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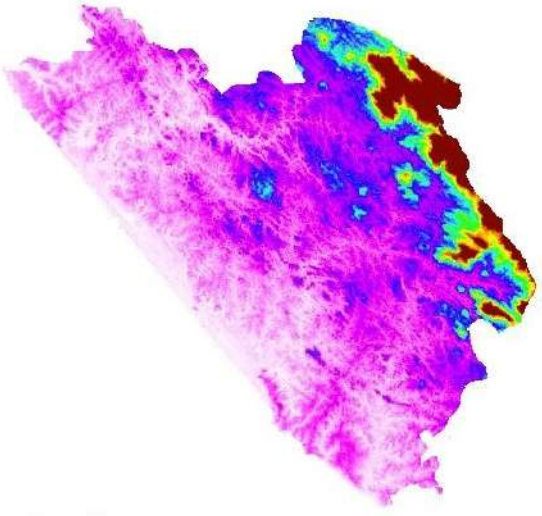
CENTRAL GROUND WATER BOARD
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
GOVERNMENT OF INDIA
KERALA REGION

AQUIFER MAPPING AND MANAGEMENT PLAN OF THIRUVANANTHAPURAM DISTRICT, KERALA



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/THIRUVANATHAPURAM
/MARCH 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 and 300 m depth in sedimentary 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 Thiruvananthapuram district.

The report titled "Aquifer Mapping and Management plan, Thiruvananthapuram district, Kerala" gives a complete and detailed scientific account of the various aspects of the hard rock and soft rock aquifers in the district including its vertical and horizontal dimensions, flow directions, quantum and quality of the resources, of both - the shallow and deeper zones in the aquifer systems. Voluminous data generated on ground water regime, ground water quality, ground water exploration, geophysical studies etc. for detailed analysis. The information is further supplemented by various data collected from Central and 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 holistic solution to the water security problems in Thiruvananthapuram district.

This document has been prepared under the overall guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer, and Sh. M. Santhana Subramani, Scientist C & Team leader. The aquifer mapping studies in coastal sedimentary areas of Thiruvananthapuram district was carried out by Smt. Rani V.R, Scientist C and hard rock areas by Smt. Anisha K, Scientist B. The painstaking efforts of the field hydrogeologists in carrying out the aquifer mapping and preparation of this final report are well appreciated. Smt. Anu V, Scientist B deserves appreciation for the meticulous scrutiny of this report before printing. I am thankful to the Chairman and Members of CGWB, Faridabad for their valuable guidance in finalizing this report. 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 Board etc 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, Smt. Tinku Biswal, IAS. The contribution of the committee in improvising the content of this report are 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 Thiruvananthapuram sdistrict.

Thiruvananthapuram,
March 2022

(Dr.A.Subburaj)
Regional Director

AQUIFER MAPPING AND MANAGEMENT PLAN OF THIRUVANATHAPURAM DISTRICT, KERALA

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1.0 INTRODUCTION

1.1 INTRODUCTION

National Project on Aquifer Mapping (NAQUIM) initiated by Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India with a vision to identity and map the aquifers in 1:50,000 scale and evolve an aquifer management plan for sustainable development of groundwater resources in the aquifer systems. Thereafter, based on the outcome of aquifer mapping, a micro-level aquifer mapping and management plan is envisaged at village/grama panchayat level with institutional arrangements for participatory management of the groundwater resources at village level.

The aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and water quality analyses are applied to characterize the quantity, quality and sustainability of ground water resources in aquifers. An aquifer management plan for sustainable development of the ground water resources in the area involving the community participation is finally evolved from the aquifer mapping. Mapping of Thiruvananthapuram district is carried out in two phases, in the first phase coastal tracts of the district were studied in detail (2014-17) and in the second phase the hard rock aquifers were studied as part of the Annual Action Plan 2017-18.

1.2 OBJECTIVES

The National Aquifer Mapping envisages integration of information available on the groundwater regime and its related components such as soil types, agro-climatic conditions, geomorphology, geology, hydrogeology, hydrochemistry, cropping pattern, irrigation, forest cover etc. and formulation of a sustainable groundwater management plan. The groundwater regime data are analysed on a GIS platform for the formulation of a ground water management plan for the aquifer systems.

The main objective of aquifer mapping is to generate an aquifer map of the area in 1:50,000 scale and to develop aquifer management plan for aquifer sustainability. The mapping of aquifer system has the following objectives.

a. Define the aquifer geometry and characterize the aquifer systems
b. Evaluate the spatio-temporal chemical quality of groundwater
c. Identify the quantitative and qualitative issues of the aquifer systems
d. Evaluation of the groundwater resources in each aquifer system
e. Prepare an aquifer map of the area
f. Evolve an effective Aquifer management Plan

1.3 SCOPE OF THE STUDY

The important aspect of the aquifer mapping programme is the synthesis of the large volume of data already generated during specific studies carried out by CGWB and various Government organizations. Data gaps have been identified after proper synthesis and analysis of the available data collected. In order to bridge the data gap, data generation programme has been formulated. The available and newly generated data are assembled, analysed, examined, synthesized and interpreted. Exploration work has been carried out in different segments of the regions and aquifer parameters have been estimated. Groundwater monitoring regime has been strengthened by establishing additional monitoring wells. Thus, finally aquifer maps as well as 2D and 3D sections have been prepared.

Water resources development in hard rock terrain in many parts of Kerala state poses a key issue in the management strategy. The sustainable aspect of the water resources in the state necessitates the need for a better water resources management. The coastal sediments of Kerala consist of multi aquifers of high potential which supports the water requirements of thick population in this area. Because of the peculiar land forms and lithological characteristics, the spatial variation in water availability is high in coastal area of Kerala. The groundwater potential and geometry of the aquifer systems had been studied out earlier for a small part of the area under SIDA assisted groundwater Project during 1980s. Large scale development of groundwater in this area thereafter for water supply has reduced the heads in all piezometers. Moreover, the piezometer network is partially functional now which makes gathering information on the changes in the groundwater scenario a difficult task. Construction of additional piezometers and exploratory wells in data gap areas is essential to understand the present flow regime in the coastal aquifer system.

1.4 APPROACH AND METHODOLOGY

The major activities envisaged under National Aquifer Mapping Programme to achieve the objectives are compilation of data, data gap analysis, data generation, data integration, preparation of thematic maps and development of aquifer models. The data gap analysis primarily involves compilation, analysis and interpretation of the existing data on the groundwater regime. The data inadequacy or data gaps identified from this study forms the base for additional data generation. The existing data and the new data generated under aquifer mapping activities have been integrated and various thematic maps depicting hydrogeology, hydrology, geomorphology, water quality etc. and cross-sections, fence diagrams, elevation models and aquifer geometry (2-D models and 3-D models) were prepared. Based on the above studies, management strategies have been evolved for augmentation of groundwater through water conservation structures and formulated plans for sustainable management of the resource.

1.5 BASIC GEOGRAPHY AND ADMINISTRATION

Thiruvananthapuram, formerly known as Trivandrum, the southern-most district of Kerala houses the State capital. The district falls lies between north latitude 8°17’27” & 8°51’54” and east

longitude 76°40’43” & 77°17’6” covers an area of 2187.97 Sq km of which 245 Sq. km is hilly area. The district is bounded by Arabian Sea on the west, Kollam district on the north and by the state of Tamil Nadu in the east and south. The district stretches 78 km along the shore of Arabian Sea. The area falls in the Survey of India Toposheets 58D/9,10, 13, 14, 15 and 58H/1, 2, 3 & 6 (1:50,000 scale). The area of study covers 11 blocks namely Athiyannur, Chirayinkeezhu, Kilimanoor, Nedumangadu, Nemom, Parassala, Perumkadavila, Pothencode, Vamanapuram, Varkala and Vellanad comprising 73-gram panchayaths, 121 revenue villages, One corporation (Thiruvananthapuram) and four municipality (Attingal, Nedumangadu, Neyyattinkara and Varkala) . The administrative map of the study area is given in **Figure 1.1.**

Population of the district is 33, 07,284 as per 2011 census of which male population is 15, 84,200 and female population is 17, 23,084. The population density is 1508 persons per sq km. The district has a literacy rate of 92.66% of which literacy rate of male is 94.6% and female is 90.89%. The decadal growth rate is 2.25% and 1088 is the sex ratio of the district as per 2011 census. The study area is well connected by good networks of roads and rails and with other parts of the state. The National Highway (NH 66) passes through the district and the State Highways viz., Main Central Road (SH-1), SH-2 & SH-3 augment the road network of the area. In addition to road network, rail and water transport system exists in the district. The district houses Thiruvananthapuram International airport. The Vizhinjam International Deep Water Multipurpose Seaport which is under construction is also in Thiruvananthapuram district.

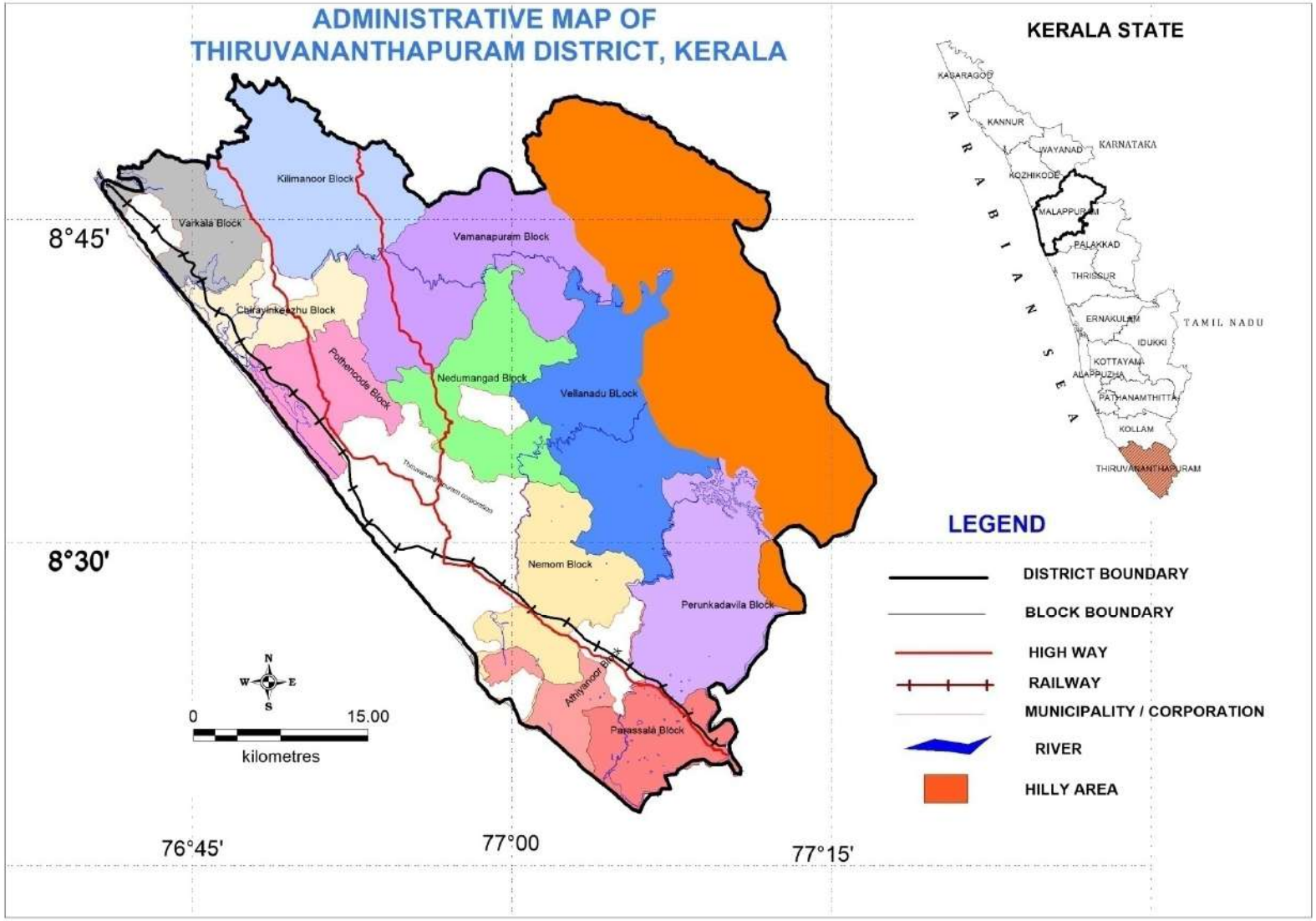


Figure 1.1: Administrative map of Thiruvananthapuram district

1.6 DATA AVAILABILITY, DATA GAP ANALYSIS & DATA GENERATION

During the Aquifer mapping, existing CGWB data such as exploration, depth to water level, water quality, geophysical survey and groundwater resources have been collected and compiled. In addition to this, relevant data have been collected from Ground water Department, Thiruvananthapuram. The data on cropping pattern, Minor irrigation data and Soil has been collected from Agricultural and Soil conservation Department, Land use /landcover data has been collected from Land use board and Rainfall data from Meteorological department. Thematic layers such as geology (GSI), soils, land use/land cover, geomorphology, drainage etc., were collected, complied and used in this study. After plotting the available historical data on 1:50,000 scale, data gaps were identified and data generation process was taken up in those gap areas to complete the Aquifer map on the desired resolution of 1:50,000 scale.

Scientific data on groundwater regime available with State and central agencies were utilised for optimizing additional data requirements. Additional data generated on ground water levels, lithology, aquifer properties, water quality were incorporated and interpreted with the objectives of generating a 3-D visualization of the aquifer systems in the area.

The data from 158 dug wells and 17 piezometers are used to monitor the ground water regime of the aquifers. 41 quality monitoring wells data were generated to monitor the phreatic aquifer. The data of 28 bore wells drilled down to a depth of 200m and other 20 bore well data is used to know the lithology, aquifer properties and water quality of confined aquifer system, which is extensively developed in recent years. Data of 131 Vertical Electrical sounding and 15-line kilometre. Wenner profiling is utilised to decipher the aquifer and its properties and also to delineate saline/fresh water interface in terms of geo-electrical parameters.

1.7 CLIMATE AND RAINFALL

Thiruvananthapuram district experiences humid tropical climate. Rainfall pattern of the region is in such a way that it receives rainfall in almost all months of the year. The area receives both south-west and north-east monsoon as well as summer showers. The annual rainfall varies from 1154.4 mm to 2252.1 mm with an annual average rainfall of 1723 mm (IMD data, 2009-18). The decadal rainfall of Thiruvananthapuram district from 2009 to 2018 is given in **Table 1.1.** The southwest monsoon contributes 44% of rainfall from June to September and the northeast monsoon contributes about 31%, remaining 25% is received in the remaining months. June is the wettest month and February the driest month. Based on the rainfall data, Isohyet map was prepared for the study area and is shown in **Fig 1.2.** The rainfall is deficient in the western part of the district and gradually increases towards the east.

The mean monthly maximum temperature ranges from 29.8 to 33.20C and the minimum ranges from 22.1to 25.1oC. The maximum temperature occurs during March and April and the minimum temperature occurs during January and December. The air is humid throughout the year

reaching peak during monsoon months and is less during summer months. Average Humidity varies from 69 (January) to 85% (June).

Table 1.1 Monthly rainfall of Thiruvananthapuram district (2009-18)

Year	Average Annual Rainfall (mm)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2009	119.4	0	3.5	44.5	206.9	183.3	204.3	87.3	183.3	119.4	346.3	42.5
2010	108.3	0	73.1	109.4	216.7	237	234.9	118.7	114.1	414.4	326	188.3
2011	43.6	73.6	15	157.3	92.9	272	97.5	84.4	131.5	141.4	240.4	168.6
2012	14.4	35.1	26.1	164.7	88.7	99.1	146.2	169.7	77.7	159.3	140.7	32.7
2013	10.5	63.1	46.8	31.7	120.9	525.3	247.9	115.8	219.7	155.9	273.9	33.6
2014	45.8	13.1	35.1	136.4	272.6	142.4	118.7	458.6	189.4	288.3	128.6	83
2015	9.6	0.4	50.6	257.3	336.8	358.7	60.6	71.4	307.1	367	275.8	156.8
2016	3.2	3.7	19	58.1	429.1	395	119.4	42.2	15.7	43.4	47.2	21.8
2017	5	0	85	54.2	228.3	318.8	52.9	123	269.3	241.4	274.7	151.2
2018	9.2	13.1	19.3	79	267.7	355.9	237.5	373.8	56.5	207.9	207.7	31.3

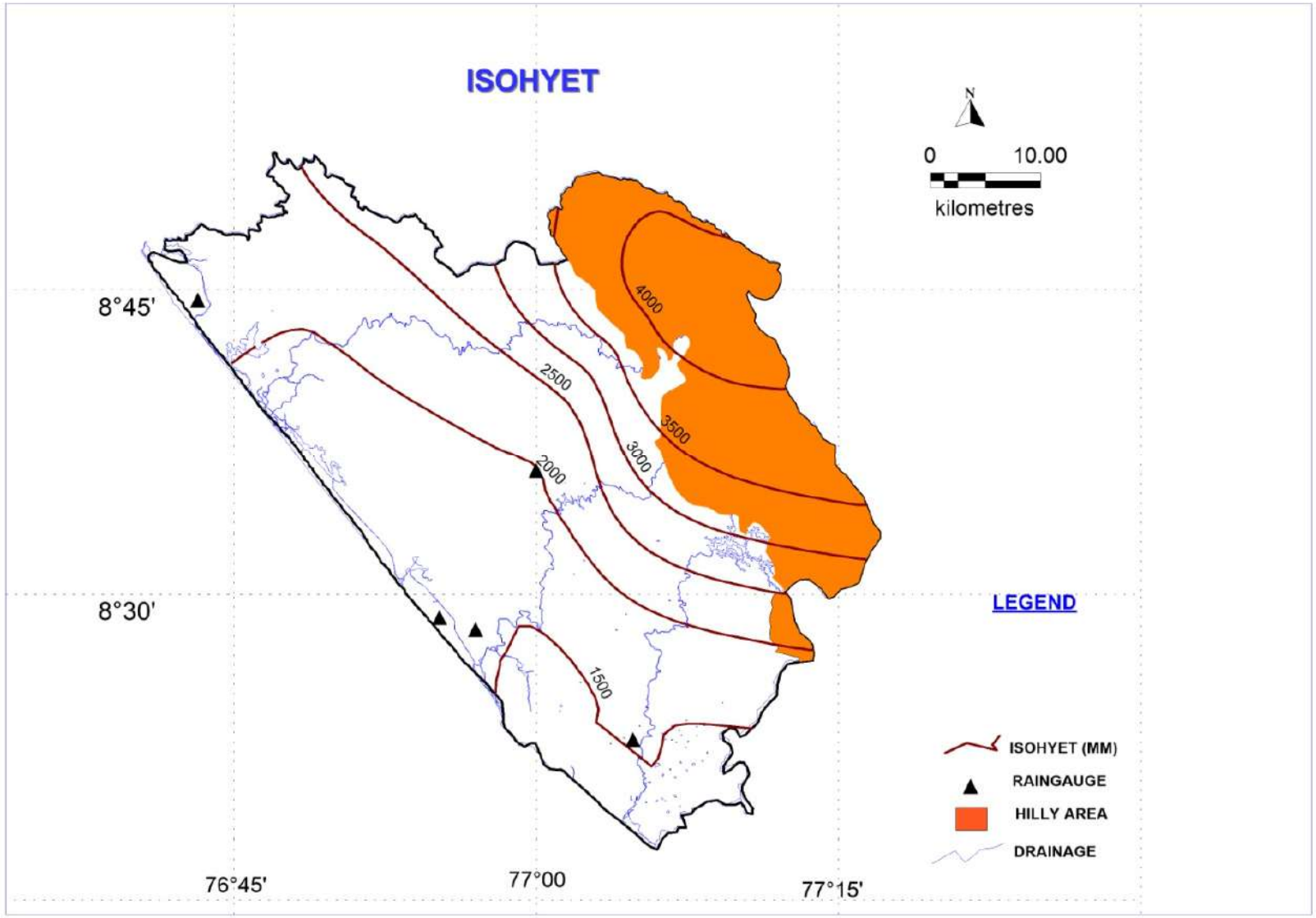


Figure 1.2: Isohyet map of Thiruvananthapuram district

1.8 PHYSIOGRAPHY

Physio graphically, the district can be divided into three units – (1) lowland (coastal plains), (2) midlands and (3) highlands. The various landforms seen in the area are carved out by a combination of marine, fluvial and denudation activities.

The lowland or coastal plain is the area with an elevation of less than 7.5 m amsl, dominated by the presence of number of back waters channels with a gently sloping terrain made up of Tertiary and Quaternary formation. In the district, lowland region covers an area of 114 Sq km. Lowland is comparatively narrow and is densely covered with coconut palms.

Midland, which rises gently from coastal plain in the west, has an elevation between 7.6 mamsl and 75 mamsl. The region is characterised by rugged topography comprising small flat topped low mounds and broad valleys with low to moderate slope. In the district, midland region have an area of 1498 sq.km. This region is intensively cultivated laterite terrain.

The highly rugged terrain in the eastern part of the district represents the highland where the elevation is more than 75 mamsl. The highland region comprising the western ghats is ideal for cash crops. Agasthyarkoodam, the second largest peak of Western Ghats with an elevation of 1869 m amsl partly falls in the district.

For a clear understanding of the topography, Digital Elevation Model (DEM) of the area is given in **Figure 1.3** and slope map in **Figure 1.4.** From the DEM, it is very clear that midland regions represented by highly rugged topography predominates the district and towards the east lies the Western Ghats with several peaks. The western part of midland lays the coastal plain/lowland. The general slope of the district is towards west. The slope of any terrain plays a vital role in allowing the infiltration of water into the subsurface system. In regions of gentle slope the runoff will be slow and will have more time for percolation of rainwater, whereas steep slope facilities high runoff allowing less residence time for rainwater to percolate. The elevation of the district ranges from 1395 mamsl in the east to sea level in the western coast.

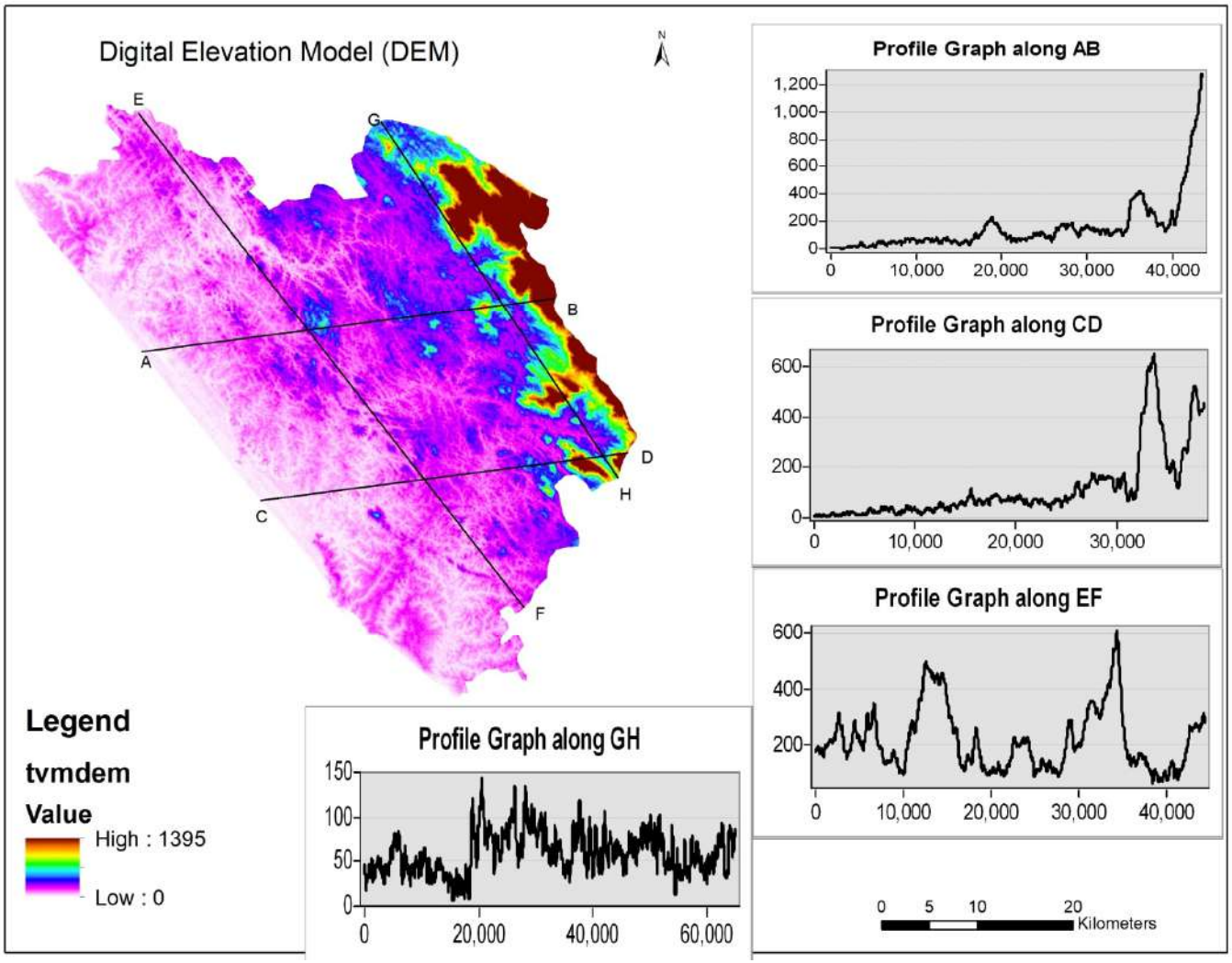


Figure 1.3: Digital Elevation Model of Thiruvananthapuram district

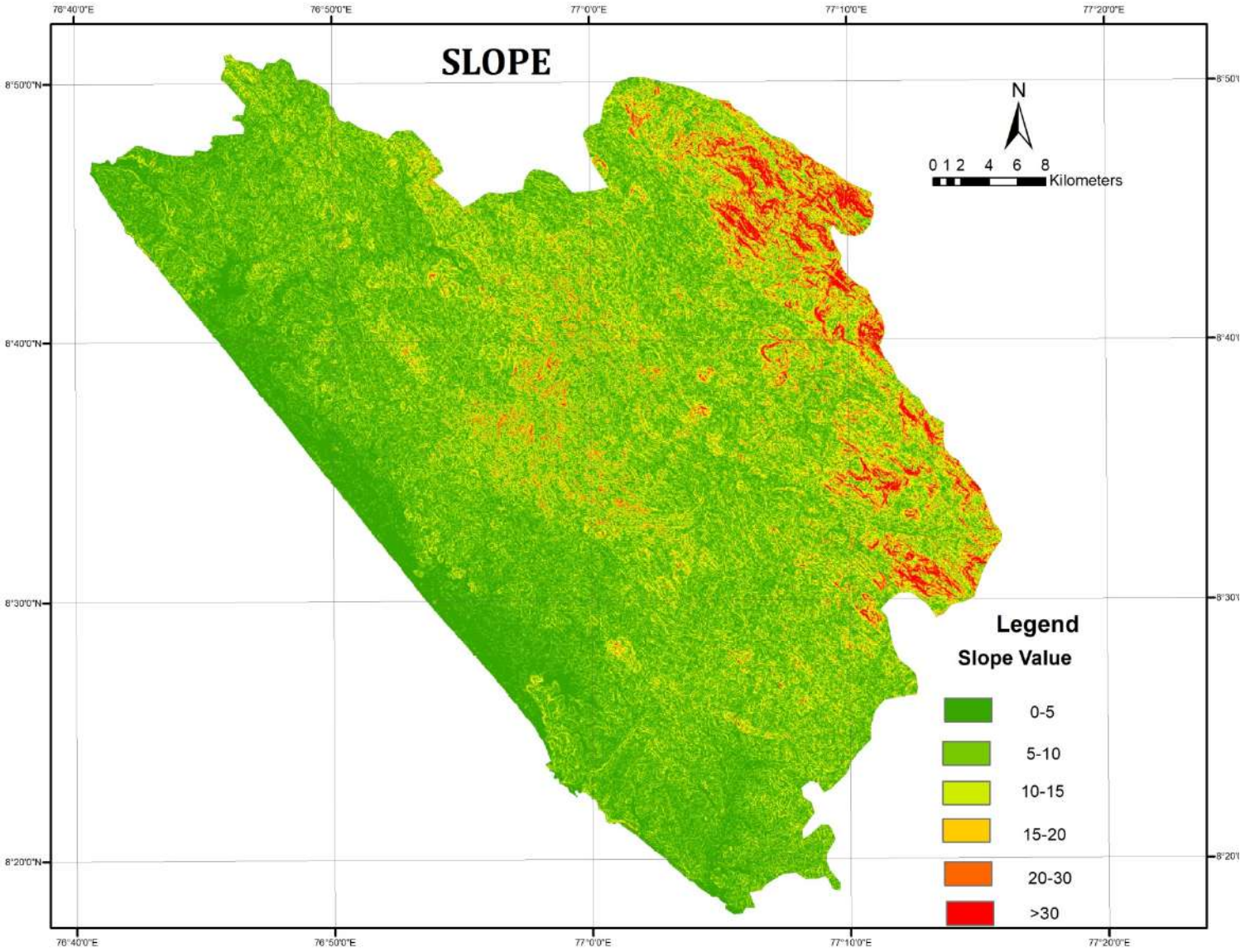


Figure 1.4: Slope Map of the district

1.9 GEOMORPHOLOGY

Geomorphologically, the landforms in the study area are carved out by a combination of fluvial and denudation activities which can be grouped into erosion and depositional landforms. The various geomorphic units seen in the area are Coastal plain, Channel bar, point bar, plateaus, valley fill, linear ridge, piedmont zone, flood plain, residual hill, residual mount, denudation hills and structural hills The geomorphologic features in the area is depicted in **Figure 1.5.**

The Coastal plain represents the depositional landforms formed by a combination of fluvial and marine action. Beaches (both sandy and rocky), spit, bar, beach ridges, estuaries, tidal flats, dunes and wave cut cliffs are the main marine landforms seen in the coastal area which are continuously modified by tidal action. Coastal erosion is very severe in the coastal area of Thiruvananthapuram. The landforms formed under fluvial environment are represented by channel bars, point bars, sand bars and flood plains which are mainly formed by the depositional activities by the rivers of the area. The depositional landforms are characterized by paddy fields, coconut cultivation and settlements. The narrow coastal plain is flanked by highly dissected pediplain on the east that represent erosional landforms formed as a result of fluvial and denudation activities. These undulating pediplain are dissected with broad valleys and isolated low mounds. The lower dissected piedmont plains are characterised by undulating to rolling topography with low hills and narrow valleys. The hills are generally covered with laterite or lateritic soils and the valleys are covered with alluvium. The easternmost part is a rugged terrain with steep sloped hills and small summits.

