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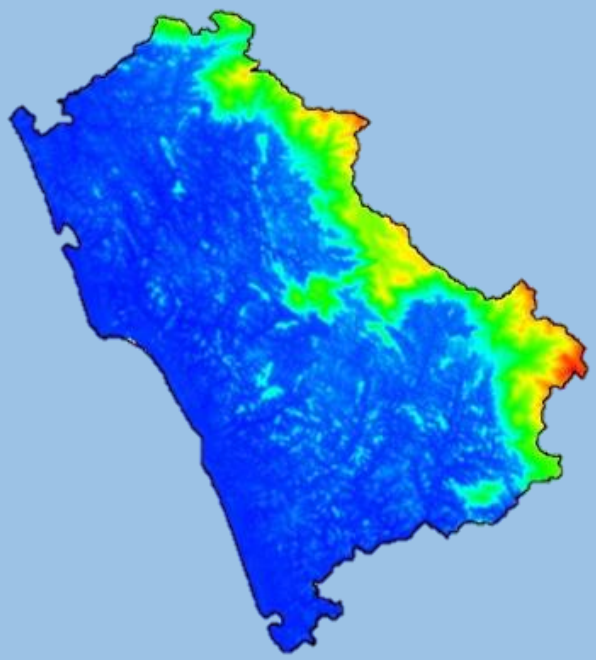
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
भारत सरकार

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

AQUIFER MAPPING AND MANAGEMENT PLAN OF KOZHIKODE DISTRICT, KERALA

(AAP 2021-22)



ROOPESH G. KRISHNAN
SCIENTIST – C

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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 Kozhikode district.

The report titled "Aquifer Mapping and Management plan, Kozhikode 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 Kozhikode district.

This document has been compiled by Shri. Roopesh G Krishnan, Scientist C under the overall guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer and Smt. Rani V.R, Scientist D &Team leader. The painstaking efforts of field hydrogeologist Shri. Roopesh G Krishnan in carrying out the aquifer mapping and preparation of this report is well appreciated. Smt. Anu V, Scientist B deserves appreciation for the meticulous scrutiny of this report before printing. I am thankful to the Shri. Sunil Kumar, Chairman and Dr.A. Subburaj, Member 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 ,CWRDM, 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.Pranab Jyoti Nath, IAS and is subject to approval of National Level Expert Committee (NLEC). 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 Kozhikode district.

Thiruvananthapuram,
November 2022

(T.S.Anitha Shyam)
Regional Director

AQUIFER MAPPING AND MANAGEMENT PLAN OF KOZHIKODE DISTRICT, KERALA

(AAP- 2021-22)

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1.0 INTRODUCTION

The Central Ground Water Board, Kerala Region has carried out aquifer mapping under National Aquifer Mapping Programme (NAQUIM) in Kozhikode district, during the annual action plan of 2015-16 (Sedimentary Area) and 2021-22 (Hard rock Area). A better understanding of the hydrogeological processes that control the distribution and availability of groundwater in the weathered and fracture zones of the aquifer system is imperative for sustainable resource management. The sustainable development and management of aquifer systems involves development of strategies for balancing the water draft and water availability. Integrated studies on various aspects of the groundwater regime have been carried out to know the disposition and productivity of the aquifer systems.

As per the Report of the Working Group on Sustainable Ground Water Management, "It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help to integrate ground water availability with ground water accessibility and quality aspects.

1.1 Objectives

The primary objective of the Aquifer Mapping can be summed up as "Know your Aquifer, Manage your Aquifer". Demystify the Science behind the storage and movement of groundwater to empower the stakeholders in groundwater management is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project.

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

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

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

1.2 Scope of the study

The important aspect of the aquifer mapping programme is the analysis of the large volume of data already generated during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale in GIS plat form.

Water resources development in many parts of Kerala state poses a key issue in the management strategy. The sustainable aspect of the water resources in this state necessitates the need for a better water resources management. Thus, the aquifer mapping of Kozhikode

district envisages the ground water requirement and its utilisation, thereby an environmentally sustainable management plan is proposed/finalised.

1.3 Approach and Methodology

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behaviour of ground water levels and status of ground water development in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps, and generation of data for filling data gaps and preparation of various thematic maps depicting hydrogeology, hydrology, geomorphology, water quality etc. and cross-sections, panel diagrams and elevation models depicting aquifer geometry and dispositions on 1: 50,000 scale Aquifer Maps and preparation of 2-D and 3-D models.

Based on the above studies, management strategies have been evolved for augmentation of groundwater through water conservation and formulated plans for sustainable management of the resource.

1.4 Basic Geography and Administration

Geographically, Kozhikode district are located between North latitude of 11°07'37.63", & 11°48'16.60" and East longitude of 75° 32' 13.42" & 76° 08' 47.62" comprising an geographical ambience of 2,344 Sq.Km in which aquifer mappable area is 1,407 Sq.Km. where hard rock area is covered by 1,212 Sq.Km. (mainly of the highlands and a good portion of midland area); sedimentary area is 195 Sq.Km. (covers the low land/coastal area). The remaining area of 937 sq.km is falls in hilly (Slope >20%) and forest area in the eastern part which is non mappable.

The study area falls in the Survey of India Topographic sheets 58A/02, 03; 49M/9,10,11,13,1415 &16 (1: 50,000 scale). The district has 4 taluks viz. Koyilandy, Kozhikode, Thamarassery and Vadakara; one corporation (Kozhikode); 7 municipalities viz. Feroke, Koduvally, Koyilandy, Mukkam, Payyoli, Ramanattukara & Vadakara; 12 blocks viz. Balussery, Chelannur, Koduvally, Kozhikode, Kunnamanagalam, Kunnumal, Melady, panthalayani, Perambra, Thodannur, Tuneri & Vadakara and comprising 70-gram panchayaths and 118 revenue villages. The administrative division map of the study area is given in Fig. 1.1. The study area is bordering on the north by Kannur and east by Wayanad District, south by Malappuram District and on the west by the Lakshadweep Sea.

Population of the district is 30,89,543 as per 2011 census. The population density is 1318 persons per sq km. Population of the district is distributed more around urban and coastal areas and along the major transportation corridor, probably due to social and occupational reasons. The population details as per census 2011 of the study area are given in Table 1.1. The study area is well connected by good networks of roads and rails and with other parts of the state. The National Highways (NH 66: Kozhikode to Mumbai; NH 766: Kozhikode to Banglore; NH 966: Kozhikode to Palakkad) passess through the district. The State Highways viz., SH-29, SH-54, SH-68 & SH-34 is connected in all major cities in the area. The Trivandrum-Mangalore-Mumbai railway passes through the district. The Karipur airport, which operates several international flights to Gulf countries, is situated at Karipur in Malappuram district, which is very close to Kozhikode city. The political history of Kozhikode is a story of treacherous and ill-conceived conspiracies hatched by the Western powers. The district houses Kappad beach (16 km north of Kozhikode) which is famous as the place where Vasco Da Gama, the leader of a trade mission from Portugal, first landed in Kerala in May 1498.

