केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KOLLAM DISTRICT, KERALA

केरल क्षेत्र, तिरुवनंतपुरम

Kerala Region, Thiruvananthapuram

भारत सरकार

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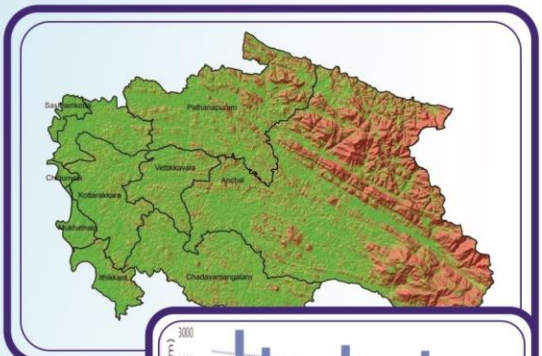
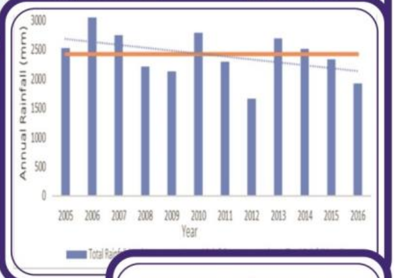
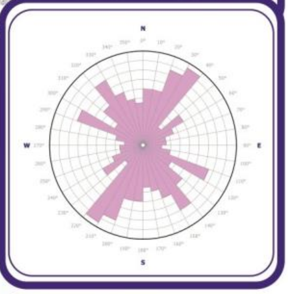
CENTRAL GROUND WATER BOARD







AQUIFER MAPPING AND MANAGEMENT PLAN OF HARD ROCK AREAS OF KOLLAM DISTRICT, KERALA (AAP- 2017-18)

Kerala Region
Thiruvananthapuram
January 2019

FOREWORD

The National Project on Aquifer Mapping (NAQUIM) is an initiative of the Ministry of Water Resources, 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 and this report pertains to aquifer mapping of the hard rock terrains of Kollam district. The target scale of investigation is 1:50,000 and envisages detailed study of the aquifer systems up to 200 m depth, to ascertain their resource, water quality, sustainability, and finally evolve an aquifer management plan.

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

This document has been prepared under the guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer, and Smt. T.S. Anitha Shyam, Scientist D & Team leader. The painstaking efforts of the field hydrogeologist Smt. Rani V R, Scientist - C in carrying out the aquifer mapping and preparation of this report iswell appreciated. Dr. K.R. Sooryanarayana, Suptdg. Hydrogeologist and Dr. V.S Joji, Scientist D deserves appreciation for their meticulous scrutiny of this report before printing. I am also thankful to the Chairman, Members and officers of CGWB, Faridabad for their valuable guidance in finalizing this document. Thanks, are also due to various organizations of Government of Kerala and Government of India for providing data required for the compilation of this document.

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 and before the DM, Kollam district. Their sincere efforts and encouragements for improvising the content of this report are acknowledged with gratitude.

I hope this compilation will be of much help to the planners, administrators and stakeholders in the water sector in Kerala and will serve as a useful guide for the optimal and sustainable management of ground water resources in the hard rock areas of Kollam district bases on sound scientific foot.

Thiruvananthapuram,
January,2019.

(V. Kunhambu)
Regional Director

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1. INTRODUCTION

1.1 Introduction

More than 95% of all the freshwater in liquid form occur as groundwater in the various aquifers across the globe. In India, 85% of rural water supply and 50% of urban and industrial demand is met from groundwater resources. It also caters to about 55% of irrigation needs of the country. Kerala State, accounting for only 1.2% of the geographical area of India, but home to nearly 3 percent of country's population, points to the high population density against the national average. In spite of high rainfall, abundant surface water resources and very high density of large diameter wells, water scarcity, especially for drinking and domestic uses, is becoming common in parts of this state, with its peak during the summer months. Factors such as its unique topography with steep slopes and a predominantly massive crystalline substratum limits the groundwater prospects of the state to a considerable extent. In the alluvial formations mainly seen along the coastal tracts are characterised by multiple aquifer systems, quality sometime constraints in the optimal development of available resources. The utilization of groundwater resources in the state is increasing steadily due to factors like increasing population, change in lifestyles, increasing urbanisation and consequent reduction in the ground water recharge.

As per the latest reports of Central Ground Water Board (CGWB) on Ground Water Resource Estimation (GEC-2013), the groundwater draft in the state is 2.635 bcm as against the net annual groundwater availability of 5.664 bcm. The stage of groundwater development works out to be 47%. Out of the 152 assessment units in the State, one fall under over-exploited category, two under critical, 18 under semi-critical while 131 assessment units fall under safe category (CGWB 2013). Thus, it can be observed that the groundwater development is not uniform in the state. Besides, geology and type of aquifer encountered, the groundwater potential of an area depends on the topography, soil, tectonic history. The coastal aquifer system of Kerala is having complex hydrogeological and hydro-chemical scenario associated with the tectonic history and depositional environment of the sediments. The major constrains in conceptualizing the coastal aquifer geometry is lack of data toward its seaward extension. The landward extension of the aquifer system was mapped for its aquifer geometry and groundwater resources. The crystalline aquifers generally have a thin mantle of weathering, which at places act as phreatic aquifer catering to the dug wells. Thus, broadly the state is characterized by highly potential Tertiary sedimentary aquifers along the coast and low yielding Precambrian crystalline aquifer on the eastern part. In the crystalline rocks, the fracture pattern varies from one place to another or even within few metres. Thus, demarcating potential fracture zones and its extension is a major constrain for development and management in hard rocks. As part of AAP 2017-18, mapping of hard rock aquifer system and aquifer management plan preparation was taken up in Kollam district, Kerala.

1.2 Objectives

The National Aquifer Mapping envisages integration of information available on soil types, agro-climatic conditions, geomorphology, geology, hydrogeology, hydrochemistry, cropping pattern, irrigation statistics, forest cover etc., on a GIS platform and formulation of the ground water management plan for individual units of optimal size in accordance with the nature of the aquifer, its quality of water, sustainability and the stress on the resource.

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

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

1.3 Methodology

In order to achieve above goals, three major activities viz;

a. Data gap analysis,
b. Data generation and integration and
c. Preparation of thematic maps and aquifer models are envisaged.

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 data generated were integrated and various thematic maps depicting hydrogeology, hydrology, geomorphology, water quality etc. and cross-sections, panel diagrams and elevation models depicting aquifer geometry and dispositions were generated. The deliverables so generated from the above activities is used to

a. Define the aquifer geometry and characterize the aquifer systems.
b. Define groundwater regime behaviour.
c. Identify the recharge characteristics, resource potential and draft.
d. Identify the hydro-chemical characteristics of aquifer systems and the extent of contaminant/pollutant in groundwater, if any.
e. Preparation of thematic maps related to all the above-mentioned objectives on 1:50,000 scale and preparation of 2-D models and 3-D models.

1.4 Scope of the study

Water constitutes one of the sensitive environmental parameters of the hydrological processes. Therefore, the study on sustainable water resources exploitation is important. 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 exploration in this state necessitates the need for a better water resources management. Thus, the present aquifer mapping on the hard rock area of Kollam district envisages the ground water requirement and its utilisation. Thereby an environmentally sustainable management plan is proposed/finalised.

1.5 Basic Geography and Administration

The hard rock aquifer system of Kerala covers an area of about 33,500 sq.km which is about eighty-eight percentage of the geographical area of the State. Current study (AAP 2017-18) area is located just east of the Coastal Aquifer Systems of Kollam district, which, was mapped during the AAP-2014-15. In Kollam district, hard rocks cover an area about of 1,883 sq.km, includes hilly area of 380sq.km, represents three-fourth area of the district which mainly covers the highland and a good portion of midland area. Geographically, the hard rock aquifers of Kollam district are located between North latitude of 8°45' & 9°10' and East longitude of 76°40' & 77°15' and covers a geographical ambience of 1,883 sq.km. The study area falls in the Survey of India Topographic sheets 58 C/12, 58C/16, 58G/4, 58D/9, 58 D/13, 58 H/1 & 58 H/5 (1:50,000 scale). The area of study covers two municipalities (Kottarakara and Punalur), five blocks completely (Anchal, Chadayamangalam, Kottarakara, Pathanapuram and Vettikavala), four blocks partly (Ithikara, Chittumala, Mukhathala and Sasthamkotta) comprising 39 panchayats (includes part of 6 panchayaths). The administrative division map of the study area is given in **Figure 1.1**. The study area is bordering on the north by Konni and Parakode blocks of Pathanamthitta District, east by Thirunelveli District of Tamilnadu and south by Vamanapuram and Kilimanoor blocks of Thiruvananthapuram District.

Population of the district is 26,35,375 as per 2011 census and is about 8.12% of the total population of the State. The total population of the study area is 11,11,238 which is about 42% of the total population of the district. Rural population (10lakh) predominates the urban population (1 lakh) in the study area which is represented by 92%. The average population density is 1129 persons per sq km. The population details as per census 2011 of the study area are given in **Table 1.1.**

Table 1.1 : Population data of the study area

Block	Area (sq.km)	HillyArea (sq.km)	Population (2011)	Density (Persons/ sq.km)	Rural Population	Urban Population
Anchal	932.59	300	219725	347	219725	0
Chadayamangalam	250.49	0	226637	905	226637	0
Chittumala	6.35	0	7326	1153	7326	0
Ithikkara	48.36	0	65947	1363	39931	26016
Kottarakkara	135.95	0	170181	1252	140393	29788
Mukhathala	22.1	0	46246	2092	0	46246
Pathanapuram	302.52	80	165675	745	165675	0
Sasthamkotta	16.28	0	19256	1182	19256	0
Vettikkavala	168.93	0	190245	1126	190245	0
Grand Total	**1883.6**	**380**	**11,11,238**	**Avg. 1129**	**10,09,188**	**1,02,050**

Source: Census 2011

The study area is well connected with other parts of the state and to almost all major cities in India by all-weather networks of roads and railways. The National Highway (NH 544) passes through the western part of the study area and the State Highways viz., Main Central Road, Kollam - Shencottah Road and Punalur – Pala - Muvattupuzha (Main Eastern Highway) connects the north-eastern parts of the district with Kollam city. MC Road together with NH 544 connects the north-eastern parts of the state with the city. In addition to road network, rail and water transport system exists in the district. The two main ports of the district are Neendakara and Kollam which lies on the western part of the study area.

1.6 Climate and Rainfall

Kollam has a tropical humid climate, with an oppressive summer, cool winters and plentiful seasonal rainfall. The period from March to the end of May is the hot season. This is followed by the southwest monsoon season, which continues till the end of September. During October and major part of November southwest monsoon retreats giving place to the north-east monsoon, and the rainfall up to December is associated with northeast monsoon season. The normal annual rainfall of the district is 2428 mm. The major source of rainfall is South West monsoon from June to September that contributes nearly 52% of the total rainfall of the year. The North-East monsoon season from October to December contributes about 26%, is considered crucial in recharging the ground water system and also in maintaining the stream flow to last the summer months, and the balance 22% is received during the month of January to May as pre-

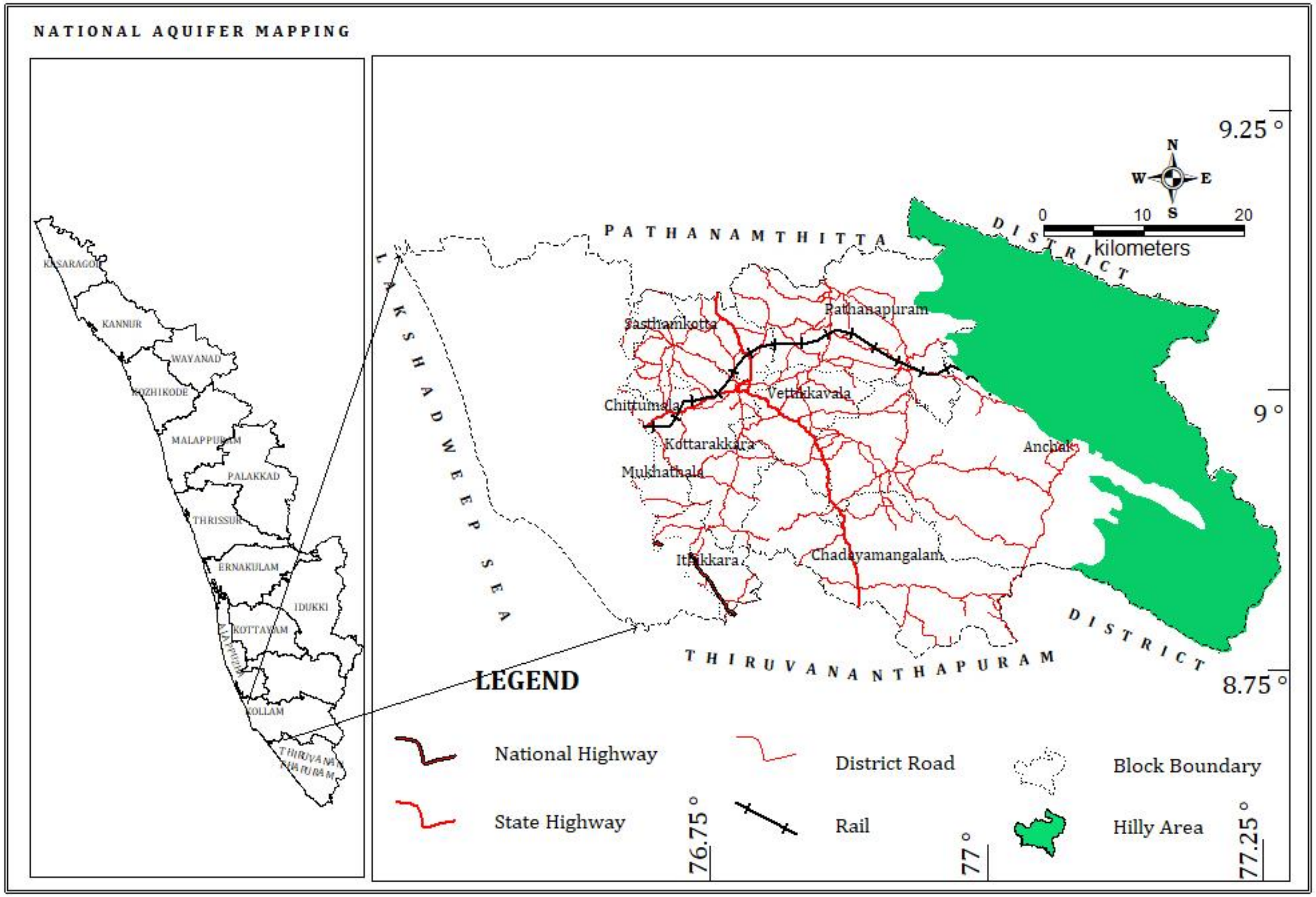


Figure 1.1: Administrative Divisions of the study area

monsoon showers. Out of the total 119 rainy days, 70 rainy days occur in the southwest monsoon season. Generally, the rainfall increases from western coast to the eastern hilly regions. The area in the southeastern part receives the maximum rainfall. The normal monthly rainfall in mm for the period 1901-1999 is given in **Table 1.2** and monthly rainfall data of Kollam district for 2005-2018 is given in **Table 1.3.**

Table 1.2: Normal Monthly Rainfall of Kollam district (1901-1999)

Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual Normal Rainfall (mm)
24.4	32	74.8	165.8	242	421	428	272.5	211	340	216	60	2428

Table 1.3: Monthly Rainfall of Kollam district (2005-2018)

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Total Rainfall (mm)
2005	26	17	31	257	213	392	464	104	284	240	311	193	2532
2006	18	26	148	242	371	273	366	302	413	584	303	0	3046
2007	0	11.7	39.7	194.2	161.3	499	574.1	263.1	408.1	445	128.8	26	2751
2008	0	41	224.9	137.6	120.8	207.1	454.8	265.1	247	360.8	122.7	25.6	2207.4
2009	2.2	3	105.7	121.9	136.4	272.3	369.7	185.5	272.6	325.9	317	15.7	2127.9
2010	11.5	0	59.1	221.1	203.5	357	362.3	304.8	258.3	527.8	388.4	95	2788.8
2011	57	99	47	200	125	417	278	225	242	214	288	101.3	2293.3
2012	13.7	20.9	77.4	228.6	145.8	167.5	210.6	272.6	149.8	240.2	111.1	17.4	1655.6
2013	10.3	58	49.2	90.2	159.6	749.5	449	205.3	373.6	290.9	213.8	39.5	2688.9
2014	0.5	15.7	51.4	151.7	290.8	283.5	287.9	591.5	260	386.6	151.7	40.1	2511.4
2015	7.7	32.9	34.6	279	226.4	411.7	185	141.1	255.8	386	307.6	68.6	2336.4
2016	1	50.3	55.3	67.3	384.4	508.5	262.8	136.7	42.9	188.9	198.2	19.7	1916
2017	21.5	1.3	147.6	137.7	356.8	532.5	128.5	282.4	412.2	322.5	369	258.5	2970.5
2018	3.5	8.6	110.7	127.3	242.3	426.9	568.1	592.5	73.5	317.9	162.2	20.1	2653.6

A histogram of annual rainfall of Kollam district for the period 2005-16 is shown in **Figure 1.2.** From **Table 1.2** and **Figure 1.2** it is observed that the rainfall was below normal during 2009, 11, 12, 15 and 2016. There was excess rainfall in the district for the rest of the years and it was above normal. Moreover, the rainfall distribution over the period shows a slight decreasing trend for the past fourteen years.

The temperature is more during the months of March to May and is less during December and January. The average mean monthly maximum temperature ranges from 29.9 to 36.4^{0}C and minimum temperature ranges from 19.4 to 23.8^{0}C. The relative humidity is higher during the monsoon period and all through the year it is higher during the morning hours. Evaporation is more during summer months of January to April and it is low during the rainy months May to August. The maximum rate of 4.8 mm per day is recorded in March and the lowest rate of 2.6 mm is recorded during July. Sunshine ranges from 4.3 to 9.7 hours/day. Maximum sunshine is during the month of February. The months of June to August record the minimum sunshine due to the cloudy sky. Generally good sunshine hours are recorded in the months of November to May. The wind speed ranges from 1.3 to 2.1 km/hour. The wind speed is high during the months of March to June and less during the months of September to December. Potential evapo-transpiration (PET) values are lower than the monthly rainfall during the month of May to October indicating water surplus for possible recharge into groundwater regime during these months. The monthly PET ranges from 119.3 to 177 mm.

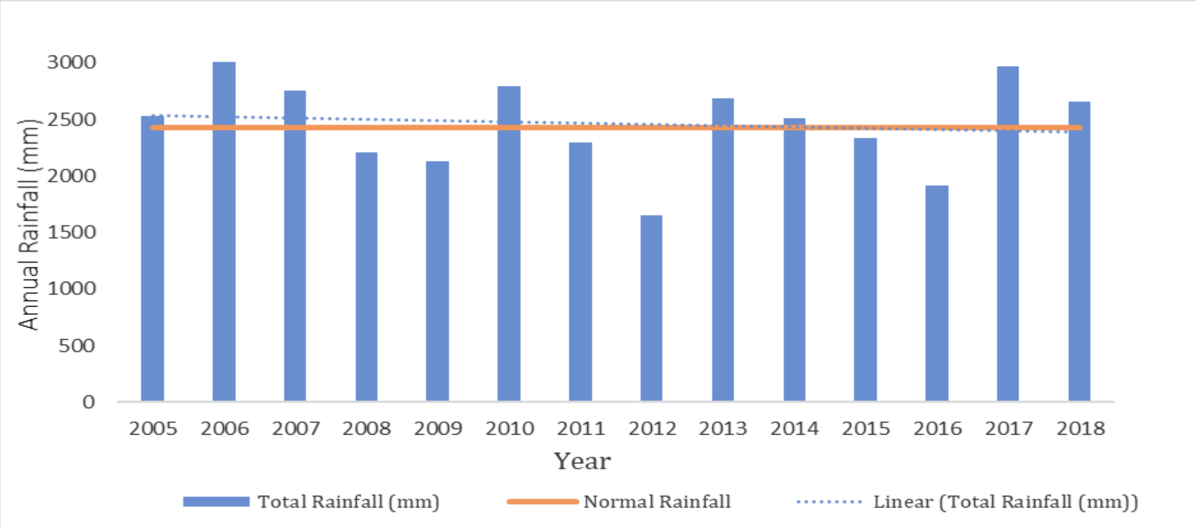


Figure 1.2: Histogram of Annual Rainfall of Kollam district (2005-18)

1.7 Physiography

Physiographically, the district can be divided into three distinct units – (1) lowland (coastal plains), (2) midlands and (3) highlands. The various landforms seen in the area are carved out by a combination of fluvial and denudational activities. The lowland or coastal plain is the area with an elevation of less than 7.5 m above msl with a gently sloping terrain made up of Tertiary and Quaternary Formation which fringes the western part of the study area. In midland, elevation is between 7.5 m and 75 m amsl consisting of low hills and valleys that are characterised by low to moderate slope towards the western coast. The lowland is comparatively narrow and is densely covered with coconut palms while the midland is an area of intense agricultural activity. The midland region sandwiched between lowland and highland represents a rolling topography. The midland area is characterised by rugged landform formed by gently to moderately sloping spurs, moderately to steeply sloping ridges, flat and domal hills with intervening narrow valleys and broad valley floors. The midland regions show a general slope towards the western coast. The Tertiaries and the basement crystalline rocks of the midland area are extensively lateritised. The thick column of lateritic soil in this region supports the growth of coconut and rubber.

The highly rugged terrain in the eastern part of the district represents the highland where the elevation is more than 75 m above msl which is covered mainly by forests and are characterised by steep slopes and narrow and small summits. Natural growth and urban development take place in the midland and low land regions. The highland region which occupies the maximum area of the study area and is bounded by 300 to 600 m contours of Western Ghats. Major parts of the catchment of river Kallada and Achankovil fall within this unit. The height of Ghats generally decreases from North to South. There are several peaks above 500 meter and the highest elevation is noticed at Karimalai (1758 m amsl). The Achankovil gap commonly known as Aryankavu pass, give an easy access for rail and road to the adjoining district of Thirunelveli in Tamil Nadu. For a clear understanding of the topography, Digital Elevation Model (DEM) of the study area draped over the hill shade map and is given in **Figure 1.3.**

From the DEM, it is very clear that study area is occupied by plateaus and flat-topped hills on the western side while the eastern part is represented by highly rugged topography with a number of peaks. The general slope is towards west. The distributions of different physiographic units in various blocks of the study area are shown in **Figure 1.3a.** It is clear that highland occupy a major portion of Anchal and Chadayamangalam blocks while in the remaining blocks midland predominates. While formulating the groundwater management

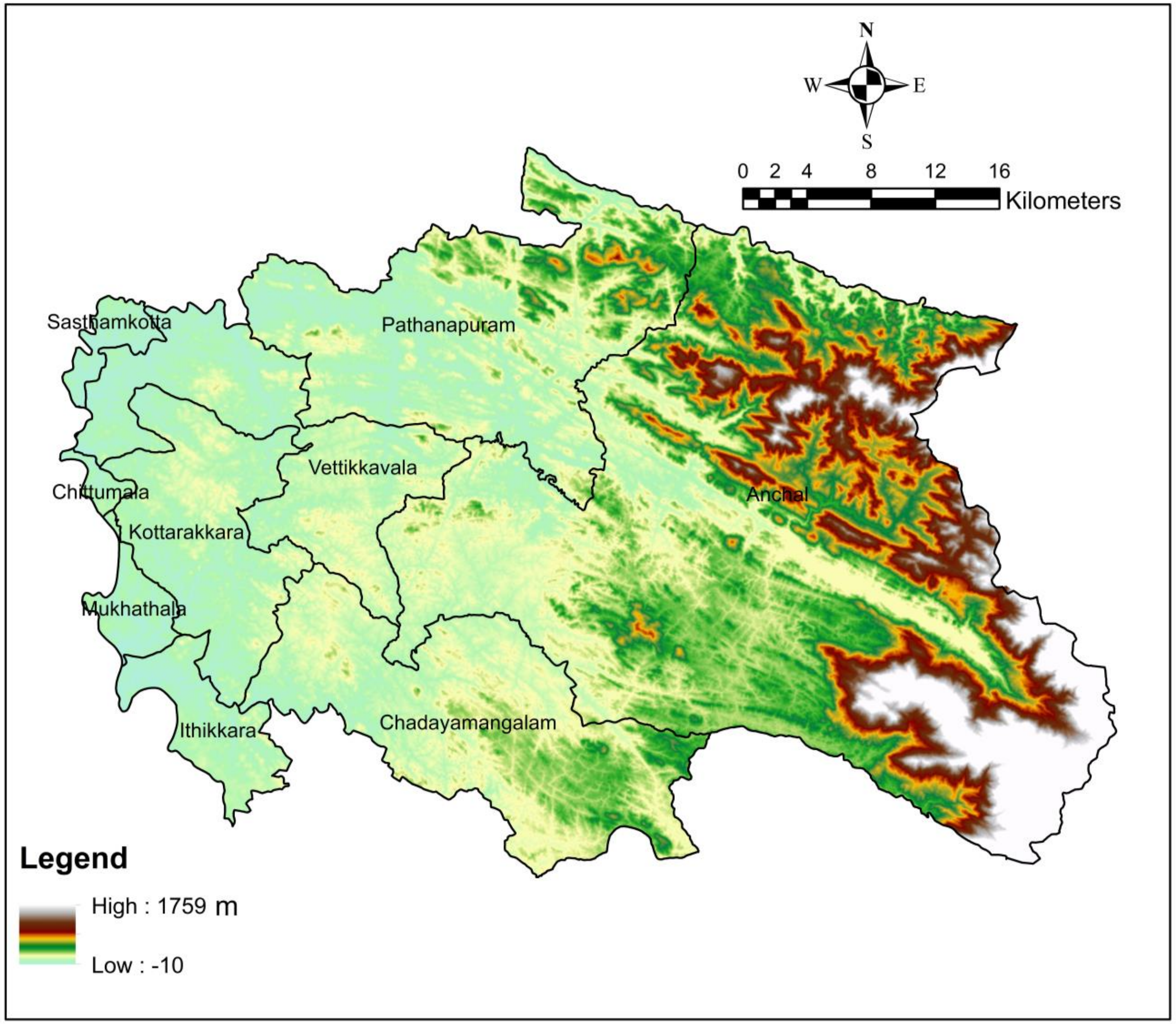


Figure 1.3: Digital Elevation Model (DEM) of the study area

practices, these division to be considered. The land use, ground water availability as well as ground water management to be formulated is different in each physiographic category.

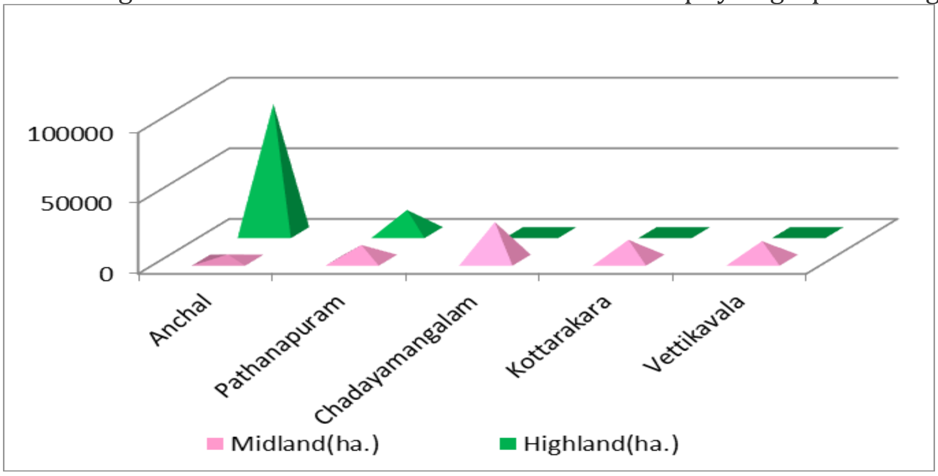


Figure 1.3a: Block-wise distribution of physiographic units in the study area

1.8 Slope

Slope is the gradient of an elevation change. A rise of 10 m in a horizontal distance of 100 m is a slope of 10 percent. Ranges of slope assigned to map units represent practical breaks on the landscape that are important for the use and management of the study area. The slope has a remarkable effect on the infiltration of surface water to recharge the aquifer, as the low slope percentage indicates that the precipitation will have more time to percolate into the subsurface. In the case of highly sloping terrain, run-off is more and which significantly reduces the ground water recharge potential. The slope of an area greatly depends on the elevation which is the characteristic of topography. The DEM prepared had given a clear picture of the topography of the study area while the slope map prepared for the study area provides a value addition and is given in **Figure 1.5.** The slope map shows that slope in the study area ranges from less than 5^0 to more than 30^0. The areas covered under various categories of slope are tabulated for different blocks and are given in **Table 1.4.** From the groundwater point of view, area with slopes greater than 20^0 are considered as run-off zone and moreover steep slopes are unsuitable for sustained agriculture as well as for groundwater interventions.

Table 1.4: Slope classification

Slope(^{0})	**0-10^0**	**10-20^0**	**20-30^0**	**>30^0**	**Percentage of total area with slope >20^0**
	Area in hectares				
Anchal	260.5	297.7	255.3	115.0	39.88
Pathanapuram	132.2	120.1	43.9	5.2	16.28
Chadayamangalam	144.0	93.8	11.0	0.3	4.54
Kottarakkara	91.9	41.4	2.3	0.0	1.68
Vettikavala	104.8	57.2	5.2	0.1	3.19
Shasthamkotta	14.6	2.6	0.0	0.0	0.08
Mukhathala	20.6	3.3	0.1	0.0	0.22
Ithikkara	38.4	10.6	1.0	0.0	1.99
Chittumala	5.8	1.5	0.0	0.0	0.04

From the table, it is clear that Anchal and Pathanapuram blocks have more area which is not groundwater worthy when slope is considered. 76% of the study area has slopes lesser than 20^o.

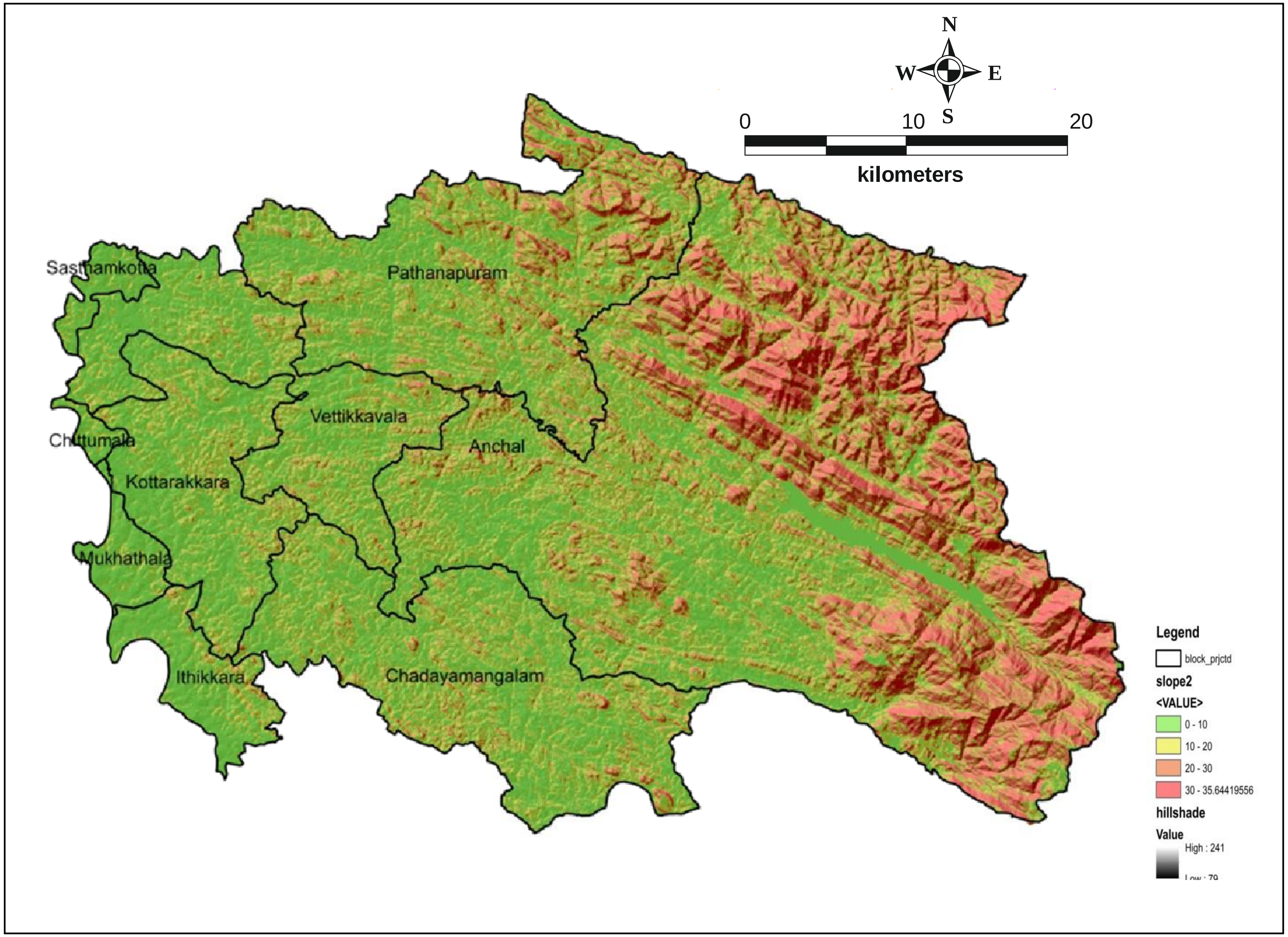


Figure 1.4: Slope map of the study area

1.9 Geomorphology

The evolution of different landforms in an area depends on the environment, lithology, climate and various other factors. Geomorphologically, the landforms in the study area are carved out by a combination of fluvial and denudational activities which can be grouped into erosional and depositional landforms. The various geomorphic units seen in the area are pediplain, plateau, piedmont zone, flood plain, residual hill, denudational hills and structural hills and are given in **Figure 1.5.**

The narrow coastal plain on the west is flanked by highly dissected pediplain on the east that represent erosional landforms formed as a result of fluvial and denudational activities. These undulating pediplain are dissected with broad valleys and isolated low mounds with elevation up to 10 m above MSL. The side slopes are gentle to moderate and cultivated with coconut intercropped with tapioca, banana, arecanut, jack, mango etc. In the valleys, paddy, banana and vegetables are raised.

The lower dissected piedmont plains are characterised by undulating to rolling lands with elevation 20-60m above MSL interspersed by broad valleys with occasional low laterite mounds. Coconut-predominant mixed cropping with arecanut, tapioca, fruit trees, pepper, yams etc, in garden lands. Paddy, banana, sesame, vegetables, pulses etc., raised in broad valleys. 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 of Kallada and Ithikara River. These depositional landforms are characterized by paddy fields, coconut cultivation and settlements. The upper piedmont plains are characterised by isolated hills of low altitude at 20-100m above MSL characterised by dissected laterite landscape with low laterite mounds & interfluves with gently sloping to flat bottom broad valleys. Coconut-predominant mixed cropping system exists. Rubber as monocrop, tapioca, pepper, cashew, banana, fruit trees etc. are cultivated. In flood plains, paddy, banana, vegetables and pulses are raised.

To the east is the hilly terrain which includes denudation hills, denudational slopes, rocky cliffs, scarp slopes with narrow valleys aqnd terraces at 600-1200 above MSL. Plantations of eucalyptus, teak and rubber are common in this area.

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 describes how a parcel of land is used while land cover refers to natural vegetation, water bodies, rock, soil, artificial cover and other resulted cover due to land transformation i.e., mainly visual surface characteristics. Land use/ land cover pattern is mainly influenced by a number of physical as well as cultural activities. According to Agricultural Statistics for 2016-17, the data on land use pattern of the district reveals that forest occupies around 27.82 per cent of the area of the district. Due to pressure for non-agricultural use, the land under non-agricultural use which was 8.96 per cent in 2000-01 has increased marginally to 11.4 per cent in 2015-16. A large part of the study area is under forest that includes Pathanapuram and Anchal blocks. The forest divisions are at Thenmala and Punalur. The geographical area of the district has been classified into 15 different types of land uses and the details are given in **Table 1.5**.

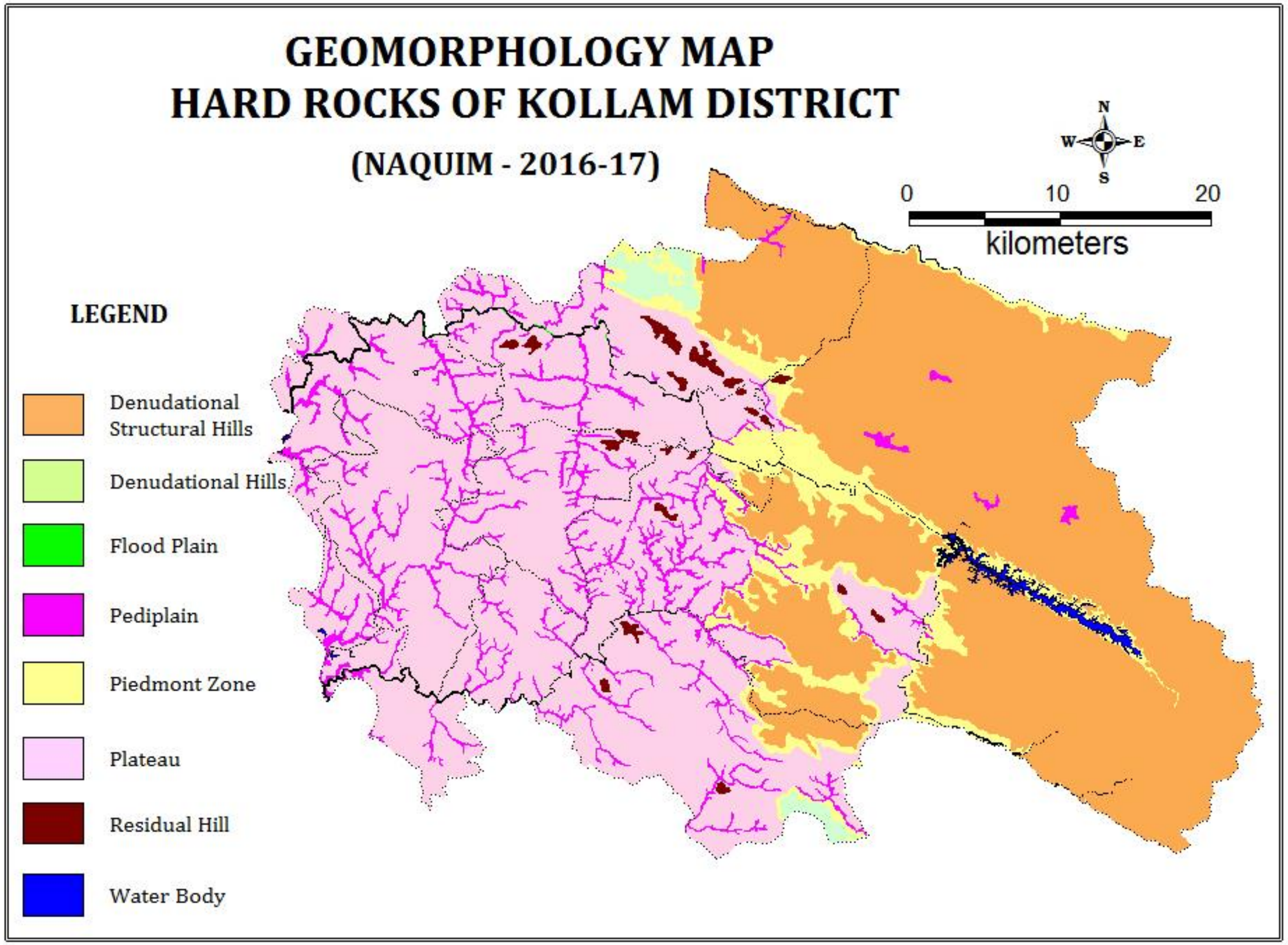


Figure 1.5: Geomorphology map of the study area

Table 1.5: Classification of area based on Land Utilisation

Land Units	Area (ha)	Percentage (%)
Forest	81438	32.7
Land put to non-agricultural use	28314	11.4%
Barren & uncultivable land	178	0.1
Land under misc. tree crops	46	0.02
Cultivable waste	2673	1.1
Fallow other than current fallow	1691	0.7
Current fallow	3255	1.3
Marshy Land	4	0.0
Still Water	6593	2.7
Water Logged Area	938	0.4
Social Forestry	95	0.04
Net area sown	123563	49.7
Area sown more than once	25754	10.4
Total cropped area	149317	60.0

Source: Agricultural Statistics 2015-16

In the study area, in general, the physical growth of Kottarakara and Punalur Municipality and the surrounding panchayats is along major transportation corridors, with concentration of urban development in a few major nodal points. To understand the land utilisation, a False Colour Composite of the area has been prepared **(Figure 1.6)** Land use/land cover map of the study rea were prepared and the various land use/land cover units identified in the study area are agricultural land, forest, built-up-land, waste lands and water bodies which is shown in **Figure 1.7** and is discussed in the following section.

a. Agricultural Land

Agricultural land consists of irrigated croplands and cultivable areas that occur predominantly in plains and around settlement areas, besides water bodies. Major part of the study area falls under this category (56%). The paddy fields witnessed a preponderance of reclamation activities for the last few years and the low-lying areas have been utilized for the construction of multi-storeyed buildings. Besides reclamation, uncontrolled exploitation of alluvial clay from paddy fields and sand from flood plains are highly rampant in the river basins for bricks and tiles. Thus, sand mining activity contributes considerably towards the deterioration of agricultural land in the recent years.

b. Forest cover

This region lies in the eastern portion of the study area with boundaries as Pamba-Kakki Forested Hills in the North, Tamil Nadu in the East, Ponmudi-Agasthiar Forested Hills in the South and Kottarakkara Undulating Upland in the West. Kulathupuzha Forested Hills comprises of parts of Pathanapuram and Kottarakkara Taluks. This hilly region is the continuation of the Western Ghats and has steep slopes towards the west. This Forested Upland has many isolated hills and knolls in its Western portion before entering into the Rolling Plain. This region forms the catchment area of the Kallada and the Achancovil Rivers which are structurally controlled. On the slopes of evergreen forested region, there are some rubber estates. The important places in this region are Kulathupuzha, Punalur, Thenmala, Aryankavu and Achaenkovil.

Figure 1.6: False Colour Composite of the study area

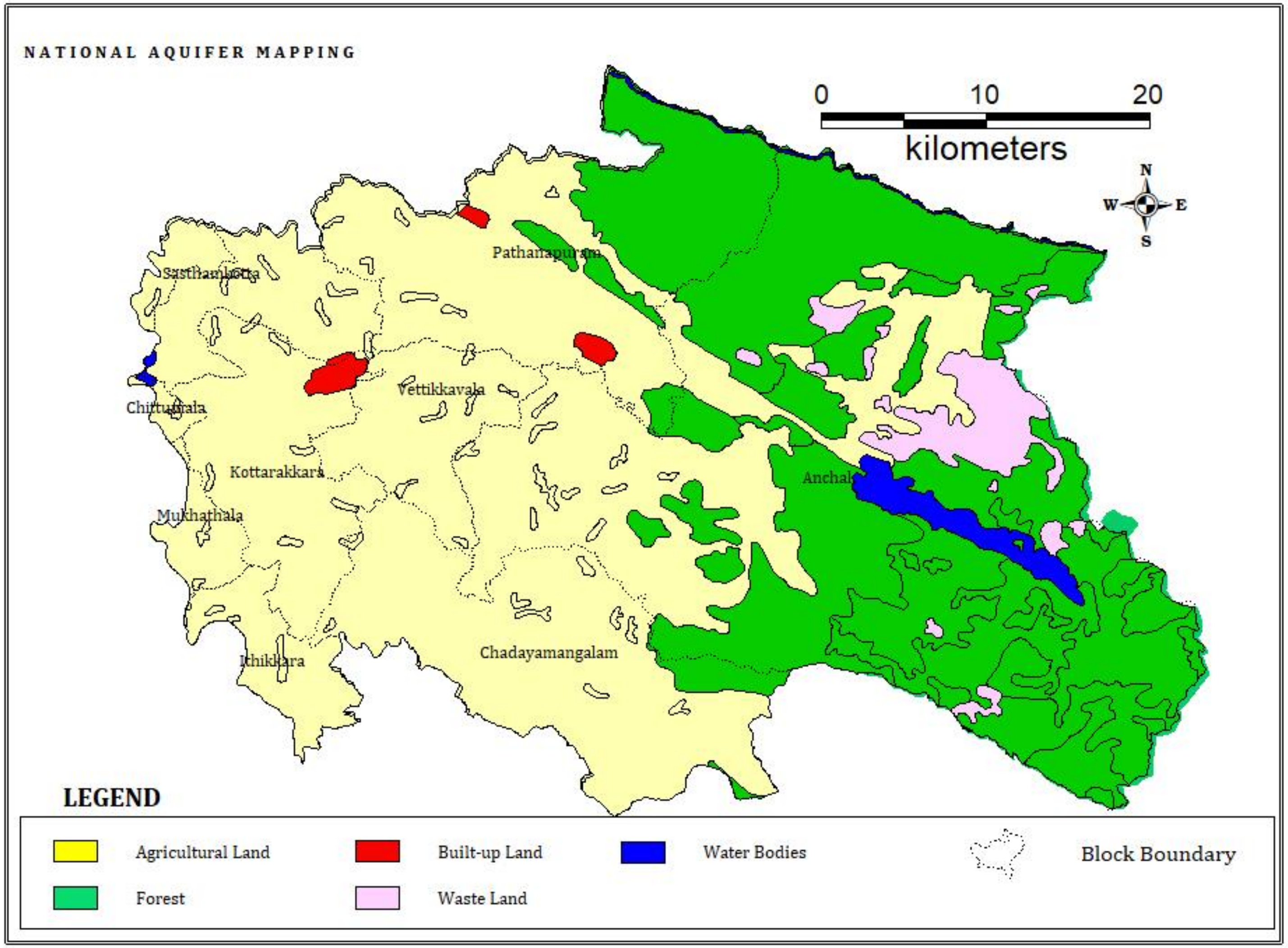


Figure 1.7: Land Use/ land cover map of the study area

c. **Built-up Land**

This is the land used for habitation which includes residential, commercial and industrial area and areas used for major transportation and communication. Industralisation in some pocket areas create a lot of employment opportunities for the people in the rural area resulted in the migration of population. In connection with this, there is a heavy demand of housing for this floating population ended up in conversion of more and more of the agricultural land into settlements. The main ubiquitous issues of this indiscriminate and unscientific construction are the reduction in water infiltration, clogging of natural drainage causing flash floods and water logging during rainy seasons.

d. **Waste Lands**

Waste lands are described as degraded lands which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes. Barren Rocky/Stony Waste are rock exposures of varying lithology often barren and devoid of soil and vegetation cover mainly seen on the eastern rugged terrain of the study area (3%). Gullied Land are the resultant of terrain deformation due to water erosion which are formed as a result of localized surface run-off affecting the unconsolidated material resulting in the formation of perceptible channels causing undulating terrain. They are mostly associated with stream courses, sloping grounds with good rainfall regions and good unconsolidated material deposit at foothill regions.

The distribution of various land use units in different blocks of the study area is given in **Table 1.6.** From the pie chart (**Figure 1.8)** it is very clear that agricultural land and forest cover are the predominat land use in the study area. The block-wise distribution of land use units in study area is shown as bar diagram in **Figure 1.9** which shows the non-uniformality in the distribution of various land use types in different blocks. This had a main control on the occurrence and availability of groundwater. The waste land should be considered while formulating the ground water management plans.

