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

WAYANAD DISTRICT, KERALA

केरल क्षेत्र, त्रिवेंद्रम

Kerala Region, Trivendrum

केंद्रीय भूजल बोर्ड, केरल क्षेत्र

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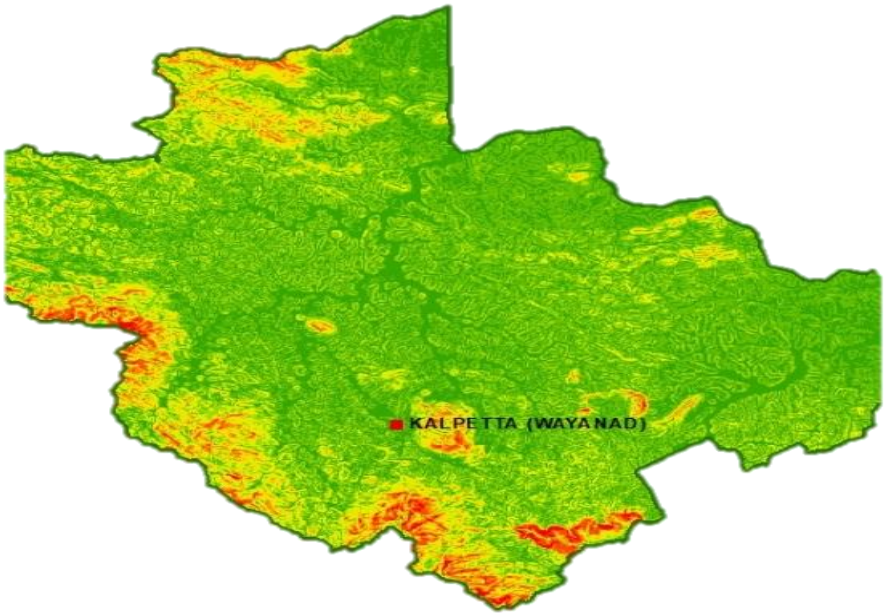
CENTRAL GROUND WATER BOARD
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
GOVERNMENT OF INDIA
KERALA REGION

AQUIFER MAPPING AND MANAGEMENT PLAN OF WAYANAD DISTRICT, KERALA (AAP: 2020-21)



SREEHARI SARANGAN M S
SCIENTIST-B

तिरुवनंतपुरम/THIRUVANATHAPURAM

फ़रवरी/FEBRUARY 2022

FOREWARD

The National Project on Aquifer Mapping (NAQUIM) is an initiative of the Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Government of India, for mapping and managing the entire aquifer systems in the country. The aquifer systems in Kerala are being mapped as part of this Programme. The target scale of investigation is 1:50,000 and envisages detailed study of the aquifer systems up to 200 m depth in hard rock and 300 m depth in sedimentary rock, to ascertain their resource, water quality, sustainability, and finally evolve an aquifer management plan. This report pertains to aquifer mapping and management plan of Wayanad district.

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

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

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

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

Thiruvananthapuram,
February 2022

(Dr.A.Subburaj)
Regional Director

AQUIFER MAPPING AND MANAGEMENT PLAN OF

WAYANAD DISTRICT, KERALA
(AAP- 2020-21)

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AQUIFER MAPPING AND GROUND WATER MANAGEMENT PLAN OF WAYANAD DISTRICT, KERALA

1.0 INTRODUCTION

During AAP 2020-21, under National Aquifer Mapping Programme (NAQUIM), CGWB Kerala Region, has taken up Aquifer mapping studies of Wayanad district. The study aims to formulate various ground water management interventions for the district after studying the characteristics of different water bearing formations (aquifer) in the district. The existing and additional data sets generated on geologic, geophysical, hydrologic and chemical quality are integrated and used to characterise the quantity, quality and sustainability of ground water in the aquifer systems. Various thematic maps on hydrogeological data are generated under a GIS environment which can be customised based on the administrative requirements. Aquifer mapping also envisages development of an Aquifer Management Plan to facilitate sustainable management of groundwater resources in the district. Major objectives of the aquifer mapping programme are (i) delineation and characterization of aquifers in three dimensions (ii) identification of issues on water quantity and quality (iii) Evaluation of groundwater water resources in various aquifer systems and, (iv) to evolve a groundwater management plan to ensure sustainable development of ground water resources. Various management plans for each aquifer system are to be prepared for different interventions to optimize ground water withdrawal/recharge. The management options also includes identification of feasible area for artificial recharge to ground water and water conservation besides, demand side management option including crop diversification, increasing water use efficiency etc. These management measures will help in the containment of declining water levels and overall improvement in the groundwater scenario. Lateral and vertical continuity of various aquifer systems need to be deciphered for evolving an efficient management.

1.1 OBJECTIVES

The objectives of mapping of aquifer systems in Wayanad are listed below.

(i) Define the aquifer geometry and depict the lateral and vertical variations through 2D and 3D maps.

(ii) Characterize the aquifer systems and its hydraulic properties

(iii) Study the influence of various components of the groundwater regime on the aquifer systems.

(iv) Evaluate the hydro-chemical characteristics of groundwater and the extent of contamination/pollution of groundwater, if any

(v) Identify the quantitative and qualitative issues of the aquifer systems

(vi)Evaluation of the groundwater resources in each aquifer system

(vii) Identify area suitable to Artificial Recharge structures to be implemented

(viii) Formulate a sustainable aquifer management plan

The objectives of the aquifer mapping are achieved through various steps/activities such as;

(i). Data gap analysis,

(ii). Data generation and integration and

(iii). Preparation of thematic maps and aquifer response models

Conceptualization of the sub surface disposition of aquifer system has been carried out by integrating all data available on the groundwater regime and from the available technical reports and publications within the department and line departments. The data gaps could be identified from the analysis of historical data which facilitated generation of new data in gap areas. The hydrogeological, hydrological, geophysical, hydro-chemical and meteorological data were analysed for data gaps. Groundwater draft from the aquifer systems has been evaluated from well inventory data and integrated use of lithological and geophysical data could refine the aquifer geometry of the area. Various thematic maps, cross sections, fence diagrams and three-dimensional view of aquifer systems are prepared in GIS platform showing the subsurface disposition of aquifer systems which can be used for various interpretations to formulate the sustainable management plans.

1.2 SCOPE OF THE STUDY

In Wayanad district, agriculture has always been climate dependent and even small changes in soil temperature and moisture levels can adversely affect the yield. Wayanad had bestowed with plenty of water earlier and the main agriculture was paddy and now the area is facing drought due to change in rainfall pattern due to climate change, deforestation and large-scale conversion of paddy fields into plantations. In 1980, there were 30,000 hectares of paddy fields in Wayanad. It has been reduced by more than 63 percent to 11053.63 hectare at present (CGWB, 2018). The climate and related environment are influenced by the geomorphological settings. The Wayanad district, famous for its agricultural traditions and bio diversity is greatly endangered today. The present scenario needs to be improved by adopting practices like afforestation, protection of paddy fields, conservation of water resources and artificial recharge to groundwater. Moreover, the impact of climatic changes on agriculture affects the livelihood of people in this district which has the highest percentage of tribal population.

1.3 LOCATION AND ADMINISTRATION

The word “Wayanad” was derived from the word “Vayal Nadu”, (Vayal- Paddy , Nadu-Land) which means the land of paddy fields and now known for its coffee plantation and picturesque hill stations. There is no town or village named same as the district (i.e., there is no "Wayanad town"). The district is located in the northern part of Kerala state bordering Karnataka and Tamil Nadu, spread over an area of 2131 sq.km which is about 5.5 % of total area of Kerala State. Earlier the district was part of Kannur district and present Wayanad district was formed on November1 ,1980 with district headquarter at Kalpetta. About 485 sq.km (23%) of area of the district is under forest. There are three Taluks viz.Vythiri, Sultan Bathery and Mananthavady and divided into four blocks viz. Kalpetta, Mananthavady, Sultan Bathery and Panamaram for administrative ease. (Fig.1.1). The district has 25 grama panchayats and three municipalities. The district is bordered by Malappuram in the south and Kozhikkod and Kannur districts on the west, Kannur district and Karnataka state are on the north

and Tamil Nadu and Karnataka states are in the east. Mananthavady block is the largest block (31.2%) and Panamaram is the smallest one (16.94 %). The urban area is about 40.74 sq. km.

Wayanad district comes under Survey of India (SOI) topographic sheets 49 M/13, 49 M/14, 58 A/1, 58 A/2, 58 A/5 and 58 A/6 and lies between North latitudes 11° 30' 08" and 11° 58' 40" and East longitudes between 75° 47' 23" and 76° 26' 40" .The famous Edakkal Caves is located in the district near Sultan Bathery which is known for ancient petroglyphs, some dating back to the Neolithic age .Wild life sanctuaries at Muthanga and Tholpetty are two prime tourist hubs famous for wild life tourism. Thirunelly temple, located in the northern part of district is an important pilgrimage destination in the district. Wayanad is well connected to the rest of Kerala by National Highways (NH -766, Kozhikode to Kollegal) and Sate high ways. The nearest railway station is at Kozhikkod in Kozhikode district about 78 km from Kalpetta and the nearest Airport is Karipur airport in Kannur district. Banasurasagar Dam in the district is considered to be the largest earth Dam in India and the second largest in Asia.

Wayanad district stand first position in the production of coffee (79.35% of total coffee production in state) and hosts 12.40% of the total area of pepper cultivation in the state, which is second largest producer in the State after Idukki. One important characteristic feature of this district is the large tribal population, consisting mainly of Paniyar, Adiyar, Kattunayakan and Kurichiyans communities.

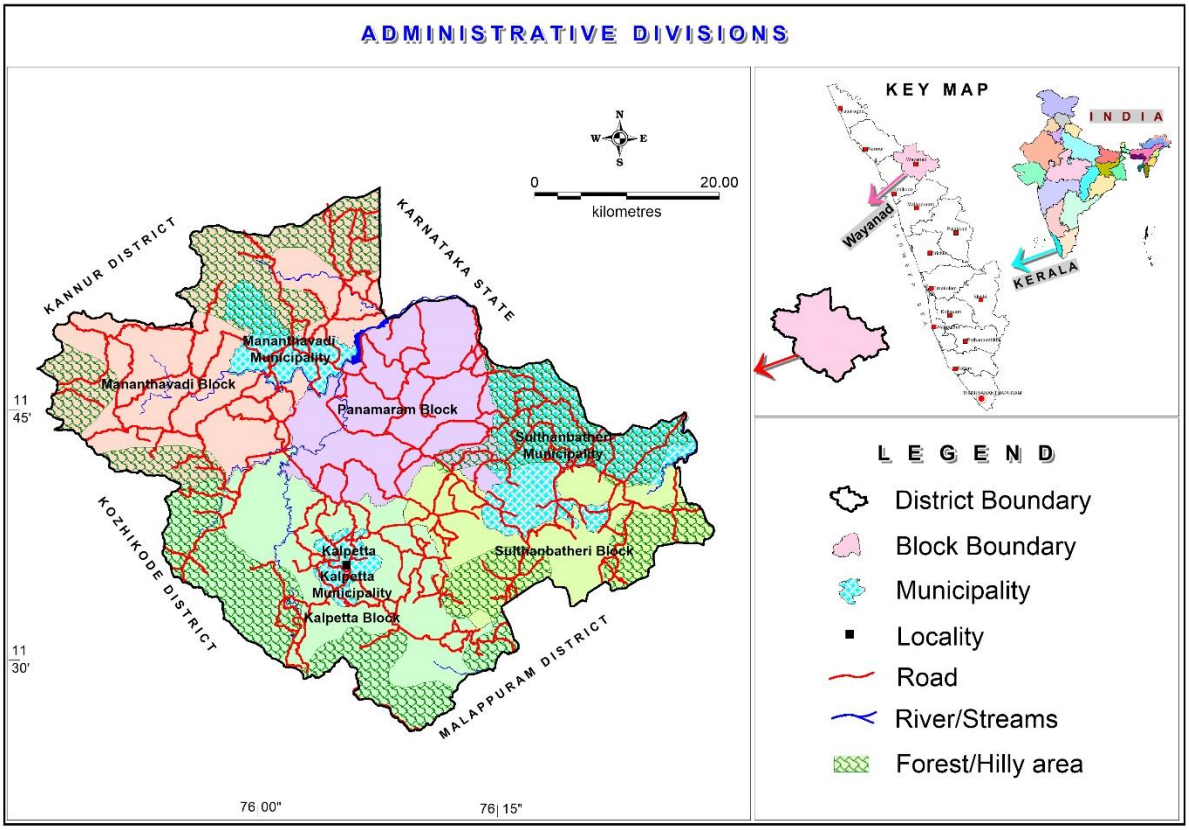


Fig.1.1 Administrative set up of Wayanad District

1.4 DEMOGRAPHY

As per Census data 2011, the total population of the district is 8,16,558 (M-4,01,314, F-4,15,244). The sex ratio is 1035 and population density is 384. The literacy rate is 89.32. Wayanad district has a large tribal population consisting mainly of Paniyas, Adiyas, Kattunayakan and Kurichiyans. Wyanad district stands first in the case of Adivasi Population (about 36%) among other districts in the state. Scheduled caste population comes only 1% of the state ST population.

1.5 CLIMATE & RAINFALL

Wayanad district is characterized by Tropical climate. Various elements of tropical climate are rainfall, temperature, humidity, wind velocity, potential evapo-transpiration, evaporation and insolation. The SW (80%) and NE (12%) monsoons mainly contribute rainfall in the area. Besides orographic precipitation and pre-monsoon "mango showers" play a role in rainfall availability in the area. It is observed that June experiences maximum rainfall and is the wettest month. Mean monthly rainfall is 2786 mm. The area experiences mild weather throughout the year which attract tourists. Areas closer to Karnataka border such as Pulpally, Mullankolly and Kappiset area there is lesser rainfall and lead to situation of rain shadow effect in these areas.

The maximum average temperature is in the range of 28.9°C to 36.2°C and minimum temperature is in the range of 17°C to 23.4 °C. December and January months experience coolest period. Even though March is comparatively hotter, temperature is always lesser than 35 °C. The severe heat waves were never recorded in the area. The wind velocity is generally low in the area and ranges between 1.91 and 5.69 km/hr in the area. The humidity in atmosphere is less during summer and it increases during rainy season. The monthly average relative humidity in the morning varies from 86.94 (morning at 8 .30 hr) to 96.16 %. On the other hand, monthly average relative humidity in the evening at 14.30 hr increases from 55.62 % to 85.23 %. The evaporation in the area is very less during rainy reason .The monthly mean evaporation ranges between 1.48 and 4.85 mm per day.

1.6 SOIL

There are four types soil encountered in Wayanad district viz. laterite soil, brown hydromorphic soil, forest loam and riverine alluvium.

Laterite soil seen in some areas of Wayanad and is reddish brown in colour, formed under tropical monsoonal climate with alternate wetting and drying condition. The organic matter in the soil is very less with moderate nitrogen, phosphorous and potash. The pH of the soil ranges between 5.5 and 6.5 and texture is clayey loam to silty loam with coarse fragments between 5 to 20%. Laterites on high grounds are more compact when compared to the low-lying areas.

Forest soil found in Mananthawady, Kalpetta and Sultan Bathery blocks. They are rich in organic matter, nitrogen and humus. Forest loam is dark reddish brown formed by weathering under forest cover with loamy to silty loam texture. The pH of the soil ranges between 5.3 and 6.3 and is slightly acidic in nature.

Brown hydromorphic soil (BHS) is mainly seen between undulating topography in Wayanad district. The BHS is very deep brownish with sandy loam to clayey texture. The BHS is formed by transportation and sedimentation of material from hill slopes. The pH of the soil ranges between 5.2 and 6.3 and is slightly acidic in nature.

Alluvial soils are found along the banks of Kabani, Chaliyar and its tributaries. Riverine alluvium is very deep with sandy loam to clayey loam texture. Majority of the area under riverine alluvium was once occupied by paddy. Those areas are now utilised for the cultivation of various crops especially plantain. The riverine alluvium contains moderate organic matter, nitrogen, phosphorous and potash. The areal distribution of various soil texture is given in table 1.1 and the soil map is depicted in fig 1.2. The clayey soil has the dominant texture and gravelly loam has negligible presence.

Table 1.1: Aerial distribution of various soil texture in the district

Texture category	**Area (sq.km)**	**%**
Clayey Soil	1407	66.03
Gravelly Clay Soil	203	9.53
Gravelly Loam	15	0.70
Loam	332	15.58
Waterbody	174	8.17

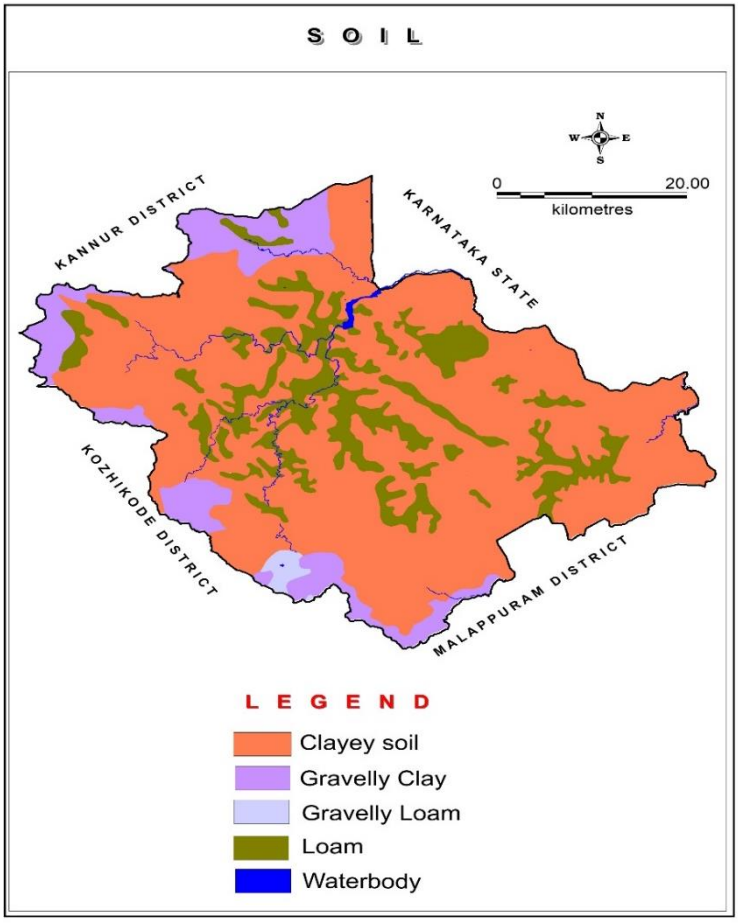


Fig.1.2 Soil Map

1.7 PHYSIOGRAPHY & GEOMORPHOLOGY

Wayanad district can be divided into three physiographic zones- Wayanad plateau (WP), Central Sahyadri High Land (CH) and Mountainous Regions of Central Sahyadri (MR) as per Soil Survey Organisation. On the basis of topographic features, the area can be divided into different physiographic zones like high ranges with rugged topography, high ranges with moderately rugged topography, intermontane valley and flood plains. There is absolutely no low and mid lands in Wayanad district as in the case of other districts in Kerala. High ranges with rugged topography include hill ranges in the west (Kalpetta and Mananthavady blocks) northwest and southwestern part of Wayanad district and elevation ranges from 1400 to 2100 m amsl. This area is occupied by dense mixed jungles with steep slopes and narrow valleys.Hill ranges along the eastern part and isolated hills come under high ranges with moderately rugged topography (Sulthan Bathery and Mananthavady blocks). The altitude of the physiographic zone ranges between 1000 and 1400 m amsl having moderate slope. Intermontane valleys are the valleys between high ranges. These areas are occupied by colluvium formed by depositional processes. Erosional intermontane valleys are also seen.

Denudational landforms are unproductive zones. Digital Elevation Model (DEM) of the study area with overlay of hilly area is given in Figure 1.3. This map indicates that the general slope is towards east.

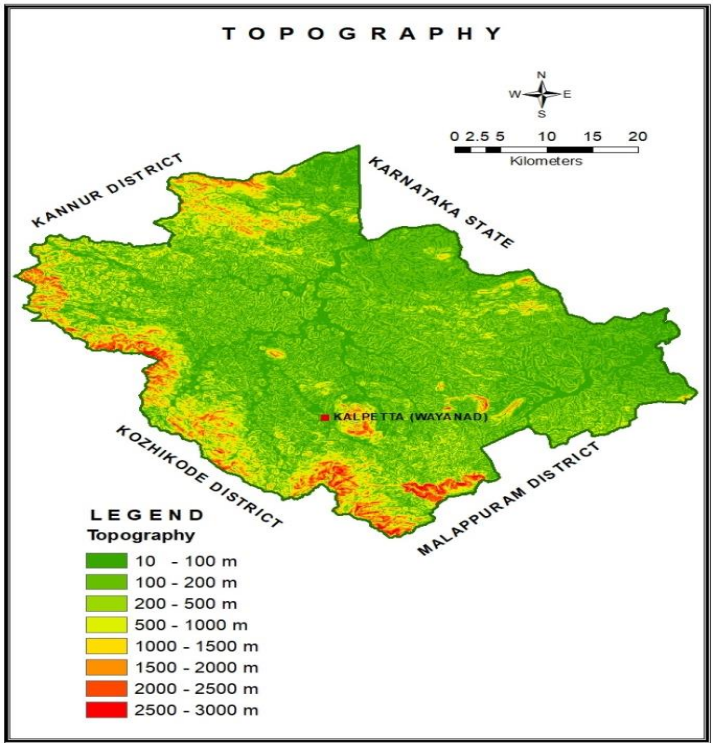


Fig.1.3 Digital Elevation Model (DEM) Map

The landform units identified in Wayanad are alluvial plain, flood plain, valley fill, residual hill, piedmont zone, structural hill, residual hill, valley fill and upper plateau. Of all these features piedmont zone (36.18%) and denudational hill (23%) are the major land form units in Wayanad district (Fig.1.4) The flood plain and valley fill are the major fluvial landforms whereas moderately sloping terrain . Flood plain is relatively smooth valley floors adjacent to and formed by alluvial deposits by rivers, which are subject to overflow. The flood

plains have thickness more than 10 m are quite common and are productive aquifers. There is no lithological control over land use in the area. Landform units with highest slope (90) identified in these area in scrap face.

In case of denudational hills there exist numerous peaks in various parts of Wayanad district. The Vavumala (Camel Hill or Camel's Hump) is the highest peak (2339 m) in the district. Other highest peaks which deserve special mention are the Vellarimala (2245m), the Banasuramala (2061m), the Elambilerimala (1839 m), the Brahmagirimala (1608 m), the Kunelippandimala (1607m), the Thariotemala (1553 m) and Muthumala (1374m). The Periya Ghat is an important pass into the Wayanad plateau.

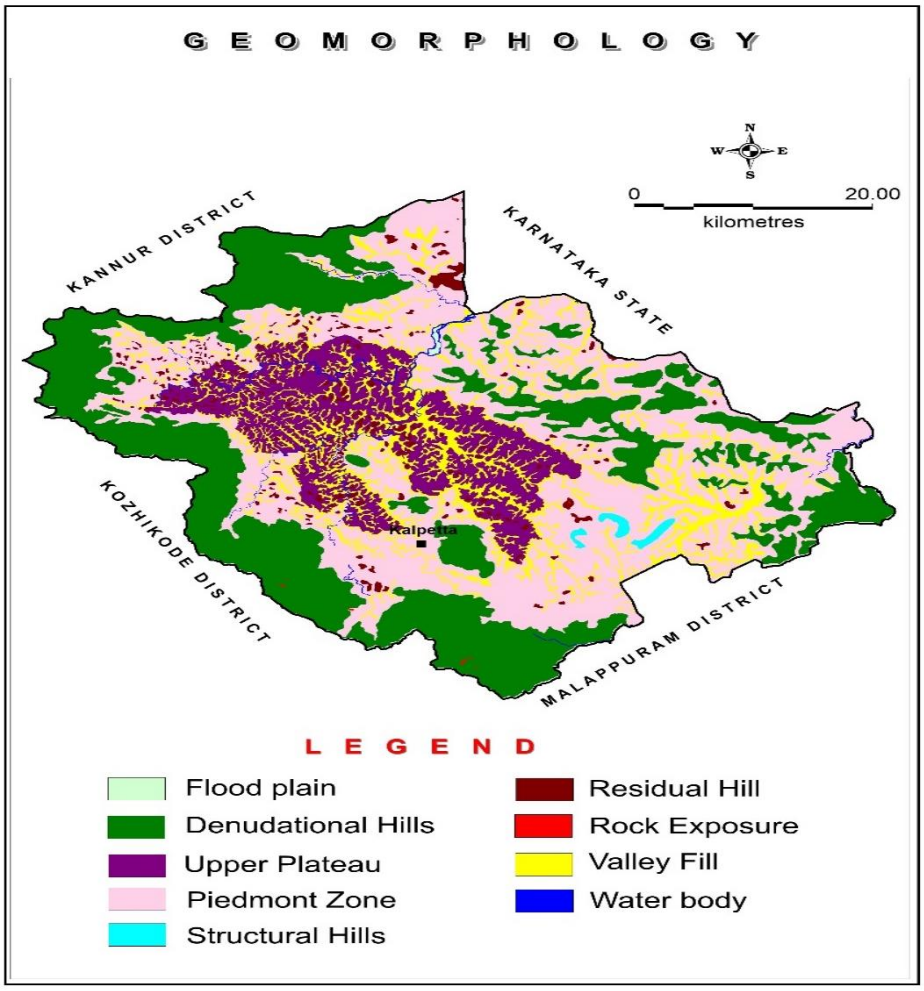


Fig.1.4 Geomorphology map

1.8 DRAINAGE

Kabani River is the major river in the district which is one of the three east flowing rivers in Kerala and is an important tributary of Cauvery. The total drainage of the Kabani river in the district is 1974 sq. km. Almost the entire Wayanad district is drained by Kabani and its three main tributaries viz. Panamaram, Mananthawady and Tirunelli. Other tributaries include Bavelipuzha and Noolpuzha. Kabani and its tributaries are mainly responsible for the present landscape of Wayanad district. Kabani river has dendritic drainage pattern and structurally controlled. Other drainages in Wayanad district are Chaliyar in the southwest and Valapattanam (Mahe river) in the northwest side of the district. The Mahe river or Mayyazhi-

puzha originates from the Western slopes of the dense forests of Mananthavady Taluk. The Chaliyar or Beypore river originates from the Elembileri Hills of Sulthan Batheri Taluk.

Panamaram river originating from Lakkidi and reaches Panamaram valley. The main tributaries of the Panamaram are Kavadam puzha, Kadaman thodu, Venniyode puzha, Karapuzha and Narassipuzha. Panamaram river joins with Mananthawady rivulet originating from Thodarmudi at an elevation of 1500m amsl. After joining with Mananthawady river, it is known as Kabani. After entering the Karnataka State Kabani joins with Cauvery. The salient morphometric characteristics of drainages in Wayanad district are compiled (Table 1.2) and the drainage map of the district is depicted in fig 1.5.

Table 1.2: Details of drainages in Wayanad District

Sl. No	Name	Basin length, km	In Wayanad	Total Catchment Area, km^2	Catchment area in Wayanad, km^2
1	Kabani	56.60	56.60	1974	1974
2	Chaliyar	169.00	12.00	2539.80	107
3	Valapattanam	54.00	6.00	421.04	50
Total		279.60	74.60	4895.34	2131

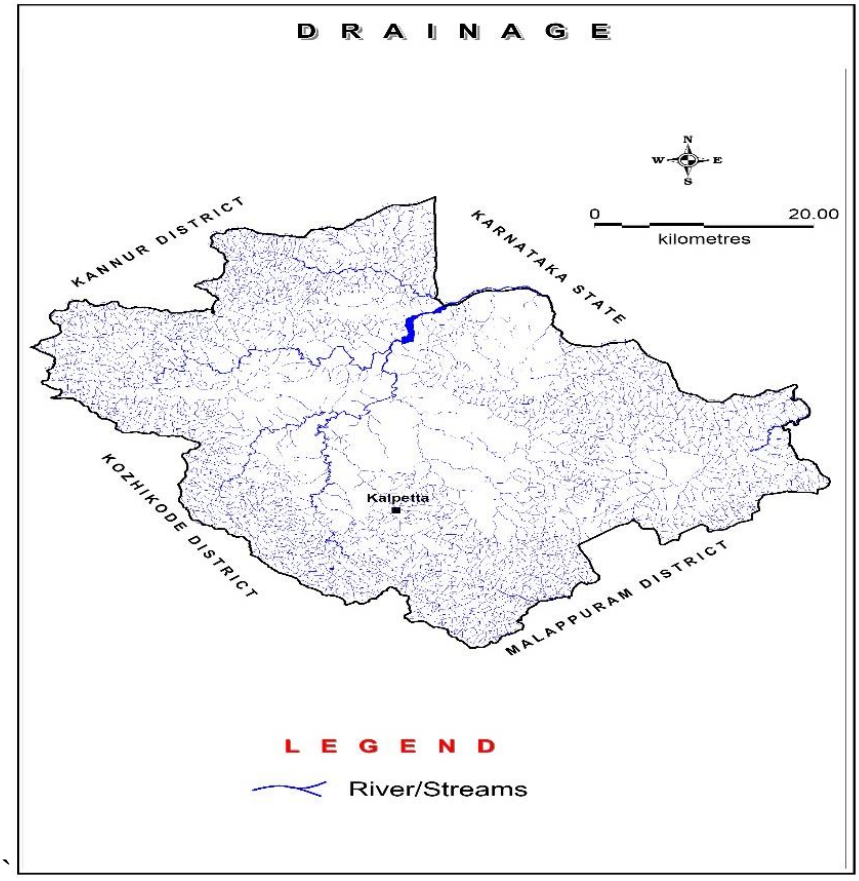


Fig1.5 Drainage map

1.9 IRRIGATION

The area is having a number of irrigation projects. There are no major irrigation projects in the area but only medium irrigation projects and minor irrigation schemes. Banasurasagar multipurpose project and Karapuzha irrigation project are the two medium irrigation projects in the Wayanad district.

The Karapuzha irrigation project (KIP) has been implemented in the Kabani sub basin of Cauveri basin. An earth dam constructed across Karapuzha at Vazhavatta to create a reservoir of 76.50 MCM storage capacity and to irrigate a proposed net ayacut of 5221 hectares of land in Vythiri and Sultan Bathery taluks of Wayanad district through a network of canals. The salient features of the projects are compiled and given in Table 1.3

Table 1.3: Salient features of Karapuzha irrigation project

Name of the project	Karapuzha irrigation project
River basin	Kabani
River	Panamarampuzha
Tributary	Karapuzha
District	Wayanad
Command area	Vythiri, Sultan's Batheri, Manan-thawady
Latitude and longitude	11 37 00 and 76 10 30
Gross command area	6800 Hectares
Cultivable command area	5600 Hectares
Gross area under irrigation	8721 Hectares
Net area under irrigation	5221 Hectares
Catchment area at headwork sight	6200 Hectares
Maximum water level	76.5 m
Dead storage level	4.5 m
Type of dam	Homogeneous, earthen and saddle dam
Capacity of reservoir	76.5 MCM
Length of main canal (LBC)	8.805 km
Length of main canal (RBC)	13.74 km
Year of starting	1977
Year of commissioning	2004

The Banasurasagar project (BSP) is a multipurpose scheme aims at harnessing Karamantho-du, tributary of Panamaram comes under Kabani basin of Cauvery river. The project consists of a reservoir of gross storage capacity of 246.78 MCM. The important features of BSP are compiled and given inTable 1.4.

Table 1.4: Salient features of Banasura Sagar Project

Name of project	Banasurasagar project
Year of starting	1971
Name of river	Karamanthodu, tributary of Kabani

Catchment area	6150 Hectors
Type of structure	Homogeneous rolled earth fill
Main dam site	Padinjarathara
District	Wayanad
Latitude	11 40 10
Longitude	75 57 20
Capacity of reservoir	246.78 MCM
Net ayacut	2800 Hectares
Gross ayacut	4740
Main canal (LBC) length	2.73 Km

1.10 LAND USE

The spatial information on land use/land cover and their pattern of change is essential for planning, utilization and management of the country's land resources. Land use/land cover inventories are assuming increasing importance in various resource sectors like agriculture planning, settlement and cadastral surveys, environmental studies and operational planning based on agro-climatic zones. Information on land use/ land cover permits a better understanding of the land utilization aspects on cropping pattern, fallow land, forest and grazing land, wasteland, surface water bodies etc., which is very vital for developmental planning.For Kerala State the preparation of latest land use/land cover maps are entrusted with Kerala State land Use Board and the data summarized from their report is given in table.1.4 (KSUUB report-Wayanad,2019). Major portion of the area is used for coffee plantation (33%) followed by different forest cover (30%). 6.26 % of area is used for Paddy cultivation (Virippu) and 3.79 % is for Virippu and Mundakan ferming. Tea plantation is spreaded in 3.61 % of the area. Land with scrub is 2.85 % and land without scrub is 1.28 %. Industrial wasteland is absent in the district (Fig.1.6 & 1.7).The Land use pattern in Wayanad District is described in Table 1.5

Table1.5 Land use pattern in Wayanad district (Source: KSLUB, Govt of Kerala 2019)

Sl. No.	Category	Area (Sq.Km)	Percentage
1	Built up land (urban) - industrial	0.09	0
2	Built up land (urban) - commercial	2.46	0.12
3	Built up land (rural) - residential	14.63	0.69
4	Built up land (rural) - mixed builtup	2.7	0.13
5	Paddy - viruppu	133.25	6.26
6	Paddy - viruppu + mundakan	80.64	3.79
7	Paddy reclaimed arecanut	40.35	1.89
8	Paddy reclaimed mixed crop	1.86	0.09
9	Paddy reclaimed banana	25.96	1.22
10	Paddy reclaimed banana +tapioca	0.15	0.01

Sl. No.	Category	Area (Sq.Km)	Percentage
11	Paddy reclaimed residential	0.77	0.04
12	Paddy - fallow	0.58	0.03
13	Tea	76.96	3.61
14	Coffee	722.06	33.9
15	Rubber	13.32	0.63
16	Mixed crop	6.1	0.29
17	Pepper	0.05	0
18	Tapioca	0.64	0.03
19	Semi evergreen/Evergreen - Dense mixed forest	255.33	11.99
20	Semi evergreen/Evergreen - Dense mixed forest (Reserve Forest)	268.72	12.62
21	Semi evergreen/Evergreen - Dense mixed forest mainly bamboo	24.17	1.13
22	Semi evergreen/Evergreen - Dense mixed forest mainly bamboo (Reserve Forest)	101.44	4.76
23	Semi evergreen/Evergreen - Open mixed forest	20.48	0.96
24	Semi evergreen/Evergreen - Scrub forest	20.13	0.95
25	Deciduous - Dense mixed forest mainly bamboo + teak	67.84	3.19
26	Deciduous - Dense mixed forest mainly teak	7.07	0.33
27	Deciduous - Dense mixed forest mainly teak (Reserve Forest)	56.09	2.63
28	Deciduous - Scrub forest	0.54	0.03
29	Forest blank	0.48	0.02
30	Forest plantation - Teak	19.32	0.91
31	Forest plantation - Teak (Reserve Forest)	10.03	0.47
32	Forest plantation - Eucalyptus (Reserve Forest)	4.89	0.23
33	Forest plantation - Soft wood	3.75	0.18
34	Grassland	6.77	0.32
35	Grassland - degraded	1.28	0.06
36	Land with scrub	60.74	2.85
37	Land without scrub	27.34	1.28
38	Mining/Industrial wastelands	0.03	0
39	Barren rocky/sheet rock area	3.43	0.16
40	Degraded land under plantation crop (Coffee)	27.97	1.31
41	Degraded land under plantation crop (Tea)	1.98	0.09
42	Degraded land under plantation crop (Rubber)	0.52	0.02
43	Under utilised/degraded notified forest	4.61	0.22
44	Sands - riverine	0.34	0.02
45	Water bodies	11.88	0.56
	Total	**2129.74**	**100**

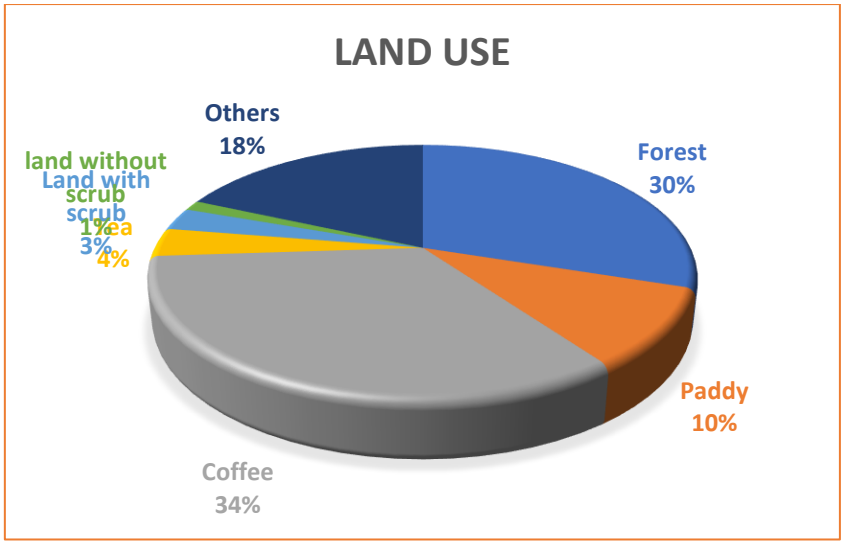


Fig. 1.6 Distribution of various land use pattern in Wayanad District

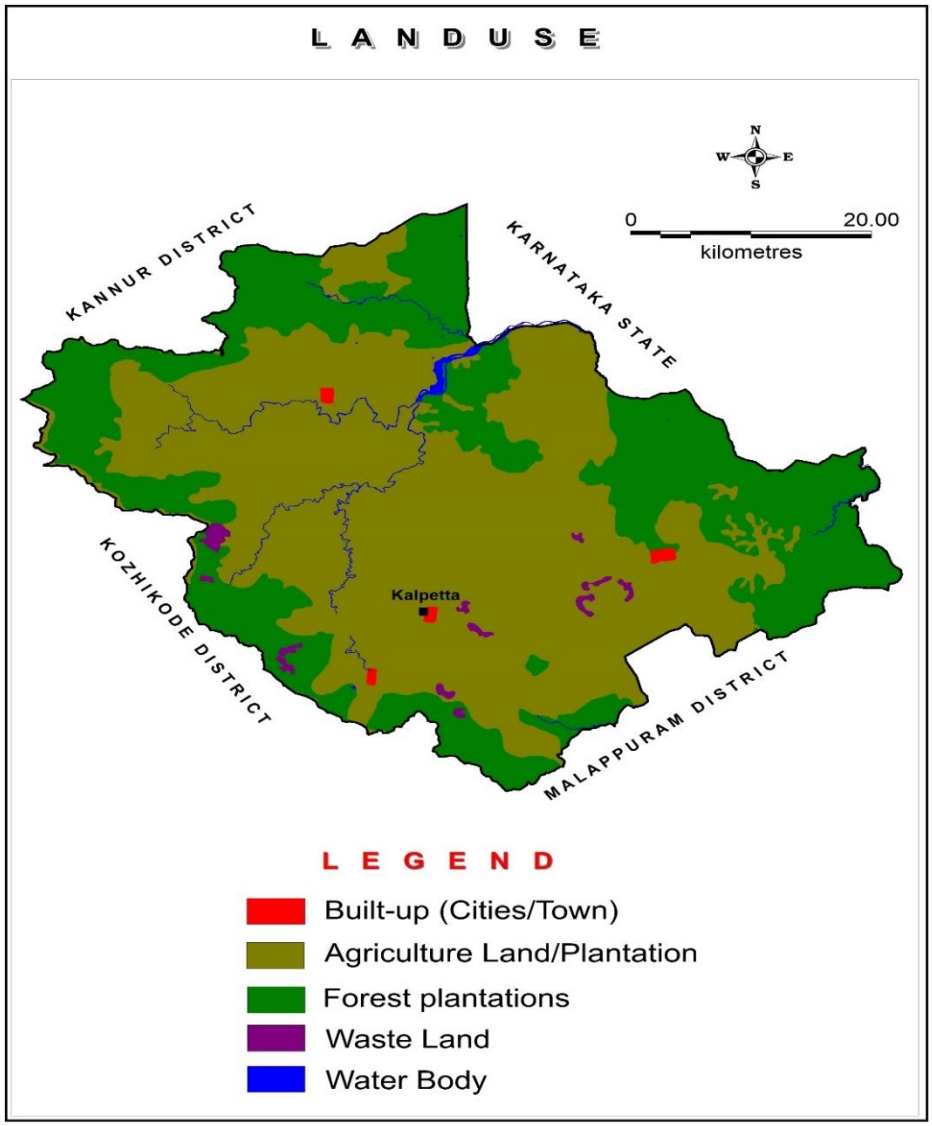


Fig.1.7 Land use map

Agriculture plays a crucial role in the Wayanad economy as it is a truly agricultural district in the sense that the principal occupation of people is Agricultural activities .The nature of soil support all types of agriculture pattern. The high altitude district is characterized by the cultivation of perennial plantation crops such as coffee and tea and spices. Major portion of plantation is practiced for Coffee. Wayanad district stand first position in the production of coffee (79.35%) of total coffee production in state and hosts 12.40% of the total area of pepper cultivation in the state, which is second largest producer in the State after Idukki.26 % of pepper ,54 % of ginger, 17% of tea and 5% of cardamom produced in the state are from the Wayanad district which accounts only 5.5% of the total area of the state.

