water Availability (Cum Per Ha)

Sl. No.	Sources	Kharif	Rabi	Summer	Total
	Surface Irrigation				
i	Minor Irrigation Tanks	243.56 CuM	97.42 CuM	0.00 CuM	340.98 CuM
	Ground Water				
ii	Deep Tube Well	7.29 CuM	2.92 CuM	0.00 CuM	10.21 CuM

Source: District Irrigation Department, Udalguri

Surface irrigation in the district is found to be common during all seasons. The total water available in kharif is more than rabi and summer. Most of the area in the district israinfed and therefore, the water availability is abundant but infrastructure facilities need to be developed for proper utilization of water.

1.15: Drainage

The different rivers flowing through the district serves as the major drainage system for the district. However, during the heavy monsoon season they seem inadequate. Recurrence of flood during monsoon due to heavy rainfalls in the district and neighboring Arunachal Pradesh and Bhutan causes loss of crops and other properties almost every year. In recent years the district experienced heavy floods, to be precise, flash floods, due to heavy deforestation towards northern part. The people of the district, who mainly depend on rain water for their cultivations, are often badly affected on onehand by floods and on the other hand by occasional dry spell. Number of perennial streams flow through the district from

north to south and join the Brahmaputra river. The major streams are Barnadi, Kulsi, Noanadi, Bega, Mara Dhansiri, JiyaDhansiri and Pachnai rivers.

Jia Dhansiri River is one of the main tributaries of the river Brahmaputra in Mangaldoi sub-division. It emanates from the Bhutan hills and has an approximate total length of about 80 kilometresfrom its source to out-fall. Another river is Noanadi, which also originates from the Bhutan hills and collects some drainage from the hills before reaching the plains. The river Nanai also has its origin in the Bhutan range of the Himalayas in the Tongsa province at an elevation of about 1220 meters above the mean sea level. After crossing the Bhutan boundary, the river enters the Udalguri district and traverses through Khalingduar forest where it flows through gorges and rapids till it enters the plains near Bhutiachang village. The drainage map is given in Fig.1.6.

1.16 Forest

Forestry occupies a significant place in the economy of the district. A considerable section of the people of the district depends upon forests for firewood, timber, bamboo, reed, thatch, tokopat, caneetc, for building of houses. A number of forest based industries such as sawmill, plywood factories, match industry, furniture workshop, bamboo and cane industries etc have been opened in the district.

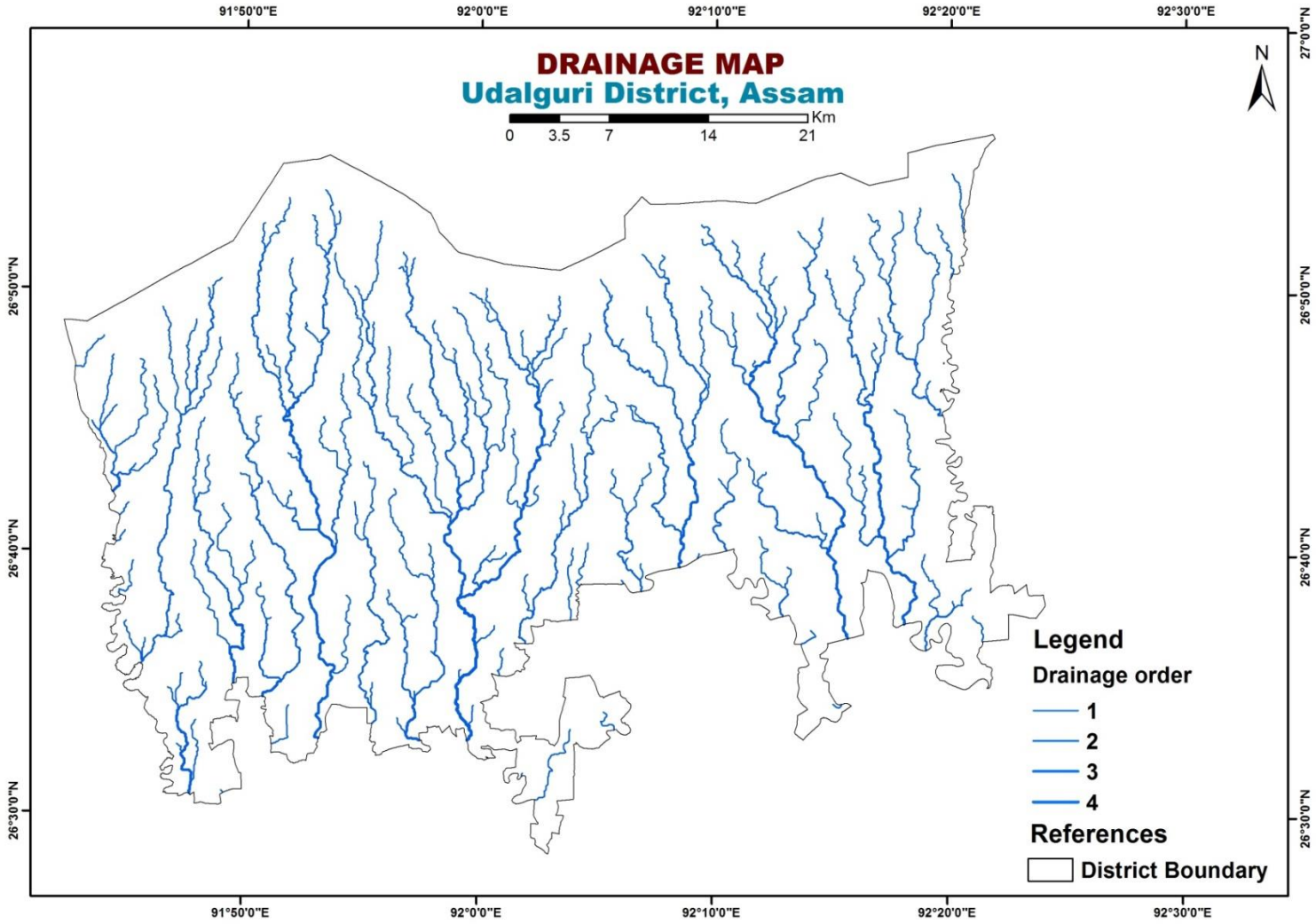


Fig. 1.6: Drainage map

CHAPTER 2.0

DATA COLLECTION AND GENERATION

The occurrence, movement, storage and availability of ground water in an aquifer depend mainly on two factors, viz. the physical framework of the aquifer systems and the recharge and discharge of water to and from the aquifers. The physical framework of the aquifer system is governed mainly by geological and geomorphological characteristics of the area. The recharge and discharge of ground water from and to the aquifers is controlled by the aquifer characteristics as well as several other factors such as soils, climate, cropping pattern, land use, surface waterfeatures, agricultural practices etc. A realistic representation of an aquifer and plan for its sustainable management needs to take into account the influence of all these factors on the aquifer system.

One of the main objectives of the study was to collect various relevant technical data from the different State Government agencies and other Institutes dealing with ground water and incorporating these data along with Central Ground Water Board data to generate data base. Data collection includes collection of rainfall data from state government/IMD, litholog collection from state groundwater departments, compilation of CGWB's earlier survey data, chemical, exploration and geophysical data. Population data is collected from Census of India. Agricultural data is collected from the Department of Agriculture, Govt. of Assam**.** Based on the data availability and data gap analysis, the required sub-surface hydrogeological data, groundwater level data, groundwater quality data and Geophysical data were generated.

2.1 Hydrogeological Data

Major part of the district is covered with alluvium formation. The different hydrogeological data are generated through intensive field data collection, ground water exploration, yield test, soil infiltration test and quality analysis.

2.1.1 Water Level Monitoring

In the district, 35key dug wells are established to study the water level, quality and its behavior periodically. Besides there are 12 ground water monitoring station in the district and 1 exploratory well and 1 observation well (drilled during the AAP) were monitored throughout the year.

Phreatic aquifer: A total of 35 dug wells were established as key wells for periodical water level monitoring to know the water level trend and its behavior. The key observation wells details are presented in annexure 1.

Confined/semi-confined aquifer: To study the piezometric head in deeper aquifer, a total of 6 nos. of tube wellsweremonitored periodically. Details of tube wells are given in annexure 1.

2.1.2 Preliminary Yield Test (PYT)

One preliminary yield test was carried out during NAQUIM programme in the district to know the aquifer parameters.

2.2 Soil Infiltration Studies

Soil infiltration test were conducted using double ring infiltrometer and the constant infiltration rates of different soils were calculated by double ring infiltrometer method. These studies were carried outindifferent locations to know the infiltration rates at different soil conditions, topography, geology and environment. Its provide a scientific approach of groundwater recharge, its suitability and the amount of water recharging in that area, rainfall infiltration factor and will help in calculating ground water resource estimation. In the district three soil infiltration tests were conducted and the details of soil infiltration test are given in table 2.1.

Table 2.1: Details Of Soil Infiltration Test

Sl. no.	Location	Latitude	Longitude	RL (m)	Soil type	Infiltration rate (cm/hr)
1	Khoirabari	26.59873	91.8191	62	Clay and loan	0.12
2	Gourabari	26.75391	92.13907	124	Sand	10.8
3	Khaurang	26.79254	92.06854	119	Sandy clay	1.14

2.3: Ground Water Exploration

Ground water exploration has been carried out in different parts of the district to delineate the potential aquifers and their geometry and to determine the hydrogeological parameters of the aquifer systems. Before NAQUIM activity was started in the district, 5 nos. of exploratory wells were constructed and during the Annual Action Planoneexploratorywell and oneobservation well were constructed during the course of study. Through outsourcing six exploratory well were drilled in the district. The exploratory wells constructed in the district are shown in table 2.2.

Table: 2.2: Exploratory Wells Drilled In The District

Sl No.	Location	Longitude	Latitude	Elevation (m)	Depth drilled (mbgl)
1	Koirabari	91.81833	26.59806	121	75.8
2	Orang	92.33	26.7	118	276
3	Harsinga	91.99028	26.72639	119	70.6
4	Dimakuchi	91.8144	26.755	130	65
5	Koirajungle	91.93472	26.77944	121	70.15
6	Mazbat	92.35	26.75694	132	67.1
7	Khaurang	9.068887	26.791972	124	305
8	Harsinga	91.990278	26.726389	119	305
9	Dimakuchi	91.8144	26.755	130	305
10	Bholabari	91.94386	26.587955	121	305
11	Bhergaon	91.82356	26.641297	125	305
12	Mazbat	92.35	26.756	132	305

2.4 Hydrochemistry

In order to study the chemical quality of ground water in the district, water samples from shallow aquifer (dug wells) and deepaquifer (EW of CGWB) were collected during the

course of field study. Ground water samples were analyzed in the regional chemical laboratory, Central Ground Water Board, North Eastern Region, Guwahati for 16 parameters. The analytical data are given in annexure 3.

2.5 Geophysical Studies

Surface geophysical studies were carried out to delineate the subsurface geology as well as supplement the data gap under the assignment of Aquifer Mapping. A total of 3 VES were conducted and HAK, HK, HKH, HAK, KQ, QH, A, K type VES curves were obtained. The inferences drawn on the basis of interpreted results could not be obtained for deeper formation due to the limitations of unavailability of large and straight stretch for current electrode separation. However, taking into account the interpreted results as well as the apparent resistivity, inferences have been approximated to shallow to deeper depth at few places. The locations of the survey carried out are tabulated below.

Table 2.3: Details OfVes Survey In The District

Sl. No.	Location	Interpretation
1	PHED Udalguri	VES 1: Top resistive rock, partially saturated: 0-10 m bgl High resistive rock, partially saturated: 10-50 mbgl Saturated rocks with conductive layers: 50-200 mbgl Potential aquifers: 60-70 & 150-170 mbgl
2		VES 2: Top resistive rock, partially saturated: 0-4 m bgl High resistive rock, partially saturated: 4-40 mbgl Resistive rock with conductive layers: 40-200mbgl Potential aquifers: 80-90 & 150-170 mbgl
3		VES 1: Top resistive rock, partially saturated: 0-6 m bgl High resistive rock, partially saturated: 6-50 mbgl Saturated rocks with conductive layers: 50-200 mbgl Potential aquifers: 70-80 &100-120 & 150-170mbgl

CHAPTER 3.0

DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1: General Hydrogeology

Physiographically, the district is mainly an alluvial tract. In the northern front along the base of the foot hills of the eastern Himalayas from where the alluvial plain gradually slopes down to the Brahmaputra River. The piedmont zone extends nearly 20km towards the south.

From the exploration and VES data, the principal aquifer of the district is identified as alluvium. Ground water occurs in extensive aquifer down to explored depth of 300m and has a very good yield prospect.