Table 1.6: Block-wise distribution of various land use units

Block/ Land Use(ha.)	Agricultural Land	Built-up land	Forest	Waste land	Water bodies	Barrenrock/ Stonywaste/ Sheetrock	Wetlands (Waterlogged)
Anchal	25605.8	271.0	57471.9	8335.3	1359.9	1332.1	0.0
Chadayamangalam	22728.4	282.0	1079.9	780.7	111.1	82.3	0.0
Chittumala	1188.7	98.3	0.0	26.8	0.7	0.0	26.8
Ithikara	6778.2	415.8	0.0	174.1	136.4	0.0	145.9
Kottarakara	12564.5	849.6	0.0	100.9	18.7	21.9	0.0
Mukhathala	2341.1	15.3	0.0	114.4	35.0	0.0	114.4
Pathanapuram	17140.9	1386.1	9963.3	1113.3	246.4	174.7	0.0
Sasthamkotta	2030.9	39.5	0.0	8.6	68.4	0.0	0.0
Vettikavala	15875.2	462.7	0.0	352.8	60.1	7.5	37.6
Percentage	55.4	2.0	35.8	5.7	1.1	0.8	0.2

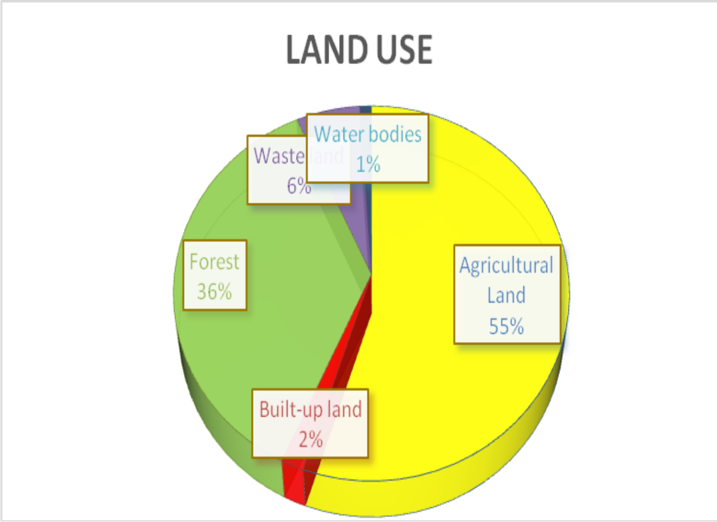


Figure 1.8: Pie chart showing the distribution of land use units in study area

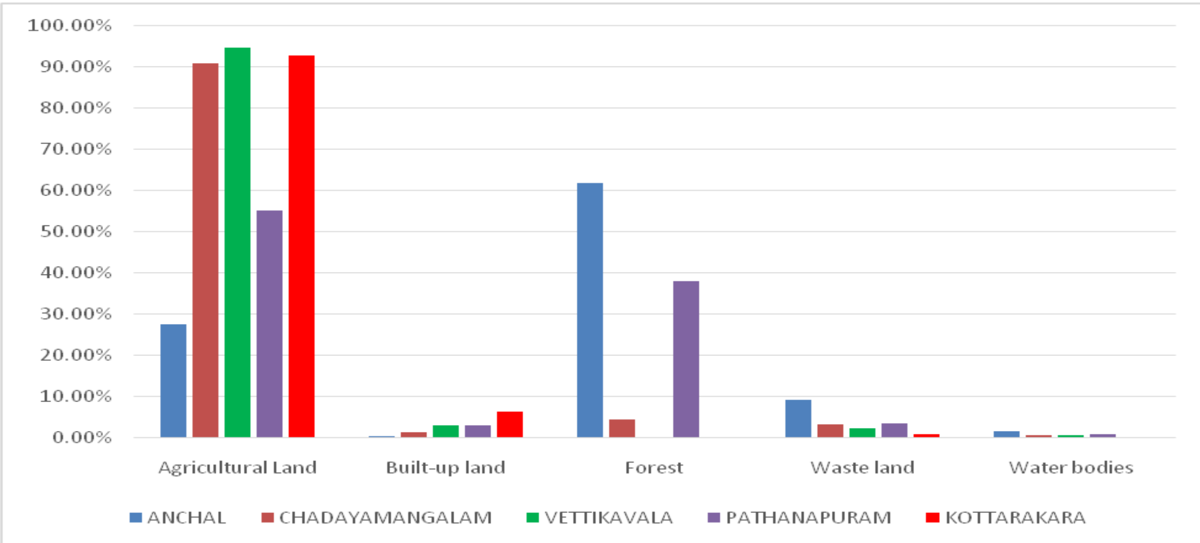


Figure 1.9: Bar diagram showing the block-wise distribution of land use units in study area

1 .11 Drainage

The major portion of the study area is drained by three west flowing rivers - Achenkovil, Kallada and Ithikara, originating in the eastern hilly region. These rivers together with their tributaries exhibit dendritic pattern of drainage. Besides these three rivers, Ayirur and Vamanapuram are the other main water sheds of the study area.

The Achankovil River originates from the Western Ghats and covers a basin area of 1484 km^2 and the main channel length is 128 km. The river joins Pamba River at Veeyapuram and finally debouches into the Vembanad Lake. The Achankovil River is set in a well-known shear zone demarcating the boundary between Kerala Khondalite Belt and Charnockites of South Indian Granulite terrain. Various studies carried out in this basin indicate that the basin architecture is much influenced by this prominent shear zone. Development of rectangular, parallel and trellis drainage patterns are clear evidences for the structural control. Further, main river course is oriented in WNW-ESE direction, which follow the trend of the Achankovil shear zone and most of the lower order streams are developed roughly at right angles to the main river course.

Ayiroor River - the smallest river in southern Kerala and it originates from Navaikulam. The length of the river is 17 km and drains an area of 66 sq km. At Nadayara the river empties into the Edava- Nadayara Kayal.

The Ithikara River originates from the Madatharaikunnu hills, south west of Kulathupuzha and drains into the Paravoor backwaters near Meenad. The Ithikara river basin has its maximum elevation north of Madathara (271 m) on the eastern side and slopes down to sea level west of Mayyanad. Ithikara River is a fourth order stream with a gradient of 8.2 m/km. The length of the river is 56 km and covers a drainage area of 659 km^2. The river flows through the settlements of Chathannoor and Pooyappally.

The Kallada River originating from the Western Ghats drains into Ashtamudi backwaters near Kollam after flowing through Punalur, Pathanapuram, Kunnathur and Kallada. The length of the river is 121 km and drains an area of 1,699 sq.km. The Kallada River is formed by three rivers, viz., Kulathupuzha, Chendurnj and Kalthuruthy. This river basin has its highest elevation at Karimalaikodkal (1763 m) on the eastern side and reaches almost sea level west of Karunagapally. Kallada dam constructed across this river is used to generate electricity in addition to its utilisation in irrigation sector. Kallada River is a fifth order stream with a gradient of 12.6 m/km.

Vamanapuram River originates from the Chemunjimotai at an elevation of 1860 m above MSL. At Chirayankeezhu, the river debouches into the Anjuthengu Kayal and travels a length of 88km.

The drainage map of the study area along with various drainage basins is shown in **Figure 1.10**. A drainage map of the area gives an idea about the permeability of rocks and also gives an indication of the yield of the basin (Wisler and Brater 1959). The details of catchment area of these rivers in the study area are given in **Table 1.7**.

Table 1.7: Details of Catchment Area in the NAQUIM area

Basin Name	Catchment Area (Sq. Km)		%
	Total	Study Area	
Achankovil	1484	163.95	12.2%
Ayirur	124.29	3.74	11.3%
Ithikara	659.72	542.33	86.17%
Kallada	1615.56	1122.82	56.3%
Vamanapuram	766.9	57.07	7.25%

1.12 Soil

The Soil of the district are broadly classified by the Soil Survey Department as a) sandy loams, b) lateritic and c) forest soil. The costal belt as well as ricwer courses has sandy loams and the forest soil is found in the eastern forest belt. Soils are also categorized on the basis of water draining capability- the major categories include imperfectly drained, moderately drained, moderately well drained to imperfectly drained, somewhat extensively drained to moderately drained, well drained to well drained rocky out crops. About 80% of soil is included in the category of well drained, the moderately well drained is another major group that occupies about 7% of total land area of Kollam district.

On the basis of soil content, the major soil groups of Kollam are categorized into Clayey, Clayey-loamy, Loamy, Rocky patches and Sandy soils. The map showing the distribution of various

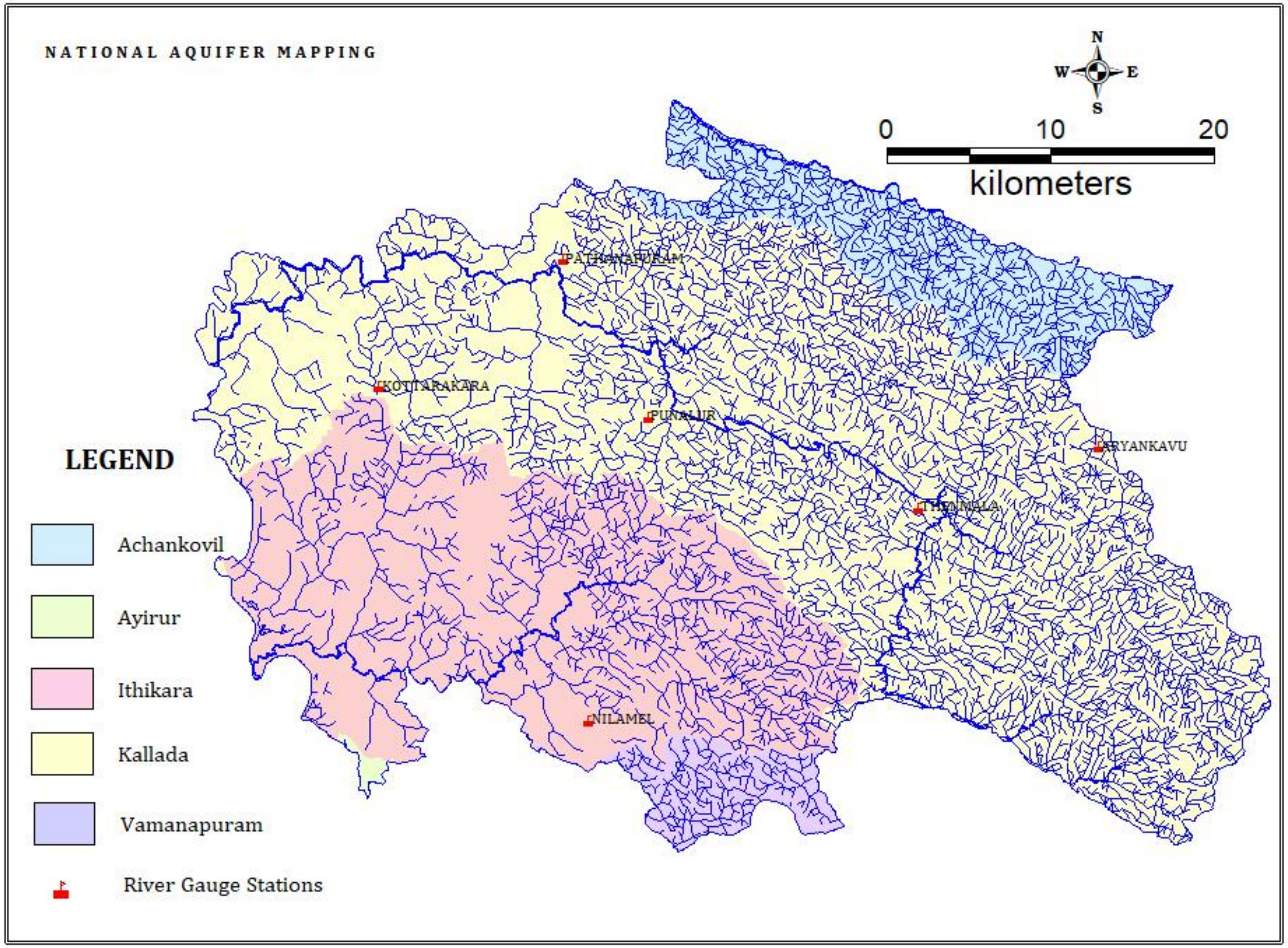


Figure 1.10: Drainage map of the area

types of soils are given in **Figure 1.11.** About 54% of soil in the study area is included in the category of gravelly clay which is most suitable for agricultural activities.

Based on the morphological features and physico-chemical properties, soils in the state have been classified into five types. They are Lateritic soils, Brown Hypidiomorphic soils, Greyish Onattukara soils, Riverine and Coastal Alluvium and Forest Loam. The main types of soil seen in the study area are lateritic soil, riverine alluvium, brown hypidiomorphic soil and forest loam that are discussed in detail in the following section.

a. Lateritic Soil

Lateritic soil is the most predominant soil type of the study area and it occurs in the midland and hilly areas and it is derived by weathering of khondalite, charnockite and migmatite group of rocks under hot humid tropical climate conditions. The texture of the soil vary from gravelly loam to gravelly clay loam and the colour ranges from reddish brown to yellowish brown in the surface and the exposed portion is normally very hard when compared to sub-surface soil. This acidic soil shows varying morphologoical characteristics depending on the nature of the parental rock. Lateritic soils are generally suitable for the dryland crops. A wide range of crops such as coconut, tapioca, rubber, arecanut, banana, tapioca, pepper, pineappale cashew etc are cultivated in this soil.

b. Riverine Alluvium

This soil mainly occurs along the banks of rivers and their tributaries ie, all along the flood plains of Kallada and Ithikara River. This soil shows wide variation in their physico- chemical properties depending on the catchment area through which the river flows. Texture of the soil ranges from sandy loam to clay loam and is moderately supplied with organic matter. The soil is highly permeable and ground water retention is very high. The riverine alluvium sand available in the Kallada and Ithikara basins are subjected to sand mining activities and have been posing a great threat to the geo-environmental balance.

c. Brown hypidomorphic soils

Brown hypidromorphic soil is confined to the valleys between undulating topography in the midlands. They have been formed as a result of transportation and sedimentation of material from adjacent hill slopes and also through deposition by rivers. These exhibit wide variation in physico-chemical properties and morphological features. The development of the soil profiles has occurred under impeded drainage conditions and the texture of this soil ranges from sandy loam to clayey loam. These soils, therefore exhibit characteristic hypidiomorphic features like grey horizons, mottling streaks, hardpans, organic matter depositions, iron and manganese dioxide concretions etc. These soils are moderately supplied with organic matter, nitrogen and potassium and are deficient in lime and phosphate.

d. Forest Loam

Being the products of weathering of crystalline rocks under forest cover, they are restricted in occurrence to the eastern part of the study area. They have immature profiles with shallow soil, followed by gneissic parent material in various stages of weathering. In areas with lesser canopy cover, signs of lateritisation have been observed in profiles. They generally show vide variation in depth and are dark reddish brown to black with loam to silty loam texture. In denuded area, leaching and deposition of humus in the lower layers are observed. The B-horizon usually contains gneissic gravels and boulders. These soils are generally acidic with pH ranging from 5.5 to 6.3 and are rich in nitrogen, but poor in the bases because of heavy leaching. Forest trees, shrubs and grasses are grown here.

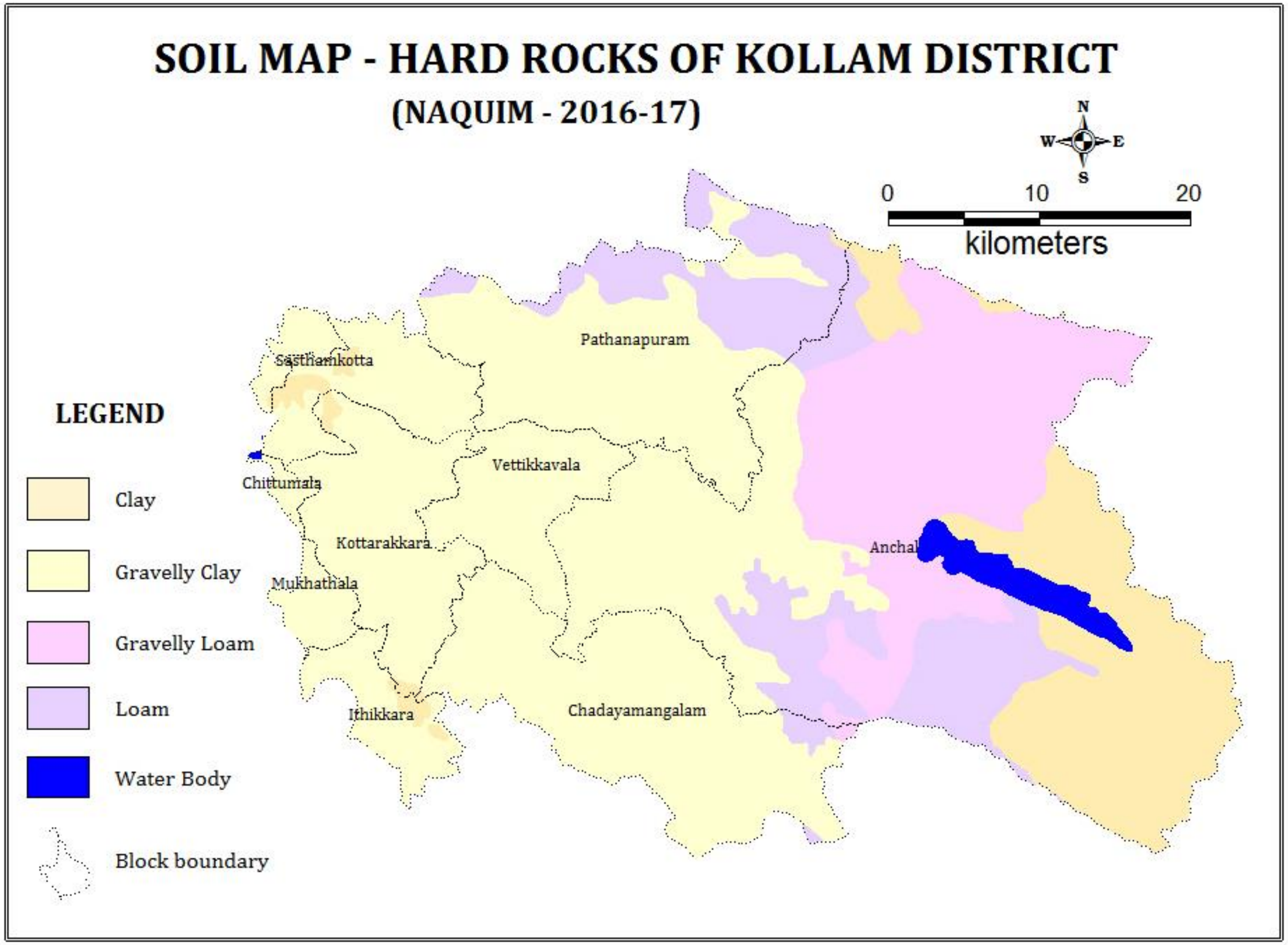


Figure 1.11: Soil map of the area

1.13 Cropping Pattern – Agriculture and Irrigation

With diverse agroclimatic conditions brought about by natural physiographic divisions, a wide variety of crops are cultivated in the study area. These include plantation crops like coconut, arecanut, cashew, pepper, tea, rubber; food crops like paddy, tapioca, pulses; fruit crops like banana, mango; and vegetables. The number of people engaged in agricultural activities has been reducing due to high returns from other entrepreneurial ventures or business and service sectors. The population of agricultural labourers is also decreasing due to migration of labour force to construction, manufacturing and service sectors. But at the same time a positive growth in urban populations has been recorded both in absolute values and their shares over the period. This may be due to the urbanisation by the formation of new Municipalities and expansion of existing urban local bodies by conversion of nearest rural Panchayats.

The midland area is occupied by coconut, rubber and tapioca cultivation which constituted more than 73 per cent of the total cropped area. The other crops such as plantains, arecanut, cashewnut, ginger and pepper together occupy only 5.4 per cent. The plantation crops such as tea, coffee and cardamom occupy a little area. There is an oil palm plantation at Bharatheepuram near Anchal, in an area of 4,000 hectares under the Oil Palm India Limited, a State Government undertaking. The rehabilitation plantation, another State Government undertaking, is located at Kulathupuzha near Thenmala.

In the district, the area under food crops was nearly 60 per cent during 2005-06 and dropped to 42.4 per cent during 2010-11. Similarly, in the case of non-food crops the proportion of area increased from 40 per cent to 57.6 per cent. The performance of Agriculture sector in the District has significant fluctuation during 2005-06 to 2010-11. Area under paddy cultivation decreased from 7218 to 3342 hectre and production of rice down from 16063 to 7155 tons during 2005-06 to 2010-11. Coconut cultivation decreased in terms of area from 66134 to 56275 and production decreased from 504 million nuts to 378 million nuts during this period. Other crops also show similar tendency in the area. The block-wise area under different crops is given in **Table 1.8.**

Table 1.8: Block-wise area under crops (2015-16)

Block	Coconut	Tapioca	Jack Fruit	Mango	Plantain	Pepper	Banana	Cashew	Paddy
Anchal	4116.73	1686.29	580.69	381.7	746.31	555.24	554.04	114.5	65.97
Chadayamangalam	4175.22	2340.84	1033.41	579.45	896.23	511.9	440.61	353.66	193.75
Chittumala	5379.81	637.11	993.63	865.48	284.22	291.34	25.6	336.07	104.01
Ithikara	4685.48	1189.84	612.62	591.1	252.44	197.38	29.37	368.81	255.76
Kottarakara	2828.85	1183.75	349.24	258.24	657.77	207.97	433.51	86.55	224.94
Mukhathala	4228.67	751.94	553.29	627.49	251.44	206.98	18.4	156.31	165.18
Pathanapuram	2062.31	1650.35	248.33	132	310.92	227.28	388.7	61.42	72.99
Sathamcotta	4256.39	1969.93	635.27	525.41	334.85	491.93	492.18	374.83	226.26
Vettikavala	3016.14	1908.02	588.33	377.61	877.28	233.04	459.34	82.63	99.09
Total Area(Ha.)	34749.6	13318.1	5594.81	4338.48	4611.46	2923.06	2841.75	1934.78	1407.95

Source: Agricultural Statistics, 2015-16

Panchayath wise area covered under various crops in four blocks which are fully covered under this study are given in **Table 1.9a to 1.9d**. From the panchayth-wise details, it is observed that rubber plantation covers a major part of each panchayath.

Even though the area is endowed with perennial supply of water from two main rivers, the

Table 1.9a: Panchayath-wise details of area covered under crops (2016-17) – Anchal Block

Crops /Area(ha.)	Anchal	Alayamon	Aryankavu	Edamulakkal	Eroor	Karavaloor	Kulathupuzha	Thenmala	Total Area Crop-wise(ha.)
Paddy	20	5		30	20	15	12	1.6	103.6
Coconut	99	100	200	400	215	52	450	95	1611
Vegetable	15	10	10	20	15	10	12	10	102
Banana	72	90	150	250	150	40	200	150	1102
Tapioca	97	98	75	125	76	50	100	30	651
Pepper	55	90	1200	200	76	30	400	210	2261
Cashew	5	1	3	10	5	5	30	15	74
Rubber	990	2350	3200	1650	2132	1500	2500	4000	18322
Ginger	10	6	10	12	8	8	10	8	72
Turmeric	6	3	10	8	4	2	10	2	45
Minor Tubers	30	20	10	50	35	25	25	20	215
Clove			150				50		200
Arecanut	15	10	100	25	20	8	25	15	218
Cardamom			25				2		27
Orange			10						10
Pine Apple	5	30		10	90	20		24	179
Betelvine	1	2	1	15	1.5	1	1.5	4	27

Table 1.9b: Panchayath-wise details of area covered under crops (2016-17) – Chadayamangalam Block

Crops /Area(ha.)	Chithara	Kadakkal	Chadayamangalam	Ittiva	Elamadu	Nilamel	Velinallur	Kummil	Total Area Crop-wise (ha.)
Paddy	7	16	25	45	25	13	50	12	193
Coconut	450	225	75	200	300	50	550	260	2110
Vegetable	35	10	14.5	17.5	4.9	24	70	5.4	181.3
Banana	400	250	180	350	160	25	438	200	2003
Tapioca	100	385	155	75	200	35	158	10	1118
Pepper	110	245	15	40	20	5	179	10	624
Cashew	30						18		48
Rubber	1973		1200	2710			985		6868
Ginger		8	2	5	5	3	22	8	53
Turmeric		8	2	5	5	3	8	5	36
Minor Tubers	560	86	10	55	25	11	130	10.4	887.4
Clove	35								35
Arecanut	13	30	5		10	1	15	5	79
Cardamom									0
Orange									0
Pine Apple									0

Table 1.9c: Panchayath-wise details of area covered under crops (2016-17) – Kottarakara Block

Crops /Area(ha.)	Veliyam	Pooyappally	Kareepra	Ezhukone	Neduvathoor	Kottarakar(M)	Total Area Crop-wise (ha.)
Paddy	50	48	132	8	2	2	242
Coconut	750	40	750	400	255	60	2255
Vegetable	35		8.5	15		20.6	79.1
Banana	300	50	140	50	450	94	1084
Tapioca	125	40	105	50	175	41	536
Pepper	100	15	80	20	8	9	232
Cashew		3		10		5	18
Rubber	1175	750	171	500	443	464	3503
Ginger	28	10	5	4	2	8	57
Turmeric		6	4	3	1	3	17
Minor Tubers	50	18	19	12	24	46	169
Clove							0
Arecanut		10	30	2	10	0.2	52.2
Cardamom							0
Orange							0
Pine Apple							0
Betelvine							0

Table 1.9d: Panchayath-wise details of area covered under crops (2016-17) –Pathanapuram Block

Crops /Area(ha.)	Vilakkudy	Thalavoor	Piravanthoor	Pathanapuram	Pattazhi	Pattazhi Vadakkekkara-North	Punlaur(M)	Total Area Crop-wise **(ha.)**
Paddy	15	23	10	1	22	8	0	79
Coconut	60	50	135	145	163	70	50	673
Vegetable		26	80	1.6	30	14	3.68	155.28
Banana		75	150	150	17.52	40	20	452.52
Tapioca	16	85	50	60	20.8	30	15	276.8
Pepper	20	15	90	35	12	5	10	187
Cashew								0
Rubber					1360.7			1360.7
Ginger	5	15	50	4	15	5	6	100
Turmeric	10	8	15		12	2	4	51
Minor Tubers	20	13	45	12	58	11	18	177
Clove			5					5
Arecanut	10	3	10	0.05	2	1	7	33.05
Cardamom								0
Orange								0
Pine Apple								0
Betelvine								0

water resources have not been so far adequately exploited. In order to augment the irrigation potential, several plans were evolved during 1953 to undertake river basin schemes. Kallada Irrigation Project (KIP) is the largest irrigation project in Kollam district. The command area of this project is distributed over Kollam, Pathanamthitta and Alappuzha district. The reservoir for KIP is formed by constructing a gravity type masonry dam across Kallada River at Parappar near Thenmala and as a saddle earthen dam at Pallamvetty. Gross storage capacity of the reservoir is 504.92 Mm^3. Kallada Irrigation project is a unique project in Kerala, where minor conveyance system consisting of a network of PVC pipe is introduced for supplying water from canal to crops. This is the most efficient system for conveying water to fields, as the loss of water is minimum. In this system water is conveyed through buried pipe lines and hence compared to field channels, land requirement is less. A pick-up weir having a capacity of 17 Mm^3 just 5 Km downstream of dam is provided at Ottakkal. The main canals (RBC and LBC) take off from the weir. The tail race water from the power house provided just at the downstream of the dam is collected at weir and used for irrigation. When there is no power generation, the irrigation valves are opened and water is collected at Ottackal. The 69 kms. right bank canal and the 57.75 kms. left bank canal takes off from the pickup weir. It is estimated that the two canals together will serve an area of 53,960 hectares.

Kallada Irrigation Project is having an ayacut of 53,514 Ha of which 32,272 Ha is in Kollam district. Kollam Corporation, Punalur Municipality and 29 Grama Panchayats are having no ayacut area of KIP. The ayacut area of 32,272 Ha is distributed in Paravoor Municipality and 40 Grama Panchayats of Kollam district. Out of the total ayacut area of 32,272 Ha in Kollam district, irrigation potential is created in 30,427 Ha. Potential yet to be created are that of Paravoor distributory (1,212 Ha), Poovattoor distributory (514 Ha) and Pulamon distributory (119 Ha). Water is being distributed through all the canals except Poovattoor distributory and tail ends of Paravoor and Pulamon distributaries. The block-wise length of irrigation canals of Kallada Irrigation Project is shown in **Table 1.10.**

Table 1.10: Block-wise length of irrigation canals

Block	Irrigation canals (Km)		
	Canals not in use	**Canals in Use**	**Total**
Anchal	0	16.7	16.7
Chadayamangalam	0	6.1	6.1
Chittumala	0	24.1	24.1
Ithikara	15.5	72.4	87.9
Kottarakara	10.8	62.6	73.4
Pathanapuram	0	62.6	62.6
Sathamcotta	3	58.2	61.2
Vettikavala	2.3	84.3	86.6
Total length(km)	**31.6**	**387**	**418.6**

Source: Irrigation Dept., KIP

The major source of irrigation in the district are government canals, private wells, tanks and lift irrigation schemes with a predominant share contributed by Government canals. The efficiency of water distribution system, in general is very poor in most of the projects including KIP due to poor maintenance of irrigation canals. Inadequacy of water for irrigation is a perennial problem, especially for the tail end farmers. The irrigation efficiency has to be further increased through the modernization and renovation of the existing water conveyance system of the district. Minor irrigation deserves priority in irrigation development. Dug wells, bore wells, filter point wells, vented cross bars and small lift irrigation schemes are the commonly used minor irrigation projects and it needs to be strengthened based on the site-specific need.

In Kollam out of the 58% area under agriculture, only 31% is irrigated area. It can be seen that out of the total irrigated area of 45271 Ha, 72% is irrigated by the Kallada Irrigation Project (KIP). Major and medium irrigation schemes are being taken up by the State Government directly. Individual minor irrigation schemes, viz., dug-wells, bore-wells, tube-wells, pump sets, drip and sprinkler irrigation systems are being financed by commercial and co-operative banks. The net area irrigated in the district by means of various sources was 4991 hectares during 2014-15. The undulating topography of the district makes minor irrigation schemes suited to the local requirements to irrigate new areas and existing fields for stabilization of crops and introduction of additional crops. The details of source-wise net area irrigated is given in **Table 1.11**. From the table it is clear that eventhough the study area is blessed with irrigation canals and ground water abstraction structures, majority of the irrigation (91%) is rain fed.

Table 1.11: Details of Source-wise area irrigated (2014-15)

Source	Area(ha)
Canal	946
Pond	69
Well	2803
BW/TW	47
Lift & Minor Irrigation	2
Other Sources	624
Rain fed	78736.5

1.14 Previous work and Present Status of Data

Central Ground Water Board has carried out Systematic Hydrogeological Survey of entire district (1959-60, 1970-71, 1974-75). In 1983-88, the SIDA assisted Coastal Kerala Ground Water Project of CGWB has carried out detailed hydrogeological studies with exploration in the western part of the district. Later Reappraisal Ground Water Management studies has been done during 1983-88, 2000-01 and 2007-08. In addition to the routine work, CGWB has also taken up a number of short-term investigation studies, exploration activities, pollution studies, geophysical activities, environmental studies – Clay mining, Sea Water Ingress studies in the district.

In the present study area Central Ground Water Board has drilled 46 exploratory wells in crystallines such as khondalites and garnetiferous-biotite gneiss. The wells drilled in khondalites were in the depth range of 30-200.5 m bgl and the discharge ranges from 30 to 1200 lpm. The transmissivity ranges from 0.94 to 9.03 m^2/day. The wells drilled in the garnetiferous-biotite gneiss were in the depth range of 172.6-200 m bgl and the yield ranges from 12-420 lpm. The bore wells tapping NNW, NE, NW lineaments in the district gives high yield. The transmissivity of the wells drilled in garnetiferous-biotite gneiss ranges from 0.54 to 16.84 m^2/day.

In order to get a realistic picture about the groundwater conditions in the study area, Central Ground Water Board has established 77 Ground Water Monitoring Wells which includes 67 dug wells and 10 piezometers tapping various formations. In addition to these monitoring wells, SGWD has established 31 wells in the study area which includes 15 dug wells and 16 piezometers which are monitored monthly. The groundwater monitoring wells established by CGWB are monitored four times a year and for the qualitative analysis, water samples have been collected during premonsoon (April) monitoring.

1.15 Geological Setup

The district can be broadly divided into three geological provinces from east to west which are orientated more or less North to the South and consists of the western most Quaternary alluvial deposits followed by a narrow N-S zone of late Tertiary sediments and the eastern most Precambrian metamorphic. The study area consists of Archean group of crystallines which are bordered on the west by laterite, the weathered product of basement crystallines. Major part of the study area is covered by the Archean crystallines comprising Migmatite and Kondalite suite of rocks of which the former predominates. The geological bed of Kulathupuzha Forested Hills is khondalite, charnockite and cordierite gneiss. The geological mapping coupled with sub-surface data has brought out the following geological sequence of formations in the area **(Table 1.12)**. The Geology map showing various rock units of the study area is shown in **Figure 1.12.**

Table 1.12: Geological Successions

ERA	AGE	FORMATION	LITHOLOGY
QUATERNARY	Sub-recent	Laterites	Laterites derived from crystalline rocks.
	Proterozoic	Intrusives	Dolerite, Gabbro, Pegmatites and Quartz veins.
PRECAMBRIAN	Archaean	Migmatite Group	Granite gneiss, Hornblende biotite gneiss, Biotite gneisses and Garnet biotite gneiss.
		Charnockite Group	
		Khondalite Group	

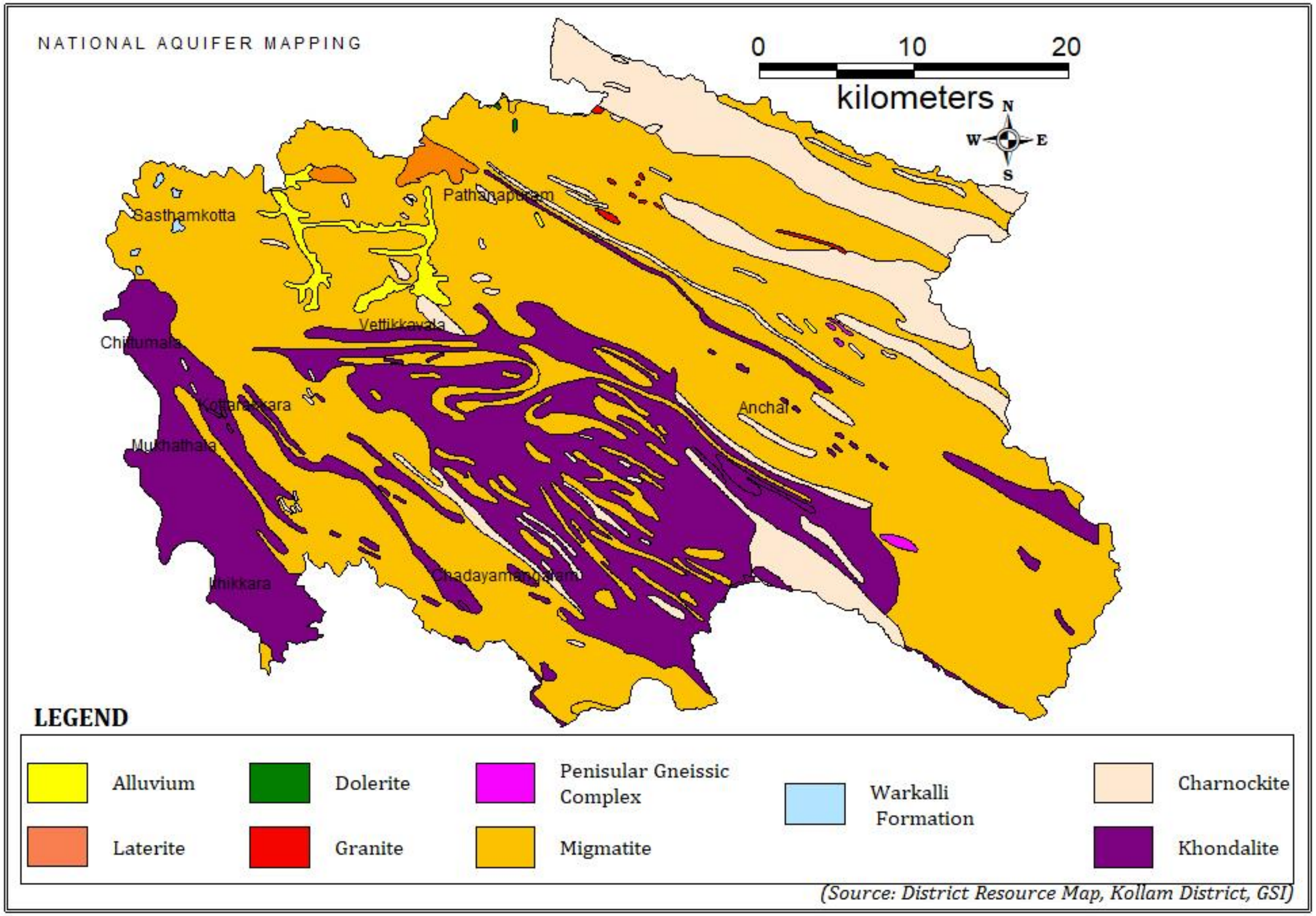


Figure 1.12: Geology map of the area

I. Archaean Crystallines

The Archaean crystalline rocks comprise Khondalite Group, Charnockite Group and Migmatite Group. These are intruded by younger basic dykes and overlain by Tertiary and Quarternary sediments.

a. **Khondalites**: High grade metamorphic rocks of Khondalite group is predominantly composed of garnetiferous biotite-sillimanite gneiss with occasional bands of calc-granulite with or without graphite and quartzite mainly cover the central part and western part of the study area. They are medium to coarse grained, banded/ foliated and less massive when compared to charnockite and granite gneiss. Garnet-sillimanite gneiss rock shows stretching and development of augens especially in parts of Punalur area. Biotite gneiss is seen as concordant within the khondalites. Granitisation of the Khondalite resulted in the formation of number of white granite bodies within Ayur-Veliyam area. They also occur as bands within the charnockite group and migmatite gneiss.

   Charnockites: This rock group shows great diversity on lithology. This group includes small patches of cordierite gneiss, hornblende granulite, pyroxene granulite, charnockite and charnockite gneiss. Charnockites are acidic to intermediate in composition, massive and shows fine to medium grained texture. They are generally massive and well foliated at places. Pyroxene granulite show both concordant and discordant relationship with charnockite and charnockite gneiss. The charnockite gneisses covers major part of the study area.

   Granite gneisses: The gneisses are represented by hornblende biotite gneiss, biotite gneiss and garnet biotite gneiss. Notable occurrence is seen around Thenmala – Aryankavu area. These are medium to fine grained, foliated and light coloured. The foliation trend varies from N- S to NNW- SSE. They are highly foliated showing band of dark coloured ferro-magnesium minerals and light coloured quartzo-feldspathic minerals

a. **Intrusives**: Basic and acidic intrusives are found to be intruded in the country rock. The charnockite rocks in the north eastern part of the study area is traversed by a swarm of dolerite dykes. The charnockite and khondalite group of rocks are traversed by pegmatite and quartz veins consisting of quartz feldspar and biotite/ magnetite. The major pegmatite occurring in the study area is the Punalur mica belt. Pegmatites occur near Kulathupuzha, Madathara and Punalur consists of Chrysoberyl and phlagopite mineralisation.

II. Laterites

The laterites of sub-recent age occur as a residual deposit due to weathering of Tertiaries and basement crystalline rocks. This formation is widely exposed in the entire midland region which are of reddish brown to buff coloured with vermicular to pisolitic texture. Laterite forms as a carapace over crystalline rocks. At many of the places the process of lateritisation is not complete and the gniessocity, foliation and joint pattern of the parent rock is well preserved. The thickness of laterite varies from place to place and is more on the western part of the area. At places, especially on the eastern part of the parent rock is overlained by a very thin corona of reddish-brown weathered particles resembling laterite. The insitu laterite developed by the weathering of khondalites is rich in clay content due to higher amount of feldspathic minerals in parent rock. The thickness of laterite capping in charnockite varies from 1 to 3 m whereas it varies from 15 to 20 m in khondalites.

1.16 Structure

The crystalline rocks occurring in the study area has undergone several periods of tectonic deformations resulting in the development of numerous sets of foliation, lineaments and fractures. The regional metamorphism is of amphibolites or granulite facies which has resulted in the formation of charnockites, pyroxene-granulites, khondalites and rocks of the migmatic complexes. The most prevalent trend of foliation in the crystalline rock is NNW- SSE and NW-SE. In general, joints are more sheared and filled with clayey material in khondalites than the charnockites. Charnockites are more brittle and have comparatively more open joints. Most of the quartz veins and pegmatites veins have intruded along fracture planes. The general structure seems to be a series of WNW-ESE trending inclinal folds. The region suffered a multiphase deformation and metamorphism. Two major shear zones could be traced within the study area. The lineament map of the area is shown in **Figure 1.13**.

Achenkovil shear extending NW-SE in the Punalur- Ranni area along which Achankovil river flows. Ultra-basic rocks together with mica, graphite is seen emplaced along this shear zone. Thenmala fracture extends upto Kottarakara along NW-SE direction. Another set of oblique NW-SE trending fracture cut across the Thenmala fracture.

1.17 Hydrogeological framework

The study area exposes geological formations ranging in age from Precambrian to Sub-Recent. Ground water occurs in all geological formations from crystallines to Sub- Recent laterite either in unconfined or semi-confined/confined conditions. Phreatic conditions mainly exist in in weathered crystalline formation/laterite while Semi-confined/confined condition exists in deep fractures of crystalline rocks.

The various aquifer systems in this area are constituted by
1. Laterites occur as capping over crystallines and
2. The weathered, fissured and fractured crystalline formations.

Shallow/ Phreatic Aquifer

Ground water occurs under phreatic condition in various shallow aquifers in weathered crystalline formation which are mostly developed by dug wells for domestic or irrigation purposes. The laterites form the most extensive and potential phreatic aquifer of midland area which include the highly weathered product of crystallines as capping over it. In crystalline formations, the water bearing properties primarily depend on the extent of development of secondary inter granular porosity either through weathering or fracturing. These aquifers are highly heterogeneous in nature due to variation in lithology and texture even within short distances.

Deeper Aquifers

Deeper aquifers are represented by deep fractures of crystalline rocks where ground water occurs under semi-confined/confined condition. In the present study area Central Ground Water Board has drilled 46 exploratory wells in crystallines such as khondalites and garnetiferous-biotite gneiss. The wells drilled in khondalites were in the depth range of 30-200.5 m bgl and the discharge ranges from 30 to 1200 lpm. The transmissivity ranges from 0.94 to 9.03 m^2/day. The wells drilled in the garnetiferous-biotite gneiss were in the depth range of 172.6-200 m bgl and the yield ranges from 12-420 lpm. The bore wells tapping NNW, NE, NW lineaments in the district gives high yield. The transmissivity of the wells drilled in garnetiferous-biotite gneiss ranges from 0.54 to 16.84 m^2/day.

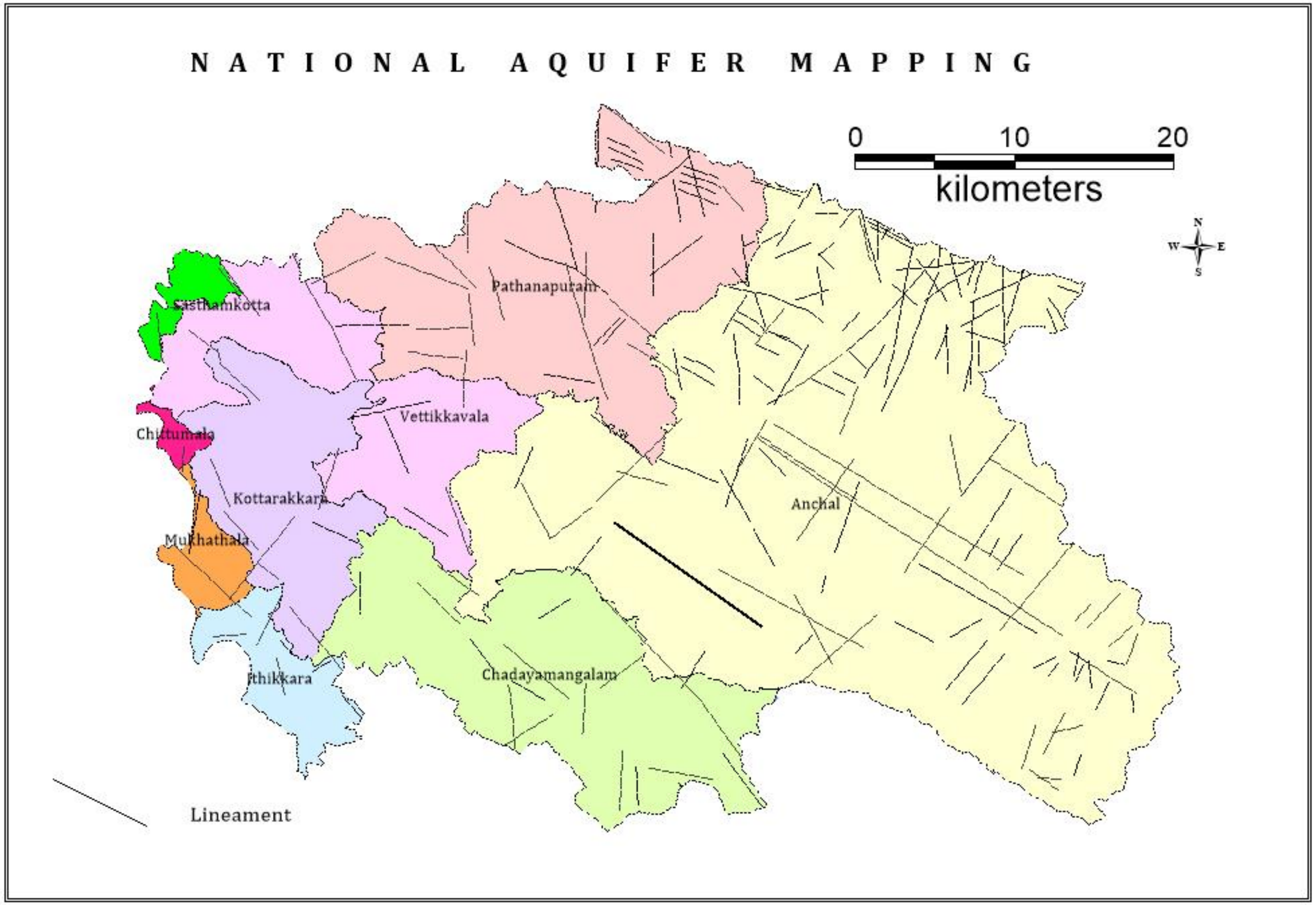


Figure 1.13: Lineament map of the area

1.18 Industries

The district is immensely rich in mineral resources such as beach sands, china clay , lime shell, bauxite, and graphite. The beach sands along the western coast have concentrations of heavy minerals like ilmenite, rutile, monosite and zircon which offer scope of exploitation for industrial purpose. Besides these, large deposits of china clay occur at the boundary of Tertiary deposits and Archean crystallines at Kundara, Mulavana and Chathannoor. Lime shell deposits are found in Ashtamudi Lake. In the study area bauxite deposits are found around Adichanallur and disseminated graphite at Punalur.

Khondalites and charnockites occupying the major part of the area are a good source of granite dimension stone as well as building material Localised quarrying for Granite building stones are highly rampant in the Kottarakara and Vettikavala block.

There were many industries flourishing on the banks of Kallada river during the British Period. Punalur Paper Mills was one of such major companies which operated near the banks of this river. Since the effluents discharged from Punalur paper mills into Kallada River was found to alter the physicochemical factors and production of plankton, this industry was closed in 1987. Even sand mining is also a great concern along the banks of this river which makes the banks more vulnerable to erosion and floods.

1.19 Water Use Demand

The district is blessed with abundant groundwater as well as surface water resources. Ground water occurs under phreatic, semi-confined and confined conditions and is mainly used for drinking and industrial purposes. Generally, the phreatic aquifers are tapped by dug wells and filter point wells fitted with 1.0 to 1.5 HP motors. While the fractured crystalline aquifers are tapped through bore wells.

The ground water in the study area is mostly developed through dug wells for domestic and agricultural purposes and to a limited extent for industrial and irrigation purposes. Recently the bore well culture has gained momentum. In the fractured crystallines, the bore wells constructed to the depth ranging from 30 to 200.5 m. Yield ranges from 0.61 to 23 lps. The general potential zones are between 40 to 75 m. Below 100 m depth, only in limited areas high yielding zones are encountered. CGWB drilled wells of 200 m depth under Ground Water Exploration Programme. The yield of borewell ranges from 50 lpm at Ezhukone, Kottarakara block to 1000 lpm at Valiyakavu, Pathanapuram Block. The data from exploratory drilling carried out by CGWB were analysed which shows that the E-W followed by NE-SW lineaments is found to be potential in the district. The borewells in the northern and north eastern parts of the district have comparatively higher discharges. The high yielding wells are constructed at Kulathupuzha (660 lpm), Aryankavu (1220 lpm), Kottarakara (1380 lpm) and Valiakavu (1000 lpm).

In the recent years due to fall in water level, the dug wells were deepened in many parts of the district and deepening of the wells were resorted to increase the yield of the dug wells. The lifting devices of water are centrifugal pump and jet pump for dug wells and submersible pumps and compressor for bore wells. Water is also being lifted by bucket and rope from dug wells for domestic purposes.

2. DATA COLLECTION, GENERATION AND INTEGRATION

2.1 DATA COLLECTION AND DATA GAP ANALYSIS

The full-scale implementation of the National Aquifer Mapping Program requires updating the ground water protocols generated/ prepared for various studies/ projects by CGWB and other organisations. This gathered information forms a baseline which then enables to identify the data gaps. One of the greatest challenges faced by water resource scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed primarily by gathering the information on geology, geophysics, hydrogeology and hydrochemistry generated by CGWB under various studies such as systematic hydrogeologial studies, reappraisal hydrogeological studies, groundwater management studies, exploratory drilling, micro-level hydrogeological studies and special studies in conjunction with the data collected from various State and Central government departments. Data gap analysis for each aquifer-wise and quadrant-wise has been carried out mainly for ground water monitoring wells, ground water quality stations, ground water exploration and geophysical surveys. The status of availability of existing data for various items are described in the subsequent section and its summary is given in **Table 2.1.**

Table 2.1 Status of CGWB Data Availability for Data Gap Analysis

Sl No	Item	Data Availability
1	Ground Water Monitoring stations – Dug Wells	67
2	Ground Water Monitoring stations – Piezometers	10
3	Ground Water Exploration	46
4	Geophysical	34
5	Ground Water Quality Stations	13

2.1.1 Water Level Monitoring

Ground water systems are dynamic and adjust continually to short-term and long-term changes in climate, ground water withdrawal and land use. Water-level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect ground-water recharge, storage, and discharge. In order to get a realistic picture about the groundwater conditions in the study area, Central Ground Water Board has established 77 Ground Water Monitoring Wells which includes 67 dug wells and 10 piezometers tapping unconfined and confined aquifers. In addition to these monitoring wells, SGWD has established 31 wells in the study area which includes 15 dug wells and 16 piezometers which are monitored monthly. The ground water monitoring wells established by CGWB are monitored four times a year and for the qualitative analysis, water samples have been collected during pre-monsoon (April) monitoring. The status of water level monitoring wells of CGWB and SGWD in the area are given in **Table 2.2**.

From the quadrant-wise Data Gap analysis for water level monitoring wells in the study area after incorporating State Ground Water Department wells, a data gap has been identified which shows that 37 new monitoring wells are required to fill up the gaps.