Surface water is the major source of irrigation in the district met through minor dams and canals. Ground water is the second source of irrigation in the district and is primarily abstracted through dug wells followed by bore wells. Panchayath ponds and irrigation tanks are also available in the district and are often less used. The source wise details of area irrigated by different sources in the district are given in Table 1.6 and fig.1.8.

Table 1.6 Source wise area irrigated in Wayanad district

Structure	Area (Ha)
Well	2543
Tube Well	29
Pond	1525
Lift Irrigation	2445
Side Protection Wall	2611
Minor Dam	4505
Others	1694
Total	**15352**

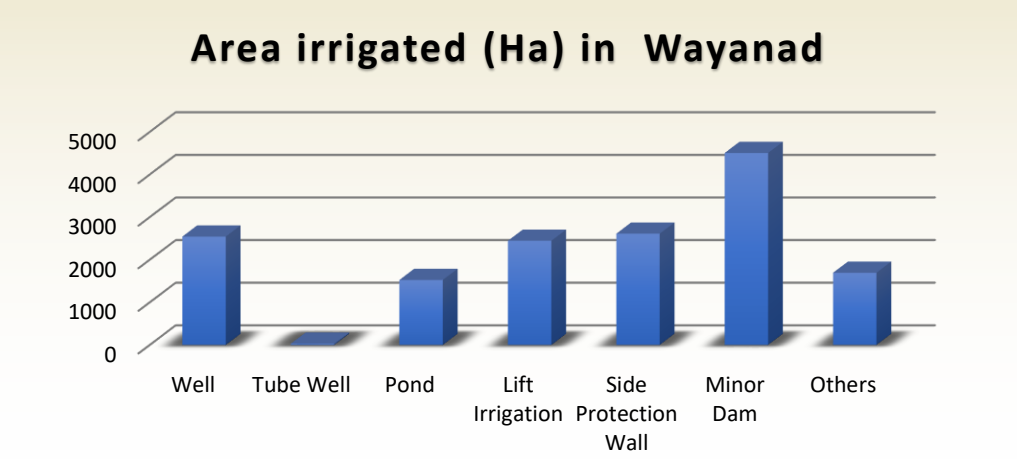


Fig.1.8 Source wise area irrigated in Wayanad district (Source: KSLUB, Govt of Kerala)

1.11 GEOLOGY

Geological succession has major role to play the ground water availability. Major part of the study area is underlain by the crystalline rocks of Archaean age (Fig.1.9). Geological formations occurred in the area are gneisses, charnockite, granite, intrusives viz. gabbro and diorite, laterite and riverine alluvium. The hill district of Wayanad is covered mainly by Peninsular Shield of Western Ghats and forms the tri junction of Charnockites of Western Ghats, Nilagiri Ranges and southward extension of Dharwars of Karnataka. Major rock groups of the district are Wayanad Supracrustals, Gneisses, Charnockite, Basic and Acidic intrusives. The rock types under wayanad supracrustals are Pyroxenite, Amphibolite, Pyroxene granulite, Talc-tremolite-actinolite schists, Migmatitic quartz rock, fuchsite quartzite, garnet-sillimanite - kyanite gneiss and quartz sericite schist and the various types of gneisses are Biotite gneiss, Hornblende biotite gneiss, Augen gneiss and Mylonites. Among these, biotite gneiss is extensively developed all over the district, followed by hornblende biotite gneiss. Hornblende biotite gneiss is restricted only in the central and northern parts of Wayanad district. Augen gneiss and mylonite occur in the vicinity of fault and shear zones with potash feldspars as augens.

Charnockites suite of rocks are exposed in and around Chundale, Vythiri, Thariyode as linear zones. Charnockites are trending in NW-SE with medium to coarse grained, mesocratic to melanocratic and xenoblastic having mineral assemblages of pyroxene, feldspars, biotite and garnet.

Basic intrusives noticed in Wayanad are Gabbro and Dolerite. Outcrops of gabbro are seen at Kattikulam, Begur, Tholpetty and Karang. The NE of Mananthawady shows anorthositic differentiates. The rocks are mesocratic to melanocratic, coarse grained, uneven texture consisting essentially of plagioclase and pyroxenes. The diorites exposed in the northern parts of Wayanad are mesocratic to melanocratic, coarse grained having mineral assemblages of grey feldspars, hornblende and biotite. The geology of the area has been prepared (Fig.1.9) and the geological succession compiled (Table 1.7).

Large bodies of intrusive pink granite occur near Kalpetta and Sulthan Bathery. Pegmatite veins are also associated with granites. Dolerite and gabbro are intrusive with older rocks. Large lenticular bodies of gabbro \ anorthosites occur north east of Mananthavady and a large body of diorite occurs near the northern boundary of the district.

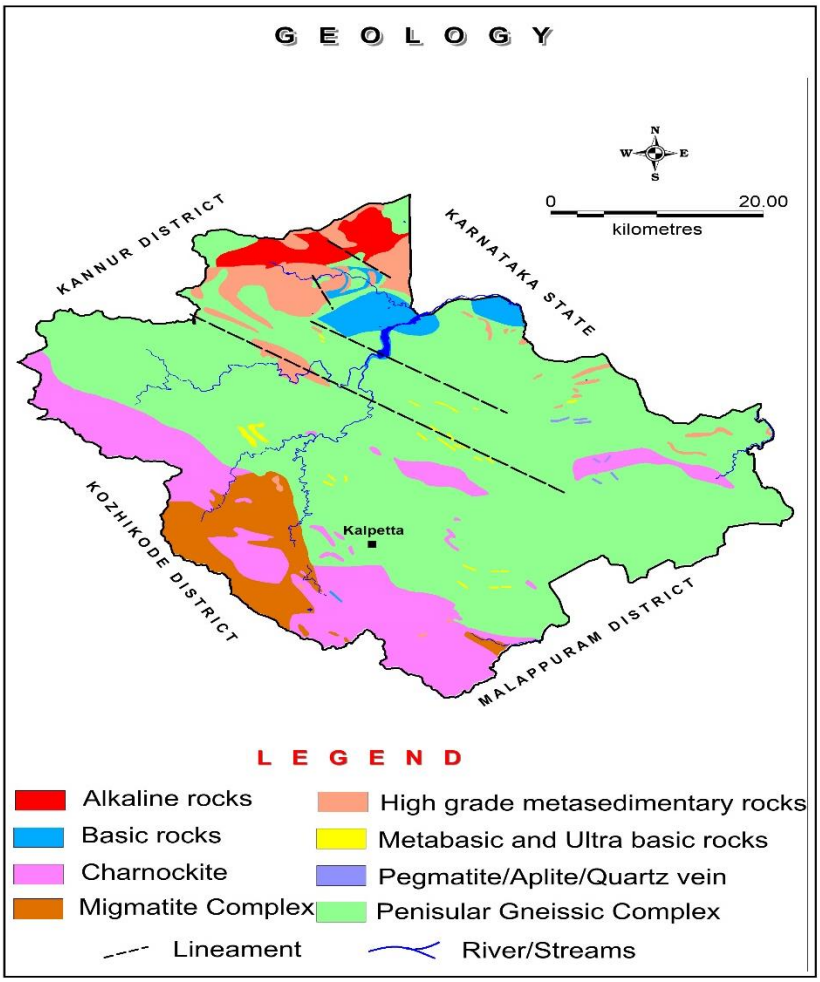


Fig.1.9 Geological map

1.12 STRUCTURE

There are different types of structures present in the study area. The most penetrative structure observed in the rocks is gneissosity evidenced by the alternate layers of dark and light minerals. Closely spaced fissility is observed in areas of shearing. Different types of folds like isoclinal and doubly plunging domal structures were reported from different parts of Wayanad district. The Baveli fault/Baveli shear zone in Wayanad is a major structure reported. The WNW-ESE shear zone passing through Bavalipuzha to Mananthavady and extend beyond Sultan Battery for a distance of 50 km is identified as a major fault (CGWB,2018). The NE-SW shear zone of Kabini river located near Kolathur is considered a second prominent one. A number of parallel sympathetic joints, faults and shear zones are also present in the area. The E-W and N-S trending lineaments are less prominent. Parallel faults and shears are reported from the area. Fault induced artesian well is developed at Irulam Kottakolly .

Lineaments are the major structures observed in the area. The lineament map (Fig.1.10) of the area prepared by using toposheets and satellite imageries.

Table 1.7: The geological succession in Wayanad District

Age	Formation	Rock type
Recent	Alluvium	Sand and clays seen along flood plains and valley fells
Sub-Recent	Laterite	Weathered crystalline rocks
Post Archaean	Dyke activity	Dolerite and Meta gabbros
	Cataclasites	Myloblastic Fissile mica gneiss
Proterozoic to Palaeozoic	Retrogression Acid intrusives	Garnet-biotite gneiss Pegmatite Granite Granite gneiss
	Basic intrusives	Gabbro Diorite
Archaean	Charnockitisation Migmatisation	Charnockite Migmatite gneiss (II)
	Wayanad Supracrustals	Quartz-Seri cite schist Garnet-sillimanite Kyanite gneiss Fuchsite quartzite Magnetite-quartzite Talc-tremolite-actinolite rock Pyroxene / amphibolite granulite
	Basement-gneiss	Migmatitic gneiss (I) Fissile

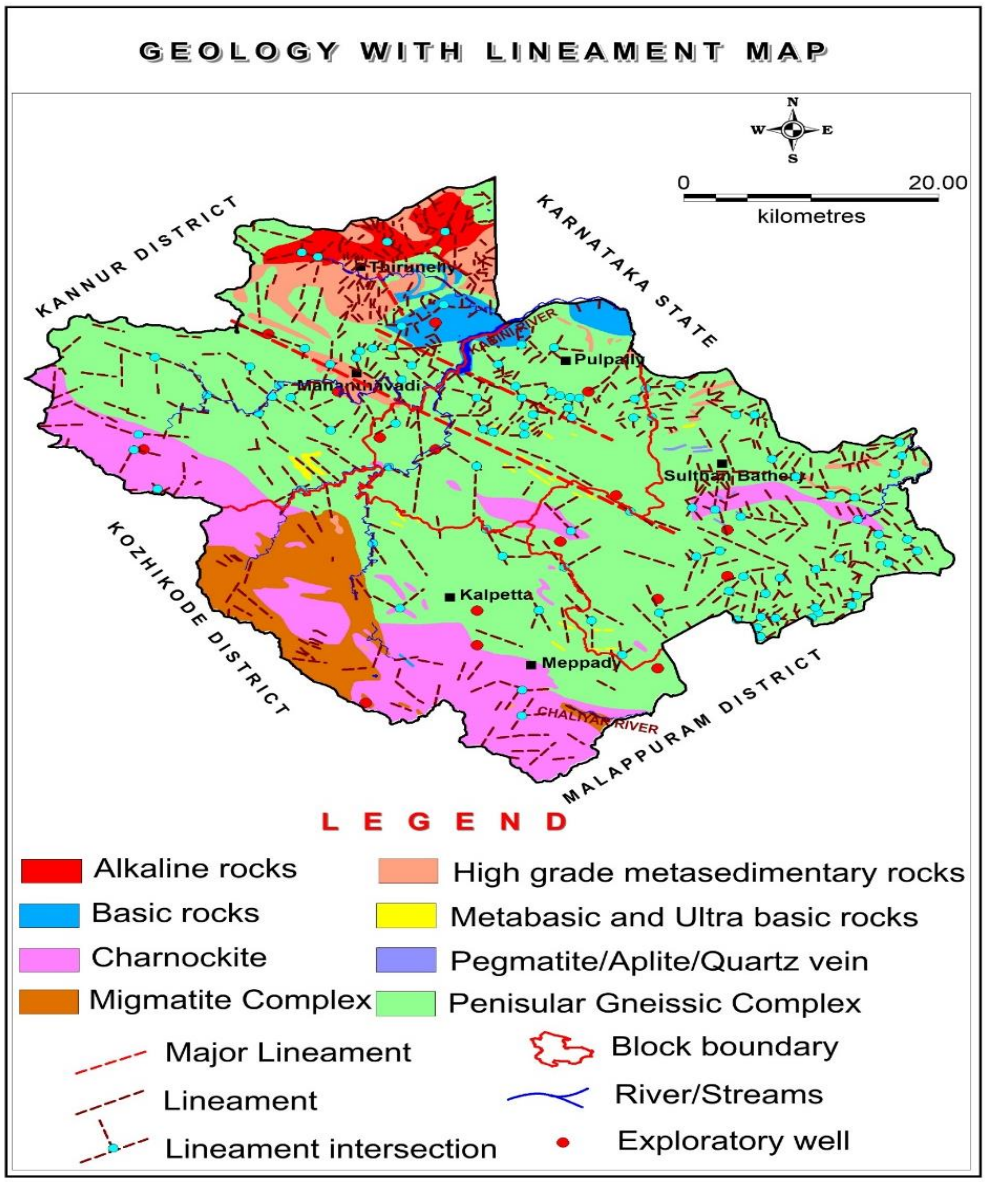


Fig.1.10 Structure map

1.13 PREVIOUS WORK

Various systematic and reappraisal surveys were carried out by Central Ground Water Board, Kerala Region in the past years. These work aim to the periodic updating of hydrogeological databases which includes exploratory,geopgysical, hadrochemical studies in different parts of district. The hydrometeorological and hydrological studies were carried out in 1993 as part of groundwater regime studies. Groundwater Exploration programme of CGWB could decipher the deep potential zones along fractures and lineaments. The report on "Ground Water Resources and Development Potentials of “Wayanad district" was issued in 1997. Geological Survey of India, Kerala Unit, carried out the geological mapping of the district. Periodical water level and water quality monitoring is being carried out in the district by CGWB and State Ground Water Department. An integrated monitoring network has been established for this purpose. An integrated study on geology, hydrogeology, hydrometeorology, geomorphometry was carried out by Central Ground Water Board in collaboration with Geological Survey of India, Kerala State Land Use Board, Soil Survey and Dept. of Agriculture, Thiru-

vananthapuram in 1992 under the title 'Operation Wayanad'. Groundwater management training was organized at Kalpetta in 2005 and pamphlets depicting groundwater scenario of the district were distributed to the public during the function. The water samples collected from the groundwater monitoring stations of the district during April every year is being analysed and studied for suitability of different uses. The hydro meteorological and hydrogeological data collected from the district is also analysed and studied periodically.

1.14 URBAN AREA, INDUSTRIES AND MINING ACTIVITIES

Wayanad district is least urbanised district in Kerala. An urban ares as per census norm can be defined as an area where more than 70% of the male working population is engaged in non- agricultural and non-fisheries fields with high population density. There are three municipalities in Wayanad district viz. Kalpetta,Mananthavady and Sulthan Bathery. In all this municipalities, majority of the people are engaged in the agricultural practices and selling various agricultural products especially spices viz. cardamom, pepper, clove, ginger and others like rubber, tea, coffee and so on. Wayanad is backward in the case of industries. There is no major industrial unit except factories like processing tea, timber mills and rice mills. The details of industrial units in Wayanad district are compiled (Table 1.8).

Table.1.*8* Details of industrial units in Wayanad District

Sl. No.	Blocks/Municipalities	Mini industrial estates	
		Extend of land, Acres	No. of industry functioning
1	Kalpetta	-	-
2	Mananthawadi	-	-
3	Sultan's Batherry	1200	3
4	Panamaram	-	-

The main mining activity in the study area is sand mining, clay mining and quarrying of the hard rocks.

2 DATA COLLECTION, GENERATION AND INTEGRATION

2.1 DATA COLLECTION AND DATA GAP ANALYSIS

The database on Hydrometeorology, Geology, Geophysics, Hydrogeology and Hydrochemistry were compiled from previous studies carried out under various studies by CGWB such as Systematic Hydrogeological studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Ground water Exploration, Micro level hydrogeological studies, short term investigation and special studies have been utilized for data gap analysis in conjunction with the data collected from various State (Land use board,GWD, MI Dept) and other Central government departments (IMD,CWC). The thematic layers on drainage, geomorphology, land use, soil and land cover were reproduced from the data obtained from concerned State departments. The existing data on various themes analysed for finding the data gaps is given in Table 2.1

Table 2.1: Data availability for data gap analysis

#	Item	Data Availability - CGWB	Data Availability – State Agency
1	Groundwater level data -DW	75	35
2	Groundwater level data -Pz	7	10
3	Groundwater quality Data	17 Dug wells. 15 Bore wells	35 Dug wells
4	Borehole Lithology Data	17	
5	Geophysical Data /VES/TEM	22	
7	Land use and Land Cover	Available	
8	Drainage	Available	
9	Geology	Available	
10	Soil	Available	
11	Climate Data	Available	

2.1.1 WATER LEVEL

Water level is the vital indicator of the status of dynamic groundwater resource which indicate the stress acting on it through the changes in rainfall, withdrawal and other natural processes like evapotranspiration etc. It is the principal parameter directly visible from nature and can be quantified for various hydrogeological studies. Water level monitoring wells maintained by Central ground water board and SGWD in the area have been made part of the monitoring network for the present study. 75 dug wells and 7 piezometers are presently monitored by Central ground water board and 15 dug wells by SGWD for water levels in the phreatic aquifer system. Central ground water board wells are being monitored four times (January, April, August and November) in a year whereas the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. The status of water level monitoring wells of CGWB in each block in the area is listed in Table 2.2. The historical data from these stations have been used for data gap analysis and identified 35 new sites to fill up the data gaps. Measurements of water levels in wells are necessary 75 for the evaluation of the quantity of groundwater and its interaction with surface water and rainfall.

Table 2.2: Status of water level monitoring wells of CGWB

Sl No	Block	DW	Pz
1	Kalpetta	20	2
2	Mananthavady	18	2
3	Panamaram	15	2
4	Sulthan Bathery	22	1
Total		75	7

From the quadrant-wise Data Gap Analysis exercise carried out during 2017 indicates that 18 new monitoring wells have been identified for filling the data gap for water level monitoring wells in the study area.

2.1.2 EXPLORATION

The subsurface disposition of aquifer systems can be deciphered by analysing exploratory drilling details. Necessary information on aquifer geometry, hydraulic properties of aquifer systems, groundwater potential of fracture systems and their characterization and quality of deeper aquifer systems are primarily inferred from exploratory drilling data. The basic data from 17 exploratory drillings in the area could be used for characterising aquifer disposition. From the quadrant-wise Data Gap Analysis exercise carried out during 2017 indicate that 24 exploratory wells are to be drilled for filling the data gap of hydraulic properties in the study area. The data gap will be accomplished in the future through in house drilling activities. Weathered thickness and depth of occurrence of fractures are also inferred from geophysical data such as Vertical Electrical Sounding (VES)/Transient Electro Magnetic (TEM) and profiling and well inventory. Geophysical methods are normally employed as a reconnaissance study before exploratory drilling. As the cost of geophysical investigation is much less when compared to exploratory drilling it is effectively used to extract subsurface information.

2.1.3 GEOPHYSICAL STUDIES

Geophysical data deciphered through VES or latest advancement like GTEM (Transient Electro Magnetic) sounding and profiling are used to extract information on the weathered thickness, basement, fracture depth, thickness of fracture etc. The aquifer geometry could be refined from the interpretation of geophysical data in conjunction with the available groundwater exploration data. from quadrant-wise Data Gap Analysis exercise carried out during 2017 indicate that 50 VES/TEM soundings have to be carried out for filling the data gap subsurface profile of aquifer system including the weathered thickness.

2.1.4 WATER QUALITY MONITORING

The historical data on water quality in the area is available from the water level monitoring stations maintained by Central ground water board. Water sampling is being done every year from these wells during pre-monsoon period (April). SGWD does the water sampling twice a year during pre-monsoon and post-monsoon period. CGWB is maintaining 17 ground water quality monitoring stations in Wayanad district. The quadrant wise data gap analysis has been carried out to find out the adequacy of information on water quality and it is observed that 9 water quality locations are to be fixed for removing the data gap on quality

2.1.5 SOIL INFILTRATION TESTS

Infiltration rate of soil depends on the clay content and porosity which is essential in accessing the recharge rate specifically. To estimate the infiltration rate of soil in the study area 10 double ring infiltration tests were conducted in various parts of the district. A double ring infiltrometer requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water from the inner ring so that the analysis of data is simplified. If wa-

ter is flowing in one dimension at steady state condition, and a unit gradient is present in the underlying soil, the infiltration rate is approximately equal to the saturated hydraulic conductivity. An inner ring is driven into the ground, and a second bigger ring around that to help control the flow of water through the first ring. Water is supplied either with a constant or falling head condition, and the operator records how much water infiltrates from the inner ring into the soil over a given time period. The ASTM standard method specifies inner and outer rings of 30 and 60 cm diameters, respectively. Details of the tests are given in annexure-VI. The infiltration rates are worked out to be 3.6 mm/hour at Padinjarathara and 0.12 mm/hour at Vythiri .

2.2 DATA GENERATION AND INTEGRATION

After determining various data gaps in the existing data set and additional data base is essential to create additional data base in order to define the aquifer and its resources for better management practices, 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. The activities include establishment of Key wells, water quality monitoring wells, geophysical survey. The data gap identified and the new addition of data under various themes is given in Table 2.3. The value addition made after data generation and integration of various components of the groundwater regime are described in the following sections.

Table 2.3: Data requirement and data generated for aquifer mapping

Themes	**Existing data**	**Data Gap**	**Total**	**Data generated**	**Additional Data requirement**
Dug wells	75	18	93	40	nil
Exploratory wells	17	50	67	nil	50
Piezometers	7	0	7	0	nil
VES/TEM	17	50	67	88	nil
Water quality	17	9	26	0	9
Soil Infiltration	0	10	10	10	nil

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 18 more monitoring wells in the area to represent the actual ground water level scenario. For this additional 40 new key wells have been established in the area and carried out for postmonsoon and premonsoon water level monitoring. Few monitoring wells of GWD were taken for fixing KOWs due to absence of dug wells in certain pockets. After integrating, the total number of ground water wells tapping unconfined aquifer becomes 93 The loca-

tions of these integrated GWMW's are given in Figure 2.2. The details of groundwater level monitoring wells are given in Annexure I (GWMWs) &II (KOWs).

2.2.2 EXPLORATION

Data gap analysis for exploration indicate an additional 24 no of EW are to be drilled which will be taken up in the future through in house drilling .As such available data has been used to interpret the aquifer geometry and its characteristics The locations of existing exploratory as well as piezometers are given in Figure 2.1. Details of exploratory wells are given in Annexure-III

2.2.3 GTEM AND PROFILING

50 VES/ GTEM surveys were identified in data gap analysis for delineating the aquifer geometry in addition to the existing data. The geophysical investigation is required in the study area to reveal weathered thickness, fracture depth, thickness of fracture and fracture pattern. TEM 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 three layered geo electric sections. The locations of these TEM locations are given in Figure 2.1 and details of G TEM are given in Annexure-IV.

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 7 quality wells is required to represent the actual hydro geochemistry of the fractured aquifer and 2 wells for top unconfined aquifer. This can be done only after exploratory drilling and as such the existing water quality data were used. The locations of these water quality stations are given fig.2.3.

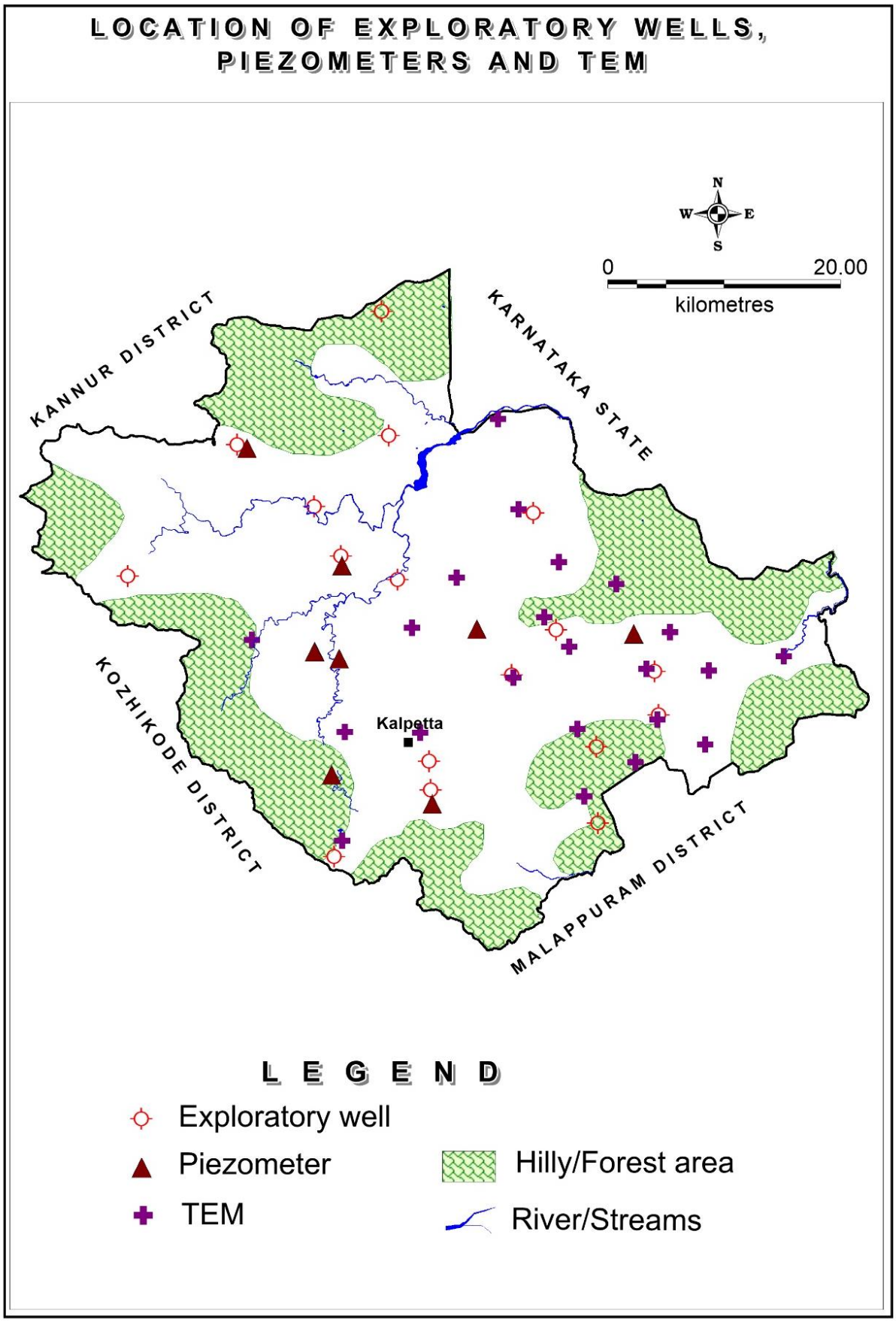


Fig.2.1 Location map of exploratory wells with TEM locations

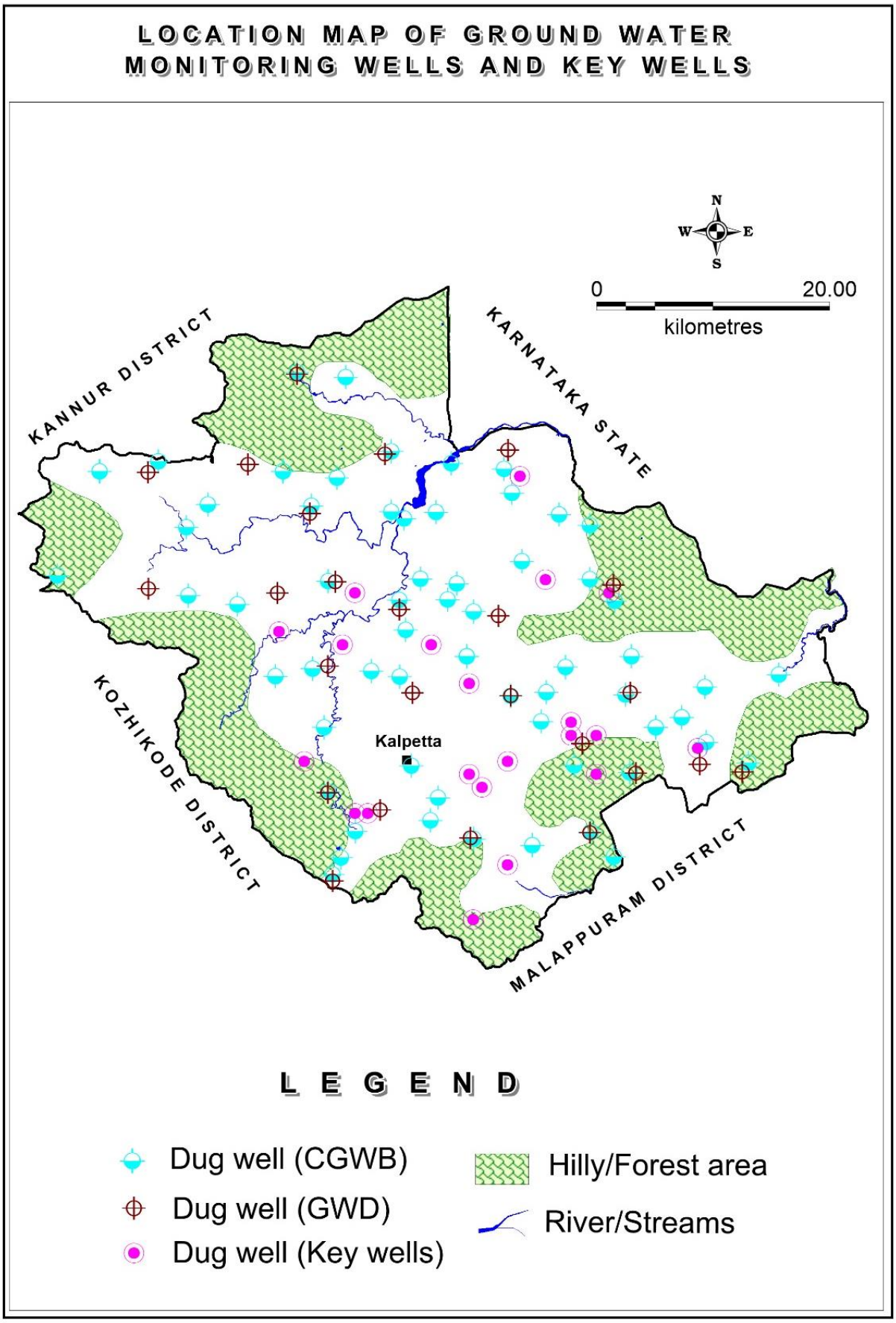


Fig.2.2 Location map of water level monitoring wells (GWMW & KW)

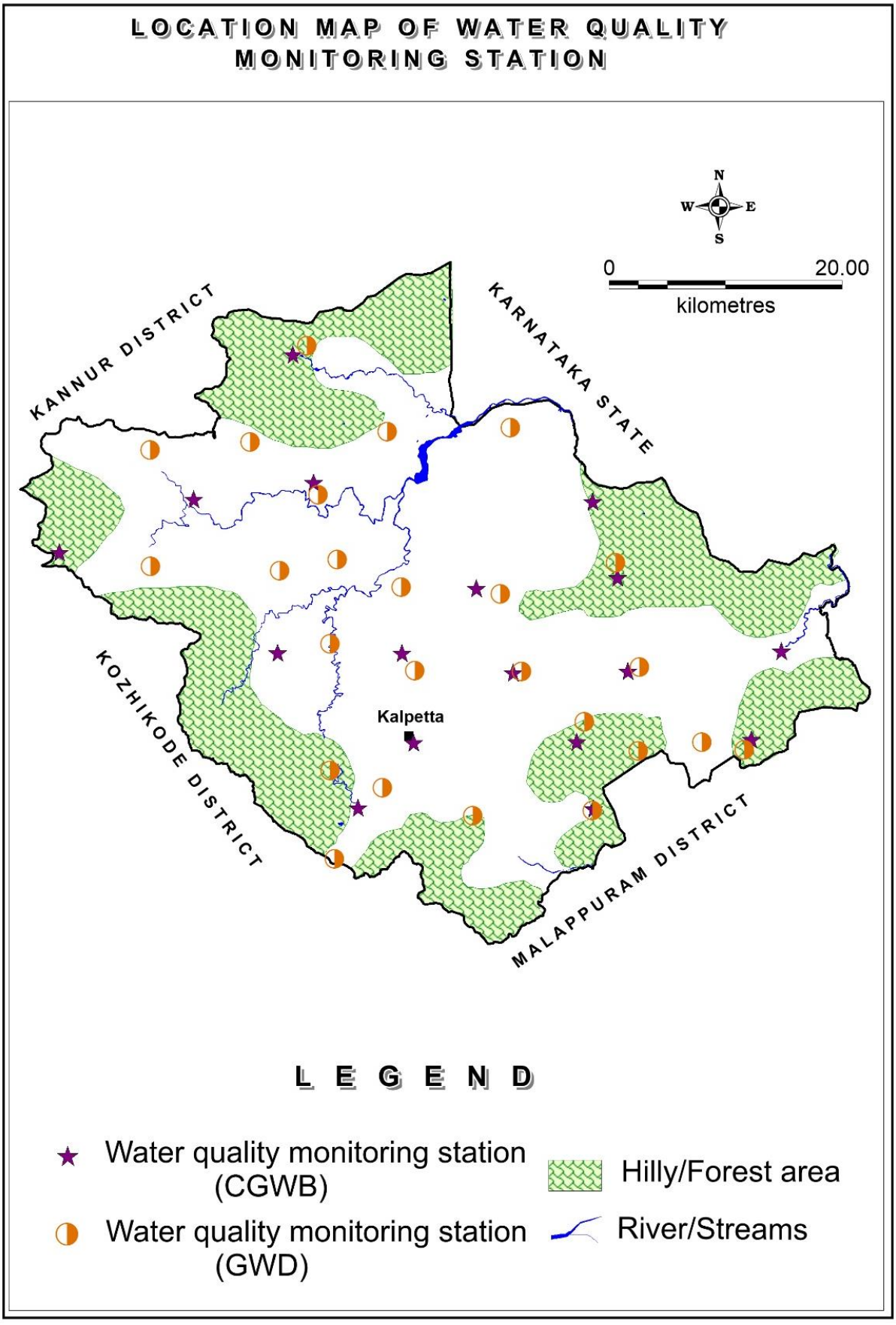


Fig.2.3 Location map of Water quality monitoring stations

3.AQUIFER MAPPING

After analysing the existing data the next step is to interpret the data with the objectives of generating a 2D and 3D disposition of the aquifer systems in the area, understand the ground water regime and quantify the resources. Thus, various aquifer maps of the area have been generated after integrating the hydrological, geological, geophysical, hydrogeological and hydro chemical data. This summarised data is the basis for preparing various strategies to develop the management of aquifer systems in the area.

3.1RAINFALL

Wayanad has a mean rainfall of 2786 mm. The district experiences heavy rainfall during southwest monsoon season (80%) followed by the northeast monsoon season (12%) and winter summer showers constitute 8 % .During January to May the rainfall is scanty with occasional summer showers which constitute the non-monsoon rainfall. March and April are the hottest months and December to February are the coldest. Besides orographic precipitation and pre-monsoon "mango showers" play a role in rainfall availability in the area. Rain shadow areas are existing in and around Pulpally, Kappiset, Mullankolly area adjoining Karnataka border. 2019 witnessed record rainfall in the order of 2500.7 mm wheras low rainfall observed during 2016.The monthly variations of rainfall pattern is provided in Table 3.1 and Fig.3.1& 3.2 and it is found that august has recorded highest rainfall and January and February months are devoid of any rainfall.

Table 3.1 Monthly rainfall data (mm) during 2015-2020. (Source : IMD)

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Total
2015	0	0	33.42	125.86	198.3	444.77	179.1	147.78	166.07	126.42	138.32	17.05	1577.09
2016	3.72	1.47	8.44	17.13	115.9	263.03	232.91	150.6	61.79	37.73	9.65	24.35	926.72
2017	14.11	0	31.7	50.25	121.96	161.38	168.36	198.48	229.43	70.94	33.09	4.42	1084.12
2018	0	13.82	59.33	77.43	230.94	331.92	555.49	615.6	87.39	218.36	32.28	9.4	2231.96
2019	0.07	16.57	14.24	138.12	132.1	133.49	293.87	965.52	334.57	358.74	88.13	25.28	2500.7
2020	2.03	1.18	20.21	130.21	130.95	271.8	194.17	723.29	486.04	105.08	86.72	30.98	2182.66

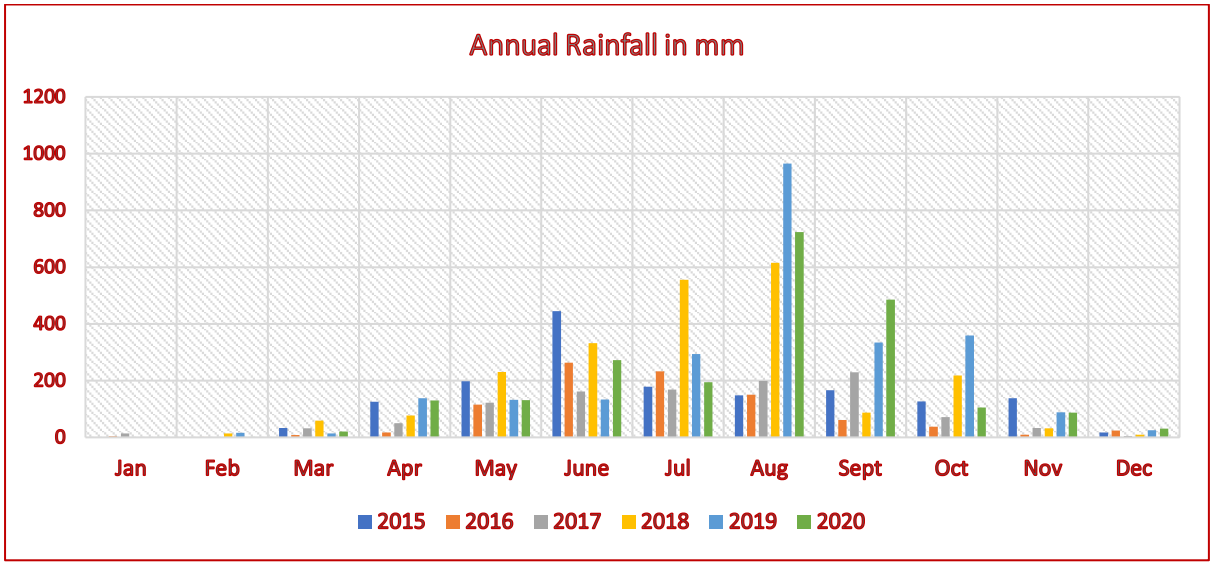


Fig.3.1 Annual rainfall variations for the period of 2015-2020

Analysis of isohyets (Fig. 3.2) revealed the actual rainfall distribution in the area. Different rain gauge stations data were collected and is used for the preparation of isohyets / isohyetal lines, which join all points that receive same amount of rainfall. It is seen that southern and southwestern areas of the district such as areas Lakkidi, Padinjarathara (bordering Kozhikode district) receive more than 2500 mm of annual normal rainfall. Eastern and northeastern areas with lesser rainfall of less than 2000 mm of annual rainfall. Some areas surrounding eastern and northeastern areas bordering Karnataka State experience drought and even some areas come under rain shadow region. There is an increase in trend of rainfall towards south and, southwestern areas.