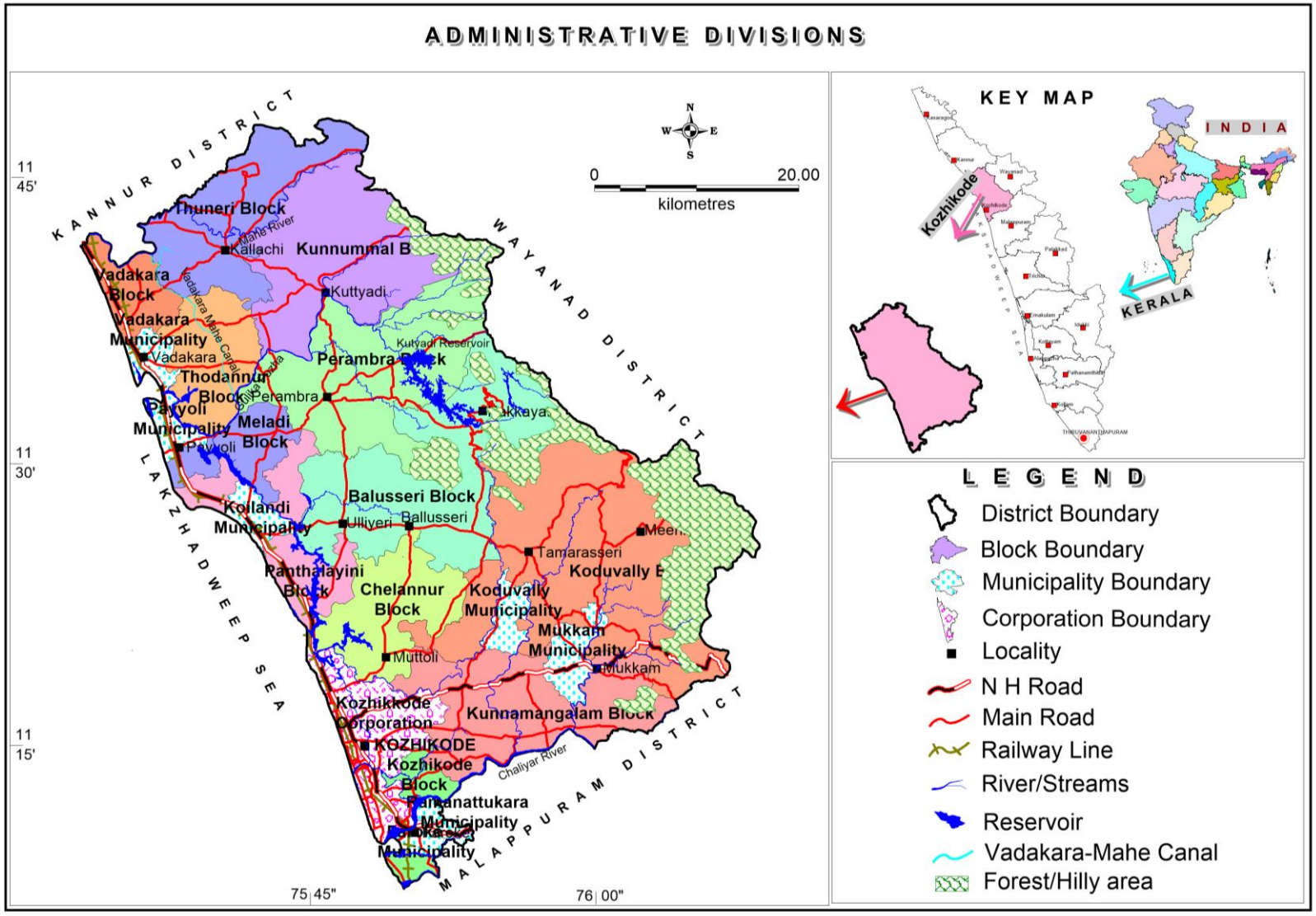


Figure 1.1 Administrative divisions of the study area

Table 1.1: Population data of the study area

Block	Area (sq.km)	Population as on 2011	Rural Population	Urban Population
Ballussery	278.53	217236	117038	100198
Chelannur	138.66	187345	47078	140267
Koduvally	390.48	272064	272064	0
Kozhikode	163.51	173183	0	173183
Kunnamangalam	338.94	306964	92241	214723
Kunnummal	262.62	157926	139895	18031
Melady	84.27	84272	23576	60696
Panthalayani	98.55	138371	75339	63032
Perambra	275.02	211544	122773	88771
Thodannur	96.77	136354	14429	121925
Tuneri	143.98	186114	57070	129044
Vadakara	72.68	131576	28650	102926
Municipality		336154	0	336154
Kozhikode Corporation		550440	0	550440
Total	**2344**	**3089543**	**990153**	**2099390**

Source: Census of India, 2011

1.5 Data availability

During the Aquifer mapping, existing data of CGWB on groundwater exploration, water level, water quality, geophysical logging and groundwater resource data have been collected and compiled. In addition to this, Borewell data, Water quality, Water level data and Groundwater exploration data have been collected from Ground Water Department, Kozhikode. Cropping pattern, Minor irrigation data and Soil data has been collected from Agricultural and Soil Conservation Department. Thematic layers such as geology (GSI), soils, land use/land cover, geomorphology, etc., from various State Government agencies were collected, compiled, and validated for the study.

1.6 Data adequacy

Exploratory well data is available for 2 wells in sedimentary terrain and 23 wells in hard rock terrain drilled by CGWB. Water level monitoring data for 146 Observation wells and Water Quality monitoring data for 40 Observation wells is available. Land use, Cropping and irrigation data has been collected from Agriculture department. After plotting the available historical data on 1:50,000 scale, data gaps were identified and data generation process was taken up in those gap areas to complete the Aquifer map on the desired resolution of 1:50,000 scale.

1.7 Data gap analysis & Data generation

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

The study area has 96 monitoring wells of CGWB and 50 monitoring wells of State departments, tapping the phreatic aquifer system. An Additional 26 key wells for hydrogeological studies and and 7 wells for water quality monitoring were established in the phreatic aquifer. Nine bore wells drilled in data gap area, down to a depth of 200m to know the litholog, aquifer properties and water quality of confined aquifer system.. The details of data gap analysis and data generation is given in Table 1.2.

Table 1.2: Data gap analysis and data generation

#	Data Requirement	Data available with State /central govt. Agencies	Data available with CGWB	Total	Additional Data generated
1	Ground water level data	17 DW 33 Pz	81 DW 15 PZ	146	26
2	Groundwater quality Data	17	23 DW 27 BW 2 TW	69	7
3	Borehole Lithology Data	-	24 BW+2 TW	26	7
4	Geophysical Data (VES+ TEM)	-	50 VES	50	15 VES 75 TEM
5	Pumping Test (EW/DW)	-	8	8	7
6	Land use and Land Cover	Kerala State Land Use Board & NRSC			
7	Drainage	Kerala State Land Use Board			
8	Geology	Geological Survey of India			
9	Soil	National Bureau of Soil Survey (NBSS)			
10	Rainfall / Meteorological data	Indian Meteorological Department / Irrigation Design and Research Board (IDRB)			

1.8 Climate and Rainfall

Kozhikode district falls under wet type of climate. The climate of the area is divided into four seasons – Summer, Southwest Tropical Monsoon period, Northeast Tropical Monsoon period and Winter. The district receives heavy rainfall during the month of June. The southwest monsoon from June to September contributes nearly 80.40%. The agricultural activity of the district depends on the onset of SW tropical monsoon. The annual rainfall ranges from 2260.1 to 4255.1 mm at different places of the district with an average of 3570 mm. The high rainfall areas in the district are at Kakkayam dam site and Kakkayam Power House. It has been noticed that rainfall displays an increasing trend towards northeastern areas of the district. The annual average rainfall of Kozhikode district from 2014 to 2021 is given in Table 1.3.

