AQUIFER MAPPING REPORT
Parts of Imphal West District, Manipur

उत्तरी पूर्वी क्षेत्र, गुवाहाटी
North Eastern Region, Guwahati
Govt. of India
Central Ground Water Board
Ministry of Water Resources, River Development &
Ganga Rejuvenation

REPORT ON AQUIFER MAPPING BY COVERING 155 SQ KM IN
PARTS OF SURVEY OF INDIA TOPSHEET NOS. 83H/13 AND 83H/14
IN IMPHAL WEST –II BLOCK, IMPHAL WEST DISTRICT ,MANIPUR
(AAP 2014-15)

North Eastern Region
Guwahati
March 2016
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1.0 INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers.

1.1 Objectives

The primary objective of the Aquifer Mapping can be summed up as “Know your Aquifer, Manage your Aquifer”. Demystification of Science and thereby involvement of stakeholders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the study. As per the Report of the Working Group on Sustainable Ground Water Management, “It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help to integrate ground water availability with ground water accessibility and quality aspects of the area.

1.2 Scope of the Study

There has been a paradigm shift from “groundwater development” to “groundwater management”. An accurate and comprehensive micro-level picture of the groundwater of the study area may be generated through this aquifer mapping programme in Imphal West II. 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. Thus the crux of NAQUIM is not merely mapping, but reaching the goal – that of ground water management through community participation irrespective of drinking and irrigational purposes.

1.3 Approach and Methodology

The mapping unit classification has been planned as per the findings of Central Ground Water Board, Geological Survey of India and other concerned state departments.

a. 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, lithologs, quantity and quality of groundwater etc.

b. There are some subtle differences in the mapping unit definition between the existing maps and results of the present study (NAQUIM);
c. The structure contours of the study area has been matched across the existing map boundaries (geological, hydrogeological) of the Imphal Valley;

d. New exploratory data is collected during NAQUIM study by selecting key areas in Imphal West-II have been re-defined in the context of local hydrogeological set up.

e. 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 for better correlation of aquifer parameters.

❖ **Methodology**

- Digital surface geology mapping was sourced from the Geological Survey of India (GSI, 2009), Space Applications Centre (ISRO), Ahmedabad and Manipur Science and Technology Council, Imphal.

- Based on the agreed relational table between geological layers, Hydrogeological Units (HGU) and Mapping Units (aquifers/aquitards), project standard 100 m grid resolutions (by using Map Info 6.5 soft ware, HGU and aquifer outcrop data sets were compiled during the study.

- The primary uses for these data were as inputs to the structure contours of aquifer elevation, water table yield estimates and in conjunction with the DTM, enabling the 3D hydrogeological modeling (through ERDAS and Surfer software).

1.4 **Area Details**

An area of 155 sq km in parts of Imphal West-II CD block in Imphal West district of Manipur was covered as per the Annual Action Plan 2014-15 of Central Ground Water Board, North Eastern Region, Guwahati.

The study area is a part of the centrally located intermontane valley, i.e. Imphal valley of Manipur. It is bounded on the north by Imphal West-I CD block, on the south by Thoubal and Bishnupur districts, on the east by Imphal East –II CD block and in the west by Bishnupur districts. The area covers the southern fertile plain of Imphal valley adjacent to the Loktak lake.

As per 2011 census, the total populations of Imphal West-II CD block is 5,14,683, out of which 2,53,628 are male and 2,61,005 are female population.

National Highway-39 (Indo-Burma/Myanmar Road) and another state road (Mayai Lambi Road) 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.

Physiographically, the study area shows three prominent units i.e. a plain topography, hilly areas and marshy land in the southern 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 study area 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 Brief Description

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 five tube wells (3 exploratory well and 2 observation wells) during NAQUIM study in the area. Public Health Engineering Department, Govt. of Manipur has also constructed 3 tube wells for domestic and irrigational purposes. In addition to these data of 3 exploratory wells constructed by CGWB, NER, Guwahati during the study on hydrogeology and ground water 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.

Present Status of Data:

The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB, 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).

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°C and the temperature ranges from 0°C to 36°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:

(i) The cold season (December, January, February)
(ii) The hot dry season (March, April)
(iii) The rainy season (May, June, July, August, September)
(iv) The Retreating monsoon season (October, November)

Rainfall

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 1345.01 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.
Table 1 Monthly Rainfall data in mm for the last 10 years in the study area
(Period: 10 years from 2005 to 2014)

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>2005</td>
<td>0.0</td>
<td>35.2</td>
<td>99.1</td>
<td>71</td>
<td>112.4</td>
<td>86.4</td>
<td>193.7</td>
<td>182.8</td>
<td>213.8</td>
<td>185.4</td>
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<td>37.4</td>
<td>70.1</td>
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<td>152.9</td>
<td>67.5</td>
<td>94.8</td>
<td>2.3</td>
<td>30.7</td>
<td>13.2</td>
<td>846.2</td>
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<td>184.7</td>
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<td>70.1</td>
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<td>169.6</td>
<td>152.9</td>
<td>67.5</td>
<td>94.8</td>
<td>2.3</td>
<td>30.7</td>
<td>13.2</td>
<td>846.2</td>
</tr>
<tr>
<td>2008</td>
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<td>31.7</td>
<td>78.9</td>
<td>14.8</td>
<td>93.2</td>
<td>170.1</td>
<td>256.0</td>
<td>200.5</td>
<td>85.6</td>
<td>95.8</td>
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<td>113.9</td>
<td>152.1</td>
<td>5.2</td>
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<td>7.0</td>
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<td>248.4</td>
<td>222.2</td>
<td>260.2</td>
<td>300.9</td>
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<td>136.9</td>
<td>194.2</td>
<td>16.1</td>
<td>47.3</td>
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<td>287.1</td>
<td>302.9</td>
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<td>27.4</td>
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<td>0.0</td>
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<td>19.6</td>
<td>0.0</td>
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<td>270.8</td>
<td>246.3</td>
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<td>137.4</td>
<td>80.8</td>
<td>0.0</td>
<td>1647.90</td>
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<td>2013</td>
<td>0.0</td>
<td>1.7</td>
<td>31.8</td>
<td>83.6</td>
<td>335.1</td>
<td>135.5</td>
<td>254.1</td>
<td>414.3</td>
<td>291.3</td>
<td>30.3</td>
<td>0.0</td>
<td>1.4</td>
<td>1639.10</td>
</tr>
<tr>
<td>2014</td>
<td>0.0</td>
<td>31.2</td>
<td>28</td>
<td>47.5</td>
<td>277.3</td>
<td>385</td>
<td>85</td>
<td>263.9</td>
<td>106.7</td>
<td>29.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1117.90</td>
</tr>
</tbody>
</table>