3.2: Aquifer Disposition

Exploration data of the CGWB and state government are integrated to know the aquifer disposition of the district.

To know the disposition of aquifer following three sections were constructed

a) North-south section from Kalikhola to Dugiapara

b) Northeast-Southwest section from Kharung to Bholabari

c) East-west section from Dimakuchi to Orang.

Aquifer disposition from piedmont to alluvial plain is shown in Fig. 3.1. Three boulder zones are found in the piedmont zone down to a depth of 240m. Two thin clay layers separated these boulder zones. All the boulder zones are pinches out in the extreme southern part of the district. The second boulder zone observed in the Dimakuchi EW is pinched out in between Dimakuchi EW and Bhergaon EW while the third boulder zone in the piedmont splits into two in the alluvial plain.The two clay zones in the piedmont are merged down in the alluvial plain and its thickness increases towards the south. Four sand layers are found in the south. In Bhergaon EW aquifer zones are sandwiched between thick clay layers thus give rise to flowing artesian well.

Aquifer disposition in the alluvial plain from near the piedmont to the distant part is shown in Fig.3.2. The aquifer material in this section is dominated by boulders down to a depth of 100m. However, in the Harisinga EW, five boulder zones are found and bottom most boulder zones are pinched out in both northeast and southwest directions. Clay layers are thin and are not continuous in the section.

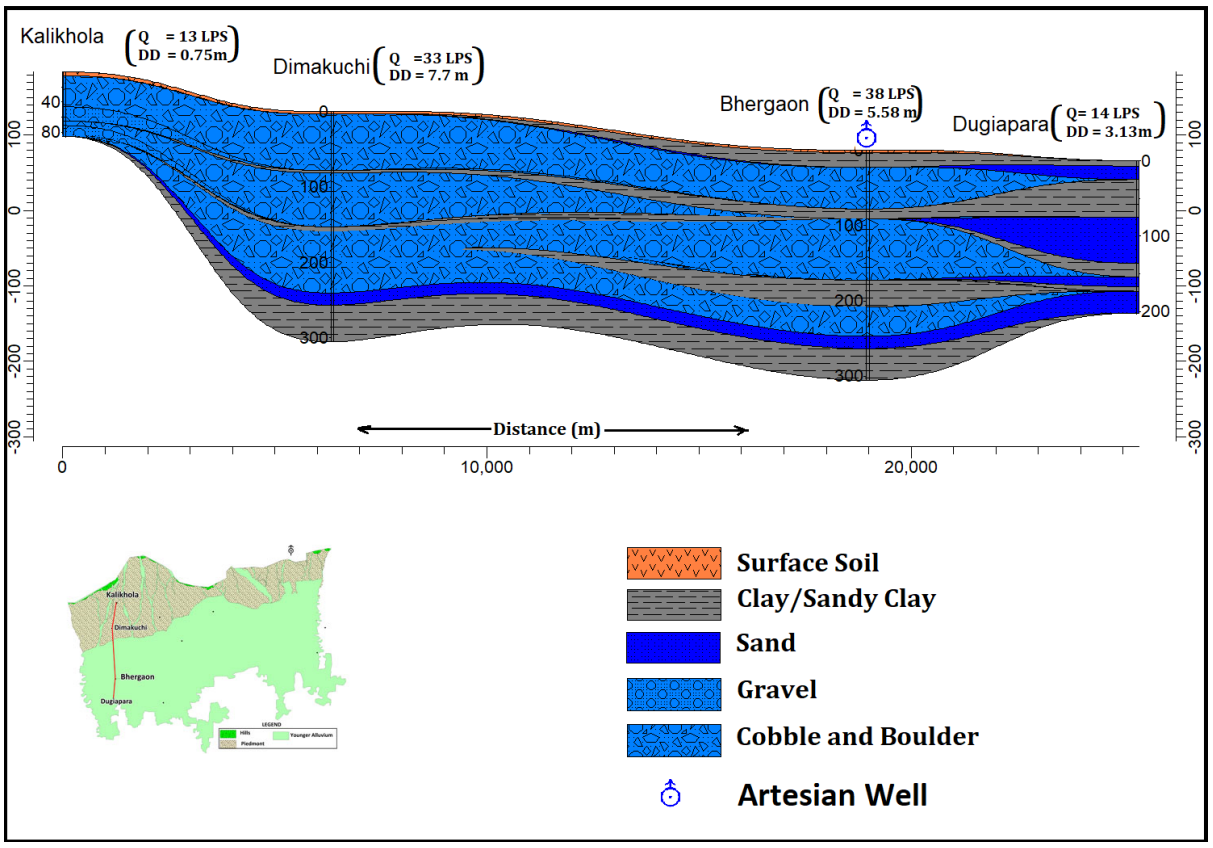


Fig. 3.1: 2D disposition of aquifer along N-S direction of the district.

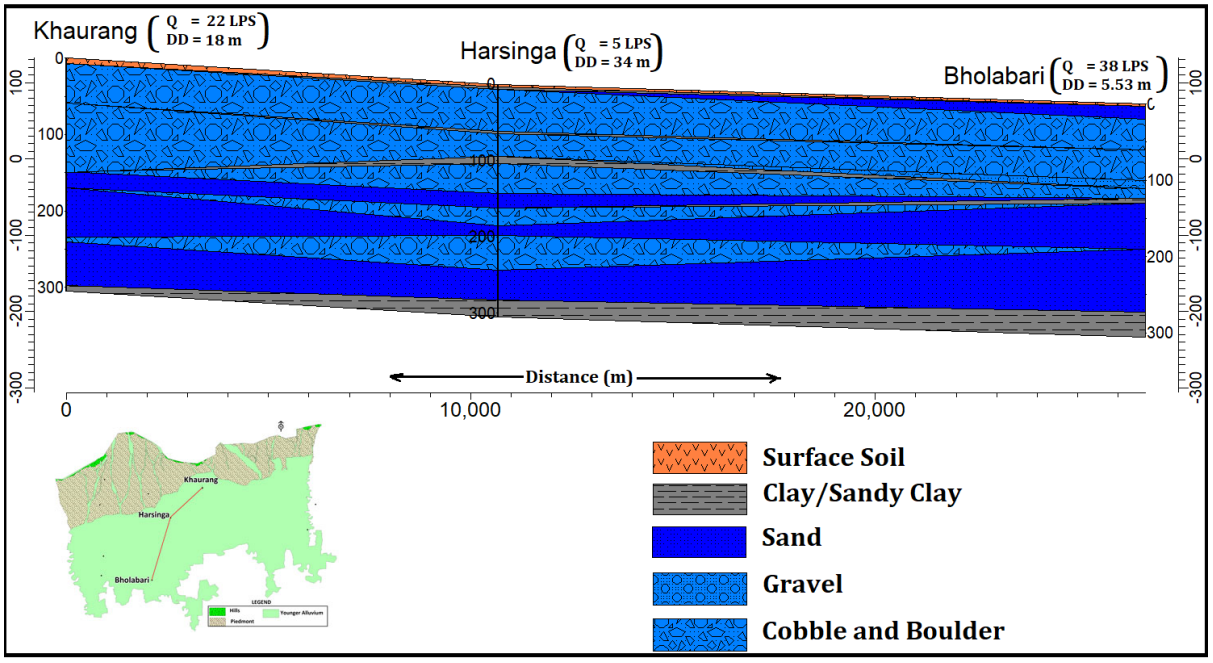


Fig. 3.2: 2D disposition of aquifer along NE-SW direction

Aquifer disposition along NW to SE direction is shown in Fig.3.3. Facies changes are noticeable in the section. The grain size is decreasing towards the south east part of the section. Gravel and sand is more towards the south east. Thin clay layers in the piedmont is pinched out towards SE. Two clay zones observed in Orang EW below 100m are pinched out towards SW.