Table 1.3: Monthly Rainfall of Kozhikode district (2014-2021)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2014	0	0	0.8	90.7	254.4	508.2	1068.2	879	318.3	331.6	105.6	9.3	**3566.1**
2015	0	0	35.3	90.5	189.5	667.9	780.5	256.9	290.1	351.3	199.3	8.8	**2870.1**
2016	0	0	32.4	5.7	260.1	916.4	604.2	268.5	98.2	42.5	8.9	23.2	**2260.1**
2017	7.7	0.1	21.3	68.1	251.8	822.5	662.9	544.6	491.6	216.2	46.1	9.1	**3142**
2018	7.7	0.9	36.9	79	563	1081.8	1037.4	836	29.3	267.8	57.5	35	**4032.3**
2019	0	0	1.9	43.4	42.9	634.2	959	1407.8	468.8	568.5	100.3	28.3	**4255.1**
2020	0	0	1.9	96	241.8	1166.7	735.9	676.1	861.7	236.4	91.8	50.4	**4158.7**
2021	164.9	5.6	1.9	46.2	589.8	527.9	820.6	537.4	402.6	625.4	373.7	33.8	**4129.8**

Source: IMD, Trivandrum

Meteorological parameters

Temperature: The maximum temperature ranges from 29.0 to 33.6^{0}C whereas the minimum from 22.8 to 26.4^{0}C. The average annual maximum temperature is 31.5^{0}C and minimum temperature 24.3^{0}C. Generally, March and April months are the hottest and December and January months are the coldest.

Relative Humidity: The humidity is higher during monsoon months from June to September and is around 85%.

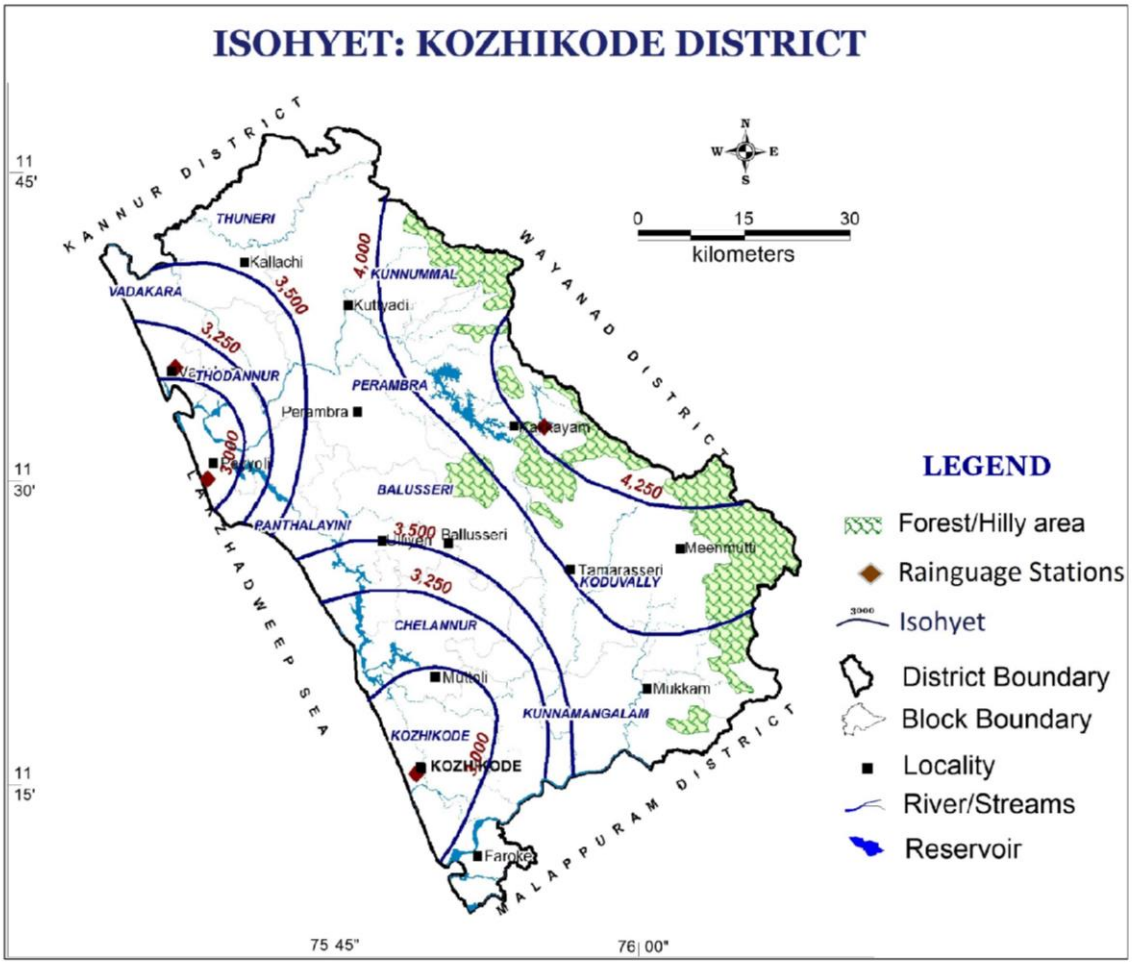


Figure 1.2 Isohyet map of Kozhikode District

Wind Velocity: The wind speed ranges from 8.1 to 12.6 km/h. The maximum wind speed is more during April amd the minimum is during November.

Potential evapotranspiration (PET): the annual PET is 1505.7 mm. the monthly Pet ranges from 92.9 to 170.2 mm. The PET is less than the rainfall from May to November indicating water surplus for recharge into ground water regime.

1.9 Physiography

Physiographically, the district can be divided into three distinct units – (1) lowland region (coastal plains), (2) midland region and (3) highland region. The various landforms seen in the area are carved out by a combination of fluvial and denudational activities.

The physiographic divisions of Kozhikode district are lowland (<7.5 m amsl), midland (7.5 to 75 m amsl) and highland (above 75 m amsl). The highest elevation of the district is 1935 m amsl at Nilamala in northeastern corner of the district.

The lowland extends as a narrow stretch of land lying along the coast from South Kadalundi to North Mahe. The height of the plain is generally less than 7.5 m amsl. The plain is interrupted by steep laterite cliffs and rock outcrops. The lowland forms 5.13 % of the total area of the district.

1.10 Geomorphology

Geomorphologically, the landforms in the study area are carved out by a combination of fluvial and denudational activities which can be grouped into erosional and depositional landforms. The various geomorphic units seen in the area are alluvial plain, flood plain, valley fill, linear ridge, hillcrest, sloping terrain and rocky slope (scarp face). The flood plain and valley fill are the major fluvial landforms whereas moderately sloping terrain, highly sloping terrain, rocky slope (scarp face), linear ridge and hillcrest are major denudational landform units. The fluvial and gently sloping terrains are promising zones of groundwater. Denudation landforms are unproductive zones as in the case of occurrence of ground water (Figure 1.4).

The midland area lies at a height between 7.5 and 75 m amsl. It may be further classified into low rolling terrain and moderately undulating terrain. The low rolling terrain has a slope of less than 15%. It consists of rolling laterite hills surrounded by valleys. The valleys are filled with flood plain alluvium and red loamy soil. The moderately undulating terrain covering large area of the district has a slope between 15 and 25%. In addition to the agricultural crops of paddy and coconut, cash crops like rubber and arecanut are also cultivated. Lower plateau (lateritic) is the most predominant geomorphic unit in the Kozhikode district followed by Valley fills and is good repository of ground water resources.

