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

IMPHAL WEST DISTRICT, MANIPUR

उत्तर पूर्वी क्षेत्र, गुवाहाटी
North Eastern Region, Guwahati

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केंद्रीय भूमि जल बोर्ड

Ministry Of Water Resources, River Development & Ganga Rejuvenation

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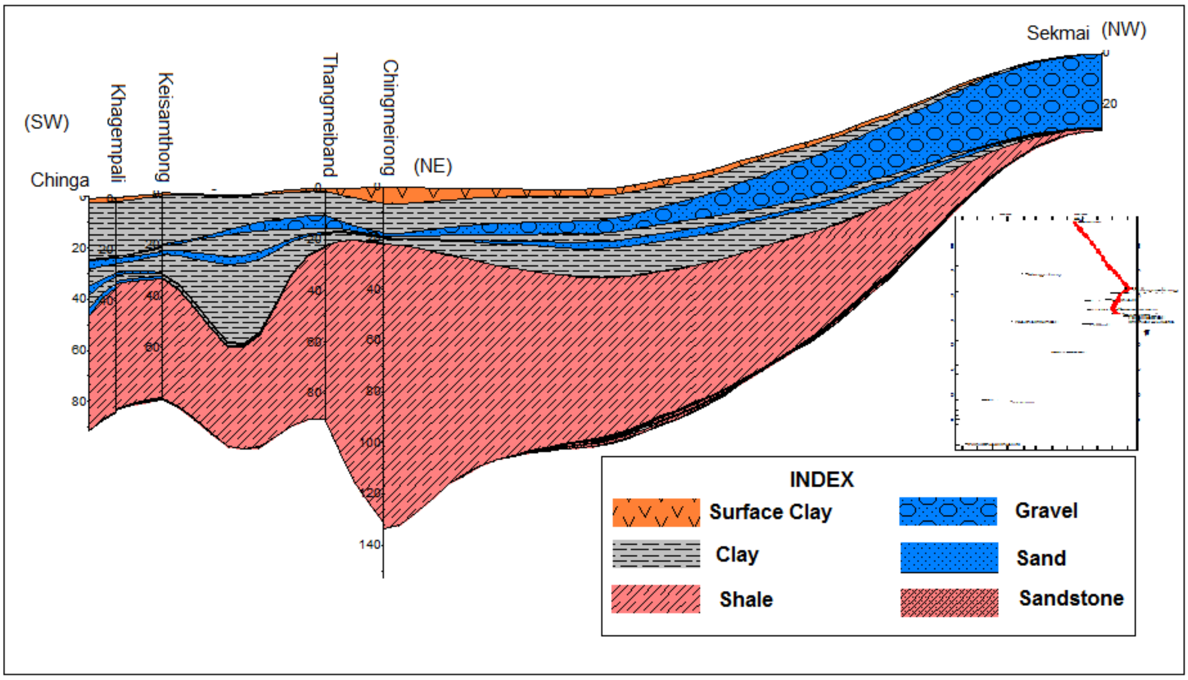

AQUIFER MAPPING AND MANAGEMENT PLAN OF IMPHAL WEST DISTRICT, MANIPUR
(AAP 2017-18)

NORTH EASTERN REGION

उत्तरपूर्वीक्षेत्र

GUWAHATI

गुवाहाटी

GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI, DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT
ON

"AQUIFER MAPPING AND MANAGEMENT PLAN OF IMPHAL WEST DISTRICT, MANIPUR"

(AAP 207-18)

By
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CENTRAL GROUND WATER BOARD
NORTH EASTERN REGION
GUWAHATI

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 Imphal West district of Manipur. The objective was to understand the aquifer system down to the depth of 300 meters, decipher the aquifer geometry, its characteristics, quantity, quality and 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.

The study of the Aquifer mapping and management plan of Imphal West district was carried out under the guidance and supervision of Regional Director, CGWB, NER, Guwahati, Technical Secretary to RD, CGWB, NER, Guwahati and Nodal officer, 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, Regional Director, CGWB, NER, Guwahati for his support and guidance during the course of study.

I render my sincere thanks to my supervisor Shri Tapan Chakraborty, Nodal officer of NAQUIM, NER and Shri Biplap 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 inputs 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, Minor Irrigation Department, Water Resources 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
AMP	Aquifer Management Plan
AQM	Aquifer Mapping
BIS	Bureau of Indian Standards
BDL	Below detectable level
BCM	Billion Cubic Metres
CGWB	Central Ground Water Board
DGM	Directorate of Geology and Mining
DTWL	Depth to water table
DW	Dug Well
°C	Degree Celsius
EC	Electrical Conductivity
EW	Exploratory Well
GEC	Ground water Estimation Committee
GL	Ground Level
GIS	Geographic Information System
GSI	Geological Survey of India
Ha	Hectare
Ham	Hectare meter
IMD	Indian Meteorological Department
IPD	Investigation & Planning Division
Km	Kilometre
LPM	Litres per minute
LPS	Litres per second
m	Metre
MASTEC	Manipur Science and Technology Council
Magl	Meter above ground level
mbgl	Meters below ground level
MCM	Million Cubic Meter
Mm	Milli meter
mg/l	milligram/litre
mamsl	Metre above mean sea level
MP	Measuring Point
MID	Minor Irrigation Department
µS/cm	Microsimens/centimetre
NAQUIM	National Aquifer Mapping and Management Plan
NER	North Eastern Region
OW	Observation Well
PHED	Public Health & Engineering Department
Ppm	Parts per million equivalents to mg/l
Pz	Piezometer
Sq.Km	Square Kilometre
SWL	Static water level
TDS	Total dissolved solid
TW	Tube Well
VES	Vertical Electrical Sounding
WRD	Water Resources Department

EXECUTIVE SUMMARY

Aquifer Mapping studies and Management Plan has been carried out in Imphal West district, Manipur 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 extend 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 519 sq.km. The district is bifurcated from old Imphal district forms a part of the small intermontane valleys located within the North Latitudes $24^{o}30^{/}$ & $25^{o}\ 00^{/}$ and East Longitudes $93^{o}\ 45^{/}$ & $94^{0}15^{/}$. The district is bounded on the north by the Senapati district, on the south by Thoubal and Bishnupur districts, on the east by Imphal East and in the west by Senapati and Bishnupur districts. The district with its headquarters at Lamphelpat (Imphal city) has 2 blocks (Imphal West I and Imphal West II) 4 sub-divisions, 10 Circles and 133 villages.

The district shows three prominent units i.e. a tiny plain topography, hilly areas and marshy land in the southwestern periphery. The valley is surrounded in all sides by hill ranges of denudostructural nature trending NNE-SSW direction. A number of isolated hillocks of denudational remnants are found within the valley. Main rivers draining are Imphal River, Nambul River and their tributaries. The district is fertile and is mainly made up of alluvial soil of recent origin. The valley was once full of swamps and marshy lands.

The district enjoys sub-tropical humid climate. Average annual rainfall in the area is 1632.4 mm. About 60 to 65 % of the annual precipitation is received during south-west monsoon from June to September. Annual average temperature of the study area is recorded to be 20.4^{0}C and the temperature ranges from 0^{0}C to 36^{0}C. The relative humidity is high. Records of rainfall in the study area are available for the periods of last fifty years. The average annual rainfall for last ten years at Imphal is 2511.69 mm (as per IMD, Airport data).

Groundwater occurs both under the unconfined and confined conditions. Groundwater in top clayey and sandy formation occurs under water table conditions. Groundwater in the deeper aquifer occurs under sub-artesian and artesian conditions. The shallow aquifers are under unconfined condition and the static water level is 15.88 mbgl to 0.69 m, agl. Groundwater in deeper layers is semi-confined to confined with static water level from 4.36 mbgl to 0.32 magl during pre-monsoon and 4.7 mbgl to 0.22 during post monsoon. Granular zones are encountered at depth of about 60 m to 100 m in Imphal valley.

The water table contour map reveals that flow of ground water is towards SW part of the valley towards Loktak Lake. The highest elevation of groundwater level is found in the northern extremity of the valley. In the northern part of the study area, the level of groundwater is found to be 842 mAMSL (around Awang Sekmai in Imphal West I). The shallow water level depth is found towards the central parts of the study area and extends towards south and lies below772 mAMSL (around Shamurou) adjacent to the marshy lands of Loktak Lake.

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 and development and long-term water level trend analysis the district can be categorized under safe category.

The total annual groundwater recharge of Imphal West district is 8729.2 ham, while 4664.3 ham is for Imphal West I block and 4064.9 ham is for Imphal West II block respectively. The annual extractable ground water resource of the district is worked out as 7856.3 ham after deducting the Environmental flows. The existing current annual gross ground water extraction for all uses is 166.24 ham of which 105.5 ham is the current annual gross ground water extraction for irrigation use, 54.89 ham is the current gross ground water extraction for domestic use and 6.0 ham is the current gross ground water extraction for industrial uses. The stage of groundwater extraction of Imphal west district is 2.12 %. As such all the assessment units falls under Safe category.

Groundwater related problems of the district so far been identified is emanation of gas while construction of deep tube wells and existence of clayey deposit down to a depth range of 30 to 50 mbgl which invites problem for construction of tube wells. As such utmost care has to be taken during construction of tube wells so that any untoward incident can be averted.

Other 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.

The district is having meager irrigation facility. Available unirrigated land of 21559 ha can be brought under irrigation using the dynamic groundwater resources available in the district. It is proposed to bring 60% of area under paddy and 40% under non-paddy cultivation. Water requirement for paddy cultivation (Δ=1.2 m) would be 15573.18 ham while that for non-paddy cultivation (Δ=0.3 m) would be 9799.30 ham. Total water requirement to bring this entire uncovered area under irrigation is 25372.3 ham.

Development of rainwater harvesting for the drinking water supply is also one of the appropriate measures for solving the scarcity of potable water as it involves relatively low cost, less time for implementation and provides almost entirely safe drinking water which does not require costly purification and treatment process.

The total domestic water demand of Imphal West district was estimated at 17.652 MCM and water supply from state government's water supply scheme (PHED) was estimated at 6.185 MCM, which fulfil only about 35% of total water demand. If rooftop rainwater is considered another 52% of water shortage can fulfilled. The shortage which is about 17% can be through rainwater storage and through private enterprise. The average annual increase in domestic water demand was predicted at 1.33% and total increased in domestic water demand from 2011 to 2031 was predicted at 26.53%. So, there will be huge domestic water demand in coming future years.

REPORT ON AQUIFER MAPPING STUDY FOR IMPHAL WEST DISTRICT OF MANIPUR, NORTH EAST INDIA

1.0 INTRODUCTION

Central Ground Water Board, North Eastern Region has carried out Aquifer mapping and management plan in Imphal West district, Manipur during AAP 2017-18 covering an area of 519 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 objective of the study can be defined as follows:

3. to define the aquifer geometry, type of aquifers, ground water regime behaviours, hydraulic characteristics and geochemistry of aquifer systems on 1:50,000 scale and
4. existing scenario of groundwater regime in shallow/deep aquifer
5. to work out a management plan for sustainable development of ground water.

1.2 Scope of the Study

This study was carried out to obtain an updated picture of groundwater occurrence, availability; its utilisation and also prevailing status of water quality with reference to the previous studies.

An accurate and comprehensive picture of the groundwater of the district may be generated by hydrogeological studies through groundwater exploration, geophysical and hydrochemial studies. The output of the study will enable robust groundwater management plans at the appropriate scale to be devised and implemented for this common-pool resource. This will help achieving drinking water security, improved irrigation facility and sustainability in water resources development in the rural as well as urban areas. This study is also important for planning suitable adaptation strategies to meet climate change in the area.

Therefore, hydrogeological information can be gathered in the district. Similarly scope of exploration and use of geophysical technique to gather subsurface information can also be carried out.

1.3 Approach and Methodology

The approach is to identify the principal aquifers and to conceptualize the aquifer system. This will help to formulate an aquifer management plan. Finally, the scientific knowledge will be disseminated to farmers, water user agencies, state government and stake holders.
The methodology can be illustrated as follows:

i. Data compilation and data gap analysis: The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB and State Groundwater Departments. All data were plotted in the base map on GIS Platform (like MapInfo using Projection category longitude/latitude (Indian for Pakistan, India, Bangladesh, Nepal projection). On the basis of available data, data gaps were identified.

ii. Data Generation: Efforts were made to fill the data gaps by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, water level monitoring, yield tests and soil infiltration studies. The structure contours of the study area have been matched across the existing map boundaries (geological, hydrogeological) of the Manipur Valley. New data of groundwater abstraction structures were collected during the aquifer mapping study by selecting key areas in the district and have been re-defined in the context of local hydrogeological set up and new findings.

iii. Aquifer Map Preparation: On the basis of integration of data generated from aforesaid studies, aquifers have been delineated and characterized in terms of its potential and quality. Various maps have been prepared by bringing out characterization of aquifers, which can be termed as aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities, quality, water level, potential and vulnerability (quality & quantity). Relationship between the groundwater management units and the mapping units has been interpreted based on the findings of aquifer parameters from the existing hydrogeological data, lithology, quantity and quality of groundwater etc.

iv. Aquifer Management Plan Formulation: Based on aquifer map and analysis of present requirement and future demand, a sustainable development plan of the aquifer is formulated.

The aquifer mapping requires the analysis of large amounts of exploratory data. To ensure an efficient and logical approach to the study, data of the existing exploratory wells of CGWB and wells constructed by State Departments were also considered for better correlation of aquifer parameters.

So, in a nut shell aquifer mapping has been carried out by adopting the following multi-disciplinary approach:

1. Geophysical Surveys through Vertical Electrical Sounding (VES)
2. Exploratory drilling and construction of tube wells tapping various groups of aquifers.
3. Ground Water Regime monitoring by establishing monitoring wells tapping different aquifers at different depths for long term monitoring of water level and quality.
4. 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.
5. 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.
6. 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.
7. Formulating a complete sustainable aquifer management plan for ground water development.

1.4 Area Details

An area of 519 sq km covering Imphal West district of Manipur has been undertaken as part of the National Aquifer Mapping Programme during the year 2017-18 by Central Ground Water Board, North Eastern Region, Guwahati.

Imphal West district of Manipur bifurcated from old Imphal district forms a part of the small intermontane valleys of Manipur state and covers an area of 519 sq. km within the North Latitudes $24^{o}30^{/}$ & $25^{o}\ 00^{/}$ and East Longitudes $93^{o}\ 45^{/}$ & $94^{0}15^{/}$. The district is bounded on the north by the Senapati district, on the south by Thoubal and Bishnupur districts, on the east by Imphal East and in the west by Senapati and Bishnupur districts. The district with its headquarters at Lamphelpat (Imphal city) has 2 blocks (Imphal West I and Imphal West II) 4 sub-divisions, 10 Circles and 133 villages.

National Highway-39 (Indo-Burma/Myanmar Road), NH-53 (Imphal-Jiribam Road), and other state roads like Mayai Lambi Road, Tiddim Road etc. were passes through the study area by connecting other parts of the state. Air-ways and other road communication are also connecting other states of the country.

As per 2011 census, the total population of the district is 5, 17,992 out of which 2, 55,054 are male and 2, 62,938 are female population.

Table: 1. Administrative Sub-Divisions of Imphal West district, Manipur

District	Block	Area in sq.km.	Sub-Division	Head Quarters	No. Of Villages
Imphal West (Lamphelpat is the district HQ)	Imphal West I	281.00	Lamphelpat	Lamphelpat	9
			Patsoi	Patsoi	25
	Imphal West II	238.00	Lamsang	Lamsang	69
			Wangoi	Wangoi	30
Total	2	519.00	4	4	133

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

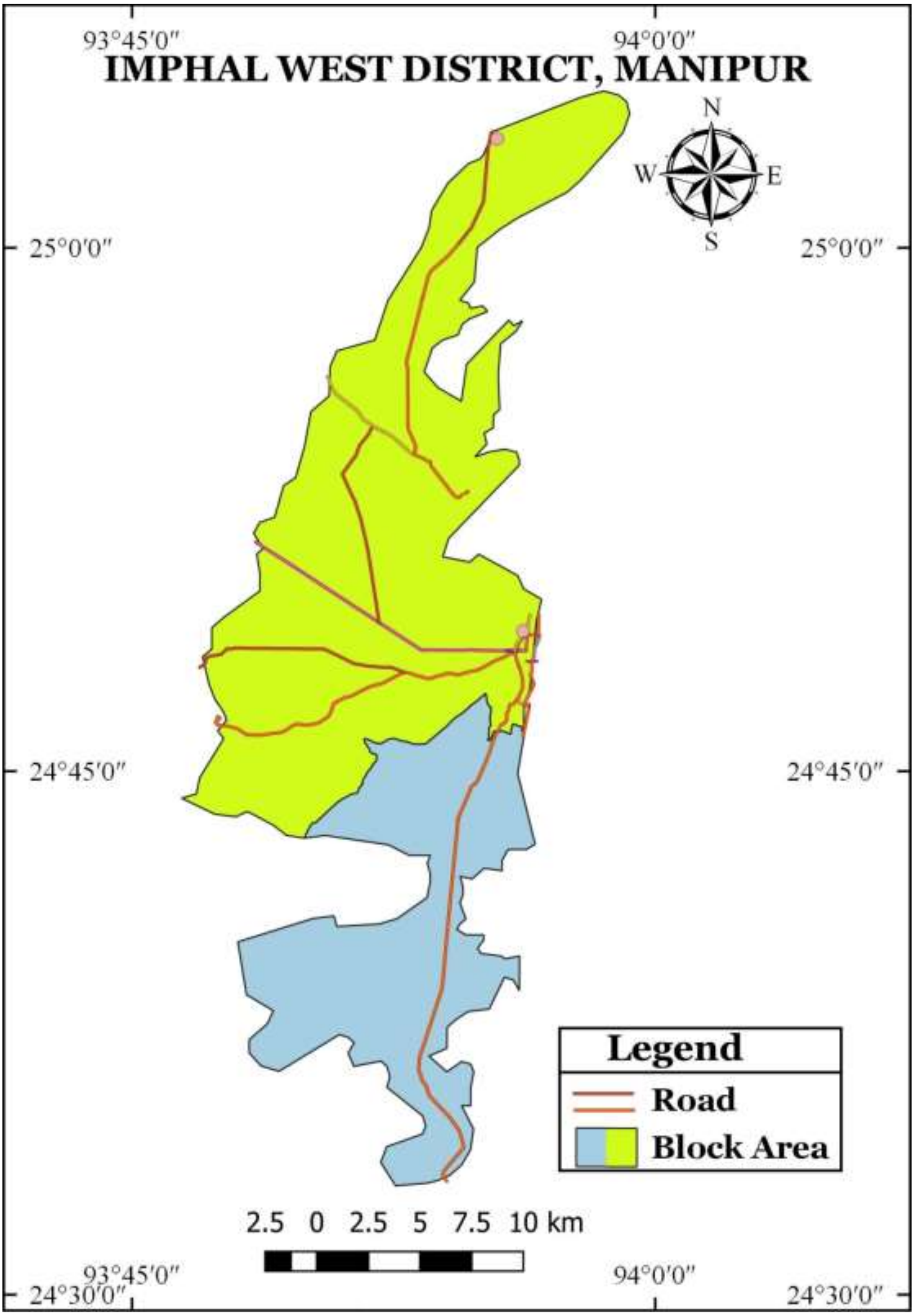


Fig.1 Index map of the NAQUIM study area: Imphal West district, Manipur

The district is a part of the centrally located intermontane valley, i.e., Imphal valley of Manipur. The area covers fertile plain of Imphal valley and Loktak Lake.

Physiographically, the district shows three prominent units i.e. a tiny plain topography, hilly areas and marshy land in the southwestern periphery. The valley is surrounded in all sides by hill ranges of denudostructural nature trending NNE-SSW direction. A number of isolated hillocks of denudational remnants are found within the valley. Main rivers draining are Imphal River, Nambul River and their tributaries. The Nambul River is made up of number of small streams on its upper course and flows through the Imphal town dividing the town almost into two equal halves. The course of the rivers is short and falls into Loktak Lake.

The district is fertile and is mainly made up of alluvial soil of recent origin. The valley was once full of swamps and marshy lands. The soils are mainly made up of shallow black, brown and alluvial soils which have been technically classified as Udalfs-Ochrepts and Orchrepts-Aquepts-Fluvents. The study area is endowed with a rich variety of vegetation. The prevailing climatic conditions are favorable for growing a wide range of herbs, shrubs, and also flowering and non-flowering trees.