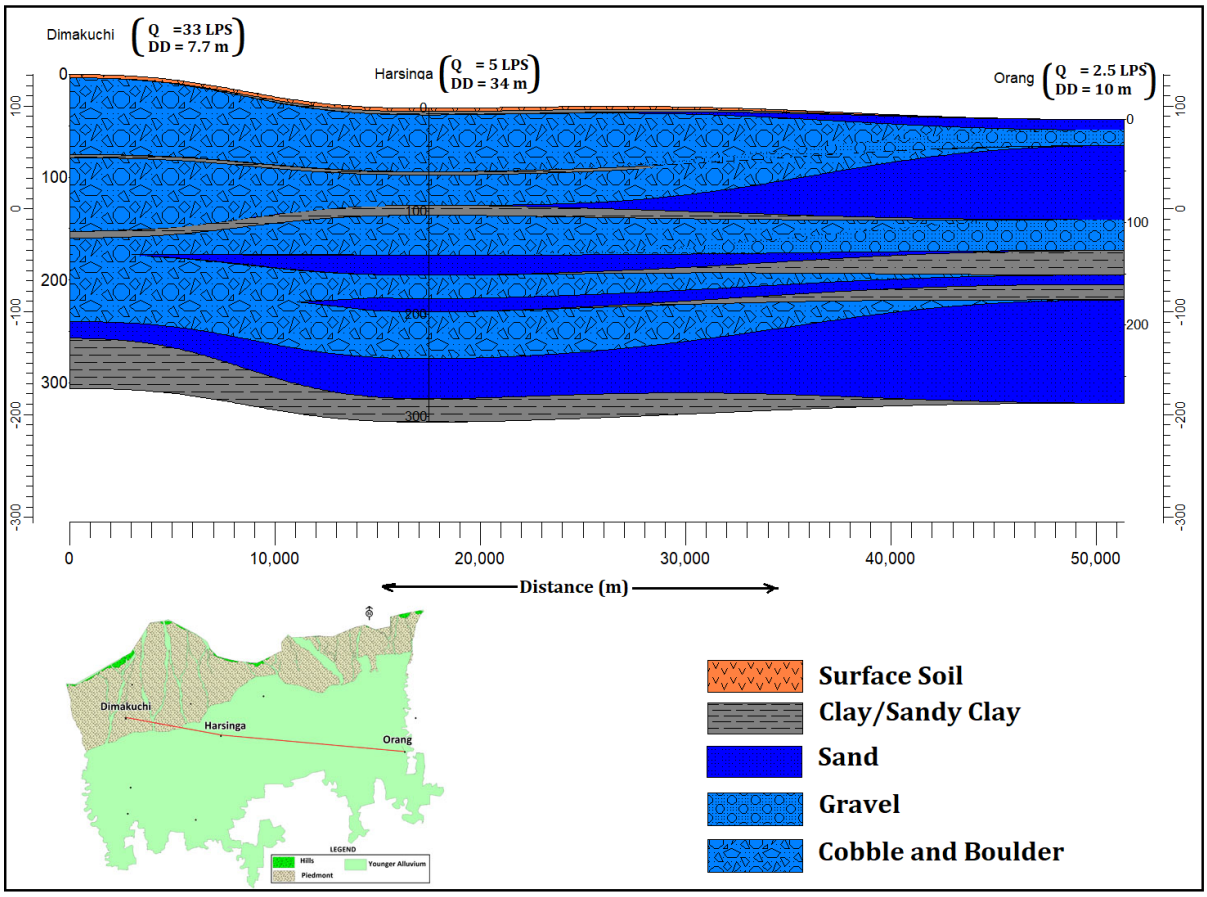


Fig.3.3: 2D disposition of aquifer along NW-SE direction

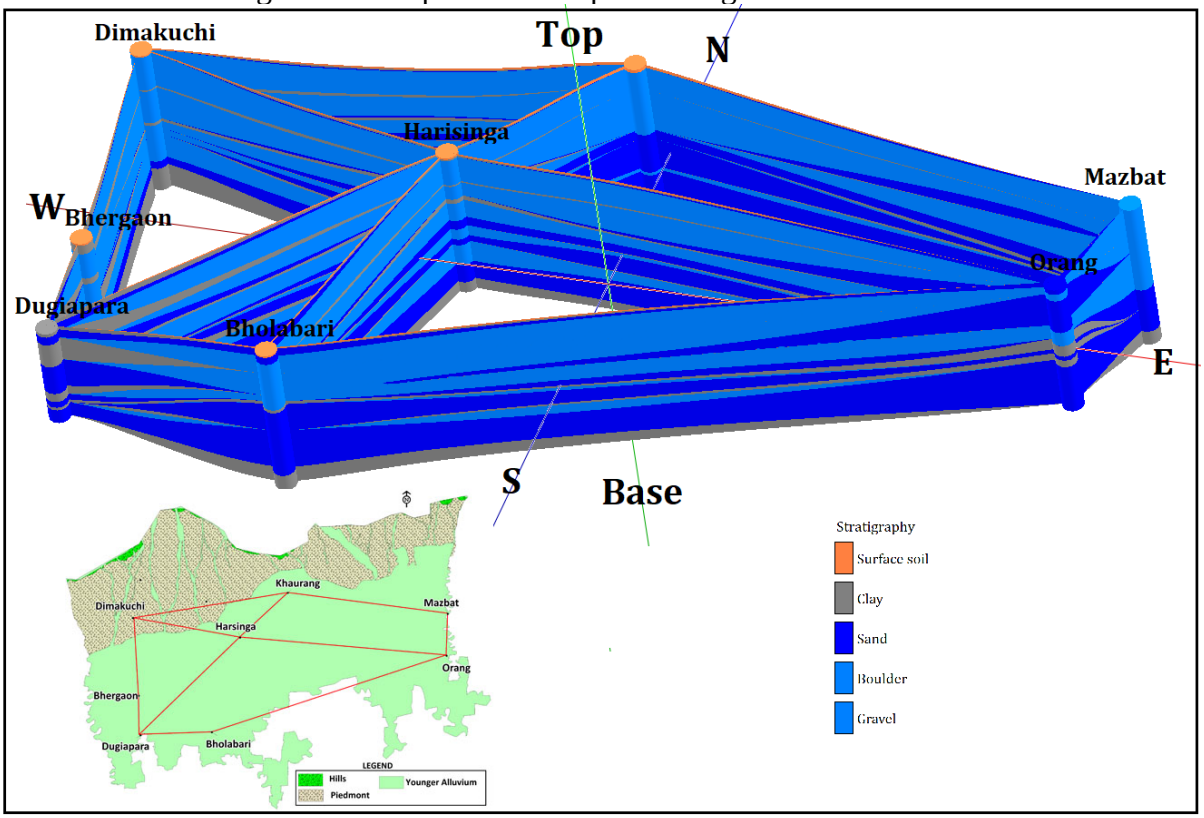


Fig. 3.4: 3D disposition of aquifer in Udalguri District, Assam

3D Disposition: The fence diagram of the district indicates that the subsurface formation in the piedmont is dominated by pebble, cobble and /or boulder down to a depth of 240m (Fig.3.4).Presence of boulder is noticed in the alluvial plain from surface down to 100m depth. Boulder zones are pinched out towards the southern boundary of the district.

Thick clay zones are encountered in the alluvial plain. However, these clay zones are not extensive throughout the district. Clay zones are generally found to pinch out. As a whole there exists a single aquifer system in the district. But wherever thick clay beds present locally it give rise to multi-aquifer system.

3.1.1 Aquifer Characteristics

Unconsolidated alluvial aquifer consists of older and younger alluvium. Older alluvial aquifer is found towards north in the piedmont zone.

The alluvial aquifer is characterized by coarse grained materials ranging in size from gravel to boulder. Bouldery zones are encountered almost in the entire district barring the extreme southern part of the district bordering Darrang. Size of the aquifer materials generally decreases towards south. Broadly the aquifer in the district can be classified into two groups for ground water extraction purposes, viz., shallow aquifer and deeper aquifer. Shallow aquifer depth limit is 50m and below which deeper aquifer exists. The cumulative thicknesses of both shallow and deeper aquifers are given in Table 3.1.

Table 3.1: Granular zones encountered in exploratory wells in Udalguri District, Assam

S.N.	Location	Depth drilled (mbgl)	Aquifer zone (m)	Cumulative thickness of granular zones (m)	
				GL to 50	50 to 300
1	Koirabari	75.8	33-45, 63-69	12	6
2	Kalikhola	85.34	46.33-56.84, 65.22-77.71, 79.84-82.89	3.67	22.38
3	Orang	276	45.95-70.73, 76-98, 99-105, 112-118, 138-145	4.05	62.73
4	Harsinga	70.6& 305.5	25-34,35-75-40.11, 42.11-46.49, 60.92-66.40, 145-151, 174-180, 220-226, 245-251, 265-271	17.74	35.48
5	Dimakuchi	65& 305.5	30.5-35.36, 37.51-53, 56.12-61.92, 110-116, 128-134, 143-149, 160-166, 192-198, 267-273	17.35	44.8
6	Khoirajungle	70.15	39.32-50. 54.20-70.15	11.24	15.95
7	Mazbat	67.1& 305.5	25.60-34.71, 47.24-49.37, 58.50-188.50, 201.50-214.50,230.75-243.75, 253.50-260.00,269.75-276.25	11.24	169
8	Bhergaon	305	22.75-78, 91.00-100.75,107.25-149.50, 182.00-188.50, 208.00-247.00	27.25	125.5
9	Khaurang	305	6.5-201, 234.00-253.5,	43.5	170.5
10	Bholabari	305	9.75-29.25, 52.00-100.75, 110.50-123.50, 156.00-178.75, 211.25-243.75, 250.25-273.00	19.50	139.75
11	Dugiapara	202	7-25, 75-101, 117-136	19	45
12	Bhutiachang	48.74	18.30-41.45, 41.75-45.42	26.82	

Shallow aquifer zone: The granular zones occurring down to a depth of 50m depth can be categorized as shallow aquifer zones. Cumulative thickness of granular zones within 50m varies from 4 to 27m (Table 3.1). However, shallow tube wells are not feasible in the piedmont zone owing to the boulder nature of the aquifer. Towards the south of piedmont deposit shallow tube wells are feasible. Directorate of Geology & Mining had constructed one shallow tube well of 49m depth at Bhutiachang. The discharge of the tube well is 74.4m^3/hr for a drawdown of 0.86m.

Deeper Aquifer Zone: The granular zones occurring below 50m can be categorized as deeper aquifer zones.Based on available information it can be confirmed that 30 to 60m cumulative thickness of granular zones are available.

The aquifers zones below 50m are in most cases are continuation of shallow zones. The zones are generally pebble, cobble and boulder mixed with sand invarying proportions. In the piedmont area boulders are dominant up to 250m while in the alluvial plain it is found below 100m in most of the exploratory wells except in the southern boundaries of the district. In the alluvial plain sand and gravels are found below the boulder zones. Clay of considerable thickness is present towards the western part of the district. However, the clay layers are localized.

Groundwater within this depth range occurs under semi-confined to confined condition as storativity value ranges from $2.7x10^{-3}$ to $7.36x10^{-5}$. Transmissivity value ranges from 129 to 5515m^2/day. Discharge varies from 27m^3/hr to 487m^3/hr. for drawdown of 1.48 to 12.53. Drawdown more than 10m is found in Missamari and Phulguri area due to poor sorting and clayey sand nature of aquifer materials. Permeability varies from 13 to 174m/day except in Missamari area where the value is 4m/day.

Table 3.2: Aquifer Properties Of Deeper Aquifer Zones

SN	Location	Depth drilled (mbgl)	Zone tapped (m)	DTWL (mbgl)	Discharge (m^3/hr)	DD (m)	T (m^2/day)	P (m/day)	S
1	Orang	276	45.95-70.73, 76-98,99-105, 112-118, 138-145	2.48	216	10.12	1875	34	
2	Harsinga	305.5	145-151, 174-180, 220-226, 245-251, 265-271	0.53	19.188	33.96	9.13	0.13	-
3	Dimakuchi	305.5	110-116, 128-134, 143-149, 160-166, 192-198, 267-273	8.94	138.06	7.70	4316.65	38.03	$5x10^{-4}$

SN	Location	Depth drilled (mbgl)	Zone tapped (m)	DTWL (mbgl)	Discharge (m^3/hr)	DD (m)	T (m^2/day)	P (m/day)	S
4	Mazbat	305.5	122-128, 136-142, 204-210, 239-245, 253-259, 269-273	3.85	11.12	16.41	210.94	1.18	$4.33x10^{-5}$
5	Bhergaon	305.5	91-97,115-121, 182-188, 206-212, 227-233	-0.63	138.06	5.58	1825.23	38.83	-
6	Khaurang	305.5	118-124, 145-151, 157-160, 184-190, 197-200, 243-249	7.05	78.58	17.95	1000	9.17	$2.49x10^{-3}$
7	Bholabari	305.5	159-165, 213-219, 230-236, 252-258, 272-278	5.42	138.08	5.53	5491.59	68.64	$6.27x10^{-4}$
8	Dugiapara	202	84-90, 123-129	2.05	48.6	3.13	4971	44	$2.28x10^{-4}$
9	Kalikhola	85.34	51.81-62.78, 65.83-76.80, 80.45-82.28	36.73	45.9	0.75			
10.	Khoirajungle	70.15	40.55-49.69, 55.18-68		67.50	1.20	270	11.81	

The depth to water level in the major part of the district generally lies between 2 to 13 m bgl. The northern part of the district is occupied by the piedmont zones and is having deeper depth to water level. The movement of ground water is southerly towards Brahmaputra river. The water table contour follows the topography of the area and lies more or less parallel to the Brahmaputra River. The hydraulic gradient becomes gentler towards south.

3.1.3 Depth To Water Level of the shallow aquifer

A total of 35 dug well were established as key well for periodical monitoring to know the ground water level trend and its behavior in phreatic condition. The depth to water level in these dug well ranges from 0.70mbgl to 12.8mbgl during post monsoon and 1.00 to 13.4 mbgl during pre-monsoon season. In the piedmont area, deeper water level is observed both during pre and post-monsoon seasons. The pre-monsoon depth to water level map is shown in Fig 3.5 and post monsoon depth to water level map is given in Fig.3.6.

Ground Water Movement: The water table contour of phreatic aquifer has been prepared based on water level data with respect to elevation of ground water monitoring stations from mean sea level (Fig. 3.7). The contour map shows that water table contour of Udalguri district varies from 140m to 70 m above mean sea level (Fig.3.10). In general groundwater

movement is towards south and conforms to the general topography of the district. The piedmont area recharges the aquifer and the rivers also contributes to the aquifer. The average hydraulic gradient in the piedmont is 6.14m/km whereas in the alluvial plain it is 3.49m/km.