Average Annual Rainfall for the last 10 years

1345.01

(Source: IMD Rainfall Data, Imphal)

Physiography

Physiographically, the study area shows three prominent units i.e. a tiny plain topography, hilly areas and marshy land in the southern periphery. The NAQUIM area as a whole falls 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.

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:

- 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.
• **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.

• **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.

• **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.

• **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.

**Geomorphology**

Flat elongated and south tapering valley with isolated hills are the main geomorphologic features around the study area. 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.2. Geomorphic units in the study area (after Singh, 1993 &1996)**

<table>
<thead>
<tr>
<th>Geomorphic Unit of Imphal Valley (After Singh, 1993)</th>
<th>Geomorphic Unit of Imphal Valley (After Singh, 1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial Plain</td>
<td>Intermontane Valley (Alluvial Plain)</td>
</tr>
<tr>
<td>Flood Plain</td>
<td>Piedmont</td>
</tr>
<tr>
<td>Abandoned Channel</td>
<td>Structuro-Denudational hill</td>
</tr>
<tr>
<td>Meander Scar</td>
<td>Denudational hill</td>
</tr>
<tr>
<td>Natural Leeves</td>
<td>Denudo-structural hill</td>
</tr>
<tr>
<td>Point bars</td>
<td></td>
</tr>
<tr>
<td>Structural Hills</td>
<td></td>
</tr>
<tr>
<td>Piedmonts</td>
<td></td>
</tr>
<tr>
<td>Valley fills</td>
<td></td>
</tr>
</tbody>
</table>
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 the valley. 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:
a. **Denudo-Structural Hill**: In the study area, it occupies the eastern, southern, and northern parts with the highest relief of about 1866 m above mean 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.

b. **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.

c. **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 lithologically of sandstone, shale, siltstone,

d. **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 have 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.
Soil Characteristic

The study area 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.

Geological Set Up

Imphal and its adjoining areas form a part of Imphal valley of Manipur, which in turn form a part of the Indo-Burmes Range (IBR). It represents the collision zone giving rise to the Manipur- Nagaland Orogenic Belt (MNOB).

Geology of the Study Area

Basically, the area is made up of alluvium of fluvio-lacusrine 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 inside the project 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.
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 amphitheatre-like north-south extension, surrounded by hills made of Disang and Barail Groups of rock. The valley consists of thick sequences of fluvial-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.

Table 3: Stratigraphic Succession of Imphal Valley (after Singh, 1993)

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

**Disang Group**

The substratum of Imphal valley involves essentially shale and silt stone of the Disang Group. This unit becomes gradually more sandy and 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 meter to several tens of meters of red clay with paleosols. 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, Langthabal, Hiyangthang, Ishok, Naran konjin etc. are exposed within the study area. 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.

**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 near the border of Bishnupur district where it presents 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.

**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 fluvo-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.

**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.

**a. 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.

**b. 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 100 m.

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)

### 2.0 HYDROGEOLOGICAL DATA COLLECTION AND GENERATION

Hydrogeologically, the study area can be sub divided into two broad litho units, viz.

i. Semi-consolidated Units,

ii. Unconsolidated

**i. Semi consolidated Unit**

Tertiary formations consisting of shale, sandstone, siltstone and mudstone of Disang and Barail Groups constitute the semi-consolidated unit in the study area. They occur in the flanking denudational, denude-structural and structure-denudational hills and also occur in the piedmont and part of the valley beneath the alluvial deposit. Highly splintery, fragile, jointed shales are predominant. The thickness of weathered rock in this unit varies from place to place. Joints and fractures control the occurrence and movement of the groundwater in these rocks. The rocks in this area are highly weathered, and jointed. At places weathered and fractured zone, as per CGWB and PHED, Manipur, fairly good amount of water is yielded as seen at Hiyangthang Lairembi, Irom Meijarao, and Lilong areas of the study area. The recorded average discharge in these places is around 272 lpm.
ii. Unconsolidated Unit

In the study area, unconsolidated unit consists of sand, silt, clay, gravel pebbles etc. with lake deposits. This unit covers the major portions in the south western sector of the study area. The thickness of unconsolidated alluvial deposits varies from place to place with maximum thickness of 90 m at Mayang Imphal (Roy, 1972), 46 m at Utlou and 67 m at Wangoi. 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 part near Mayang Imphal area lying just north of Loktak Lake.

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 of the study area is mono aquifer; however, locally it may behave like multi-aquifer system (Fig. 3.3). The aquifer property identified by CGWB are given in Table

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 Imphal river area.

