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

IDUKKI DISTRICT, KERALA

केरल क्षेत्र, त्रिवेंद्रम

Kerala Region, Trivendrum

केंद्रीय भूजल बोर्ड, केरल क्षेत्र

जल शक्ति मंत्रालय

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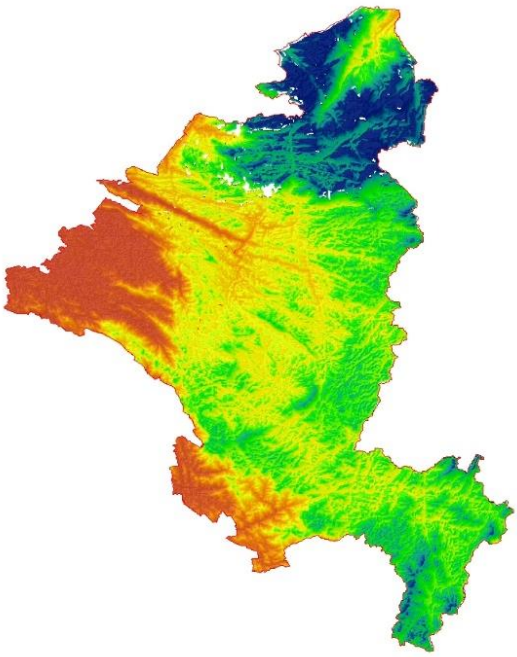
भारत सरकार

CENTRAL GROUND WATER BOARD
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
GOVERNMENT OF INDIA
KERALA REGION

AQUIFER MAPPING AND MANAGEMENT PLAN OF IDUKKI DISTRICT, KERALA (AAP: 2019-20)



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जनवरी/JANUARY 2022

FOREWARD

The National Project on Aquifer Mapping (NAQUIM) is an initiative of the Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Government of India, for mapping and managing the entire aquifer systems in the country. The aquifer systems in Kerala are being mapped as part of this Programme. The target scale of investigation is 1:50,000 and envisages detailed study of the aquifer systems up to 200 m depth in hard rock, to ascertain their resource, water quality, sustainability, and finally evolve an aquifer management plan. This report pertains to aquifer mapping and management plan of Idukki district.

The report titled "Aquifer Mapping and Management plan, Idukki district, Kerala" gives a complete and detailed scientific account of the various aspects of the hard rock aquifer in the area including its vertical and horizontal dimensions, flow directions, quantum and quality of the resources, of both - the shallow and deeper zones of the hard rock aquifers. Voluminous data were generated consequent to hydrogeological, ground water regime monitoring, ground water quality, exploratory drilling, geophysical studies etc. in the district, and incorporated in the report. The information is further supplemented by various data collected from State departments. It portrays the various ground water issues pertaining to the area along with recommendation for suitable interventions and remedial measures. Thus, it provides a total and holistic solution to the water security problems in Idukki district.

This document has been prepared under the guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer, and Sh. M.Santhana Subramani, Scientist C & Team leader. The painstaking efforts of the field hydrogeologist Sh.Vijesh V K, Scientist B for carrying out the aquifer mapping and preparation of this report are well appreciated. Smt. Anu V, Scientist B deserves appreciation for their meticulous scrutiny of this report before printing. I am also thankful to the officers of CGWB, Kerala Region, Thiruvananthapuram for their technical support and suggestion rendered during field investigation and preparation of report. Thanks, are due to various organizations of Government of Kerala such as Ground Water Department, Irrigation Department, Agriculture Department, Land Use Boardetc and Central Government Departments such as GSI, IMD and Survey of India for providing data for aquifer mapping studies.

This report evolved in the present form through incorporations and modifications as suggested during the presentation of the report before the State Ground Water Coordination Committee (SGWCC), Chaired by the Water Resources Secretary, Kerala State, Sh. Pranabjyoti Nath, IAS. The contribution of the committee in improvising the content of this report is acknowledged with gratitude.

I hope that this compilation will be of much help to the planners, administrators and stakeholders in the water sector for the optimal and sustainable management of ground water resources in Idukki district.

Thiruvananthapuram
January 2022

(Dr.A.Subburaj)
Regional Director

AQUIFER MAPPING AND MANAGEMENT PLAN OF IDUKKI DISTRICT, KERALA (AAP- 2019-20)

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AQUIFER MAPPING AND GROUND WATER MANAGEMENT PLAN, IDUKKI DISTRICT, KERALA

1.0 INTRODUCTION

1.1 Introduction

In XII five-year plan, National Aquifer Mapping (NAQUIM) has been taken up by CGWB to carry out detailed hydrogeological investigation on topographic sheet scale (1:50,000). Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers.

The vagaries of rainfall, inherent heterogeneity of hard rock aquifers, over exploitation and lack of regulation mechanisms had a detrimental effect on ground water scenario of the country in last decade or so, demanding a paradigm shift from "traditional groundwater development concept" to "modern groundwater management concept".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at robust and implementable ground water management plans. The proposed management plans will provide the "Road Map" ensuring sustainable development of ground water resources, thereby primarily improving drinking water security and irrigation requirement. Thus, the crux of NAQUIM is not merely mapping, but reaching the goal of community participation in ground water management.

By understanding the goals of NAQUIM, during the Annual Action Plan of 2019-20, Idukki district of Kerala state covering a geographical area of 4358 sq.km. has been taken up. The aquifer maps and management plans formulated subsequently by this study will be shared with the Idukki district administration for its effective implementation.

1.2 Objectives & Scope of the Study

Aquifer mapping itself is an improved form of groundwater management– recharge, conservation, harvesting and protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e., the aquifer map and management plan. The activities under NAQUIM are aimed at:

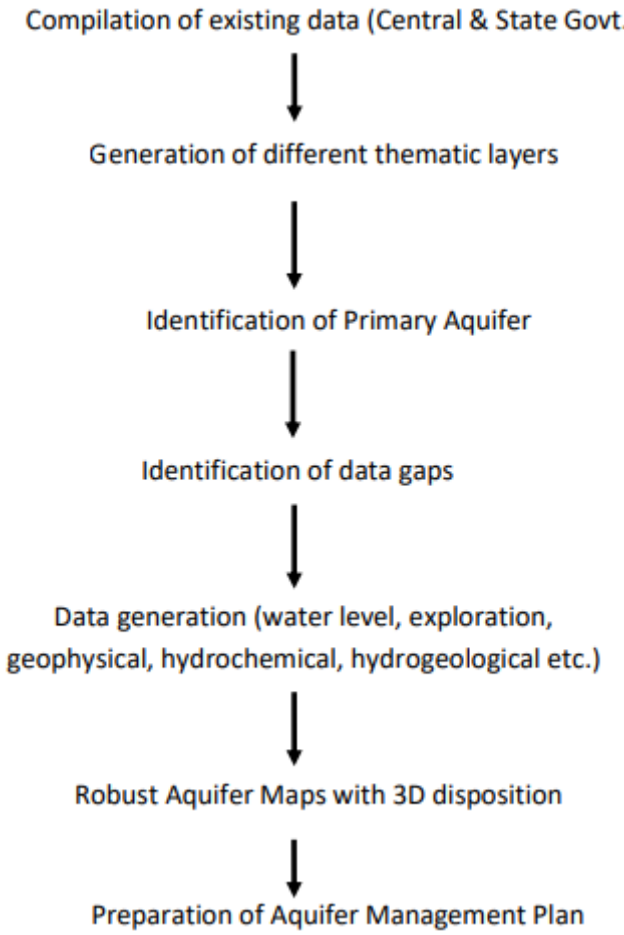
- Identifying the aquifer geometry,
- Aquifer characteristics and their yield potential
- Quality of water occurring at various depths
- Aquifer-wise assessment of ground water resources
- Preparation of aquifer maps and
- Formulate ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water sector to ascertain the volume of water available for various uses as well as the need of management measures implemented to achieve a Sustainable development goal.

1.3 Approach and Methodology

The ongoing activities of NAQUIM include topographic sheet wise micro-level hydrogeological data acquisition, geophysical and hydro-chemical investigations supplemented by ground water exploration down to the depth of 200 meters. The data on various components thus collected were brought on GIS platform by geo-referencing for its

utilisation in the preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:



1.4 Study area

Idukki is the second largest district in Kerala state covering an area of 4358 sq.km, constituting 11.2% of the total area of the state. The district is covered with dense tropical forests, plantations, scrublands and grasslands situated entirely in the lofty hills of the Western Ghats with a mappable area of 871 sq.km. The district is located between North latitudes 9º16'30" and 10º21'00"and East longitudes 76º38'00" and 77º24'30", with maximum length of about 115 km from north to south and width about 67 km from east to west. The district is included in the Survey of India Topographical Maps (Scale 1:50,000) bearing Nos.58 B/16, 58 C/9, 58 C/13, 58 C/14, 58 C/15, 58 F/3, 58 F/4, 58 F/7, 58 F/8, 58 G/1, 58 G/2, 58 G/3, 58 G/5, 58 G/6, and 58 G/7. Idukki district is bounded by Ernakulam district in the northwest, Kottayam in the south-west and Pathanamthitta district in the south. The northern and eastern parts of the district are bordered by the State of Tamil Nadu.

The National Highways 85, 183, 183A, 185 and more than 10 state highways pass through this district, which facilitate significant transportation. Agriculture is the main occupation of the people and most of the income is derived from agriculture and allied occupations. Being hilly, the district is not connected with rail routes. Administratively, the district is divided into 5 taluks (Devikulam, Peerumedu, Udumbanchola, Thodupuzha and Idukki), 8 development blocks (Adimali, Azutha, Devikulam, Elamdesom, Idukki, Kattappana, Nedumkandam and Thodupuzha), 2 Municipalities (Kattappana and Thodupuzha) and 52 Gramapanchayaths and 1 township (Idukki). As of 2011 census the total population of the district is 11,08,974 with

population density of 254 per sq.km. Administrative map of the district is given in figure 1.1. The district headquarters is at Painavu, since June 1976, located at 'Kuyilimala' a hill station surrounded by reserve forests in Thodupuzha taluk.

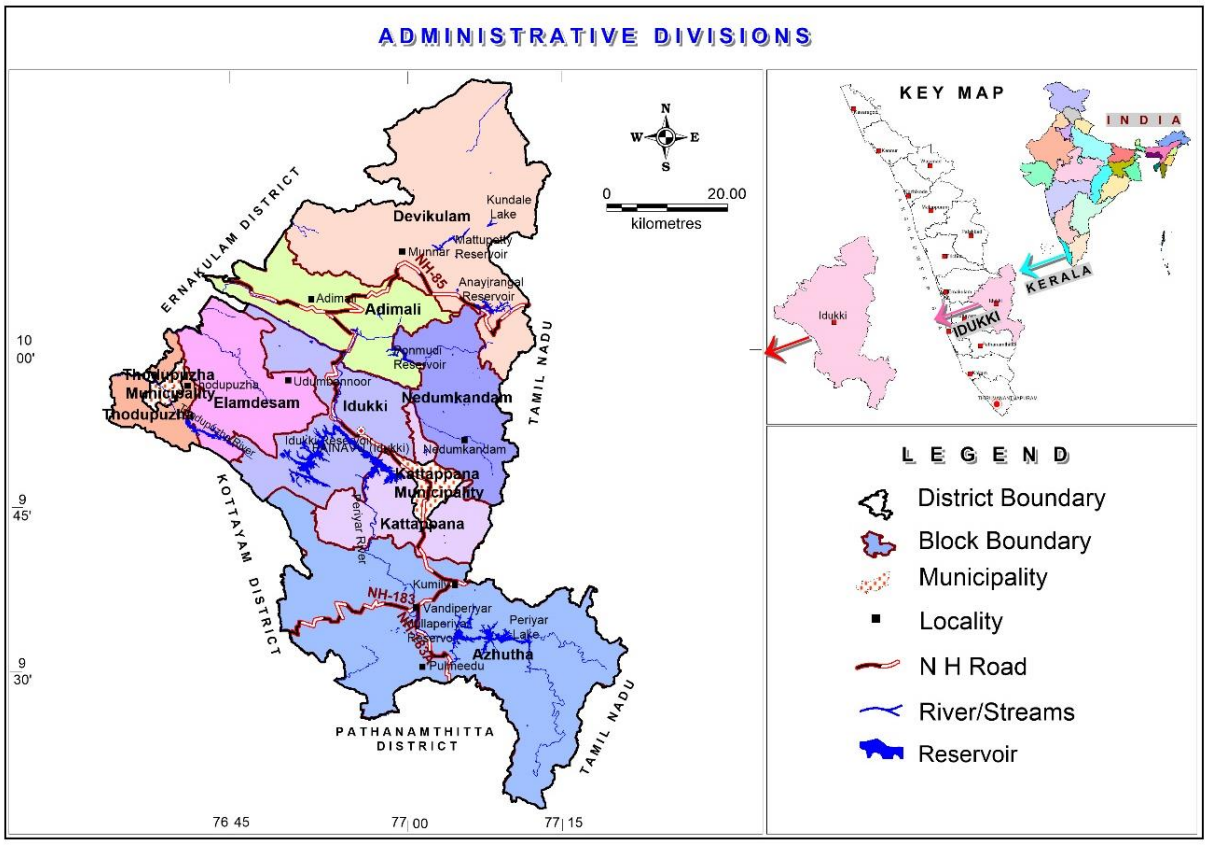


Figure 1.1 Administrative set-up, Idukki district

1.5 Data Adequacy, Data Gap Analysis and Data Generation:

The available data on Exploration activities, Geophysical Surveys, Ground water monitoring and ground water quality of Central Ground Water Board were compiled and analysed for aquifer mapping studies. In addition to these, data on ground water monitoring and ground water quality from State Ground Water Department, Govt. of Kerala (GWD) were also utilised. The data adequacy and data gap analysis were carried out for each quadrant of topographic sheet as per the criteria suggested in the manual of Aquifer Mapping in respect of the following primary and essential data requirements. viz., Exploratory Wells, Geophysical Surveys, Ground Water Monitoring and Ground Water Quality.

1.6 Rainfall and Climate

As per Koppen climatic classification, Idukki district experiences tropical monsoon with seasonally excessive rainfall and hot summer. The weather and climate of Idukki is characterized by the presence of monsoon winds. To understand the characteristics of climate, knowledge of physiography is very important. The movement of monsoon current is normally blocked by the mountain ranges. Consequently, uplifting and condensation of air takes place, which provide rainfall on windward side and scarcity of rainfall on the leeward side. Thus, orographic precipitation is responsible for most of the rains in Idukki and the precipitation varies in different altitudinal ranges that subjects to fluctuation of wind by orientation of hill. Generally, climate varies from east to west with the descending elevation of landscapes.

Table 1. Data Gap Analysis

Sl. No.	Items	Data available with State govt. Agency	Data available with CGWB	Data Requirement/ Data gap identified	Data generated	Total
1	Ground water level data	20 DW+24 PZ	68 DW+7 PZ+24 EW	40 DW+2 EW	40 DW+2 EW	185
2	Ground water quality Data	24 PZ	DW-20 + EW-22	39 DW+ EW-1	39 DW+ EW-1	106
3	Borehole Lithology Data	--	24 EW	2 EW	2 EW	26
4	Geophysical Data (VES/TES)	--	0	16 VES 15 TEM	16 VES 15 TEM	16 VES 15 TEM
5	Pumping Test (EW)	--	5	1	1	6
6	Soil infiltration tests	--	--	3	3	3
7	Land use and Land Cover, Drainage	Kerala State Land Use Board				
8	Geology	Geological Survey of India				
9	Soil	National Bureau of Soil Survey (NBSS)				
10	Rainfall / Meteorological data	Indian Meteorological Department / Irrigation Design and Research Board (IDRB)				

The annual rainfall in the district varies from less than 1000 (at Marayoor) to 4500 mm (at Peerumed). The normal annual rainfall as per Agricultural Statistics (2018-19) is 3345.4 mm. Based on weather and climatic situation in Idukki, year is broadly divided in to four seasons:

- Winter (January-February)
- Hot Weather Period (March-May)
- South West Monsoon (June-September)
- North East Monsoon (October-December)

The south west monsoon contributes a major share (60.4%) of the rainfall in Idukki district whereas the northeast monsoon season accounts for about 24.4%. The balance 15.2% is contributed during the period from January to May. The rain shadow regions, namely, Vattavada, Marayoor, Kovilkadavu receive less than 1000 mm rainfall annually. The isohyets of normal annual rainfall in Idukki district is depicted in **figure 1.2**. The monthly rainfall during the last five years from 2014 to 2018 is given in **table 2** and graphical representation of the same is given in **figure 1.3.** From the figure it is very clear that the Idukki district received maximum rainfall during 2018 (~4900 mm), marked by severe flood and landslides which caused massive destruction to transport network

Table 2. Monthly rainfall (2014-18)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
	Rainfall (mm)												
2014	7.9	14.1	27.1	86.8	237.2	493	898.7	904.7	410.4	421.6	127.1	54.4	**3683**
2015	1.4	14.4	78.4	280.6	165.9	644.9	436.3	271.3	344	253.6	248.1	127.6	**2866.5**
2016	5.1	5.1	26.4	39.1	292.7	586.3	540.8	322.6	119.8	117.1	37.9	19.1	**2112**
2017	12.8	1.1	122.2	71.1	210	517.9	293.4	713.1	534.5	285.3	117.1	91	**2969.5**
2018	1.8	41.5	52.6	134.8	356	806.4	1296	1478.9	212.4	325.6	194.3	6.5	**4906.8**

Generally, temperature varies between 21^{o}C and 27^{o}C with minimum seasonal variation in the district. But in eastern highlands, the temperature seasonally varies between -1^{o}C and 15^{o}C from November to January and 15^{o}C to 20^{o}C during March/April. The mean monthly maximum temperature ranges from 25.1^{o}C to 31.5^{o}C and minimum temperature from 18.6^{o}C to 14.0^{o}C.

The mean annual potential evapotranspiration value shows a maximum of 6.19 mm in March and 4.76 mm in July. The seasonal variability ranges from 4.89 mm in the rainy season to more than 5 mm in other seasons. In general, the potential evapotranspiration is 26 % in winter, 28 % in hot weather and 23 % during south west and north east monsoon seasons.

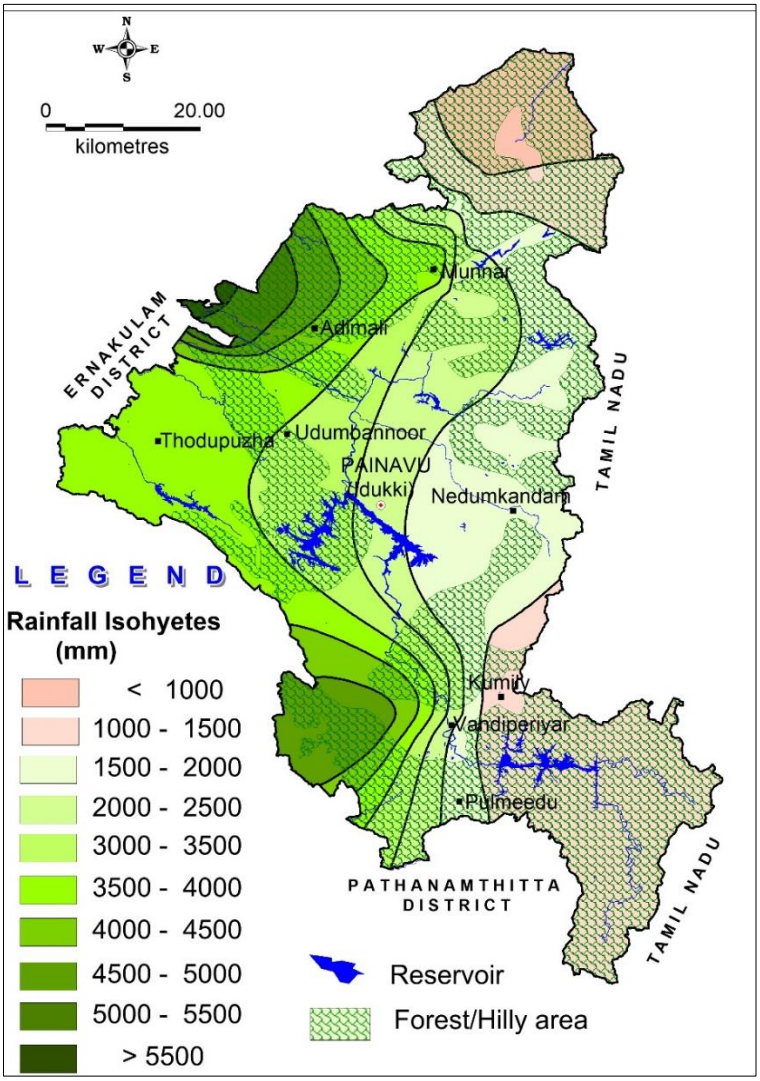


Figure 1.2. Isohyets of Normal Annual Rainfall in Idukki district

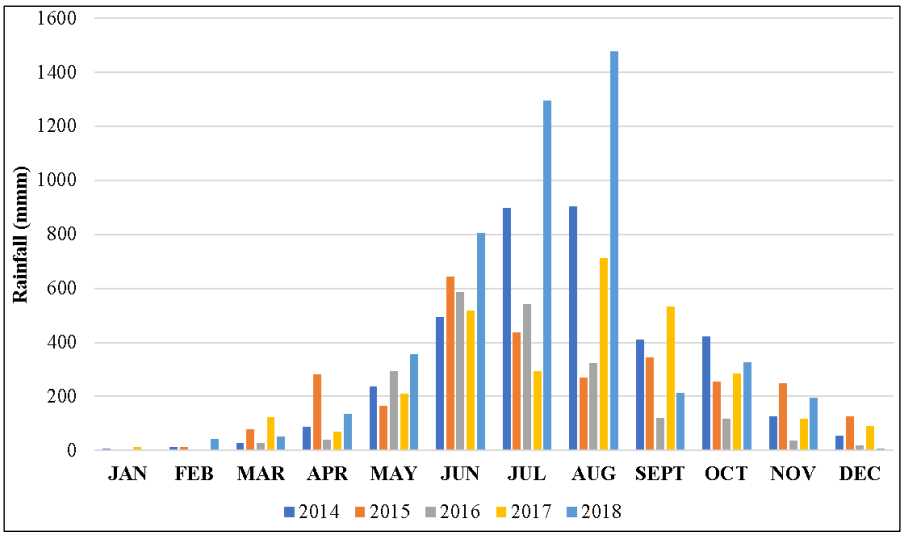


Figure 1.3. Monthly rainfall variation-Histogram (2014-18)

1.7 Physiography

The area can be broadly divided into two district physiographic units i.e., the highlands (elevation above 75 m amsl) and the midlands (between 75 and 7.5 m amsl) (**table 3**). Around 98% of the district falls under the highland category and the remaining 2% under midlands. A digital elevation model (SRTM-USGS) depicting the major physiographic features in the district is given in figure 1.4. Anamudi, the 2,695 m peak in the Eravikulam National Park is the highest peak in peninsular India as well as the tallest mountain in Kerala.

Table 3. Area, percentage and altitudes of physiographic units in Idukki district

Physiographic Unit	Elevation	Area (Km^2)	Percentage of district area
High land	above 75 amsl	4256.4	97.67
Mid land	between 7.5 to 75	101.6	2.33
Total		4358	100

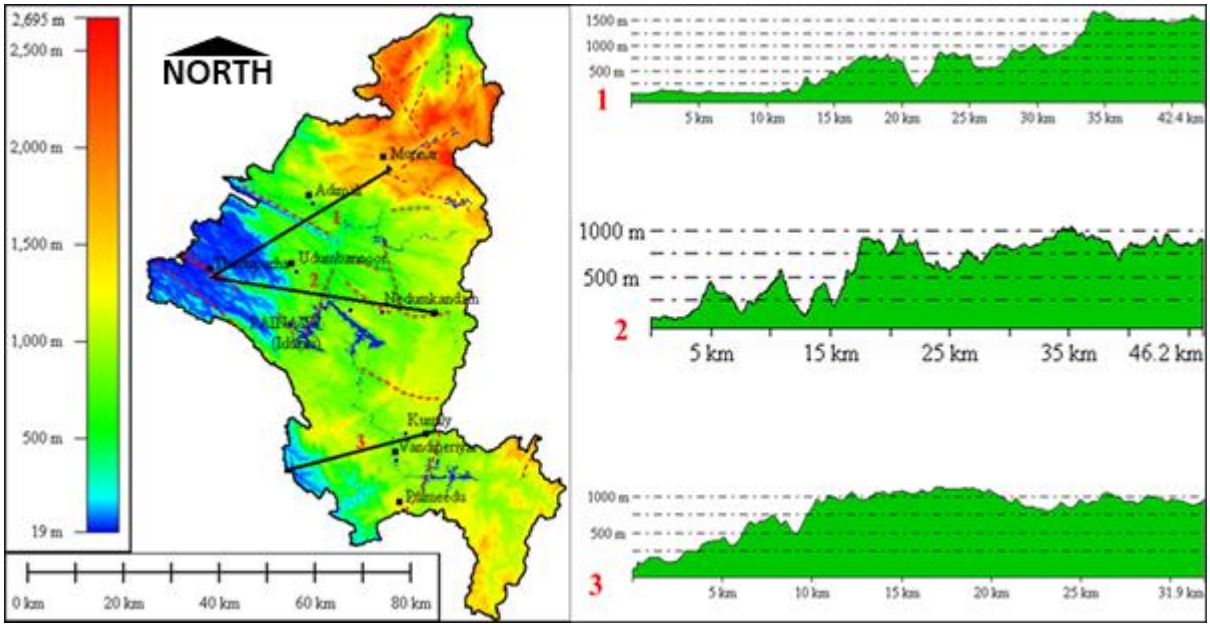


Figure 1.4. Digital Elevation Model of Idukki district

1.8 Geomorphology

The major geomorphic features present in the district are carved out by denudational and fluvial activities, including denudational hill, dissected plateau, lateritic plateau, valleys and river channels. Denudational hills are the remnants of the natural dynamic process of denudation and weathering. The ground water potential of these geomorphologic features is limited and if any, depends on the presence of secondary porosity instigated by tectonic process and subsequent deformations. Denudational hills occupy a major part of the district constituting about 63% of the total area.

The foothills represent the midland region characterised by plateau. Plateau section is generally divided into dissected middle plateau and lateritic lower plateau based on the elevation. Dissected plateau region constitutes 19% of the total area and is mostly confined to Nedumkandam and Kattappana blocks. In addition to this, northern part of Ranni reserved forest section in Azutha, Mannankandan reserved forest section in Adimali, linear stretch between Mannankandam and Thodupuzha reserved forest section, south of Mannavan chola and the area surrounded by Nanchivayal in Devikulam block have a dissected topography. Lateritic plateau encompasses 5% of the district area, and mostly confined in Thodupuzha and Elamdesom blocks.

The major rivers and streams in Idukki are encircled by valleys, which occupy 5% of the study area in the western part of the region in Thodupuzha, Kattappana Adimali, and Devikulam blocks. River channel is recognized as a significant geomorphological feature with 0.3% of the area primarily associated along Periyar which exhibits the largest network of streams. Reservoir island constitutes a minor feature with 0.05% of the study area found in the midst of Idukki reservoir. Generally, ground water potential is more in valley fills, lower plateaus (Lateritic), flood plains and piedmont zones. The geomorphology map of the area is shown in figure 1.5.

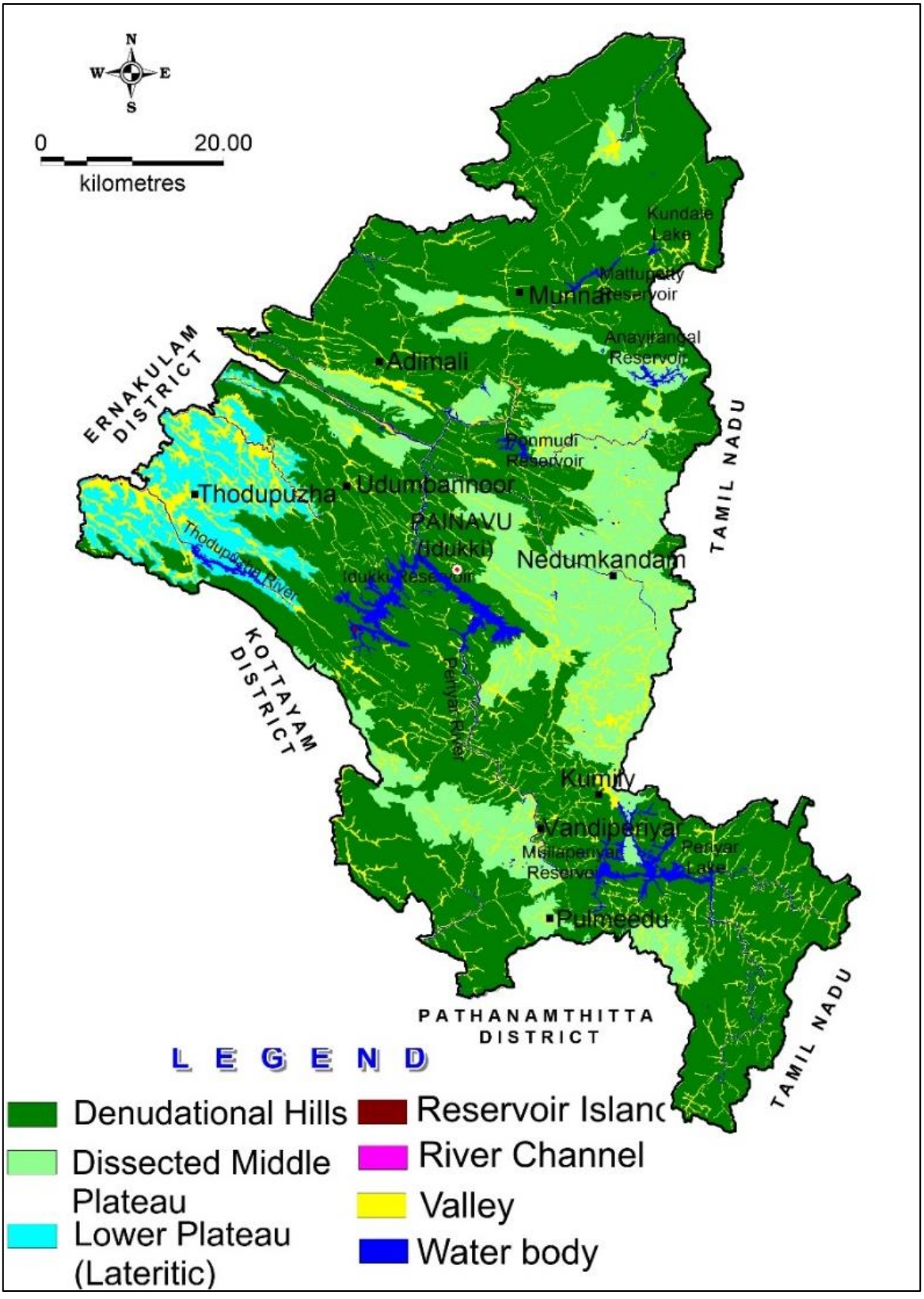


Figure 1.5. Geomorphology map

1.9 Land Use, Soil, Agriculture, Irrigation and Cropping Pattern

An understanding of land use/ land cover is important as it has a direct relation with ground water resource availability and utilisation. As per Agricultural Statistics 2018-19, 45% of Idukki district comes under forest area (1984.13 Km^2). Summarised land use pattern and cropped area of the district is given in table 4. The waste lands in the district includes under-utilized degraded forests, steep sloping land, barren sheet rock areas and undulating uplands. The land use map of the district is shown in figure 1.6. The major crops raised in the district are pepper, rubber, cardamom, tea, coffee, coconut etc. The area under different crops is given in table 5.