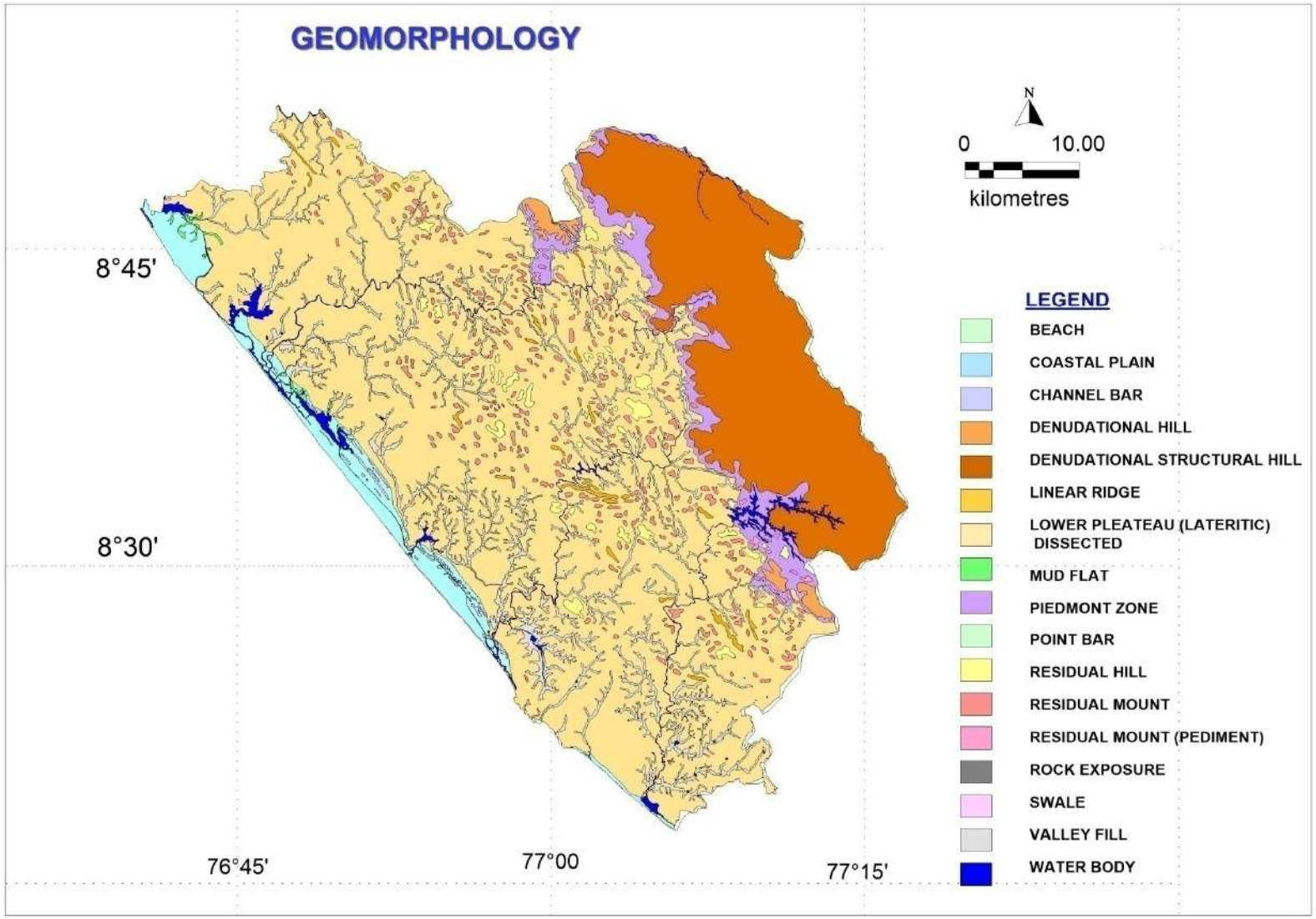


Figure 1.2: Geomorphology Map of the district

1.10 LAND USE/ LAND COVER

An understanding of the land use/ land cover pattern of an area is very important from groundwater point of view since the availability and development of this resource depends upon the surface run-off and infiltration which are controlled to a large extent by the type of land use/ land cover. Land use refers to the man's use and other uses which are carried on land and land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others resulting die to land transformation. Land use/land cover of Thiruvananthapuram district is broadly categorized into Agriculture land, Built up land, Forest, Waste land and Water bodies. Major part of the district is agriculture land (59%), which includes land under both irrigated crops and non-irrigated crops. Forest area (23%)is mostly in the eastern part. The urban development in the midland and lowland region of Thiruvananthapuram district is at a rapid pace. The classification of the area based on land utilisation and its details is given in **Table 1.2**

Table 1.2: Classification of the area based on land utilization

Land Units	**Area (in Ha)**
Forest	49861
Land put to non-agricultural use	32516
Barren & uncultivable land	228
Land under misc. tree crops	39
Culturable waste land	596
Fallow other than current fallow	907
Current fallow	2760
Marshy land	1
Still water	2696
Water logged	16
Social forestry	22
Area sown more than once	30916
(Source: Agriculture Statistics 2018-19)	
Category	**Area(in Ha)**
Gross Cropped Area	160055
Net Cropped area	129139
Cropping intensity	124
Land put to non-agricultural uses	32516
Current Fallow (up to 1yr)	2760
Other Fallow land (1to 5 years)	907
Cultivable waste	596
Source : Dept of Economics and Statistics,2018-19	

1.11 SOIL

Based on the morphological features and physio-chemical properties, the soil of the district are broadly categorized into 6 types (1) Lateritic soil (2) Coastal Alluvium (3) Mixed Alluvium (4) Brown Hydromorphic soil (5) Red Loam and (6) Forest soil.

Lateritic soil: Most predominant soil in the district is Lateritic soil and is mainly found along the midland. The texture of the soil varies from gravelly loam to gravelly clay loam and the colour ranges from reddish brown to yellowish red. These soils are well drained, low in organic matter and plant nutrients. This acidic soil shows varying morphological characteristics depending on the nature of the parental rock. A wide range of crops such as coconut, tapioca, rubber, arecanut, pepper, cashew etc are cultivated in this soil.

Coastal Alluvial soil: these low fertile acidic soils of marine origin are seen all along the coastal tracts as a narrow strips. These are highly permeable soil with low water holding capacity. The texture varies from clayey loam to sandy loam. The water table is generally shallow. Main constituents are quartz, feldspar, heavy minerals and shell fragments and the soil is less in Organic matter, clay and CECs. The low content of organic matter and clay has resulted in low cation exchange capacity of the soil.

Mixed Alluvium: These soils are developed from fluvial sediments of marine, laccustrine and riverine sediments or its combinations. They occur below 20mmsl in the lowland plains, basins, valleys and along the banks of river. Riverine alluvium mainly occurs along the banks of rivers and their tributaries. This soil shows wide variation in their physio- chemical properties depending on the catchment area through which the river flows. Texture of this light grey to very dark brown soil ranges from sandy clay loam to clay and is moderately supplied with organic matter. The soil is highly permeable and ground water retention is very high. It is suited for a large variety of crops like coconut, paddy, arecanut, pepper, vegetables etc.

***Brown Hypidomorphic soils*:** This fertile soil is mostly confined to the valley bottoms in the undulating topography of midland region and low-lying area of coast. These exhibit wide variation in physio-chemical properties and morphological features. These soils therefore exhibit characteristic hypidiomorphic features like grey horizons, mottling streaks, hardpans, organic matter depositions, iron and manganese dioxide concretions etc. The soil is enriched in clay content and plant nutrients. The soil is suitable for paddy cultivation. Texture of this soil ranges from sandy loam to clayey loam.

***Red Loam*:** Red loamy soil are highly porous, friable and low in organic matter soil showing sandy loam to clayey loam texture found in the southern part of the district. This soil is mainly derived from the weathering of ferruginous sand/siltstone of Tertiary Formation. The acidic soil is deep red in colour which is sand-rich and loamy. Groundwater table is very deep and potential is less.

***Forest Soil*:** These soils are developed from crystalline rocks of Archean age under forest cover generally above the elevation of 300m amsl. The soil is generally immature. Gneissic boulders under different stages of weathering are noticed in the subsoil. The texture of the soil ranges from sandy clay loam to clay with reddish brown to very dark brown

Based on textural characteristics five types of soil are encountered in the area; they are gravelly clay, loamy soil, clayey soil, gravelly loam and sandy soil. Gravelly clay is the most predominant soil type in the area and is seen all over the study area except the north-eastern part. Gravelly soil is light reddish brown in colour and well suited for agriculture. Loamy soil is the mixture of soil seen along the hilly region and is ideal for plant growth. Clayey soil has high water retaining power. The soil map based on textural classification of the area modified after the soil map published by Kerala land Use board is shown in **Figure 1.6**.

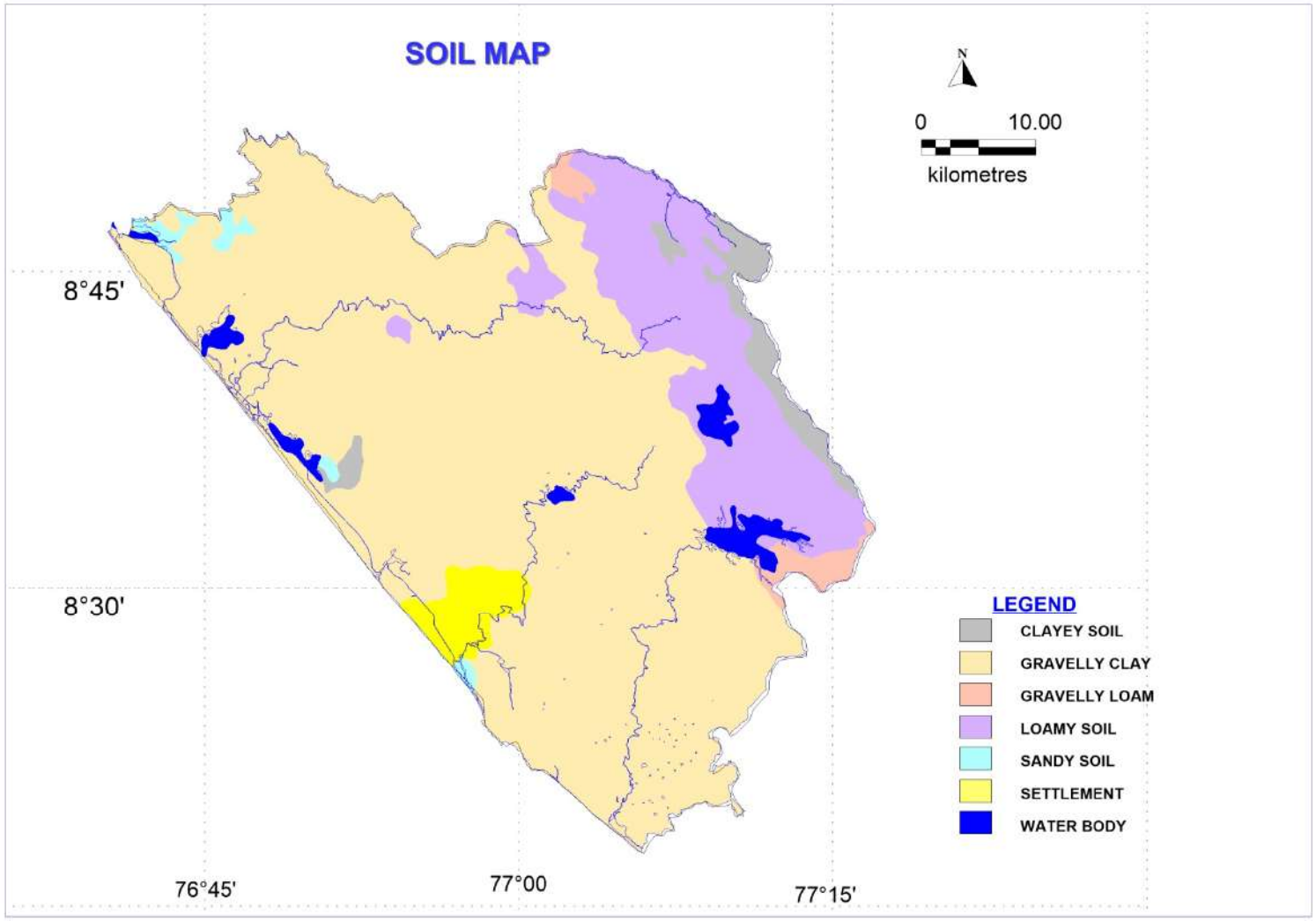


Figure 1.6: Soil Map of the district

1.12 DRAINAGE AND HYDROLOGY

The area is drained by three important west flowing rivers, viz Neyyar, Karamana and Vamanapuram, originating in the western portion of the Western Ghat region. These rivers together with their tributaries exhibit dendritic pattern of drainage. Dendritic pattern drainage is common in the flat lying rocks and in areas where the preferential zones of structural weakness are minimal. The tributaries joining the major rivers are showing trellis pattern in some area. The drainage pattern of the district is shown in **Figure. 1.7**. The location of River gauge and discharge (G&D) site is given in **table 1.3.**

Table 1.3: The location of G&D site

#	G&D Site Location	Basin Name
1	Amaravilla	Neyyar
2	Ottasekeramangalam	Neyyar
3	Mankattukadavu	Karamana
4	Maruthankuzhi	Karamana
5	Valayinkil	Vamanapuram
6	Mylammoodu	Vamanapuram
7	Vamanapuram	Vamanapuram
8	Ayilam	Vamanapuram

The Neyyar River with catchments of 497 Sq.km originates from Agasthyamala at about 1860 m above msl and joins Arabian Sea near Poovar. The Neyyar Irrigation Project is one among the Major Irrigation Project constructed across Neyyar River near Kattakkada in Thiruvananthapuram district. Neyyar River is a 6th order basin, incorporating 15 well marked drainage basins. The straight course of the river and its right-angled bends indicate that the structural features like fault or fracture systems have a direct control over the flow of the Neyyar River. The overall drainage pattern of the Neyyar River is dendritic to subdentritic superimposed with a rectangular pattern, The Neyyar river grades from a youth stage in the highlands to late mature stage in the lowlands. This might be the result of the upliftment of Agastya malai, exposing it to the second cycle of denudation. A significant decrease in the drainage density from highland to midland and then to low land is observed in the basin. The area with low drainage density indicates possibility of high recharge. Hence lowland and midland area is good for recharge. The Bifurcation ratio varies from 3.030 to 4.50. The stream length varies from 0.462 km to 0.568km in the highland, 0.631km to 0.873km in the midlands and 1.41km to 1.58km in the lowlands. The length of the river is only 60.50 km. The longitudinal profile in the basin gave a slope of 2° from coastline towards inland up to the piedmont of the Western Ghats.

Karamana River, the other major perennial river of the district originates from Chemmunji Motta and Agastyamalai at 1717 m above msl and joins the Arabian Sea near Pachallur with a total catchment area of 703 sq.km. Karamana river basin is a 6th order basin and exhibits dendritic

pattern to sub dendritic pattern, the main tributaries of Karamana river such as killi Ar and Chittar exhibits trellis pattern. The two dams constructed across the river are Peppara dam and the Wellington water works (Aruvikkara Dam). Both Peppara Dam and Aruvikkara Dam provides drinking water supply to Trivandrum city. Thiruvananthapuram urban water supply scheme draws water from the Karamana River from 3 places namely the reservoirs at Peppara, Aruvikkara and Kundaman kadavu near Thirumala.

The Vamanapuram River originates from the Chemunji motta hills of the Western Ghats. It is also called Attingal River. This river has a length of 88 km and a catchment area of 799 sq km. and it spreads along the districts of Thiruvananthapuram and Kollam. The river generally possesses dendritic pattern characterized by irregular branching of tributaries in many directions and indicates lack of structural control and is controlled by the lithology. Vamanapuram River is a seventh order stream. The drainage density varies from 1.6 to 4.48 and bifurcation ratio varies from 2.5 to 4.35 with an average of 3.5 which shows the dissected nature of Vamanapuram river basin and this variation is due to lithological and geological development. The drainage density is high to very high in eastern and north eastern portion of the basin and medium to low in the midland area. Based on drainage density the midland area is good for recharging. The elongation ratio of 6.1 proves the basin is oval in shape and the area is generally associated with strong relief and steep ground slopes. The Upper Chittar, Kallar and Manjaprayar are the tributaries of this river. The river meanders its way to the Anchuthengu back waters through Attingal town. The northern parts of district draw water from the Vamanapuram.

Mamam:- The river originates in panthalacode hills Trivandrum district and flows 27 KM westward direction and ends up at Anchuthengu lake. Mamam river catchment areas are 114 Sq. Km out of which only 8 Sq. Km falls within the study.

Ayiroor River: The river has a length of 17 km and originates at Navaikulam and debouches into Edava- Nadayarakayal. The river have a catchment area of 66 Sq km flows through Kollam and Thiruvananthapuram district.

A small portion of Kallada river basin and Ithikara river basin also falls in the northern part of the district. Thiruvananthapuram is studded with a number of backwater channels and estuaries viz. Poovar Kayal, Poonthura Kayal, Vellayani Kayal, Veli Kayal, Mongottu Kayal, Kozhithottam Kayal, Kadinamkulam Kayal, Anchuthengu Kayal and Edava- Nadayara Kayal. Among this only Vellayani Kayal is freshwater lake which is supplying water to major portion of Nemom block. Another conspicuous feature of the drainage system is its orientation which reflects the structural and topographic control. All the kayals are oriented parallel to the coast in NNE-SSW direction with a small land sandwiched between the coast and kayal. Moreover, the quality of water suggests that these lakes have been formed due to regression of sea in geologic past except Vellayani Lake. In addition, the area is criss-crossed by a number of channels connecting the rivers and backwaters, thus providing a network of canals for navigation.

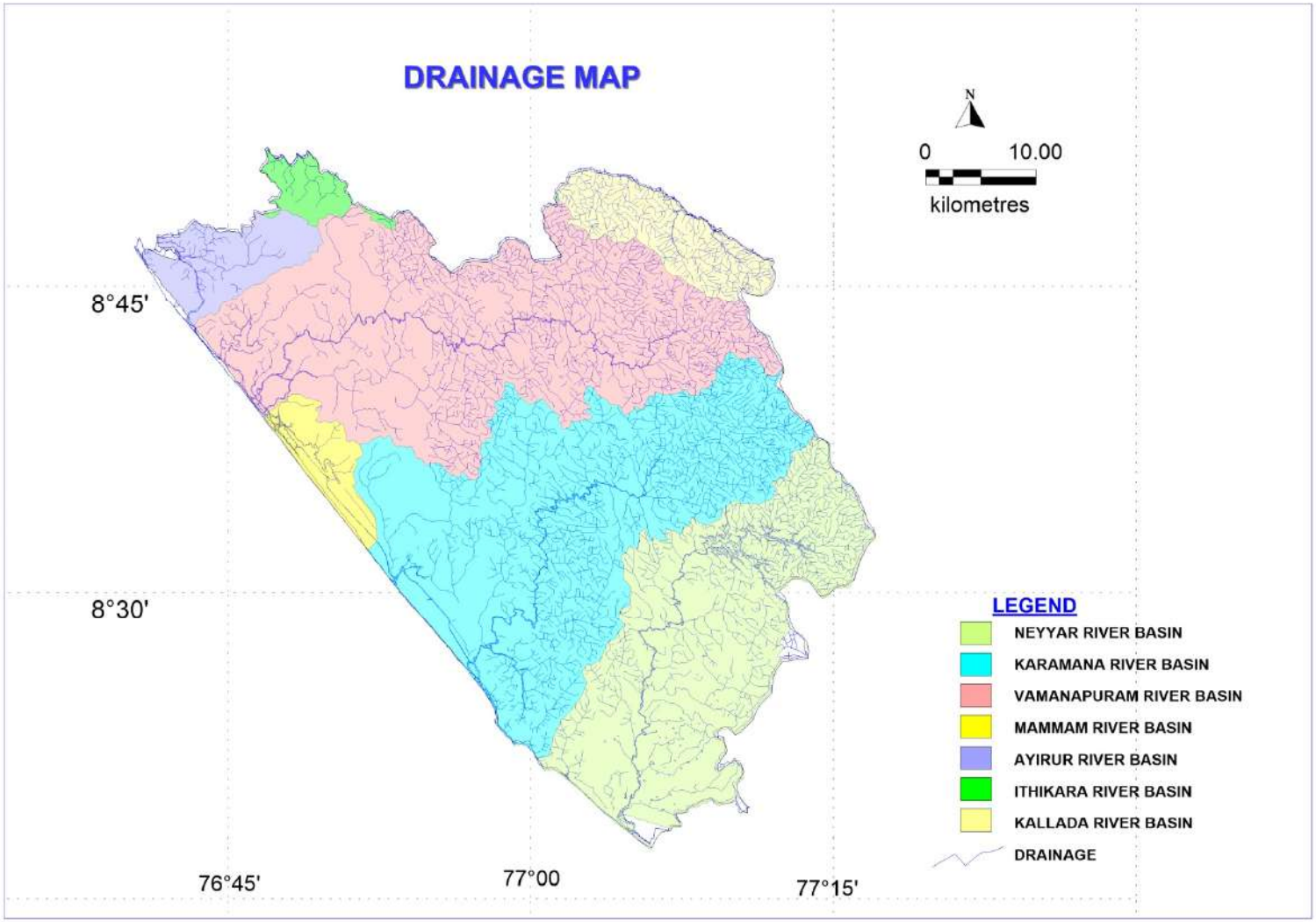


Figure 1.7: Drainage Map of Thiruvananthapuram district with river basins

1.13 AGRICULTURE AND IRRIGATION

Agriculture of a terrain depends on factors like Climate, type and characteristics of soils and irrigation facilities available and many others. With a high density of population, the land availability for agriculture is highly limited in Thiruvananthapuram. Agriculture in the district is low and stagnant. A wide variety of crops are being cultivated in the study area. Agriculture crop in the district are broadly classified as food crops and non-food crops. Food crops are cereals and millets, sugar crops, spices and condiments, fruits and vegetables and major non-food crops include rubber, betel leaves, lemon grass etc. The area under different major crops in the district is shown in **table 1.4**. A comparative study on paddy cultivated areas in 2010-11 and 2018 indicates decline in paddy cultivated area from 2919 Ha to 2038.79 Ha whereas the cultivated area of non-food crops such as rubber has been increasing. Low returns from paddy cultivation and high cost of production is the reason for low paddy area. Coconut is cultivated in the midland and in the coastal area. The coconut in the coastal area is irrigated by ground water.

Table 1.4: Area under major crops

Crops	**Area (Ha)**
Paddy	2038.79
Pulses	138.79
Sugar crops	25.38
Pepper	2003.4
Spices and Condiments	1812.86
Tapioca	13037.83
Tubers	983.25
Vegetables	3306.28
Fruits	25472.07
Coconut	71157.95
Betel Leaves	12.32
Tea	835.59
Rubber	32200
Source: Agriculture Statistics 2018-19	

The Irrigation of Thiruvananthapuram district is under incumbent stage as only 12% of the net sown area is irrigated by ground water while remaining 88% is under rain fed irrigation. Due to the undulating terrain, it is not possible to bring all the cultivated land under the command of the project hence minor irrigation schemes is feasible. Source wise net area under irrigation is given in table 1.5

Table 1.5: Source wise net area under irrigation

Source	**Type**	**Area(Ha)**
Small stream (Thodu/Canal)	Government	3931.99
	Private	0
Pond	Government	295.83

Source	Type	Area(Ha)
	Private	40.74
Well	Government	11.55
	Private	2790.43
Bore well/Tube well		92.21
From River & Lake	Pump	3.19
	Other Method	0.08
	Total	3.27
Other sources		451.82
Grand Total		7617.84
Source: Agriculture Statistics2018-19		

The Neyyar Irrigation Project, a medium Irrigation Project constructed across Neyyar River near Kattakkada was completed in 1973 and it envisages in irrigating an ayacut of 11740 Ha and catchment area of 140 km2. The scheme has now become an integral part of the lives of the people of Neyyatinkara Taluk and its surroundings, since it is the main source of water for agricultural and drinking purpose. The project consists of a straight masonry dam across Neyyar River. This project consists of two canal systems viz; the Right Bank Main Canal and Left Bank Main Canal. Particulars of the branches of the Right Bank Canal and Left Bank Canal are given in Table 1.6.

Table 1.6: Particulars of branches of Neyyar project

Sl No	Left Bank Canal	Length (km)
1.	Main Channel	33.82
2.	Perumkadavila Branch	5
3.	Chaikottukonam Branch	8
4.	Kollayil	12
5.	Notchiyoor	5
6.	Chenkal Minor	5
7.	Chenkal Major	8
8.	Karumanur Left Branch	2
9.	Karumanur Right Branch	8
10.	Kode	23
11.	Chulliyur Branch	1.50
12.	Veeyanoor Sub Channel	2
13.	Vadakara	150
14.	Kulathumel	0.50
15.	Chaikottukonam Sub Branch	5.00
16.	Palappally	1.50
17.	Vlathankara Field	-

Sl No	Right Bank Canal	Length (km)
1.	Main Channel	33.40
2.	Vadakode Branch	8
3.	Perumbazhatoor Tributary	1
4.	Vizhijam	22
5.	Vellayani	10
6.	Marukil Branch	2
7.	Vellayani East	4
8.	Vellayani West	12
9.	Poovar East	18
10.	Poovar West	12
11.	Olathani	6
12.	Kodangavila	3
13.	Poovar	21
14.	Mavinkadavu filed	
15.	Chowara Branch	21

1.14 RECHARGE PRACTICES

Recharge of ground water is inevitable in the fast-growing district like Thiruvananthapuram where it is impossible to draw a boundary between urban and rural. CGWB has implemented a number of demonstrative artificial recharge structures and rainwater harvesting schemes in the area. The demonstrative schemes of CGWB on artificial recharge are given in Table 1.7. These schemes are successful and the district is ideal for construction of more recharge structures.

Table 1.4 Artificial Recharge Schemes implemented by CGWB in Thiruvananthapuram district

Sl No	Location	Type of Structure and Year	District
1	Ayilam, Chirayinkil Block	Sub-surface Dam (2000)	Trivandrum
2	Mambazhakara, Neyyattinkara Municipality	Sub-surface Dam (1997)	Trivandrum
3	Thalayilmottakavu, Manikkal Panchayat, Vamanapuram Block	Sub-surface Dam (2003)	Trivandrum
4	Secretariat Building, Trivandrum	Rainwater Harvesting, Artificial recharge (2003)	Trivandrum

Groundwater is being augmented through the recharge structures constructed by departments/ agencies of the state such as State ground water department, Agricultural Department, Agricultural University, PWD, Soil Conservation Department and Irrigation department.

1.15 GEOLOGY

The district is mostly underlain by crystalline rocks (1790Sq km) of Archean age. The major rock types of the district are Khondalites and Charnockites. The sedimentary formations ranging in age from Miocene to Recent are seen along the western part of the area. The general stratigraphic succession of rocks in Thiruvananthapuram district is given in Table 1.8 and its spatial distribution is depicted in Figure 1.8.

Table 1.5: General stratigraphic succession of rocks in Thiruvananthapuram district

ERA	AGE	FORMATION	LITHOLOGY
QUARTERNARY	Recent	Alluvium	Sands and clays along the coast, flood plain deposits, river alluvium and valley fill deposits.
	Sub-recent	Laterites	Laterites and lateritic clays derived from Tertiary sediments and crystalline rocks.

ERA	AGE	FORMATION	LITHOLOGY
TERTIARY	Lower Miocene	Warkali beds Quilon bed Vaikom bed	Sandstone and clay with thin bands of lignite. Limestone, marl and calcareous clay. Gravel, coarse to medium sand and carbonaceous clay.
----------Unconformity----------			
	Undated	Intrusives	Dolerite, gabbro, Pegmatites and Quartz veins.
PRECAMBRIAN	Archaean	Migmatite Group Charnockite Group Khondalite Group	Granite gneisses, Charnockite, Biotite Gneisses and Garnet Sillimanite gneiss, Graphite gneiss.

Khondalites: The Khondalite group of rocks are predominantly made up of Garnet-Sillimanite gneisses and are seen in the midland and eastern parts of Thiruvananthapuram district. They are medium to coarse grained with relatively high density of fractures and lineaments compared to Charnockites and Granite gneisses. Graphite is found associated with Sillimanite gneiss around Vellanad, Ottasekharamangalam, and Perunkadavila areas which is often intruded by Pegmatites. Biotite gneiss is seen as concordant bands within the Khondalites.

Charnockites: These rocks show great diversity in lithology. This group includes small patches of Cordierite gneisses, Hornblende granulite and Pyroxene granulite. Charnockites are observed in north eastern and central part of Thiruvananthapuram district. These rocks are fine to medium grained in texture and are very massive when compared to other crystalline rocks. They are generally massive and well foliated at places. The Pyroxene granulite show both concordant and discordant relationship with Charnockite and Charnockite gneisses.

Migmatites: These are evenly distributed in the central part of Thiruvananthapuram district as narrow zones within Garnetiferous Silimanite gneiss.

Intrusives: The Charnockites, Migmatite and Khondalite group of rocks are intruded by a number of Dolerite dykes, but their distribution is restricted to the midland region of Thiruvananthapuram district. Thin veins of Pegmatites and Quartz veins are very common, and many of the pegmatite has gained importance because of their gemstone (Chrysoberyl) content.

Tertiary Formations

Tertiary sedimentary formations are made up of three distinct formations viz Warkali beds (middle Miocene to early Pliocene), Quilon beds (early Miocene) and Vaikom beds. The outcrop pattern of the sedimentary formations represents only a fringe of the eastern portion of tertiary

basin and the rest is under Arabian Sea. Carbonaceous clay with peat bed is observed in the cliff sections.

Warkali Beds: This is the top most among the tertiary beds and is found along the coast. These beds are exposed in the cliff section in Warkali and Karichal in Thiruvananthapuram district. The top portion of these formations is lateritised. They are seen along Pulluvila, Puvar, Meenamkulam, Pudukuruchi, Edava and Varkala of Thiruvananthapuram district. The thickness of Warkali beds varies from 20m to a maximum of 140m. These are made up of alternate layers of fine to medium grained sand with clays and thin seams of lignite. The age of Warkali beds were considered to be lower Miocene.

Quilon Beds: This is composed of limestone, marl and calcareous clay. This formation is encountered in the boreholes located on the northern part. The thickness of the formation ranges from 34 to 64m around Varkala and Edava areas.

Vaikom Beds: This is composed of gravel, coarse to medium sand and carbonaceous clay. This formation is encountered in the boreholes located on the northern part. The thickness of the formation ranges from few meters to more than 200m and is encountered in northern parts of the district only.

Laterites

The laterites of sub recent age occur as a residual deposit due to weathering of crystalline and sedimentary rocks. This formation is widely exposed along this midland of the district. The typical laterite profile seen in crystalline terrain consists of lateritic soil at the top followed by soft laterite, lithomargic clay and weathered zone. The laterite derived from the Tertiary is light, homogeneous, soft and devoid of sand fragments and occur below the alluvium. The thickness of laterite capping in Charnockite varies from 1 to 3 meters and it varies from 15 to 20 m in Khondalites.

Recent Alluvium

Recent alluvial deposits are represented by coastal sands, lagoon and flood plain deposits, river alluvium and valley fill deposits. Beach sands occur along the coast with an average width of 0.5 to 1.5 km, which are essentially made up of fine to medium quartz grains. The lagoon deposits are represented by clay and the flood plain deposits consist of fine to medium grained sand. The river alluvium consists of fine to coarse sand and sandy clay is seen along the major rivers. The thickness of these deposits is ranging from 6 to 30m. The valley fills are deposited along the valleys in the midland and the hilly region.

1.16 STRUCTURE

The crystalline rocks exposed in the district exhibit evidences of intensive shearing and fracturing. The regional strike of foliation in Charnockites and Khondalites in the central part of the district is generally NW-SE and varies from WNW-ESE to NNW-SSE with south-westerly dip ranging from 250 to 800. Doubly plunging anticline is seen near Nedumangadu. The crystalline

rocks have undergone several periods of tectonic deformation. The earliest phase appears to be folding and metamorphism on a regional scale. The regional metamorphism is of amphibolite or granulite facies which has resulted in the formation of Charnockites, Pyroxene-Granites, Khondalite and Migmatite complex.

Most of the quartz and pegmatite veins have intruded along the fracture planes. Similarly, all the three major rivers are observed to flow along fracture zones. Evidence of fracturing and faulting are observed at Vellanad, Perumkadavila, Vithura etc. The Gneisses and Charnockites are traversed by two well-developed major sets of joints trending NW-SE, one of which is parallel to the regional foliation and the other perpendicular to it. Intensity of joints is found to be more in Khondalites.

Geological structures like fractures, lineaments, faults, joints, intrusive rocks etc influence the occurrence and movement of groundwater. Such information extracted from field investigations as well as from the study of toposheets and imagery was utilized to identify potential lineaments and fractures in the area. The lineaments and dykes identified trend various directions such as NW-SE, N-S, NNE-SSW and E-W. The prominent lineaments in the area mainly trend in NNW-SSE and N-S direction. The Rose diagram of the Lineaments of the Hard rock area of the district is shown in figure 1.9.

Mineral resources

Thiruvananthapuram district has a distinctive place in the mineral map of Kerala, with the occurrence of China clay, Bauxite and Chrysoberyl. Good quality white plastic sedimentary clay occurs over a large basin from Kazhakuttom to Pallippuram. Vellanad, Changa, Sankaramugham area of district was famous for its high quality Graphite deposits. Gemstones like Chrysoberyl is reported in the pegmatites of the district and also found in the stream courses of Karamana River.