The sub-surface strata at the foothill of Langthabal hill area shows sand with gravel and clay overlying. The Naran Konjin hill area shows thick layer of clay overburden above the soft shale.

The sub surface lithology in around Ghari, Utlou and Irom Meijrao 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. Ghari, Canchipur and Lilong area shows complex sub surface picture. The lithology of the area has revealed two to three horizons of aquifer in somewhat disconnected fashion. Disang shale in lensoid form occurs...
below topmost clay layer near Imphal town area in the section. Sand horizon also occurs adjacent to sandstone body.

In the southern sector of the study area around Mayang Imphal, Wangoi and Shamurou area shows maximum thickness of shale containing carbonaceous materials. Thickness of granular horizon increases in areas bordering to Bishnupur district which are tapers away towards the central part of the study area, followed by thick layer of clay. The fan deposits extend towards further east of Bishnupur at sub-surface upto a depth of about 50 m and sharply truncates against the clay deposit of the valley indicating anomalies which could represent neo-tectonic fault within the alluvial deposit in the sub surface. Further east of the anomaly zone, it is reportes at Mayang Imphal upto 91 m. This possibly represent lacustrine deposit topped by river alluvial deposit.

The sub surface section between sections in the western fringe 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.

![Sub surface 2D section along Mayang Imphal - Wangoi - Shamurou – Canchipur (South to North section)](image)

Though more or less single horizon of aquifer layer exists in the western part of the study area, there exists two to three aquifer horizons, intercepted by impermeable layers/horizon, within a depth of approximately 90 to 145 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.

Fig. 7.3D Fence View of Aquifers in the study area

GROUNDWATER OCCURRENCE AND RECHARGE

Occurrence of groundwater in the study area mainly due to two main aquifers-

(i) **Weathered Rock Aquifer**

Moderately thick weathered shales are responsible for this type of aquifer. The water yielding properties are highly variable depending upon nature of the weathered material and surface cover.

(ii) **Alluvium Aquifer**

The various geomorphic landforms constitute this type of aquifers. The nature of aquifer material is from unconsolidated to semi consolidated (sand, gravel, pebbles, gravel mixed with sand.). Large alluvial plains form the potential source of groundwater.

The valleys have superficial alluvium which is underlined by Tertiary rocks of Barial Series in Imphal. **Groundwater in top sandy and clayey formation occurs under water table conditions with the average depth of water varying from 3 to 4 metres bgl.** 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 2 to 4.7 mbgl.**
Groundwater in deeper layers is semi-confined to confined with static water level from 5 mbgl to 0.5 magl.

In the upper horizons of Alluvial plain, groundwater occurs under water table conditions with water table varying from 1.82 to 4.7 mbgl. At relatively higher areas the water level varies from 1.6 to 4.09 mbgl. Groundwater at granular piedmonts occur under unconfined to semi confined aquifer conditions where as at the valley area, groundwater occurs under semi-confined to confined aquifer systems, with piezometric level varying from 5 mbgl to 0.5 magl. The annual groundwater fluctuation is 1 to 3 m.

Recharge

The average annual rainfall in the study area is around 1500 mm. The vast piedmont plain in the study area covered by infilled channel sediments have gravelly and sandy layer or interconnected granular horizons at relatively shallow depth. In the above areas, there is no continuous impervious layer. These fulfill the primary requirement for recharge from precipitation as well as influent seepage from streams flowing through this zone to build up shallower water table conditions. With the continuity of monsoon precipitation, the amount of surface runs off increases progressively. All the water from the surrounding hills flows towards the valley, some amounts of water is recharged at the piedmont and rest of it comes as surface run off and drained by the streams.

The entire piedmont zone forms the main recharge zone in the area. The geologic conditions in these areas are excellent for obtaining groundwater in fairly large quantities from wells sunk into their permeable materials. Water infiltrates readily in the coarse materials at the head of the fans and move downwards. This piedmont zone can be described as the primary recharge area as it constitutes the main area in which recharge is taking place by all process viz. influent seepage from braided and fanning streams flowing through this zone. Due to main recharge in this piedmont deposit and suspected neo tectonic fault ground water condition is expected within the piedmont zone, in the west of the neo tectonic fault.

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 816 mAMSL. The shallow water level depth is found towards the central parts of the study area and extends towards south and lies below 780 mAMSL 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, where as 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.
Aquifer Characteristics
Depending upon the constitution of aquifer systems, the yield of exploratory well and tube well differs from place to place in the study area. 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 comparatively higher amount of water.

Based on the hydrogeological conditions and geomorphological features, a granular horizons are well developed along the peripheral (piedmont) zone of the valley, this area can be considered as feasible for groundwater exploration. This area can be developed through properly located and spaced STW down to 10m to 40 m with expected discharge of 10 to 15 m³/hr for drawdown less than 4 m.

The valley portions in the study area is 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.