Table 4. Land use pattern

Item	Area (Ha)	Percentage to total district area
Forest	198413	45.47
Land put to non-agricultural use	14494.47	3.32
Barren and uncultivable land	1364	0.31
Land under miscellaneous tree crops	154.72	0.04
Cultivable waste land	1921.34	0.44
Fallow other than current fallow	1150.99	0.26
Current fallow	1788.18	0.41
Still water	10560	2.42
Social forestry	1190	0.27
Net area sown	205291.27	47.05
Area sown more than once	60584.98	13.89
Total Area Cropped	265876.25	60.93

Idukki is the powerhouse of Kerala generating major share of the state's electricity mainly from hydroelectric projects located in the district. The most important power station is at the Idukki double curvature arch dam constructed across Periyar river, which is one of the highest arch dams in Asia, with a height of 168.91 meters. Length of the dam at top is 365.85 meters and width at top is 7.32 meters.

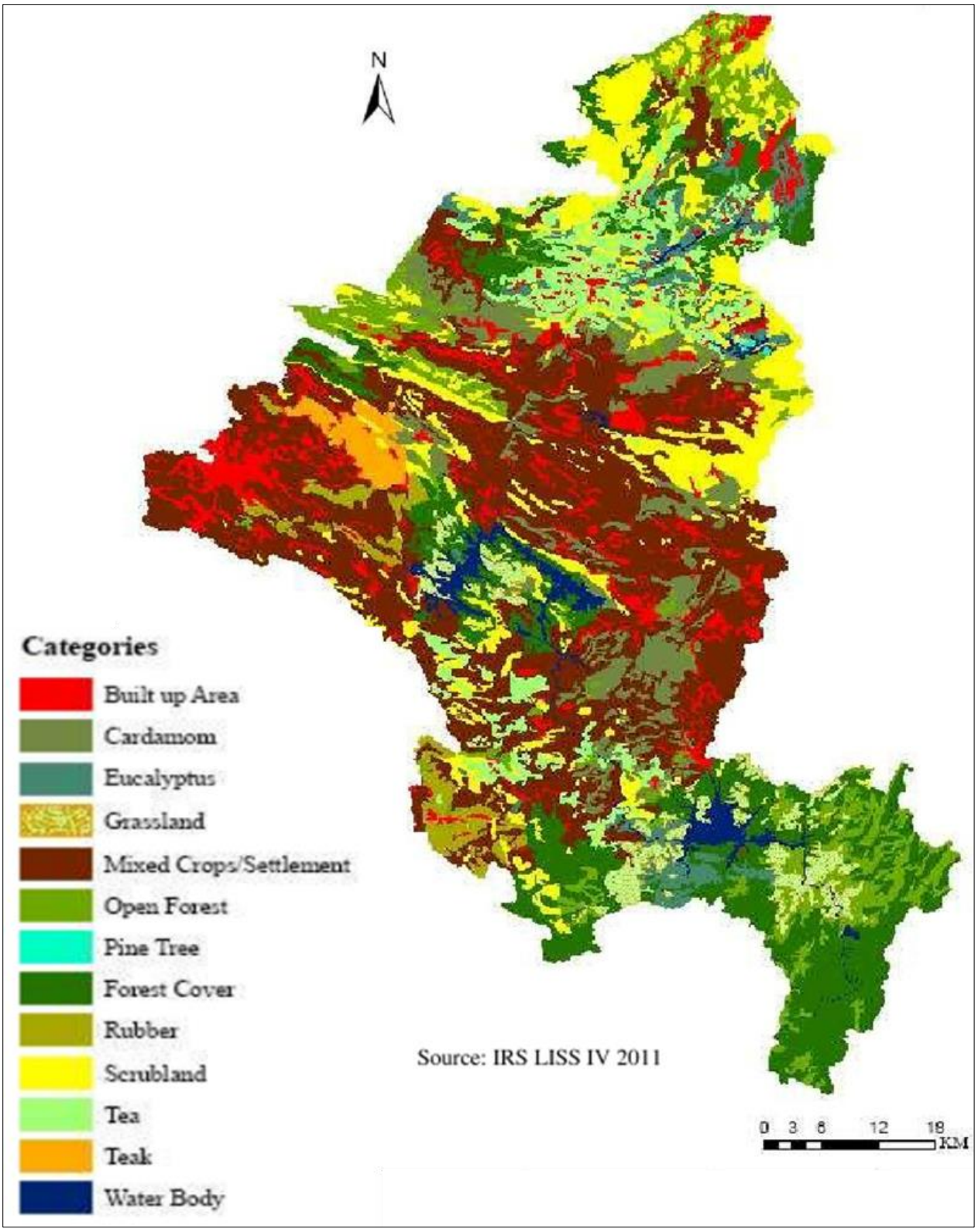


Figure 1.6. Land use/ Land cover – Idukki district

Table 5. Area under different crops
(Source: Agricultural Statistics 2018-19, Kerala)

Crop	Area (Ha)	Percentage of total cropped area
Paddy	688.30	0.26
Pepper	43103.78	16.21
Rubber	40600.00	15.27
Cardamom	30968.00	11.65
Tea	25588.03	9.62
Coconut	14513.61	5.46
Coffee	12717.00	4.78
Tapioca	5962.25	2.24
Other tubers	1321.92	0.50
Vegetables	5067.01	1.91
Nutmeg	3652.14	1.37
Arecanut	1784.00	0.67
Sugar cane	888.00	0.33

Even though Idukki is the second largest district in the state, the area under irrigation in the district is comparatively less. The main reason for this is the highly undulating nature of the terrain. The source wise area irrigated as per Agricultural Statistics 2018-19 is given in table 6.

Table 6. Sources of Irrigation
(Source: Agricultural Statistics 2018-19, Kerala)

Source	Area irrigated (Ha)	Percentage of net irrigated area
Small Stream (Thodu/Canal)	2153.93	4.58
Pond	20891.61	44.42
Well	8851.7	18.82
Bore well	6616.34	14.07
Lift & Minor Irrigation	1.3	0.003
From River and Lake	1033.38	2.20
Other sources	7478.5	15.90
Grand Total	**47026.76**	

There are four major soil types identified in the district- forest loam, laterite soil, brown hydromorphic soil and alluvial soil (CESS, 1984). A major portion of the district is covered by forest loam which is the product of weathering of the rock characterized by a surface layer rich

in organic matter. They are generally acidic, high in nitrogen content and poor in bases, due to heavy leaching and are dark reddish brown to black with a texture of loam to silty loam. In highland region where the denudation has occurred, leaching and deposition of humus is common. The lateritic soil is the next prominent category and is seen in the midland regions, particularly in Elamdesom and Thodupuzha blocks. It is well drained and low in plant nutrients and organic matter. The fertility of the soil is generally poor with low availability in nitrogen and phosphorous. The brown hydromorphic soils are confined to valleys formed as a result of transportation and sedimentation of materials from the adjoining hill slopes. Alluvial soil is seen as narrow strips and is common along the banks of Thodupuzha river and is fertile in nature. For the current study, soil classification based on texture is used and the details are given in **table 7**. Soil map of the district is given in figure 1.7.

Table 7. Area and percentage of textural varieties of soil in Idukki district

Sl. No.	**Texture Category**	**Area (Sq. Km)**	**Percentage**
1	Clay	3714.7	85.24
2	Gravelly Clay	280.6	6.44
3	Gravelly Loam	223.01	5.12
4	Loam	31.86	0.73
5	Waterbodies	107.84	2.47
Total		4358 Sq. Km	

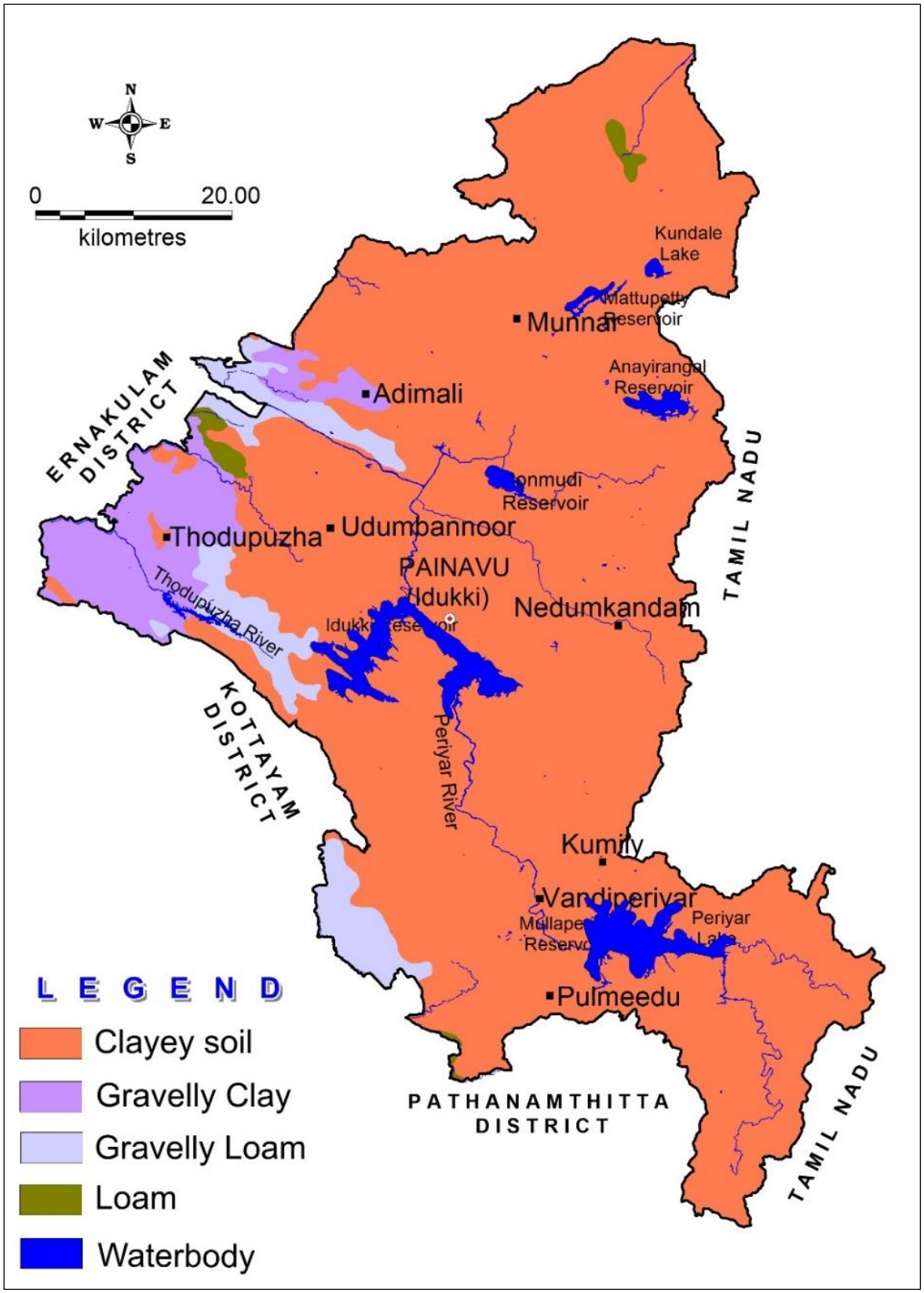


Figure 1.7 . Soil map

1.10 Hydrology and Drainage

There exist 5 river basins in the district, viz. Periyar (69.85% of Idukki district area), Muvattupuzha (14.12%), Pambar (8.82%), Manimala (2.45%), Pamba (4.64%) and Meenachil (0.12%). Major part of the district is drained by 2 west flowing (Periyar and Muvattupuzha) and 1 east flowing river (Pambar). Drainage map of the district is given in figure 1.8

a. Periyar river: This is the longest river in Kerala (total length 244 km, covering a basin area of 5284 km^2) and originates at the south-eastern border of the district at an elevation of 1830 mamsl at Sivagiri mala. The main tributaries are Muthirapuzha Ar, Perinjankutty, Idamalayar and Mangalapuzha. From the Periyar lake in the upper reaches, the river takes a roughly northwest course downward to Ayyappankovil and thereafter a northern course for about 20 km till Kumbalankudi. From there, the river takes almost a straight-line course in roughly N-W direction till it flows out of the district boundary. The Periyar river and its tributaries exhibits good structural control and are aligned along major lineaments. There exist 4 hydro-electric projects in Periyar viz., Sengulam, Neriamangalam, Panniar and Idukki.

b. Muvattupuzha River: The river, Muvattupuzha, is 121 km in length and has a basin area of 1554 km^2 . It originates from Tarangamkanam with an elevation of 1094 m from mean sea level. The major tributaries of this river are Kaliyar, Thodupuzha and Kothamangalam. The Malankara reservoir to store tail water from Idukki dam (to distribute through the canal network of Muvattupuzha Valley Irrigation Project, MVIP) is constructed in this River.

Two major tributaries of Muvattupuzha river in the district are Kaliyar and Thodupuzha Ar. The Thodupuzha river flows in a north-western direction through Thodupuzha town till it joins with Kaliyar near Muvattupuzha town. The Kaliyar river originates near Painavu (at 1036 m amsl) in Idukki district and flows in a NW direction for about 25 km with the name Velurpuzha and then takes the name Kaliyar river. Kannadi river joins the Kaliyar near Venmattam. One of the major tributaries of Kaliyar river is Karimannur river. Kaliyar river changes its trend near Naduvakad and flows in a westerly direction for about 20 km till the confluence with Thodupuzha river.

c. Pambar River: This is one of the 3 east flowing rivers in the state. The north-eastern part of the district is drained by the tributaries of Amaravati river viz. Pambar and Tenar. The Thenar originates from Chunduvarai at an elevation of 2523 m amsl and flows towards north for about 10km before taking an easterly direction. The Pambar River originates near Anamudi in Idukki district. The river is having steep gradients; several waterfalls are present with a fall of 245 m to 102 m within the area.

There are 18 perennial springs in the district. Utilization of the unique physiography is reflected in massive construction of structures for hydroelectric and irrigation purposes such as 15 man-made reservoirs (for hydroelectric projects as well as for diversion purpose and for irrigation purposes). The major dams include Idukki, Cheruthony, Kulamavu, Ponmudy, Anayirankal, Kundala, Mattupetty, Chenkulam, Kallarkutty, Bhoothathankettu, Lower Periyar, Thekkady, Malankara, Irattayar, Kallar and Gruhanadapuram. The Idukki Hydro Electric Project (IHEP) is the largest hydroelectric project in Kerala. Installed capacity of this project is 780 MW. The powerhouse has six generators of 130 MW capacity each. This is the first arch dam constructed in India. There are three Dams associated with this project. They are: Idukki Arch Dam, Cheruthoni Dam & Kulamavu Dam.

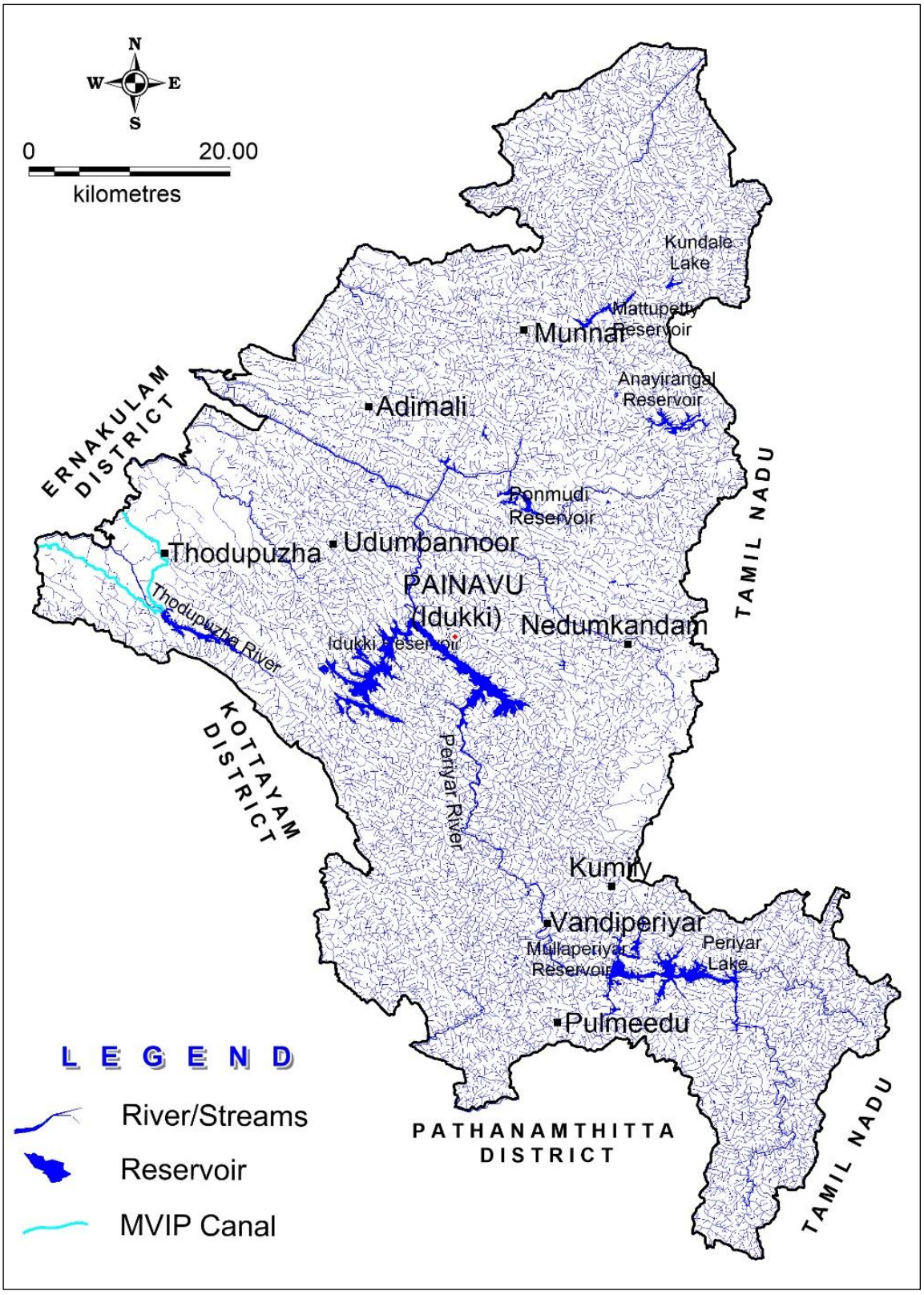


Figure 1.8. Drainage map

The Muvattupuzha Valley Irrigation Project (MVIP): Malankara dam is a gravity dam constructed across Muvattupuzha river for irrigation purposes. The dam is constructed to make use of the tail water from the Moolamattam powerhouse. The project is run under the

Muvattupuzha Valley Irrigation Project and Kerala State Electricity Board (KSEB). The artificial lake, Malankara reservoir, covers an area of around 11 square km. This project is designed to irrigate a total area of 18,616 hectares of land in Idukki, Ernakulam and Kottayam districts through its right and left bank canals. The dam and reservoir are located on Thodupuzha- Moolamattam road. The project consists of a combination of Masonry dam having length of 254m and an earthen dam of length 206m.

The Kerala state government maintains 10 Gauge and Discharge (G&D) stations in Idukki district viz. Perinjankutty Dam, Chemmannur, Panniyoor, Mudirapuzha, Kunjithani, Rajakkadu, Thuvallur, Irythukanam (Periyar River Basin); Malankara and Thodupuzha (Muvattupuzha River basin). Besides this, the Central Water Commission maintains 1 gauge, discharge, quality and rainfall station at Vandipperiyar in Periyar basin

1.11 Prevailing Water Conservation and Recharge Practices

The State Ground Water department, Department of agriculture development and farmers welfare, Department of soil survey and soil conservation, Department of irrigation and Forests etc., are carrying out extensive water conservation and artificial recharge activities in the district. Watershed wise soil conservation activities are carried out in the district by soil conservation department in watersheds like Chinnar, Meenmutty, Kozhimalakandom, Mavadithodu, Pottenkad, Palanippadi, Nellippara, Puthedu, Poovanchi, Ratnapara, Kokkattumedu etc. Almost all government buildings are fitted with rooftop rainwater harvesting and dug well recharge schemes by the State ground water department. Social forestry schemes are practiced by forest department for the effective conservation of the water resources in the district. Department of irrigation has constructed many check dams, Nala bunds etc. in the district to ensure water conservation. Also, protection of springs which is a major source of water for domestic use are undertaken by the Irrigation department.

2 DATA COLLECTION AND GENERATION

The primary data such as water levels, quality, and lithological inputs available with CGWB as well as GWD, Govt. of Kerala has been collected and utilised as baseline data. However, ancillary data such as numbers of ground water abstraction structures, irrigation facilities, rainfall, etc. have been collected from the various State/Central govt. departments and compiled.

2.1 Data Collection and Compilation and Generation

The data collection and compilation for various components were carried out as given below.

- **i.** Hydrogeological Data – Current and historical water levels along with water level trend data from 75 (68 Dug wells (DW) and 7 piezometers (PZ)) monitoring wells in Idukki district representing Aquifer-I (Weathered crystallines). The water levels of 23 (out of 24) exploratory wells(EW) in Idukki district representing Aquifer-II (Deeper Fractured crystallines) were also collected and compiled.
- **ii.** Hydrochemical Data - Ground water quality data from 20 (existing Ground Water Monitoring Stations of CGWB) wells in Idukki district representing Aquifer-I and data of 22 exploratory wells in Idukki district representing Aquifer-II were also collected and compiled.
- **iii.** Exploratory Drilling – Ground water exploration data of 24 existing exploratory wells in Idukki district were complied.
- **iv.** Geophysical Data –No available Vertical Electric Sounding (VES) data.
- **v.** Hydrology Data – Data on various irrigation projects, their utilisation status, number of ground water abstraction structures, and area irrigated from irrigation department were compiled.

vi. Hydrometeorological Data – Long-term rainfall data of all rain gauge stations (Both of IMD and State Government) in the district were collected and compiled.

vii. Water Conservation Structures – Numbers, type and storage potential of water conservation structures prevailing in the area were complied.

viii. Cropping Pattern Data – Data on prevailing cropping pattern from Agriculture Dept. were complied.

2.2 Data Generation

After taking into consideration, the data available with CGWB on Ground Water Exploration, Geophysical survey, Ground Water Monitoring Wells (GWMW) and Ground Water Quality, the data adequacy were compiled. The requirement and data availability are analysed and based on gap analysis additional data were generated and the details are given in table 1 and discussed below:

2.2.1 Ground Water Exploration

Historic data of exploratory wells drilled by CGWB indicated the presence of 24 wells in Idukki district. However, based on data gap analysis 2 more wells were drilled. The details of existing and newly constructed exploratory and observation wells are given in Annexure I

2.2.2 Ground Water Monitoring Wells

Data gap analysis revealed the existence of 75 GWMWs (68 Dw+7 PZ) in Idukki district. Additional 40 KOWs wells were fixed for regime monitoring and micro-level data acquisition pertaining to Aquifer-1. Previously there existed deeper water level data for 23 EWs (Aquifer-II). Based on the data gap 1 more additional data was generated for the same. The details of GWMWs and KOWs are given in Annexure-II

2.2.3 Ground Water Quality

As stated in table 1 already there existed 20 water quality data for Aquifer-1. Additionally, 39 samples were collected from KOWs for major element analysis. Also, 40 acidified samples were collected for trace metal analysis. For Aquifer-II the existing quality data from the exploratory wells drilled by CGWB was 22. Additionally, 1 quality data was generated by exploratory drilling. The details of quality monitoring stations are given in Annexure-III

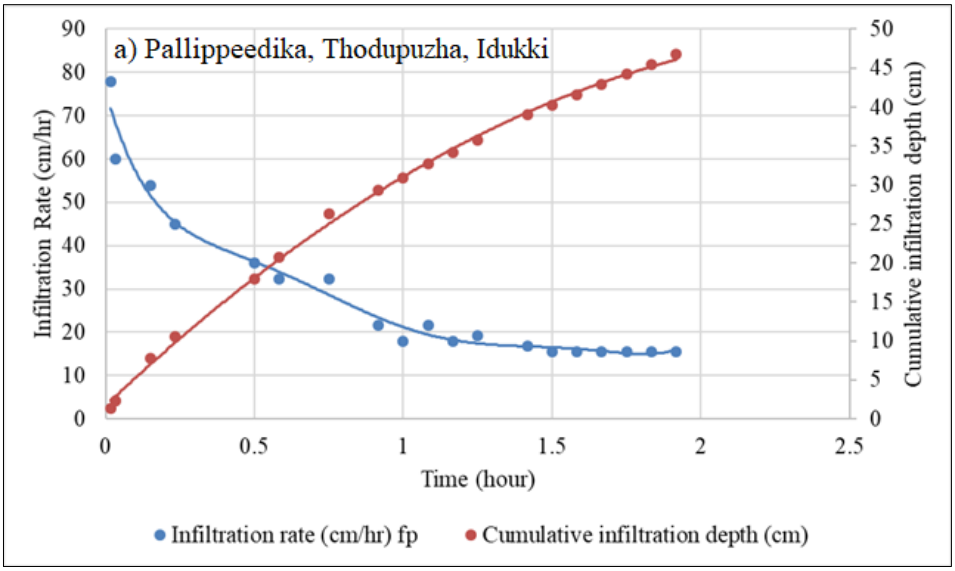
2.2.4 Soil Infiltration test

To estimate the actual rate of infiltration of various soil cover and their impact on recharge to ground water, 3 infiltration tests were conducted in Idukki district. The data has been analysed and the salient features of the infiltration tests are presented in table 8, whereas the data is presented in Annexure-IV and the plots of soil infiltration tests are presented in figure 2.1.

Table 8. Details of Soil infiltration tests

Location	Date	Soil Type	Duration (min.)	Cumulative depth of infiltration (cm)	Final Infiltration rate (cm/hr.)	Horton's Equation established
Private Agricultural Farm, Pallippeedika,	19.2.20	Gravelly clay	115	46.8	15.6	$F(t)=15.6+(61.23)*(e^{-2.4187*t})$

Thodupuzha, Idukki						
Section Forest Office, Chullikkandam, Idukki	19.2.20	Loam	120	32.6	9	$F(t)=9+(41.19)*(e^{-2.0995*t})$
Cardamom Research Station, Pampadumpara, Idukki	20.2.20	Clay	100	27.9	12	$F(t)=12+(38.21)*(e^{-2.4908*t})$



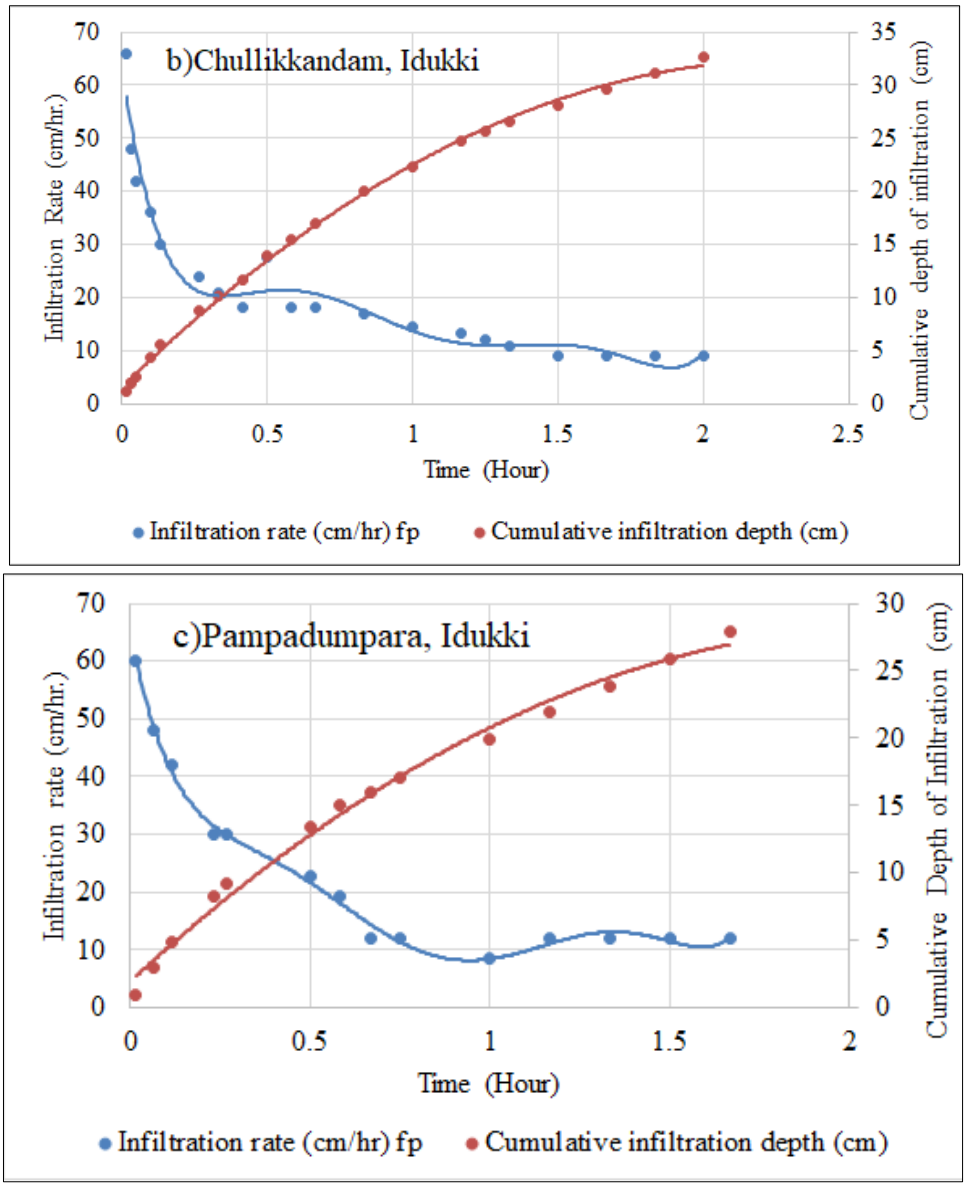


Figure 2.1. Time versus soil infiltration rate and Cumulative depth of Infiltration

2.2.5 Thematic Layers

The following five thematic layers were also generated on the GIS platform, which supported the primary database and provided precise information to assess the present ground water scenario and also to propose the future management plan.

1. Drainage
2. Physiography/Dem
3. Geomorphology
4. Soil
5. Land Use – Land Cover
6. Geology and Structure

A map showing the integrated location of existing groundwater structures and the exploratory wells constructed for the current study is given in figure 2.2 (a), (b) and (c).