1.17 PREVIOUS WORK AND PRESENT STATUS OF DATA

Central Ground Water Board has carried out Systematic Hydrogeological Survey in the district during 1974-75 and 1980-81. Later the same area was covered under Reappraisal Hydrogeological survey during 1997-98 and 2004-05. In 1983-88, the SIDA assisted Coastal Kerala Ground Water Project of CGWB has carried out detailed hydrogeological studies with exploration covering northern parts of the district mainly the Vamanapuram basin. Since 1969, Central Ground Water Board is monitoring the ground water levels and water quality in the district through a network of Ground Water Monitoring Wells. In addition to the routine work, CGWB has also taken up a number of short-term investigation studies, exploration and geophysical activities, sea water ingress studies, pollution studies, environmental impact studies in the district.

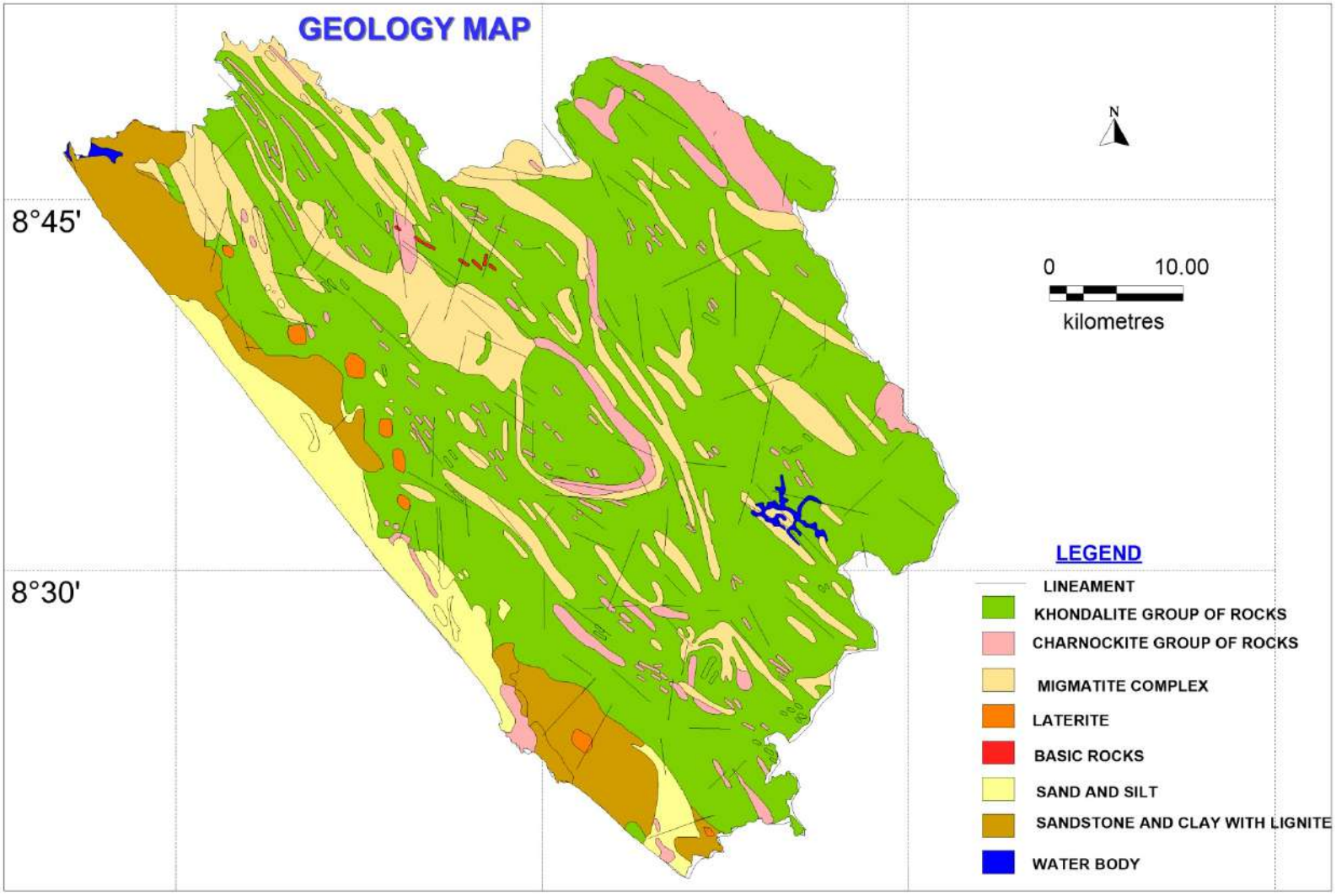


Figure 1.8: Geology Map of the district

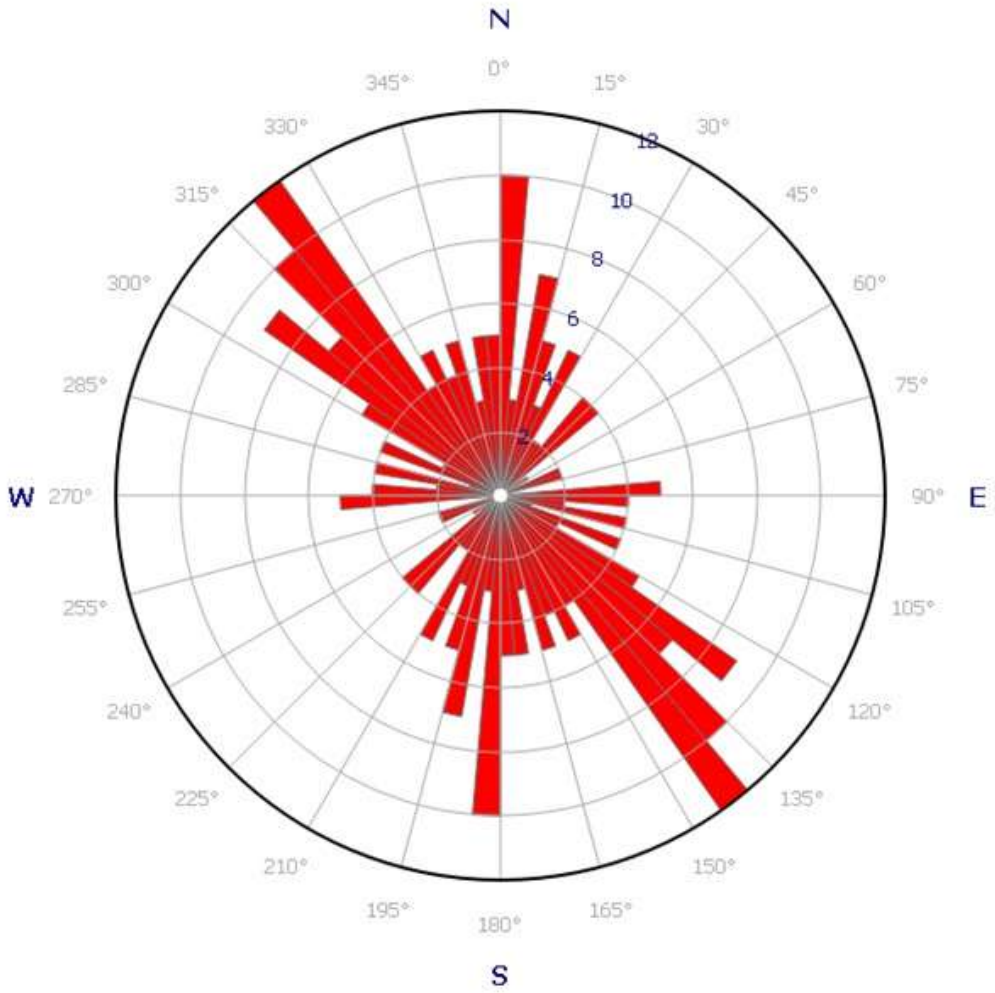


Figure 1.9: Rose diagram of the Lineaments of the Hard rock area of the district

2.0 DATA COLLECTION AND GENERATION

2.1 DATA COLLECTION AND DATA GAP ANALYSIS

The historical or available data on Geology, Geophysics, Hydrogeology and Hydrochemistry generated under various studies by the CGWB such as Systematic Hydrogeological studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Exploratory drilling and special studies have been utilized for data gap analysis in conjunction with the data collected from various State and Central government departments. The thematic layers on drainage, geomorphology, land use and land cover were reproduced from the data obtained from concerned State departments. The existing data on various themes are analysed for finding the data gaps.

Periodical data pertaining to water levels, ground water quality and pumping tests were collected during aquifer mapping studies. In addition, geophysical data has been generated through conducting Geo-electrical soundings after evaluation of data gap analysis.

2.2 HYDROGEOLOGICAL DATA

Water level is the fundamental indicator of the status of groundwater resource. The periodical monitoring of groundwater level implies the groundwater recharge and discharge (natural and manmade) occurring in the aquifer systems. It also reveals that the interaction between rainfall, surface and sub-surface water systems. CGWB wells are being monitored four times (January, April, August and November) in a year. The historical data from these stations have been used for data gap analysis and identified new sites to fill up the data gaps. In the district, 158 Nos. of groundwater monitoring wells which included CGWB regular monitoring wells, state ground water department wells as well as key wells and 17 piezometers of CGWB. The locations of monitoring wells are presented as Figure 2.1

2.3 HYDRO CHEMICAL DATA

The historical data on water quality in the area is available from the water level monitoring stations maintained by CGWB. Water sampling is being done every year from these wells during pre-monsoon period (April). The data gap analysis has been carried out to find out the adequacy of information on water quality and identified 8 new locations for additional sampling. The groundwater quality was studied by analysing water quality data of 41 monitoring open wells and 36 bore wells of CGWB . The sample locations is presented in Figure 2.2.

2.4 GEOPHYSICAL DATA

The geophysical survey conducted in the study area consists of Vertical Electrical Soundings (VES) by employing Schlumberger configuration and Wenner Profiling. The objective of the study is to decipher the sub surface information on weathered thickness, depth of occurrence of fractures and depth to massive rocks from geophysical data. In the coastal area Wenner Resistivity profiling is conducted to delineate saline/fresh water interface in terms of geo-electrical parameters. A total number of 131 VES and 15 line kilometre Wenner profiling

were carried out and geo electric layers were inferred through interpretation of the results obtained. The locations of the VES are presented in Figure 2.3.

2.5 GROUNDWATER EXPLORATION DATA

Data of 32 Nos. of exploratory wells in the hard rock area and 9 no in the soft rock area of the district drilled prior to National Aquifer Mapping project was compiled and analysed. These wells were plotted on the 1:50,000 scale topographical map and as per the NAQUIM guidelines for the hard rock & soft rocks, data requirements were identified on the plotted topographical map. Based on the data requirements, 16 Nos. of exploratory wells have been drilled as part of the data generation. Thus, data such as lithology, fracture depth, yield, water level, aquifer properties etc. of 48 bore wells and 9 tube wells were utilised to depict the prevailing aquifer systems. The figure 2.4 shows the location of exploratory wells of the district.

2.6 HYDROLOGICAL PARAMETERS ON GROUND WATER RECHARGE

Twelve infiltration tests were conducted in parts of Thiruvananthapuram district and the details are as shown below in Table 2.1.

Table 2.1: Details of Soil Infiltration test

Sl No	Infiltration Test site	Type of soil	Rate of infiltration in mm/hour
1	Vellanad CGWB Drilling camp, Thiruvananthapuram district.	Laterite coarse sand (Laterite, Partially compacted)	3.24
2	Pattakulam Grama Panchayath Market ground on Kattakada-Kallikad dam Road,Thiruvananthapuram.	Laterite clay compacted	1.32
3	ECHS Dispensary Pangode Military Campus, Thiruvananthapuram.	Clay Loam (Laterite, Partially compacted)	1.20
4	KSEB Power station Balaramapuram, Thiruvananthapuram.	Laterite soil	1.50
5	Nemom Railway station premises, nearby CGWB bore well, Thiruvananthapuram.	Laterite clay	0.24
6	KSEB Power station campus, ,near CGWB bore well at Parassala, Thiruvananthapuram.	Laterite, Partially compacted	1.32
7	ITI Campus, Aryanad, Thiruvananthapuram.	Laterite soil, Partially compacted	2.10
8	Old Panchayath Ground, Thattathumala, Thiruvananthapuram.	Laterite soil, loosely packed	5.10
9	SNDP,Saratha Vidya Peedam Campus,Neyyatinkara (Near CGWB bore well),Thiruvananthapuram	Laterite Soil	4.80

Sl No	Infiltration Test site	Type of soil	Rate of infiltration in mm/hour
10	SNDP,Saratha Vidya Peedam Campus, Aruvipuram, ,Neyyatinkara (Near CGWB bore well), Thiruvananthapuram	Laterite Sand Compacted	1.08
11	KSEB Power station campus, ,Near CGWB bore well at Vizhinjam, Thiruvananthapuram.	Laterite sand compacted	0.72
12	CTCRI Campus, Sreekaryam, Thiruvananthapuram (Near CGWB borewell)	Laterite soil near agriculture field.	3.30

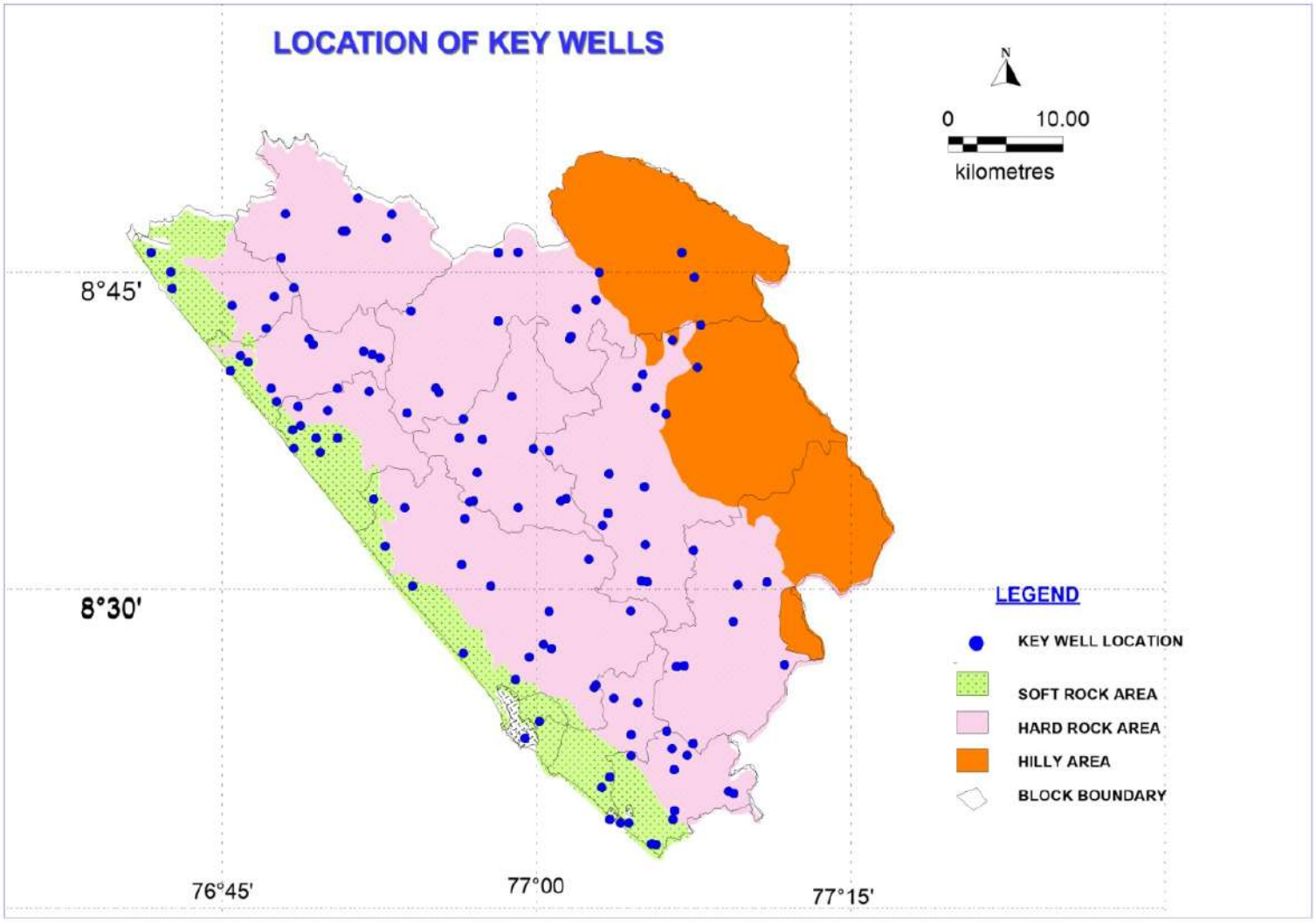


Figure 2.1: Location of monitoring wells

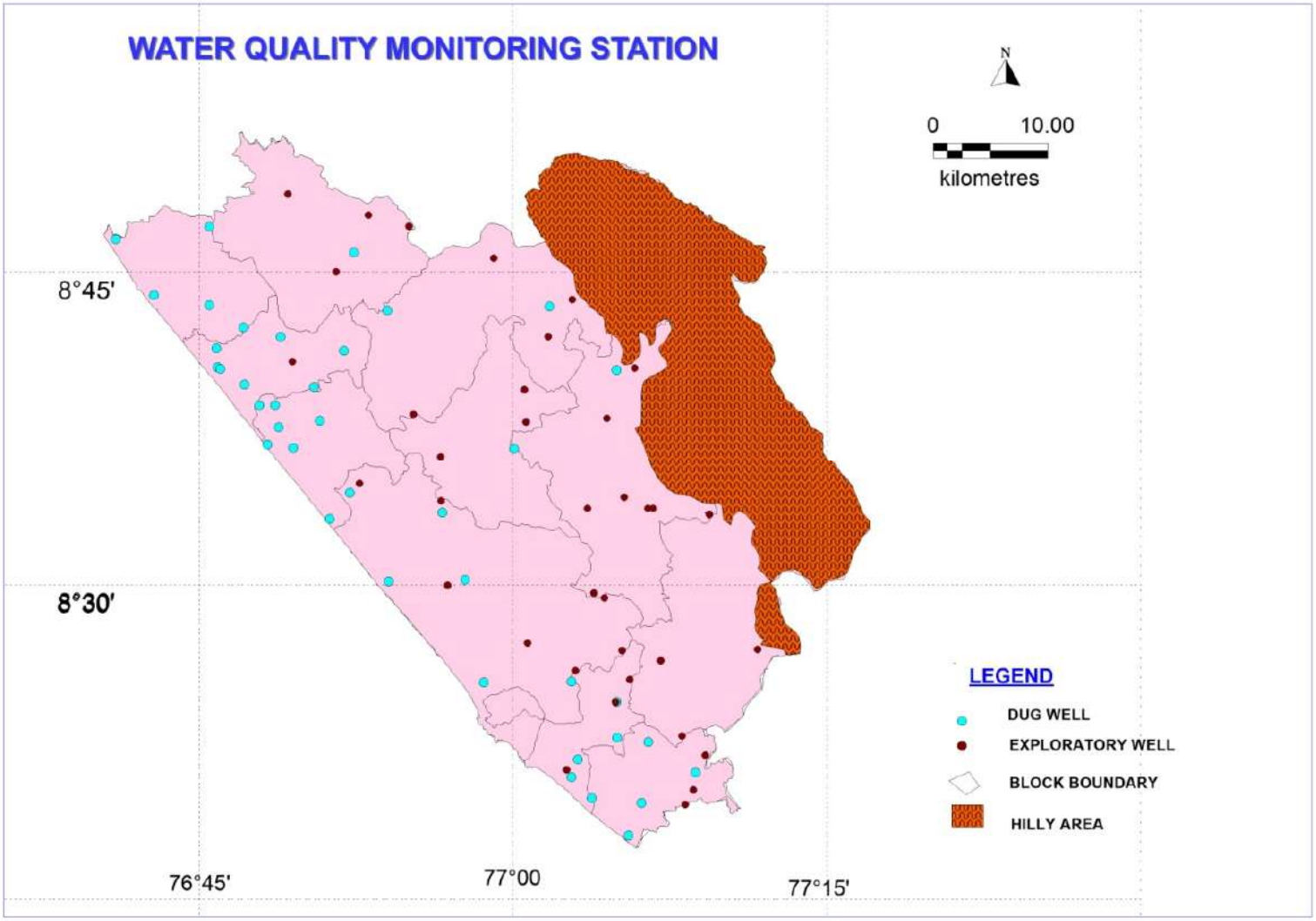


Figure 2.2: Location of Water quality monitoring stations

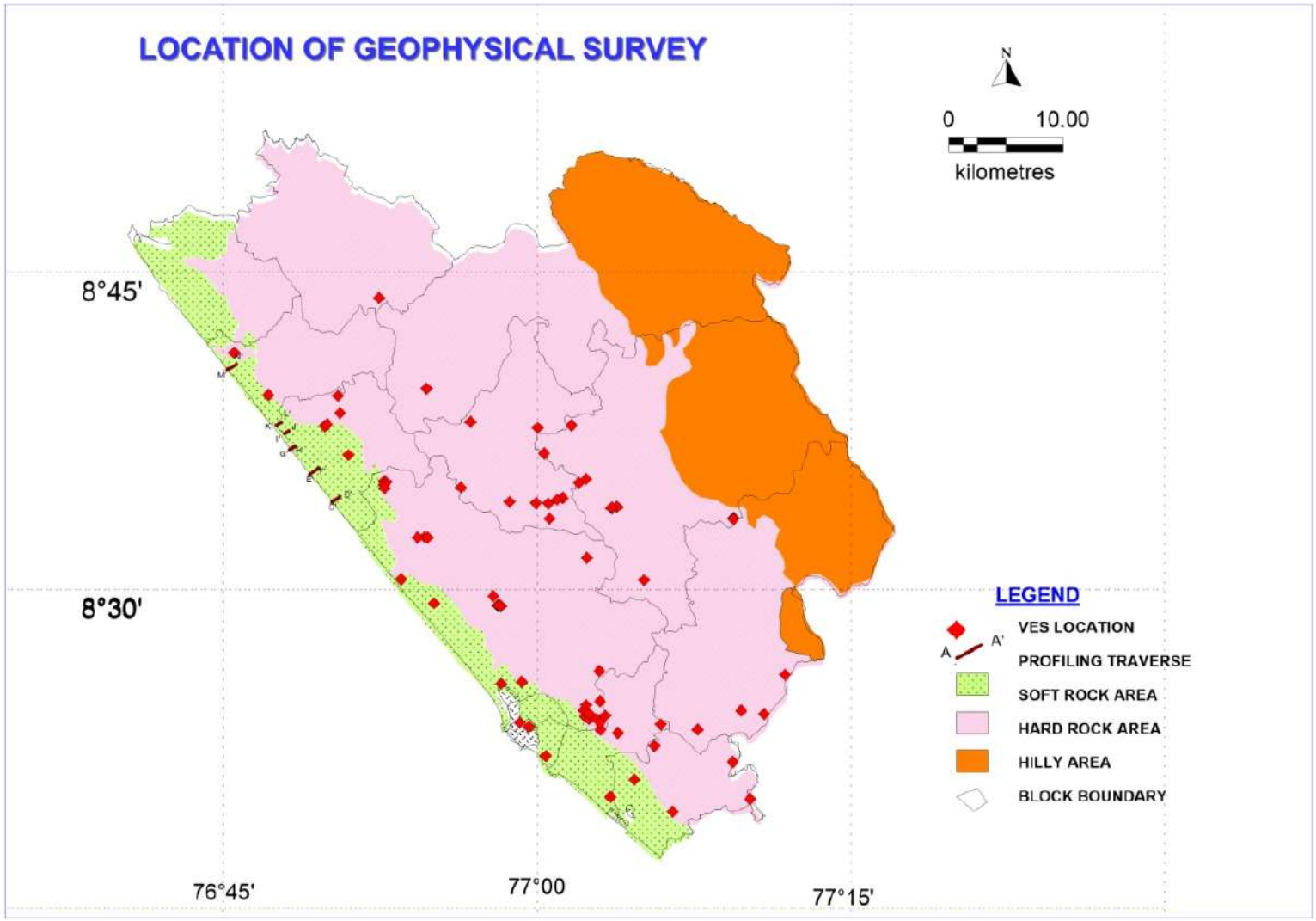


Figure 2.3: Location of Geophysical Survey

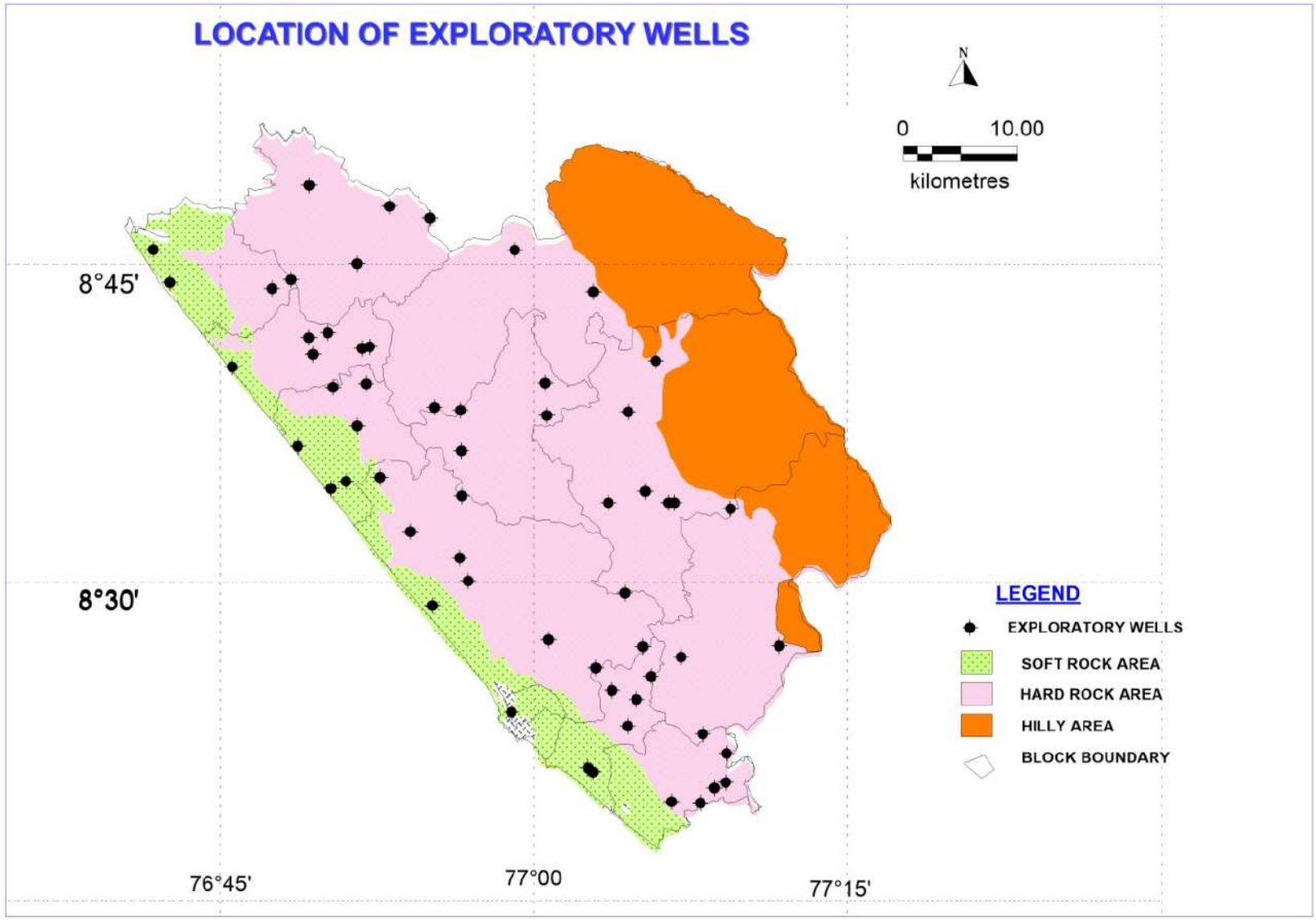


Figure 2.4: Location of exploratory wells

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 HYDROGEOLOGICAL DATA INTERPRETATION

Thiruvananthapuram district comprises of both hard rock and soft rock. Hard rock represents area mainly underlined by Khondalite group of rocks followed by Migmatite Complex and Charnockite group of rocks. Aquifer units identified in the hard rock area comprises of laterite/weathered zone and associated shallow fractures to some extent (phreatic Aquifer) and deeper fractures in the Khondalites, Migmatites and Charnockites (deeper Aquifer). Soft rock represents area underlined by Sedimentary rocks. The aquifer units falling in soft rock area are Alluvium (Aquifer I), Tertiary Laterite (Aquifer II) and Warkali formation (Aquifer III).

3.2 GROUND WATER LEVEL INTERPRETATION

During aquifer mapping studies ground water regime are monitored regularly in order to know the behaviour of the groundwater regime. During pre-monsoon (April), major part of the district shows depth to water level in the range of 5 to 10 mbgl and shallow water level is observed along the coast. Depth of analysed well ranges from 3.86 to 50 mbgl .Depth to water level for pre monsoon varies from 0.84 to 48.31 mbgl and during post monsoon, depth to water level varies from 0.47 to 48.45 mbgl. During post monsoon also major part of the district shows water level in the range of 5-10 mbgl and the wells falling in 2-5 mbgl range also increased showing recharging of ground water during monsoon. The details of ground water monitoring wells is given in **Annexure I**

Water level fluctuation in the observation wells in an area between two periods is indicative of the net changes in the groundwater storage during the period in response to the recharge and discharge components and is an important parameter for planning for sustainable groundwater development. The seasonal water level fluctuation in the area has been analysed using the water level data of April and November which indicate the extent of replenishment of the shallow aquifer due to the monsoon rainfall. The 4% of the analysed well showed fall in water level in the range of -2 to 0. 49% showed rise in the range of 0to 2m, 45% showed rise in the range of 2-5 and 2% showed more than 5m rise in water level. Depth to water level map for both pre monsoon (April) and Post monsoon (November) as well as Fluctuation map of the district is prepared and is given in figures 3.1, 3.2 and 3.3 respectively.