Table.4 Ground Water Monitoring stations in the study area

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Location of key wells</th>
<th>Type</th>
<th>Latitude</th>
<th>Longitude</th>
<th>MP (m,agl)</th>
<th>RL of G.L (mmsl)</th>
<th>Formation</th>
<th>Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ghari</td>
<td>STW</td>
<td>24.77440</td>
<td>93.9083</td>
<td>0.32</td>
<td>779.374</td>
<td>Alluvium followed by Tertiary</td>
<td>Manipur River basin</td>
</tr>
<tr>
<td>2</td>
<td>Monsangei MAA</td>
<td>STW</td>
<td>24.7653</td>
<td>93.9221</td>
<td>0.32</td>
<td>773.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Canchipuir ( MU)</td>
<td>DTW</td>
<td>24.7526</td>
<td>93.9294</td>
<td>1.00</td>
<td>773</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Langthabal P M</td>
<td>STW</td>
<td>24.74276</td>
<td>93.9120</td>
<td>773.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Lilong Thongkhong</td>
<td>DTW</td>
<td>24.7222</td>
<td>93.9421</td>
<td>0.30</td>
<td>773.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Hiyangthang L</td>
<td>STW</td>
<td>24.71302</td>
<td>93.8878</td>
<td>0.32</td>
<td>773.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Irom Meijarao</td>
<td>STW</td>
<td>24.70943</td>
<td>93.8910</td>
<td>0.65</td>
<td>778.324</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Shamurou</td>
<td>DTW</td>
<td>24.69561</td>
<td>93.9067</td>
<td>1.00</td>
<td>772</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Wangoi Kabui</td>
<td>DTW</td>
<td>24.66853</td>
<td>93.9022</td>
<td>0.60</td>
<td>777.511</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Mayang Imphal</td>
<td>DTW</td>
<td>24.62004</td>
<td>93.8890</td>
<td>0.65</td>
<td>773.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Sekmaiin A L</td>
<td>STW</td>
<td>24.555026</td>
<td>93.905144</td>
<td>0.32</td>
<td>772</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DTW = deep tube well; STW= Shallow Tube well; MP = measuring point;

The NAQUIM study has been taken up to delineate the horizontal and vertical disposition of aquifer as well as to study the aquifer character. In this connection five key observation wells were taken up for data generation. To know the aquifer disposition in the study area, exploratory wells data, VES data available with CGWB and some data of state departments, Govt. of Manipur were utilized in this report.
Study revealed that groundwater occurs both under the unconfined and confined conditions. Granular zones are encountered at depth of about 60 to 100m 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.

Exploratory data available in Central Ground Water Board and state agencies like IPD wing, PHED, Govt. of Manipur has been compiled in order to delineate the deeper aquifers and to arrive at a definite conclusion.

Table 5. Depth to Water Level (in mbgl) for monitoring stations in the study area

<table>
<thead>
<tr>
<th>Location</th>
<th>Type</th>
<th>Mar’15 (Pre-monsoon)</th>
<th>Nov’14 (post-monsoon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghari</td>
<td>STW</td>
<td>1.37</td>
<td>0.22 magl</td>
</tr>
<tr>
<td>Monsangei MAA</td>
<td>STW</td>
<td>5.90</td>
<td>5.02</td>
</tr>
<tr>
<td>Canchipur (MU)</td>
<td>DTW</td>
<td>0.50 magl</td>
<td>artesian</td>
</tr>
<tr>
<td>Langthabal Phura Makhong</td>
<td>STW</td>
<td>5.72</td>
<td>5.53</td>
</tr>
<tr>
<td>Lilong Thongkhong</td>
<td>DTW</td>
<td>1.6</td>
<td>0.20</td>
</tr>
<tr>
<td>Hiyangthang Lairembi Maning</td>
<td>STW</td>
<td>6.92</td>
<td>6.78</td>
</tr>
<tr>
<td>Irom Meijarao</td>
<td>STW</td>
<td>5.78</td>
<td>4.7</td>
</tr>
<tr>
<td>Shamurou</td>
<td>DTW</td>
<td>4.11</td>
<td>3.52</td>
</tr>
<tr>
<td>Wangoi Kabui</td>
<td>DTW</td>
<td>1.75</td>
<td>0.80</td>
</tr>
<tr>
<td>Mayang Imphal</td>
<td>DTW</td>
<td>4.35</td>
<td>4.09</td>
</tr>
<tr>
<td>Sekmaijin Awang Leikai</td>
<td>STW</td>
<td>5.90</td>
<td>5.11</td>
</tr>
</tbody>
</table>

Ground Water Exploration

Central Ground Water Board has constructed five tube wells (3 exploratory well and 2 observation wells) during NAQUIM study in the area. Public Health Engineering Department, Govt. of Manipur has also constructed 3 tube wells for domestic and irrigational purposes. In addition to these data of 3 exploratory wells constructed by CGWB, NER, Guwahati during the study on hydrogeology and ground water 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. The depths of the wells in the study area are ranged from 40 mgl to 145 mbgl.

Table 6: Hydrogeological data of the EWs in the study area

<table>
<thead>
<tr>
<th>Well Location</th>
<th>Depth of construction (m)</th>
<th>Aquifer Zone Tapped (m)</th>
<th>SWL (mbgl)</th>
<th>Discharge (m3/hr)</th>
<th>Draw Down (m)</th>
<th>Transmissivity (m2/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghari</td>
<td>90</td>
<td>12</td>
<td>0.50</td>
<td>-</td>
<td>-</td>
<td>17.8</td>
</tr>
<tr>
<td>Utlo</td>
<td>46</td>
<td>9.0</td>
<td>1.82</td>
<td>-</td>
<td>-</td>
<td>1.4</td>
</tr>
<tr>
<td>Canchipur</td>
<td>145.4</td>
<td>24</td>
<td>0.50</td>
<td>-</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>Lilong</td>
<td>91</td>
<td>24</td>
<td>1.6</td>
<td>-</td>
<td>-</td>
<td>3.52</td>
</tr>
<tr>
<td>Shamurou</td>
<td>64.5</td>
<td>21</td>
<td>3.52</td>
<td>-</td>
<td>-</td>
<td>4.7</td>
</tr>
<tr>
<td>Irom Meijarao</td>
<td>67</td>
<td>18</td>
<td>4.7</td>
<td>-</td>
<td>-</td>
<td>0.80</td>
</tr>
<tr>
<td>Wangoi Kabui</td>
<td>67</td>
<td>9</td>
<td>0.80</td>
<td>-</td>
<td>-</td>
<td>4.09</td>
</tr>
<tr>
<td>Mayang Imphal</td>
<td>91.5</td>
<td>12</td>
<td>4.09</td>
<td>-</td>
<td>-</td>
<td>3.26</td>
</tr>
</tbody>
</table>
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-7.