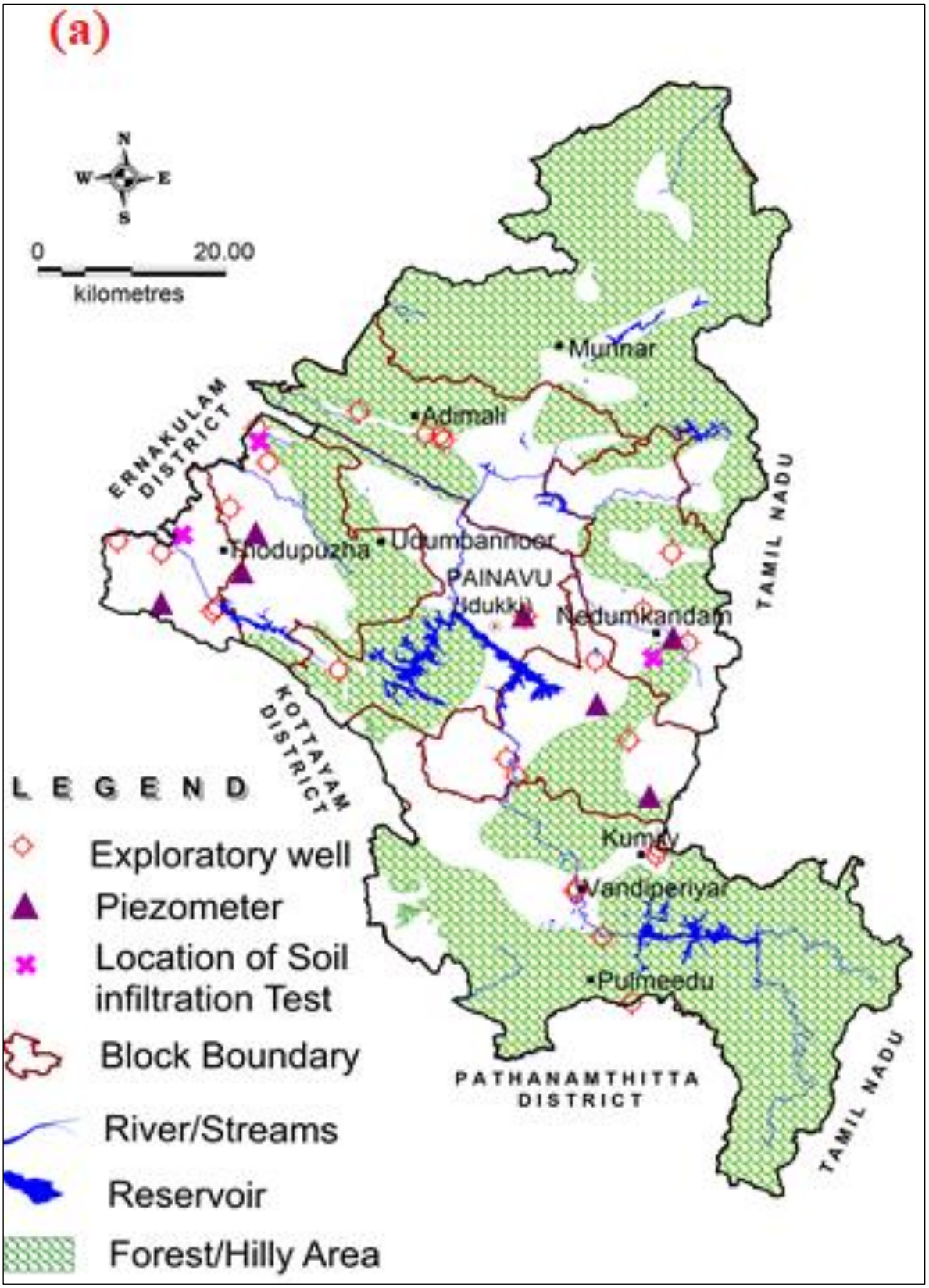


Figure 2.2.(a) Location of EWs, PZs and soil infiltration test sites in the study area

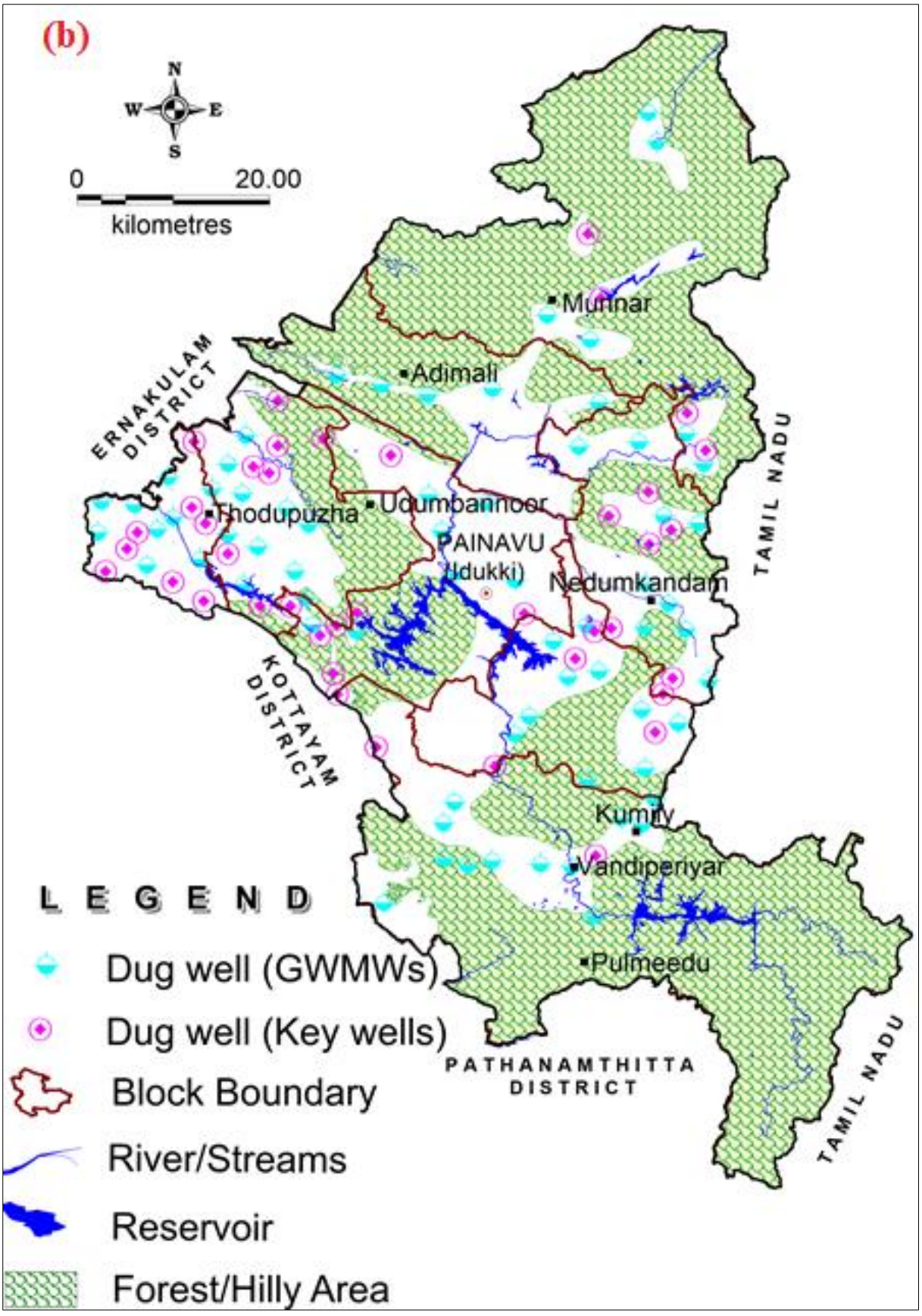


Figure 2.2.(b) Location of water level monitoring stations (DWs) in the study area

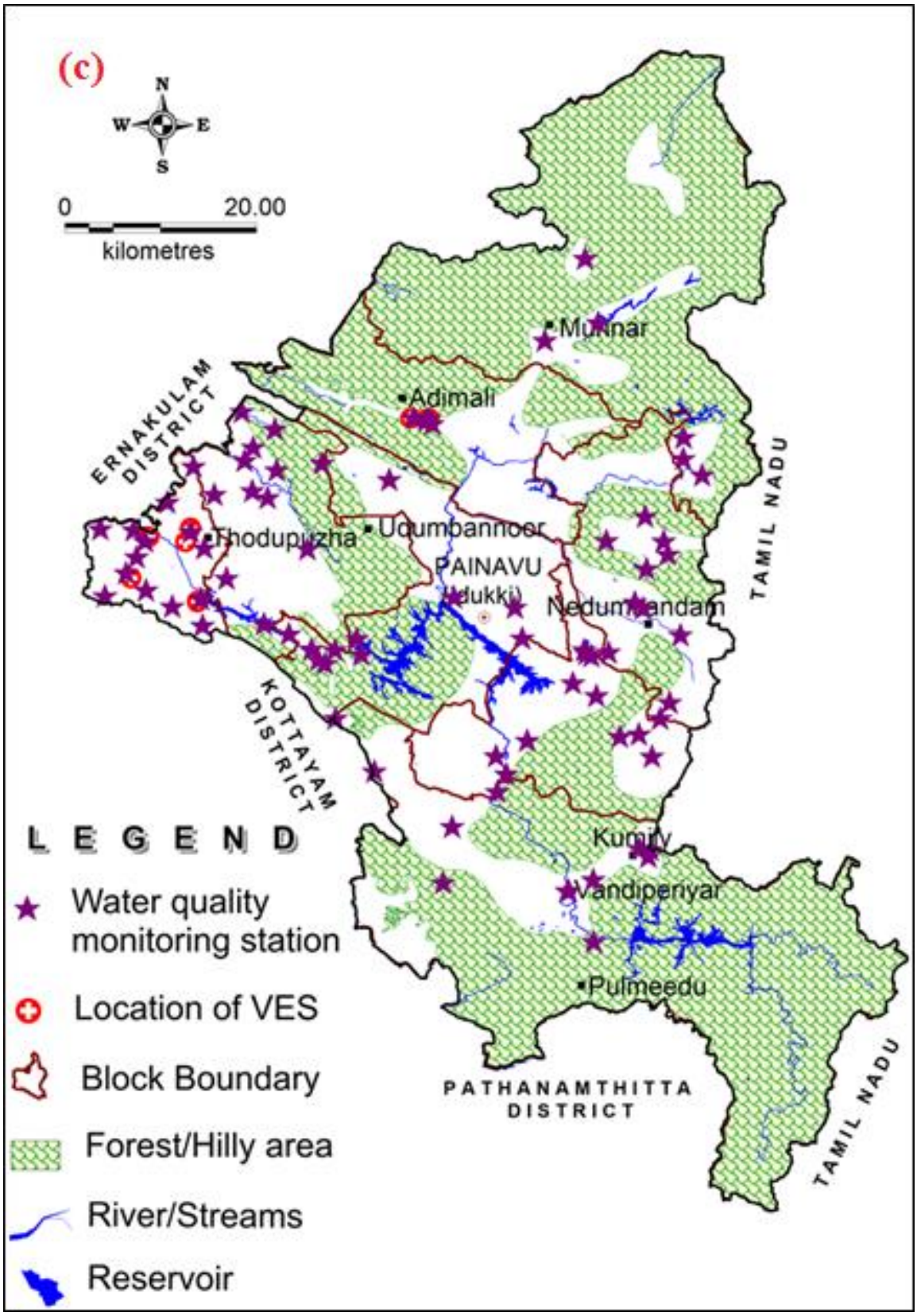


Figure 2.2.(c) Location of water quality sampling stations and VES in the study area

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Various data pertaining to hydrogeology, geophysics and exploratory drilling were collected and validated. Using this data maps of ground water level scenario, quality aspects, 2-D and 3-D sub-surface aquifers disposition, yield potential etc. were prepared. Finally, aquifer maps were generated and their characteristics are discussed in detail below.

3.1 Geology

Idukki district comprises mostly of rocks belonging to Archean metamorphic complex as established by the Geological Survey of India. The main rock types encountered in the district are charnockites, hornblende-biotite gneiss and granite gneiss. The geological succession is given below in table 9 and the geological map of the district is given in figure 3.1

Charnockites are encountered in southern half of the district and along the south-eastern border especially in Nedumkandam, Kattappana and Azhutha blocks. It is also encountered in the western part of Thodupuzha block; south-eastern part of Idukki and Adimaly blocks. Charnockites are well foliated along NNE – SSW to NS direction with a gentle dip towards the west.

Table 9: Geologic succession -Idukki district

Period	Geology	Rock Type
Cenozoic	Basic Intrusives	Dykes (Dolerite, Gabbro)
Proterozoic	Acid Intrusives	Quartz vein, Pegmatite, Granite
Archean	Migmatite Complex	Biotite gneiss and Hornblende biotite gneiss
	Charnockite Group	Magnetite quartzite, Charnockite, Pyroxene granulite
	Khondalite Group	Quartzite, Calc-granulite
	Peninsular Gneissic Complex	Granite gneiss

The second major rock type encountered in the district is the hornblende-biotite gneiss, which is a mesocratic and medium grained rock. It occurs in the west central parts of the district in Idukki, Thodupuzha and Elamdesam blocks. Minor occurrence of hornblende-biotite gneiss is encountered in Devikulam block also especially in Devikulam and Kanthalloor Panchayats. It is especially a Quartzo-feldspathic gneiss with hornblende and biotite as accessories. These rocks follow the regional trend of foliation.

In the northern part of the district the granite gneiss is the major rock type and is encountered in Adimaly block and parts of Devikulam block. These rocks are well jointed. They are coarse grained and leucocratic. Basic intrusives like dolerites are seen along the western border of the district. They conform to the general trend of foliation i.e., NNW-SSE direction. Occasionally pegmatite and quartz veins are also encountered at places. The prominent lineament directions in the district are WNW-ESE, NW-SE, NNW-SSE, NNE-SSW and ENE-WSW.

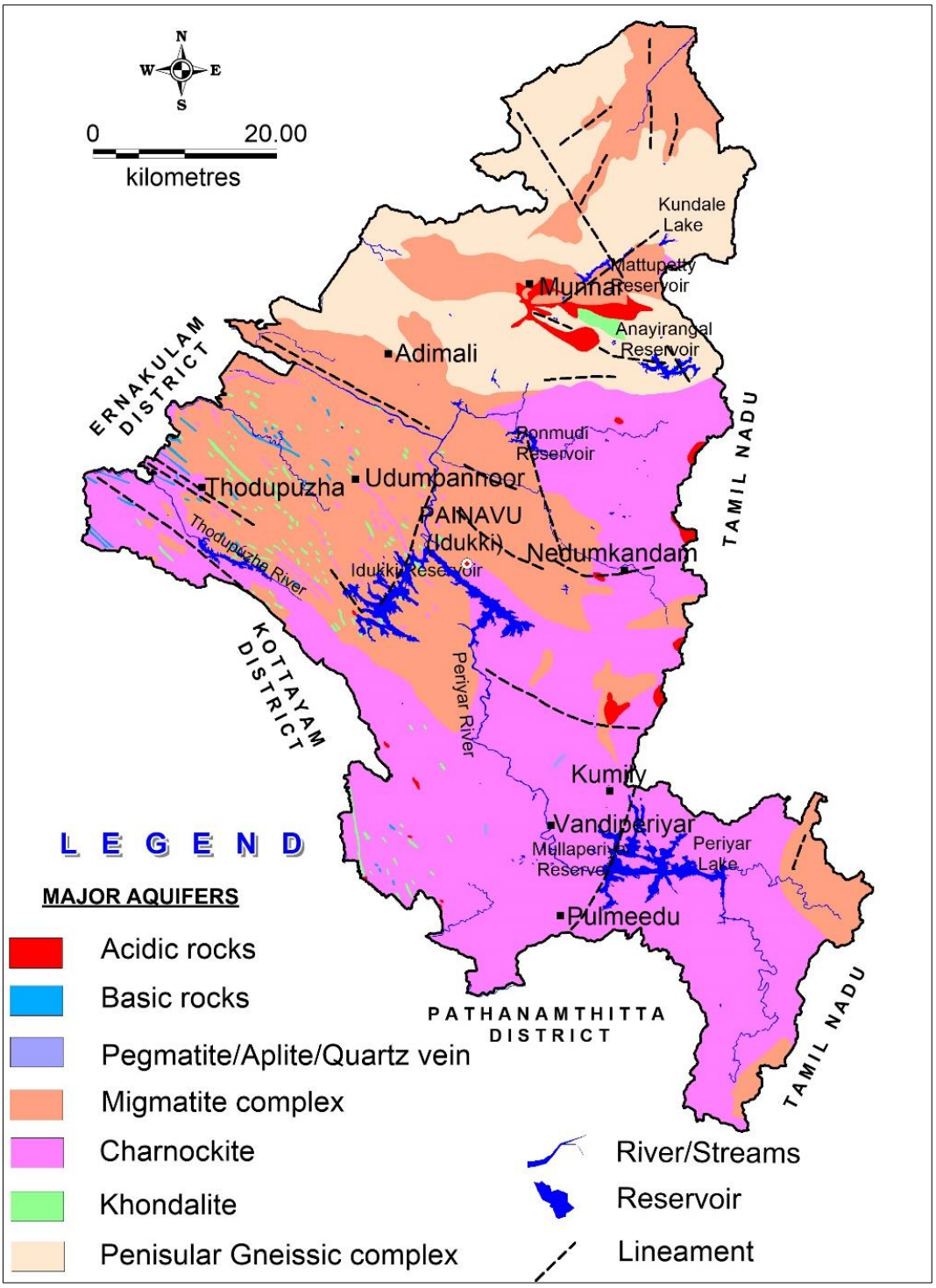


Figure 3.1. Geology-Idukki district.

3.2 Hydrogeology

Ground water occurs in *phreatic conditions* in the weathered Crystallines and laterites (Aquifer-I) throughout the district. Laterites occur mainly in Thodupuzha and western parts of Elamdesam, Adimaly, Nedumkandam and Kattappana blocks along gentle slopes and valleys. The thickness of weathering and laterization ranges from 2.5 to 27 m bgl. The weathered thickness is maximum (goes above 25 m) at the south-east of Kattappana along Vandanmedu-Anakkara belt (in Kattappana Block). Along steep slopes and high ranges in the district, pedogenesis is limited; soil occurs as very thin veneer and mostly devoid of any perennial

phreatic aquifer (Mostly in parts of Devikulam, Kattappana and Elamdesam blocks). The depth to weathering map of the district is given in figure 3.2

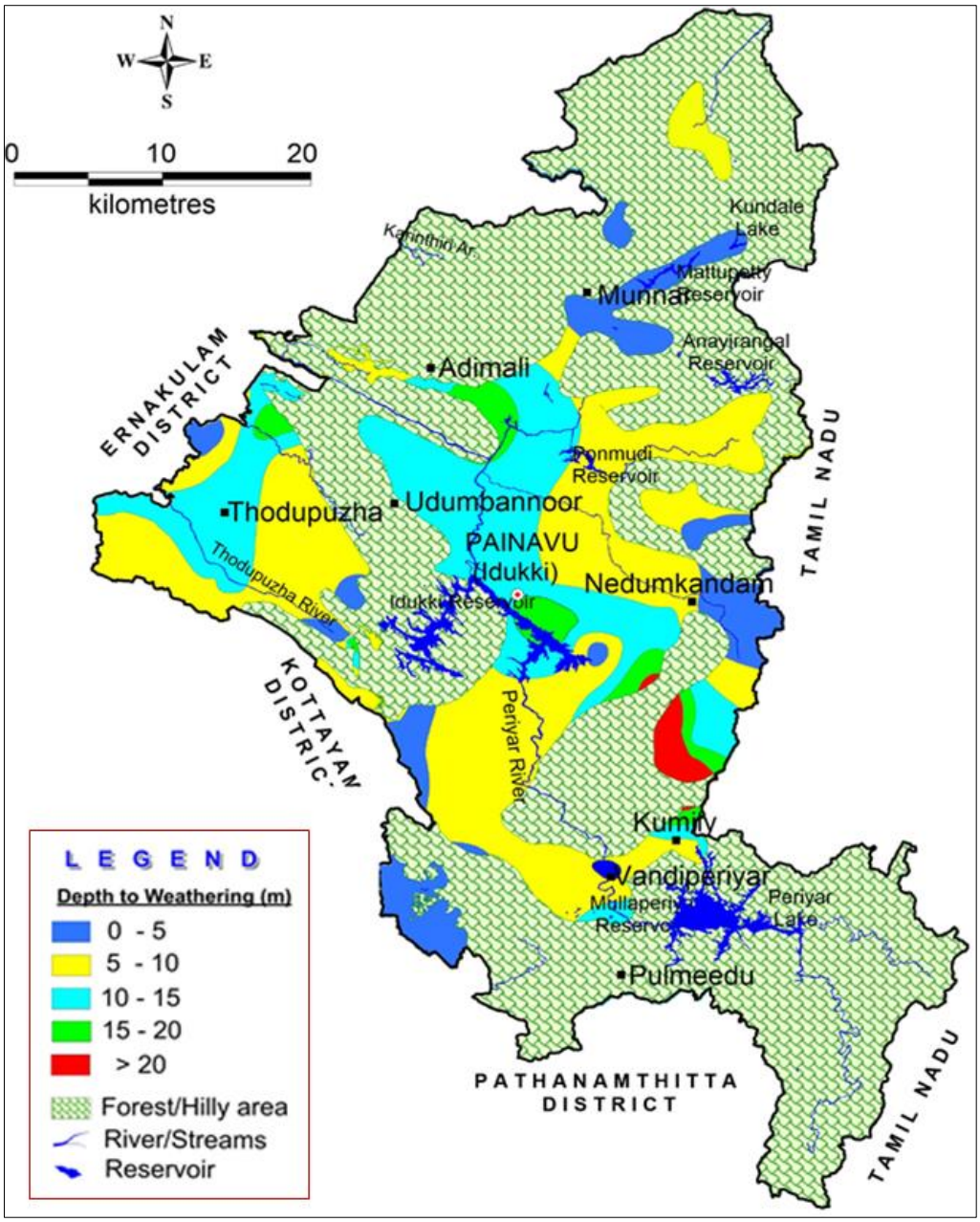


Figure 3.2 Depth to weathering map-Idukki district.

In the deeper aquifers, the occurrence and movement of ground water is controlled by the incidence and inter-connection of fractures or joints. The ground water in deeper aquifer occurs under *semi-confined to confined* conditions. Based on the available data with state government agencies, it is observed that the depth of bore wells in the district ranges from 45-100 m depth with average between 60-70 m bgl. The yield of bore wells generally ranges from 0.3 to 3 lps. Occasionally, bore wells yielding as high as 10 lps are encountered at Peerumedu (Azhutha block), Moolamattom (Idukki block), Karimannoor and Velliyamattom (Elamdesam block), Kuzhiyanal and Vazhithala (Thodupuzha block), Adimali (Adimali block) and at Thookkupalam (Nedumkandam block).

The phreatic aquifers in the district are controlled mostly by local geomorphology rather than geologic structures. Hence, dug wells tapping the weathered crystallines/ laterites located in valley portion and flats are perennial, whereas those along hill slopes dry up during summer, especially where the thickness of overburden is limited, as in the case of charnockite terrain.

3.2.1 Occurrence of Ground Water in Aquifer-I

Ground water occurs under atmospheric pressure conditions in aquifer-I. The shallow phreatic aquifers of weathered Crystallines and laterites are generally developed through dug wells. The depth of dug wells ranges from 4 to 15 mbgl. Generally, dug wells tapping aquifers in charnockites are found to be shallower than that of in gneisses. The yield of dug wells ranges between 500-6000 lpd (along hill slopes and high ranges) to 15000-20000 lpd (along valley portions). In acute summer months wells located along hill slopes dries up.

3.2.2 Occurrence of Ground Water Deeper Aquifer-II

The deeper fractured aquifers are under confined to semi-confined conditions. As evident from the drilling activities carried out by Ground Water Department, Kerala potential fractures are encountered up to 87 mbgl, however generally confined within 60 mbgl. Again, exploratory drilling carried out by CGWB indicated the presence of occasional prospective fractures down to the depth of 120 mbgl. Random chances of getting deeper fractures up to 170 m bgl are noticed in charnockite terrains in the district. Generally, drilling borewells beyond the depth of 120 m bgl is a pointless exercise.

3.3 Geophysical Survey (VES)

In Idukki district, geophysical surveys using Vertical Electrical Soundings (VES) were carried out to know the subsurface conditions to recommend sites for ground water exploration and to supplement additional information for aquifer mapping. In Idukki district, 16 Nos of VES were carried out by employing the Schlumberger & Half Schlumberger electrode configuration. The obtained VES data were interpreted using computer interpretational techniques. The interpreted results have been compiled and is given in Annexure V. The location map of VES survey carried out in Idukki district is shown in **Figure 3.3.** The interpreted results have given rise to 3 to 6 layered geoelectric sections, mostly in all sites; the last geoelectric layer is showing an increasing trend due to massive formation. The main types of the curves observed are QH, KHK, HKH & KHKH. Based on the results of geophysical surveys (VES), borewells have been recommended at sites - Muttom, Thodupuzha, Mannamkandam (Govt.HSS) & Adimaly GHS, etc. Drilling activities have been conducted in some of these sites and have given good yield. Eg: Thodupuzha (8.4 lps), Mannamkandam (4.0 lps) & Adimaly GHS (>3 lps) etc.

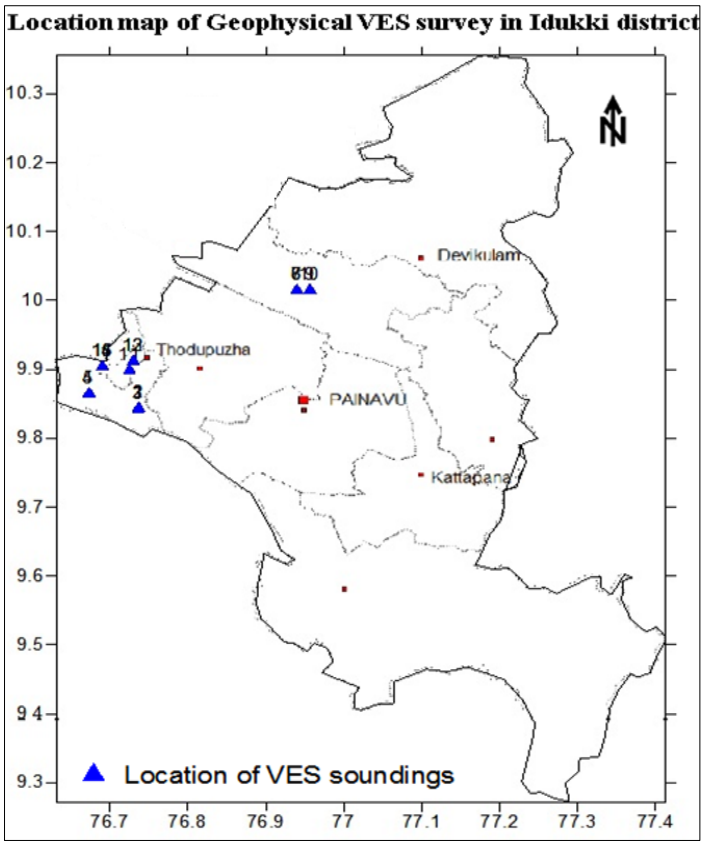


Figure 3.3. Location map of VES survey in Idukki district

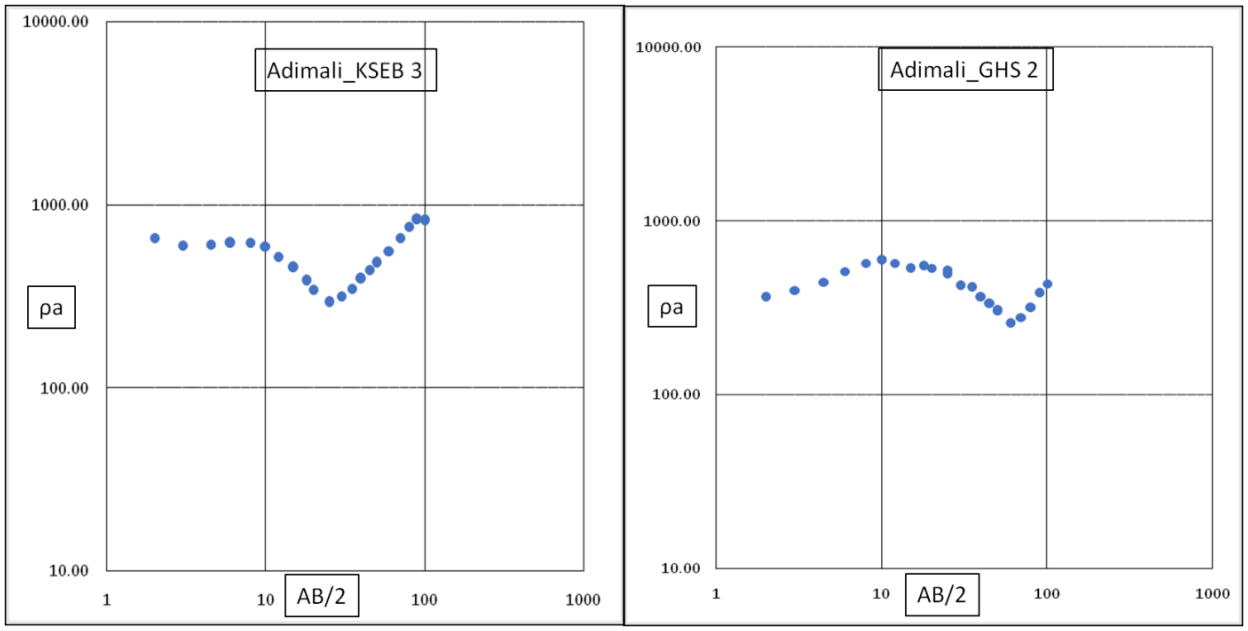


Figure 3.4. Representation of different field curves in Idukki district

The interpreted results have given rise to 3 to 6 layered geoelectric sections. The first layer resistivity value was varying in the range of 203-4745 ohm.m with thickness in the range of 0.3-2.6 m, which is topsoil. The second layer resistivity value was varying in the range of 280-7783 ohm.m, which was considered as hard laterite formation. The thickness of this layer was varying in the range of 1-9 m. The third layer resistivity was varying in the range of 99-5035 ohm.m

which is fractured to hard formation. The thickness of this layer was varying in the range of 2.5-17 m. The fourth layer resistivity was varying in the range of 118-VH ohm.m. The thickness of this layer was varying in the range of 5.4 -13.6 m and at some sites this layer was extending in nature. The fifth layer was encountered at about five sites with resistivity range of 28-5006 ohm.m. The representation of different field curves in Idukki district has been presented (Figure 3.4).

Transient Electromagnetic (TEM) Survey

The Transient Electromagnetic Method (TEM) works on principle of Faraday's law of induction i.e., changing magnetic field will produce an electric field, which in turn will create an electric current. Thus, the rapidly changing magnetic field induces eddy-currents to flow in nearby conductors producing small secondary magnetic fields. The secondary magnetic fields attenuate with time, hence the use of the terms "transient" and "time-domain" to describe the method.