Table 2.2 Status of Ground Water Monitoring Wells in Kollam Hard rock area

Well Type	CGWB	SGWD	Total
Dug well	67	15	82
Piezometer	10	16	26
Grand Total	**77**	**31**	**108**

2.1.2 Exploration

The exploration activities give an insight on the distribution of resources, the hydraulic characteristics of the aquifer as well as the regional and temporal variations of the water quality. The study area is mainly comprised of hard rock (Precambrian) aquifer system. The hard rocks are mainly capped by laterites, the product of weathering of the crystallines. In the present study area, Central Ground Water Board has drilled 46 exploratory wells in crystallines such as khondalites and garnetiferous-biotite gneiss. In addition to these exploratory wells, SGWD has drilled 16 wells in the study area. Aquifer-wise and Quadrant-wise data gap analysis of the data shows that there is no data gap in the case of exploration data.

2.1.3 VES and Profiling

The study area is covered by laterite and crystalline rocks. The geophysical investigation such as Vertical Electrical Sounding (VES) and profiling is inevitable in the study area as geophysical results may reveals weathered thickness, fracture depth, thickness of fracture and fracture pattern. Moreover, the interpretation of geophysical data in conjunction with the available ground water exploration refines the aquifer geometry. In the study area, 23 VES has been carried out during SIDA project and 9 during 2013-14. Thus, a total of 34 VES data is available. Aquifer-wise and Quadrant-wise data gap analysis of the geophysical data indicates a gap of 16 more locations.

2.1.4 Ground Water Quality Monitoring

The sustainable development of groundwater resources in the hard rock area requires a thorough understanding of the hydrogeological regime including the geophysical properties and hydrochemical behaviour of groundwater. The ground water quality data provides a perception about the factors influencing the ground water chemistry. It also provides the details about the extent of pollution which will improve the precaution to be taken while formulating the management techniques for a particular aquifer. In the present study area, historical ground water quality data is available for ground water monitoring wells maintained by CGWB and SGWD. Ground water sampling is being done every year during Pre-monsoon period (April) by CGWB while SGWD does the water sampling twice a year (pre-monsoon and post-monsoon). CGWB is maintaining 13 ground water quality monitoring stations in the study area. Aquifer-wise and Quadrant-wise data gap analysis of Ground Water Quality Monitoring Wells indicates that an additional 19 more quality wells is required. Water sampling analysis from the quality stations has been proposed for outsourcing.

2.2 DATA GENERATION AND INTEGRATION

Detailed data gap analysis of the existing data based on aquifer-wise and quadrant-wise helped to identify the gaps in the existing data on various aspects of the aquifer being mapped and also to optimize the additional data requirements for a realistic depiction of aquifer system and management of its ground water resources. The data generation activity after the data gap analysis include establishment of new key wells for water level monitoring, water quality monitoring, geophysical surveys and aquifer evaluation. Prior to data generation various data available with other departments has been collected and finally integrated. The value addition made after data generation and integration is discussed in the following sections.

2.2.1 Water Level Monitoring

Data gap analysis carried out based on aquifer-wise as well as on quadrant-wise indicates the requirement of 37 more monitoring wells in the area to represent the actual ground water level scenario. Thus 37 new key wells have been established and were monitored four times a year for the period April 2016-Apri 2017 along with the other monitoring wells of CGWB and SGWD. Later as per the direction from CHQ, the key wells are monitored only during pre-monsoon (April) and post-monsoon (November) period. After integrating, the number of ground water wells tapping unconfined aquifer becomes 119 and piezometric level has been measured from 26 bore wells. The locations of these integrated GWMW's are given in **Figure 2.1.**

2.2.2 Exploration

Aquifer-wise and Quadrant-wise data gap analysis of the existing data shows that there is no data gap in the case of exploration. Thus, after integrating 62 exploratory wells, available data has been used to interpret the aquifer geometry and its characteristics. The locations of these integrated exploratory as well as piezometers are given in **Figure 2.2.**

2.2.3 VES and Profiling

The 16 locations identified in data gap analysis for geophysical survey. The geophysical investigation is required in the study area to reveal weathered thickness, fracture depth, thickness of fracture and fracture pattern. VES has been carried out 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. The locations of these VES locations are given in **Figure 2.3.**

2.2.4 Ground Water Quality Monitoring

Aquifer-wise and Quadrant-wise data gap analysis of ground water quality monitoring wells indicates that an additional 19 quality wells is required to represent the actual hydrogeochemistry of the study area. Thus, the existing ground water quality wells of CGWB and selected wells of SGWD and newly established key wells has been integrated to fill the data gap noticed during analysis of existing data. Water sampling analysis from the quality stations has been proposed for outsourcing. The locations of these integrated quality stations are given in **Figure 2.4.**

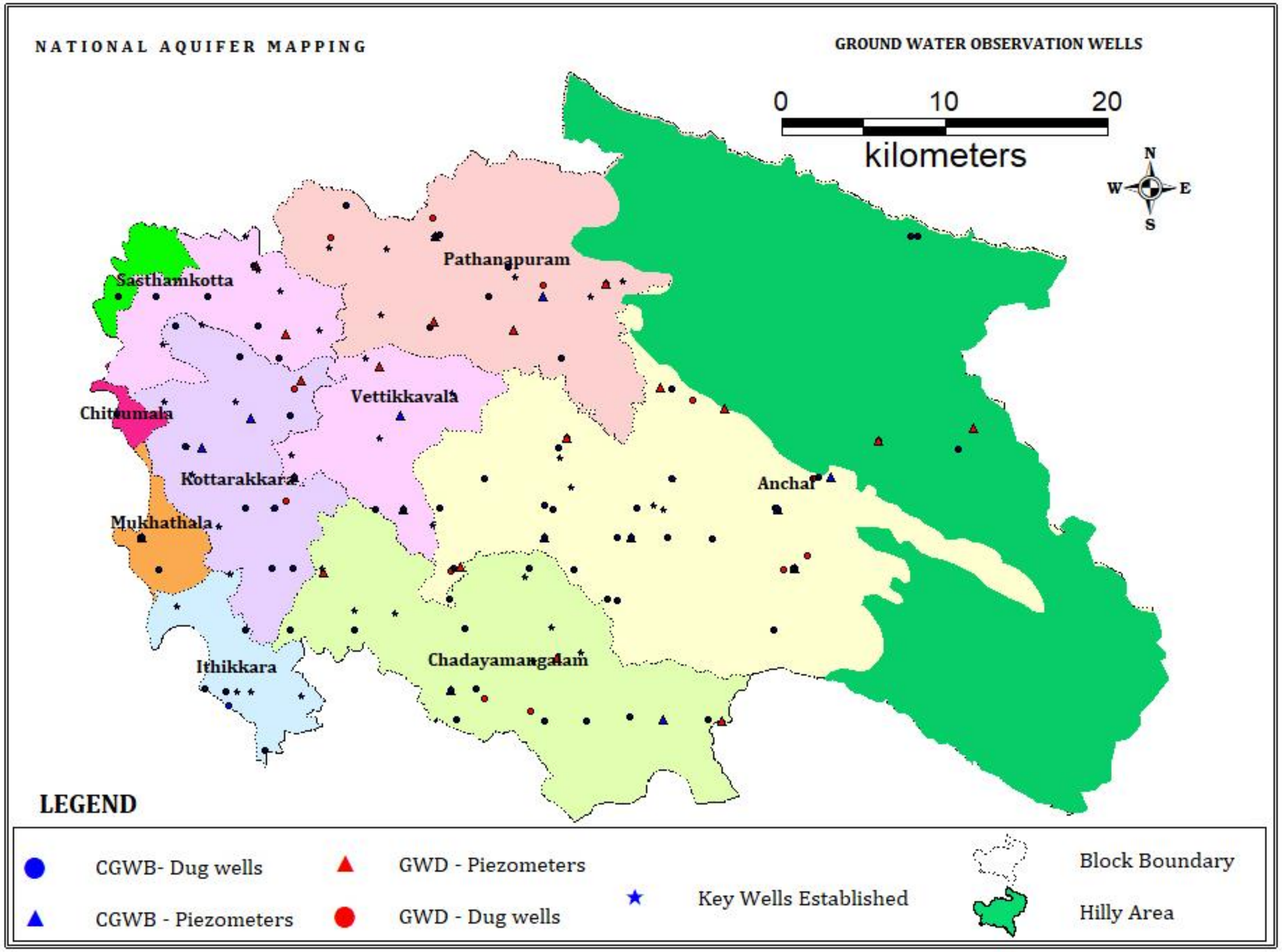


Figure 2.1: Location of monitoring wells in study area

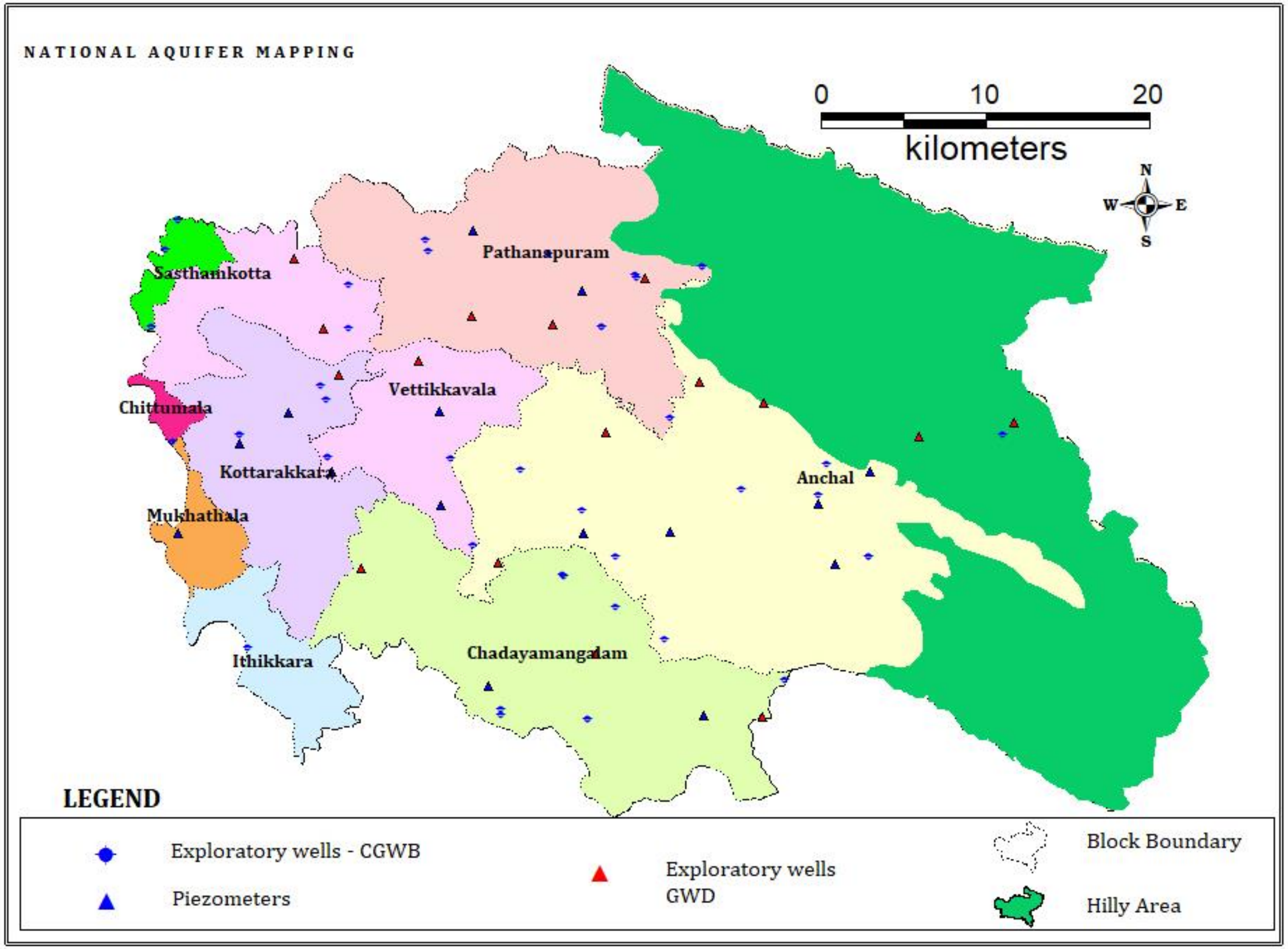


Figure 2.2: Location of exploratory wells in study area

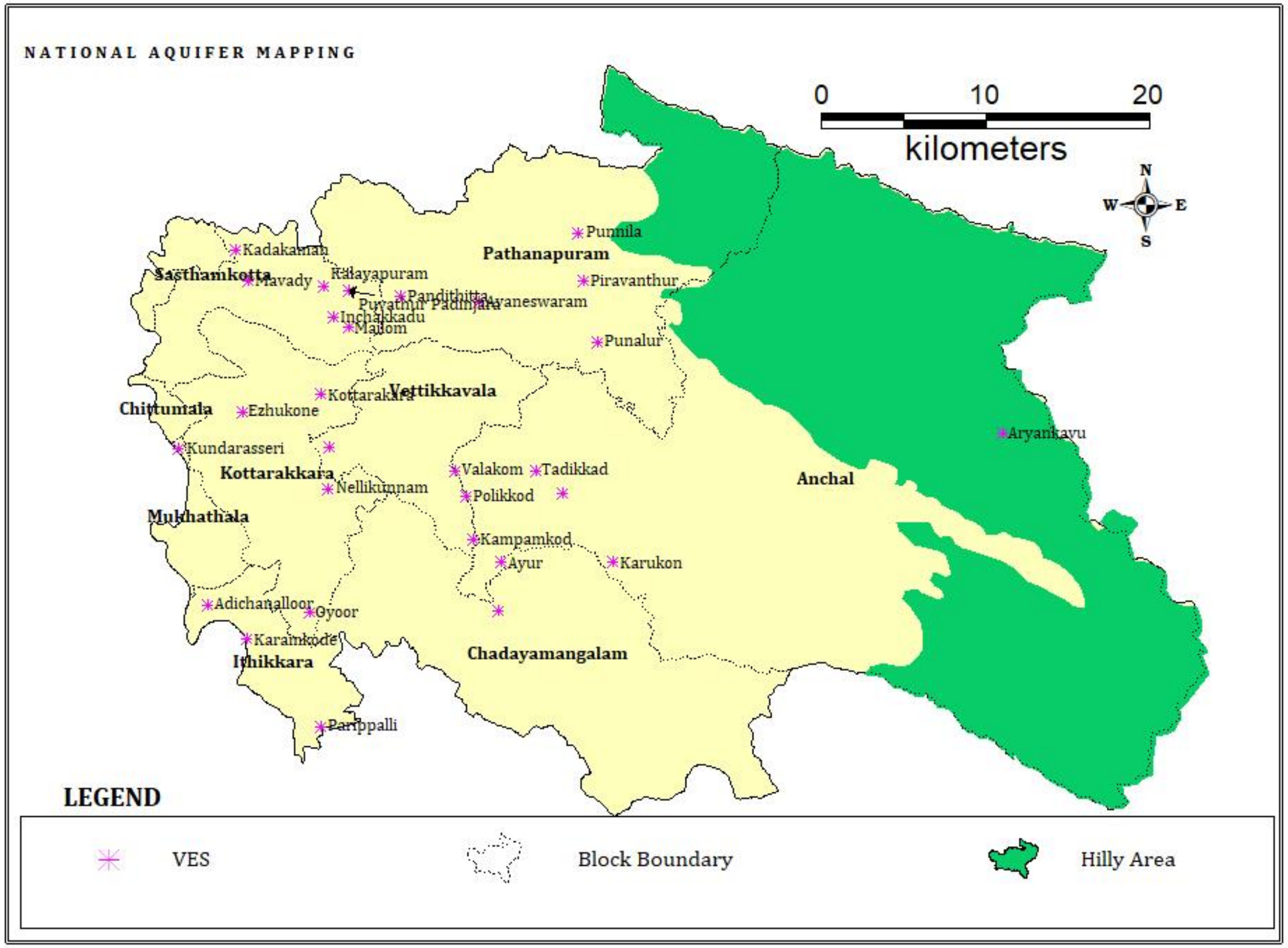


Figure 2.3: Location of VES in study area

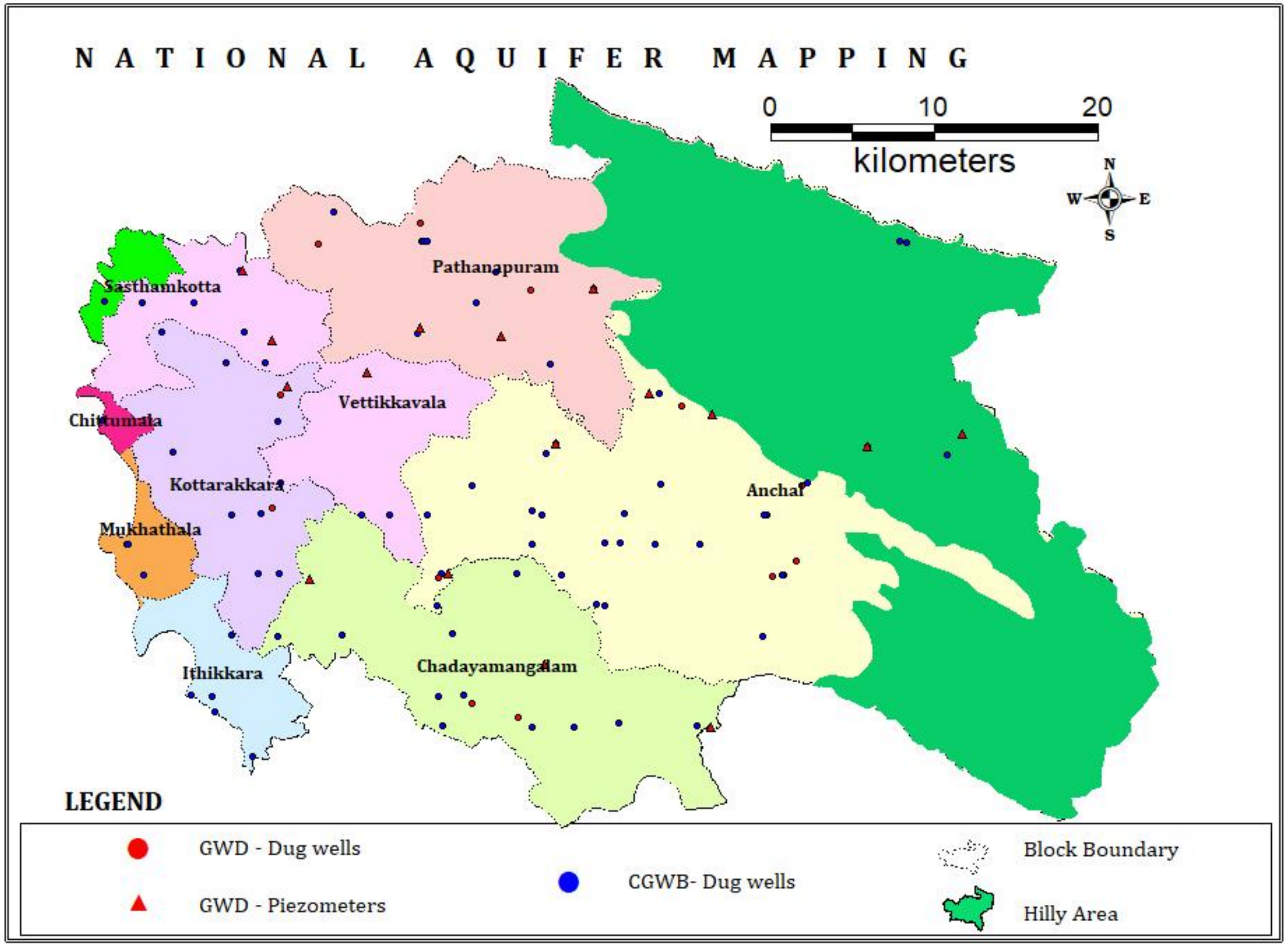


Figure 2.4: Location of water quality monitoring wells in study area

3. DATA INTERPRETATION AND AQUIFER MAPPING

Once the available data is collected, validated, compiled in a standard format, the next step is to interpret the available data with the objectives of generating a 3D visualization of the aquifer systems in the area, understand the ground water regime and to identify the data gaps for planning investigations to generate additional data to fill them. Thus, aquifer map of the area has been generated based on the integrated inputs of geological, geophysical, hydrological, hydrogeological and hydrochemical data.

3.1 Rainfall

The study area experiences a tropical humid climate, with an oppressive summer, cool winters and plentiful seasonal rainfall. The district receives an average of about 2555 mm rainfall annually. Based on 1901-2004 rainfall data (Source: IMD), the South West monsoon from June to September which contributes nearly 52% of the total rainfall of the year. The North-East monsoon season from October to December contributes about 26%, is considered crucial in recharging the ground water system and also in maintaining the stream flow to last the summer months and the balance 22% is received during the month of January to May as pre-monsoon showers. Out of the total 119 rainy days, 70 rainy days occur in the southwest monsoon season. The spatial variation of rainfall over the study area is represented by the isohyets in **Figure 3.1.** Generally, the rainfall increases from western part to the eastern hilly regions. The areas on the south-eastern part receives the maximum rainfall.

The rain gauge stations nearby the study area have been studied in detail. From the Thiessen polygon network, it is found that rainfall of 11 rain gauge stations influence the water availability of the area. Out of 11 stations, only 6 rainfall stations fall within the area. The rainfall data for 104 years (1901-2004) of all the 11 stations has been analysed after normalising the rainfall data to weighted average value. The year to year variability of annual rainfall is 23.08%. In general, it varies from 19.16 to 26.31%. The maximum coefficient of variation is for Adur and the minimum is for Nilamel. The summary of the statistical analysis for the rain gauge stations using the long-term rainfall data is given in **Table 3.1.**

Table 3.1: Summary of Rainfall Data Analysis (1901-2004)

Sl. No.	Station	District	Percentage of Influence	Average	Standard Deviation	Coefficient of Variation (%)	Slope
1	Aryankavu	KOLLAM	39.41	933.31	195.85	20.98	-1.87
2	Kollam	KOLLAM	17.72	404.51	86.64	21.42	-0.58
3	Kottarakara	KOLLAM	91.33	2236.85	506.08	22.62	-5.80
4	Nilamel	KOLLAM	68.53	1836.58	351.94	19.16	-3.99
5	Punalur	KOLLAM	100	2908.09	595.23	20.47	-6.19
6	Thenmala	KOLLAM	98.48	3256.03	676.12	20.77	-7.69
7	Adur	PATHANAMTHITTA	5.41	140.93	37.08	26.31	-0.53
8	Konni	PATHANAMTHITTA	0.25	6.73	1.60	23.71	-0.01
9	Pathanapuram	PATHANAMTHITTA	62.98	1210.65	267.04	22.06	-2.23
10	Attingal	THIRUVANANTHAPURAM	1.13	1830.36	516.22	28.20	-3.94
11	Ponmudi	THIRUVANANTHAPURAM	20.19	20.68	5.83	28.20	-0.04

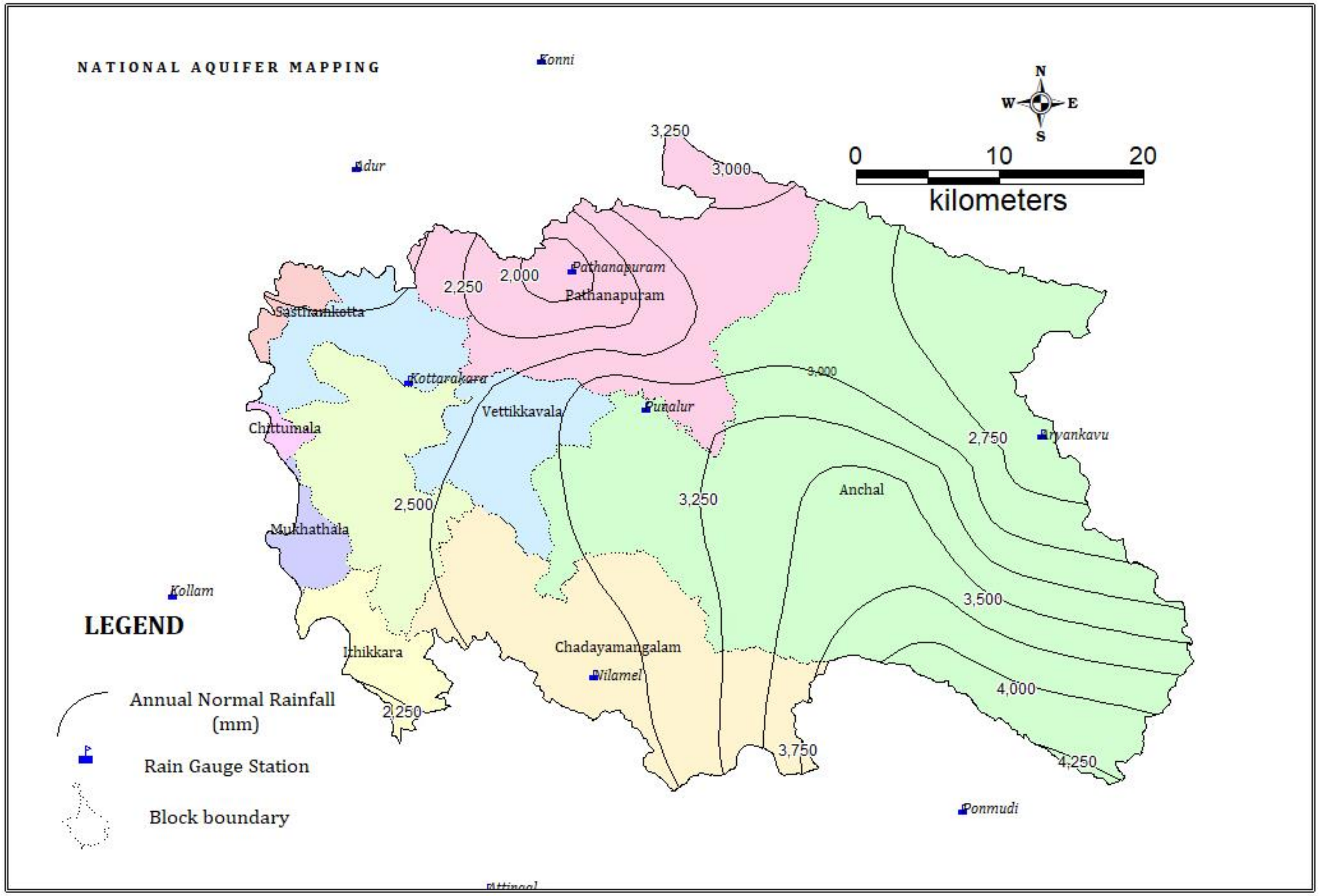


Figure 3.1: Isohyetal map of the study area

The rainfall data (2001-14) of Punalur rain gauge station is given in **Table 3.2** and monthly and annual rainfall distribution is shown as histogram in **Figure 3.2 and 3.3** respectively.

Table 3.2: Rainfall data of Punalur Rain gauge station

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2001	101.8	128.0	16.4	346.8	238.6	493.6	361.6	314.6	162.6	381.4	195.2	6.8
2002	6.8	24.6	68.6	301.6	207.3	330.1	330.3	299.0	139.0	710.0	498.0	0.0
2003	3.8	50.2	77.8	214.6	127.8	221.6	368.2	272.4	50.4	466.4	69.2	29.4
2004	0.0	54.4	92.6	232.6	563.0	417.0	224.4	169.6	190.6	320.4	121.2	8.2
2005	38.0	19.2	16.6	244.8	236.5	386.5	465.6	46.7	246.2	166.8	277.0	145.4
2006	11.4	28.2	142.4	159.0	324.0	258.1	861.0	203.7	378.5	465.6	384.2	0.7
2007	0.0	-	8.7	247.2	137.0	364.8	533.6	222.1	358.0	503.8	123.8	36.0
2008	0.0	55.8	223.6	282.8	55.6	168.8	478.4	-	-	-	-	-
2009	2.6	0.0	128.2	114.4	191.2	281.0	338.2	237.2	251.2	365.4	228.4	0.0
2010	1.2	0.0	123.0	329.4	194.8	402.2	395.6	410.8	223.8	636.4	494.2	90.4
2011	89.6	171.8	121.0	204.0	121.6	397.8	331.2	239.4	199.4	149.0	184.4	195.8
2012	16.2	18.6	82.6	315.0	79.4	198.0	227.2	295.4	161.6	244.2	123.6	11.0
2013	0.0	74.4	94.2	126.6	243.2	745.4	463.4	187.8	338.0	412.2	287.5	19.5
2014	0.6	12.2	42.6	265.8	395.1	279.4	-	-	-	-	-	-

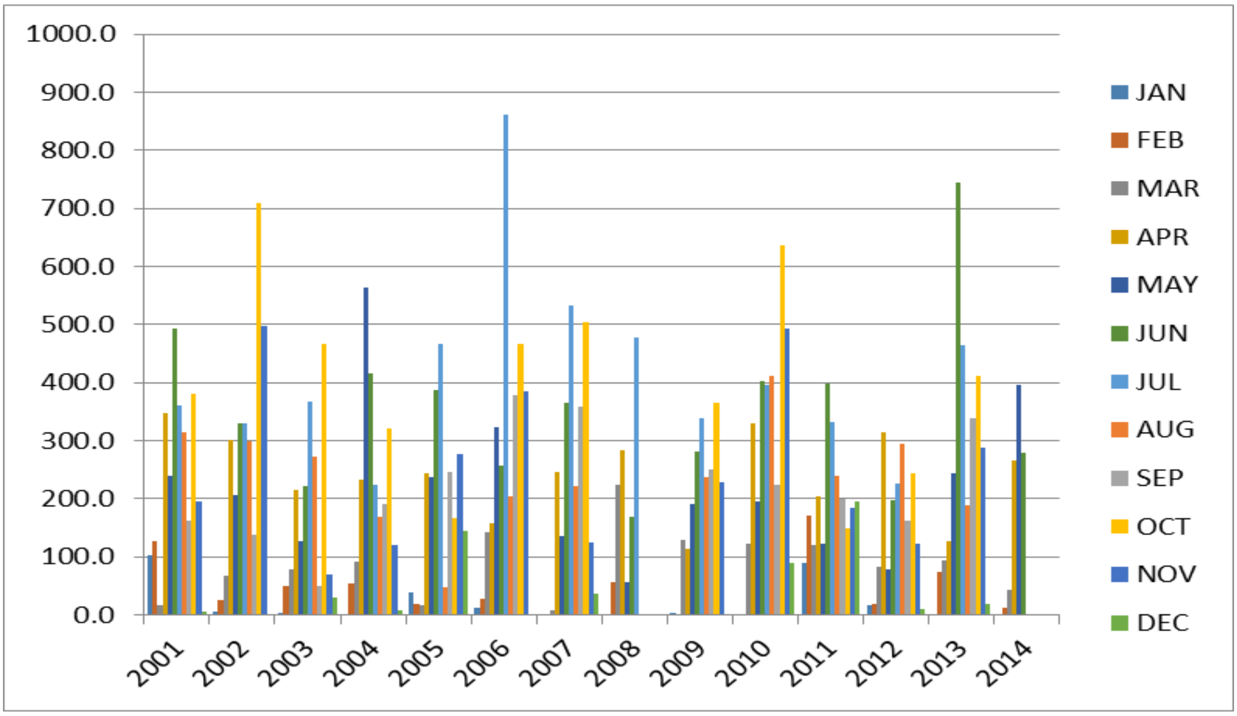


Figure 3.2 Histogram of monthly rainfall distribution at Punalur Rain gauge station

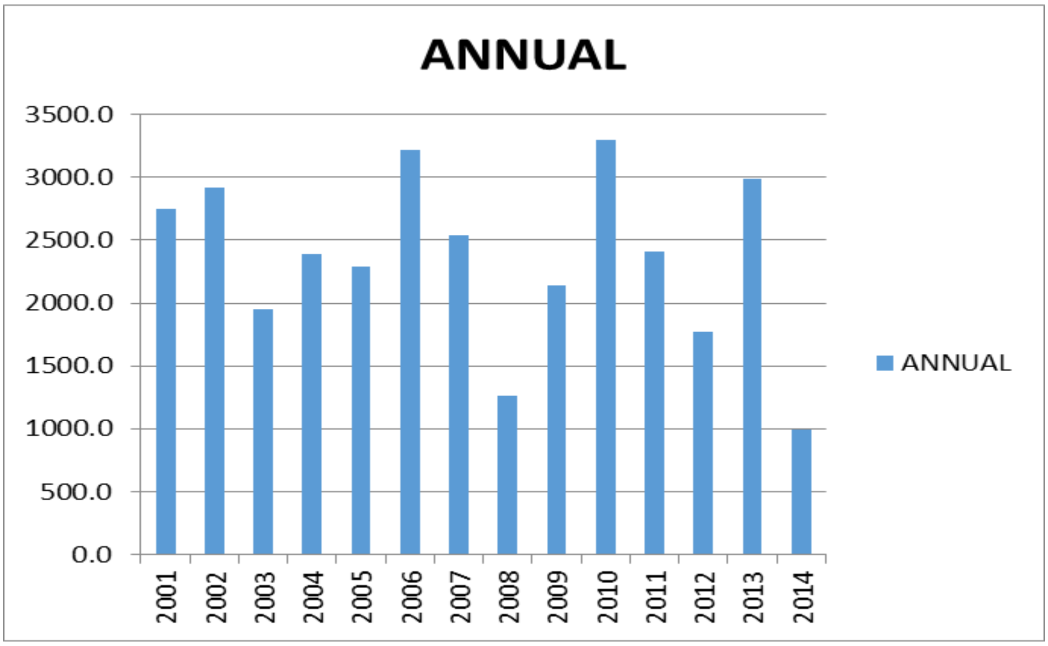


Figure 3.3: Histogram of annual rainfall distribution at Punalur Rain gauge station

3.2 Drainage

Drainage pattern in a region largely depend on the topography, geology, structure and tectonic activities. The shape and other characteristics of a basin depend upon the lithology, tectonic history, rates of landscape dissection and denudation. Structural controls on drainage development and the interactions between tectonic activities and fluvial morphology are widely documented. Morphometric analysis of drainage basins provides significant information regarding the topographic, geologic and climatic controls on drainage network organization and basin geometry (Horton 1932, 1945; Strahler 1964; Melton 1965; Williams & Fowler 1969; Guarnieri & Pirrotta 2008). Satellite images are increasingly being used in groundwater exploration because of their utility in identifying various geomorphic features. A number of studies have been carried out in the study area using satellite data and GIS to delineate the groundwater potential zones using various thematic maps and morphometric analysis (Hema et.al. 2017). Morphometric analysis includes linear, areal and relief aspects of river basins. Since the study area undergone different phases of tectonic deformation, literature discussing the morphometric analysis of Kallada, Ithikara and Achankovil River has been consulted.

Achankovil is a 7th order basin which traverses through highland, midland and lowland (Dhanya, V., 2015). This river basin is elongated in a trough-like setup in east west direction and the river follows a straight-line course there by manifesting tectonic control on the stream basin shape and development since its evolution is connected with Achankovil Shear Zone (ASZ). The WNW–ESE trending ASZ in southern India is a major crustal discontinuity of Proterozoic age which separates Kerala Khondalite Belt (KKB) in the south from the Southern Garnulite Terrain/Charnockite massif in the north. The Achankovil river drains through this structural valley. Although the river bears imprints of various geologic events, including neotectonic activities, it could maintain a straight course even in the lowland indicating its antecedent nature.

The Achankovil river has two sixth order tributaries, ten fifth order tributaries and forty-one fourth order tributaries. The drainage pattern is sub-dendritic to sub-parallel, in general, and the higher order streams, in particular, show more or less trellis drainage pattern. Most of the higher and medium order streams follow general structural trend which indicates structural control. The tributaries are oriented in the WNW-ESE, NW-SE, NNE-SSW, NE-SW and ENE-WSW directions and most of the tributaries are short in length and align perpendicular to the main stream. The basin is confined and has restricted north-south development. Detailed morphometric analysis has not been included in this report since the study area covers a part of the basin (only 11%).

Literature survey reveals that by comparing drainage layout with that of lineament distribution, it is observed that most of the channel courses, including deflection in the channels are structurally controlled. In the south-eastern part, a few lineaments trending ENE– WSW to E–W cut across the general NW–SE foliation trend and may represent brittle joints/faults. In general, for the whole basin, the NW–SE trending lineaments predominate. The other directions of lineaments in the order of prominence are NE–SW and WNW–ESE. The main stream maintains a general NW–SE direction throughout its course. The tributaries are short in length and oriented in the WNW– ESE, NW–SE, NNE–SSW, NE–SW and ENE–WSW directions.

A drainage map **(Fig. 3.4)** of the area gives an idea about the permeability of rocks and also gives an indication of the yield of the basin (Wisler and Brater 1959). Drainage density is an inverse function of permeability, so it is an important parameter in evaluating the groundwater zone. High drainage density indicates less infiltration and hence acts as poor groundwater potential zone compared to low drainage density zones, implying an inverse relation between the two. Low network of drainage course indicates existence of highly resistant and permeable rock where as high drainage course indicates highly weak and impermeable rocks (Karanth 1999). For groundwater prospecting, higher rank is usually assigned to low drainage density zones and a lower rank is assigned to a high drainage density zone. The drainage density of entire study area varies from 3.44 to 14.39 km/km^2**.**

The Kallada river basin is a seventh order basin with an elongated shape and low discharge. Ithikara river basin (IRB) is a 6th order basin. The stream ordering system reveals a high hierarchization and high degree of ramification of the watershed. The total number of streams in IRB is 1,110 and lower order streams dominate (>75%) the basin. The main stream length of IRB is 55.17 km and the total stream length in IRB is 1,093.42 km. The development of stream segments is affected by slope and local relief and these may produce differences in drainage density from place to place. The general drainage pattern is dendritic. Major rock types of the basin include garnetiferous biotite gneiss, garnetiferous quartzofeldspathic gneiss, charnockite gneiss, pyroxene- and calc-granulites. Elevation of the basin reaches up to 430 m above mean sea level and majority of the land is utilized for agriculture purposes. The linear aspects and areal aspects of Kallada and Ithikara river basin are given in **Table 3.3** and **Table 3.4** respectively.

Table 3.3 Linear Aspects of Kallada and Ithikara RB

Linear Aspect	**Kallada**	**Ithikara**
Maximum Basin Length(km)	94.74	
Main Channel Length(km)	141.16	
Length of Overland Flow(km)	0.2	0.28
Bifurcation ratio	4.14	4.27
Stream Length Ratio	2.56	2.54

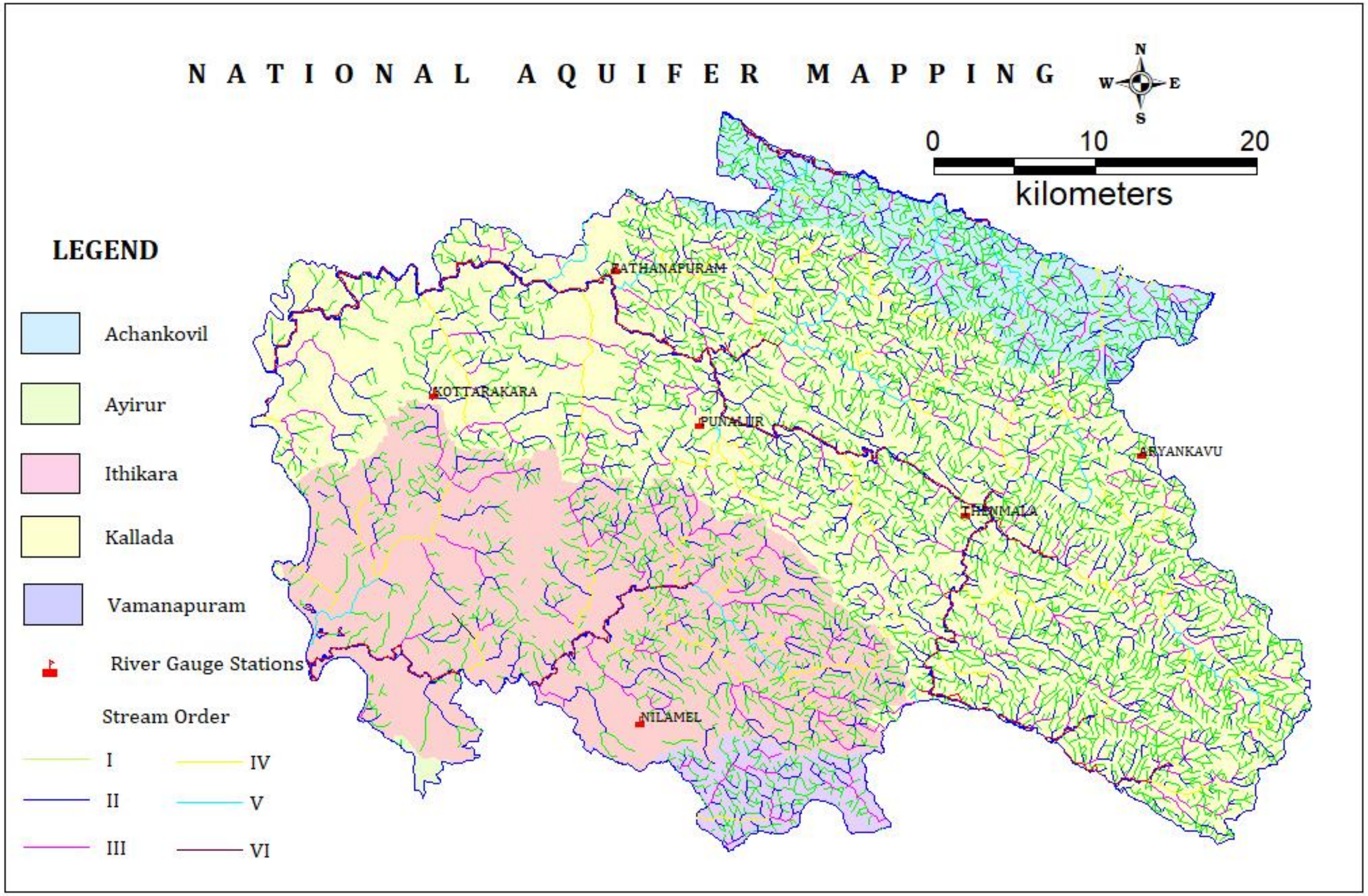


Figure 3.4: Drainage map of the study area with stream ordering

Table 3.4 Areal Aspects of Kallada and Ithikara RB

Areal and Relief Aspect	Kallada	Ithikara
Area	1654	598.95
Perimeter(km)	289.9	194.51
Form factor	0.18	0.24
Shape Factor	2.01	
Circularity Ratio	0.25	0.2
Elongation ratio	0.48	0.55
Drainage Density(km/km2)	2.46	1.76
Stream Frequency	3.64	2.11
Constant of Channel maintenance	0.41	
Relief Ratio, R	0.121	0.01

3.3 Geophysical Studies

Geophysical surveys play an important role in ground water exploration as they help in better understanding of the ground water occurrence based on surface investigations. Geophysical methods can be classified into surface and subsurface methods depending upon whether measurement made on the ground surface or below the ground in drilled boreholes. Surface Geophysical surveys have wide applications in ground water investigations. In hard rock terrain, geophysical methods are employed for

i. Estimation of the thickness of weathered zone
ii. Delineation of structures like dykes, faults, fracture zones which control the ground water movement
iii. Delineation of lateral extent of aquifers
iv. Estimation of depth to massive rock/basement
v. Study the quality of ground water.

3.3.1 Surface Geophysical Survey

In hard rock terrain, electrical resistivity techniques such as profiling and gradient/ radial arrays are quite effective in detecting presence of fractures at depth. Gradient resistivity profiling is one of the profiling techniques which is useful in hard rock terrain and is usually conducted to delineate saturated fracture zones. Since water bearing zones in hard rock terrain depend on the degree of fracturing, the field techniques were selected with these aspects in mind. In some cases, the water bearing fractures have been located indirectly by detecting the structural features like dykes and faults associated with them. The unique method of resistivity prospecting in combination with electromagnetic and magnetic methods has been applied at many sites in the study area. The methodology and layout of investigations have been chosen depending on the direction of lineament and other structural features and accessibility of the area.

Integrated geophysical surveys by electrical, electromagnetic, magnetic and seismic methods were conducted in the study area during 1985-87, as part of multi-disciplinary studies in the Coastal Kerala Ground Water Project and 2001-10 as part of exploration activities. Hydrogeological and remote sensing studies conducted earlier revealed the presence of several deep-seated fractures as linear features and the objective of the geophysical survey include confirmation of the same and facilitate selection of suitable sites for exploratory drilling as well as quantification of geo-electric parameters in a regional scale. Geophysical surveys consisting of resistivity profiling and Vertical Electrical Soundings were carried out in study area for ground water exploration purpose during 2010-16 also. Resistivity profiling to a length of 1290 m and 34 VES were carried out covering 21 sites. Initially resistivity profiling was carried out at these sites and wherever low resistivity were obtained VES were conducted. The results of the VES were presented in **Table 3.5**.

Based on the results of geophysical surveys, 8 sites have been recommended for drilling in the study area. It was observed that in most of the sites the actual lithology matched well with the survey results. The boreholes at Kottarakara, Tadicaud, Kampamkod and Aryankavu were high yielding wells. It was observed that a typical geo-electric (resistivity) sequence of thin 400-800 ohm.m layer (top dry laterite) underlain by thin 50-100 ohm.m layer (highly weathered rock) which is again underlain by thick 100-400 ohm.m layer (fractured rock) represents a much disturbed but very productive crystalline formation.

The detailed electromagnetic and resistivity studies at four sites between Kottarakkara and Enathu (58 C/16) delineated wide multiple fractures at depth characterized by very low resistivities. But the drilling to a depth of 300m near Mailom (north of Kottarakkara) penetrated through fractured Khondalites gave a very low discharge. The detailed electromagnetic, magnetic and resistivity surveys across a major NW-SE lineament (north of Punalur to Marur) in the eastern parts of Kallada basin indicated narrow and vertical fracture zones with resistivities in the range of 200-300 ohm.m (it was less than 100 ohm.m at Marur).The boreholes drilled at Marur encountered weathered Khondalites with clay, resulting in meagre discharge while at Kadakaman it pierced through quartz reef, fractured gneisses and calc granulites yielding 15 lps.

At many of the sites where detailed geophysical surveys are not feasible individual sites were taken up for investigation. The interpreted results of VES conducted near Ariyankavu (NE-SW lineament) were in agreement with the lithological logs of the boreholes drilled at both these sites, which have yielded about 20 LPs.

From the geophysical survey, it was observed that electromagnetic techniques appear to be effective tools for shallow to moderate depth investigations (100 to 150m). They are quite sensitive and able to detect narrow fractures as compared to normal VES methods. Integrated geophysical surveys conducted in a few sites identified zones of mineral concentration, water bearing fractures, fracture pattern and basement topography. Magnetic survey at Tadicaud, deciphered the contact of fractured gneisses associated with the disseminated graphite. Similarly, magnetic survey at Punalur, identified strong anomalies over a dolerite dyke of width 24-28m at a depth of 17.5 to 24m.

Based on the analysis of field data and from results of exploratory drilling the most suitable geophysical method for ground water prospecting in crystalline rocks in the sudy area is found to be a combination of electromagnetic survey followed by electrical resistivity.

3.3.2 Subsurface Geophysical Logging

In crystalline rocks geophysical well logging was carried out by using electrical, gamma, caliper and temperature probes. Analysis of various logs in conjunction with related borehole data could reveal different physical and nuclear characteristics of the rock formation encountered in these boreholes. The fracture zones could be deciphered from the SP-PR and 16" and 64" normal resistivity logs, caliper and gamma logs. The pegmatite and quartz veins are picked up in gamma log. Logging details are discussed in following section after grouped on the basis of river basin.

Table 3.5: Interpretation of geophysical survey (VES)

Sl No	VES No	Location	AB/2	Interpreted results										Total depth	Remarks
				ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4	h_5	in m	
1	1	Karamkode	300	550	1375	390	75	350	0.7	10.5	30	210	-	252	
2	2	Kottarakara	300	139	98	2000	-	-	2	89.4	-	-	-	91.4	
3	3	Nellikunnam	200	270	1354	50	150	VH	2.6	7.8	22	60	-	92.4	Recommended
4	4	Valakam	400	400	45	75	210	-	1.8	9.9	36	-	-	48	
	5		600	80	240	-	-	-	20	-	-	-	-	20	
5	6	Kampamkod	400	1200	400	171	VH	-	1	54	72	-	-	128	
6	7	Tadicaud	200	525	225	130	3000	-	2.2	12.1	75	-	-	89.3	
	CI		240	537	256	125	3851	-	1.8	27.2	36	-	-	65	
7	8	Anchal	400	2000	240	330	700	140	1.3	10.7	36	48	33	129	Recommended
8	9	Ayur	200	1200	171	100	165	480	2	12	13	95	-	122	Recommended
9	10	Karukone	240	530	200	250	280	-	4	16	40	-	-	60	
10	11	Chadayamangalam	600	110	252	110	221	-	3.1	15.5	85.4	-	-	104	
	12		600	160	371	90	180	VH	2.2	20.8	46	210	-	279	Recommended
11	13	Punalur	-	205	250	1150	-	-	13	39	-	-	-	52	
	14		-	750	250	390	183	900	1.4	10.5	37.5	75	-	124.4	Recommended
	CI		-	830	224	373	143	1137	1.4	3.82	36.96	65.47	-	107.65	
	15		-	900	300	1200	-	-	2.2	17.6	-	-	-	19.8	
12	16	Punnila	160	640	213	5.4	300	-	2.2	17.6	-	-	-	34.5	
	17		240	130	144	450	216	2000	3.4	6.8	10	150	-	170.2	Recommended
13	18	Piravanthur	160	150	147	273	-	-	4.2	5	-	-	-	9	
14	19	Kadakaman	160	471	89	188	418	-	10	18.5	53	-	-	81.5	
15	20	Pandithitta	300	600	250	180	300	-	0.5	11.5	48	-	-	60	
16	21	Inchekkadu	160	1100	28	210	-	-	3	36	-	-	-	39	
17	22	Mailom	400	600	67	100	300	-	2	12	56	-	-	70	Recommended
	CI		400	691	59	106	351	-	2.02	3.34	71.9	77.2			

											2	8			
18	23	Puvatturpadinjara	240	540	108	600	188	-	2.2	13.2	40	-	-	55.2	
	24		240	1800	200	1900	197	-	1.65	9.9	7.2	-	-	18.75	
	CI		240	2230	308	143	239	-	1.4	49.2	44.6	-	-	95.2	Recommended
19	25	Adichanalloor	180	1200	300	58			1.5	3.5	Ext.				Ter
20	26	Ezhukone	180	220	80	150	300	VH	1.8	6.2	20.0	122.00		150	HR
21	27	Mavady	120	1200	200	90	260		2.0	7.0	14.0	Ext.			HR
	28	Nellikunnam	180	300	230	470			6.0	9.0	Ext.				HR
	29	Oyoor	200	2000	70	160	VH		2.0	16.0	112.0			130	HR
22	30	Parippalli	150	550	115	270			6.0	34.0	Ext.				Ter

3.3.2.1 Geophysical logging in Ithikkara river basin

In Ithikkara river basin, at about 6 sites borehole logging was carried out. The geophysical logging carried out consists of self potential, resistivity, natural gamma, caliper and temperature logging. The bore wells were located in Karakod, Karukone, Kampankod, Nellikunnam, Tadicaud and Kottarakkara. The major part of the study area is underlain by crystalline rocks of Archaean age. The crystalline rocks were extensively lateritised. The crystalline rocks are composed predominantly of khondalites followed by garnet-biotite gneiss and charnockite. Dolerite, gabbro and pegmatite are the major intrusive into these crystalline. The bore wells were drilled to a depth range of 115-200 mbgl and the logging was carried out a depth range of 17-200 mbgl. The lithological log and geophysical logs obtained at Nellikunnam of Ithikkara basin was presented in **Figure 3.5**. The interpreted results of geophysical logging in 14 sites are given in **Table 3.6.**

The analysis of the resistivity logs indicated that at various depth ranges different resistivities were recorded which corresponds to the clayey formation, fractured/less fractured and massive formations. In general, the resistivity ranges from 100 to 500 ohm.m for fractured formations and above 500 to 2000 ohm.m for massive formation. In some locations viz., Karamkode, the top layers have very low resistivity values of less than 200 ohm.m probably due to the excess clay content in them.