**Table 7 Distribution of granular zone in various depths in the study area**

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Within 50 m</th>
<th>50 - 100 m</th>
<th>100– 150 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of</td>
<td>3-8 m</td>
<td>5 – 15 m</td>
<td>5– 20 m</td>
</tr>
<tr>
<td>Granular zone</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Geophysical Studies**

Geophysical studies have been carried out in Imphal valley. As part of the geophysical studies, Vertical electrical sounding (VES) have been conducted at 10 prime location of the study area by CGWB as per requirement of Aquifer mapping. The result and interpretation of VES studies were given in the next chapter.

**Geochemical Studies**

To know the water quality of the study area, water sampling done from both shallow and deeper aquifers. Four key observation wells of the NAQUIM area in Imphal valley 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. Details of the samples are given in Table 1. Water samples collected during the study were analyzed for the different chemical constituents at the regional chemical laboratory of CGWB, NER Guwahati.

**Table 8 Estimation Methodology**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Analytical Technique</th>
<th>Method of Preservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Portable digital pH meter</td>
<td>-</td>
</tr>
<tr>
<td>Electrical Conductivity (EC)/TDS method</td>
<td>Portable digital EC/TDS meter</td>
<td>-</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Titration method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Hardness</td>
<td>EDTA Titration method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Chloride (Cl(^-))</td>
<td>Argentometric method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Fluoride (F(^-))</td>
<td>SPADNS method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Calcium (Ca(^{2+}))</td>
<td>EDTA Titration method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>EDTA Titration method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Iron (Fe(^{2+}/Fe^{3+}))</td>
<td>Phenanthroline method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Sulphate (SO(_4^{2-}))</td>
<td>Turbidimetric method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Sodium &amp; Potassium</td>
<td>Flame Photometric method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Disulphonic acid method</td>
<td>Preserved in Polyethylene bottle</td>
</tr>
</tbody>
</table>

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.

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER

Results and Interpretations of Hydrogeological Studies

Aquifer Characteristics

Investigations 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 with an average depth of water varying from 3 to 4 m bgl. 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 2 to 4.7 mbgl. Groundwater in deeper layers is semi-confined to confined with static water level from 5 mbgl to 0.50 magl. Granular zones are encountered at depth of about 60 to 100m 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.

Ground Water Level Conditions

The pre-monsoon water level in the Shallow zone ranges from 1.37 to 6.92 mbgl and the piezometric level varies from 5 mbgl to 0.50 magl. During post-monsoon the depth to water level in Imphal valley recorded between 0.20 to 6.78 mbgl and the piezometric level varied between 4.7 mbgl and 0.22 m agl. Water level fluctuation between pre and post monsoon ranged between 0.14 and 1.08 m.

Findings from Exploration

It has been observed from the findings of exploration by CGWB and PHED that 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.

<table>
<thead>
<tr>
<th>Type of Aquifer</th>
<th>Depth range of the aquifers (mbgl)</th>
<th>Thickness (m)</th>
<th>Yield (m³ per hr)</th>
<th>Draw down (m)</th>
<th>T (m²/day)</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer - I (Unconsolidated)</td>
<td>GL to 50</td>
<td>5 to 10</td>
<td>10</td>
<td>18</td>
<td>55</td>
<td>1.5×10⁻³</td>
</tr>
<tr>
<td>Aquifer - II (Tertiary sandstone)</td>
<td>50 to 150</td>
<td>5 to 20</td>
<td>15</td>
<td>18</td>
<td>82</td>
<td>3.4×10⁻⁴</td>
</tr>
</tbody>
</table>
Fig. 9 Aquifer Disposition in the study area

Ground Water Movement

The groundwater movement is essentially towards the southwestern lower part from the peripheral higher elevation of the study area 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 study area. The nature is radial from peripheral higher
elevations to the lower levels of the central part of the valley. 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 (along Iril River).

**Yield Potential of Aquifers**

Depending upon the degree of differential weathering between hilltops and valley floors, depression was formed and sediments were deposited, as channels and meander belts etc. The alluvial deposits in the area occur down to 100 to 150 m depth below which consolidated Tertiary sediments are encountered.

The discharge ranges from 19.00 to 110.00 m$^3$/hr in the study area. The highest discharge recorded is 110 m$^3$/hr with transmissivity of 5.3 m$^2$/day with a drawdown of 11m and the lowest recorded is 19.00 m$^3$/hr with a transmissivity value of 0.1 m$^2$/day.

**Findings of Geophysical Studies**

According to the results of interpretation of VES curves, correlation of the data with hydrogeological details of exploratory boreholes and taking into account the apparent resistivity following conclusions have been drawn in Imphal valley.