In Idukki district, TEM survey was deployed first time by CGWB, KR during AAP 2019-20 to delineate subsurface hydrogeological features. Total 150 TEM soundings were carried out in hard rock terrains of the district by employing Coincident loop configuration of 40*40m (27 Nos) and 20*20m (123 Nos) loops respectively depending on the availability of the space. The obtained TEM data has been downloaded from instrument and stored in the computer. The downloaded data has been processed and profile pseudo sections have been prepared by using TEM fast software & interpreted by using IX1D software.

In Idukki district, a total of 150 TEM soundings were conducted in 25 sites/villages situated in 5 blocks (Thodupuzha, Elamdesam, Idukki, Adimali, & Nedumkandam). The site wise location details of TEM soundings carried out in Idukki district during AAP 2019-20 are compiled (Table 10) and the location map of TEM survey in Idukki district during AAP 2019-20 is as shown in Fig.3.5.

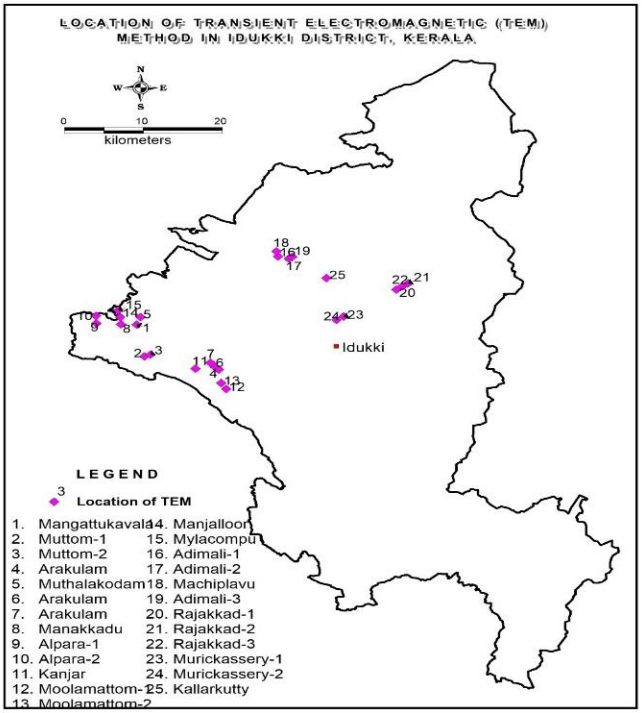


Fig. 3.5 Location Map of TEM Survey

Sl No	Block	Location	Longitude	Latitude
1	Thodupuzha	Mangattukavala	76.7250	9.89897
2		Muttom-1	76.7362	9.84364
3		Muttom-2	76.7396	9.84604
4	Elamdesam	Arakulam-1	76.4926	9.48862
5	Thodupuzha	Muthalakodam	76.7303	9.91180
6	Elamdesam	Arakulam-2	76.4987	9.48428
7		Arakulam-3	76.4935	9.48939
8	Thodupuzha	Manakkadu	76.4144	9.54204
9		Alpara-1	76.6663	9.90794
10		Alpara-2	76.3995	9.54514
11	Elamdesam	Kanjar	76.8087	9.82297
12	Idukki	Moolamattom-1	76.8526	9.78782
13		Moolamattom-2	76.8455	9.79778
14	Thodupuzha	Manjalloor	76.6967	9.91145
15		Mylacompu	76.6988	9.92401
16	Adimali	Adimali-1	76.9266	10.01676
17		Adimali-2	76.9417	10.01277
18		Machiplavu	76.9259	10.01906
19		Adimali-3	76.9467	10.01617
20	Nedumkandam	Rajakkad-1	77.0969	9.96358
21		Rajakkad-2	77.1122	9.97008
22		Rajakkad-3	77.1035	9.96500
23	Idukki	Murickassery-1	77.0161	9.91161
24		Murickassery-2	77.0101	9.90716
25	Adimali	Kallarkutty	76.9958	9.97913

Table 10: Location details of TEM survey in Idukki district, Kerala

Totally 150 TEM soundings were carried out in 25 sites/villages falling in 5 blocks. Geologically the Study area is underlain by Charnockite Group of rocks and Migmatitic Complex. 27 TEM soundings could not be interpreted due to high noise level in TEM data.

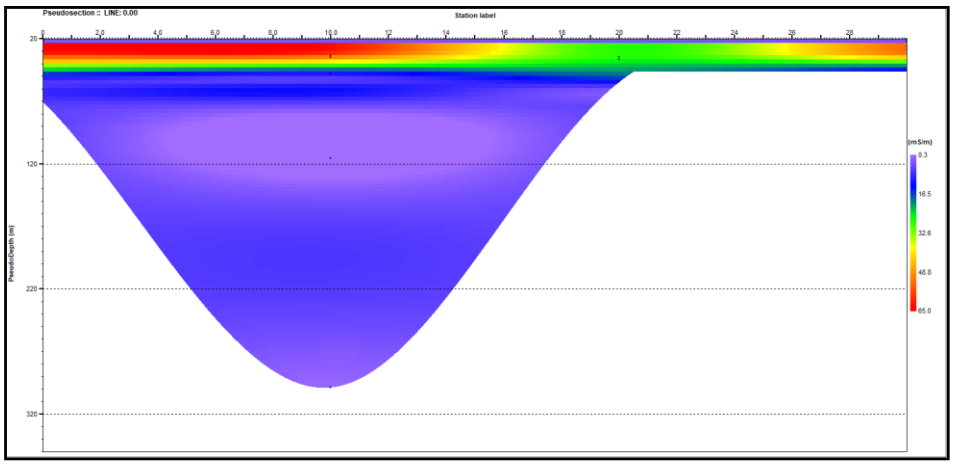


Fig. 3.6: TEM Profiling Pseudo section at Murickassery-2

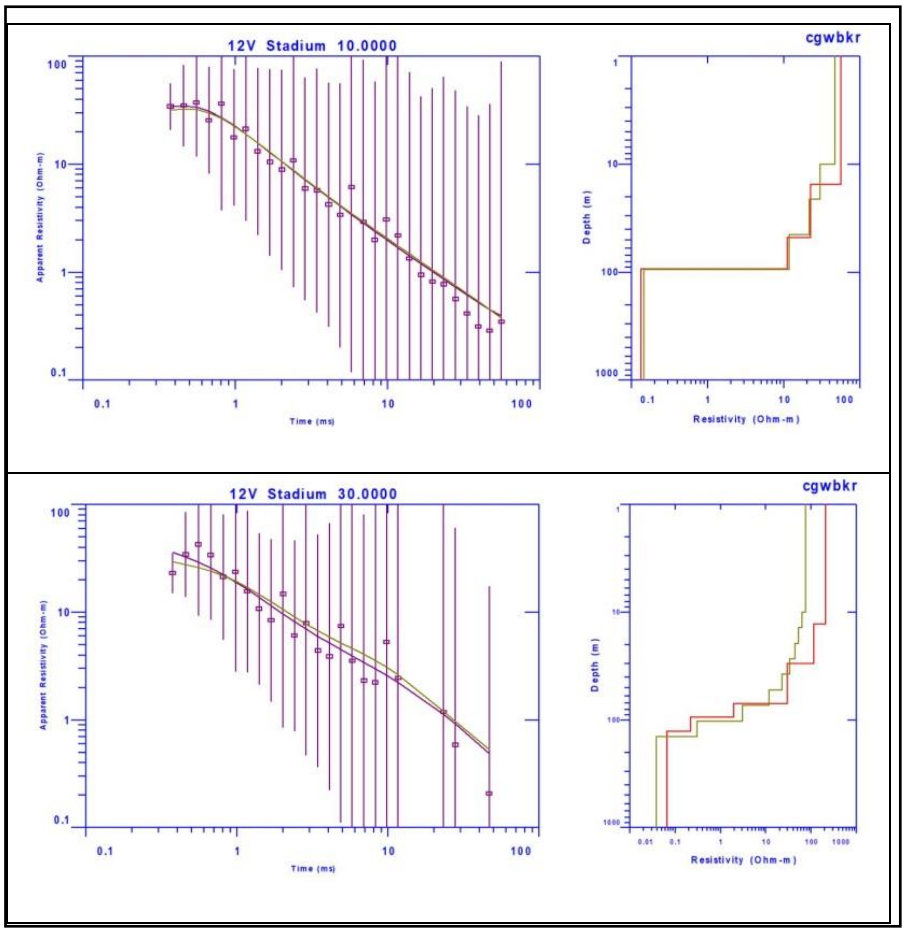


Fig. 3.7: Example of interpreted TEM curves at Murickassery-2

TEM No	Interpreted Results										
	Resistivity (Ohm.m.)						Thickness (m.)				Total Depth (m.)
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5		h_1	h_2	h_3	h_4	
1	23747	2669.3	197.33	18.88	0.24		10.95	9.86	22.95	32.89	76.64
2	55.66	22.39	11.21	0.13			15.34	32.29	46.19		93.81
3	10854	425.4	12.80	0.78	0.01		10.93	10.49	28.09	48.27	97.77
4	206.38	19.95	0.46				6.77	88.21			94.98

ρ_1 - First layer resistivity in Ohm.m h_1 - First layer thickness in m

Table 11: The interpreted results of TEM at Murickassery-2

In Idukki district, interpretation of TEM soundings indicated 3 to 8 layered behaviour. And in most of the sites the main type of the curve showing that decreasing trend (i.e., 'Q' type curve) it means that low resistivity values occurred in deeper depths. The TEM Profiling of pseudo section at Murickassery and the interpreted TEM curve is depicted in fig 3.6 and 3.7 respectively and is described in table 11. The General behaviour of these layers have been arrived at based on results of 120 TEM soundings and attributed to the following subsurface hydrogeological dispositions as given in Table 12

Table 12:Hydrogeological disposition of subsurface layer by use of TEM.

Sl No	Formation	Thickness range (mbgl)	Total depth range (H) (mbgl)
1	Top soil	0.5 – 5	1-30
2	Weathered/Semi weathered	Up to 30	
3	Massive / Noise Erratic data		30 – 60

Total depth of information obtained from TEM results in Idukki district is approximately 150 mbgl (With Coincident loop configuration of 40*40m). Beyond this depth TEM data indicated noisy signals. However, no fractures were indicated in TEM results. On correlating with VES data wherever available nearer to TEM sounding point, it is found that, good correlation is seen in terms of resistivity values of weathered zones (At only one site). However, there is not much correlation in depth of various layers between TEM and VES.The General behaviour of the layers have been arrived at based on results of 120 TEM soundings. From these results, it is observed that the topsoil thickness range is 0.5 to 5 mbgl, the thickness of weathered layer is up to 30 mbgl and the depth range of Massive/ Noise data occurred at range of 30 to 60 mbgl.

3.4 Ground Water Dynamics

To decipher the ground water dynamics of shallow Aquifer-I, other than the existing GWMWs of CGWB, 40 additional key observation wells were established. Also, to understand the ground water dynamics of the deeper Aquifer-II, water level data from the existing 24 EWs drilled by CGWB were used. The water level data from the monitoring wells during pre and post monsoon seasons (2019) were collected and analysed. The ground water level scenarios for Aquifer-I and Deeper Aquifer-II are described in the following section.

3.4.1 Depth to water level (Shallow Aquifer-I)

To understand the depth to water level scenario in Idukki district, water level measurement from all the observation wells were carried out in the month of April (pre-monsoon) and November (post-monsoon). The pre and post monsoon data collected from these KOWs along with the data collected by CGWB from there network monitoring stations have been used to ascertain the water level scenario and preparation of depth to water level maps of the area.

3.4.1.a Pre-monsoon Depth to Water Level (April 2019)

The depth to water levels in Idukki during April 2019 ranges between 0.6 (Thalayar, Devikulam Block) and 12.27 (Machiplavu, Adimaly Block) m bgl (n=89). Shallow water levels in the range of 0-2 mbgl are noticed along valleys and river channels in Thalayar, Munnar, and Pooppara (Devikulam Block); Chathurangappara (Nedumkandam Block), Elappara (Azhutha Block), Nirmalam city, and Thankamani (Idukki Block). Deeper water levels above 10 mbgl are recorded at Blathy Kavala (Elamdesam Block), Machiplavu (Adimaly Block), Murikkasserry (Idukki Block) and Kattappana (Kattappana Block). Water levels above 15 m were noticed at few isolated places at Idukki-8th mile (Idukki Block) and around Anakkara (Kattappana Block). However, generally water level range ranges between 5-7 m bgl in the district during pre-monsoon season. Details of the analysis are given in table 13 and figure 3.8

3.4.1.b Post-monsoon Depth to Water Level (November 2019)

The depth to water levels in Idukki during November 2019 ranges between 0.1 (Thalayar, Devikulam Block) and 9.88 (Murikkasserry, Idukki Block) m bgl (n=89). Shallow water levels in the range of 0-2 mbgl are noticed around places like Thalayar, Koilkadavu, Munnar and Pooppara (Devikulam Block); Chappath (Kattappana Block), Carady Goody Estate, Elappara, Kumily, Pambanar and Peruvanthanam (Azhutha Block), Chathurangappara (Nedumkandam Block); Chinikuzhy and Manjapra (Elamdesom Block), Churuli, Nirmalam city and Thankamani (Idukki Block);Vazhithala and Njarkutty (Thodupuzha Block). Moderately deep-water levels above 5 m bgl and up to 10 m were noticed around Blathy Kavala and Elamdesom (Elamdesom Block); Chemmannar, Rajakkad and Udumpanchola (Nedumkandam Block); Nadukani, Kulamavu, Moolamattam and Murikkasserry (Idukki Block); Anakkara, Marykulam and Kattappana (Kattappana Block) Byson Valley, Machiplavu, Valara (Adimaly Block); Thodupuzha (Thodupuzha Block) and Vandipperiyar (Azhutha Block). During pot-monsoon season, deeper water levels above 10 mbgl were not recorded in any of the monitoring wells during the current study. About 81% of the wells studied, showed water levels in the range of 0-5 mbgl during post monsoon season. Generally during post-monsoon season the water level ranges between 3-5 mbgl in the district. Details are given in table 14 and figure 3.9.

Table 13. Percentage of wells and depth to water level range (Aquifer-I, Pre-Monsoon, 2019)

Depth to water level range (mbgl)	No. of wells	Percentage of wells
0 to 2	7	8
2 to 5	42	47
5 to 10	36	40
above 10	4	4
Total	**89**	**100**

Table 14. Percentage of wells and depth to water level range (Aquifer-I, Post-Monsoon, 2019)

Depth to water level range (mbgl)	No. of wells	Percentage of wells
0 to 2	19	21
2 to 5	53	60
5 to 10	17	19
above 10	0	0
Total	**89**	**100**

3.4.2 Depth to water level (Deeper Aquifer-II)

The depth to water levels in the deeper aquifers were analysed using the water level data from EWs drilled by CGWB (n=24). The depth of water level in the EWs ranges between 0.50 magl (Mannamkandam, Adimaly Block) and 35.2 m bgl (Irattayar, Kattappana Block). Two EWs drilled at Adimaly (0.11 magl) and Mannamkandam were found to be artesian. About 42% of the wells are having deeper water levels > 10 mbgl and 46% showed water levels in the range of 2-10 mbgl. Deeper water levels above 20 m bgl were noticed at Vandanmedu, Aladi, Erattayar (Kattappana Block), Kumily (Azhutha Block), Nedumkandam-Nedumkandam Block

and at Vannappuram in Elamdesam Block. Shallow water levels in the range of 2 to 5 mbgl are noticed at Muttam and Arikuzha (Thodupuzha Block); Upputhara -Kattappana Block, Thankamai-Idukki Block, Kumily and Vandipperiyar (Azhutha Block) Adimaly (Adimaly Block) and Chullikkandam-Elamdesam Block. Details are tabulated in table 15.

Table 15. Percentage of wells and depth to water level range in Aquifer-II

Depth to Water level	No of EWs	Percentage (%)
Artesian Wells	2	8
0 -5 mbgl	7	29
5 -10 mbgl	4	17
10 - 20 mbgl	4	17
Above 20 mbgl	7	29
Total	**24**	**100**

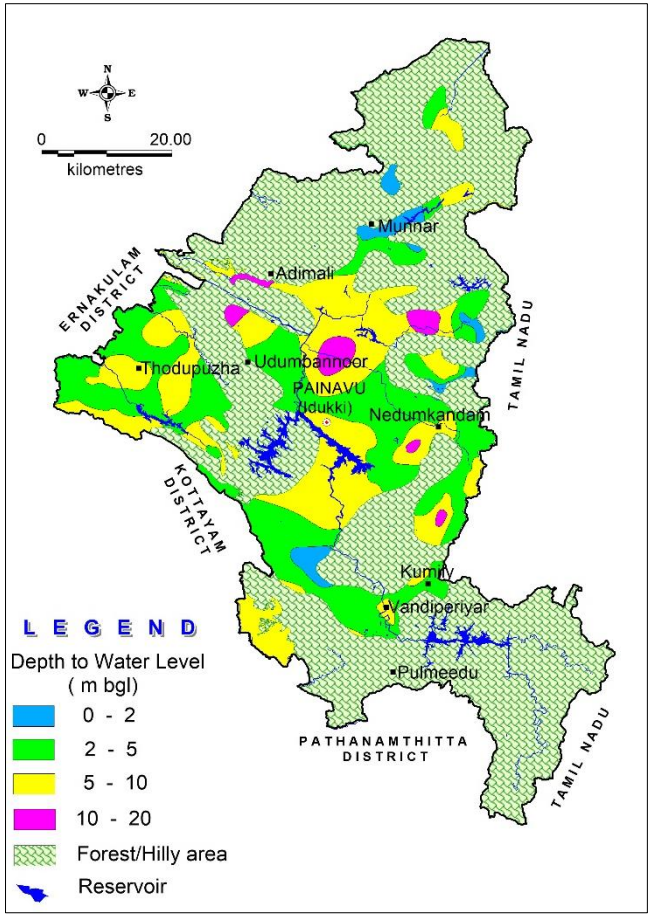


Figure 3.8. Pre-monsoon depth to water level map, Idukki district

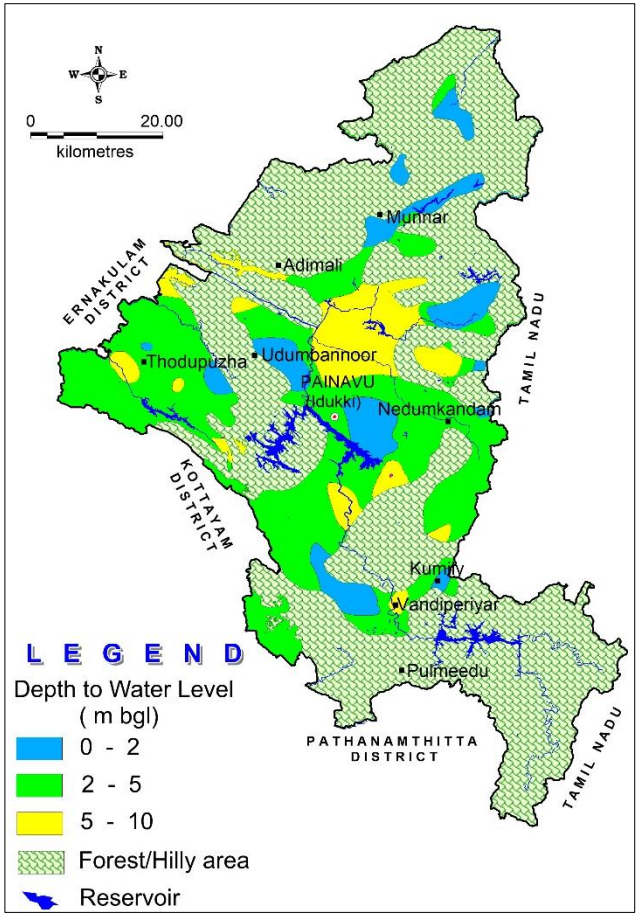


Figure 3.9. Pre-monsoon depth to water level map, Idukki district

3.4.3 Water Level Fluctuation, Shallow Aquifer-I

The pre to post monsoon fluctuation of water level is an important parameter in understanding the storage capacity of an aquifer. It has been observed in Idukki district that, even after having a quiet good amount of rainfall, about 72% of the wells analysed, indicated water level fluctuations in the range of 0-2 m. It directly implies the limited storage capacity of the aquifer, due to steep terrain gradients prevalent in the area. The water level fluctuation map of the area is given in figure 3.10.

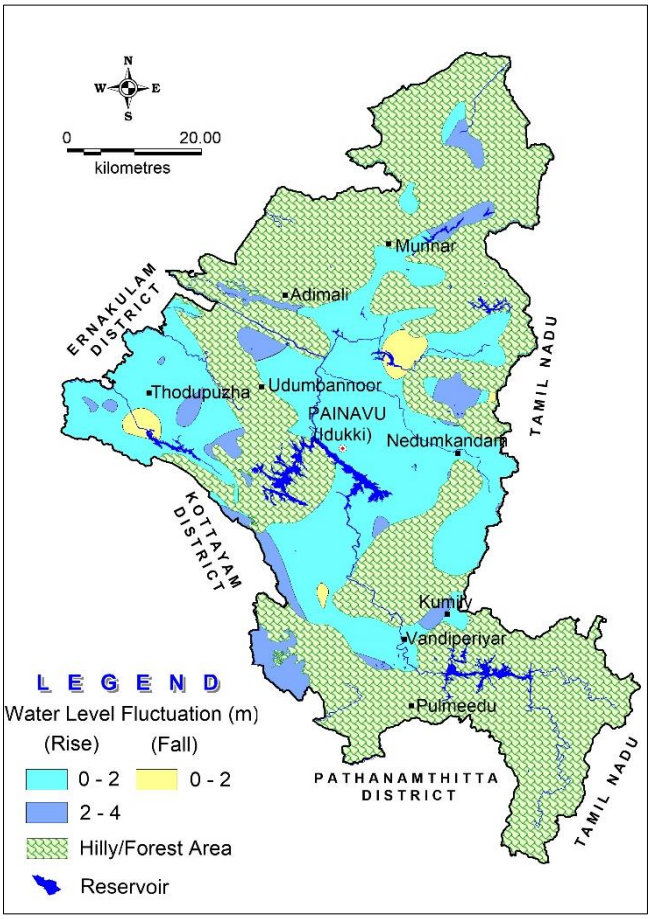


Figure 3.10. Water level fluctuation map, Idukki district

The range of pre to post water level fluctuation ranges between -1.54 m (Perumuttam, Thodupuzha Block) and 8.75 (Peruvanthanam, Azhutha Block). Analysis of water level fluctuations in aquifer-I revealed that 96 percentage of the wells (n=89) showed rise in water level after monsoon season. Only 4 percentage was found under falling water levels conditions in the range of 0 to -2m (at Chathurangappara and Rajakkad-Nedumkandam Block, Elappara - Azhutha Block and Perumuttam -Thodupuzha Block) even after monsoon and it may be attributed to to localized extraction, high rates of baseflow etc. Positive fluctuation (rise) between 4 to 8 m was noticed in 3 wells at Koilkadavu-Devikulam Block, Machiplavu-Adimaly Block and Peruvanthanam-Azhutha Block, may be due to the contributions from surface run-ff to the GWMW to external water sources and limited ground water extraction during rainy season . The analysis details of water level fluctuations and their ranges are given in table 16.

Table 16. Details of water level fluctuation

Water level fluctuation (m)					
Rise			***Fall***		
Range of fluctuation (m)	**No of wells**	**Percentage**	**Range of fluctuation (m)**	**No of wells**	**Percentage**
0 to 2	64	72	0 to 2	4	4
2 to 4	18	20	2 to 4	Nil	NA
4 to 8	3	3	4 to 8	Nil	NA
Total	85	96	Total	4	4

3.4.4 Long Term Water Level Trend (2009-2018) and Hydrograph analysis

The variation in water level with reference to time and space is the net result of groundwater extraction and recharge. The long-term change in water level is apparent from the trend of water levels over a period of time and is best reflected in a hydrograph. The decadal trend (2009-2018) of groundwater levels, for pre-monsoon and post-monsoon periods is given below in table 17. Analysis of decadal trend shows that there is no significant rise or fall in water level trends during both the seasons. Some of the representative hydrographs depicting, long term water level trend scenario in Idukki is given in figure 3.11.

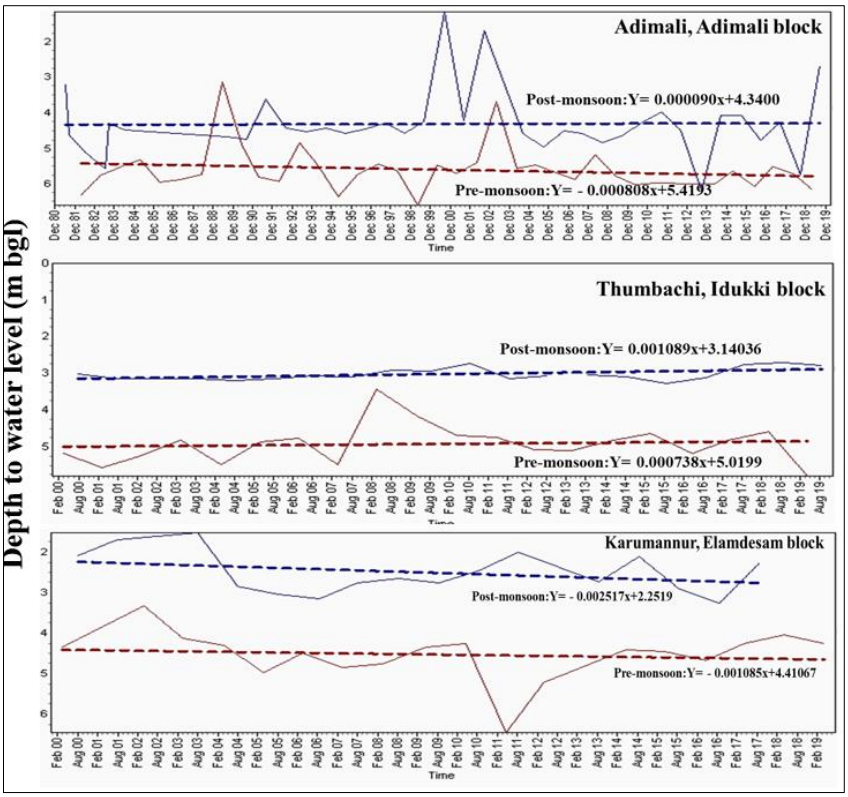


Figure 3.11. Hydrographs of selected GWMWs in Idukki district.

Table 17. Decadal water level trend of GWMWs

Sl.No	Location	Trend (m/year)			
		Pre-monsoon		Post-monsoon	
		Rise	Fall	Rise	Fall
1	Adimaly	0.0263			0.0679
2	Alacode-PZ		0.0055	0.0238	
3	Cheenikuzhi		0.0381		0.0081
4	Elappara	0.0165		0.0049	
5	Idukki	0.0188			0.0109
6	Vellilamkandam		0.0142		0.0702
7	Vandiperiyar	0.0155		0.0144	
8	Thumbachi		0.0312		0.0019
9	Thankamoni-PZ		0.0762	0.0359	
10	Santhanpara		0.2510		0.0102
11	Pooppara		0.0255		0.0078
12	Peruvanthanam	0.1916			0.1020
13	Pambadumpara		0.1005	0.0079	
14	Kuttikkanam	0.1918			0.1497
15	Mundieruma-PZ	0.1317		0.0489	
16	Kulamavu	0.0637		0.0000	
17	Kattappana DW	0.0187		0.0077	
18	Karumannoor-PZ	0.0850			0.0301
19	Karimkunnam-PZ		0.0718		0.0475

3.4.5 Ground Water Flow

Equipotential lines, the lines joining points of equal head on the potentiometric surface, were drawn for pre-monsoon period, based on the variation of the head in the aquifer. Based on the Water table elevation, ground water flow directions can be identified (Figure 3.12). It has been observed that:

a. Topography of the area is the main controlling factor in determining ground water flow direction. Also, the effluent nature of streams (gaining streams) is evident from the contour pattern.
b. In Muvattupuzha and Manimala river basin the flow direction is towards western side; In Periyar basin, the general direction is towards northwest; In Pampa basin it is towards south, whereas in Pambar it is towards northeast.
c. In the north eastern part of Periyar basin the flow lines are closely packed indicating high gradients of ground water flow; the same is observed in Manimala basin. And these areas are found to be happened with frequent drying up of wells during summer seasons.

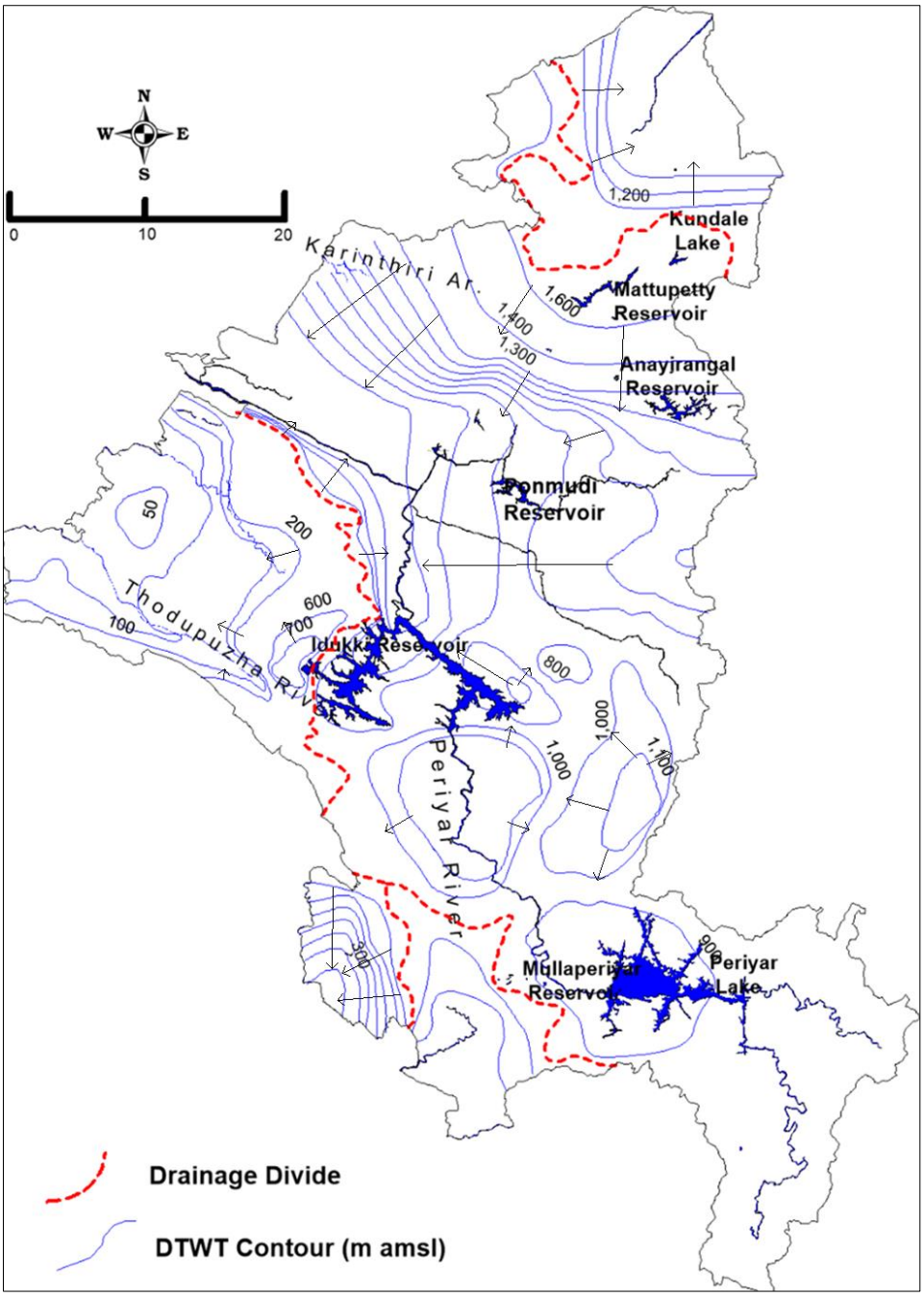


Figure 3.12. Pre-monsoon DTWT map (m amsl)-Phreatic aquifer system

3.5 Ground Water Quality

The suitability of ground water for drinking/irrigation and industrial purposes is determined by the abundance of various chemical constituents in water. Though many ions are very essential for the growth of plants and human body, when present in excess, have an adverse effect on health. For estimation of the quality of ground water, ground water samples from 39 KOWs and 20 GWMWs (shallow dug wells representing phreatic aquifer) have been collected during premonsoon. Similarly, for Aquifer – II, the ground water samples (23 samples) were collected from exploratory wells drilled by CGWB. Also, 40 acidified samples were collected from KOWs for heavy metal analysis. The aquifer wise ranges of different chemical constituents present in ground water are given in Table 18. All the major ions are within permissible limits, except for nitrate (> 45 mg/l) in 3 samples from Irattayar, Kattappana and Vandiperiyar. Also,

iron concentration is reported above permissible limit from few isolated places (>1mg/l) at Blathykavala-Elamdesam block, Santhanpara-Devikulam, Vallippara-Thodupuzha and Nadukani-Idukki block.