The natural gamma logging indicated background radiation of 28-140 cps. The count rate was varying in the range of 40-320 cps. Higher count value is indicative of fractured nature of the rocks as well as their radioactive content present in the country rock. At Kottarakara, peaks of more than 320 cps are indicated at 68.5-70 and 91-96 mbgl which may be due to the high degree of fracturing.

In general, caliper logs indicated a slight increase in borehole diameter against the fracture zones. The caliper log has shown very irregular pattern in some boreholes probably due to caving and loose weathered formation causing irregular increase in diameter. The diameter increases upto 1.5 inch near fracture zone (Karamkode). At Karukone, a thick cavity is indicated between 79.5 and 83.5 mbgl.

The SP log does not indicate any quality problem at Kottarakara. At the remaining sites the log was featureless. The temperature log is featureless in all the wells.

3.3.2.2 Geophysical logging in Kallada River basin

In Kallada river basin, at about 11 sites borehole logging was carried out but only 8 sites fall in the study area. These bore wells are located at Kundara, Ariankavu, Punalur, Mailam, Puvattur padinjaru, Ambalattumbhagam, Kadakaman and Idakkattu. The geophysical logging carried out consists of Self potential, Resistivity, Natural Gamma, Caliper and Temperature logging. The major part of the study area is underlain by crystalline rocks of Archaean age. The crystalline rocks are composed predominantly of khondalites followed by garnet-biotite gneiss and charnockite which were extensively lateritised. Dolerite, gabbro and pegmatite are the major intrusive into these crystallines. The bore wells were drilled to a depth range of 129.9-301 mbgl and the logging was carried out a depth range of 56-300 mbgl.

The analysis of the resistivity logs indicated that at various depth ranges different resistivities were recorded which corresponds to the clayey formation, fractured/less fractured and massive formations. In general, the resistivity ranges from 100-500 ohm.m for fractured formations and above 500 to 2000 ohm.m for massive formation. At Kadakaman up to 84 m the resistivity recorded was 30-140 ohm.m which is clay. After 84 m depth the resistivity was more than 2000 ohm.m which represents massive formation.

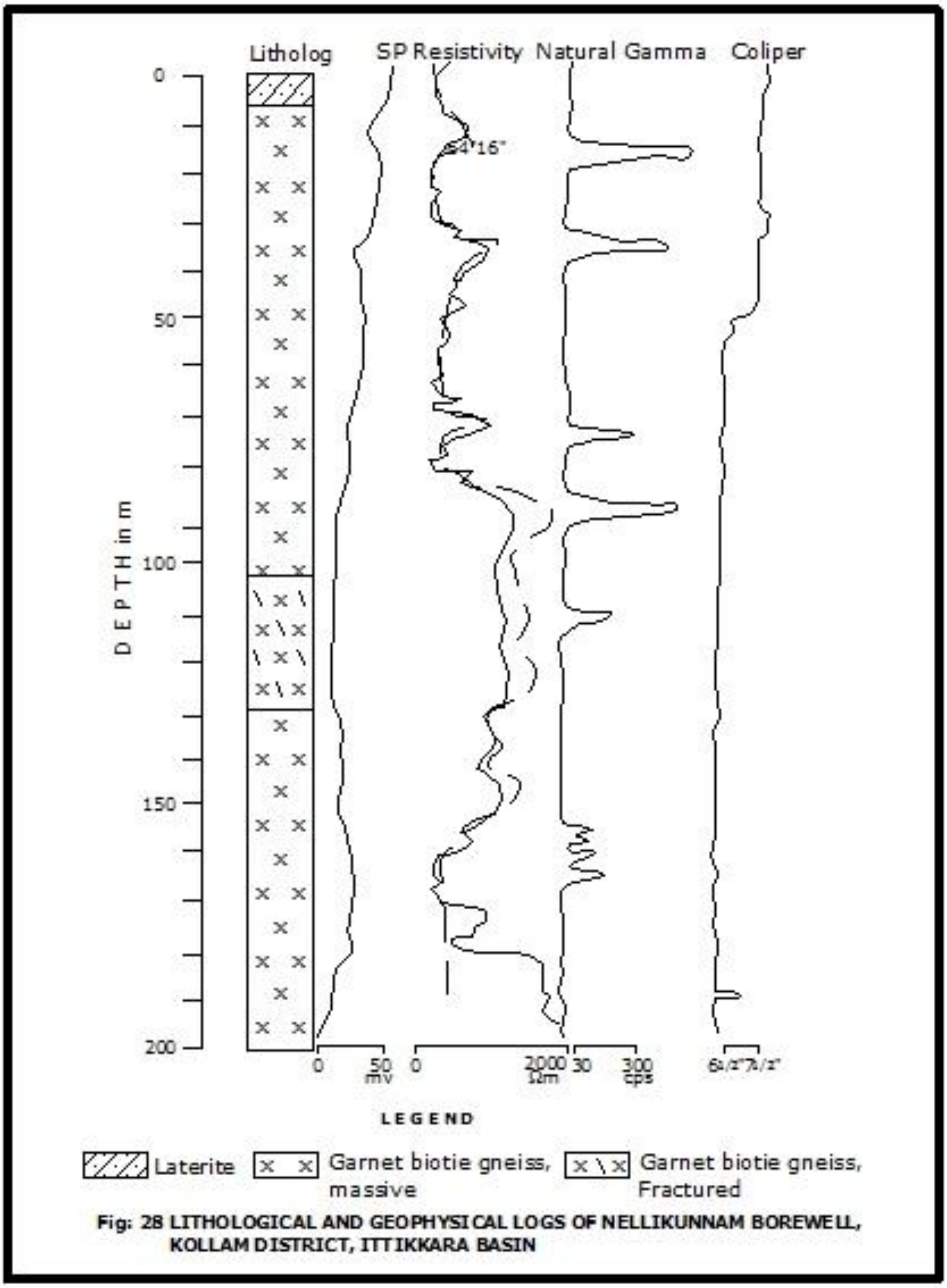


Figure 3.5: Lithological and geophysical logs of Nellikunnam BW, Kollam district, Ithikkra basin

The natural gamma logging indicated background radiation of 34-120 cps. The count rate was varying in the range of 30-400 cps. At Kundara and Ambalattumbhagam, the gamma log was oscillating in the range of 100-500 cps. Higher count encountered against the fractures or may be due to increase in radioactive content in gneissic rock.

In general, caliper logs indicated a slight increase in borehole diameter against the fracture zones. The caliper log has shown very irregular pattern in some boreholes probably due to caving and loose weathered formation causing irregular increase in diameter. At Kundara the log is highly disturbed one. At Ariyankavu the bore hole diameter was increased from 0.5 to 2 inch in depth ranges of 12-15, 26-27, 39-41, 57-58 and 71-72 mbgl, at Mailom the bore hole diameter was increase up to 1.5 inch and at Idakkattu increase of 1 inch in depth ranges of 52-55, 64-65, 106-107, 113-114 mbgl. At Ariankavu in the depth range of 57-58 mbgl and at Kadakanam in the depth range of 150-155 m cavities were observed.

The SP log does not indicate any quality problem at Ariyanakavu and at Idakkattu except a facial shift at 132.5 m. At the remaining sites the log was featureless. The temperature log was featureless at most of the sites. Only at Mailom in the range of 27.6 and 27.8°C, at Puvattur padinjaru in the range of 27.9 to 28.1° C. The temperature was varying at the time of logging in all the sites.

3.4 Water Level Monitoring

A total number of 145 monitoring wells were established in the area for periodical monitoring of water levels that includes the ground water monitoring wells of CGWB (77DW+10Pz), SGWD (15DW+16Pz) and newly established key wells (16DW). The CGWB Ground Water Monitoring Wells (GWMW) were monitored during four seasons viz; January, April, August and November while the SGWD wells were monitored monthly. In the case of key wells, water level monitoring has been done similar to CGWB wells for the period April 2016-April 2017. Later, the water levels were monitored during April and November as the pre-monsoon and post- monsoon data respectively. From the study of the data and hydrographs, it is observed that there are two periods in a year viz. recession and recharge. The stabilization in the recession is observed to commence after the attainment of peak water level during southwest monsoon, from June to September. The contribution from northeast monsoon is a critical factor in sustaining the system. The actual recession period commences in December and continues till the onset of southwest monsoon in June. The recharge period commences from June. The long-term changes in water level are studied from the GWMW maintained by CGWB in the area. In addition to this the historic water levels from 31monitoring wells of State Ground Water Department were also collected and the static data of wells maintained by both departments are given in **Annexure 1**. The dug well represents the water level of the unconfined aquifer while the piezometer represents the semi-confined/ confined aquifer. Since it represents the two-aquifer system existing in the study area, the water level behaviour is discussed separately in the following section.

Table 3.6: Interpretation of Geophysical Logging carried out during SIDA project

Sl.No.	Location	Resistivity			SP	Gamma		Caliper
		Ohm.m	Fracture depth (m bgl)	Massive Rock depth (m bgl)		Count value cps	Fracture depth (m bgl)	Fracture depth (m bgl)
1	Karamkode	< 200	45-75 76-77 81-83 92-97 105-107 112-117 121-123 125-135 164-188		No specific Feature	Background – 140 Counter -140-240	85-92 122-32 148-153 168-172 172-185	Irregular upto 93mbgl 125-126 133-134
2	Karukone	150-350	17-25 34-36 45-51 77-83 90-93 106-110 113-116 145-150 153-157 182-186		No specific Feature	Background – 60 Counter -160	23-27 58-67 75-77 85-90 110-112 130-132	Cavity between 79.5-83.5 Fractures below 90 mbgl
3	Kampamkod	250-500 > 500-massive	44.5-47.5 51.5-53.5 56-71 72-73 79.5-120 130-137 169-174		Featureless	Background – 38 Counter -80-300	42-45 437-141 163-166	40-42 66-66.5 Below 146mbgl
4	Nellikunnam	< 500	21-225.5 22.5-29		Featureless	Background – 28	30017-23 36-43	32-37 46-49

		> 2000 massive	29-30.5 30.5-34.5 53-56.5 66-70 72-73.5 83-85.5 162-173			Counter -130-300	77-80 91-96 114-117 157-168	56-58 63-75 85-93
5	Tadikad	200-300 600-1225 Massive	35-37 41-47 49-51 51.5-53.5 57-58 125-130 158-165 165-169		Featureless	Background – 36 Counter -40-180	46-51 54-57 112-115 147-151	17-27 55-61 63.5-66 128-133 145.5-146
6	Kottarakara	< 500	63-64 67-68 70-75 77-82 92.5-94 100-103 106.5-108.5		No quality problem	Background – 32 Counter -40-320 >320 – highly fractured	19-20 29-30 43-44 53-55 68-70 76.5-78 91-97 68.5-70 91-96	62-63.5 96-97
7	Kadakaman	30-140-clay >2000-massive	63-64 67-68 70-75 77-82 92.5-94 100-103 106.5-108.5		Featureless			
8	Kundara	500			Featureless		100-500	

		>1000- massive						
9	Aryankavu	125-500 Fracture		22-24 28-31 38-42 63-67 78-82 86-87 93-95	No quality problem			12-15 26-27 39-41 57-28 71-72 0.5-2 inch increased
10	Ounalur	100-140	24-25 36-39 47.5-52 52-55 55-60 60-64.5 64.5-70				45.5-48	
11	Mailom	75-450	20-23 33-55 55-60 67.5-69 73-77 80-82 95-102 102-104.5 104.5+-107 107-111 111-120 120-127 127-131 131-133 133-140 140-143.5				108-124 180-187	

			164-168 168-185 189-208					
12	Puvattur Padinjaru	175-400	6-12.5 14.5-21 45-60 52-63 72-83 86-95 97-116 116-125 130-147 172-179 193-194				13-16 34-39	
13	Ambalathumbhagam	< 500	70-88 113-119 147-155.5 156-159 181-184 211-218 220-225 225-244.5 254-267 267-284 292-299					
13	Idakkatu	150-500	135-170		No quality problem		26-30	52-55 64-65 106-107 113-114

3.5 Aquifer Systems

Occurrence and movement of ground water in an area is controlled by various factors such as topography, climate, geomorphological setting, geological and structural characteristics. In hard rock terrain, ground water occurs under phreatic as well as semi-confined to confined condition. In laterites and weathered crystallines, the shallow fractures which are hydraulically connected to it, ground water occurs under phreatic condition. The deep massive rocks are characterized by deep fracture zones and ground water occurs under semi-confined to confined conditions. Thus, on the basis of the depth of occurrence of potential aquifer zones, the aquifers can be categorized into two groups:

1. Shallow Aquifers- Weathered zone with shallow fractures
2. Deep fractured Aquifer

3.5.1 Shallow Aquifers- Weathered zone with shallow fractures

The shallow aquifers are made of highly weathered zone (laterite) and partly weathered and fractured rock occurs just below the weathered zone. The thickness of the shallow aquifers depends upon the mineralogical composition and structural characteristics of the parent rock as well as the topography and drainage conditions of the terrain and thus show a wide variation in the yielding capacity. Khondalites are more susceptible to weathering followed by migmatites and charnockites. Hence the shallow aquifers in the area occur generally within a depth of 25 m in the case of khondalites and 15 m in the case of charnockites. But the weathering of khondalites gives rise to more clayey material and forms a relatively poor aquifer. While in the case of charnockite and migmatite, the weathered thicknesse is less but often get saturated with the onset of monsoon.

The lateral and vertical variation in the thickness of weathered zone has been elucidated from the data collected from the exploratory drilling activities of CGWB- 46 wells in the study area. Weathered zone includes the weathered formation and the hydraulically connected shallow fractures and the thickness varies from 3.6 to 63 m. To understand the spatial variation, contour map depicting the weathered zone is prepared and is shown in **Figure 3.6.** It shows that the weathered thickness is less towards the eastern hilly region and increases towards the west. It attains a maximum thickness of 63m along the boundary of Tertiary-Crystalline rock contact zone. Moreover, the thickness of weathered zone is more over the Khondalite than Charnockite, which occurs on the southern part of the area.

A lithological cross-section has been prepared using the lithologs of boreholes drilled in the crystalline rocks for a better perspective of the subsurface geology and the panel diagram is shown in **Figure 3.7** and the details of the formations encountered in the boreholes(litholog) are given in **Annexure II**.

Ground water is extensively developed by means of dug wells, dug-cum bore wells and shallow bore wells in these shallow aquifers. The depth of the dug wells ranges from 4.2 to 22 m bgl and that of the shallow bore well to a depth of 30m. The water levels in the weathered zone were analyzed using the data collected by monitoring of 119 dug wells in the area **(Annexure III)**. Depth to water level ranges from 2.83 to 21.6 mbgl during pre-monsoon period (April17) and from 2.27 to 19 mbgl during post-monsoon period (November 2017). The analysis of the water level data shows that 60% of wells show water level within 10m during pre-monsoon while it rose to 77% of monitoring wells during post-monsoon. Map showing depth to water level during April17 and November 17 has been prepared and is shown in **Figure 3.8 and 3.9** respectively. The pre-monsoon water level map shows a deeper water level in the central

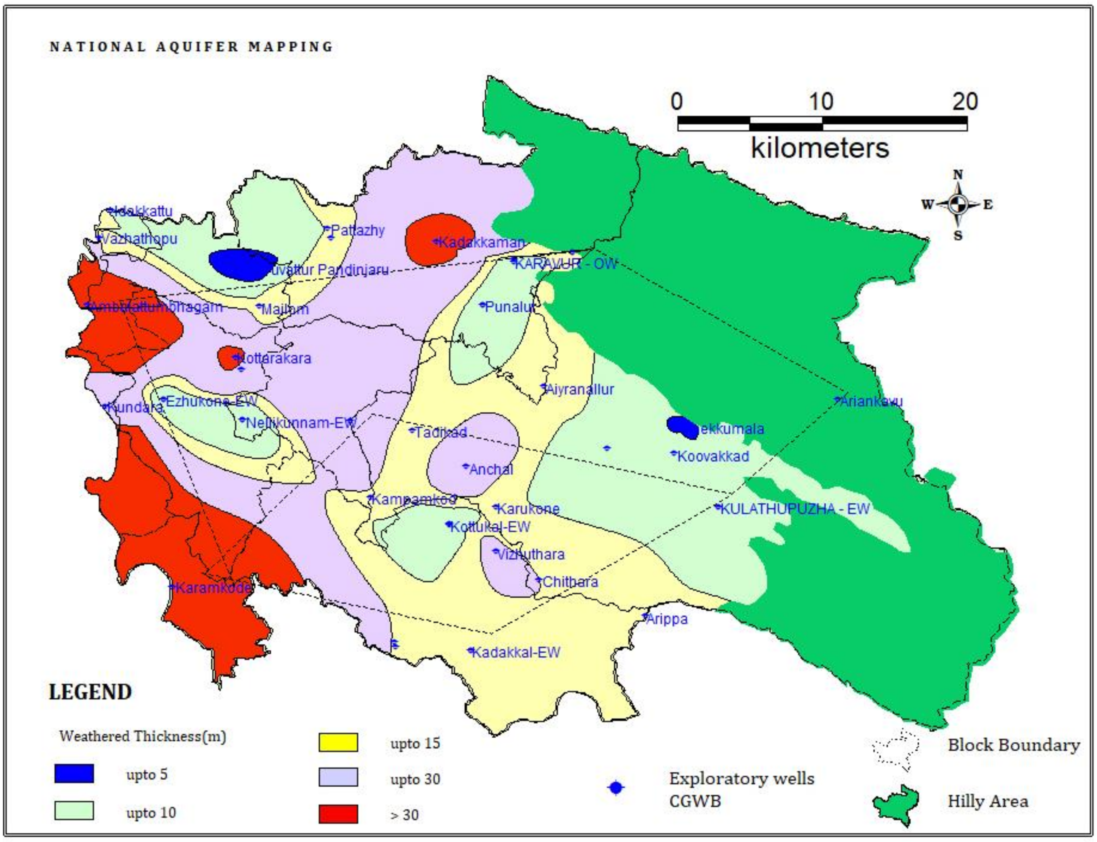


Figure 3.6: Contour map showing weathered thickness

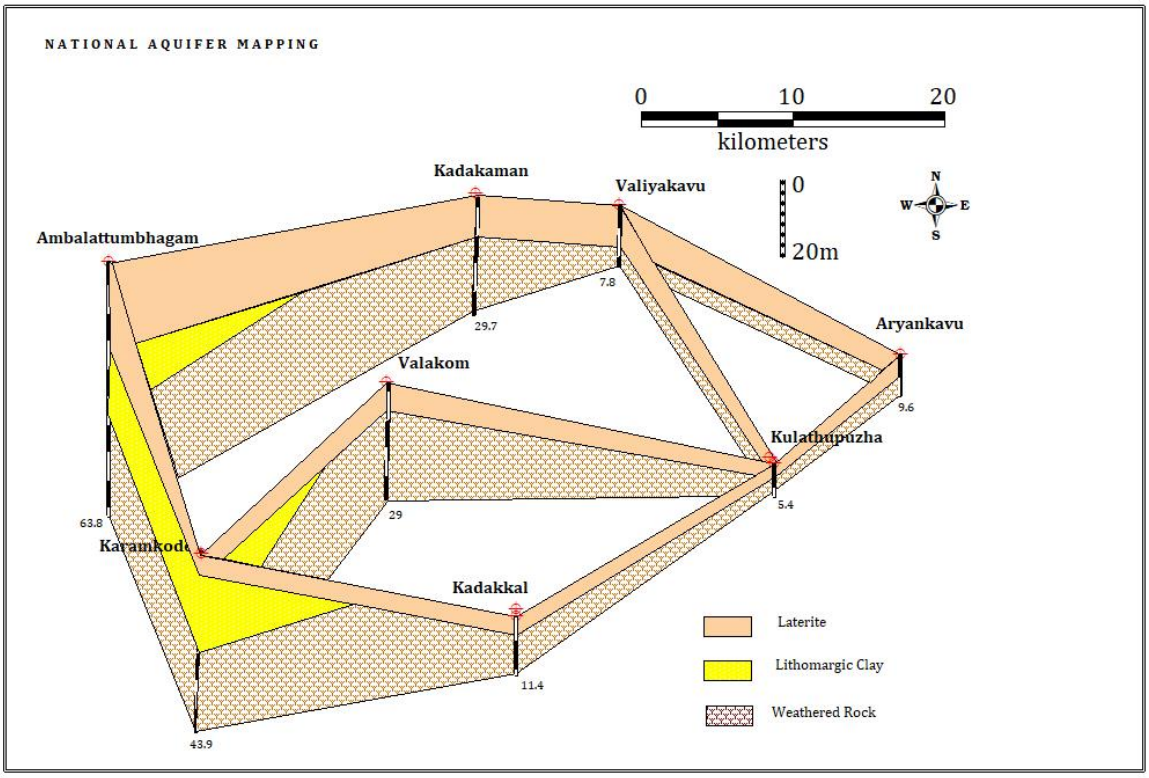


Figure 3.7: Panel diagram showing aquifer disposition of Shallow Aquifer

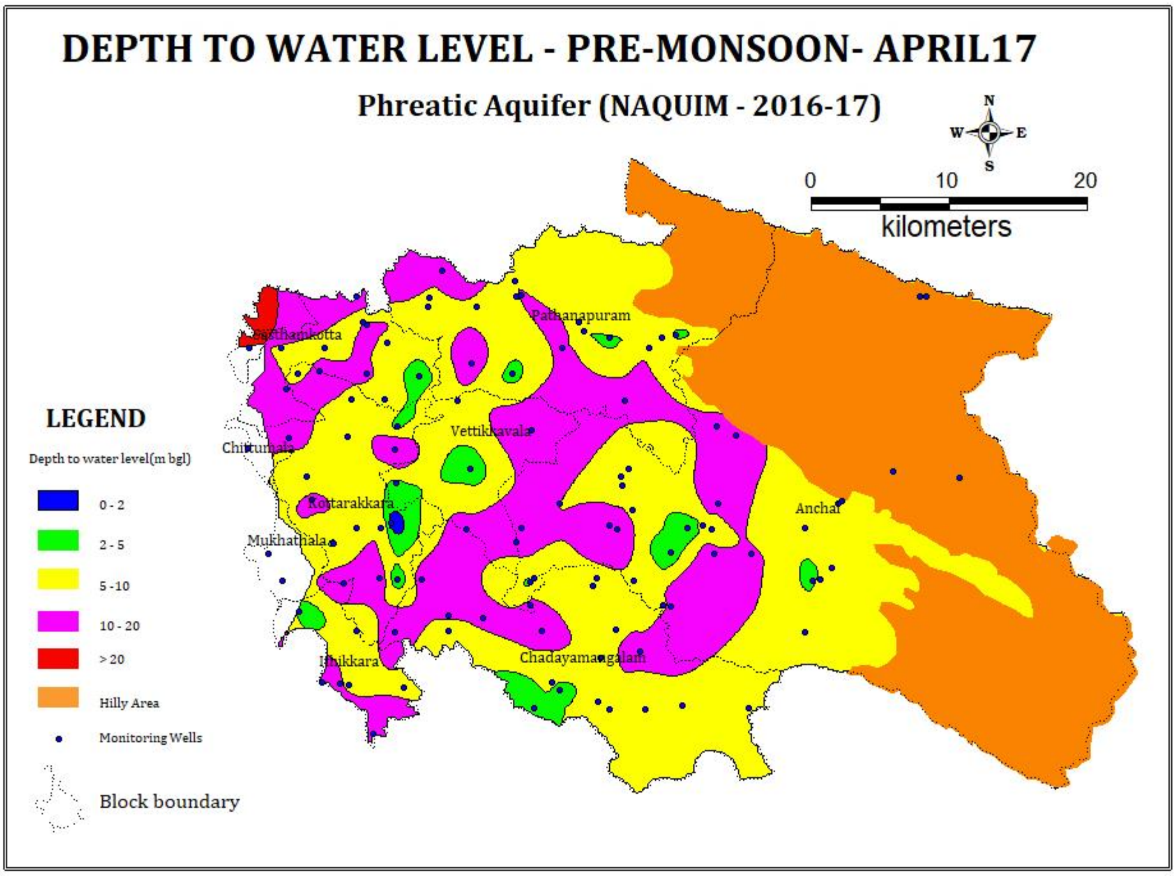


Figure 3.8: Depth to Water Level – Pre-monsoon

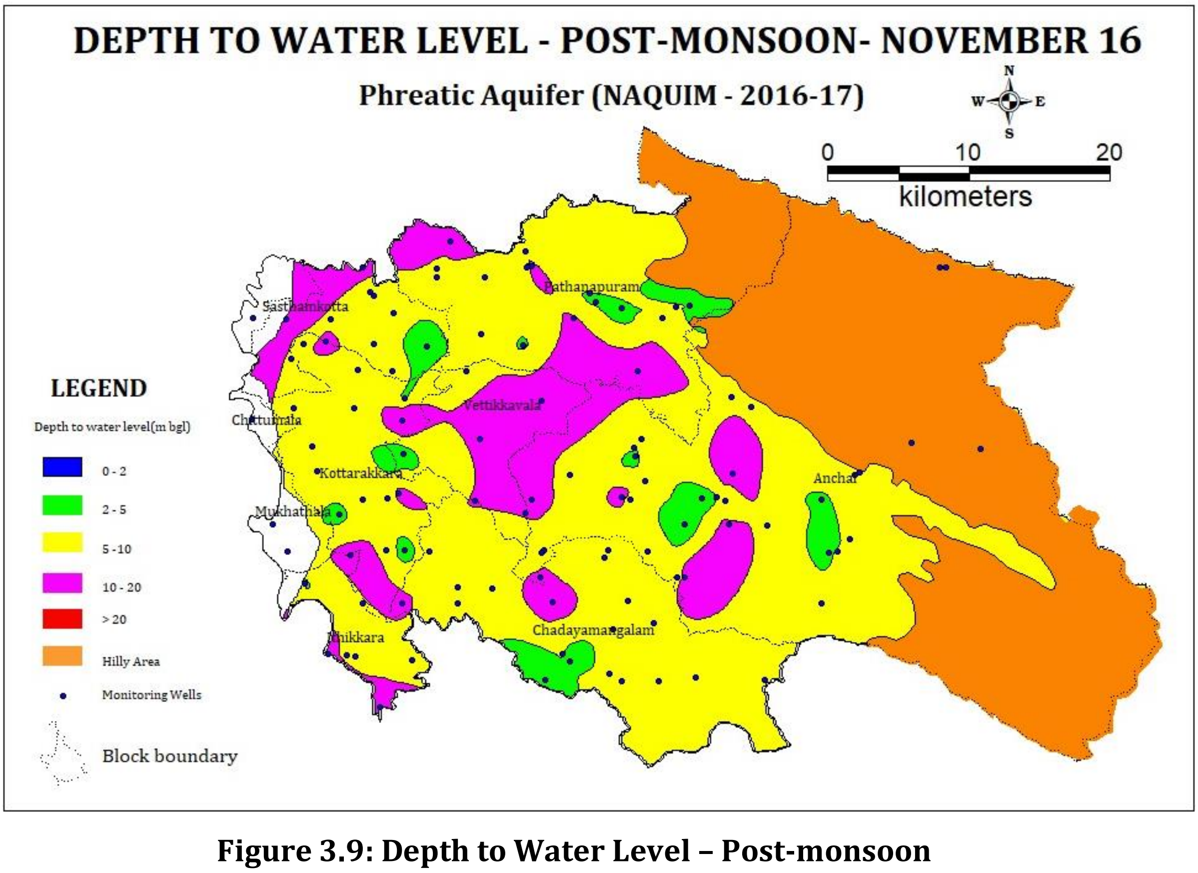


Figure 3.9: Depth to Water Level – Post-monsoon

portion whereas the shallow water level of 5-10 m bgl become more prominent and deeper water level were confined to certain pockets during the post-monsoon period.

In order to understand the flow direction, ground water table contour has been prepared for the phreatic aquifer and is shown in **Figure 3.10**. The ground water table contour shows a flow towards the west from the eastern foothills.

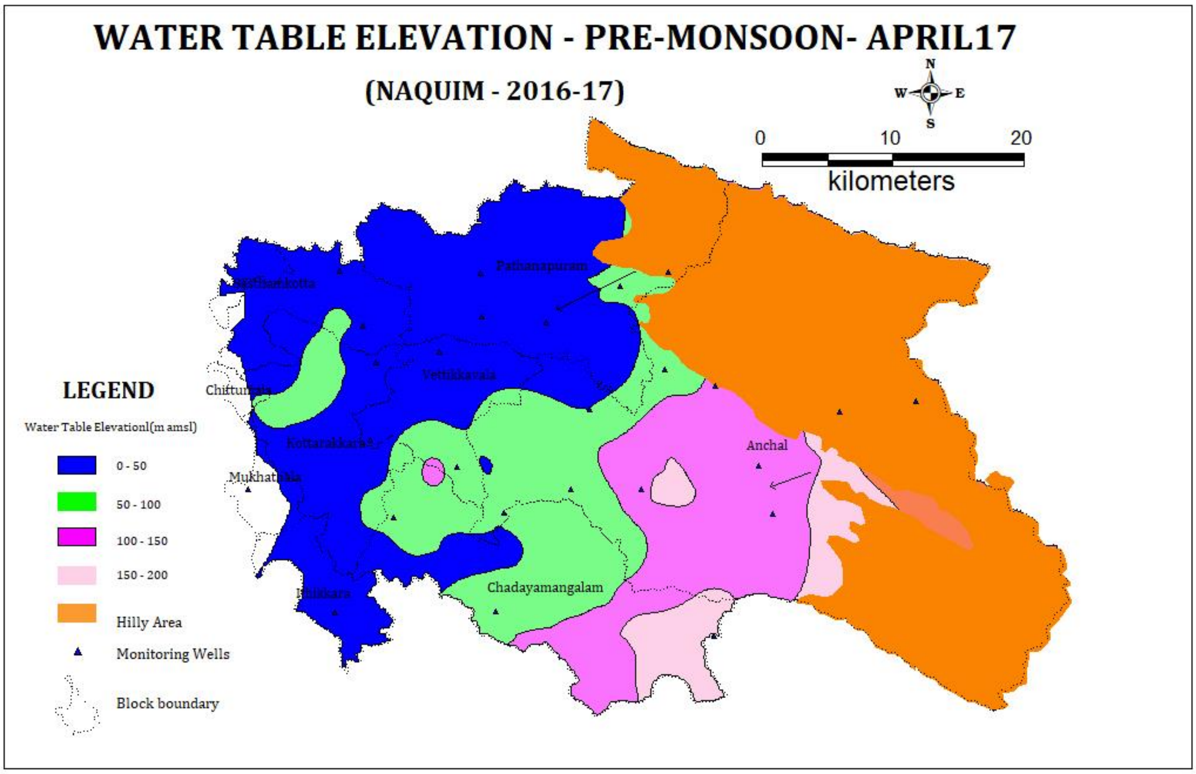


Figure 3.10: Water Table Elevation contour- Pre-monsoon

Water level fluctuation is very important in the estimation of natural recharge to ground water regime. Hence water level fluctuation between pre-monsoon and post-monsoon (April17 vs November 17) and Annual water level fluctuation (April16 vs April17) has been computed and is shown in **Figure 3.11 and 3.12** respectively. In general, the water level fluctuation is within 4 m during both times. Major part of the area shows fall in the water level in the range of 0-2 m which is represented by 62% of the monitoring wells indicates an inadequate compensation of groundwater draft by the monsoon and other recharge components is indicated by a fall in water level.

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 long-term water level data of 27 monitoring wells tapping the shallow aquifer was analysed for the period of 2007-2016. The analysis of pre-monsoon water level trend for the last decadal period indicates that only 36.4% of GWMWs in the study area have recorded negligible change in water level in the range of +0.05 to –0.05 m/year. 51.5% of monitoring wells have recorded declining trend while 12.1% of monitoring wells have recorded rising trend. In the case of post-monsoon water level trend, for the last decadal period, indicates that only 30.3% of GWMWs have recorded

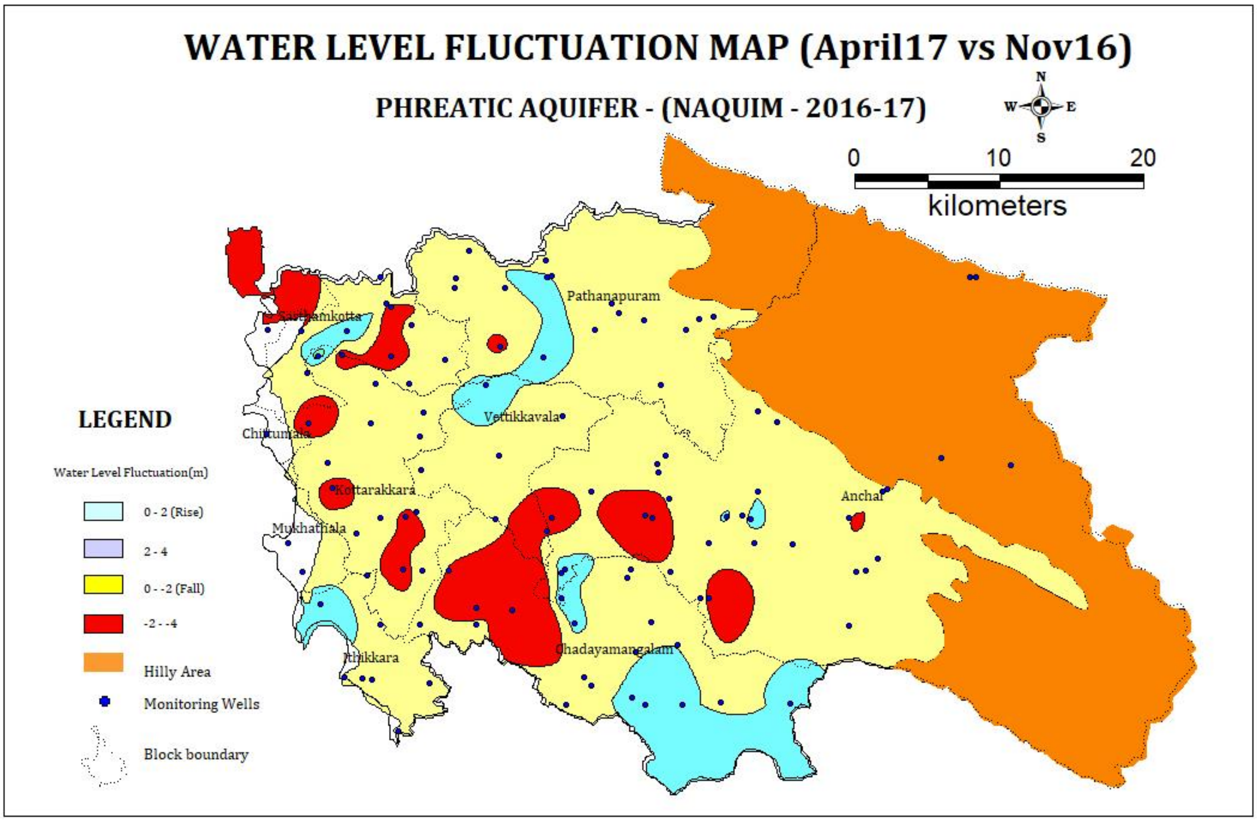


Figure 3.11: Water level fluctuation contour- Pre-monsoon vs Post-monsoon

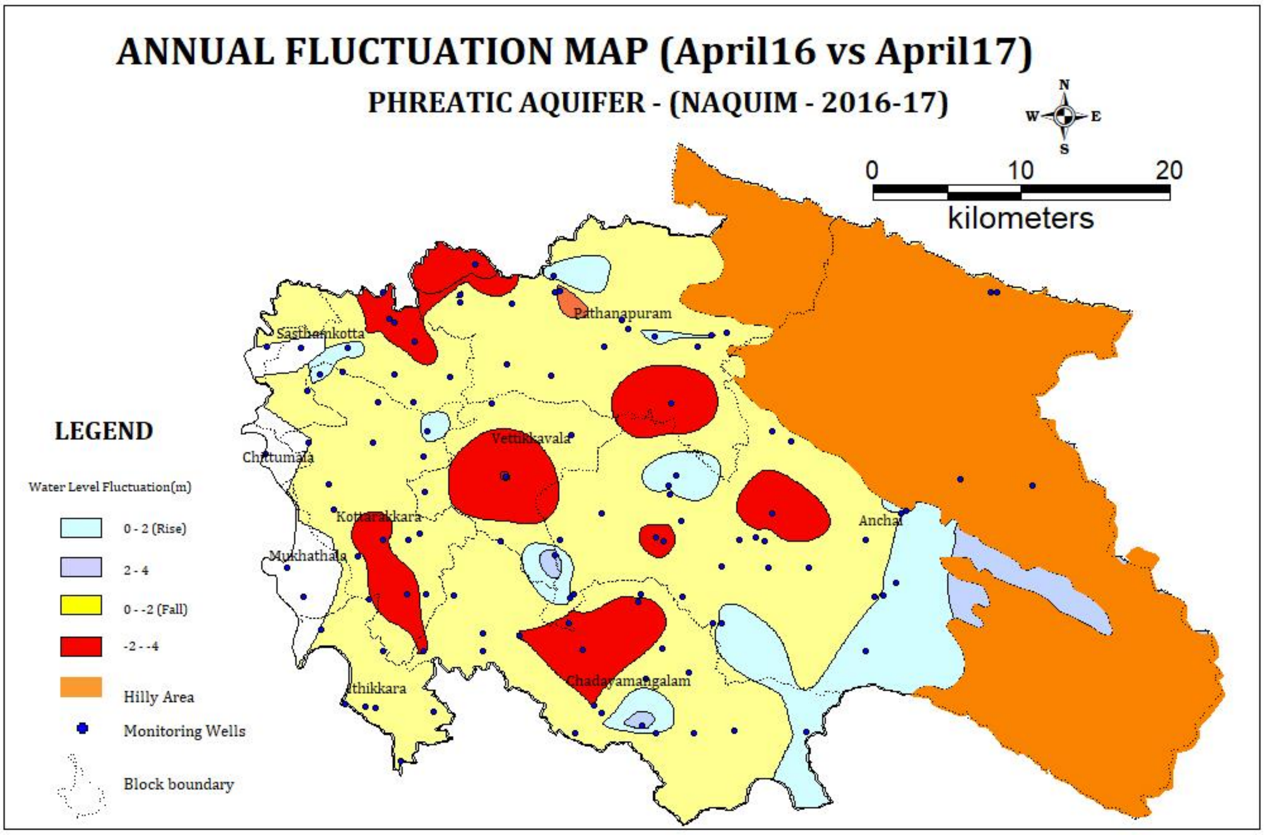
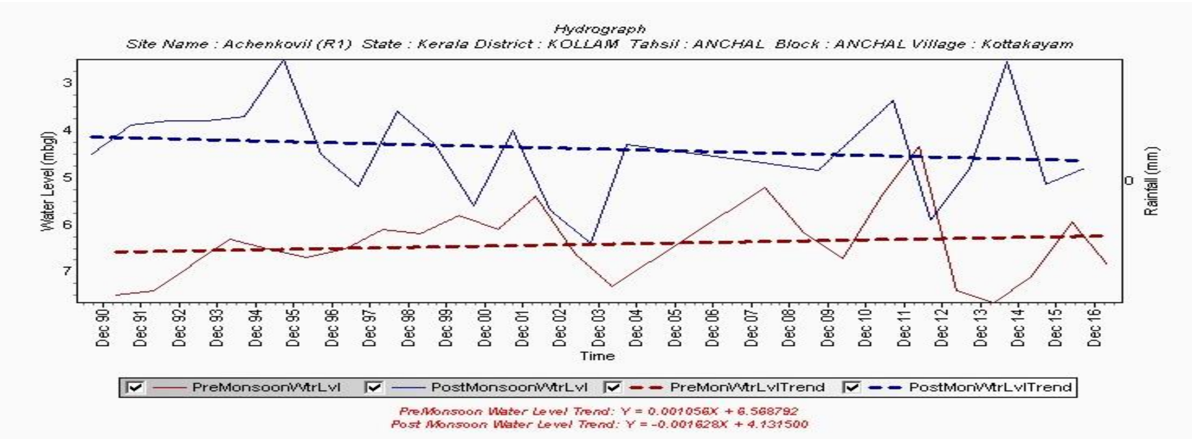


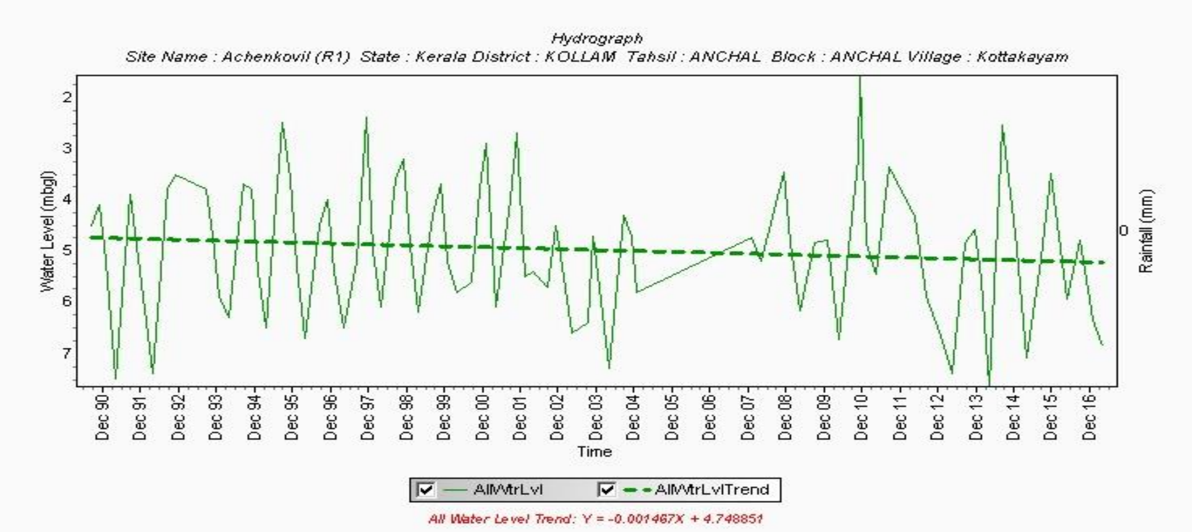
Figure 3.12: Annual Water level fluctuation (April16 vs April17)

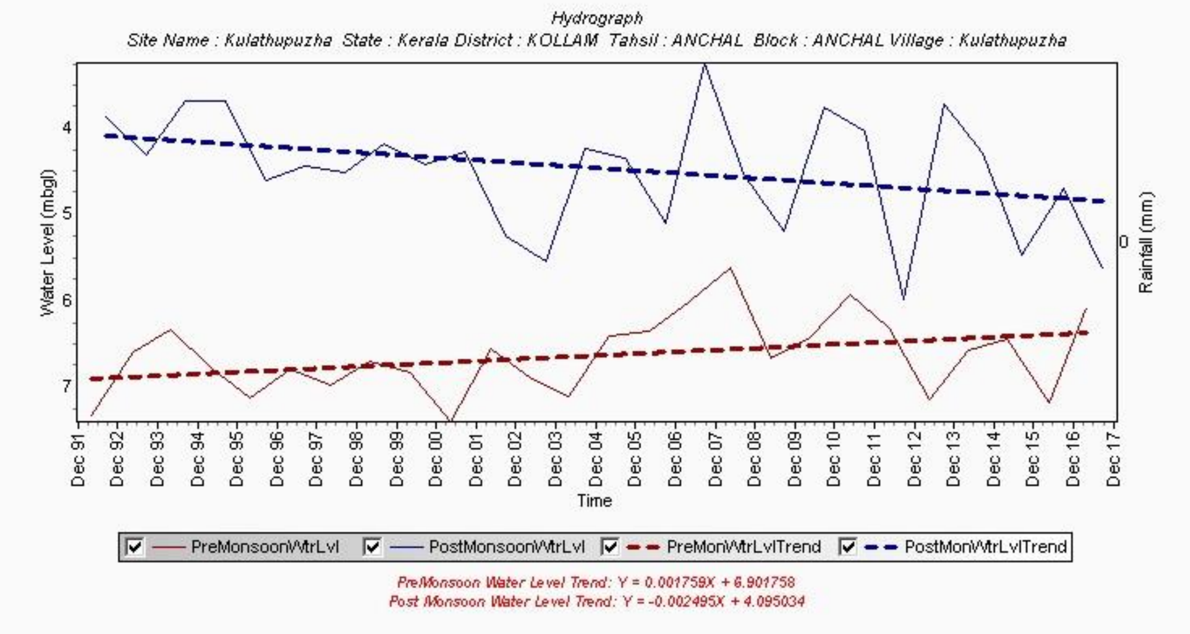
negligible change in water level in the range of +0.05 to –0.05 m/year. 45.5% of monitoring wells have recorded declining trend while 24.2% of monitoring wells have recorded rising trend. The data analysis indicates that the long-term ground water level trend shows a declining trend in major portions of the study area represented by about 57.6% of the total wells. Salient details of water level trends during pre- and post-monsoon seasons for a period of 10 years are furnished in **Table 3.7 and Figure 3.13.**

Table 3.7: Decadal Trend of water level (2007-16)

Sl No	Site Name	No: of Data Analysed	Pre-monsoon Trend (m/yr)	No: of Data Analysed	Post-monsoon Trend (m/yr)	No: of Data Analysed	Trend
1	Achenkovil (R1)	9	-0.1552	8	-0.0401	30	-0.0943
2	Ailara	10	-0.0208	11	-0.0141	41	-0.0208
3	Ariyankavu	10	-0.5919	10	-0.1279	33	-0.2653
4	Avaneswaram	10	-0.0825	9	0.1391	38	0.0189
5	Ayur	10	-0.0727	11	-0.2295	41	-0.0897
6	Chadayamangalam (R1)	9	0.0366	11	-0.1745	39	-0.1385
7	Channapetta	10	-0.152	11	-0.132	41	-0.0968
8	Chenkulam	9	-0.0204	10	0.0332	35	-0.0097
9	Edamon	10	-0.1277	11	-0.1665	41	-0.1008
10	Kadakkal	10	0.1438	11	-0.1686	39	-0.0664
11	Kalluvathukkal	10	-0.2415	10	0.0597	38	-0.1202
12	Kottakayam	10	0.0181	9	-0.0278	32	-0.0177
13	Kottarakara (R1)	10	0.1994	11	0.185	41	0.0552
14	Kulakada	9	-0.0841	10	-0.2771	37	-0.0948
15	Kulathupuzha	10	-0.111	11	-0.1106	39	-0.0887
16	Kunnada	9	0.176	9	-0.1587	37	0.0484
17	Kutavettur	10	0.0334	10	-0.2481	39	-0.0723
18	Madathara	7	-0.0217	6	-0.1319	32	-0.0509
19	Nallila	10	0.043	11	0.0235	40	-0.0084
20	Oyur	10	0.0383	11	0.061	41	-0.0063
21	Paripally1	10	-0.4533	11	0.0524	40	-0.202
22	Pattanapuram	8	-0.3993	7	-0.5954	28	-0.5009
23	Pavitreswaram	10	-0.0478	11	-0.0382	40	-0.0362
24	Punalur-I (R1)	9	-0.1026	8	-0.1648	32	-0.1495
25	Thenmala	8	-0.1917	10	-0.0918	36	-0.1122
26	Ummannur	10	0.1054	11	-0.001	41	0.0156
27	Yeroor	9	-0.0233	11	-0.0397	40	-0.0336


Hydrograph
Site Name : Achenkovil (R1) State : Kerala District : KOLLAM Tahsil : ANCHAL Block : ANCHAL Village : Kottakayam
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001056X + 6.568792
Post Monsoon Water Level Trend: Y = -0.001628X + 4.131500


Hydrograph
Site Name : Achenkovil (R1) State : Kerala District : KOLLAM Tahsil : ANCHAL Block : ANCHAL Village : Kottakayam
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
AllWtrLvlTrend
All Water Level Trend: Y = -0.001467X + 4.748851


Hydrograph
Site Name : Kulathupuzha State : Kerala District : KOLLAM Tahsil : ANCHAL Block : ANCHAL Village : Kulathupuzha
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001759X + 6.901758
Post Monsoon Water Level Trend: Y = -0.002495X + 4.095034

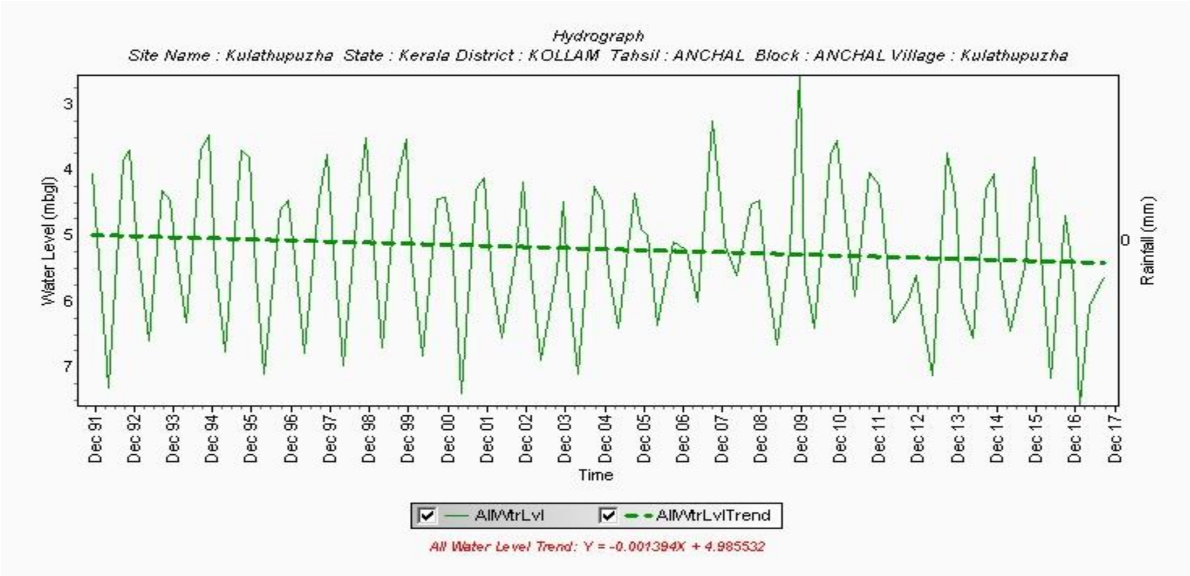


Figure 3.13: Hydrographs of Shallow aquifers

3.5.2 Deep Fractured Aquifers

The post-crystalline tectonic deformations have developed deep seated fractures in the crystalline rocks and the thickness of fracture zone varies spatially and ground water occurs under semi-confined to confined condition. Since the study area have undergone several periods of tectonic deformation, a large number of inter-connected fractures developed, that offer a very good conduits and storage space for groundwater. The exploratory drilling carried out by CGWB reveals that deep seated fractured rock occurs in the form of vertical to sub vertical narrow linear zones of restricted width as well as horizontal zones of varying thickness within the massive rocks. CGWB has drilled 46 numbers of exploratory wells in the study area, and the depth of the wells ranges from 68.7 to 300 m bgl. The depth of the fractures ranges from 10 to 145 m and the discharge ranges from 0.6 to 23 lps. In addition to exploratory wells, 15 piezometers are drilled during Hydrology Project in the depth range of 30 to 200 m with the purpose of monitoring.