<table>
<thead>
<tr>
<th>Resistivity section</th>
<th>Resistivity value Wm</th>
<th>Depth (mbgl)</th>
<th>Inferred Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>0 to 5mbgl</td>
<td>Top soil: clays with boulders of compact nature</td>
<td></td>
</tr>
<tr>
<td>100 to 250</td>
<td>5 to 50mbgl</td>
<td>Saturated formation: Sands, clays with pebbles etc.</td>
<td></td>
</tr>
<tr>
<td>&gt;150</td>
<td>below 50 mbgl</td>
<td>Saturated formation: Pebbles with sands and clays occasionally with boulders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70-80</td>
<td>clays predominance intercalated with thin bands</td>
<td></td>
</tr>
</tbody>
</table>

i. The top soil with resistivity in the range of 30 and 260 Ohm with thickness within 10m comprises top soil with clays / hard clays etc.

ii. The underlying layers below the top soil in the depth below the top soil layer with varying resistivity within 60 Ohm m in general is indicative of sandy formation intercalated with clays / hard clays etc. Comparatively high resistivity above 100 Ohm m is indicative of the hard clay/semi-consolidated or consolidated formation.

iii. The inferences for bottom portion are drawn on the basis of interpreted results of surface resistivity surveys, apparent resistivity pertaining to extreme portion of VES curves and hydrogeological data.
During the survey H, HK, HA type VES curves were obtained. The inferences drawn on the basis of interpreted results could not be obtained for deeper formation due to the limitations of unavailability of large and straight stretch for current electrode separation. Interpreted results of VES and inferences with respect to possible sub-surface geology are given in Table 10.

**Ground Water Quality**

In general, the ground water of the study area is slightly alkaline to neutral in nature. Electrical conductivity, total dissolved solids 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 state. However, the shallow water bearing zone in the valley, the Iron content in ground water is more than permissible limit.

The pH of the Ground water varies from 7.53 to 8.52 indicating pH of the water is within permissible limits. The value of EC varies from 180.7 to 1194 µs/cm at 25°C. The fluoride content of water samples are varies from 0.08 to 0.92 mg/l. The iron content in the shallow tube wells varies from 0.46 to 4.69 mg/l and it is BDL for deep tube well samples. Location of higher concentration of iron in groundwater is depicted in **Fig.10**. Summary of results of chemical analysis data showing concentration of iron in groundwater is shown in table below.

**Table: 11 Summary of chemical analysis data showing concentration of iron in groundwater**

<table>
<thead>
<tr>
<th>SI. No</th>
<th>Fe (mg/l)</th>
<th>No. of samples</th>
<th>% of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.0 to 0.3</td>
<td>01</td>
<td>14.25</td>
</tr>
<tr>
<td>02</td>
<td>0.3 to 1.00</td>
<td>01</td>
<td>14.25</td>
</tr>
<tr>
<td>03</td>
<td>&gt; 1.00</td>
<td>05</td>
<td>71.42</td>
</tr>
</tbody>
</table>

It can be seen from the above table that 28.50% water samples collected from shallow tube wells are having iron content within desirable limit (set by BIS). And 71.42% 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.

**Hydrochemical Findings in Detail**

The analytical results of various parameters of water quality in the 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, the overall water temperature ranged from 21°C to 24°C; total dissolved solids from 90.98 mgL⁻¹ to 345.6 mgL⁻¹; pH from 7.53 to 8.52; electrical conductivity varied from 180.7 µs cm⁻¹ to 1194 µs cm⁻¹; chloride values ranged from 29 mgL⁻¹ to 250 mgL⁻¹; total hardness ranged from 96 mgL⁻¹ to 192 mgL⁻¹; sulphate values ranged from 0.989 mgL⁻¹ to 4.593 mgL⁻¹; nitrate from 0.3 mgL⁻¹ to 2.7 mgL⁻¹; fluoride values ranged from 0.08 mgL⁻¹ to 0.92 mgL⁻¹; sodium varied from
8.99 mgL\(^{-1}\) to 118.2 mgL\(^{-1}\); potassium value ranged from 1.87 mgL\(^{-1}\) to 3.4 mgL\(^{-1}\); magnesium value ranged from 8.74 mgL\(^{-1}\) to 35 mgL\(^{-1}\); calcium value ranged from 17.6 mgL\(^{-1}\) to 43.2 mgL\(^{-1}\); while iron values varied from 0.46 mgL\(^{-1}\) to 4.69 mgL\(^{-1}\).

Fig. 10 Map showing iron content in ground water of the study area

4.0 GROUND WATER RESOURCES
Total Availability of Ground Water Resources

In the present report, the smallest administrative unit viz. Imphal west-II block is 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 238 sq.km (Imphal West-II CD block), which covered 155 sq km of 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 draft 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. Draft during monsoon and non-monsoon periods have been estimated separately by taking 04 months as monsoon and 08 months as non-monsoon period. The annual unit draft has been taken as 1.0 ham for shallow tube wells, considering the average discharge of wells as 15 m³/hour with two hours pumpage per day.

Block-wise groundwater draft for irrigation was estimated based on the number of structures as provided by Minor Irrigation Department. The unit annual draft has been taken as 3 ham as given in GEC’97 for the states of some of the North Eastern States. Groundwater in the State is mostly used for domestic and irrigational purposes. Groundwater for Industrial draft is negligible. The details of canals have been collected from Irrigation and Flood Control 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 Irrigation and Flood Control 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 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 a whole. Recharge from tanks and ponds and Recharge from water conservation structure have been taken as Nil. 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-II block is 4472.59 ham. The net groundwater availability worked out 4025.33 ham after deducting the natural discharge during non-monsoon season. The existing gross groundwater draft for all uses is 16.03 ham of which 12.04 ham is the gross groundwater draft for irrigation use and 3.99 ham is the gross groundwater draft for domestic use. The stage of groundwater development in Imphal West II block is 0.40 %. As such the assessment unit falls under Safe category. Since there is no saline/brackish water infested area in the Aquifer Mapping area, the entire assessment area has been considered as fresh water bearing area.
The pre-monsoon (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 12. Balance of ground water availability for future use as per dynamic ground water resources in Imphal west-II block