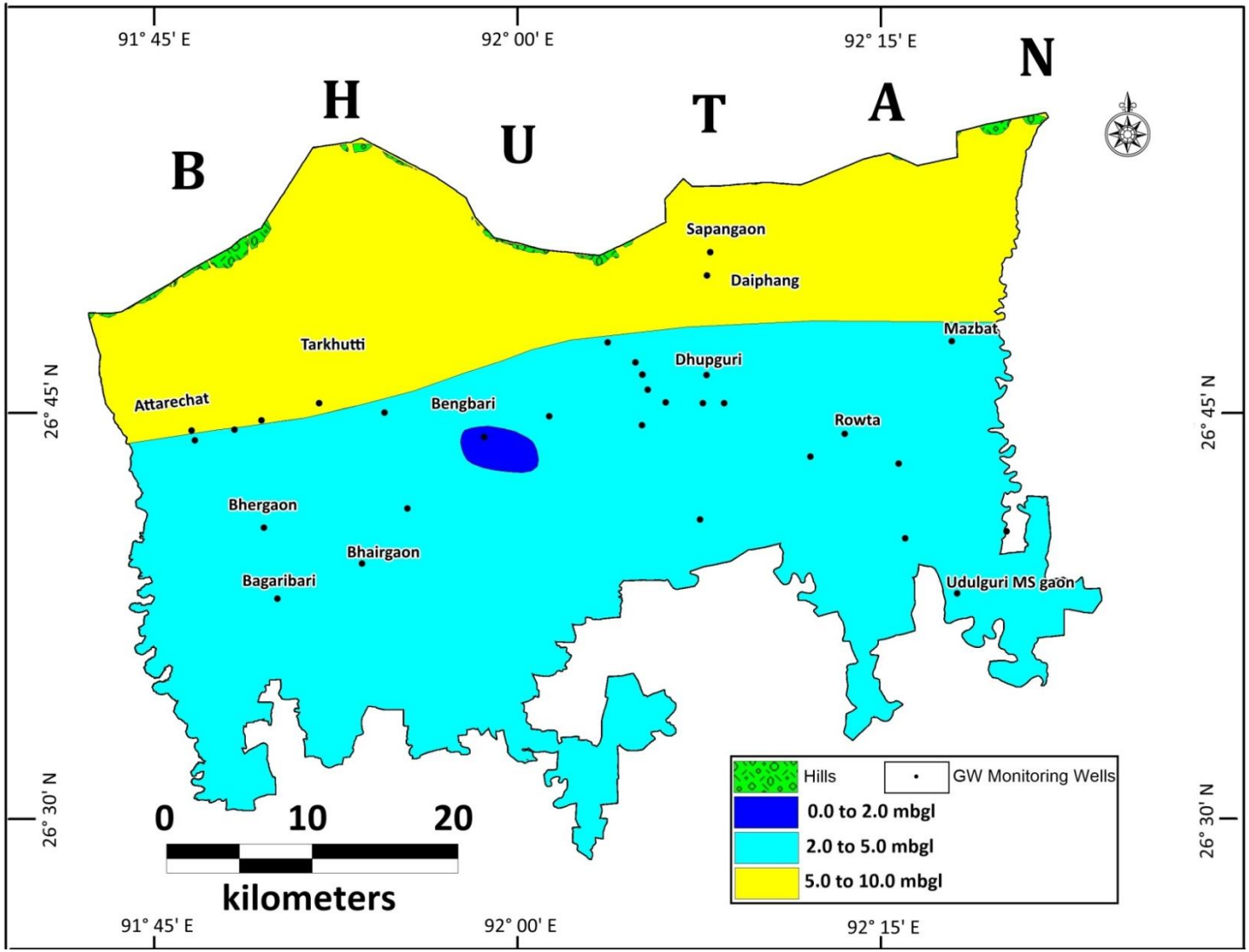


Fig. 3.5: Pre-Monsoon Depth to water level map

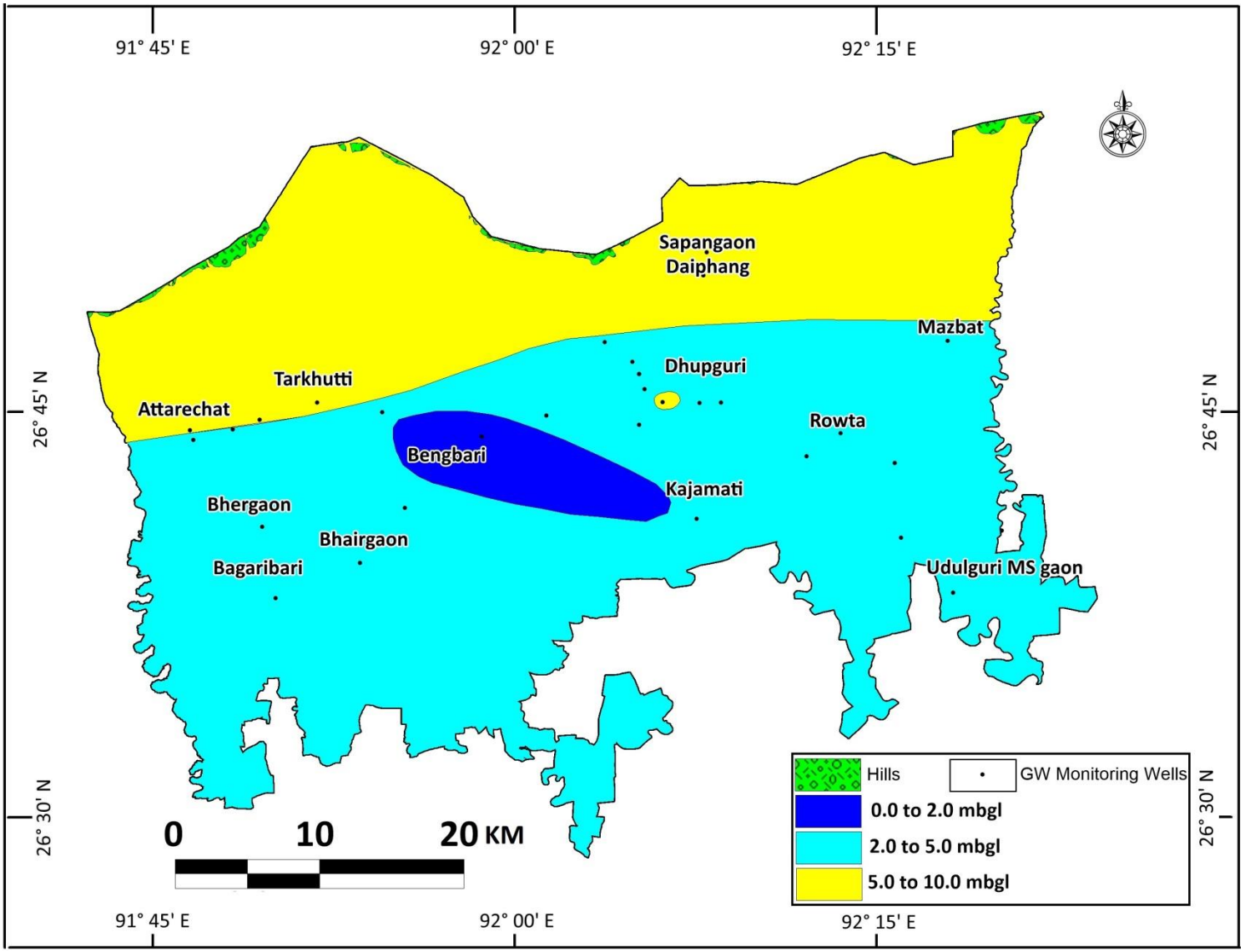


Fig.3.6: Post-Monsoon Depth to water level map

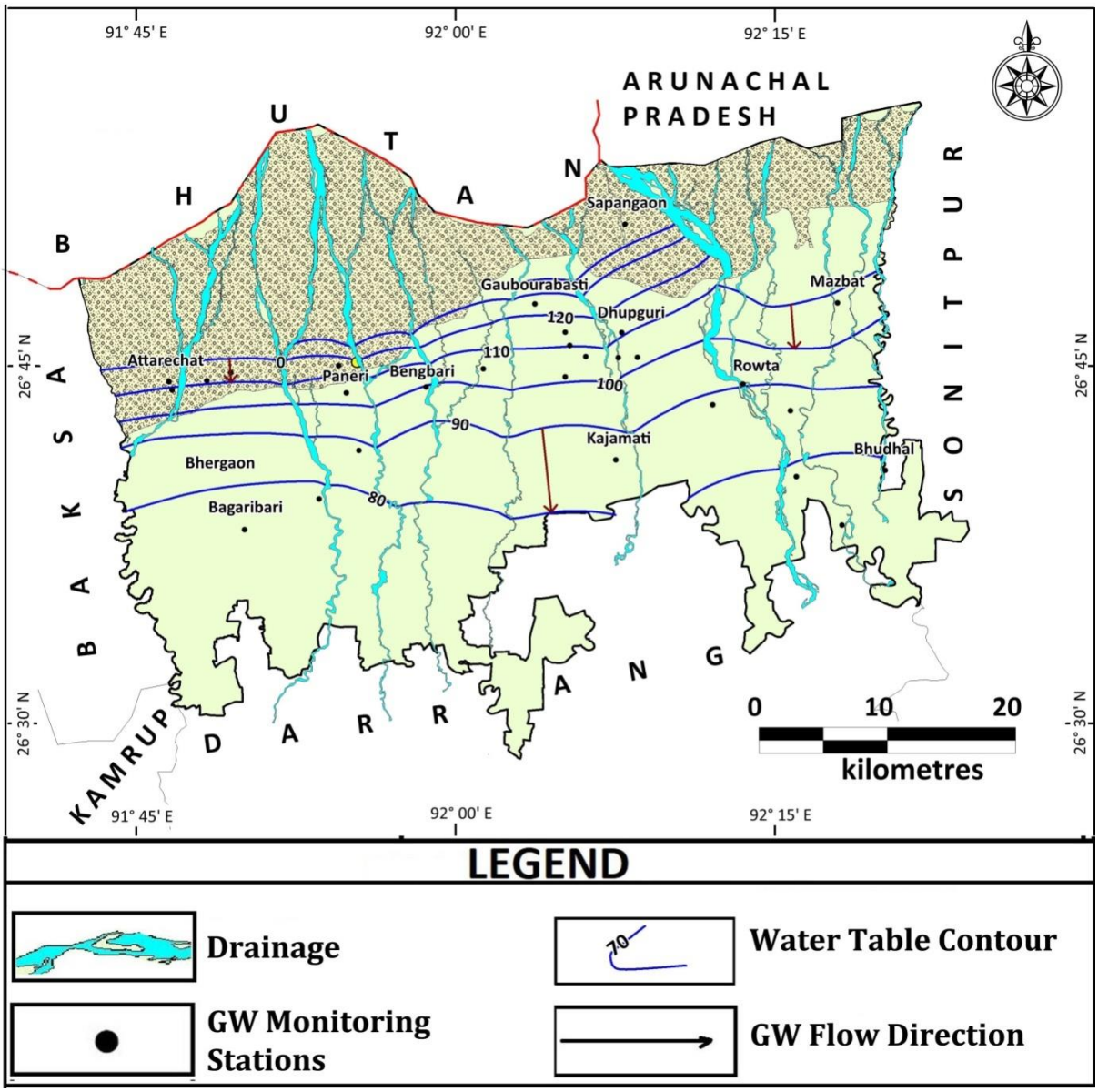


Fig.3.7: Water table contour map of Udalguri District, Assam

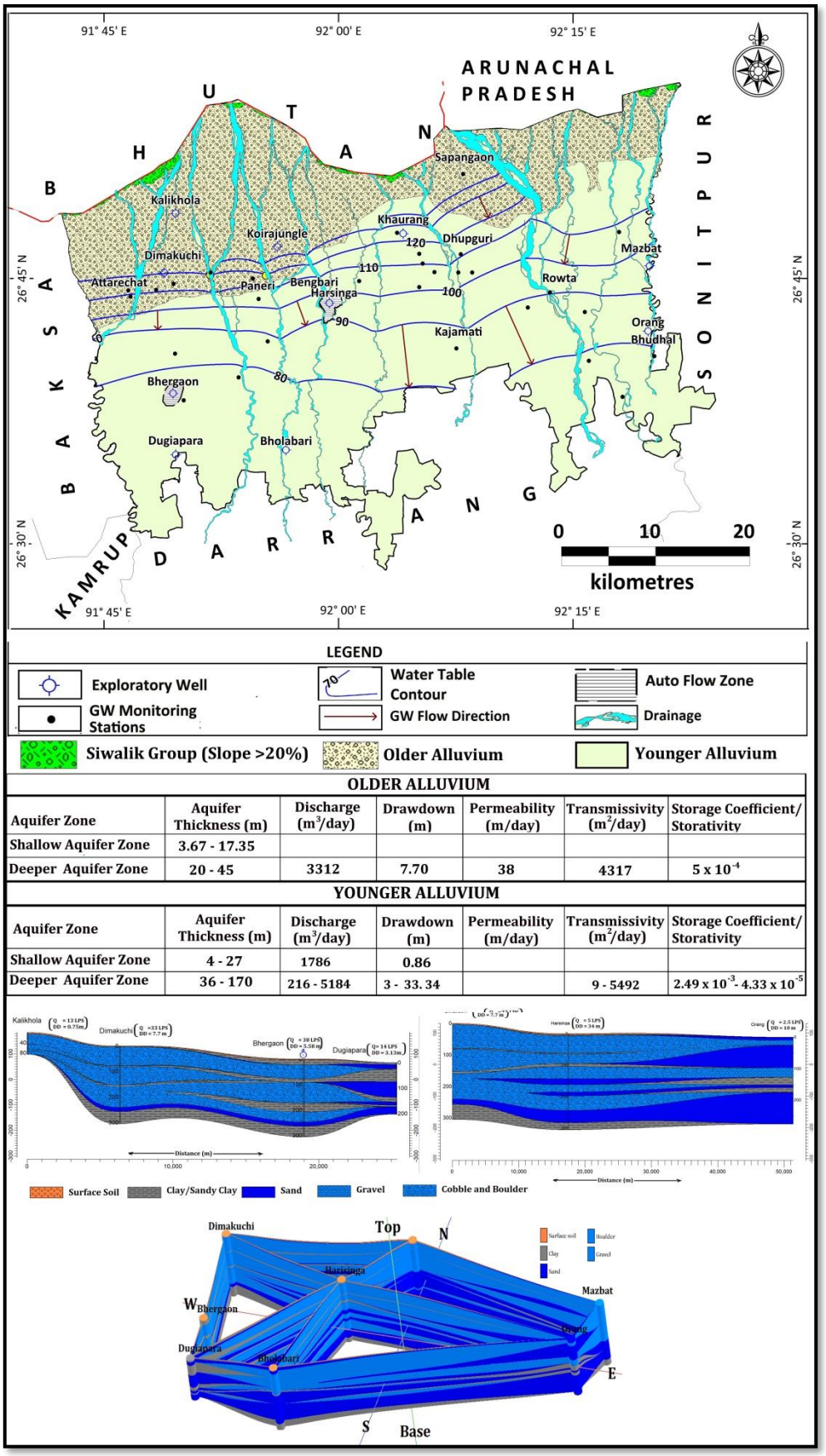
To study the piezometric head, tube wells drilled by Central Ground Water Board and State government were monitored. The piezometric head ranges from 2.48mbgl at Orang to 6.89mbglatKhoiraijungle. The hydrogeological details of the tube wells are given in annexure 1 and the piezometric head is shown in table 3.3.