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

The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB, State Groundwater Departments etc. All data were plotted in base map on GIS Platform (like MapInfo using Projection category longitude/latitude (Indian for Pakistan, India, Bangladesh, Nepal projection).

GSI has carried out geological studies in Imphal valley to delineate the lithological units, their structures and stratigraphic disposition. Central Ground Water Board has also constructed 03 exploratory wells and 03 observation wells as part its exploratory drilling programme under the NAQUIM studies in Imphal West district during AAP 2014-15 and 2015-16. Public Health Engineering Department, Govt. of Manipur has also constructed 727 nos of tube wells and hand pumps in the district for domestic and drinking water supply and out of which 525 tube wells were successful. Presently, a total of 375 tube wells/hand pumps (188 nos. in Imphal West I block and 187 in Imphal West II bloc) are functional (as per report of

PHED, Manipur). The exploratory wells constructed by CGWB, NER, Guwahati during the study on hydrogeology and groundwater conditions of Imphal valley in the year 1975, which falls in the NAQUIM area has been incorporated for better comparison with the present exploratory data.

1.6 Rainfall-spatial, temporal and secular distribution:

The study area enjoys sub-tropical humid climate. Average annual rainfall in the area is 1632.4 mm. About 60 to 65 % of the annual precipitation is received during south-west monsoon from June to September. Annual average temperature of the study area is recorded to be 20.4^{0}C and the temperature ranges from 0^{0}C to 36^{0}C. The relative humidity is high.

The beginning of winter is marked by a steep fall in temperature during December. January is the coldest month. In February the temperature starts rising gradually. The winter winds are generally weak and variable. The average annual temperature ranges from 18°C-20°C to 23°C-25°C respectively in the higher and lower elevation. The monsoon lasts for five months from May to September with June, July and August being the wettest months. The following agro-climatic zones are the main characteristic zones in the area:

3 The cold season (December, January, February)
4 The hot dry season (March, April)
5 The rainy season (May, June, July, August, September)
6 The retreating monsoon season (October, November)

Table.2 Monthly Rainfall data in mm for the last 10 years in the study area (Period: 10 years from 2009 to 2018)

Rainfall in mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	0	22.5	40.1	74.4	105.3	108.1	183.1	203.4	113.9	152.1	5.2	0	967.99
2010	7.8	7	98.4	248.4	222.2	260.2	300.9	93	136.9	194.2	16.1	47.3	2060.49
2011	25.1	2.3	45.5	35.6	299.2	332.5	287.1	302.9	126.4	27.4	0	0	1484
2012	19.6	0	56.8	158.7	93.3	311.9	270.8	246.3	272.3	137.4	80.8	0	1647.9
2013	0	1.7	31.8	83.6	335.1	135.5	254.1	414.3	291.3	30.3	0	1.4	1639.1
2014	0	31.2	28	47.5	277.3	385	85	263.9	106.7	29	0	0	1117.9
2015	21	0.3	11.8	555.7	176	377.2	486.4	362	157.7	35.2	2.6	11.2	2197.1

2016	0.5	65.2	111.1	561.7	643.2	642.9	484	372.4	737.6	237	52.9	0.8	3909.3
2017	0	13.6	178.2	479.7	189.6	546.9	690.3	803.3	510.5	382.6	2	102.1	5915.8
2018	2.5	0.5	80.1	219.7	526.6	497.4	243	338.6	167.2	53	0	30.7	4177.3
Average Annual Rainfall for the last 10 years													**2511.69**

(Source: IMD Rainfall Data, Imphal)

Records of rainfall in the study area are available for the periods of last fifty years. The average annual rainfall for last ten years at Imphal is 2511.69 mm (as per IMD, Airport data). The maximum rainfall is observed in the month of June and minimum is in the month of January. About sixty-eight per cent of the annual rainfall is received during the period of June to September, July being the rainiest month of the year. Rainfall mostly as thundershowers occurs in the pre-monsoon months of April and May and in October**.**

1.7 Physiographic set up

Physiographically, the study area shows three prominent units i.e. a tiny plain topography, hilly areas and marshy land in the southwestern periphery. The NAQUIM area as a whole fall in Imphal valley and it is virtually a flat alluvium filled valley. The valley area is nearly 780 m high above the mean sea level with a very low southerly gradient. The valley is surrounded in all sides by hill ranges of denudostructural nature trending NNE-SSW direction. A number of isolated hillocks of denudational remnants are found within the valley. Main rivers draining are Imphal River, Nambul River and their tributaries. The Nambul River is made up of a number of small streams on its upper course. The course of the river is short and its outlet falls on Loktak Lake. These rivers have a nearly NNE-SSW trend concurring with the regional structural trend. Loktak Lake, the largest fresh water lake in the entire northeast India, lies in the south-western portion of the study area. Possibly it represents the lowest elevation of the valley. The course of the rivers is short and falls in the Loktak Lake. The lake also has a distinct and separate drainage system. The lake itself serves as an inland basin.

A considerable area in the southwestern part of the study area is covered by the lakes like Loktak, Ngakrapat, Awangsoi, Laisoi, Zingpat, Loukoipat, and Ikokpat etc. Loktakpat, which is the largest in Land Lake not only in Manipur but also in the North-eastern India, covers an area of about 247 sq.km during the rainy season with an average depth of about 10-15 metres. Keibul Lamjao, the National Park is situated on the southeastern side of the Loktak

Lake and it has an area of 40 sq.km. The Sonapat, Utrapat, Samusang, Kharungpat and Ikokpat are also worth-mentioning lakes in the study area.

1.8 Geomorphology

Flat elongated and south tapering valley with isolated hills are the main geomorphologic features in the district. The study area is part of an intermountain valley surrounded by hillocks. The western part is flanked by abruptly rising hills while by low-lying rolling hills bound the eastern side. The average trend of slope is down from north to south from an altitude of 880 to 770 meters above MSL, which is common in Imphal valley.

Geomorphologically, the study area is classified into the following geomorphic units

Table.3. Geomorphic units in the study area (after Singh, 1993 &1996)

Geomorphic Unit of Imphal Valley (After Singh, 1993)	Geomorphic Unit of Imphal Valley (After Singh, 1996)
Alluvial Plain Flood Plain Abandoned Channel Meander Scar Natural Leeves Point bars Structural Hills Piedmonts Valley fills	Intermontane Valley (Alluvial Plain) Piedmont Structuro-Denudational hill Denudational hill Denudo-structural hill

i. Structural Hills : These hills are confined along the border of Imphal which further extends into the valley. Langol hill, Naran Konjin, Langthabal and Waithou are few isolated patches of structural hills occurring in Imphal West district. They consist of shales and intercalations of sandstone belonging to the Disang Group. The drainage patterns are of sub-dendritic to sub-trellis. The structural hills are further sub classified into the following:

1. **Denudo-Structural Hill:** In the study area, it occupies the eastern, southern, and northern parts with the highest relief of about 1866 m above men sea level. It consists of splintery shale, sandstones and siltstones of Disang Group of Upper Cretaceous to Eocene age. These hills have dendritic to sub dendritic drainage pattern. The drainage density is moderate to high as studied qualitatively.
2. **Residual Hill (Denudational Hill):** Residual hills are demarcated in the central part of the study area, with relief ranging from 900 to 1100 m above mean sea level. These are flanked on all sides by alluvial plain deposits. These hillocks lithologically consist of

splintery shale, with sandstone and siltstone belonging to Disang Group of Eocene to Upper Cretaceous age. Sub-dendritic and radial drainage pattern are observed with moderate to fine drainage texture.

3. **Structuro-Denudational Hill:** These hills occupy the western part of Imphal valley with highest relief of about 2331 m above mean sea level and consist of sandstone, shale, siltstone,
4. **Piedmont:** It is well demarcated in the western margin of the alluvial valley surrounding the foot hill. It consists of colluvial and alluvial deposits comprising gravel, pebble, boulder, sand with silt/clay intercalations, formed by deposition of materials brought down by streams draining from the surrounding hills. This piedmont zone in the study area shows sensorial, coarse, braided and fanning stream patterns. Alluvial fans are prominently seen in this zone, which consists of sand, silt and clay.

ii. Alluvial plain (Intermontane valley): It occupies the central part of the study area. The elongated intermontane valley consists of thick sequence of fluviolacustrine deposits. The average relief is about 780 m above mean sea level. The alluvial plain is made of rhythmic layering of sand, silt and clay. This zone shows coarse meandering to dendritic drainage pattern. The Imphal River is the major river with most of the major streams joining it. This unit, as a whole, was reported to have been a lake and filled in with the sediments brought down by streams draining from the surrounding hills. The southern part of the plain is covered by water bodies and marshes which are flooded during rainy season. Infilled channels seen in the alluvial valley consists of gravel, sand and clay in order of sequence. In the study area, a few infilled lakes e.g. The Lamphelpat (pat locally means lake) has been observed. This has been filled up with sediments.

iii. Flood Plain: Flood Plain is the essential product of stream erosion. In the study area the flood plains are present along the Imphal and Nambul River. The common associated fluvial landforms such as meander scars meander loop, ox-bow lakes, natural leaves and river bars were identified by Singh (1993). Lithologically, it consists of sandy clay, gravel mixed with sand etc.

iv. Valley Fills: Valley fills in the study area consist of unconsolidated and imperfect unsorted materials comprising of clay matrix embedded with pebbles and boulders.

1.9 Slope and Relief

Slope and Relief play role for land utilisation and geo-environment assessment. Main factors that controlled the evolution of slope are structure, lithology, geologic processes and time. Slope and Relief of the study area are studied. So far seven classes of slope have been identified in and around the study area:

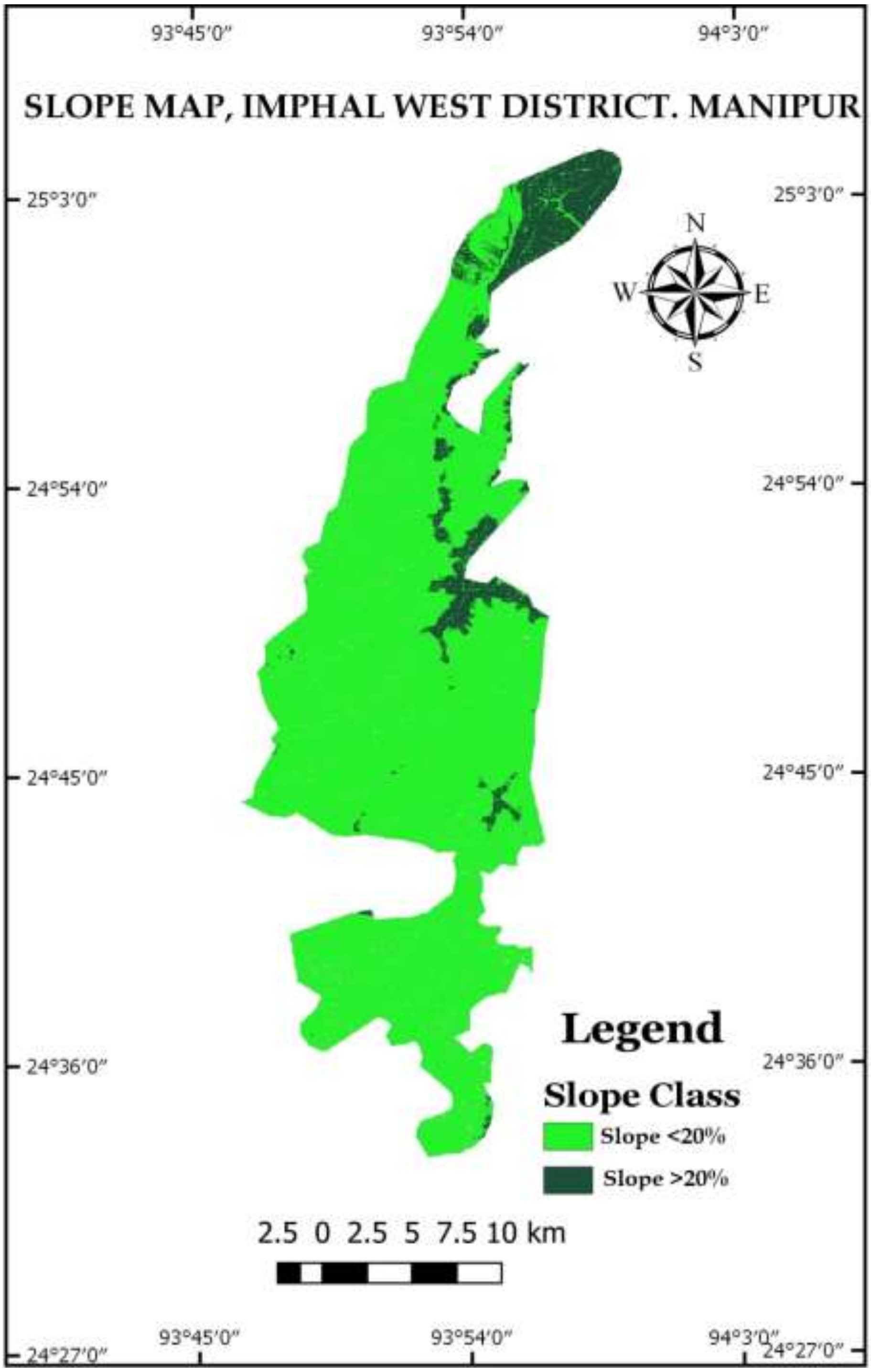


Fig. 2 Slope map of Imphal West district, Manipur

(1) **Nearly level (0-1%):** The slope class is observed in most part of the study areas, which are basically plain and are adjacent to the wetlands, agricultural lands and settlements.

(2) **Very Gently Sloping (1-3%):** This class of slope is observed mainly on the eastern and north-eastern part of the study area. Important land use categories found in this area are agricultural land (terrain for cultivation and horticulture) and settlements.

(3) **Gently Sloping (3-5%): This** class of slope is mainly on the northern, eastern and some western part of the study area. Important land use categories found in this area are agricultural land and settlement.

(4) **Moderate Sloping (5-10%):** This class of slope is mainly found in northern, eastern and central part of the area. Agriculture land scrub forest and water body are important land use categories.

(5) **Strong Sloping (10-15%):** This class is observed in the central and southern part of the area, the main land use Patterns are agricultural land, scrubland and settlement.

1.10 Land use Pattern

Land use pattern of the villages in different blocks are given in the following table (Table: 3)

Table 3: Land use pattern of Imphal West district

Sl No	Name of NQUIM Area	Area in Hectare
1	Imphal West t District	51900
2	Imphal West I CD Block	23290
3	Imphal West II CD Block	47610
4	Net sown area	21136
5	Net Cultivated area	21150
6	Net Irrigated Area	1049
7	Irrigated area by canals	637
8	Irrigated area by other sources	412
9	Irrigated area for All Crops	1100
10	Unirrigated area for all crops	21956
11	Gross Cropped Area	**23056**
12	Area under current Fallow	14
13	Land not available for cultivation	100

(Source: Statistical Hand book of Manipur 2017)

1.11 Soil Characteristic

The district is fertile and is mainly made up of alluvial soil of Recent origin. However, the soils are acidic with pH ranging between 4.5 to 6.8, rich in organic carbon. Availability of N is medium to high, P is low to medium and K is medium to high. The texture of soil varies from sandy to loam to clayey. The availability of N is not in proportion of the reserve N due to low rate of mineralization and crop is highly responsive to N and P fertilizers. Initially, factors such as soil parent material, rainfall, and type of vegetation are the major determinants of soil acidity.

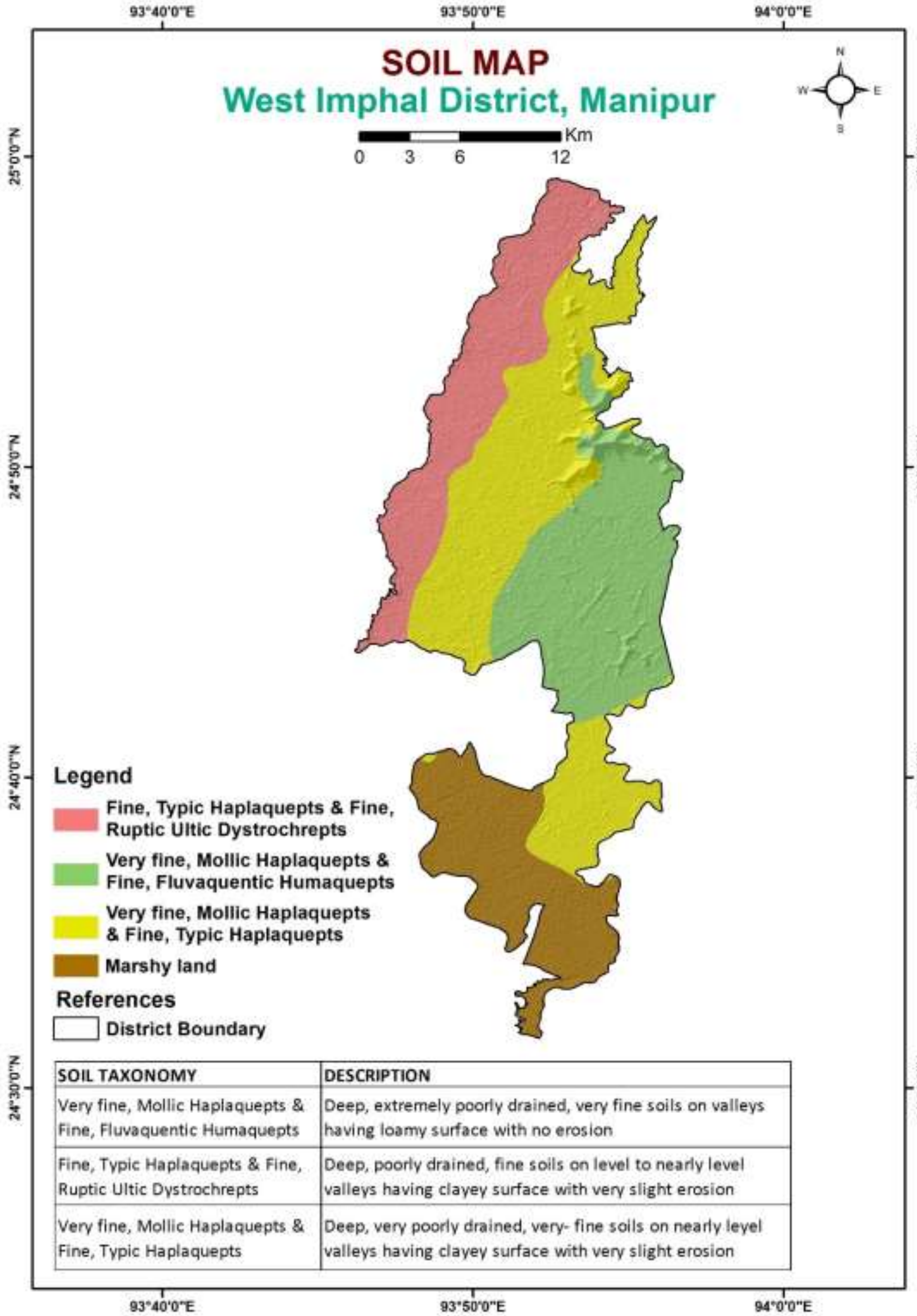
Soil acidity problems are increasing in the study area because of continuous cropping and use of acidifying fertilizers. On the other hand, though soils of the area have moderate phosphorus as soil reserve, this is practically of no use to plants, as it is present in fixed or insoluble forms due to soil acidity. It also renders supplied phosphorus into insoluble form within a short period of time. All phosphorus ions either as primary orthophosphate ions or as secondary phosphate ions are subjected to fixation with hydroxides of aluminum and iron. In the nearby bordering hills, where soils are rich in organic matter, the availability of P is comparatively better which is mainly due to microbial activity.

Two major types of soils are found in the study area - residual and transported, which cover both the hills and plains. The residual soils are either laterised or non- laterised. It contains rich portion of nitrogen and phosphate, a medium acidity and lesser amount of potash.

The transported soils are of two types – alluvial and organic. The alluvial soils represent the soils of Imphal valley. The soils have general clayey warm texture and grey to pale brown colour. They contain a good proportion of potash and phosphate, a fair quantity of nitrogen and organic matter and are less acidic. The organic soils cover the low-lying areas of the valley. With dark grey colour and clayey loam texture, these peaty soils have high acidity, abundance of organic matter, a good amount of nitrogen and phosphorous but are poor in potash.