The variation in water level with reference to time and space is the net result of groundwater development and recharge. The long-term change in water level is discernible from the trend of water levels over a period of time and is best reflected in a hydrograph. The Decadal trend (2007-2016) of ground water levels, for pre- monsoon and post monsoon periods is given below in table 3.1. Analysis of decadal trend shows that during pre-monsoon 30% of the analysed wells shows rise and 70 % of the wells shows fall and during post monsoon period 45% of the wells shows rise and 55% shows fall. The hydrographs of some wells are given in Figure 3.4

Table 3.1: Decadal Trend of water level

SL. No.	Location	Pre _monsoon Trend(m/year)	Post monsoon Trend (m/year)
1	Aruvikara	-0.339	0.032
2	Attingal	-0.452	-0.230
3	Kallambalam(R1)	-0.098	0.130
4	Kallar	-0.080	-0.020
5	Kallikkad	0.029	-0.150
6	Kattakkada	-0.136	-0.012
7	Kilimannor	-0.118	-0.060
8	Korani	-0.067	-0.050
9	Madavur	-0.052	0.016
10	Mannanthala	0.090	0.102
11	Maruthamala	-0.122	-0.011
12	Nedumangad	-0.081	0.065
13	Nemom	-0.421	-0.470
14	Neyyattinkara	0.115	0.040
15	Palode	-0.064	-0.004
16	Panavoor	0.018	0.059
17	Pangode	-0.111	-0.026
18	Parassala	0.052	-0.005
19	Perumgur(R1)	0.310	0.232
20	Perunkadavila	0.164	0.359
21	Pirappankod	-0.013	0.057
22	Ponmudi(R1)	-0.054	-0.080
23	Pothencod	-0.186	-0.012
24	Trivandrum	-0.223	-0.273
25	Vamanapuram	-0.368	-0.026
26	Vellanad	-0.053	-0.069
27	Vellarada(R1)	0.007	-0.036
28	Vithura	-0.155	0.046
29	Anjengo	-0.02	0.00
30	Chirayinkeezh	0.03	0.06

SL. No.	Location	Pre _monsoon Trend(m/year)	Post monsoon Trend (m/year)
31	Kadakkavur(R1)	-0.01	0.01
32	Murukumpuzha(R1)	-0.14	-0.05
33	Nagapuram	1.63	-0.48
34	Nemom	-0.42	-0.01
35	Parassala	0.05	0.08
36	Mannanthala	0.09	0.10
37	Kochuveli(R1)	-0.04	0.01
38	Perumathura	0.04	-0.01
39	Poonthura	-0.11	-0.05
40	Poovar-ii	-0.01	0.41
41	Pozhiyoor(R1)	-0.29	-0.03
42	Pudukurichi	-0.01	0.02
43	Puvar School	-0.21	-0.34
44	Vellayani (Poonkulam)	0.41	0.31

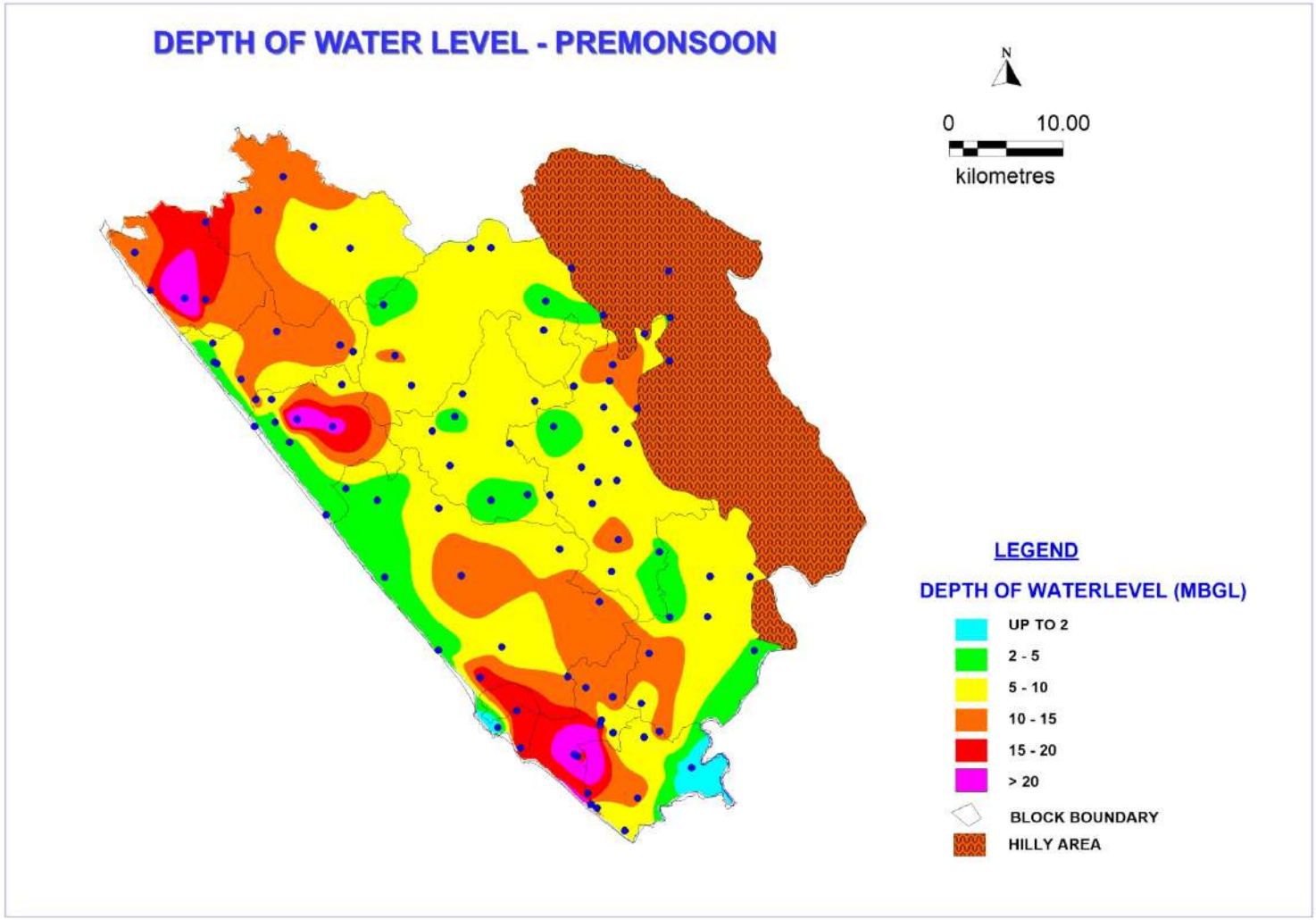


Figure 3.1: Depth to water level- Pre monsoon

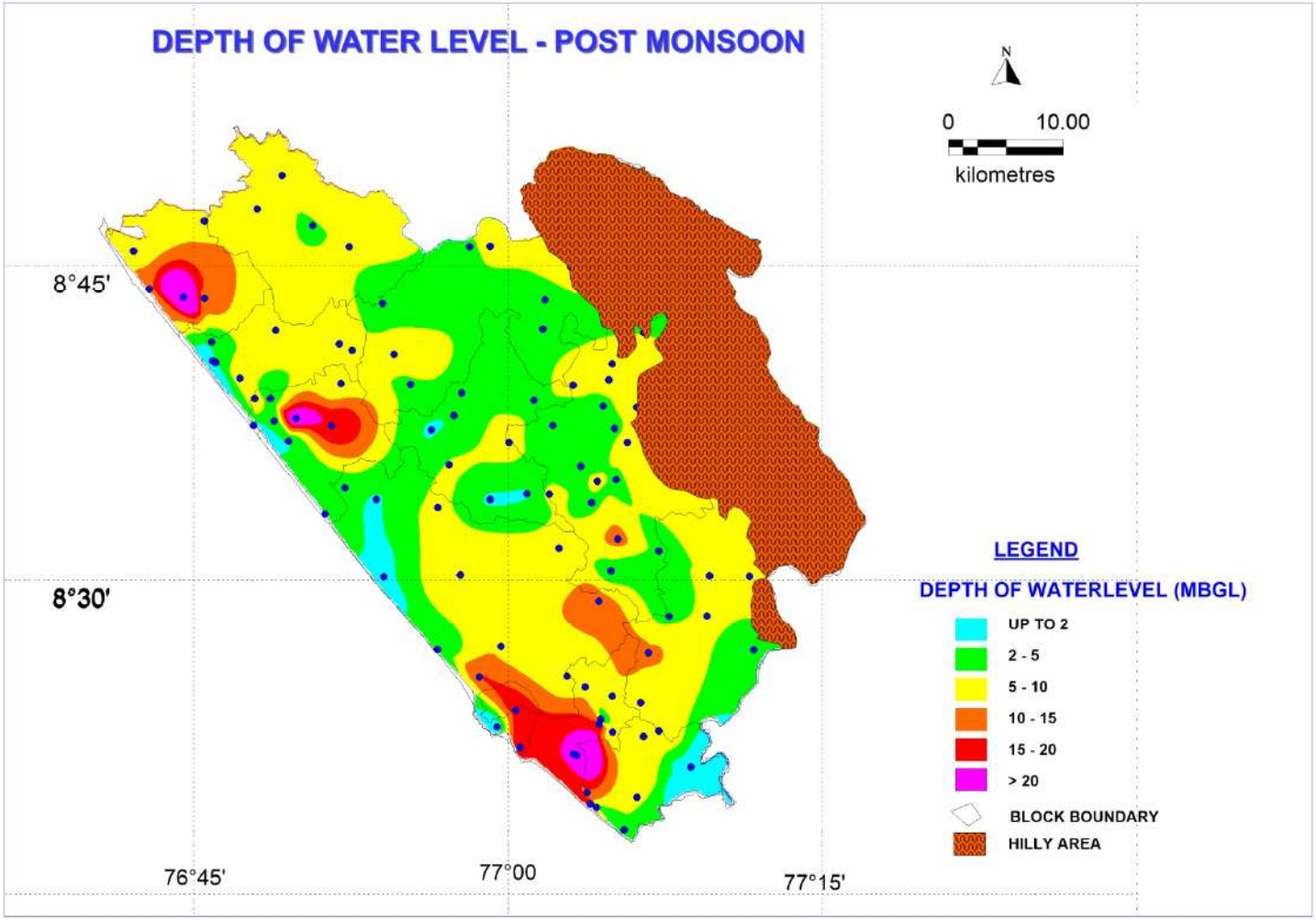


Figure 3.2: Depth to water level Post monsoon

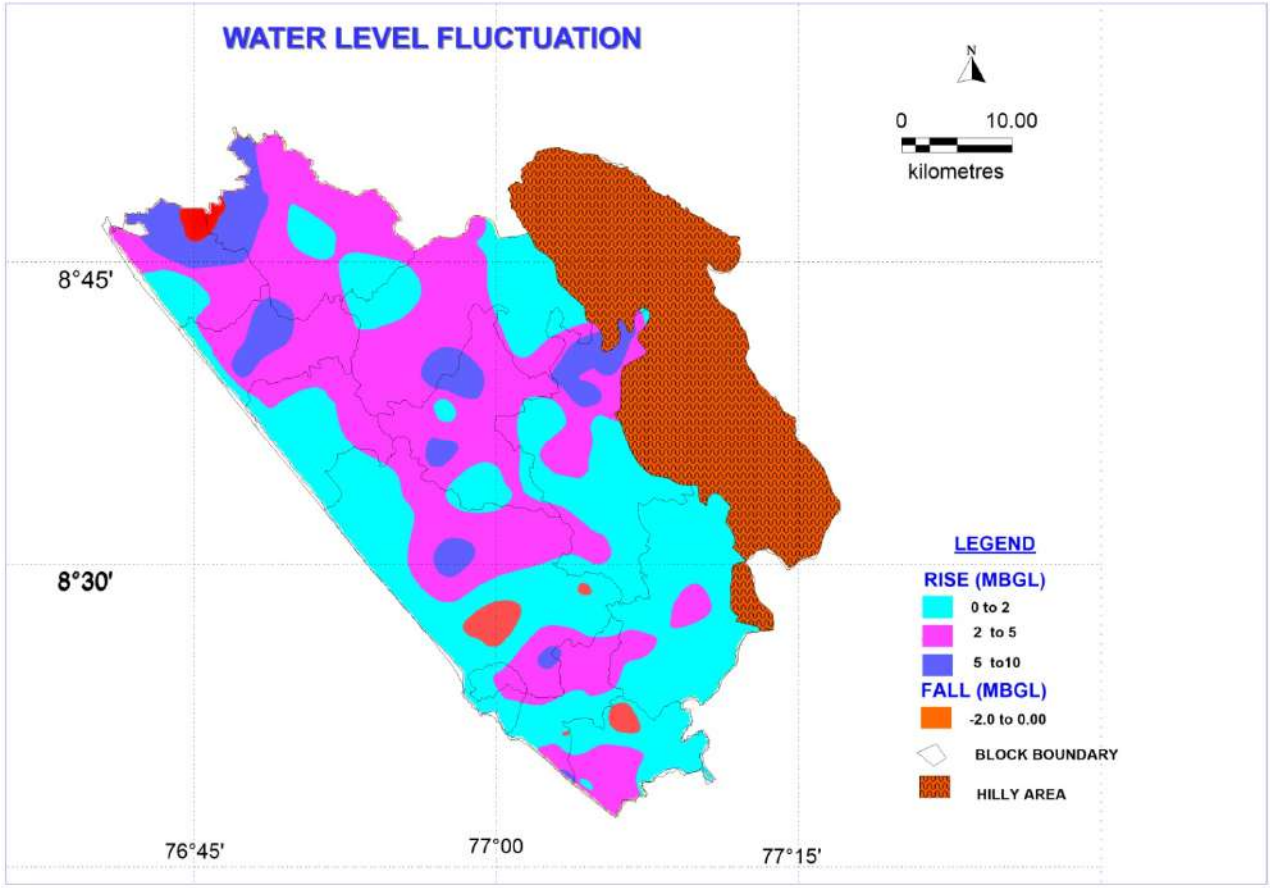


Figure 3.3: Water level fluctuation Map

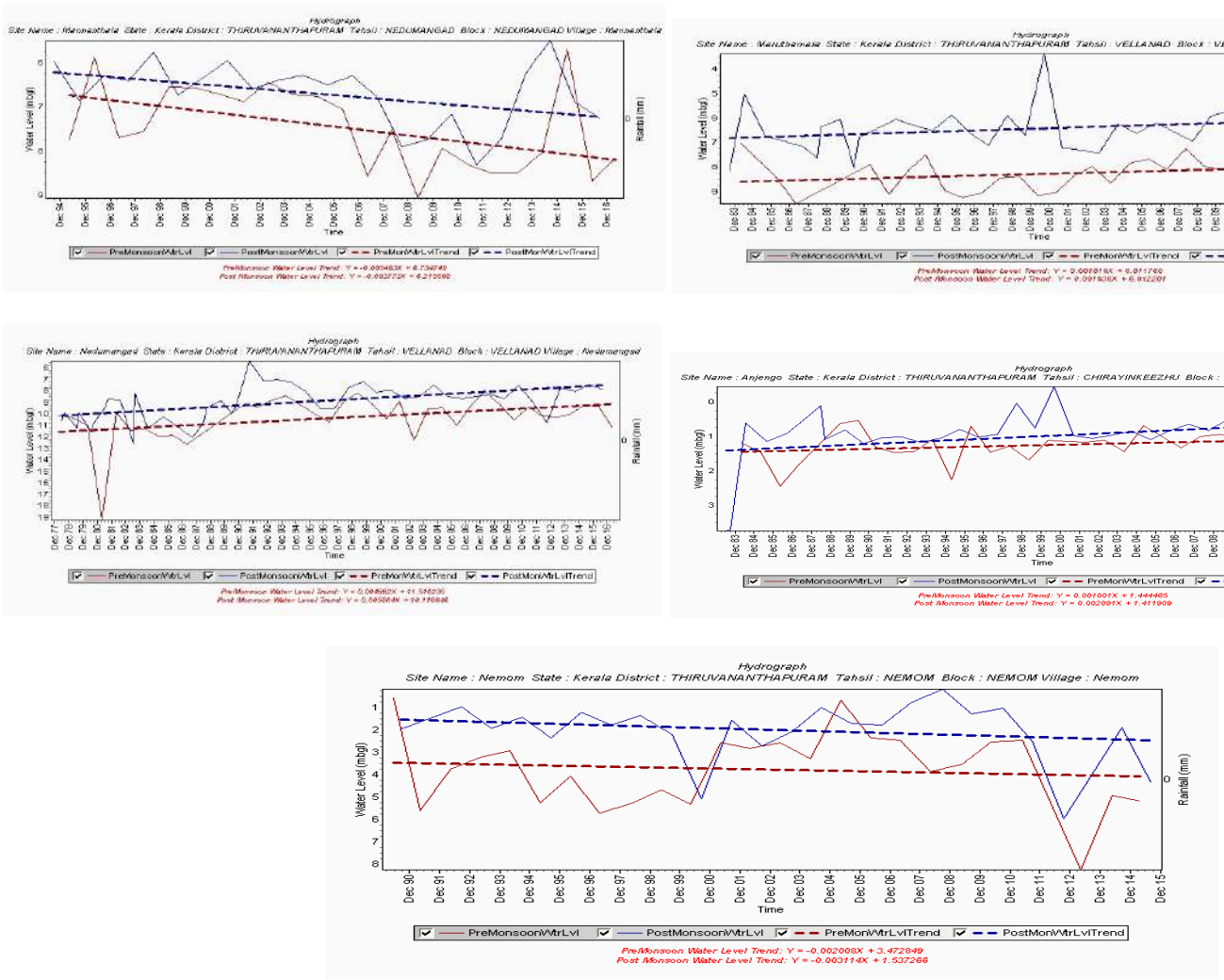


Figure 3.4: Hydrograph of some long-term monitoring wells.

3.3 GROUND WATER QUALITY INTERPRETATION

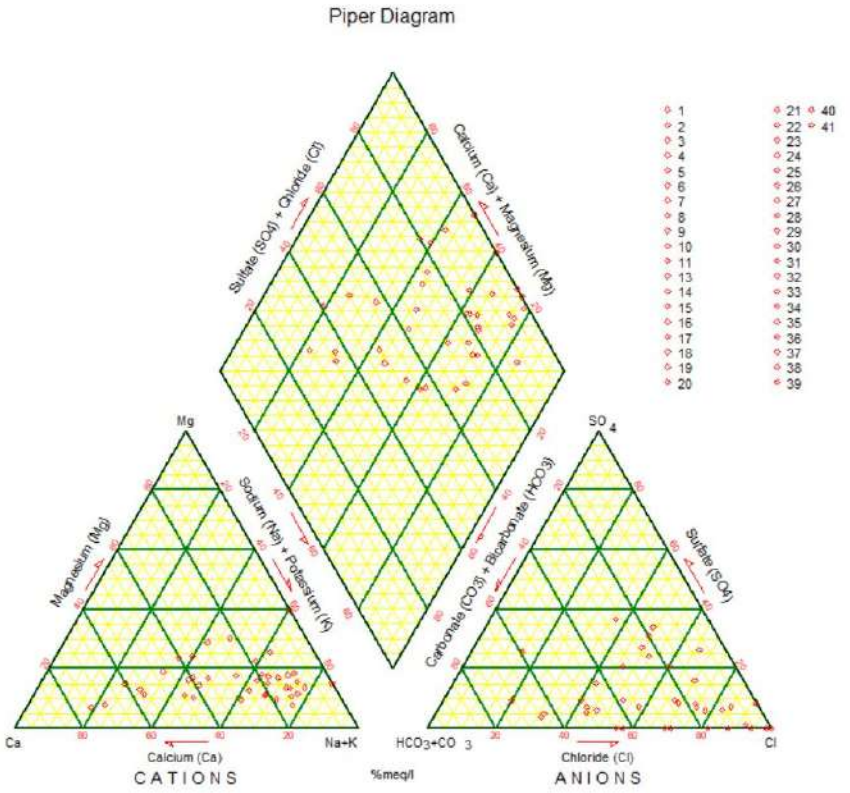
In a groundwater flow regime water chemistry constantly undergoes modification due to various processes such as dissolution of minerals, precipitation of dissolved ions under unstable conditions, cation exchange etc. The chemical composition of subsurface water is controlled by various factors such as the amount of dissolved CO2 in rain water and soil, the composition of the rocks through which the water percolates and the duration of contact between the water and the soil/rock. Further there is a direct relationship between hydraulic conductivity of aquifers and TDS of groundwater. Thus, with the decrease in hydraulic conductivity there is general increase in chemical concentration of various ions in groundwater. The ground water quality of the district is studied with the analytical data of groundwater samples collected from Network stations of Central Ground Water Board and exploration.

Ground water quality data deciphered from 9 number of tube wells shows that the quality of ground water in deeper sedimentary rocks is poor. In the district the water in the Warkali formation is brackish in the coastal parts between Chakkai and Anchuthengu but further north of Anchuthengu the formation yields fresh water. The tube well at Pallom yielded fresh water.

3.3.1 Phreatic aquifer

The existing water quality data from 41 dug wells (Annexure II) for pre monsoon (April) have been analysed for extracting information on regional distribution of water quality and their suitability for various uses. The groundwater quality in the district is generally good for all purposes. The pH of ground water in the analysed samples ranges from 4.29 to 7.73. The electrical conductivity (in µS/cm at 25^{o}C) ranges from 56 to 1570. EC above 750 is noticed in Balaramapuram and Pozhiyoor and Chloride is below 250 mg/l in all samples except the one collected from Pozhiyoor. Fluoride content in the observation wells monitored is in the range of 0.06 to 0.44 mg/l in the study area. Nitrate above the permissible is noted in four locations i.e. samples collected from Kazhakuttom, Perumkuzhi, Pudukurichi and Balaramapuram. A study conducted by State Ground Water department has found that about 70% of the wells of Thiruvananthapuram are contaminated with coliform bacteria.

In order to understand the hydro geochemical facies of the ground water, the samples were plotted in Hill Piper Trilinear diagram (figure 3.5). Majority of the samples fall in Na-Cl type and mixed type where chemical properties are dominated by alkalis and strong acids.



p

Figure 3.5: Hill-Piper diagram of Phreatic Aquifer

To understand the suitability of ground water for agriculture purpose, the analytical data on Sodium Absorption Ratio and electrical conductivity is plotted on US salinity diagram (figure 3.6). The majority of the samples fall in C1S1 and C2S1 category showing the irrigation suitability of ground water.

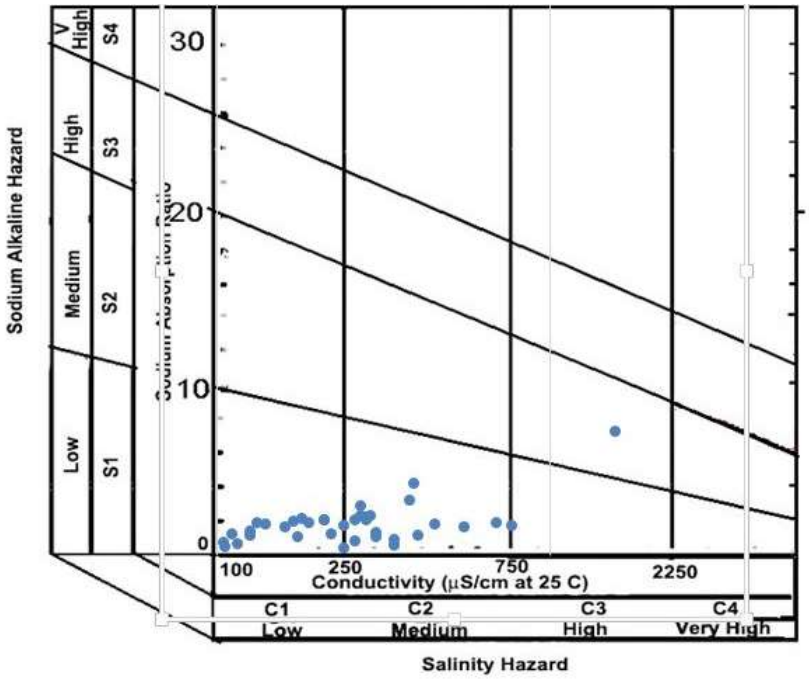


Figure 3.6: US Salinity diagram of Phreatic aquifer

3.3.2 Chemical quality of water in fractured aquifer

Water samples collected from fractured aquifers during the construction of bore wells and piezometers were analysed for EC, pH, major cations, anions and Fluoride. The analysis include samples from same well at different depth also. The details of the samples are given in the **Annexure III**. The pH of the samples ranges from 6.47 to 9.45. EC values ranged from 78 to 470 except at Kuravara well where the EC was 4240 µS/cm at 25ºC at a fracture encountered in 40m bgl. Fluoride above permissible limit is reported in the bore wells at Vamanapuram as it encountered a pegmatite vein. Other parameters like Chloride and Nitrate are within permissible limit. The analysis of the data shows that water in the fractured zones of hard rock terrain in Thiruvananthapuram district is of alkaline nature and quality of the water is generally good.

The samples plotted in Hill- Piper diagram fall in Ca-HCO_3 type, mixed type and Na- HCO_3 type (figure 3.7). While plotting on the USSL diagram (figure 3.8) the samples fall in C1S1 and C2S1 category indicating the irrigation suitability of water.

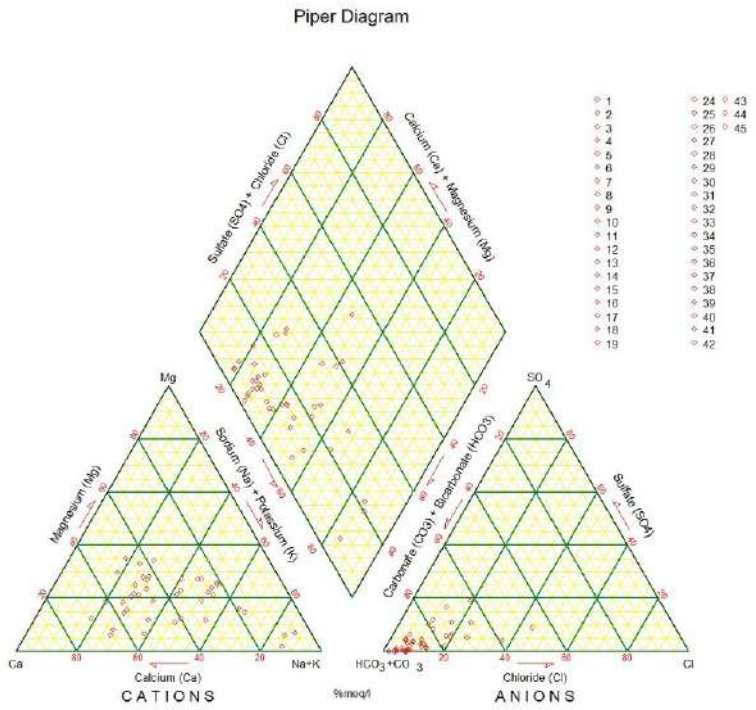


Figure 3.7: Piper diagram of water of fractured aquifer

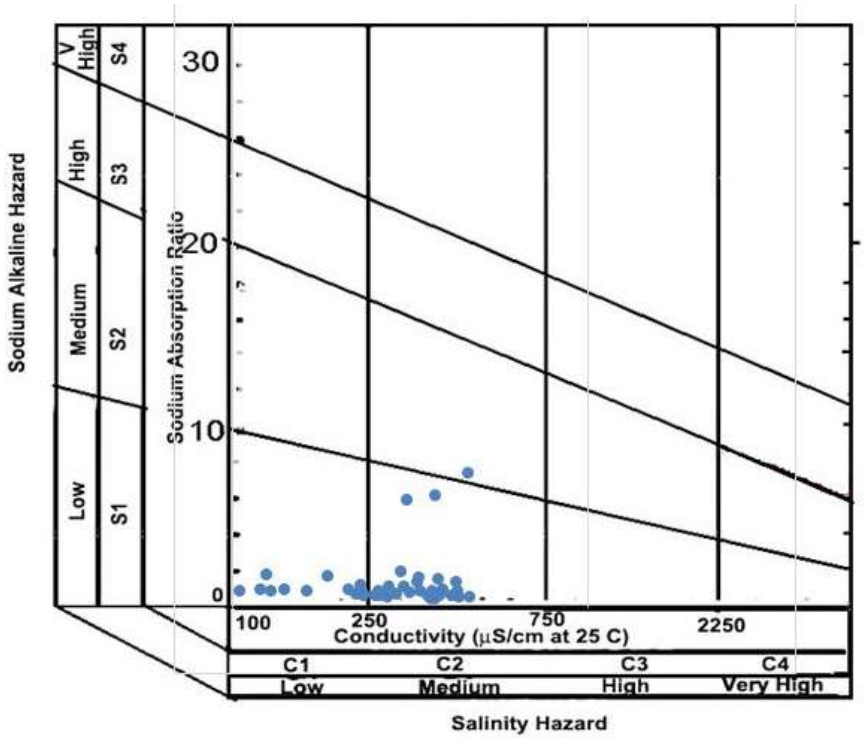


Figure 3.8: US Salinity Diagram of Fractured aquifer

3.4 GEOPHYSICAL INTERPRETATION

(i) Hard rock area

Geophysical surveys consisting of resistivity profiling and Vertical Electrical Soundings were carried out in Trivandrum district. The obtained VES curves were interpreted by computer interpretational techniques. The interpreted results have given rise to 3 to 5 – layered geoelectric section.

The interpreted results of the 63 VES indicates that the first layer resistivity varyies in the range of 49-5227ohm.m. At about 59 VES locations, the resistivity is in the range of 49-3194 ohm.m represents the top soil. Lower order of resistivity indicates clayey nature of soil. In the remaining four VES resistivity was varying in the range of 3743-5227 ohm. m (Venpackal, Mangalapuram, Tanumoodu and Kappukadu) indicating the Lateritic nature. The thickness of first layer is varying in the range of 0.26-5.54 m.

The second layer resistivity was varying in the range of 9-1686 ohm.m except at four VES where it was varying in the range of 2810-4160 ohm.m. The thickness of this layer was varying in the range of 0.92-24.4 m except at one VES where it was 36.6 m (Kinfra). In this resistivity range the formation with resistivity upto 50 ohm.m was considered as Clay in nature and was recorded at 6 no. of VES. The resistivity of the second layer at these 6 VES was varying in the range of 9-46 ohm.m with thickness in the range of 0.71-4.7m. At 21 VES the resistivity was recorded as the range of 58-163 ohm.m with thickness of 1.6-10.35 m (except at three VES No's: 29, 36 & 45 where it was varying 18, 21.4 & 36 m respectively) may be of weathered nature. At the remaining 36 VES the resistivity of the second layer is varying in the range of 256-4165 ohm.m. The higher order of this resistivity indicates compactness of lateritic material. The thickness of this formation is varying in the range of 1-24 m.

The third layer resistivity was varying in the range of 4-1812 ohm.m except at two VES the resistivity was around 2450 ohm.m (at VES - 14) and 3520 ohm.m (at VES -18) respectively. The thickness of this layer was varying in the range of 1.47-41 m except at two VES the thickness was recorded as around 58m (at VES - 35) and 55 m (at VES – 51) respectively. In this resistivity range the formation with resistivity up to 40 ohm.m was considered as Clay in nature and was recorded at 14 no. of VES. The resistivity of the third layer at these 14 VES was varying in the range of 4-43 ohm.m with thickness in the range of 4.59-14.56m. Except at four VES the thickness was varying in the range of 22-41 m. At 22 VES the resistivity was recorded as the range of 50-190 ohm.m with thickness of 1.5-36 m (except at two VES No's: 35 & 51 where it was varying 58 & 55 m respectively) was considered as weathered in nature. At the remaining 27 VES the resistivity of the third layer is varying in the range of 200-3520 ohm.m. The higher order of this resistivity indicates compactness of lateritic material. The thickness of this formation is varying in the range of 4-37 m. The third layer was extending in nature at three VES (VES- 1, 41 and 45).

The interpreted results have given rise to fourth layer at about 60 VES only. Out of this 60 VES at about 5 VES the fourth layer was recorded as massive formation (resistivity was recorded as VH). At about 28 VES the fourth layer was extending in nature with resistivity range of 53 ohm.m to very high (VH). At the remaining 27 VES the resistivity of the fourth layer was varying in the range of 12-2961 ohm.m with thickness in the range of 2.3-106.6 m.

The interpreted results have given rise to fifth layer at about 32 VES only. Out of this 32 VES at about 19 VES the fifth layer was extending in nature. At the remaining 13 VES the resistivity was varying in the range of 17-837 ohm.m with thickness in the range of 8.4-43.7 m. The Interpreted Geophysical (VES) data is given in **Annexure IV.**

(ii) In soft rock area

In Trivandrum district. a total of 21 vertical Electrical Soundings (VES) were carried out in the soft rock area by employing the Schlumberger electrode configuration up to a maximum spread length (AB/2) of 200 m. The obtained VES curves of H, QH, KH, HA, AA, KHA and QHA type were interpreted by employing computer interpretational techniques. The interpreted results have given rise to 3 to 5 layered geo electric sections.

At 9 VES was only the last layer was recorded as massive formation whereas at the remaining 12 VES the last layer was extending with depth and the thickness of this layer could not be estimated due to non-availability of spread length. The depth to massive formation was in the range of 38-105 m.

The interpreted VES results indicated that the first layer resistivity was varying in the range of 140-5200 ohm.m which is soil to lateritic soil in nature except at three sites namely Chirayankeezh, Veli and Chackai where it was sand. The thickness of this formation is varying in the range of 0.8-5 m except at two VES where it was 5.8 and 10 m respectively. In this range the resistivity of the formation up to 160 ohm.m was considered as soil and the remaining range of 240-3500 ohm.m was considered as laterite in nature. The resistivity of sand was recorded in the range of 350-5200 ohm.m.

The second layer resistivity was varying in the range of 50-1100 ohm.m with thickness in the range of 8 to 36 m. except at one VES where it was extending in nature. At about 9 VES namely Vailur2, Mangalapuram, Pallipuram, Mudapuram, Chantavala1, Vellayani, Poonkulam, Kovalam the second layer resistivity was varying in the range of 350-1100 ohm.m which was also considered as lateritic in nature. The thickness of this formation was varying in the range of 7.5-11.8 m except at two sites where it was 25 and 27 m. respectively. At about 3 VES namely Vailur1, Chantavala2 and Poovar the second layer resistivity was varying in the range of 270-610 ohm.m with thickness in the range of 8-36 m. which was considered as hard formation. At 6 VES namely Chirayankeezh, Sreekariyam, Veli, Chackai, Venganoor and Venpakal the second layer resistivity was varying in the range of 80-300 ohm.m with thickness in the range of 7.5-13 m. which was sand. At the VES namely Vakkom, Thirupuram and Mulloor the second layer r4esistivity was varying in the range

of 50-68 ohm.m which was clay to sandy clay in nature. The thickness of this formation was in the range of 8.5m to extending in nature.