Generally, the Irrigation suitability is good except for 1 sample from aquifer-II at Nedumkandam where *high* salinity hazard (EC is 875 µS/cm) and *very high* sodium hazard is reported. USSL plot depicting the classification of irrigation water quality with respect to salinity hazard and sodium hazard for both the aquifers are given in figure 3.13. The details of water quality analysis of Aquifer I and II is given in Annexure VI.

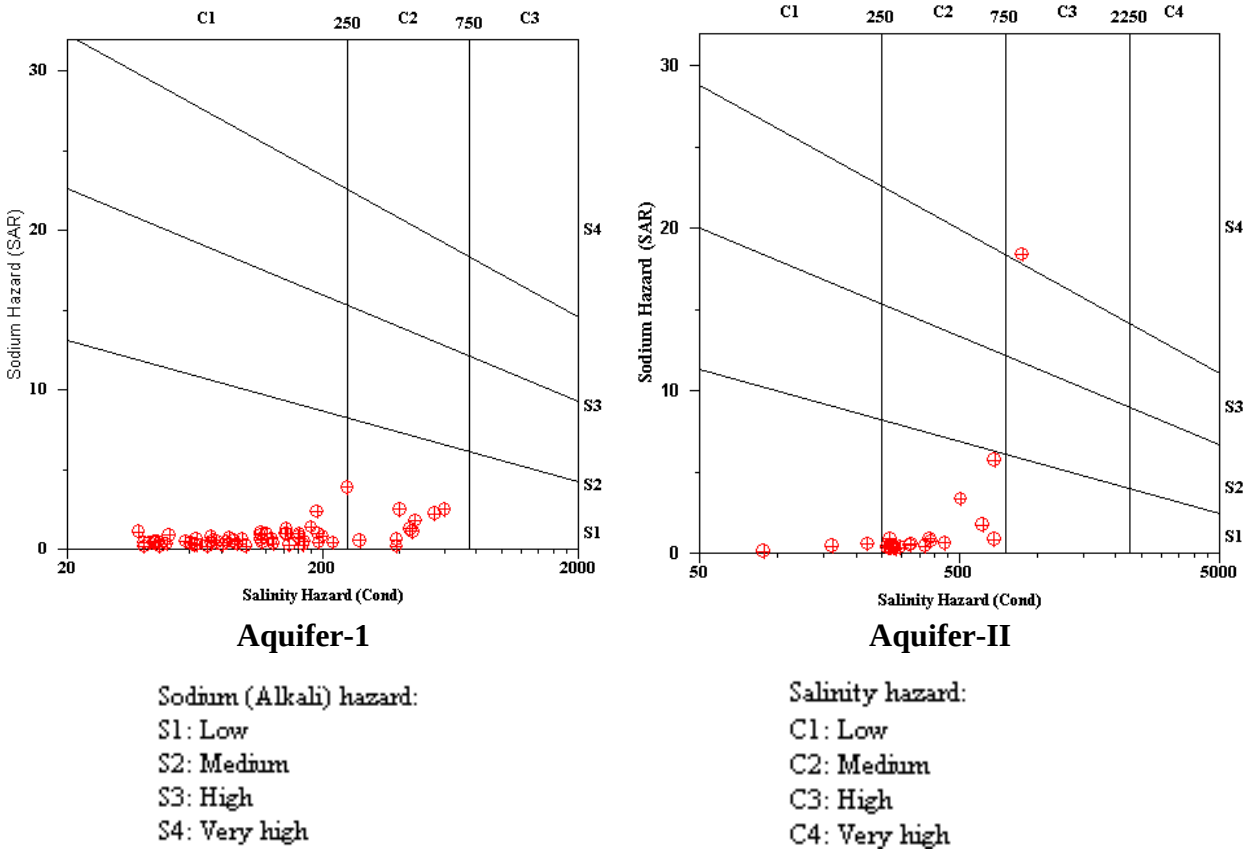


Figure 3.13. Classification of irrigation based on USSL diagram

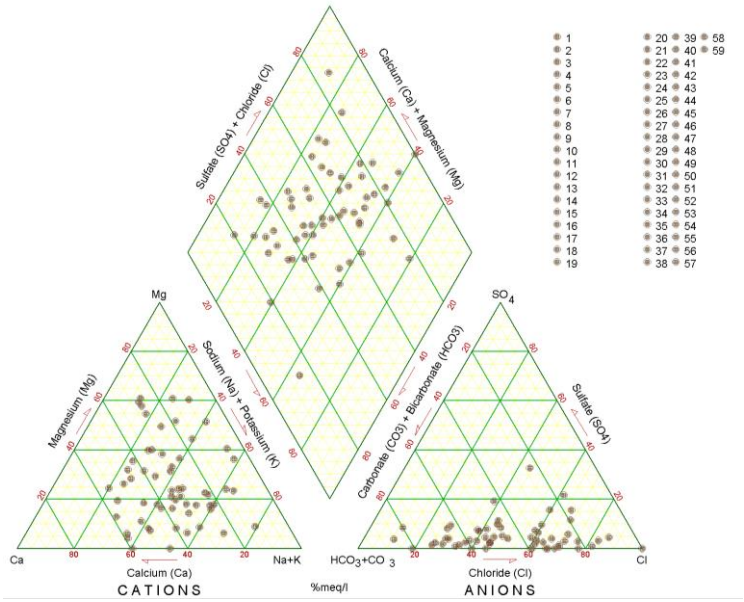
To understand the hydrochemical facies, Hill piper diagrams were prepared separately for both the aquifers. In the current study it has been observed that the water samples from aquifer-I shows no-dominant cation predominance, whereas the anions are mostly dominated by $HCO_3+CO_3>Cl>SO_4$. The order of predominance of anions can be attributed to the high rainfall recharge followed by natural flushing out process existing in the phreatic aquifer system. In Aquifer II, the general trend of cation abundance can be represented as Ca>Mg>Na+K and anions as $HCO_3+CO_3>SO_4>Cl$. The specific cation copiousness in aquifer-II is due to relatively higher residence time of ground water in the deeper aquifer system and increased rock water interactions. Hill piper diagrams for both the aquifers are given in figure 3.14

Also, to understand the geochemical evolution of ground water, Gibbs diagrams were also prepared. Here in Aquifer-1, most of the ground water samples falls in the precipitation dominant field indicating the effect of rainfall on hydrochemical signature. Most of the samples from aquifer-II, falls in the rock-dominance filed, indicating the effect of prolonged rock water

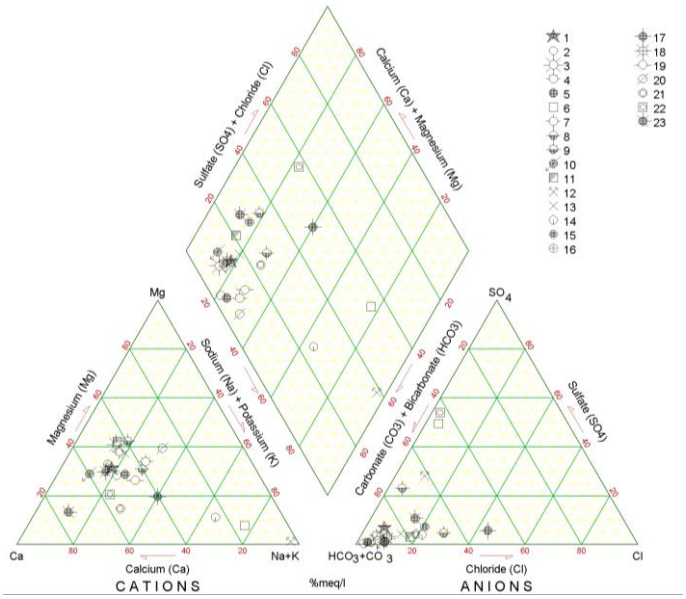
interaction due to considerably higher residence time in the aquifer. Gibbs diagram for aquifer-I and II are given in figure 3.15.

Table 18: Aquifer wise ranges of chemical constituents in Idukki district

Constituents	Aquifer-I		Aquifer-II	
	Min	**Max**	**Min**	**Max**
pH	2.98	7.94	6.26	8.4
EC (µS/cm)	38	600	88	875
TH (mg/l)	6	170	--	--
Calcium (mg/l)	0.8	46.09	3.2	68
Magnesium (mg/l)	0	28.2	1	20
Potassium (mg/l)	0.4	32	0	12
Sodium (mg/l)	0	57.4	1.95	147
Carbonate (mg/l)	--	--	0	4.8
Bi carbonate (mg/l)	0	156.16	46	255
Chloride (mg/l)	1	101	2.8	78
Sulphate (mg/l)	0	31.05	0.9	175
Nitrate (mg/l)	0.2	117	0	27
Fluoride (mg/l)	0	0.54	0	0.98



Aquifer-1



Aquifer-II

Figure 3.14. Hill piper Diagram

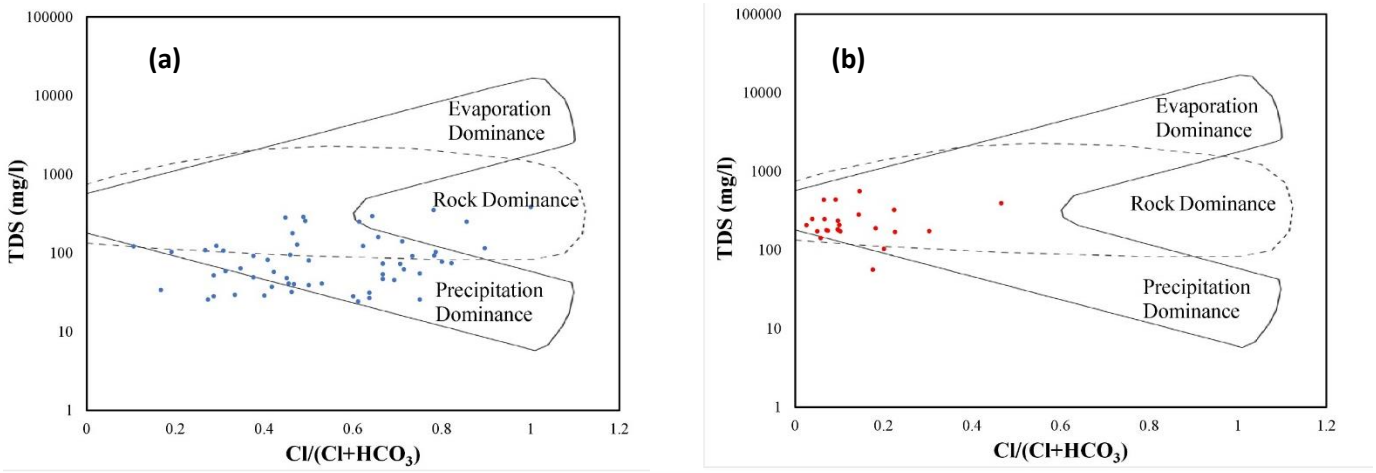


Figure 3.15. Gibbs Diagram – (a) Phreatic aquifer, (b) Deeper aquifer

3.6 3-D and 2-D Aquifer Disposition

Based on the analysis of existing and generated data through hydrogeological surveys and ground water exploration, following two types of aquifer systems were identified in Idukki district. The details of ground water exploration are given in Annexure-I. The litholog data from ground water exploration data has been used to generate the 2D and 3D disposition aquifers. The aquifer disposition models clearly depict the vertical and horizontal extension of various litho-units and the zones tapped, forming aquifers. Based on the ground water exploration and micro-level hydrogeological survey, lithological fence diagrams and cross sections were prepared and are given in figure 3.16 and 3.17 respectively.

The aquifer units in each of the formation are listed below:

- Aquifer I – Aquifer I consists of weathered crystallines/laterites and associated shallow fractures. The thickness of the first aquifer ranges up to 40 m and the thickness is highly variable. Along hill slopes it is virtually absent; thickness is maximum along valleys and plateau regions. The thickness of aquifer I is more in gneissic terrains, when compared with that of charnockites due to the susceptibility to weathering.

- Aquifer-II – Aquifer II consists of massive crystallines and associated fractures. As per drilling data by GWD, Kerala, potential fractures are limited down up to 87 mbgl. Also, most of the potential fractures are found within 60 mbgl limit. However, exploratory drilling studies carried out by CGWB revealed rare instances of occurrence of , potential fractures upto 120 mbgl. Hence ground water drilling beyond 120 m bgl may be a pointless exercise.

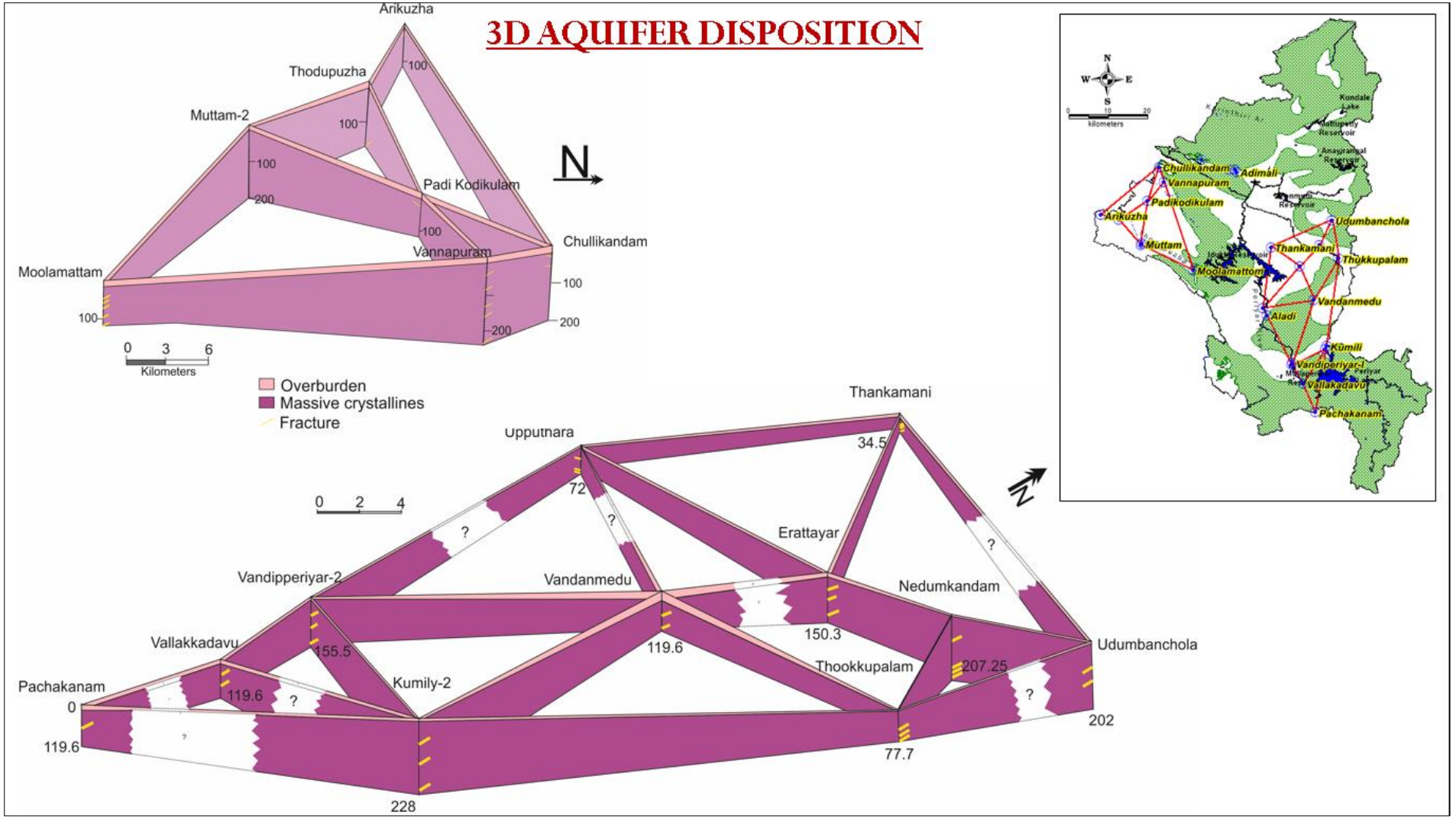


Figure 3.16. 3D Fence Diagram

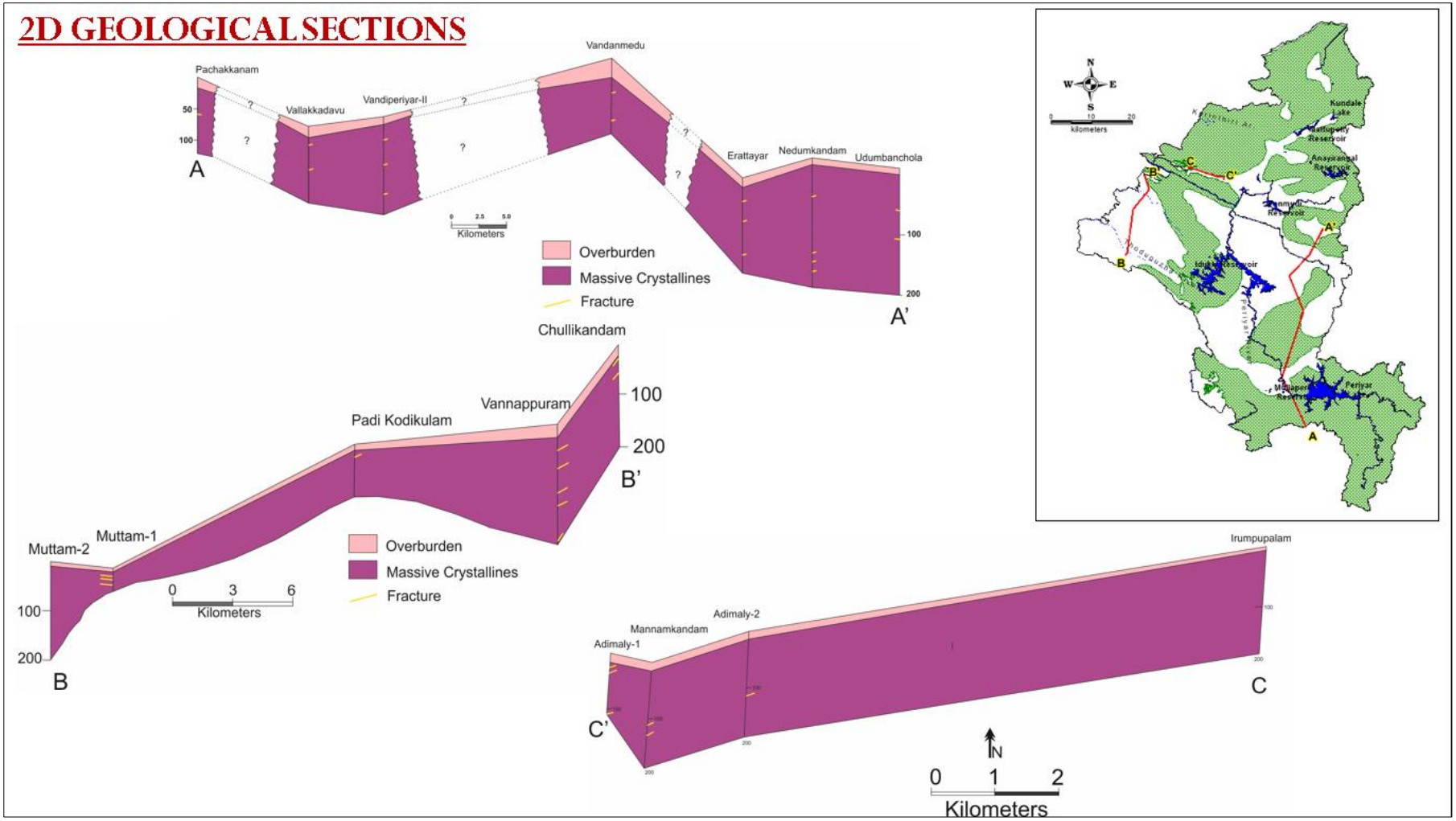


Figure 3.17. 2D cross sections

3.7 Aquifer Characteristics

The salient features of the two aquifer systems in the district is summarized in table 19 and is given below:

Table 19. salient features of the aquifer systems in Idukki district.

Type of aquifer	**Aquifer-I**	**Aquifer-II**
Formation	Weathered crystallines/Laterite/Alluvium	Fractured Crystallines
Maximum vertical limit (mbgl)	Up to 40 m (including in storage part of unconfined aquifer)	Generally, up to 87 m. Rare chances of getting potential fractures up to 120 m mbgl)
SWL	Generally 5-7 mbgl	Generally 4-23 mbgl.
Thickness	1.5 to 5.00	1 to 15 m
Weathered/Fractured zones encountered	Mostly weathered formations up to 10 mbgl; Shallow fractures may extend upto 30 m (as part of phreatic aquifer system) and rarely up to 40 mbgl	Up to 120 mbgl.
Yield	500-6000 lpd (along hill slopes and high ranges) to 15000 lpd (along valley portions). In acute summer months dug wells along hill slopes yield poor/dries up.	Generally, 0.3 to 3 lps (Dry wells occasional). Rare instances of getting zones with yield above 10 lps.
Sustainability	less than 1 hour to 3 hours	<1 to 6 hours
Aquifer Parameter (Transmissivity- m^2/day)	up to 30 m^2/day	0.7 to 503.4; mostly less than 50 m^2/day
Sy/S	0.015 to 0.025	0.00028 to 0.01
Suitability for drinking & irrigation	Yes	Yes
Remarks	Suitable abstraction structure: Dug wells; Upto 10-15 m in midlands and valley portions with diameter of 3m; Up to 12-14 m bgl along foothills with diameter 2-3 ; upto 8-12 m in Plateau region with diameter of 2-3 m.	Borewells: 100 mm dia for hand pumps and 152 mm for energisation; Optimum depth recommended up to 60 mbgl.

3.8 Structural analysis

In order to understand relationship between geologic structures and yield/discharge characteristics of bore wells tapping Aquifer-II, structural analysis was carried out. On analysis it has been found that, out of the 26 EWs drilled by CGWB, 54% of the wells are high yielding (Discharge> 3 lps). The prominent lineament directions are WNW-ESE, NW-SE, NNW-SSE, NNE-SSW and ENE-WSW. It has also been observed that 79 % of the high yielding wells falls along/near to lineaments with WNW direction; 14% along NNE and 7% along ENE. The outputs of structural analysis are given in figure 3.18.

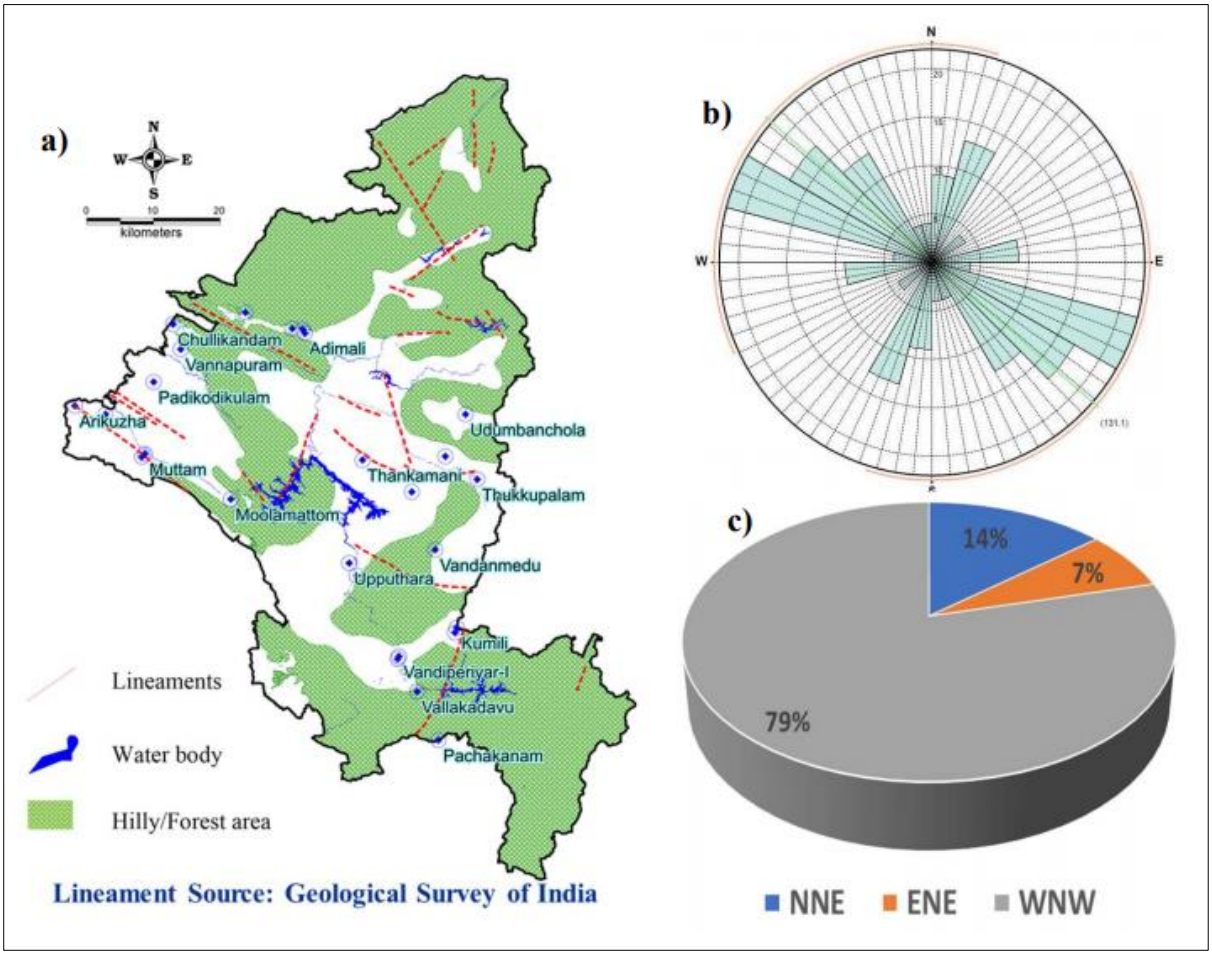
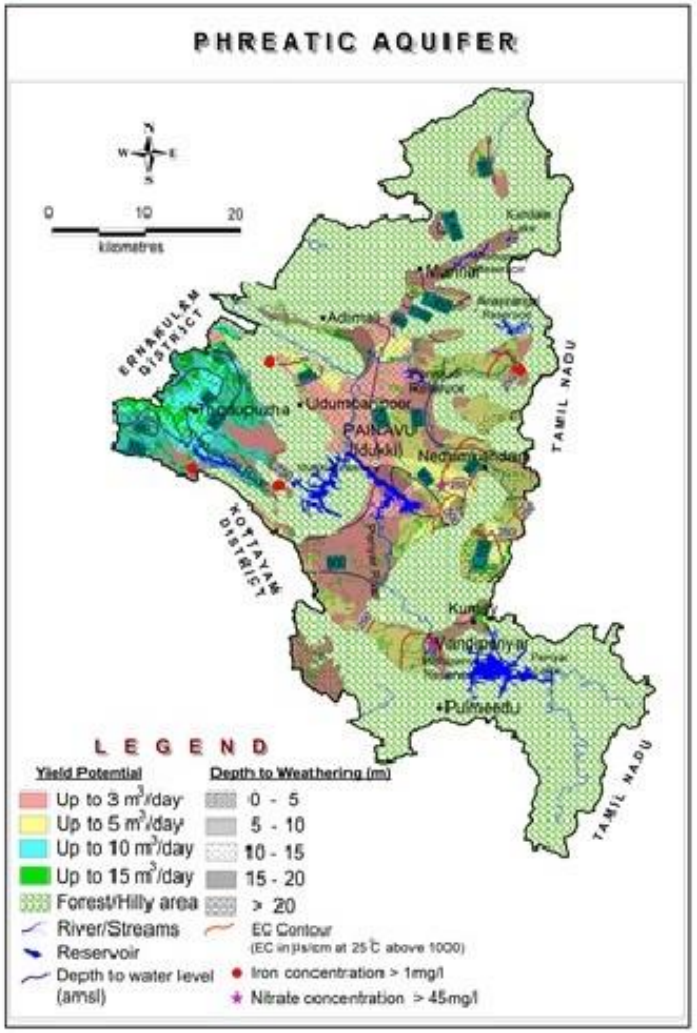


Figure 3.18. Structural analysis; a) Map showing lineament directions and locations of high yielding wells) Rose diagram of lineaments in Idukki district; c) Percentage of high yielding wells and lineament direction

3.9 Aquifer maps

An aquifer map of the area is evolved out finally, based on aquifer geometry, aquifer characteristics, ground water resources, yield characteristics and water quality. The aquifer map of the phreatic (Aquifer-I) and fracture aquifer systems (Aquifer-II) are shown in figure 3.19 and 3.20 respectively.