Main Soil classification of the study area –

(i) Younger alluvial soil
(ii) Older alluvial soil
(iii) Red gravelly sandy and loamy soil.
(iv) Piety and saline soil.



SOIL TAXONOMY	DESCRIPTION
Very fine, Mollic Haplaquepts & Fine, Fluvaquentic Humaquepts	Deep, extremely poorly drained, very fine soils on valleys having loamy surface with no erosion
Fine, Typic Haplaquepts & Fine, Ruptic Ultic Dystrochrepts	Deep, poorly drained, fine soils on level to nearly level valleys having clayey surface with very slight erosion
Very fine, Mollic Haplaquepts & Fine, Typic Haplaquepts	Deep, very poorly drained, very- fine soils on nearly level valleys having clayey surface with very slight erosion

Fig. 3: Soil Map of the study area, Imphal West district, Manipur

1.12 Drainage

Main rivers draining are Imphal River, Nambul River and their tributaries. The Nambul River is made up of a number of small streams on its upper course. The course of the river is short and its outlet falls on Loktak Lake. These rivers have a nearly NNE-SSW trend concurring with the regional structural trend. Loktak Lake, the largest fresh water lake in the entire northeast India, lies in the south-western portion of the study area. Possibly it represents the lowest elevation of the valley. The course of the rivers is short and falls in the Loktak Lake. The lake also has a distinct and separate drainage system. The lake itself serves as an inland basin.

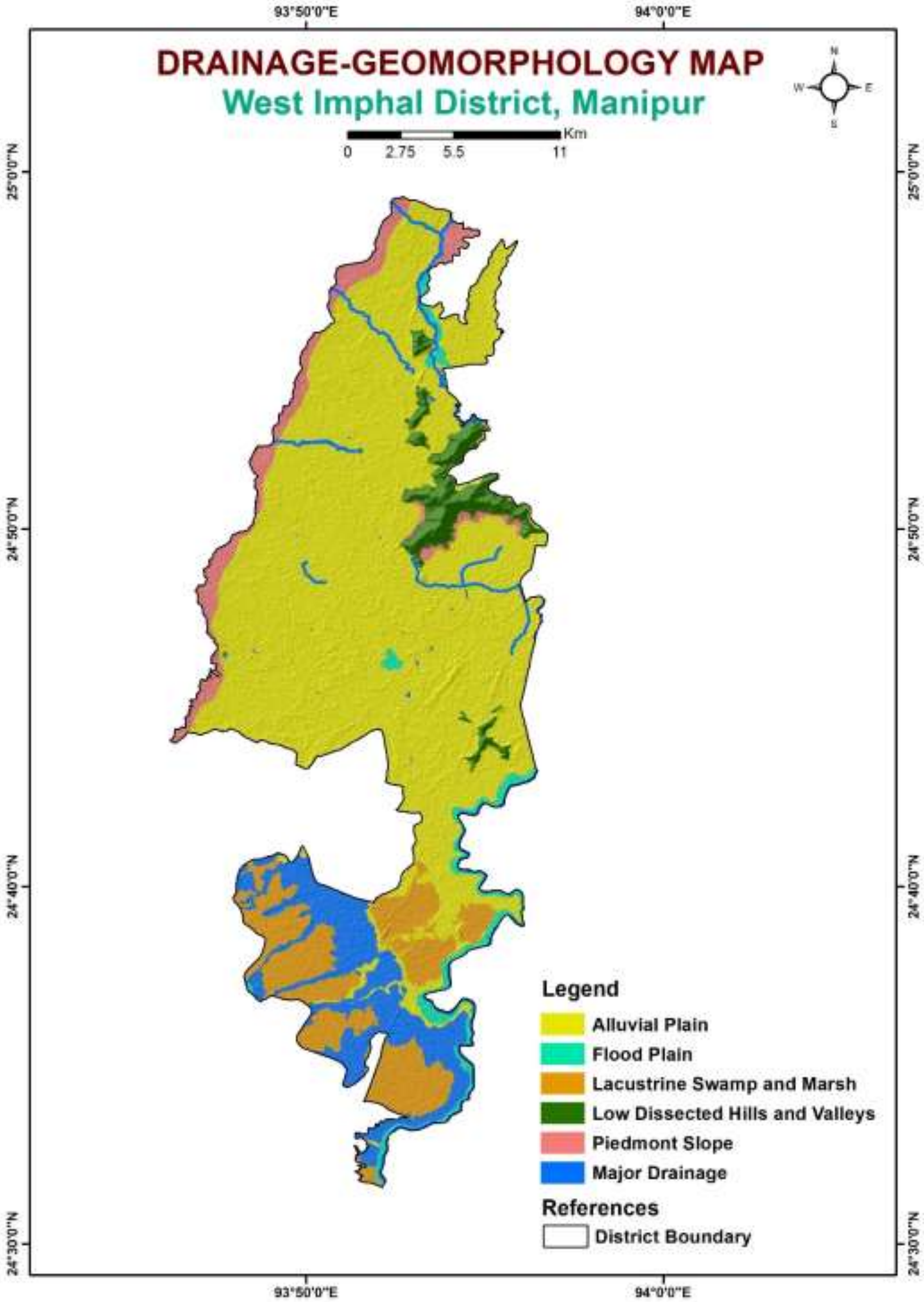


Fig. 4 : Drainage -Geomorphology of the study area

A considerable area in the southwestern part of the study area is covered by the lakes like Loktak, Ngakrapat, Awangsoi, Laisoi, Zingpat, Loukoipat, and Ikokpat etc. Loktakpat, which is the largest in Land Lake not only in Manipur but also in the North-eastern India, covers an area of about 247 sq.km during the rainy season with an average depth of about 10-15 metres. The Sonapat, Utrapat, Samusang, Kharungpat and Ikokpat are also worth-mentioning lakes in the study area.

1.13 Regional Geology

The Hills of Manipur lie between the Naga–Patkai Hills on the north and northeast, and the Chin-hills on the south forming an integral part of the Indo-Myanmar (Burma) Ranges (IMR). The structural and tectonic pattern is transitional between the NE–SW trending pattern of Naga–Patkai Hills and N–S trend of Mizoram and Chin Hills (Brunnschweiler 1974). It comprises geologically young rock formations that were uplifted by the Tertiary orogeny of the Himalayas from the shallow bed of the Tethys Sea. The rocks are dominantly Tertiary and Cretaceous sediments with minor igneous and metamorphic rocks. Flysch sediments of Tertiary age underlie nearly 70% of the state (Soibam 1998).

Disang and Barail flysch sediments underlie much of Imphal valley or central valley. The oldest formation, the Disang Series (Eocene) comprises splintery shale with minor mudstone, siltstone, sandstone and limestone. The Disang is overlain by the Oligocene Barail Formation contained abundant carbonaceous matter. The Barail is succeeded by the predominantly argillaceous Surma and the Tipam formations. The sediments of the Surma basin is molasse (Nandy 1980). Ultrabasic igneous rocks, of the Ophiolite Zone, are intruded into the Disang Group in east of Manipur. The general tectonic trend of rock formations in the state is NNE-SSW, but varies between N–S and NE–SW, and locally NNW–SSE. Almost all the major structural elements such as folds reverse and thrust faults follow this regional strike/trend.

Topographically, Manipur comprises a ridge and furrow terrain where sediments derived from surrounding ridges are deposited in the furrows (Soibam 1998). In the Manipur Valley, lenses of argillaceous sediments were deposited in the Assam–Arakan trough. Manipur is divisible into a central valley and the surrounding mountains. About 25% of the valley is occupied by lakes, wetlands, barren uplands and hillocks. The NNW–SSE oriented valley is oval shaped, and slopes gently to the south. The Imphal or Manipur River meanders

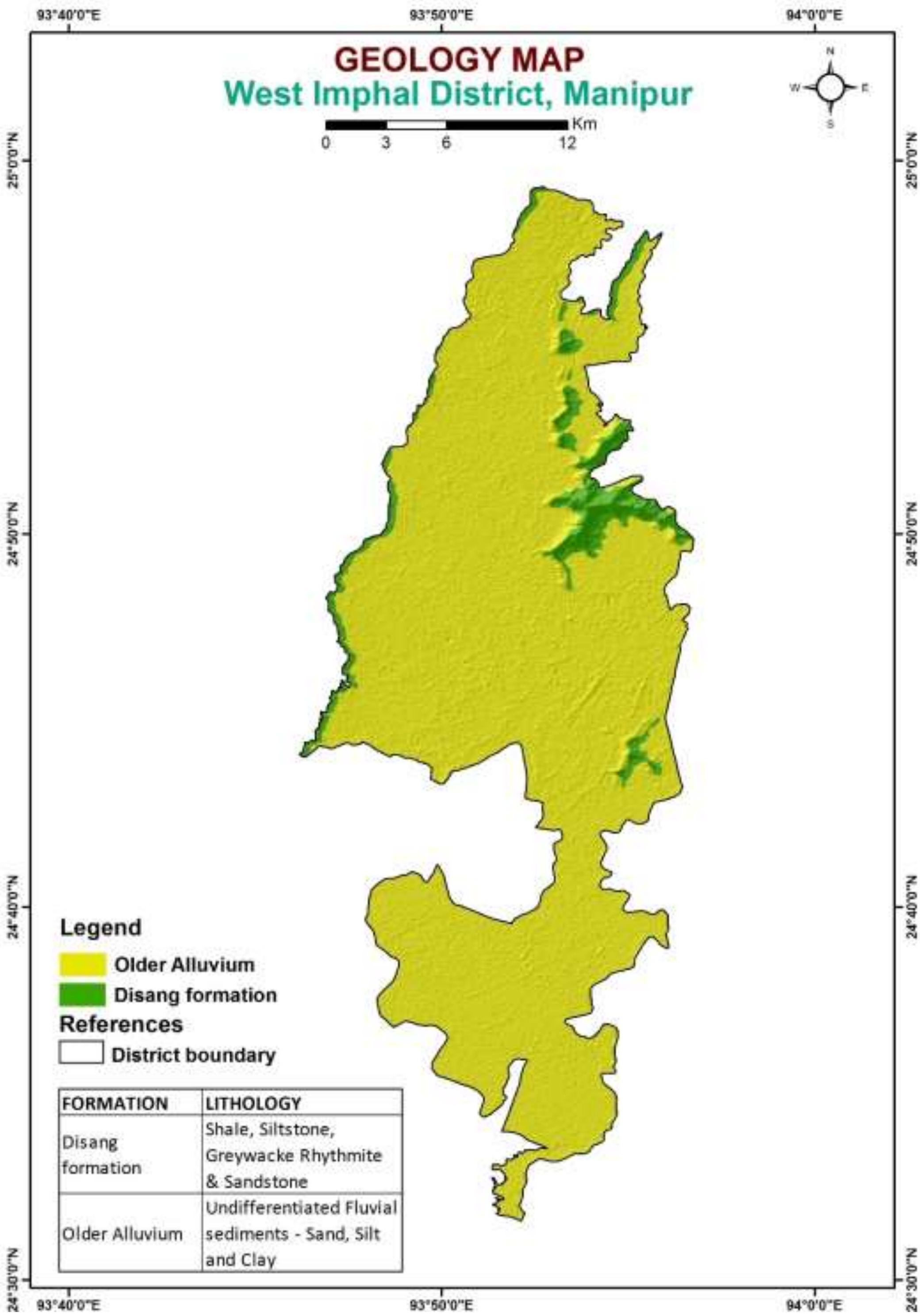


Fig.5 Map showing Geological set up of the study area

through the Manipur Valley in a NW–SE direction and passes through a gorge to flow out of the state to join the Chindwin River in Myanmar. The formation of the Manipur River and its tributaries that drain the area was closely connected with the upliftment of the South Manipur Hills and subsequent erosion of the weak crest of the anticlinorium. There were multiple episodes of low energy, fluvio-lacustrine deposition during the Quaternary, and these sediments are encountered to depths of 150 m. Disconnected lenticular water bodies dominate the valley.

The Manipur Valley has been infilled by thick alluvium which is subdivided into the Older (Pleistocene) and Newer Alluvium. The Older Alluvium is made up of clay, silt, coarse sand, gravel, pebble and boulders, deposited adjacent to the foothills and forming older river terraces in the lower part of Manipur Valley. The Newer Alluvium is composed of clay, sand, silt and dark clay with carbonaceous matter, deposited mainly in the central and upper part of the Manipur Valley.

1.13.1 Geology of the Study Area

Basically, the area is made up of alluvium of fluvio-lacustrine origin. They are usually dark grey to black in colour. The principal constituents are clay, silt and sand whereas sand, gravel, pebbles and boulders are found in the foothill regions. The hillocks in the study area are basically composed of Disang shales but some have sandstone capping. Alluvium covers the widest aerial extent in the area. They are mainly dark grey to black carbonaceous clay, silt and sand of which clay forms the main sediments while silt and sand are subordinate. Major parts of the area belong to Alluvial formation which is further divided into older and younger alluviums due to change in lithology.

Table.4: Stratigraphic Succession of Imphal Valley (after Singh, 1993)

Stratigraphic Units and Age	Formations	Description of rocks
Alluvium (Holocene to Pleistocene (?))	Newer Alluvium	Dark grey to black clay, silt and sand deposits of fluvio-lacustrine origin. Flood plain deposits of the rivers/streams
	Older Alluvium	Clay, sand, gravel and boulder deposits of the foothills. Possibly lower deposits of the valley.
Stratigraphic Break		
Barail Group (Oligocene to Upper Eocence)		Light to brownish grey, bedded, sandstone alternating with shales. Sometimes considerably thick sand and shale beds are occasionally present. Flysch sediments show turbidite character
Disang Group (Eocene to Upper Cretaceous)		Dark grey to black, laminated splintery shales. Intercalations of shales, siltstones and sandstones show occasionally rhythmite nature. Flysch sediments sometimes exhibit turbidite character.
Unconformity		

Basement rocks		Unseen

The study area occupies major part of the Alluvial formation of Imphal valley in Manipur. The valley is a large intermontane piedmont alluvial plain, representing a depositional environment. It has a general amphitheater-like north-south extension, surrounded by hills made of Disang and Barail Groups of rock. The valley consists of thick sequences of fluvio-lacustrine assemblages of sand, silt and clay. In the study area, there are two major geological sequences made of Disang and Barail Groups of Tertiary age.

a. Disang Group

The substratum of Imphal valley involves essentially shale and silt stone of the Disang Group. This unit becomes gradually sandier and more carbonated upward in the Upper Disang. The Disang shale is deeply weathered, particularly at the periphery of the inselbergs or ridges and all around the present or former ponds, giving several meters to several tens of meters of red clay with paleosoils. They are in part of local origin by denudation, weathering and leaching of the emerging paleo-hills. However, hydrogeological point of view, pebbles and gravel continue to be provided by sandy and shally parts of this formation.

In the study area, Disang Groups are exposed in the eastern section and also in the sectors north and south of the valley area. The rocks consist of dark-grey to buff colour, thinly laminated splintery shales, with distinct intercalations of fine-grained sandstones as narrow bands and also isolated lensoid form. The thickness of these bands varies from place to place as also the size of the lensoid bodies. In general, the thickness of the bands ranges between 10 m and 15 m.

The majority of the lineaments in the study area have trend NNE-SSW to NE-SW in the Disang Group of rocks. The general trend of the lithologic units varies from N-S to NE-SW directions dipping both in easterly and westerly directions. A longitudinal lineament which may probably be extension of Lainye fault, observed in the satellite image, passes along the contact between the eastern boundary of the valley and the Disang.

The hillocks (remnants of denude-structural hills) viz, Langol, Langjing, Langthabal, Hiyangthang, etc. are exposed in Imphal west district. These hillocks are made up of Disang shales, reddish brown in colour probably due to weathering of these rocks. These hillocks contain discontinuous bands or lenses of sandstone. The shales, observed in these hillocks, are characterized by fractures/joints of diverse orientation and are found to be highly weathered.

The rocks of Disang Group have been assigned Upper Cretaceous to Eocene age on the basis of faunal assemblages.

b. Barail Group

This formation is essentially composed of sandstone. Barail Groups are usually light to brownish gray, fine to medium grain sandstone often interbedded with shales. They are mainly brownish in colour after alteration. They were formed in flysh which has the turbidite character. The Barail Group forms the crests of the water divide in the NW of the area. In the SW, it can be observed in the border area of Bishnupur district where its presence of classical thickening up turbidity sequences (Laishong Formation). Strike slip or transverse faults are associated with the main stress direction and generally oriented NW- SE as shown by the river direction and more obvious in the sandstone deposits of the Barail Group.

In the study area, Barail Group of rocks is exposed in the western part of the study area and overlies the Disang Group of rocks. At places, Barail Groups are exposed above the Disang Group. The contact between Disang and Barail Group has been under discussion for quite some time. The change into the lithofacies is the diagnostic feature for demarcation of the rocks of Disang and Barail groups. The gradual increase in sand particles/ sand bands is predominant in Barail Group. Barail Group in the study area consists of light to brownish grey, fine to medium grained, thickly bedded sandstone with shale partings.

Lineaments as observed in satellite images (Lansat TM, FCC) trend in N-S and NNE-SSW direction in Barail Group of rocks. A major lineament which may probably be extension of Tapu fault is observed at the contact between the western boundary of the alluvium and the Barail Group of rocks (Singh, 1996). Barail Group of rocks belongs to Upper Eocene to Oligocene age.

c. Plio- Quaternary Valley Fills

Plio- Quaternary valley fills are mainly composed of gravel, sand and clay. The more recent infill is due to black clay rich in organic matter covering almost the whole area, except the far north-west. The present older fluvial deposits are continuous from NW to downstream of the present Imphal River. They are probably fluvio-lacustrine deposits of confined and low energy environment. Sections across this formation can be seen on several meters in the drainage troughs of the paddy fields. The contact between Disang ridges and Quaternary sediments is steep, without transitions between tectonised silty shale or pale soils of weathered shale and quaternary clays. On the western edge of the valley, alluvial fans of limited extent occur in the study area.

d. Alluvium

Alluvium forms the youngest Pleistocene-Holocene (Singh, 1994) sediments in the study area. It covers the majority portion of the study area. The alluvial deposits in the study area consists of dark grey to black clay, silt and clay, evaporates and piedmonts clastics. Alluvium in the study area is of two categories viz, Younger/Newer Alluvium and Older Alluvium.

4 **Older Alluvium:** Older Alluvium refers to the earlier cycle of deposition. The alluvium formed in a large intermontane plain consisting of alternate layers of sand, silt and clay as well as piedmont clastics consisting of sand, gravel and pebble with silt/clay formed at the foothills are considered to belong to Older Alluvium in the study area.

5 **Younger Alluvium:** Younger/Newer Alluvium refers to the late cycle of deposition. The alluvium consisting of gravel, sand, clay and silt formed at either side or along the palaeo streams, and flood plains comprise the younger alluvium in the study area.

The thickness of the alluvium varies from place to place. In the northern part of the study area, the thickness reaches up to 40 m whereas at the eastern margin of the alluvial plain, it goes up to more or less 100m.

Few sets of lineaments showing varying orientations are observed in the satellite imageries of the study area. Two major lineaments trending almost in N-S direction delimit the western and eastern boundary of the alluvial plain. These two lineaments appear to have exerted control over the shape as well as tectonic origin of the valley. The lineament which traverses the western boundary of the alluvium represents part of Tapu fault whereas the lineament crossing the eastern boundary of the alluvium is part of Lainye Fault(Jha et al., 1994).

1.14 Agriculture

Agriculture being the main occupation of the people in the area, it has an important place in the economy of the district. Agriculture sector contributes a major share to the total state domestic product and provides employment to about 63.95% of the total working force in the area. In fact, the domestic product fluctuates depending on the performance of agricultural sector. Despite the crucial importance of this primary sector in the economy of the area, the irregular and erratic behavior of monsoon accompanied by inadequate irrigation facilities have resulted in severe of fluctuations in agricultural production. Agriculture becomes points of employment and income; agriculture plays a very crucial role in the economy.

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

1.15 Irrigation

CHAPTER 2.0

DATA COLLECTION AND GENERATION

2.1 Data collection

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 water features, 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.

The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB, Water Resources Department, Minor Irrigation Department (Manipur), IPD wing PHED (Manipur), Geological Wing-Directorate of Industries & Commerce (Manipur) and MASTEC. All data were plotted in base map on GIS Platform (MapInfo-6.5 using Projection category longitude/latitude (Indian for Bangladesh, India and Nepal projection).