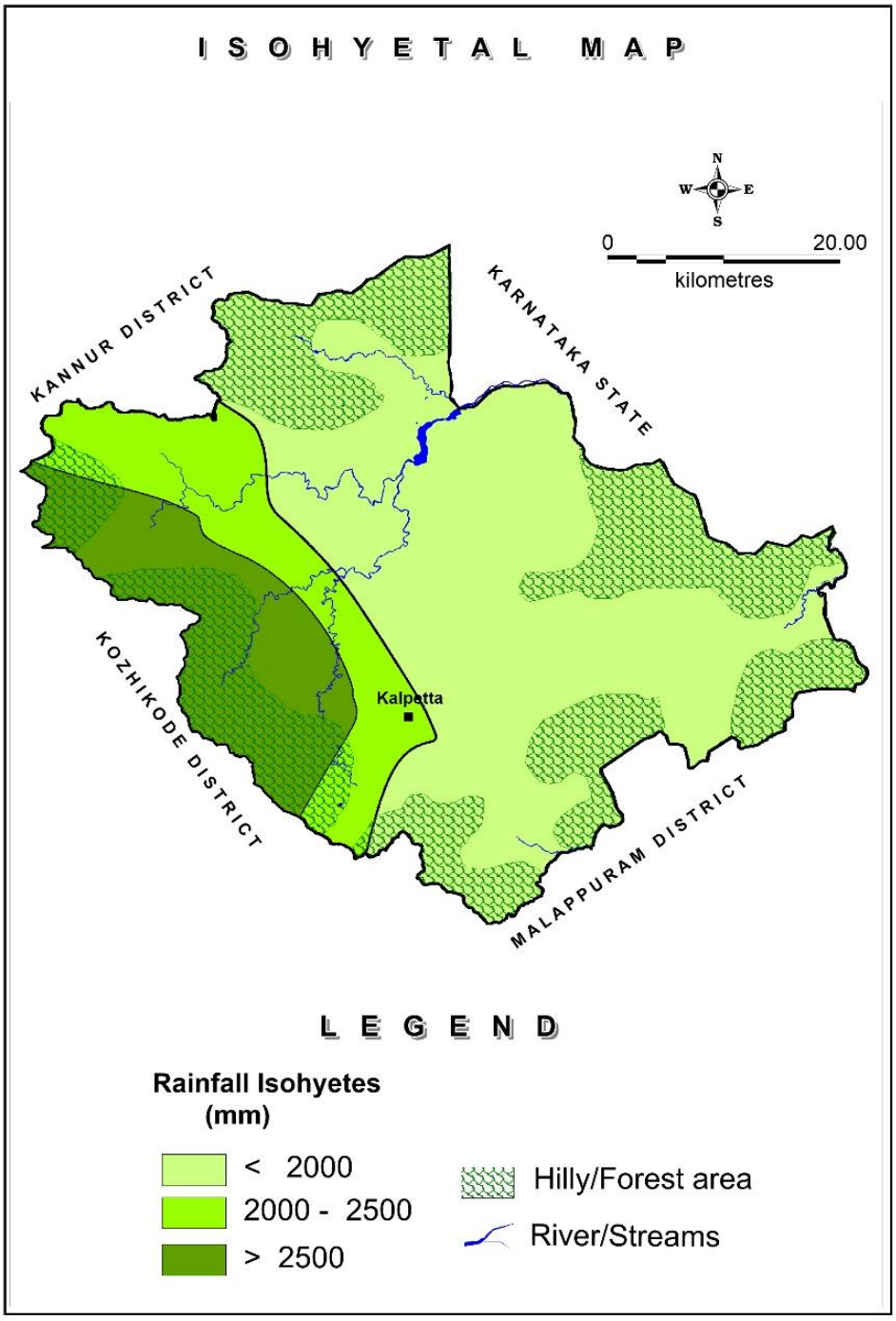


Fig.3.2 Isohyetal map.

3.2 GEOPHYSICAL INVESTIGATIONS

Ground TEM (Transient Electromagnetic) or GTEM sounding is a geophysical technique used to obtain vertical resistivity soundings and a method which responds most strongly to conductive materials. This method is non-destructive and uses a series of wire loops for transmitting and receiving signals in the ground so no marks will be left in the survey area after measurements are finished.

The TEM procedure is remarkably efficient: with just a 40×40 meter square transmitter loop and 1 or 2 smaller receiver coils, it is possible to reach depths of 200-250 meters and to get from setting-up to a resistivity model only takes a few minutes. With a suitable system configuration, it is possible to reach depths of more than 800 meters, without a huge increase in survey times.

The advantages are (i) good depth of penetration (ii) stability to anisotropy (iii) lack of necessity for galvanic grounding make the surveys independent of place, season, and weatherand (iv) possibility of using loop sizes smaller than target depths.

TEM is an inductive method which means that it does not require a direct galvanaic (electric) contact with the ground. The modus operandi is that a transmitter loop on the ground induces a transient current within the subsurface and the receiver antennas then measure the rate of change of magnetic field associated with that current as it propagates through the earth. Transmitter loops and receiver coils are available in different sizes depending upon depth penetration. Smaller transmitter and receiver loops are suited to shallow response, larger loops are better for recording deeper depth responses.

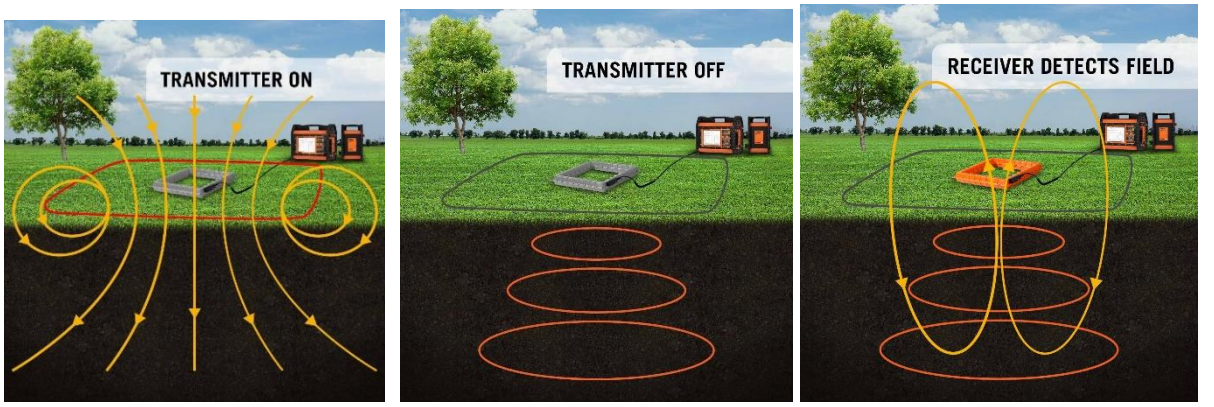


Fig.3.3 Conceptual diagram of working of TEM soundings

TEM is sensitive to electromagnetic source and it may not appropriate for locations close to buildings, utilities, infrastructure as these are potential noise source and therefore bad data.

TEM is adopted in defining the subsurface disposition of aquifers in the data gap area and to recommend sites for exploratory drilling . Total 88 TEM were carried out in 22 locations by employing the loop and antenna configuration. The obtained VES data was interpreted by

using the computer interpretational techniques. The interpreted results obtained are presented in annexure -III.

Totally 88 GTEM soundings/Profiles were carried out in 22 villages falling in 4 blocks. TEM locations conducted in Wayanad district is compiled (Fig-3.4) and interpreted results of selected TEM soundings as layer parameters in the form of resistivity and thickness are presented in Annexure-IV . Results are discussed block wise in the following paragraphs.

From the interpretation of TEM data in Wayanad district it is demarcated that the top soil thickness is varying from 2.1 to 7.1 m, the weathered zone thickness is varying from 4.5 to 24 m and the depth to massive layer is varying from 6.5 to 27.5 m.

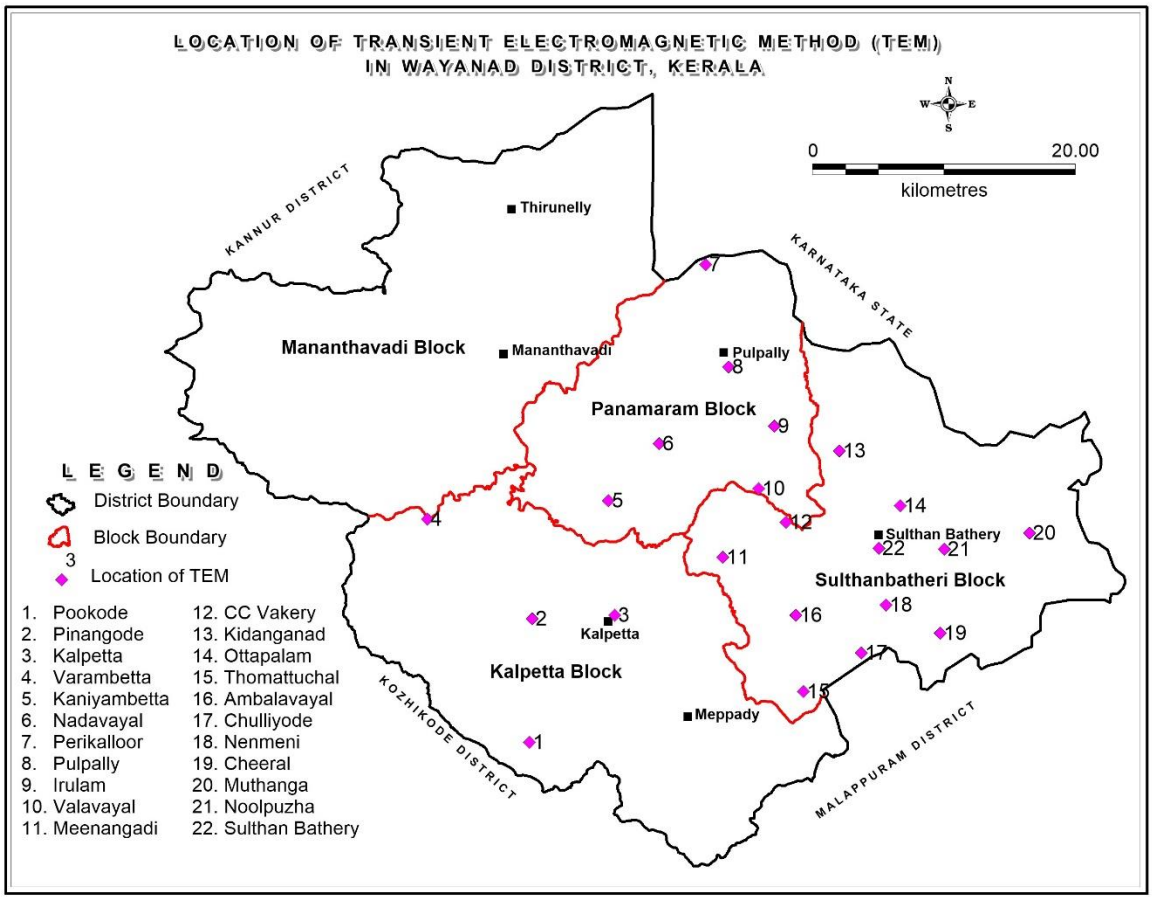


Fig. 3.4: Location of TEM soundings conducted in Wayanad District, Kerala

3.2.1 kalpetta block:

At Kalpetta block totally 14 GTEM soundings/Profiles were carried out in 4 villages. Main rock formation in majority of study area is weathered granite, weathered charnockites and granitic gneisses. Interpretation of TEM soundings indicated four layered behaviour which can be correlated with Topsoil/and depth of weathering and compactness. Out of 14 Soundings 1 sounding could not be interpreted for layer parameters due to high noise level in the data. General behaviour of these layers have been arrived at based on results of 13 TEM soundings, and attributed to the following subsurface hydrogeological dispositions (Table. 3.2)

Table-3.2 Interpreted parameters of TEM in Kalpetta Block

S.No	Location	TEM No	ρ1	ρ2	ρ3	Top Soil Thickness	Weathered Thickness	Depth to Massive
1	Pookode	1	52	211	967	3.9	17.4	21.2
2		2	54	212	966	3.7	17.6	21.3
3		3	55	215	964	5.2	16.3	21.5
4	Kalpetta	1	136	1290	82369	4.8	13.3	18.1
5		2	220	1248	80325	5.6	12.6	18.2
6		3	330	1815	80558	3.1	15.1	18.2
7		4	186	1451	80530	2.9	15.5	18.3
8	Varambet-ta	1	56	173	1923	2.3	11.9	14.2
9		2	37	143	1158	2.1	12.3	14.5
10		3	28	155	1386	3.0	10.9	13.9
11	Pinangode	1	297	44	4904	2.8	11.5	14.3
12		2	246	49	4977	3.2	11.2	14.4
13		3	227	46	4966	3.2	11.0	14.2
14		4	Not Interpretable					

3.2.2 Panamaram Block:

At Panamaram block totally 25 GTEM soundings/Profiles were carried out in 6 villages. Main rock formation in majority of study area is weathered granite, weathered charnockites and granitic gneisses. Interpretation of TEM soundings indicated four layered behaviour which can be correlated with Topsoil/and depth of weathering and compactness. Out of 24 Soundings 1 sounding could not be interpreted for layer parameters due to high noise level in the data. General behaviour of these layers have been arrived at based on results of 24 TEM soundings, and attributed to the following subsurface hydrogeological dispositions (Table.3.3)

Table.3.3 Interpreted parameters of TEM in Panamaram Block

S.No	Location	TEM No	ρ1	ρ2	ρ3	Top Soil Thick-ness	Weathered Thickness	Depth to Massive
1	Kaniyambet-ta	1	358	101	2041	3.5	12.4	15.9
2		2	454	92	2035	3.2	12.4	15.5
3		3	Not Interpretable					
4		4	358	99	204	3.8	12.1	15.9

S.No	Location	TEM No	ρ1	ρ2	ρ3	Top Soil	Weathered	Depth to
						Thick-ness	Thickness	Massive
					0			
5	Valavayal	1	24	58	180	3.2	5.5	8.7
6		2	26	57	173	3.2	5.4	8.6
7		3	26	65	173	3.2	5.5	8.7
8		4	26	54	164	3.9	4.8	8.7
9		5	24	47	160	3.2	5.7	8.9
10	Perikalloor	1	311	17	1695	3.3	23.8	27.2
11		2	389	14	1695	3.3	23.9	27.3
12		3	287	20	1700	3.1	24.2	27.3
13		4	287	24	1696	3.2	24.4	27.6
14	Pulpally	1	141	426	1850	5.7	8.2	13.9
15		2	151	449	2241	7.1	6.7	13.8
16		3	140	352	1913	6.1	7.8	13.9
17		4	131	294	2153	6.0	7.7	13.7
18	Irulam	1	142	13	2338	2.9	14.8	17.7
19		2	76	15	322	3.1	14.6	17.7
20		3	71	13	346	2.8	15.2	18.0
21		4	69	10	379	3.1	14.2	17.3
22	Nadavayal	1	345	60	2437	4.5	9.9	14.4
23		2	379	60	2230	4.6	10.0	14.5
24		3	363	55	2332	4.9	9.2	14.1
25		4	350	57	2500	4.7	9.6	14.2

3.2.3 Sulthan Bathery Block:

At Sulthan Bathery block totally 49 GTEM soundings/Profiles were carried out in 6 villages. Main rock formation in majority of study area is weathered granite, weathered charnockites and granitic gneisses. Interpretation of TEM soundings indicated four layered

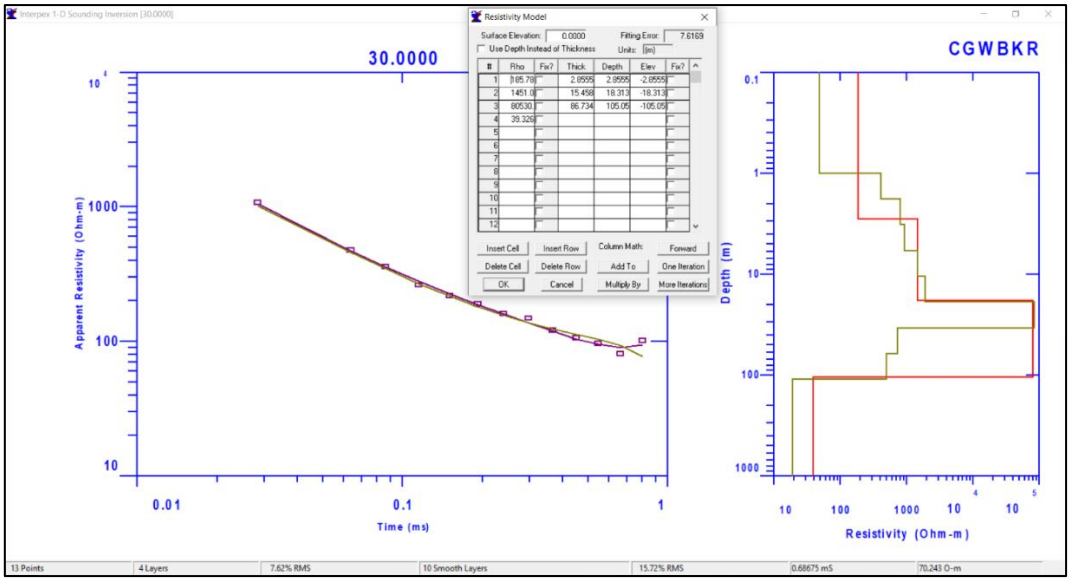
behaviour which can be correlated with Topsoil/and depth of weathering and compactness. Out of 38 Soundings 11 sounding could not be interpreted for layer parameters due to high noise level in the data. General behaviour of these layers have been arrived at based on results of 38 TEM soundings, and attributed to the following subsurface hydrogeological dispositions (Table.3.4)

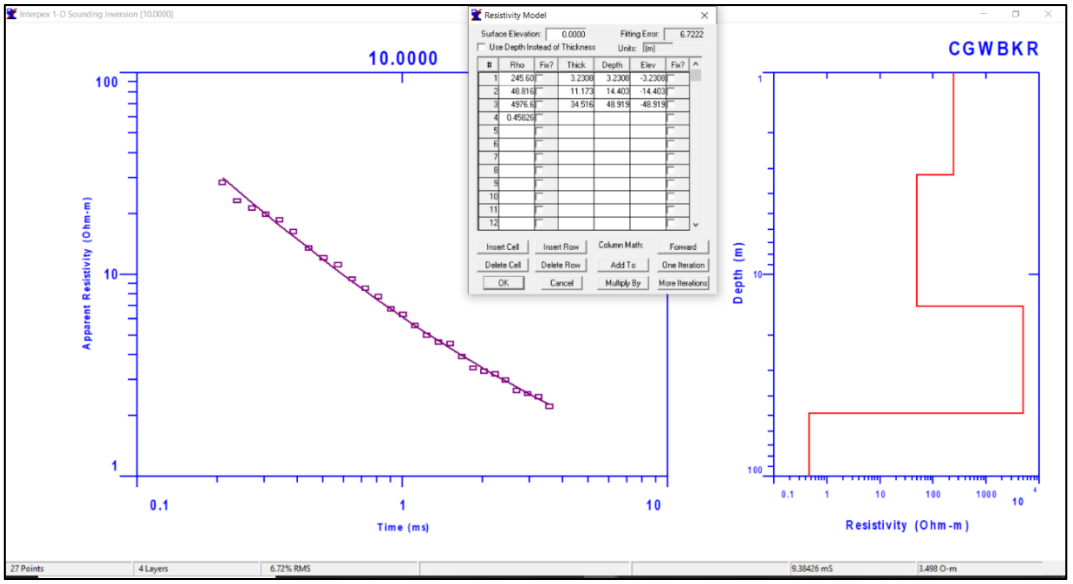
Table.3.4 Interpreted parameters of TEM in Sulthan Bathery Block

S.No	Location	TEM No	ρ1	ρ2	ρ3	Top Soil	Weathered	Depth to
						Thickness	Thickness	Massive
1	Noolpuzha	1	381	129	3997	2.6	7.8	10.4
2		2	296	126	3990	2.4	7.6	10.0
3		3	443	129	4000	3.0	7.0	10.0
4		4	449	117	3960	3.5	7.2	10.7
5	CC Vakery	1	153	31	1515	2.7	6.5	9.2
6		2	143	32	1508	2.6	6.3	8.9
7		3	Not Interpretable					0.0
8		4	Not Interpretable					0.0
9	Thomattuchal	1	191	29	1552	2.8	9.3	12.1
10		2	324	35	1506	2.5	10.0	12.5
11		3	199	19	1493	2.7	9.4	12.2
12		4	242	31	1737	2.5	9.8	12.3
13	Meenangadi	1	504	24	1431	4.1	10.9	15.0
14		2	450	24	1289	4.2	11.1	15.3
15		3	427	29	1282	4.4	11.0	15.4
16		4	418	34	1307	4.3	10.9	15.1
17	Sulthan Bathery	1	586	16	3404	20.2	6.6	26.8
18		2	804	13	3734	20.2	5.7	25.8
19		3	597	35	3838	13.7	12.4	26.1
20		4	400	18	5122	19.1	7.2	26.3
21	Cheeral	1	43	491	5763	2.7	4.5	7.2
22		2	42	417	6412	2.3	5.0	7.3
23		3	40	383	6135	2.1	5.0	7.2
24		4	54	414	6742	2.2	5.1	7.2
25		5	55	306	5747	2.4	4.9	7.2
26	Kidangad	1	21	52	296	3.0	15.0	17.9
27		2	20	66	296	2.4	15.6	17.9
28		3	21	63	321	2.4	15.7	18.1
29		4	Not Interpretable					
30	Odapallam	1	64	19288	1	13.5	0.0	13.5

S.No	Location	TEM No	ρ1	ρ2	ρ3	Top Soil	Weath-ered	Depth to
						Thick-ness	Thickness	Massive
31		2	65	19285	1	13.9	0.0	13.9
32		3	79	19316	13	13.9	0.0	13.9
33		4	69	19277	7	14.0	0.0	14.0
34	Muthanga	1	280	46	1530	3.9	10.2	14.1
35		2	315	45	1528	4.4	9.8	14.2
36		3	Not Interpretable					
37		4	Not Interpretable					
38	Ambalavayal	1	151	56	488	1.5	5.0	6.5
39		2	146	60	502	1.5	5.1	6.6
40		3	Not Interpretable					
41		4	174	56	499	1.5	4.9	6.4
42	Nenmeni	1	Not Interpretable					
43		2	22	99	881	4.7	6.7	11.3
44		3	30	84	226	1.9	9.5	11.3
45		4	27	90	729	4.8	6.5	11.4
46	Chulliyode	1	Not Interpretable					
47		2	Not Interpretable					
48		3	Not Interpretable					
49		4	Not Interpretable					

Some selected type curves of TEM with interpreted results are given in fig.3..5




10.0000
CGWBKR
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Time (ms)
Depth (m)
Resistivity (Ohm-m)
Resistivity Model
27 Points
4 Layers
6.72% RMS

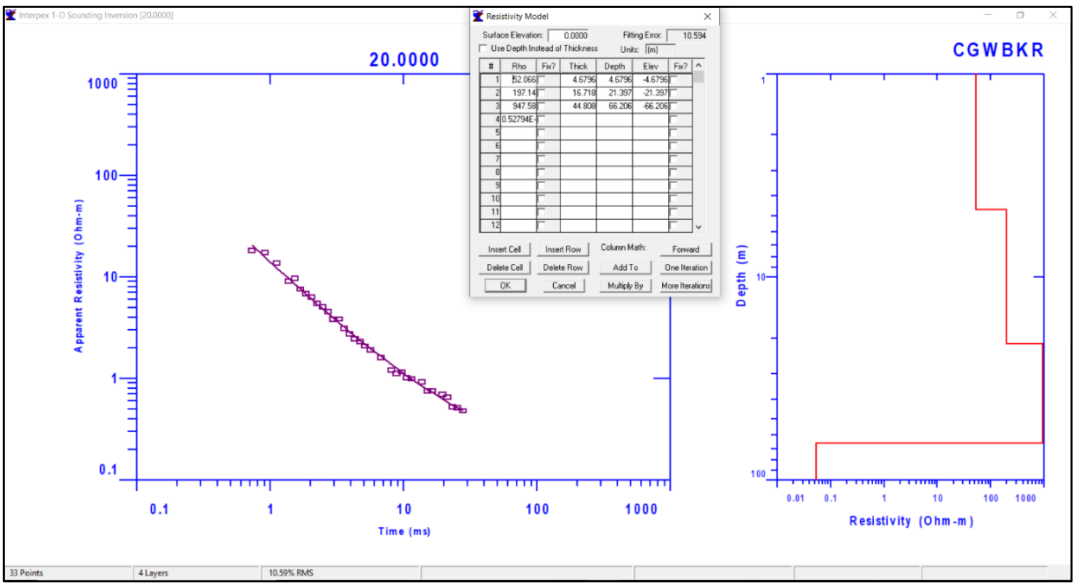
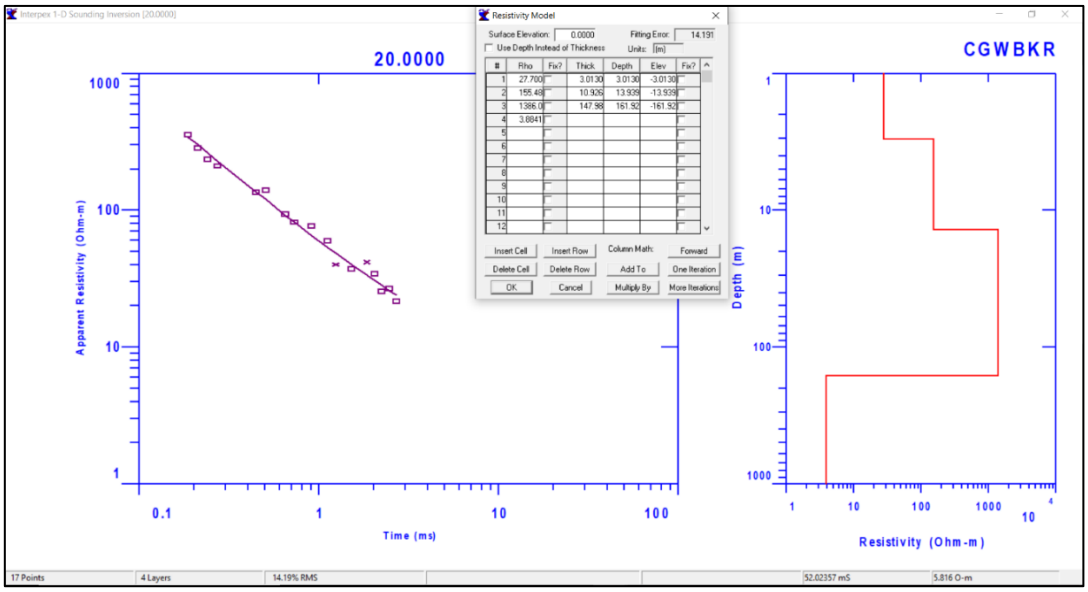
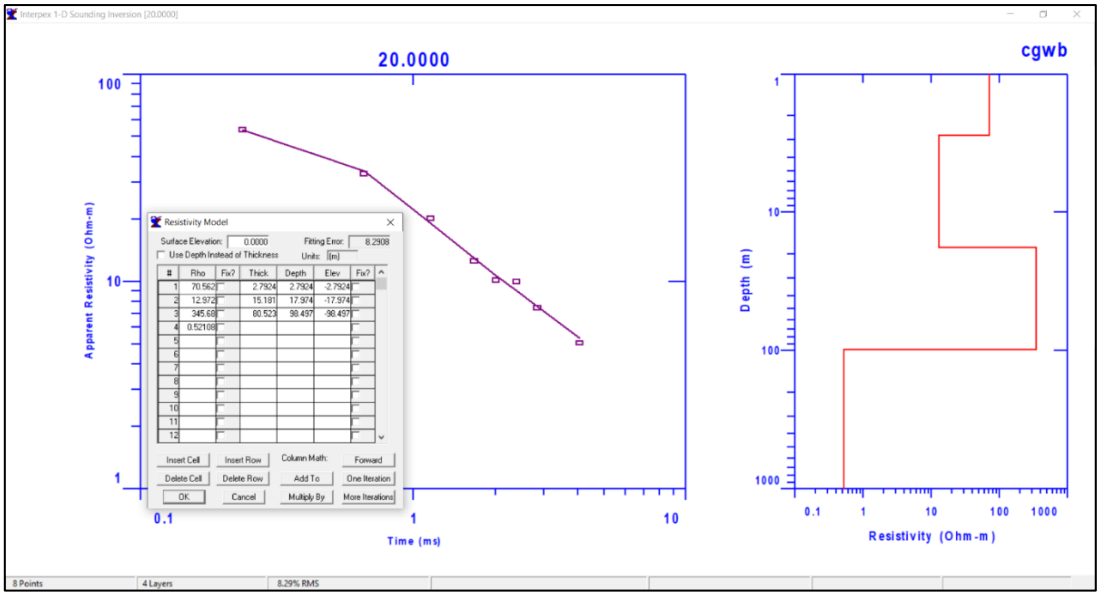

20.0000
CGWBKR
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
Resistivity Model
33 Points
4 Layers
10.59% RMS

Fig.


20.0000
CGWBKR
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
Resistivity Model
17 Points
4 Layers
14.19% RMS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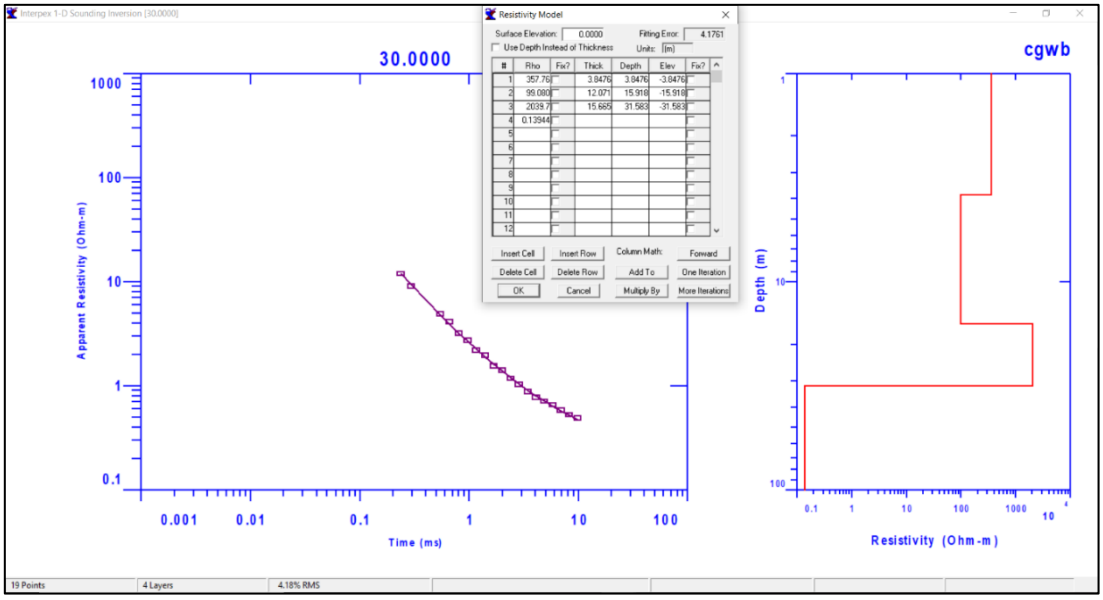
20.0000
cgwb
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
Resistivity Model
Surface Elevation: 0.0000
Fitting Error: 8.2908
Use Depth Instead of Thickness
Units: [m]
Insert Cell
Insert Row
Column Math:
Forward
Delete Cell
Delete Row
Add To
One Iteration
OK
Cancel
Multiply By
More Iterations
8 Points
4 Layers
8.29% RMS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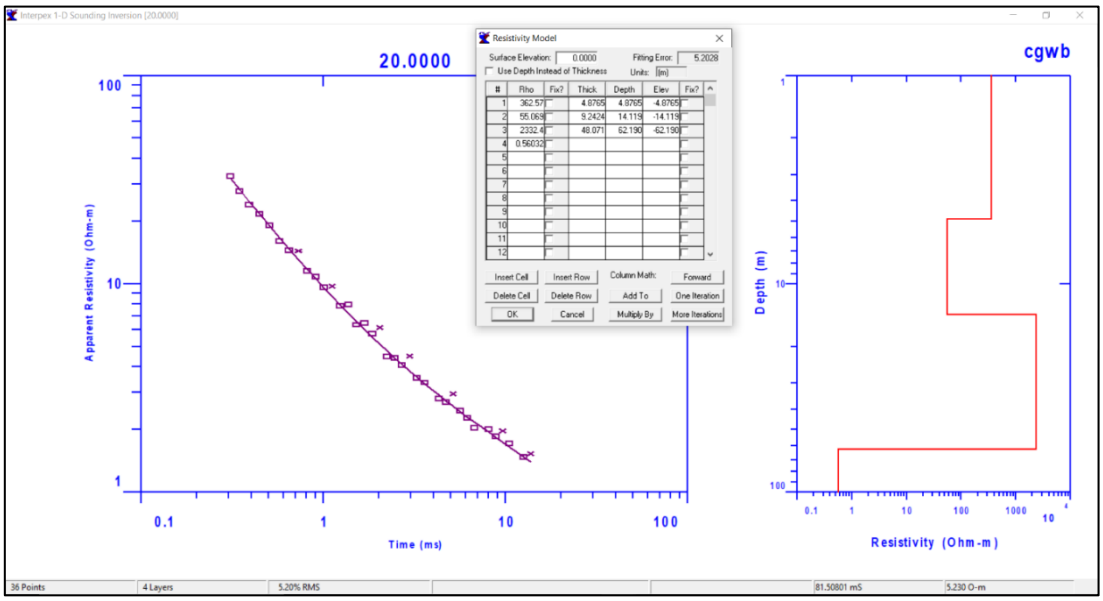
30.0000
cgwb
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
Resistivity Model
Surface Elevation: 0.0000
Fitting Error: 4.1761
Use Depth Instead of Thickness
Units: [m]
Insert Cell
Insert Row
Column Math:
Forward
Delete Cell
Delete Row
Add To
One Iteration
OK
Cancel
Multiply By
More Iterations
19 Points
4 Layers
4.18% RMS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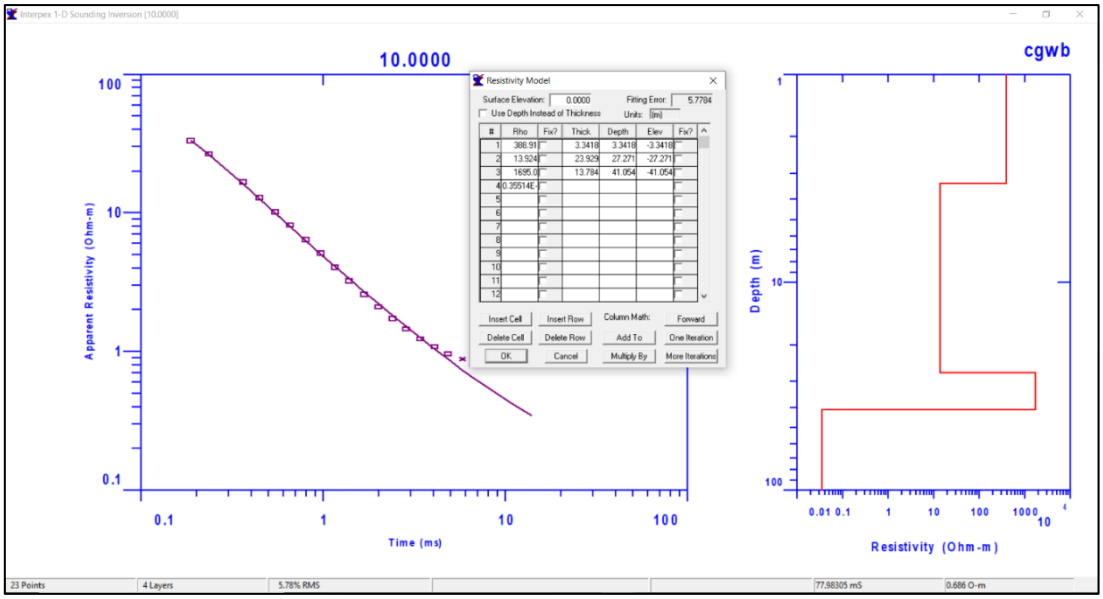
20.0000
cgwb
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
Resistivity Model
Surface Elevation: 0.0000
Fitting Error: 5.2028
Use Depth Instead of Thickness
Units: [m]
Insert Cell
Insert Row
Column Math:
Forward
Delete Cell
Delete Row
Add To
One Iteration
OK
Cancel
Multiply By
More Iterations
36 Points
4 Layers
5.20% RMS
81.50801 mS
5.230 O-m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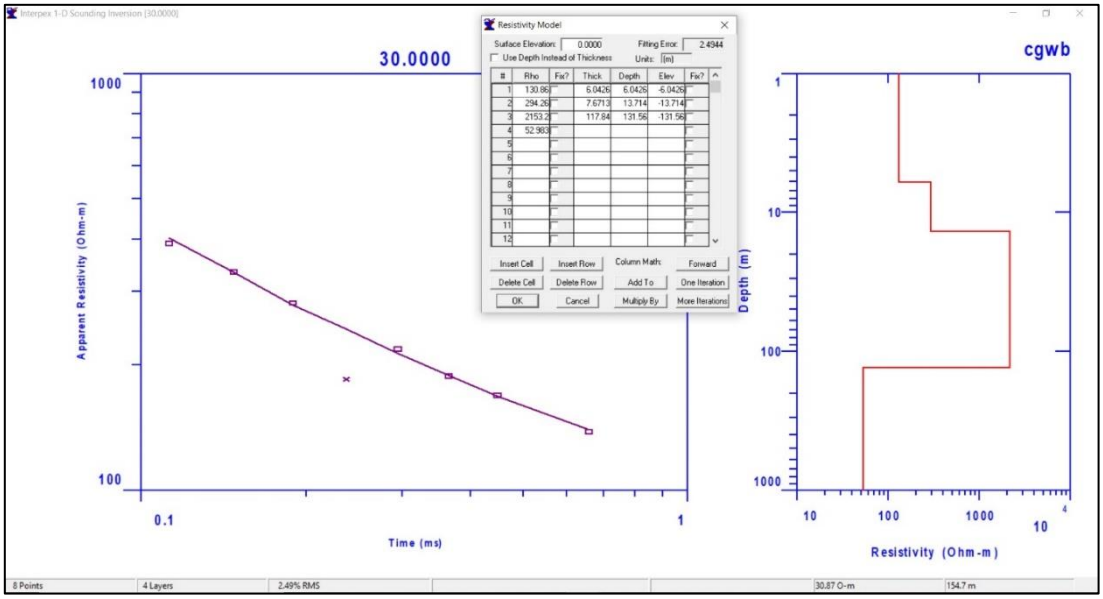
10.0000
cgwb
Resistivity Model
Surface Elevation: 0.0000
Fitting Error: 5.7784
Use Depth Instead of Thickness
Units: [m]
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
23 Points
4 Layers
5.78% RMS
77.98305 mS
0.686 O-m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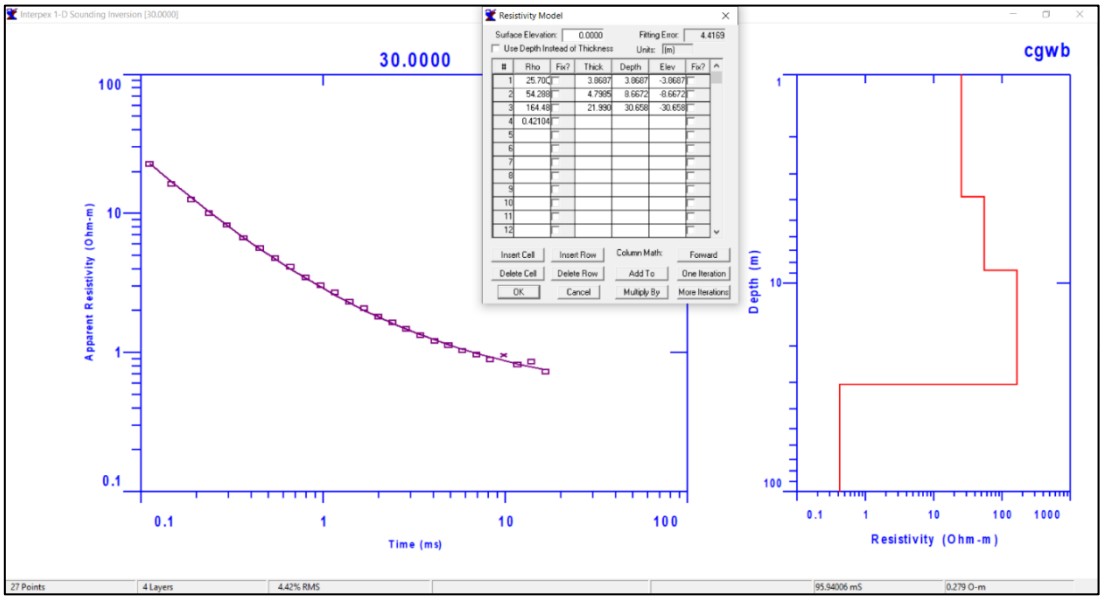
30.0000
cgwb
Resistivity Model
Surface Elevation: 0.0000
Fitting Error: 2.4944
Use Depth Instead of Thickness
Units: [m]
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
8 Points
4 Layers
2.49% RMS
30.87 O-m
154.7 m


Interpex 1-D Sounding Inversion [30.0000]
30.0000
cgwb
Resistivity Model
Surface Elevation: 0.0000
Fitting Error: 4.4169
Use Depth Instead of Thickness
Units: [m]
Apparent Resistivity (Ohm-m)
Time (ms)
Depth (m)
Resistivity (Ohm-m)
27 Points
4 Layers
4.42% RMS
95.94006 mS
0.279 O-m

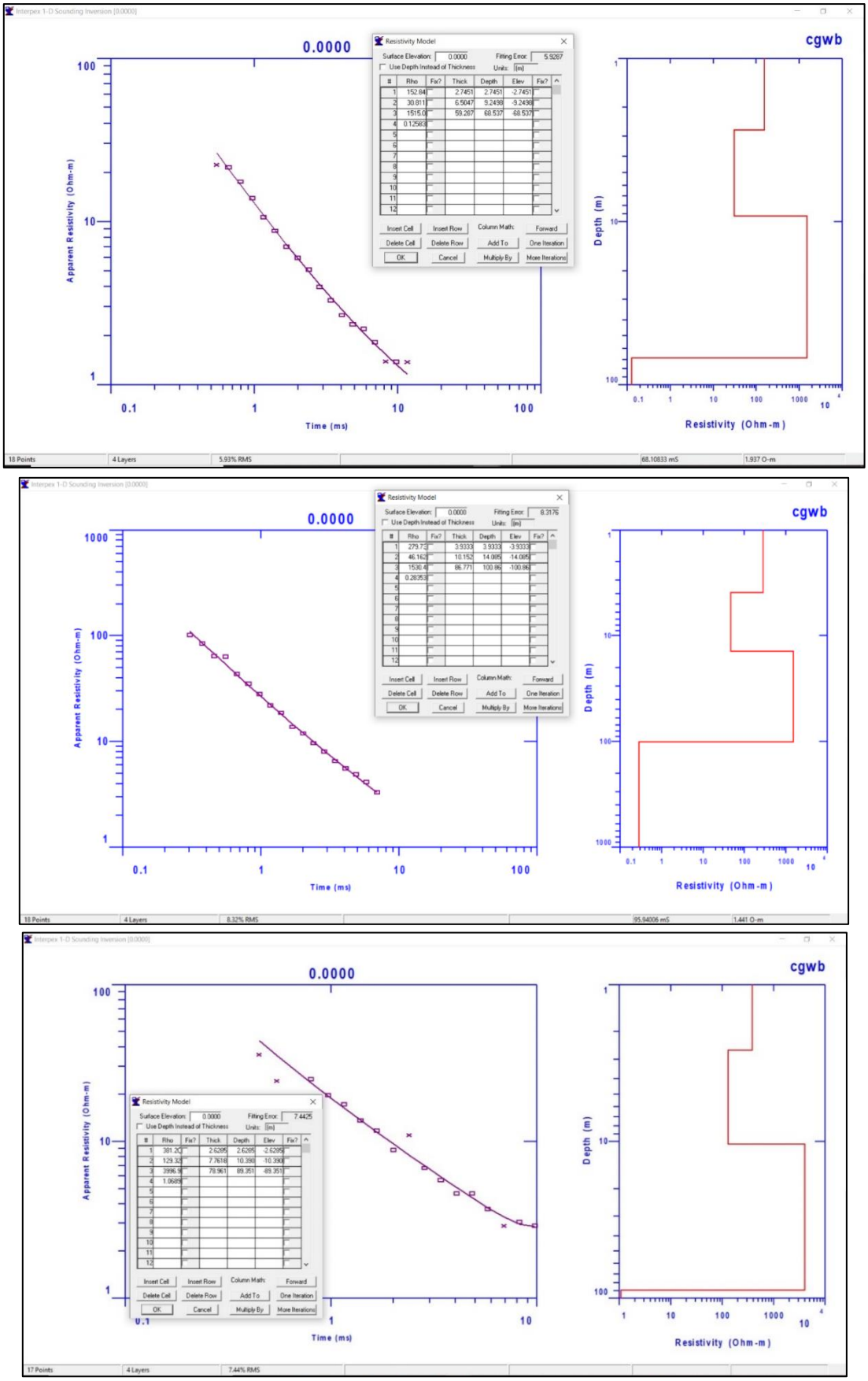


Fig.3.5 Type curves of TEM with interpreted results of selected locations

3.3 NATURE AND TYPE OF AQUIFERS

Based on the geophysical interpretation and available exploratory data it is interpreted that the aquifer system in Wayanad consists of two types

1. Phreatic Aquifer System (Aquifer I)
2. The Deeper Fracture system (Aquifer II)

The laterites and weathered Charnockites associated with shallow fractures form the phreatic aquifer system where groundwater exists under phreatic (unconfined)condition . The laterites of Sub-Recent age occur as a residual deposit due to weathering of crystalline rocks. The typical laterite profile seen in crystalline terrain consists of lateritic soil at the top followed by soft laterite, lithomargic clay and weathered zone. The occurrence and movement of groundwater in the weathered zone is mainly influenced by the depth of weathering gradient and topography. Groundwater abstraction structures in this zone include dug wells mainly and through shallow bore wells. The yielding capacity of phreatic aquifers varies spatially and temporally and is related to the hydraulic characteristics, rainfall and thickness of weathered residuum.