Aquifer Map and Yield Potential (Phreatic Aquifer System)



Thickness of Aquifer – I

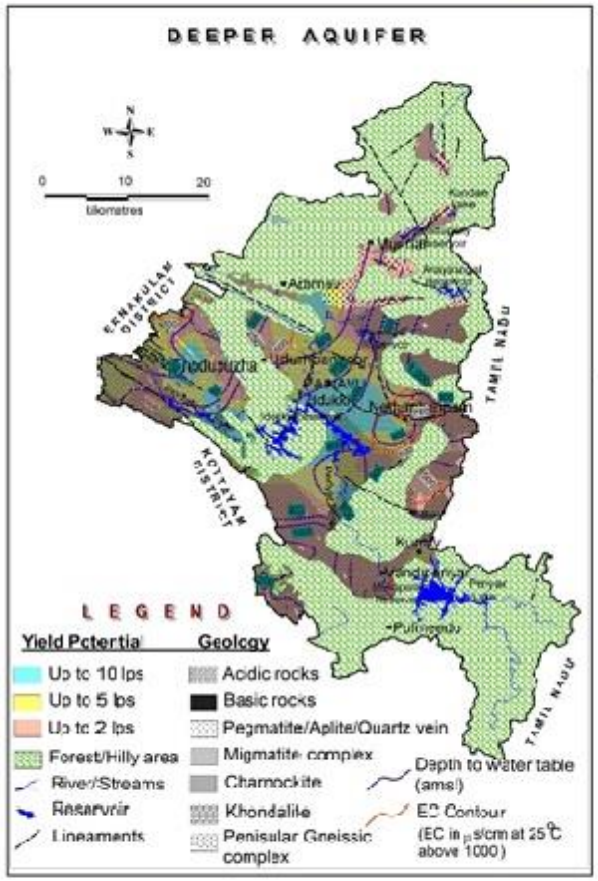
- Laterite and Weathered crystallines form the Aquifer – I (Phreatic aquifer).
- Thickness of Phreatic aquifer ranges from 2.5 to 27 mbgl except along hilly areas.
- Average thickness is about 15 m in the plateau region and valley portions. It is 7 m in hilly region.
- Maximum thickness of above 25 m is observed in the south-east of Kattappana block along Vandanmedu-Anakkara belt.
- Generally depth of weathering decreases towards east & absent along hilly areas

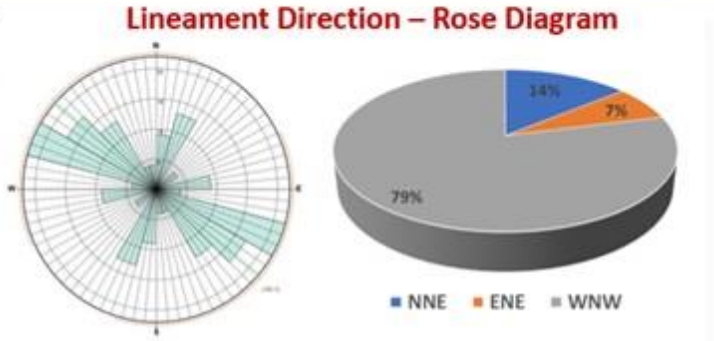
Yield of Dug wells

- 500-3000 lpd along hill slopes and high ranges
- Up to 5,000 lpd along piedmont zone
- Up to 10.000 lpd in the Lower plateau
- Up to 15,000 lpd in the Lower plateau & the valley portion of hill ranges.

Figure 3.19. Aquifer map-Phreatic aquifer system

Aquifer Map and Yield Potential (Deeper Fractured Aquifer System)





- Number of wells analysed : 26
- Depth drilled : 200m.
- Occurrence of potential fractures: 27 to 170 mbgl
- 54% of wells yielded >3 lps
- High yielding wells (>3lps) found along Lineament.
- Major Lineament : WNW–ESE, NNE-SSW, ENE- WSW

Yield of bore wells :-

- Up to 10 Lps in parts of Thodupuzha, Elamdesam and Idukki blocks.
- Up to 5 Lps in parts of Thodupuzha, Elamdesam, Idukki & Nedunkandam blocks.
- Up to 2 Lps in parts of Adimali, Azhutha, Medunkandam, Kattapana and Devikulam blocks

Figure 3.20. Aquifer map-Deeper aquifer system

4 GROUND WATER RESOURCES

Aquifer wise and block-wise estimation of ground water resources have been carried out for the 2 aquifers existing in the area i.e., Aquifer-I (the phreatic aquifer) and Aquifer-II (the fractured aquifer system) using GEC-2015 methodology. The details of the assessment are discussed below.

4.0(a) Recharge parameters used in the phreatic aquifer (Aquifer-I)

The outcomes of the ground water resource assessment as on March 2017 carried out for all the blocks as per GEC-2015 methodology (for all the 8 blocks falling under non-command category) and the details of block-wise resources are given in tables 20 and 21 respectively.

During monsoon season, the rainfall recharge is the main recharge component, which is estimated as the sum of the change in storage and gross extraction. The change in storage is computed by multiplying groundwater level fluctuation between pre and post monsoon periods with the area of assessment and specific yield. Monsoon recharge is calculated both by rainfall infiltration factor method and by water table fluctuation method. For Water table fluctuation it is calculated as follows:

$$\mathbf{R = (h \times Sy \times A) - GE}$$ where,

h = rise in water level in the monsoon season,

Sy = specific yield

A = area for computation of recharge,

GE = gross ground water extraction

The existing specific yield values as evident from various studies conducted by CGWB has been used in the estimation. The specific yield values used for the current study ranges between 0.015 to 0.02 (for unconfined aquifer in the zone of fluctuation) and a value of 0.004 is used for the in-storage part of unconfined aquifer. The maximum limit of fluctuation in phreatic aquifer used for the current estimation is 6-8 mbgl. The groundwater resource in the below the dynamic zone (i.e. the zone of water level fluctuation) in the phreatic aquifer is the in-storage, the thickness of which varies between 27-40 m in the area. The monsoon ground water recharge has two components viz; the rainfall recharge and the recharge from other sources. The other sources of groundwater recharge during monsoon season include seepages from canals, surface water irrigation, tanks and ponds, ground water irrigation, and water conservation structures. During the non-monsoon season, rainfall recharge is computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non-monsoon recharge. As the area is occupied by crystalline rocks, the RIF values applied varies from 0.06 to 0.08 depending on soil characteristics, extend of weathering etc.

4.0 (b) Recharge parameters used in the fracture aquifer system (Aquifer-II)

The ground water resource of the Aquifer – II was also estimated to have a correct quantification of resources so that proper management strategy can be framed.

In order to estimate the resources of aquifer-II, the following equation was used:

Ground Water Resource, **GWR = Area x Thickness of aquifer x Storativity**

Values ranging between 0.001 to 0.002 were used as Storativity values as observed from the pump tests conducted by CGWB. The thickness of the aquifer-II used in the estimation ranges between 110-115 m.

4.1 Ground water resources in the Phreatic aquifer (Aquifer-I)

The annual extractable ground water recharge of aquifer-I was estimated to be 186.14 mcm. As per estimation the annual gross extraction for all uses is 108.66 mcm with irrigation sector being the major consumer having a draft of 62.96 mcm. The annual draft for domestic and industrial uses together accounts for about 45.71 mcm. The allocation for domestic use up to 2025 is about 45.58 mcm (Table 20). Out of the 8 blocks Elamdesam, Kattappana and Nedumkandam falls under semi-critical category and the remaining 5 viz. Adimaly, Azhutha, Devikulam, Idukki and Thodupuzha under safe category. Hence, as per estimation there is enough potential for future ground water development in the district. The total in-storage ground water resources of unconfined aquifer was estimated and it came to about 138.48 mcm

4.2 Ground Water Resources in the fracture aquifer system – Aquifer-II

By applying above formula (section 4.1.2), the ground water resources of Aquifer-II were estimated and presented below in Table-21. The total resources of Aquifer-II have been computed to be 177.65 mcm.

The total ground water resources of the entire aquifer system (Aquifer-I and II) was estimated to about 499.27, out of which 324.62 mcm is from Aquifer-I and the remaining 174.65 mcm is accounted in aquifer-II.

Table 20. Ground water resources in the phreatic zone of Idukki district (Aquifer-I; Dynamic and in-storage)

Sl.No.	Block	Annual Extractable Ground Water Recharge of Unconfined Aquifer/ Dynamic (mcm)	Existing Gross Ground Water Extraction for Irrigation (mcm)	Existing Gross Ground Water Extraction for Domestic and Industrial Water Supply(mcm)	Existing Gross Ground Water Extraction for All Uses (4+5) (mcm)	Annual Ground Water Allocation for Domestic Use as on 2025(mcm)	Net Ground Water Availability for Future Use (3-4-7) (mcm)	Stage of Ground Water Extraction {(6/3) * 100} (%)	In Storage Ground Water Resources of Unconfined Aquifer (mcm)	Ground Water Resources –Phreatic Aquifer-I (mcm) (3+10) (mcm)	Categorization of units
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Adimaly	30.27	8.74	5.45	14.19	5.43	16.09	46.86	22.90	53.17	Safe
2	Azhutha	28.04	7.42	5.69	13.12	5.63	14.93	46.77	19.20	47.24	Safe
3	Devikulam	22.08	2.58	4.91	7.49	4.91	14.59	33.90	17.33	39.41	Safe
4	Elamdesam	17.85	7.93	5.24	13.17	5.23	4.68	73.80	24.71	42.56	Semi critical
5	Idukki	25.64	6.92	4.69	11.61	4.69	14.03	45.29	15.64	41.28	Safe
6	Kattappana	22.93	10.98	7.70	18.68	7.68	4.26	81.43	12.14	35.07	Semi critical
7	Nedumkandam	20.73	11.11	6.35	17.47	6.34	3.26	84.28	13.17	33.90	Semi critical
8	Thodupuzha	18.59	7.27	5.67	12.94	5.66	5.65	69.63	13.41	32.00	Safe
Total (MCM)		**186.14**	**62.96**	**45.70**	**108.66**	**45.58**	**77.48**	**58.38**	**138.48**	**324.62**	Safe

Table 21. Aquifer wise total ground water resources of the study area

Assessment Unit (Blocks)	Annual Extractable Ground Water Recharge of unconfined Aquifer (mcm)	In storage Ground Water Resources of Unconfined Aquifer (mcm)	Ground Water Resources –Phreatic Aquifer-I (mcm) (1+2)	Ground Water Resources-Fracture Aquifer-II (mcm)	Total Ground Water Resources (mcm) (3+4)
	1	2	3	4	5
Adimaly	30.27	22.90	53.17	31.80	84.97
Azhutha	28.04	19.20	47.24	21.09	68.33
Devikulam	22.08	17.33	39.41	24.06	63.47
Elam Desom	17.85	24.71	42.56	27.15	69.71
Idukki	25.64	15.64	41.28	20.22	61.5
Kattappana	22.93	12.14	35.07	16.86	51.93
Nedumkandam	20.73	13.17	33.9	18.29	52.19
Thodupuzha	18.59	13.41	32	15.19	47.19
Total (MCM)	**186.14**	**138.48**	**324.62**	**174.65**	**499.27**

5 GROUND WATER RELATED ISSUES

The extraction of ground water resources in Idukki district has been increasing over the years. It is evident from the comparison of ground water resources carries out as on 2009 and 2017 by CGWB and GWD, Kerala. In 2009, there were only two blocks that were under semi-critical category (Kattappana and Nedumkandam), but as per estimation made in 2017, three blocks were categorized as semi-critical. (Elamdesam, Kattappana and Nedumkandam). In 2009 'the existing gross draft for all uses was estimated to be 82.98 mcm, and in 2017 it turned out to be 108.66 mcm. The major share in this increase in draft was from irrigation extraction which significantly increased from 28.74 mcm in 2009 to 62.96 mcm in 2017. During 2009, the stage of extraction of Idukki district was 42.22% whereas, on 2017 it was increased to 58.38 %. The major ground water related problems observed in the district are detailed below:

5.1 Water Scarcity during summer

Many parts of the district experiences shortage for ground water due to the drying up of dug wells and springs in highlands due to high rates of base flow which is attributed to limited aquifer and/soil thickness, high gradients of the terrain. Other localized problems are associated with cropping and indiscriminate quarrying activities.

5.1.a Shortage of water during summer season: The shortage of water during summer season is more evident in many parts of the district. The problem aggravates in the absence of summer showers. Areas where this problem noticed are given in table 22.

Table 22. Block wise details of areas having summer scarcity for ground water in Idukki district

Block	Panchayath/Municipality (Partrs)
Thodupuzha	Purappuzha, Thodupuzha Municipality, Kumaramangalam, Manakkad, Karimkunnam Muttam
Elamdesam	Karimannur, Vannapram, Kodikulam, Udumbannur, Velliyamattam, Kudayathur
Adimaly	Adimaly, Pallivasal
Nedumkandam	Rajakumary, Pampadumpara, Karunapuram, Nedumkandam, Rajakkad, Udumbanchola
Kattappana	Kattappana municipality, Vandanmedu, Chakkupallam
Azhutha	Kumily, Vandipperiyar, Peerumedu, Elappara
Devikulam	Devikulam
Idukki	Vazhathoppu, Arakkulam

5.1.b Problems associated with quarrying: Quarrying in parts of Manakkad, Thodupuzha, Purappuzha villages in Thodupuzha block causes localised ground water issues (reduction in yield) in shallow aquifers due to reduced recharge and discontinuity in groundwater flow resulting from the removal of overburden and drainage through exposed fractures.

5.1.c Problems associated with Land use: Eucalyptus plantations in the high land areas (especially Kanthalloor, Vattavada, Kottakkamboor villages) of Idukki district are **reported** to be a major cause of ground water depletion (reported extensively around Vattavada area). Eucalyptus is a well-known forest species of high-water uptake ranging from 50 Lt/d/plant to even 90 Lt/d/plant, depending upon the adequacy of supply. But it is also reported that, in stress situation, its roots can grow even up to 20-30 feet and extract more water. High water requiring (due to high rates of transpiration) plantations like Eucalyptus which are suitable for marshy/swampy areas are planted here and it is claimed by local farmers as a major cause for ground water shortage in these areas.

5.2 Quality Problems

Generally, the ground water quality in the district is good. However, some isolated problems are reported from parts of the district and are described below:

5.2.a Geogenic Problems: As per the water quality analysis carried out by CGWB high concentrations of Iron (Above 1 mg/l) in ground water is reported from few places in parts of Vannappuram, Muttam, Arakkulama and Santhanpara villages.

5.2.b Anthropogenic Problems: **A**nthropogenic water quality problems reported in the district are nitrate and bacteriological contamination. Nitrate above 45 mg/l is seen in the observation wells of CGWB at Vandipperiyar (Manjumala Village), Kattappana (Kattappana Village) and Irattayar (Kalkoonthal Village).

Again, from the water quality data published by the National Drinking Water Programme, Department of Drinking Water & Sanitation, Ministry of Jal Shakti, the major quality problems

reported in the district are bacteriological, iron and nitrate contamination in pockets in the order of prevalence. The anthropogenic contamination may be attributed to the improper waste disposal measures and leakage from septic tanks.

A comprehensive map depicting the major ground water related issues is given in figure 5.1 below:

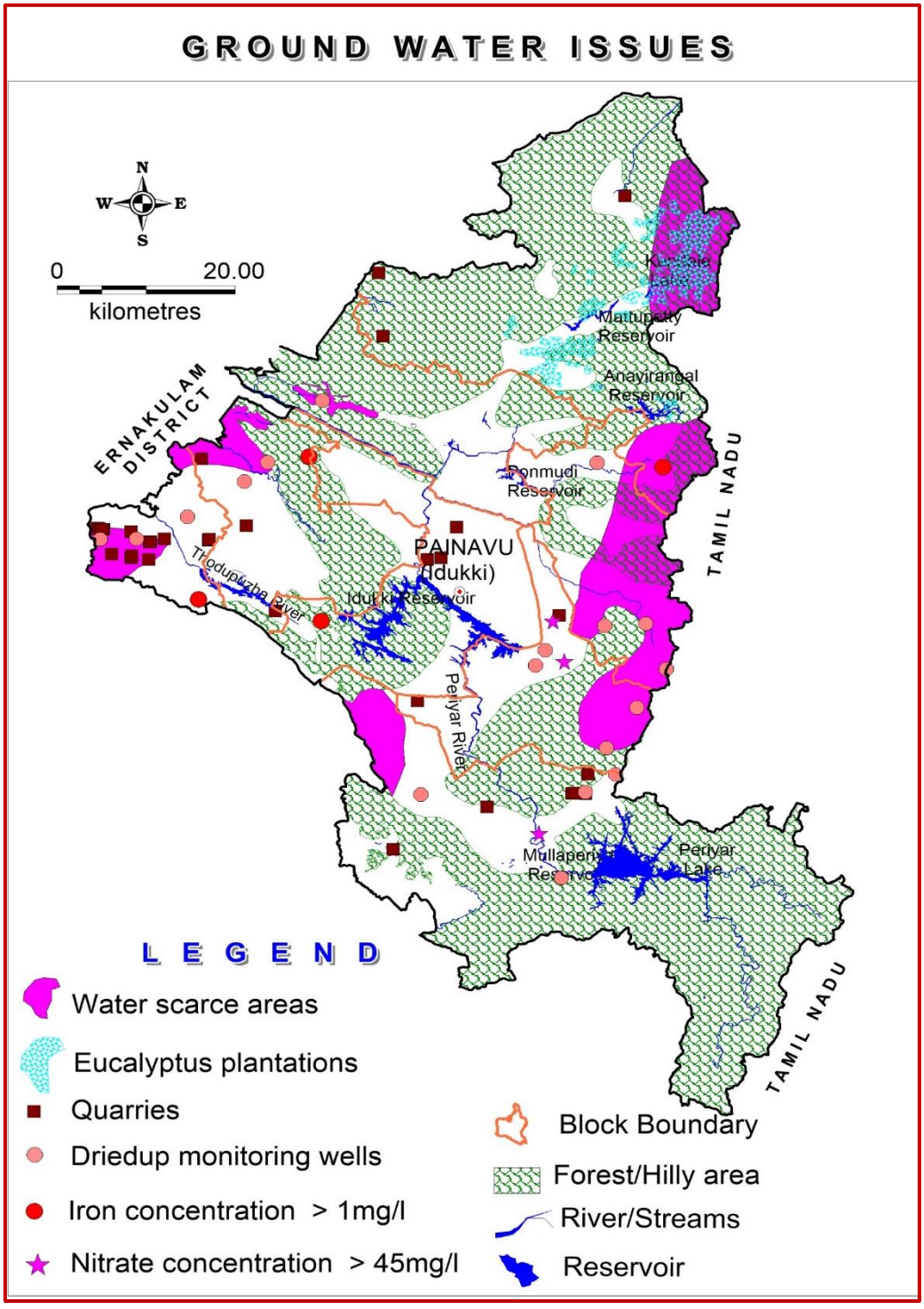


Figure 5.1. Major ground water related issues in Idukki district

6.0 MANAGEMENT STRATEGIES & AQUIFER MANGEMENT PLAN

The groundwater management strategies are inevitable either when there is much demand to the resource than the available quantity or when the quality of resource deteriorates due to contamination in each geographical unit. Hence, it is the need to formulate sustainable management of the groundwater resource in a more rational and scientific way. In the present study, in Idukki district, the sustainable management plan for aquifer is being proposed after a detailed understanding of the aquifer disposition down to a depth of 200 m bgl.

Even though the study area receives good annual rainfall close to 3345 mm, it has been experiencing increasing incidents of water scarcity in summer for meeting the irrigation as well as domestic requirements. This ironic situation is mainly attributed by natural reasons such as undulating topography with steep slopes and the limited thickness of aquifer material. Subsequently, these factors resulted in high run-off and low recharge. Besides this, the shallow depth to massive bed rock along hill slopes of the area limits groundwater storage in the aquifer system. Hence, development of water resources in this area demands a scientific management system co-ordinating the efforts of all concerned agencies for a swift development in the agricultural sector of the area. While formulating various ground water development and management strategies, geology of the area should be given importance.

6.1 Sustainable plan

An effective ground water management practice must be preceded by an accurate assessment of the total available resources. Even though there exists scope for resource development, the main limitation in this district is the non-uniform distribution of the groundwater resources because of its typical undulating topography with steep slopes and limited thickness of aquifer. From the ground water resource estimation, out of 8 development blocks, three blocks (Elamdesam, Kattappana and Nedumkandam) are categorised as semi-critical and the remaining 5 (Thodupuzha, Idukki, Adimaly, Azhutha and Devikulam) are safe. So, there is scope for further ground water development for irrigation in these safe blocks, where the stage of extraction is low. Also, the usage of groundwater has to be reduced by 20 percent of the existing extraction for the sustainability of the resource in the 3 semi-critical blocks. Otherwise, the availability has to be augmented through artificial recharge methods to bridge the gap between extraction and availability. The dependence on groundwater can be reduced through application of water efficiency methods in irrigation sector like drip and or sprinkler irrigation (especially in Nedumkandam, Kattappana blocks where irrigation extraction is relatively high).

6.2. Supply Side Management Plan

Augmentation of groundwater can be achieved through construction of additional recharge structures like check dams, vented cross bars, percolation ponds etc. Normally it can be attained through capturing surface runoff. Artificial Recharge and Water Conservation Plans proposed for the district utilizing the uncommitted surface run-off will improve the current water scarcity especially in the semi-critical blocks. Groundwater development should be coupled with management of water resources through the implementation of new rainwater harvesting and artificial recharge schemes and by the maintenance and desilting of the existing structures to ensure proper recharge. Periodic de-siltation as well as cleaning of existing panchayath ponds and irrigation tanks, check dams/Vented cross bars, individual and community ponds has to be carried out in the study area to increase the storage capacity as well as infiltration rate.

6.2.1. Artificial Recharge and water conservation Plan

Based on the water level monitoring in different seasons across the district, as well as after having better understanding of the disposition and extent of the aquifer system through exploratory drilling, pumping tests etc., recharge/ conservation structures suiting the area are suggested. It has been proposed to implement additional 40 check dams and 96 vented cross bars at the identified placed in the district (with limited field check) as given in table 23 and figure 5.2. Site selection for new water conservation/recharge structures should be dealt with utmost caution as the area is highly undulating and susceptible for landslides and other earthflows. Again, Nallah bunds and contour terracing may be attempted at suitable places

considering the slope, geology and weathering thickness of the terrain. The expected recharge through these artificial recharge structures is in the order of 4.08 mcm.

Table 23. Details of management structures feasible in the area

S.No.	Block	Tentative No. of Check Dams Proposed	Tentative No. of Vented Cross Bars Proposed	Quantum Water Estimated to be Recharged/ Developed (mcm)
1	Thodupuzha	3	6	0.27
2	Elamdesam	7	19	0.78
3	Devikulam	6	13	0.57
4	Kattappana	7	6	0.39
5	Idukki	6	19	0.75
6	Adimaly	3	5	0.24
7	Azhutha	4	11	0.45
8	Nedumkandam	4	17	0.63
Idukki District		**40**	**96**	**4.08**

Due to steep slope with shallow depth to bed rock, springs emerges in various parts of the district, which can be developed to meet the requirements during summer season especially in Adimaly, Azhutha and Idukki blocks. By incorporating the present mapping with previous surveys, a total of 18 perennial springs in the district has been identified. Out of this 9 (Valanchankanam-1200 lpm, Pullupara, 2 springs-15 and 12 lpm, Kaduvapara-14 lpm, Mettupagam-600 lpm, Tharangangannam-vagamon-17 lpm, Pattamudi Jn. 12lpm (Azhutha block) ; Pallikavala-30 lpm (Idukki Block), Kavunti-15lpm (Kattappana block)) can be developed. If it is developed in a scientific manner, it is expected to conserve 0.495 ham of water by means of spring development.

Abandoned quarries in the district, especially in the water scarce areas of Thodupuzha block in Manakkad, Purappuzha, and SW parts of Thodupuzha municipality can be converted to rainwater storage tanks that can be further utilised for domestic and irrigation purpose during lean period after proper treatment. Presently, these quarries are the site for the inflow of polluted water from adjoining areas. These activities need to be discontinued and appropriate fencing to be done. Finally, the maintenance of these quarries to be entrusted to local people for proper functioning.

Large scale implementation of roof-top rainwater harvesting through existing dug wells in highland areas to be taken up on priority based on vulnerability of the area in terms of water scarcity. Recharge of monsoon rainfall through many such wells is expected to improve ground water availability over a period. Since the aquifer system is thin with high gradient leads to fast drain, rainwater harvesting as storage cum recharge is highly recommended.

Community based roof top rainwater harvesting (preferably storage) is suggested in large diameter wells and/or tanks are suggested in the water scarce areas. Dug well recharge should be promoted in all panchayaths and the filter medium of the existing schemes must be cleaned annually before the onset of every monsoon season.

Use of existing yielding bore wells drilled by Central Ground Water Board with potable water quality may be handed over to LSGDs to address the drinking water needs of the populace especially during summer season.

It is also suggested for the enhancement of water utilization capacity of Muvattupuzha Valley Irrigation Project by maintenance and renovation of the existing irrigation canal network system in Thodupuzha block to improve irrigation potential in 3566 ha of land.

6.3. Demand side Management Plan

Demand side management can be accomplished through change in irrigation pattern. Farmers may be encouraged to adopt modern irrigation techniques like drip and micro irrigation to have optimal use of the available resources especially in semi-critical blocks -Elamdesam, Kattappana, Nedumkandam and in Thodupuzha block (where the SOE is nearing 70%). An area of 66.85 sq. km. can be brought for adopting drip/ sprinkler irrigation to increase the water-use efficiency by saving a substantial amount of water. Since it supplies water directly to the crop, rather than the land around, water losses occurring through evaporation and distribution are significantly reduced. There is water saving up to 50% and productivity improvement in the range of 30-60% for different crops like coconut, arecanut, banana, vegetables under drip method of irrigation. Block wise details of area proposed under drip and Sprinkler irrigation area given in table 24

Table 24 Block wise details of drip/Sprinkler irrigation feasible in the area

S.No.	Name of Block	Drip Irrigation (Ha)	Sprinkler irrigation(Ha)
1	Thodupuzha	1050	490
2	Elamdesam	245	155
3	Devikulam	440	440
4	Kattappana	800	400
5	Idukki	400	350
6	Adimaly	350	500
7	Azhutha	200	200
8	Nedumkandam	370	295
Total		**3,855**	**2,830**

6.3.1 Creation of irrigation potential through ground water

Additional irrigation potential can be created in the district considering the relatively low stage of ground water development in the blocks. This will promote the financial stability and economic growth of the farmers in the district. The following approaches are suggested in this perspective:

6.3.1.(a). General suggestions for the creation of irrigation potential through ground water

Creation of irrigation potential through groundwater depends upon yield potential of underlying aquifers. Hence, any new construction of groundwater well should be based on the data/ knowledge available for the area with the Central/ State Agencies involved in groundwater development and management. Some of the important points to be considered while planning any groundwater development are as below:

- The groundwater management schemes should not be planned in areas classified as over-exploited, critical and semi critical areas. Further eligibility criteria has been laid down in subsequent paras.
- Groundwater development will be carried out preferably through Dug wells and or BWs in hard rock areas whereas shallow/deep tube wells are recommended alluvial areas. Bore wells are to be taken up in areas where hydro-geological setup and groundwater aquifers justifies their suitability.
- Promotion and adoption of water use efficiency & conservation practices viz. drip/sprinkler, diversification to low water demand crops, promoting on-farm rainwater harvesting etc shall be encouraged by the State Govt/ Project Authorities.
- The State agencies involved in planning and execution of ground water schemes shall formulate the proposals in consultation with State Ground Water Department & CGWB duly considering nature of aquifer system in the area, spatio-temporal behaviour of water level, ground water resource availability, artificial recharge structures suitable for that area, sites for their construction etc.
- To minimize the failure of wells geophysical and hydro-geological investigations may be carried out for proper site selection.

6.3.1.(b). Eligibility criteria

1. Ground Water irrigation facility through Dug wells, Dug cum Bore wells, Tube wells and Bore wells etc. can be funded for schemes in areas other than Over Exploited (OE), Critical or Semi-Critical meeting the following criteria:
    - Less than 60 per cent of the annual replenishable groundwater resources have been developed.
    - Average annual rainfall of 750 mm or more should be received to enable enough water for recharge.
    - Shallow groundwater levels within range of 15m below ground level or less during pre-monsoon period. Ground water development for irrigation can be planned in such a way that after implementation of the project, stage of Ground Water Development (SOD) in an area should not exceed 70% at any time. However, as already mentioned Scheme in unclassified areas shall be considered on case-to-case basis depending upon various criterions laid down in the guidelines.
2. The beneficiary under this scheme shall be small and marginal farmers only with priority to be given to SC/ST and Women farmers
3. The scheme is applicable for individual farmer, group of farmers/ cooperatives, Govt. Scheme utilising Govt. Land etc

Considering the above guidelines, creation of additional irrigation potential through ground water can only be admissible only in 4 blocks viz., Adimaly, Idukki, Azhutha and Devikulam. The details of the tentative number of new abstraction structures feasible in these blocks are given in table 25. Even though, groundwater availability for constructing 7029 Dug Wells (DWs) and 1431 Bore Wells (BWs) are possible in these 4 blocks, considering undulating topography and availability of cultivable waste land only limited abstraction structures are feasible and is shown in table 26.

Table 25. Additional abstraction structures possible in the 4 blocks, where SOE <60%

S.No	Block	Annual Extractable Ground Water Resources (Ham)	Existing Gross Ground Water Extraction for All uses (Ham)	Stage of Ground Water Extraction (%)	GW resource available for future Development (Ham)	60% of the Annual extractable GWR (Ham)	GW Resource available for Development (Ham)	GW Resource to be developed through DW (Ham)	GW Resource to be developed through BW (Ham)	No. of DW to be feasible	No. of BW to be feasible
1	Adimali	3027.28	1418.57	46.86	1608.71	1816.37	397.80	238.68	159.12	1328	497
2	Azhutha	2803.95	1311.39	46.77	1492.57	1682.37	370.98	222.59	148.39	1239	462
3	Devikulam	2207.97	748.6	33.9	1459.37	1324.78	576.18	576.18	--	3201	--
4	Idukki	2564.39	1161.428	45.29	1402.96	1538.63	377.20	226.32	150.88	1261	472
Total		-	-	-	-	-	**1722.17**	**1263.78**	**458.39**	**7029**	**1431**

Table 26. Additional abstraction structures recalculated as per the availability of cultivable waste land.

Block	Cultivable Waste Land available (Ha)	Tentative area to be irrigated (Ha)		Tentative No. of Structures Proposed	
		By DWs	By BWs	DW	BW
Adimaly	180	108	72	216	72
Azhutha	135	81	54	162	54
Devikulam	670	402	268	804	268
Idukki	116	70	46	139	46
Total	**1101**	**661**	**440**	**1321**	**440**

Since groundwater is an invisible common pool resource, it brings with it a set of complexities about who uses and who provides. When a potential user overuses groundwater for personal consumption, it leads to a situation where it decreases the availability of water for a community. Similarly, dilemmas arise about who develops and manages the water and who uses it because with a common pool resource it becomes difficult to exclude users. Participation brings a discipline into this process of management. It brings users together to arrive at mutually agreed decisions on usage and recharge. Simultaneously, it builds in an ethos of self-regulation and sustainable use of groundwater to be followed by all.