<table>
<thead>
<tr>
<th>District (p)</th>
<th>Stage of Ground Water development (%)</th>
<th>Net GW Availability (ham)</th>
<th>Existing Ground Water Draft for Irrigation (ham)</th>
<th>Existing Gross Ground Water Draft for All Uses (ham)</th>
<th>Provision for Domestic &amp; Industrial requirement for up to 2025 (ham)</th>
<th>Net GW Availability for Irrigation (ham)</th>
<th>GW Availability for Future Irrigation@60% Net GW Availability (ham)</th>
<th>No. of STW feasible as per Resource (Unit draft 3 ham)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imphal West II block</td>
<td>0.40</td>
<td>4025.33</td>
<td>12.04</td>
<td>16.03</td>
<td>942.37</td>
<td>3070.92</td>
<td>1842.55</td>
<td>614</td>
</tr>
</tbody>
</table>

**In-storage Resources of Confined Aquifer down to Explored Depth** which can be exploited safely (say 450 m.) The average thickness of total saturated aquifer below ground level has been considered based on the lithological logs of the bore holes drilled so far by CGWB.

As per the revised guidelines, the actual granular/ productive zones within the aquifers have been considered for the computation. Average Storability value of confined aquifer has been taken as 0.000169.

**Salient features of the Total Availability of Groundwater Resources Assessments including spatial variation**

The Total Availability of Ground Water Resources has been estimated for the base year 2008-09. There is no saline/ brackish water bearing aquifer in Imphal valley. The computation shows that the Net Ground Water Availability of Imphal West district as a whole (as on 2009) is 7789 ham. The Total Fresh In-Storage Ground Water Resource for Imphal west district (by 2009) is 77229.50 ham. The Total Fresh Ground Water Availability in Imphal West district as on 2009 has been computed as 85018.60 ham.

**5.0 GROUND WATER RELATED ISSUES**

**Major Groundwater Issues in the Area**

Ground water related problems in the study area has so far been identified as emanation of gas while constructing deep tube wells and existence of clayey deposit down to depth range of 30 to 50 m bgl which invites problem for construction of shallow tube wells. As
such utmost care has to be taken during construction of deep tube wells so that any untoward incident can be averted.

Other groundwater related issues found in the study area are-
  a. Low stage of development;
  b. Flood is a primary hazard in the valley during the monsoon season every year damaging crops and properties of the people;
  c. In places, high concentration of iron in groundwater also observed;
  d. Water scarcity during lean period

**Manifestation and Reasons of Issues**

The pre-monsoon water level in the Shallow zone ranges from 1.37 to 6.92 mbgl and the piezometric level varies from 5 mbgl to 0.50 magl. During post-monsoon the depth to water level in Imphal valley recorded between 0.20 to 6.78 mbgl and the piezometric level varied between 4.7 mbgl and 0.22 magl. Water level fluctuation between pre and post monsoon ranged between 0.14 and 1.08 m.

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 $20.4^\circ$C and the temperature ranges from $0^\circ$C to $36^\circ$C. 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 13. Details of net sown area and irrigated area**

<table>
<thead>
<tr>
<th>SI No.</th>
<th>District (p)/Block(p)</th>
<th>Study area (in Ha)</th>
<th>Net Area Sown (in Ha)</th>
<th>Land under Irrigation (in Ha)</th>
<th>Land which can be brought under Irrigation (in Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Imphal West II block</td>
<td>15500</td>
<td>3137.86</td>
<td>6315</td>
<td>1655</td>
</tr>
</tbody>
</table>

The pH of the Ground water varies from 7.53 to 8.52 indicating pH of the water is within permissible limits. The value of EC varies from 180.7 to 1194 µs/cm at 25ºC. The fluoride content of water samples are varies from 0.08 to 0.92 mg/l. The iron content in the shallow tube wells varies from 0.46 to 4.69 mg/l and it is BDL for deep tube well samples.

It can be seen from the analysis data that 40 % water samples collected from shallow tube wells are having iron content within desirable limit (set by BIS). And 60% 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.

**6.0 MANAGEMENT STRATEGIES**

Water is a state subject and the management of ground water resources is a prerogative of the concerned State Government. The unplanned and non-scientific development of ground water
resources, mostly driven by individual initiatives has led to sharp depletion of the resources and also degradation of quality at many places. The adverse impacts can be observed in the form of long-term decline of ground water levels, de-saturation of aquifer zones, increased energy consumption for lifting water from progressively deeper levels and quality deterioration due to saline water intrusion in coastal area in different parts of the country. There is urgent need for coordinated efforts by all the stakeholders for evolving and implementing suitable ground water management strategies in the country.

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

The NAQUIM area (Imphal West II) 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 145 m bgl 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.

The study area in Imphal West II CD block possesses moderate ground water potential to the tune of 4472.59 ham and net resource of 4025.33 ham. This moderate resource can be developed for irrigation and other domestic purposes. The draft created by existing tube-wells has been computed to be 16.03 ham and development is found to be 0.40 %, as such scope exists for development of ground water in the area. Based on the irrigation water requirement, additional medium duty tube well to the tune of 1342 may be constructed, which will be able to generate irrigation potential of 1611 ham. The conjunctive use of surface and ground water 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 ground water.

Lack of information and absence of a knowledge-driven decision support system are major barriers for sound planning and strategies for development and management of ground water resources including their conservation, augmentation, protection from pollution and regulation of extraction.