Table 3.3: PiezometricHeadof Tube Well

Aquifer	No. of tubewell monitored	Depth of the well (mbgl)	Piezometric head (mbgl)
Alluvium	6	65-305	2.48 to 6.89

3.1.4 Water Level Trend

In the district, there are 12 Ground Water Monitoring Stations (GWMS). The historical water level data of GWMSwere analyzed and it was found that the water level maintain more or less a steady state except a few. The depths to water level were monitored throughout the year and the detail result is given in annexure 4.



OLDER ALLUVIUM

Aquifer Zone	Aquifer Thickness (m)	Discharge (m^3/day)	Drawdown (m)	Permeability (m/day)	Transmissivity (m^2/day)	Storage Coefficient/ Storativity
Shallow Aquifer Zone	3.67 - 17.35					
Deeper Aquifer Zone	20 - 45	3312	7.70	38	4317	5×10^{-4}

YOUNGER ALLUVIUM

Aquifer Zone	Aquifer Thickness (m)	Discharge (m^3/day)	Drawdown (m)	Permeability (m/day)	Transmissivity (m^2/day)	Storage Coefficient/ Storativity
Shallow Aquifer Zone	4 - 27	1786	0.86			
Deeper Aquifer Zone	36 - 170	216 - 5184	3 - 33. 34		9 - 5492	2.49×10^{-3} - 4.33×10^{-5}

Fig.3.8: Aquifer map of Udalguri District, Assam

3.3: Hydrochemistry

In order to study the chemical quality, water samples from representative dug well, and deep tube wells were collected during the course of field work during pre-monsoon and post monsoon studies. The parameters analyzed are pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, Na, K, HCO_3, NO_3, F, Ca, Mg, TH and Fe. The details of chemical analysis were given in the Annexure 3.

3.3.1: Ground Water Quality Of Unconfined Aquifer

A total of 48number of ground water samples from dug wellwere collected during pre and post-monsoon studies and therange of concentration of different chemical constituent present in the dug wells are given in table 3.4

Table 3.4: Chemical quality of GW samples from dug well

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range		BIS (IS 10500-91)	
		Min	Max	Desired Limit	Max Permissible Limit
1	pH	6.761	8.35	6.5 to 8.5	No relaxation
2	EC (µS/cm at 25°C)	89.96	770.5		
3	Turbidity(NTU)	0.1	0.4		
4	TDS	46.13	493.12	500	2000
5	CO_3	0	60		
6	HCO_3	35.028	158.7269		
7	TA as $CaCO_3^*$	35.028	175.14		
8	Cl	7.09	173.705	250	1000
9	SO_4	4.416	87.1935	200	400
10	NO_3	0	15.9377	45	100
11	F^-	0.09	0.81	1.00	1.5
12	Ca	9.968	89.972	75	200
13	Mg	1.200971	26.68835	30	100
14	TH	40	165	300	600
15	Na	2.09	85.31		
16	K	1.12	69.5		
17	Fe	0.0299	5.5118	0.3	1.0

It is deciphered from table 3.7that all of the chemical parameters are within permissible limit for all uses except for Iron concentration.

3.3.3: Ground Water Quality In Confined Aquifer

A total of 9 number of water samples were collected from hand pump/tube well in the district. Based on chemical analysis data therange of concentration of different chemical constituent present in the deeper aquifer are given in table 3.6.

Table 3.5: Chemical Quality Of Water Samples From Hand Pump

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range	
		Min	Max
1	pH	7.2	8.11
2	EC (µS/cm at 25°C)	134.1	225
3	Turbidity(NTU)	0	0.5
4	TDS	79.35	119.4
5	CO_3	0	0
6	HCO_3	40.032	109.8878
7	TA as $CaCO_3^*$	40.032	109.8878
8	Cl	10.635	46.085
9	SO_4	3.4157	26.8254
10	NO_3	0	13.7103
11	F^-	0.14	0.56
12	Ca	10.008	49.972
13	Mg	2.412621	12.12913
14	TH	55	85
15	Na	3.94	22.36
16	K	1.31	12.5
17	Fe	0.0941	5.4536

It can be inferred from above table that except iron, other parameters are within the permissible limit. Table 3.7 shows the concentration of Ironin Ground water.

Table 3.6: Concentration Of Iron In Ground Water

Type of Structure	No. of Sample analysed	Conc. of Iron (mg/ lit)	
		> 1	Percentage
Dug well	48	9	19%
HP/tube well	9	8	89%

From the above table, the concentration of iron beyond permissible limit is found only in 9 dug wells and 8 hand pump/tube well. The range of Iron concentration in dug well ranges from 0.029 to 5.5 mg/l and in hand pump it ranges from 0.094 to 5.45 mg/l.

3.3.4 Hydro-geochemical Facies

Piper plots are very powerful tools for visualizing the relative abundance of common ions in water samples. A piper plot is comprised of three components: a ternary diagram in the lower left representing cations (magnesium, calcium, and sodium plus potassium), a ternary diagram in the lower right representing anions (chloride, sulfate, and carbonate plus bicarbonate), and a diamond plot in the middle which is a matrix transformation of the two ternary diagrams (Fig.3.8).

Suitability for Irrigation: The preliminary investigation of the ground water by deploying piper diagram, it can be infer that the HCO_3^- and CO_3^{2-} ion are the dominant anion with no

dominant cation in the ground water. Overall the water is mixed type with some Magnesium-Bicarbonate characteristic.

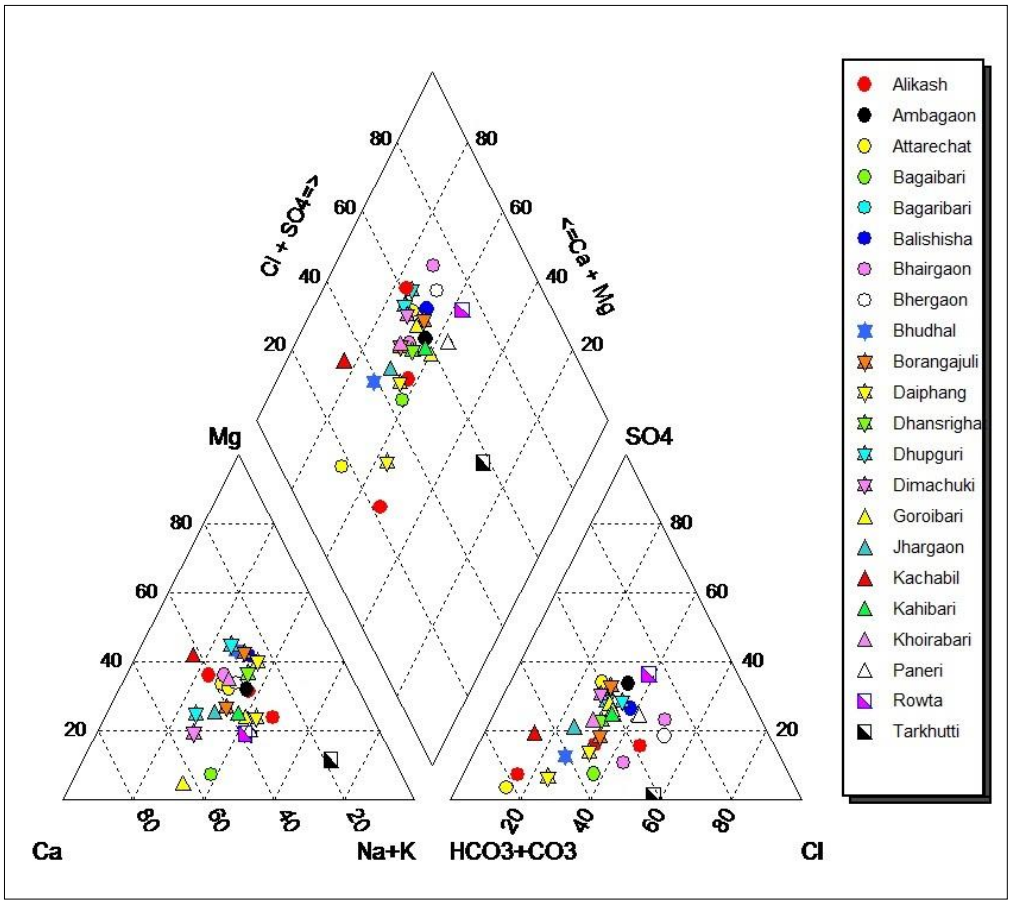


Fig.3.8: Piper plot of chemical analysis of GW samples

The overall irrigational water quality of the collected samples from the district is assessed by using water quality indices Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), Permeability Index (PI), Sodium Percentage (Na%), Kelly Ratio (KR) and USSL salinity diagram. The calculated indices for the district are shown in the table 3.7.

Table 3.7 Irrigation Indices

Location	SAR	MH	RSC	PI	Na %	KR
Khoirabari	1.31	45.37	-0.38	105.59	47.78	0.88
Bhergaon	0.46	49.94	0.13	89.24	37.11	0.29
Borangajuli	0.55	33.22	0.33	88.85	45.64	0.41
Attarechat	0.8	49.94	0.38	83.81	36.23	0.51
Dimachuki	0.59	46.61	0.6	72.65	28.46	0.34
Bagaibari	0.74	46.61	-0.22	91.25	31.02	0.42
Bhairgaon	0.81	11.67	0.06	82.87	38.51	0.44
Alikash	0.43	46.99	0.88	62.16	23.42	0.23
Paneri	0.69	61.47	0.56	76.3	32.14	0.43
Tarkhutti	0.5	49.93	0.94	61.36	27.79	0.28

Location	SAR	MH	RSC	PI	Na %	KR
Ambagaon	0.64	49.94	0.38	82.63	32.29	0.41
Daiphang	0.65	49.94	0.63	74.06	32.29	0.42
Dhupguri	0.29	59.95	0.35	75.54	27.74	0.17
Kahibari	0.56	61.05	0.65	68.78	30.19	0.29
Goroibari	0.72	39.92	0.6	74.1	32.99	0.41
Bhairgaon	0.71	61.85	0.46	71.05	35.41	0.35
Bagaribari	1.12	41.59	-0.2	99.11	43.1	0.73
Alikash	0.73	55.5	0.65	70.83	34.18	0.39
Tarkhutti	0.5	59.95	0.76	66.85	25.29	0.29
Borangajuli	0.45	33.26	0.68	68.49	25.38	0.26
Attarechat	0.58	26.57	0.6	72.59	27.5	0.34
Kachabil	0.54	7.06	0.5	75.66	31.7	0.32
Ambagaon	0.81	39.93	0.26	91.08	39.83	0.57
Dhupguri	0.54	36.75	0.59	68.93	30.42	0.28
Daiphang	0.33	49.93	0.8	60.02	15.98	0.16
Goroibari	0.86	39.92	0.51	77.4	37.16	0.5
Balishisha	0.57	49.93	0.61	71.22	29.62	0.32
Rowta	1	35.64	0.5	79.89	42.84	0.6
Dhansrighat	0.86	33.26	0.84	69.33	42.44	0.5
Jhargaon	2.35	66.61	-0.34	68.06	54.07	0.91
Bhudhal	3.46	39.06	-1.25	86.51	70.49	1.61

It is evident from the Table 2 that the SAR value of the groundwater in the district varies from a minimum of 0.29 to a maximum of 3.46, which falls in the excellent category in the SAR scale, suggesting no risk in terms of SAR value. The MH index for the suitability of irrigation reveals around 23% of the location has MH value higher than the critical value of 50%, rendering unsuitability of the ground water for irrigation. The locations with higher value of MH are Jhargaon, Bhairgaon, Paneri, Kahibari, Tarkhutti, Dhupguri and Alikash. The RSC of the ground water suggests excellent quality for irrigation. The ground water of the district falls in the good to suitable range for irrigation in terms of the permeability index (PI). The Na% index divulges about 74% of the ground water falls in the good category for irrigation, 19% falls in the poor category, around 3% each in excellent and doubtful category. The Kelly's ratio of the ground water in the district renders suitability of the water for irrigation. Although, the ground water is needed to be treated for Mg and Na hazard, largely the groundwater of the district is found to be suitable for irrigation, which is also evident from the USSL salinity diagram