Data collection includes collection of rainfall data from IMD and state government, litholog collection from state groundwater departments, compilation of CGWB's earlier survey data, exploration and geophysical data. Population data is collected from Statistical Handbook of Manipur, 2017 and census of India website. Agricultural data is collected from the website of Ministry of Agriculture, Govt. of India.

CGWB had carried out hydrogeological studies in Imphal valley during 2004-05. The available hydrogeological data is incorporated in the present study. GSI has carried out geological studies in Imphal valley to delineate the lithological units, their structures and stratigraphic disposition.

Central Ground Water Board has constructed 03 exploratory wells and 03 observation wells during NAQUIM study in Imphal West district during AAP 2014-15 and 2015-16. Public Health Engineering Department, Govt. of Manipur has also constructed 727 nos of tube wells and hand pumps in the district for domestic and drinking water supply and out of which 525 tube wells were successful. Presently, a total of 375 tube wells/hand pumps (188 nos. in Imphal West I block and 187 nos. in Imphal West II block) are functional (as per report of PHED, Manipur). In addition to these data of 3 nos. of exploratory wells constructed by CGWB, NER, Guwahati during the study on hydrogeology and groundwater conditions of Imphal valley (1975), has also been incorporated for better comparison with the present exploratory data.

Litholog of 28 nos. of tube wells have been collected from different sources like PHED, GSI, CGWB etc. Details of the wells are given in Table 2.5. Rainfall data was collected from Indian Meteorological Department (IMD) website and statistical Hand book of Manipur 2017. Ground water monitoring stations of Imphal West district established during the District Groundwater Development and Management studies, 2004-05 in Manipur valley were incorporated for water level data analysis.

2.2 Data Generation

2.2.1 Hydrogeological data:

In Manipur activities of ground water exploration is very limited. Exploration by Central Ground water Board (CGWB) has revealed that Imphal valley has groundwater potential but could not explore up to the desirable limit due to its nature of geological framework.

The present study area of NAQUIM in general is proved to be moderately potential from ground water point of view by the studies carried out by CGWB. Exploratory wells constructed down to 150 mbgl shows presence of granular zones in the area. No major, medium and small irrigation schemes are implemented so far in the district for irrigational purposes.

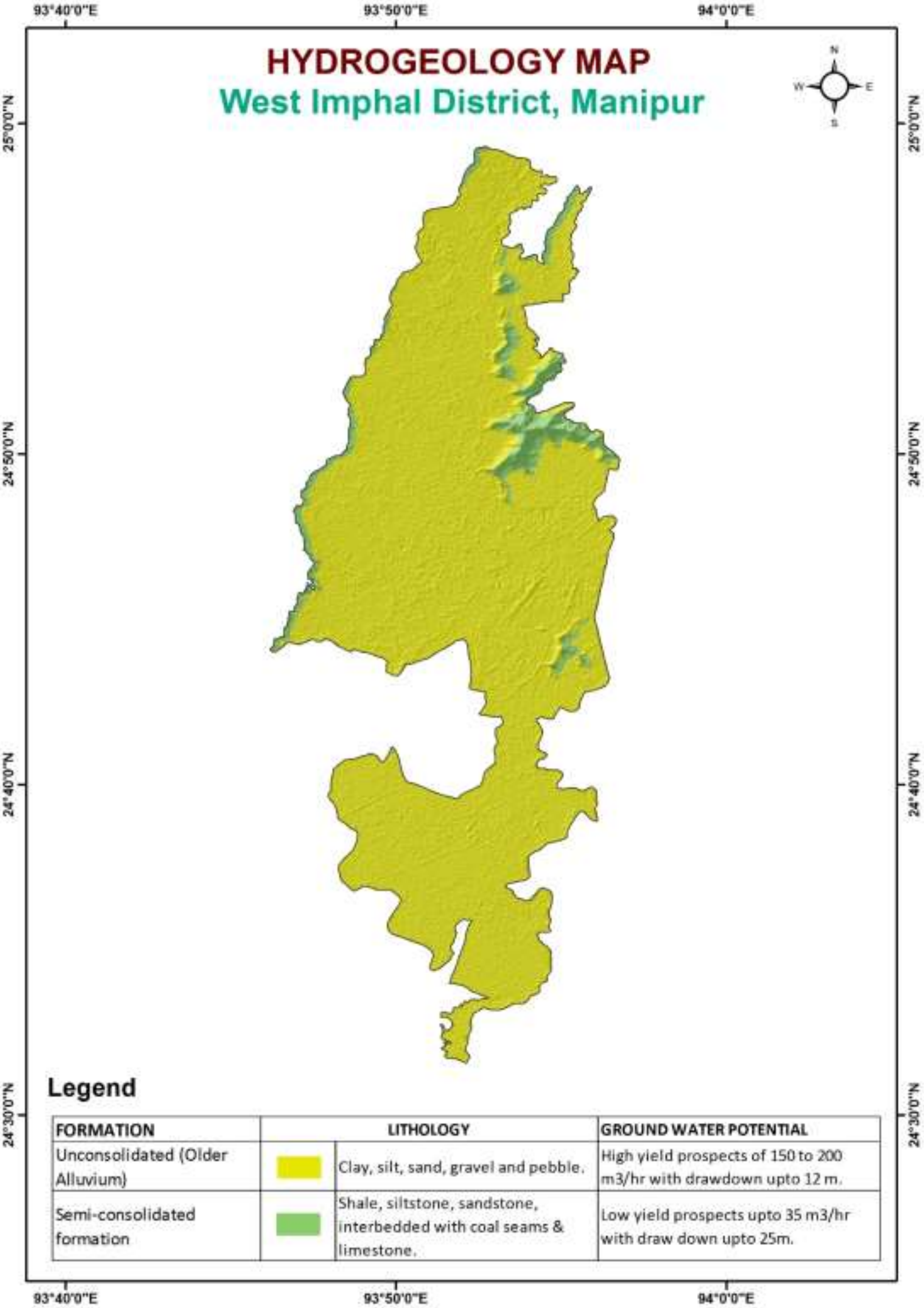


Fig.6 Hydrogeological map of the study area

Ground water in the deeper aquifers occurs under sub-artesian and artesian conditions. Granular zones are encountered at a depth of about 150 m in Imphal valley. Tube wells have been installed at various places of the valley areas with the yields ranging from 0.6 to 4 m3/hr.

Considering the clayey nature of formation in the top aquifer, groundwater development is not considered promising on a large scale either in irrigation of water supply.

Hydrogeological study has revealed that Imphal valley is underlined by a thin veneer of alluvial deposits, which is largely clayey in nature, underlined by rocks of Tertiary age. Since the upper formations are mainly silty and clayey, dug wells/open wells have poor yield prospects. However, the deeper zone, consisting of sand stones of Tertiary age, forms good aquifers which are under semi confined conditions, Auto flow conditions are observed in Imphal where the yield of the tube wells vary from 0.5 to 4 m3/hr.

The thickness of unconsolidated alluvial deposits varies from place to place with maximum thickness of more than 145m at Mayang Imphal (Roy, 1972). The peripheral zone of the valley consists predominantly of sand, gravel whereas the rest is covered dominantly with thick layer of clay. The average thickness of alluvial deposits varies generally from 30 m to 110 m as per the findings of CGWB and PHED, Manipur. Below the depth of 110 m semi-consolidated sedimentary rocks are found. The unconsolidated unit formed at the foothill, i.e., western peripheral zone of the valley, forming higher piedmont, consists of colluvial materials. These colluvial materials taper away within a short distance.

The study area has alternate layers of sand, silt and clay. The thickness of clay layer varies from place to place. It goes on increasing from periphery towards the center of the valley. The thickness of clay layer at places, in the study area goes up to 61 m, and maximum thickness of clay occurs in the south-central parts lying just north of Loktak Lake.

2.2.2 Water level data: The entire NAQUIM area of Imphal West district is covered by regular monitoring of 31 nos. of key observation wells. All these wells are under monitoring after establishment. The water level data of Shallow and deeper aquifers are given in Table 5 and 6

Table 5: Water level data of shallow aquifer key wells

Sl. No	Location	Latitude	Longitude	RL (mAMSL)	Water Table (m, AMSL)		DTW (mbgl)		Water level fluctuation (m)
					Pre-monsoon (Mar, 2018) (mbgl)	Post – monsoon (Nov'2017) (mbgl)	Pre-monsoon (Mar'18) (mbgl)	Post – monsoon (Nov'17) (mbgl)	
1	Yurembam	24° 47'22"	93°52'00"	785.240	783.8	785.04	1.44	0.20	1.24
2	Tharoijam	24° 48'10"	93°51'54"	785.860	785.78	785.66	0.08	0.20	-0.12
3	Phayeng	24° 50'34"	93°49'18"	806.675	805.765	805.875	0.91	0.8	0.11

4	Khurkhul	24º 55’01"	93º51’44"	810.879	800.512	801.742	1.33	0.1	1.23
5	Tingri	24º 55’03"	93º54’40"	800.273	805.949	806.679	4.93	4.20	0.73
6	Sekmai Sabal Leikai	24º 57’03"	93º53’06"	832.913	796.873	798.273	3.40	2.0	1.4
7	Khurkhul	24º 55’10"	93º52’12"	811.349	821.463	824.413	11.45	8.5	2.95
8	Potsangbam	24º 54’29"	93º54’16"	799.177	806.879	808.229	4.47	3.12	1.35
9	Sekmai	24º 57’33"	93º52’22"	841.047	795.677	795.927	3.50	3.25	0.25
10	Mana Ingkhol	24º 52’25"	93º52’41"	795.708	828.167	829.047	12.88	12.0	0.88
11	Mana Ingkhol	24º 52’23"	93º52’37"	795.948	796.398	795.678	-0.69	0.03	-0.72
12	Kadangband	24º 52’28"	93º48’57"	830.170	796.468	795.928	-0.52	0.02	-0.54
13	Kadangband	24º 52’40"	93º49’07"	825.823	826.48	825.97	3.69	4.20	-0.51
14	Phayeng DBS	24º 51’27"	93º48’51"	827.806	817.063	820.423	8.76	5.4	3.36
15	Sangaithel	24º 48’28"	93º47’54"	819.595	811.926	818.086	15.88	9.72	6.16
16	Laimaram	24º 42’41"	93º47’34"	796.237	820.095	815.595	-0.5	4.0	-4.5
17	Haorang Lamkhai	24º 48’31"	93º50’16"	786.857	796.787	796.737	-0.55	-0.5	-0.05
18	Awang Leikinthabi	24º55’32"	93º53’49"	809.594	787.357	787.157	-0.5	-0.3	-0.2
19	Khurkhul Makha Leikai	24º 55’20"	93º52’14"	812.00	804.834	807.844	4.76	1.75	3.01
20	Awang Sekmai	24º 57’37"	93º53’35"	842.00	811.64	809.8	0.36	2.2	-1.84
21	Potsangbam Wabgai	24º 54’30"	93º54’30"	800.00	839.39	839.16	2.61	2.84	-0.23
22	Awang Sekmai Nongthonban	24º 57’39"	93º58’38"	842.00	797.89	797.94	2.11	2.06	0.05
23	Tendongyan, NH-39	24º 54’05"	93º53’03"	807.00	839.42	839.52	2.58	2.48	0.1
24	Kanto Khunou, Leimakhong	24º 55’28"	93º52’17"	868.00	804.08	804.2	2.92	2.80	0.12
25	Khurkhul	24º 55’10"	93º52’12"	812.00	866.28	866.34	1.72	1.66	0.06
26	Luwangsangban	24º 53’12"	93º55’19"	788.80	810.1	810.15	1.9	1.85	0.05
27	Keithelmanbi Bazar	25º 05’48"	93º56’45"	832.56	782.18	782.69	6.62	6.11	0.51
28	Lamsang Tiniali	24º 49’15"	93º52’05"	792.69	826.03	826.07	6.53	6.49	0.04
29	Mantripukhri (near pond)	24º 56’56"	93º56’14"	788.00	787.59	787.79	5.1	4.9	0.2
30	Kodompokpi Lamkhai	24º 44’24"	93º51’53"	778.00	781.74	781.79	6.26	6.21	0.05
31	Langjing Acouba	24º 47’28"	93º53’52"	822.00	772	772.18	6.0	5.82	0.18

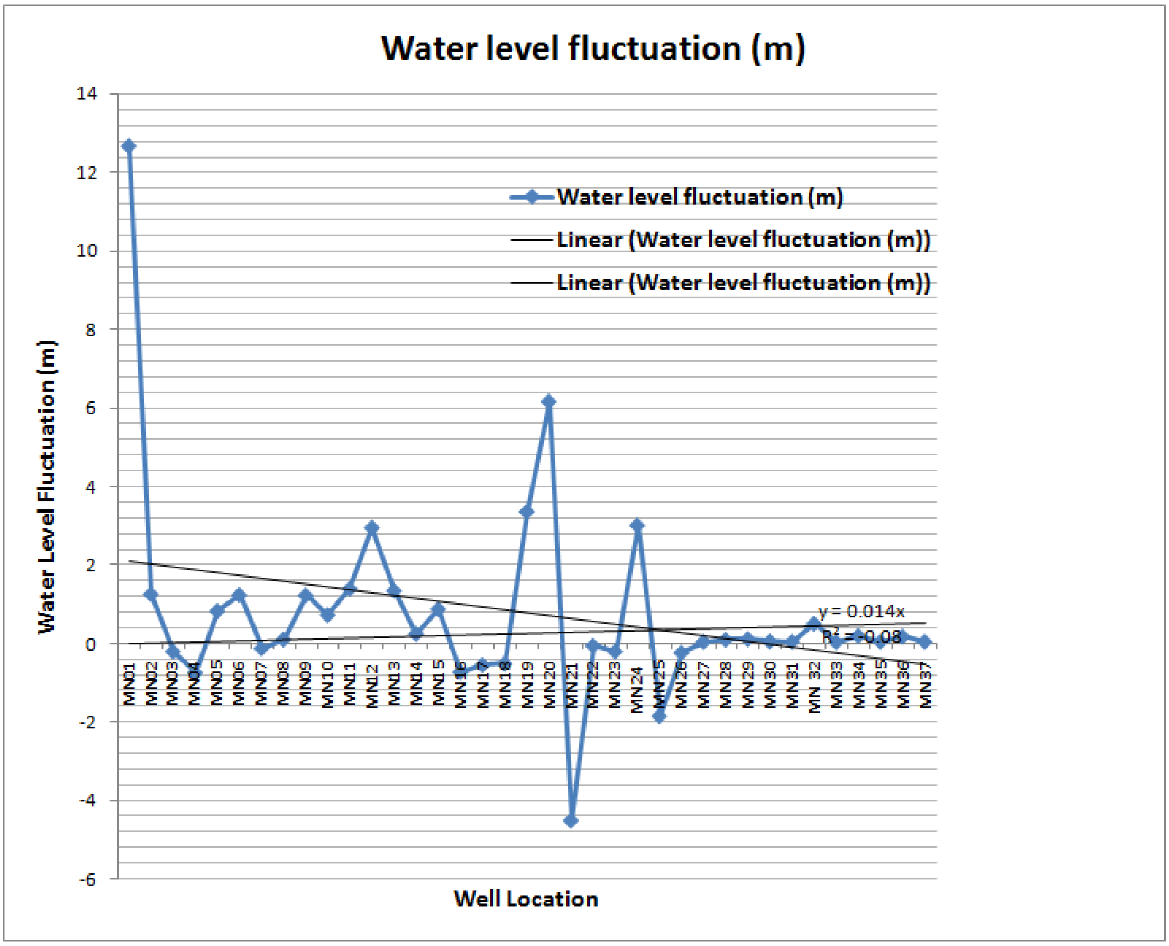


Fig.7 Water level fluctuation - linear trend of the monitoring wells in the study area

Table 6: Water level measurement of deeper aquifer key wells

Sl. No	Location	Latitude	Longitude	RL (m AMSL)	Water Table (m, AMSL)		DTW (mbgl)		Water level fluctuation (m)
					Pre-monsoon (Mar, 2018) (mbgl)	Post – monsoon (Nov'2017) (mbgl)	Pre-monsoon (Mar, 2018) (mbgl)	Post – monsoon (Nov'2017) (mbgl)	
1	Potsangbam	24° 54'46"	93°53'54"	801.842	800.512	801.742	1.33	0.1	1.23
2	Chinga MC. Road	24° 47'02"	93°56'20"	784.795	781.415	782.245	3.38	2.55	0.83
3	Shamurou	24.69561	93.9067	772					
4	Irom Meijarao	24.70943	93.89109	778.324	773.964	773.624	4.36	4.7	-0.34
5	Wangoi Kabui	24.66853	93.9022	777.511	776.791	776.711	0.72	0.80	-0.08
6	Canchipur	24.7526	93.92943	773	781.06	781.77	0.91	0.20	0.71
7	Heinoupok	24.79124	93.898	822					
8	Ghari	24.77440	93.90838	779.374	779.694	779.594	-0.32	-0.22	-0.1

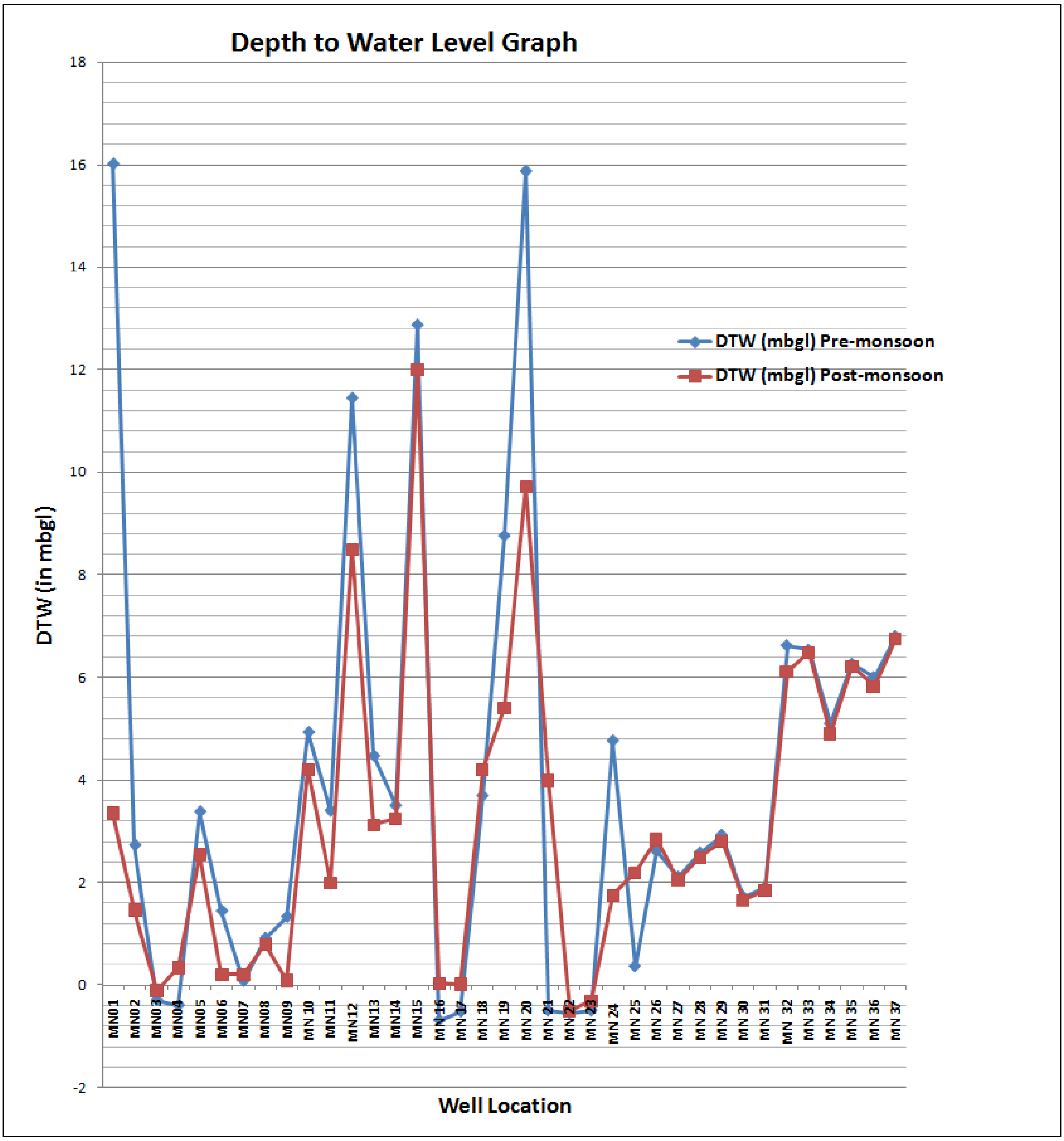


Fig.8 Water level fluctuation graph of the monitoring wells in the study area

2.2.3 Water Quality

To know the water quality of the study area, water sampling done from both shallow and deeper aquifers. Ten key observation wells in the NAQUIM area have been selected for determination of chemical constituents amongst the existing ground water abstraction structures. The sampling sites are prominent places of the study area and the samples are the major sources of drinking for the locals. Water samples collected during the study were analyzed for the different chemical constituents at the regional chemical laboratory of CGWB, NER Guwahati.