The weathered granite and granitic gneiss in Kalpetta and Sultan Bathery blocks form potential phreatic aquifers along valleys and topographic lows. The depth of dug wells generally varies in the range of 6 to 9m with water levels ranging from 4 to 8 mbgl during pre-monsoon and from 3 to 5 mbgl during post monsoon.

The weathered chanockites seen in Kalpetta block and along the hill ranges of the Western Ghats form poor aquifer, and can sustain only domestic wells. The depth of wells generally varies in the range of 7 to 10 m with water levels ranging from 4 to 9 mbgl during pre-monsoon and from 3 to 7 m during post monsoon.

3.3.1 THICKNESS OF WEATHERED ZONE

Weathered zone is a distinctive layer of weathered material that extends roughly parallel to the ground surface. It differs physically, chemically, and mineralogically from the layers above and/or below. The thickness of weathered formation is controlled by (i) the degree of structural deformation happened in the terrain(ii) intensity and duration of rainfall and (iii) the gradient of the topography. Higher the structural deformation, higher will be the degree of weathering. The weathered zone in general is sum up of the weathered regolith/soil and the underlying shallow fractures up to a depth of 30-35 m and its thickness of weathered zone varies in the range of 7 to 29 m. It is also reported that as the gradient of the terrain increase is inversely proportional to the thickness of weathering. The weathered thickness in the area vary highly as observed from exploratory drillings and the data inferred from geophysical soundings. in weathered zone. The casing depth of 17 bore wells and 88 TEMs carried out in the district have been taken into consideration for better understanding of the spatial variations in the thickness of weathered zone.The geology of the area indicate the presence of

Charnockite rocks with migmatite and peninsular gneisses rcks in major parts of the district.

Charnockite and migmatites are less prone to weathering and therefore shallow aquifer system exist within a thickness of 15-20m.The weathering of Charnockite and migmatites create less clay content due to mineralogical assemblages and are acting as good aquifers and often get saturated with onset of monsoon. Gneisses are known for more clayish content and lead to clay rich weathered regolith and retard the recharging process due to low permeability.

To understand the spatial variation, contour map depicting the weathered zone is prepared and is shown in Figure 3.6. The thickness of the weathered zone generally decreases towards the south central part towards Sulthan bathery side and , where it becomes less than 10m on an average . In Mananthavadi and Muthunga side the weathered zone has developed into maximum thickness of 29 m . The zone with 15-20 m range has been noticed as widely distributed one.

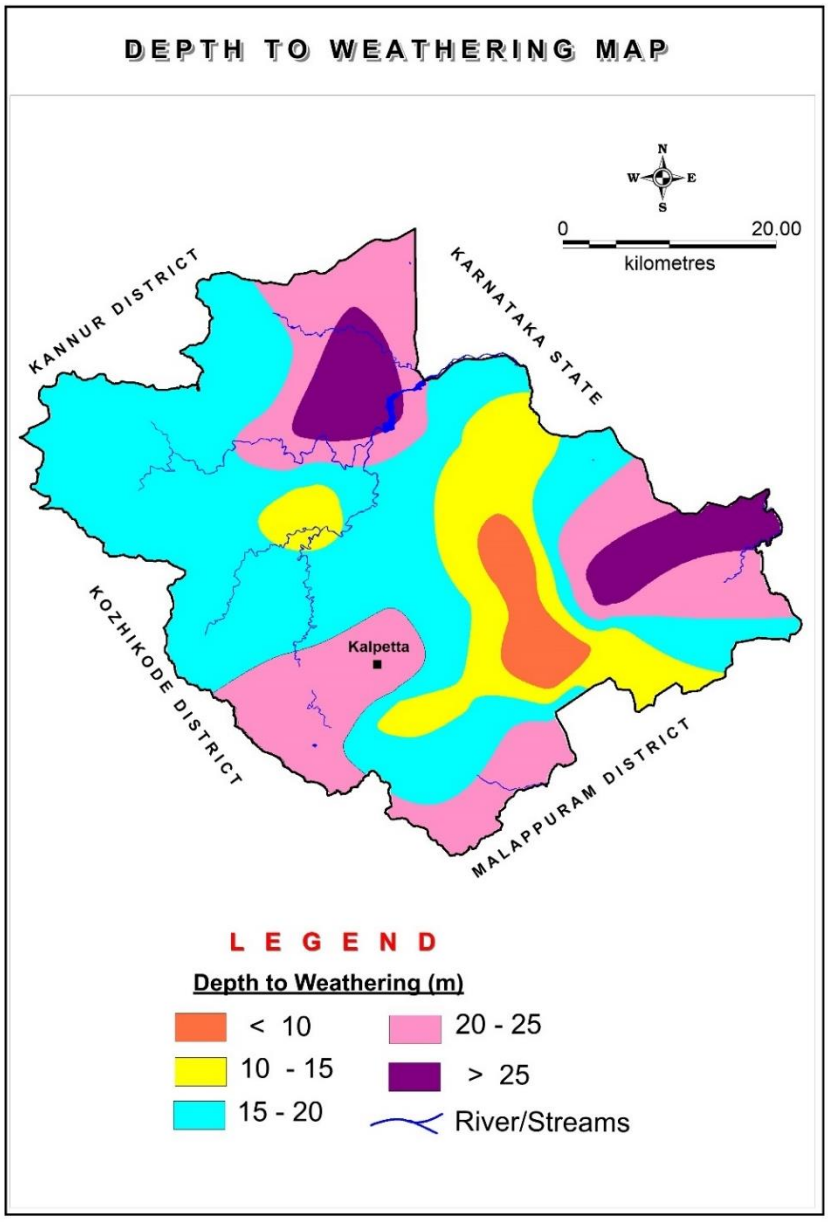


Fig.3.6 Spatial distribution of weathering thickness

3.3.2 WATER LEVEL VARIATIONS

Water level is a direct manifestation of the availability of groundwater in an area. It is the most reliable information for any hydrogeological studies and best tool in understanding hydrodynamic of the area of concern. It indicate the balance between interplay of Rainfall and discharge. It depends on soil moisture, porosity and permeability of the weathered zone. 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 3.95 to 23.1 m bgl and that of the shallow bore well to a depth of 30m.The water levels of 82 GWMWs of CGWB (75 dug wells and 7 Piezometers) were taken four times in a year (April, August, November and January). The water levels of the 40 newly established KOWs were taken during pre- and postmonsoon periods, i.e. during April and November. The water level data of GWMWs and KOWs are given in annexure I & II respectively.

The water levels in the weathered zone were analysed using the data collected by monitoring of 82 dug wells in the area and depth to water level ranges from 1.11 to 20 mbgl during pre-monsoon period (April19) and from 0.78 to 16.68 mbgl during post-monsoon period (November 2019).The pre-monsoon water level map shows a deeper water level in the central and eastern side 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.

The analysis of the water level data shows that 67 % of wells show water level within 10m during pre-monsoon while it rose to 84 % of monitoring wells during post-monsoon. During pre monsoon and post monsoon periods the water level in majority of area is within 2-10 m bgl .Map showing depth to water level during April 19 and November 19 has been prepared and is shown in Figure 3.7 and 3.8 respectively.

Water level fluctuation map indicate that there is averall rise in water level in the range of 2-4 m and fall is restricted to eastern margins and isolated pockets. Water level fluctuation between pre and post monsoon period is indicative of the net changes in the groundwater storage in response to the recharge and discharge components. The study area shows a fall in water level from 0.23 to 2.04 m and rise in water level from 0.18 to 3.89 m; the fluctuation map is given in Fig.3.9.The rise in water level in major part of area indicates an sufficient filling up of groundwater draft by the monsoon and other recharge components. Some of the hydrographs of representing the area are given in Fig. 3.10.

The water table elevation contour map (Fig 3.11 & 3.12) shows that the general flow of groundwater is towards the west towards Kabani river. The pre and post monsoon water table contour maps show identical nature.

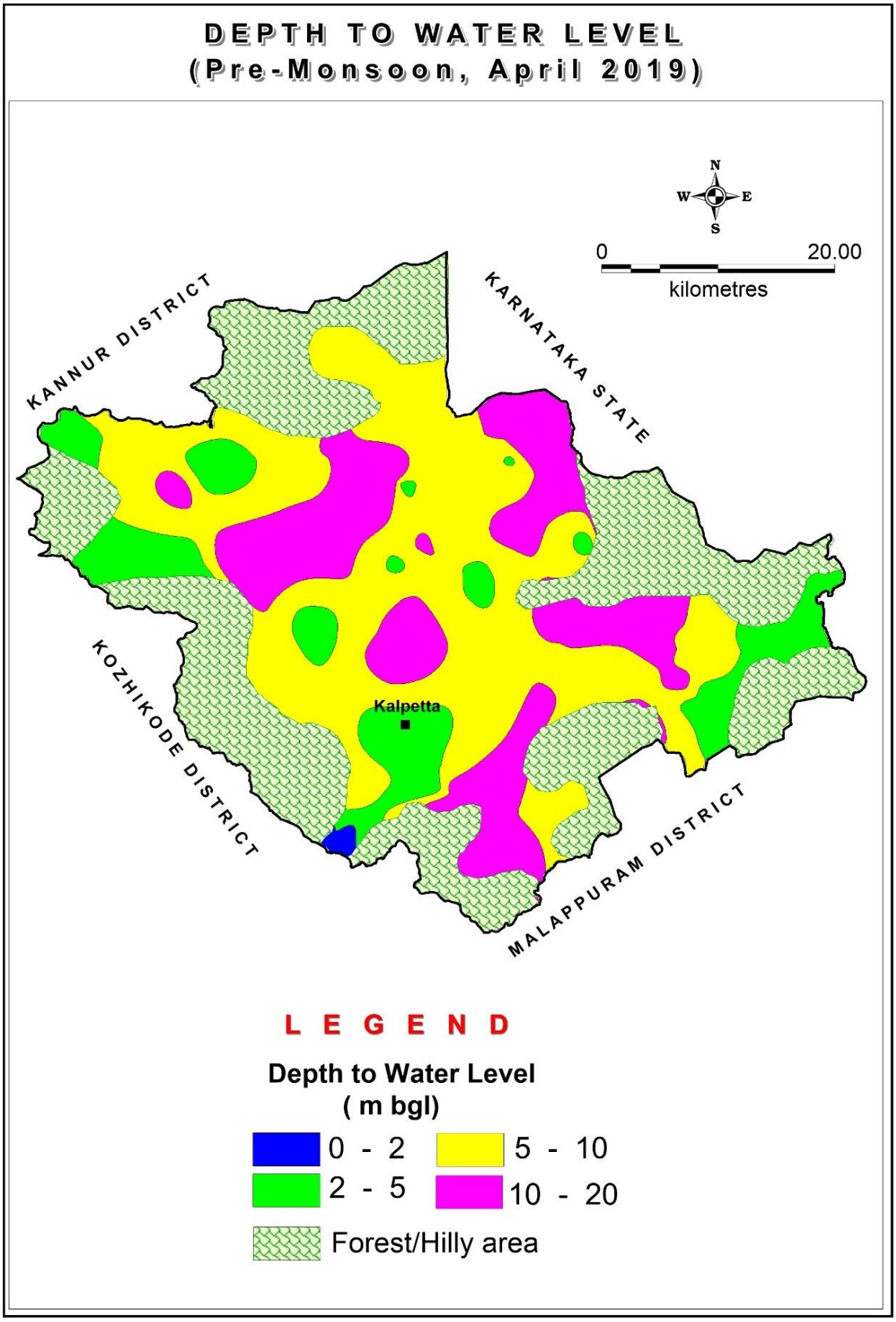


Fig.3.7 Depth to Water level map of Phreatic aquifer (Premonsoon)

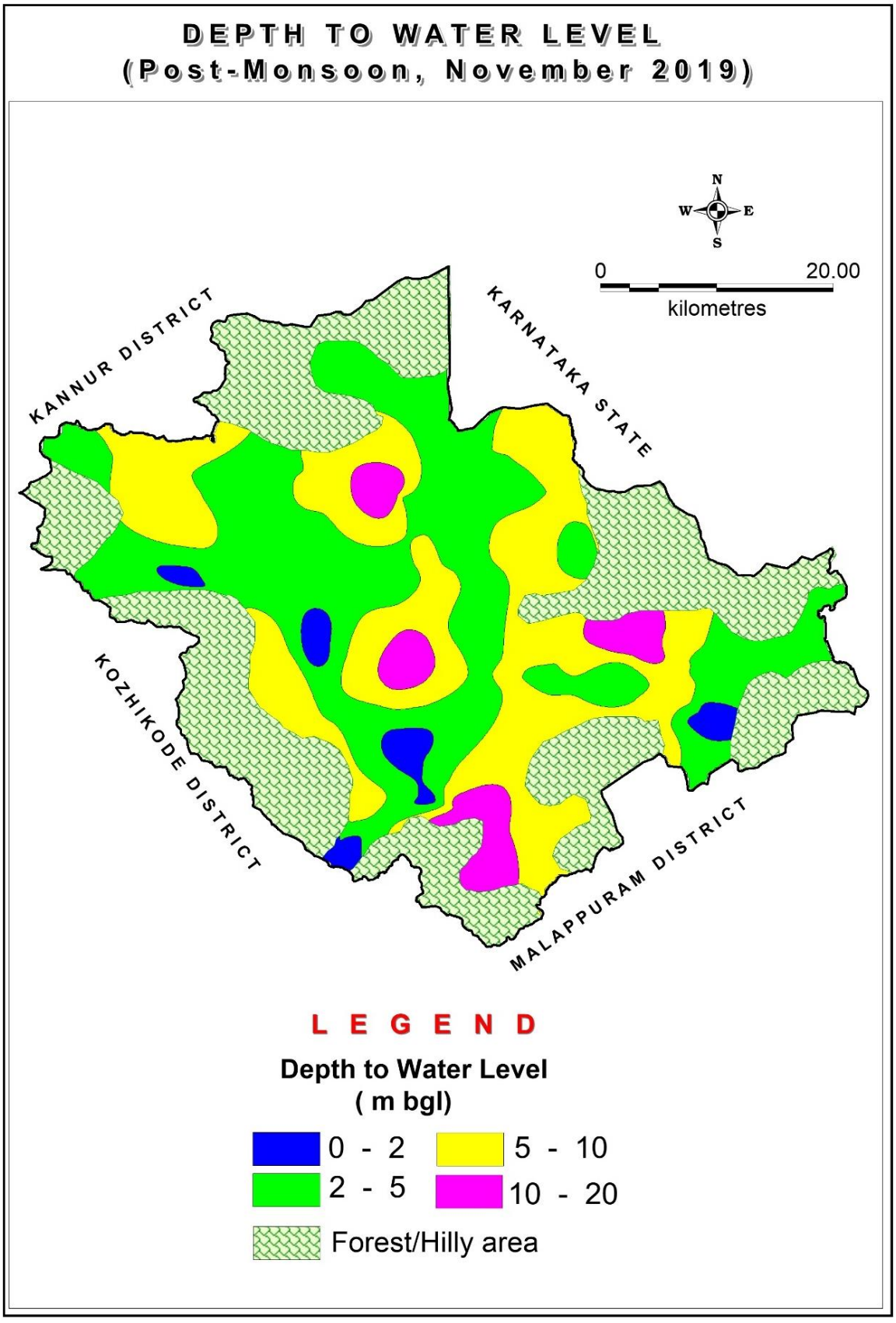


Fig.3.8 Depth to Water Level map of Phreatic aquifer (Postmonsoon)

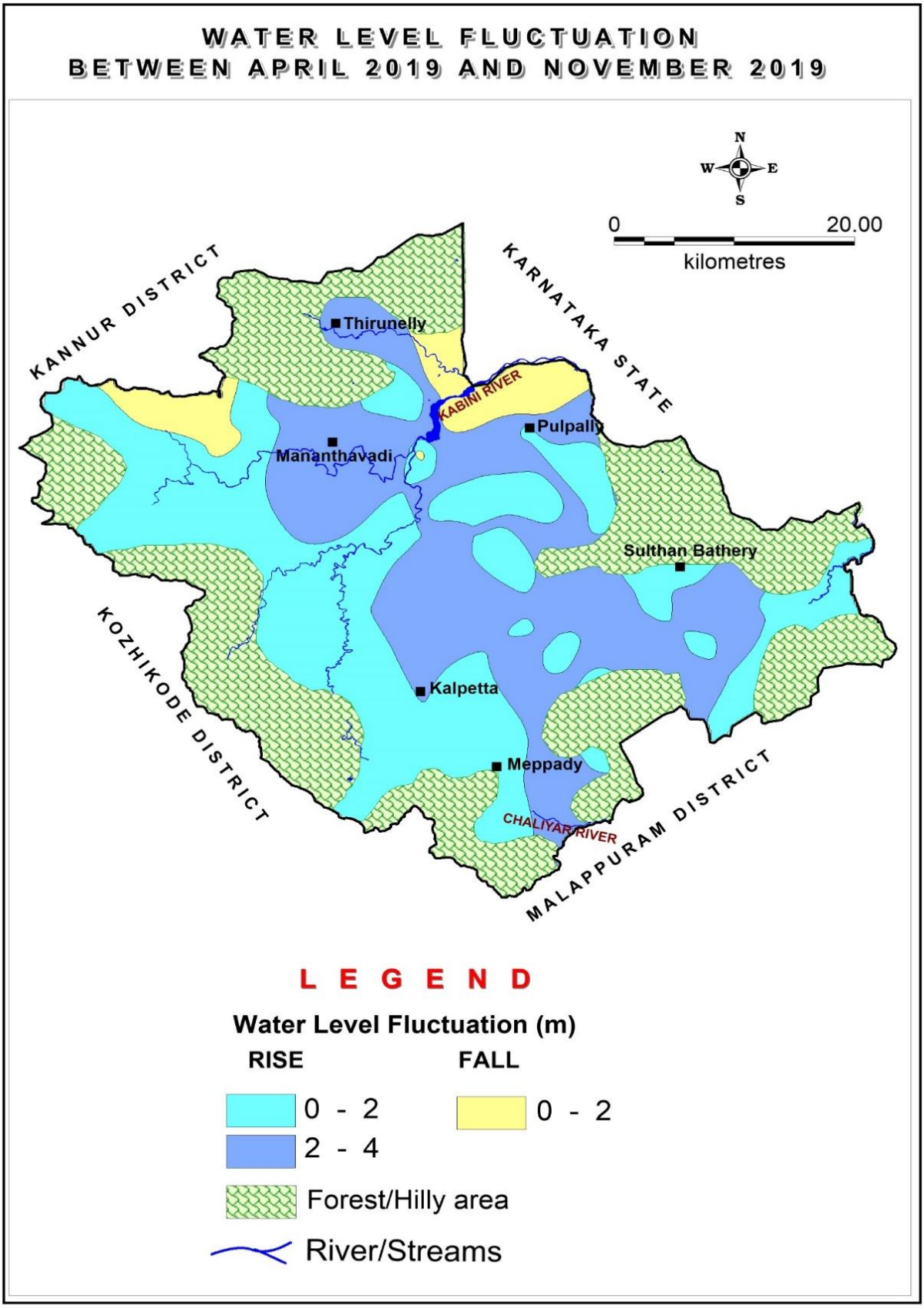
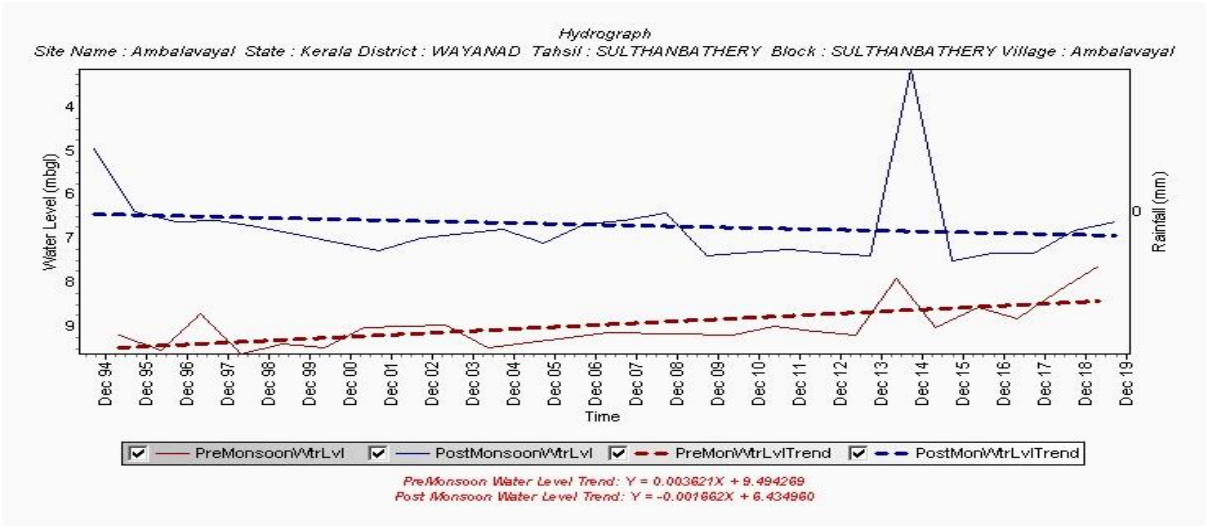
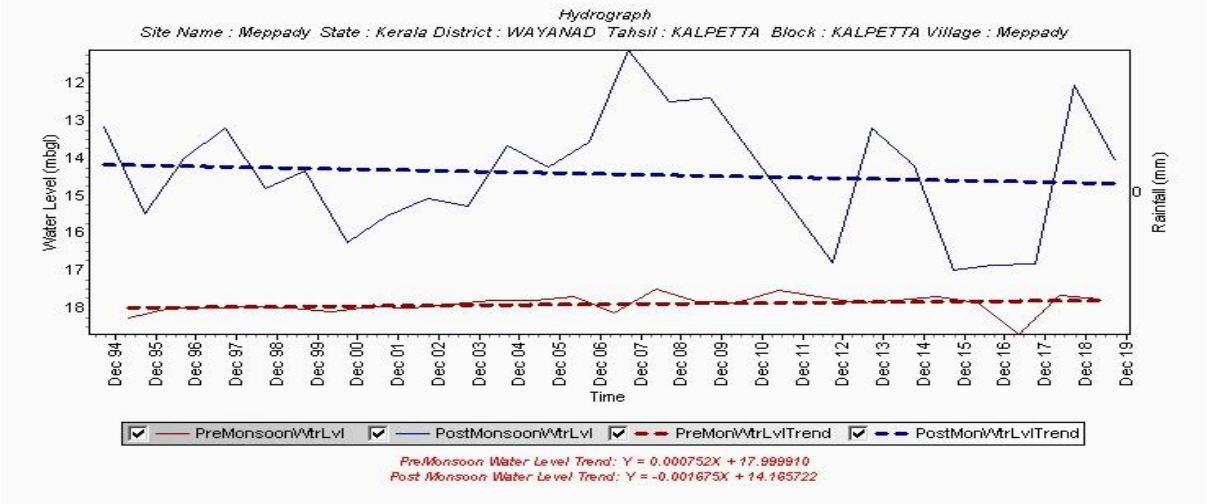
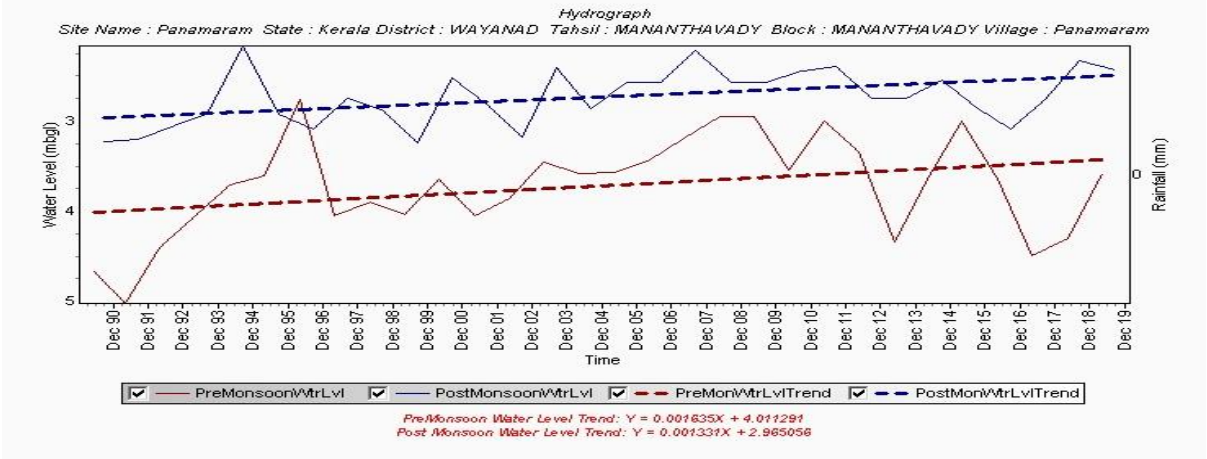
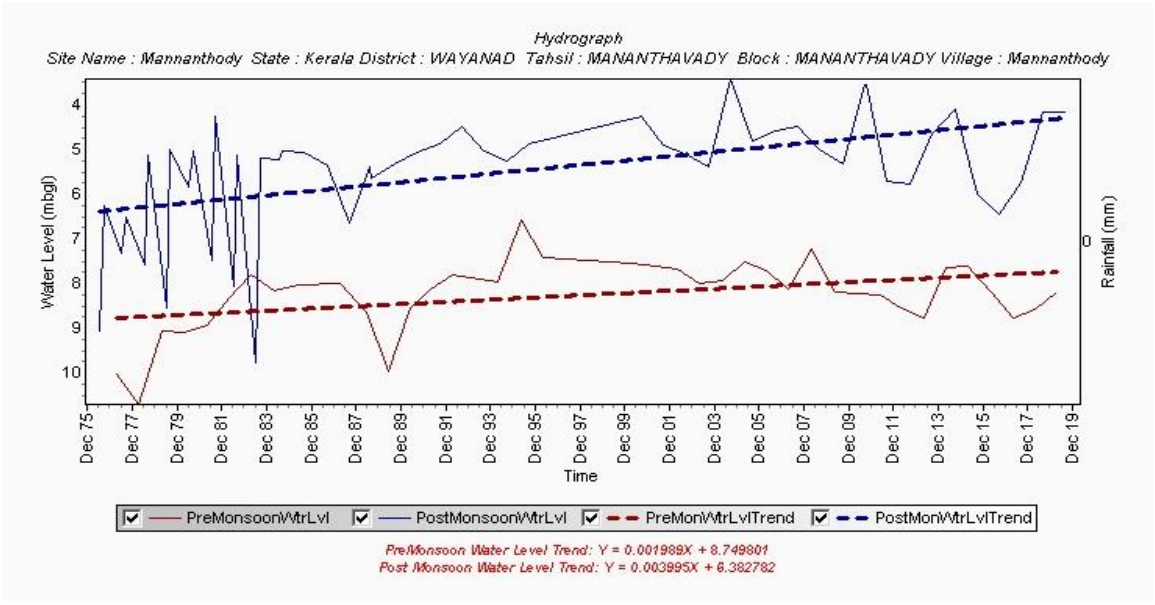


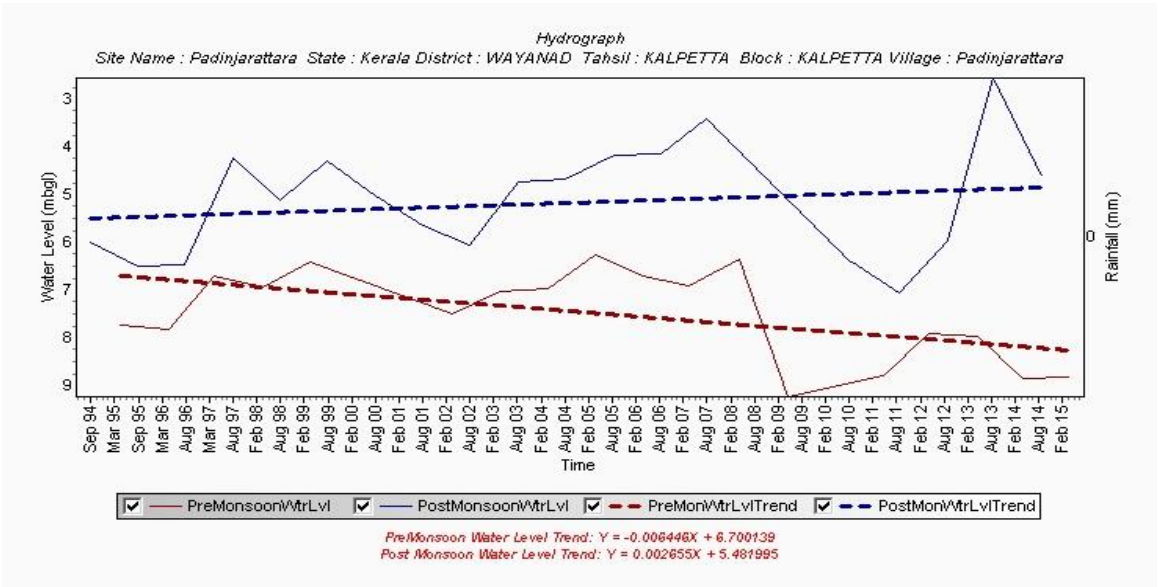
Fig.3.9 Water level fluctuation map of Phreatic aquifer


Hydrograph
Site Name : Ambalavayal State : Kerala District : WAYANAD Tahsil : SULTHANBATHERY Block : SULTHANBATHERY Village : Ambalavayal
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.003621X + 9.494269
Post Monsoon Water Level Trend: Y = -0.001662X + 6.434960


Hydrograph
Site Name : Meppady State : Kerala District : WAYANAD Tahsil : KALPETTA Block : KALPETTA Village : Meppady
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.000752X + 17.999910
Post Monsoon Water Level Trend: Y = -0.001675X + 14.165722


Hydrograph
Site Name : Panamaram State : Kerala District : WAYANAD Tahsil : MANANTHAVADY Block : MANANTHAVADY Village : Panamaram
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001635X + 4.011291
Post Monsoon Water Level Trend: Y = 0.001331X + 2.965056





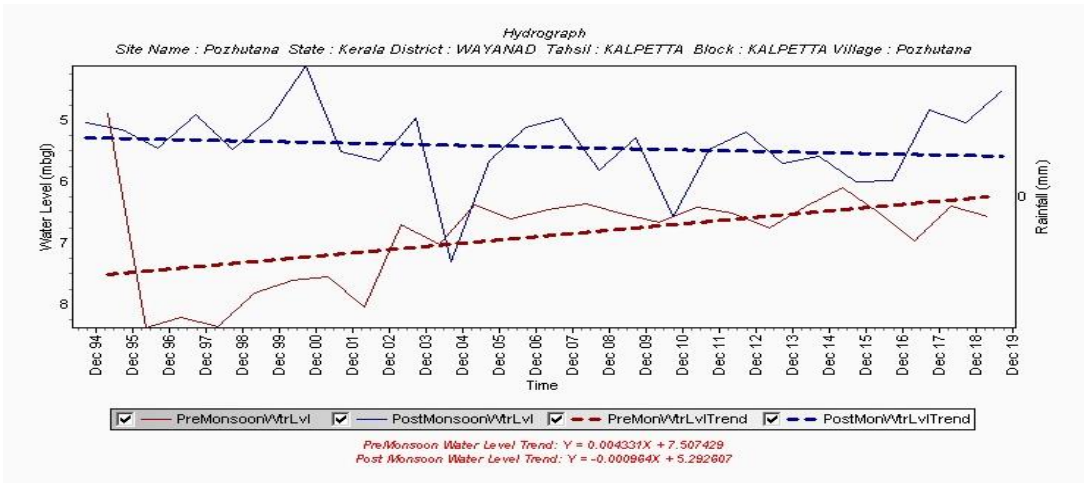


Fig.3.10 Hydrographs of selected wells tapping shallow aquifer

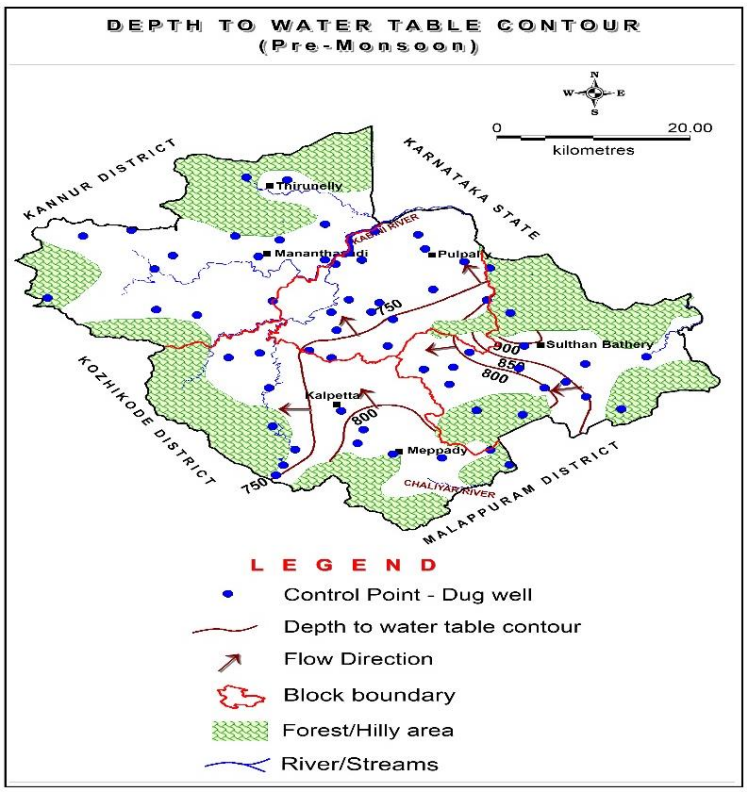


Fig.3.11 Water table elevation contour map of Phreatic aquifer (Pre monsoon)

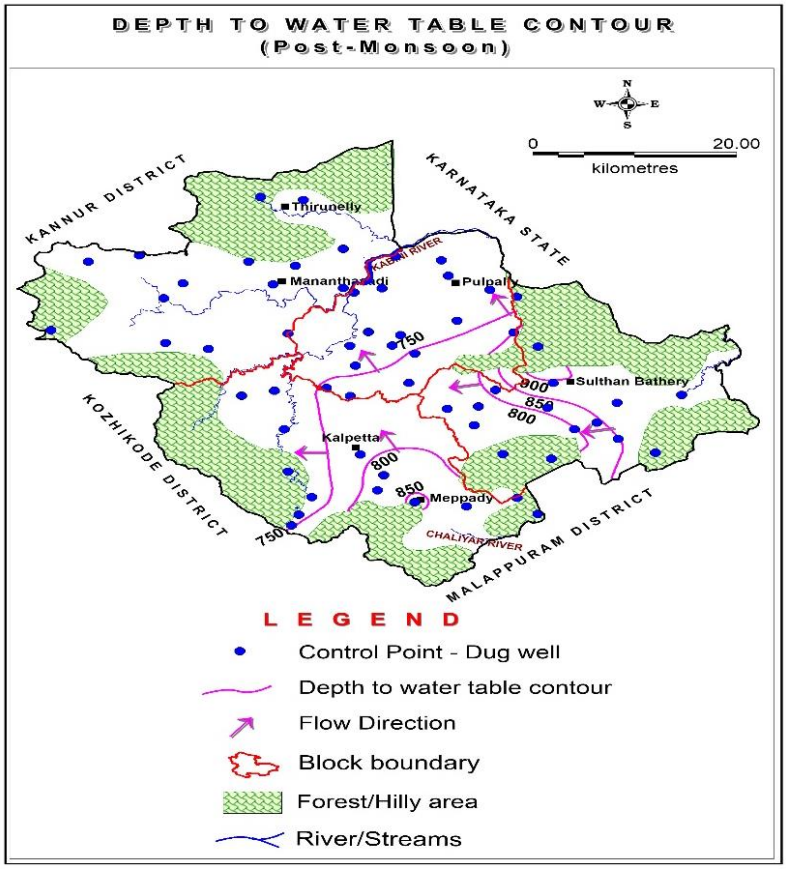


Fig.3.12 Water table elevation contour map of Phreatic aquifer (Post monsoon)

3.3.3. WATER LEVEL TREND

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 apparent from the trend of water levels over a period of time and is best reflected in a hydrograph. The decadal trend (2010-2019) of groundwater levels, for pre-monsoon and post-monsoon periods is given below in table 3.5. The analysis of pre-monsoon water level trend for the last decadal period (i.e during indicates that only 34 % of GWMWs have recorded negligible change in water level in the range of +0.05 to –0.05 m/year. The 32 % of monitoring wells have recorded declining trend in the range of 0.05 to 0.2 m/year and 12% of monitoring wells have recorded declining trend above 0.2 m/year.