To get a better perspective of the subsurface geology, lithological cross-sections and fence diagram has been prepared using the lithologs of boreholes drilled in the crystalline rocks and is shown in **Figure 3.14 and 3.15** respectively. Potential as well as the dry fractures are marked in the diagram. From the figure, it is clear that in the southern part of the area various types of rock units occur and the thickness of the weathered zone varies according to the type of parent rock. While preparing the cross-sections and fence diagram of deep fractured aquifer, different rock types has been marked discontinuously. Keeping in mind that there exists a hydraulic connectivity between the weathered parts of the various crystalline rocks, the entire weathered horizon has been considered as a single unit. Due to non-availability of dip amount and direction of massive rocks, the contact zone was not clear. From the geological map, the planar boundary has been marked and vertically down a zigzag boundary is drawn in that area since that is an inferred one. Dry fractures are encountered on the western part of the area. High yielding fractures are encountered in the eastern and north-eastern parts of the area. In the northern part, major portion is occupied by charnockites/ garnetiferous biotite gneiss and becomes easy to prepare the cross-section. The yield of borewell ranges from 50 lpm at Ezhukone, Kottarakara block to 1000 lpm at Valiyakavu, Pathanapuram Block. The high yielding wells are constructed at Kulathupuzha (660 lpm), Aryankavu (1220 lpm), Kottarakara (1380 lpm) and Valiakavu (1000 lpm).

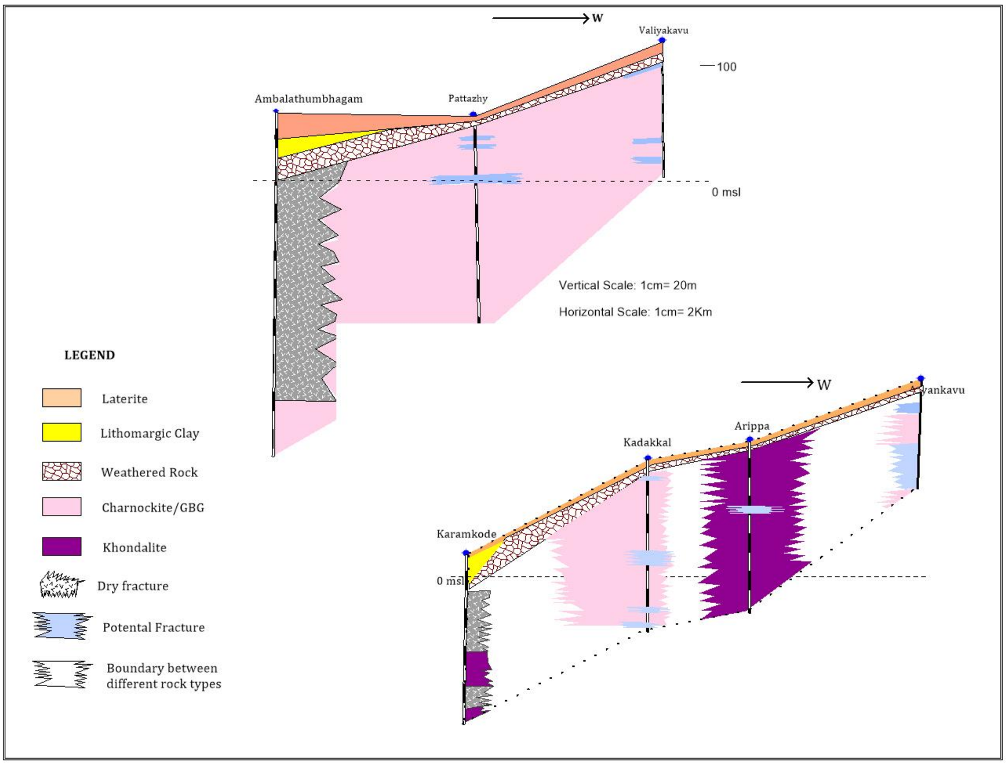


Figure 3.14: Cross-sections showing the dry and potential fractures in deeper aquifers

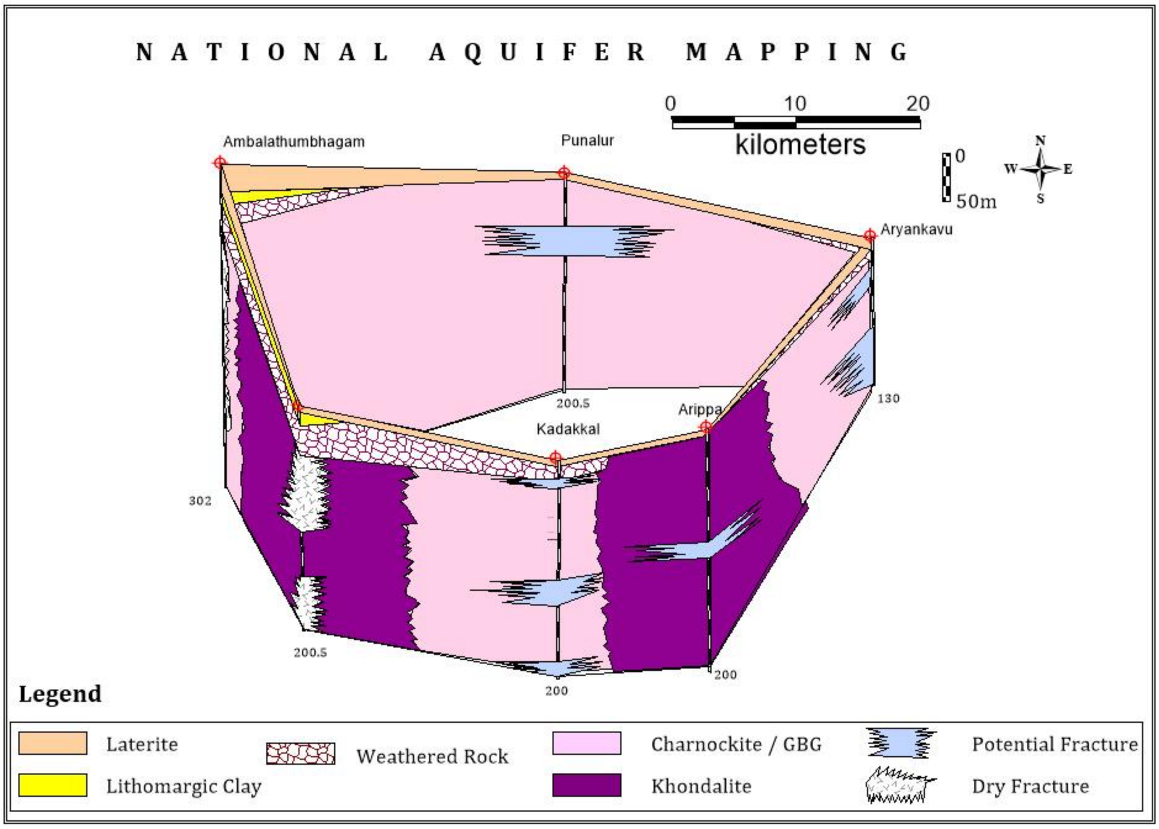


Figure 3.15: Panel diagram showing the deeper aquifers

The water level from piezometers of CGWB (10 nos) and GWD (26 Nos) has been used to analyze the water level behavior of deep fractured aquifer. The depth to piezometric heads in bore wells ranges from 1.02 to 13.6 m bgl during pre-monsoon period and 3.98 to 10.92 m bgl during post-monsoon period. The map showing the piezometric head scenario is shown in **Figure 3.16**. From the map it is clear that about 90% of the bore wells in the hard rock areas are showing piezometric head of less than 10 m bgl. The piezometric head elevation contour plotted for post-monsoon shows that head is towards west similar to phreatic aquifer **(Figure 3.17).** But annual fluctuation map shows that the central and southern part of the area shows a declining trend while the northern and eastern part shows a rising trend **(Figure 3.18)**. The annual fluctuation of piezometric head is in the range of 0.09 to 4.2 m (between April and November) and 0.05 to 2.8 m (between April16 and April17).

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 long-term water level data of 6 monitoring wells tapping the deep fractured aquifer was analysed for the period of 2007-2016. The data analysis indicates that the long-term ground water level trend shows a declining trend in major portions of the study area represented by about 66 % of the total wells**(Figure 3.19)**. Salient details of water level trends during pre- and post-monsoon seasons for a period of 10 years are furnished in **Table 3.8.**

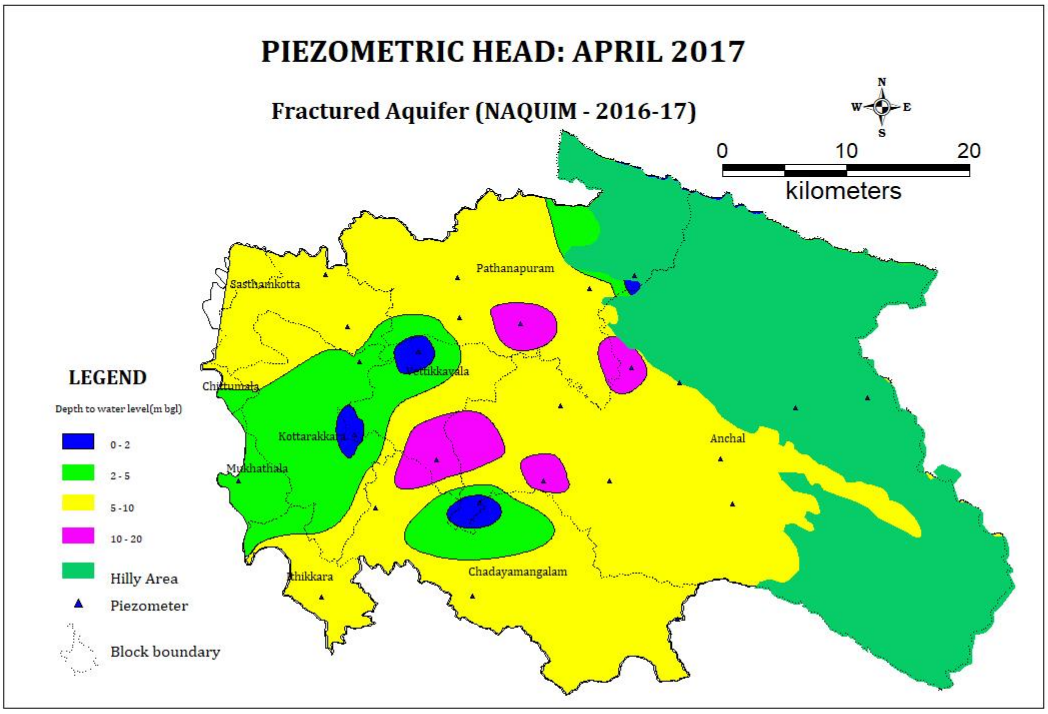


Figure 3.16: Piezometric head of Deeper Aquifers: April 17

Table 3.8: Decadal Trend of water level (2007-16)

Sl No	Site Name	No: of Data	Pre-monsoon	No: of Data	Post-monsoon	No: of Data Analysed	Trend
1	Anchal	10	-0.0704	9	-0.0751	36	-0.025
2	Kalluvathukkal	10	-0.2415	10	0.0597	38	-0.1202
3	Kulathupuzha1	10	-1.7494	6	0.095	33	-0.6666
4	Pathanapuram	9	-0.0189	9	0.0162	33	0.0149
5	Ummmannur	6	0.0057	7	0.1428	30	0.1137
6	Yeroor1	7	-0.281	6	-0.0396	30	-0.0783

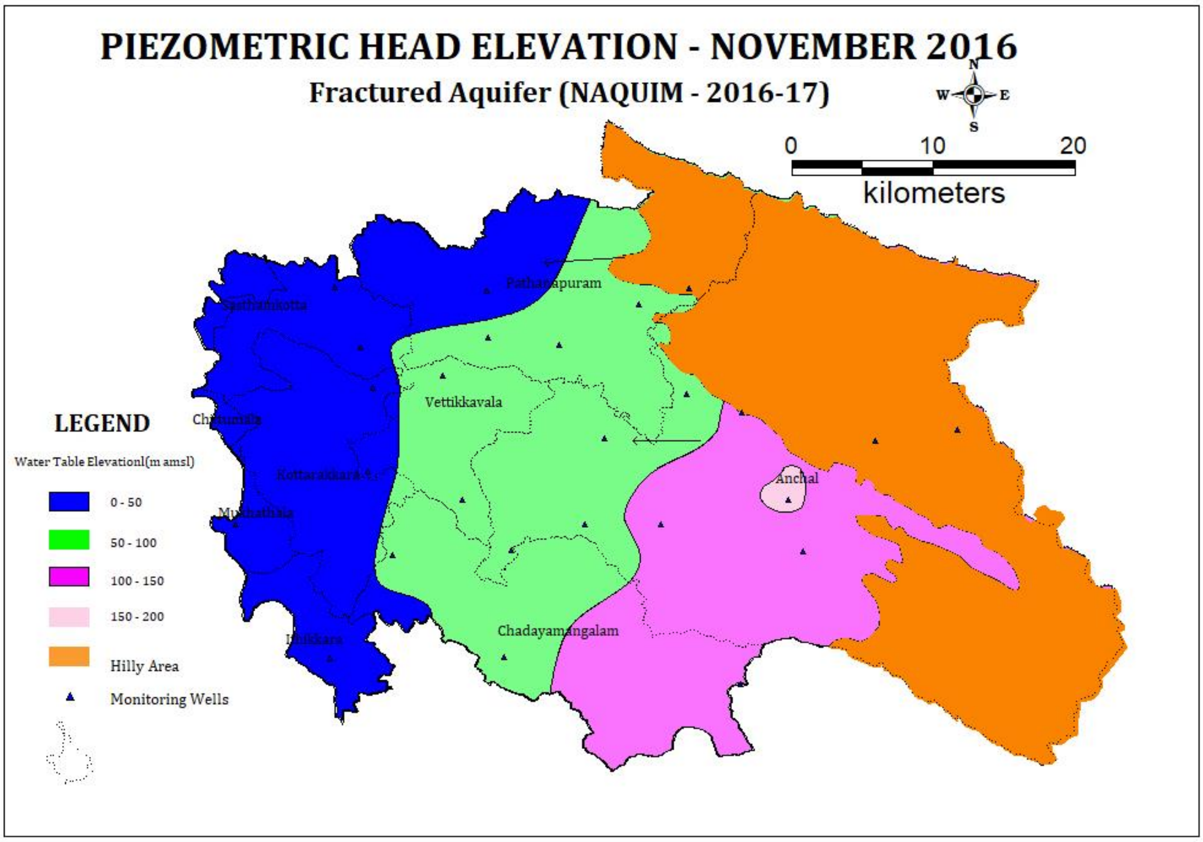


Figure 3.17: Piezometric head of Deeper Aquifers

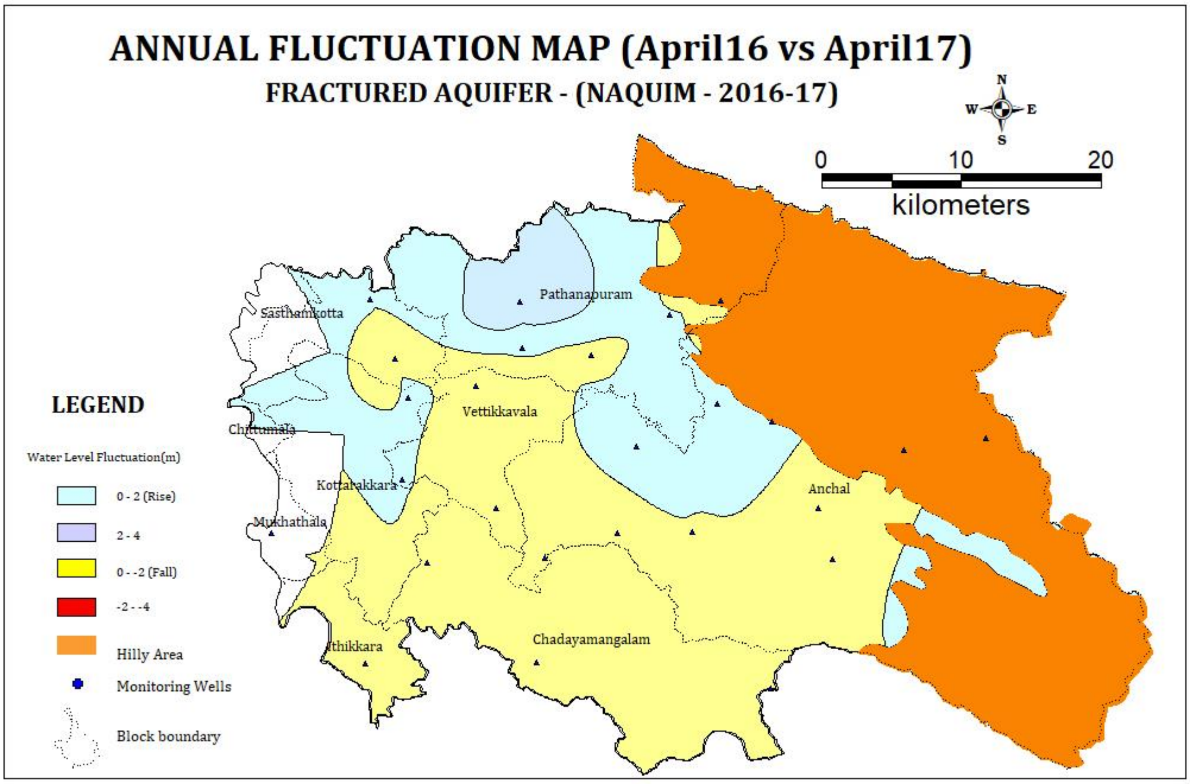


Figure 3.18: Annual Water Level Fluctuation map of Deeper Aquifers

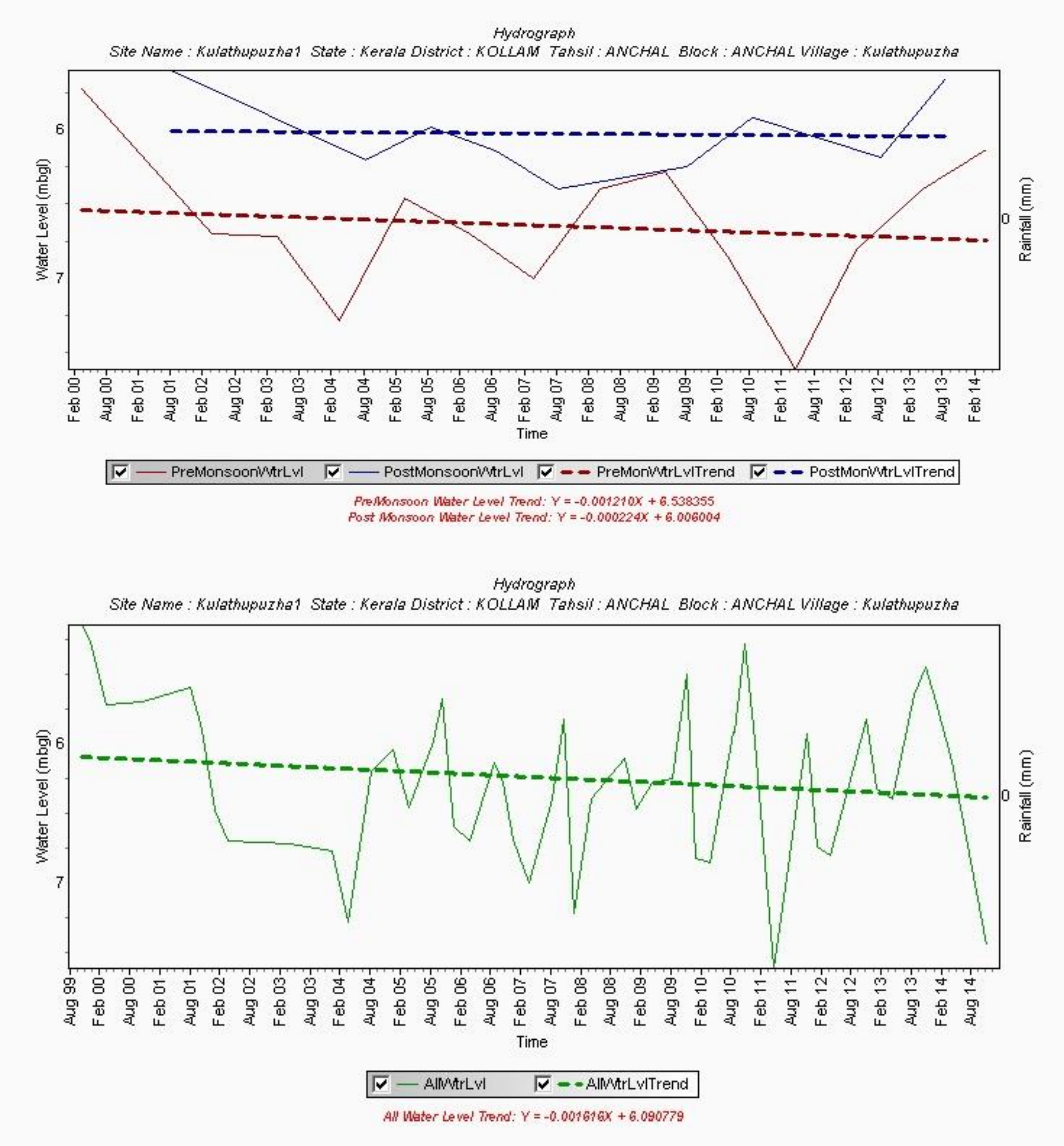


Figure 3.19 Hydrographs of Deeper aquifers

3.6 Structure and Ground Water Potential

The occurrence and movement of ground water in an area depends upon the intensity of fractures, joints and lineaments. Lineaments are surface manifestations of structurally controlled features, such as joints, straight course of streams and vegetation alignment. Lineaments are linear or curvilinear features and are identifiable by their long, narrow and approximately straight alignments visible as tonal differences with respect to other terrain surfaces. Lineaments being weak zones, usually serve as conduits for movement or accumulation of groundwater in the subsurface; therefore, lineaments analysis of an area when extracted from the remotely sensed data give important information on subsurface features that may control the movement and/or storage of groundwater.

To find out the relationship exists between lineaments and ground water yield of wells in the area, lineament direction was extracted from the available lineament map and is shown in **Figure 3.20.** The lineament identified in the area trends in NNE-SSW, NE-SW, ESE-WNW, NW-SE and NNW-SSE. The prominent lineaments trend in NNE- SSW. Intersection of lineaments was also noticed at Aryankavu where yield is very high. A lineament buffer map has been prepared with a buffer zone of 300 m to identify the potential lineament direction. But the analysis has not been completed since the lineament identified in the earlier literature is not matching with the lineament orientation of the present map. Thus, it has been decided to extract the lineament from satellite data and will continue in further studies.

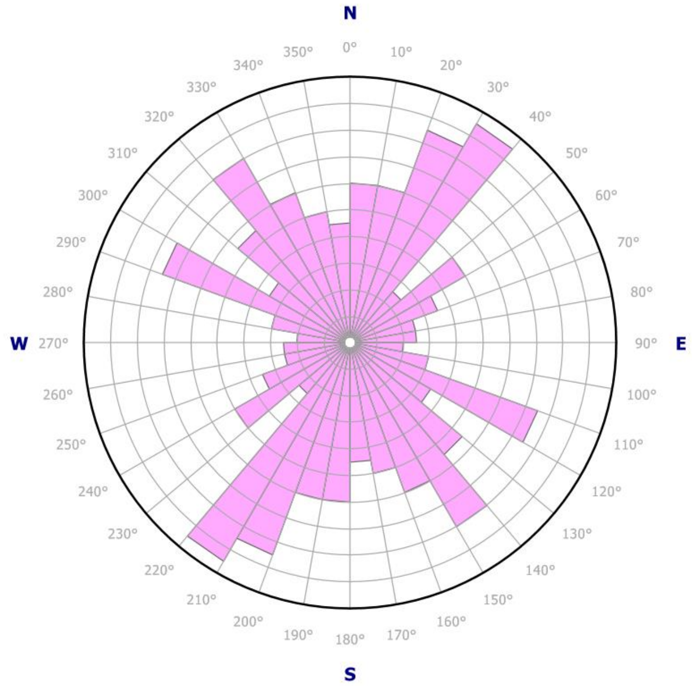


Figure 3.20: Rose Diagram showing the lineament trend

3.6.1 Aquifer Characteristics

The geologic setting is much more enigmatic in the fractured-rock groundwater environment. The wells completed in fractured rock are invaluable in many areas as a source for domestic wells, and occasionally serve as a reliable source for higher production; they tend to be less predictable and less reliable than other wells. The reason lies in the fundamental difference in the way fractured-rock aquifers transmit water. In a fractured-rock environment, water can only be transmitted through cracks and fractures that resulted from tectonic activities and the structural deformations acted on the rock over time. Fractures create secondary permeability and the capacity of the aquifer depends upon the amount of open space (the size of the fracture) and lateral extent of the aquifer (fracture zones are not consistent throughout the rock). To understand the hydraulic properties of the fractured aquifer system, pumping tests has been carried out and the results are given in **Annexure IV.** The transmissivity values vary from 0.83 to 80.6 m^2/day in granite biotite gneiss and it ranges from 0.43 to 52.84 m^2/day in wells drilled in khondalitic terrain.

An analysis of the yields of the bore wells constructed indicate that 5% of them yield more than 20 lps, 19% yield between 10 to 20 lps and 57 % yield between 1 and 10 lps and 19% yield less than 1 lps. The yield of bore wells drilled in granite biotite gneiss is better compared to khondlite group of rocks.

4 GROUND WATER QUALITY

The chemical quality of ground water depends upon the water quality of the recharge zone, the solubility of chemical constituents of the geologic materials, residence time, the amount of dissolved carbon dioxide and the various reaction that occur along its flow path. In addition to these natural changes, anthropogenic activities such as sewage disposal, agricultural practices and industrial pollution also affect the ground water quality.

The quality aspects of ground water have been studied using the analytical data of ground water samples collected from Ground Water Quality Monitoring stations of CGWB and GWD. Historical chemical quality data of selected wells has been used to study the temporal variation in the groundwater quality. The chemical quality of water samples collected during exploration activities of CGWB and water quality data of GWD has been used to study the deep fractured aquifers. The sampling locations are shown in **Figure 4.1.**

4.1 Quality of Ground Water in Phreatic Aquifer

To characterize the chemical quality of shallow phreatic aquifer, the hydrochemical data of ground water samples collected from Ground Water Quality Stations of CGWB (13 nos) and GWD (10nos) during April 2017 have been used. The samples were analyzed for physical parameters, major cations and anions using the standard procedures recommended by APHA (APHA, 1998).

In general, groundwater in this area is colourless, odourless and slightly alkaline in nature with majority of the samples showing pH >7. The descriptive statistics of physical parameters and various chemical constituents in the ground water samples analysed for the study area are furnished in **Table 4.1** and the entire analytical results are given in **Table 4.2**. The data reveals that there is a considerable spatial variation in ground water chemistry of phreatic aquifer particularly in the case of electrical conductivity followed by bicarbonate, total hardness, sodium and chloride concentration.

Table 4.1 Statistics of physical and chemical constituents of phreatic aquifer

Sl No	Parameters	No: of samples	Min	Max	Mean	Median	Std Deviation	CV(%)
1	pH	23	3.66	8.6	7.21	7.35	1.05	15
2	EC	23	47	640	205.78	146	160.07	78
3	TH	23	8	135	41.17	24	38.54	94
4	Ca	23	1.6	32	10.03	5.6	9.41	94
5	Mg	23	0	28	4.03	2.4	5.95	147
6	Na	23	3.6	142	26.17	20	29.91	114
7	K	23	0.23	18	4.66	2.9	5.00	107
8	CO_3	23	0	35	3.37	0	8.48	252
9	HCO_3	23	0	276	65.61	26	80.40	123
10	SO_4	23	0	44	6.93	4	9.37	135
11	Cl	23	7.1	54	24.33	19	14.43	59
12	F	23	0	3.8	0.34	0.14	0.78	229
13	NO_3	23	0.06	30	7.06	3.6	8.60	122

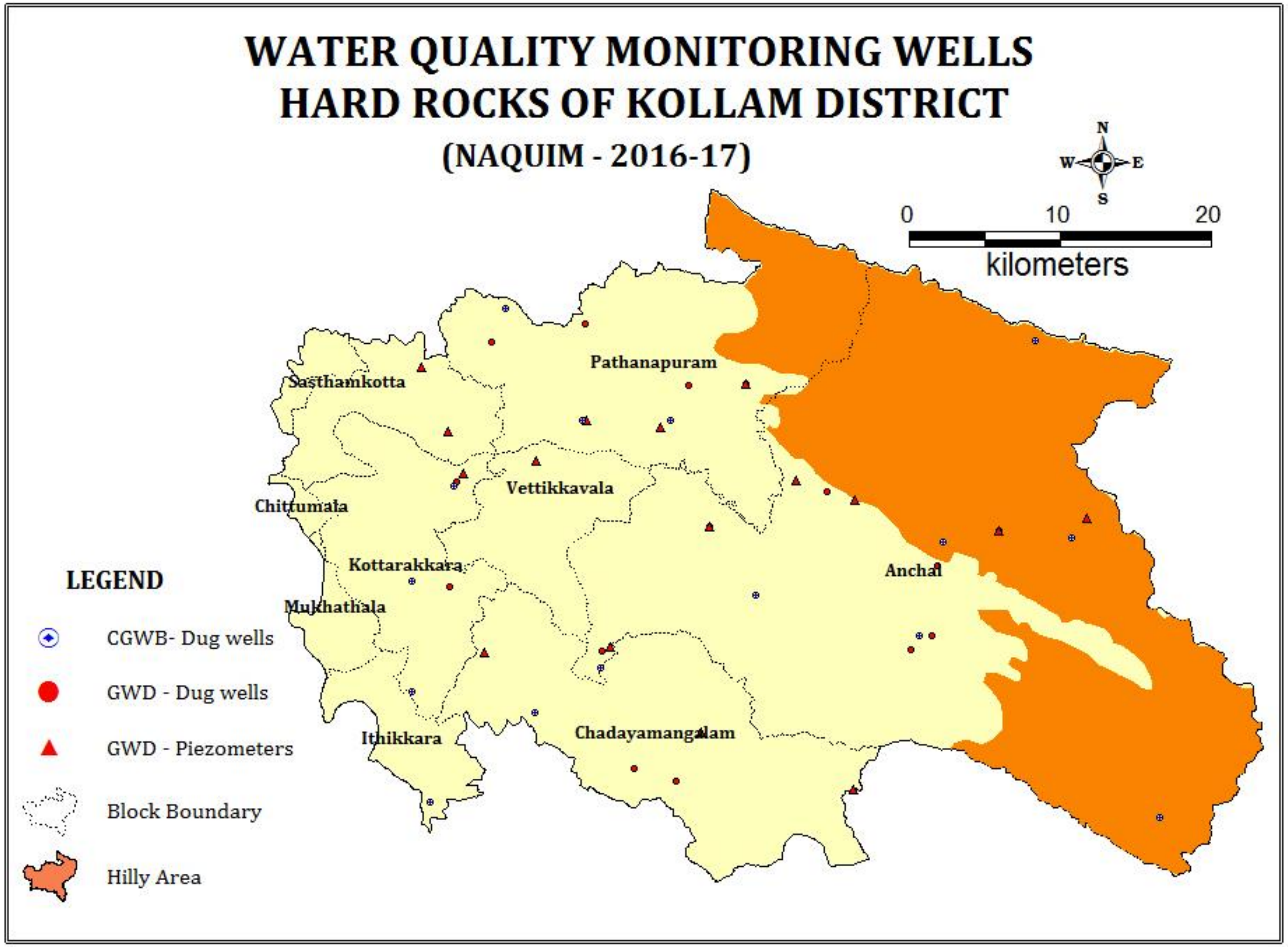


Figure 4.1: Location of water quality monitoring wells in study area

Table 4.2 Chemical Analysis data of ground water samples collected from phreatic aquifer(in ppm)

Sl No	Location	Agency	pH	EC	Total Hardness	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
1	Achenkovil	CGWB	7.81	250	74	20	5.8	9.9	18	0	115	14	19	0.66	15
2	Avaneeswaram	CGWB	7.41	66	10	3.2	0.49	6.4	2.4	0	24	1	13	0.06	2
3	Ayoor	CGWB	6.83	57	12	4	0.49	5.4	2.7	0	24	1	7.1	0.12	7.9
4	Chenkulam	CGWB	7.01	107	16	4.8	0.97	16	1.7	0	32	0	17	0.6	13
5	Kottarakkara	CGWB	7.63	210	50	14	3.9	20	5.5	0	81	13	28	0.26	6.3
6	Kulathupuzha	CGWB	6.92	270	24	5.6	2.4	35	16	0	17	12	54	0.14	30
7	Kunnada	CGWB	7.35	103	10	3.2	0.49	12	5.8	0	22	1	19	0.06	4.7
8	Kuttavettur	CGWB	7.5	183	38	11	2.4	20	1.4	0	44	2.5	31	0.36	21
9	Madathara	CGWB	7.11	72	22	6.4	1.5	16	4.8	0	20	9	28	0	9
10	Nallila	CGWB	3.66	146	10	4	Trace	8.4	2	0	0	2.5	16	0.04	26
11	Punalur II	CGWB	7.72	138	38	11	2.4	3.6	3.3	0	46	8	11	0.18	9.9
12	Thenmala	CGWB	7.06	47	8	1.6	0.97	4.2	1.3	0	9.8	1	8.5	0.26	3.6
13	Yeroor	CGWB	7.94	500	105	32	6.1	56	5.3	0	256	15	53	0.5	4.1
14	Ayoor	GWD	7.8	114	15	2	2.44	66	4.2	14.4	124	2.3	19	0.25	3.6
15	Karavoor	GWD	8.4	344	135	8	28	28	2.9	17	148	7	20	0.01	0.3
16	Kazhuthurutty	GWD	8.6	640	70	24	1.2	142	16.1	35	276	44	38	0.25	0.06
17	Kulathupuzha	GWD	5.2	244	20	4	2.4	27	1.8	0	26	4.5	42	0	0.27
18	Pathanapuram	GWD	7	167	25	4	3.7	26	3.1	0	11	4	30	0.01	2.9
19	Pattazhy	GWD	7.2	87	25	4	3.7	6.4	1.3	0	26	1.1	10	0	1.6
20	Piravanthur	GWD	8.4	366	120	32	9.7	26.4	1.8	11	182	5	21	0.01	0.2
21	Thenmala	GWD	6.7	50	15	4	1.2	6.7	0.23	0	18	0.5	8	0.01	0.11
22	Veliyam	GWD	6.9	111	15	6	0	27	2.2	0	4.9	1.8	17	3.8	0.11
23	Veliyam	GWD	7.7	461	90	22	8.5	33.5	3.3	0	2.44	9.2	50	0.25	0.77

The statistical analysis shows that the differences in the mean and median values of the sample distribution except in the case of pH indicate that the chemical constituents are not normally distributed. Among the major constituents, sodium (Na) from the cation category has the highest median concentration whereas in the case of anion, bicarbonate (HCO_3) shows the highest median value. On comparison of the standard deviation values of cations and anions, it is noticed that major anions show a wide distribution with the high values. The spatial distribution of specific electrical conductance is shown in **Figure 4.2.** The EC value varies from 47 to 640 µS/cm.

To ascertain the suitability of water for drinking purpose, samples were categorized based on the permissible limits of standards as recommended by BIS and the results are given in **Table 4.3**. It is observed that, in general, ground water is suitable for drinking purpose with all the major constituents within the desirable limit.

Table 4.3 Suitability of Ground Water for Drinking Purpose

Sl. No	**Parameters**	**BIS Standards**		**Range**		
		Desirable	Permissible	Min	Max	No: of samples exceeding limit
1	pH	**6.5-8.5**	**6.5-9.2**	3.66	8.6	0
2	EC in µS/cm at 25^0 C	**750**	**2250**	47	640	0
3	Total Hardness as $CaCO_3$ (mg/l)	**300**	**600**	8	135	0
4	Calcium(mg/l)	**75**	**200**	1.6	32	0
5	Magnesium(mg/l)	**30**	**100**	0	28	0
6	Sulphate(mg/l)	**200**	**400**	0	44	0
7	Chloride(mg/l)	**250**	**1000**	7.1	54	0
8	Nitrate(mg/l)	**45**	**100**	0.06	30	0

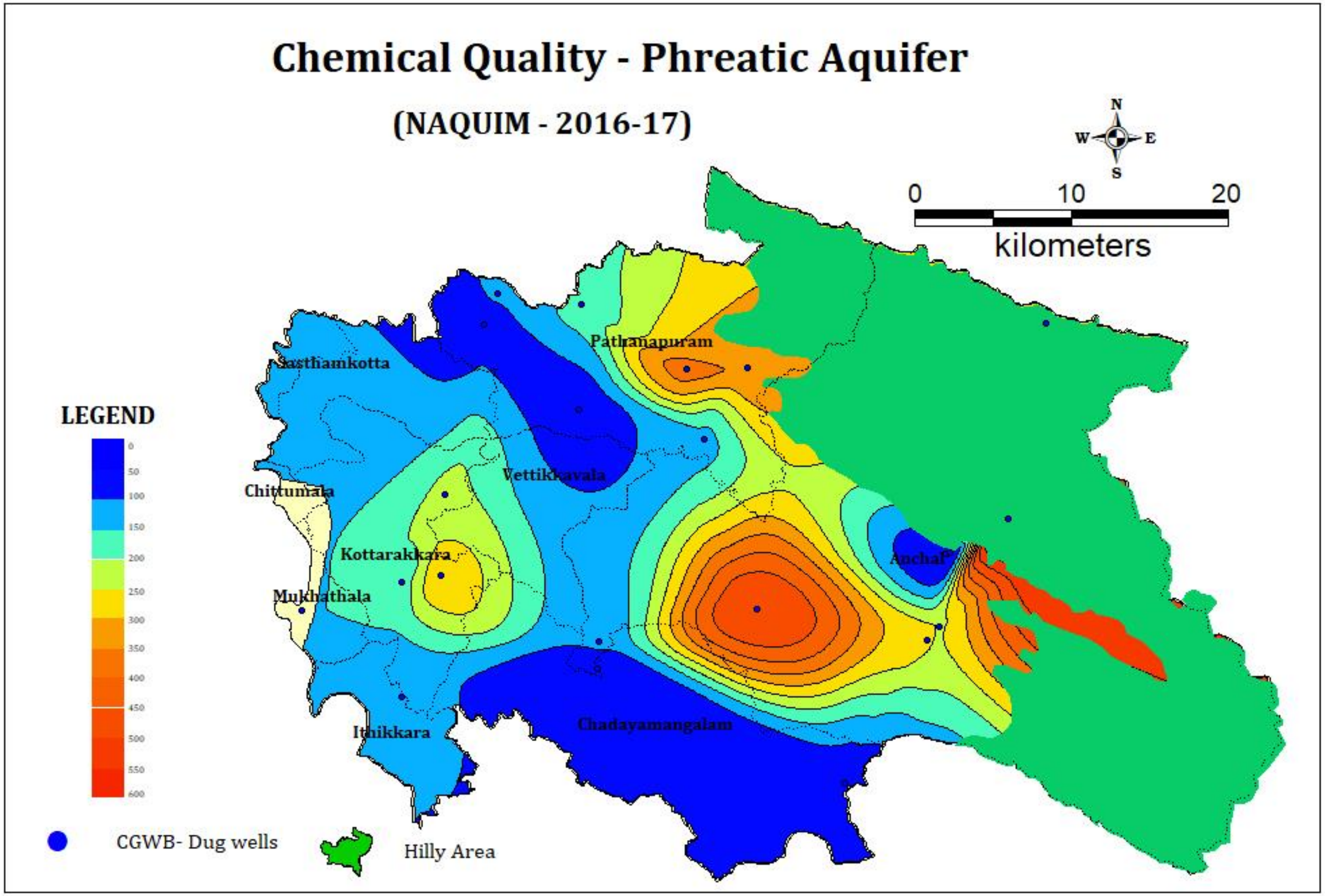


Figure 4.2: Spatial distribution of Electrical Conductivity in Phreatic Aquifer

4.1.1 Ground Water Types

Natural waters are classified according to the type and degree of mineralization to facilitate interpretation as to their origin and interaction with the hydrogeological environment using Hill Pipers Trilinear diagram. The hydrochemical data have been plotted in Hill Piper Trilinear diagram to determine the type of ground water available in phreatic aquifer and is shown in **Figure 4.3**. Ground water samples of CGWB are marked in blue colour and GWD as green colour. The plot of the sample indicates that different types of ground water are available in the phreatic zone. From the plotting position of samples in the diamond shaped field of the diagram, it is clear that majority of the sample fall in mixed type followed by Sodium chloride type of water.

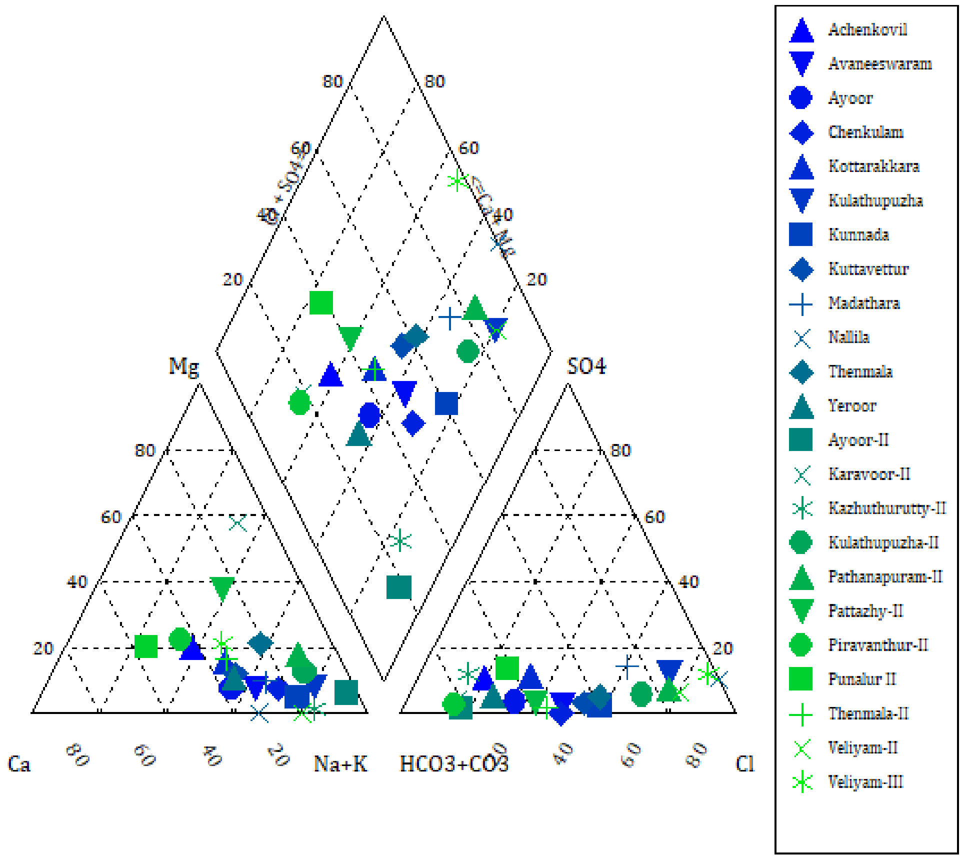


Figure 4.3: Hill Piper diagram showing plots of Phreatic Aquifer

The plot clearly brings out the hydrogeochemical variations in ground water in phreatic aquifers. Alkali metals (Na) is found to exceed alkaline earth metals (Ca+Mg) in 78% samples. Similarly weak acidic ions exceeds the strong acidic ions in 70% of the samples. 21% samples show predominance of alkaline earth metals over alkali metals. It is observed that majority of samples are fall in mixed type, only less than 10% of the water samples show problems related to foaming, salinity and hardness.

During 2010, under IWIN programme ground water samples were collected during pre-monsoon and post-monsoon period and the hydrochemical data is given in **Table 4.4 & 4.5** respectively. This data has been used to understand the temporal variations.