Table 7 Estimation Methodology

Parameters	Analytical Technique	Method of Preservation
pH	Portable digital pH meter	-
Electrical Conductivity (EC)/TDS method	Portable digital EC/TDS meter	-
Alkalinity	Titration method	Preserved in Polyethylene bottle
Hardness	EDTA Titration method	Preserved in Polyethylene bottle
Chloride (Cl^-)	Argentometric method	Preserved in Polyethylene bottle
Fluoride (F^-)	SPADNS method	Preserved in Polyethylene bottle
Calcium (Ca^{+2})	EDTA Titration method	Preserved in Polyethylene bottle
Magnesium (Mg)	EDTA Titration method	Preserved in Polyethylene bottle
Iron (Fe^{+2}/Fe^{+3})	Phenanthroline method	Preserved in Polyethylene bottle at pH < 2 with HCl
Sulphate (SO_4^{-2})	Turbidimetric method	Preserved in Polyethylene bottle
Sodium & Potassium	Flame Photometric method	Preserved in Polyethylene bottle
Nitrate	Disulphonic acid method	Preserved in Polyethylene bottle

The procedures were followed from standard books and manual. The analysis was carried out immediately for pH, electrical conductivity, and odour and for all the other parameters within the recommended preservation time. The various parameters and the estimation methodology are presented in Table 8.

Different physical parameters studied are appearance, colour, odour, taste, electrical conductivity and total dissolved solids. The values obtained for these parameters are given in Table xx. Different chemical parameters studied are pH, alkalinity, total hardness, calcium, magnesium, iron, sodium, potassium, nitrate, chloride, fluoride and sulphate. All the samples are found to be colorless, odorless and agreeable in taste.

2.2.4 Geophysical Studies

No Data of VES survey of CGWB was available for Imphal west district

2.2.5 Exploratory Drilling: During the NAQUIM study in AAP 2017-18, exploratory drilling activity was not carried out in Imphal West district, Manipur. However, Old drilling data of CGWB including 3 exploratory welss and 3 observation construction during 2014-15 & 2015-16 during NAQUIM study as well as data of Public Health Engineering Department were collected and examined. A list of wells constructed in the area was prepared incorporating location, well designs, etc.

Table 8: Details of exploratory wells in the study area

Sl No	Location	Longitude	Latitude	RL	Depth (in m)	Discharge (lpm)
1	Iroisemba	93.89691	24.809	789.8	74	
2	Langol Complex	93.93304	24.82357	789.22	61	268
3	Thangmeiband	93.94179	24.82301	788.12	91	315
4	Chingmeirong	93.95147	24.82968	788.737	153	
5	Wahengbam Leikai	93.96935	24.82301	788.23	97	
6	Keisampat	93.93811	24.79559	788	137	
7	Keisamthong	93.93142	24.79298	788	73	
8	Khagempali	93.93429	24.78451	784	50	
9	Chinga	93.93997	24.7832	784.795	91	408
10	Keithelmanbi	93.79726	24.77115	832.56	54	
11	Kangchup	93.81412	24.85744	830.17	72	
12	Kadangbal	83.82072	24.875	825.823	30	254.25
13	Sekmai	93.8813	24.951	841.047	29	40.22
14	Ningthoukhong	93.73487	24.54949	804	26.95	
15	Toubul	93.79279	24.62341	772.02	118.5	
16	Bishenpur	93.75966	24.62806	773.33	45.7	126.62
17	Buri Bazar (Nambol)	93.84487	24.71743	772.04	84.7	
18	Tulihal	93.89369	24.7663	779.8	83.16	10.58
19	Imphal College	93.94704	24.77036	780.83	117.42	13.33
20	Kwakeithel	93.94632	24.77786	781.66	82.39	66.66
21	Uripok	93.92527	24.81053	782.24	133.98	
22	Lamsang	93.92527	24.81053	792.69	111.65	
23	Heinoupok	93.898	24.79124	822	105.8	Auto flow
24	Canchipur	93.92943	24.7526	773	145.4	Auto flow
25	Shamurou	93.9067	24.69561	772	64.5	Auto flow

CHAPTER 3.0

DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Data Interpretation

3.1.1 Geophysical and aquifer Characterization:

No Geophysical studies have been carried out by CGWB during the period 2017-18.

3.2 .0 Results and Interpretations of Hydrogeological Studies

3.2.1 Aquifer Characteristics

Studies carried out by CGWB shows that that groundwater occurs both under the unconfined and confined conditions. Groundwater in top clayey and sandy formation occurs under water table conditions. Groundwater in the deeper aquifer occurs under sub-artesian and artesian conditions. The groundwater in the shallow aquifers is unconfined and the static water level is 15.88 mbgl to 0.69 m, agl. Groundwater in deeper layers is semi-confined to confined with static water level from 4.36 mbgl to 0.32 magl during pre-monsoon and 4.7 mbgl to 0.22 during post monsoon. Granular zones are encountered at depth of about 60 m to 100 m in Imphal valley. Tube wells have been installed at various places of the valley area with the yields ranging from 0.6 to 4 cum/hr.

The water table contour map reveals that flow of ground water is towards SW part of the valley towards Loktak Lake. The highest elevation of groundwater level is found in the northern extremity of the valley. In the northern part of the study area, the level of groundwater is found to be 842 mAMSL (around Awang Sekmai in Imphal West I). The shallow water level depth is found towards the central parts of the study area and extends towards south and lies below772 mAMSL (around Shamurou) adjacent to the marshy lands of Loktak Lake.

Since Imphal River flows in the central part draining the valley, it is seen that the river takes under underground water from all directions and discharged towards south along its own flow. However, at places, e.g., areas bordering to Thoubal district, storage of groundwater is enhanced due to influent seepage from the river.

The groundwater level of the shallow tube wells in the study area goes down when the level of water in the Imphal river system is at the bottom surface or vice versa. Hence, shallow tube wells sometimes have no water or water at the bottom during especially lean period, whereas deep tube wells are never dry in the area. This shows that there is intergranular link with the river environment. The central and south-central portion of the study area has very shallow water table. Private ponds of about 3 m depth have storage of surface water throughout the year.

Depending upon the constitution of aquifer systems, the yield of exploratory well and tube well differs from place to place in the study area. The exploratory well constructed for tapping groundwater horizons with cumulative thickness of 10 meter at Sekmai area (Pebble, gravel mixed with sand) yield 480 liters per minute for a drawdown of 6m whereas exploratory well constructed in almost similar aquifer system consisting of boulder, pebble, gravel mixed with sand, at Bishnupur area, yield 100 liters per minute of discharge at drawdown of 17 m. This may be due to the variation in grain size of the particles forming the aquifer, thickness of aquifer, orientation of grains, compactness. However, tube wells constructed at the foot of residual hill, tapping deposits consisting of soil mixed with sand, gravel and underlain by soft shale followed by hard shale, give discharge of 100 to 180 lpm. In places where there is sandstone layer at depth, tube wells give comparativelt higher amount of water.

The valley portions in the study area are capped by clay horizon below which sand horizon occurs can be developed through moderately deep tube well. In Imphal area and adjoining areas, where fine to medium sand horizons occur, groundwater can be developed through shallow tube wells for domestic purposes.

Locally developed alluvial fans at the foot of residual hills can also be developed through shallow to moderate depth tube wells with expected yield of 130 to 270 lpm. Wells should be properly spaced and located, the areas occupied by infilled channel traces where there is sequential order of gravel overlain by sand and capped by clay layer at the top can be developed for moderate depth to deep tube wells for drinking as well as agricultural activities as is evidenced from the tube wells of Loitang Khunou and Khurkhul area with a quantum of yield about 1024 litres per minute. This represents the maximum discharge of water observed at infilled channel traces in the study area.

3.2.2 Findings from Exploration

Central Ground Water Board, North Eastern Region, Guwahati have been constructed 3 nos. of exploratory wells and 3 nos. of observation wells in parts of Imphal West district. Public Health Engineering Department has also been constructed 727 nos. of tube wells/hand pumps in the district for domestic supply. However, only 25 nos. of lithologs are included in this study after proper verification of lithologs available. From the examination of these lithologs, it has been observed that down to a maximum explored depth of 145.40 m in the sequence from 50 m is dominated by clay, sand, gravel with mixtures of silt and ground level to 50 mbgl is dominated by clay, shale, sand.

In general, Layers of clay beds occur at surface all over the alluvial deposit ranging in thickness from 5 to 10 m and existence of clayey deposit down to depth range of 30 to 65 m bgl which invites problem for construction of shallow tube wells. The tube wells drilled in alluvial deposits show alternate beds of sand, gravel, shale and thin beds of clay. Ground water related problems in the district have so far been identified as emanation of gas while constructing deep tube wells in some places.

The lithologs of exploratory wells and tube wells constructed by PHED have also been incorporated in the litholog analyses in order to understand the actual picture of 2D and 3D disposition of aquifer.

3.2.3 2D disposition: Two sections are constructed to visualize the aquifer disposition

(a) a north to south section (fig.9a)

(b) a north east-south west section (Fig. 9b)

(c) a north west to south east section (Fig. 9c).

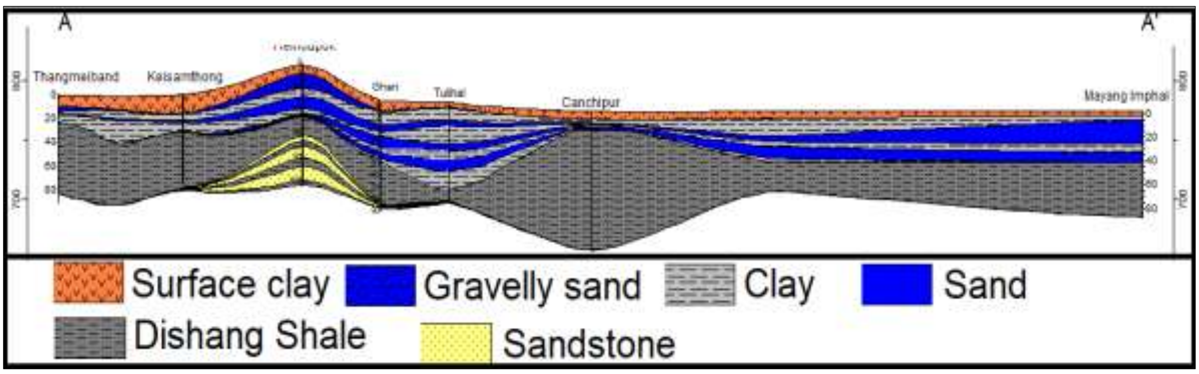


Fig.9 a: (N-S) section showing aquifer disposition: Thangmeiband to Mayang Imphal

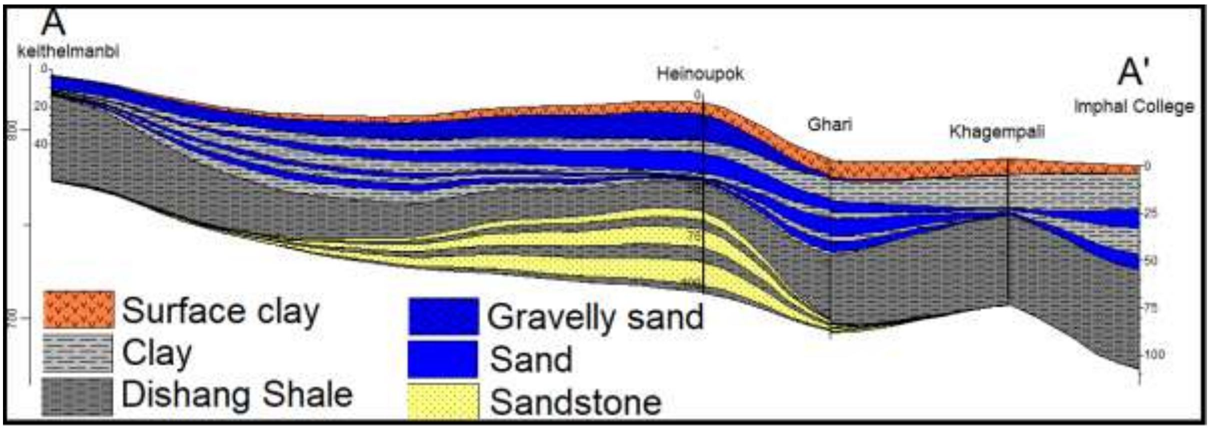


Fig.9 b: (NE-SW) section showing aquifer disposition: Keithelmanbi-Imphal College

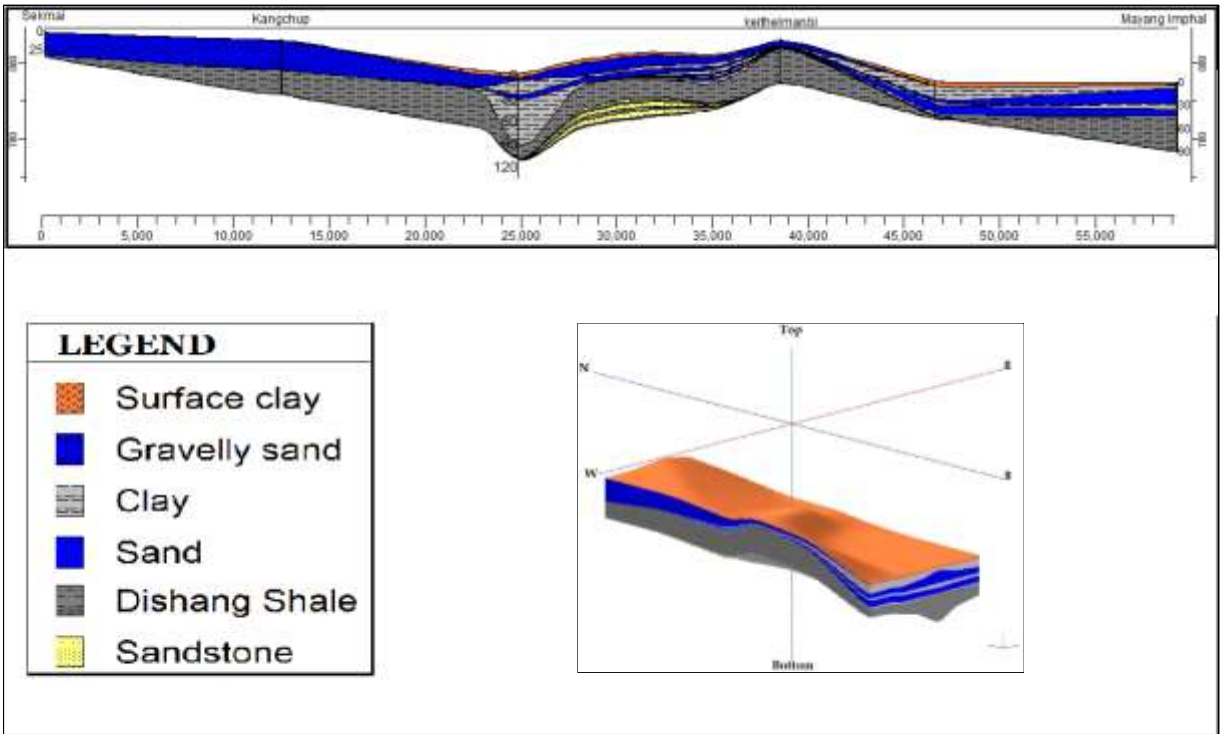


Fig.9c: (NW-SE) section showing aquifer disposition: Sekmai – Mayang Imphal

3D disposition of aquifer: The aquifer disposition of the area in the 3D block diagram indicates existence of a single aquifer in the area. The confining layers are not continuous throughout the area.