16 % of monitoring wells have recorded rising trend in the range of 0.05 to 0.2 m/year and 6 % of monitoring wells have recorded rising trend above 0.2 m/year. Hence it is very clear that long-term ground water level trend shows a falling trend in major portions of the state represented by about 44 % of the total wells excluding the wells showing negligible change in water level

The analysis of post-monsoon water level trend for the last decadal period (i.e during 2010 - 2019) indicates that only 27% of GWMWs have recorded negligible change in water level in the range of +0.05 to –0.05 m/year. The 26 % of monitoring wells have recorded declining trend in the range of 0.05 to 0.2 m/year and 5 % of monitoring wells have recorded declining trend above 0.2 m/year. 24 % of monitoring wells have recorded rising trend in the range of 0.05 to 0.2 m/year and 18 % of monitoring wells have recorded rising trend above 0.2 m/year. Hence it is very clear that long-term ground water level trend shows a rising trend in major portions of the state represented by about 42 % of the total wells excluding the wells showing negligible change in water level.

Table.3.5 : Decadal Trend of water level (2010-19)

Premonsoon				**Postmonsoon**			
Location	**Data Points**	**Rise (m/year)**	**Fall (m/year)**	**Location**	**Data Points**	**Rise (m/year)**	**Fall (m/year)**
Ambalavayal	9	0.0946		Ambalavayal	9	0.0352	
Appapara	10		0.1379	Appapara	11	0.0194	
Begur	6		0.0970	Arimula	6		0.5571
Chenad	10		0.2431	Begur	6		0.0761
Cheyyambam	8		0.2323	Chenad	9	0.0916	
Dasanakkara	6		0.1398	Cheyyambam	11		0.0225
Kalpetta-R1	6		0.1975	Dasanakkara	6	0.2737	
Kamblakat	9	0.0260		Kamblakat	11	0.0644	
Kattikulam	10		0.1541	Kattikulam	10		0.1083
Kavumandam	9		0.0942	Kavumandam	11	0.0922	
Kellur -5th	8		0.5462	Kellur -5th	11	0.0416	

Premonsoon				Postmonsoon			
Location	**Data Points**	**Rise (m/year)**	**Fall (m/year)**	**Location**	**Data Points**	**Rise (m/year)**	**Fall (m/year)**
Mile				Mile			
Koliyadi	6	0.0801		Koliyadi	6	0.1693	
Koodal Ka-davu	6		0.0474	Koodal Ka-davu	6	0.2547	
Koroth	9	0.0858		Koroth	8	0.0057	
Kottathara	8	0.1783		Kottathara	10	0.2188	
Kuppadi(east)	6		0.2949	Krishnagiri	6		0.3828
Lakkidi	10	0.0420		Lakkidi	11	0.0619	
Mampayil	6	0.0367		Mampayil	6		0.1260
Manjapara	6	0.1255		Manjapara	6		0.0643
Mannanthody	9		0.0193	Mannanthody	11		0.0993
Meppady	10		0.0365	Meppady	8		0.1821
Minangadi	10	0.0073		Minangadi	11	0.1263	
Moolankavu	6		0.2139	Moolankavu	6		0.1063
Nadavayal	6		0.1919	Muthunga	6		0.5306
Naykatti	10		0.1288	Nadavayal	6	0.0403	
Nedugarana	6		0.0493	Naykatti	10		0.0506
Nenmeni Kun-nu	6	0.4654		Nedugarana	6	0.0447	
Noolpuzha (R1)	10		0.0656	Nenmeni Kun-nu	6	0.1072	
Padinjarattara	6	0.0657		Noolpuzha (R1)	11		0.0181
Panamaram	10		0.1220	Padinjarattara	6	0.7341	
Pattanikoopu	6		0.1207	Panamaram	11		0.0262
Perikallur	8		0.0898	Pattanikoopu	6		0.0359
Perya	10		0.0111	Perikallur	10	0.0698	
Pookode	7		0.0471	Perya	11	0.2500	
Poothady (Arimula)	6	0.0983		Pookode	7	0.0399	
Pozhutana	10	0.0004		Poothady (Arimula)	6	0.2058	
Pozhutana1	9		0.0242	Pozhutana	11	0.0820	
Pulpally	10		0.0045	Pozhutana1	7	0.4272	
Talapuzha	10		0.0624	Pulpally	11	0.0468	
Taruvana	10	0.3227		Punchvayal	6	0.1527	
Thirunelly	6	0.4380		Talapuzha	11	0.1058	
Ullissery(w)	8	0.0382		Taruvana	11	0.3344	
Vaduvanchal	10		0.0528	Thirunelly	6	0.4173	

Premonsoon				Postmonsoon			
Location	**Data Points**	**Rise (m/year)**	**Fall (m/year)**	**Location**	**Data Points**	**Rise (m/year)**	**Fall (m/year)**
Valad	6		0.1435	Ullissery(w)	6	0.1682	
Vallathur	6		0.1744	Vaduvanchal	11	0.0159	
Valliyur-kavu(e)	9	0.0269		Valad	7	0.3986	
Valliyur-kavu(w)	8	0.0267		Vallathur	6	0.1101	
Varayal	6		0.0679	Valliyur-kavu(e)	10		0.1204
Vellamunda	7		0.7452	Valliyur-kavu(w)	10		0.1103
Vyittiri	10	0.0885		Varayal	6		0.1871
				Vellamunda	11		0.1159
				Vengapalli	6		0.1853
				Vyittiri	11		0.0140

3.3.4 DEEPER FRACTURE AQUIFER SYSTEM (AQUIFER II)

In hard rock area the ground water is purely the interplay of fracture zones and lineaments which is resultant of structural deformations.(see fig.1.1). The disposition of the deeper fracture aquifer system can be inferred through integrated study using the geology and exploration data in the form of various lithologs. A total of 17 bore wells have been drilled in the hard rock area, tapping fractured crystallines. The exploratory data analysis indicate that deep seated fractured rock occurs in the form of vertical to sub vertical narrow linear zones and horizontal zones of varying thickness within the massive rocks. The depth of the wells ranges from 60 to 200 m bgl. The depth of the fractures ranges from 16 to 199 m and the discharge ranges from 0.33 to 11 lps and these bore wells were located along NW-SE, NNE-SSW, NS and EW lineaments. It has been observed that wells falling along E-SW and E-W lineaments have got relatively higher discharges when compared to others. In addition to exploratory wells, 09 piezometers are drilled during Hydrology Project in the depth range of 30 to 40 m with the purpose of monitoring.

Out of 17 wells drilled, 11 wells are tapping Granite gneisses where depth of occurrence of fracture zones limited to 170 m. Maximum no of fractures (45%) are encountered in the depth ranges of 0-50m which is followed by 50-100 (20%) and only limited fracture zones (15%) are available in the depth range of 150-200 m. In case of remaining 11 wells tapping Charnockites, potential fracture zones are in 0-50m (45%) and 100-150m (30%), Deeper fracture zones (199 m) are encountered in Charnokite rocks whereas maximum yield (11 lps) is recorded in Granite Gneiss rocks.

The information on weathered thickness and fracture zones from exploratory wells have been used for the preparation of various diagrams like fence, 3D model etc. to represent the sub-surface aquifer disposition of the area. The cross sections of the sub surface aquifer disposition prepared from the lithologs of EWs drilled by CGWB is shown in fig. 3.13 and fence diagram of the area is shown in fig. 3.14. Only 30 % of the wells drilled in the hard rock area yielded discharge more than 3 lps (180 lpm). Groundwater in the deeper fractured aquifer system exists under semi-confined to confined state and the depth to water level ranges from 0.3 to 10.95 mbgl.

3.3.5 GROUNDWATER POTENTIAL AND GEOLOGICAL STRUCTURES

It is well known fact that in hard rock area the structural features like fractures, joints and lineaments are guiding the movement of ground water . These features can be observed in the field (toposheets)or identify using satellite data by analysing the tonal differences with respect to other terrain surfaces. Lineaments are linear or curvilinear surface manifestations of structurally controlled features, such as joints, the straight course of streams/rivers and vegetation cover and being weak zones, it serve as conduits for movement or accumulation of groundwater in the subsurface. Hence lineament analysis of an area when extracted from the remotely sensed data give important information on subsurface features to assess the ground water potential.

Baveli shear zone is the major lineament in Wayanad district having NW-SE trend Other lineaments are parallel to this main one. Other minor lineaments are identified and are aligned to NNE-SSW, NS and EW The rose diagram of the lineaments is shown in the Fig. 3.15. The highest yield is encountered at Tholpetty area which rest on a lineament .

The yield of the boreholes had a direct bearing on the tectonic history and the rock types. The yield from bore wells varies in the area. Within the same geological formation, the spatial variation in yield is very common in hard rocks. The comparative study of the yield of the wells

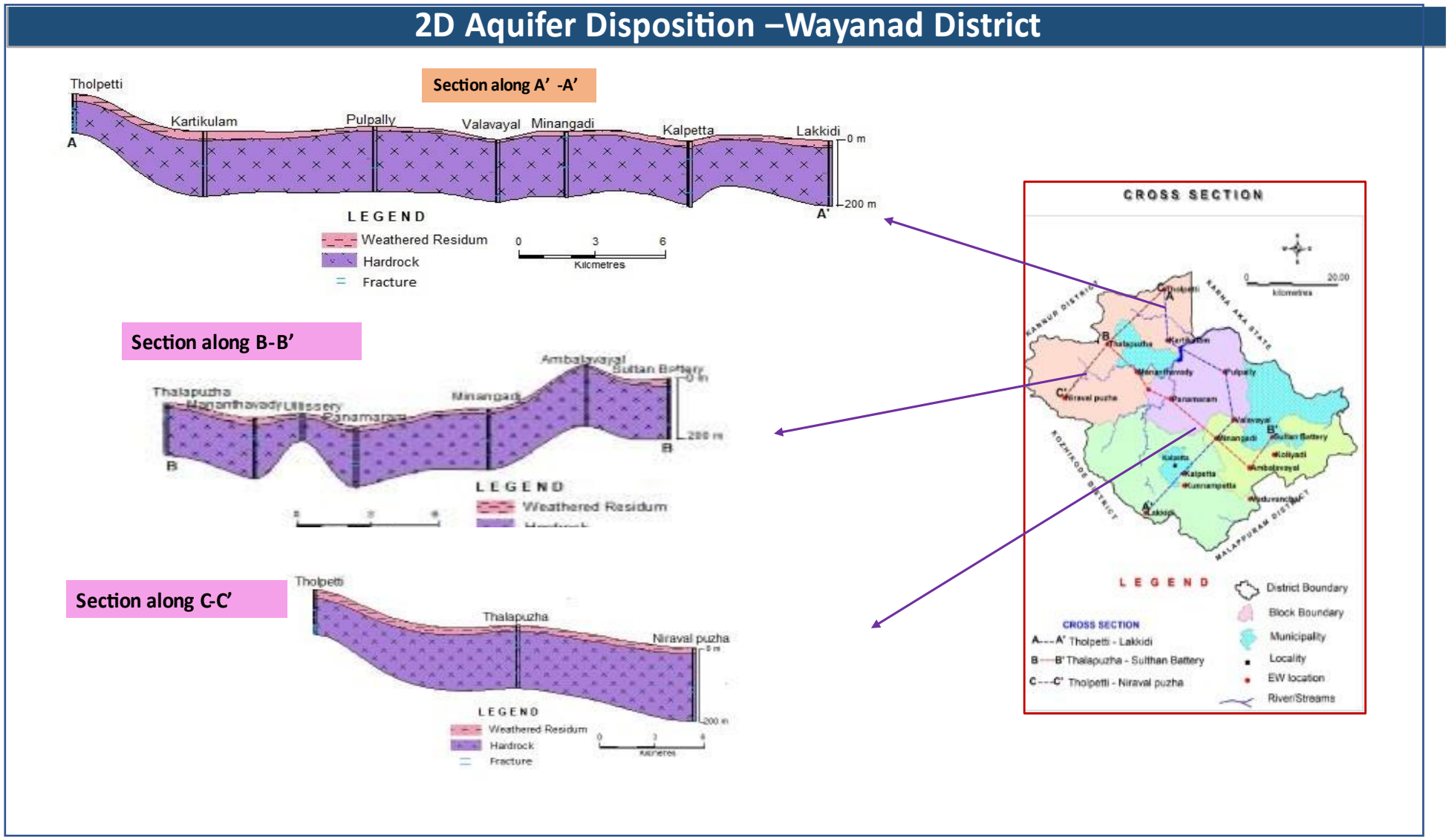


Fig.3.13: Cross section along different directions

3D Aquifer Disposition –Wayanad District

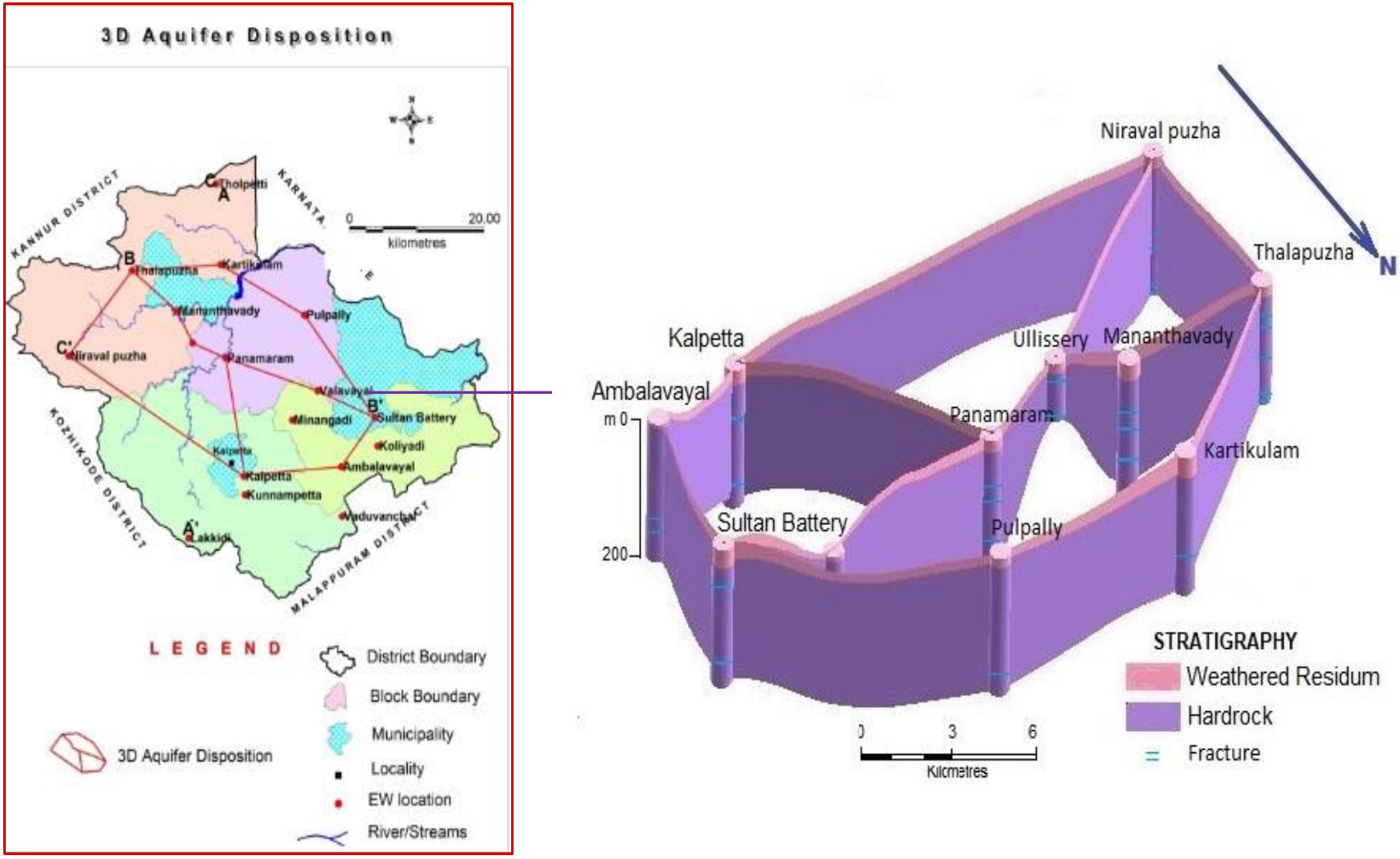


Fig.3.14: Fence diagram showing the disposition of Aquifer system

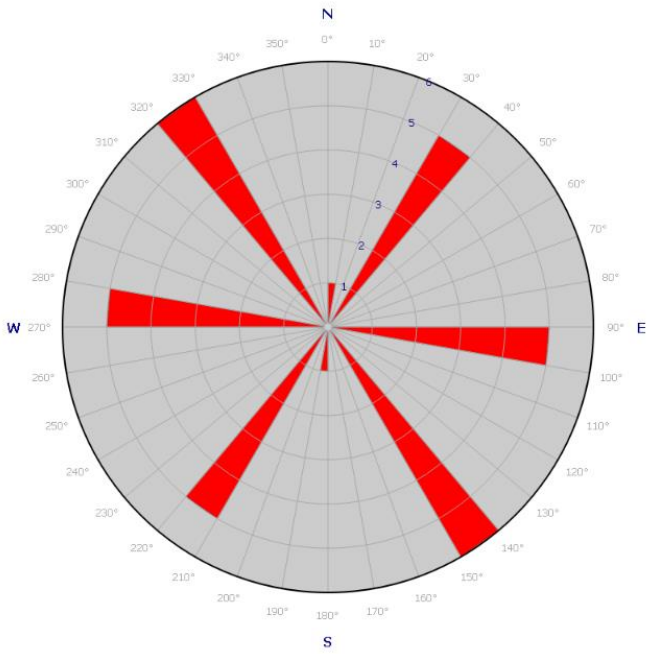


Fig.3.15 Rose diagram showing lineament trend

with lineaments indicates that the NNE-SSW and NNW-SSE lineaments are relatively more potential. The number of wells having varying yield ranges and details of high yielding wells and lineaments are given in Table.3.6. The relationship of the high yielding wells with lineament direction in the study area is given in table 3.7.

Table. 3.6 Frequency of bore wells in different yield ranges

Yield of EW	**No of wells**	**%**
Up to 1 lps	7	41
Betwenn to 3 lps	4	24
>3 lpw	6	35
Total	17	

Table.3.7 Details of high yielding wells and lineament

Sl No	Location of EW	Block	Yield (lps)	Geology	Lineament
1	Tholpetty	Mananthavady	11	Granite Gneiss	E_W
2	Mananthavady	Mananthavady	10.17	Hornblende Gneiss	E-SW
3	Valavayal	Sulthan Bathery	8	Granite Gneiss	NE-SE
4	Kunnampetta	Kalpetta	6	Hornblende Gneiss	NNW-SSE

3.4 SOIL INFILTRATION STUDIES

The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 11 mm/hour means that a water layer of 11 mm on the soil surface, will take one hour to infiltrate.

In dry soil, water infiltrates rapidly. This is called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate. This is called the basic infiltration rate (Table 3.8).

Table.3.8 Basic Infiltration rate of soil

Soil Type	Basic Infiltration rate (mm/hr)
Sand	<30
Sandy loam	20-30
Loam	10-20
Clay loam	5-10
Clay	1-5

The infiltration rate depends on soil texture (the size of the soil particles) and soil structure (the arrangement of the soil particles and is a useful way of categorizing soils from an irrigation point of view . The most common method to measure the infiltration rate is by a field test using a cylinder or ring infiltrometer. The measurement of the water volume is done on the inner ring only. The experiment is carried out till a constant infiltration rate is obtained. Based on the steady state infiltration capacity, soils can be divided into four categories (K. Subramanya, 2015) and is detailed in table 3.9 below

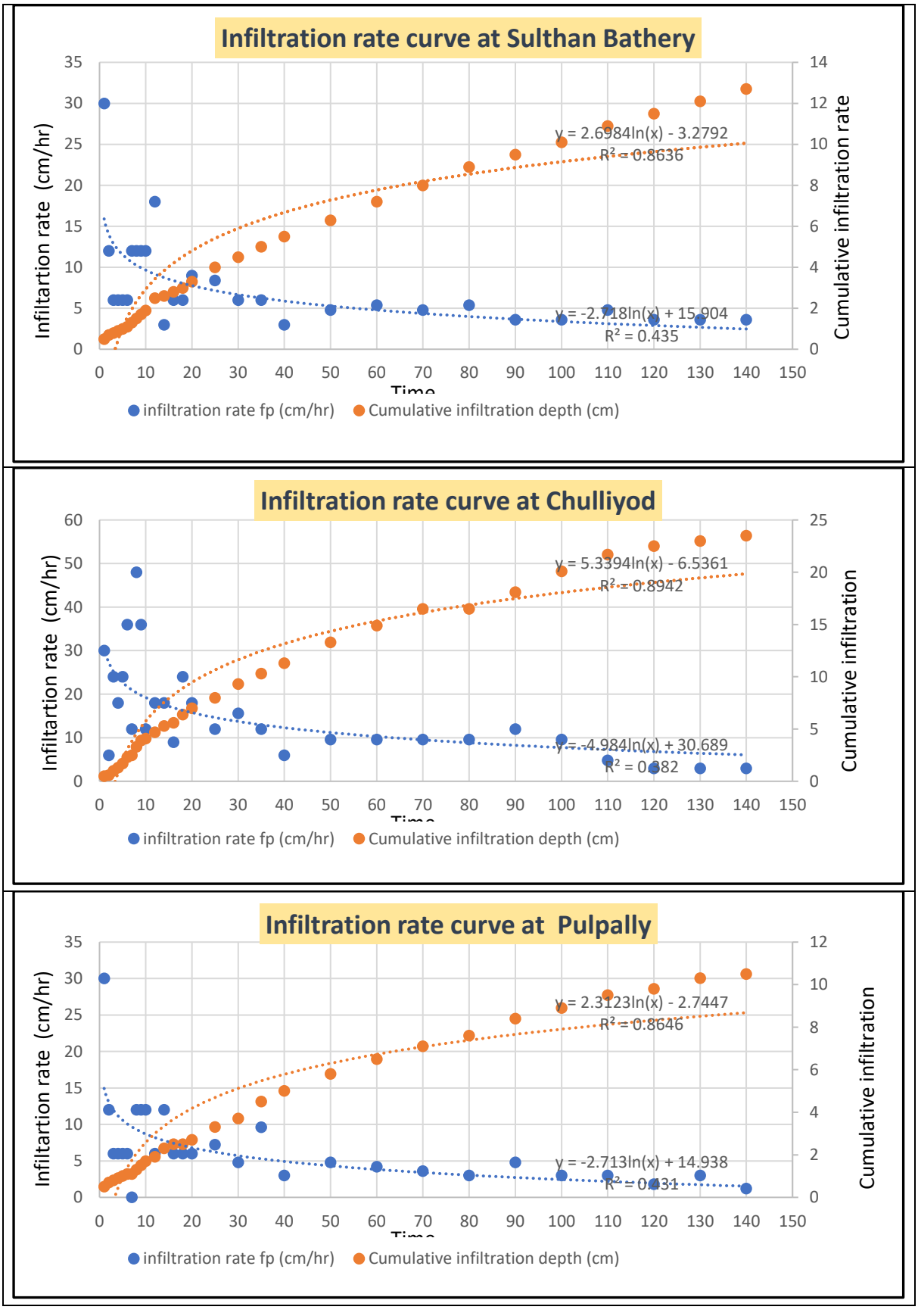
Table.3.9 Classification of Infiltration capacities

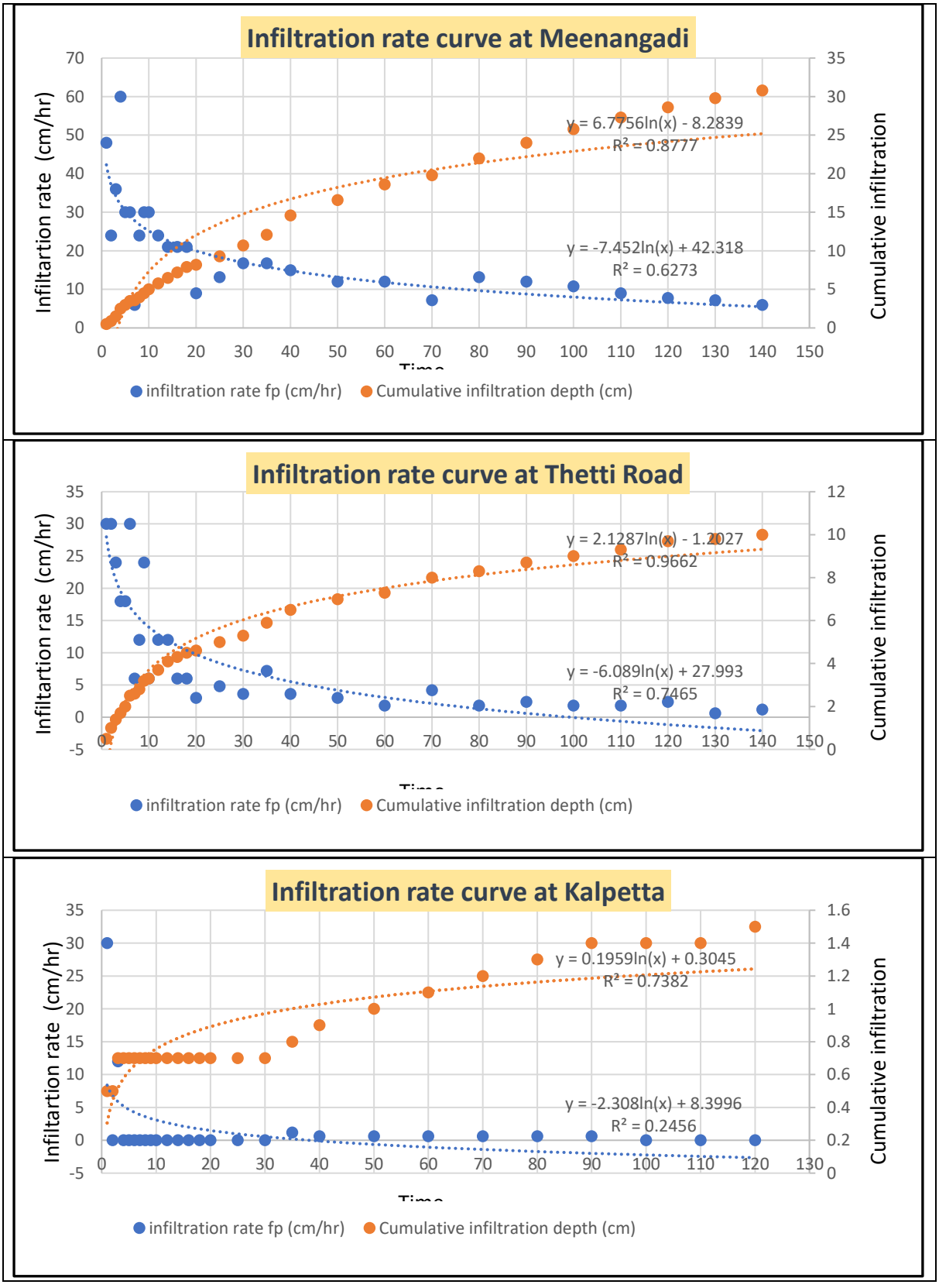
Infiltration rate	Infiltration capacity (mm/hr)	Soil description
Very low	<2.5	Highly clayey soils
Low	2.5-12.5	Shallow soils, Clay soils, Soils low in organic matter
Medium	12.5-25	Sandy loam and silt
High	>25	Deep sand , well drained aggregated soil

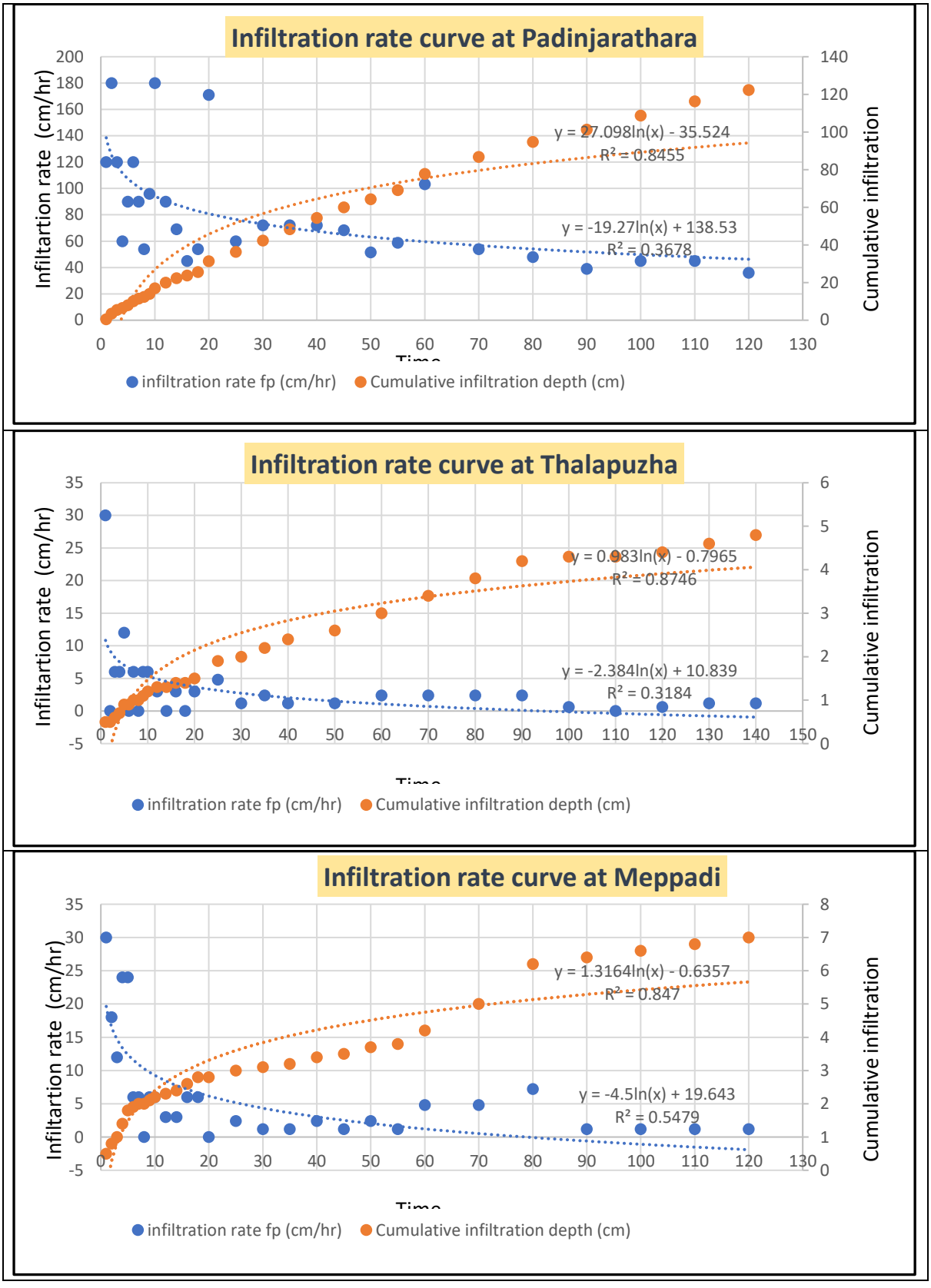
In the present study 10 soil infiltration tests were carried out in various parts of district dueing the month of March,2021.The summarized outcomes of the tests are given in table 3.10. The curves of Infiltration and cumulative depth of infiltration versus time in minutes are given in fig.3.13.

Table.3.10 Location wise summarised results of Soil Infiltration tests

Sl No	Location	Details	Block	Date	Soil type	Duration (mts)	Cumulative depth of infiltration (cm)	Final Infiltration rate (mm/hr)
1	Sulthan Bathery	Sarvajana High School	Sulthan Bathery	11/03/2021	Clay Sand	140	12.7	0.36
2	Chulliyod	Parking area of Safas Grand Party Hall	Sulthan Bathery	11/03/2021	Sandy loam	140	24	0.3
3	Pulpally	SNDP Yogam Br	Panamaram	12/03/2021	Partially compacted sand	170	12	0.3
4	Thetty Road	Forest Quarters	Mananthavady	12/03/2021	Clay loam	140	10	0.12
5	Meenangadi	Muhammed Salim, Edayakkaparambil house	Sulthan Bathery	13/03/2021	Red Lateritic soil	170	32.8	0.6
6	Kalpetta	Saraladevi memorial LP School	Kalpetta	13/03/2021	Clay loam	120	1.6	0.06
7	Padinjarathara	Govt Higher Sec School	Kalpetta	14/03/2021	Gravel sand compacted	140	134.3	3.6
8	Thalapuzha	CK Beeran,Chirayangad House	Mananthavady	14/03/2021	Clay loam	160	4.8	0.12
9	Meppady	Arrapetta Estate Staff club	Sulthan Bathery	15/03/2021	Clay loam	120	5.4	0.12
10	Vythiri (Lakkidi)	Govt LP School	Kalpetta	15/03/2021	Clay loam	130	13.9	0.12


Infiltration rate curve at Sulthan Bathery
Infiltartion rate (cm/hr)
Cumulative infiltration rate
y = 2.6984ln(x) - 3.2792
R² = 0.8636
y = -2.718ln(x) + 15.904
R² = 0.435
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)
Infiltration rate curve at Chulliyod
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 5.3394ln(x) - 6.5361
R² = 0.8942
y = -4.984ln(x) + 30.689
R² = 0.682
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)
Infiltration rate curve at Pulpally
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 2.3123ln(x) - 2.7447
R² = 0.8646
y = -2.713ln(x) + 14.938
R² = 0.431
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)


Infiltration rate curve at Meenangadi
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 6.7756ln(x) - 8.2839
R² = 0.8777
y = -7.452ln(x) + 42.318
R² = 0.6273
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)
Infiltration rate curve at Thetti Road
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 2.1287ln(x) - 1.2027
R² = 0.9662
y = -6.089ln(x) + 27.993
R² = 0.7465
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)
Infiltration rate curve at Kalpetta
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 0.1959ln(x) + 0.3045
R² = 0.7382
y = -2.308ln(x) + 8.3996
R² = 0.2456
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)


Infiltration rate curve at Padinjarathara
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 27.098ln(x) - 35.524
R² = 0.8455
y = -19.27ln(x) + 138.53
R² = 0.3678
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)
Infiltration rate curve at Thalapuzha
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 0.983ln(x) - 0.7965
R² = 0.8746
y = -2.384ln(x) + 10.839
R² = 0.3184
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)
Infiltration rate curve at Meppadi
Infiltartion rate (cm/hr)
Cumulative infiltration
y = 1.3164ln(x) - 0.6357
R² = 0.847
y = -4.5ln(x) + 19.643
R² = 0.5479
Time
infiltration rate fp (cm/hr)
Cumulative infiltration depth (cm)

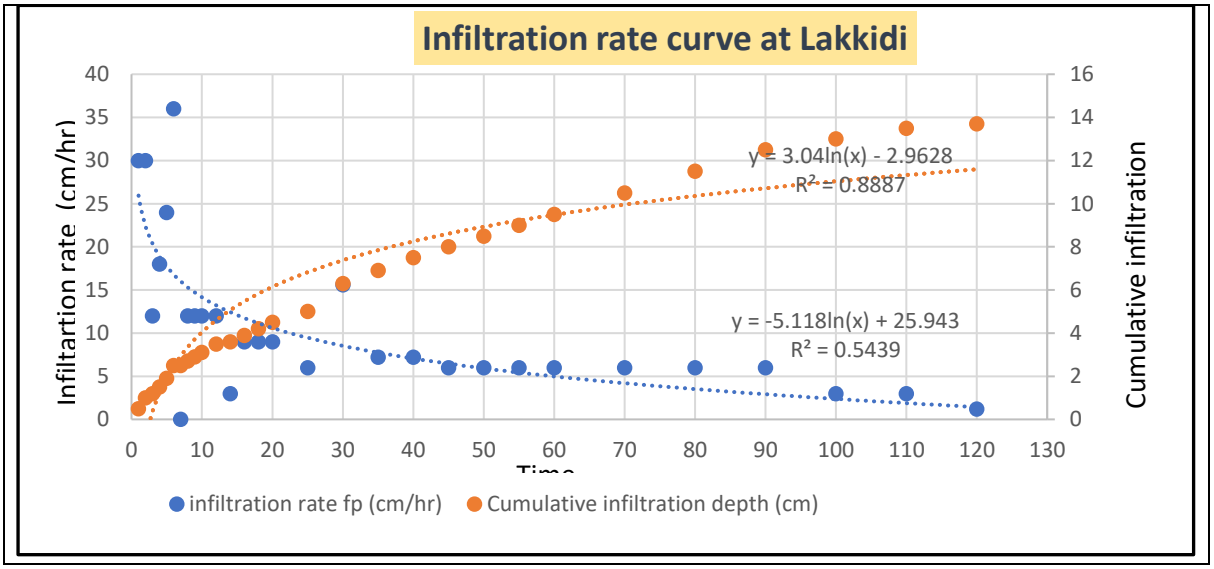


Fig.3.16 Curves of infiltration and cumulative depth of infiltration of different locations

The detailed analysis of soil infiltration test data indicate that the soil infiltration rate varies from 0.12mm /hr to 3.6 mm/hr. The total cumulative depth of infiltration varies from 4.8 cm to 134.3cm. It is observed that the infiltration capacities in the study area falls in class of highly clayey soils which have very low high infiltration capacities in mm/hr. Relatively higher infiltration rate (3.6 mm/hr) is encountered at Padinjarathara where the soil is clay mixed one.

3.5 CHEMICAL QUALITY OF GROUND WATER

The chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc.The movement of percolating water through larger pores is much more rapid than through the finer pores. The overall effect of all these factors is that the composition of ground water varies from time to time and from place to place.

Unconfined aquifers are extensively tapped for drinking purpose and therefore, its quality is of paramount importance. The chemical parameters like TDS, Chloride, Fluoride, Iron, Arsenic and Nitrate etc are main constituents defining the quality of ground water in unconfined aquifers. Therefore, presence of these parameters in ground water beyond the permissible limit in the absence of alternate source has been considered as ground water quality hotspots.

Maps depicting distribution of electrical conductance (salinity) and chloride are regional in nature and have contours, whereas fluoride, iron, & nitrate are depicted as hot spots/ locations having concentrations exceeding the permissible limit prescribed by Bureau of Indian Standards for drinking water

The water samples collected from the monitoring wells tapping phreatic aquifer were analysed. The chemical data indicate that the pH ranges between 6.98 and 8.56 indicating that at places it is slightly acidic and some places indicating the water is alkaline. EC values ranges

between 73 to 760 µs /cm at 25^0C. Highest EC value is observed in Pulpally area. All other parameters fall under the permissible limit except Nitrate, Iron and Manganese which are observed in specific locations. In General, the water from all the dug wells are suitable for domestic and agricultural uses. The chemical quality of phreatic aquifers is presented in Fig. 3.17 and in table 3.11

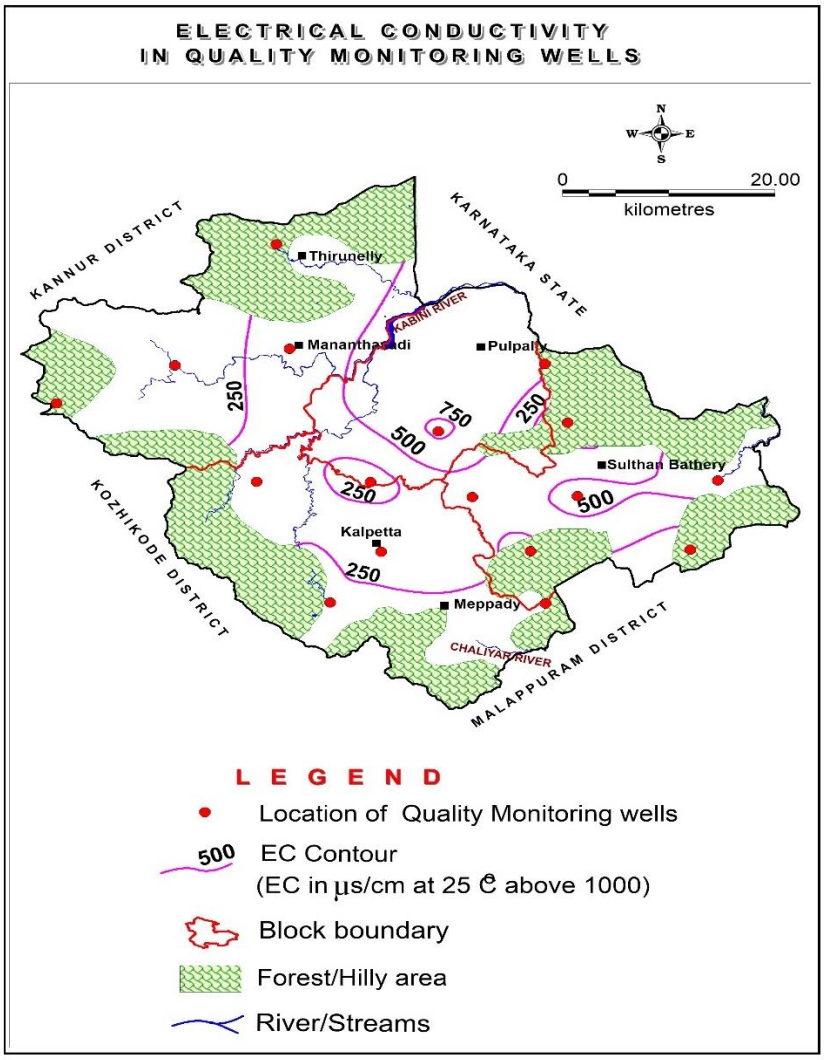


Fig.3.17 Distribution of Electrical conductivity

Table.3.11 Ground Water quality of Phreatic Aquifers

Sl. No	Location	pH	EC in µs/cm at 25^{0}C	TH as $CaCO_3$	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
				<----------Conc. In mg/L---------->										
1	Ambalavayal	7.23	220	34	10	1.9	17	1.4	0	27	3.2	26	0.25	23
2	Chenad	7.05	159	46	12	3.9	14	1.2	0	63	0	16	0.19	12
3	Kalpetta	7.36	410	110	33	6.8	37	16	0	189	21	30	0.52	17
4	Kamblakat	7.26	200	46	11	4.4	17	1.5	0	54	0	13	0.24	40
5	Koroth	7.27	89	20	6.4	0.97	4.7	1.3	0	27	0	8.5	0.12	5
6	Mananthody	7.43	390	114	31	8.8	32	14	0	140	30	34	0.03	41
7	Minangadi	8.52	360	84	24	5.8	29	1.7	30	43	15	28	0	24
8	Muthanga	7.55	570	185	54	12	63	2.8	0	262	15	71	0	2.9
9	Noolpuzha	7.57	172	56	9.6	7.8	17	2.1	0	110	1.5	8.5	0	0.49
10	Padinjarattara	7.17	300	66	18	5.4	25	1.5	0	37	7.7	27	0	64
11	Perikallur	7.6	540	155	38	15	60	1.6	0	195	16	68	0	29
12	Pulpally(new well)	7.67	760	285	52	38	72	1.6	0	336	36	92	0	10
13	Sulthan Bath-ery	7.71	550	125	28	13	61	2.9	0	171	38	57	0	13
14	Tirunelly	7.6	270	80	26	3.9	18	2	0	134	3.2	9.9	0	4.3
15	Vaduvanchal	7.46	230	56	16	3.9	10	5	0	44	0.23	21	0	41
16	Valatt	7.43	73	16	5.6	0.49	6	0.4	0	27	1.7	5.7	0	2.3
17	Vyttiri	-	159	34	8.8	2.9	13	4.1	-	-	1.8	17	0.23	8.9

3.5.1HYDROCHEMICAL FACIES

Piper plots (also known as Trilinear diagrams) are very powerful tool for visualizing the relative abundance of common ions in water samples. Although there are other plot types that can show abundance of ions in groundwater, this plot type is especially useful because it allows you to plot multiple samples on the same plot, thus allowing for grouping water samples by groundwater facies and other criteria.