Some of the local educated people may be identified and imparted basic training on ground water occurrence and its management, thus bringing a participatory approach to the management of this precious resource. These trained persons, called para- hydrogeologists will be responsible for basic data collection like water level monitoring, well inventory, awareness raising etc. They can also be entrusted with activities like water budgeting, assessment of crop water requirements etc.

Participatory Ground Water Management (PGWM) should be carried out on aquifer-wise and community-centric approach has to be developed as an alternative for managing groundwater as a common pool resource. The units of groundwater management should be aquifers, watersheds and/or habitations.

In views of rapid urbanization in urbanised parts of Kattappana, Thodupuzha and edumkandam blocks, the domestic water needs are escalating and the water wastage component is increasing and thereby causes localised anthropogenic contamination (Nitrate and coliform bacteria). In order to address this, double chamber soak pits and proper waste disposal strategies are to be implemented.

Adjustment of cropping patterns according to irrigation water availability, such as reducing the area of water-intensive crops (like Eucalyptus Grandis) or changing crop types to ones with more efficient water use, provides a potential means of alleviating irrigation water scarcity. This may help in mitigating the reported problems of water scarcity ascribed by inappropriate land utilization practices in Vattavada, Kanthalloor panchayaths in Devikulam block.

Many areas of Nedumkandam and Kattappana blocks in the high ranges are facing shortage of water for irrigation and domestic needs especially during summer because of indiscriminate sinking of borewells. Karunapuram grama panchayat, bordering Tamil Nadu in Nedumkandam block, has the largest number of borewells in the State. Local people go in search of deeper aquifers when the available one becomes dry. In Karunapuram and neighbouring panchayaths including Ramakkalmedu, there is a high emergence in the number of borewells particularly along the rain shadow area, where rainfall is scarce even for groundwater recharge. Also, digging borewells with depth above 90-120 metres is common but there is less probability of water availability in this depth. The guideline that borewells should not be dug within 30 metres of public wells and ponds too is flouted. This has resulted in depletion of water level in sources used by the public for domestic use. Henceforward, stringent law enforcement in this regard has to be ensued to safeguard the drinking water requirements of the local population.

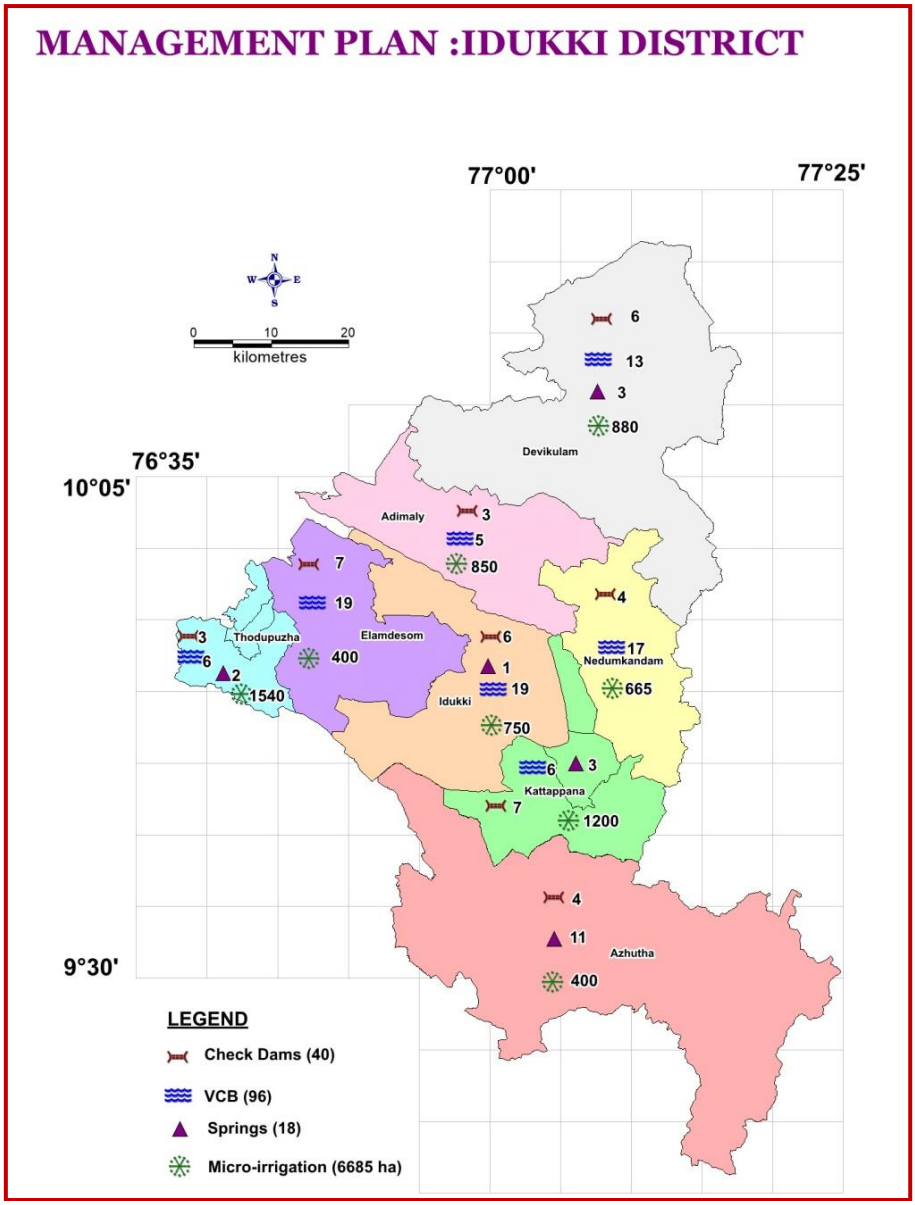


Figure 5.2: Feasible water conservation structures in the study area

ANNEXURES

ANNEXURE-I: DETAILS OF EWS DRILLED BY CGWB IN IDUKKI DISTRICT

Sl. No	Location	lock	Latitude	Longitude	Year of construction	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones/yield (lpm)	SWL (mbgl)	Discharge (lps)	Draw down (m)	T(m^2/day)	S
1	**Muttam**	Thodupuzha	9.8458	76.7403	2003-04	37.1	Hb-Biotite Gneiss	6.2	16.7-17.7/12, 23.9-24.9/248, 32.33-35.37/840	2.4	14	5.05	49	0.0017
2	**Padikodikulam**	Elamdesam	9.9431	76.7528	2003-04	110.5	Hb-Biotite Gneiss	10.85	25 – 26/wet,45.5-46.5/120	6.5	1.2	25.35	1.5	
3	**Arikuzha**	Thodupuzha	9.9111	76.6444	2003-04	110.35	Hb-Biotite Gneiss	10.3	17.0-18.0,/.24, 22.0-23.0/180	4.5	3	16.15	9	
4	**Vandanmedu**	Kattappana	9.7167	77.1389	2003-04	119.6	Hb-Biotite Gneiss	27	55.5-56.0/wet, 96.0-97.0/12	31.5	0.2			
5	**Kumili**	Azhutha	9.6111	77.1681	2003-04	119.5	Hb-Biotite Gneiss	13.5	100.0-101.0	27.9	0.25			
6	**Vallakadavu**	Azhutha	9.525	77.1139	2003-04	119.6	Hb-Biotite Gneiss	12.85	24.0-25.0/6 , 64.0-65.0/30	7	0.5		1	
7	**Pachakanam**	Azhutha	9.4597	77.1431	2003-04	119.6	Hb-Biotite Gneiss	12.9	55.0-56.0/6	12.5	0.1		0.7	0.01
8	**Vandiperiyar-I**	Azhutha	9.5722	77.0889	2003-04	119.5	Charnockite	4.7	7.65-8.65/wet, 55.45-56.45/72,	5.03	1.2		1.86	
9	**Upputhara**	Kattappana	9.6986	77.0208	2003-04	72	Hb-Biotite Gneiss	5.4	16.0-17.0/wet 58.0-59.0/105 62.0-63.0/360	4.85	6	6.05	226	0.0024
10	**Thankamani**	Idukki	9.8375	77.0389	2003-04	34.5	Hb-Biotite Gneiss	10.1	12.0-13.0/12, 16.0-17.0/30, 19.0-20.0/72, 34.0-34.5/420	2.7	7	5.40	45	0.00145

Sl. No	Location	lock	Latitude	Longitude	Year of construction	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones/yield (lpm)	SWL (mbgl)	Discharge (lps)	Draw down (m)	T(m^2/day)	S
11	**Adimali**	Adimali	10.0092	76.96	2004-05	108.8	Granite gneiss	17	15.5 - 20.5 /120 28.0 -31.0/300 98.5 - 108.8/720	0.11 agl	12	9.24	60.79	
12	**Udumbanchola**	Nedumkandam	9.8994	77.1806	2004-05	202	Hb-Biotite Gneiss	5.5	60.0 - 64.0/wet,105.0 - 110.0/12	15	0.2			
13	**Nedunkandam**	Nedumkandam	9.8425	77.1528	2004 - 05	207.25	Charnockite	7.1	59.0 - 62.0/dry,150.0 - 152.0/dry 161.0 - 165.0/60 176.0 - 181.0/150	23.47	2.5	31.81	1.44	
14	**Thukkupalam**	Nedumkandam	9.8117	77.1964	2004-05	77.7	Hb-Biotite Gneiss	2.65	38.0 - 41.0/30, 57.0 - 62.0/120,75.0 - 77.7/840	12.4	14	1.29	503.4	
15	**Kumily**	Azhutha	9.6047	77.1658	2004-05	228	Charnockite gneiss	9	59.0 - 62.0/108,119.0 - 124.0/264,207.0 - 215.0/264	3.9	4.4	30.0	5.27	
16	**Vandiperiyar-II**	Azhutha	9.5689	77.0875	2004-05	155.5	Charnockite	7	32.0 - 35.0/120, 62.0 - 72.5/300,120.0 - 124.0/480	3.68	6.2	30.65	7.91	
17	**Aladi**	Kattappana	9.6817	77.0306	2004-05	119	Hb-Biotite Gneiss	8	52.0 - 57.0 /dry,101.0 - 105.0/180,111.0 - 119.0/480	26.2	8	12.4	31.64	
18	**Erattayar**	Kattappana	9.7944	77.1067	2004-05	150.3	Hb-Biotite Gneiss	11.5	34.0 - 36.0 /dry,65.0 -	35.2	5	3.43	33.19	

Sl. No	Location	lock	Latitude	Longitude	Year of construction	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones/yield (lpm)	SWL (mbgl)	Discharge (lps)	Draw down (m)	T(m^2/day)	S
									69.0/120 110.0 - 118.0/300					
19	**Moolamattom**	Idukki	9.785	76.8583	2004-05	114	Garnet biotite gneiss	17.5	38.4 - 41.4/dry,48.8 - 51.8 /12 57.0 - 68.0/300, 85.0 - 90.0/300,110.0 - 114.0/720	11.58	12	19.72	13.51	
20	**Vannapuram**	Elamdesam	9.9875	76.79	2004-05	233.2	Hb-Biotite Gneiss	17.7	38.0 - 42.0/12,75.0 - 78.0 /60, 124.0 - 128.0 /60,150.0 - 154.0 /60,220.0 - 228.0/60	26.7	1			
21	**Muttom**	Thodupuzha	9.8422	76.7367	2018-19	200	Charnockite	7.1			Dry			
22	**Thodupuzha**	Thodupuzha	9.8997	76.6869	2018-19	165.9	Charnockite	11.4	164.0-165.0/504	9	8.4	7.54	110.5	
23	**Adimali**	Adimali	10.015	76.9425	2018-19	200	Hb.Bio Gneiss	14.5	111.00-114.00/30	2.5	0.5			
24	**Mannamkandam**	Adimali	10.0139	76.9569	2018-19	200	Hb.Bio Gneiss	15.3	107.90-111.00, 126.20-129.30	0.50 agl	4	24.09	6.38	0.0003
25	**Irumpupalam**	Adimali	10.03680556	76.87816667	2019-20	200	Bio Gneiss	5.4						
26	**Chullikandam**	Elamdesam	10.02094444	76.77897222	2019-20	200	Bio Gneiss	10.4	13.40-16.40/30,40.80-45.90/228	1.99	3.8	8.47	42.01	0.00028

ANNEXURE-II: DETAILS OF GROUND WATER MONITORING WELLS, PIEZOMETERS AND KEY OBSERVATION WELLS

Location	Block	TYPE	Geology	Latitude	Longitude	MP (Magl)	Diameter (m)	Depth	pre wl (mbgl) 2019	post wl (mbgl) 2019	Fluctiation 2019 (m)
Adimaly	Adimaly	GWMW	Hb-Biotite Gneiss	10.0133	76.9546	0.73	1.85	7.7	6.17	4.54	1.63
Alacode	Elamdesam	GWMW	Hb-Biotite Gneiss	9.8825	76.7648	0.7	2.75	6.57	4.6	4	0.6
Alakode	Elamdesam	PZ	Hb-Biotite gneiss	9.8824	76.7650	0.67	0.152		4.83	3.78	1.05
Amaravati	Azhutha	GWMW	Charnockite	9.6361	77.1686	0.7	2.25	4.35	3.45	2.4	1.05
Ambazhachal	Adimaly	GWMW	Granite gneiss	10.0188	77.0156	0.8	2.25	6.5	5.4	4.1	1.3
Anakkara	Kattappana	GWMW	Charnockite	9.6638	77.1595	0.9	2	9	6.4	5.6	0.8
Anakkara	Kattappana	PZ	Charnockite	9.6638	77.1595	0.6	0.152		NA	NA	NA
Anavilasam	Kattappana	GWMW	Charnockite	9.6538	77.1058	0.7	2.1	10.5	7.3	4.8	2.5
ARAKKULAM	Idukki	KOW	Hb-Biotite gneiss	9.8126	76.8240	0.7	2.2	7.3	6.2	4.85	1.35
Arikuzha	Thodupuzha	GWMW	Charnockite	9.9139	76.6450	0.75	2.75	6.15	4.9	4.33	0.57
ARIKUZHA	Elamdesam	KOW	Hb-Biotite gneiss	9.9465	76.7889	0.65	2.3	7.9	7.7	NA	NA
Balagram	Nedumkandam	GWMW	Charnockite	9.7939	77.1984	0.7	2	6	3.54	2.7	0.84
BLATHYKAVALA	Elamdesam	KOW	Hb-Biotite gneiss	9.9724	76.8551	0.7	2.6	12.1	10.9	7	3.9
Byson Valley	Adimaly	GWMW	Granite gneiss	10.0057	77.1162	0.7	1.6	15	9.81	9.3	0.51
Carady Goody Estate	Azhutha	GWMW	Charnockite	9.5750	77.0605	0.7	2.5	6.64	2.2	1.4	0.8
Chathurangappara	Nedumkandam	GWMW	Charnockite	9.8934	77.2110	0.9	2.75	1.7	0.78	1	-0.22
CHEMMANNAR	Nedumkandam	KOW	Charnockite	9.9227	77.1629	0.75	1.8	9.05	7.75	5.6	2.15
Cheriyar	Devikulam	GWMW	Charnockite	9.9490	77.2155	0.8	3	4.3	2.8	2.55	0.25
CHETTUKUZHY	Kattappana	KOW	Charnockite	9.7340	77.1770	0.65	3.5	6.15	4.85	3.2	1.65
Chinikuzhy	Elamdesam	GWMW	Hb-Biotite Gneiss	9.8922	76.8413	0.8	3	4	2.75	1.25	1.5
Chittur	Thodupuzha	GWMW	Charnockite	9.9101	76.6762	0.8	2	5.1	4.05	3.2	0.85

Location	Block	TYPE	Geology	Latitude	Longitude	MP (Magl)	Diameter (m)	Depth	pre wl (mbgl) 2019	post wl (mbgl) 2019	Fluctiation 2019 (m)
Churuli	Idukki	GWMW	Hb-Biotite Gneiss	9.9198	76.9548	0.72	1.8	3.81	2.61	1.88	0.73
Cumbum mettu	Nedumkandam	GWMW	Charnockite	9.7463	77.2202	0.65	2.5	7.5	5.65	3.63	2.02
DARBHATHOTTY	Elamdesam	KOW	Hb-Biotite gneiss	9.9660	76.8121	0.7	2.6	8.55	8.15	NA	NA
Devikulam	Devikulam	GWMW	Granite gneiss	10.0648	77.1078	0.8	2	4.56	3.4	2.75	0.65
EDADU	Idukki	KOW	Charnockite	9.7530	76.8644	0.9	1.8	6.5	6.3	5	1.3
EDAVETTI	Thodupuzha	KOW	Charnockite	9.8934	76.7435	0.9	2.7	8.7	8.3	NA	NA
Elamdesom	Elamdesam	GWMW	Hb-Biotite Gneiss	9.8711	76.7929	0.8	2.5	8.5	7.5	5.17	2.33
Elappara	Azhutha	GWMW	Charnockite	9.6324	76.9793	0.88	3.16	5.65	1.57	1.62	-0.05
ELAPPARA	Azhutha	KOW	Charnockite	9.7340	76.8682	0.8	3.3*3.3 (Sq.Well)	5.2	2.3	NA	NA
ERATTAYAR	Kattappana	KOW	Hb-Biotite gneiss	9.7924	77.1117	0.7	2.5	7.3	7.05	NA	NA
Idukki	Idukki	GWMW	Hb-Biotite Gneiss	9.8471	76.9810	0.75	2.6	7.8	4.81	3.2	1.61
IDUKKI-8TH MILE	Idukki	KOW	Charnockite	9.8090	77.0456	0.75	2.8	17.95	17.45	NA	NA
INCHIYANI	Elamdesam	KOW	Hb-Biotite gneiss	9.8648	76.7645	0.8	1.7	3.65	3	2.6	0.4
Irattayar	Kattappana	GWMW	Hb-Biotite Gneiss	9.7977	77.1048	0.8	3	5.3	3	2.3	0.7
Kaliyar	Elamdesam	GWMW	Hb-Biotite Gneiss	9.9751	76.7818	0.8	2.5	8.37	5.73	4.6	1.13
KALLUPALAM	Nedumkandam	KOW	Charnockite	9.8873	77.1845	0.6	1.7	2.7	2	NA	NA
Kanchiyar	Kattappana	GWMW	Charnockite	9.7497	77.0871	0.7	2.3	12.2	NA	10.1	NA
Karimkunnam	Thodupuzha	GWMW	Charnockite	9.8539	76.6879	0.7	2.74	6.1	3.2	2.8	0.4
Karimkunnam	Thodupuzha	PZ	Charnockite	9.8517	76.6869	0.8	0.152	33	2.55	2.4	0.15
Karumannur	Elamdesam	GWMW	Hb-Biotite Gneiss	9.9207	76.7782	0.8	3.17	5.75	4.05	2.8	1.25
Karumannur	Elamdesam	PZ	Hb-Biotite gneiss	9.9205	76.7782	0.74	0.152	26	4.27	3.06	1.21
Kattappana	Kattappana	GWMW	Charnockite	9.7550	77.1163	0.7	2.5	4.9	3.7	2.25	1.45
Kattappana	Kattappana	PZ	Charnockite	9.7535	77.1087	0.66	0.152		11.2	7.99	3.21

Location	Block	TYPE	Geology	Latitude	Longitude	MP (Magl)	Diameter (m)	Depth	pre wl (mbgl) 2019	post wl (mbgl) 2019	Fluctiation 2019 (m)
K-CHAPPATH	Azhutha	KOW	Charnockite	9.6652	77.0222	0.8	4.7	4.85	2.1	2	0.1
KEERITHODE	Nedumkandam	KOW	Charnockite	9.9000	77.1258	0.81	12.3	5.3	2.5	NA	NA
Kochera	Kattappana	GWMW	Charnockite	9.7062	77.1913	0.7	2.8	5.3	4.25	3.75	0.5
Kodikulam East	Elamdesam	GWMW	Hb-Biotite Gneiss	9.9484	76.7649	0.8	2.75	10	6.25	4.2	2.05
Koilkadavu	Devikulam	GWMW	Hb-Biotite Gneiss	10.2495	77.1713	0.75	2	6.36	6.1	1.15	4.95
Kolani	Thodupuzha	GWMW	Charnockite	9.8874	76.6980	1.2	2.5	7	5.15	2.8	2.35
Kolapra	Elamdesam	GWMW	Charnockite	9.8286	76.7763	0.8	2.75	6.88	5.05	4.1	0.95
KUDAYATHOOR	Elamdesam	KOW	Charnockite	9.8222	76.8001	0.6	1.65	6.1	4.2	3.2	1
Kulamavu	Idukki	GWMW	Hb-Biotite Gneiss	9.7934	76.8926	0.7	4.2	10	8.4	5.4	3
Kumaramangalam	Thodupuzha	GWMW	Charnockite	9.9360	76.7082	0.6	2.5	5.44	4.22	3.8	0.42
kumily	Azhutha	GWMW	Charnockite	9.6121	77.1571	0.75	2.1	5.7	3.5	1.65	1.85
KUNINJI	Thodupuzha	KOW	Charnockite	9.8482	76.6487	0.8	1.7	8.1	7.5	NA	NA
kuttikkanam	Azhutha	GWMW	Charnockite	9.5801	76.9704	0.6	2.4	9.1	7.18	NA	NA
Machiplavu	Adimaly	GWMW	Hb-Biotite Gneiss	10.0227	76.9105	0.7	2.75	13	12.27	6.55	5.72
Manjapra	Idukki	GWMW	Hb-Biotite Gneiss	9.8862	76.9672	1.2	2	3.8	2.65	1.2	1.45
Marayur	Devikulam	GWMW	Hb-Biotite Gneiss	10.2768	77.1632	0.8	1.35	6.77	3	2.17	0.83
Marykulam	Kattappana	GWMW	Charnockite	9.6961	77.0367	1	2.5	9	7.07	6.1	0.97
MATTUPPETTY	Devikulam	KOW	Hb-Biotite gneiss	10.1038	77.1179	1	4.5*4.5 (Sq.Well)	2.75	0.18	NA	NA
Memala	Azhutha	GWMW	Charnockite	9.6129	76.9690	0.45	2.7	6.5	NA	3.95	NA
MOOLAMATTAM	Idukki	KOW	Charnockite	9.7886	76.8520	0.6	1.1	3.5	3.3	NA	NA
Moolamattom	Idukki	GWMW	Hb-Biotite Gneiss	9.7985	76.8453	0.7	2.3	7.38	5.65	5.02	0.63
MULLARINGAD	Elamdesam	KOW	Hb-Biotite gneiss	10.0043	76.8107	0.5	1.2	3.8	3.1	NA	NA

Location	Block	TYPE	Geology	Latitude	Longitude	MP (Magl)	Diameter (m)	Depth	pre wl (mbgl) 2019	post wl (mbgl) 2019	Fluctiation 2019 (m)
Mundiyeruma	Nedumkandam	GWMW	Charnockite	9.8183	77.1820	0.9	1.3	7	6	4.65	1.35
Mundiyeruma	Nedumkandam	PZ	Charnockite	9.8182	77.1821	0.6	0.152	6.5	NA	4.85	NA
Munnar	Devikulam	GWMW	Hb-Biotite Gneiss	10.0874	77.0672	0.7	1.6	4.35	1.9	1	0.9
Murikkasserry	Idukki	GWMW	Hb-Biotite Gneiss	9.9119	77.0093	0.8	1.85	15	11.12	9.88	1.24
Murukkady	Azhutha	GWMW	Charnockite	9.6178	77.1377	0.8	2.9	8	7.1	3.3	3.8
MUTHALAKODAM	Thodupuzha	KOW	Charnockite	9.9083	76.7307	0.7	2.65	7.4	6.8	4.9	1.9
MUTHIYURUNDAYAR	Idukki	KOW	Hb-Biotite gneiss	9.8085	76.8885	0	2.3	4.66	4.55	NA	NA
NADUKANI	Idukki	KOW	Hb-Biotite gneiss	9.7980	76.8677	0.6	3.4	8.1	7.7	5.7	2
NEDIYASALA	Thodupuzha	KOW	Charnockite	9.8847	76.6790	0.7	1.2	6.7	5.22	4	1.22
Nedumakandam	Nedumkandam	GWMW	Charnockite	9.8368	77.1606	0.7	1.9	6.6	4.5	3.12	1.38
Nirmalam city	Kattappana	GWMW	Charnockite	9.7833	77.0733	0.8	2.9	4	2	0.7	1.3
Njarkutty	Elamdesam	GWMW	hb-Biotite Gneiss	9.9253	76.7494	0.7	2.5	4.5	3.4	1.8	1.6
Pambadumpara	Nedumkandam	GWMW	Charnockite	9.7959	77.1595	0.94	2.4	5.73	4.36	2.31	2.05
Pambanar	Azhutha	GWMW	Charnockite	9.5780	77.0149	0.63	3.2	6.5	2.1	0.85	1.25
Pannimattom	Elamdesam	GWMW	Hb-Biotite Gneiss	9.8482	76.8285	0.8	3	5.27	4.05	2.9	1.15
PARATHODE	Nedumkandam	KOW	Charnockite	9.8736	77.1641	0.8	2.6	2.2	1	NA	NA
PAZHAYAMATTAM	Thodupuzha	KOW	Charnockite	9.8385	76.7127	0.8	2.5	7.3	5.7	4.96	0.74
Peerumedu	Azhutha	GWMW	Charnockite	9.5741	76.9917	0.7	1.7	5	2.88	2.75	0.13
Perumuttom	Thodupuzha	GWMW	Charnockite	9.8535	76.7370	0.75	2.15	8.68	2.78	4.32	-1.54
Peruvanthanam	Azhutha	GWMW	Charnockite	9.5385	76.9129	1	2.8	10.5	8.75	0	8.75
Pooppara	Devikulam	GWMW	Charnockite	9.9769	77.1989	0.8	2.4	4.8	1.56	0.75	0.81
POOPPARA	Devikulam	KOW	Granite Gneiss	9.9966	77.1994	0.55	14.7	5.25	4.85	NA	NA
POTHINKANDAM	Nedumkandam	KOW	Charnockite	9.7487	77.1860	0	2.3	5.1	4.3	3.05	1.25

Location	Block	TYPE	Geology	Latitude	Longitude	MP (Magl)	Diameter (m)	Depth	pre wl (mbgl) 2019	post wl (mbgl) 2019	Fluctiation 2019 (m)
PURAPPUZHA	Thodupuzha	KOW	Charnockite	9.8697	76.6690	0.68	2.6	5.72	2.62	2.2	0.42
PUTTADI	Kattappana	KOW	Hb-Biotite gneiss	9.6981	77.1693	0.75	2.5	13.95	13.15	NA	NA
Rajakkad	Nedumkandam	GWMW	Charnockite	9.9646	77.0973	0.8	2.2	14.5	8.98	9.4	-0.42
Rajakumary	Nedumkandam	GWMW	Charnockite	9.9690	77.1540	0.7	2.65	14.5	11.43	NA	NA
SANTHANPARA	Devikulam	KOW	Charnockite	9.9615	77.2171	0.65	1.7	4.15	1.45	NA	NA
THALAYAR	Devikulam	KOW	Hb-Biotite gneiss	10.1640	77.1057	1	1.5	4.1	0.6	0.1	0.5
Thankamani	Idukki	GWMW	Hb-Biotite Gneiss	9.8400	77.0371	0.8	1.2	4.86	2	1.38	0.62
Thankamani	Idukki	PZ	Hb-Biotite gneiss	9.8401	77.0373	0.7	0.152	13	3.43	1.98	1.45
THENKULAM	Elamdesam	KOW	Hb-Biotite gneiss	9.9402	76.8036	0.9	1.1	4.2	3.6	3.1	0.5
Thodupuzha	Thodupuzha	GWMW	Charnockite	9.8983	76.7128	1	2.65	13.51	7.6	6.9	0.7
THOMMANKUTHU	Idukki	KOW	Hb-Biotite gneiss	9.9571	76.9193	0.7	4.3	8.7	6.6	3.1	3.5
Thumbachi	Idukki	GWMW	Hb-Biotite Gneiss	9.8228	76.8385	0.81	2.45	7.9	5.81	2.89	2.92
Udumbanchola	Nedumkandam	GWMW	Charnockite	9.9000	77.1777	0.95	2.92	10.4	9.35	5.35	4
Udumbannur	Elamdesam	GWMW	Hb-Biotite Gneiss	9.9071	76.8206	0.71	2.42	8.9	5.75	3.74	2.01
VAGAMON	Azhutha	KOW	Charnockite	9.6843	76.9053	0.65	2.6	3.85	2.85	NA	NA
Valara	Adimaly	GWMW	Hb-Biotite Gneiss	10.0316	76.8680	0.82	2.6	10.66	9.68	7.28	2.4
VALIYATHOVALA	Nedumkandam	KOW	Charnockite	9.7956	77.1278	0.7	2.6	13.6	11.9	NA	NA
Vallakkadavu	Azhutha	GWMW	Charnockite	9.5264	77.1114	0.8	1.75	6.37	4.72	2.95	1.77
VALLIPPARA	Thodupuzha	KOW	Charnockite	9.8209	76.7419	0.8	2.5	8.1	7	5	2
Vandanmedu	Kattappana	GWMW	Charnockite	9.7192	77.1566	0.8	1.94	3.8	3.59	2.55	1.04
Vandiperiyar	Azhutha	GWMW	Charnockite	9.5725	77.0903	0.7	3.3	10.2	6.75	5.7	1.05
VANDIPERIYAR	Azhutha	KOW	Charnockite	9.5829	77.1132	0.5	2.4	5	3.3	2.2	1.1

Location	Block	TYPE	Geology	Latitude	Longitude	MP (Magl)	Diameter (m)	Depth	pre wl (mbgl) 2019	post wl (mbgl) 2019	Fluctiation 2019 (m)
VAZHAKKALA	Thodupuzha	KOW	Hb-Biotite gneiss	9.9696	76.7329	0.5	2.3	4	3.6	3.1	0.5
Vazhithala	Thodupuzha	GWMW	Charnockite	9.8845	76.6414	0.72	2.75	8	5.48	1.98	3.5
VELLAYAMKUDI	Kattappana	KOW	Charnockite	9.7671	77.0939	0.6	2.6	4.9	4.4	NA	NA
Vellilamkandam	Kattappana	GWMW	Charnockite	9.7129	77.0504	0.75	2.82	7.98	6.28	4.25	2.03
GWMW: Ground Water Monitoring Well, KOW: Key Observation Well											