Table 4.4 Chemical Analysis data of ground water samples collected from phreatic aquifer (IWIN: Pre-monsoon, April 2010)

Sl No	SITE_NAME	pH	EC	TH	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
1	Avaneswaram	7.66	81	24	7.2	1.5	5.2	4.3	0	29	1.2	7.1	0.25	6
2	Chadayamangalam (R1)		156	14	4	0.98	17	4.5			0.22	26	0.44	2
3	Channapetta	8.49	260	38	8.8	3.9	26	6.6	7.2	20	4.7	37	0.28	28
4	Edamon	7.43	51	12	4.8	0.01	3.7	2.2	0	12	1.6	7.1	0.17	6.3
5	Kadakkal	5.89	470	75	18	7.32	34	32	0	-99	1.3	71	1.37	119
6	Kottakayam	7.56	51	14	4.8	0.49	3.4	0.9	0	22	0.66	2.8	0.27	1.2
7	Kottarakara (R1)	8.45	200	38	11	2.57	19	5.7	4.8	27	3.2	30	0.15	17
8	Kulakada	8.49	280	104	37	2.84	10	4.7	7.2	100	12	14	0.22	4.1
9	Kulathupuzha	7.54	270	34	10	2.2	26	8.9	0	22	2.2	41	0.2	46
10	Kunnada	8.05	97	22	7.2	0.98	8	4.7	0	27	1.2	14	0.13	7.4
11	Kutavettur	7.64	125	32	10	1.71	10	1	0	34	3.2	13	0.22	14
12	Nallila	7.1	84	22	7.2	0.98	5.9	1.7	0	15	1.8	13	0.08	14
13	Pavitreswaram	7.89	100	12	3.2	0.98	11	2.5	0	9.8	1.5	20	0.31	3.3
14	Punnala	8.25	104	22	7.2	0.97	9	4.7	0	34	1.8	11	0.25	6.2

Table 4.5 Chemical Analysis data of ground water samples collected from phreatic aquifer (IWIN: Post-monsoon, November 2010)

Sl No	SITE_NAME	pH	EC	TH	CA	MG	NA	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
1	Avaneswaram	7.54	59	12	3.2	0.98	6	3.7	0	17	0.98	7.1	0.05	5.5
2	Chadayamangalam (R1)	7.36	192	4	1.6	0	32	3.7	0	12	0.2	48	0.09	13
3	Channapetta	7.03	340	40	8.8	4.39	46	6.8	0	7.3	2.2	62	0.06	69
4	Edamon	7.33	37	6	2.4	0	4.1	1.8	0	9.8	0.59	4.3	0.01	4.5
5	Kadakkal	6	194	26	8	1.47	16	13	0	15		31	0.06	30
6	Kottakayam	7.48	49	10	3.2	0.49	4.4	1.2	0	12	0	5.7	0.04	7.8
7	Kottarakara (R1)	7.57	146	24	6.4	1.95	16	3.5	0	20	1.7	30	0.06	11
8	Kulakada	7.57	98	18	5.6	0.98	12	1.4	0	22	0.98	17	0.06	8.3
9	Kulathupuzha	7.64	230	30	8	2.44	26	9.2	0	20	5.2	40	0.06	32
10	Kunnada	7.06	76	6	2.4	0	11	2.9	0	4.9	0.79	20	0	4.6
11	Kutavettur	8.33	128	20	5.6	1.47	16	1	0	24	1.2	21	0	15
12	Nallila	6.44	88	10	2.4	0.98	11	1.4	0	4.9	1.1	18	0.04	10
13	Pavitreswaram	7.22	47	4	0.8	0.49	5.7	1.7	0	4.9	0.69	11	0.06	0.64
14	Punnala	7.46	98	16	4	1.46	12	3.6	0	15	1.6	23	0	6.1

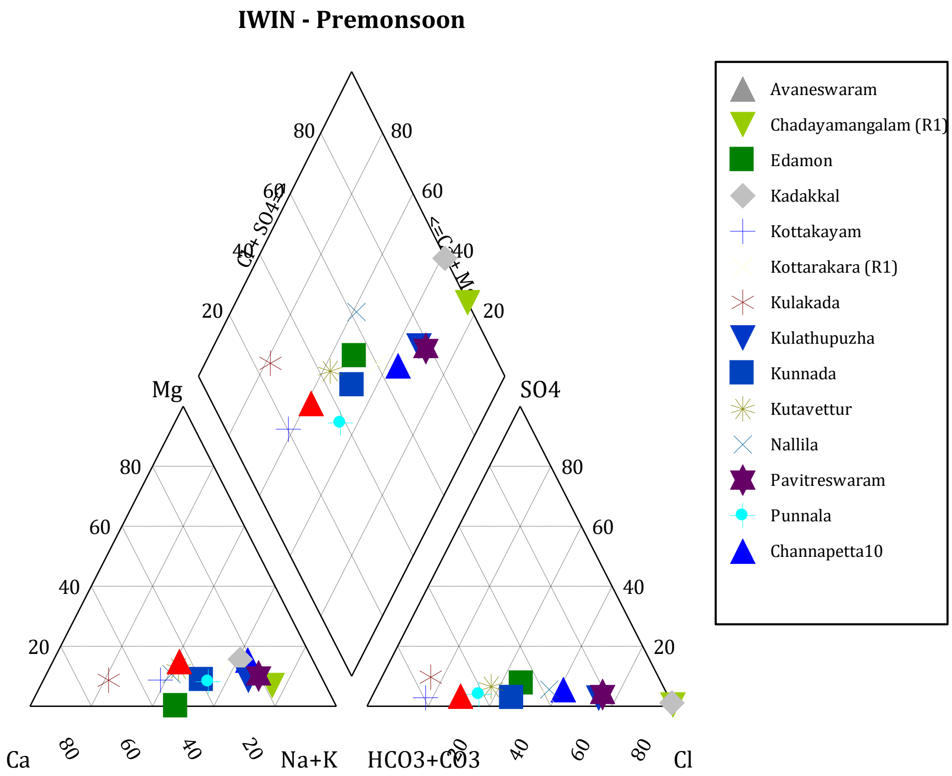


Figure 4.4: Hill Piper diagram showing plots of Phreatic Aquifer- IWIN- Pre-monsoon

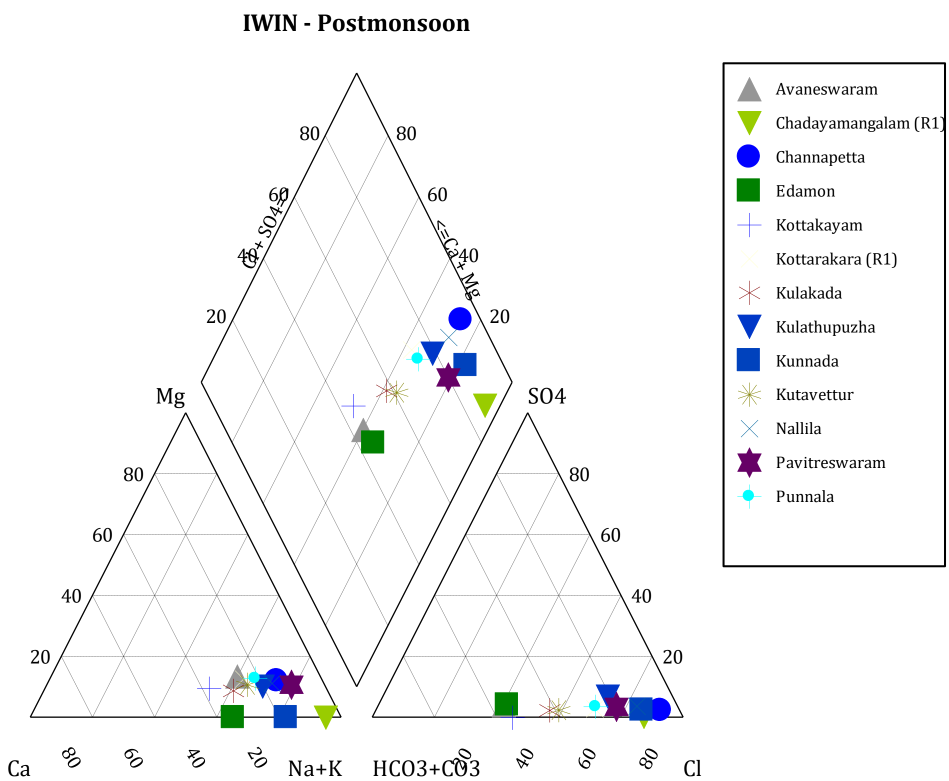


Figure 4.5: Hill Piper diagram showing plots of Phreatic Aquifer- IWIN- Post-monsoon

By comparing the plots, it is seen that there is a shift in the hydrochemical facies of ground water before and after monsoon. During pre-monsoon period, there is an equal distribution of samples in the Na-Cl type and Ca- HCO_3 type of ground water but in the post-monsoon period entire samples fall in Na-Cl type. This shift can be attributed to the leaching of salt/ minerals into the phreatic aquifer due to rainfall.

4.1.2 Long Term Quality Variations

Water quality data of the pre-monsoon period for selected Ground Water Monitoring Wells in the study area from 1981 has been used to study the long-term temporal variation in the quality of phreatic aquifer. The long-term variation was studied mainly using electrical conductivity of ground water samples, as represented in **Figure 4.6**. It is observed that the pattern of fluctuation of chloride concentration is similar to electrical conductivity in the case of Achenkovil well. Since there is data gap in the chloride data which is not included in rest of the stations. The quality doesn't show any noticeable trend variation in any of the wells. It is observed that year to year fluctuations are of high amplitude probably in response to variation in the recharge and discharge facilitated by the rainfall.

4.1.3 Origin of Groundwater Chemistry- Phreatic Aquifer

The chemical composition of subsurface water is controlled by various factors such as the amount of dissolved CO_2 in rain water, CO_2 content in the root zone of the soil, the chemical composition of the rocks through which the water percolates and the duration of contact between the water and the soil/rock. Studies reveal that 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.

Gibbs (1970) concluded that three mechanisms viz. atmospheric precipitation, rock dominance and evaporation-crystallization process, are the major factors controlling the composition of **t**he dissolved salts of the world's water. Second order factors, such as relief, vegetation and composition of material in the basin cause only minor deviations within the zones dominated by the three above prime factors. The diagram of Gibbs (1970) forms an excellent tool in understanding the chemical evolution of the surface water and groundwater. Chemical analysis data of ground water samples collected from phreatic aquifers during April 16 has been plotted on the Gibbs diagram - TDS vs Na^+/Na^++Ca^{2+} (**Figure 4.7**) and TDS vs $Cl^-/Cl^-+HCO_3^-$ (**Figure 4.8**). In the study area, the ground water shows a wide variation in the total dissolved solids ranging from 30.08(Location: Thenmala) to 409.6 ppm (Location: Kazhuthuruthy) ppm with a median value of 93.44 ppm. All the samples fall in fresh water category with a TDS value less than 1000 mg/l.

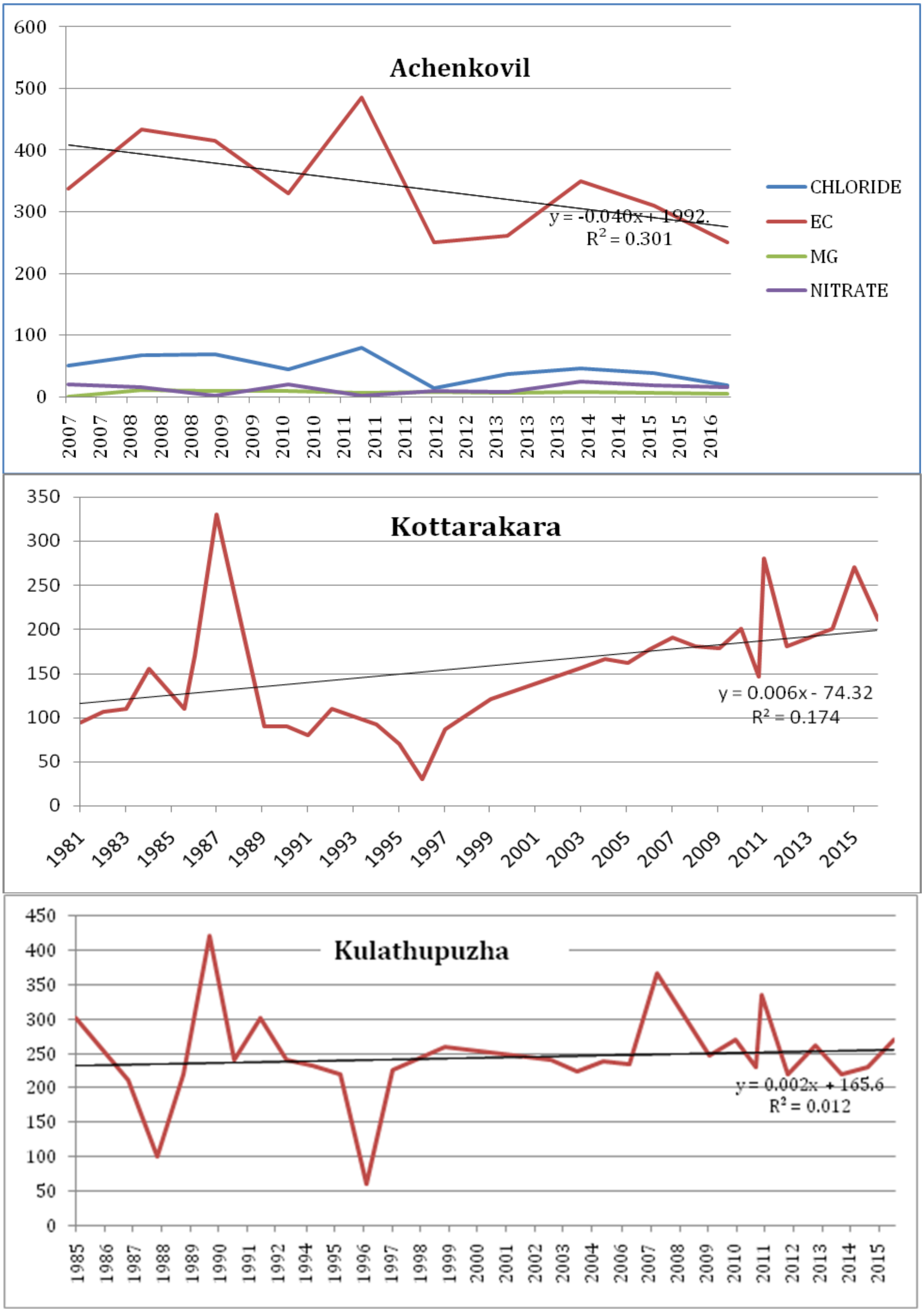


Figure 4.6: Long-term Water Quality Trends in Phreatic Aquifer

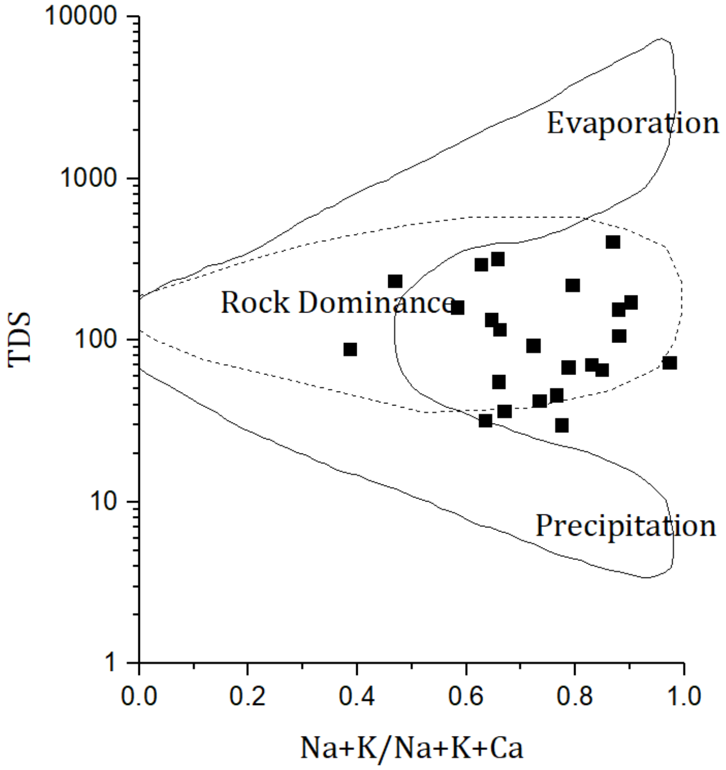


Figure 4.7: Gibb's Diagram showing plots of ground water samples - (Na+K)/(Na+K+Ca) Vs TDS –Phreatic Aquifer

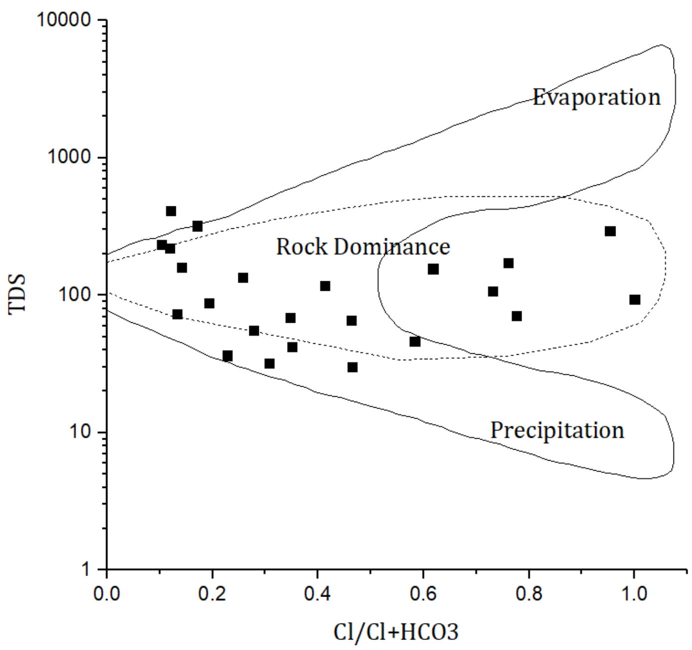


Figure 4.8 Gibb's Diagram showing plots of ground water samples – Cl/(Cl+HCO$_3$) Vs TDS-Phreatic Aquifer

From the figure, it is observed that majority of the sample fall in rock dominance area. Hence it can be concluded that rock water interaction is the main process controlling the chemical composition of groundwater in the study area.

4.2 Quality of Ground Water in Deep Fractured Aquifer

The chemical quality of deep fractured aquifer is characterized by using the hydrochemical data of ground water samples collected during exploration activities by CGWB (8 nos) and GWD (7nos) during April 2017 have been used. The samples were analyzed for physical parameters, major cations and anions using the standard procedures recommended by APHA (APHA, 1998).

The descriptive statistics of physical parameters and various chemical constituents in the ground water samples analysed for the study area and are furnished in **Table 4.6** and the entire analytical results are given in **Table 4.7**. In general, groundwater in the deeper fractured aquifer is colourless, odourless and slightly alkaline in nature with majority of the samples showing pH greater than 7. Similar to phreatic aquifer, in deep fractured aquifer also there is a considerable spatial variation in ground water chemistry particularly in the case of electrical conductivity followed by bicarbonate, total hardness, sulphate, calcium and chloride concentration.

Table 4.6 Statistics of Physical and Chemical constituents of Deep Fractured Aquifer

Parameters	No: of samples	Min	Max	Mean	Median	Std Deviation	CV(%)
pH	17	6.2	10.24	7.97	7.98	1.11	13.97
EC	17	75	443	225.59	215	117.95	52.28
TH	17	10	125	49.82	54	34.23	68.70
Ca	17	1.2	59	24.33	17	17.68	72.66
Mg	17	0.63	9.4	3.15	2.5	2.27	72.10
Na	17	2	30	11.81	8	8.30	70.28
K	17	1	26	5.00	3.7	6.00	120.17
CO_3	17	0	14	0.83	0	3.39	410.75
HCO_3	17	4.9	178	67.25	53	47.80	71.08
SO_4	17	4.3	93	24.62	12	27.28	110.79
Cl	17	0.01	45	7.77	4.3	10.67	137.32
NO_3	12	0	23	3.46	0.5	6.70	194.01

The hydrochemical data have been plotted in Hill Piper Trilinear diagram to determine the type of ground water available in deep fractured aquifer and is shown in **Figure 4.9**. Ground water samples of CGWB are marked in blue colour and GWD as green colour. The plot of the sample indicates that different types of ground water are available in the deep fractured zone. Based on the plotting positions of samples in the diagram, the ground water in the fractured aquifer may be grouped into Na – HCO_3, Ca- Mg – HCO_3 and Na-Cl type. The plot clearly brings out the hydrogeochemical variations in ground water in these aquifers. Alkali metals (Na) is found to exceed alkaline earth metals (Ca+Mg) in 65% samples. Similarly weak acidic ions exceeds the strong acidic ions in 70% of the samples. 35% samples show predominance of alkaline earth metals over alkali metals.

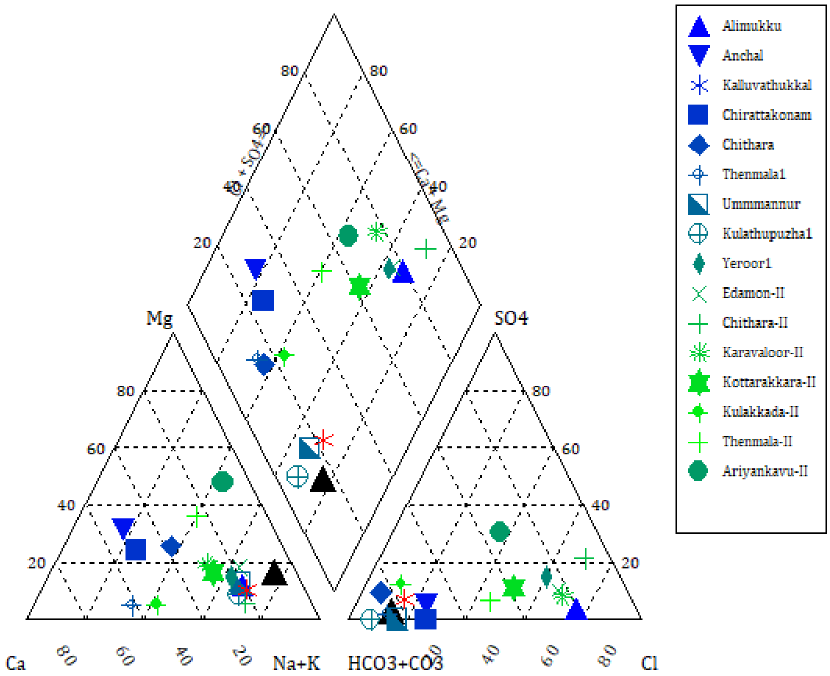


Figure 4.9: Hill Piper diagram showing plots of Deep Fractured Aquifer

4.2.1 Origin of Groundwater Chemistry – Deep Fractured Aquifer

Gibbs diagram is widely used to establish the relationship of water composition and aquifer lithological characteristics. Similar to ground water samples from phreatic aquifer, chemical analysis data of ground water samples collected from bore wells has been plotted on the Gibbs diagram - TDS vs Na^+/Na^++Ca^{2+} (**Figure 4.10**) and TDS vs $Cl^-/Cl^-+HCO_3^-$ (**Figure 4.11**). In the study area, the ground water shows a wide variation in the total dissolved solids ranging from 48(Location: Edamon, Thenmala) to 284ppm (Location: Ariyankavu) with a median value of 137.6 ppm. All the samples fall in fresh water category with a TDS value less than 1000 mg/l.

From the figure, it is observed that chemical data were mainly around the chemical weathering of rock-forming mineral zone and therefore indicated that the chemical composition of these water were mainly controlled by weathering reactions and can be modified from the underlying biotite gneisses, biotite schists, khondalite and clay as well as from dissolution of both carbonate and silicate minerals from them and by the interaction between the aquifer rocks and groundwater.

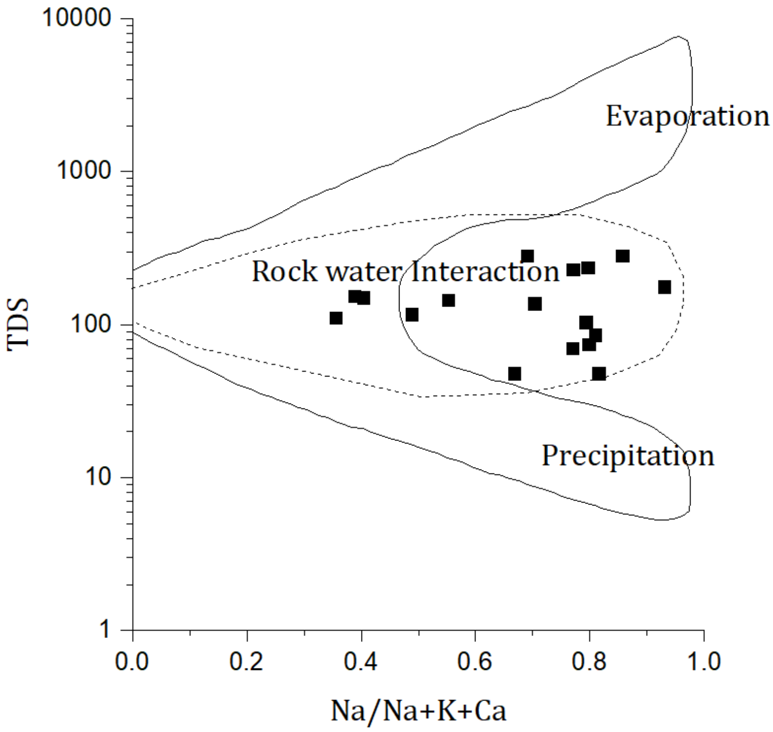


Figure 4.10 Gibb's Diagram showing plots of ground water samples - (Na+K)/(Na+K+Ca) Vs TDS – Deep Fractured Aquifer

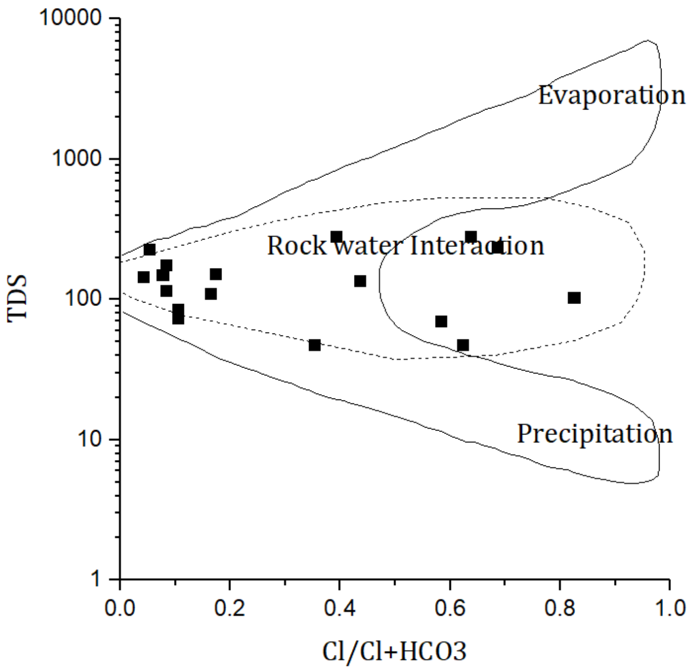


Figure 4.11 Gibb's Diagram showing plots of ground water samples – Cl/(Cl+HCO_3) Vs TDS– Deep Fractured Aquifer

Table 4.7 Chemical Analysis data of ground water samples collected from fractured aquifer(in ppm)

Sl No	Location	Agency	WellType	pH	EC	Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4	NO_3
1	Alimukku	CGWB	Bore Well	8.85	370	56	2.5	15	5.3	0.01	42	91	6	23
2	Anchal	CGWB	Bore Well	10.24	174	1.2	3.2	8	3	0.01	51	10	3	0.3
3	Chirattakonam	CGWB	Bore Well	7.98	240	15	4	30	8.7	0	124	26	0.01	
4	Chithara	CGWB	Bore Well	9.04	227	12	4	13	5.3	0.01	98	4.3	8.5	
5	Kalluvathukkal	CGWB	Bore Well	8.17	134	18	2.3	4.8	1.5	0	61	7.1	4.3	
6	Kulathupuzha1	CGWB	Bore Well	8.55	359	59	1.3	18	4	14	178	10	0.01	
7	Pathanapuram	CGWB	Bore Well	9.12	277	41	1.5	3.2	4.8	0.01	120	11	3.1	0.5
8	Thenmala1	CGWB	Bore Well		235	11	2.5	20	1	0.01	102	8.5	1.8	0.5
9	Ummmannur	CGWB	Bore Well	8.15	116	14	1.8	4	1.5	0	49	5.7	0.01	
10	Yeroor1	CGWB	Bore Well	7.52	110	14	2	4.8	1.9	0	15	21	7	6.6
11	Ariyankavu-II	GWD	Bore Well	6.8	443	40	7.8	8	26	0	62	40	45	7.9
12	Chithara-II	GWD	Bore Well	7.3	162	27	3.6	8	1.22	0	4.9	23	9.5	0
13	Edamon-II	GWD	Bore Well	6.2	75	7	1.8	2	1.22	0	7.3	12	2.5	1.3
14	Karavaloor-II	GWD	Bore Well	7.4	440	44	9.4	24	9.7	0	53	93	15	0.3
15	Kottarakkara-II	GWD	Bore Well	6.6	215	30	3.1	14	4.9	0	44	34	10	0.17
16	Kulakkada-II	GWD	Bore Well	7.7	183	17	2.1	20	1.2	0	110	10	14	0.4
17	Thenmala-II	GWD	Bore Well	6.6	75	7.4	0.63	4	3.7	0	22	12	2.3	0.5

5.0 AQUIFER MAP

The areal and vertical extension of the major aquifers is fundamental to the determination of groundwater availability of an area. The National Aquifer Mapping envisages integration of information available on soil types, agro-climatic conditions, geomorphology, geology, hydrogeology, hydrochemistry, cropping pattern, irrigation statistics, forest cover etc., on a GIS platform and resulted in the preparation of Aquifer maps.

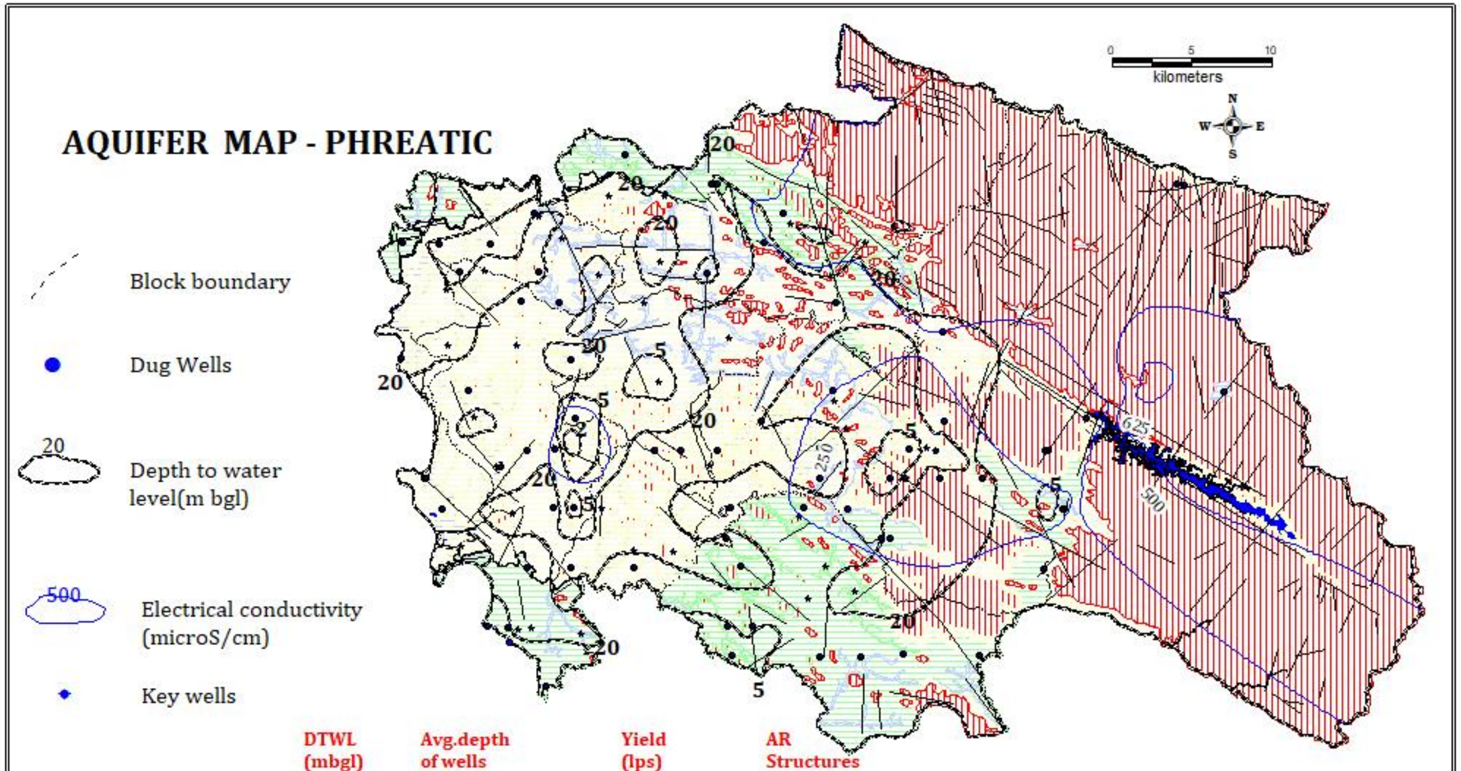
5.1 Phreatic Aquifer

By integrating the available data along with aquifer mapping, an aquifer map of the phreatic aquifer has been prepared which is shown in **Figure 5.1**. The final map categorised the area into four categories based on the type of aquifer, depth to water level, average depth of the wells, sustainable yield, ground water quality as well as the groundwater prospects.

1. **Category I- Alluvium:** Mainly seen along the flood plains, alluvial plains and sand bars of Kallada and Ithikkara River which are the more promising sites of groundwater. The aquifer materials possess high porosity and permeability. The depth to water level is shallow with a yield of 200 lps which can sustain 3hrs of pumping. These are the main recharge zones mainly composed of loose sediments and homogeneity exists in the aquifer material but these areas are under the high threat of sand mining and waste disposal.
2. **Category II - Laterite:** The weathered laterite seen in the southern parts of Chadyamangalam & northern parts of Pathanapuram block where the thickness of this aquifer varies from 10 -20 m belongs to this category. Normally, dug wells collapse at the lithomargic zone and groundwater occurs at a deep-water level. Wells dried up during summer shows the less yielding capacity of this aquifer. Recharge pits and percolation tanks can be suggested in this aquifer to maintain the groundwater level during lean period.
3. **Category III - Laterite II:** This type of aquifer covers the major part of the midland area represented by undulating topography dotted with residual hills and residual mounts with varying laterite thickness. Yield mainly controlled by overburden thickness. Check dams, gully plug and nala bunds can be suggested in the area.
4. **Category IV - Massive rocks:** The hilly area seen on the western part of the study area are characterised by structural and deudational hills with high drainage density and thin soil cover are included under this category. This represents the run-off zone with low groundwater prospects. Since the slopes are more than 20^0, these areas are totally discarded from resource estimation. The intervening valleys with gentle to moderate slope where there is a high degree of weathering contribute moderate to high groundwater potential yield. No need of any kind of artificial recharge structures in this zone.

5.2 Fractured Aquifer

By integrating the available exploration details such as lithologs, casing depth, puming details, depth to water level, lineament map and ground water quality data, an aquifer map for fractured aquifer is prepared and is shown in **Figure 5.2.** The area is categorized under four groups. The success rate of wells drilled in hard rocks depends upon the development of interconnected secondary porosity. Lineament controlled valleys hold promising sites for borewell. Wells drilled particularly along the western boundary of the study area encountered a number of dry fractures.



	DTWL (mbgl)	Avg.depth of wells	Yield (lps)	AR Structures	
Alluvium	0- 5	3-8	upto 200 for 3 hrs	---	Good Recharge zones.Sand mining/urban waste disposal common.
Laterite/ Weathered	10-25	15-33	upto 100 for 2-3 hrs	Recharge Pit	Laterite thickness not uniform. Dug wells collapse at lithomargic zone.
Laterite/ Weathered	2-12	5-15	upto 50	Check Dam/Gully Plug/Nala Bunds	Undulating topography with varying laterite thickness.Dotted with SH/RH/RM unfavourable for GW potential/Recharge.
Massive	---	---	---	---	Run-off zone. Prospects seen mainly along valleys.

Figure 5.1: Aquifer Map of Phreatic Aquifer

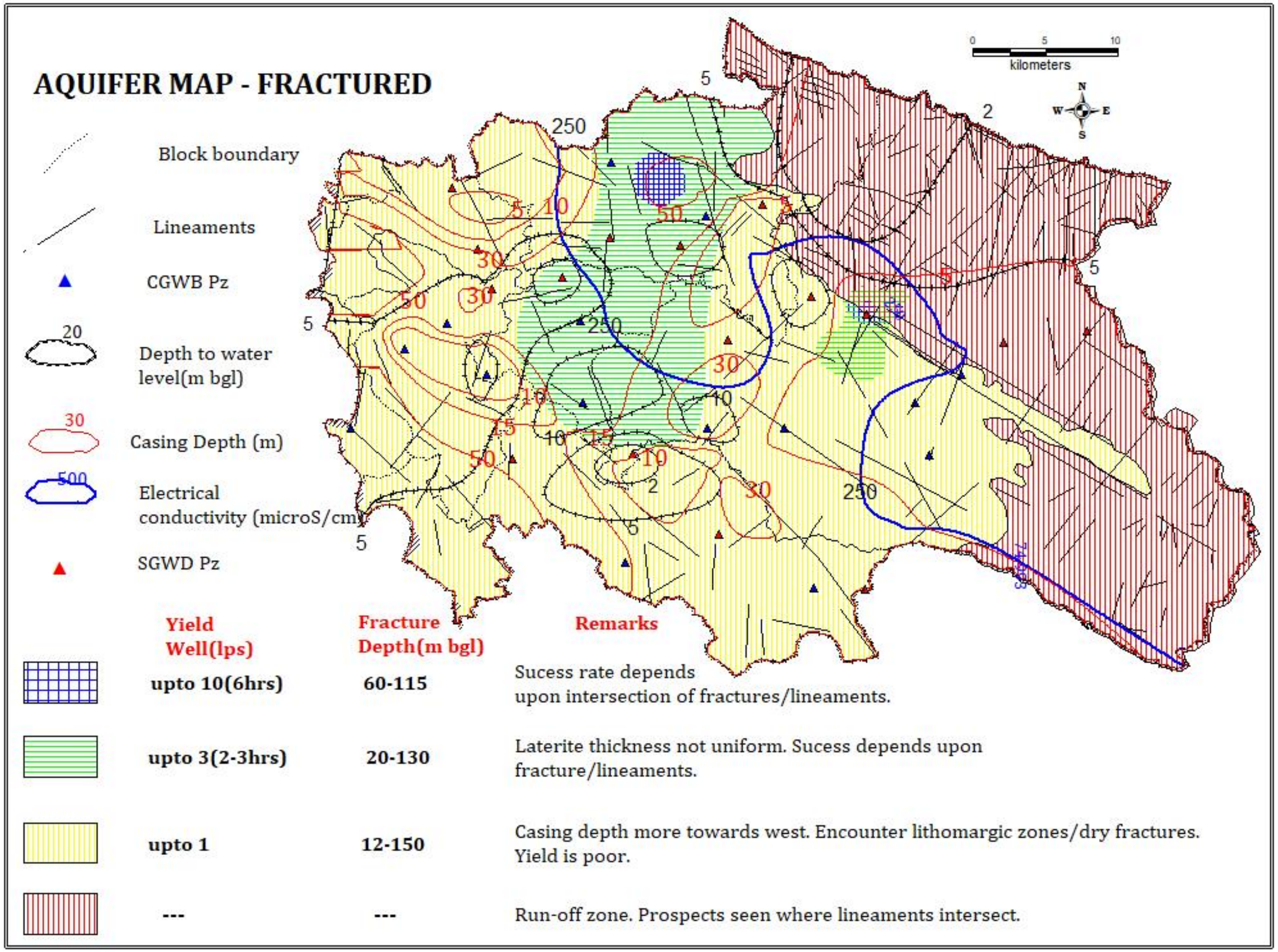


Figure 5.2: Aquifer Map of Fractured Aquifer

6.0 GROUNDWATER RESOURCES

6.1 Dynamic Ground Water Resources in the weathered zone

The study area is blessed with ground water resources in the weathered zone (phreatic aquifer) which can be developed in the future. 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. In spite of these abundant resources, some areas experience shortage of ground water during summer months, which is due to the unplanned and non-scientific development of ground water besides the topographic control.

The dynamic ground water resources in the area are estimated based on the methodology proposed by Ground Water Estimation Committee (GEC 2015- Methodology) for administrative units with block as the assessment unit. The area under command and non-command could not be separated mainly due to non-availability of data pertaining to canal command areas. Further, the irrigation projects of Kallada River are mostly planned for irrigating paddy along the topographic lows and there are large areas along the upstream side of the canal, which do not get benefits of surface water irrigation. Due to the highly undulating topography of the midland area where most of the canals exist, it is quite difficult to accurately demarcate the areas under command and non-command. In view of the factors mentioned above, the computations have been made by taking all assessment units as non-command area. The recharge from canal segments and return seepage from irrigation due to surface water in the command area have, however, been incorporated into the computations.

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. Ground water extraction is mainly for domestic and irrigation purposes in the area. In view of the non-availability of data on the number of wells being used for domestic purposes, the ground water extraction for domestic uses has been computed as the product of the population (2011 projected for 2017) and the per-capita water requirement (assumed as 150 L/day/person) and the share of groundwater varying from 25 to 100% on the basis of availability of surface water sources for domestic water supply. The groundwater extraction has been computed by multiplying the number of irrigation wells in each block with the corresponding unit draft.

The Total Annual Extractable Groundwater Resource has been computed as **204.59 Million Cubic Metre (MCM)** whereas the gross groundwater extraction is **80.29 MCM**, thus keeping a balance of 124.30 MCM for future ground water development**.** Rainfall recharge accounts for about 90 percent of the annual recharge, with the remainder contributed by other sources. The stage of ground water extraction is **39.25%**. Out of 8 blocks, only one block (Mukhathala) is Semi-critical and the rest are Safe. The block wise ground water resources estimated for the area is given in Table **6.1**.

Table 6.1 Dynamic Ground Water Resources estimated for NAQUIM- Kollam(part)hard rock area

Sl. No.	**Assessment Unit/ Block**	**Mapped Area in Sq.Km**	**Annual Extractable Ground Water Resource** (ha.m)	**Existing Gross Ground Water Extraction for irrigation** (ha.m)	**Existing Gross Ground Water Extraction for domestic and industrial water supply** (ha.m)	**Existing Gross Ground Water Extraction for All uses (ha.m) (5+6)**	**Provision for domestic and industrial use up to 2025** (ha.m)	**Net Ground Water Availability for future irrigation development (ha.m) (4-5-8)**	**Stage of Ground Water Extraction {(7/4) * 100} (%)**	**Category**
1	2	3	4	5	6	7	8	9	10	11
1	Anchal	932.59	7325.31	689.06	323.53	1012.59	1108.77	5527.48	13.82	Safe
2	Chadayamangalam	250.49	3446.15	588.08	997.30	1585.38	1016.57	1841.50	46.00	Safe
3	Chittumala	7.35	104.54	30.19	63.37	93.56	64.68	9.67	89.50	Safe
4	Ithikkara	50.36	886.58	139.85	449.20	589.05	458.44	288.29	66.44	Safe
5	Kottarakkara	135.95	2109.97	444.02	842.83	1286.85	858.76	807.19	60.99	Safe
6	Mukhathala	24.1	499.26	62.65	340.70	403.35	345.21	91.40	80.79	Semi-Critical
7	Pathanapuram	302.52	3145.68	481.42	933.86	1415.28	952.61	1711.65	44.99	Safe
8	Sasthamkotta	17.28	295.59	62.70	133.70	196.40	135.88	97.01	66.44	Safe
9	Vettikkavala	168.93	2645.68	505.90	940.83	1446.73	960.01	1179.77	54.68	Safe
	TOTAL (ha.m)		**20458.76**	**3003.87**	**5025.32**	**8029.19**	**5900.93**	**11553.96**	**39.25**	
	TOTAL (MCM)		**204.59**	**30.04**	**50.25**	**80.29**	**59.01**	**115.54**	**39.25**	

6.1.1 In-storage in the weathered zone

The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. Presently there is no fine demarcation to distinguish the dynamic resources from the static resources. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage. In-storage computation is necessary not only for estimation of emergency storage available for utilisation in case of natural extremities (like drought) but also for an assessment of storage depletion in over-exploited areas for sensitising stakeholders about the damage done to the environment.

The computation of the static or in-storage ground water resources of weathered zone has been done after delineating the aquifer thickness and specific yield of the aquifer material. Aquifer thickness is computed by taking the difference of average depth of weathering in each block from exploration and average depth to water level in the pre-monsoon period. Since specific yield studies for the static zone of weathered zone is not readily available, 50% of the dynamic zone has been considered for computation.

$$SGWR = A * (Z2 - Z1) * SY$$

Where, SGWR = Static or in-storage Ground Water Resources
A = Area of the Assessment Unit
Z2 = Bottom of Unconfined Aquifer
Z1 = Pre-monsoon water level
SY = Specific Yield in the In storage Zone
The in-storage computed for each block is shown in **Table 6.2**. Total in storage in the weathered zone below the dynamic zone is estimated as **219.13 MCM**.

Table 6.2 In-storage in the weathered zone

Sl. No.	Assessment Unit/ Block	Mapped Area in ha.	Hilly Area ha.	Max Apr W/L (m bgl)	Aquifer Thickness (m)	Specific Yield %	Net Annual Ground Water Availability
1	2	3	4	5	6	7	8
1	Anchal	93259.3	30000	7.96	1.84	0.015	1745.96
2	Chadayamangalam	25048.8	0.00	7.51	3.04	0.015	1142.23
3	Chittumala	735	0	11.12	13.88	0.02	204.04
4	Ithikkara	5036	0	9.81	34.09	0.055	9442.25
5	Kottarakkara	13595	0	9.24	2.56	0.015	522.05
6	Mukhathala	2410	0	8.81	36.34	0.08	7006.35
7	Pathanapuram	30252	8000	8.44	1.5	0.015	500.67
8	Sasthamkotta	1728	0.00	21.6	6.26	0.02	216.35
9	Vettikkavala	16893	0.00	7.43	4.47	0.015	1132.68
	TOTAL (ha.m)						**21912.56**
	TOTAL (MCM)						**219.13**

6.1.2 Assessment of Total Ground Water Availability in Weathered Zone

The sum of Annual Exploitable Ground Water Resource and the In-storage ground water resources of weathered zone is the Total Ground Water Availability of unconfined aquifer. Thus the total annual exploitable groundwater resource in the weathered zone is the sum of dynamic resources and the in-storage which comes about **423.72** MCM.

6.2 Ground Water Resources in the Deep Fractured Aquifer

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred metre and subsidence of land surface posing serious geo-tectonical problems. To assess the ground water resources of the confined aquifers, ground water storage approach is recommended. Moreover, there is a need to have sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed. Hence the resources available under pressure are only considered as the ground water potential. If any development activity is started in the confined aquifer, then there is a need to assess the dynamic as well as in storage resources of the confined aquifer.

It is assumed that ground water developmental activity has not started from the fracture aquifer system of the study. The groundwater resources in the fracture aquifer system are estimated based on the depth of occurrence of fracture and on the assumption that the storativity/ specific yield of the fracture and associated matrix as about 10% of the in-storage of weathered zone. The total water resource in the fracture system thus computed is about **258 MCM** (**Table.6.3**).

Table 6.3 In-storage in the fractured zone

Sl. No.	Assessment Unit/ Block	Mapped Area in Ha.	Hilly Area Ha.	Thickness (m)	Storativity/ Specific Yield (%)	Net Annual Ground Water Availability (Ha.m)
1	2	3	4	5	6	7
1	Anchal	93259.3	30000.00	130.2	0.0015	12354.54
2	Chadayamangalam	25048.8	0.00	114.45	0.0015	4300.25
3	Chittumala	735	0	55	0.002	80.85
4	Ithikkara	5036	0	36.1	0.0055	999.90
5	Kottarakkara	13595	0	68.2	0.0015	1390.77
6	Mukhathala	2410	0	34.85	0.008	671.91
7	Pathanapuram	30252	8000.00	80.06	0.0015	2672.24
8	Sasthamkotta	1728	0.00	52.14	0.002	180.20
9	Vettikkavala	16893	0.00	123.1	0.0015	3119.29
	TOTAL (ha.m)					**25775.9493**
	TOTAL (MCM)					**257.76**

7.0 GROUND WATER RELATED ISSUES

Ground water problems in the area can be broadly grouped into natural or anthropogenic, which in turn affects this natural resource either in a quantitative or, qualitative manner. Similar to any other region, the major problem that affects any ecological system of the study area is due to the increase in population and accompanied changes in land use pattern. With the urban expansion, more area has been reclaimed/converted resulting in ecosystem changes and biodiversity loss. Consequent to these anthropogenic activities, there is an increase in household waste especially solid waste results in indiscriminate dumping of bio-degradabale and non-biodegradable waste to surface water bodies or abandoned wells or used for wet land filling for large scale reclamation, unprecedented increase of sand and clay mining, quarrying of building stones from highlands last but not least haphazard development of tourism also plays major roles in the depletion of the quantity and quality of ground water in the area in a minor scale.

In the study area, although there are no major problems to be highlighted, experience minor issues that can be rectified by adopting site specific management practices. A few issues are discussed here:

1. **Water Scarcity** - Acute water shortage during summer months are reported from eastern hilly areas. The panchayats having water scarcity problem are Aryankavu, Alayamon, Karavaloor, Pattazhy, Elamadu, Velinaloor, West Kallada, Poothakkulam and Thrikkadavur. Dug wells in these panchayats usually gets dried-up during summer months as the laterite formations which are highly porous with low retention capacity loose water as base-flow in the summer months. The water availability is meagre especially in hilltops, steep slopes and isolated hillocks due to undulating topography. Areas such as Aryankavu, Clappana, Perinadu, Pavithreswaram and Thalavoor gramapanchayat experince this problem. The nearest potable water source is of greater distance (>0.5 km).

2. **Bacteriological Contamination -** Biological contamination of ground water may occur when human or animal waste enters an aquifer. Availability of drinking water, good sanitation and pollution free environment are the three essential factors of a healthy society. Studies carried out by GWD shows that about 70% of ground water samples collected from the area contains coliform bacteria.

3. **Waste Disposal** - High population density areas like Kottarakkara, Anchal and Punalur faces problems in the disposal of solid waste and sewage. Municipal solid waste and sewage are the major pollutants and are the main sources of pathogens in the eco-system. The urban wastes include hospital wastes, market and slaughter house wastes and sewage and wastes generated from other commercial and residential areas. The people living near the water bodies in the rural stretches are depositing the household wastes into the system that is mainly due to the absence of centralised waste management system. In the absence of proper arrangements for the collection, treatment and disposal of all the wastes produced from every human settlement, accumulation of wastes will create various adverse conditions like disease causing bacteria will spread up in the stagnant water and the health of the public will be in danger; drinkable water will be polluted etc.

4. **Land Use Changes** - Unauthorized encroachment as well as unscientific land use and agricultural practices along with deforestation in uplands and in midland areas leads to soil erosion. Initially most of the encroachments are for agriculture purposes; later these areas were reclaimed and used for various other purposes. Utilization of lands for

purposes other than the originally envisaged is common practice in many places such as Anchal and Pathanapuram blocks, which lead to the change in the ecosystem. Excessive sand mining from the riverbeds especially Kallada and Ithikara river, downstream has substantially lowered the local water table. Also, the unscientific human interference including improper land use in the upper catchments in the watersheds has caused severe gaps in the recharge of ground water in the locality.

5. **Unregulated Ground Water Exploitation –** Urbanisation in towns like Kottarakara, Anchal and Punalur demands a huge domestic water requirement which was met through unscientific construction of bore wells resulted in an unregulated exploitation of ground water. The number of wells has increased manifold during the last decade. The survey shows that Kottarakara town has the maximum density of bore wells constructed in an unscientific manner. Even though resources are available for development the continuing practices may result in decline in water level in the future.