Area with elevation above 75 m amsl is called the highland and mainly found in the eastern part of the district. The high land is characterized by steep slopes and barren rocks which is prone to landslides and land slips. Digital Elevation Model of the Kozhikode district is given in Figure 1.3; in which three sections W-E, NW-SE & NNW-SSE were prepared to understand the physiography and the relief of the area. The section -2 NW-SE clearly indicates the undulting nature of the terrain with isolated hillocks and comes in the midland topography. The predominant geomorphic units exists in this area is the piedmont zones and these are also the good repository of gound water.

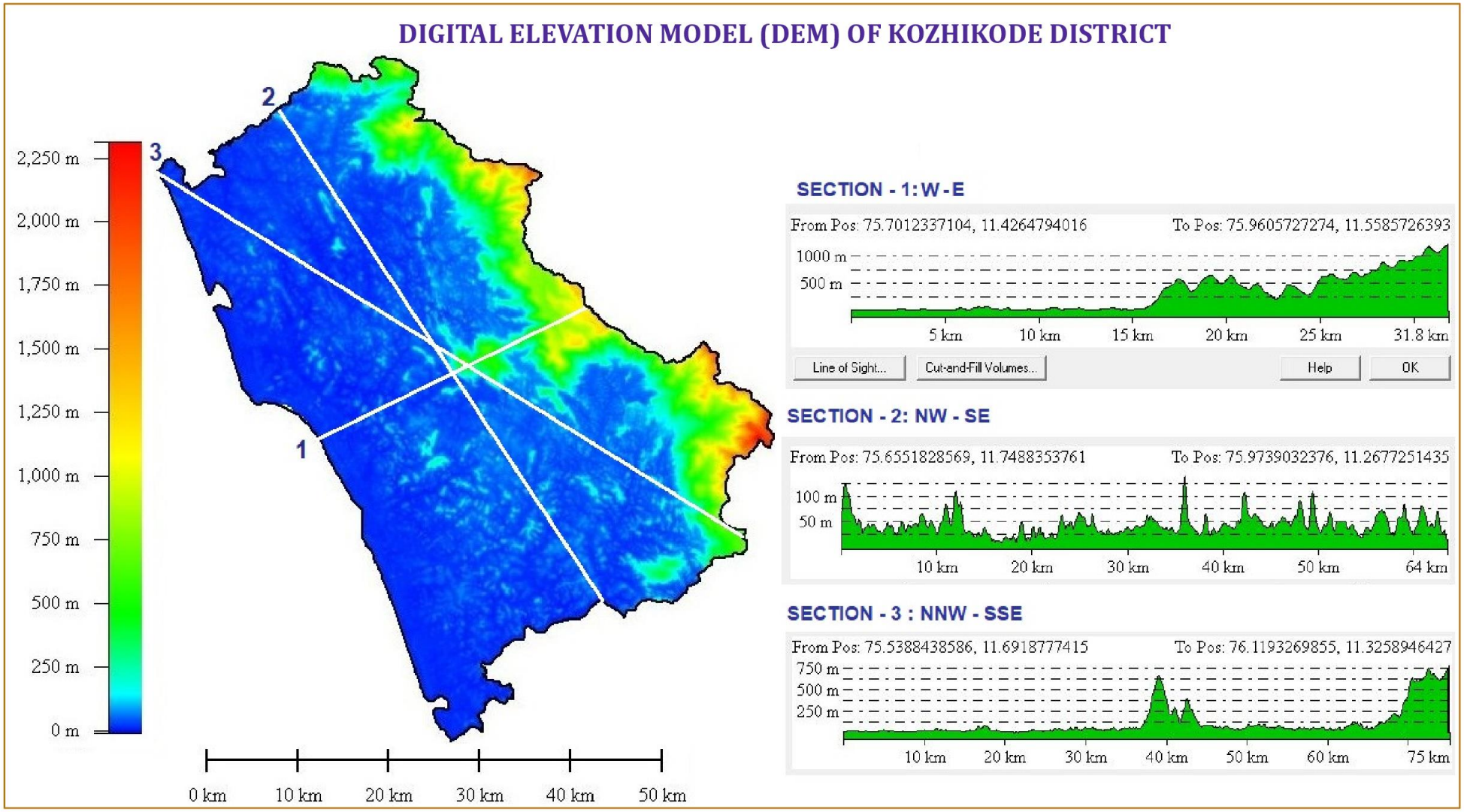


Figure 1.3 Digital Elevation Model (DEM) of Kozhikode district

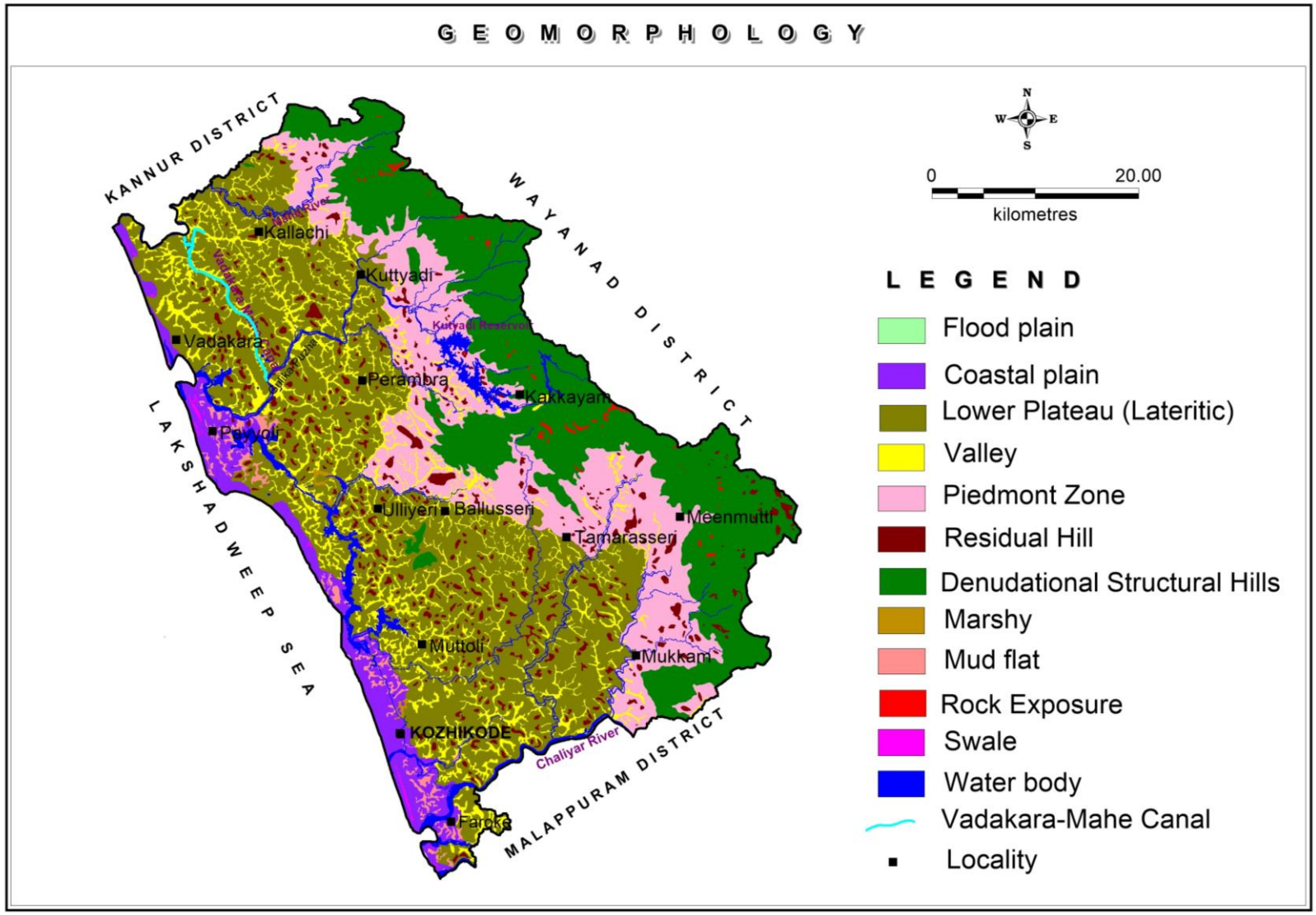


Figure 1.4 Geomorphology of the study area

1.11 Land Use/ land cover

Land use/ land cover pattern of an area is very important from groundwater point of view since the availability and development of this resource depends upon the surface run-off and infiltration which are controlled to a large extent by the type of land use/ land cover. In this district, out of a total geographical area of 2344 Sq.Km., about 18% is forest area. The total cropped area is about 1930.37 Sq.Km. and 61 % is the net sown area (1438.63 Sq.Km.). Based on land use, the study area is divided into three units – arable, forest land and waste land. The coastal area is thickly populated. Most of the area are under coconut and arecanut plantations. Paddy crops are confined to valleys. Major part of the district is arable land which includes irrigated and unirrigated land. Forest is mostly in the eastern part of the district. Plantation crops like rubber, pepper, cardamom, tea and coffee are grown. The land use / land cover map of Kozhikode district is shown in Figure 1.5. The landuse classification of the district is given in Table 1.4.

Table 1.4: Classification of area based on land utilisation of Kozhikode district

Land Units	Area (Sq.Km)
Forest	413.86
Land put to non-agricultural use	364.79
Barren & uncultivable land	5.54
Land under misc. tree crops	1.69
Cultivable waste	26.56
Fallow other than current fallow	16.63
Current fallow	18.77
Still Water	54.06
Waterlogged Area	5.51
Social Forestry	0.37
Net area sown	1438.63
Area sown more than once	491.75
Total cropped area	1930.37

Source: Agricultural Statistics 2020-21

From the pie chart (Figure 1.6) agricultural land is the predominant land use in the study area, which was main control on the occurrence and availability of groundwater. But while formulating the ground water management plans the cultivable waste land should be considered. (*Source: National resource databank 2017-18, Kerala State*)