The third layer resistivity was varying in the range of 9-2000 ohm.m with thickness in the range of 30 m to extending in nature. At 6 VES namely Chirayankeezh, Mangalapuram, Mudapuram, Veli, Chackai and Venpakal the third layer resistivity was varying in the range of 9-48 ohm.m with thickness in the range of 30-41 m which was clayey in nature. At 5 VES namely Sreekariyam, Poovar, Kulathur, Thirupuram and Mulloor the third layer resistivity was varying in the range of 110-130 ohm.m with thickness in the range of 40 m. to extending in nature which was weathered to semi/partially weathered formation in nature. At one VES namely Kovalam the resistivity and thickness values of this formation was 2000 ohm.m and 50m respectively which is expected to be massive in nature. At Vailur 1 and 2 the third layer resistivity was varying around 450and 900 ohm.m respectively which was considered as hard formation. At Chantavala 1 and 2 the third layer resistivity was varying around 300 and 450 ohm.m which was considered as sand. At about 4 VES namely Pallipuram, Poonkulam, Vellayani and Venganoor the third layer resistivity was varying in the range of 75-120 ohm.m which was expected to be sandy clay and the thickness was varying in the range of 87 m. to extending in nature.

The fourth layer was recorded at 12 VES only and at 50% of the sites it was massive in nature. At the remaining 6 VES namely Vailur 2, Mudapuram, Poovar, Kulathur, Kovalam and Venpakal the fourth layer resistivity was varying in the range of 75-500 ohm.m with thickness in the range of 15 m. to extending in nature. At Vailur 2 this formation was considered as sandy clay in nature whereas at Venpakal it was expected as weathered in nature. At the remaining 4 VES it was expected as hard/massive formation. Out of this 4 VES only at Kovalam this formation was devoid of any fractures and at the remaining 3 VES this formation was expected to be fractured in nature.

The fifth layer was recorded only at 2 VES namely Mudapuram and Venpakal which is expected to be massive in nature.

Along the coast and perpendicular to it in seven E-W traverses, a total of 76 VES and about 15 line km Wenner Sounding and Wenner Profiling were carried out using ABEM SAS 300c Terrameter during summer season. The interpreted results of VES and resistivity survey and profiling along the seven traverses are discussed in the following sections. The seven traverses from south to north are

Thumba traverse (A' – B')
Vettuthura traverse (C' – D')
Shantipuram traverse (E' – F')
Pudukurichi traverse I (G' – H')
Pudukurichi traverse II (I' – J')
Matanvila traverse (K' – L') and
Anjengo traverse I (M' – N') and the traverses are shown in figure 2.3

1. Thumba traverse (A'-B'): Along this traverse Wenner resistivity profiling to a length of 120 m perpendicular to coast and 3 VES were carried and the interpreted results showed that the resistivity is moderately high below 8 m and hence no indication of quality problem.
2. Vettuthura traverse (C'-D'): Resistivity profiling (220 line m) and soundings (3 VES) were carried out along this traverse. The interpreted results showed that the resistivity is high even below 13 m and hence no indication of quality problem.
3. Shantipuram traverse (E'-F'): Resistivity profiling to a length of 100 line m and 3 VES were carried out perpendicular to the coast along this third traverse. The VES result indicated that the resistivity is high below 5 metres and hence there is no quality problem in the area.
4. Pudukuruchi I traverse (G'-H'): In the premises of St. Micheal church, near Pudukurichi resistivity profiling and soundings were carried out perpendicular to the coast. Along this traverse 8VES were carried out using Wenner method. The VES results showed that the resistivity, in general, is low below 5 m. The ground water quality along this traverse is probably influenced by the presence of backwaters/kayals located on the eastern side of the traverse. To establish this low resistivity value by brackish water contamination.
5. Pudukurichi II traverse (I'-J'): In the premises of Dr Salil's clinic located in between coast and Kadinakulam kayal, north of Pudukuruchi I traverse several resistivity profiles of various spacing intervals of 30 and 40 m were carried out perpendicular to the coast. The resistivity profiling carried out along this traverse of spacing 30 and 40 m for station interval of 10 m showed an apparent resisitivity of 2 ohm.m and 10 ohm.m respectively. In addition to resistivity profiling, 3 VES using Wenner Method were carried out along this profile. The interpreted results reveal very low resistivity of 2.5-8.6 ohm.m below depth range of 5-6 m pointing towards the poor quality of formation/ ground water. Moreover, Wenner electrical sounding was carried out in front of dug cum filter well in the same location and the results supports the above resistivity surveys that a low resistivity zone of 10 ohm.m was encountered below 6m. In the same dug cum filter well, pumping was done for one and a half hours and groundwater samples were collected before and after pumping for chemical analysis.
6. Matanvila traverse(K'-L'): Resistivity profiling perpendicular to the coast and 3 VES were carried out along the traverse. The profiling of separation 15m and 25 m with station interval of 15 m showed very low resistivity of 11 ohm.m and 6 ohm.m respectively. The VES results indicated that low resistivity of around 7 to 9 ohm.m was recorded below 4-6 m depth indicating ground water quality problem. Along this traverse also ground water samples were collected.
7. Anjengo traverse(M'-N'): Two resistivity profiling perpendicular to the coast and 3 VES were carried out along the traverse. Resistivity profiling with separation 10 m and 15 m with a station interval of 10 m was carried out. The profiling results showed a low resistivity of less than 10 ohm.m. The VES results also indicated low resistivity of 2 ohm.m

below 2 m depth. The low resistivity along the Anjego traverse indicates abnormal ground water quality and hence ground water samples were collected along this traverse.

In the area located north of Anjengo coast namely Varkala and Kappil coast, the resistivity is high indicating that these areas are free from ground water quality problems which is tallying with the ground water exploration details.

Out of seven traverses conducted from south to north only along four traverses namely Pudukuruchi I, Pudukurchi II, Matanvila and Anjengo showed low resistivity zones at shallow depth, indicating the presence of brackish/saline ground water. The location of these four traverses itself is conducive for saline water intrusion since the narrow stretch of land where low resistivity is encountered is sandwiched between coast and backwaters. Therefore a conclusion cannot be arrived at and periodical geophysical surveys and chemical analysis of ground water samples should be done to ascertain the reason for the ground water quality deterioration. Care should be taken in the narrow stretch of land between coast and back water to avoid over exploitation of fresh water resource and to prevent quality deterioration of ground water.

3.5 AQUIFER MAPPING

3.5.1 Hydrogeology of hard rock region

Hard rock region comprising an area of 1790 Sq.km covers major share of the district. Khondalite group of rocks, Migmatite complex and Charnockite group of rocks is found in the central and eastern portions of the district. The Khondalite group of rocks covers an area of 1266.38 Sq.km and Migmatite complex an area of 324.15 Sq.km. The Charnockite formation covers an area of 120.19 sq.km. The two aquifer units identified in the hard rock region are Laterite/weathered zone and associated shallow fractures (Phreatic Aquifer) and deeper fracture/joints aquifer unit (Deeper Aquifer).

(i) Phreatic aquifer

Laterite/weathered zone and associated shallow fractures forms the potential aquifer in the study area, and it is hydraulically connected with deeper fracture zones. Groundwater occurs in unconfined condition. The occurrence and movement of groundwater in the weathered zone is mainly influenced by the depth of weathering and topography and the groundwater follows the topography. Groundwater abstraction structures in this zone include dug wells and shallow bore wells. The weathered thickness in the area vary highly as observed from exploratory drillings and the data have been used to elucidate the lateral and vertical changes in weathered zone. The information from bore wells has been analyzed for understanding the spatial variations in the thickness of weathered zone. The weathered aquifer unit occurs from the ground level and weathering thickness ranges from 5 to 31m bgl. The thickness of the weathered zone is high in the southern part (Parassala) and northern part (Kilimanoor) of the district. A bore well drilled by

CGWB at Nanniyode has not encountered hard rock even after drilling upto 52m bgl. The Spatial variations of weathered zone thickness in the area are given in Figure 3.9.

The depth of dug wells ranges from 3.86 to 17 mbgl. The water level ranges from 2.71 to 14.02 mbgl during the pre-monsoon period and 1.86 to 11.6 mbgl during post monsoon period. Ground water is generally potable except in isolated locations where Iron and Nitrate above permissible limit is detected. The wells located in this aquifer zone yield groundwater of <5 to 60 m^3/day and sustains 1 to 3hrs of pumping.

(ii)Fractured Aquifer

This aquifer unit comprises of fractures and joints in hard rock such as Khondalite and gneisses and these basement rocks are found below the weathered zone. The water in bore wells occurs in confined or semi-confined state. The analysis of data from 48 bore wells indicates the possibility of occurrence of 3 to 4 Fracture zones up to the depth of 193 m bgl. The depth of the bore wells analysed varies from 40-200m. The bore well at Korani have 7 sets of fractures up to the depth of 175m bgl. The general depth of occurrence of potential fractures is 40-80m bgl. Analysis of data on distribution of the fractures with depth indicates that cumulatively 43% of the fractures are found up to 50m depth, 58% of fractures with in 80m depth, 73% within 110m depth, 81% upto the depth of 140m, 94% up to 170m and remaining 6% is found up to 193 m. Drill time discharge of wells ranges from 0.01 to 20lps while some of the wells were dry. Khondalites have a smaller number of fractures and open joints and is more susceptible for weathering and produce clay minerals. Hence along shear zones and weathered surface more of clayey minerals are observed. However due to high zone of weathering Khondalites area forms better phreatic aquifer of limited potential. The fracture zones of Khondalite are not so good aquifers as they are filled with clay formed by the weathering of Khondalites. The Transmissivity value varies from 0.54 to 17.58 m2/day and the Storativity values varies from 0.00007to0.001. The ground water in the fracture zone is generally potable with Ec value of 105 to 510 µS/cm. In all the water samples EC is found to be less than 500 µs/cm at 25ºC except in Vamanapuram EW and Fluoride content less than 0.5 mg/l except Balaramapuram EW. The details of exploratory wells drilled in the hard rock area is given in **Annexure V.**

The yield of the boreholes had a direct bearing on the Tectonic history and the rock types. The yield from bore wells varies in the area. Within the same geological formation, the spatial variation in yield is very common. The comparative study of the yield of the well with lineament indicates that the NW-SE and NNW-SSE lineaments are potential. The number of wells having varying yield ranges are given in Table 3.2

Table 3.2 Frequency of bore well in different yield ranges

Yield of Exploratory Wells	No of wells
>or=3 lps	12
1 to 2.9 lps	12
< 1 lps to dry	24

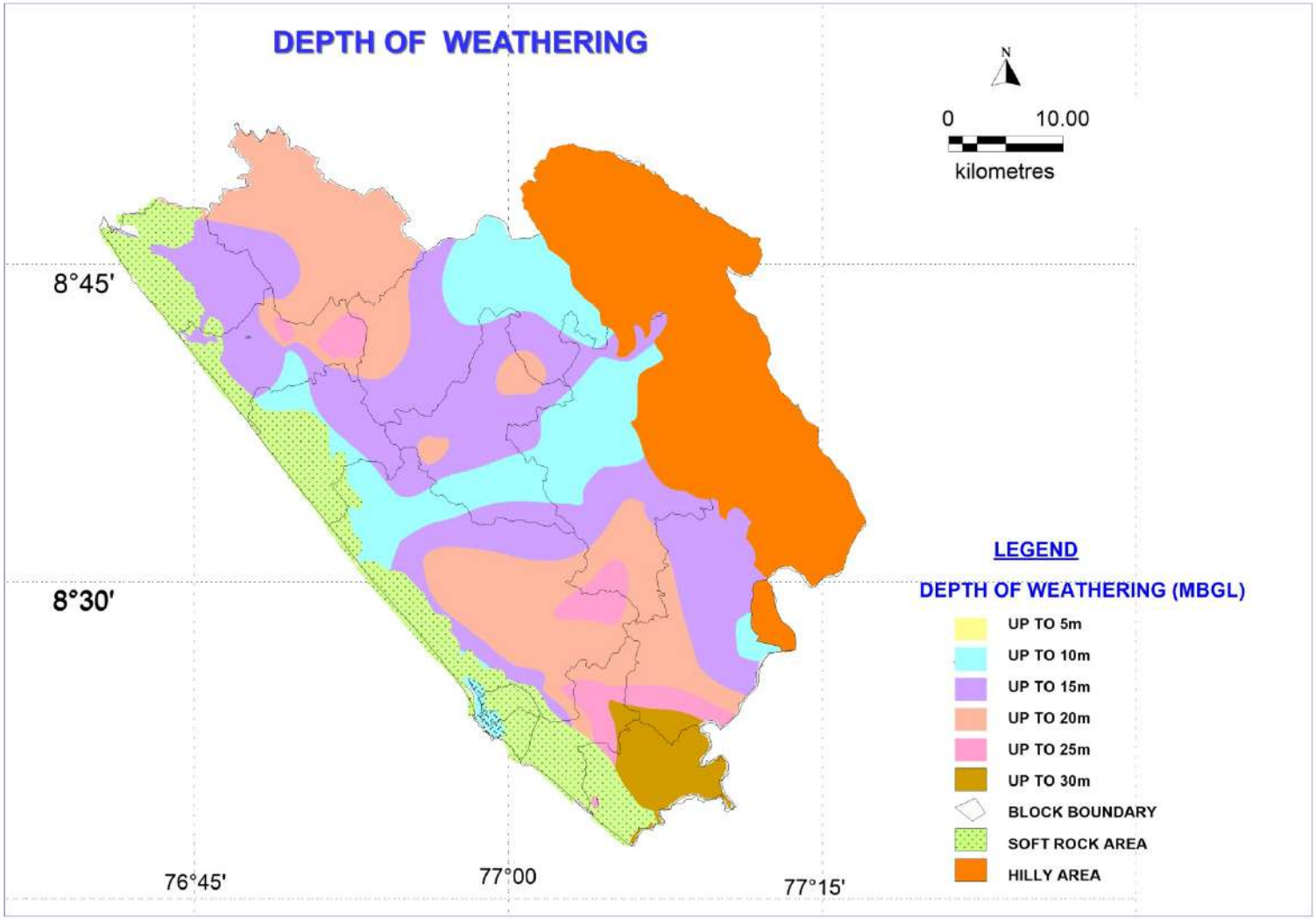


Figure 3.9: Map showing depth of weathering

3.5.2 Hydrogeology of Sedimentary formations in the district

Sedimentary area comprising of Alluvium, Tertiary Laterites and Tertiary formations occupy the western part of the district. The aquifer units falling in sedimentary area are Alluvium (Aquifer I), Tertiary Laterite (Aquifer II) and Warkali formation (Aquifer III). Tertiary laterites form phreatic aquifers where ever it is exposed and these laterites at depth, below Recent alluvium are considered as a demarcating zone and are remnants of the eroded laterite before the deposition of Recent alluvium. Hence, tertiary laterites below Recent alluvium do not form any aquifer. Thus, alluvium and the exposed Tertiary laterites together form the phreatic aquifer system in the sedimentary area.

(i) Alluvium (Aquifer – I)

Ground water occurring under phreatic condition in the coastal Alluvium is developed by means of small diameter dug well and filter point wells. The thickness of the aquifer generally varies from 3 to 12m and while moving towards east its thickness gradually decreases. In Thiruvananthapuram district the maximum thickness of alluvium is 18 m as encountered at Chakkai. It is absent towards northern parts of the district as in Edavai and Varkala. Filter point wells are found to be more economically feasible in the area wherever the saturated thickness of sand exceeds 5 m. Depth of the wells ranges from 2.5 to 8 m and depth to water level is shallow. All along the coast a fragile equilibrium exists between the freshwater and saline water which may be disturbed by over pumping. Depth to water level of the aquifer ranges from 0.99 to 5.24 mbgl in the pre-monsoon and 0.8 to 4.41 mbgl in the post monsoon. Yield of the well ranges between 15-50m^3/day.

(ii)Tertiary Laterite (Aquifer – II)

The thickness of the Tertiary Laterite in the district varies from 3 to 31m and the thickness of laterite encountered in the bore wells drilled by CGWB in the district varies from 2 – 24 m. Depth to water level of the aquifer ranges from 3.22 to 26.69 mbgl in the pre monsoon and 2.8 to 26.54 mbgl in the post monsoon. Ground water occurring under phreatic condition are being developed by dug wells. Electrical conductivity of the of the groundwater ranges from 170 to 440 micro seimens /cm. Yield of the well ranges from 0.5 to 6m^3/day and sustains 4 hour pumping.

(iii)Warkali beds (Aquifer – III)

Deeper aquifer of the Sedimentary area represented by Warkali beds has limited potential in the district. It is encountered in the bore-wells drilled in the district from Pulluvila in the south to Edavai in the north. Thickness of the formation varies from 7 to 97m. The groundwater in this aquifer is developed through tube wells and deep dug wells. The thickness of the Warkali bed encountered in the bore wells drilled by CGWB in the district varies from 30 to 110mm. Depth to water level varies from 3.63 to 27.44 mbgl in pre monsoon and 2.78 to 26.49 mbgl in post monsoon and yield ranges up to 380lpm. Transmissivity ranges from 69.76 to 232.24m2/day. The water in

the Warkali formation is brackish in the coastal parts between Chakkai and Anchuthengu. But further north of Anchuthengu the formation yielded fresh water. The well at Pallom in southern part of the district also yielded fresh water.

In the sedimentary area, hard rock basement is encountered in the depth range between 42 to 119m. At Pulluvila the basement is encountered at 119 m bmsl whereas it is encountered at 42 m bmsl at Chittattumukku and 87 m bmsl at Anjengo. The details of exploratory wells drilled in the sedimentary area is given in Annexure VI.

3.5.3 Aquifer disposition

Lithological cross-sections (figure 3.10) and fence diagram (figure 3.11) have been prepared, for a better perspective of the subsurface geology using the litholog of boreholes drilled. Moving towards east from the coastal area, the sedimentary aquifer pinches out giving way to hard rock aquifer. Cross section view along the coast shows the thickness and distribution of sedimentary aquifer.

3.5.4 Aquifer maps

(i) Aquifer map of phreatic aquifer system

By integrating the data on weathered zone thickness, water levels, ground water yield and quality, the aquifer map of the phreatic aquifer is prepared (figure 3.12). Even though the wells in Alluvium area is good in yielding, the coastal alluvium shows quality problem in pockets. Wells in Valley fills are high yielding and they are good aquifers. The area covered by denudation hill and residual hill are mainly runoff zones and in hilly region ground water prospects is limited to valley portion. In Pediment areas yield of the well is controlled by local topography and weathered thickness.

(ii) Aquifer map of fractured aquifer system

An aquifer map of the fracture aquifer system is prepared by integrating various thematic maps (Figure 3.13). In hard rock area the success rate of wells depends upon the existence of secondary porosity. The tube wells in the coastal area are insufficient for a better understanding of the deeper coastal aquifers. Hence, more tube wells have to be drilled in the district's coastal area for a better understanding on the disposition of the deeper coastal aquifer.

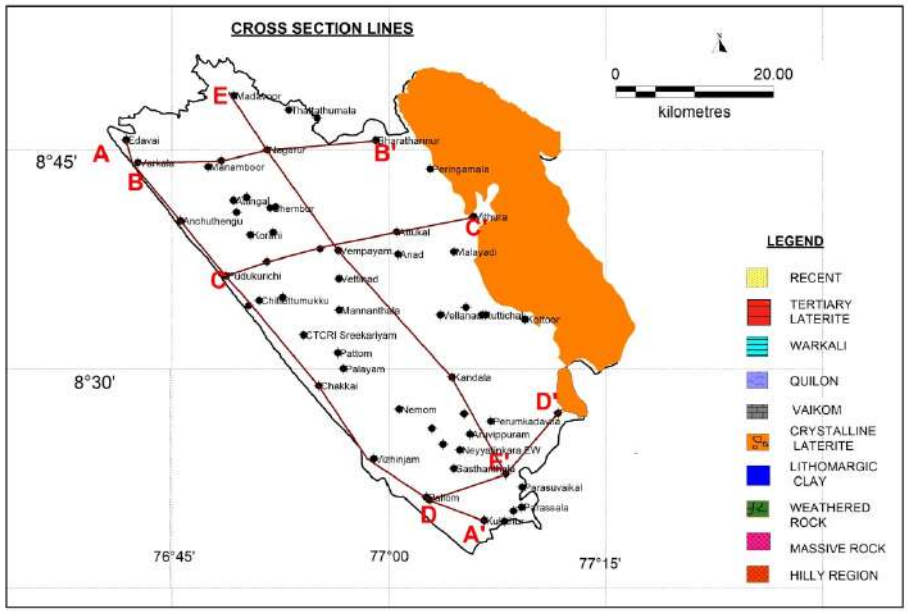
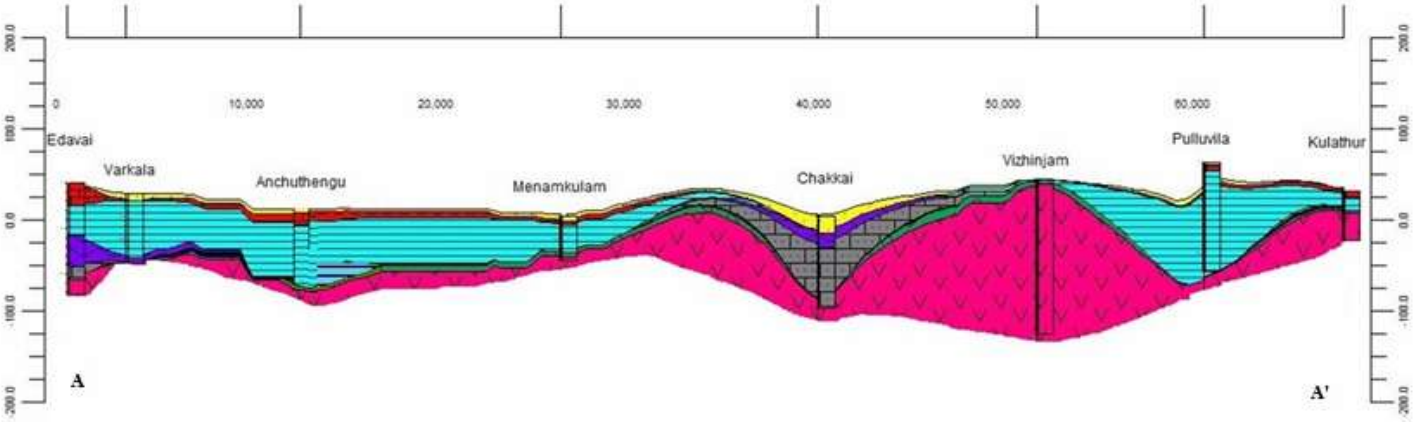
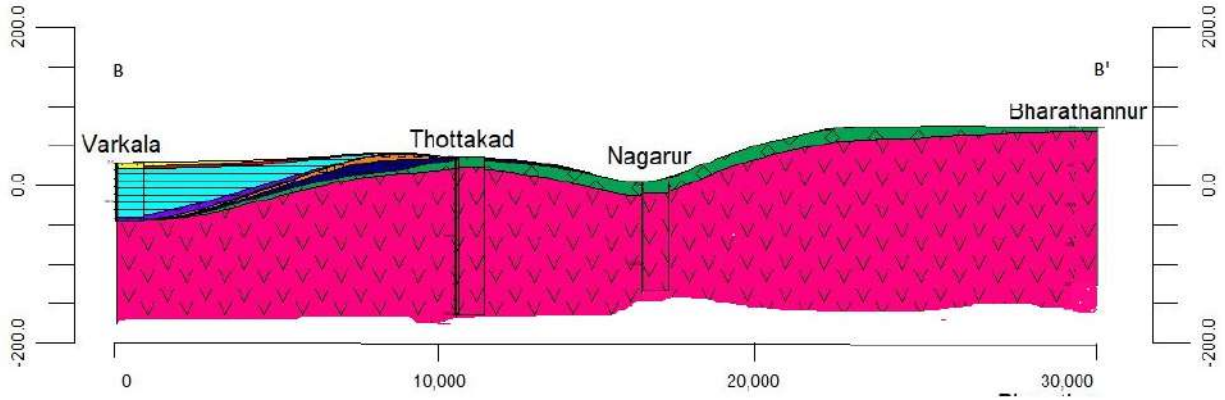


Figure 3.10: Cross sections




B
B'
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Thottakad
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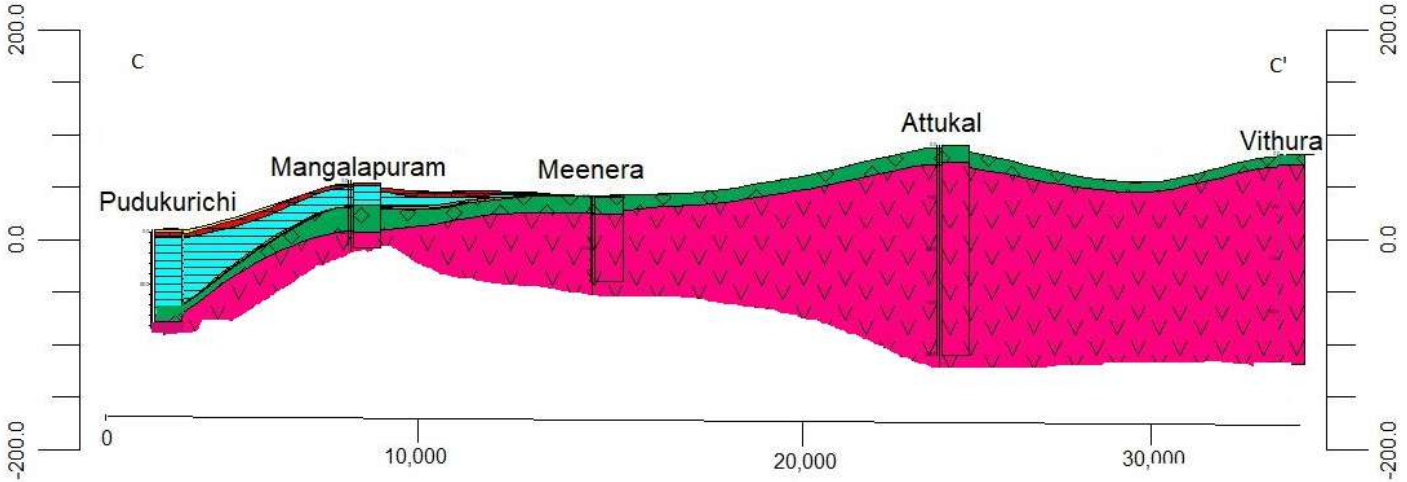
C
C'
Pudukurichi
Mangalapuram
Meenera
Attukal
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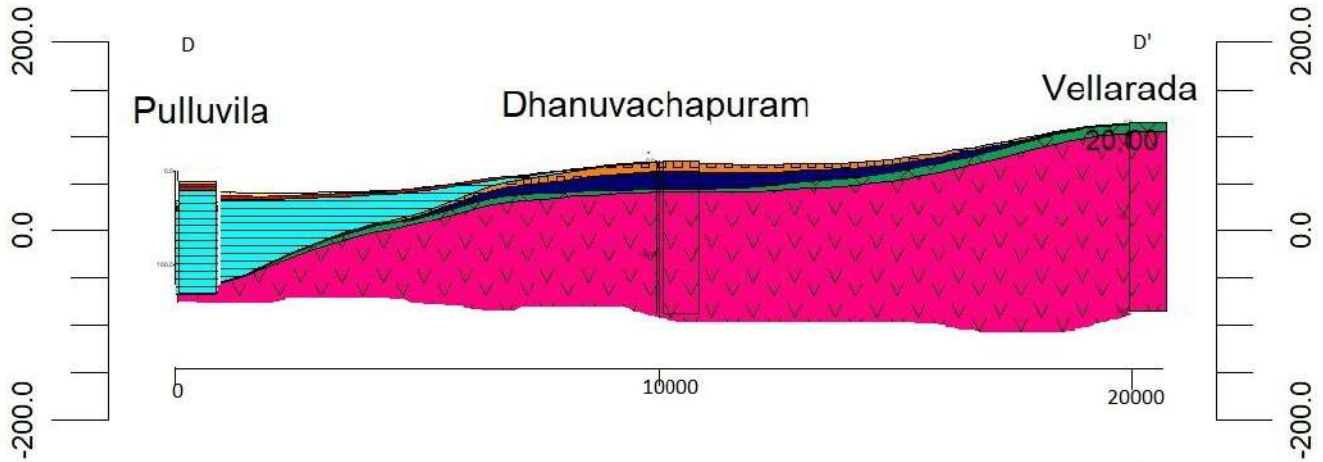
D
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Pulluvila
Dhanuvachapuram
Vellarada
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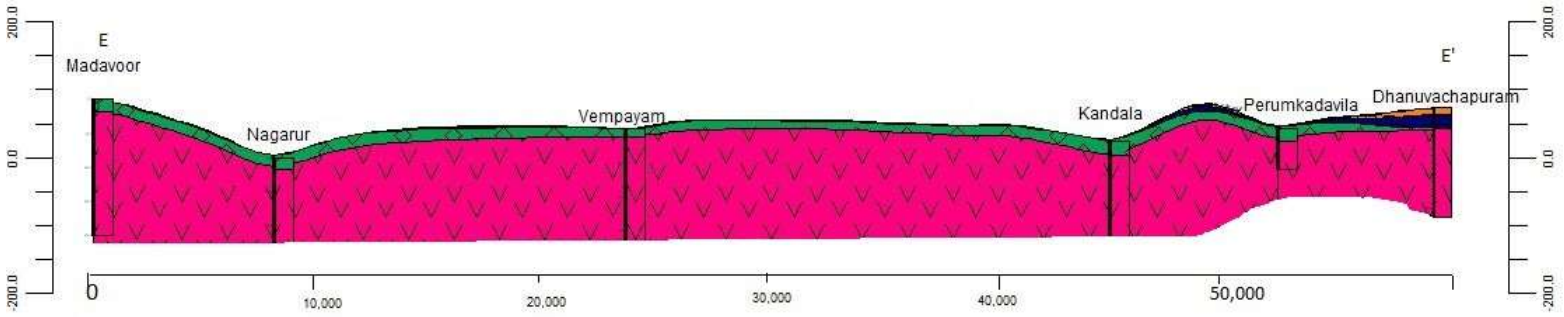
E
E'
Madavoor
Nagarur
Vempayam
Kandala
Perumkadavila
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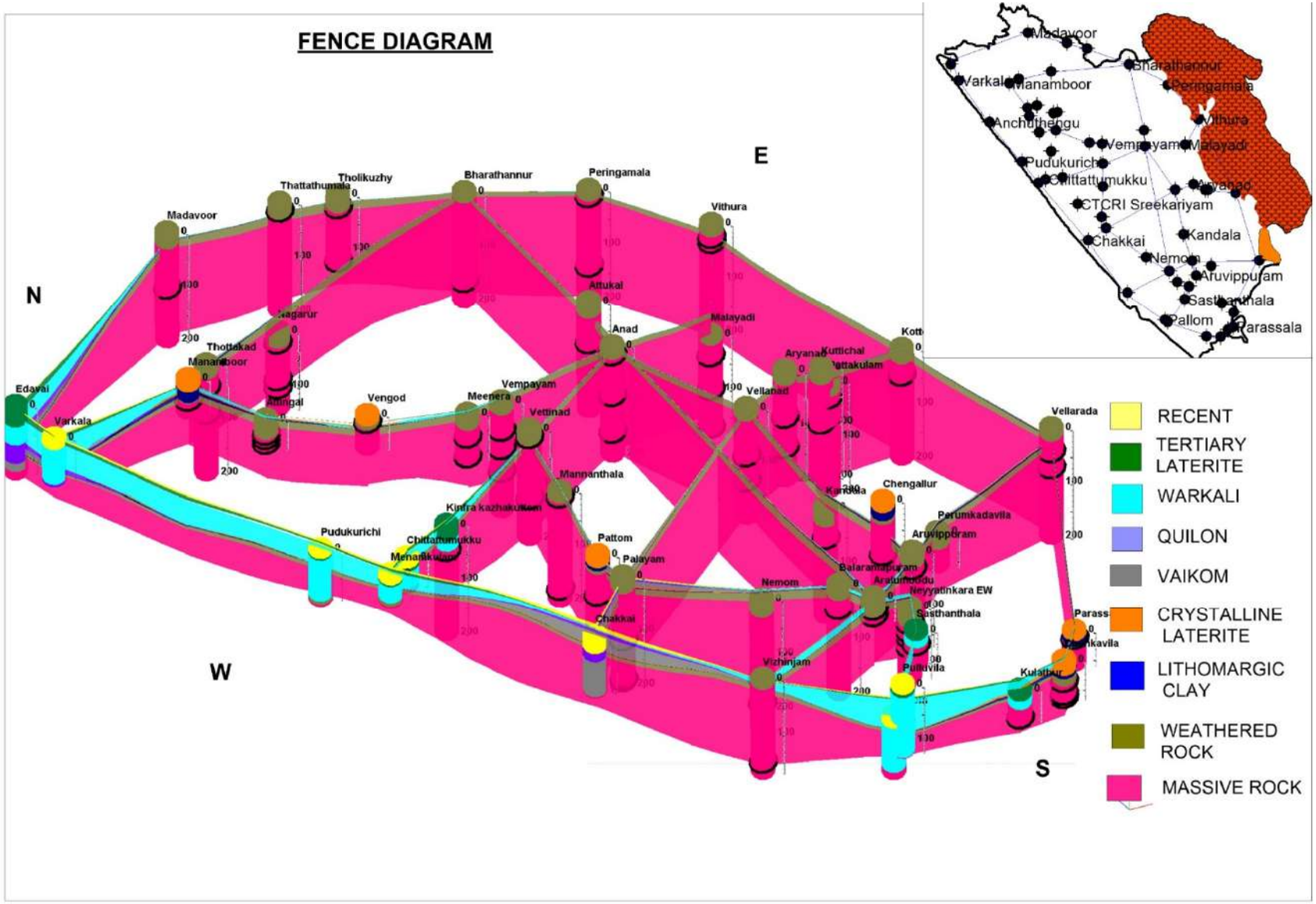