6. **Soil Erosion and Run-Off -** Soil erosion is one of the serious environment degradation problems in the highland parts of Chadayamangalam, Anchal and Pathanapuram blocks of the area which results in siltation in lowland area. Laterite soils are by far the most important soil group occupy the larger area. Run off and soil loss has positive linear correlation with rainfall as well as with vegetation cover and runoff. The intense soil erosion in the high slopes has reduced the overburden thickness resulted in water scarcity in these areas. Soil erosion to a good extent can be limited by implementing contour farming/agricultural practices, planting of trees, grasses and bushes in open slopes. Thereby soil erosion can be reduced meanwhile recharge to groundwater can be enhanced.

7. **Quarrying –** Khondalites and charnockites occupying the major part of the area are a good source of granite dimension stone as well as building material which has colour ranging from pale green with mottled red, bluish green with cordierite, deep dark green, greyish white. Localised quarrying for Granite building stones are highly rampant in the Kottarakara and Vettikavala block particularly in Neduvathur, Puthur, Odanavattom, Veliyam, Kareepra, Pooyapally, Ezhukone, Vettikavala, Pavithreswaram, Ummannur, Valakom, parts of Mylam and Kalayapuram village and parts of Chadayamangalam blocks particularly in Elamad, Velinalloor, Nilamel, Chadayamangalam, Kottukal, Ittiva, Kadakkal, Mankode, Kummil and Chakkuvarakkal village. In addition to granite building stone, quarrying/mining of brick/tile clay is common in the fringing area of soft rock and hard rock. Illegal quarries are mushrooming in and around Veliyam panchayath and local residents of the area have highlighted environmental problems as well as issue of water scarcity they are facing due to quarrying.

8. **Iron contamination –** Presence of iron enriched groundwater is another minor natural problem of the study area. Studies reveal that the Iron enriched ground water samples have a good correlation with the geological & hydrogeological set up of the area. The high correlation between Khondalitic terrain with iron content in groundwater can be attributed to garnet which is releasing the iron in the course of weathering from the weathered mantle overlying the Khondalites.

8.0 GROUND WATER MANAGEMENT

The sustainable management of groundwater resources requires good planning and concerted efforts. In addition to responding to acute resource degradation, planning for groundwater protection needs the attention of all stakeholders. Even though the study area receives good annual rainfall and has best climatic conditions as in other parts of Kerala, it has been experiencing increasing incidents of water scarcity in summer for meeting the irrigation as well as domestic requirementss. Even in the years of normal rainfall, summer water scarcity problems are there in the midland and highland regions of the study area. This ironic situation araised mainly due to natural reasons such as undulating topography with steep slopes resulted in high run-off and low recharge. Besides, this the limited thickness of aquifer material and shallow depth to massive bed rock in the eastern part of the area limits groundwater storage in the aquifer sysytem.

The spatial and temporal availability of groundwater is highly uneven in the study area even though the mean annual rainfall in the area is close to 2500 mm. This results in long dry spells and moisture stress especially in high lands during summer. In situ conservation of rain water and conservation of surplus run-off during monsoon so as to supplement the domestic and irrigation needs are the possible solutions to overcome this problem.

An effective ground water management practice must be preceded by an accurate account of the total available resources. From the estimation, it is clear that there is scope for further ground water development for irrigation in majority of the blocks of the study area where the stage of development is low. Eventhough the scope for resource development is high; the availability of the resource is not uniformly distributed in the block. Hence, the ground water development should be coupled with management of water resources through rainwater harvesting and artificial recharge schemes. Topography of the area are suitable for various artificial recharge structures such as percolation ponds, check dams, contour bunding, trenching, pitting, terrace cultivation and sub-surface dykes. Meanwhile, periodic de-siltation as well as cleaning of existing check dams, bunds and ponds is recommended for increasing the storage capacity as well as infiltration rate.

Development of water resources needs a scientific management system co-ordinating the efforts of all concerned agencies for a speedy development of the agricultural sector in the area. While formulating various ground water development and management plans, geology of the area should be given prior importance. For blocks like Pathanapuram, Chadayamangalam, Vettikavala, Anchal and Kottarakara bore wells are feasible. In Punalur municipality, open as well as bore wells can be constructed. Laterite aquifer in the north-eastern parts can be developed through open dug wells ranging in depth from 10 to 12 m with a diameter of 1.5 to 3.5 m. There is a big gap between dynamic phreatic groundwater resource available and utilised in the study area. Accelerated groundwater development would bring more area under irrigation since there is a lot of resource untapped. Farmers may be encouraged to adopt modern irrigation techniques like drip and micro irrigation to have optimal use of the available resources and community irrigation schemes have to be encouraged.

8.1 CONSTRAINTS IN MEETING THE WATER REQUIREMENTS

- Drying up of shallow wells or reduction in their yields during summer months, resulting in localized water scarcity.
- Existing supplies unable to cope with the rapidly increasing demands for drinking and domestic uses.

- Contamination of water supply sources due to indiscriminate disposal of untreated solid and liquid municipal / domestic waste.

8.2 RECOMMENDATIONS

8.2.1 POSSIBLE SHORT-TERM LOCAL SOLUTIONS FOR MEETING UNSATISFIED DEMANDS

- Large scale implementation of roof-top rainwater harvesting for storage and direct use.
- Renovation of existing water bodies for augmentation of water supply for domestic/agricultural uses. Rennovation of ponds (31 nos.) – Yeroor, Edamulakkal panchayath
- Maintenance of existing canal system – Veliyam, Pooyapally, Mailom Panchayaths which can improve irrigation in 900ha of land.
- Use of existing bore/tube wells drilled by Central Ground Water Board/ State Ground Water Department for augmenting water supply, especially in rural areas. Immediate attention is needed in the following panchayats for water supply schemes viz. Anchal, Erur, Alayaman, Idamulakal, Thenmala, Ariyankavu, Chithara, Kadakkal, Nilamel, Veliyam, Vettikavala and Kilikollur. These areas may be explored with adequate technical support. For solving the water crisis of the area, an integrated water management policy should be evolved.
- Springs present in the highland areas of Anchal and Pathanapuram can be developed to meet the drinking water needs.
- Soil Conservation measures like terrace farming; contour bunding should be practiced in Thenmala, Alayamon, Ittiva, Kottukal Panchayaths.
- A number of abandoned quarries are available in Kottarakara and Vettikavala blocks, which can be converted to water harvesting structures.
- Encouraging use of water efficient domestic fixtures like taps/ flush tanks and micro-irrigation techniques to improve water use efficiency and reduce wastage.
- Decentralized garbage / waste treatment systems to prevent further contamination of available fresh water resources.
- Encouraging use of scientifically constructed septic tanks and improved sanitation to minimize bacteriological contamination.
- Regulation of ground water extraction for commercial uses.

8.2.2 POSSIBLE LONG-TERM LOCAL SOLUTIONS FOR MEETING UNSATISFIED DEMANDS

- Identification of high-yielding bore/tube wells drilled by Central Ground Water Board / Kerala Ground Water Department for water supply through tankers during water scarcity.
- To suplement domestic demand – construct 30-50 bore well, large diameter wells in Eroor, Alayamon, Piravanthur and Thalavoor panchayaths. The Panchayats suitable for constructing borewells are Anchal, Erur, Alayaman, Idamulakkal, Thenmala, Ariyankavu, Chithara, Kadakkal, Nilamel, Veliyam, Vettikavala and Pooyapalli. Proper site selection is needed to locate the wells in lineaments for better results.
- Identification of one or two perennial tanks in each panchayat, to be developed as sources of water for domestic and other uses in water scarce situations. Such tanks identified shall be de-silted, renovated and their supply channels repaired to ensure that they receive sufficient water during the monsoons. Steps shall also be taken to prevent

contamination of water in such tanks. The maintenance of these tanks shall be the responsibility of PRI/ water user associations at the local level.

- ❖ Additional 1500 structures are feasible for irrigated agriculture spread over 5 blocks (Anchal, Chadayamangalam, Pathanapuram, Kottarakara and Vettikavala blocks)
- ❖ Construction of a series of regulators/check dams /vented dams along river courses, at strategic locations having road/rail bridges, after detailed feasibility studies. These regulators will help in storing non-monsoon base flow along stretches of river without problems of land submergence.
- ❖ Large scale implementation of roof-top rainwater harvesting through existing dug wells in highland areas on priority on the basis of their vulnerability to droughts to be taken up. Recharge of monsoon rainfall through a large number of such wells is expected to improve ground water availability over a period of time. Since the aquifer system is thin with high gradient leads to fast drain, rain water harvesting as storage cum recharge is highly recommended.
- ❖ Waste land identified in various panchayaths (11,000ha) can be brought under agricultural practices with the help of local government bodies.
- ❖ Prevention of contamination of water bodies and ground water sources through decentralized waste disposal and treatment and better sanitation.
- ❖ Sensitization and capacity building of stakeholders at all levels on the importance of water conservation and ways and means for its judicious management for ensuring long-term sustainability of water resources.

Details of block-wise feasible management structures proposed is given in **Table 8.**1 and is shown in **Figure 8.1.**

Table 8.1 Details of Management Structures feasible in the area

Block	Total Area	Area Feasible	Type	No: of Structures Feasible
Anchal	930	143	Check dam	10
			Percolation Pond	39
			Gully Plug	3730
			Nalla Bund	744
			Contour Bund	797
			Bore well	29
Chadayamangalam	250	53	Check dam	10
			Percolation Pond	15
			Gully Plug	2300
			Nalla Bund	270
			Contour Bund	296
			Bore well	23
Kottarakara	135	41	Check dam	7
			Percolation Pond	6
			Gully Plug	1037

			Nalla Bund	126
			Contour Bund	135
Pathanapuram	301	148	Check dam	12
			Percolation Pond	40
			Gully Plug	6409
			Nalla Bund	769
			Contour Bund	823
			Bore well	22
Vettikavala	168	88	Check dam	5
			Gully Plug	150
			Nalla Bund	20
			Contour Bund	125
			Bore Well	28
			RWH	4000

8.2.3 Measures for Groundwater Regulation

Building awareness among public that even though the groundwater storage is vast, its rate of replenishment is finite and mainly limited to the shallower aquifers. The quality of these aquifers can also be seriously and even irreversibly degraded via excessive resource development, uncontrolled urban and industrial discharges, and agricultural intensification. Inorder to prevent further deteroioration of aquifer, groundwater protection zones of 168 sq.km has been identified in the study area. The area fringing the Tertiary- Precambrain requires an urgent regulation in further development **(Figure 8.2).** In order to fulfill the demand of the society some regulatory measures have to be implemented.

1. RESTRICTIONS ON GROUNDWATER USE AND WELL DEVELOPMENT: In a limited number of places effective local restrictions on groundwater use are to be implemented especially in Kottarakara Municipality, Anchal, parts of Chadayamangalam and Pathanapuram blocks such as minimum distance rules, bans on certain crops mainly acacia and eucalyptus or bans on certain types of wells.

2. REDUCING AGRICULTURAL WATER DEMAND: Simple techniques can be used to reduce the demand for water. The underlying principle is that only part of the rainfall or irrigation water is taken up by plants, the rest percolates into the deep groundwater, or is lost by evaporation from the surface. Therefore, by improving the efficiency of water use, and by reducing its loss due to evaporation, we can reduce water demand. There are numerous methods to reduce such losses and to improve soil moisture. (a) Mulching, i.e., the application of organic or inorganic material such as plant debris, compost, etc., slows down the surface run-off, improves the soil moisture, reduces evaporation losses and improves soil fertility – can be implemented in no: of panchayaths under MGNREA. (b) Soil covered by crops slows down run-off and minimizes evaporation losses. Hence, fields should not be left bare for long periods of time especially this is a common practice in various panchayths of Chadayamangalam and Vettikavala block. (c)Ploughing helps to move the soil around. As a consequence, it retains more water thereby reducing evaporation. Shelter belts of trees and bushes along the edge of agricultural fields slow

down the wind speed and reduce evaporation and erosion. Planting of trees, grass, and bushes breaks the force of rain and helps rainwater penetrate the soil. Farmers recognise the efficiency of contour-based systems for conserving soil and water. (d)Use of efficient watering systems such as drip irrigation reduces the water consumption by plants.

3. REGULATING PUMPING: In the case of ground water extraction industries, strict limits on the amount of water that can be withdrawn, including a limit of withdraw especially in dry months, the installation of monitoring equipment in every well to measure extraction and changes in the water table level; and leving fees for the break of limits.

4. CONTROL ON SAND MINING along Kallada river to safeguard natural recharge capacity. The removal of sand and gravel from rivers reduces the capacity of river to store water and recharge shallow aquifers. This activity has exacerbated the water scarcity problems all along the banks of Kallada and Ithikara rivers in the study area.

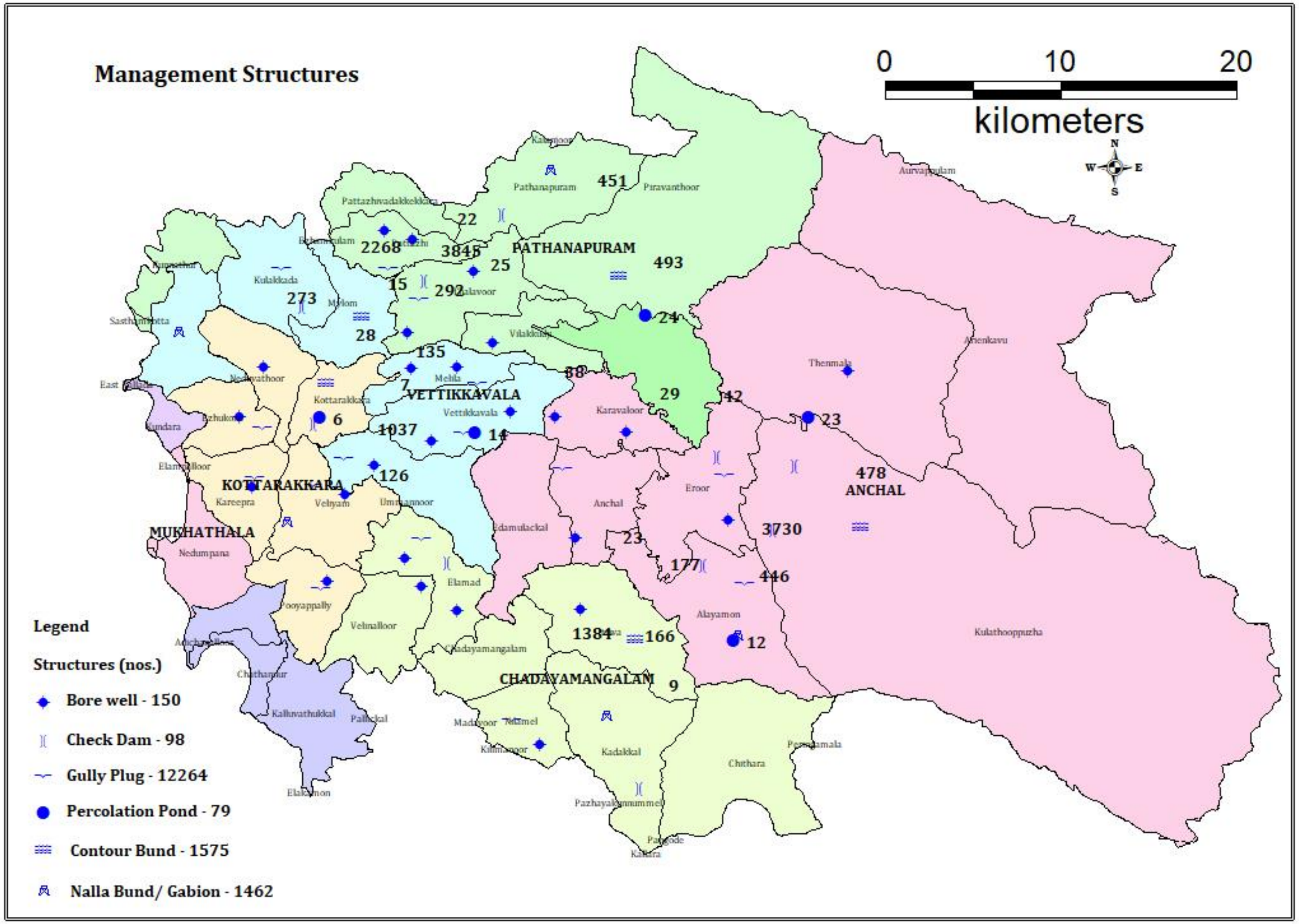


Figure 8.1: Feasible Management Structures in the study area

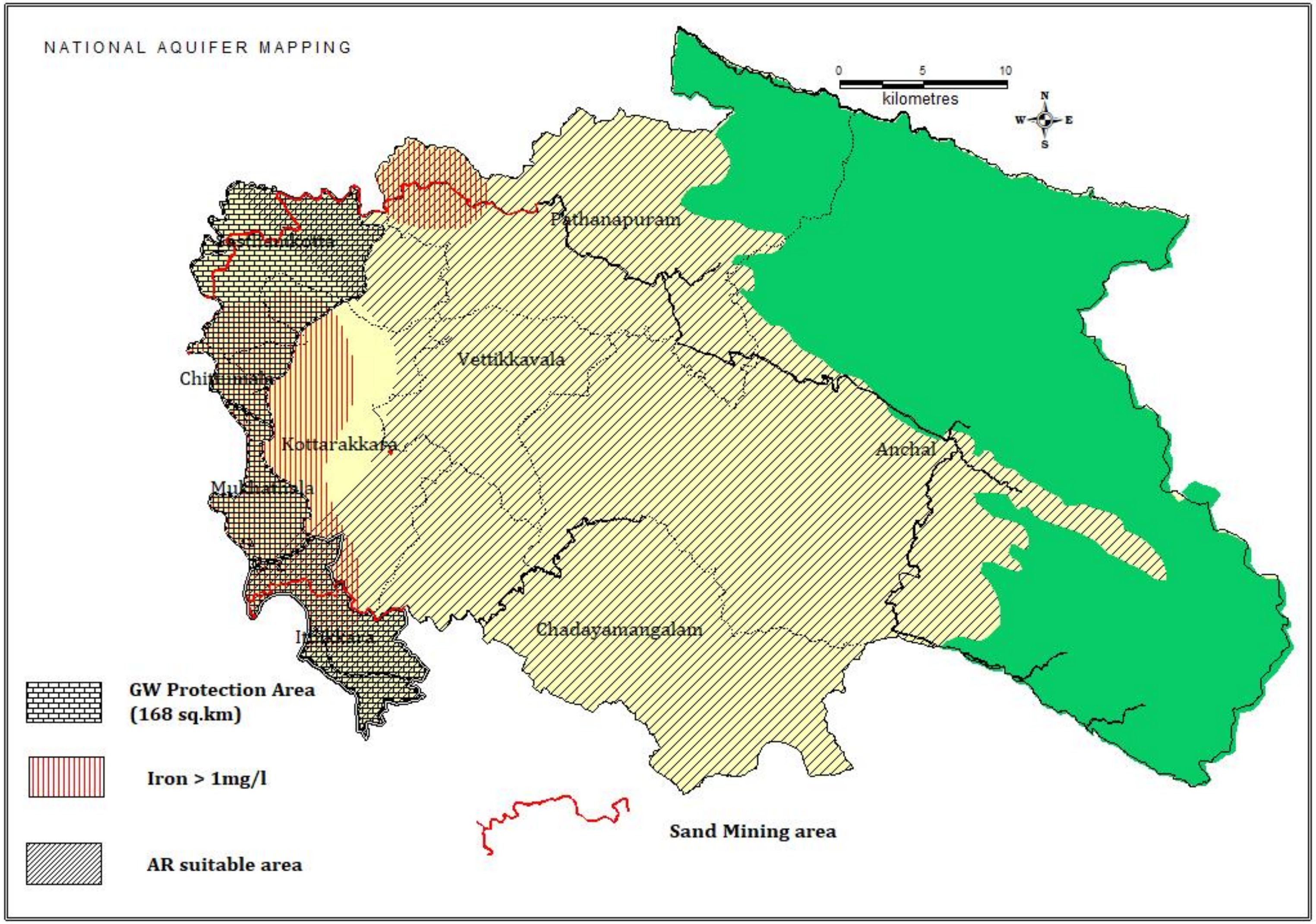


Figure 8.2: Groundwater Protection zones identified in the study area

9.0 SUMMARY

MAPPING OF HARD ROCK AQUIFER SYSTEM AND AQUIFER MANAGEMENT PLAN OF KOLLAM DISTRICT, KERALA			
Sl NO	**Items**	**Details**	
1	**Area**	1883 sq.km	
2	**Geographic Details**	North latitude of 8°45' & 9°10' East longitude of 76°40'& 77°15'	
3	**Municipalities**	2	
4	**Blocks**	5 completely(Anchal, Chadayamangalam, Kottarakara, Pathanapuram and Vettikavala) four blocks partly (Ithikara, Chittumala, Mukhathala and Sasthamkotta)	
5	**Panchayath**	39 (includes part of 6 panchayaths).	
6	**Population**	11,11,238 (2011)	
7	**Rainfall**	2428 mm	
8	**Physiography**	Midland and Highland	
9	**Slope**	76% of the area < 20^0	
10	**Geomorphic Units**	Pediplain, plateau, piedmont zone, flood plain Residual hill, denudational hills and structural hills	
11	**Land Use/Land cover**	Agricultural land (56%), forest(36%), built-up-land(2%), waste lands(5.7%) and water bodies(1.1%)	
12	**Drainage**	Achenkovil, Kallada, Ithikara, Ayirur and Vamanapuram	
13	**Soil**	Lateritic soils, Brown Hydromorphic soils, Greyish Onattukara soils, Riverine Alluvium and Forest Loam	
14	**Cropping Pattern**	Rubber, Coconut, banana and other crops	
15	**Irrigation Project**	Kallada Irrigation Project	
16	**Geology**	Archean group of crystallines - Charnockite and Khondalite Sub-recent – Laterite (weathered product)	
17	**Structure**	Achenkovil shear zone Lineament - NNW- SSE and NW-SE	
18	**Hydrogeology**	Shallow/ Phreatic Aquifer - Laterites occur as capping over crystallines Deeper Aquifer - weathered, fissured and fractured crystalline formations	
19	**Industries**	Localised quarrying for Granite building stones and dimension stone, Clay mining for brick tiles	
20	**Water level monitoring**	Dug wells Piezometers CGWB – 67 10 SGWD 15 16 Key wells 37 **Total – 145 wells**	
21	**Exploration**	46	
22	**Aquifer Systems**	Single aquifer system with two horizons	
		Shallow/ Phreatic Aquifer	Deeper Aquifer
		Weathered zone(laterites) with shallow fractures	Weathered, fissured and fractured crystalline formations
	Development Structures	Dug wells, dug-cum bore	Bore wells

<table>
<tr><td></td><td>**Thickness Depth**

Water level – Premonsoon

Postmonsoon</td><td>wells and shallow bore wells
3.6 to 63 m
Increases towards west
4.2 to 22 m bgl(DW)
30m (SBW)

2.83 to 21.6 mbgl
2.27 to 19 mbgl</td><td>
35 to 130 m

68.7 to 300 m bgl
Fracture
Depth : 10 to 145 m
1.02 to 13.6 m bgl
3.98 to 10.92 m bgl</td></tr>
<tr><td>**23**</td><td>**Ground Water Quality**</td><td colspan="2">Origin : Rock dominance over rainfall
Contamination: Iron – Geogenic
Potable and good for irrigation purpose</td></tr>
<tr><td>**24**</td><td>**Ground Water Resources**</td><td>**Phreatic/ Weathered Zone**
Dynamic Ground Water Resource : 205 MCM
Ground water Extraction : 80 MCM
Stage of ground water extraction : **39.25%**.
In- storage : 219 MCM</td><td>**Fractured Aquifer**
NIL

In- storage : 258 MCM</td></tr>
<tr><td></td><td></td><td colspan="2">Only 124 MCM is available for further ground water development which is unevenly distributed. The in-storage resource can't be exploited for development.</td></tr>
<tr><td>**25**</td><td>**Ground Water Issues**</td><td colspan="2">❖ Water Scarcity in high lands
❖ High spatial variability in groundwater resource availability
❖ Vagaries in rainfall affects crop sustenance and fallowing of cultivable land
❖ Land Use Changes
❖ Sand Mining
❖ High density of Ground Water Structures
❖ Waste Disposal
❖ Soil Erosion & Run-off
❖ Quarrying
❖ Bacteriological & Iron contamination</td></tr>
<tr><td>**26**</td><td>**Aquifer Management Plan**</td><td colspan="2">❖ Thin aquifer system with high gradient leads to fast drain especially in highlands. Hence **rainwater harvesting as storage cum recharge** recommended.
❖ **Springs** present in the highland areas **can be developed to meet the drinking water needs.**</td></tr>
</table>

		❖ To supplement domestic demand – **construct 30-50 bore well** in each block and **large diameter wells** in Eroor, Alayamon, Edamulakkal, Thenmala, Karavaloor, Piravanthur and Thalavoor panchayaths ❖ **Soil Conservation measures** – terrace farming, contour bunding – in all the panchayaths of Anchal, Pathanapuram and Chadayamangalam block. ❖ **Maintenance of existing canal system** – in majority of the Panchayaths ❖ **Renovation of ponds** – in all panchayath. ❖ Waste land(11,000ha) can be brought under agricultural practices with the help of local government bodies. ❖ Additional **1500 structures** are feasible for irrigated agriculture spread over 5 blocks (Anchal, Chadayamangalam, Pathanapuram, Kottarakara and Vettikavala blocks). ❖ Resulted in an increase in the irrigation potential: 20000 ha ❖ Regulation of ground water extraction for commercial uses.
27	**Measures for Groundwater Regulation**	❖ Demarcate & Regulate development in Ground Water Protection zones ❖ Development of springs in Nedumpana panchayath of Mukhathala block to be regulated ❖ Restrictions on groundwater use and well development ❖ Reducing Agricultural Water Demand ❖ Regulating Pumping ❖ Control on Sand Mining

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Annexure I:Details of Ground Water Monitoring Wells by CGWB and GWD

SITE_NAME	SITE_TYPE	Agency	Latitude	Longitude	TOPOSHEET NO	Rock Type
Achenkovil (R1)	Dug Well	CGWB	9.08	77.13	58G	hard rock
Ailara	Dug Well	CGWB	8.93	76.97	58D	hard rock
Alayamon	Dug Well	CGWB	8.93	76.92	58 D/13	hard rock
Alumoodu	Dug Well	CGWB	9.07	76.90	58 C/16	hard rock
Anchal	Bore Well	CGWB	8.92	76.92	58D13	hard rock
Anchal DW	Dug Well	CGWB	8.94	76.92	58 D/13	hard rock
Ariyankavu	Dug Well	CGWB	8.97	77.15	58H	hard rock
Avaneswaram	Dug Well	CGWB	9.03	76.85	58C	hard rock
Ayur	Dug Well	CGWB	8.88	76.86	58D	hard rock
Bharathipuram	Dug Well	CGWB	8.92	76.99	58 D/13	hard rock
Chadayamangalam (R1)	Dug Well	CGWB	8.87	76.87	58D	hard rock
Chadayamangalam Pz	Bore Well	CGWB	8.83	76.86	58 D/13	hard rock
Channapetta	Dug Well	CGWB	8.88	76.96	58D	hard rock
Chenkulam	Dug Well	CGWB	8.87	76.75	58D	hard rock
Chithara	Dug Well	CGWB	8.82	76.96	58 D/13	hard rock
Choorakulam Jn	Dug Well	CGWB	8.90	76.91	58 D/13	hard rock
Edamon	Dug Well	CGWB	9.00	76.99	58D	hard rock
Edamulakkal	Dug Well	CGWB	8.90	76.87	58 D/13	hard rock
Edayam	Dug Well	CGWB	8.93	76.86	58 D/13	hard rock
Ezhamkulam	Dug Well	CGWB	8.92	77.01	58 H/1	hard rock
Ezhukone (R1)	Dug Well	CGWB	8.97	76.72	58D	hard rock
Kadakkal	Dug Well	CGWB	8.82	76.92	58D	hard rock
Kalluvathukkal	Bore Well	CGWB	8.83	76.75	58D09	hard rock
Kalluvathukkal	Dug Well	CGWB	8.83	76.74	58 D/9	hard rock
Kamukanchery	Dug Well	CGWB	9.05	76.89	58 C/16	hard rock
Kandanchiramukku	Dug Well	CGWB	8.87	77.05	58 H/1	hard rock
Kanjiramvila	Dug Well	CGWB	9.05	76.73	58 C/12	hard rock
Karamkode	Dug Well	CGWB	8.83	76.73	58 D/9	hard rock
Karavaloor	Dug Well	CGWB	8.97	76.92	58 D/13	hard rock
Karukone	Dug Well	CGWB	8.90	76.93	58 D/13	hard rock
Karunthalakode	Dug Well	CGWB	8.82	76.87	58 D/13	hard rock
Koovakad	Bore Well	CGWB	8.93	77.05	58 H/1	hard rock
Koovakad DW	Dug Well	CGWB	8.93	77.05	58 H/1	hard rock
Kottakayam	Dug Well	CGWB	9.08	77.12	58G	hard rock
Kottarakara (R1)	Dug Well	CGWB	8.98	76.78	58D	hard rock
Kottathala	Dug Well	CGWB	9.02	76.75	58 C/12	hard rock
Kottiyam	Dug Well	CGWB	8.92	76.69	58 D/9	hard rock
Kulakada	Dug Well	CGWB	9.07	76.75	58C	hard rock
Kulapadam	Dug Well	CGWB	8.90	76.70	58 D/9	hard rock
Kulathupuzha	Dug Well	CGWB	8.90	77.06	58H	hard rock
Kulathupuzha1	Bore Well	CGWB	8.90	77.06	58H01	hard rock

Kunnada	Dug Well	CGWB	9.10	76.81	58C	hard rock
Kunnathur	Dug Well	CGWB	9.05	76.68	58 C/12	hard rock
Kutavettur	Dug Well	CGWB	8.93	76.75	58D	hard rock
Madathara	Dug Well	CGWB	8.82	77.01	58H	hard rock
Mulavana	Dug Well	CGWB	8.99	76.68	58 D/9	hard rock
Muthukumel	Dug Well	CGWB	8.88	76.95	58 D/13	hard rock
Nallila	Dug Well	CGWB	8.92	76.69	58D	hard rock
Nallila Pz	Tube Well	CGWB	8.92	76.69	58D/9	hard rock
Nellikunnam DW	Dug Well	CGWB	8.90	76.78	58 D/13	hard rock
Nellikunnam Pz New	Bore Well	CGWB	8.95	76.78	58 H/1	hard rock
Nilamel	Dug Well	CGWB	8.83	76.88	58 D/13	hard rock
Odanavattom	Dug Well	CGWB	8.93	76.77	58 D/9	hard rock
Ottakkal	Dug Well	CGWB	8.90	77.06	58 H/1	hard rock
Oyur	Dug Well	CGWB	8.87	76.78	58D	hard rock
Palamoodu	Dug Well	CGWB	9.08	76.86	58 C/16	hard rock
Pallickal	Dug Well	CGWB	9.02	76.77	58 C/16	hard rock
Pangalukadu	Dug Well	CGWB	8.82	76.94	58 D/13	hard rock
Paripally1	Dug Well	CGWB	8.80	76.76	58D	hard rock
Pathanapuram	Bore Well	CGWB	9.08	76.86	58C16	hard rock
Pattanapuram	Dug Well	CGWB	9.08	76.86	58C	hard rock
Pavitreswaram	Dug Well	CGWB	9.05	76.70	58C	hard rock
Perumkulam	Dug Well	CGWB	9.03	76.76	58 C/16	hard rock
Punalur-I	Dug Well	CGWB	9.02	76.93	58C	hard rock
Punalur-I (R1)	Dug Well	CGWB	9.02	76.93	58C	hard rock
Puthoor	Dug Well	CGWB	9.03	76.71	58 C/12	hard rock
Roduvila	Dug Well	CGWB	8.87	76.81	58 D/13	hard rock
Tadicaud (R1)	Dug Well	CGWB	8.95	76.88	58D	hard rock
Thattamala	Dug Well	CGWB	8.87	76.81	58 D/13	hard rock
Thenmala	Dug Well	CGWB	8.95	77.07	58H	hard rock
Ummannur	Dug Well	CGWB	8.93	76.82	58D	hard rock
Ummmannur	Bore Well	CGWB	8.93	76.84	58D13	hard rock
Vazhathoppu	Dug Well	CGWB	8.87	76.81	58 D/13	hard rock
Veliyam	Dug Well	CGWB	8.90	76.76	58 D/13	hard rock
Vilakkupara	Dug Well	CGWB	8.95	76.99	59 B/15	hard rock
Yeroor	Dug Well	CGWB	8.92	76.96	58D	hard rock
Yeroor1	Bore Well	CGWB	8.92	76.97	58D13	hard rock

Details of Ground Water Monitoring Wells by GWD

SITE_NAME	SITE_TYPE	Agency	Latitude	Longitude	TOPOSHEET NO	Rock Type
Ariyankavu	Bore Well	GWD	8.98	77.16	58H/01	Charnockite
Ariyankavu(kazhuthurutty)	Bore Well	GWD	8.97	77.10	58H/01	Gneiss
Avaneeswaram	Bore Well	GWD	9.04	76.85	58C/16	Khondalite
Ayoor	Dug Well	GWD	8.90	76.86	58D/13	Laterite
Chithara	Bore Well	GWD	8.82	77.02	58D/13	Khondalite
Edamon	Bore Well	GWD	9.00	76.98	58C/16	Khondalite

Edamon	Dug Well	GWD	8.99	77.00	58C/16	Laterite
Edamullackkal	Bore Well	GWD	8.90	76.87	58D/12	Khondalite
Kadakkal	Bore Well	GWD	8.85	76.92	58D/13	Granite
Kadakkal	Dug Well	GWD	8.82	76.91	58D/13	Laterite
Karavaloor	Bore Well	GWD	8.97	76.93	58D/13	Khondalite
Karavaloor	Dug Well	GWD	8.97	76.93	58D/13	Laterite
Karavoor	Bore Well	GWD	9.06	76.95	58C/16	Gneiss
Karavoor	Dug Well	GWD	9.06	76.95	58C/16	Laterite
Kazhuthurutty	Dug Well	GWD	8.97	77.10	58H/01	Laterite
Kottarakkara	Bore Well	GWD	9.00	76.78	58C/16	Khondalite
Kottarakkara	Dug Well	GWD	9.00	76.78	58D/13	Laterite
Kulakkada	Bore Well	GWD	9.07	76.76	58C/16	Khondalite
Kulathupuzha	Dug Well	GWD	8.91	77.06	58H/01	Khondalite
Melila	Bore Well	GWD	9.01	76.83	58C/16	Khondalite
Mylom	Bore Well	GWD	9.03	76.77	58C/16	Khondalite
Nilamel	Dug Well	GWD	8.83	76.88	58D/13	Laterite
Pathanapuram	Dug Well	GWD	9.09	76.85	58C/16	Laterite
Pattazhy	Dug Well	GWD	9.08	76.80	58C/16	Laterite
Piravanthur	Dug Well	GWD	9.06	76.92	58D/13	Laterite
Thenmala	Dug Well	GWD	8.95	77.07	58H/01	Khondalite
Thenmala(urukunnu)	Bore Well	GWD	8.99	77.02	58H/01	Gneiss
Velinallur	Bore Well	GWD	8.90	76.79	58D/13	Khondalite
Veliyam	Dug Well	GWD	8.94	76.77	58D/13	Laterite
Vilakudy	Bore Well	GWD	9.03	76.90	58C/16	Khondalite
Yeroor	Dug Well	GWD	8.90	77.05	58H/01	Laterite

ANNEXURE II

LITHOLOGS OF EXPLORATORY WELLS

1. VAZHATHOPU

Unique ID	
Village	Vazhathopu(Kadakkaman)
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 C/16
Latitude	09^0 04' 20"
Longitude	76^0 39' 40"
RL(m amsl)	
Drilled Depth	200
Casing	12.8
SWL (mbgl)	
Discharge (lps)	Dry
Date/Year	24.08.07

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	7.3	7.3	Reddish brown colour, coarse to medium grained, Laterite.
7.3	10.3	3	Dark grey colour, fine to medium grained, partially weathered charnockite
10.3	22.5	12.2	Bluish green colour, fine grained, charnockite
22.5	25.6	3.1	Dark bluish green colour, medium grained, slight to moderately fractured, charnockite
25.6	31.7	6.1	Dark grey colour, fine grained, massive, charnockite
31.7	37.8	6.1	Dark grey colour, fine to medium grained, charnockite
37.8	43.9	6.1	Dark grey colour, medium grained, charnockite
43.9	200	156.1	Dark grey colour, fine to very fine grained, massive, charnockite

2. EZHUKONE

Unique ID	
Village	Ezhukone
Taluka/Block	Kottarakara
District	Kollam
Toposheet No.	58 D/9
Latitude	08^{0} 58' 15"
Longitude	76^{0} 43' 32"
RL(m amsl)	
Drilled Depth	123.1
Casing	6.4
SWL (mbgl)	3
Discharge (lps)	0.85
Date/Year	28.07.07

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Yellowish brown colour, fine to medium grained, Laterite.
4	7.3	3.3	Dark Grey colour, fine to medium grained, partially weathered garnet-biotite gneiss
7.3	13.4	6.1	Greyish white colour, medium to fine grained, garnet-biotite gneiss
13.4	16.4	3	Dark Grey colour, fine to medium grained, slightly fractured, garnet-biotite gneiss
16.4	19.5	3.1	Dark Grey colour, fine grained, garnet-biotite gneiss
19.5	22.5	3	Dark grey colour, very coarse grained, highly fractured, garnet-biotite gneiss
22.5	43.9	21.4	Greyish white colour, fine to medium grained, garnet-biotite gneiss
43.9	46.9	3	Dark grey colour, medium grained, moderately fractured, Abundant chips of quartz and ferromagnesian minerals, garnet-biotite gneiss
46.9	53	6.1	Dark grey colour, fine to medium grained, garnet-biotite gneiss
53	123	70	Greyish white colour, fine to very fine grained, massive, garnet-biotite gneiss

3. KARAVUR EW

Unique ID	
Village	Karavur
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 C/16
Latitude	09^0 03’ 45”
Longitude	76^0 56’ 45”
RL(m amsl)	
Drilled Depth	200
Casing	9.5
SWL (mbgl)	2.53
Discharge (lps)	4
Date/Year	15.11.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Reddish brown colour, medium grained, laterite.
4	10.3	6.3	Bluish green colour, medium to coarse grained, weathered, charnockite
10.3	16.4	15.3	Bluish green colour, medium to fine grained, slightly fractured, charnockite
16.4	25.6	9.2	Bluish green colour, fine grained, charnockite
25.6	26.6	1	Bluish green colour, coarse to medium grained, moderately fractured, charnockite
26.6	77.4	50.8	Bluish green colour, fine grained, charnockite.
77.4	80.5	53.9	Bluish green colour, medium grained, moderately fractured, charnockite.
80.5	117.1	36.6	Bluish green colour, medium to fine grained, charnockite
117.1	120.1	3	Bluish green colour, medium grained, moderately fractured, charnockite.
120.1	147.6	27.5	Bluish green colour, medium to fine grained, charnockite
147.6	200	52.4	Bluish green colour, fine grained, charnockite

4. KARAVUR OW

Unique ID	
Village	Karavur
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 C/16
Latitude	09^0 01' 40"
Longitude	76^0 45' 30"
RL(m amsl)	
Drilled Depth	200
Casing	5.2
SWL (mbgl)	2.53
Discharge (lps)	1.21
Date/Year	30.11.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Dark brown colour, fine grained, laterite.
4	7.3	3.3	Dark grey colour, medium to fine grained, weathered, charnockite
7.3	19.5	12.2	Bluish green colour, very fine to medium grained, charnockite
19.5	22.5	3	Bluish green colour, coarse to medium grained, moderately fractured, charnockite
22.5	50	27.5	Bluish green colour, fine to very fine grained, charnockite
50	80.5	30.5	Bluish green colour, medium to fine grained, charnockite
80.5	123.2	42.7	Bluish green colour, fine to very fine grained, charnockite.
123.2	126.2	3	Bluish green colour, medium grained, moderately fractured, charnockite
126.2	200	73.8	Bluish green colour, fine grained, charnockite

5. KOTTUKAL

Unique ID	
Village	Kottukal
Taluka/Block	Chadayamangalam
District	Kollam
Toposheet No.	58 D/13
Latitude	08^0 53' 38 "
Longitude	76^0 54' 41 "
RL(m amsl)	
Drilled Depth	200
Casing	7.4
SWL (mbgl)	21.06
Discharge (lps)	1.5
Date/Year	30.06.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	7.3	7.3	Yellowish brown colour, Fine to medium grained, laterite.
7.3	10.3	3	Greyish white colour, coarse to medium grained, partially weathered garnet-biotite gneiss
10.3	19.5	9.2	Greyish white colour, very fine grained, massive, garnet-biotite gneiss
19.5	25.6	6.1	Grey colour, fine to medium grained, garnet-biotite gneiss
25.6	28.6	3	Greyish white colour, very fine grained, massive, garnet-biotite gneiss
28.6	31.7	3.1	Greyish white colour, fine to medium grained, slightly fractured, garnet-biotite gneiss
31.7	62.2	30.5	Pinkish white colour, very fine grained, massive, garnet grains and biotite specks abundant, garnet-biotite gneiss
62.2	65.2	3	Pinkish white colour, fine to medium grained, moderately fractured, garnet grains and biotite specks abundant garnet-biotite gneiss.
65.2	107.9	42.7	Dark grey colour, fine to medium grained, garnet-biotite gneiss

107.9	114	6.1	Greyish white colour, coarse to medium grained, slightly fractured, garnet-biotite gneiss
114	123.2	9.2	Greyish white colour, coarse grained, highly fractured, garnet-biotite gneiss
123.2	141.5	18.3	Greyish white colour, fine to medium grained, garnet-biotite gneiss
141.5	144.5	3	Dark grey colour, medium grained, slightly fractured, garnet-biotite gneiss
144.5	150.6	6.1	Pinkish white colour, fine grained, garnet grains abundant, garnet-biotite gneiss
150.6	153.7	3.1	Dark grey colour, coarse to medium grained, moderately, biotite specks abundant, garnet-biotite gneiss
153.7	200	46.3	Pinkish white colour, fine to medium grained, garnet grains abundant, garnet-biotite gneiss.

6. KULATHUPUZHA EW

Unique ID	
Village	KulathupuzhaEW
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58 H/1
Latitude	08^0 54' 15"
Longitude	77^0 04' 30"
RL(m amsl)	
Drilled Depth	115
Casing	5.4
SWL (mbgl)	
Discharge (lps)	
Date/Year	26.04.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Reddish brown colour, coarse grained laterite.

4	7.3	3.3	Greyish white colour, coarse grained, partially weathered garnet-biotite gneiss
7.3	10.3	3	Greyish white colour, fine to medium grained, garnet-biotite gneiss
10.3	13.4	3.1	Greyish white colour, fine to very fine grained, garnet-biotite gneiss
13.4	37.8	24.4	Grey colour, fine to medium grained, quartzo-feldspathic gneiss
37.8	40.8	3	Grey colour, medium grained, moderately fractured, quartzo-feldspathic gneiss
40.8	56.1	15.3	Greyish white colour, fine to medium grained, quartzo-feldspathic gneiss
56.1	59.1	3	Dark grey colour, medium grained, moderately fractured, garnet-biotite gneiss, garnet grains and biotite specks abundant.
59.1	65.2	6.1	Pinkish white colour, fine to medium grained, garnet-biotite gneiss
65.2	71.3	6.1	Dark grey colour, fine to medium grained, moderately fractured, garnet-biotite gneiss
71.3	95.7	24.4	Dark grey colour, fine to medium grained, garnet-biotite gneiss
95.7	98.8	3.1	Greyish white colour, coarse grained, highly fractured, quartzo-feldspathic gneiss
98.8	111	12.2	Greyish white colour, fine grained, quartzo-feldspathic gneiss
111	115	4	Greyish white colour, coarse grained, highly fractured, quartzo-feldspathic gneiss

7. KULATHUPUZHA OW

Unique ID	
Village	KulathupuzhaOW
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58 H/1
Latitude	08^0 55’ 15”
Longitude	77^0 06’ 30”
RL(m amsl)	
Drilled Depth	200

Casing	4.9
SWL (mbgl)	1.2
Discharge (lps)	2.9
Date/Year	16.05.07

Depth Range (mbgl)		Thickness (m)	Litholog
From	**To**		
0	4	4	Reddish brown colour, coarse grained, laterite.
4	5.5	1.5	Greyish white colour, medium grained, weathered quartzo-feldspathic gneiss
5.5	62.2	56.7	Greyish white colour, fine grained, quartzo-feldspathic gneiss
62.2	65.2	3	Grey colour, fine to medium grained, slightly fractured, quartzo-feldspathic gneiss
65.2	74.4	9.2	Grey colour, fine grained, quartzo-feldspathic gneiss
74.4	80.5	6.1	Dark grey colour, fine to medium grained, slightly fractured, quartzo-feldspathic gneiss
80.5	92.7	12.2	Greyish white colour, fine grained, quartzo-feldspathic gneiss
92.7	98.8	6.1	Greyish white colour, medium grained, moderately fractured, quartzo-feldspathic gneiss
98.8	111	12.2	Greyish white colour, fine to very fine grained, quartzo-feldspathic gneiss
111	114	3	Greyish white colour, coarse to medium grained, moderate to highly fractured, quartzo-feldspathic gneiss
114	150.6	36.6	Greyish white colour, fine grained, quartzo-feldspathic gneiss
150.6	168.9	18.3	Greyish white colour, fine to medium grained, quartzo-feldspathic gneiss
168.9	187.2	18.3	Greyish white colour, fine to very fine grained, quartzo-feldspathic gneiss
187.2	190.3	3.1	Greyish white colour, medium grained, moderately fractured, quartzo-feldspathic gneiss
190.3	200	9.7	Greyish white colour, very fine grained, quartzo-feldspathic gneiss

8. NELLIKUNNAM

Unique ID	
Village	Nellikunnam
Taluka/Block	Kottarakara
District	Kollam
Toposheet No.	58 D/13
Latitude	08^0 57' 58"
Longitude	76^0 46' 38 "
RL(m amsl)	
Drilled Depth	165.9
Casing	9
SWL (mbgl)	0.2
Discharge (lps)	1.3
Date/Year	16.07.07

Depth Range (mbgl)		Thickness (m)	Litholog
From	**To**		
0	4	4	Yellowish brown colour, coarse grained, laterite.
4	7.3	3.3	Dark Grey colour, fine to medium grained, partially weathered garnet-biotite gneiss
7.3	9	1.7	Greyish white colour, medium to coarse grained, slightly fractured, garnet-biotite gneiss
9	16.4	7.4	Pinkish grey colour, fine to medium grained, garnet grains abundant, garnet-biotite gneiss
16.4	22.5	6.1	Greyish white colour, fine grained, massive, garnet-biotite gneiss
22.5	46.9	24.4	Greyish white colour, fine to medium grained, garnet-biotite gneiss
46.9	50	3.1	Greyish white colour, coarse to medium grained, slightly fractured, garnet-biotite gneiss
50	83.5	33.5	Dark Grey colour, fine to medium grained, garnet-biotite gneiss

83.5	86.6	30.5	Pinkish white colour, coarse grained, moderately fractured, garnet-biotite gneiss
86.6	135.4	48.8	Greyish white colour, fine to medium grained, garnet-biotite gneiss
135.4	165.9	30.5	Greyish white colour, fine grained, massive, garnet-biotite gneiss

9. PATTAZHI

Unique ID	
Village	Pattazhi
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 C/16
Latitude	09^0 49’ 15”
Longitude	76^0 48’ 20”
RL(m amsl)	
Drilled Depth	200
Casing	9.9
SWL (mbgl)	4.52
Discharge (lps)	1.2
Date/Year	10.08.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	7.3	7.3	Brick red colour, Medium to coarse grained, laterite.
7.3	10.3	3	Greyish white colour, fine to medium grained, weathered garnet biotite gneiss
10.3	19.5	9.2	Greyish white colour, fine to very fine grained, garnet biotite gneiss
19.5	22.5	3	Dark bluish green colour, medium grained, charnockite
22.5	25.6	3.1	Dark bluish green colour, fine grained,charnockite
25.6	28.6	3	Bluish green colour, medium grained, moderately fractured, charnockite

28.6	40.8	12.2	Bluish green colour, fine to very fine grained, charnockite
40.8	53	12.2	Greyish white colour, very fine grained, massive, garnet biotite gneiss
53	56.1	3.1	Greyish white colour, medium to fine grained, finely fractured, garnet biotite gneiss
56.1	159.8	103.7	Greyish white colour, fine to very fine grained, massive, garnet biotite gneiss
159.8	162.8	3	Greyish white colour, medium grained, garnet biotite gneiss
162.8	200	37.2	Greyish white colour, very fine grained, massive, garnet biotite gneiss

10. THOTTATHARA EW

Unique ID	
Village	ThottatharaEW
Taluka/Block	Chadayamangalam
District	Kollam
Toposheet No.	58 D/13
Latitude	080 53’ 42”
Longitude	760 51’ 40”
RL(m amsl)	
Drilled Depth	200
Casing	9.7
SWL (mbgl)	5
Discharge (lps)	2.9
Date/Year	30.05.07

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Reddish brown colour, coarse grained laterite.
4	10.3	6.3	Greyish white colour, fine to medium grained, weathered quartzo-feldspathic gneiss
10.3	16.4	6.1	Grey colour, fine grained, quartzo-feldspathic gneiss

16.4	19.5	3.3	Grey colour, coarse to medium grained, slightly fractured, quartzo-feldspathic gneiss.
19.5	25.6	6.1	Greyish white colour, medium grained, quartzo-feldspathic gneiss
25.6	28.6	3	Pinkish white colour, coarse grained, moderately fractured, garnet biotite gneiss.
28.6	59.1	30.5	Greyish white colour, fine grained, massive, quartzo-feldspathic gneiss
59.1	86.6	27.5	Dark grey colour, fine to medium grained, slight to moderately fractured quartzo-feldspathic gneiss
86.6	98.8	12.2	Greyish white colour, fine grained, massive, quartzo-feldspathic gneiss
98.8	104.9	6.1	Dark colour, coarse grained, moderate to highly fractured, biotite specks abundant, garnet-biotite gneiss.
104.9	141.5	36.6	Greyish white colour, fine to medium grained, quartzo-feldspathic gneiss
141.5	144.5	3	Greyish white colour, medium grained, moderately fractured, quartzo-feldspathic gneiss
144.5	193.3	48.8	Greyish white colour, fine to medium grained, quartzo-feldspathic gneiss
193.3	200	6.7	Dark pink colour, fine to very fine grained, massive, garnet biotite gneiss.