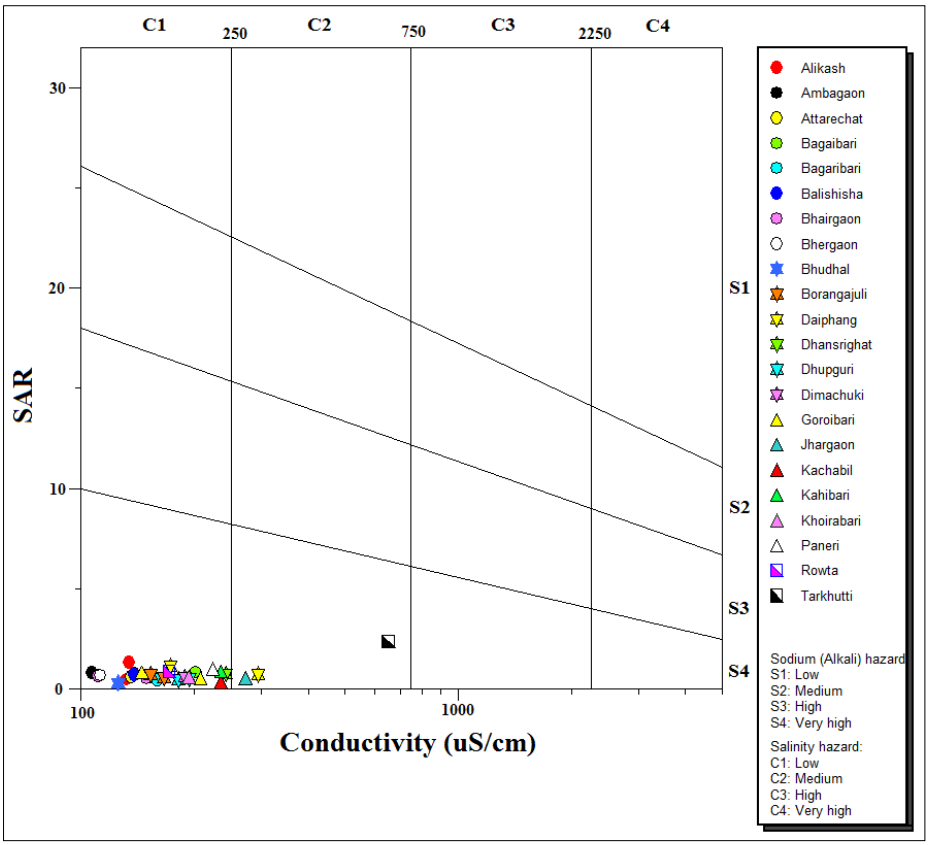


Fig.3.9: USSL Salinity diagram

CHAPTER 4.0

GROUNDWATER RESOURCES

Dynamic Groundwater Resources of the district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The Ground water Resource Potential for the district as on March 2020 is as follows.

Table 4.1: Net Ground Water Availability (Ham)

Total GW recharge				Total annual ground water recharge	Environmental Flow (ham)	Net Annual Ground Water Availability (ham)
Monsoon season		Non-monsoon season				
Rainfall recharge	Recharge from other source	Recharge from rainfall	Recharge from other source			
37653	5576	22261	1602	67093	3354	63738

Table 4.2: Categorization of Ground Water Resources (Ham)

Annual Extractable GW Resources	Annual GW extraction				Domestic uses up to 2025	Ground water availability for future use	Stage of ground water extraction (%)
	Irrigation	Domestic extraction	Industrial extraction	Total			
63738	4467	3376	366	8209	3540	58652	12.88

The stage of Ground Water extraction is defined as the ratio between the existing gross ground water drafts for all uses by net annual ground water availability multiplied by 100. The various units of assessment are categorized based on the stages of Ground Water development and long term trend of pre and post monsoon water level. The stage of ground water extraction for the district as on March 2020 is 12.88%. Based on the stages and development and long-term water level trend analysis the district can be categorized under safe category.

CHAPTER 5.0

GROUND WATER RELATED ISSUES

Major groundwater related issues found in the district are low stage of ground water extraction. As per ground water resource estimation March 2020, the stage of ground water extraction is only12.88%. At present the irrigation practice by utilizing ground water (constructing tube well) is not practice in large scale by individual villagers due to small land holding, high cost for construction and running of a well compared to production outcome. Moreover, dry season agriculture land remains fallows and the current cropping intensity is 150%.Another major obstacle in accelerating ground water irrigation is the absence of power lines in most of the cultivated/cultivable area and meager irrigational infrastructure in major parts of the district.

Groundwater in the shallow aquifer is infested with iron (Fig. 5.1). Moreover, it was found that ground water in the deeper aquifer has moderately high concentration of iron which needs to be treated before consumption.

Water logged areas are found in the alluvial plain/ flood plain where the depth to water level varies within 2.0 mbgl in pre-monsoon. The approximate water logged areas/ prone to water logging is 45 km².

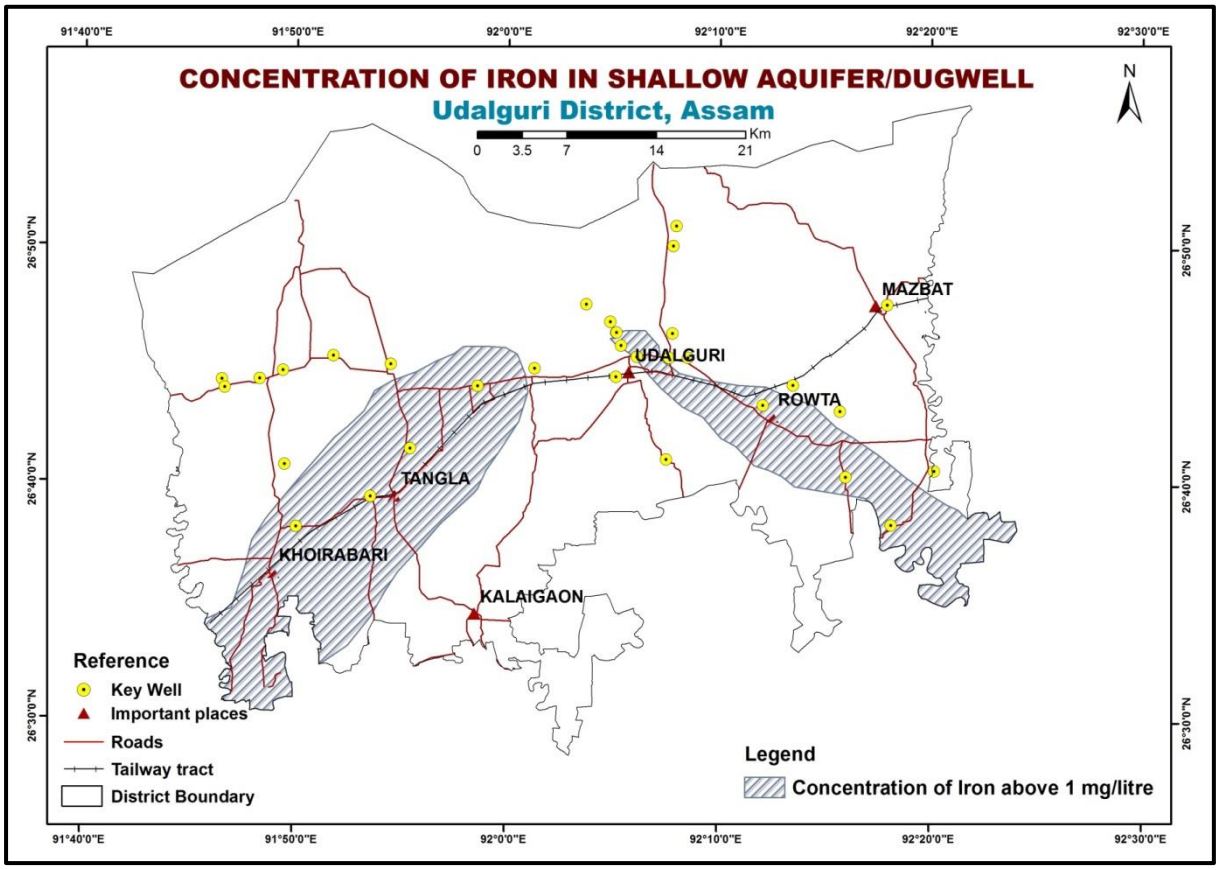


Fig. 5.1: Concentration of iron in shallow aquifer

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 management of the ground water resources has to be taken up after understanding the varied hydrogeological characteristics. In addition, the development of ground water requires thorough understanding of the heterogeneity of the formation. The peneplained surfaces, buried pediments and valley fills are the most favorable localities for development of ground water. Structures such as dug well andtube well are the feasible ground water structures.

The objective of management is to utilize the available ground water resources to fulfill 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 demand of various sectors and adjusting the demand with available resource.

As per dynamic ground water resource of Udalguri district, net ground water availability is 63738ham and stage of ground water extraction is 12.88%. The district is having balance net ground water availability for future irrigation use in the tune of 58652ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 35191 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.

The net sown area in the district is **110200**ha, area sown more than once is**56330** ha and cropping intensity is about 151%. 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.

As per Agriculture Census 2015-16 (https://agcensus.dacnet.nic.in/DL/disttabledisplay6b.aspx), kharif paddy is cultivated in 65314 ha, of which 53418 ha is cultivated under rain fed condition and 11895 ha is under irrigated condition. After kharif crops were grown the area remains fallow during rabi season. The intention is to bring this fallow land of 53418 ha under assured irrigation during rabi season which will help to increase gross cropped area to 126420 ha and thereby increase cropping intensity up to 200%. 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.Crop sowing season has been taken from KrishiVigayan Kendra (KVK), Udalguri Contingency Plan and Packages of Practices for Rabi Crops of Assam (2015). The proposed cropping plan as used in CROPWAT 8.0 is shown in Table 6.1. Crop-wise and month-wise precipitation deficit has been estimatedusing CROPWAT after giving necessary meteorological, soil, crop plan inputs (Table 6.2).The precipitation deficits have been converted to volume of water by multiplying

crop area (in Ha) with precipitation deficit (mm) (Table 6.2).Proposed cropping pattern with water deficit months, IWR and peak water requirement for Irrigation in table 6.3.Crop-wise and month-wise Irrigation water requirement in ham has been further calculated in table 6.4.

Table 6.1 Cropping pattern and proposed cropping pattern in the district

CROPPING PATTERN DATA

(File: H:\Office_Lockdown 2021\NAQUIM Reports\NAQUIM 2019-20\Processed NAQUIM Reports2019-20\Management Plan\Udalguri_Rice.PAT)

Cropping pattern name: Udalguri_Winter Rice

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1	...Data\CROPWAT\data	Rice	15/05	11/09	5
2	...Data\CROPWAT\data	Rice	30/05	26/09	10
3	...Data\CROPWAT\data	Rice	10/06	07/10	17
4	...Data\CROPWAT\data	Rice	05/07	01/11	13
5	...Data\CROPWAT\data	Rice	30/07	26/11	5
6	...a\CROPWAT\data\cr	Pulses	10/11	27/02	5
7	...a\CROPWAT\data\cr	Pulses	20/11	09/03	5
8	...ata\CROPWAT\data\	MAIZE (Grain)	20/10	21/02	5
9	...CROPWAT\data\crop	Winter Wheat f.f.	05/11	02/07	3
10	...\CROPWAT\data\cro	Potato	25/10	03/03	2
11	...\CROPWAT\data\cro	Potato	15/11	24/03	5
12	...PWAT\data\crops\F	Mustard	20/10	01/06	6
13	...PWAT\data\crops\F	Mustard	30/10	11/06	2
14	...CROPWAT\data\crop	Small Vegetables	30/09	02/01	2
15	...CROPWAT\data\crop	Small Vegetables	10/11	12/02	6
16	...CROPWAT\data\crop	Small Vegetables	20/01	24/04	5
17	...a\CROPWAT\data\cr	MILLET	25/01	09/05	2
18	...a\CROPWAT\data\cr	MILLET	05/02	20/05	3

Table 6.2: Precipitation deficiency (mm) inUdalguri district, Assam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Rice	0	0	0	49.3	149.1	0	0	0	3.5	0	0	0
2. Rice	0	0	0	0.5	146.5	0	0	0	0	0	0	0
3. Rice	0	0	0	0	49.7	98	0	0	0	0	0	0
4. Rice	0	0	0	0	0	147.1	50.1	0	0	50.4	2.7	0
5. Rice	0	0	0	0	0	0.5	146.1	0	0	56.9	67.2	0
6. Pulses	72.6	16.7	0	0	0	0	0	0	0	0	21	41.6
7. Pulses	71.2	29.5	7.4	0	0	0	0	0	0	0	10.3	28
8. MAIZE (Grain)	71.7	7.3	0	0	0	0	0	0	0	1	35.6	60.3
9. Winter Wheat f.f.	53.2	20.8	83.5	8.8	0	0	2.1	0	0	0	45.7	37.5
10. Potato	72.3	22.9	3.4	0	0	0	0	0	0	5.6	40.2	55.5
11. Potato	71.2	35.8	54.8	0	0	0	0	0	0	0	19.6	32.8
12. Mustard	59.2	21.7	75.8	3.5	0	1.6	0	0	0	4.5	51	49.1
13. Mustard	59.2	21.7	75.8	3.5	0	1.6	0	0	0	2.5	39	48
14. Small Vegetables	3.8	0	0	0	0	0	0	0	2.5	23.9	72.8	55.1
15. Small Vegetables	66.1	15.9	0	0	0	0	0	0	0	0	37.2	47
16. Small Vegetables	18.5	12.8	87	8.3	0	0	0	0	0	0	0	0
17. MILLET	4.6	2	79.2	5.1	0	0	0	0	0	0	0	0
18. MILLET	0	0	69.4	5.1	0	0	0	0	0	0	0	0