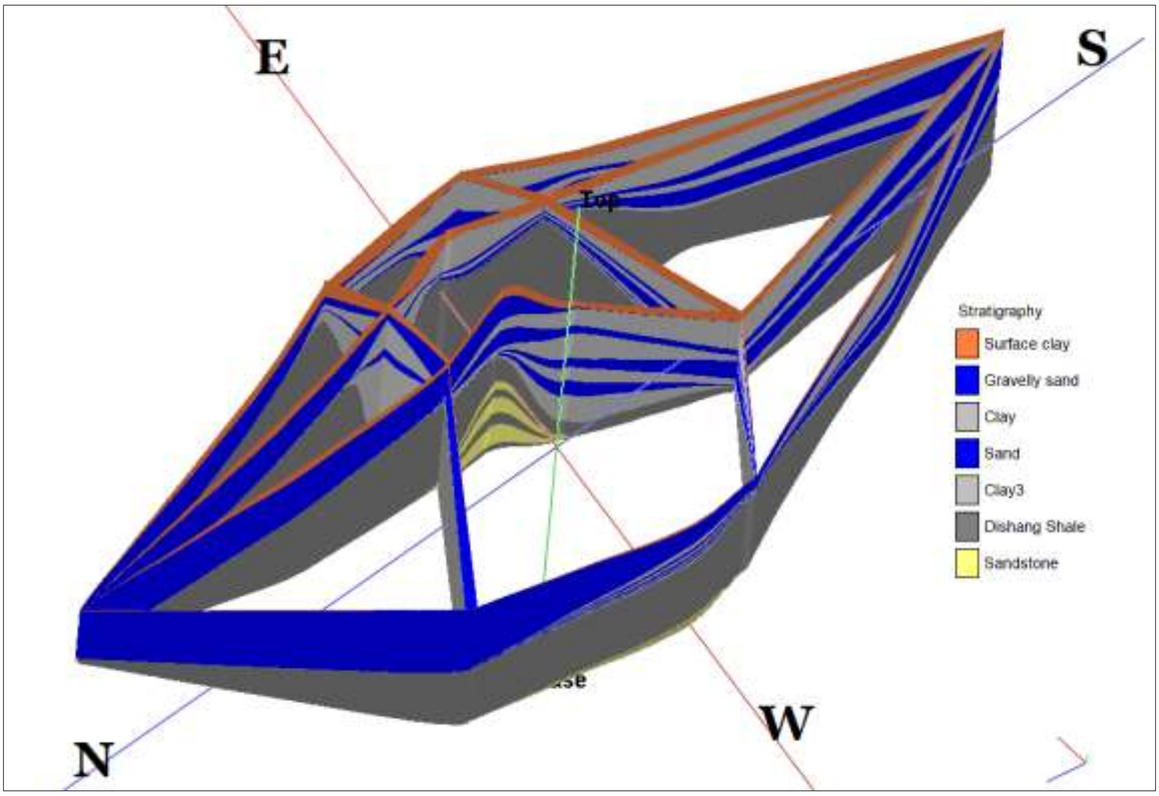


Fig. 10a: 3D disposition of aquifer in the study area

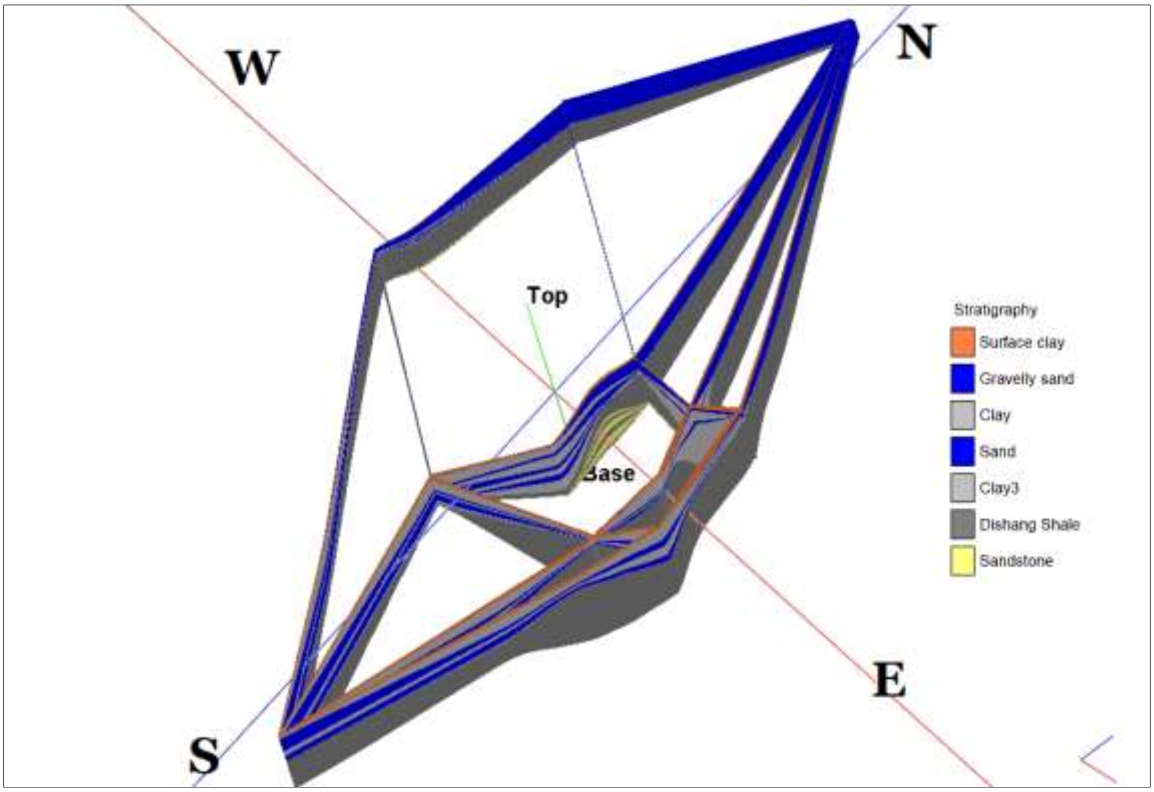


Fig. 10 b: 3D disposition of aquifer in the study area

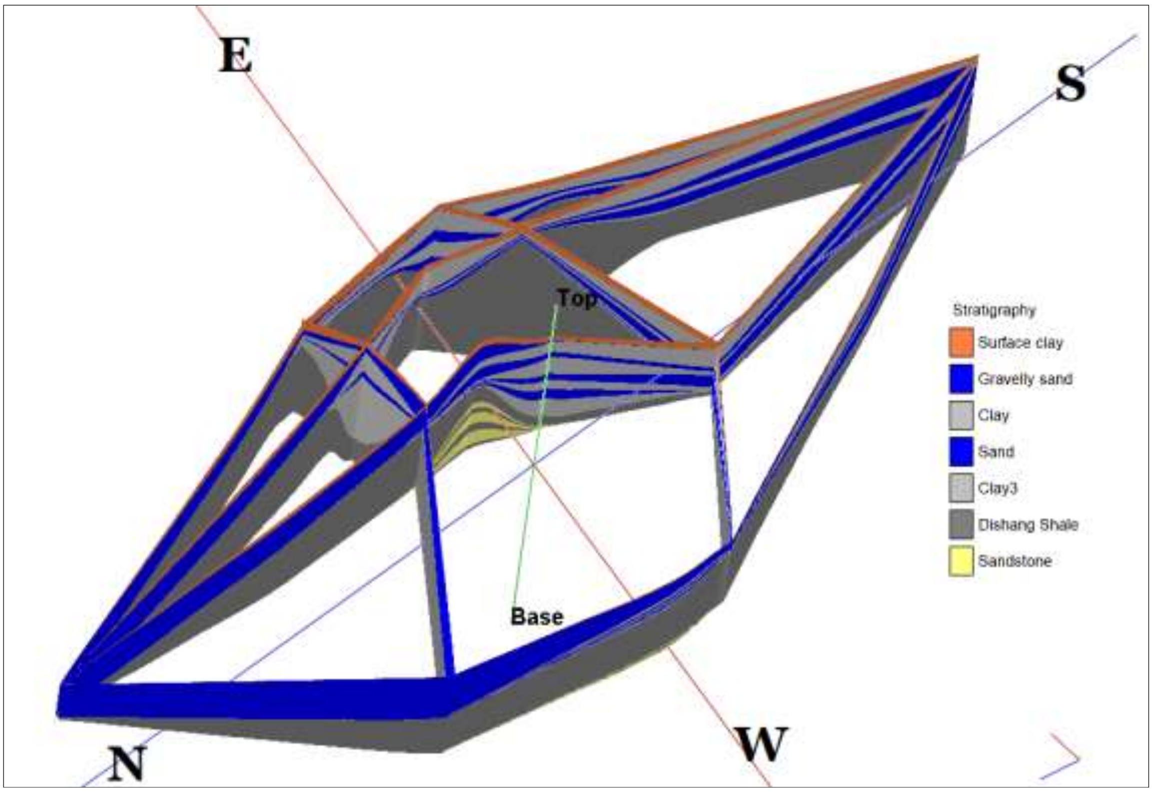


Fig. 10 c: 3D disposition of aquifer in the study area

Table 9: Aquifer parameters

Parameters	**1st Aquifer**	**2nd Aquifer**
Depth Range	0.9 to 105 m	34.10 to 61.50
Depth to Water Level(mbgl)	3.65	
Zones Tapped	-	24-29; 32-38; 42-46
Yield (m3/hr)	2.4	24.24 to 49
Transmissivity (m2/day)	664	2032.40 to 9831
Draw down(m)	6.21	0.86 to 4.92

3.2.4 Sub-Surface Geology

The sub-surface geology of the study area is presented in the panel diagram using exploratory tube well data of CGWB and PHED, Manipur. A perusal of the 2D and 3D disposition of the aquifers reveals that the aquifer system in the district is multi-aquifer system (Fig. 3.3). The aquifer property identified by CGWB are given in Table 3.2

3.2.5 2D Disposition of Aquifers and 3d Fence View

The northern extremity of the study area has thick granular horizons as seen very distinctly along the river section. The thickness of the granular zone goes up to 40 m around Sekmai area.

The sub-surface strata at the foothill of Langol hill area shows sand mixed with gravel and finally capped by thin layer of clay. The Naran Konjin hill area shows thick layer of clay overburden above the soft shale.

The sub surface lithology in around Yurembam, and Ghari has shown variable clay thickness below which sand horizons of cumulative thickness of 46 m occurs within 90 m depth.

The sub surface lithology near to Imphal town area, i.e., Chingmeirong to Akampat via Kangjabi, Kangabam leikai, Khagempalli area shows complex sub surface picture. The lithology of the area has revealed two to three horizons of aquifer in somewhat disconnected fashion. Sandstone in lensoid form occurs below topmost clay layer at Kangjabi and Kangabam leikai in the section. Sand horizon also occurs adjacent to sandstone body.

The sub surface section between sections in the North- South fringes of the study area shows the existence of more or less single horizon of aquifer consisting of coarse clastic materials within a depth of 45.7 m with thin clay intercalations. It shows a typical fan deposit at piedmont parallel to the Imphal River. Perched water table condition may also exist above the clay layer.

2D SECTION ALONG CHINGA- KHAGEMPALI- KEISAMTHONG- THANGMEIBAND - CHINGMEIRONG - SEKMAI

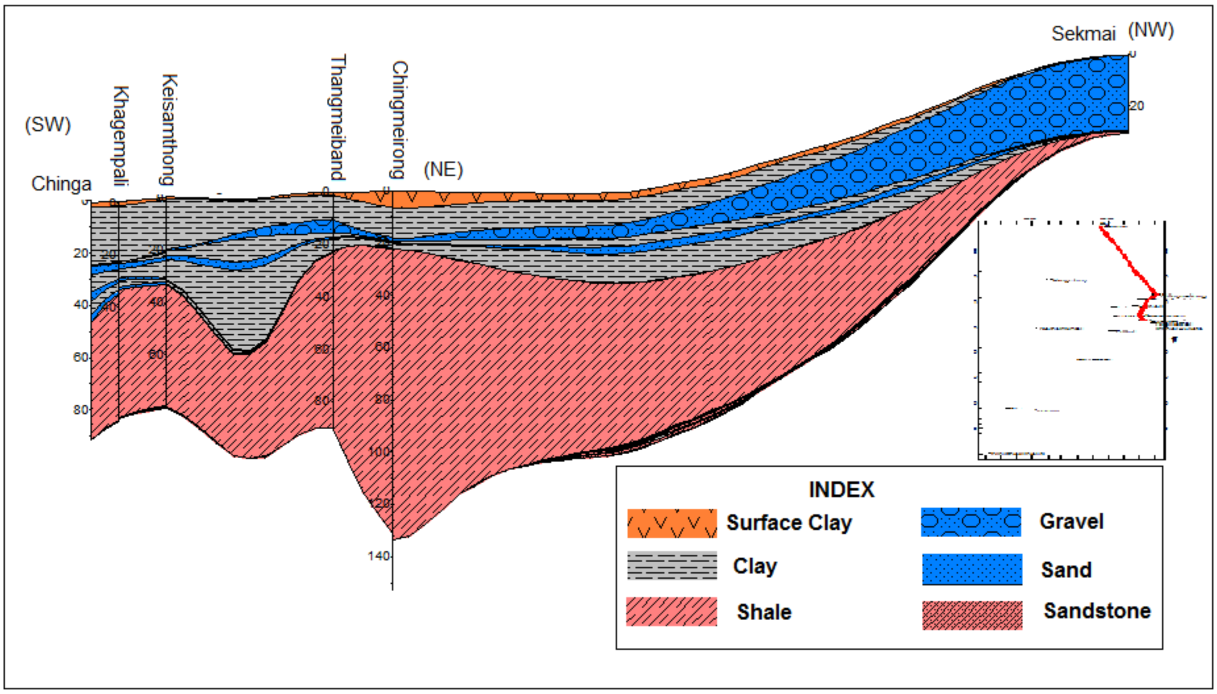


Fig.11 Sub surface 2D section along Chinga-Khagempali-Keisamthong-Thangmeiband-Chingmeirong- Sekmai in the study area

Though more or less single horizon of aquifer layer exists in the western part of the district, there exists two to three aquifer horizons, intercepted by impermeable layers/horizon, within a depth of approximately 90 to 100 mbgl in the eastern fringe of the below which sedimentary rocks (may be basement rocks probably forming lower extension of piedmont floor in the valley) are encountered. It represents possibly the deposits of infilled lake and infilled channel in part of the valley. Though the thickness of the granular horizon at the periphery of the valley, i.e., in the bordering district of the study area is considerably high, it tends to reduce its thickness towards the central portion of the study area and followed by thick layer of clay. The areas in the northern extremity of the valley about 10 kms from the study area reveal the existence of thick layer of coarse-grained materials.

3.2.6 Aquifer Map

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

The exploration reveals prevalence of both unconsolidated rocks belonging to Recent to Sub-Recent and semi-consolidated rocks belonging to Upper Tertiary age. Thickness of alluvium ranges from less than 10 m to maximum of 20 m, found increasing towards north and central parts of the study area.

Depth-wise distribution of aquifer granular materials from drilling has been shown in Table-10.

Table 10 Distribution of granular zone in various depths in the study area

Depth Range	Within 50 m	50 - 100 m	100– 150 m
Thickness of Granular zone	3-8 m	5 – 15 m	5– 20 m

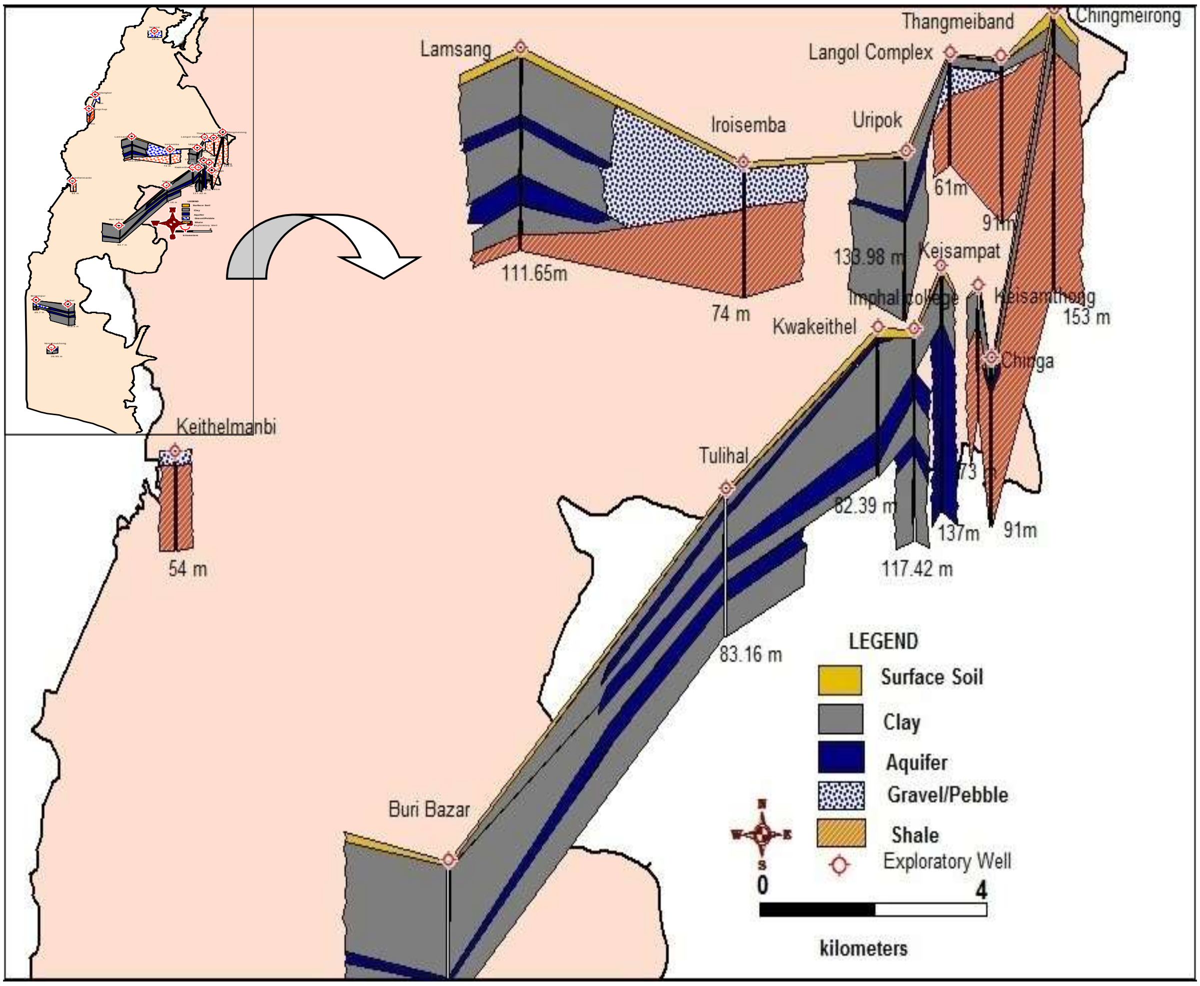


Fig.12 Aquifer Disposition in the north- central part of the study area

Table. 11 Aquifer character in the study area

Type of Aquifer	**Depth range of the aquifers (mbgl)**	**Thicknes s (m)**	**Yield (m^3 per hr)**	**Draw down (m)**	**T (m2/day)**	**S**
Aquifer - I (Unconsolidated)	GL to 50	5 to 10	10	18	55	$1.5x10^{-3}$
Aquifer - II (Tertiary sandstone)	50 to 150	5 to 20	15	18	82	$3.4x10^{-4}$

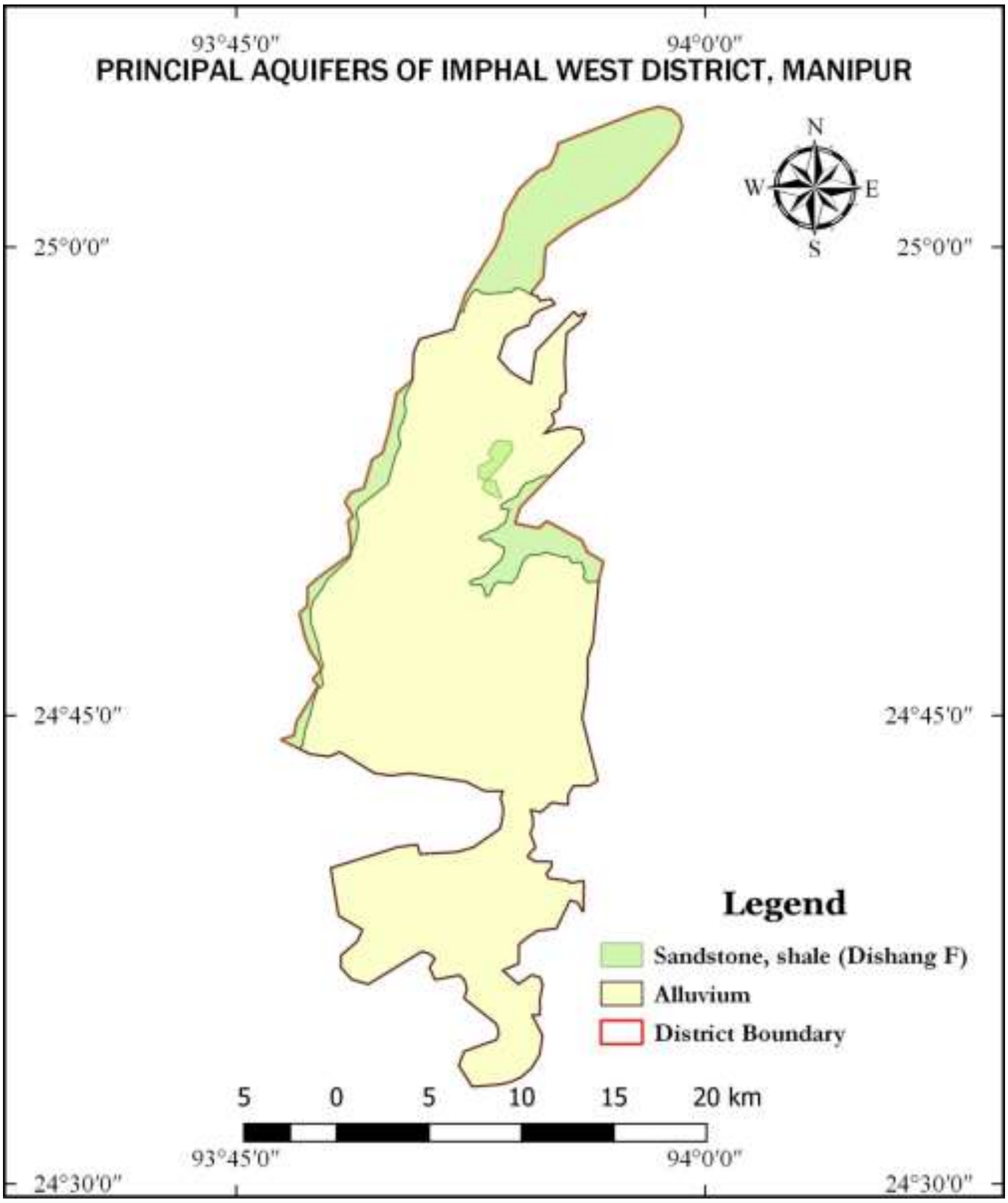


Fig.13 Map showing Principal Aquifers in the study area

3.2.7 Ground water level

Depth to water level in the shallow aquifers is unconfined and the static water level is 15.88 mbgl to 0.69 m, agl during pre-monsoon and it varies from 12 mbgl to 0.5 magl during post-monsoon. The depth to water level deeper aquifers varies from 4.36 mbgl to 0.32 magl during pre-monsoon and 4.7 mbgl to 0.22 during post monsoon.

3.2.8 Ground Water Movement

The groundwater movement is essentially towards the southwestern lower part from the peripheral higher elevation of the district and finally results in a north to south hydrologic gradient during pre-monsoon and north to south-west-south (SWS) region during post-monsoon period in the district. Since there are variations in the lithology and texture of the underlying formations there are great variations in the hydraulic gradient also in the study area especially in between Disang and Barail parts of the valley. The hydraulic gradient in the south-western fringe area is 12 m/km while it is 3.6 m/km in the eastern fringe. The hydraulic gradient in the southern part is 4.4 m/km.

3.2.9 Ground water quality

In general, the ground water of the district is slightly alkaline to neutral in nature. Electrical conductivity (EC), total dissolved solids (TDS) are very less, indicating soft water. Other constituents are within permissible limit of drinking, agricultural and industrial water standard set by BIS. So far, no chemical pollution has been detected in the district. However, the shallow water bearing zone, the Iron content in ground water is more than permissible limit.