The Piper plot of the all 17 samples indicate that the most of water samples are falling in Calcium Bicarbonate type of water in the phreatic zone as shown in Fig.3.18.The Alkaline earth metals (ca+Mg) have dominance over Alkali metals (Na +K) in 80% samples. Samples collected from southern part of the district such as Chenad, Ambalavayal, Minangadi , Kalpetta and Sulthan Bathery falls in the Calcium rich and sodium +potassium less water quality.

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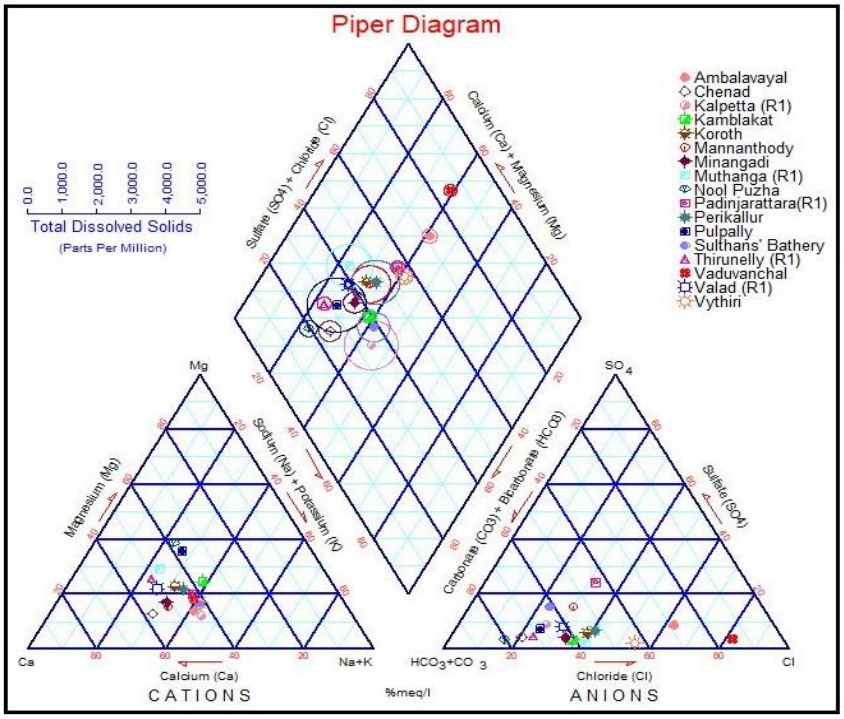

Fig.3.18 Hill-Piper diagram showing Geochemical Classification of phreatic aquifer

Two parameters commonly used for judging suitability for irrigation are salinity and sodium. Salinity is reflected in EC and sodium hazard is reflected in Sodium Absorption Ratio (SAR). The Sodium Absorption Ratio (SAR) of 17 representative samples have been worked out using the equation

$$SAR = Na / \sqrt{(Ca+Mg)/2}$$

The SAR values are plotted and shown in the Fig.13.19. It indicate that 41 % of all samples are confined to low salinity hazard and sodium hazard whereas major fraction of samples (53%) are showing medium salinity and sodium hazard indicating that the ground water of phreatic aquifer is good for irrigation. Only one sample is of high salinity hazard.

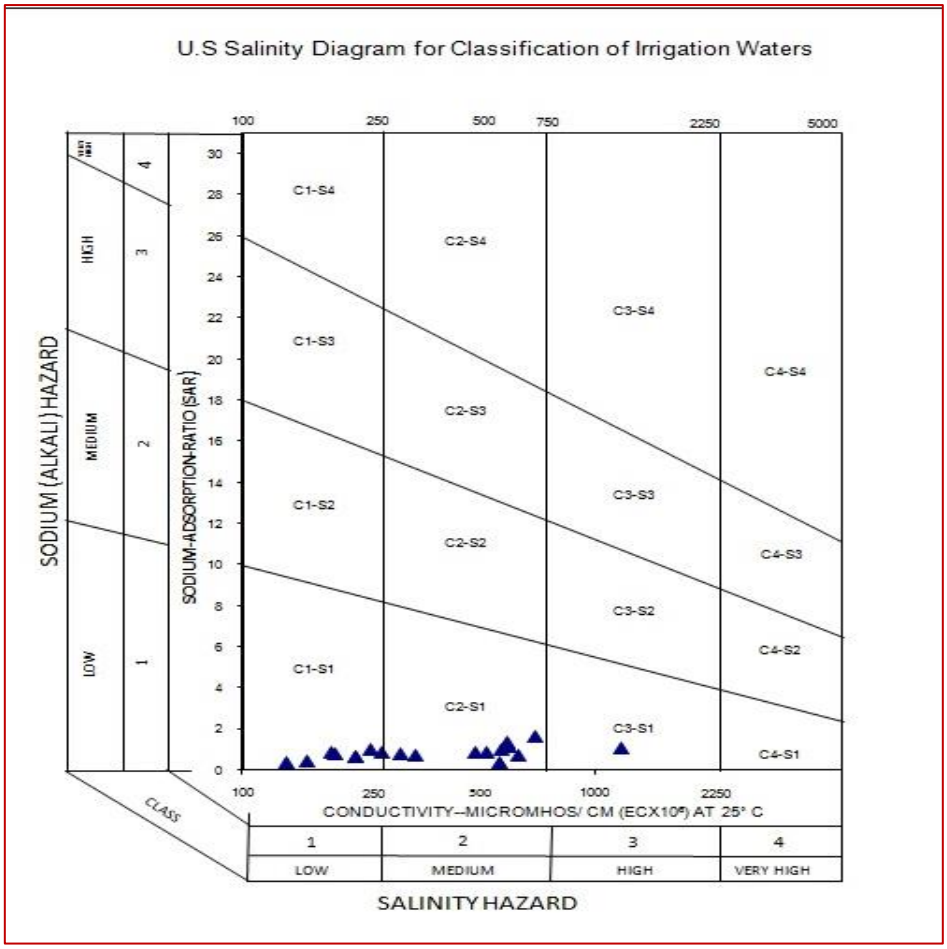

Fig.3.19 Salinity diagram of Phreatic aquifer

3.6 AQUIFER MAP

The ultimate aim of doing aquifer mapping exercise is to prepare aquifer maps depicting all information which is useful to design management plans for the administrators and experts. An aquifer map of the area is evolved out of various studies on aquifer geometry, aquifer characteristics and water resources in the aquifer systems, yield characteristics and water quality described in the previous paragraphs. The aquifer map of the phreatic (weathered zone) and fracture aquifer systems are shown in fig. 3.20 and 3.21 where integration of different data has been attempted.

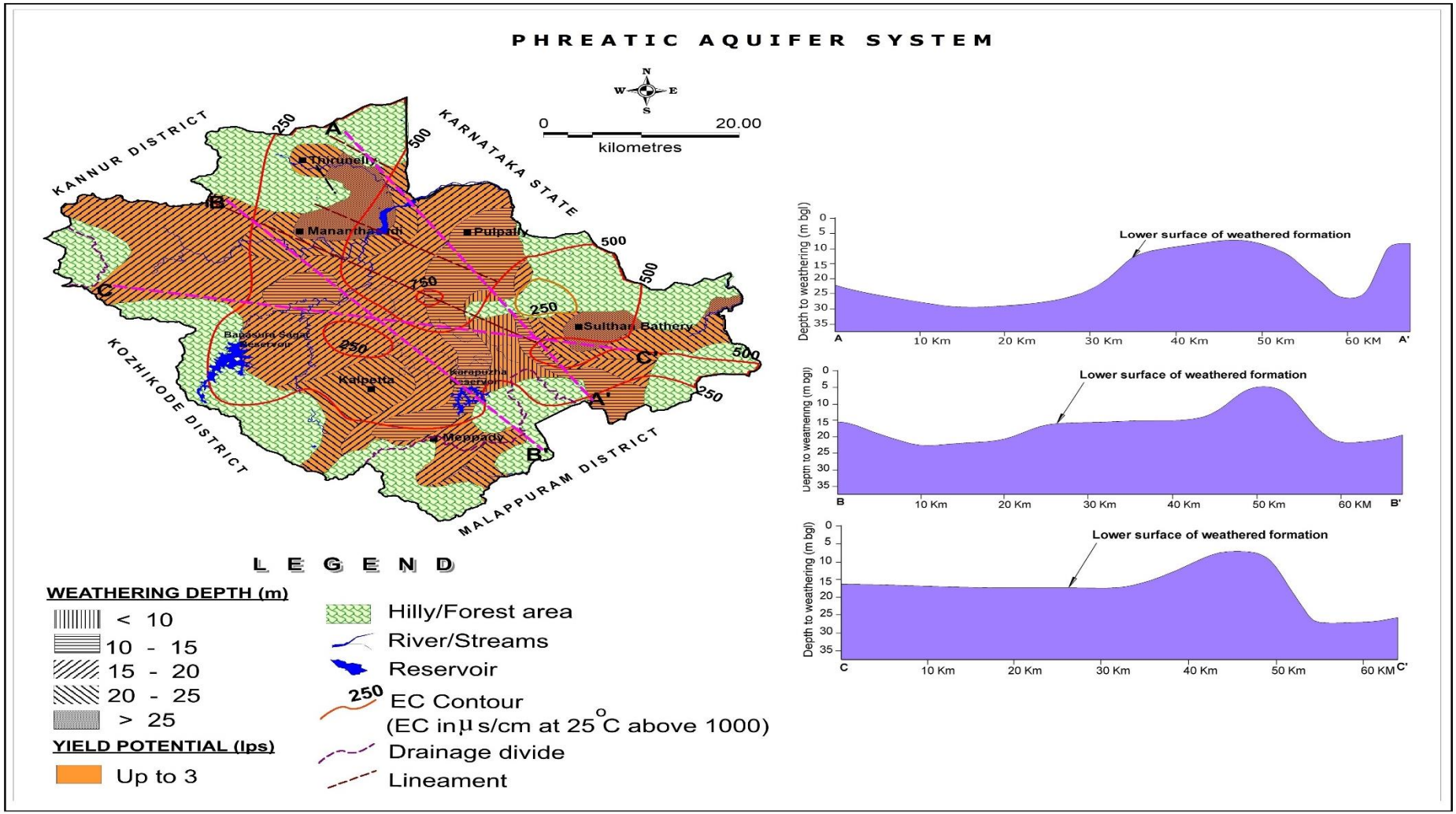

Fig.3.20 Aquifer map of Phreatic aquifer system

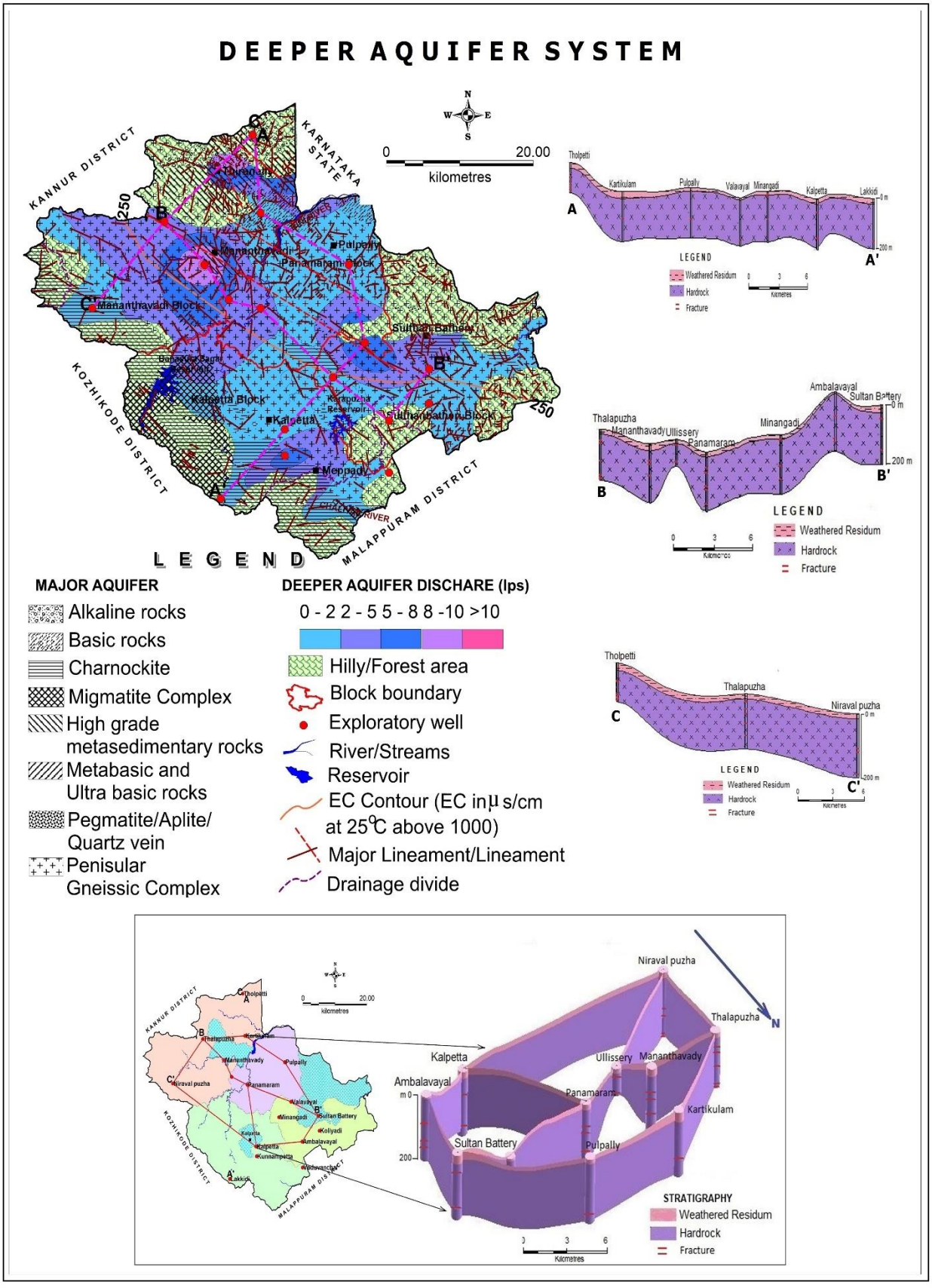

Fig 3.21 Aquifer map of Deeper Aquifer system

4 GROUND WATER RESOURCES

The quantification of ground water resources is important to assess the availability and trend of utilization pattern existing in an area to design and implement ground water management strategies. The availability of ground water is dependent on various factors like rainfall, topography, geomorphological feature, geological set up and hydrogeological conditions reflected through water level etc. Rainfall is the major source of recharge for groundwater. Increasing population, rapid urbanization and changes in cropping pattern, conversion of agriculture land into cash crops etc has resulted in increasing use of ground water resources in the district. Recharge, draft and the balance of resources left are to be kept in mind while considering the management plans .Judicious and planned development of ground water and its scientific management have become necessary to ensure long-term sustainability of this precious natural resource.

4.1 DYNAMIC GROUNDWATER RESOURCES IN THE WEATHERED ZONE

Phreatic aquifers are the major source of groundwater in Wayanad district. 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 irrigation purposes. It is observed that some areas especially areas adjoining Karnataka State such as Mullankolly, Pulpally,Kappiset areas experience shortage of ground water during summer months ,due to topographic characteristics coupled with the unscientific development of ground water.

The groundwater resources in the area are estimated based on the Groundwater Estimation Methodology (GEC) 2015. The administrative blocks are the basic unit for groundwater assessment. The area under command and non-command could not be separated mainly due to non-availability of data pertains to canal command areas exist in the district. The irrigation projects such as Banasura Sagar and Karapuzha dam are mostly planned for irrigating paddy cultivation along the topographic lows and as such the areas outside the influence of canal system do not get benefits of surface water irrigation from these projects. Due to paucity of the data pertaining to command and non-command area for the whole district, the entire area is considered as non-command area for computations. The block wise groundwater resources in the area is calculated for both phreatic (Aquifer-1) and deeper fractured aquifer system (Aquifer-II). The storage parameter values used in the estimation for phreatic aquifer vary from 0.003 to 0.08, whereas as for the deeper fractured aquifer, it varies from 0.0015 to 0.002. 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 recharge to groundwater has been computed based on specific yield and water table fluctuations of different geological units available in the district. The water level fluctuation data was calculated from the ground water monitoring wells of CGWB. The specific yield values used for the recharge calculation is as shown in table in 4.1.

Table 4.1 Specific Yield values of different hydrogeological units (GEC-2015)

Sl.No.	Hydrogeological unit	Specific yield (%)
1	Sandy alluvial area	12-18
2	Valley fills	10-14
3	Silty/clayey alluvial area	5-12
4	Granites	0.2-2
5	Laterite	2-5
6	Weathered Granites & Gneisses	1-4
7	Massive/poorly fractured rocks	0.2-0.5

The method adopted for computation of rainfall recharge during monsoon season depends on the Percentage Departure (PD), which is the difference between the recharge computed using Water Table Fluctuation (WTF) method and Rainfall Infiltration Factor (RIF) methods, expressed as a percent of recharge computed by the latter method. In cases where PD is between +20 and -20, monsoon rainfall recharge computed by Water Table Fluctuation Method is used, whereas in other cases, recharge computed by Rainfall Infiltration Method is used.

The recharge thus calculated were checked with Rainfall Infiltration Factor (RIF) method and if the difference between RIF and Water Table Fluctuation (WTF) exist between +20 and -20, monsoon rainfall recharge computed by Water Table Fluctuation Method is used, whereas in other cases, recharge computed by Rainfall Infiltration Method is used.

As per GEC-2015, per-capita requirement of 150 Litre/ day has been assumed for domestic uses in the State. Due to 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 per-capita water requirement. The fractional load of this requirement is computed on the basis of the extent of surface water supply available for domestic use (25 to 100%) in the assessment unit. Irrigation draft has been calculated by multiplying the number of irrigation wells in each assessment unit with the corresponding unit draft. For energized dug wells it is 0.3 to 0.54 ha.m and for non-energized dug wells it is 0.06 to 0.12 ha.m .

The Total Annual Groundwater Resource availability has been worked out as 231.6 Million Cubic Metre (MCM) whereas the gross groundwater extraction is 56.8 MCM only and have a sufficient a balance of 174.8 MCM for future ground water development. Draft for Irrigation activity is highest in Sulthan Bathery block (5.67 MCM) whereas draft for domestic and industrial activites is highest in Kalpetta block (11.3 MCM) owing to the fact that Kalpetta is highly urbanised as compared to other municipalities in the district. The average stage of ground water extraction is 25.42%. Minimum stage of development is encountered in Mananthavadi block (22%) and maximum stage of development observed in Panamaram block (33.2 %). Panamaram block has lowest net ground water availability (38.08 MCM) indicate sufficient scope for augmentation of ground water All blocks are coming under safe category. The block wise ground water resources estimated for the area is given in Table 4.2 and Fig.4.1.District wise scenario is presented in Fig.4.2 and 4.3.

Table 4.2 Dynamic Ground Water Resources estimated of Wayanad District (Phreatic aquifer) as on 31st March 2017

Sl. No.	**Assessment Unit/ District**	**Area**	**Net Annual Ground Water Availability (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 (4-5-8)**	**Stage of Ground Water Extraction {(7/4) * 100} (%)**	**Category**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Kalpetta	58770	6653.8	342.3	1130.5	1472.9	1128.7	5182.8	22.1	Safe
2	Mananthavady	66660	6638.9	408.1	1052.3	1460.5	1045.3	5185.5	22.0	Safe
3	Panamaram	35130	3808.3	348.0	914.7	1262.7	883.1	2577.1	33.2	Safe
4	Sulthanbathery	52540	6062.1	567.0	914.7	1481.6	883.1	4612.0	24.4	Safe
	TOTAL (ha.m)	**213100**	**23163.1**	**1665.5**	**4012.1**	**5677.6**	**3940.2**	**17557.5**	**Avg:25.42**	Safe
	Total (mcm)	**2131**	**231.6**	**16.7**	**40.1**	**56.8**	**39.4**	**175.6**	**Avg:25.42**	

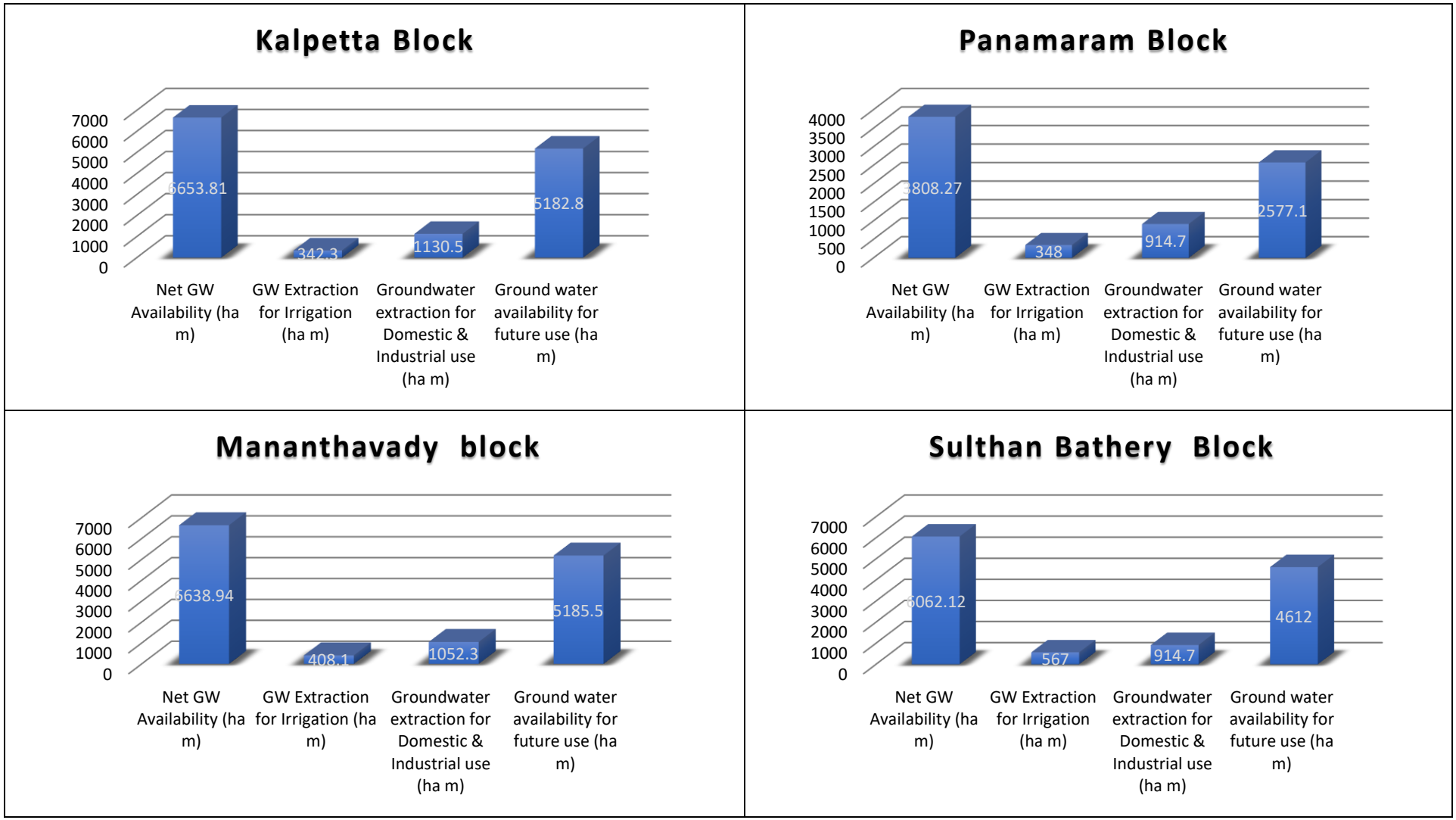

Fig. 4.1 Block wise groundwater resources in Wayanad District as on 31st March 2017

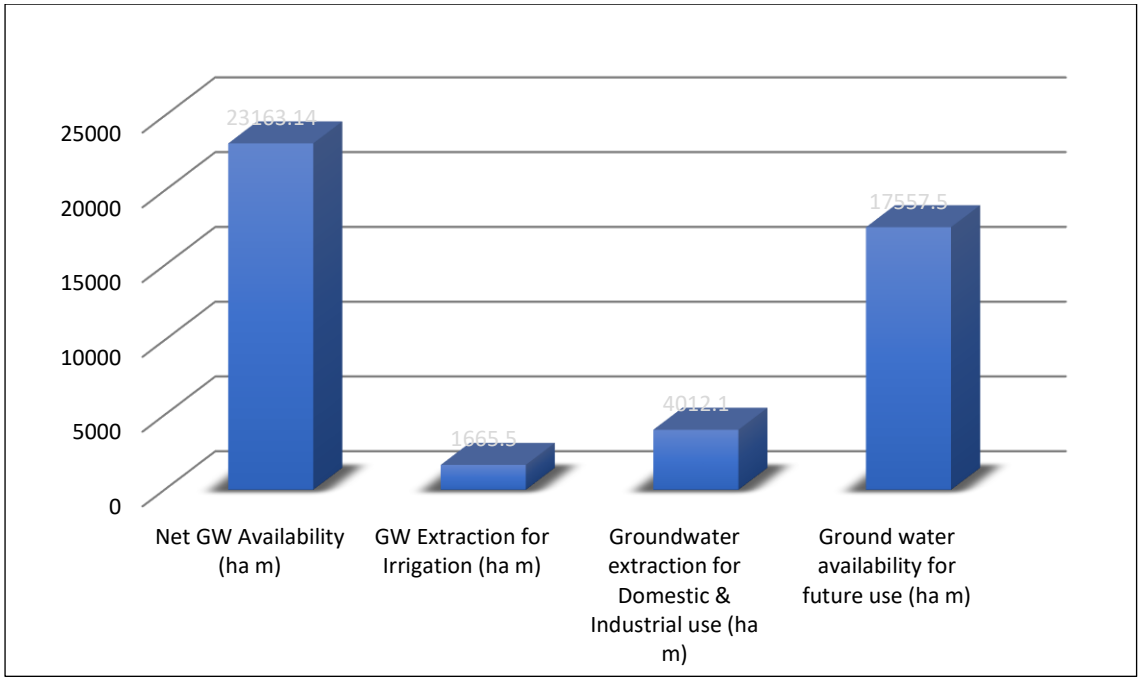

Fig.4.2 Availability of resources and draft break up

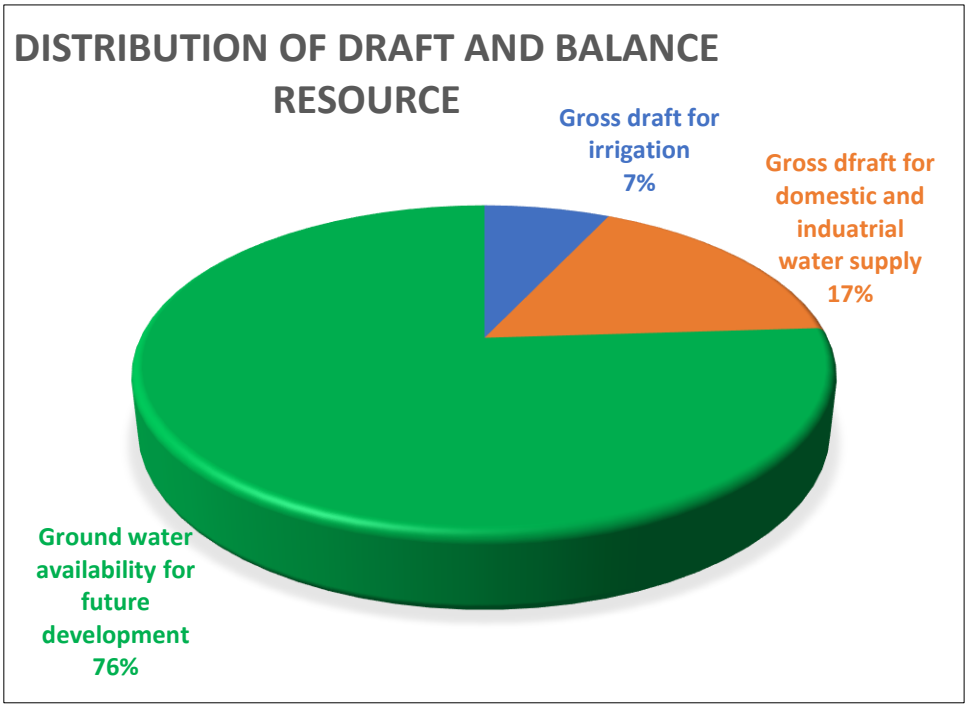

Fig.4.3 Distribution of Ground water Draft and Availability

4.2 TEMPORAL VARIATION OF GROUND WATER RESOURCES

(A) NET AVAILABILITY AND DRAFT

The ground water resources are dynamic in nature and variation in resources is subjected to variations in recharge and changes in draft pattern. By analysing the resources with previous years data it has been observed that there is drop in recharge component compared to 2013 data reflecting the changes in rainfall pattern. This is corroborated by the deficit in annual average rainfall during 2013 as 1839 mm against 1200 mm during 2017. Total draft of the district is marginally increased from 5477.53 ha.m during 2013 to 5677.6 ha.m during 2017 Details are shown in Table.4.3.

Table 4.3 Groundwater Draft (MCM) and GW availability in Wayanad District during 2013 and 2017

Sl No	**Block**	Net Groundwater availability (ha.m)		Groundwater for irrigation (ha.m)		Groundwater draft for domestic, industrial (ha.m)		Groundwater draft for all uses (ha.m)	
		2013	**2017**	**2013**	**2017**	**2013**	**2017**	**2013**	**2017**
1	Kalpetta	8084.65	6653.8	321.40	342.3	1097.79	1130.5	1419.19	1472.9
2	Mananthavady	8059.16	6638.9	388.06	408.1	1022.00	1052.3	1410.06	1460.5
3	Panamaram	4607.39	3808.3	318.65	348.0	889.05	914.7	1207.70	1262.7
4	Sulthan Bathery	7344.52	6062.1	547.53	567.0	889.05	914.7	1436.58	1481.6
Total		**28095.73**	**23163.1**	**1575.64**	**1665.5**	**3897.89**	**4012.1**	**5473.53**	**5677.6**

(B) STAGE OF DEVELOPMENT

The comparison of the stage of development with previous resource estimation (Table4.4) indicate that on an average 5 % increase in the development of ground water in Wayanad district and all the blocks are categorised as safe block. This shows that ground water dependability among people is increasing day by day.

Table 4.4 Comparison of stage of development in Wayanad district during 2013 and 2017

Sl No	Block	Stage of Groundwater development (%)		Categorization of block	
		2013	**2017**	**2013**	**2017**
1	Kalpetta	17.55	22.1	Safe	Safe
2	Mananthavady	17.50	22.0	Safe	Safe
3	Panamaram	26.21	33.2	Safe	Safe
4	Sulthan Bathery	19.56	24.4	Safe	Safe
	Avg	**20.20**	**25.42**		

4.3 NUMBER OF GROUND WATER STRUCTURE FOR FUTURE DEVELOPMENT

Considering the present stage of development and unit draft per structure, a total of 9219 no of structures can be constructed by developing 70% of the balance resource available for

irrigation .Since all the four blocks fall under safe category, abstraction structures can be constructed keeping in view the groundwater sustainability of the region

4.4 IN-STORAGE IN THE WEATHERED ZONE

Static or In storage is the water resource available below the water level fluctuation zone. In-storage ground water resources could be considered for development during exigencies like draught. The in storage is not affected under sustainable groundwater development in the phreatic zone. The extraction of resource from in storage lead to the condition of over- exploitation of groundwater. However, the in storage is not accounted for future utilization for irrigation.

Total in storage in the weathered zone is worked out based on the total rechargeable area of 1427 sq km, total thickness of 10m and specific yield of 0.006. The in-storage in this zone is estimated as 171.31 MCM. The total groundwater availability in the weathered zone is the sum of dynamic resources and the in-storage which comes about 402.94 MCM. The in-storage computed for each block is shown in Table 4.5

4.5 IN STORAGE IN THE FRACTURE ZONE

The groundwater resources in the fracture aquifer system are estimated as instorage in the fracture system. It exist in semi confined to confined condition. It is estimated based on the depth of occurrence of fracture and on the assumption that the storativity/ Sp. yield of the fracture and associated matrix which is about .003 to .0009 for the area. The instorage of semi confined aquifer is 214.14 MCM and for confined aquifer it is 149.9 MCM.Total in storage of fractured aquifer is 364.04 MCM. The total water resources of all aquifer system in the district worked out to be about 766.95 MCM (Table.4.5).

Table.4.5 . Aquifer wise total groundwater resources in Wayanad District

Assessment Unit (Blocks)	Total Geographical area (Sq.Km)	Annual Extractable Ground Water Recharge of unconfined Aquifer (mcm)	In storage Ground Water Resources of Unconfined Aquifer (mcm)	Ground Water Resources –unconfined Aquifer-I (mcm) (2+3)	Ground Water Resources-Fracture Aquifer-II (mcm) (Semi-confined)	Ground Water Resources-Fracture Aquifer-II (mcm) (Confined)	Total GW Resources - Deeper aquifer	Total Ground Water Resources (mcm) (4+8)
	1	2	3	4	6	7	8	9
Kalpetta	587.7	66.54	49.62	116.16	62.03	43.42	105.45	221.61
Mananthavady	666.6	66.39	49.26	115.65	61.58	43.1	104.68	220.33
Panamaram	351.3	38.08	27.94	66.02	34.92	24.45	59.37	125.39
Sulthanbathery	525.4	60.62	44.49	105.11	55.61	38.93	94.54	199.65
Total	**2131**	**231.63**	**171.31**	**402.94**	**214.14**	**149.9**	**364.04**	**766.98**

5 GROUNDWATER RELATED PROBLEMS

In the study area, the stage of development is within 25 % and all blocks are categorised as safe blocks. In the district there are no major ground water problems to be highlighted, minor

issues are existing that can be rectified by adopting site specific management practices The main groundwater related problems in the study area are as follows

(i) **Ground water Scarcity:** In the study area groundwater from phreatic aquifer is extracted mainly through dug wells and at some places bore wells are drilled as part of government initiative. For the last few decades it was observed that dug wells are getting drying up during summer season especially during rain deficient periods especially in the high lands. In high land terrain also bore wells are common structures as the dug wells in this area usually dries up. The physiography and geological settings of the area as well as the anthropogenic activities further worsen the situation. The summer scarcity is commonplace in Panamaram block especially in areas close to the Karnataka Border such as Mullankolly, Kappiset, Pulpally etc. Deeper water levels observed in these areas are due to topographic characteristics. The low rainfall in these areas is the main reason behind the ground water scarcity. More over there is limited surface water schemes to supplement the water requirement of the area. People are depending on tanker water from private players on payment basin. No mechanism is existing to assess the quality of this tanker water. Topographic settings Inability to conserve the surplus run-off available during the monsoons, due to topographic characteristics and destruction of traditional water storage structures such as ponds, tanks and wetlands.

(ii) **Quality issues**: Electrical conductivity is within the prescribed limit in all places of Wayanad district.Concentration of Nitrate above permissible limit (more than 45 mg/l)is observed in certain pockets viz. Vaduvanchal and Vythiri and concentration of Manganese is observed more than permissible limit in certain pockets viz. Vaduvanchal.

(iii) **Anthropogenic activities**: Rapid urbanization, tourist inflow and lack of facility for waste disposal in municipalities, change in land-use and cropping pattern, indiscriminate dumping of biodegradable and non-biodegradable waste into abandoned wells and surface water bodies, wet land filling, cultivable land encroachments, illegal sand mining along river beds and conversion of paddy fields have adverse effects on the quantity and quality of the water. 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.

(iv) **Quarrying:** Charnockite group of rocks occupying the highland and midland region of the study area are good sources of building materials.There are 106 granite quarries in Sulthan Bathery, Kalpetta and Mananthavady blocks. Quarrying of these rocks creates localized groundwater problems. In addition to granite building stone, mining of brick or tile clay is common in Wayanad district. in localised areas especially low lying valley fill areas.33 such clay mining centres are reported. These clay mining is catering the local needs of construction

(v) **Land Use Changes:** Wayanad district is known for its plantation crops.Earlier paddy cultivation was the prime agricultural activity which now converted into cash crops for which land pattern is severely compromised. Deforestration, unauthorized encroachment , unscientific agricultural practices leads to soil erosion. Initially most of

the encroachments are for agriculture purposes; later these areas were reclaimed and used for various other purposes 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. The mushrooming of illegal resorts for attracting tourists is making irreparable loss to the soil profile and water holding capacity of soil and finally result in heavy surface run off and landslide.This is common in Kalpetta (vythiri area) and Mananthavady (Thirunelly area)and Sulthan Bathery blocks9Meppady area).

(vi) **Lack of awareness**: Awareness among people and their participation for judicious use of precious resources are inevitable for the effective management of ground water. Creating awareness on water or building water literacy especially in a district where good proportion of population are of Tribal communities who do not have basin infrastructure to maintain hygienic conditions around drinking water sources. It is the collective efforts of the concerned government; non-government organisations and local body institutions would lead to safer drinking water provisions. An ideal groundwater management approach will be one that will not only construct structures but also make an effort to sensitize and involve the community to work on the issue. There is an urgent need for a concerted effort to integrate science and community participation for groundwater management.

6.MANAGEMENT STRATEGIES &AQUIFER MANAGEMENT PLAN.

Average stage of ground water development in the district is 25 % and remaining 75 % is yet to be tapped for various developmental activities. Considering the fact that Wayanad is known for coffee and tea plantation as major cropping pattern, use of ground water through sustainable irrigation practices may yield more production and the per capita income of people will go up. Therefore, effective utilization of ground water resource is the challenging part in management of groundwater resource in Wayanad district. Hence, it is pertinent to formulate a practical and scientific management plan suitable to the area. In the present study, sustainable management plan for groundwater resources is being proposed after a detailed understanding of the aquifer disposition down to the target depth of 200 m bgl and estimation of available resources.

Even though the study area receives good annual rainfall and has best climatic conditions ,it has been experiencing incidents of water scarcity in summer months for consummating domestic and irrigation requirements. It is observed that even in the years of normal rainfall, summer water scarcity problems are existing in areas close to Karnataka border. This perplexing condition is attributed due to natural reasons such as highly undulating topography with steep slopes create some sort of rain shadow effect coupled with undulating topography result in low recharge rate. In addition to this ,limited weathered residuum limits groundwater storage in the aquifer system. In situ conservation of rain water and conservation of surplus run-off during monsoon and other artificial recharge measures to supplement the domestic and irrigation needs are the possible solutions to overcome this problem.