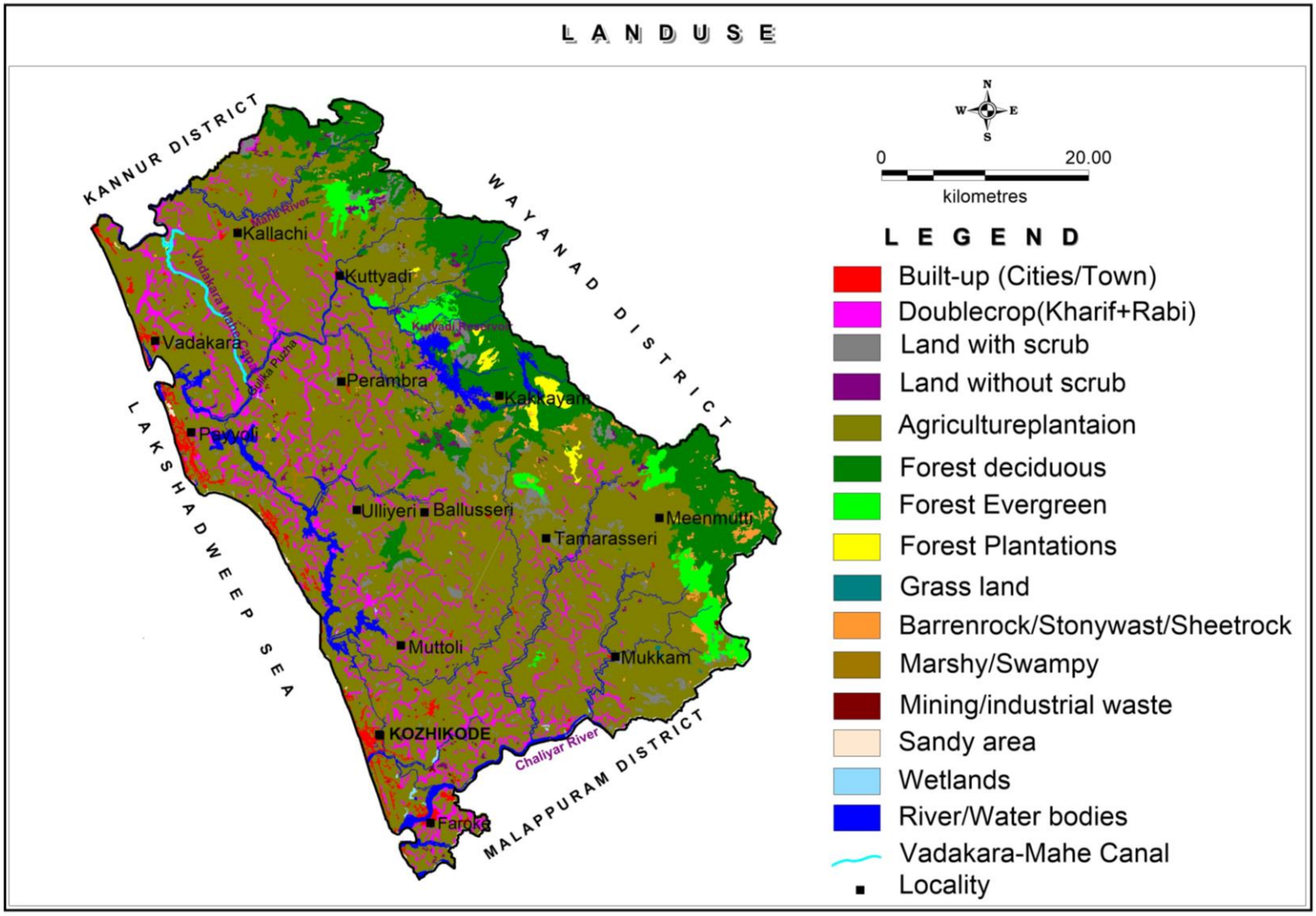


Figure 1.5 Land use /land cover map of Kozhikode district

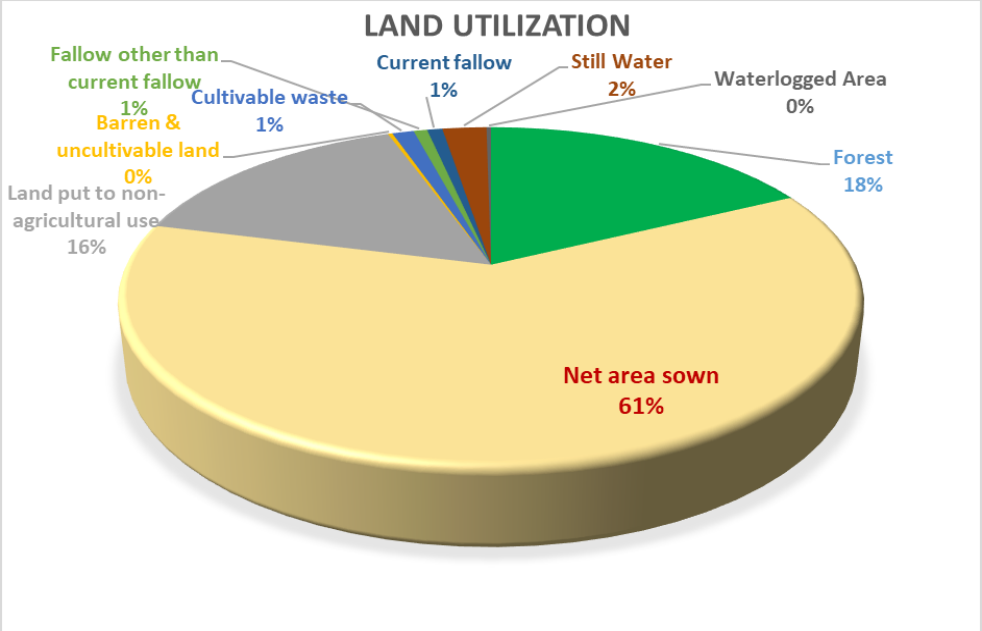


Figure 1.6 Pie chart showing the distribution of land use units in study area

1.12 Soil

Based on soil type, the soils are classified as alluvial soil, lateritic soil, and forest loam. The Alluvial soil is seen mostly along the coastal plain and valley. They are coastal alluvial and river alluvial soils. They are moderately to excessively drain and are of sandy to clayey textures. Majority of the area under riverine alluvium was once occupied by paddy cultivation. But 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 soils of the district are classified into sandy, laterite and hilly or forest soil. The sandy soil occurs all along the western side of Vadakara, Quilandi and Kozhikode taluk. The laterite soil occurs east of the sandy track which covers in major part of the district. Based on soil texture, the souils area classified as clay, gravelly clay, gravelly loam and sandy; in which gravelly clay is predominant in the district followed by clay and gravelly loam. Soil map of the study area is shown in Fig1.7.

The lateritic soil is derived from the laterite under tropical climate with alternate wet and dry conditions. It is reddish in colour and is well drained and shows gravelly to clayey texture. They are found mostly along the midland portion of the district. The organic matter in the soil is very less with moderate nitrogen, phosphorous and potash. The pH of soil ranges between 5.5 and 6.5 and texture is clayey loam to silty loam with 5 to 20% coarse fragments. The laterites on high grounds are more compact when compared to the low-lying areas.

The Forest loam shows wide variation with depth and is dark reddish brown to red colour. This soil is well drained and shows loamy to clayey textures. They are rich in organic matter, nitrogen, and humus. Forest loam is formed by weathering of crystalline rocks under forest cover. The pH of the soil ranges between 5.3 and 6.3 and is slightly acidic in nature.

1.13 Hydrology and Drainage

The important rivers in the district are Chaliyar, Kallai, Korapuzha, Kuttiadi and Mahe. Kadalundi River also drains in the southern end of the district.The stream Pooraparamba also drains in the district. The Chaliyar River is a medium river originates at a height of 2066 m amsl in Ilambalari hills of Western Ghats of Gudallur district, Tamil Nadu. The Chaliyar also known as Beypore River, drains into Beypore estuary. It is a sixth order stream with a length of 169 km. At its upper reaches it is formed by Punnurpuzha, Pandiyur, Karimpuzha, Cherupuzha, Kanhirampuzha, Kurumbanpuzha, Vathatpurampuzha and Iruvantipuzha. At its lower reaches near Cheruvannur, it is flowing as a broad river developing inlets. Chaliyar River flows to