Figure 3.11: Fence diagram

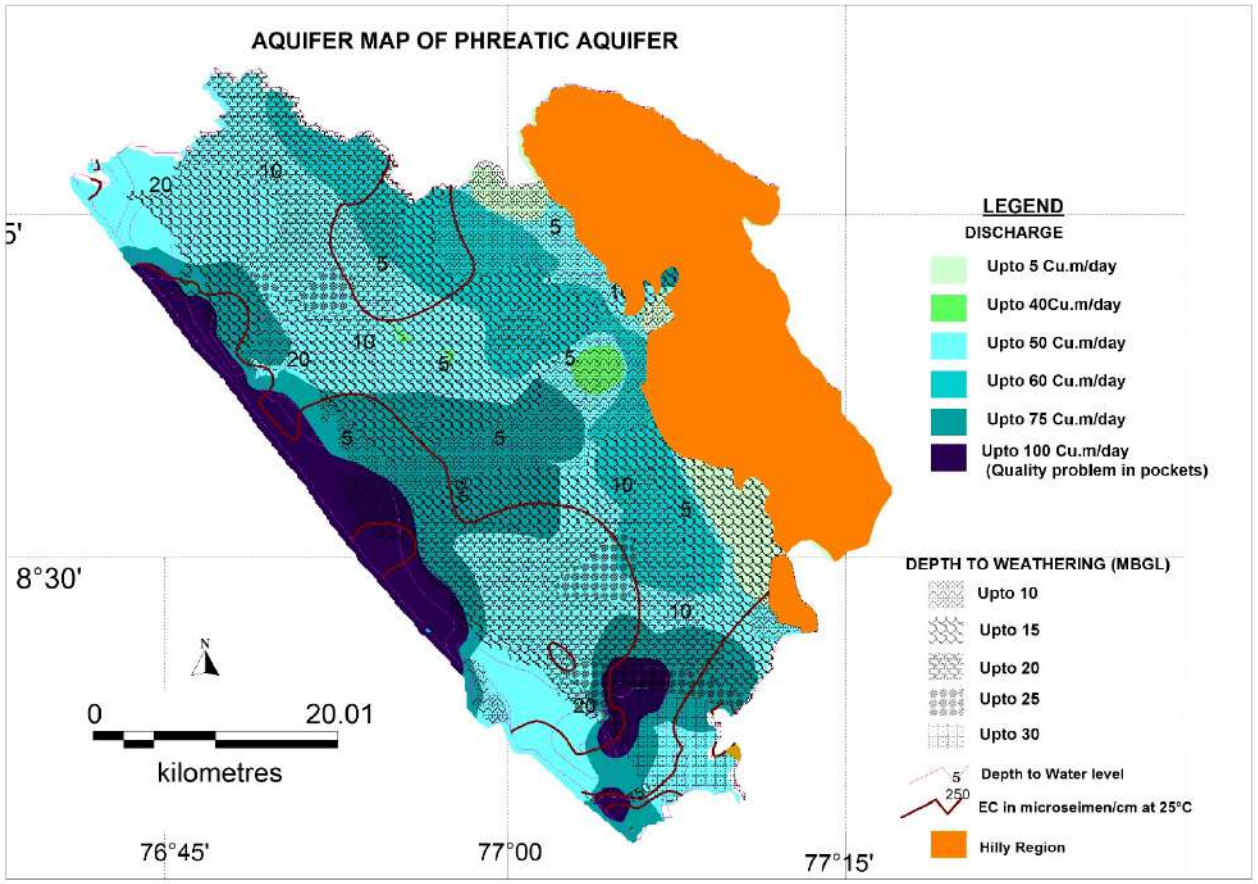

Figure 3.12 Aquifer Map of Phreatic Aquifer

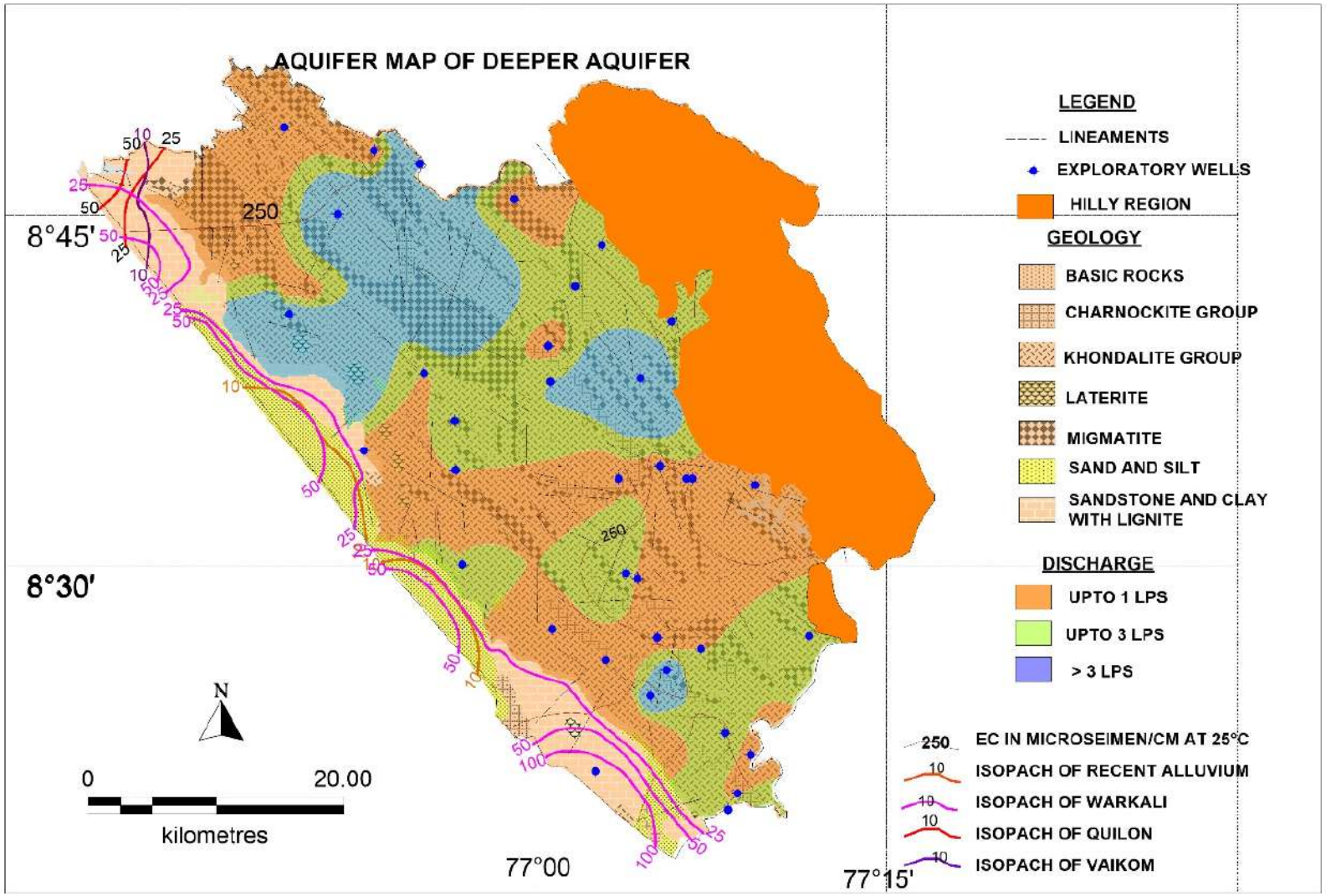

Figure 3.13: Aquifer Map of Deeper Aquifer

4.0 GROUNDWATER RESOURCES

The occurrence of groundwater availability varies from place to place. Increasing population, rapid urbanization and industrialization has resulted in increasing use of ground water resources. Judicious and planned development of ground water and its scientific management have become necessary to ensure long-term sustainability of this precious natural resource. Planning future utilizations depends on a clear understanding of the status of the resource, the amount that has already been extracted, the amount remaining, and the impact of further depletion. Phreatic aquifers are the major source of water in the area. The dynamic as well as in-storage resources of unconfined aquifer is calculated together with in-storage of confined aquifer

The assessment of dynamic ground water Resources of the study area has been carried out jointly by CGWB and State Ground water Department, Govt. of Kerala based on Ground Water Estimation Committee (2015) methodology. The data pertaining to Command and non-command area are not available hence the entire area is considered as non-command area. Ground water draft in the study area is mainly for irrigation and domestic uses. In view of the non-availability of data on the number of wells being used for domestic purposes, the ground water draft for domestic uses has been computed block-wise on the basis of 2011 population, projected to the year of assessment (2013). Domestic requirement of water in the study area has been computed as the product of the population and the per-capita water requirement (assumed as 150 L/day/person). The ground water draft has been computed from the data on the block-wise number of irrigation wells collected by the State Ground Water Dept., Government of Kerala. The ground water draft Figures are arrived at by multiplying the number of wells with the corresponding unit draft.

4.1 GROUND WATER RESOURCES IN THE PHREATIC AQUIFER

4.1.1 Dynamic ground water resources in the weathered zone

The ground water in the shallow weathered zone is mostly developed through dug wells for domestic and agricultural purposes and to a limited extent for industrial and irrigation purposes. The total annual recharge of groundwater has been computed using average water level fluctuation in Ground Water Monitoring Wells and Specific Yield of the respective aquifers.

The Annual Extractable Ground Water Recharge of the district is 269.70 MCM and existing Gross Ground Water Extraction is of the order of 172.16 MCM. The Stage of Ground Water Extraction is 64%. Out of 11 blocks, 5 are ‘Semi critical’(Athiyannur, Chirayinkil, Nedumangad, Parassala and Pothencode) and 6 are ‘Safe’. The block wise dynamic ground water resources estimated for unconfined aquifer for the district is given in Table 4.1 and the Map of categorisation of block is given in the figure 4.1.

4.1.2 In-storage in the weathered zone

For sustainable ground water development, it is necessary to restrict ground water extraction to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes.

In-storage in the weathered zone is the product of area, weathered zone thickness and specific yield. Aquifer thickness is computed by taking the difference of average depth of weathering in each block from groundwater exploration and average depth to water level in the pre-monsoon period. In storage Ground Water Resources of Unconfined Aquifer (Ham) of Thiruvananthapuram district is 353.07 MCM.

4.1.3 Ground water resources in the fractured aquifer

Assessment of ground water resources of confined aquifers assumes critical importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. To assess the ground water resources of the confined aquifers, ground water storage approach is recommended. Moreover, there is a need of more observation wells tapping exclusively deeper aquifers. The ground Water resource in the fractured zone is worked out based on the common depth of occurrence of fracture, area and storativity. The total instorage water resource in the fracture system thus computed is about 410.49 MCM and the particulars are shown in Table 4.2.

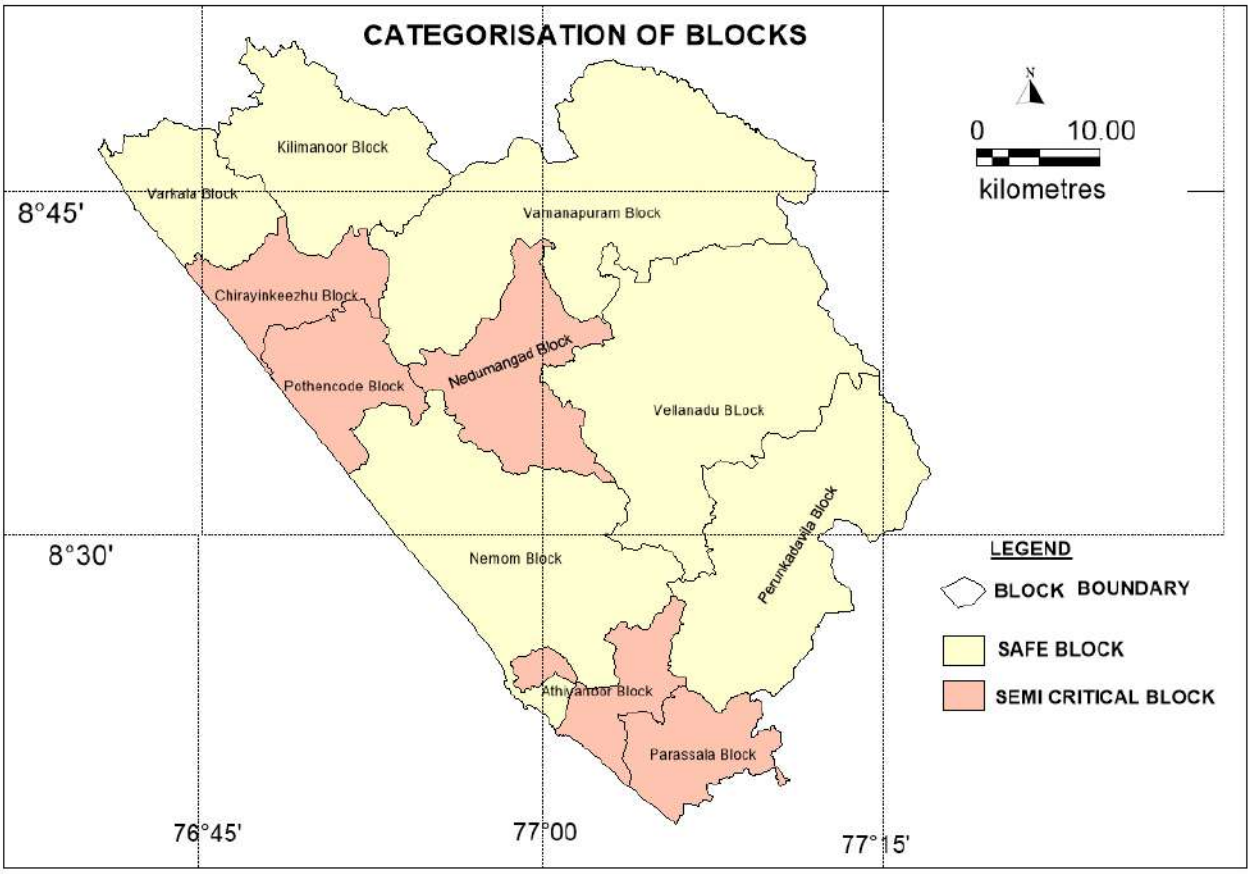

Figure 4.1: Categorisation of blocks

Table 4.1 Ground water in Phreatic Aquifer

Sl. No.	Assessment Unit/ Block	Annual Extractable GroundWater Recharge (Ham)	Annual Ground Water Extraction for Irrigation Use	Annual Ground Water Extraction for Industrial Use	Annual Ground Water Extraction for Domestic Use	Total Extraction (4+5+6)	Annual Groundwater Allocation for Domestic use as on 2025	Net Ground Water Availability for future use (3-4-5-8)	Stage of Ground Water Extraction (%) (7/3)*100	In storage Ground Water Resources of Unconfined Aquifer (Ham)	Ground Water Resources –Phreatic Aquifer-I (Ham) (3+11)
1	2	3	4	5	6	7	8	9	10	11	12
1	Athiyannur	1281.84	361.75	0.033	777.84	1139.623	803.57	116.48	88.91	1068.06	2349.9
2	Chirayinkil	1595.77	337.31	0.098	988.005	1325.413	1020.69	237.67	83.06	3146.81	4742.58
3	Kilimanoor	2762.03	452.76	0	1072.224	1524.984	1107.69	1201.58	55.21	4026.848	6788.878
4	Nedumangad	1883.67	543.94	0	1057.468	1601.408	1092.45	247.28	85.02	3120.6	5004.27
5	Nemom	4710.70	514.30	0	2750.26	3264.56	2841.23	1355.17	69.30	2428.344	7139.044
6	Parassala	1516.99	599.60	0	643.466	1243.066	664.75	252.64	81.94	2466.3	3983.29
7	Perumkadavila	3325.92	585.39	0	1008.861	1594.251	1042.24	1698.30	47.93	2703.8	6029.72
8	Pothencode	1434.51	614.35	2.17	641.631	1258.151	662.85	155.14	87.71	3855.8	5290.31
9	Vamanapuram	3301.56	517.36	0	966.228	1483.588	998.19	1786.01	44.94	4229.94	7531.5
10	Varkala	1651.06	314.00	0	837.437	1151.437	865.14	471.92	69.74	3879.42	5530.48
11	Vellanad	3506.42	588.50	0.00	1040.82	1629.32	1075.25	1842.67	46.47	4381.8	7888.22
	TOTAL (ha.m)	**26970.46**	**5429.26**	**2**	**11784**	**17216**	**12174.05**	**9364.85**	**63.83**	**35307.72**	**62278.18**

Table 4.2 Ground Water in Fractured aquifer

Sl. No.	Assessment Unit	Non-command area (Ha)	Maximum limit of fluctuation in phreatic aquifer (mbgl)	Phreatic aquifer thickness (in storage, m)	Semi-confined thickness (in storage, m)	Confined thickness (in storage, m)	Phreatic in storage parameter	Semi-confined in storage parameter	Confined in storage parameter	Phreatic in storage volume (Ha-m)	Semi-confined in storage volume (Ha-m)	Confined in storage volume (Ha-m)	Total In storage volume (Ha-m)
1	Athiyannur	7629	15	35	25	75	0.004	0.002	0.001	1068.06	381.45	572.175	2021.69
2	Chirayinkil	10151	9	31	0	0	0.01	0.005	0.0025	3146.81	0	0	3146.81
3	Kilimanoor	17977	12	28	30	80	0.008	0.004	0.002	4026.848	2157.24	2876.32	9060.41
4	Nedumangad	15603	10	25	35	80	0.008	0.004	0.002	3120.6	2184.42	2496.48	7801.50
5	Nemom	33727	9	36	30	75	0.002	0.001	0.0005	2428.344	1011.81	1264.763	4704.92
6	Parassala	8221	15	25	30	80	0.012	0.006	0.003	2466.3	1479.78	1973.04	5919.12
7	Perumkadavila	27038	10	25	30	85	0.004	0.002	0.001	2703.8	1622.28	2298.23	6624.31
8	Pothencode	7415	9	26	35	80	0.02	0.008	0.004	3855.8	2076.2	2372.8	8304.80
9	Vamanapuram	27115	9	26	35	80	0.006	0.003	0.0015	4229.94	2847.075	3253.8	10330.82
10	Varkala	10209	12	38	50	50	0.01	0.005	0.0025	3879.42	2552.25	1276.125	7707.80
11	Vellanad	29212	10	25	30	85	0.006	0.003	0.0015	4381.8	2629.08	3724.53	10735.41
Total		***194297***								***35307.72***	**18941.6**	**22108.3**	**76357.6**

5.0 GROUND WATER RELATED ISSUES

The groundwater in the district is mostly developed through dug wells. Now a days bore wells /tube wells are also common as the dug wells in this area usually dries up. Thiruvananthapuram district receives fairly good rainfall and have rich water resources, in spite of this it is ironic that the district experiences both quantitative and qualitative ground water problems. The reason for the issues can be categorised as natural and anthropogenic. Anthropogenic activities like rapid urbanization, change in land-use and cropping pattern, indiscriminate dumping of bio-degradable and non-biodegradable waste into abandoned wells, surface water sources, wet land filling, cultivable land encroachments, Latrine pits, illegal sand mining in River beds and paddy fields have adverse effects on the quantity and quality of the water.

About 80% of the area falls under hard rock terrain and the distribution and availability of ground water is not uniform in the area. As per the Ground Water Resource estimation, of the 11 blocks, 5 blocks fall under Semi Critical category whereas the remaining 6 falls under safe category indicating further scope for ground water development. Even though the area falls in safe and semi critical category, drying up of wells during summer season and in rain deficient years is common in the region. The major ground water issues in the region include water scarcity /drying of wells, water quality deterioration, land reclamation, mining and quarrying.

Water scarcity /drying of the wells: Even though the region experiences fairly good rainfall, drying of dug wells during summer is a common ground water issue due to the low water holding capacity, surplus runoff and base flow. The rugged and rolling topography, slope and high drainage density leads to rapid runoff of the infiltrated water. Rapid runoff and base flow, shortly after monsoon season, leads to the fall in water level and drying of the majority of dug wells during summer. Delay in the onset of monsoon also affects the quantity of ground water in the phreatic zone. Drying up of shallow wells and reduction in sustainability of dug wells is noticed in the region can be well elucidated by the falling of decadal water level trend.

Paddy fields play a major role in ground water recharge apart from maintaining the productivity. The reclamation and conversion of these wetlands for non-agricultural purposes has resulted in an irreversible transformation of the ecosystem. Human encroachment into the flood plain and river banks, change in land use pattern and change in the cropping pattern also affected the ground water scenario of the region

The reason for water scarcity can be attributed to the inability to conserve the surplus run-off available during the monsoons, due to topographic characteristics and destruction of traditional water storage structures such as ponds, tanks and wet lands, Rapid urbanization resulting in increased water consumption and reduced water conservation and ground water recharge. Recent changes in land use and cropping pattern, resulting in conversion of land from agricultural to non-agricultural uses and consequent reduction in water conservation and groundwater recharge.

Water quality issues: Generally the ground water of the area is good for all purpose but localized Iron, Nitrate and bacteriological contamination is reported in the ground water. The unscientific construction of septic and sewerage tanks affects the groundwater quality. Iron contamination in ground water is mainly due to natural reasons. Fertilizers and sewerage waste tips to nitrate and bacteriological contamination. Unscientific waste disposal in the urban area coupled with improper sewage treatment pollutes the ground water in the urban area.

Groundwater in the narrow stretch of land sandwiched between coast and backwaters is under tidal influence and is conducive for sea water ingress. During high tide brackish water flows inland through the water channels, not only influence the quality of the ground water in the coastal area but also the paddy cultivation. In coastal area of Chirayikeezhu ground water is shallow but the ground water is not used for drinking purpose due to quality problem.

The coastal region is blessed with surface water bodies such as backwater, rivers, ponds and water channels. But least care is given to these water bodies as waste, both biodegradable and non-biodegradable, are being indiscriminately dumped in the water bodies without any control and regulation.

The deeper wells with depth greater than 25 m bgl in the vicinity of clay mines in Pothencode block have low pH value and high Sulphate concentration, due to exposure of pyrite during mining.

Formation and its limited potential: Khondalites, the major rock type of the area, have fewer number of fractures and open joints and it is more susceptible for weathering thus producing clay minerals. Hence along shear zones and weathered surface more of clayey minerals are observed. However due to high zone of weathering Khondalite area form better phreatic aquifer of limited potential. The fracture zones of Khondalite are not so good aquifers as they are filled with clayey particles formed by the weathering of the rock.

Quarrying: The massive rocks such as charnockite and gneiss occupying the highland and midland of the region are good sources of building materials and dimension stone. Quarries are common in Nedumangadu, Kilimanoor, Nemom, Vamanapuram , Parassala blocks. Quarrying of these rocks create localized ground water problems. Laterite quarries are common in Varkala, Chemmaruthy and Ayroor villages which are in the fringes of soft rock and hard rock.

Mining: Indiscriminate clay mining has caused change in the topography, hydro-geological condition, land use pattern and agriculture. During clay mining considerable aquifer material is removed resulting in loss of the resource which in turn creates a reversal of hydraulic gradient, inducing ground water to flow towards the mine area from the aquifer, causing deepening of water levels, drying up of shallow wells and reduction in the sustainability of ground water abstraction structures in the zone of influence of the clay mines.

Mining of sand was rampant in the rivers and in inland paddy fields of the area. Sand mining results in lowering of water levels and deterioration of water quality in the riparian tracts of the river course. Following the stringent measures by the administration, illegal mining is rested in Kerala.

Waste disposal: One of the major challenges faced by the fast growing district like Thiruvananthapuram is waste disposal. Unscientific disposal of solid waste and sewerage affects the ground water quality as these waste are the main source of pathogens. Study conducted by GWD in association with an NGO on deterioration of quality of Karamana River, the main source of municipal water supply for the city of Thiruvananthapuram concluded that parameters like conductivity, total hardness, chloride etc are increasing towards the river mouth and all the samples were highly affected with faecal coliform. Karamana River passes through the highly residential area hence disposal of solid waste is a major issue. The waste so deposited settles down downstream thus reducing the depth and carrying capacity of river which results in immediate floods during downpour.

6.0 AQUIFER MANGEMENT PLAN

The ground water management strategies are inevitable when increase in water demand put stress on the available water resources or increased draft leads to deterioration of water quality. In such a situation, it is necessary to formulate sustainable management plan of the groundwater resource in a more rational and scientific way. Utmost importance should be given to carry out management practices via aquifer wise or watershed wise.

As per latest Ground water resource estimation (2017) among the 11 eleven blocks of the district, 6 falls under safe category and 5 under semi critical category. The number of blocks falling in semi critical category has risen from 3 to 5 compared to the earlier estimation. Even if the scope for ground water resource development for further irrigation and industrial use exists in the district the unequal distribution of groundwater resources in these areas is a great hurdle. In the region like Thiruvananthapuram where the geology and topography varies widely within a short distance it is very challenging to manage the available water resources and use it in a sustained manner without degrading the environment and resources.

For the sustainability of the resource care should be given to reduce the usage of ground water or have to increase the groundwater availability through artificial recharge methods or reducing the demand through water efficient techniques to bridge the gap between draft and availability. While constructing artificial recharge structures higher priority must be given to shallow valley fills, , slightly dissected plateau and pediment area.

The draft can be reduced through application of water efficiency methods in irrigation sector, encouraging the use of water efficient fixtures in households and public buildings and through the use of treated waste water. The availability of ground water can be augmented through rainwater harvesting and artificial recharge.

The immediate short term measures that can be adopted to provide quality drinking water during water scarce summer months include identification and regular maintenance of perennial ponds or tanks, regular de-siltation of existing check dams, bunds and ponds and augmentation of water resource in the phreatic aquifer. Identification of high yielding, government bore wells drilled by various agencies with potable water quality helps to mitigate the drinking water needs of the populace especially during summer but this is can only be considered as a short-term measure.

Long term water management practices by water shed development include both engineering and agronomical measures. Engineering measures include contour bunds, terrace, construction of check dams, earthen embankments, farm ponds and subsurface dyke. Agronomical measures which can be practiced include strip cropping, grass land farming pasture cropping (maintaining the living plant cover of the soil) and change in cropping pattern such as avoid planting Water intensive crops.

6.1 SUPPLY SIDE MANAGEMENT

1. Regular de-silting and renovation of the Ponds: The area is bestowed with 1706 ponds and 34 irrigation tanks. Conservation of these water bodies will improve the water scenario in the Panchayat by increasing the storage capacity as well as infiltration rate. Ponds shall be maintained, repaired and de-silted to conserve the monsoon runoff. Perennial ponds which can be developed as sources of water for domestic and other uses in water scarce situations have to be identified and those ponds shall be de-silted, renovated and their supply channels maintained to ensure that they receive enough water during the monsoons. Steps shall also be taken to prevent contamination of water in such ponds. The de-siltation of these ponds shall be carried out once in 3 years to maintain its efficacy.

2. Conservation of Paddy fields: Paddy fields in the area have to be conserved as they play a major role in ground water recharge apart from maintaining the productivity. The reclamation and conversion of these wetlands to non-agricultural purposes such as rubber cultivation and building has resulted in an irreversible transformation of the ecosystem. Maintenance and repairing of the existing minor irrigation structures such as tanks, ponds, Vented Cross bars etc, and ensuring water up to the tail end of the Neyyar irrigation canals in Parassala, Perumkadavila blocks and Athiyanoor blocks can improve the situation. It is also recommended to construct and maintain tidal regulators at strategic locations where the salt water flows inland through the water channels during high tide affecting both ground water and agriculture in Chirayikeezhu and Pothencode blocks.

3. Large diameter dug wells supplement the domestic water demand in water scarce area where the depth of weathering and aquifer thickness is less and water holding capacity of the aquifer is very low. Dug well is the most preferred abstraction structure to provide water supply to domestic and

agriculture purpose. Large diameter dug wells can be constructed in Varkala, north eastern part of Chirayinkkezhu,western part of Parassala, and Athiyannur block at feasible locations.

4. Dug well recharge through rain water harvesting: Open dug wells are the major ground water abstraction structure in the region and the region receives sufficient rainfall in both south-west and North-east monsoon. Hence dug well recharge through Roof Top Rain water harvesting is the most economical way to tackle the water scarcity during summer. It is recommended to promote the use of the domestic wells in the water scarce area as recharge wells for the rainwater harvested from their roof tops and the filter medium must be cleaned yearly before the onset of the monsoon. This practice will improve the ground water availability as well as the sustainability of the wells in the area.

5. In the district there exist about 30 number of perennial springs both in sedimentary and crystalline terrain, mostly in Varkala, Athiyanur, Kilimanoor, Vellanad, Nedumangadu, Vamanapuram and Parassala blocks. Small rural drinking water schemes can be developed through these perennial streams. Development of springs is expected to conserve 0.34 MCM of water per year.

6. Integrating the data on water level, long term water level trend, geology and aquifer properties 41 number of check dams /Vented Cross Bars are recommended in the district, with limited field checks in second order and third order streams. These structures help in arresting the surplus runoff during monsoon season as well as in recharging ground water. Percolation ponds (183 no) can be constructed in the slighltly dissected pleateau and in valley fills. The soil and water conservation structures like recharge pit, gully plug, nallah bund and contour bunding may be constructed at suitable locations considering the slope, weathered thickness, geology etc as they will retain the soil moisture and benefit the agriculture production and increase the sustainability of the wells. It is also recommended to increase the water holding capacity of the Neyyar irrigation project and to ensure the irrigation water up to the tail end of the canal. It is also recommended to increase the storage capacity of other two dams, Aruvikkara and Peppara dam, the source of piped drinking water of the district. Cleanliness of the water in the reservoir is to be ensured.

6.2 DEMAND SIDE MANAGEMENT

1. Rainwater Harvesting through Storage tanks: In coastal areas of the district, alluvium being the aquifer gets recharged naturally so there is no need for artificial recharge in the area. But the local residents are not using the ground water for domestic purpose because of the quality deterioration. Artificial recharging results in water logging in the area where water level is less than 5m. In such areas it is proposed to have Rainwater Harvesting through storage tanks and its direct usage.
2. Along the coast a fragile equilibrium exits between the ground water and sea water which gets disturbed during continuous pumping. The area around Kadinamkulam Kayal is vulnerable to sea water ingress. Hence along the coast controlled and intermitted pumping of the wells using low HP pump is recommended as excessive and uncontrolled pumping results in saline ingress.