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

Crop	Area (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total IWR (Ham)
1. Rice	5	0	0	0	263	796.5	0	0	0	19	0	0	0	1078.51
2. Rice	10	0	0	0	5.34	1565	0	0	0	0	0	0	0	1570.49
3. Rice	17.5	0	0	0	0	929.2	1832	0	0	0	0	0	0	2761.45
4. Rice	12.5	0	0	0	0	0	1964	669.06	0	0	673.07	36.06	0	3342.64
5. Rice	5	0	0	0	0	0	2.67	780.44	0	0	303.95	358.97	0	1446.03
6. Pulses	5	387.81	89.21	0	0	0	0	0	0	0	0	112.18	222.22	811.42
7. Pulses	5	380.34	157.58	39.53	0	0	0	0	0	0	0	55.02	149.57	782.04
8. MAIZE (Grain)	5	383.01	39	0	0	0	0	0	0	0	5.34	190.17	322.11	939.63
9. Winter Wheat f.f.	3	170.51	66.67	267.62	28.2	0	0	6.73	0	0	0	146.47	120.19	806.39
10. Potato	2	154.48	48.93	7.26	0	0	0	0	0	0	11.97	85.9	118.59	427.13
11. Potato	5	380.34	191.24	292.73	0	0	0	0	0	0	0	104.7	175.21	1144.22
12. Mustard	5	316.23	115.92	404.91	18.7	0	8.55	0	0	0	24.038	272.43	262.28	1423.06
13. Mustard	2.5	158.12	57.96	202.45	9.35	0	4.27	0	0	0	6.6773	104.17	128.2	671.2
14. Small Vegetables	2.5	10.15	0	0	0	0	0	0	0	6.7	63.835	194.44	147.17	422.27
15. Small Vegetables	5	353.09	84.93	0	0	0	0	0	0	0	0	198.71	251.06	887.79
16. Small Vegetables	5	98.82	68.38	464.74	44.3	0	0	0	0	0	0	0	0	676.28
17. MILLET	2.5	12.29	5.34	211.54	13.6	0	0	0	0	0	0	0	0	242.79
18. MILLET	2.5	0	0	185.36	13.6	0	0	0	0	0	0	0	0	198.98

Table 6.4: Summarised result of crop water requirement ofUdalguri district, Assam

Cropping pattern (s)				
	Present Cultivated area	Area to be cultivated	Area to be cultivated (**ha**)	Irrigation requirement (**ha m**)
Rice-Wheat-Vegetables	(**ha**)	(**%**)		
Rice-Pulses				
Rice-Millet				
Rice-Rapseed Mustard				
	1	2 (= % of)	3	4
Rice (main crop)	53418	100	53418	10199.12
Pulses		20	10683.6	1593.46
Potato		14	7478.52	1571.35
Wheat		6	3205.08	806.39
Rapseed Mustard		15	8012.7	2094.26
Winter Vegetables		15	8012.7	1310.06
Summer Veg		10	5341.8	676.28
Maize		10	5341.8	939.63
Millet		10	5341.8	441.77
		100	53418	9433.2
Net cultivated area	53418	106836	53418	
Gross cultivated area (Paddy/+Maize/+Wheat+Pulses+ Millet)	53418		**106836**	
Total irrigation requirement				**29065.52**
With 70% irrigation efficiency				**41522.17**
Cropping intensity			**200% (Intended)**	

Table 6.5:Proposed cropping pattern with water deficit months, iwr and peak water requirement for irrigation

Crop	Growing period (Months)	Periods/months of water deficit	Irrigation requirement (ham)	Peak water requirement for Irrigation
Rice	4	1 – 2	11121	June
Mustard	5	4	2882	December
Vegetables	3	3	1812	March
Pulses	4	4	611	December
Maize	3	3	1990	December
Wheat	4	4	3538	Nov-December
	Total water requirement		21954	
	70% irr. Efficiency		31363	

The results of exploration carried out by Central Ground Water Board and State department pointed out that the sub-surface of major part of the district is dominated by highly permeable materials. The piedmont or bhabar zone is composed mostly of boulders, pebbles or cobbles. Due to its high porosity as well as permeability, shallow tube wells are not feasible in the piedmont zone. State government had constructed few shallow tube wells in the area. CGWB had also constructed few deep tube wells down to a depth of 300m. The results of exploration in the piedmont zone clearly indicates presence of productive zones within the depth range of 50 to 100m, 100-200m and 200-300m. Tube wells tapping 12m granular zone can give discharge of 40 to 45m^3/hr.

In the alluvial plain also shallow tube wells are very limited. State government had constructed one shallow tube well at Bhutiachang which tapped nearly 25m of granular zone to give discharge of 74m^3/hr for a drawdown of 0.86m. Although CGWB had not constructed any shallow tube wells in the district, presence of productive zones are observed during drilling of deep tube wells. Considering the results of exploration, it can be expected that shallow tube wells can give discharge of 40 to 70m^3/hr by tapping 15 to 25m granular zones.Thus the unit draft can be calculated by allowing a pump to withdraw water at a rate of 40 m^3/hrfor 8hr pumping per day. For 120 days pumping, the unit draft will be 3.84ham.

Therefore, to meet irrigation demand of **41522**ham, 10813 numbers of tube wellshave to be constructed. Considering 200m safe distance between two tube wells, 13355 numbers of tube wells can be constructed in the district. Hence to meet the irrigation demand of 31363 ham, it can construct 13355 numbers of tube wells in the district. In the piedmont zone, however, shallow tube wells are not feasible and as such it is suggested to construct tube wells of 100m depth tapping20 to 25m granular zones to get yield of 40 to 68m^3/hr.

In water logged areas (flood plain), shallow tube wells/dug well can be constructed.

In addition, groundwater in the district is infested with Iron in deeper aquifer in certain pocket of the district, therefore before consumption for domestic use, filtering/installation of Iron removal plant have to be adopted.

Annexure 1: Dynamic ground water level data of dug well key (key wells**)**

Sl.no	Name of village/site	Latitude	Longitude	RL (mamsl)	Depth of DW (mbgl)	Measuring point (magl)	Diameter	DTWL 06/2019	DTWL 08/2019	DTWL 12/2019	DTWL 03/2020
1	Bhairgaon	26.657	91.89333	113	5.3	1	0.7	2.3	2.33	2.41	3.7
2	Bagaribari	26.635	91.835	80	6.3	1.2	0.8	2.2	2.18	2.26	3.6
3	Alikash	26.691	91.92444	91	5.4	0.9	0.6	2.5	2.55	2.52	3.27
4	Tarkhutti	26.756	91.86361	132	12.3	1.05	0.6	7.8	7.89	7.91	8.1
5	Borangajuli	26.739	91.80556	113	5.3	1.1	0.7	4.2	4.19	3.8	4.75
6	Attarechat	26.739	91.77583	124	10.76	0.82	1	7.96	7.8	5.4	7.98
7	Kachabil	26.75	91.90861	130	3.01	1	0.8	2	2.05	2.11	3.9
8	Ambagaon	26.748	92.02194	112	5.8	1.1	1	3.05	2.96	4	4.4
9	Dhupguri	26.773	92.13028	120	4.31	0.95	0.95	3.41	3.55	3.88	3.9
10	Daiphang	26.834	92.13056	157	13.5	0.3	0.9	10.45	10.4	9.4	11.4
11	Sapangaon	26.849	92.13278	173	15.2	1.6	0.9	13.4	13	12.83	13.5
12	Goroibari	26.756	92.1425	113	4.27	1.07	1.05	3.06	3.05	3.12	3.4
13	Balishisha	26.723	92.20167	100	3	1.1	0.7	2.2	2.2	2.3	3.01
14	Rowta	26.737	92.22528	101	5.5	0.7	0.8	3.7	3.85	3.63	4.21
15	Dhansrighat	26.719	92.2625	93	6.7	0.8	1	2.03	2.09	2.01	2.69
16	Jhargaon	26.673	92.26694	84	4.94	0.65	0.75	2.11	2.13	2.15	2.89
17	Udulguri MS gaon	26.639	92.30278	79	6.9	1.5	0.9	2.3	2.29	2.31	3.25
18	Bhudhal	26.677	92.33667	86	3.6	0.5	0.75	1.92	2.01	2.05	2.71
19	Mazbat	26.793	92.29917	117	6.9	0.5	0.6	3.3	3.28	3.3	4.21
20	Kajamati	26.684	92.12568	76	6.2	1	0.8	2.3	2.01	2.12	2.98
21	Bhergaon	26.679	91.82571	79	8.5	1	0.9	3.6	2.8	3.65	4.21
22	Paneri	26.726	91.145	102	3.7	1.2	0.6	2.41	2.2	2.3	3.27
23	Dimachuki	26.745	91.82404	124	12	1	0.8	6.45	6.22	6.2	7.58
24	Manpur	26.764	92.0897	111	10.05	1.1	0.9	4.32	4.3	4.5	4.75
25	Jungle bourigaon	26.781	92.0814	154	8	0.9	0.8	2.85	2.88	3	2.5

Sl.no	Name of village/site	Latitude	Longitude	RL (mamsl)	Depth of DW (mbgl)	Measuring point (magl)	Diameter	DTWL 06/2019	DTWL 08/2019	DTWL 12/2019	DTWL 03/2020
26	Gaubourabasti	26.793	92.06229	118	11.5	0.8	0.89	4.55	4.54	4.5	3.42
27	Khaurang	26.773	92.08606	114	8.9	1.1	1.02	3	2.3	3.02	3.6
28	NalbariPragatipur	26.756	92.10217	117	8	1	0.65	3.98	6.5	4.05	6.77
29	Kahibari	26.756	92.12768	86	3.9	0.9	0.86	3.3	3.1	3.3	3.42
30	Sukhlai	26.733	91.77818	101	9.3	1.2	1	3.9	3.72	4.2	5.1
31	Bengbari	26.735	91.97725	121	2.1	0.3	0.8	1	0.9	0.7	0.8
32	Paneri (TE)	26.782	91.142	103		0.9	0.8	4.6	4.02	3.69	4.7
33	Chandana	26.774	92.08613	118	8.2	0.7	1.6	3.3	3.01	2.51	3.3
34	Sapkaiti	26.742	92.086	112	3.83	0.84	0.95	3.77	3.24	2.78	3.83
35	Rowmari	26.279	91.7689	105	3.7	0.9	0.8	2.92	2.56	1.99	2.9

Annexure 2: Ground water monitoring data of NHNS well

S. No	Well No	Block	Village	Lat	Long	Well Type	MP	RL	Depth	Dia	DTWL (mbgl) March-19	DTWL (mbgl) Aug-19	DTWL (mbgl) Nov-19	DTWL (mbgl) Jan-20
1	ASDR31	Udalguri	Goroibari	26.75	92.14	DUG	0.90	49.00	3.60	0.80		1.33	2.51	
2	ASDR28	Udalguri	Thekerabari.1	26.66	91.91	DUG	0.80	53.00	6.80	0.75	4.90	3.36		
3	ASDR03	Udalguri	Bengbari	26.73	91.96	DUG	1.00	101.00	5.60	1.00		3.08	4.68	5.15
4	ASDR04	Rowta	Bhalukmari	26.70	92.24	DUG	0.82	45.00	6.10	0.85	3.38	2.48	4.50	5.04
5	ASDR12	Mazbat	Hatitopagaon	26.77	92.31	DUG	0.76	52.00	5.40	0.70	4.03	3.14	4.30	4.80
6	ASDR13	Kalaigaon	Kalaigaon	26.57	91.98	DUG	0.77	65.00	8.00	0.50		1.19	2.15	2.36
7	ASDR17	Rowta	Madhupur	26.64	92.17	DUG	0.90		5.80	0.70	3.50	2.75		
8	ASDR21	Mazbat	Orang	26.70	92.34	DUG	1.20		5.90	0.80	0.14	0.81		
9	ASDR22	Paneri	Paneri	26.73	91.96	DUG	0.95	99.00	4.80	1.00		3.25	3.31	4.11
10	ASDR24	Rowta	Rowtachariali	26.71	92.21	DUG	0.90		4.70	0.90	2.95	2.60	3.15	3.42
11	ASDR27	Udalguri	Token katta, Tangla	26.63	91.91	DUG	0.80	74.00	5.10	1.00		1.80	3.13	
12	ASDR29	Udalguri	Udalguri	26.75	92.10	DUG	0.70		4.00	1.00		1.60	3.00	3.44