6.1 SUSTAINABLE PLAN

The effective utilization of existing resources is kept under consideration while preparing sustainable plans which can be done easily in case of blocks in Wayanad as all blocks are in safe category and resources are under utilised. The average stage of development in all blocks is about 25% which means that there is scope for further ground water development for irrigation in all blocks where the stage of extraction is low. Considering the present stage of development and unit draft per structure, there is potential for a total of 9219 no of groundwater extraction structures for optimal development of the available groundwater resources. While formulating various ground water development and management plans, the role of geology and geomorphology of the area on the ground water regime should be given due importance.

Even though the stage of development in the district is low there are specific areas where groundwater is scarce due to reasons explained earlier. Water use efficient irrigation techniques like drip and sprinkler irrigation methods can be adopted in those areas. Such irrigation techniques have a major impact in boosting the production of coffee and other cash crops. Since it supplies water directly to the crop, rather than the land around, water losses occurring through evaporation and distribution are significantly reduced. There is water saving of 30-70 per cent for different crops like coffee, arecanut, nut meg, banana and plantains under drip/sprinkler method of irrigation. Farmers may be encouraged to adopt these modern irrigation techniques to have optimal use of the available resources in water scarce areas. An area of 36104 Ha. can be brought under sprinkler irrigation and 1473 Ha under drip irrigation crop specific distribution of water in identified water scarce areas.

6.2 AUGMENTATION PLAN

Topography of the area is suitable for implementing various artificial recharge structures such as percolation ponds, check dams (CD), vented cross bars (VCB) contour bunding, trenching, pitting, terrace cultivation and sub-surface dykes\ etc. Enough measures must be taken to prevent building up of saturated soil condition especially along steep valley slops and hilly area to avoid land slide. Periodic de-siltation as well as cleaning of existing check dams, bunds and ponds are recommended for increasing the storage capacity as well as infiltration rate. In order to reduce the surface, run off, gully plugs are suitable for along 1st order streams , nallah bunds/cross bars for 2ndorder and check dams is recommended for 3rd and higher order. This is to ensure that flow in rivers during summer months by limiting rainfall run off.

6.3 SCOPE OF ARTIFICIAL RECHARGE STRUCTURES

Wayanad district is a plantation/agriculture-based district and there is ample scope for artificial recharge structures to maintain the availability of water throughout the year for farming/plantation activities even though it is getting high rainfall and low groundwater development. The undulating topography and thin weathered aquifer systems resulted in limited groundwater storage space. There are 375 check dams existing in the area and a sizeable number of lift irrigation structures (43945) are functioning to boost the agriculture activities. The surface water bodies are also augmenting the recharge. There are 804 farm ponds, 50 panchayat owned ponds, and 5 temple ponds.

In order to improve the groundwater scenario in the specified water scarce areas ground water recharge through rainwater harvesting and artificial recharge are recommended. It is proposed to have 25 check dams and 7 Vented Cross bars in the area as shown in fig 6.1. Apart from this development of 23 springs is also recommended. These recommended structures are in addition to various other structures proposed in the on-going PMKSY District Irrigation Plan of Wayanad district. Full details including location wise and project wise details are given in PMKSY report for reference (Pages: 105 to 314). This will create an irrigation potential of 43795.72 ha. Details of the on-going schemes, are given table 6.1and the recommended structures are given in table 6.2.

6.4 AQUIFER MANAGEMENT PLAN

6.4.1 SHORT-TERM LOCAL SOLUTIONS FOR GROUNDWATER MANAGEMENT

The distribution of water should be equitable across users particularly marginalised and poorer user groups in water scarce areas like Irulam tribal belt, Pulpally, Kappiset Mullankolli areas and adjoining Panchayats. Significant role is vested with local governing body and govt. institutions to coordinate all stake holders to manage the issues at micro-level. This is done by preparing comprehensive water management system and water allocation plans on a participatory approach, involving users, planners and policy makers at all levels. All the existing recharge/conservation structures must be cleaned on annual basis before onset of monsoon. Identification of high yielding bore wells drilled by various government agencies help to meet the drinking water needs of the populace especially during summer.

The domestic water needs of urban areas like Kalpetta, Mananthavady and Sulthan Bathery are to be dealt separately and the water wastage component is increasing mainly because of leakages through distributary system. Wastewater collection and disposal are equally important like supply of protected water in maintaining public health. Roof top rain water harvesting system must be part of all houses and larger concrete buildings which will reduce the scarcity of water during lean periods. The effective implementation of roof top rainwater harvesting system is essential for sustainability of water resources. In High land areas community based RTRWH (Storage) for drinking/domestic purpose is recommended.

Renovation of 50 Panchayat ponds will cater the additional requirement for domestic/agricultural uses.

Table.6.1 Breakup of various ongoing water harvesting structures

Ongoing /completed structures-Block wise break up										
Sl. No	Block	Check Dam	Ponds	Rain pits	Community water tanks	BW	Water lifting devices (Electrical)	Water lifting devices (Solar/wind)	Renovation of small tanks	Insitu water conservation
1	Kalpetta	3	20	99000	5	36	525	8	29	100
2	Mananthavady	22	32	99000	4	36	525	8	29	100
3	Panamaram	125	331	99000	4	36	525	8	29	100
4	Sultan Bathery	4	31	99000	4	36	525	8	29	100
	Total	154	414	396000	17	144	2100	32	116	400

Table.6.2 Additional structures recommended for artificial recharge

Sl. No	Block	Check Dam	Vented Cross Bars	Springs
1	Kalpetta	15	3	6
2	Mananthavady	5	2	9
3	Panamaram	5	2	5
4	Sultan Bathery	0	0	3
Total		25	7	23

6.4.2 LONG-TERM LOCAL SOLUTIONS FOR GROUND WATER MANAGEMENT

Based on ground water resource estimation it is found that groundwater extraction for irrigation in Wayanad district is low (29.32 % of the total groundwater extraction) and extraction for domestic and industrial use account for the major component (70.68 %). Net groundwater available for future use is 175.58 MCM and stage of extraction is about 25 %. More than 70 % of the groundwater resources are unutilised which substantiate the scope for further development of the ground water resources. Hence, it is proposed to construct ground water abstraction structures (144 bore wells) for creating additional irrigated agriculture in cultivable/Culturable waste land area of about 365.22 ha in the district and the block wise tentative details in this regard is given in Table 6.3, in which suitable abstraction structures will be taken up depending on the suitability of the area .

Roof top rainwater harvesting can be practiced by all including individuals with small land holding especially in the block of Kalpetta. Gully plugs are suitable for all high land areas with local break in slope such as the plateau terrains of Kalpetta, S. Bathery and Mananthavady blocks. Percolation Tanks are suitable for areas with thick alluvial patches like Kainatty, Panamaram, Muttil and areas with valley fill, colluvium and highly weathered rocks. Check dams can be constructed across small streams with gentle slope with permeable beds and such sites are available in all blocks. Sub-surface dyke along gently sloping wide valleys with narrow out let are effective ground water conservation structures for Ambalavayal and Thrikkaipatta areas. Dug well recharge can be practiced in and around Pulpally, Perikallur, Kappiset, Mullankolli areas bordering Karnataka State.

Periodical maintenance of existing canal irrigation distributary system of Banasura Sagar Project (BSP) and Karapuzha Irrigation Project (KIP) which are irrigating an area of 8021 ha of land is required. The canal system of Karapuzha project is still being developed and this will further enhance the area irrigated to an additional area of 3500 Ha.

Table 6.3: Block wise details of abstraction structures proposed for Wayanad District

Block	Total area (sq.km)	Culturable Waste Land, ha	Nos. of abstraction structures proposed/ constructed (BW)
Kalpetta	587.7	158.31	36
Mananthavady	666.6	88.48	36
Panamaram	351.3	58.69	36
Sulthan Bathery	525.4	59.74	36
Total	2131	365.22	144

Identification of 116 number small tanks for the whole district is to be developed as sources of water in water scarce situations. Such tanks identified must be de-silted, renovated and their feeding channels repaired to ensure that they receive enough 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.

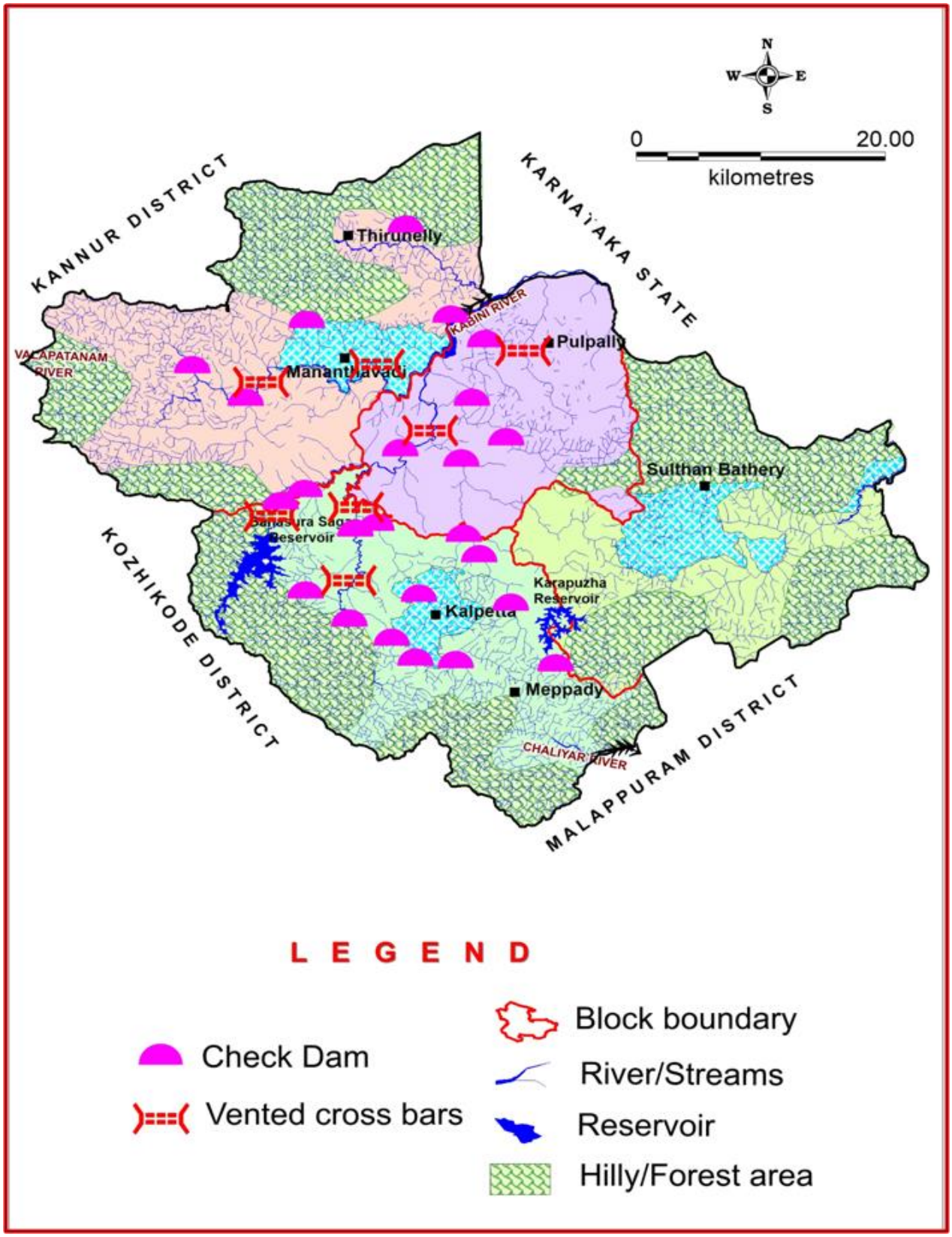

Fig.6.1 Feasible water conservation structures in Wayanad District

Several abandoned quarries are available in the district. These quarries can be converted to water harvesting structures. As per Land Use Board estimate there are about 108 granite quarrying sites in Wayanad district and half of them are abandoned due to various reasons (Fig.6.2) and these can be converted into storage of water for utilization during summer months. These quarries are located in the topographic high and distribution is quite easy due to elevation difference. Precaution must be taken as there is inflow of polluted water from adjoining areas. A retaining wall should be constructed around the quarry to prevent the inflow of water from surrounding areas. The water stored in the quarries should be removed and completely cleaned before domestic use. If the inflow of water from surrounding areas is facilitated, then the water should be purified/treated before usage. Also, quarries can be used as rainwater storage tanks which is used for domestic and irrigation purpose during lean period.

Fig.6.2 Panoramic view of two abandoned quarries near Ambalayaval

Horticulture and vegetable cultivation are ideal for the area. Pollution free Industries may be proposed in identified panchayats falling along the banks of major rivers without affecting the local groundwater regime.

There are 8 Tanks existing in Wayanad district. Largest one is Pookode lake (57062.7 m^2) and smallest one is Kalyere Mandiram Chira (4900 m^2). All these ponds need

rejuvenation due to siltation. The desiltation can increase the water holding capacity of the ponds and increase infiltration into the ground water systems. These surface water resources can be used for various micro irrigation practices in the adjoining Panchayats.

6.4.3 SPRINGS

Based on available data there are 24 perennial springs and seepages (Source: Springs of Kerala-An inventory, Centre for Water Resources Development and Management (CWRDM) ,1988) are available in Wayanad district (CGWB,2010). Spring is a natural outlet though which ground water emanates at ground surface as concentrated discharge from an aquifer and discharge rate from a spring depends on rate of rainfall / snowfall or other water accretion in the area, size of recharge area above it, geology and geomorphology of the area, aqui-

fer geometry and aquifer parameters. Springs play a major role in solving drinking and domestic water demands of the rural population. Springs are common in areas of highly undulating or steep sloping geomorphology which favour formation of springs from base flow. To supplement the domestic demand in water scarce panchayaths falling along hilly areas spring development is suggested. The salient features of springs which are perennial are given in Annexure V. Panamaram block is devoid of any springs and Kalpetta has maximum number of springs.

Approximate summer discharge of springs ranges between 2 and 180 lpm. The highest discharge observed at 42 Mananthawady-Koothuparamba road near Varayal with summer discharge of 180 lpm and lowest at Chelod (Vythiri) with discharges of 1 lpm . Land use / land cover around Chelod (Vythiri) is coffee and that of 42 Mananthawady-Koothuparamba road near Varayal is paddy and coffee. Kunnakode spring is catering maximum people (2000) for irrigation and washing purpose. The water quality of few springs are not good (Kamblakkad, Beenachi Estate, Kunnakode) and hence it is not recommended for drinking purpose. Spring water is generally suitable for domestic, irrigation and industrial purposes (Fig.6.3). These springs are the perennial sources for drinking water schemes and required no pumping also. Proper development and maintenance of this resource should be kept in high priority as the spring water can be supplied to the down stream area just by gravity flow.

Fig.6.3 Springs at Thrissileri , Thirunelly area (left) and Pookode, Vythiri (right)

6.4.4 MICRO IRRIGATION METHODS

Micro irrigation practices are modern water use efficient method to reduce the water requirement and increase the crop yield by giving the water as and when required during the growth of crop. Drip irrigation and Sprinkler irrigation techniques are two popular micro irrigation practices. These two techniques can be effectively used in the district and the block wise area that can be irrigated through these two methods is provided in Table 6.4 and Fig. 6.4 which indicate that 36104 Ha can be irrigated through Sprinkler Irrigation and 1473.24 Ha by Drip irrigation method. Kalpetta block is credited with large area worth for drip and sprinkler irrigation compared to another district.

Table.6.4 Area irrigated through Micro irrigation practices

Sl No	Block	Sprinkler Irrigation		Drip Irrigation	
		Area (Ha)	%	Area (Ha)	%
1	Kalpetta	15180	42.05	900.82	61.15
2	Mananthavady	7553	20.92	161.95	10.99
3	Panamaram	4055	11.23	204.89	13.91
4	Sultan Bathery	9316	25.80	205.58	13.95
	Total	**36104**		**1473.24**	

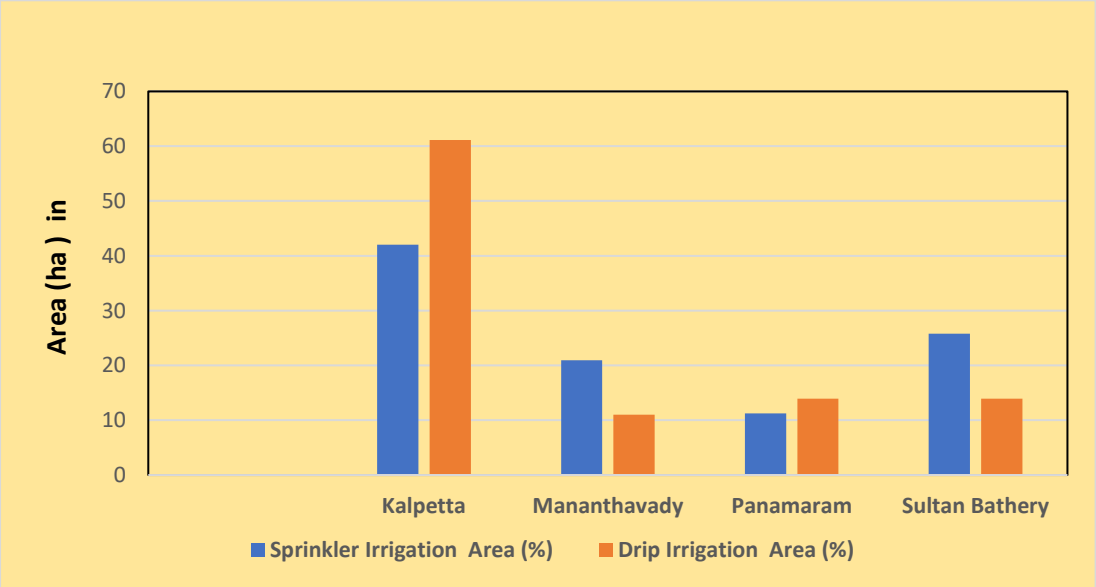

Fig.6.4 Block wise break up of Micro irrigation methods

6.4.5 ARTESIAN CONDITION

Water in artesian wells stands at some height above the water table because of the pressure (artesian pressure) of the aquifer. The level at which it stands is the potentiometric surface and if it is above the land surface, the well is a flowing artesian well. A flowing well has

water that comes up to the surface because of internal pressure in the underground aquifer containing the water.

There are two-auto flow wells (free flow wells) in the district. These auto flow wells are situated at Irulam-Kottakalli (Fig. 6.5) in between Sulthan Batheri-Pulpally and Kappiset which is located 4.5 km east of Pulpally. In Irulam well now the flow is reduced due to lowering of piezometric head. The discharge of Kappiset well is quite meagre and measured as 0.48 lps (CGWB,2010). The water quality data indicate that water of the well is suitable for domestic and non-domestic purposes(CGWB,2010)

Fig.6.5 Autoflow well at (A) Irulam (CGWB,2018) and (B) Kappiset (CGWB,2010)

6.4.6 OTHER TRADITIONAL WATER CONSERVATION METHODS

Wayanad is known for the presence of large number of tribal population. Kenis or sacred wells reveal the ancient knowledge and wisdom of tribes of Wayanad in water conservation and sustainable utilization of perennial water sources. “Panam Keni” (Toddy palm well) is the special type of well used by Mullu kuruma hamlets (Fig.6.6). Mullu kurumas is concentrated and are mainly found in the panchayaths of Noolpuzha, Kidanganad, Muppainad, Muttil, Parakkadi, Tirunelli and Mananthavadi. This type of wells are being used by kurumas for hundreds of years. Kenis are located on the edge or middle of paddy fields and near forests. Cylindrical in shape, they have a diameter and depth of around four feet only. The wall is of Toddy palm (Caryota urens). Usually the bottom stem portion of large palms are used to make wooden cylinders after retting them in water for a long time so that the inner core gets rotten and degraded and the hard outer layer remains. The wooden cylinders are immersed in the spots where there is good ground water spring and that is the secret of abundant water even in hottest summer months. Now there may be around 200 kenis in Wayanad. These wells reveal the ancient knowledge and wisdom of tribes of Wayanad in locating, preserving and sustainable utilization of perennial water sources

Fig.6.6 Representative picture of Panam Keni in the field.

6.4.7 IEC ACTIVITIES

Various Government departments/NGOs are working on conservation of water and implementing artificial recharge methods in Wayanad district. The main agency / organization involved in the rainwater harvesting is Jalanidhi, a World Bank aided project of Kerala Water Authority. Jalanidhi is mainly doing storage of rainwater than recharging the water to the ground water system. The prominent NGOs viz. Sreyas Social Service Centre (SSSC), Wayanad Social Service Society (WSSS), HILDA Trust, Mirror-Centre for Social Change, Wayanad Muslim Orphanage (WMO) and Women's Welfare Association (WWA), have been working in the field of water conservation for number of years and have worked in tandem with 'Jaladhini', Western Ghats Development, NWDPRA and rain water harvesting.

The understanding on the hydrogeology of the area need to be conveyed to common people to sensitise the importance of water conservation. For this two Mass Awareness Program (MAP)was conducted at Mananthavady dueing the period 2007-08.MAP was attended by more than 350 people, majority of them were women and tribals (adivasis). Water Management Training Programme of 2 days duration was also conducted in Sulthan Batheri, Wayanad district in January of 2012. The main aim of the programme was to provide training to different stakeholders on various aspects of ground water management techniques. They can also be entrusted with activities like water budgeting, assessment of crop water requirements etc. About 150 people participated in the programme and discussions were held on different groundwater related issues in the area to make the public aware of the importance of groundwater and rainwater harvesting. Also a one day training programme called "Hamara Jal, Hamara Jeevan" was conducted in January of 2015 aiming for an integrated water resources development and management by identifying Jal Gramam in the district.

During December 2019, two Tier-III Training programmes were conducted at Meenangadi and Panamaram with an aim to create awareness among locally educated people on the ground water conservation and artificial recharge methods suitable at local level.

6.5 SUMMARY

- Two aquifer systems were identified in the district viz; the phreatic aquifer system (Aquifer-I) and the fracture aquifer system (Aquifer-II). The phreatic aquifer system comprises weathered zone and underlying shallow fracture system extending up to 35 mbgl. The deeper fractured crystalline aquifers are under confined to semi confined conditions and the potential fractures are encountered up to 199 m bgl. Baveli shear zone is the major lineament in Wayanad district having NW-SE trend. The water level in majority of area is within the range of 2-10 m bgl.
- The district is bestowed with abundant groundwater resources in the tune of about 767 MCM. Of which, the total resource in the phreatic aquifer is 403 MCM and Fractured aquifer is 364 MCM). All the four blocks in the district are in Safe category. The average stage of development is about 25 % only. Therefore, sufficient scope exist for further GW development.
- There are no major issues related to groundwater availability or water quality as per the findings of aquifer mapping carried out in the district. However, shortage of drinking water in highland areas is commonplace during lean periods due to limited aquifer thickness and high rates of base flow. Of the four blocks, Panamaram block experiences high water scarcity during lean periods due to low recharge.
- Water conservation practices are proposed under aquifer management plan for the highland areas where shortage of water is being experienced during summer and its implementation in convergence with ongoing MNREGS and PMKSY. Additionally, water conservation structures like 3896 Check dams, 2301 Farm Ponds,15 Nallah Bunds,140 Percolation Tanks,228 Fishery Ponds, and 51 in situ structures are recommended at identified places which will create an additional irrigation potential of 103651.18 ha in the district.
- Extraction of ground water through renovation of 24 recommended for providing sustainable drinking water supply to 9787 people living in various tribal hamlets and for collection of water from springs 13 storage tanks are required.
- Encourage traditional knowledge like Panam Keni which has been used for conserving ground water by Tribal people.

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ANNEXURES

ANNEXURE-I : Details of GWMWs in the Study area

Sl No	Location	Block	Lat	Long	MP (m)	Dia (m)	Total Depth (m)	Geology	Use	Apr-18	Non-18	Aquifer type
1	Ambalavayal	Sulthan Bath-ery	11.61	76.21	2.90	10.70	2.15	Laterite	Domestic	8.21	7.57	Unconfined
2	Appapara	Mananthavady	11.91	76.03	0.75	9.26	3.30	Laterite	Domestic	6.58	2.91	Unconfined
3	Arimula	Sulthan Bath-ery	11.69	76.13	0.80	10.40	2.50	Laterite	Domestic	9.20	6.17	Unconfined
4	Baveli	Mananthavady	11.84	76.12	0.80	9.00	2.00	Laterite	Domestic	9.04	3.27	Unconfined
5	Begur	Mananthavady	11.76	76.17	0.90	13.10	3.00	Laterite	Domestic	11.69	6.51	Unconfined
6	CC Junction	Sulthan Bath-ery	11.68	76.21	0.80	14.00	2.00	Laterite	Domestic	11.71	9.11	Unconfined
7	Cheenkeri	Sulthan Bath-ery	11.64	76.19	1.00	11.83	2.30	Laterite	Domestic	10.30	5.51	Unconfined
8	Chellakod	Sulthan Bath-ery	11.54	76.24	0.90	10.50	1.35	Laterite	Domestic	8.74	6.19	Unconfined
9	Chenad	Sulthan Bath-ery	11.73	76.24	1.00	19.40	2.55	Laterite	Domestic	16.84	11.15	Unconfined
10	Cheyyambam	Sulthan Bath-ery	11.75	76.23	0.80	4.50	1.50	Laterite	Domestic	3.98	2.88	Unconfined
11	Chulliyod	Sulthan Bath-ery	11.60	76.26	0.98	16.00	2.40	Laterite	Domestic	14.76	11.01	Unconfined
12	Dasanakkara	Panamaram	11.80	76.08	0.60	7.00	2.00	Laterite	Domestic	3.75	4.09	Unconfined
13	Kalpetta-R1	Kalpetta	11.61	76.08	0.85	9.98	1.40	Laterite	Domestic	3.07	1.06	Unconfined
14	Kamblakat	Kalpetta	11.68	76.08	1.50	21.00	1.80	Laterite	Domestic	18.00	15.58	Unconfined
15	Kanjirangad	Mananthavady	11.74	75.91	0.75	3.95	2.00	Laterite	Domestic	2.29	1.64	Unconfined
16	Kappiset	Panamaram	11.80	76.20	0.70	11.30	2.30	Laterite	Domestic	14.00	5.37	Unconfined

Sl No	Location	Block	Lat	Long	MP (m)	Dia (m)	Total Depth (m)	Geology	Use	Apr-18	Non-18	Aquifer type
17	Karani	Sulthan Bath-ery	11.73	76.11	1.00	14.10	2.40	Laterite	Domestic	9.55	6.79	Unconfined
18	Kattikulam	Mananthavady	11.85	76.07	0.85	10.80	1.80	Laterite	Domestic	6.75	5.75	Unconfined
19	Kavumandam	Kalpetta	11.64	76.02	2.20	10.70	2.30	Laterite	Domestic	6.16	4.75	Unconfined
20	Kellur -5th Mile	Kalpetta	11.75	76.02	0.80	12.22	3.07	Laterite	Domestic	12.90	3.29	Unconfined
21	Koliyadi	Panamaram	11.64	76.28	0.68	4.25	0.85	Laterite	Domestic	2.69	1.90	Unconfined
22	Koodal Kadavu	Panamaram	11.80	76.07	0.80	17.70	2.00	Laterite	Domestic	16.03	13.26	Unconfined
23	Koroth	Mananthavady	11.75	75.81	0.60	9.80	1.80	Laterite	Domestic	3.60	2.76	Unconfined
24	Kottathara	Kalpetta	11.68	76.02	0.53	6.65	2.60	Laterite	Domestic	5.33	4.35	Unconfined
25	Kottavayal	Kalpetta	11.58	76.11	0.90	5.25	2.50	Laterite	Domestic	4.66	3.89	Unconfined
26	Krishnagiri	Kalpetta	11.66	76.19	0.85	7.55	2.50	Laterite	Domestic	7.34	3.51	Unconfined
27	Kuppadi	Sulthan Bath-ery	11.69	76.26	0.80	20.00	3.00	Laterite	Domestic	20.00	15.69	Unconfined
28	Lakkidi	Kalpetta	11.52	76.02	1.10	5.30	2.08	Laterite	Domestic	1.11	0.93	Unconfined
29	Mampayil	Mananthavady	11.81	75.92	0.65	5.35	2.50	Laterite	Domestic	2.38	2.89	Unconfined
30	Manjapara	Mananthavady	11.55	76.18	0.85	15.75	2.50	Laterite	Domestic	8.76	5.61	Unconfined
31	Mannanthody	Mananthavady	11.81	76.01	0.75	11.70	3.00	Laterite	Domestic	8.57	5.40	Unconfined
32	Melaputhenkunnu	Mananthavady	11.64	76.30	0.55	20.00	3.00	Laterite	Domestic	17.80	11.53	Unconfined
33	Meppady	Kalpetta	11.55	76.13	0.80	20.00	2.20	Laterite	Domestic	17.65	16.68	Unconfined
34	Minangadi	Sulthan Bath-ery	11.66	76.16	1.35	11.85	2.52	Laterite	Domestic	7.14	5.24	Unconfined
35	Moolankavu	Sulthan Bath-ery	11.69	76.13	0.75	9.25	2.50	Laterite	Domestic	8.21	4.12	Unconfined
36	Mullankolly	Panamaram	11.82	76.16	0.00	7.16	1.80	Laterite	Domestic	4.83	2.98	Unconfined
37	Muthunga (R1)	Sulthan Bath-	11.68	76.37	0.00	8.30	1.34	Laterite	Domestic	3.82	2.31	Unconfined

Sl No	Location	Block	Lat	Long	MP (m)	Dia (m)	Total Depth (m)	Geology	Use	Apr-18	Non-18	Aquifer type
		ery										
38	Muttil	Kalpetta	11.64	76.11	0.95	6.80	2.50	Laterite	Domestic	3.49	2.03	Unconfined
39	Nadavayal	Sulthan Bath-ery	11.75	76.12	0.90	10.10	2.50	Laterite	Domestic	8.19	3.51	Unconfined
40	Naykatti	Sulthan Bath-ery	11.67	76.32	0.75	9.05	2.77	Laterite	Domestic	6.61	4.07	Unconfined
41	Nedugarana	Kalpetta	11.55	76.18	0.75	9.55	2.25	Laterite	Domestic	8.95	6.73	Unconfined
42	Neeravaram	Panamaram	11.77	76.08	1.06	23.10	3.00	Laterite	Domestic	16.82	11.38	Unconfined
43	Nenmeni Kunnu	Sulthan Bath-ery	11.69	76.13	1.00	6.60	2.00	Laterite	Domestic	3.11	1.28	Unconfined
44	Noolpuzha (R1)	Sulthan Bath-ery	11.61	76.35	0.60	5.00	2.00	Laterite	Domestic	3.48	2.19	Unconfined
45	Ondyangadi	Mananthavady	11.83	76.03	0.70	17.45	2.25	Laterite	Domestic	10.83	8.71	Unconfined
46	Pachilakkad	Panamaram	11.71	76.08	0.80	11.88	2.00	Laterite	Domestic	9.95	6.33	Unconfined
47	Padinjarattara (R1)	Kalpetta	11.68	75.98	0.65	10.24	2.25	Laterite	Domestic	8.80	6.93	Unconfined
48	Pakkam	Panamaram	11.80	76.10	0.90	7.74	2.75	Laterite	Domestic	7.06	3.59	Unconfined
49	Pallikunnu	Kalpetta	11.68	76.05	0.80	10.50	1.80	Laterite	Domestic	9.55	7.43	Unconfined
50	Panamaram	Panamaram	11.73	76.07	0.75	6.95	2.30	Laterite	Domestic	4.31	2.65	Unconfined
51	Pattanikoopu	Panamaram	11.84	76.16	0.70	11.50	1.75	Laterite	Domestic	10.50	5.35	Unconfined
52	Perikallur	Panamaram	11.79	76.23	0.70	14.25	0.00	Laterite	Domestic	13.75	6.27	Unconfined
53	Perya	Mananthavady	11.83	75.84	0.60	13.18	2.50	Laterite	Domestic	5.56	5.21	Unconfined
54	Pookode	Kalpetta	11.56	76.10	1.15	5.60	1.80	Laterite	Domestic	2.41	1.65	Unconfined
55	Pozhutana	Kalpetta	11.59	76.02	1.00	10.23	2.53	Laterite	Domestic	6.40	6.16	Unconfined
56	Pulpally	Panamaram	11.73	76.13	0.80	18.00	1.70	Laterite	Domestic	3.40	2.94	Unconfined

Sl No	Location	Block	Lat	Long	MP (m)	Dia (m)	Total Depth (m)	Geology	Use	Apr-18	Non-18	Aquifer type
57	Punchvayal	Panamaram	11.75	76.09	0.60	11.00	2.50	Laterite	Domestic	10.34	5.91	Unconfined
58	Sulthan Battery	Sulthan Bathery	11.66	76.25	0.70	11.00	2.50	Laterite	Domestic	6.91	3.02	Unconfined
59	Talapuzha	Mananthavady	11.83	75.98	0.90	4.30	2.50	Laterite	Domestic	2.40	1.33	Unconfined
60	Taruvana	Mananthavady	11.83	75.98	0.90	12.85	2.22	Laterite	Domestic	11.13	7.05	Unconfined
61	Thetti Road	Mananthavady	11.90	76.07	1.00	15.90	1.50	Laterite	Domestic	15.90	7.47	Unconfined
62	Thirunelly (R1)	Mananthavady	11.91	75.99	0.90	7.80	1.50	Laterite	Domestic	6.40	4.31	Unconfined
63	Theolpetty	Mananthavady	11.94	76.07	0.70	12.00	2.00	Laterite	Domestic	11.56	3.49	Unconfined
64	Thonichal	Mananthavady	11.77	76.00	0.78	8.30	2.42	Laterite	Domestic	6.55	3.68	Unconfined
65	Ullisseri	Mananthavady	11.64	76.30	0.70	6.00	1.50	Laterite	Domestic	4.77	0.98	Unconfined
66	Uppupara	Kalpetta	11.59	76.14	0.83	10.80	1.70	Laterite	Domestic	7.04	6.26	Unconfined
67	Vaduvanchal	Sulthan Bathery	11.56	76.23	0.75	11.50	2.10	Laterite	Domestic	9.37	7.70	Unconfined
68	Valad (R1)	Mananthavady	11.79	75.91	0.70	12.90	1.65	Laterite	Domestic	10.89	9.86	Unconfined
69	Vallathur	Sulthan Bathery	11.62	76.32	0.75	4.70	2.50	Laterite	Domestic	2.87	0.87	Unconfined
70	Vallithodu (Periye)	Mananthavady	11.84	75.89	0.70	11.00	3.40	Laterite	Domestic	7.72	9.75	Unconfined
71	Valliyur kavu	Mananthavady	11.68	76.01	1.10	7.10	2.40	Laterite	Domestic	2.51	1.08	Unconfined
74	Vengapalli	Kalpetta	11.64	76.28	0.75	15.20	2.50	Laterite	Domestic	15.23	12.01	Unconfined
72	Varayal	Mananthavady	11.83	75.84	0.85	5.95	2.00	Laterite	Domestic	4.35	4.13	
73	Vellamunda	Mananthavady	11.73	75.95	0.80	12.50	2.80	Laterite	Domestic	12.68	4.41	
75	Vyittiri	Kalpetta	11.56	76.04	0.80	9.75	2.40	Laterite	Domestic	7.56	7.11	

ANNEXURE-II : Details of KOWs in the Study area

Sl No	Location	Block / Mandal	Sub Basin	Geology	Latitude	Longitude	Well use	Surface Water Influence	MP	Dia	TD	WL (Jan-2020)	Elevation of Ground Level	Land Use
1	Chundale NH	Kalpetta	Kabani	LTR	11°34' 12"	76°2' 60"	Domestic	Nil	0.6	2	7.2	3.68	780	Rural
2	Thinapuram Ring Well	Panamaram	Kabani	ALV	11°31' 48"	76°9' 36"	Domestic	Nil	0.76	1.04	8	4.78	877	Rural
3	Mundakolli	Panamaram	Kabani	LTR	11°37' 12"	76°18' 36"	Domestic	Nil	0.8	1.74	21	13.7	750	Rural
4	Chethalayam	Sulthanbathery	Kabani	LTR	11°44' 24"	76°14' 24"	Domestic	Nil	0.75	2.4	11.5	1.65	903	Rural
5	Irulam	Sulthanbathery	Kabani	LTR	11°45' 0"	76°11' 24"	Domestic	Nil	1	2.6	12.5	8.78	900	Rural
6	Padichira	Panamaram	Kabani	ALV	11°49' 48"	76°10' 12"	Domestic	Nil	0.43	2.5	18	14	773	Rural
7	Karyambadi	Panamaram	Kabani	ALV	11°40' 12"	76°7' 48"	Domestic	Nil	0.68	2.4	15	10.1	763	Rural
8	Varadoor	Panamaram	Kabani	LTR	11°41' 60"	76°5' 60"	Domestic	Nil	0.8	2.6	16	9.53	720	Rural
9	Vilambukandam	Panamaram	Kabani	LTR	11°41' 60"	76°1' 48"	Domestic	Nil	0.81	1.81	25	16.41	765	Rural
10	Anjukunnu	Sulthanbathery	Kabani	LTR	11°44' 24"	76°2' 24"	Domestic	Nil	0.5	2.6	18	11.85	750	Rural
11	Aruwal	Sulthanbathery	Kabani	LTR	11°42' 36"	75°58' 48"	Domestic	Nil	0	1.85	8	3.85	736	Rural
12	Beenachi	Sulthan-	Kabani	LTR	11°35' 60"	76°13' 48"	Domestic	Nil	1.1	2.33	12	6.9	896	Rural

Sl No	Location	Block / Mandal	Sub Basin	Geology	Latitude	Longitude	Well use	Surface Water Influence	MP	Dia	TD	WL (Jan-2020)	Elevation of Ground Level	Land Use
		bathery												
13	Kolagapara	Sulthan-bathery	Kabani	LTR	11°38' 24"	76°12' 36"	Domestic	Nil	0.8	1.32	14	7.47	813	Rural
14	Ayiramkolli	Sulthan-bathery	Kabani	LTR	11°37' 48"	76°12' 36"	Domestic	Nil	0.65	1.62	18	11.33	920	Rural
15	Edakkal Caves	Sulthan-bathery	Kabani	LTR	11°37' 48"	76°13' 48"	Domestic/ Public	Nil	1.3	2.6	8	2.51	944	Rural
16	Malakkad	Sulthan-bathery	Kabani	LTR	11°22' 48"	76°9' 0"	Domestic	Nil	0.7	1.8	16	10.1	751	Rural
17	Karapuzha dam	Sulthan-bathery	Kabani	LTR	11°36' 36"	76°9' 36"	Domestic	High	0.87	1.97	15	8.13	769	Rural
18	Mukkamkun-nu	Kalpetta	Kabani	LTR	11°35' 24"	76°8' 24"	Domestic	Nil	1	4.48	8	1.4	783	Rural
19	Trikkaipetta	Kalpetta	Kabani	LTR	11°35' 60"	76°7' 48"	Domestic	Nil	1	2	14	7.1	767	Rural
20	Choondale estate	Kalpetta	Kabani	LTR	11°34' 12"	76°2' 24"	Domestic	Nil	0.93	3.45	8	1.85	777	Agricul-tural
21	Ediyamvayal	Kalpetta	Kabani	LTR	11°36' 36"	76°0' 0"	Domestic	Nil	0.77	3.27	16	11.77	735	Rural
22	Chundale	Kalpetta	Kabani	LTR	11°34'19"	76°03'35"	Domestic	Nil	0.75	2.6	12	5.49	781	Rural
23	Meppady	Kalpetta	Kabini	LTR	11°33'02"	76°07'51"	Domestic	Low	0.72	2.5	14.2	9.23	865	Rural
24	Ambalavayal	Sulthan-bathery	Chali-yar	ALV	11°37'23"	76°13'08"	Domestic	Nil	0.55	2.8	10.5	4.63	889	Agricul-tural

Sl No	Location	Block / Mandal	Sub Basin	Geology	Latitude	Longitude	Well use	Surface Water Influence	MP	Dia	TD	WL (Jan-2020)	Elevation of Ground Level	Land Use
25	Sulthanbathery	Sulthanbathery	Kabani	LTR	11°39'45"	76°15'24"	Domestic	Nil	0.90	3	18	13.69	885	Urban
26	Panamaram	Manantha-vady	Kabani	ALV	11°43'36"	76°04'29"	Domestic	Nil	0.80	2.7	12	6.13	726	Agricultural
27	Kellur	Manantha-vady	Kabani	LTR	11°44'53"	76°01'09"	Domestic	Nil	0.80	2.7	18.5	12.1	764	Rural
28	Tharuvana	Manantha-vady	Kabani	LTR	11°44'22"	75°58'44"	Domestic	Nil	0.85	3.1	22	15.74	770	Agricultural
29	Korome	Manantha-vady	Kabani	LTR	11°44'34"	75°52'38"	Domestic	Nil	0.80	2.4	11.6	6.79	738	Rural
30	Periya	Manantha-vady	Kabani	LTR	11°49'57"	75°52'37"	Domestic	Nil	0.70	2.4	12.5	7.37	735	Agricultural
31	Lakkidi	Kalpetta	Kabani	ALV	11°31'02"	76°01'20"	Domestic	Nil	0.95	2.2	6.4	1.32	755	Rural
32	Manantha-vady	Manantha-vady	Kabani	LTR	11°48'02"	76°00'15"	Domestic	Nil	0.95	2.7	12.8	6.1	750	Urban
33	Kartikulam	Manantha-vady	Kabani	ALV	11°50'48"	76°03'49"	Domestic	Nil	0.75	2.5	13.4	8.03	785	Rural
34	Thirunelly	Manantha-vady	Kabani	ALV	11°54'29"	75°59'39"	Domestic	Low	0.55	3.2	30	23.24	780	Agricultural
35	Padinharetha-ra	Kalpetta	Kabani	LTR	11°40'59"	76°01'07"	Domestic	Nil	0.75	2.4	15.6	9.82	744	Rural
36	Pozhuthana	Kalpetta	Kabani	ALV	11°35'07"	76°01'07"	Domestic	Nil	0.90	2.2	12.7	7.22	732	Rural

Sl No	Location	Block / Mandal	Sub Basin	Geology	Latitude	Longitude	Well use	Surface Water Influence	MP	Dia	TD	WL (Jan-2020)	Elevation of Ground Level	Land Use
37	Madakkimala	Kalpetta	Kabani	ALV	11°39'44"	76°05'07"	Domestic	Low	0.85	2.1	9.8	4.45	737	Agricultural
38	Meenangadi	Sulthanbathery	Kabani	ALV	11°39'36"	76°09'45"	Domestic	Nil	0.80	2.8	20.9	14.56	767	Urban
39	Vaduvanchal	Kalpetta	Chaliyar	LTR	11°33'16"	76°13'30"	Domestic	Nil	0.70	2.7	22	14.34	878	Rural
40	Chulliyode	Sulthanbathery	Chaliyar	ALV	11°36'01"	76°15'40"	Domestic	Nil	0.85	2.6	15.7	8.42	884	Agricultural

ANNEXURE-III Details of Exploratory wells drilled by CGWB in the study area

Sl. No	Location	Latitude	Longitude	Year of con-struction	Depth drilled (mbgl)	Major li-thology en-countered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL	Discharge	Draw down (m)	T	S	EC	Cl ppm
	Lakkidi	11 31 20	76 1 20	1993-94	200	Granite gneiss	21.7	177.3-179.3		1	NA			130	5.7
2	Vaduvanchal	11 32 53	76 13 49		60	Granite gneiss	21.8	Nil	7.95	0.33		NA		NA	NA
3	Kunnampetta	11 34 25	76 5 55		124	Hornblende gneiss	12.6	15.6-17.6,39-40,74.6-75.6,122.4-124.4	1.95	6					
4	Kalpetta	11 35 45	76 5 50	1993-94	200.00,	Granite gneiss	21	30.9-31.9, 149.9-150.9	2.6	0.33	NA				
5	Ambalavayal	11 36 25	76 13 45		200	Granite gneiss	5.8		NA	dry					
6	Koliyadi	11 37 54	76 16 41	1993-94	200	Granite gneiss	11.5	75.5-76.5	0.3	0.4	NA			240	
7	Minangadi	11 39 45	76 9 45		200	Granite gneiss	15	15.6-17.6, 100-101	8.1	1					
8	Sultan Battery	11 39 55	76 16 30		200	Hornblende gneiss	26.5	30.9-31.9, 149.9-150.9	8.39	2.17					
9	Valavayal	11 41 50	76 11 50		190.5	Granite gneiss	7.6		5.41	8					

Sl. No	Location	Latitude	Longitude	Year of construction	Depth drilled (mbgl)	Major lithology encountered	Depth to bed rock (casing depth)	Fracture zones with yield lpm	SWL	Discharge	Draw down (m)	T	S	EC	Cl ppm
10	Panamaram	11 44 10	76 4 20		200	Hornblende gneiss	16.7	43-44, 54-56, 97-98, 113-115	5.5	2.5					
11	Niraval puzha	11 44 20	75 51 35		200	Charnockite	16	102-103, 107-108, 195-196,198-199	5.56	1.5					
12	Ullissery	11 45 15	76 1 40		83.8	Granite gneiss	13.7	16-17, 66-67	1.02	5					
13	Pulpally	11 47 15	76 10 46	1993-94	200	Granite gneiss	13.6	Jul-14	14	0.5	NA			320	9.9
14	Mananthavady	11 47 15	76 0 15		200	Hornblende gneiss	23.8	44-45, 49-50,141-142	9.325	10.17					
15	Thalapuzha	11 50 25	75 56 45		171.5	Granite gneiss	15.4	16.6,27.80, 41,81.70, 126, 170	1.67	2.92					
16	Kartikulam	11 50 50	76 3 56		200	Gabbro& Diorite	29.1	Nil	NA	dry					
17	Tholpetti	11 56 35	76 3 35		120		23.3	24, 33, 39, 71, 77,95, 101, 110	10.98	11	11				

ANNEXURE-IV : Layer parameters of GTEM conducted in Wayanad District.