Nilambur, Mambad, Edavanna, Areecode and Vazhakkad in Malappuram district and Feroke in Kozhikode district before it joins the Lakshadweep Sea.

The Kuttiadi River originates at a height of 1334 m amsl on the western slopes of Wayanad plateau. The river is also known by the name of Murat River. It has a length of 75 km and flows through Badakara and Quilandy taluks. The river passes through Oorakuzhi, Kuttiyadi, Thiruvalur, Muyipot, Maniyur and Karuvancheri. It flows in northerly direction at first then bends and takes southwesterly direction of flow. At Turaiyur it is joined by the Agalapuzha. Further it takes a "U" turn and flow northwesterly direction as the Murat River developing lagoons and joins the sea at Kottakkal near Badagara. The river is dammed at Kakkayam for the hydroelectric project and the tail end waters of the project are stored at Peruvannamamuzhi for irrigation. The historical Kottakkal fort situated at the mouth of the river.

The Mahe River also known as Mayyazhipuzha originates at a height of 910 m amsl at Vanchimagate hills of Wayanad in Western Ghats and flows in the northeastern corner of the district and forms northern boundary of the district. Near its lower reaches it bends and turns at Kariyad and flow in northwesterly direction and join the sea at Mahe. It has a length of 54Km. This river flows through the villages of Naripettah, Vanimel, Iyyancode, Bhekiyad, Iringannur, Tripangathur, Peringalam, Edachery, Kacheri, Eramala, Kariyad, Olavilam, Kunnumakkara, Azhiyoor and Mahe.

The Kallayi River has a length of 22 km. It originates at Cherukulathur, which is at a height of 45 m amsl and drains through Cherukulathur, Kovur, Olavanna, Manava and Kallai before it reaches the Lakshadweep Sea near Kozhikode. It is connected by man-made Buckingham Canal with the river Chaliyar.

The Korapuzha is a small river with a length of 40 km formed by the confluence of Agalapuzha and Punnurpuzha. It debounches into the Arabian Sea at Elathur. Agalapuzha originates from Kodiyandumala. Pooraparambu is a small stream with a length of 8 km.

The Kadalundi River formed by the union of Olipuzha and Veliyarpuzha has a length of 130 km. It enters the district at near its mouth of flow with only 14 km length in the district.

In the upstream areas of the district the drainage pattern of the rivers is Dendritic to Sub-trellis type. In the lower reaches, the drainage follows the dendritic pattern. The drainage characteristics of the five river basins are given in Table 1.5**.** The drainage map of the study area along with various drainage basins is shown in Figure 1.8.