Annexure 3: Ground water quality data in the district

Location	**Source**	**Date of sampling**	**pH**	**EC µS/cm at 25°C**	**Turbidity (NTU)**	**TDS**	**CO_3**	**HCO_3**	**TA as $CaCO_3$ ***	**Cl^{-1}**	**SO_4^{-2}**	**NO_3**	**F^-**	**Ca**	**Mg**	TH	**Na**	**K**	**Fe**
Khoirabari	HP	04.12.19	7.70	134.10	BDL	79.35	BDL	90.07	90.07	10.64	6.55	8.02	0.56	12.01	6.06	55.00	22.36	1.31	4.81
Bhergaon	DW	05.12.19	7.64	132.10	BDL	78.64	BDL	65.05	65.05	24.82	15.85	BDL	0.15	12.01	7.28	60.00	8.12	13.84	0.38
Borangajuli	DW	05.12.19	7.26	97.42	BDL	57.94	BDL	35.03	35.03	21.27	28.52	BDL	0.09	12.01	3.63	45.00	8.50	15.03	BDL
Attarechat	DW	05.12.19	7.38	106.90	BDL	63.67	BDL	50.04	50.04	21.27	30.37	BDL	0.13	12.01	7.28	60.00	14.17	2.55	BDL
Dimachuki	DW	05.12.19	7.45	135.80	BDL	80.79	BDL	55.04	55.04	21.27	37.07	BDL	0.16	16.01	8.49	75.00	11.71	3.40	BDL
Bagaibari	HP	05.12.19	7.79	138.30	0.20	82.10	BDL	105.08	105.08	10.64	3.42	BDL	0.35	16.01	8.49	75.00	14.64	1.47	4.11
Bhairgaon	HP	06.12.19	7.57	201.30	BDL	119.40	BDL	100.08	100.08	39.00	10.37	BDL	0.27	30.02	2.41	85.00	17.11	12.50	5.45
Alikash	HP	06.12.19	7.20	159.50	BDL	94.46	BDL	50.04	50.04	35.45	15.91	1.69	0.21	18.01	9.70	85.00	9.13	4.78	4.78
Paneri	DW	06.12.19	7.52	138.40	BDL	81.66	BDL	45.04	45.04	28.36	26.33	BDL	0.19	10.01	9.70	65.00	12.79	2.30	0.07
Tarkhutti	HP	07.12.19	7.39	149.20	BDL	88.56	BDL	40.03	40.03	42.54	26.83	1.43	0.14	16.01	9.70	80.00	10.18	6.73	0.09
Ambagaon	DW	07.12.19	7.39	111.30	BDL	66.28	BDL	50.04	50.04	28.36	9.32	BDL	0.12	12.01	7.28	60.00	11.33	3.10	0.90
Daiphang	DW	08.12.19	7.38	112.70	BDL	66.95	BDL	35.03	35.03	35.45	16.96	0.29	0.16	12.01	7.28	60.00	11.58	2.68	0.03
Dhupguri	DW	08.12.19	7.55	125.60	0.20	75.08	BDL	70.06	70.06	17.73	11.41	BDL	0.17	12.01	10.92	75.00	5.73	12.73	0.34
Kahibari	DW	08.12.19	7.68	165.80	BDL	98.94	BDL	70.06	70.06	28.36	20.88	BDL	0.45	14.01	13.34	90.00	12.18	9.68	1.01
Goroibari	DW	08.12.19	7.49	152.80	BDL	90.81	BDL	55.04	55.04	24.82	37.72	BDL	0.16	18.01	7.27	75.00	14.27	4.58	0.05
Bhairgaon	DW	11.06.19	8.10	294.90	BDL	188.74	BDL	100.08	100.08	35.45	20.14	2.64	0.29	16.01	15.77	105.00	16.68	16.58	4.09
Bagaribari	DW	11.06.19	7.98	172.90	BDL	110.66	BDL	85.07	85.07	17.73	6.23	0.30	0.38	14.01	6.06	60.00	20.03	1.46	4.31
Alikash	DW	11.06.19	7.92	242.30	BDL	155.07	BDL	70.06	70.06	28.36	27.89	2.26	0.32	16.01	12.13	90.00	15.96	9.37	2.92
Tarkhutti	DW	11.06.19	8.01	193.70	BDL	123.97	BDL	45.04	45.04	24.82	27.45	2.07	0.20	12.01	10.92	75.00	9.92	2.97	0.09
Borangajuli	DW	12.06.19	8.11	181.00	BDL	115.84	BDL	50.04	50.04	21.27	27.36	1.53	0.11	20.02	6.06	75.00	8.87	4.85	0.13
Attarechat	DW	12.06.19	8.16	188.20	0.30	120.45	BDL	55.04	55.04	21.27	31.58	1.86	0.17	22.02	4.84	75.00	11.62	2.48	0.09
Kachabil	DW	12.06.19	8.16	206.90	BDL	132.42	BDL	55.04	55.04	24.81	30.16	1.88	0.16	26.02	1.20	70.00	10.32	7.84	0.16
Ambagaon	DW	12.06.19	7.78	145.10	BDL	92.86	BDL	45.04	45.04	21.27	22.85	0.36	0.22	12.01	4.85	50.00	13.21	3.41	0.13
Dhupguri	DW	13.06.19	7.85	272.50	BDL	174.40	BDL	80.06	80.06	21.27	24.62	3.92	0.20	24.02	8.48	95.00	12.09	11.88	0.11
Daiphang	DW	13.06.19	8.09	234.50	BDL	150.08	BDL	85.07	85.07	10.64	19.54	15.9	0.33	22.02	13.34	110.00	7.99	2.76	0.13
Goroibari	DW	13.06.19	8.18	235.30	0.20	150.59	BDL	60.05	60.05	28.36	28.33	BDL	0.17	18.01	7.27	75.00	17.08	5.61	0.18
Balishisha	DW	14.06.19	7.85	192.90	BDL	123.46	BDL	60.05	60.05	21.27	23.00	8.12	0.48	16.01	9.70	80.00	11.71	6.39	4.01
Rowta	DW	14.06.19	8.10	223.10	0.20	142.78	BDL	55.04	55.04	39.00	31.34	0.95	0.26	18.01	6.06	70.00	19.20	8.35	0.41
Dhansrighat	DW	15.06.19	7.18	171.60	BDL	109.82	BDL	40.03	40.03	35.45	45.41	0.71	0.19	20.02	6.06	75.00	17.22	13.92	0.10
Jhargaon	DW	15.06.19	8.32	653.30	BDL	418.11	60.00	100.13	160.13	145.35	7.75	2.57	0.81	22.02	26.69	165.00	69.35	33.82	2.44

Location	Source	Date of sampling	pH	EC µS/cm at 25°C	Turbidity (NTU)	TDS	CO_3	HCO_3	TA as $CaCO_3$ *	Cl^{-1}	SO_4^{-2}	NO_3	F^-	Ca	Mg	TH	Na	K	Fe
Bhudhal	DW	15.06.19	8.35	770.50	BDL	493.12	40.00	135.14	175.14	173.71	4.42	2.29	0.25	28.02	10.91	115.00	85.31	69.50	BDL
Bhergaon	DW	11.03.2020	8.080	155.20	BDL	78.57	0.00	103.78	103.78	24.82	18.6449	0	0.16	24.97	6.06	60.00	11.25	11.19	0.5608
Barengajuli	DW	11.03.2020	7.956	115.70	0.20	58.29	0.00	42.73	42.73	17.73	30.1265	0	0.13	19.98	4.85	45.00	8.68	4.21	0.2111
Sukhai	DW	12.03.2020	8.065	173.20	BDL	87.75	0.00	67.15	67.15	31.91	26.7566	0.78	0.10	24.97	6.06	60.00	12.10	9.98	0.0672
Paneri TE	DW	12.03.2020	6.792	91.56	BDL	46.13	0.00	42.73	42.73	7.09	25.9579	0	0.22	14.98	3.64	40.00	7.95	1.52	0.077
Attarchat	DW	12.03.2020	6.761	106.80	0.30	53.67	0.00	48.84	48.84	10.64	26.2155	0	0.17	19.98	4.85	45.00	6.64	2.43	0.0465
Kachabil	DW	12.03.2020	6.831	127.80	BDL	65.06	0.00	67.15	67.15	14.18	28.8223	0	0.23	19.97	4.85	55.00	10.91	5.11	0.1705
Paneri II	DW	12.03.2020	6.996	146.20	BDL	75.85	0.00	85.47	85.47	10.64	36.3587	0	0.28	19.97	4.85	60.00	18.24	2.15	0.0411
Alikash	DW	12.03.2020	7.042	247.20	BDL	126.50	0.00	109.89	109.89	42.54	87.1935	9.58	0.24	74.98	18.20	100.00	2.09	1.33	3.3836
Bengbari	DW	12.03.2020	7.210	213.30	BDL	107.90	0.00	109.89	109.89	28.36	25.0843	0	0.35	39.97	9.70	80.00	7.17	5.35	5.5118
Ambagaon	DW	12.03.2020	7.144	98.92	0.20	50.01	0.00	42.73	42.73	24.82	49.4303	4.25	0.17	24.98	6.06	45.00	18.75	2.24	1.7162
Goraibari	DW	12.03.2020	7.382	151.50	0.10	77.55	0.00	103.78	103.78	17.73	16.8924	0	0.25	9.97	2.42	50.00	27.22	24.30	0.1931
Kahibari	DW	13.03.2020	7.333	242.60	BDL	123.90	0.00	134.31	134.31	28.36	26.7583	0	0.65	39.97	9.70	80.00	17.46	13.71	0.8112
Dhupguri	DW	13.03.2020	7.392	157.10	BDL	80.21	0.00	73.26	73.26	28.36	12.7694	0	0.18	24.98	6.06	45.00	6.06	17.09	0.6651
Daiphang	DW	13.03.2020	7.731	130.30	0.30	67.21	0.00	67.15	67.15	14.18	19.3085	0	0.32	19.98	4.85	50.00	6.07	3.01	0.1367
Manpur	DW	13.03.2020	7.621	209.20	BDL	108.60	0.00	85.47	85.47	39.00	27.0897	0	0.21	29.97	7.27	65.00	21.87	10.37	0.0752
Chandana	DW	13.03.2020	7.494	194.20	0.40	99.45	0.00	109.89	109.89	35.45	6.8125	0	0.23	19.96	4.84	70.00	21.50	15.04	1.6855
Jungle Baurigaon	DW	13.03.2020	7.455	132.90	BDL	68.46	0.00	54.94	54.94	17.73	30.9303	0	0.25	19.98	4.85	40.00	4.47	14.72	0.1873
Khaurang	DW	13.03.2020	7.149	89.96	BDL	46.80	0.00	48.84	48.84	14.18	18.0864	0	0.09	19.98	4.85	40.00	4.02	3.43	0.0603
Gauburabasti	DW	13.03.2020	8.059	556.90	0.10	292.60	0.00	158.73	158.73	67.36	59.4655	8.69	0.22	89.97	21.84	125.00	2.15	1.21	2.4178
Udalguri	DW	13.03.2020	7.539	335.60	BDL	174.50	0.00	73.26	73.26	70.90	26.5913	12.5	0.17	59.98	14.56	90.00	3.07	1.12	0.3371
Sapkaiti	DW	13.03.2020	7.677	175.00	BDL	91.36	0.00	97.68	97.68	21.27	21.4753	2.68	0.21	39.97	9.70	80.00	2.34	1.62	0.1132
Rowmari	DW	14.03.2020	7.606	233.40	BDL	122.60	0.00	61.05	61.05	67.36	33.493	0.27	0.10	29.97	7.27	65.00	24.84	14.81	0.5248
TanglaGaon	HP	13.03.2020	7.407	225.00	0.50	118.00	0.00	103.78	103.78	46.09	24.0445	13.7	0.24	49.97	12.13	85.00	7.36	3.89	5.0117
Bagaribari	HP	14.03.2020	7.665	183.40	BDL	97.13	0.00	109.89	109.89	17.73	4.9391	1.02	0.26	29.97	7.27	65.00	7.38	3.68	4.4524
Umananda	HP	15.03.2020	7.367	193.10	0.30	100.60	0.00	103.78	103.78	17.73	16.9542	5.11	0.38	34.97	8.49	70.00	3.94	2.44	3.1468
Khairabari	TW	18.10.2020	8.11	181.70	0.00	93.13	0.00	95.08	95.08	17.73	14.15	0.00	0.28	10.01	9.70	70.00	14.34	4.93	2.81

PHOTOGRAPHS

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