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
1	Pookode	1	11.535344	76.028414	52	211	967	0.6	3.9	17.4	59.0	21.2	Kalpetta	Wayanad
2		2	11.535344	76.028414	54	212	966	0.8	3.7	17.6	66.2	21.3	Kalpetta	Wayanad
3		3	11.535344	76.028414	55	215	964	0.3	5.2	16.3	70.1	21.5	Kalpetta	Wayanad
4	Kalpetta	1	11.621785	76.087708	136	1290	82369	14.2	4.8	13.3	90.6	18.1	Kalpetta	Wayanad
5		2	11.621785	76.087708	220	1248	80325	8.3	5.6	12.6	86.5	18.2	Kalpetta	Wayanad
6		3	11.621785	76.087708	330	1815	80558	31.8	3.1	15.1	82.2	18.2	Kalpetta	Wayanad
7		4	11.621785	76.087708	186	1451	80530	39.3	2.9	15.5	86.7	18.3	Kalpetta	Wayanad
8	Varambetta	1	11.690566	75.95715	56	173	1923	2.4	2.3	11.9	187.0	14.2	Kalpetta	Wayanad
9		2	11.690566	75.95715	37	143	1158	4.4	2.1	12.3	158.6	14.5	Kalpetta	Wayanad
10		3	11.690566	75.95715	28	155	1386	3.9	3.0	10.9	148.0	13.9	Kalpetta	Wayanad
11	Pinangode	1	11.619277	76.030471	297	44	4904	0.3	2.8	11.5	56.5	14.3	Kalpetta	Wayanad
12		2	11.619277	76.030471	246	49	4977	0.5	3.2	11.2	34.5	14.4	Kalpetta	Wayanad
13		3	11.619277	76.030471	227	46	4966	0.6	3.2	11.0	26.4	14.2	Kalpetta	Wayanad
14		4	11.619277	76.030471	Not Interpretable								Kalpetta	Wayanad
15	Kaniyambet-ta	1	11.699817	76.08352	358	101	2041	0.1	3.5	12.4	35.6	15.9	Panamaram	Wayanad

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
16		2	11.699817	76.08352	454	92	2035	0.3	3.2	12.4	63.2	15.5	Panamaram	Wayanad
17		3	11.699817	76.08352	Not Interpretable								Panamaram	Wayanad
18		4	11.699817	76.08352	358	99	2040	0.1	3.8	12.1	15.7	15.9	Panamaram	Wayanad
19	Valavayal	1	11.708028	76.188001	24	58	180	0.5	3.2	5.5	43.6	8.7	Panamaram	Wayanad
20		2	11.708028	76.188001	26	57	173	0.4	3.2	5.4	35.9	8.6	Panamaram	Wayanad
21		3	11.708028	76.188001	26	65	173	0.3	3.2	5.5	24.8	8.7	Panamaram	Wayanad
22		4	11.708028	76.188001	26	54	164	0.4	3.9	4.8	22.0	8.7	Panamaram	Wayanad
23		5	11.708028	76.188001	24	47	160	0.5	3.2	5.7	24.9	8.9	Panamaram	Wayanad
24	Perikalloor	1	11.860753	76.151296	311	17	1695	0.1	3.3	23.8	22.2	27.2	Panamaram	Wayanad
25		2	11.860753	76.151296	389	14	1695	0.0	3.3	23.9	13.8	27.3	Panamaram	Wayanad
26		3	11.860753	76.151296	287	20	1700	0.1	3.1	24.2	26.6	27.3	Panamaram	Wayanad
27		4	11.860753	76.151296	287	24	1696	0.2	3.2	24.4	43.5	27.6	Panamaram	Wayanad
28	Pulpally	1	11.791095	76.167248	141	426	1850	9.4	5.7	8.2	110.1	13.9	Panamaram	Wayanad
29		2	11.791095	76.167248	151	449	2241	5.7	7.1	6.7	141.5	13.8	Panamaram	Wayanad
30		3	11.791095	76.167248	140	352	1913	21.6	6.1	7.8	123.0	13.9	Panamaram	Wayanad
31		4	11.791095	76.167248	131	294	2153	53.0	6.0	7.7	117.8	13.7	Panamaram	Wayanad
32	Irulam	1	11.750485	76.199136	142	13	2338	0.3	2.9	14.8	61.5	17.7	Panamaram	Wayanad
33		2	11.750485	76.199136	76	15	322	4.9	3.1	14.6	79.9	17.7	Panamaram	Wayanad
34		3	11.750485	76.199136	71	13	346	0.5	2.8	15.2	80.5	18.0	Panamaram	Wayanad
35		4	11.750485	76.199136	69	10	379	0.3	3.1	14.2	66.6	17.3	Panamaram	Wayanad

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
36	Nadavayal	1	11.738646	76.118766	345	60	2437	0.7	4.5	9.9	56.4	14.4	Panamaram	Wayanad
37		2	11.738646	76.118766	379	60	2230	0.8	4.6	10.0	54.6	14.5	Panamaram	Wayanad
38		3	11.738646	76.118766	363	55	2332	0.6	4.9	9.2	48.1	14.1	Panamaram	Wayanad
39		4	11.738646	76.118766	350	57	2500	0.5	4.7	9.6	44.5	14.2	Panamaram	Wayanad
40	Noolpuzha	1	11.666768	76.31757	381	129	3997	1.1	2.6	7.8	79.0	10.4	Sulthan Bathery	Wayanad
41		2	11.666768	76.31757	296	126	3990	0.4	2.4	7.6	78.5	10.0	Sulthan Bathery	Wayanad
42		3	11.666768	76.31757	443	129	4000	0.3	3.0	7.0	72.6	10.0	Sulthan Bathery	Wayanad
43		4	11.666768	76.31757	449	117	3960	0.3	3.5	7.2	65.6	10.7	Sulthan Bathery	Wayanad
44	CC Vakery	1	11.685172	76.207354	153	31	1515	0.1	2.7	6.5	59.3	9.2	Sulthan Bathery	Wayanad
45		2	11.685172	76.207354	143	32	1508	0.2	2.6	6.3	63.8	8.9	Sulthan Bathery	Wayanad
46		3	11.685172	76.207354	Not Interpretable							0.0	Sulthan Bathery	Wayanad
47		4	11.685172	76.207354	Not Interpretable							0.0	Sulthan Bathery	Wayanad
48	Thomattuchal	1	11.569764	76.219401	191	29	1552	0.2	2.8	9.3	79.8	12.1	Sulthan Bathery	Wayanad
49		2	11.569764	76.219401	324	35	1506	0.2	2.5	10.0	85.4	12.5	Sulthan Bathery	Wayanad

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
50		3	11.569764	76.219401	199	19	1493	0.3	2.7	9.4	112.8	12.2	Sulthan Bathery	Wayanad
51		4	11.569764	76.219401	242	31	1737	0.5	2.5	9.8	99.5	12.3	Sulthan Bathery	Wayanad
52	Meenangadi	1	11.661239	76.163268	504	24	1431	0.3	4.1	10.9	133.4	15.0	Sulthan Bathery	Wayanad
53		2	11.661239	76.163268	450	24	1289	0.2	4.2	11.1	156.0	15.3	Sulthan Bathery	Wayanad
54		3	11.661239	76.163268	427	29	1282	0.1	4.4	11.0	136.1	15.4	Sulthan Bathery	Wayanad
55		4	11.661239	76.163268	418	34	1307	0.1	4.3	10.9	135.2	15.1	Sulthan Bathery	Wayanad
56	Sulthan Bathery	1	11.667392	76.271959	586	16	3404	0.3	20.2	6.6	91.6	26.8	Sulthan Bathery	Wayanad
57		2	11.667392	76.271959	804	13	3734	0.1	20.2	5.7	63.7	25.8	Sulthan Bathery	Wayanad
58		3	11.667392	76.271959	597	35	3838	0.7	13.7	12.4	87.6	26.1	Sulthan Bathery	Wayanad
59		4	11.667392	76.271959	400	18	5122	0.1	19.1	7.2	49.0	26.3	Sulthan Bathery	Wayanad
60	Cheeral	1	11.609614	76.31464	43	491	5763	2.0	2.7	4.5	123.2	7.2	Sulthan Bathery	Wayanad
61		2	11.609614	76.31464	42	417	6412	5.9	2.3	5.0	136.1	7.3	Sulthan Bathery	Wayanad

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
62		3	11.609614	76.31464	40	383	6135	6.1	2.1	5.0	125.6	7.2	Sulthan Bathery	Wayanad
63		4	11.609614	76.31464	54	414	6742	7.6	2.2	5.1	128.8	7.2	Sulthan Bathery	Wayanad
64		5	11.609614	76.31464	55	306	5747	9.8	2.4	4.9	146.8	7.2	Sulthan Bathery	Wayanad
65	Kidangad	1	11.733727	76.244499	21	52	296	0.3	3.0	15.0	67.0	17.9	Sulthan Bathery	Wayanad
66		2	11.733727	76.244499	20	66	296	0.5	2.4	15.6	71.9	17.9	Sulthan Bathery	Wayanad
67		3	11.733727	76.244499	21	63	321	0.2	2.4	15.7	74.9	18.1	Sulthan Bathery	Wayanad
68		4	11.733727	76.244499	Not Interpretable								Sulthan Bathery	Wayanad
69	Odapallam	1	11.696318	76.286839	64	19288	1	0.0	13.5	10.1	7.9	13.5	Sulthan Bathery	Wayanad
70		2	11.696318	76.286839	65	19285	1	0.0	13.9	10.2	7.7	13.9	Sulthan Bathery	Wayanad
71		3	11.696318	76.286839	79	19316	13	0.0	13.9	7.8	28.2	13.9	Sulthan Bathery	Wayanad
72		4	11.696318	76.286839	69	19277	7	0.0	14.0	9.5	18.4	14.0	Sulthan Bathery	Wayanad
73	Muthanga	1	11.677732	76.376785	280	46	1530	0.3	3.9	10.2	86.8	14.1	Sulthan Bathery	Wayanad

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
74		2	11.677732	76.376785	315	45	1528	0.3	4.4	9.8	127.0	14.2	Sulthan Bathery	Wayanad
75		3	11.677732	76.376785	Not Interpretable								Sulthan Bathery	Wayanad
76		4	11.677732	76.376785	Not Interpretable								Sulthan Bathery	Wayanad
77	Ambalavayal	1	11.621808	76.213971	151	56	488	7.4	1.5	5.0	85.8	6.5	Sulthan Bathery	Wayanad
78		2	11.621808	76.213971	146	60	502	8.5	1.5	5.1	90.0	6.6	Sulthan Bathery	Wayanad
79		3	11.621808	76.213971	Not Interpretable								Sulthan Bathery	Wayanad
80		4	11.621808	76.213971	174	56	499	4.4	1.5	4.9	99.3	6.4	Sulthan Bathery	Wayanad
81	Nenmeni	1	11.628861	76.276992	Not Interpretable								Sulthan Bathery	Wayanad
82		2	11.628861	76.276992	22	99	881	15.8	4.7	6.7	155.1	11.3	Sulthan Bathery	Wayanad
83		3	11.628861	76.276992	30	84	226	1.2	1.9	9.5	175.2	11.3	Sulthan Bathery	Wayanad
84		4	11.628861	76.276992	27	90	729	6.5	4.8	6.5	282.6	11.4	Sulthan Bathery	Wayanad
85	Chulliyode	1	11.595977	76.259603	Not Interpretable								Sulthan Bathery	Wayanad

S.No	Location	TEM No	Lat	Long	Layer Parameters							D to M	Block	District
					ρ1	ρ2	ρ3	ρ4	h1	h2	h3			
86		2	11.595977	76.259603	Not Interpretable								Sulthan Bathery	Wayanad
87		3	11.595977	76.259603	Not Interpretable								Sulthan Bathery	Wayanad
88		4	11.595977	76.259603	Not Interpretable								Sulthan Bathery	Wayanad

ANNEXURE-V Details of Springs

Sl. No	Location	Block	Land use around the spring	App. RL, mamsl	Perenniality	Summer discharge, lpm	Water quality	No of persons using	Type of use	Storage structure	Future possibility
1	Kambalakkad	Kalpetta	Paddy/ Banana	700	Perennial	2	Not good	100	Irrigation, Washing	No	To continue the system
2	Amba (Chennaikavala)	Kalpetta	Cardamom / Pepper	700	Perennial	8	Potable	100	Drinking, Washing	Storage Tank	To continue the system
3	42 Manantha-wady- Koothu-parambu Road (Varayal)	Mananthavady	Paddy/Coffee Pepper	750	Perennial	180	Potable	200	Irrigation, Drinking	No	Can be developed
4	Kaniyaram	Mananthavady	No	700	Perennial	2	Potable	100	Drinking	No	To continue the system
5	Achur Plantation IV group	Kalpetta	Cardamom, Pepper	700	Perennial	60	Potable	300	Irrigation, Drinking	Storage Tank	Can be developed
6	50 Acre, Pozhuthana (Sugandhagiri Cardamom Board)	Kalpetta	Cardamom, Pepper	700	Perennial	19	Potable	125	Irrigation, Drinking	Storage Tank	Can be developed
7	Puthur Vayal (Kottapadi)	Kalpetta	Coffee	950	Perennial	5	Potable	10	Irrigation, Washing	Storage Tank	To continue the system
8	Arunagiri-Vythiri	Kalpetta	Forest	800	Perennial	20	Potable	500	Irrigation, Drinking	No	Can be developed

Sl. No	Location	Block	Land use around the spring	App. RL, mamsl	Perenniality	Summer discharge, lpm	Water quality	No of persons using	Type of use	Storage structure	Future possibility
9	Kuppumchal	Mananthavady	Paddy, Banana, Areca nut	700	Perennial	3	Potable	300	Irrigation, Drinking	No	To continue the system
10	Suritambath Tribal colony	Kalpetta	Paddy	700	Perennial	3	Potable	500	Irrigation, Drinking	No	To continue the system
11	Kalyanamandiram Estate	Kalpetta	Coffee, Estate	700	Perennial	30	Potable	500	Irrigation, Drinking	Storage Tank	To continue the system
12	Valiyambadichira-Kalpetta	Kalpetta	Coffee, Paddy	750	Perennial	60	Potable	500	Irrigation, Drinking	Storage Tank	Can be developed
13	Kunhakode-Vythiri (Ravindra Estate)	Kalpetta	Paddy, Coffee Pepper	700	Perennial	20	Not good	2000	Irrigation, washing	Storage Tank	Can be developed
14	Chelode-Vythiri	Kalpetta	Coffee	750	Perennial	1	Potable	150	Irrigation, Drinking	No	To continue the system
15	Pathil Manantha-wady	Mananthavady	Paddy, Banana	700	Perennial	3	Potable	100	Irrigation, Drinking	No	To continue the system
16	Tavinjal Bhagavati Estate	Mananthavady	Tea	750	Perennial	120	Potable	600	Irrigation, Drinking	Storage Tank	Can be developed
17	Tavinjal	Mananthavady	Tea	700	Perennial	120	Potable	250	Irrigation, Drinking	No	Can be developed
18	Chanthanthodu-	Mananthavady	Tea, Paddy,	750	Perennial	30	Potable	50	Irrigation,	No	Can be

Sl. No	Location	Block	Land use around the spring	App. RL, mamsl	Perenniality	Summer discharge, lpm	Water quality	No of persons using	Type of use	Storage structure	Future possibility
	Periya		Coconut						Drinking		developed
19	Periya 34	Mananthavady	Paddy, Banana	700	Perennial	10	Potable	500	Irrigation, Drinking	No	Can be developed
20	Thalapuzha Kutti Plantation	Sultan Bathery	Paddy, Banana	800	Perennial	20	Potable	2500	Irrigation, Drinking	No	Can be developed
21	Beenachi Estate I	Sultan Bathery	Coffee	750	Perennial	4	Not good	12	Washing	Storage Tank	To continue the system
22	Beenachi Estate II (Arivayal)	Sultan Bathery	Coffee	750	Perennial	5	Potable	20	Drinking	Storage Tank	To continue the system
23	Beenachi Estate Block 24	Sultan Bathery	Coffee	800	Perennial	2	Not good	20	Irrigation, Drinking	Storage Tank	To continue the system
24	Annimoola	Mananthavady	Pepper, Paddy	750	Perennial	4	Potable	50	Irrigation, Drinking	No	To continue the system

ANNEXURE-VI Details of soil infiltration tests carried out in the study area

Location : Sulthan Bathery						
Location details: In the premises of Sarvajana High School, Sulthan Bathery, Nr VHSC Block						
Block : Sulthan Bathery						
Date:11/03/2021						
Coordinates: 76.26 & 11.66						
Soil Type : Clayey Soil						
Soil Nature:Weathered soil						
TIME (MIN)	TIME DIFFER-ENCE (MIN)	INI-TIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMULA-TIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	20.5	0	0	0.00	
1	1	20.5	20	0.5	0.50	30
2	1	20.5	19.8	0.7	0.20	12
3	1	20.5	19.7	0.8	0.10	6
4	1	20.5	19.6	0.9	0.10	6
5	1	20.5	19.5	1	0.10	6
6	1	20.5	19.4	1.1	0.10	6
7	1	20.5	19.2	1.3	0.20	12
8	1	20.5	19	1.5	0.20	12
9	1	20.5	18.8	1.7	0.20	12
10	1	20.5	18.6	1.9	0.20	12
12	2	20.5	18	2.5	0.30	18
14	2	20.5	17.9	2.6	0.05	3
16	2	20.5	17.7	2.8	0.10	6
18	2	20.5	17.5	3	0.10	6
20	2	20.5	17.2	3.3	0.15	9
25	5	20.5	16.5	4	0.14	8.4
30	5	20.5	16	4.5	0.10	6
35	5	20.5	15.5	5	0.10	6
40	10	20.5	15	5.5	0.05	3
50	10	20.5	14.2	6.3	0.08	4.8
60	10	20.5	13.3	7.2	0.09	5.4
70	10	20.5	12.5	8	0.08	4.8
80	10	20.5	11.6	8.9	0.09	5.4
90	10	20.5	11	9.5	0.06	3.6
100	10	20.5	10.4	10.1	0.06	3.6
110	10	20.5	9.6	10.9	0.08	4.8
120	10	20.5	9	11.5	0.06	3.6
130	10	20.5	8.4	12.1	0.06	3.6
140	10	20.5	7.8	12.7	0.06	3.6

Location : Chulliyod						
Location: In the parking slot of Safas Grand Party Hall						
Block : Sulthan Bathery						
Date:11/03/2021						
Coordinates: 76.25 & 11.60						
Soil Type : Sandy Loam						
Soil Nature:Weathered						
TIME (MIN)	TIME DIF-FER-ENCE (MIN)	INI-TIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMULA-TIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	20.8	0	0	0.00	
1	1	20.8	19.8	0.5	1.00	60
2	1	20.8	19.7	0.6	0.10	6
3	1	20.8	19.3	1	0.40	24
4	1	20.8	19	1.3	0.30	18
5	1	20.8	18.6	1.7	0.40	24
6	1	20.8	18	2.3	0.60	36
7	1	20.8	17.8	2.5	0.20	12
8	1	20.8	17	3.3	0.80	48
9	1	20.8	16.4	3.9	0.60	36
10	1	20.8	16.2	4.1	0.20	12
12	2	20.8	15.6	4.7	0.30	18
14	2	20.8	15	5.3	0.30	18
16	2	20.8	14.7	5.6	0.15	9
18	2	20.8	13.9	6.4	0.40	24
20	2	20.8	13.3	7	0.30	18
25	5	20.8	12.3	8	0.20	12
30	5	20.8	11	9.3	0.26	15.6
35	5	20.8	10	10.3	0.20	12
40	10	20.8	9	11.3	0.10	6
50	10	20.8	7	13.3	0.20	12
60	10	20.8	5.4	14.9	0.16	9.6
70	10	20.8	3.8	16.5	0.16	9.6
		11				
80	10	11	10	17.5	0.10	6
90	10	11	8.4	19.1	0.16	9.6
100	10	11	6.4	21.1	0.20	12
110	10	11	4.8	22.7	0.16	9.6
120	10	11	4	24	0.08	4.8
130	10	11	3.5	24	0.05	3
140	10	11	3	24	0.05	3

Location: Pulpally						
Location: In the premises of SNDP Yogam Pulpally Branch on Kappiset Road						
Block : Panamaram						
Date:12/03/2021						
Coordinates: 76.17 & 11.79						
Soil Type : Clayey Soil						
Soil Nature:Weathered soil						
TIME (MIN)	TIME DIFFER-ENCE (MIN)	INITIAL HEAD (CM)	FALL IN HEAD (CM)	CUM-MULA-TIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	20.5	0	0	0.00	
1	1	20.5	20	0.5	0.50	30
2	1	20.5	19.8	0.7	0.20	12
3	1	20.5	19.7	0.8	0.10	6
4	1	20.5	19.6	0.9	0.10	6
5	1	20.5	19.5	1	0.10	6
6	1	20.5	19.4	1.1	0.10	6
7	1	20.5	19.4	1.1	0.00	0
8	1	20.5	19.2	1.3	0.20	12
9	1	20.5	19	1.5	0.20	12
10	1	20.5	18.8	1.7	0.20	12
12	2	20.5	18.6	1.9	0.10	6
14	2	20.5	18.2	2.3	0.20	12
16	2	20.5	18	2.5	0.10	6
18	2	20.5	18	2.5	0.00	0
20	2	20.5	17.8	2.7	0.10	6
25	5	20.5	17.2	3.3	0.12	7.2
30	5	20.5	16.8	3.7	0.08	4.8
35	5	20.5	16	4.5	0.16	9.6
40	10	20.5	15.5	5	0.05	3
50	10	20.5	14.7	5.8	0.08	4.8
60	10	20.5	14	6.5	0.07	4.2
70	10	20.5	13.4	7.1	0.06	3.6
80	10	20.5	12.9	7.6	0.05	3
90	10	20.5	12.1	8.4	0.08	4.8
100	10	20.5	11.6	8.9	0.05	3
110	10	20.5	11	9.5	0.06	3.6
120	10	20.5	10.7	9.8	0.03	1.8
130	10	20.5	10.2	10.3	0.05	3

140	10	20.5	10	10.5	0.02	1.2
150	10	20.5	9.5	11	0.05	3
160	10	20.5	9	11.5	0.05	3
170	10	20.5	8.5	12	0.05	3

Location:Thetti Road (Thetrode)						
Location: In front of Forest Staff Quarters at road diversion to Tholpetty						
Block : Mananthavady						
Date:12/03/2021						
Coordinates: 76.06 & 11.96						
Soil Type : Clayey Soil						
TIME (MIN)	TIME DIF-FER-ENCE (MIN)	INI-TIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMULA-TIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	22.7	0	0	0.00	
1	1	22.7	22.5	0.5	0.20	12
2	1	22.7	22	1	0.50	30
3	1	22.7	21.6	1.4	0.40	24
4	1	22.7	21.3	1.7	0.30	18
5	1	22.7	21	2	0.30	18
6	1	22.7	20.5	2.5	0.50	30
7	1	22.7	20.4	2.6	0.10	6
8	1	22.7	20.2	2.8	0.20	12
9	1	22.7	19.8	3.2	0.40	24
10	1	22.7	19.7	3.3	0.10	6
12	2	22.7	19.3	3.7	0.20	12
14	2	22.7	18.9	4.1	0.20	12
16	2	22.7	18.7	4.3	0.10	6
18	2	22.7	18.5	4.5	0.10	6
20	2	22.7	18.4	4.6	0.05	3
25	5	22.7	18	5	0.08	4.8
30	5	22.7	17.7	5.3	0.06	3.6
35	5	22.7	17.1	5.9	0.12	7.2
40	10	22.7	16.5	6.5	0.06	3.6
50	10	22.7	16	7	0.05	3
60	10	22.7	15.7	7.3	0.03	1.8
70	10	22.7	15	8	0.07	4.2
80	10	22.7	14.7	8.3	0.03	1.8
90	10	22.7	14.3	8.7	0.04	2.4
100	10	22.7	14	9	0.03	1.8

110	10	22.7	13.7	9.3	0.03	1.8
120	10	22.7	13.3	9.7	0.04	2.4
130	10	22.7	13.2	9.8	0.01	0.6
140	10	22.7	13	10	0.02	1.2

Location:Meenangadi						
Location: In front of house owned by Mr Md Salim,Edayakkaparambil House, near Panchayat Play Ground						
Block : Sulthan Bathery						
Date:13/03/2021						
Coordinates: 76.16 & 11.60						
Soil Type : Red lateritic soil						
TIME (MIN)	TIME DIFFERENCE (MIN)	INITIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMULATIVE DEPTH (CM)	INFILTRATION RATE (CM/MINUTE)	INFILTRATION RATE (CM/HOUR)
	0	22.8	0	0	0.00	
1	1	22.8	22	0.5	0.80	48
2	1	22.8	21.6	0.9	0.40	24
3	1	22.8	21	1.5	0.60	36
4	1	22.8	20	2.5	1.00	60
5	1	22.8	19.5	3	0.50	30
6	1	22.8	19	3.5	0.50	30
7	1	22.8	18.9	3.6	0.10	6
8	1	22.8	18.5	4	0.40	24
9	1	22.8	18	4.5	0.50	30
10	1	22.8	17.5	5	0.50	30
12	2	22.8	16.7	5.8	0.40	24
14	2	22.8	16	6.5	0.35	21
16	2	22.8	15.3	7.2	0.35	21
18	2	22.8	14.6	7.9	0.35	21
20	2	22.8	14.3	8.2	0.15	9
25	5	22.8	13.2	9.3	0.22	13.2
		22.3	22.3			
30	5	22.3	20.9	10.7	0.28	16.8
35	5	22.3	19.5	12.1	0.28	16.8
40	10	22.3	17	14.6	0.25	15
50	10	22.3	15	16.6	0.20	12
60	10	22.3	13	18.6	0.20	12
70	10	22.3	11.8	19.8	0.12	7.2
		22.5	22.5	19.8		

80	10	22.5	20.3	22	0.22	13.2
90	10	22.5	18.3	24	0.20	12
100	10	22.5	16.5	25.8	0.18	10.8
110	10	22.5	15	27.3	0.15	9
120	10	22.5	13.7	28.6	0.13	7.8
130	10	22.5	12.5	29.8	0.12	7.2
140	10	22.5	11.5	30.8	0.10	6
150	10	22.5	10.5	31.8	0.10	6
160	10	22.5	9.5	32.8	0.10	6

Location:Kalpetta						
Location: In the premises of Saraladevi Memorial LP School, Kalpette						
Block : Kalpetta						
Date:13/03/2021						
Coordinates: 76.108 & 11.62						
Soil Type : Clay loam						
TIME (MIN)	TIME DIF-FER-ENCE (MIN)	INITIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMU-LATIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	23.5	0	0	0.00	
1	1	23.5	22.7	0.5	0.80	48
2	1	23.5	22.5	0.7	0.20	12
3	1	23.5	22.5	0.7	0.00	0
4	1	23.5	22.5	0.7	0.00	0
5	1	23.5	22.5	0.7	0.00	0
6	1	23.5	22.5	0.7	0.00	0
7	1	23.5	22.5	0.7	0.00	0
8	1	23.5	22.5	0.7	0.00	0
9	1	23.5	22.5	0.7	0.00	0
10	1	23.5	22.5	0.7	0.00	0
12	2	23.5	22.5	0.7	0.00	0
14	2	23.5	22.5	0.7	0.00	0
16	2	23.5	22.5	0.7	0.00	0
18	2	23.5	22.5	0.7	0.00	0
20	2	23.5	22.5	0.7	0.00	0
25	5	23.5	22.5	0.7	0.00	0
30	5	23.5	22.4	0.8	0.02	1.2
35	5	23.5	22.3	0.9	0.02	1.2
40	10	23.5	22.2	1	0.01	0.6
50	10	23.5	22.1	1.1	0.01	0.6

60	10	23.5	22	1.2	0.01	0.6
70	10	23.5	21.9	1.3	0.01	0.6
80	10	23.5	21.8	1.4	0.01	0.6
90	10	23.5	21.8	1.4	0.00	0
100	10	23.5	21.8	1.4	0.00	0
110	10	23.5	21.7	1.5	0.01	0.6
120	10	23.5	21.6	1.6	0.01	0.6

Location:Padinjarathara						
Location: In the premises of Govt HSS Padinjarathara						
Block : Kalpetta						
Date:14/03/2021						
Coordinates: 75.97 & 11.68						
Soil Type : Gravelly sand						
TIME (MIN)	TIME DIFFER-ENCE (MIN)	INITIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMU-LATIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	21.5	0	0	0.00	
1	1	21.5	19.5	0.5	2.00	120
2	1	21.5	16.5	3.5	3.00	180
3	1	21.5	14.5	5.5	2.00	120
4	1	21.5	13.5	6.5	1.00	60
5	1	21.5	12	8	1.50	90
6	1	21.5	10	10	2.00	120
		22	22	10		
7	1	22	20.5	11.5	1.50	90
8	1	22	19.6	12.4	0.90	54
9	1	22	18	14	1.60	96
10	1	22	15	17	3.00	180
12	2	22	12	20	1.50	90
		23.3	23.3	20		
14	2	22.8	21	22.3	1.15	69
16	2	22.8	19.5	23.8	0.75	45
18	2	22.8	17.7	25.6	0.90	54
20	2	22.8	12	31.3	2.85	171
25	5	22.8	7	36.3	1.00	60
		22	22	36.3		
30	5	22.3	16	42.3	1.20	72
35	5	22.3	10	48.3	1.20	72
		23	23	48.3		
40	5	23	17	54.3	1.20	72

45	5	23	11.3	60	1.14	68.4
50	5	23	7	64.3	0.86	51.6
		23	23	64.3		
55	5	23	18.1	69.2	0.98	58.8
60	5	23	9.5	77.8	1.72	103.2
		23	23	77.8		
70	10	23	14	86.8	0.90	54
		23	23	86.8		
80	10	23	15	94.8	0.80	48
90	10	23	8.5	101.3	0.65	39
		23	23	101.3		
100	10	23	15.5	108.8	0.75	45
110	10	23	8	116.3	0.75	45
		23	23	116.3		
120	10	23	17	122.3	0.60	36
130	10	23	11	128.3	0.60	36
140	10	23	5	134.3	0.60	36

Location: Thalapuzha						
Location: In the private plot of Mr CK Beeran, Chirayangad,Thalapuzha						
Block : Mananthavady						
Date:14/03/2021						
Coordinates: 75.94 & 11.84						
Soil Type : Clayey sand						
TIME (MIN)	TIME DIFFER-ENCE (MIN)	INI-TIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMULA-TIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	22	0	0	0.00	
1	1	22	21.4	0.5	0.60	36
2	1	22	21.4	0.5	0.00	0
3	1	22	21.3	0.6	0.10	6
4	1	22	21.2	0.7	0.10	6
5	1	22	21	0.9	0.20	12
6	1	22	21	0.9	0.00	0
7	1	22	20.9	1	0.10	6
8	1	22	20.9	1	0.00	0
9	1	22	20.8	1.1	0.10	6
10	1	22	20.7	1.2	0.10	6
12	2	22	20.6	1.3	0.05	3
14	2	22	20.6	1.3	0.00	0

16	2	22	20.5	1.4	0.05	3
18	2	22	20.5	1.4	0.00	0
20	2	22	20.4	1.5	0.05	3
25	5	22	20	1.9	0.08	4.8
30	5	22	19.9	2	0.02	1.2
35	5	22	19.7	2.2	0.04	2.4
40	10	22	19.5	2.4	0.02	1.2
50	10	22	19.3	2.6	0.02	1.2
60	10	22	18.9	3	0.04	2.4
70	10	22	18.5	3.4	0.04	2.4
80	10	22	18.1	3.8	0.04	2.4
90	10	22	17.7	4.2	0.04	2.4
100	10	22	17.6	4.3	0.01	0.6
110	10	22	17.6	4.3	0.00	0
120	10	22	17.5	4.4	0.01	0.6
130	10	22	17.3	4.6	0.02	1.2
140	10	22	17.1	4.8	0.02	1.2
150	10	22	16.9	5	0.02	1.2

Location: Meppadi						
Location: In the premises of Arrapetta Tea Estate Staff Club, Meppadi						
Block : Kalpetta						
Date:15/03/2021						
Coordinates: 76.15 & 11.54						
Soil Type : Clayey sand						
TIME (MIN)	TIME DIF-FER-ENCE (MIN)	INI-TIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMULA-TIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	22.5	0	0	0.00	
1	1	22.5	22.3	0.5	0.20	12
2	1	22.5	22	0.8	0.30	18
3	1	22.5	21.8	1	0.20	12
4	1	22.5	21.4	1.4	0.40	24
5	1	22.5	21	1.8	0.40	24
6	1	22.5	20.9	1.9	0.10	6
7	1	22.5	20.8	2	0.10	6
8	1	22.5	20.8	2	0.00	0
9	1	22.5	20.7	2.1	0.10	6
10	1	22.5	20.6	2.2	0.10	6
12	2	22.5	20.5	2.3	0.05	3

14	2	22.5	20.4	2.4	0.05	3
16	2	22.5	20.2	2.6	0.10	6
18	2	22.5	20	2.8	0.10	6
20	2	22.5	20	2.8	0.00	0
25	5	22.5	19.8	3	0.04	2.4
30	5	22.5	19.8	3.1	0.02	1.2
35	5	22.5	19.7	3.2	0.02	1.2
40	5	22.5	19.6	3.4	0.04	2.4
45	5	22.5	19.4	3.5	0.02	1.2
50	5	22.5	19.3	3.7	0.04	2.4
55	5	22.5	19.1	3.8	0.02	1.2
60	5	22.5	19	4.2	0.08	4.8
70	10	22.5	18.6	5	0.08	4.8
80	10	22.5	19.4	6.2	0.12	7.2
90	10	22.5	18.2	6.4	0.02	1.2
100	10	22.5	18	6.6	0.02	1.2
110	10	22.5	17.8	6.8	0.02	1.2
120	10	22.5	17.6	7	0.02	1.2

Location: Lakkidi (Vythiri)						
Location: In the premises of Govt LP School, Lakkidi, Vythiri						
Block : Kalpetta						
Date:15/03/2021						
Coordinates: 76.02 & 11.52						
Soil Type : Clayey sand						
TIME (MIN)	TIME DIFFER-ENCE (MIN)	INITIAL HEAD (CM)	FALL IN HEAD (CM)	CUMMU-LATIVE DEPTH (CM)	INFILTRA-TION RATE (CM/MINUTE)	INFILTRA-TION RATE (CM/HOUR)
	0	22.8	0	0	0.00	
1	1	22.8	22	0.5	0.80	48
2	1	22.8	21.5	1	0.50	30
3	1	22.8	21.3	1.2	0.20	12
4	1	22.8	21	1.5	0.30	18
5	1	22.8	20.6	1.9	0.40	24
6	1	22.8	20	2.5	0.60	36
7	1	22.8	20	2.5	0.00	0
8	1	22.8	19.8	2.7	0.20	12
9	1	22.8	19.6	2.9	0.20	12
10	1	22.8	19.4	3.1	0.20	12
12	2	22.8	19	3.5	0.20	12
14	2	22.8	18.9	3.6	0.05	3

16	2	22.8	18.6	3.9	0.15	9
18	2	22.8	18.3	4.2	0.15	9
20	2	22.8	18	4.5	0.15	9
25	5	22.8	17.5	5	0.10	6
30	5	22.8	17	6.3	0.26	15.6
35	5	22.8	16.2	6.9	0.12	7.2
40	5	22.8	15.6	7.5	0.12	7.2
45	5	22.8	15	8	0.10	6
50	5	22.8	14.5	8.5	0.10	6
55	5	22.8	14	9	0.10	6
60	5	22.8	13.5	9.5	0.10	6
70	10	22.8	13	10.5	0.10	6
80	10	22.8	12	11.5	0.10	6
90	10	22.8	11	12.5	0.10	6
100	10	22.8	10	13	0.05	3
110	10	22.8	9.5	13.5	0.05	3
120	10	22.8	9	13.7	0.02	1.2
130	130	22.8	8.5	13.9	0.02	1.2