The pH of the ground water varies from 8.02 to 8.51 indicating pH of the water within permissible limits. The value of EC varies from 185.3 to 844 µs/cm at 25^{0}C. The fluoride content of water sample varies from 0.04 to 1.2 mg/l. The iron content in the shallow aquifers varies from 0.21 to 10.8 mg/l and it is BDL for deep tube well samples. Summary of results of chemical analysis data showing concentration of iron in groundwater is shown in table below.

Table: 12 Summary of chemical analysis data showing concentration of iron in groundwater

Result of Water samples from Shallow aquifers			
SI. No	Fe (mg/l)	No. of samples	% of samples
01	0.0 to 0.3	01	10
02	0.3 to 1.00	03	30
03	> 1.00	04	40

It can be seen from the above table that 60 % water samples collected from shallow tube wells are having iron content within desirable limit (set by BIS). And 40% water samples collected from the shallow tube wells are having iron content more than the desirable limit. No iron was detected in the deep tube wells.

3.2.10 Hydrochemical Findings in Detail

The analytical results of various parameters of water quality in the study area are highlighted to integrate in the aquifer mapping. Various physico-chemical parameters viz., temperature, pH, total dissolved solids, electrical conductivity, hardness, nitrate, chloride, sulphate, fluoride, sodium, potassium, magnesium, calcium and total iron content in the groundwater were analyzed. Among the various parameters recorded, total dissolved solids from 95.08 mgL^{-1} to 438 mgL^{-1}; pH from 8.02 to 8.51; electrical conductivity varied from 185.3 µs cm^{-1} to 844 µs cm^{-1}; chloride values ranged from 37.71 mgL^{-1} to 156.81 mgL^{-1} ; total hardness ranged from 72 mgL^{-1} to 264 mgL^{-1}; sulphate values ranged from 0.988 mgL^{-1} to 3.652 mgL^{-1}; nitrate from 0.1 mgL^{-1} to 4.1 mgL^{-1} ; fluoride values ranged from 0.04 mgL^{-1} to 1.2 mgL^{-1}; sodium varied from 7.79 mgL^{-1} to 118.07 mgL^{-1}; potassium value ranged from 1.49 mgL^{-1} to 18.78 mgL^{-1}; magnesium value ranged from 4.85 mgL^{-1} to 45.63 mgL^{-1} ; calcium value ranged from 12.8 mgL^{-1} to 75.2 mgL^{-1} ; while iron values varied from BDL to 10.8 mgL^{-1}.

Detail of chemical quality analysis data of the groundwater samples collected in the NAQUIM study area is given in Annexure III.

CHAPTER 4.0

GROUND WATER RESOURCES

4.1 Ground Water resources estimation (as per GEC 2015)

The computation of ground water resources available in the existing two blocks of Imphal West district has been carried out by using GEC 2015 methodology. The Dynamic Resource estimation presented here is taken from the Dynamic Groundwater Resources of Manipur 2017 in block level.

In the present report, the smallest administrative unit viz. Imphal West-I block and Imphal West II block have been considered for resources assessment. Area with more than 20% slope has been excluded for the recharge assessment. The total area considered for the resources estimation is 519 sq.km, which is the NAQUIM area in Imphal valley.

Since the poor-quality groundwater is only a localized phenomenon, the block-wise poor-quality area have been taken as Nil. The sub-unit demarcation into command and non-command is not carried out since the data for the same are not available.

Groundwater extraction for domestic use has been estimated based on the number of different types of groundwater abstraction structures and their unit draft per year. The State Government authorities like PHED, IFCD, Minor Irrigation, MASTEC, DGM etc. provided the number of groundwater structures. Groundwater extractions during monsoon and non-monsoon periods have been estimated separately by taking four months as monsoon and eight months as non-monsoon period. The annual unit groundwater extraction has been taken as 1.0 ham for shallow tube wells, considering the average discharge of wells as 15 m^3/hour with two hours pumpage per day.

Block-wise groundwater extraction for irrigation was estimated based on the number of structures as provided by Minor Irrigation Department, Manipur. The unit annual extraction has been taken as 3 ham as given in GEC 2015 for the states of some of the North Eastern States. Groundwater in the district is mostly used for domestic and irrigational purposes. Groundwater extraction for Industrial uses is in the nascent stage or negligible. The details of canals have been collected from Water Resources Department, Govt of Manipur. All the canals are unlined and the canal seepage factor has been taken as 15 ham/day/million sq.m of wetted area. For estimating the recharge from surface water irrigation, details regarding various major and medium irrigation projects are collected from Water Resources Department, Govt of Manipur.

The return flow factor for surface water irrigation has been taken as 0.50 for paddy and 0.30 for non-paddy, which works out to be 0.374 for the assessment unit as the weighted average of return flow factor as a whole. Return flow factor for groundwater irrigation has been taken as 0.45 for paddy and 0.25 for non-paddy which works out to be 0.292 for the assessment unit as the weighted average of groundwater return flow factor a whole. Recharge from tanks and ponds and Recharge from water conservation structure have been taken for non-monsoon. As the data on the field studies for computing recharge from Tanks & Ponds are very limited, it is recommended to follow the same norm as followed in GEC 1997 in this assessment also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day. In the absence of water level data, the recharge from rainfall has been calculated using Rainfall Infiltration Factor. Following the norms recommended by GEC'97, Rainfall Infiltration Factor has been taken as 0.12 for Tertiary Sedimentary Formations. The natural discharge during non-monsoon period is taken as 10% since only RIF method is considered. The population has been projected to 2025 based on decadal growth rate as given in Census of India, 2011. Categorization of assessment units are done based on stage of groundwater development only, since data on long term water level trend is absent.

The total annual groundwater recharge of Imphal West district is 8729.2 ham, while 4664.3 ham is for Imphal West I block and 4064.9 ham is for Imphal West II block respectively. The annual extractable ground water resource of the district is worked out as 7856.3 ham after deducting the Environmental flows. The existing current annual gross ground water extraction for all uses is 166.24 ham of which 105.5 ham is the current annual gross ground water extraction for irrigation use, 54.89 ham is the current gross ground water extraction for domestic use and 6.0 ham is the current gross ground water extraction for industrial uses. The stage of groundwater extraction of Imphal west district is 2.12 %. As such all the assessment units falls under Safe category.

The pre-monsoon (in the month of March) water level from monitoring wells of CGWB in the study area has been considered as the maximum depth below ground level up to which the zone of water level fluctuation occurs. Since the study area 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. The specific yield of aquifer in Unconsolidated Alluvium Formation has been taken as 0.12.

Table.13. Balance of ground water availability for future use as per dynamic groundwater resources in the NAQUIM area

Assessment Unit	Stage of Ground Water Extraction (%)	Annual Extractable Ground Water Resource (ham)	Gross Ground Water Extraction for Irrigation (ham)	Gross Ground Water Extraction for domestic supply (ham)	Gross Ground Water extraction for Industrial Use (ham)	Gross Ground Water Extraction for All Uses (ham)	Allocation of Ground Water for Domestic Supply up to 2025 (ham)	Net GW Availability for Future use (ham)	GW Availability for Future use @ 60% Net GW Availability (ham)	No. of STW feasible as per Resource (Unit draft 3 ham)
IW I	3.43555	4197.87	93.31	6	44.91	144.22	363.9	3734.66	2518	839
IW II	0.60189	3658.43	12.04	0	9.98	22.02	848.13	2798.26	2195	731
IW	2.12	7856.3	105.35	6	54.89	166.24	1212.03	6532.92	4713	1570

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

Table 14: Public water supply scenario in the study area

Block	Total number of Public Water Supply Scheme	Source
Imphal West I	188 nos. of tube wells/ hand pumps Are under working condition	Deep Tube Well
Imphal West II	188 nos. of tube wells/ hand pumps Are under working condition	Deep Tube Well

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

4.3 Present Groundwater Development

Development of groundwater through construction of tube wells/bore wells for water supply of Imphal began in June 1996 in the Potsangbam well filed. The well field comprises 10 nos. of production tube wells depths ranging from 45 m and 60 m with discharges ranges from 1,087 to 1,512 liters per minute.

Table 15. Water supply situation of Imphal West District

Sources of Water	Production (in MLD) [1 MLD = 1000 m^3/day] (As on 2017)	Production (in MLD) [1 MLD = 1000 m^3/day] (As on 2030)
Surface Water	68.57	
Ground Water	6.557	
Total	75.127	
Water Demand	*120.92*	
Deficit in Water Supply	*15.67*	

(Investigation and Planning Division, PHED, Govt of Manipur)

CHAPTER 5.0

GROUNDWATER RELATED ISSUES

5.1 Major Groundwater Issues in the Area

Groundwater related problems of the district so far been identified **is emanation of gas w**hile construction of deep tube wells and existence of clayey deposit down to a depth range of 30 to 50 mbgl which invites problem for construction of tube wells. As such utmost care has to be taken during construction of tube wells so that any untoward incident can be averted.

Other groundwater related issues found in the study area are-

- **Low stage of development:** As per ground water resource estimation March 2017, the stage of ground water extraction is only 4.0 %. At present the irrigation practice by utilizing groundwater (constructing tube well) is not practice in large scale by individual villagers (small and marginal farmers) due to small land holding, high cost for construction and running of a well compared to production outcome. Another major obstacle in accelerating groundwater irrigation is the absence of power lines in most of the cultivated/cultivable area and meager irrigational infrastructure and in major parts of the study area.
- **High concentration of Iron:** In places, high concentration of iron in groundwater also observed;
- **Water scarcity:** Water scarcity during lean period
- **Regular Flood** is a primary hazard in the valley during the monsoon season every year damaging crops and properties of the people;

5.2 Manifestation and Reasons of Issues

Depth to water level in the shallow aquifers is unconfined and the static water level is 15.88 mbgl to 0.69 m, agl during pre-monsoon and it varies from 12 mbgl to 0.5 magl during post-monsoon. The depth to water level deeper aquifers varies from 4.36 mbgl to 0.32 magl during pre-monsoon and 4.7 mbgl to 0.22 during post monsoon. Water level fluctuation between pre and post monsoon ranged between -1.84 to + 12.66m.

The study area enjoys sub-tropical humid climate. Average annual rainfall in the area is 1632.4 mm. About 60 to 65 % of the annual precipitation is received during south-west monsoon from June to September. Annual average temperature of the study area is recorded to be 20.4^0C and the temperature ranges from 0^0C to 36^0C. The relative humidity is high.

Infrastructure for irrigation in the study area is very meager. Rain fed agriculture is practiced in the area and the groundwater withdrawal for irrigation purpose is practically nil. The following table shows the rain fed irrigation data in the study area.

Table 16 Irrigation details of Imphal West district

Sl. No	**Particulars of Irrigation**	**Imphal West I CD Block (in hectare)**	**Imphal West II CD Block (in hectare)**	**Total district area (in hectare)**
1	Net sown area	12847	8782.42	21629.42
2	Net Cultivated area	12862	8789.94	21651.94
3	Net Irrigated Area	1035	3060.64	4095.64
4	Irrigated area by cannals	637	2125.34	2762.34
5	Irrigated area by other sources	398	3060.64	3458.64
6	Irrigated area for All Crops	1086	3067.22	4153.22
7	Unirrigated area for all crops	13165	8394.2	21559.2
8	Gross Cropped Area	**14251**	**11461.42**	25712.42

The pH of the Ground water varies from 8.02 to 8.51 indicating pH of the water is within permissible limits. The value of EC varies from 185.3 to 844 µs/cm at 25^0C. The fluoride content of water samples is varying from 0.04 to 1.2 mg/l. The iron content in the shallow tube wells varies from 0.21 to 10.8 mg/l and it is BDL for deep tube well samples.

It can be seen from the analysis data that 60 % water samples collected from shallow tube wells are having iron content within desirable limit (set by BIS). And 40% water samples collected from the shallow tube wells are having iron content more than the desirable limit. No iron was detected in the deep tube wells

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

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

Table 16: Projected population

Block	Population (in '000) [as per 2011 census]	Projected population at the end of 2025 ('000)	Area	Projected population density at the end of 2025 in 1000/sq.km.	Extend dependence on GW to meet Domestic and Industrial Water	Area	Annual Allocation of ground water for domestic supply up to 2025
			sq.km.			hectare	ham
Imphal West I	155.521	183.787	281	0.654	0.9	28100	363.90
Imphal West II	362.471	428.351	238	1.800	0.9	23800	848.13
	517.992	**612.138**	**519**	**1.179**	**0.9**	**51900**	**1212.03**

Table 17: Projected population and water demand for domestic purpose of the area

Block	Block Population 2011	Growth rate	Projected Population			Projected Water Demand considering per person water need of 60 liter per day (ham)		
			2016	**2025**	**2030**	2016	**2025**	**2030**
Imphal West I	155521	0.012		183787		61.4343	68.3968	72.6033
Imphal West II	362471			428351		19.2561	21.4385	22.756
District total	517992			612138		80.08	89.1556	94.6348

5.3 Existing Sources of water in Manipur State

At the beginning of the twentieth century, there were approximately 500 lakes in Manipur State with innumerable small ponds, swamps and marshes along lakesides and inter-riverine tracts and many community and household ponds. Many of these water bodies no longer exist due to encroachments for paddy cultivation and human settlement. At present there are still a number of large and small lakes. Loktak in Bishnupur district is the largest and most important freshwater lake (289 km2) in the North Eastern Hill states and could be used as a potable water resource after appropriate treatment. There are 155 water bodies covering an area of 530 km2 (World Bank 2007). Two main rivers drain Manipur: the Barak drains the west and the Manipur drains the east, including the Manipur Valley. The Manipur catchment has an area of 6,332 km2 and an average annual yield is 51.9 9 108 m3.

Manipur receives rainfall from the SW and NE monsoons, with an average annual rainfall of about 2,000 mm. A water balance calculation, considering water demand and the available surface water resources, by MASTEC (2007) showed that the annual availability of 18.5 9 109 m3 of water is 66% in excess of current annual requirement of 11.1 9 109 m3. With the prospect of water recycling, various departments dealing with water resources and supply are optimistic that there is sufficient water to meet the long-term needs of the Manipur Valley.

Water use in Manipur State

Before 1980, almost 100% of water used for domestic purposes was from rivers, lakes, ponds (local name Pukhris) and in hilly areas dug-wells and streams. Still now rainwater is the main source for agricultural water. With the increase in population, use of land for human settlement, agricultural activities and extensive use of fertilizers, pesticides, insecticides, herbicides have not only reduced water availability but also led to deteriorating water quality.

Presently groundwater is readily available. It has been identified 1,173 Public Health Engineering Department (PHED) installed and 841 private tube wells. During interviews, villagers said that they do not like the taste of tube well water and mainly drink pond water. It appears that most villagers are not aware of the danger of drinking untreated pond water. In some cases, there are indications that sufficient surface water is not available. Now, local people have started installation of private tube wells for domestic uses. Presently, there are 10 tube well-based schemes covering 31 villages in the Manipur Valley (PHED 2006). At present, underground water is not used for agriculture.

Water demand supply assessment

Water demand of the district was assessed based on population data on daily basis and later converted to monthly basis. Average monthly water demand was estimated as 1.471 MCM. Water supply through PHED could not fulfill the domestic water in all the months. Average monthly shortage of water supply was estimated at 0.956 MCM. Potential monthly rooftop rainwater harvesting was estimated using monthly rainfall data, residential data and residential condition of the household available in the Imphal West district. During monsoon season there is high scope for harvesting of rooftop rainwater. Maximum rooftop rainwater can be harvested in the month of July at about 1.385 MCM and followed by June, May, April and August.

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

Table 18: Block wise water requirement for winter paddy cultivation through irrigation						
Block	Irrigated Area(ha)	Un Irrigated Area (ha)	Total Area (ha)	60% of net sown area bring under paddy cultivation and irrigation	Depth of water required to raise a crop over a unit area is considered as 1.2m	Water requirement for 60% of net sown area (ham)
Imphal West I	1035.00	13165	14200	7708.20 ha	1.2	9249.84
Imphal West II	3060.40	8394.20	11454.6	5269.45 ha		6323.34
Total water requirement						**15573.18** Ham

Table 19: Block wise water requirement for rabi crops other than paddy through irrigation				
Block	Total Area(ha)	in m	Base period for crops other than Rice	Water requirement for 40% of net sown area (ham)
Imphal West I	19636	1.2		6765.6
Imphal West II	8612	1.2		3033.6
Total water requirement				**9799.30**

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

Table 20 : Total water requirement for the area

Block Name	Drinking water requirement up to 2025 Ham	Water requirement to bring 60% of net sown area under irrigation for paddy cultivation Ham	Water requirement to bring 40% of net sown area under irrigation for non-paddy cultivation Ham	Water allocated for drinking and domestic purposes up to 2025 Ham	Water allocated for irrigation up to 2025 Ham
Imphal West I	2462.286	10148.4	6765.6	363.9	3734.66
Imphal West II	771.786	4550.40	3033.6	848.13	2798.26
Total	3234.072	**14698.80** Ham	**9799.30**	1212.03	6532.92

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

Table 21: Supply and demand gap in drinking water sector

Block Name	Drinking water demand up to 2025 Ham	Water allocated for drinking and domestic purposes up to 2025 Ham	Gap between supply and demand Ham
Imphal West I	2462.286	363.9	2098.386
Imphal West II	771.786	848.13	-76.344
Total	3234.072	1212.03	2022.042

Table 22: Supply and demand gap in irrigation

Block Name	Total irrigation demand Ham	Water allocated for irrigation up to 2025 Ham	60% of the allocated water for irrigation available for use	Gap between supply and demand Ham
Imphal West I	2782.25	3734.66	2018.898	1715.762
Imphal West II	6708.57	2798.26	4001.64	-1203.38
Total	9490.82	6532.92	5596.008	936.912

The district is facing acute drinking water shortage as the government's water supply facilities fully depends on the rivers and which are generally remain dry during the dormant season. Rooftop rainwater can be one of the best options to stored quality water for use during the dormant months. During the water crisis period, there are many other private traders who supply the drinking at much higher price, which increases hardship to the common people. Groundwater resources are not yet exploited in Manipur, so groundwater can be one of the options for supplies of water during non-rainy months and same groundwater can be recharged during the monsoon months.