3. An additional ground water irrigation potential through ground water via dug well and shallow bore wells can be created in the 4 blocks (Kilimanoor, Perumkadavila, Vamanapuram and Vellanad) of the district without augmenting the stage of ground water extraction above 70%. 2823 dug wells and 1882 bore wells is the feasible number of additional abstraction structures that can be constructed in the district. With the construction of these structures more area can be brought under protective irrigation. About 1917 Ha of culturable wasteland in the Kilimanoor, Perumkadavila, Vamanapuram and Vellanad block can be brought under cultivation by constructing 460 dug well and 256 bore well (Tentative).
4. In Clay mines during clay mining the water from the mines are drained away non judiciously for preparing the land for fresh excavations. This has led to acute water shortage in the neighbouring areas (in parts of Pothencode and Chirayinkeezhu block). During acute summer this Mine water should be discharged free of cost to the local people for domestic as well as irrigation purposes after quality check, as mine water have quality problems like low pH, high Sulphate and heavy metal concentration.
5. Vertical recharge shaft with injection wells is the recharge technique suitable for regions having thick clay formations (Pothencode block) in the sub surface where the aquifer is available at greater depth say more than 15 m. The diameter of shaft should normally be more than 2m to accommodate more water and a filter should be provided in the shaft. Inside the shaft an injection well of diameter 10-30cm diameter may be constructed. The injection well may be filled with gravel. The efficiency of this technique is high and is cost effective.
6. Mining pits for water storage: Due to clay mining, pits of different dimensions are formed in Sasthavattom, Veiloor, Kannukalivanam, Chilambil and Mangalapuram of Pothencode block. Some of the pits are later on filled up with water to form artificial ponds. These ponds can also be developed as water storage structure for agriculture, irrigation, fish farming or for some recreation purposes. Otherwise pits created by mining should be back-filled and have to be developed as recreation area, park, for planting indigenous species etc.
7. Quarries for water storage: Developing decommissioned quarries as rain water harvesting structures is an emerging rainwater harvesting technique. Rain water and runoff can be stored in the decommissioned quarries and can be used for agriculture, irrigation, domestic, construction purpose or fish farming. Rainwater and runoff water in the catchment area of the quarry has to be directed towards decommissioned quarry so that the water can be used for fruitful purpose. Before using the stored water sufficient quality checking and water treatment has to be carried out. Proper fencing of the quarry premises is also recommended. Abandoned quarries are copious in Pothencode, Perumkadavila, Nedumangadu, Kilimanoor and Vamanapuram blocks
8. Water Use Efficiency (WUE) practices are yet to pick up in the district. Hence it is recommended to encourage the farmers to adopt Drip/sprinkler irrigation in about 6168 Ha of land, which will be better than flood irrigation for reducing of the consumption of water and avoiding the wastage of water.
9. Training in water and crop management to the stake holders: The policy makers should educate the farmers in their jurisdiction about high yielding crop varieties, growing crops with minimum

water requirement with the technical guidance of agriculture experts and need to adopt new irrigation pattern. Also a thorough understanding of the consequences of indiscriminate usage of the water should be propagated among users. Participatory ground water management should be carried out and community-centric approach has to be developed as an alternative for managing groundwater as a common pool resource.

10. The number of feasible ground water conservation structures that can be constructed in the district is shown in figure 4.2

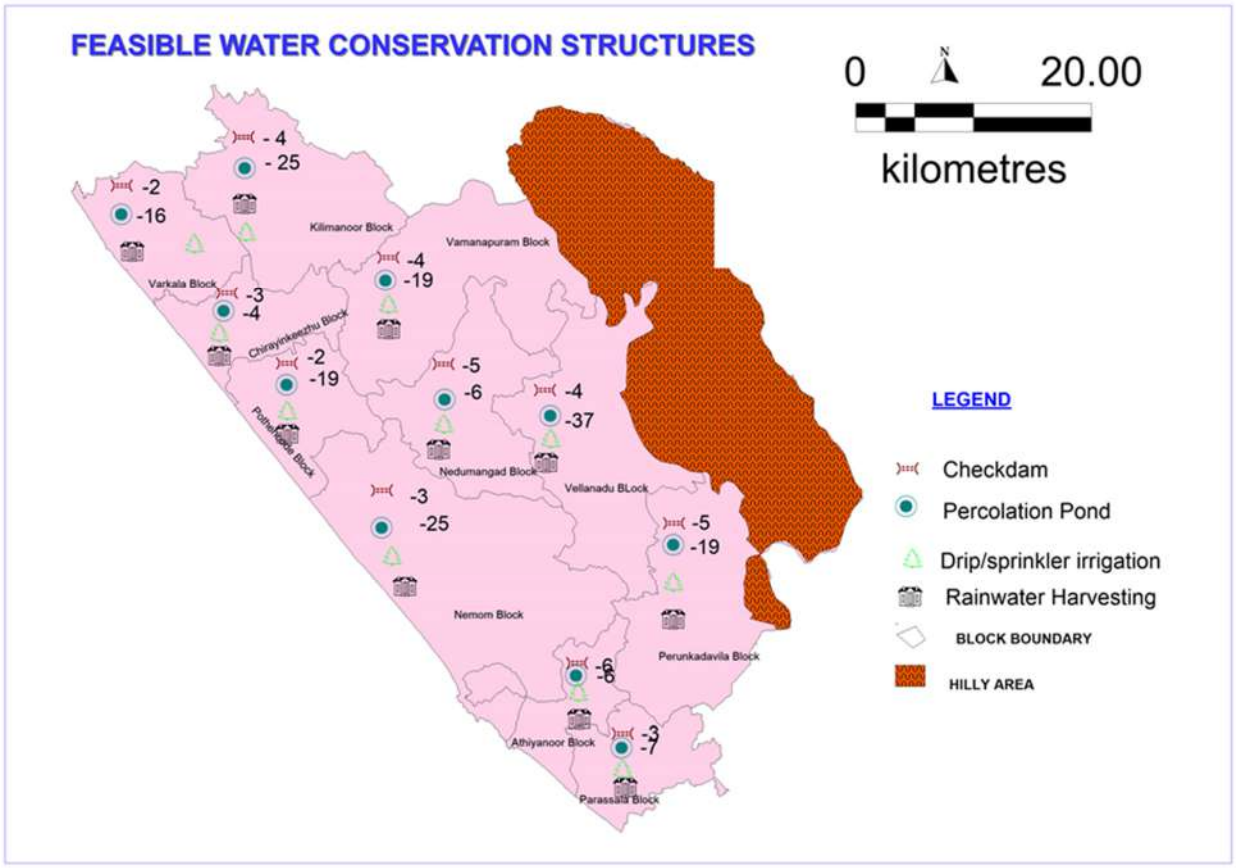

Figure 4.2: Map showing the number of feasible ground water conservation structures in the district

ANNEXURES

Annexure I: Details of Ground Water monitoring wells

Sl No	Location	Latitude	Longitude	Depth	MP	Type	Pre monsoon_water level	Post monsoon_water level
1	Amboori	8.5033	77.19	11.9	0.7	NHS	8.52	7.63
2	Anappara	8.69639	77.11	10.61	0.55	NHS	9.51	4.97
3	Aralumoodu	8.41472	77.06	19.89	0.75	NHS	12.69	9.75
4	Ariyanadu	8.57992	77.09	8.1	0.7	NHS	5.23	4.33
5	Arukannukuzhi	8.70875	77.07	6.5	0.77	NHS	4.53	3.47
6	Arumanoor	8.342778	77.075833			KOW	6.6	6.63
7	Aruvikara	8.56859	77.01	9.7	0.75	NHS	4.11	1.89
8	Athazhamangalam	8.38479	77.07	21.95	0.7	NHS	19.52	18.62
9	Attingal	8.69833	76.82	15	0.85	NHS	12.26	8.03
10	Attukal	8.65694	77.01	8.35	0.8	KOW	6.63	6.93
11	Ayyankode	8.475	77.16	10.09	0.66	NHS	8.26	5.83
12	Azhoor	8.644167	76.798611	15.5	0.7	KOW	11.31	7.49
13	Balaramapuram	8.425	77.05	15	0.9	NHS	10.01	5.65
14	Beemapalli	8.45	76.938333			KOW	3.02	3.27
15	Bharathanoor	8.76556	76.99	10.18	0.8	NHS	7.78	5.82
16	Bounder mukku	8.61667	77.1	9.7	0.74	KOW	8.84	6.23
17	Changa	8.57846	77.07	12.55	0.7	NHS	6.98	5.18
18	Chaykottukonam	8.40222	77.11	12.5	0.6	NHS	9.36	4.61
19	Cheeranikara	8.64877	76.96	10	0.8	NHS	9.79	7.31
20	Chembur	8.6825	76.88	13.8	0.75	NHS	9.95	6.39
21	Chengottukonam	8.582	76.902			KOW	5.62	7.18
22	Chenkal DW	8.3675	77.099444			NHS	6.5	12.39
23	Chenkal Pz	8.372222	77.104167		0.75	NHS	13.98	13.07
24	Chennampara	8.65917	77.08	13.15	0.65	NHS	9.95	6.39
25	Cheriyakonni	8.54472	77.02	12.96	0.66	KOW	8	8.67
26	Cherunniyur	8.72361	76.76	17	0.8	NHS	15.27	13.38
27	Chettachal	8.68875	77.06	4	0.8	KOW	2.5	2.42

Sl No	Location	Latitude	Longitude	Depth	MP	Type	Pre monsoon_water level	Post monsoon_water level
28	Chirayankeezh	8.658333	76.788889	13.58	1.7	NHS	9.95	6.96
29	Chowara	8.359722	77.021389			KOW	20.6	20.4
30	Chullimanoor	8.64286	77.02	9.63	0.65	NHS	6.96	4.55
31	Cicilapuram	8.400833	77.016111			KOW	1.71	1.38
32	Ithye	8.60936	77.09	10	0.7	NHS	8.5	7.11
33	Kadinakulam	8.603889	76.820833			KOW	1.49	1.63
34	Kallar	8.70944	77.13	9.47	0.84	NHS	4.51	3.4
35	Kallikkad	8.53056	77.13	7.3	1	NHS	1.99	0.1
36	Kamukinkode	8.394444	77.062222			KOW	5.13	-1.09
37	Kandala	8.48345	77.07	15	0.7	NHS	11.58	11.6
38	Kanjiramkulam church	8.361667	77.051944	29.55	0.84	KOW	23.36	21.04
39	Kannanoor	8.48444	77.19	30	0.88	KOW	14.46	18.12
40	Kannaravila	8.388333	77.049444			KOW	11.25	10.56
41	Karakulam	8.56417	76.99	9	0.7	NHS	2.73	1.89
42	Kariavattom	8.56417	76.9	8.5	0.7	NHS	3.3	1.94
43	Karinga	8.62776	77.04	3.86	0.65	NHS	2.71	2.18
44	Karipur	8.62306	77.02	11.1	0.7	KOW	8.44	9.05
45	Kattakkada	8.5075	77.08	8.9	0.95	NHS	5.2	2.75
46	Kaypadi	8.57833	76.98	11.6	0.78	KOW	6.7	7.9
47	Kazhakootam	8.573333	76.87			KOW	3.35	2.63
48	Kilimannor	8.77639	76.88	10.4	0.81	NHS	8.29	6.22
49	Kollankonam	8.52083	77.03	14	0.7	KOW	10.51	11.02
50	Korani	8.65833	76.84	10.4	0.8	NHS	6.78	6.4
51	Kovalam	8.390833	76.976944			KOW	8.43	7.45
52	Kowdiar	8.52194	76.96	11	1	KOW	9.95	9.82
53	Kulathur	8.32694	77.1	17.05	0.74	NHS	11.12	7.18
54	Kulathur Pz	8.3275	77.101667		0.7	NHS	13.52	12.2
55	Madanvila	8.628056	76.799444			KOW	0.99	1.04

Sl No	Location	Latitude	Longitude	Depth	MP	Type	Pre monsoon_water level	Post monsoon_water level
56	Madavoor	8.82217	76.82	14.9	1	NHS	12.23	8.73
57	Malayadi	8.30056	77.17	8.35	0.85	NHS	9.15	4.27
58	Manacaud	8.474167	76.946667			KOW	4.89	4.38
59	Mangalapuram	8.62278	76.86	24.22	0.68	NHS	20.82	18.88
60	Mangalapuram Pz	8.623056	76.859444		0.7	NHS	21.98	18.95
61	Mannanthala	8.55791	76.94	11.5	0.7	NHS	8.04	5.67
62	Mannaram	8.63534	77.09	9	0.77	KOW	6.98	5.65
63	Marapalam	8.35	77.05			KOW	10.92	10.84
64	Maruthamala	8.675	77.13	11	0.74	NHS	8.15	5.74
65	Maruthurkonam	8.382778	77.026667			KOW	19.35	18.73
66	Meenangal	8.63722	77.1	11	0.7	NHS	10.15	6.88
67	Melvettoor	8.72472	76.74	40.45	0.75	NHS	34.55	34.33
68	Mudakkal Pz	8.687778	76.8625		0.6	NHS	9.37	10.01
69	Mudapuram DW	8.687778	76.8625			KOW	9.54	6.14
70	Muduvila	8.71111	76.97	12.8	0.72	KOW	6.73	9.73
71	Mulloor School	8.366111	77.01	25	0.84	NHS	20.8	24.46
72	Mullur 2	8.368056	77.004444			KOW	1.15	1.53
73	Mundela	8.58137	77.03	13.27	0.8	KOW	10	10.31
74	Murukumpuzha	8.61	76.824722			KOW	2.78	2.51
75	Muttakad	8.409167	76.988056			KOW	9.1	6.93
76	Muzhi	8.63917	77	6.7	0.72	NHS	3.29	3.3
77	Nagapuram	8.319444	77.058333	20.2	0.74	NHS	17.44	14.51
78	Nanniyode	8.69944	77.03	9	0.95	NHS	5.57	4.28
79	Naruvamoodu	8.44736	77.04	12	0.8	KOW	9.75	10.78
80	Navaikulam	8.79556	76.8	19.56	0.9	NHS	13.4	8.94
81	Nedumangad	8.60944	77	13.3	0.65	NHS	9.08	5.79
82	Nemom	8.452222	77.006389			KOW	3.58	2.75
83	Neyyar dam	8.53306	77.14	5.5	0.65	KOW	2.25	2.59

Sl No	Location	Latitude	Longitude	Depth	MP	Type	Pre monsoon_water level	Post monsoon_water level
84	Neyyattinkara	8.40722	77.08	16.47	0.8	NHS	13.7	9.8
85	Olathani	8.378611	77.082778	10.19	0.62	NHS	6.08	5.99
86	Ookod	8.44694	76.99	13	0.7	NHS	8.17	8.94
87	Ottashekharamangalam	8.61083	77	7.47	0.65	NHS	4.05	3.96
88	Pachalur	8.423056	76.9675			KOW	3.85	3.5
89	Pallithura	8.545555	76.861866			KOW	3.25	3.22
90	Palode	8.7225	77.03	10.04	1.1	NHS	3.98	2.77
91	Pangode	8.76528	76.97	8.31	0.65	NHS	7.28	4.71
92	Parandakuzhi	8.81629	76.9	17.76	0.65	NHS	11.35	16.08
93	Parandode	8.62028	77.09	7.5		NHS	5.61	3.8
94	Parassala	8.34389	77.15	5	0.75	NHS	0.84	0.47
95	Paruthipalli	8.55694	77.11	6.8	0.72	KOW	2.43	2.51
96	Pazhya chantha	8.74806	76.93	8.7	0.8	KOW	5	5.06
97	Peringamala	8.74944	77.05	10	0.75	NHS	7.8	7.55
98	Perumgulam	8.72444	76.81	8.9	0.75	NHS	7.37	7.7
99	Perumgur(R1)	8.61944	76.94	8.5	0.92	NHS	5.34	1.86
100	Perumkuzhi	8.629167	76.8125	5.52	0.77	NHS	3.63	2.78
101	Perunkadavila	8.44194	77.11	16.88	0.85	NHS	7.8	7.55
102	Pirappankod	8.65556	76.92	10	0.8	NHS	7.8	7.55
103	Ponganadu	8.78222	76.84	12	0.7	NHS	7.8	7.55
104	Ponmudi(R1)	8.74704	77.13	5.4	0.8	NHS	4.98	3.84
105	Poojapura	8.4971	76.98	15	0.7	KOW	8.11	13.79
106	Poonkulam	8.4225	76.976667			KOW	15.98	14.68
107	Poonthura	8.444444	76.943889	7.3	1.5	NHS	3	3.26
108	Poovachal	8.53528	77.09	16	0.7	NHS	12.98	11.14
109	Poovar	8.321389	77.065278	31	1	NHS	23.97	20.1
110	Pothencod	8.62111	76.89	13.39	0.82	NHS	10.49	11.24
111	Pozhiyoor	8.3	77.095			KOW	1.1	0.8

Sl No	Location	Latitude	Longitude	Depth	MP	Type	Pre monsoon_water level	Post monsoon_water level
112	Pudukulangara	8.59613	77.03	8.05	0.55	KOW	6	6
113	Pudukurichi	8.611111	76.806944	5	0.61	NHS	3	3.19
114	Pulluvila 3	8.345	77.039167			KOW	21.21	20.71
115	Pulluvila2	8.343611	77.0375			KOW	3.27	4.15
116	Punnakulam	8.373056	77.023611			KOW	1.72	0.84
117	Puthenthope	8.53	76.937778			KOW	3.05	3.16
118	Puvanvila	8.366944	77.082222			KOW	5.5	11.22
119	Puvar School	8.316667	77.066667	12.51	1.48	NHS	5.24	
120	sasthanthala	8.38611	77.08	9.25	0.86	NHS	4.68	2.9
121	Sasthavattom	8.64417	76.81	12.1	0.85	NHS	5.58	2.49
122	Shankaramugham	8.57111	77.02	8.3	0.7	NHS	6.64	5.46
123	Sreekaryam DW	8.541194	76.910583			KOW	5.85	6.92
124	Sreekaryam Pz	8.541194	76.910583		0.7	NHS	13.56	10.57
125	Statue	8.4975	76.95	15	0.82	KOW	9.25	9.88
126	Tekkada	8.63056	76.96	6.15	0.65	NHS	3.52	2.31
127	Tennoor	8.70704	77.07	9.2	0.8	KOW	6.63	5.74
128	Thalikuzhy	8.74278	76.91	16.32	0.65	KOW	13.05	13.9
129	Tholicode	8.65472	77.05	10.1	0.8	NHS	9.77	5.59
130	Thonakkal	8.619444	76.841667	27	0.65	NHS	18.08	7.67
131	Thumba	8.533889	76.879722	5.3	0.8	NHS	3.35	3.03
132	Tirupuram	8.320833	77.060833	28.4	0.96	NHS	27.44	26.49
133	Trivandrum	8.50431	76.96	17.36	0.63	NHS	14.02	9.57
134	Uchakada	8.306944	77.094444			KOW	15.85	18.05
135	Udyankulangara	8.37972	77.12	16.9	0.7	NHS	11.63	9.92
136	Uriyakode	8.54917	77.06	9.63	0.6	KOW	6.48	6.54
137	Uzhamalakkal	8.59056	77.06	8.5	0.7	NHS	5.74	6.24
138	Valakkad	8.68694	76.87	14	0.69	NHS	12.37	9.29
139	Valiathope	8.476111	76.898889			KOW	2.47	2.28

Sl No	Location	Latitude	Longitude	Depth	MP	Type	Pre monsoon_water level	Post monsoon_water level
140	Vamanapuram	8.71944	76.9	8.62	0.8	NHS	3.16	2.2
141	Vattapara	8.59167	76.95	12.15	0.85	NHS	9.55	5.16
142	Vattavila	8.37528	77.11	13	0.7	NHS	7.47	8.98
143	Vattiyoorkavu	8.52916	76.99	10	1	KOW	8.29	9.22
144	Vazhichal	8.50361	77.16	10	0.7	NHS	5.99	5.34
145	Veeranakavu	8.52333	77.12	6.27	0.45	NHS	5.99	5.34
146	Veiyloor	8.619444	76.825	29.3	1.08	KOW	25.59	25.72
147	Vellaikadavu	8.53361	77.01	12	0.7	KOW	4.75	4.28
148	Vellanad	8.5615	77.07	9.18	1	NHS	5.8	4.3
149	Vellarada(R1)	8.44417	77.2	8.89	0.8	NHS	4.76	3.2
150	Venganoor	8.396111	77.006111	27.64	0.98	KOW	22.12	18.92
151	Vengod	8.65611	76.87	10.36	0.7	NHS	7.94	5.83
152	Vengod Pz	8.656111	76.866944		0.65	NHS	7.37	5.44
153	Venjaramoodu	8.67925	76.91	13.9	0.71	NHS	10.28	7.54
154	Venkulam	8.321667	77.109722			KOW	2.31	1.88
155	Venpakal	8.38	77.069722	11.2	0.5	KOW	6.1	8.49
156	Vettukad	8.493694	76.898972			KOW	2.06	1.95
157	Vilapilshala	8.52556	77.04	12	0.6	NHS	9.16	6.25
158	Vizhinjam	8.383056	76.991111	4.47	0.6	NHS	1.08	1.12

Annexure II: Details of Water quality monitoring wells -Phreatic

Sl.	Location	Date of	pH	EC in µS/cm at 25°C	TH as CaCO3	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
1	Anjengo	03.04.18	7.47	340	136	49	3.4	16	3.6	0	164	17	27	0.28	0.75
2	Attingal	05.04.18	6.55	220	52	15	3.4	20	0.93	0	56	4.5	28	0.2	21
3	Azhoor	03.04.18	7.02	290	34	8.8	2.9	30	3.9	0	22	8	53	0.23	13
4	Balaramapuram	04.04.18	7.12	770	200	40	24	56	16	0	37	16	160	0.3	123
5	Cherunniyoor	05.04.18	4.79	115	14	2.4	2	5.6	0.62	0	traces	2.5	20	0.17	7.5
6	Chirayinkeezh	03.04.18	6.25	390	36	5.6	5.4	57	1.5	0	2.4	0	99	0.28	36
7	Chittagodu	04.04.18	7.52	270	50	10	5.8	36	4	0	31	9.5	75	0.28	28
8	Kadakkavur	03.04.18	6.46	300	76	18	7.3	21	3	0	22	34	36	0.4	35
9	Kallar	06.04.18	6.74	105	10	2.4	0.97	5.2	0.95	0	15	1.5	8.5	0.08	1.7
10	Kanjiramkulam (church)	04.04.18	7	280	18	4.8	1.5	21	12	0	7.3	20	37	0.3	29
11	Kappil	03.04.18	7.39	260	76	22	5.4	16	3.5	0	61	17	34	0.31	6.9
13	Kazhakuttam (DCB)	05.04.18	7	450	132	42	6.3	46	2.4	0	68	73	54	0.11	61
14	Kilimanoor	05.04.18	7.62	240	28	6.4	2.9	21	0.87	0	39	0	30	0.2	18
15	Kochuveli	03.04.18	7.39	240	96	35	2	8.6	2.8	0	88	30	13	0.19	5.3
16	Korani	05.04.18	6.35	140	12	2.4	1.5	14	2.4	0	20	0	26	0.1	6.2
17	Kulathur	04.04.18	6.41	111	16	4.8	0.97	11	1	0	24	0	17	0.06	1.4
18	Mannanthala	06.04.18	6.87	270	26	4	3.9	33	3.3	0	7.3	1	58	0.12	42
19	Murukumpuzha	05.04.18	5.72	106	22	5.6	2	5.5	0.35	0	9.8	12	14	0.08	0.31
20	Nagapuram	04.04.18	6.16	125	18	2.4	2.9	13	0.35	0	17	0	24	0.11	4.9
21	Nedumangad	07.04.18	6.62	75	20	6.4	0.97	2.7	0.56	0	22	2.5	11	0.2	1
22	Neyyattinkara	04.04.18	7.07	210	26	4.8	3.4	24	2.9	0	12	0	31	0.4	30
23	Palayamkunnu	03.04.18	7.37	174	38	10	2.9	15	1	0	34	6.6	27	0.31	5.1
24	Palode	06.04.18	6.72	189	24	6.4	2	21	3.4	0	22	7	37	0.22	21
25	Parassala	04.04.18	7.5	380	54	14	4.4	53	14	0	73	12	71	0.4	8.8
26	Perumgulam	03.04.18	4.29	210	20	4	2.4	21	5	0	0	0	31	0.31	42
27	Perumkuzhi	03.04.18	6.85	550	150	42	11	46	12	0	49	40	64	0.44	117
28	Pudukurichi	03.04.18	7.45	690	190	54	13	58	11	0	183	27	85	0.34	68
29	Pozhiyoor	04.04.18	7.57	1570	230	36	34	248	12	0	244	218	291	0.31	34
30	Pulluvila	04.04.18	5.74	132	8	1.6	0.97	12	0.06	0	2.4	0	23	0.1	4

Sl.	Location	Date of	pH	EC in µS/cm at 25°C	TH as CaCO3	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
31	Sasthavattom	03.04.18	7.23	170	18	2.4	2.9	19	4	0	17	5	30	0.17	2.3
32	Thonnakkal	05.04.18	5.48	160	18	4	2	16	0.63	0	4.9	3.5	30	0.2	19
33	Thumba	03.04.18	7.05	300	72	23	3.4	25	6.7	0	46	23	38	0.2	33
34	Thriuvananthapuram	04.04.18	6.58	260	36	7.2	4.4	28	5.4	0	17	5	48	0.24	31
35	Vakkom	03.04.18	6.95	280	42	11	3.4	30	1.6	0	24	21	44	0.23	13
36	Vamanapuram	05.04.18	7.61	340	135	44	6.1	24	4.8	0	159	9.5	46	0.07	10
37	Varkala	03.04.18	4.44	220	32	traces	7.8	21	2.4	0	0	0	38	0.36	30
38	Vattavila	04.04.18	7.59	56	2	0	0.49	4.5	1.2	0	4.9	0	20	0.33	3
39	Vellayani (Poonkulam)	07.04.18	7.73	400	150	50	6.1	31	2.7	0	189	9	53	0.12	31
40	Vidura	06.04.18	6.47	125	18	3.2	2.4	11	1.3	0	7.3	6.5	21	0.14	21
41	Vazhakkad	05.04.18	5.42	179	14	3.2	1.5	18	3	0	traces	0	27	0.15	35

Annexure III: Details of Water quality of fractured aquifer

#	Location	Longitude	Latitude	Depth (m bgl)	pH	EC (µS/cm)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	F (mg/L)
1	Anad	77.011	8.631	200	8.82	371	237.44	7.2	2.9	76	1	24	171	9.9	traces		0.12
2	Attukal	77.009	8.656	200	8.22	297	190.08	17	8.8	40	3.7	0	207	7.1	2		0.08
3	Bharathannur	76.985	8.761	200	9.23	332	212.48	24	8.5	30	2.3	18	146	17	2		0.14
4	Chenkavila	77.138	8.326	40	7.92	373	238.72	45	8.3	14	4.9	0	217	20	2.9	1.7	0.16
5	Chenkavila	77.138	8.326	63	8.48	383	245.12	41	8.3	17	7.7	17	156	28	11	8.9	0.14
6	Dhanuvachapuram	77.135	8.380	51	8.74	251	160.64	22	8.3	14	5.2	6	141	11	4	3.8	0.16
7	Dhanuvachapuram	77.135	8.380	161.8	8.5	260	166.4	20	11	14	4.8	12	115	14	26	3.5	0.23
8	Kollode	77.065	8.494	50	7.47	120	76.8	4.8	3.4	11	4.5	0	56	8.5	4	4.7	0.02
9	Kollode	77.065	8.494	200	7.63	105	67.2	4	2.9	9.2	3.4	0	51	7.1	1	1	0
10	Kuravara	77.960	8.488	42	8.23	4240	2713.6	50	13	30	2.3	0	300	9.9	11	0.83	0
11	Kuravara	77.960	8.488	98.8	8.5	391	250.24	42	11	28	1.6	6	250	8.5	11	0.22	0
12	Malayadi	77.075	8.633	172.6	8.78	364	232.96	51	2.9	24	0.85	14	227	5.7	0	0.89	0.02
13	Malayadi OW	77.075	8.633	163	8.9	337	215.68	50	3.9	24	1.2	4.8	244	2.8	0	0.56	0.02
14	Mamam EW	76.824	8.679	76	8.41	223	142.72	22	4.9	15	50	9.6	115	7.1	4.5		0.64
15	Mamam EW	76.824	8.679	200	8.72	314	200.96	40	6.1	20	4	17	176	8.5	0.5		0.6
16	Mamam OW	76.824	8.679	196	8.81	426	272.64	48	3.6	37	3.2	24	207	8.5	10		0.24
17	Mannanthala	76.943	8.567	200	8.64	228	145.92	18	3.4	22	4.4	14	112	7.1	5		0.16
18	Mannanthala Pz	76.943	8.567	65.5	9.45	289	184.96	32	10	18	3.5	0.01	178	8.5	1	1.5	0.18
19	Meenara	76.921	8.637	80.5	7.22	272	174.08	24	9.2	13	7	0	161	8.5	4		0.25
24	Nagarur EW	76.859	8.750	141.5	8.44	258	165.12	24	6.1	19	3.8	7.2	146	8.5	1		0.45
25	Nagarur OW	76.859	8.750	200	8.35	261	167.04	24	9.7	17	3.4	traces	173	8.5	0.5		0.53
26	Nanniyode EW	77.028	8.699	52	8.89	360	230.4	44	4.9	12	2.5	18	177	9.9	traces		0.2
27	Nemom	77.012	8.454	200	8.29	459	293.76	4.8	3.9	89	2.4	12	237	18	27	1	0.15

#	Location	Longitude	Latitude	Depth (m bgl)	pH	EC (µS/cm)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	F (mg/L)
28	Neyyattinkara EW	77.082	8.407	77	8.79	304	194.56	18	9.2	24	3.3	14	151	14	2.7	0.28	0.18
29	Neyyattinkara EW	77.082	8.407	129	8.66	275	176	17	6.8	22	3	14	127	11	6.4	0.78	0.14
30	Neyyattinkara OW	77.082	8.407	117	8.17	162	103.68	7.2	4.4	12	3.6	0	68	14	8.9	4.7	0.08
31	Neyyattinkara OW	77.082	8.407	190	7.99	128	81.92	4.8	2.9	9.8	3.7	0	44	16	2.5	1.3	0.02
32	Palayam EW	76.948	8.500	120	8.01	377	241.28	17	11	33	4.6	0	210	17	5.7	0.47	0.3
33	Palayam EW	76.948	8.500	200	8.07	334	213.76	16	6.3	30	2.6	0	146	26	36	0.98	0.16
34	Pattom	77.043	8.353	200	8.59	185	118.4	5.6	2.9	20	3.4	traces	95	8.5	8	6.9	0.11
35	Peringamala	77.048	8.728	200	8.36	212	135.68	24	3.4	19	1.9	9.6	124	7.1	1	3.3	0.03
36	Perumkadavila Pz	77.118	8.440	61	8.79	92	58.88	6.4	1	6.8	2.1	0.01	20	11	3	1.5	0.1
37	Thattathumala	76.885	8.795	200	7.3	233	149.12	20	6.3	13	4.4	0	137	5.7	3.5		0.2
38	Tholikuzhy EW	76.918	8.786	25	8.15	352	225.28	30	14	16	5.3	0	229	8.5	13		0.2
39	Tholikuzhy EW	76.918	8.786	125	8.13	464	296.96	46	21	19	2.8	0	317	7.1	3		0.17
40	Tholikuzhy OW	76.918	8.786	125	8.6	433	277.12	46	16	17	2.6	30	232	7.1	1		0.2
41	Vellanad	77.059	8.561	200	7.54	413	264.32	42	9.7	17	4.4	0				0.08	
43	Vellarada	77.195	8.449	200	7.93	140	89.6	5.6	2.9	11	3	0	63	8.5	3.8	1.6	0.08
44	Vettinad	76.943	8.603	200	7.66	430	275.2	46	7.8	24	4.6	0	198	27	24		0.11
45	Vithura EW	77.097	8.674	200	8.17	234	149.76	26	6.3	15	1.2	0	161	4.3	0	0.81	0
47	Aruvippuram	77.093	8.425		7.55	470		50	24			0	348	20	3.2	0.48	0.04
48	Aruvippuram	77.093	8.425		6.77	230		13	3.9			0	76	28	3.6	3.1	0.26
49	Parasuvaikal	77.153	8.365		6.71	124		4.8	2.4	19	3	0	68	14	4	4.2	0.01
50	Kuttichal	77.108	8.561		6.970	78		26	3.4			0	171	11	4	1	1