Table 1.5: Details of catchment area in the NAQUIM area

Basin Name	**Catchment Area (Sq. Km)**		**Percentage of Area**
	Total	**Kozhikode District**	
Chaliyar	2541	631.15	24.84
Kuttiyadi	669.4	669.4	100
Kallayi	87.9	87.9	100
Korapuzha	662.9	662.9	100
Mahe	429.5	282.06	65
Kadalundi	1099	10.99	1
		2344.4	

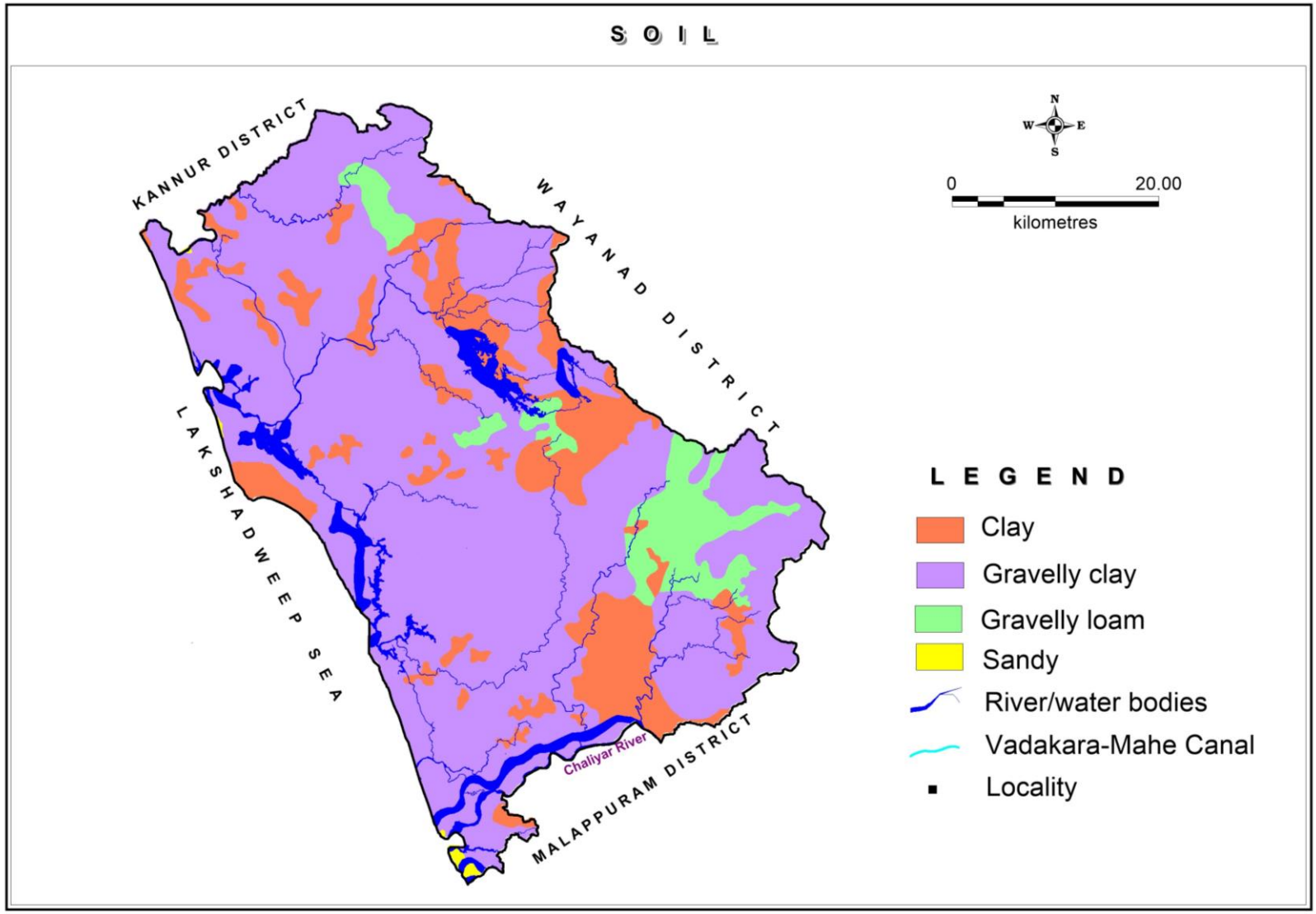


Figure 1.7 Soil map of the study area

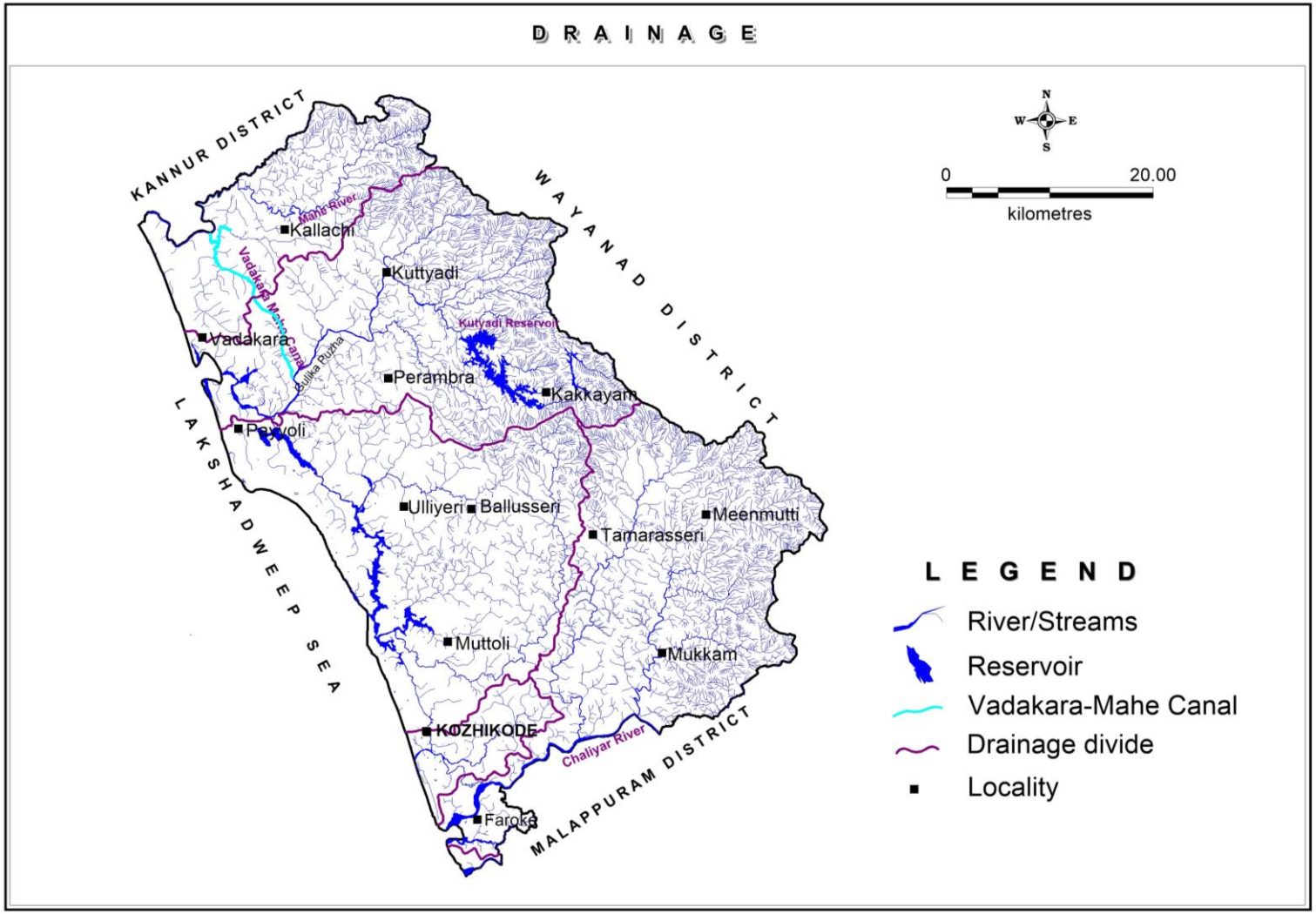


Figure 1.8 Drainage map with River Basins

1.14 Cropping pattern – Agriculture and Irrigation

With diverse agroclimatic conditions brought about by natural physiographic divisions, a wide variety of crops are cultivated in the study area. These include plantation crops like coconut, rubber, arecanut, cashew, pepper; food crops like paddy, tapioca, pulses; fruit crops like banana, mango; and vegetables. The net sown of the district is 1452.18 sq.km with cropping intensity of 134%. Variations in cropping pattern for four decades in Kozhikode district is given in Table 1.6.