CHAPTER 6.0

Management Strategy

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

The objective of management is to utilize the available groundwater 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.

a) Based on the hydrogeological condition, existing aquifer horizons and their yield potential, prospects for groundwater development in the district is confined to the valley sector only. The eastern and northern region are feasible for the development of groundwater through shallow to moderately deep tube wells down to 75 m tapping about 10 to 30 m of cumulative thickness of granular horizon capable of yielding 20 to 40 m^3/hr for drawdown up to 12 m.

b) Depending upon the constitution of aquifer systems, the yield of tube wells differs from place to place in the district. The exploratory well constructed for tapping groundwater horizons with cumulative thickness of 10 meter at Sekmai area (Pebble, gravel mixed with sand) yield 480 liters per minute for a drawdown of 6 m.

c) However, tube wells constructed at the foot of residual hill, tapping deposits consisting of soil mixed with sand, gravel and underlain by soft shale followed by hard shale, give discharge of 100 to 180 lpm. In places where there is sandstone layer at depth, tube wells give comparativelt higher amount of water.

d) In the western part, shallow tube wells down to 25 to 60 m depth are feasible with discharge of 15 to 20 m^3/hr. Owing to encounterance of boulders up to a depth of 20 to 30 m in the northern part, i.e., Sekmai area up to the border areas of Kangpokpi district, tube wells may be limited to 25 to 30 m only, tapping 5 to10 m of the saturated horizons. Such tube wells are expected to yield 15 m^3/hr with a reasonable drawdown.

e) In the central part of the district fine-grained granular horizons of cumulative thickness of 10 to 20 m are encountered up to 100 m. The area is suitable for the construction of tube wells for domestic supplies. In the eastern and southern part of the tube wells of moderate depth are considered to be feasible with discharges of 20 to 50 m^3/hr.

f) The present water supply system in the district is largely gravity fed from the reservoirs, which has been located over hills, which are fed by water treatment plants either by gravity or through pumping.

g) The study area possesses moderate ground water potential and available net groundwater resource is to the tune of 6532.92 ham. This available resource can be developed for irrigation and other domestic purposes. The groundwater extraction by existing tube-wells for irrigation was 105.35 ham and development are found to be 2.11 %, as such scope exists for development of groundwater in the district. Based on the irrigation water requirement, additional 1570 nos. (by taking 3 hams per well per year) of medium duty shallow tube wells may be constructed, which will be able to generate irrigation potential of 4713 ham. The conjunctive use of surface and groundwater may be done for better ecological conditions of the district. As the study area is blessed with good amount of rainfall, rain water harvesting structures may also be constructed for storing and artificial recharge of groundwater.

h) The study area is having meager irrigation facility. Available unirrigated land of 21559 ha can be brought under irrigation using the dynamic groundwater resources available in the district. It is proposed to bring 60% of area under paddy and 40% under non-paddy cultivation. Water requirement for paddy cultivation (Δ=1.2 m) would be 15573.18 ham while that for non-paddy cultivation (Δ=0.3 m) would be 9799.30 ham. Total water requirement to bring this entire uncovered area under irrigation is 25372.3 ham.

i) Tube wells can be designed in the study area within a depth of 90 m, tube wells can be constructed by tapping 10 to 20 m of granular zone and expected yield is 15 m^3/hr for a maximum drawdown from 12- to18 m. Wells may be constructed by using $6^{//}$ dia casing pipe down to 20m, $6^{//}$ dia 1 to 1.5 mm slot pipes for 20m and $6^{//}$ dia 10 m blank pipe. Although, groundwater cannot supply the entire irrigation water requirement, it can safely fulfil the demand of rabi crops including the rabi rice. However, kharif rice irrigation demand has to be filled up by surface irrigation schemes. Groundwater shortage can be further be reduced by increasing the irrigation efficiency.

j) Development of rainwater harvesting for the drinking water supply is also one of the appropriate measures for solving the scarcity of potable water as it involves relatively low cost, less time for implementation and provides almost entirely safe drinking water which does not require costly purification and treatment process.

k) As per PHED, the total domestic water demand of Imphal West district was estimated at 17.652 MCM and water supply from state government's water supply scheme (PHED) was estimated at 6.185 MCM, which fulfil only about 35% of total water demand. If rooftop rainwater is considered another 52% of water shortage can fulfilled. The shortage which is about 17% can be through rainwater storage and through private enterprise. The average annual increase in domestic water demand was predicted at 1.33% and total increased in domestic water demand from 2011 to 2031 was predicted at 26.53%. So, there will be huge domestic water demand in coming future years.

l) Rooftop rainwater harvesting is yet to be exploited in Imphal West district, Manipur. The district is facing acute drinking water shortage as the government's water supply facilities fully depends on the rivers and which are generally remain dry during the dormant season. Rooftop rainwater can be one of the best options to stored quality water for use during the dormant months. During the water crisis period, there are many other private traders who supply the drinking at much higher price, which increases hardship to the common people. Groundwater resources are not yet exploited in Manipur, so groundwater can be one of the options for supplies of water during non-rainy months and same groundwater can be recharged during the monsoon months.

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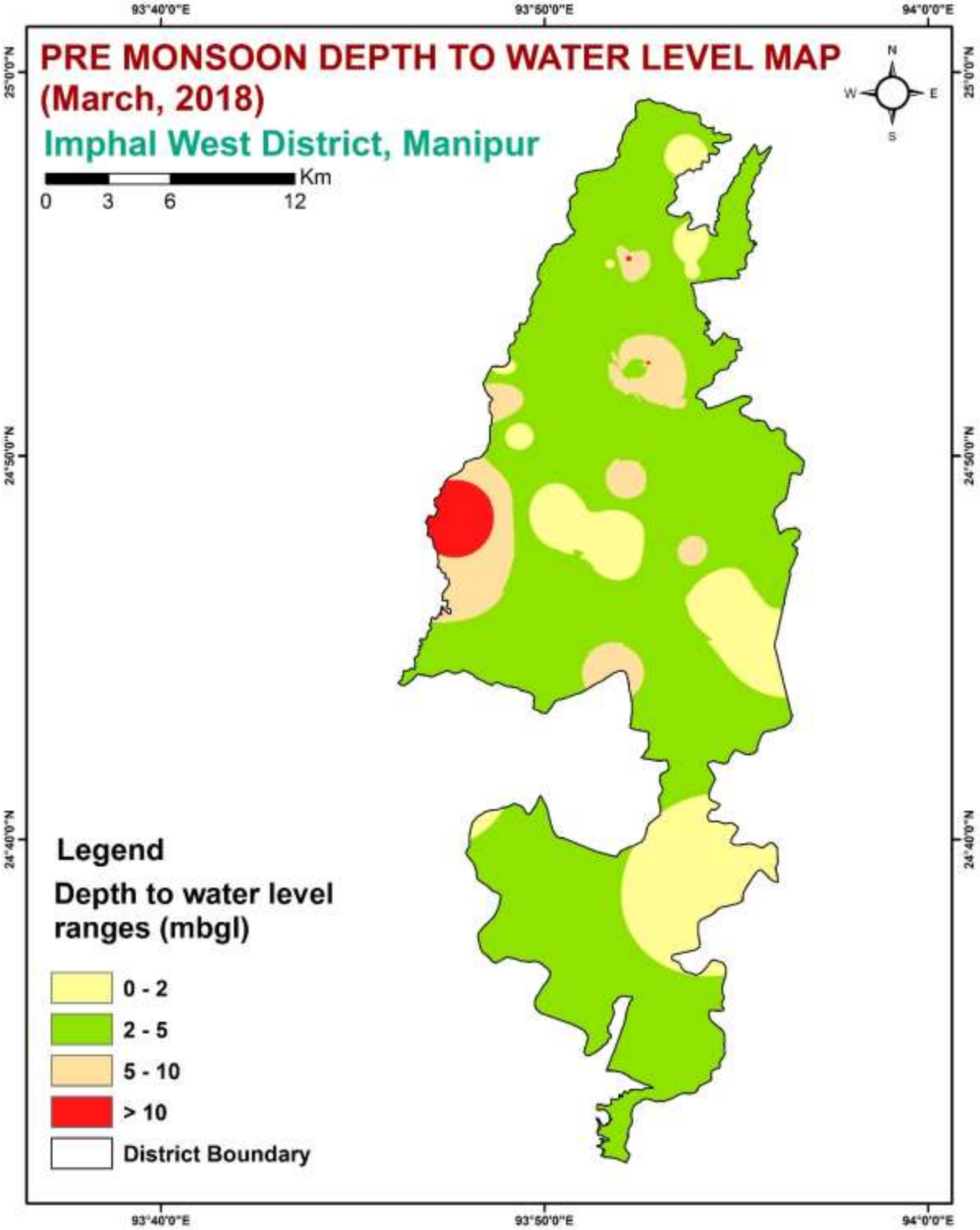
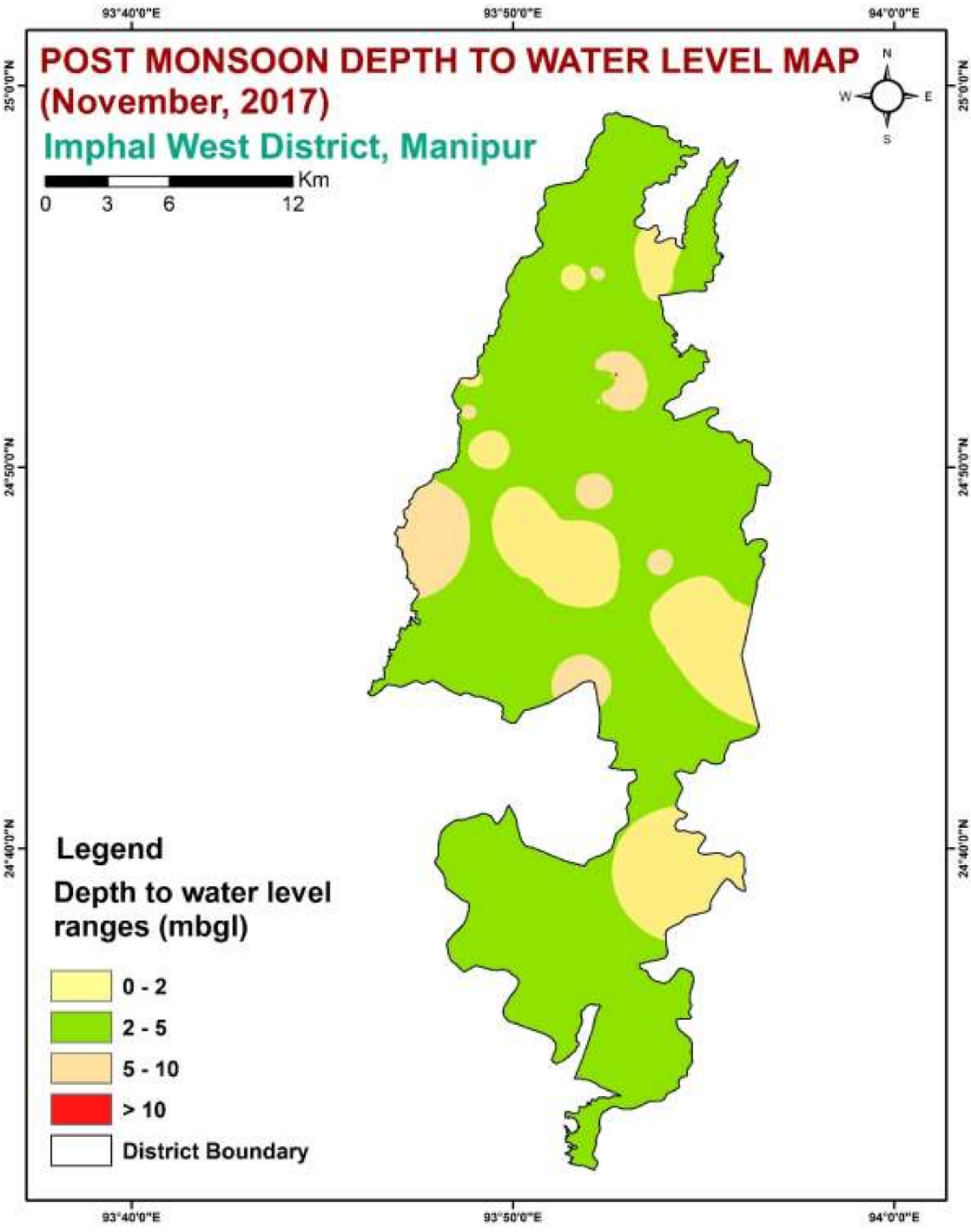
ANNEXURE I A

PRE-MONSOON DEPTH TO WATER LEVEL, IMPHAL WEST DISTRICT



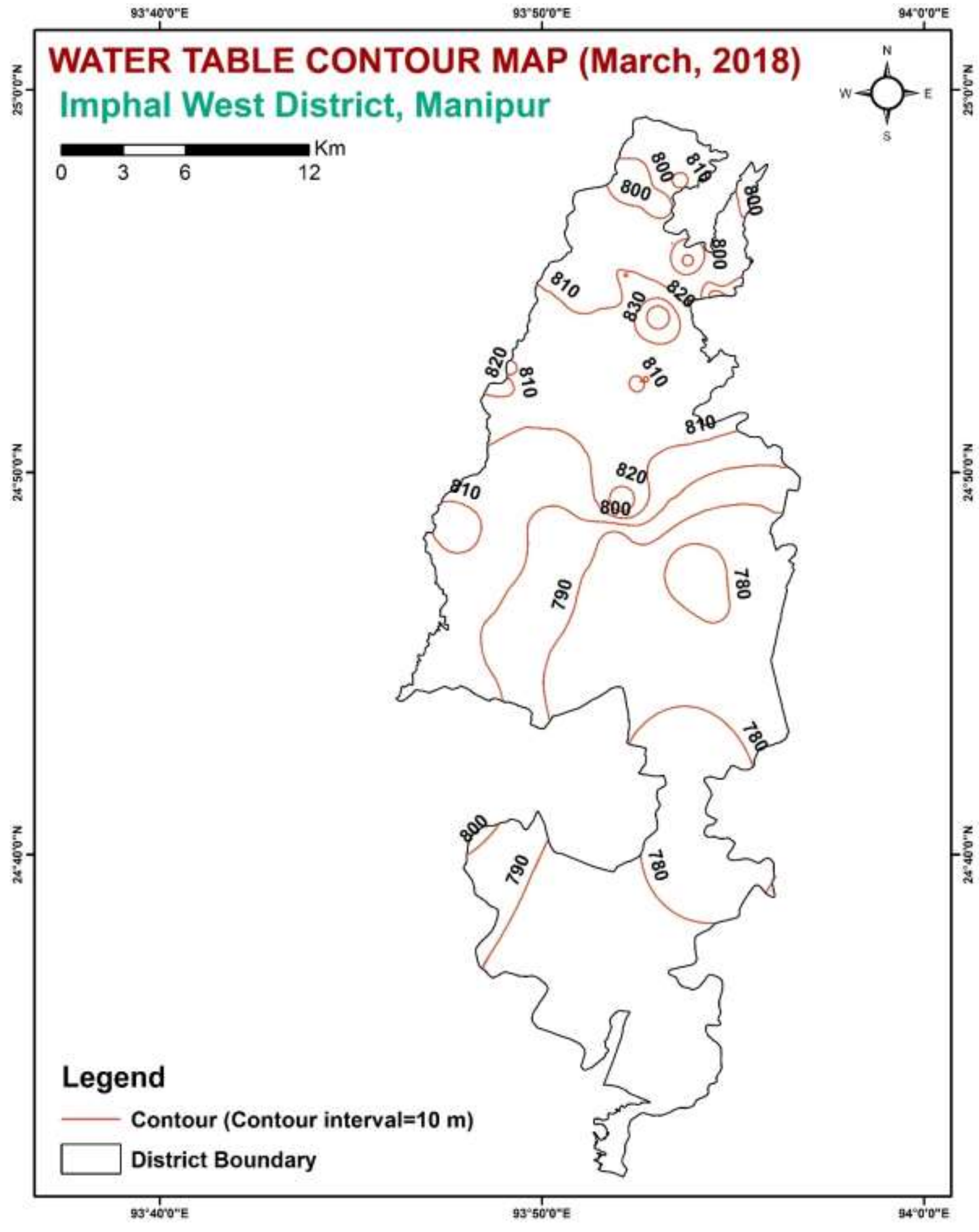
ANNEXURE I B

POST MONSOON DEPTH TO WATER LEVEL, IMPHAL WEST DISTRICT



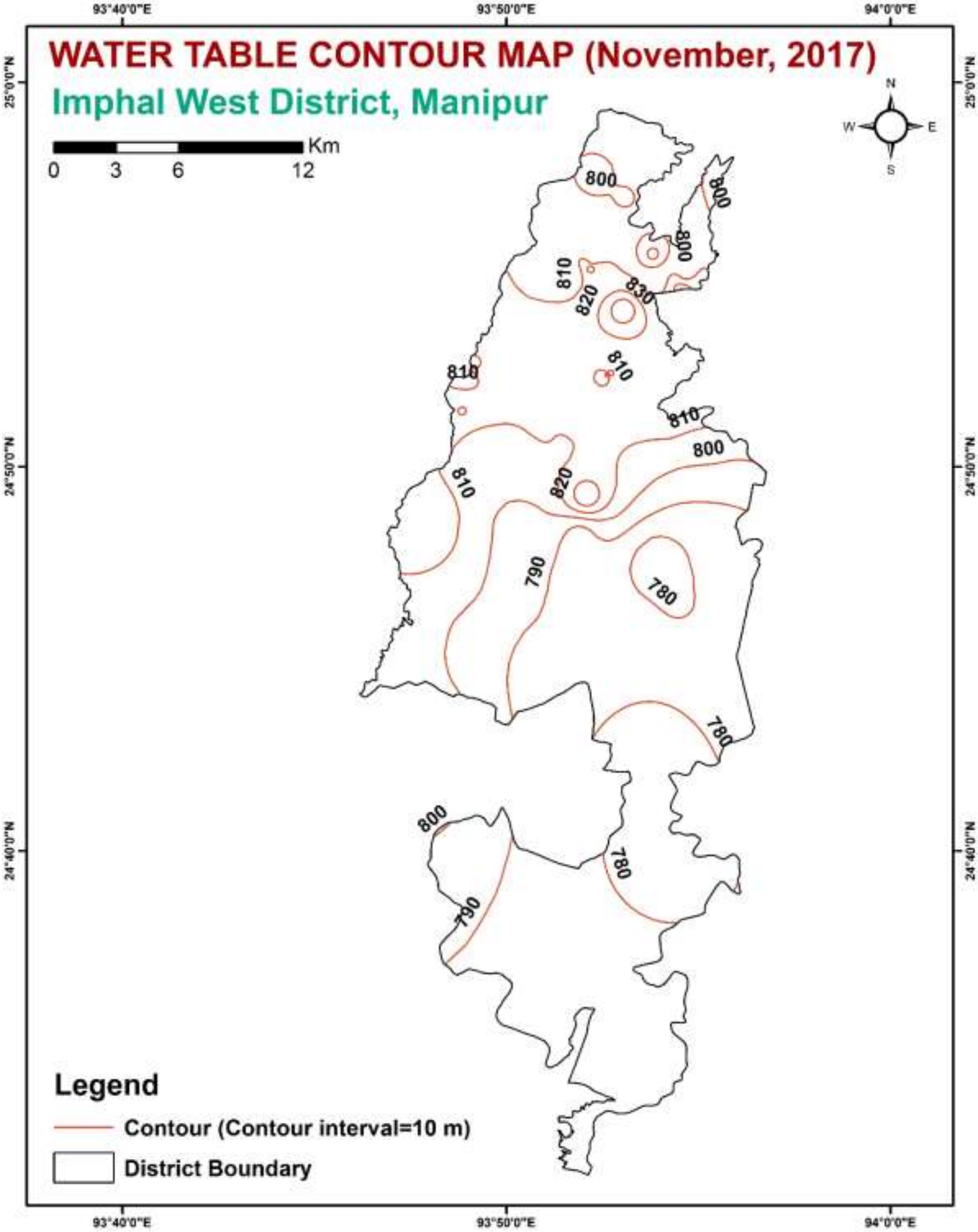
ANNEXURE II A

WATER TABLE CONTOUR MAP (MARCH 2018)



ANNEXURE II B

WATER TABLE CONTOUR MAP (NOVEMBER 2017)



ANNEXURE III

CHEMICAL QUALITY DATA OF THE GROUNDWATER SAMPLES COLLECTED IN THE STUDY AREA

Sl. No	Sampling Location	Type	pH	EC	Turbidity	TDS	CO_3^{-2*}	HCO_3^{-1*}	Cl^{-*}	SO_4^{-2}	NO_3^{-1}	F^-	Ca^{+2*}	Mg^{+2*}	TH*	Na*	K*	Fe
				micro siemens/ litre		mg/l												
1	Awang Sekmai Nongthonban	DW	8.23	285.6	0.2	147.4	BDL	64	95.28	0.9889	1.2	0.1	22.4	10.68	100	15.91	3.62	0.21
2	Tendongyan NH-39	DW	8.11	185.3	1.1	95.08	BDL	56	73.45	1.0516	0.4	0.06	17.6	11.65	92	7.79	4.1	0.53
3	Kanto Khunou, Leimakhong	DW	8.02	244.6	0.6	126.2	BDL	60	103.2	1.4589	0.3	0.04	16	8.7379	76	21.51	4.81	0.32
4	Khurkhul	DW	8.32	536	BDL	280.2	64	60	156.8	0.9889	2.5	0.09	56	17.476	212	27.1	18.78	1.74
5	Luwangsangban	STW	8.51	498	BDL	257.5	64	132	53.6	1.1926	3.4	0.18	28.8	5.8252	96	88.86	1.49	1.06
6	Keithelmanbi Bazar	STW	8.49	361.4	0.2	187.4	32	108	91.31	0.9889	0.1	0.41	24	4.8544	80	48.54	1.51	10.8
7	Lamsang Tiniali	STW	8.27	191.6	0.5	98.7	BDL	80	57.57	1.0516	0.4	0.19	16	7.767	72	8.57	5.04	0.69
8	Mantripukhri (near pond)	STW	8.48	719	0.7	377	96	264	109.2	0.9889	1.2	0.9	48	11.65	168	111.89	1.57	3.73
9	Kodompokpi Lamkhai	STW	8.45	844	1.6	438	128	232	37.72	1.4746	2.7	1.2	75.2	18.447	264	118.07	3.8	BDL
10	Langjing Achouba (Heinoupok)	STW	8.24	324	0.2	168.4	BDL	88	119.1	3.6526	4.1	0.45	12.8	45.631	220	26.64	9.21	BDL