#	Location	Longitude	Latitude	Depth (m bgl)	pH	EC (µS/cm)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	F (mg/L)
51	Kottoor	77.157	8.556		6.7	360		34	9.7			0	222	13	3.6	1.9	0
52	Karode	77.144	8.337		7.65	330		48	11			0	165	28	0	0.75	0.28
53	Chengallur	77.087	8.448		6.77	240		6	3.7			0	66	8.5	6.6	2.8	0.22
54	Madavoor	76.821	8.812		6.54	168		4	2.9			0	27	27	2	1.7	0
55	Kandala	77.073	8.490		6.56	149		4	2.4			0	44	8.5	31	1.6	0.12
56	Kinfra kazhakuttom	76.878	8.581		6.47	270		14	14				195	14	1.5	0.21	0.12
57	Aryanad	77.089	8.570		6.8	210		19	3.4			0	78	20	10	10	0.05
58	Pattakulam	77.112	8.561		6.97	410		33	3.4			0	165	33	12	20	0.31
59	Balaramapuram	77.050	8.432		7.36	310		10	0.97	72	17	0	207	16	25	16	1.18

Annexure IV: Interpreted results of Vertical Electrical Survey

#	Location	Long	Lat	Interpreted results											Total Depth	Remarks
				ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5		
1	Punnakulam	77.020833	8.359722	102	34	250				3	6.5				9.5	
2	Puttanpalem	77.026389	8.358889	550	18	50				1.8	13.2				15	
3	Thingavila	77.025556	8.361111	1200	40	180				1.4	9.6				11	
4	Kollakonam	77.026389	8.372222	180	65	220				1	2				3	
5	Kottukal 1	77.031944	8.375000	250	70	210				0.8	2.2				3	
6	Nellimoodu	77.043056	8.375000	650	360	800				6	17				23	
7	Kidarakuzhi	77.018056	8.379167	750	1500	560				1	2				3	
8	Maruthurukonam	77.027778	8.380556	500	410	50				1.5	32.5				34	
9	Puthallam	77.037500	8.379167	320	35	180				1.2	3.3				4.5	
10	Puliyurukonam	77.026389	8.386111	1600	600	140				1.5	20.5				22	
11	Mavanakuzhi	77.030556	8.386111	1600	3600	440	100			1	6	33			40	
12	Muriyathotam	77.036111	8.384722	600	360	250				3	12				15	
13	Puliyuru	77.027778	8.389444	2500	1400	340				1.8	18.2				20	
14	Payattuvila	77.030556	8.391667	1100	340	58				1.5	9.5				11	
15	Kottukal 2	77.045833	8.388889	3500	140	180	VH			2.3	29.7	33			65	
16	Avanakuzhi	77.050556	8.390278	135	65	240				4.5	25.5				30	
17	Kattachalkuzhi	77.030556	8.394444	2500	680	1500	150			1.5	9.5	24			35	
18	Palachakonam 1	77.038333	8.400556	75	190	420				1.8	13.2				15	
19	Palachakonam 2	77.041667	8.398611	320	45	110				1.8	6.2				8	
20	Mangalathukonam	77.037500	8.405556	2100	3500	480	60			1	3	16			20	
21	Palachalkonam	77.041667	8.402778	150	20	VH				1	2.8				3.8	
22	Tanomoodu 1	77.047222	8.398611	The data is not interpretable												
23	Tanomoodu 2	77.050000	8.395833	1000	500	180	VH			3	9	28			40	
24	Tanomoodu 3	77.054167	8.401389	3800	300	90	VH			2.1	4.9	43			50	
25	Paniyurkunnur	77.038889	8.409722	700	1500	400	210			1	2	12			15	
26	Putuchal	77.050000	8.412500	260	150	180	VH			3	9	56			68	
27	Korani	76.841667	8.652778	400	57	86	VH			7	33	160			200	
28	Rameswaram	77.098611	8.394444	260	48	140				2	23				25	
29	Nadurkolla	77.127778	8.390278	52	68	150	VH			2	13	43			58	
30	Vandicher	77.093306	8.377778	800	40	65	VH			2.8	12.2	85			100	
31	Parasuvaikal			350	33	65	VH			1.5	9.5	11			22	
32	Parassala 1			195	60	320	VH			2	6	57			65	

#	Location	Long	Lat	Interpreted results											Total Depth	Remarks
				ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5		
33	Parassala 2	77.169444	8.336111	50	70	280				2	20				22	
34	Nilimamoodu	77.180556	8.402778	370	110	240				1.4	18.6				20	
35	Cheriyakolla			1700	175	VH				1.5	20.5				22	
36	Kalinganada	77.197222	8.433333	265	110	250	VH			1.5	6.5	72			80	
37	Vailur-1	76.830889	8.629139	410	610	900				2	8				10	
38	Vailur-2	76.833083	8.630361	150	375	450	75			1	9	37			47	
39	Chirayankeezh	76.786389	8.653417	1600	300	36	VH			2.5	7.5	30			40	
40	Mangalapuram	76.843306	8.639417	3500	800	30	VH			1.2	7.8	28			37	
41	Pallipuram	76.850056	8.606556	1750	1100	120	VH			1.2	11.8	87			100	
42	Mudapuram	76.833083	8.630361	80	350	48	150	VH		0.8	7.2	34	63		105	
43	Vakkom	76.759222	8.686917	1250	68					5.8					5.8	
44	Chantavala-1	76.872778	8.58025	1700	470	300				1	8				9	
45	Chantavala-2	76.874361	8.579667	650	270	450	VH			4	36	35			75	
46	Sreekariyam	76.905	8.541083	1100	300	130				5	13				18	
47	Veli	76.891944	8.5085	350	80	9	VH			1.3	7.7	41			50	
48	Chackai	76.918139	8.489333	5200	300	28				1.6	8.4				10	
49	Poonkulam	76.971342	8.426394	240	1100	80				5	25				30	
50	Vellayani	76.9878	8.427808	320	900	75				3	27				30	
51	Venganoor	76.9934	8.3925	800	530	115				4	10				14	
52	Poovar	77.0586	8.3376	160	270	130	500			5	25	40			70	
53	Thirupuram	77.0775	8.3511	320	50	130				10	55				65	
54	Kulathoor	77.1079	8.3263	150	400	110	300			1	8	51			60	
55	Kovalam	76.9861	8.3956	380	750	2000	500			1.5	8.5	50			60	
56	Mulloor	77.007111	8.369806	140	50	130	VH			1.5	8.5	85			95	
57	Venpakal	77.0642	8.3879	300	130	20	75	VH		2	10	41	15		68	
58	Pallipuram-1	76.85667	8.650556	437	99	32	VH			1.4	5.9	6.74			14.04	
59	Pallipuram-2	76.89889	8.670556	787	87	5633	58	979	7	0.62	0.97	0.40	2.04	10.97	15	
60	Pallipuram-3	76.89167	8.622222	672	136	801	42	VH		0.64	1.63	7.38	14.55		24.2	
61	Pallipuram-4	76.87222	8.641667	368	165	39	113			1.8	10.3	62.8			74.9	Recommended
62	Pallipuram-5	76.87222	8.658333	299	66	492	46	435	81	0.83	1.84	4.4	11.3	26.63	45	Recommended
63	Pujappura1	76.9714	8.487332	261	79	213	59	994		1.71	7.71	5.35	15.78		30.55	
64	Pujappura2	76.9651	8.4952	490	84	331	230			3.11	10.35	21.64			35.10	
65	Pujappura3	76.96904	8.48755	741	4008	367	131	612		0.61	0.92	11.61	106.6		119.74	

#	Location	Long	Lat	Interpreted results											Total Depth	Remarks
				ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5		
66	Pujappura4	76.96905	8.48785	358	843	156	1236			1.21	5.32	54.79			61.32	
67	Pujappura5	96.96906	8.48805	498	744	425	186			0.52	1.15	6.23			7.90	
68	Pujappura6	76.97011	8.487978	484	2013	44	136	20		2.83	1.45	13.09	52.9		70.27	
69	Kariavattom1	76.8858	8.566328	2553	732	1288	202	12	147	0.37	5.41	3.24	23.30	12.75	45.06	
70	Kariavattom2	76.8862	8.566344	249	1489	272	625			1.66	3.34	7.43			12.42	
71	Krishi vignan1	77.06361	8.564958	430	818	165	5389			5.54	24.4	36.06			66.00	Recommended
72	Krishi vignan2	77.06365	8.564865	403	965	85	1394	53	VH	2.98	1.83	3.91	7.91	13.86	30.49	Recommended
73	Mitraniketan1	77.05932	8.564139	778	226	54	VH			3.11	11.53	9.41			24.05	
74	Mitraniketan2	77.05937	8.564235	2266	1032	716	88	VH		0.65	1.93	14.52	12.44		29.54	
75	Mitraniketan3	77.05934	8.564415	586	842	414	260	3375		0.89	1.99	14.14	60.49		77.51	
76	Kappukadu1	77.15638	8.555811	1772	380	65	144			0.4	11.5	58.3			70.20	
77	Kappukadu2	77.15642	8.555617	1304	98	40	157			3.5	21.4	30.8			55.70	
78	Kappukadu3	77.15635	8.556134	3743	825	368	169	1294		1.34	9.43	31.8	28.53		71.10	
79	CTCRI(Sreekaryam)	76.91026	8.54116	638	287	30	105	15	5004	1.7	3.7	4.2	20.7	12.4	42.7	Recommended
80	CTCRI(Sreekaryam)	76.91026	8.54116	The data is not interpretable												
81	CTCRI(Sreekaryam)	76.91026	8.54116	1307	4	92	1856			2.1	2.7	4.7			9.5	
82	CTCRI(Sreekaryam)	76.91289	8.54094	The data is not interpretable												
83	CTCRI(Sreekaryam)	76.91289	8.54094	662	2254	101	13	2709		0.8	1.4	1.4	23.8		27.4	
84	KSEB(Vizhinjam)	76.98518	8.39455	162	720	280	38	9417		0.5	1.4	9.3	10.8		22	
85	KSEB(Vizhinjam)	76.98518	8.39455	717	205	388	53	10297		0.6	1.2	9.3	12.6		23.7	
86	Balarampuram(66KV)	77.04942	8.43641	332	963	86	14	3822		1.2	1.2	10.9	15		28.3	Recommended
87	Kunnathukkal	77.16249	8.40536	93	249	20	3002	-		1.5	4.7	12.1			18.3	
88	Karode-1	77.11017	8.32036	493	105	22	53	-	-	4.4	3.4	13.5			21.3	
89	Karode-2	77.11017	8.32036	776	383	18	84	17	263	1.0	2.9	5.3	7.5	12.5	29.2	Recommended
90	Parassala	77.15578	8.36523	319	1686	286	32	3288	-	1.5	2.1	18.9	13.1		35.6	Recommended
91	Palamoodu-1	76.94700	8.63249	1183	412	179				3.9	5.4				9.3	
92	Palamoodu-2	76.94700	8.63249	618	3522	363	48	VH		0.6	1.0	14.2	16.4		32.2	
93	Puthenpalem-1	77.00061	8.62802	550	63	1625	92	3482		1.8	3.0	6.7	16.6		28.1	
94	Puthenpalem-2	77.00061	8.62802	934	65	521	76			1.8	1.7	25.1			28.6	
95	Kallingal-1	77.00556	8.60778	165	68	183	378			0.8	3.5	30.8			35.1	
96	Kallingal-2	77.00556	8.60778	81	12	396	984			1.3	1.1	30			32.4	
97	Karippur-1	77.02750	8.62972	2385	155	18	95	20	198	0.6	2.5	5.7	8.5	17.3	34.6	
98	Karippur-2	77.02750	8.62972	487	96	5	2990			2.0	8.4	30			40.4	

#	Location	Long	Lat	Interpreted results											Total Depth	Remarks
				ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5		
99	Mundela-1	77.03306	8.58389	260	103	426	78	502		0.8	3.5	4.4	7.8		16.5	Recommended
100	Mundela-2	77.03306	8.58389	957	74	777	99	2800		1.3	1.6	3.9	8.5		15.3	
101	Pudukulangara-1	77.03889	8.58694	113	271	189	283	168	500	0.5	2.4	3.3	9.2		15.4	
102	Pudukulangara-2	77.03889	8.58694	230	82	192	64	130	-	2.2	4.4	10.4	19.2		36.2	Recommended
103	Mullassery-1	76.97833	8.56917	560	1596	330	2961	113	1426	0.6	2.0	3.2	5.2	15.2	26.2	
104	Mullassery-2	76.97833	8.56917	819	617	2454	318	41	1531	0.9	2.4	2.4	2.3	8.4	16.4	
105	Karakulam(Aruvikkara)	77.00901	8.56774	147	20	4	52	118	-	1.6	4.7	6.3	18.6		31.2	
106	Maruthamkodu(Aruvikkara)	76.99931	8.56820	142	9	17	89	300	-	1.2	3.1	5.3	8.7		18.3	
107	Vilapilsala-1	77.03944	8.52528	1855	680	518	701	138	898	0.5	1.1	5.3	8.1	9.7	24.7	
108	Vilapilsala-2	77.03944	8.52528	3194	427	3528	VH			1.6	17.3	10			28.9	
109	Kattakada-1	77.08500	8.50778	2226	675	306	883			1.1	4.2	30			35.3	
110	Kattakada-2	77.08500	8.50778	3137	635	117	1678	82		0.5	8.9	6.4	22.1		37.9	
111	Kinfra(Kazhakuttam)	76.87988	8.58461	442	119	12	-	-		3.0	9.7				12.7	
112	Kinfra(Kazhakuttam)	76.87988	8.58461	2584	693	43	212	58		1.2	5.1	6.8	11.2		24.3	
113	Kinfra(Kazhakuttam)	76.87825	8.58254	1534	334	1812	VH	-		1.0	20.0	9.0			30	
114	Kinfra(Kazhakuttam)	76.87825	8.58254	1601	757	13	155	-		4.2	8.8	21.9			34.9	
115	Kinfra(Kazhakuttam)	76.87840	8.58517	633	84	9948	-	-		2.9	36.6				39.5	Recommended
116	Kinfra(Kazhakuttam)	76.87865	8.57969	661	256	1104	185	52		1.4	1.7	2.6	5.4		11.1	
117	Kinfra(Kazhakuttam)	76.87865	8.57969	968	499	36	69	-		0.3	8.5	30.3			39.1	
118	Pirappancod(GVHSS)	76.91196	8.65855	508	256	1148	104	6341		2.1	2.1	4.4	12.2		20.8	
119	Pirappancod(GVHSS)	76.91196	8.65855	2679	148	1168	98	7570		2.7	2.3	5.0	12.5		22.5	Recommended
120	Aruvikkara(Dam)	77.02030	8.57182	684	84	6	662	-	-	2	9.7	19.4			31.1	Recommended
121	Aruvikkara(HSS)	77.01594	8.57067	1155	287	74	614	38	-	0.4	3.2	5.7	16		25.3	
122	Mailom(GV Raja SS)	77.00998	8.55577	214	1175	314	1064	17	-	1.3	5.4	10.3	18		35	
123	Mailom(GV Raja SS)	77.00884	8.55756	108	194	47	VH	-	-	1.7	12.3	11.9			25.9	Recommended
124	Mailom(GV Raja SS)	77.00821	8.55698	606	84	1141	107	-	-	2.7	7.3	19.3			29.3	
125	Mailom(GV Raja SS)	77.00996	8.55641	69	555	29	126	18	113	0.5	1.2	2.7	6	11.9	22.3	
126	Mailom(GV Raja SS)	77.00996	8.55604	409	33	3230				1.7	13.3				15	
127	VIP.Jn(Nedumangad)	76.99644	8.59384	125	846	137	1098			0.5	0.8	19.3			20.6	
128	Eliyavoor	77.06102	8.58614	46	288	109	149			1.9	3.3	15.4			20.6	Recommended
129	Moonattumukku.	77.09819	8.59708	442	1884	92	3764			1.9	4.2	14.5			20.6	
130	Moonattumukku.	77.09732	8.59681	153	247	66	418	104	577	1.4	1.3	3	5.9	14	25.6	
131	Peppara	77.13396	8.62994	2810	293	3615				7.1	19				26.1	

#	Location	Long	Lat	Interpreted results											Total Depth	Remarks
				ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5		
132	Peppara	77.13230	8.63020	392	6491	1677	315	1521		0.5	1.5	7	13.5		22.5	
133	Peppara	77.10472	8.63313	1627	739	1710	485	970		0.5	1.9	11.5	21.1	-	35	Recommended
134	Aruvippuram	77.09386	8.42441	59	601	157	627			0.5	1.1	7.9			9.5	Recommended
135	Aruvippuram	77.09308	8.42482	94	301	80	1857			0.8	6.4	5.9			13.1	
136	Aruvippuram	77.09322	8.42489	38	521	23	4385			1.6	2.3	7.4			11.3	
137	Aruvippuram	77.09550	8.41933	212	810	7979	-			0.5	15.7	Ext.			16.2	
138	Aruvippuram	77.09534	8.41949	194	431	80	2113			0.9	2.8	6.3			10	
139	Kandala	77.07263	8.48330	198	446	239	98			0.5	1.0	6.5			8	
140	Kandala	77.07272	8.48356	631	296	66	3305			3.3	8.4	12.4			24.1	Recommended
141	Kandala	77.07247	8.48339	546	124	490	165			1.0	1.2	3.1			5.3	
142	Kandala	77.07217	8.48350	1153	530	297				1.2	4.8				6	
143	Kandala	77.07203	8.48350	125	363	862				0.3	19.8				20.1	
144	Venjaramoodu	76.93114	8.65431	175	411	21	124			0.4	8.8	11.9			21.1	Recommended
145	Venjaramoodu	76.93139	8.65433	600	346	16	401			2.6	6.0	12.7			21.3	
146	Venjaramoodu	76.93146	8.65308	996	293	23	272			3.2	6.8	13.6			23.6	
147	Eruthalamoola	77.06498	8.65002	543	224	85	1517	37		4.1	2.8	6.9	17		30.8	
148	Pattankulichapara.	77.07823	8.65137	261	2272	479	261	1107		0.6	2.0	9.0	29.9		41.5	Recommended
149	Pattankulichapara.	77.07823	8.65137	525	1109	278				0.8	6.2				7	
150	Anappara	77.10528	8.69294	2062	392	768	213	100	914	0.5	1.6	2.3	14.1	17.4	35.9	
151	Maruthamala	77.12573	8.67795	171	942	57	675			1.9	2.7	5.6			10.2	
152	Maruthamala	77.12544	8.67764	458	1676	128	567			1.0	2.0	6.6			9.6	
153	Pattakulam	77.11306	8.52083	250	109	298				8	10				18	
154	Pattakulam	77.11222	8.52125	92	54	1966				2	18				20	Recommended
155	Neyyar Dam School	77.14306	8.53444	471	116	VH				2	23				25	
156	Kallingal School	77.14306	8.55472	157	703	208	880			0.5	5.5	10			16	
157	Kuttichal Market	77.14083	8.56417	532	387	93	863			0.4	5	5			10.4	
158	Kuttichal Market	77.14083	8.56417	148	668	82	1480			1	2	17			20	Recommended
159	Kuttichal PHC	77.10722	8.56111	573	127	289	79			3	10	7			20	
160	Kuttichal PHC	77.10722	8.56111	706	319	77	3234			3	9	11			23	Recommended
161	Pangode (ECHS)	76.98353	8.50378	184	324	1413	76			1.2	4.5	8.6			14.3	
162	Pangode (ECHS)	76.98354	8.50389	362	229	1943	65	4545		1.3	1.8	4.1	17.9		25.1	Recommended
163	Pangode (K.V)	76.98343	8.50067	1848	275	108	68	-		0.4	1.9	9.8			12.1	
164	Pangode (K.V)	76.98329	8.50239	471	1014	354	75	186		0.7	1.7	6.6	16.1		25.1	

#	Location	Long	Lat	Interpreted results											Total Depth	Remarks
				ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5		
165	Pangode (K.V)	76.98339	8.50250	954	410	28	215	-		4.9	5.2	16			26.1	
166	Pangode (K.V)	76.98342	8.50264	468	3239	443	102	-		0.7	1.4	10.8			12.9	
167	Chengallur	77.087052	8.448277	1933	872	126	-			1.57	7.45				9.02	
168	Chengallur	77.086815	8.448080	1457	602	494	54.6			1.93	7.78	10.9			20.61	
169	Chengallur	77.086852	8.448279	1255	623	116	-			2.4	12.2				14.6	
170	Thannivila	77.042694	8.438034	The data is not interpretable												
171	Thannivila	77.042694	8.438034	VH	379	290	2.45			0.19	4.08	16.2			20.47	
172	Thannivila	77.042694	8.438034	1000	102	1381	31.2	VH		1.2	1.28	2.68	18		23.16	
173	Balaramapuram	77.051175	8.431304	595	234	38.9	179	25.1		3.28	4.12	6.93	17.6		31.93	
174	Balaramapuram	77.051175	8.431332	1483	173	1366	30	1894		1.14	1.4	3.77	15.8		22.11	
175	Balaramapuram	77.051174	8.431331	1127	329	74	18.8	2150		0.61	4.73	10.9	16.9		33.14	
176	Balaramapuram	77.044836	8.442108	VH	600	141	43.9			0.31	3.09	5.91			9.31	
177	Balaramapuram	77.044835	8.442107	VH	560	126	40.3			0.31	3.14	6.24			9.69	
178	Vellayani1	77.02556	8.40472	8726	813	100				0.6	33.4				34.0	
179	Vellayani2	77.02556	8.40472	3884	568	1363	128			1.8	6.5	18.1			26.4	
180	Vellayani3	77.02556	8.40472	2102	432	1250	324			3.2	10	7.5			20.7	

Annexure V: Details of Exploratory wells of Hard Rock area

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
1	Anad	77.0106	8.6306	200	Leptynite	11.5	17.00-20.00 92.00-94.00 160.00-163.00	1.16	3.00	25.75	4.65		371	9.9	
2	Aruvippuram	77.0933	8.4250	173	Biotitie Gneiss	13.5	32-33,147-148, 160-163	3.4	3.35				470		
3	Aryanad	77.0889	8.5700	200	Khondalite	13.5	87-88, 143-144	10.5	1.00				210		
4	Attukal	77.0092	8.6561	200	Khondalite	17.5	77.00-78.00	17.8	0.50				297	7.1	
5	Avanavancherry	76.8361	8.6956	62.2	Khondalite	23.5	19.00-22.00 29.00-32.00	-	0.50				292	17	Drilling stopped due to caving in.
6	Balaramapuram	77.0497	8.4317	200	Khondalite	16	45-46	-	0.60				310		
7	Bharathannur	76.9850	8.7608	200	Khondalite	6.5	10.50-14.00-dry 38.00-41.00-dry	2.4	0.30				332	17	

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
							166.00-168.00								
8	Chemburu	76.8633	8.6833	191	Khondalite	22	54/30, 88.2/120, 123/204, 164.4/270	14.9	5.00	24.19	1.17		230	13	
9	Chengallur	77.0869	8.4483	200	GBG	29.5	100-103						240		
10	Ctcri sreekariyam	76.9018	8.5385	200	Khondalite	10.65	35-36, 58-59						240		
11	Chenkavila	77.1375	8.3256	68.3	Khondalite	38.65	39.00-41.00, 62.00-68.30	12.2	3.00	16.45	4.59		425	20	Drilling stopped due to highly fractured zones
12	Dhanuvachapuram	77.1347	8.3797	161.8	Khondalite	32.3	36.80-39.00, 49.00-53.00	11.4	1.50	25.67	1.13		260	14	
13	Kandala	77.0725	8.4903	200	Khondalite	21	57-58	13.2	0.30				149		
14	Karode	77.1439	8.3372	200	Khondalite	30	42-43	11.3	1.00				330		

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
15	Kinfra kazhakuttom	76.8778	8.5812	200	Khondalite	36.5	48-49		Meagre				270		
16	Kollode	77.0647	8.4936	200m	Khondalite	16.9	16.40-19.50, 38.00-41.00, 75.00-77.00	6.53	2.40	23.14	1.2		105	7.1	
17	Korani	76.8403	8.6528	183.29	Khondalite	30	22.4/30, 42.9/120, 84/180, 103.5/300, 122/390, 152.8/500, 175/1200	5.36	20.00	18.89	9.03		510	14	
18	Kottoor	77.1567	8.5564	200	Leptinite	13	49-50	8.75	0.20				360		
19	Kuravara	77.1264	8.4881	98.8	Khondalite	9	9.00-12.00, 40.00-44.00, 77.00-87.00	1.02	5.00	21.4	2.59		391	8.5	Drilling stopped due to highly fractured zones
20	Kuttichal	77.1075	8.5611	200	Khondalite	16.5	103-104	16	0.50				300		

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
21	Madavoor	76.8214	8.8117	200	Khondalite	17.5	104-105		0.50				168		
22	Malayadi	77.0750	8.6333	172.6	Garnetiferous gneiss	6	40.00-42.00 102.00-104.00, 172.50-172.60	3.35	7.00	17.02	16.8		364	5.7	one OW
23	Mamam	76.8244	8.6786	200	Khondalite	10.3	29.00-32.00 76.00-80.00 123.00-126.00 157.50-160.00	2.8	7.00	14	9.54	0	314	7.1	
24	Mannanthala	76.9428	8.5667	200	Khondalite	9.1	12.00-14.00 182.00-184.00	4.26	1.00				228	7.1	
25	Meenera	76.9208	8.6367	80.5	Khondalite	17.5	38.00-40.00 74.00-80.50	8.85	1.00				272	8.5	Drilling stopped at 80.50 m because of caving in.

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
26	Melattumuzhi	76.9236	8.7111	144.5	Charnockite/Gabbro	5.5	53.00-56.00 105.00-108.00 144.00-144.50	5.19	10.00	12.21	17.6	0	398	20	Drilling stopped due to high discharge
27	Nagarur	76.8594	8.7500	141.5	Khondalite	18	22.00-24.00 90.00-93.00 105.00-109.00	5.14	7.00	17.3	5.89	0	258	8.5	Drilling stopped at 141.50 m because of caving in.
28	Nanniyode	77.0283	8.6986	52	Pegmatite vein/ Khondalite	47.5	42.00-48.00	2.24	1.50	22.45	6.45	0	360	9.9	Drilling stopped for want of hard rock.
29	Nemam	77.0119	8.4536	200	Khondalite	19.7	44.00-47.00, 148.00-150.00, 193.00-196.00	3.09	0.30				459	18	

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
30	Neyyattinkara	77.0819	8.4069	129.3	Khondalite	25.6	31.70-36.70, 47.00-50.00, 57.00-59.00, 75.00-77.50	2.67	6.00	31.24	5.54		275	11	one OW, Drilling stopped due to high discharge
31	Palayam	76.9477	8.5000	200	Garnetiferous biotite gneiss	19.6	78.00-80.00, 119.00-122.00, 192.00-194.00	2.35	1.50	33	0.54		334	26	
32	Parasuvaikal	77.1535	8.3646	200	Khondalite	31.5	36-37		0.70				124		
33	Pattakulam	77.1119	8.5611	200	Khondalite	13	30-31	13.5	0.50				410		
34	Pattom	76.9410	8.5179	200	Garnetiferous biotite gneiss	24.2	30.00-33.00, 75.00-78.00	11.9	0.20		-		185	8.5	
35	Peringamala	77.0475	8.7281	200	Khondalite	8.8	13.50-15.00, 142.00-146.00	1.75	1.50	30	0.9		212	7.1	
36	Thattathumala	76.8850	8.7953	200	Khondalite	19	16.00-19.00 35.00-	4	0.20				233	5.7	

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
							38.00 62.00-65.00								
37	Tholikuzhy	76.9175	8.7861	125	Khondalite	19	24.50-26.50 123.50-125.00	7.45	10.00	18.41	6.41	0	464	7.1	Drilling stopped due to high discharge.
38	Thottakkad	76.8069	8.7375	200.53	Khondalite	4.4	4.4-13/30	20.4	0.50		NA		460	14	
39	Vamanapuram	76.8986	8.7222	200.53	Khondalite	14.8	14.17/30, 76.61/120, 107.09/324, 130.0/390	12.5	8.33	24.91	4.63	0	640	131	one OW
40	Vellanad	77.0594	8.5611	200	Khondalite	7.8	89.00-92.00, 135.00-137.00	4.79	0.50				413	20	
41	Vellarada	77.1953	8.4489	200	Khondalite	10.3	44.00-46.00, 74.00-77.00	2.32	1.30	36	1.04		140	8.5	
42	Vempayam	76.9417	8.6347	200.53	Khondalite	11	54.09/30, 88/60, 130/90, 160/144	10.5	2.40	32.48	0.93		460	11	

Sl. No	Location	Longitude	Latitude	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL mbgl	Discharge (lps)	Drawdown (m)	T m2/day	S	EC Microseimens/cm	Cl ppm	Remarks
43	Vettinad	76.9425	8.6028	200	Khondalite	17.6	16.00-19.00 129.00-132.00	1.4	1.50	28.5	1.46		430	27	
44	Vidura	77.0972	8.6736	200.53	Khondalite	14.7	35/30, 103.5/60, 122.33/90	6.56	1.50	31.89	0.94		220	7	
45	Vithura	77.0994	8.6736	200	Khondalite	9.6	26.00-29.00, 35.00-41.00	0.65	3.00		6.03		234	4.3	one OW
46	Vizhinjam	76.9824	8.3969	170	Khondalite	6	154-155		Meagre						

Annexure VI: Details of Exploratory wells of Soft Rock area

Sl. No	Location	Longitude	Latitude	Depth drilled (m bgl)	Depth constructed m bgl	Major lithology encountered	Depth of bedrock if found	Zones encountered	Zones tapped	Static water level (mbgl)	Discharge lps	Drawdown (m)	T m2/day	S	E.C micro seimen/cm	Cl (ppm)	Remarks
1	Pallam	77.043	8.353	100.75	66	Clay, sand	88		28-38,59-64, 72-78,85-88	0.64	6.91		NA		430		
2	Pulluvila	77.0472	8.35	120.29	103.63	Laterite, clay, sand	112.8	56.5-62.3, 91.6-101.9	56.5-62.3, 91.6-101.9	49.23	6.3	2.57	232.4	NA	460	1.45	
3	Chakkai	76.9194	8.4806	100.5	57	Clay, sand	97.5	42-54, 60-79		NA	NA	NA	NA	NA	Top - 4127, Bottom - 6485	NA	Slim hole
4	Meenamkulam	76.83722222	8.572222222	49.3	30.4	sand & clay	45.7	6.4-13.7, 19.5-28.95	19.8-28.95, (Warkalai)	NA	1.66	NA	NA	NA	18120 to 19320	665.7	Abandoned due to poor discharge.
5	Chittattumukku	76.85055556	8.578055556	51.82	30.4	Laterite, clay, sand	42.7	12-15, 33-36	19.8-28.95, (Warkalai)	NA	NA	NA	69.76	NA	NA	NA	Slim hole
6	Pudukurichi	76.81027778	8.606111111	92.35	19.6	clay, sand	88	7.15-17, 76-82	13.47-16.6, (Warkalai formation)	NA	NA	NA	NA	NA	11330 to 26000	97.29	Abandoned due to poor discharge.
7	Anjengo	76.75833333	8.668888889	103.2	70	Laterite, clay, sand, lithomargic clay	100.6	"8-17, 46-54, 57 - 68"	57 - 67	NA	Free flow	NA	NA		31080 to 43740	14496	Artescean water is saline.

Sl. No	Location	Longitude	Latitude	Depth drilled (m bgl)	Depth constructed m bgl	Major lithology encountered	Depth of bedrock if found	Zones encountered	Zones tapped	Static water level (mbgl)	Discharge lps	Drawdown (m)	T m2/day	S	E.C micro seimen/cm	Cl (ppm)	Remarks
8	Varkala	76.7083	8.7353	75.3	69	Laterite, clay, sand			56.4-62.5	49.93	6.31		232.4		70		
9	Edavai	76.6972	8.76111	121.9	109	Laterite, clay, sand	106.7	73-79, 91-103	73.0-79.0, 91.0-106.0	NA	Very low	NA	NA	NA	NA	NA	Abandoned due to poor discharge.