11. VALIYAKAVU EW

Unique ID	
Village	ValiyakavuEW
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 C/16
Latitude	09^0 03’ 45”
Longitude	76^0 59’ 00”
RL(m amsl)	
Drilled Depth	108
Casing	7.8
SWL (mbgl)	9.03
Discharge	16.66

(lps)	
Date/Year	17.12.07

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	7.3	7.3	Reddish brown colour, fine grained, laterite.
7.3	10.3	3	Reddish brown colour, medium grained, laterite
10.3	13.3	3	Bluish green colour, medium to fine grained, weathered, charnockite
13.3	19.5	6.2	Bluish green colour, fine grained, charnockite
19.5	22.5	3	Bluish green colour, very coarse grained, charnockite
22.5	28.6	6.1	Bluish green colour, medium to fine grained, charnockite
28.6	50	21.4	Pinkish grey colour, very fine grained, massive, garnet grains abundant, garnet-biotite gneiss
50	86.6	36.6	Greyish white colour, fine to very fine grained, massive, garnet-biotite gneiss
86.6	89.6	3	Greyish white colour, coarse to medium grained, highly fractured, garnet-biotite gneiss
89.6	95.7	6.1	Pinkish grey colour, fine to medium grained, garnet grains abundant, garnet-biotite gneiss
95.7	101.8	6.1	Greyish white colour, fine grained, massive, garnet-biotite gneiss
101.8	104.9	3.1	Pinkish grey colour, coarse to medium grained, quartzite vein intrusion noted, highly fractured, garnet-biotite gneiss
104.9	108	3.1	Greyish white colour, fine to medium grained, garnet-biotite gneiss

12. VALIYAKAVU OW

Unique ID	
Village	ValiyakavuOW
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 C/16
Latitude	09^{0} 01' 30"
Longitude	76^{0} 52' 00"
RL(m amsl)	
Drilled Depth	123
Casing	11.4
SWL (mbgl)	10.6
Discharge (lps)	14
Date/Year	31.12.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	10.3	10.3	Reddish brown colour, medium grained, laterite.
10.3	13.4	3.1	Dark grey colour, medium to fine grained, weathered, charnockite
13.4	37.8	24.4	Bluish green colour, very fine grained, massive, charnockite
37.8	43.9	6.1	Bluish green colour, coarse to medium grained, quartzite vein intrusion noted, slightly fractured, charnockite
43.9	53	9.1	Bluish green colour, medium grained, charnockite
53	56.1	3.1	Bluish green colour, very coarse grained, moderately fractured, charnockite
56.1	62.2	6.1	Bluish green colour, medium to fine grained, charnockite
62.2	65.2	3	Greyish white colour, very coarse grained, highly fractured, quartzite vein intrusion noted
65.2	68.3	3.1	Greenish white colour, very coarse grained, highly fractured, serpentinised dunite.

68.3	74.4	6.1	Greyish white colour, coarse to medium grained, pegmatite and quartzite vein intrusion noted, highly fractured, garnet-biotite gneiss
74.4	77.4	3	Dark grey colour, fine grained, garnet-biotite gneiss
77.4	80.5	3.1	Pinkish grey colour, coarse to medium grained, quartz and garnet grains abundant, highly fractured, garnet-biotite gneiss
80.5	101.8	21.3	Greyish white colour, fine grained, garnet-biotite gneiss
101.8	123	21.2	Greyish white colour, fine to medium grained, garnet-biotite gneiss

13. KADAKKAL

Unique ID	
Village	Kadakkal
Taluka/Block	Chadayamangalam
District	Kollam
Toposheet No.	58 H/1
Latitude	08^0 48’ 54”
Longitude	76^0 55’ 10”
RL(m amsl)	
Drilled Depth	200
Casing	11.4
SWL (mbgl)	2.32
Discharge (lps)	1.3
Date/Year	13.06.07

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Brownish yellow colour, Fine to medium grained, laterite.
4	12	8	Whitish brown colour, Fine to medium grained, weathered garnet-biotite gneiss
12	19.5	7.5	Greyish white colour, fine grained, garnet-biotite gneiss

19.5	22.5	3	Grey colour, medium grained, slightly fractured, garnet-biotite gneiss
22.5	28.6	6.1	Grey colour, medium grained, garnet-biotite gneiss
28.6	59.1	30.5	Dark grey colour, fine grained, charnockite
59.1	89.6	30.5	Grey colour, fine to medium grained, garnet-biotite gneiss
89.6	101.8	12.2	Dark grey colour, fine to medium grained, charnockite
101.8	120.1	18.3	Greyish white colour, medium grained, slightly fractured, garnet-biotite gneiss
120.1	123.2	3.1	Grey colour, medium grained, moderately fractured, charnockite
123.2	144.9	21.7	Grey colour, fine grained, charnockite
144.9	159.8	14.9	Greyish white colour, fine to medium grained, garnet-biotite gneiss
159.8	187.2	27.4	Pinkish white colour, fine grained, garnet-biotite gneiss
187.2	190.3	3.1	Greyish white colour, medium grained, moderately fractured, garnet-biotite gneiss
190.3	200	9.7	Greyish white colour, fine to medium grained, garnet-biotite gneiss

14. AMBALATHUMBHAGAM

Unique ID	
Village	Ambalathumbhagam
Taluka/Block	Sasthamkotta
District	Kollam
Toposheet No.	58C/12
Latitude	09^{0} 01’ 20”
Longitude	76^{0} 39’ 40”
RL(m amsl)	
Drilled Depth	301.89
Casing	63.86

SWL (mbgl)	-
Discharge (lps)	0.5
Date/Year	May-86

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	22.36	22.36	Clay, reddish brown sticky Laterite
22.36	39.6	17.24	Clay lithiomargic white
39.6	63.47	23.87	Granet biotite gneiss,highly weathered
63.47	107.09	43.62	Garnet biotite gneiss hard and massive occasionally fractures
107.09	190.91	83.82	Garnet biotite gneiss slightly fractured
190.91	256.97	66.06	Garnet biotite gneiss occasionally fractured with abundance of quartz and feldspar
256.97	301.89	44.92	Garnet biotite gneiss hard and massive

15. ARIANKAVU

Unique ID	
Village	Ariankavu
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58 H/1
Latitude	08^0 58’ 15”
Longitude	77^0 09’ 00”
RL(m amsl)	
Drilled Depth	129.95
Casing	9.59
SWL (mbgl)	2.15
Discharge (lps)	
Date/Year	23.10.87

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	9.59	9.59	Topsoil with lithomargic clay, laterite
9.59	27.27	17.68	Garnet-Biotite gneiss weathered occasionally hard and massive

27.27	43	15.73	Garnet-Biotite gneiss moderately to highly fractured
43	82	39	Garnet-Biotite gneiss hard and massive
82	94.85	12.85	Garnet-Biotite gneiss moderately fractured
94.85	129.92	35.07	Garnet-Biotite gneiss moderately fractured

16. IDAKATTU

Unique ID	
Village	Idakattu
Taluka/Block	Sasthamkotta
District	Kollam
Toposheet No.	58 C/12
Latitude	09 05’ 40”
Longitude	76^0 37’ 50”
RL(m amsl)	
Drilled Depth	200.53
Casing	7
SWL (mbgl)	0.56
Discharge (lps)	
Date/Year	31.10.87

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	5	5	Topsoil- Lateritic clayey, reddish brown colour
5	8.25	3.25	Clay- lithomargic
8.25	50	41.75	Garnet-Biotite gneiss slightly fractured
50	84.23	34.23	Garnet-Biotite gneiss- hard and massive with occasional fractures
84.23	152.81	68.58	Garnet-Biotite gneiss - moderately fractured
152.81	200.53	47.72	Garnet-Biotite gneiss- hard and massive with occasional fractures

17. KADACKAMON

Village	Kadackamon
Taluka/Block	Pathanapuram
District	Kollam
Toposheet No.	58 H/1
Latitude	09^0 04’ 10”
Longitude	76^0 53’ 50”
RL(m amsl)	
Drilled Depth	168.05
Casing	29.68
SWL (mbgl)	12.47
Discharge (lps)	15.2
Date/Year	14.11.87

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	10	10	Topsoil, Lateritic, reddish brown colour
10	38.02	28.02	Quartz feldspathic Vein - highly weathered
38.02	44	5.98	Quartz feldspathic Vein- slightly fractured
44	99.47	55.47	Calc granulite- slightly fractured
99.47	42.19	142.19	Calc granulite- hard and massive
42.19	168.05	168.05	Calc granulite-highgly fractured

18. KAMPANKOD

Unique ID	
Village	Kampankod
Taluka/Block	Vettikavala
District	Kollam
Toposheet No.	58 D/13
Latitude	08^0 54’ 50”
Longitude	76^0 51’ 20”
RL(m amsl)	
Drilled Depth	200.53

Casing	13.94
SWL (mbgl)	6.59
Discharge (lps)	5.5
Date/Year	2.9.87

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	7.24	7.24	Laterite-ferrugenous
7.24	13.94	6.7	Clay - Lithomargic, yellowish brown in colour
13.94	47.5	33.56	Garnet-Biotite gneiss moderately fractured
47.5	114.71	67.21	Garnet-Biotite gneiss occassionally massive
114.71	200.53	85.82	Garnet-Biotite gneiss moderately fractured

19. KARAMKODE

Unique ID		
Village	Karamkode	
Taluka/Block	Ithikara	
District	Kollam	
Toposheet No.	58 D/9	
Latitude	08^0 57' 20"	
Longitude	76^0 43' 20"	
RL(m amsl)		
Drilled Depth	200.53	
Casing	43.84	
SWL (mbgl)		Dry
Discharge (lps)		
Date/Year	Sep-87	

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Topsoil-Lateritic clayey
4	22.48	18.48	Clay-carbonaceous black in colour
22.48	37.72	15.24	Clay-white and sticky
37.72	43.84	6.12	Clay- Lithomargc mixed with weathered gneiss
43.84	50.13	6.29	Khondalite- Highly fractured
50.13	95.85	45.72	Khondalite- Slightly fractured

95.85	114.71	18.86	Khondalite- Occassionally fractured
114.71	156.81	42.1	Khondalite- Hard and massive
156.81	182	25.19	Khondalite- Slightly fractured
182	200.53	18.53	Khondalite- Hard and massive

20. KARUKONE

Unique ID	
Village	Karukone
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 54’ 15”
Longitude	76^0 56’ 05”
RL(m amsl)	
Drilled Depth	200.53
Casing	10.55
SWL (mbgl)	7
Discharge (lps)	2
Date/Year	29.09.87

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	10	10	Topsoil-Lateritic clayey
10	10.55	0.55	Clay- Lithomargic
10.55	35.25	24.7	Khondalite- Hard and massive
35.25	57	21.75	Khondalite- Highly fractured
57	77	20	Khondalite- Occasionally massive
77	93	16	Khondalite- Hard and massive with slickenslides along fracture zones
93	200.53	107.53	Khondalite- less fractured

21. KOTTARAKARA

Unique ID	
Village	Kottarakara
Taluka/Block	Kottarakara
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 59' 50"
Longitude	76^0 46' 15"
RL(m amsl)	
Drilled Depth	114.7
Casing	4.37
SWL (mbgl)	0.68
Discharge (lps)	11.04
Date/Year	08.10.87

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Topsoil-Lateritic mixed with clay
4	8.37	4.37	Garnet-Biotite gneiss slightly weathered and moderately fractured
8.37	63	54.63	Garnet-Biotite gneiss moderately fractured
63	114.71	51.71	Garnet-Biotite gneiss fractured with occasional massive layers

22. NELLIKUNNAM

Unique ID	
Village	Nellikunnam
Taluka/Block	Vettikavala
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 57' 30"
Longitude	76^0 46' 30"

RL(m amsl)	
Drilled Depth	200
Casing	4
SWL (mbgl)	2.56
Discharge (lps)	1.2
Date/Year	17.09.89

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Laterite-reddish brown in colour
4	4.5	0.5	Garnet-Biotite gneiss highly weathered
4.5	103.47	98.97	Garnet-Biotite gneiss hard and massive occassionally fractured
103.47	129.95	26.48	Garnet-Biotite gneiss moderately fractured
129.95	200	70.05	Garnet-Biotite gneiss hard and massive

23. PUNALUR

Unique ID		
Village	Punalur	
Taluka/Block	Pathanapuram	
District	Kollam	
Toposheet No.	58C/16	
Latitude	09^0 01’ 35”	
Longitude	76^0 55’ 30”	
RL(m amsl)		
Drilled Depth	200.53	
Casing	6.76	
SWL (mbgl)	6.76	
Discharge (lps)	0.33	Abandoned-low discharge

Date/Year	07.05.86

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	6.76	6.76	Topsoil,Laterite-reddish brown sticky
6.76	47.5	40.74	Garnet-Biotite gneiss hard and massive
47.5	70.5	23	Garnet-Biotite gneiss slightly weathered
70.5	118.71	48.21	Garnet-Biotite gneiss hard and massive
118.71	200.53	81.82	Garnet-Biotite gneiss hard and massive

24. PUVATTUR PADINJARU

Unique ID		
Village	Puvathur Padinjaru	
Taluka/Block	Vettikavala	
District	Kollam	
Toposheet No.	58C/16	
Latitude	09^0 03’ 10”	
Longitude	76^0 45’ 00”	
RL(m amsl)		
Drilled Depth	200.53	
Casing	3.36	
SWL (mbgl)	5.82	
Discharge (lps)	0.33	Abandoned-low discharge
Date/Year	15.05.86	

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	3.36	3.36	Topsoil,Laterite-reddish brown in colour
3.36	46.47	43.11	Garnet-Biotite gneiss hard and massive occassionally fractured
46.47	103.47	57	Garnet-Biotite gneiss slightly fractured

103.47	129.95	26.48	Garnet-Biotite gneiss hard and massive
129.95	156.81	26.86	Garnet-Biotite gneiss hard and massive with minor fractures
156.81	200.53	43.72	Garnet-Biotite gneiss hard and massive with minor fractures

25. THADICAUD

Unique ID	
Village	Thadicadu
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 57’ 05”
Longitude	76^0 52’ 55”
RL(m amsl)	
Drilled Depth	175.67
Casing	11.12
SWL (mbgl)	12.9
Discharge (lps)	4.5
Date/Year	22.09.87

Depth Range (mbgl)		Thickness (m)	Litholog
From	**To**		
0	7.12	7.12	Clay-reddish brown in colour
7.12	11.12	4	Khondalite- Highly weathered with quartz
11.12	80.61	69.49	Khondalite- Highly fractured with abundance of feldspar occassionally massive
80.61	172.05	91.44	Khondalite- moderately fractured with ferrugeneous minerals occasionally massive
172.05	175.67	3.62	Dyke- Dolerite, fresh and massive

26. ANCHAL PZ

Unique ID	
Village	**Anchal**
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 55' 40"
Longitude	76^0 55' 00"
RL(m amsl)	
Drilled Depth	41.2
Casing	12.2
SWL (mbgl)	7.7
Discharge (lps)	0.21
Date/Year	21.07.98

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Laterite brick red in colour
4	12	8	Clay - fine grained yellowish
12	28	16	Khondalite- Massive
28	41.2	13.2	Khondalite- Fractured

27. ALIMUKKU

Unique ID	
Village	**Alimukku**
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58C/16
Latitude	09^0 03' 20"
Longitude	76^0 54' 58"
RL(m amsl)	
Drilled Depth	61
Casing	12.8
SWL (mbgl)	48.47
Discharge (lps)	0.03
Date/Year	16.07.1998

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	7	7	Laterite- brick red in colour

7	10	3	Khondalite- semi-weathered
10	13	3	Khondalite- semi-weathered
13	28	15	Khondalite- Massive unweathered
28	34	6	Khondalite- massive
34	43	9	Khondalite- Fractured
43	61	18	Khondalite- massive

28. CHIRATTAKONAM

Unique ID	
Village	**ChirattakonamPz**
Taluka/Block	Vettikavala
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 59’ 05”
Longitude	76^0 50’ 12”
RL(m amsl)	
Drilled Depth	41.2
Casing	20.4
SWL (mbgl)	17.2
Discharge (lps)	0.21
Date/Year	13.07.1998

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Laterite brick red in colour
4	13	9	Clay
13	19	6	Khondalite- semi-weathered
19	25	6	Khondalite- massive
25	28	3	Khondalite-fractured
28	31	3	Khondalite-massive
31	41.2	10.2	Khondalite-fractured

29. CHITHARA PZ

Unique ID	
Village	**Chithara Pz**
Taluka/Block	Chadayamangalam
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 49’ 05”

Longitude	76^0 59' 00"
RL(m amsl)	
Drilled Depth	41.2
Casing	18.3
SWL (mbgl)	15.229
Discharge (lps)	0.21
Date/Year	21.07.98

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Laterite brick red in colour
4	7	3	Clay
7	18	11	Khondalite- semi-weathered, fractured
18	28	10	Khondalite- massive
28	41.2	13.2	Khondalite-slightly fractured

30. KALLUVATHUKAL PZ

Unique ID	
Village	**Kalluvathukkal Pz**
Taluka/Block	Ithikara
District	Kollam
Toposheet No.	58D/9
Latitude	08^0 49' 00"
Longitude	76^0 45' 10"
RL(m amsl)	
Drilled Depth	30.5
Casing	12.8
SWL (mbgl)	7.9
Discharge (lps)	0.31
Date/Year	11.07.1998

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Laterite red in colour
4	7	3	Clay -yellow
7	12	5	Khondalite- semi-weathered
12	30.5	18.5	Khondalite-fractured, unweathered

31. KULATHUPUZHA PZ

Unique ID	
Village	**Kulathupuzha Pz**
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58H/1
Latitude	08^0 54' 30"
Longitude	77^0 03' 24"
RL(m amsl)	
Drilled Depth	41.2
Casing	12.8
SWL (mbgl)	6.75
Discharge (lps)	0.75
Date/Year	20.07.1998

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	1	1	Laterite dark brick red in colour
1	13	12	Clay
13	19	6	Khondalite- unweathered, fractured
19	34	15	Khondalite- massive
34	41.2	7.2	Khondalite- fractured

32. PATHANAPURAM PZ

Unique ID	
Village	**Pathanapuram Pz**
Taluka/Block	Pathanapuram Pz
District	Kollam
Toposheet No.	58C/16
Latitude	09^0 05' 12"
Longitude	76^0 51' 20"
RL(m amsl)	
Drilled Depth	82.3
Casing	14.3
SWL (mbgl)	56.8
Discharge (lps)	0.03
Date/Year	14.07.1998

Depth Range (mbgl)	Thickness	Litholog

From	To	(m)	
0	1	1	Laterite red in colour
1	13	12	Khondalite- semi-weathered with clay
13	31	18	Khondalite- massive, unweathered
31	49	18	Khondalite- massive
49	67	18	Khondalite- Fractured
67	70	3	Khondalite- Fractured massive
70	73	3	Khondalite- Fractured
73	76	3	Khondalite- massive
76	79	3	Khondalite- massive
79	82.3	3.3	Khondalite- massive

33. THENMALA PZ

Unique ID	
Village	**Thenmala Pz**
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58H/1
Latitude	08^0 57' 55"
Longitude	77^0 04' 35"
RL(m amsl)	
Drilled Depth	30.5
Casing	11.3
SWL (mbgl)	9.5
Discharge (lps)	0.5
Date/Year	17.07.1998

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	1	1	Laterite brick red in colour
1	10	9	Khondalite- semi-weathered
10	11	1	Khondalite- semi-weathered
11	16	5	Khondalite- massive
16	19	3	Khondalite- Fractured

19	25	6	Khondalite- massive
25	28	3	Khondalite- Fractured
28	30.5	2.5	Khondalite- massive

34. UMMANNUR PZ

Unique ID	
Village	**Ummannur Pz**
Taluka/Block	Vettikavala
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 56’ 00”
Longitude	76^0 50’ 16”
RL(m amsl)	
Drilled Depth	45.7
Casing	14.3
SWL (mbgl)	18.43
Discharge (lps)	1.45
Date/Year	12.07.1998

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	1	1	Laterite- dark brown in colour
1	4	3	Laterite - Red in colour
4	7	3	Reddish yellow Clay with semi-weathered khondalite
7	10	3	Khondalite- semi-weathered
10	13	3	Khondalite- semi-weathered
13	43	30	Khondalite- Fractured
43	45.7	2.7	Khondalite- Highly Fractured

35. YEROOR PZ

Unique ID	
Village	**Yeroor Pz**
Taluka/Block	Anchal
District	Kollam
Toposheet No.	58D/13
Latitude	08^0 55’ 56”
Longitude	76^0 57’ 25”

RL(m amsl)	
Drilled Depth	61
Casing	8.5
SWL (mbgl)	8.5
Discharge (lps)	0.03
Date/Year	18.07.1998

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	9	9	Laterite- dark brown in colour
9	28	19	Khondalite- unweathered, fractured
28	49	21	Khondalite-massive
49	61	12	Khondalite- fractured

ANNEXURE III

WATER LEVEL DATA OF KEY WELLS IN STUDY AREA

SITE_NAME	SITE_TYPE	Agency	Apr-16	Nov-16	Apr-17
Ariyankavu(kazhuthurutty)	Bore Well	GWD	6.44		8.06
Anchal	Bore Well	CGWB	9.98	7.06	11.25
Velinallur	Bore Well	GWD	8.06		8.77
Mylom	Bore Well	GWD	5.48		6.17
Kalluvathukkal	Bore Well	CGWB	6.43	5.62	6.68
Chithara	Bore Well	GWD	9.025	8.965	9.13
Yeroor1	Bore Well	CGWB	6.87	5.98	6.92
Kulakkada	Bore Well	GWD	8.05	6.82	8.00
Nellikunnam Pz New	Bore Well	CGWB	1.76	1.33	1.7
Achenkovil (R1)	Dug Well	CGWB	5.93	6.12	7.71
Ailara	Dug Well	CGWB	2.47	2.96	2.92
Alayamon	Dug Well	CGWB	9.48	8.52	
Alumoodu	Dug Well	CGWB	9.18		9.61
Anchal DW	Dug Well	CGWB	12.76	10.7	15.05
Ariyankavu	Dug Well	CGWB	12.5	7.92	8
Avaneswaram	Dug Well	CGWB	4.23	4.85	4.36
Ayur	Dug Well	CGWB	7.85	11.18	10.68
Bharathipuram	Dug Well	CGWB	9.9	10.4	11.71
Chadayamangalam (R1)	Dug Well	CGWB	8.1	11.38	11.2
Channapetta	Dug Well	CGWB	14	11.16	13.67
Chenkulam	Dug Well	CGWB	5.48		6.67
Chithara	Dug Well	CGWB	8.64	7.62	9.1
Choorakulam Jn	Dug Well	CGWB	7.42	7.55	8.39
Edamon	Dug Well	CGWB	9.8	9.8	10.23
Edamulakkal	Dug Well	CGWB	6.03	6.91	6.57
Edayam	Dug Well	CGWB	13.12	11.81	14.7
Ezhamkulam	Dug Well	CGWB	9.8	9.58	10.3
Ezhukone (R1)	Dug Well	CGWB	4.13	5.55	5.54
Kadakkal	Dug Well	CGWB	8.54	9.05	8.58
Kalluvathukkal	Dug Well	CGWB	9.45	8.66	10.32
Kamukanchery	Dug Well	CGWB		10.15	10.44
Kandanchiramukku	Dug Well	CGWB		7.91	8.7
Kanjiramvila	Dug Well	CGWB	8.95	9.4	8.29
Karamkode	Dug Well	CGWB	11.67	12.91	13.03
Karavaloor	Dug Well	CGWB			7.052
Karukone	Dug Well	CGWB	8.23	7.88	9.1
Karunthalakode	Dug Well	CGWB	2.31	2.46	3.32
Koovakad DW	Dug Well	CGWB	4.4	4.63	5.72
Kottakayam	Dug Well	CGWB	8.79	8.3	
Kottarakara (R1)	Dug Well	CGWB	16.4	16.95	17.68
Kottathala	Dug Well	CGWB		8.33	9.43

Kottiyam	Dug Well	CGWB	9.86	10.62	10.39
Kulakada	Dug Well	CGWB		7.79	8.14
Kulapadam	Dug Well	CGWB	8.57	8.04	9.77
Kulathupuzha	Dug Well	CGWB	7.18	6.5	6.98
Kunnada	Dug Well	CGWB	8.8	13.34	13.76
Kunnathur	Dug Well	CGWB		19	21.6
Kutavettur	Dug Well	CGWB	6.6	8.29	8.72
Madathara	Dug Well	CGWB	5.32	6.04	5.28
Mulavana	Dug Well	CGWB	10.7	10.85	11.12
Muthukumel	Dug Well	CGWB	6.48	7.01	7.32
Nallila	Dug Well	CGWB	5.28	7.74	6.27
Nellikunnam DW	Dug Well	CGWB	1.13	2.5	2.83
Nilamel	Dug Well	CGWB	4.41	5.23	6.42
Odanavattom	Dug Well	CGWB	8.74	7.24	9.7
Ottakkal	Dug Well	CGWB	7.74		7.41
Oyur	Dug Well	CGWB	9.73	10.26	11.75
Palamoodu	Dug Well	CGWB	10.9	12.78	11.2
Pallickal	Dug Well	CGWB	6.32	7.21	7.32
Pangalukadu	Dug Well	CGWB	6.14	7.37	6.2
Paripally1	Dug Well	CGWB		12	13.72
Pattanapuram	Dug Well	CGWB	7.59	11.44	11.55
Pavitreswaram	Dug Well	CGWB	4.75		5.55
Perumkulam	Dug Well	CGWB	8.9	7.41	10.26
Punalur-I	Dug Well	CGWB			9.32
Punalur-I (R1)	Dug Well	CGWB	8.73	11.31	12.67
Puthoor	Dug Well	CGWB	8.12	8.83	6.57
Roduvila	Dug Well	CGWB	8.48	8.69	9.58
Tadicaud (R1)	Dug Well	CGWB	8.9	8.3	10.01
Thattamala	Dug Well	CGWB		4.3	3.7
Thenmala	Dug Well	CGWB	9.77	8.4	8.61
Ummannur	Dug Well	CGWB	9.95	10.05	11.12
Vazhathoppu	Dug Well	CGWB	9.68	8.1	9.21
Veliyam	Dug Well	CGWB	9.82	9.64	12.63
Vilakkupara	Dug Well	CGWB	7.8	11.61	11.65
Yeroor	Dug Well	CGWB	2.8	3.01	3.51
Adichanallur	Dug Well	KW		4.86	3.28
Ambalamkunnu	Dug Well	KW		9.1	11.12
Chakkuvarakkal	Dug Well	KW	13.1	13.35	14.2
Chengamanad	Dug Well	KW	7.55	8.98	8.74
Chunda	Dug Well	KW	6.7	6.23	
Kalayapuram	Dug Well	KW	5.9	6.85	8.2
Kalluvadakkal	Dug Well	KW			9.14
Karalikonam	Dug Well	KW	8.9		10.92
Karavur	Dug Well	KW	8.85	9.22	9.81

Karippira	Dug Well	KW		8.02	10.79
Karuvel	Dug Well	KW		8.86	11.71
Killoor	Dug Well	KW		5.54	6.62
Kottathala	Dug Well	KW	11.13	10.57	12.98
Kottukal	Dug Well	KW	4.1	5.24	6.98
Kuriyanayyam	Dug Well	KW	4	4.1	4.97
Mailom	Dug Well	KW	2.45	3.31	4.28
Manchallur	Dug Well	KW	2.8	3.64	4.52
Mathra	Dug Well	KW	4.7	5.42	4.88
Mavila	Dug Well	KW	4.65	4.24	4.94
Miyannur	Dug Well	KW		11.32	12.83
Neduvankavu	Dug Well	KW		4.3	4.92
Nellikunnam	Dug Well	KW		3.35	4.78
Nettayam	Dug Well	KW	7.25	7.22	9.02
Nilakkal	Dug Well	KW			
Panaveli	Dug Well	KW			4.02
pattazhi	Dug Well	KW	7.1	6.99	7.68
pattazhi-ii	Dug Well	KW	4.97	5.53	
Pavithreswaram Jn	Dug Well	KW	9.7	9.58	10.64
Piravanthur	Dug Well	KW	4.9	4.45	5.18
Poredam	Dug Well	KW	9.25		10.5
Puthurmukku	Dug Well	KW	10.8	9.14	13.47
Randalamoodu	Dug Well	KW	10.65	9.48	11.6
Roaduvila	Dug Well	KW			10.44
Thumbod	Dug Well	KW	6	5.37	6.6
Vayakkal	Dug Well	KW	2.9		
Velamanur	Dug Well	KW		8.18	9.53
Vellarvattom	Dug Well	KW	6.75		
Karavoor	Bore Well	GWD	8.32	8.28	8.19
Kazhuthurutty	Dug Well	GWD	5.82	5.53	6.84
Pattazhy	Dug Well	GWD	7.23	7.17	7.05
Veliyam	Dug Well	GWD	9.54	10.47	11.11
Avaneeswaram	Bore Well	GWD	7.55		7.26
Thenmala(urukunnu)	Bore Well	GWD	7.03		6.59
Kottarakkara	Bore Well	GWD	5.32	4.88	4.63
Ariyankavu	Bore Well	GWD	6.52		5.73
Karavaloor	Bore Well	GWD	7.78	6.82	6.63
Kadakkal	Bore Well	GWD	10.85		8.00
Edamullackkal	Bore Well	GWD	6.72		1.11
Edamon	Bore Well	GWD	10.96	9.67	1.18
Kulathupuzha1	Bore Well	CGWB	41.2	6.76	
Karavoor	Dug Well	GWD	8.32	8.28	8.19
Vilakudy	Bore Well	GWD	11.52		1.25
Koovakad	Bore Well	CGWB		2.45	5.3

Ummmannur	Bore Well	CGWB		10.92	13.6
Karavaloor	Dug Well	GWD	7.78	6.82	6.63
Melila	Bore Well	GWD		3.98	1.11
Pathanapuram	Bore Well	CGWB			1.02
Kadakkal	Dug Well	GWD	10.85		8.00
Nilamel	Dug Well	GWD		2.27	3.07
Ayoor	Dug Well	GWD	4.98	5.42	4.69
Yeroor	Dug Well	GWD	3.76	2.45	4.19
Kulathupuzha	Dug Well	GWD	7.31	5.53	6.92
Thenmala	Dug Well	GWD	8.31	8.55	8.77
Chadayamangalam Pz	Bore Well	CGWB	5.45		
Edamon	Dug Well	GWD	10.96	9.67	
Piravanthur	Dug Well	GWD	4.56	3.52	4.38
Pathanapuram	Dug Well	GWD	8.66	7.76	8.42
Nallila Pz	Tube Well	CGWB			
Kottarakkara	Dug Well	GWD	5.32	4.88	4.63

ANNEXURE IV

PUMPING TEST DETAILS OF EXPLORATORY WELLS

Village/ Location	Taluk/ Block	District	Depth	Dia(mm)	Date of pumping Test	SWL (mbgl)	Discharge (lps)	Draw Down	Transmisivity (m^2/day)	Storativity/` S.Yield	Specific capacity (lpm/m of dd)
Vazhathopu (Kadakkaman)	Pathanapuram	Kollam	**200**	**178**	**-**	**Dry**	**-**	**-**	-	-	-
Ezhukone	Kottarakara	Kollam	123.1	178	02.08.2007	3	0.35	10.54(100min)	0.644	1.99	
KaravurEW	Pathanapuram	Kollam	200	178	14.01.08	2.53	3.05	7.00(500min)	45.43	-	26.57
KaravurOW	Pathanapuram	Kollam	200	178	04.12.2007	1.21	1.2	28.29(100min)	1.28	-	2.55
Kottukal	Chadayamangalam	Kollam	200	178	03.07.2007	21.06	0.87	15.70(100)	2.26	-	3.32
KulathupuzhaEW	Anchal	Kollam	115	178	27.04.07	2.15	5.5	11.25(100)	52.84(Jacobs)	-	-
KulathupuzhaOW	Anchal	Kollam	200	178	18.05.2007	1.2	2.6	21.55(100)	65.62	-	6.93
Nellikunnam	Kottarakara	Kollam	165.9	178	19.07.2007	0.2	1	36(100)	0.83	-	1.67
Pattazhi	Pathanapuram	Kollam	200	178	14.08.2007	4.52	0.71	22.93(100)	1.16	-	1.86
ThottatharaEW	Chadayamangalam	Kollam	200	178	01.06.07	5	2.48	22.12(100)	7.403	-	6.73
ValiyakavuEW	Pathanapuram	Kollam	108	178	21.12.07	9.03	7.9	7.20(100)	31.27(Theis recovery)	-	-
ValiyakavuOW	Pathanapuram	Kollam	123	178	03.01.2008	10.6	6	5(100)	45.16	-	72
Kadakkal	Chadayamangalam	Kollam	200	178	19.06.2007	2.32	1.3	29.50(100)	1.083	-	2.64
Ambalathumbhagam	Sasthamkotta	Kollam	301.89	178	-	-	-	-	-	-	-

Ariankavu	Anchal	Kollam	129.95	178	23.10.87	2.15	20	14.85(100)		-	56.76
Idakattu	Sasthamkotta	Kollam	200.53	178	31.10.87	0.56	2.5	26.58(100)	3	-	1.47
Kadackamon	Pathanapuram	Kollam	168.05	178	14.11.87	12.47	15.2	22.80(1000)	35	-	17.12
Kampankod	Vettikavala	Kollam	200.53	178	02.09.87	6.59	5.5	16.58(500)	10	-	10.09
Karamkode	Ithikara	Kollam	200.53	178	-	-	-	-	-	-	-
Karukone	Anchal	Kollam	200.53	178	29.09.87	7	2	25.72(500)	0.43	-	0.86
Kottarakara	Kottarakara	Kollam	114.71	178	08.10.87	0.68	13	10.63(1000)	51.4	-	73.38
Nellikunnam	Vettikavala	Kollam	200		17.09.87	2.56	0.72	23.01(575)	1.17	-	1.86
Punalur	Pathanapuram	Kollam	200.53		-	-	-	-	-	-	-
Puvathur Padinjaru	Vettikavala	Kollam	200.53	-	-	-	-	-	-		-
Thadicadu	Anchal	Kollam	175.67		22.09.87	12.9	2.09	20.44(1000)	5.17	-	6.14

RD-7
1/1/18

GOVERNMENT OF KERALA

No.GW1/426/2017/WRD

Water Resources (GW) Dept.,
Thiruvananthapuram,
Dated, 28/12/2017.

From

The Secretary to Government.

To

Shri V.Kunhambu, Regional Director& Member Secretary, CGWB.

Shri John Kurian , Former CGM, NABARD.

Shri John Koshy, Executive Engineer, KWA.

Shri Thomas Scaria, District Officer, GWD.

Shri. Jose James, Director, Suptdg HG, GWD.

Smt Ambili G K, Scientist, CWRDM.

Shri Jayakumaran Nair, Deputy Director, Industries & Commerce.

Shri Raju Varghese, Administrative Assistant, Directorate of Panchayath.

Shri K Shoukathali, Additional Development, commissioner, Rural Development Department.

Shri K Balakrishnan, Scientist D, CGWB.

Dr.N.Vinayachandran, Scientist D, CGWB.

Smt.T.S. Anitha Shyam, Scientist D, CGWB.

Smt Minichandran, Scientist D, CGWB.

Smt. Rani V. R, Scientist C, CGWB.

T-spl send copy to
1 all member of SCTCC
2 M Sonty
3 PMU, CtG Pandit
1/1/18

Sir,

Sub:-WRD– Minutes of the 5th meeting of the State Level Coordination Committee for NAQUIM Kerala forwarding of - reg.

I am to forward herewith the minutes of the meeting held on 13.12.2017 in the South Conference Hall, Secretariat for information and necessary action.

Yours faithfully,

S. MURALEEDHARAN
DEPUTY SECRETARY
FOR SECRETARY TO GOVERNMENT

Approved for issue,

Reena

Section Officer.

6

Minutes of the 5th meeting of the State Level Coordination Committee for NAQUIM Kerala

The Fifth meeting of the State Level Coordination Committee of National Aquifer Mapping Programme of CGWB was held on 13.12.2017 at 15.00 hours in the South Conference hall, Secretariat. Smt. Tinku Biswal, IAS, Secretary, Water Resources Department, Govt. of Kerala and Chairman, SLCC of NAQUIM chaired the meeting.

The following Members attended the meeting:

Sl.No	Name & Designation	Organization
1.	Shri V.Kunhambu, Regional Director& Member Secretary	CGWB
2.	Shri John Kurian , Former CGM	NABARD
3.	Shri John Koshy, Executive Engineer	KWA
4.	Shri Thomas Scaria, District Officer	GWD
5.	Shri. Jose James, Director, Suptdg HG	GWD
6.	Smt Ambili G K, Scientist	CWRDM
7.	Shri Jayakumaran Nair, Deputy Director	Industries & Commerce
8.	Shri Raju Varghese, Administrative Assistant	Directorate of Panchayath
9.	Shri K Shoukathali, Additional Development commissioner	Rural Development Department
10.	Shri K Balakrishnan, Scientist D	CGWB
11.	Dr.N.Vinayachandran, Scientist D	CGWB
12.	Smt.T.S. Anitha Shyam, Scientist D	CGWB
13.	Smt Minichandran, Scientist D	CGWB
14.	Smt Rani V R, Scientist C	CGWB

At the outset, the Chairperson welcomed the members and invited Regional Director, CGWB to appraise the members of the developments and progress of NAQUIM as per agenda set up for the meeting.. Shri V Kunhambu, Regional Director, CGWB, Kerala Region informed that all actions as decided in previous meeting has been completed except the data on rainfall not received from Irrigation department. The Chairperson agreed to do the needful to make available the required data from Irrigation department. Regional Director informed that 22 exploratory wells are to be constructed in sedimentary areas per NAQUIM recommendations has been allocated to WAPCOS. Followed by this item, a power point presentation on report on Aquifer Mapping and Management plan of Kollam and Palakkad district presented by Dr N Vinayachandran, Sc- D and Nodal Officer, CGWB. The committee appreciated the contents of report. Chairperson also desired that after completing the report district wise, it is to be apportioned to make River basinwise aquifer mapping and management plan including Modeling. Based on the recommendations of the report a comprehensive management plan for Bharathapuzha Basin is to be prepared for submission to Govt of India for financial support.

Action: CGWB, GWD & Irrigation Dept

Additional item:

Regional director, CGWB informed that major rainfall in Kerala goes as runoff and most of the river under the bridge areas prone to sand mining. A proposal can be made for construction of Bridge cum regulator so that the water covered upstream can reach the flood plain which can act as repository of saturated water from where water can be extracted for various purposes including for minor irrigation.

Chairperson agreed to this and advised to prepare a feasibility report of one most suitable river basin for onward submission to Govt of India.

Action: CGWB, Irrigation Dept & KWA

The meeting ended with thanks to the Chair.

Minutes of the

Fourth meeting of the National Level Expert Committee

held under the Chairmanship of Chairman, CGWB

29th May 2018, 1st June 2018& 6th June 2018 at Faridabad/ New Delhi**.**

List of participants is annexed. (Annexure-I)

Fourth meeting of the National Level Expert Committee for review and finalization of aquifer maps and management plans was held during 29th May 2018, 1st June 2018 & 6th June 2018 at CGWB Faridabad/ New Delhi under the Chairmanship of the Chairman, CGWB. Presentations were made in respect of area covered in the states of Uttar Pradesh, Uttarakhand, Madhya Pradesh, Maharashtra, Tamil Nadu, Puduchchery, Andhra Pradesh, Kerala, West Bengal, Bihar, Jharkhand, Chhattisgarh, North Eastern States and Odisha. Major decisions that emerged during the presentations/deliberations are summarized hereinafter.

- Uttar Pradesh (16892 sqkm)

The work carried out under NAQUIM by NR Lucknow was reviewed. Major modifications were recommended in respect of data, maps and management plans. Committee suggested to restrict the presentation as per the prevailing guidelines and focus more on the outcomes of Management Plans. Various other improvements and modifications as suggested by the Committee is to be incorporated and duly appraised to concern administrative Member before representing all presentations to the committee again.

– **Action**: Member (N&W) / RD, NR, Lucknow.

Uttarakhand (3000 sqkm)

Presentations in respect of areas covered under Aquifer mapping by the UR, Dehradun were made by the respective RD/HOO. Presentations on Uttarkashi and Doiwala (Dehradun), is approved by the Committee with minor modifications and suggestion in management plans. Committee suggested that management plans should be made more comprehensive including area specific management options.

– **Action**: RD/HOO, UR Dehradun/Member(N&W)

Madhya Pradesh (12769 sqkm)

Presentations in respect of area of Panna districts (6631 sqkm) covered under Aquifer mapping by the NCR, Bhopal were made by the officer of NCR CGWB in presence of RD. The committee suggested to include ground water development measures and expansion of agriculture and horticulture in proposed management plan apart from several minor suggestions. Committee approved presentation after inclusion of modification suggested and duly vetted by concerned Member.

– **Action**: Member(N&W) / RD, NCR, Bhopal

Himachal Pradesh (2400 sqkm)

Presentation on Nalagarh valley, Himachal Pradesh was made by Officers representing RD, NHR Dharamshala. Expert Committee suggested inclusion of existing data of exploratory drilling, and ground water quality studies carried out in past to ascertain ground water quality scenario in the area. Committee recommended to include area specific measures in quantitative terms in management plan instead of recommending generic suggestions. Committee approved study with rider to revise Management Plan and inclusions of suggestions of the committee and duly vetted by the concerned administrative Member.

- **Action**: Member(N&W) / RD, NHR, Dharamshala

- Tamil Nadu (14154 sqkm)

Presentation of Lower Cauvery basin made by RD SECR, Chennai was also approved by the Committee with rider to include suggestions of NLEC in Consultation with concern Administrative Member.

– **Action**: Member(S)/RD, SECR, Chennai

- Maharashtra (14626 sqkm)

Presentation of aquifer mapping areas of parts of Pune, Sangli, Satara and Dhule was made by RD CR, Nagpur. The presentation was accepted by NLEC.

– **Action**: RD, CR, Nagpur

- Andhra Pradesh (6950 sqkm)

Presentations in respect of area of East Godavari & West Godavari districts covered under Aquifer mapping by the SR Hyderabad were made by RD, SR, Hyderabad. The committee suggested to include creek regulators in management plan to manage tidal water to prevent saline water ingress. Committee approved presentation after inclusion of modification suggested and duly vetted by concerned Member.

- **Action**: Member(S)/RD, SR, Hyderabad

- Kerala (6400 sqkm)

  Presentation on Pattenamittha district, Kerala was made by RD, KR, Trivendrum. Expert Committee suggested that ground water resources to be estimated as per aquifer dispositions and their resource potentials. Incorporating resources estimation as per GEC-2015 can be restricted depict the extent of variance from GEC-2015 and Aquifer-wise resources under NAQUIM. Committee recommended to modify the management plan and duly vetted from respective administrative Member, CGWB. Presentation deemed approved by Committee.

  - **Action**: Member(S)/RD, KR, Trivendrum

- North Eastern States (8679 sqkm)

  Presentation of East Sing district was made by officer from NER, Guwahati. The aquifer maps and management plan. In the similar line, the aquifer maps and management plans of 8679 sqkm of NE states was prepared and submitted. The committee also suggested that detail data on springs particularly in and around Shillong city may be incorporated in these report.

  -Action: RD,NER, Guwahati /SOU, Shillong

- Odisha (3101 sqkm)

  Presentation of Kendrapada district was made by officer from SER, Bhubaneshwar. Thorough revision is required for aquifer maps and management plan for the areas of 3101sqkm as recommended by committee. Revised presentation should made as the circulated template.

  -Action: Member(East)/RD,SER, Bhubaneshwar

- West Bengal (2261 sqkm)

  The officer from ER, Kolkata has presented the aquifer maps and management plan for parts of Nadia, district. Committee suggested that the ground water resources should be estimated as per the finding of Aquifer Mapping. The revised aquifer maps and management plans may be prepared as suggested and duly approved by Member In- charge. With these modification and revision committee approved the aquifer maps and management plans.

-Action: Member(East)/ RD, ER, Kolkata

- Bihar (4627sqkm)

Officer from MER, Patna was presented the aquifer maps and management plan for Bhojpur, Patna, Buxar, Bhagalpur and Kathiar districts. The sections and maps may be modified and the exploration & water quality data interpretation may be carried out by better methods as suggested by committee. With these modification, the aquifer maps and management plan was approved by committee.

-Action: Member(East)/ RD, MER, Pa

- Jharkhand (1702 sqkm)

Presentation was made by officer from SUO, Ranchi for Sahebganj district (1702 sqkm). The committee suggested to consult GSI geological maps for better understanding of disposition of lava flows and Rajmahal Traps. The management plan can be improvised by incorporating the feasibility of ground water development through wells with pumps (Solar/Diesel/Electric). The revised aquifer maps and management plans may be prepared as suggested and duly approved by Member In-charge. With these modification and revision committee approved the aquifer maps and management plans.

-Action: Member(East)/ RD,MER, Patna/SUO,Ranchi

Chhattisgarh (8906 sqkm)

For an area of 8906 sqkm, the aquifer maps and management plans was presentation by officer form NCCR, Raipur. Committee suggested that the ground water resources should be estimated as per the finding of Aquifer Mapping. Through aquifer management plan, the state government may be suggested for better management option instead of presentpractice used by Chhattisgarh state of withdrawing the ground water to fill the ponds/lakes. The committee approved the aquifer Maps and management plan for areas presented during the meeting.

Action: Member(East)/ RD, NCCR, Raipur

The Expert Committee once again emphasized that during aquifer mapping studies ground water estimations should be made on aquifer –wise resources. Reflecting ground water resources estimation as per GEC 2015 methodology is not objective of Aquifer mapping. Further, the objective of NAQUIM should always be kept in mind by all the Regional Directorates. Presentations should be focused on objectives and desired outputs and possible outcomes. It is not appropriate to incorporate artificial recharge measures in all management plans as a thumb rule for ground water management. Areas with low development of ground water should suggest ground water development plans with area to be developed appropriately demarcated on maps based on agriculture demand.

- **Action**: All Regional Directors

National Level Expert Committee recommended major revision and repeat presentation for the states of Uttar Pradesh, Madhya Pradesh and Odisha.

Meeting ended with thanks to the Chair.

Annexure-I: List of participants

1	Shri K C Naik, Chairman, CGWB - in Chair
2	Dr G.C.Pati, Member (East)
3	Dr. E Sampath Kumar, Member (South)
4	Shri Alok Dubey, Member (North and West), CGWB
5	Dr. D K Chadha, Ex-Chairman, CGWB
6	Shri Sushil Gupta, Ex-Chairman, CGWB
7	Dr. A. K. Keshari, Professor, IIT, Delhi
8	Dr. S. Mukherjee, Professor, JNU, New Delhi
9	Dr. Bharat Sharma, Scientist Emeritus (WR), IWMI
1	Dr. P.K. Purchure, Regional Director, CR, Nagpur
1	Shri Sunil Kumar, Regional Director, RGI
1	Shri S Marwaha, Regional Director, CGWB, Faridabad
1	Shri C Paul Prabhakar, RD, SECR, Chennai
1	Shri. Subba Rao, Regional Director, SR, Nagpur
1	Shri Parvinder Singh, RD, NCR, Bhopal
1	Shri. Y.B. Kaushik, Regional Director, NR, Lucknow
1	Shri. V. Kunhambu, Regional Director, KR, Thiruvananthapuram
1	Shri. M. Muttukkannan, Suptdg. Hydrogeologist, SWR, Bangalore
1	Shri Sujeet Sinha, Scientist-D, CHQ, Faridabad
2	Shri. S. K. Junejha, Scientist-D, CGWA, New Delhi
2	Shri. Anurag Khanna, HOO, UR, Dehradun
2	Shri. A. Ashokan, Scientist-D, SECR, Chennai
2	Shri. Devendra Joshi, Scientist D, NCR, Bhopal
2	Shri. M.K.Garg, Scientist-D, CHQ, Faridabad
2	Shri Vidhya Nand Negi, Scientist D, NHR, Dharamshala
2	Shri. Ratikant Nayak, Scientist-D, CHQ, Faridabad
2	Shri. T. B.N. Singh, Scientist-D, SUO, Ranchi
2	Dr. S. Brahma, Scientist-D, ER, Kolkata
2	Shri. Tapan Chakroborty, Scientist-D, SUO, Shillong
3	Shri. P. K. Tripathi, Scientist-D, NR, Lucknow
3	Dr. S. K. Srivastava, Scientist-D, CHQ, Faridabad
3	Shri Gulab Prasad, Scientist D, CGWB, SER, Bhubaneswar
3	Shri S.N. Dewivedi, Scientist-C, CHQ, Faridabad
3	Smt. Rumi Mukherjee, Scientist-C, CHQ, Faridabad
3	Shri. Ravikalyan Bussa, Scientist-C, UR, Dehradun
3	Shri. Dr. Vikas Ranjan, Scientist-C, NR, Lucknow
3	Shri, Vidya Bhooshan, STA, NHR, Dharamshala
3	Shri S.K.Swaroop, Scientist B (JHG), CHQ, Faridabad
3	Shri. Debashish Bagchi, Asst. Hydrogeologist, CGWB, UR, Dehradun
4	Ms. Shilpi Gupta, Scientist B (JHG), CHQ, Faridabad
4	Shri. T. Madhav, Scientist-B, CHQ, Faridabad
4	Smt. Ritu K. Oraon, Scientist-B,NCR, Bhopal
4	Shri. P Yadaiah, AHG,CGWB, NewDelhi

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