The water resources in the state are also facing threat due to various natural and human influences. In the study area most of the drinking water is harnessed from ponds, rivers and natural streams/springs. However, many are becoming seasonal and polluted. The natural hydrological cycle has been altered due to deforestations and destruction of the catchment areas. This has resulted in reducing the infiltration capacity and the crucial link feeding the source of the rivers, streams and underground aquifers is being lost. Apart from this, pollution from untreated sewage, industrial effluent, agricultural run-off, etc are also contaminating the water sources.

With the population of Imphal valley increasing at an alarming rate, water requirements for drinking and other purposes is also increasing at high proportion. As per the population census 2011, Imphal West II block has the rural population of 74262 comprising 51 % of the rural population of the state. To meet the growing demand for drinking, domestic and industrial sector and to address various issues related to ground water, there is an imperative need to prepare a comprehensive road map with identified strategies for scientific and sustainable management of the available ground water resources.
The first step towards achievement of this task is creation of a reliable hydrogeological database for exploration, assessment, development, management, and regulation of ground water, the lack of which is negatively impacting the planning and implementation of development and management initiatives. Therefore, a systematic hydrogeological study was carried out in the study area to provide scientific database on ground water.

The study area is having meager irrigation facility. Available land of 3137.86 ha does not have any ground water irrigation facility which can be brought under irrigation using the dynamic groundwater resources available in the area. It is proposed to bring 60% of area under paddy and 40% under non-paddy cultivation. Water requirement for paddy cultivation ($\Delta=1.2$ m) would be 2260 ham while that for non-paddy cultivation ($\Delta=0.3$ m) would be 376 ham. Total water requirement to bring this entire uncovered area under irrigation is 2636 ham.

As per the report on dynamic groundwater resources of Manipur, the study area is having balance groundwater availability for future uses to the tune of 3070.92 ham. If a plan is made to develop 60% of the balance dynamic groundwater resources available (1842.55 ham) in the study area for the irrigation purposes, then 614 nos. of tube wells (considering a unit draft of 3 ham/yr) can be constructed in the area.

The study area has moderate groundwater potentiality and this can be sustainably developed to irrigate available lands in the area. A tube well yielding 15 m$^3$/hr, runs for 12 hrs/day for 120 days will create a draft of 2.2 ham. To meet the water requirement of 2636 ham for paddy, 1198 nos. of such tube well will be required (considering a unit draft of 2.2 ham/yr).

But in 3137.86 ha area maximum 170 tube wells can be constructed which can deliver 367 ham water that can irrigate 1254 ha non-paddy area.

Tube wells can be designed in the study area within a depth of 50 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 of 18 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.

Though GW resource is available but farmers in the area are poor and it may not be possible for them to construct tube wells individually. Community based irrigation schemes through groundwater may be taken up by Govt., which will greatly boost the socio-economic conditions in the area.

Cost Estimates
One time expenditure to construct 170 tube wells @ Rs. 4, 50,000/= is Rs. 7.65 crores.

MANAGEMENT PLAN

By providing irrigation facilities to 1254 ha of non-paddy land, 627 to 92796 metric tons of oilseeds or potato can be produced. This will boost the economy by providing Rs. 0.32 to 4.8 crores per annum income (recent minimum price of vegetables Rs. 520/Qn to Rs. 3000/ Qn of oilseeds). Total one time expenditure will be Rs. 7.65 crores and benefit is Rs. 0.32 to 4.8 crores per annum.
In some pockets, groundwater in the area is infested with iron, therefore, before consumption aeration/ filtering/ installation of Iron Removal Plant is necessary.

Farmer’s co-operative societies may be formed which will look after maintenances of the tube wells.

**Traditional Water Management Practices in the Study area**

Ponds or pukhris are the most prevalent traditional water harvesting structures. Till a few decades ago, almost every household had a pond of its own. Community ponds are also commonly found in the settlements. These are generally larger in size and better maintained than private ponds. The water supply situation in the area in terms of coverage and adequacy continues to be pathetic in most settlements. Hence, even today, a large majority of the population depends on ponds to meet their water requirements.

Private ponds are drying up in townships and heavy settlement areas where the premium on land is high. However, fortunately, the community ponds in these areas are still untouched. In fact, the heritage of the community pond seems to have strengthened in the absence of a satisfactory or reliable water supply system. Paradoxically, the extension of piped water supply worsened the water situation in some settlements as the residents began neglecting the ponds in their area. As the ponds went into disuse and dried up, water supply services became unavailable or very poor in many of these places.

A substantial amount of the vegetables produced are grown in private kitchen gardens, which use water from ponds. It was quite common to have a small pond at the lower end of the plot in paddy fields. It was useful during the dry spells between the rains after sowing. However, most of these ponds are now filled up and reclaimed for cultivation.

Rainwater harvesting is suitable for meeting the domestic water requirements in the study area. This is due to the following reasons-

- heavy and widespread precipitation;
- many houses already have GI sheet-covered sloping roof tops, and installing the simple structure required will be easy;
- most of the residential houses are small, owner-occupied houses;
- people are familiar with this concept, and
- the relatively pollution free atmosphere.

**Irrigation and the Economy**

With appropriate rainwater management, the monsoon rain should suffice for the growth of Rabi crops in the area. The temporal spread of rain may be more conducive to traverse intercropping instead of multiple cropping. The creation of irrigation facilities would encourage the farmers to adopt modern inputs, such as improved and/or high yield variety seeds, fertilizers and multiple cropping. The combined impact of all these can result in a quantum jump in production. It is worth mentioning that paddy cultivation is an extremely labour-intensive activity. Increased cropping intensity here would mean more employment opportunities. The construction and maintenance works related to irrigation facilities also creates employment. A well functioning irrigation system will thus promote agricultural productivity and employment generation.
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