ANNEXURE-III:DETAILS OF WATER QUALITY MONITORING STATIONS

Sl.No.	Location	Block	Latitude	Longitude	Type	Aquifer	Source
1	Adimaly	Adimaly	10.0133	76.9545	DW/GWMW	Phreatic	DW
2	Adimaly-I	Adimaly	10.0092	76.9600	EW/BW	Deeper	BW
3	Adimaly-II	Adimaly	10.015	76.9425	EW/BW	Deeper	BW
4	Aladi	Kattappana	9.6817	77.0306	EW/BW	Deeper	BW
5	Anikuzha	Elamdesam	9.9465	76.7889	DW/KOW	Phreatic	DW
6	Arakkulam	Idukki	9.8126	76.8240	DW/KOW	Phreatic	DW
7	Arikuzha	Thodupuzha	9.9111	76.6444	EW/BW	Deeper	BW
8	Blathykavala	Elamdesam	9.9724	76.8551	DW/KOW	Phreatic	DW
9	Chemmannur	Nedumkandam	9.9227	77.1629	DW/KOW	Phreatic	DW
10	Chenappara	Thodupuzha	9.8482	76.6487	DW/KOW	Phreatic	DW
11	chenttukuzhy	Kattappana	9.7339	77.1769	DW/KOW	Phreatic	DW
12	Chinikuzhy	Elamdesam	9.8921	76.8413	DW/GWMW	Phreatic	DW
13	Chittur	Thodupuzha	9.9100	76.6762	DW/GWMW	Phreatic	DW
14	Chullikandam	Elamdesam	10.0209	76.7789	EW/BW	Deeper	BW
15	Darkhathotty	Elamdesam	9.9659	76.8121	DW/KOW	Phreatic	DW
16	Edavetty	Thodupuzha	9.8933	76.7434	DW/KOW	Phreatic	DW
17	Elappara	Azhutha	9.7339	76.8681	DW/KOW	Phreatic	DW
18	Elappara	Azhutha	9.6323	76.9792	DW/GWMW	Phreatic	DW
19	Erattayar	Kattappana	9.7944	77.1067	EW/BW	Deeper	BW
20	Erattayar	Kattappana	9.7924	77.1117	DW/KOW	Phreatic	DW
21	Erattayar	Kattappana	9.7977	77.1047	DW/GWMW	Phreatic	DW
22	Idukki	Idukki	9.8470	76.9809	DW/GWMW	Phreatic	DW
23	Idukki 8th mile	Idukki	9.8090	77.0456	DW/KOW	Phreatic	DW
24	Inchiyani	Elamdesam	9.8647	76.7645	DW/KOW	Phreatic	DW
25	Kaliyar	Elamdesam	9.9750	76.7817	DW/GWMW	Phreatic	DW
26	Kallupalam	Nedumkandam	9.8873	77.1845	DW/KOW	Phreatic	DW
27	Karimkulam	Azhutha	9.6651	77.0222	DW/KOW	Phreatic	DW
28	Karimkunnam1	Thodupuzha	9.853905	76.6878	DW/GWMW	Phreatic	DW
29	Kattappana	Kattappana	9.755036	77.1163	DW/GWMW	Phreatic	DW
30	Keerithode	Nedumkandam	9.9000	77.1258	DW/KOW	Phreatic	DW
31	Kulamavu	Idukki	9.7934	76.8925	DW/GWMW	Phreatic	DW
32	Kumaramangalam	Thodupuzha	9.9359	76.7081	DW/GWMW	Phreatic	DW
33	Kumily	Azhutha	9.6120	77.1571	DW/GWMW	Phreatic	DW
34	Kumily-I	Azhutha	9.6111	77.1681	EW/BW	Deeper	BW
35	Kumily-II	Azhutha	9.6047	77.1658	EW/BW	Deeper	BW
36	Kundayathoor	Elamdesam	9.8222	76.8001	DW/KOW	Phreatic	DW
37	Kuttikkanam1	Azhutha	9.5800	76.9704	DW/GWMW	Phreatic	DW
38	Mannamkandam	Adimaly	10.0139	76.9569	EW/BW	Deeper	BW
39	Mattupetty	Devikulam	10.1038	77.1179	DW/KOW	Phreatic	DW
40	Molamattam	Idukki	9.7985	76.8452	DW/GWMW	Phreatic	DW
41	Moolamattom	Idukki	9.785	76.8583	EW/BW	Deeper	BW
42	Moolamattom	Idukki	9.7885	76.8519	DW/KOW	Phreatic	DW
43	Mullarvingad	Elamdesam	10.0042	76.8107	DW/KOW	Phreatic	DW
44	Munnar	Devikulam	10.0874	77.0671	DW/GWMW	Phreatic	DW
45	Muthalakoodam	Thodupuzha	9.9083	76.7307	DW/KOW	Phreatic	DW
46	Muthirundayar	Idukki	9.8084	76.8884	DW/KOW	Phreatic	DW

Sl.No.	Location	Block	Latitude	Longitude	Type	Aquifer	Source
47	Muttam-I	Thodupuzha	9.8458	76.7403	EW/BW	Deeper	BW
48	Nadukani	Idukki	9.7980	76.8676	DW/KOW	Phreatic	DW
49	Nediyasala	Thodupuzha	9.8847	76.6789	DW/KOW	Phreatic	DW
50	Nedumkandam	Nedumkandam	9.8425	77.1528	EW/BW	Deeper	BW
51	Nedumkandam	Nedumkandam	9.8368	77.1605	DW/GWMW	Phreatic	DW
52	Padi-Kodikulam	Elamdesam	9.9431	76.7528	EW/BW	Deeper	BW
53	Parathode	Nedumkandam	9.8736	77.1640	DW/KOW	Phreatic	DW
54	Pazhayamattam	Thodupuzha	9.8384	76.7127	DW/KOW	Phreatic	DW
55	Pooppara	Devikulam	9.9965	77.1994	DW/KOW	Phreatic	DW
56	Pooppara	Devikulam	9.9768	77.1989	DW/GWMW	Phreatic	DW
57	pothinkandam	Nedumkandam	9.7486	77.1859	DW/KOW	Phreatic	DW
58	Purapuzha	Thodupuzha	9.8696	76.6689	DW/KOW	Phreatic	DW
59	Puttady	Kattappana	9.6980	77.1693	DW/KOW	Phreatic	DW
60	Santhanpara	Devikulam	9.9614	77.2170	DW/KOW	Phreatic	DW
61	Thalayar	Devikulam	10.1640	77.1056	DW/KOW	Phreatic	DW
62	Thankamani	Idukki	9.8375	77.0389	EW/BW	Deeper	BW
63	Thenkulam	Elamdesam	9.9402	76.8035	DW/KOW	Phreatic	DW
64	Thodupuzha	Thodupuzha	9.8997	76.6869	EW/BW	Deeper	BW
65	Thommankuthu	Idukki	9.9571	76.9192	DW/KOW	Phreatic	DW
66	Thookkupalam	Nedumkandam	9.8117	77.1964	EW/BW	Deeper	BW
67	Udumbanchola	Nedumkandam	9.8994	77.1806	EW/BW	Deeper	BW
68	Upputhara	Kattappana	9.6986	77.0208	EW/BW	Deeper	BW
69	Vagamon	Azhutha	9.6843	76.9052	DW/KOW	Phreatic	DW
70	Valiyathovala	Nedumkandam	9.7955	77.1277	DW/KOW	Phreatic	DW
71	Vallakkadavu	Azhutha	9.5250	77.1139	EW/BW	Deeper	BW
72	Vallippara	Thodupuzha	9.8209	76.7418	DW/KOW	Phreatic	DW
73	Vandanmedu	Kattappana	9.7167	77.1389	EW/BW	Deeper	BW
74	Vandanmedu	Kattappana	9.7191	77.1566	DW/GWMW	Phreatic	DW
75	Vandiperiyar	Azhutha	9.5828	77.1132	DW/KOW	Phreatic	DW
76	Vandiperiyar	Azhutha	9.5724	77.0903	DW/GWMW	Phreatic	DW
77	Vandiperiyar-I	Azhutha	9.5722	77.088	EW/BW	Deeper	BW
78	Vandiperiyar-II	Azhutha	9.5722	77.088	EW/BW	Deeper	BW
79	Vannapuram	Elamdesam	9.9875	76.79	EW/BW	Deeper	BW
80	Vazhakkala	Thodupuzha	9.9696	76.732	DW/KOW	Phreatic	DW
81	Vellayamkudi	Kattappana	9.7670	77.093	DW/KOW	Phreatic	DW
82	Vellilamkandam	Kattappana	9.7128	77.050	DW/GWMW	Phreatic	DW

DW:Dug Well, GWMW:Ground Water Monitoring Wells,KOW:Key Observation Well,EW:ExploratoryWells, BW:Bore Well

ANNEXURE-IV:DATA AND INTERPRETED RESULTS OF SOIL INFILTRATION TESTS IN IDUKKI DISTRICT

<u>Site-I</u>

Date:19.02.2020

Project Name: NAQUIM, Hard rock areas of Idukki District

Location Details : In the premises Private Agricultural Farm, Pallippeedika, Thodupuzha, Idukki

Longitude: 76.7064, Latitude:9.9176

Soil Type: Gravelly Clay, Geology: Laterite

Site belongs: Private

Time since start(min)	Cumulative infiltration depth (cm)	Time Interval (min)	Incremental depth in interval (cm)	Infiltration rate (cm/hr) fp
1	1.3	1	1.3	78
2	2.3	1	1	60
3	3.3	1	1	60
4	4.1	1	0.8	48
5	4.9	1	0.8	48
6	5.6	1	0.7	42
7	6.3	1	0.7	42
8	6.9	1	0.6	36
9	7.8	1	0.9	54
10	8.4	1	0.6	36
12	9.1	2	0.7	21
14	10.6	2	1.5	45
16	11.3	2	0.7	21
18	12.1	2	0.8	24
20	12.9	2	0.8	24
25	15	5	2.1	25.2
30	18	5	3	36
35	20.7	5	2.7	32.4
40	23.6	5	2.9	34.8
45	26.3	5	2.7	32.4
50	27.6	5	1.3	15.6
55	29.4	5	1.8	21.6
60	30.9	5	1.5	18
65	32.7	5	1.8	21.6
70	34.2	5	1.5	18
75	35.8	5	1.6	19.2
80	37.6	5	1.8	21.6
85	39	5	1.4	16.8
90	40.3	5	1.3	15.6
95	41.6	5	1.3	15.6
100	42.9	5	1.3	15.6
105	44.2	5	1.3	15.6

Time since start(min)	Cumulative infiltration depth (cm)	Time Interval (min)	Incremental depth in interval (cm)	Infiltration rate (cm/hr) fp
110	45.5	5	1.3	15.6
115	46.8	5	1.3	15.6

Site-II

Date:19.02.2020

Project Name: NAQUIM,Hard rock areas of Idukki District

Location Details : In the premises of Forest Section Office, Chullikkandam, Idukki,

Longitude: 76.7793

Latitude:10.0188

Soil Type: Loam Geology:Weathered Hb-Biotite Gneiss

Site belongs: Govt.Land

Time since start(min)	Cumulative infiltration depth (cm)	Time Interval (min)	Incremental depth in interval (cm)	Infiltration rate (cm/hr) fp
1	1.1	1	1.1	66
2	1.9	1	0.8	48
3	2.6	1	0.7	42
4	3.3	1	0.7	42
5	3.8	1	0.5	30
6	4.4	1	0.6	36
7	5.1	1	0.7	42
8	5.6	1	0.5	30
9	5.9	1	0.3	18
10	6.5	1	0.6	36
12	7.6	2	1.1	33
14	8	2	0.4	12
16	8.8	2	0.8	24
18	9.5	2	0.7	21
20	10.2	2	0.7	21
25	11.7	5	1.5	18
30	14	5	2.3	27.6
35	15.5	5	1.5	18
40	17	5	1.5	18
45	18.6	5	1.6	19.2
50	20	5	1.4	16.8
55	21.1	5	1.1	13.2

Time since start(min)	Cumulative infiltration depth (cm)	Time Interval (min)	Incremental depth in interval (cm)	Infiltration rate (cm/hr) fp
60	22.3	5	1.2	14.4
65	23.6	5	1.3	15.6
70	24.7	5	1.1	13.2
75	25.7	5	1	12
80	26.6	5	0.9	10.8
90	28.1	10	1.5	9
100	29.6	10	1.5	9
110	31.1	10	1.5	9
120	32.6	10	1.5	9

Site-III

Date:20.02.2020

Project Name: NAQUIM,Hard rock areas of Idukki District

Location Details : In the premises of Cardomom Research Station, Pampadumpara, Idukki dustrict

Longitude: 77.1617

Latitude: 9.7974

Soil Type: Clay, Geology:Weathered Charnockite

Site belongs: Govt. Land

Time since start(min)	Cumulative infiltration depth (cm)	Time Interval (min)	Incremental depth in interval (cm)	Infiltration rate (cm/hr) fp
1	1	1	1	60
2	1.7	1	0.7	42
3	2.2	1	0.5	30
4	3	1	0.8	48
5	3.5	1	0.5	30
6	4.2	1	0.7	42
7	4.9	1	0.7	42
8	5.1	1	0.2	12
9	5.3	1	0.2	12
10	6.4	1	1.1	66
12	7.2	2	0.8	24
14	8.2	2	1	30
16	9.2	2	1	30
18	9.5	2	0.3	9
20	10.5	2	1	30

Time since start(min)	Cumulative infiltration depth (cm)	Time Interval (min)	Incremental depth in interval (cm)	Infiltration rate (cm/hr) fp
25	11.5	5	1	12
30	13.4	5	1.9	22.8
35	15	5	1.6	19.2
40	16	5	1	12
45	17	5	1	12
50	18.5	5	1.5	18
60	19.9	10	1.4	8.4
70	21.9	10	2	12
80	23.9	10	2	12
90	25.9	10	2	12
100	27.9	10	2	12

ANNEXURE-V:DETAILS OF VERTICAL ELECTRICAL SOUNDINGS CONDUCTED IN THE STUDY AREA

Sl.No.	Location	Long	Lat	Interpreted results											Depth to Massive	Total Depth	Remarks
				r_1	r_2	r_3	r_4	r_5	r_6	h_1	h_2	h_3	h_4	h_5			
1	Muttom-1	76.7367	9.84309	2399	487.9	1492	1032			0.3	4.4	34.3			4.7	38.98	Recommended
2	Muttom-2	76.737116	9.843182	1472	2131	5035				2.6	44.4					46.99	
3	Muttom-3	76.736403	9.842501	1846	4493	666	VH	27.6		2.2	1.1	3.8	13.6		7.1	20.73	
4	Purapuzha	76.6733	9.865	617.2	1560	420.3	5451			1.5	1.1	10.3			12.9	12.94	Recommended
5	Purapuzha-1	76.67313	9.86477	203	5294	200	2866			0.7	0.9	2.8			4.4	4.36	
6	Adimali 110 KV KSEB 1	76.94	10.0143	**Data not interpretable**													
7	Adimali 110 KV KSEB 2	76.9397	10.0144	1155	279	99	7903			2.1	7.2	4.5	8.7		18	22.5	
8	Adimali 110 KV KSEB 3	76.9396	10.0145	858	292	1552	118	5006		1	1	2.5	10.5		15	15	
9	Adimali GHS 1	76.957	10.0139	252	345	162	851	99		1	3.4	7.3	20.4		12	32.1	
10	Adimali GHS 2	76.956	10.0141	335	1219	414	1204	35	VH	2	1.6	3.5	5.4	6.3	18.5	18.8	Recommended
11	Mangattukavala	76.72526	9.89857	1310	417.5	2845	22.49			2.0	9.7	16.4			11.66	28.1	Recommended
12	Muthalakodam 1	76.73011	9.91148	398.8	2173	505.6	1780			1.0	1.4	2.7				5.1	
13	Muthalakodam 2	76.73023	9.91168	367	7783	198	21732	64.4		0.7	1.3	5.9	6.6			14.4	
14	Manakkadu 1	76.69041	9.90329	4745	237.6	2083				0.4	8.0				8.35	8.4	
15	Manakkadu 2	76.69037	9.90331	489.6	218.6	1515				0.9	5.6					6.5	
16	Manakkadu 3	76.69071	9.90339	679	1744	673	74696			0.3	3.5	27.9			31.74	31.7	Recommended

ANNEXURE-VI:RESULTS OF WATER QUALITY ANALYSIS DATA IN IDUKKI DISTRICT

Sl No.	Site Name	Block	Latitude	Longitude	Source	pH	EC (µS/cm)	CO3	HCO3	Cl	SO4	NO3	F	Total Hardness	Ca	Mg	Na	K
								<---------- Conc.in mg/L ---------->										
1	Adimali	Adimali	10.0092	76.9600	BW/EW	7.7	285	0	172	10.6	2.2	0	0.59	133	36	10.6	7.2	1.1
2	Adimali	Adimali	10.0150	76.9425	BW/EW	6.26	162	0	68	9.9	3	1.7	0	48	15	2.4	7	3.4
3	Adimaly	Adimali	10.0133	76.9546	DW/GWMW	7.69	180		7.32	36.92	2.6	12.1	0	30	1.6032	6.3232	17.5	2.7
4	Aladi	Kattappana	9.6817	77.0306	BW/EW	7.4	280	0	169	10.6	1.6	0	0.57	124	30	11.6	10.6	0
5	Anikuzha	Elamdesam	9.9465	76.7889	DW/KOW	5.85	97		4.88	7.1	2.5	10.2	0.47	10	3.2064	0.4864	4.5	10.27
6	Arakkulam	Idukki	9.8126	76.8240	DW/KOW	5.71	115		14.64	17.04	3.7	28.4	0.01	38	6.4128	5.3504	8.47	4.2
7	Arikuzha	Thodupuzha	9.9111	76.6444	BW/EW	8.07	280	0	161	7.1	2.4	0.2	0.17	118	25	14	8.3	2.2
8	Blathykavala	Elamdesam	9.9724	76.8551	DW/KOW	5.78	73		7.32	8.52	0.74	19.4	0.4	16	5.6112	0.4864	4.26	2.19
9	Chemmannur	Nedumkandam	9.9227	77.1629	DW/KOW	6.96	220		26.84	38.34	0.42	30.3	0.24	75	13.6272	9.9712	8.68	6.25
10	Chenappara	Thodupuzha	9.8482	76.6487	DW/KOW	5.84	46		19.52	5.68	0.23	0.72	0	16	4.008	1.4592	2.01	0.53
11	chenttukuzhy	Kattappana	9.7340	77.1770	DW/KOW	6.98	400		156.16	88.04	31.05	0.3	0	84	19.2384	8.7552	53	4.7
12	Chinikuzhy	Elamdesam	9.8922	76.8413	DW/GWMW	7.28	92		26.84	7.1	1.28	18	0	30	11.2224	0.4864	4.33	6.3

Sl No.	Site Name	Block	Latitude	Longitude	Source	pH	EC (µS/cm)	CO3	HCO3	Cl	SO4	NO3	F	Total Hardness	Ca	Mg	Na	K
								<---------- Conc.in mg/L ---------->										
13	Chittur	Thodupuzha	9.9101	76.6762	DW/GWMW	7.25	45		21.96	8.52	0	3.3	0	14	4.008	0.9728	4.1	1.12
14	Darkhathotty	Elamdesam	9.9660	76.8121	DW/KOW	5.94	77		24.4	8.52	1.1	7.8	0.05	22	8.016	0.4864	4.9	1.16
15	Edavetty	Thodupuzha	9.8934	76.7435	DW/KOW	5.83	143		9.76	15.62	0.92	38.5	0	24	8.016	0.9728	11.34	1.44
16	Elappara	Azhutha	9.7340	76.8682	DW/KOW	6.84	44		9.76	8.52	0	7.02	0	14	3.2064	1.4592	4.1	2.11
17	Elappara	Azhutha	9.6324	76.9793	DW/GWMW	7	161		14.64	31.24	1.63	25.8	0	44	10.4208	4.3776	11.7	5.7
18	Erattayar	Kattappana	9.7944	77.1067	BW/EW	7	615	0	154	78	14	27	0.39	182	49	14.5	54	3
19	Erattayar	Kattappana	9.7924	77.1117	DW/KOW	6.61	168		65.88	17.04	7.74	1.5	0	60	8.016	9.728	5.1	1.6
20	Erattayar	Kattappana	9.7977	77.1048	DW/GWMW	7.28	250		26.84	29.82	29.9	50	0	28	6.4128	2.9184	47.2	3.5
21	Idukki	Idukki	9.8471	76.9810	DW/GWMW	7.14	75		26.84	12.78	0	6.5	0	30	5.6112	3.8912	7.22	2
22	Idukki 8th mile	Idukki	9.8090	77.0456	DW/KOW	5.07	42		9.76	9.94	1.7	4.24	0.27	15	0.8016	3.1616	3.88	1.45
23	Inchiyani	Elamdesam	9.8648	76.7645	DW/KOW	5.73	84		10	11	0.6	34.8	0.13	28	6	2.9	5.3	1.8
24	Kaliyar	Elamdesam	9.9751	76.7818	DW/GWMW	7.16	126		29	17	4.3	17.2	0.00	40	11	2.9	9.2	5.6

Sl No.	Site Name	Block	Latitude	Longitude	Source	pH	EC (µS/cm)	CO3	HCO3	Cl	SO4	NO3	F	Total Hardness	Ca	Mg	Na	K
								<---------- Conc.in mg/L ---------->										
25	Kallupalam	Nedumkandam	9.8873	77.1845	DW/KOW	6.63	193		83	20	1.7	3.8	0.43	58	15	4.9	7.4	2
26	Karimkulam	Azhutha	9.6652	77.0222	DW/KOW	6.57	100		41	13	0.71	9.0	0.00	55	7.2	9.0	3.3	1.8
27	Karimkunnam1	Thodupuzha	9.8539	76.6879	DW/GWMW	7.21	200		49	26	17.4	29.8	0.00	48	12	4.4	13.4	6.4
28	Kattappana	Kattappana	9.7550	77.1163	DW/GWMW	2.98	600		0	92	0	117.0	0.00	100	24	9.7	57.4	20.2
29	Keerithode	Nedumkandam	9.9000	77.1258	DW/KOW	6.92	144		49	17	1.56	9.8	0.25	40	2	8.3	18.7	3
30	Kulamavu	Idukki	9.7934	76.8926	DW/GWMW	6.68	145		12	26	12.2	41.5	0.00	40	10	3.9	14.1	3.6
31	Kumaramangalam	Thodupuzha	9.9360	76.7082	DW/GWMW	6.64	86		12	21	2.35	12.1	0.00	22	6	1.9	7.6	2
32	Kumili	Azhutha	9.6111	77.1681	BW/EW	8.24	388	4.8	246	6	2.2	1	0.30	154	38.0	14.0	21.0	1.9
33	Kumily	Azhutha	9.6047	77.1658	BW/EW	6.8	505	0	233.0	39	10	0	0.31	89	24.0	6.8	72.0	3.5
34	Kumily	Azhutha	9.6121	77.1571	DW/GWMW	7.76	450		128	71	21.6	22.4	0.00	160	28.1	21.9	33.1	2.1
35	Kundayathoor	Elamdesam	9.8222	76.8001	DW/KOW	5.87	61		15	9	1.29	2.3	0.00	14	4.8	0.5	3.5	2.3

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								<---------- Conc.in mg/L ---------->										
36	Kuttikkanam 1	Azhutha	9.5801	76.9704	DW/GWMW	7.35	192		41	40	1.81	1.31	0.00	46	13	3.4	15.5	4.9
37	Mannamkandam	Adimali	10.0139	76.9569	BW/EW	7.5	680	0	177.0	7	175	1.2	0.58	230	68.0	15.0	30.0	2.1
38	Mattupetty	Devikulam	10.1038	77.1179	DW/KOW	6.01	71		10	13	0	10.6	0.54	24	5.6	2.4	2.2	1.8
39	Molamattam	Idukki	9.7985	76.8453	DW/GWMW	7.03	90		27	11	2.8	9.2	0.00	28	8	1.9	6.4	1.1
40	Moolamattom	Idukki	9.7850	76.8583	BW/EW	7.4	270	0	161	11	3.5	0.0	0.29	112	29	9.8	9.9	1
41	Moolamattom	Idukki	9.7886	76.8520	DW/KOW	7.05	50		17	9	1.25	1.4	0.00	14	4.8	0.5	7.6	1.4
42	Mullarvingad	Elamdesam	10.0043	76.8107	DW/KOW	5.8	49		10	10	0.79	4.5	0.00	20	2.4	3.4	3.3	0.7
43	Munnar	Devikulam	10.0874	77.0672	DW/GWMW	7.04	115		22	26	0	5.2	0.00	26	6	2.4	12.0	3.6
44	Muthalakoodam	Thodupuzha	9.9083	76.7307	DW/KOW	5.87	114		12	17	0.42	18.1	0.04	20	5.6	1.5	9.4	1.9
45	Muthirundayar	Idukki	9.8085	76.8885	DW/KOW	6.01	390		29.3	101	5.23	31.5	0.17	170	21.6	28.2	5.1	11.3
46	Muttam	Thodupuzha	9.8458	76.7403	BW/EW	7.1	275	0	154	7	9.4	1.0	0.30	110	27	10.0	10.0	1.7
47	Nadukani	Idukki	9.7980	76.8677	DW/KOW	6.92	190		124	9	4.27	1.6	0.22	42	6	6.8	36.1	0.4

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								<---------- Conc.in mg/L ---------->										
48	Nediyasala	Thodupuzha	9.8847	76.6790	DW/KOW	6.66	148		32	16	1.25	3.7	0.00	32	12.8	0.0	3.8	10.8
49	Nedumkandam	Nedumkandam	9.8368	77.1606	DW/GWMW	7.94	440		128	60	15.7	19.0	0.08	140	46.1	6.1	34.9	7.9
50	Nedunkandam	Nedumkandam	9.8425	77.1528	BW/EW	7.5	875	0	251	25	90	0.0	0.98	12	3.2	1.0	147.0	0.0
51	Padikodikulam	Elamdesam	9.9431	76.7528	BW/EW	8.14	323	0	188	3	0.9	0.2	0.24	126	32	11	13.0	4.2
52	Parathode	Nedumkandam	9.8736	77.1641	DW/KOW	6.73	116		12	33	0.5	3.5	0.15	54	7.2	8.8	7.5	2.0
53	Pazhayamattam	Thodupuzha	9.8385	76.7127	DW/KOW	5.76	58		17	7	0.72	5.6	0.00	14	3	1.5	4.3	1.6
54	Pooppara	Devikulam	9.9966	77.1994	DW/KOW	6.16	128		39	16	4.24	9.3	0.27	40	7	5.4	5.2	3.0
55	Pooppara	Devikulam	9.9769	77.1989	DW/GWMW	7.52	460		61	64	9.28	10.2	0.00	110	28	9.7	43.5	13.8
56	pothinkandam	Nedumkandam	9.7487	77.1860	DW/KOW	7.18	280		107.36	53.96	3.85	2.1	0	104	22.4448	11.6736	13.4	1.3
57	Purapuzha	Thodupuzha	9.8697	76.6690	DW/KOW	6.03	64		19.52	12.78	1.41	1.7	0	26	5.6112	2.9184	3.6	2.35
58	Puttady	Kattappana	9.6981	77.1693	DW/KOW	7.12	38		17.08	15.62	0	0.5	0	16	2.4048	2.432	10	2.9
59	Santhanpara	Devikulam	9.9615	77.2171	DW/KOW	6.32	170		80.52	17.04	2.1	2.3	0.15	54	17.6352	2.432	8.55	2.4

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								<---------- Conc.in mg/L ---------->										
60	Thalayar	Devikulam	10.1640	77.1057	DW/KOW	6.03	81		24.4	5.68	1.13	0.2	0.24	18	0.8016	3.8912	2.5	2.08
61	Thankamani	Idukki	9.8375	77.0389	BW/EW	7.03	272	0	107	27	6	0.4	0.11	102	20	13	8.4	3.7
62	Thenkulam	Elamdesam	9.9402	76.8036	DW/KOW	5.81	40		20	4.26	0.31	0.3	0.29	20	5.6112	1.46	1.9	0.7
63	Thodupuzha	Thodupuzha	9.8997	76.6869	BW/EW	7.22	270	0	188	5.7	1.7	9.8	0	106	18	15.00	21	3.2
64	Thommankuthu	Idukki	9.9571	76.9193	DW/KOW	5.71	40		2	4.3	0	2.7	0.11	6	2.4048	0.00	2.22	0.76
65	Thukkupalam	Nedumkandam	9.8117	77.1964	BW/EW	7.8	440	0	255	24.8	11	0.0	0.53	175	38	20.00	19.5	0.4
66	Udumbancholа	Nedumkandam	9.8994	77.1806	BW/EW	8.1	295	0	165	21.3	5.2	0.0	0.49	138	28	16.50	9.7	1.7
67	Upputhara	Kattappana	9.6986	77.0208	BW/EW	8.22	385	2.4	173	7.1	45	0.2	0.39	134	30	14.00	24	1.50
68	Vagamon	Azhutha	9.6843	76.9053	DW/KOW	6.67	63		20	9.9	0.58	8.4	0	24	7.2144	1.46	2.83	1.56
69	Valiyathovala	Nedumkandam	9.7956	77.1278	DW/KOW	6.81	162		83	11.4	0	11.0	0	60	6.4128	10.70	17.1	1.3
70	Vallakadavu	Azhutha	9.5250	77.1139	BW/EW	8.04	683	0	189	11.00	160	0.0	0.54	75	20	6.10	114	1.3
71	Vallippara	Thodupuzha	9.8209	76.7419	DW/KOW	5.68	64		15	7.1	1	5.2	0.33	10	3.2064	0.49	4.61	3.3
72	Vandanmedu	Kattappana	9.7167	77.1389	BW/EW	7.7	221	0	122	4.3	4	1.2	0.17	76	16	8.80	12	3.5

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73	Vandanmedu	Kattappana	9.7192	77.1566	DW/GWMW	6.87	121		10	22.7	7.12	22.4	0.09	24	4.8096	2.92	11.1	5.3
74	Vandiperiyar	Azhutha	9.5829	77.1132	DW/KOW	7.23	390		41	38.3	4	25.2	0	102	8.02	19.94	14	1.64
75	Vandiperiyar	Azhutha	9.5725	77.0903	DW/GWMW	7.01	550		43	88.8	20.2	97.5	0	100	22.044	10.94	51.2	32
76	Vandiperiyar-I	Azhutha	9.5722	77.0889	BW/EW	7.87	369	0	210	13.0	2.2	0.2	0.25	152	33	17.00	13	2.6
77	Vandiperiyar-II	Azhutha	9.5689	77.0875	BW/EW	7.5	265	0	126	21.30	10.2	0.0	0.27	99	26	8.80	9.2	0
78	Vannapuram	Elamdesam	9.9875	76.7900	BW/EW	8.2	325	0	165	10.60	4.8	2.1	0.37	118	30	10.70	15	12
79	Vazhakkala	Thodupuzha	9.9696	76.7329	DW/KOW	5.97	44		12	2.84	1.21	5.7	0.05	12	2.4048	1.46	3.12	0.62
80	Vellayamkudi	Kattappana	9.7671	77.0939	DW/KOW	6.65	53		12	1.42	1	7.7	0.34	20	2.4048	3.40	0.01	2.26
81	Vellilamkandam	Kattappana	9.7129	77.0504	DW/GWMW	7	73		15	17.04	0	4.5	0	16	3.2064	1.95	7.2	2.9