Table 1.6: Areas of principal crops in Kozhikode district (ha)

Crops	1981-82	1996-97	2006-07	2016-17	2019-20
Rubber	16311	17349	18880	21930	21930
Coconut	96772	124584	129401	119064	114865
Paddy	11535	8316	4295	1987	2128
Pepper	12948	15578	10652	3755	3422

Source: Agriculture Statistics, 2011-19

From the table, it is seen that paddy cultivation and pepper is decreasing trend from 11535 ha to 2128 ha and 12948 ha to 3422 ha respectively. On the contrary Coconut has been going up steadly from 96772 ha to 114865 ha.

Agriculture is the major occupation of the rural population of the district. Since the density of population is remarkably high there is acute pressure on land for agriculture use. The farming pattern in the district shows coconut farming system prevails in the coastal and mid lands with several inter-crops like pepper, arecanut, nutmeg, tapioca, cocoa, banana, pulses, and oil seeds; plantation crops like Rubber, pepper, cashewnut, tea etc are grown in the elevated areas of the district. The block-wise area under different crops is given in Table 1.7.

There is only one major irrigation project in the district namely Kuttiyadi irrigation project across the Kuttiyadi river. The Kuttiadi Irrigation Project, as its name implies, aims at the harnessing of the water of Kuttiadi River for originally for irrigation purposes only. This project is the third major irrigation project in the Kerala State. The project which started in 1962 was partially commissioned in 1973. The project started functioning in full swing since 1993 when it was completed. Original proposed to irrigate an ayacut area of 14568.70 hectares, in Kozhikode, Koyilandy and Vadakara taluks.

In this project a Masonry dam was built across the Kuttiadi River, with 13 earth Saddle dams for the total length of 1844m having a canal system. The maximum height of the gravity dam above the deepest bed level is 35.36 metres across Kuttiyadi at Peruvannamuzhi. The reservoir has a water-spread area of 1052 hectares and has got a live capacity of 113.44 MM^3 at FRL of 44.41 m for regulating the yield from the catchment below the Kuttiyadi hydel dam and the tail waters of Kuttiyadi power station. The L.B. Main canal is of 40.02 KM in length and RB Main canal is of 34.27 Km in length. Total length of 10 Nos. branch canals is 136.325 Km and the length of distributaries and sub distributaries are 330 Km.

Major crop in the command area were paddy and tapioca. Summer crops like blackgram, peas etc. are grown after the harvest of paddy. Coconut, Jack and Mango are themain fruit –bearing trees grown in the area. Before the implementation of this irrigation project, only one crop of paddy was cultivated in most of the lands due to the lake of irrigation facilities. However, after the implementation of the project, second and third crop of paddy was also made possible. The present condition of the irrigation canals and structures of Kuttyadi project are far from satisfactory.

Table 1.7: Block-wise area under crops (2019-20) for the study area

Name of Block	Paddy	Spices	Arecanut	Tamaring	Nut meg	Fruits	Plantain& Banana	Tubers	Cashew	Vegetables	Coconut	Medicinal leaves	Teak
Kozhikode	16.55	29.85	79.21	9.32	2.3	352.42	83.69	13.18	12.15	70.8	2148.45	1.33	7.69
Chelannur	194.71	160.14	521.09	49.36	23.3	1279.75	278.26	157.09	72.12	177.75	7398.76	3.59	62.12
Kunnamangalam	228.65	201.68	1037.74	56.8	41.86	2097.84	884.12	211.49	81.35	372.76	10820.72	3.04	92.91
Koduvally	128.57	539.17	1908.93	58.26	486.2	2606.24	820.36	543.95	135.47	604.41	14305.35	15.43	190.02
Balussery	234.75	514.76	1444.83	109.06	104.43	2553	511.52	303.69	186.12	466.84	14015.7	10.88	75.08
Perambra	478.16	438.39	967.93	56.76	38.8	1329.49	348.57	175.9	164.29	313.76	11372.84	7.59	60.58
Melady	64.85	79.31	152.2	20.4	2.69	662.05	156.38	34	55.67	145.23	3954	4.27	19.72
Panthalayani	129.85	117.06	247.4	38.6	4.3	768.22	151.74	23.39	69.62	143.11	5753.23	1.49	19.55
Vatakara	19.19	79.41	196.69	22.01	3.46	746.77	155.23	17.46	50.08	104.62	3336.34	5.83	26.79
Thodannur	279.68	222.63	277.32	41.2	5.91	1361.4	274.82	57.42	89.62	207.9	6792.47	5.39	20.85
Thuneri	65.02	447.45	702.15	38.99	9.32	1699.55	329.47	88.76	286.66	278	10244.48	7.5	50.07
Kunnummel	207.4	359.24	998.03	40.21	27.78	1689.12	458.23	184.5	208.59	419.59	10494.32	4.41	100.27
Blocks Total	2047.38	3189.09	8533.52	540.97	750.35	17145.85	4452.39	1810.83	1411.74	3304.77	100636.7	70.75	725.65
Municipality	76.18	220.73	733.86	56.66	21.54	1792.57	556.81	160.97	61.04	272.12	8826.87	6.22	67.09
Corporation	4.47	89.6	467.5	17.05	10.56	907.46	223.75	23.88	11.77	175.87	5401.78	3.21	19.67
District	2128	3499	9735	615	782	19846	5233	1994.94	1485	3751	114865	79	812

Source: Agriculture Statistics, 2019-20

In many places the canals and aqueducts are in conditions of serious leakages. In northern parts of the district like Avala pandy and Velom Ayanchery which are major rice growing tracts, there are instances of inundation of paddy fields due to seepage of water from Kuttyadi canals resulting in even complete crop loss of Mundakan crop when canals are opened in February. So urgent lining works of canals are required. Some proposals are included in this plan to rectify such defects of the canal.

A drinking water project with installed capacity of 174 MLD water, from Kuttiyadi irrigation project reservoir is completed and now 150 MLD of water is drawing from the reservoir to supply water to major parts of Kozhikode district under the JBIC scheme. On request sufficient water is released to Kuttiady River through the Spill way and Canal sluice to reduce the salinity near intake well of Kerala Water Authority at Gulikappuzha pumping station in Velomgramapanchayath for supply of drinking water to Vatakara Municipality and adjoining gramapanchayaths. The Salient features of Kuttiyadi Irrigation project is given below.

Sl.No	Location of Project	Name of River	Catchment area (Sq.Km.)	Maximum Storage (MCM)	Full Reservoir Level (m)	Area Benefitted (Sq.Km.)	
						Net	Gross
1	Kuttiyadi	Kuttiyadi	108.78	120.52	+44.41	175.55	280.80

(*Source: Irrigation department, Kozhikode District*).

The status of command area of the project is given in the Table 1.8

Table 1.8: Status of command area of Kuttiyadi Irrigation Project

Sl. No	Name of Block	Name of Village	Information of Canal Command area in ha.
1	Kozhikode	Kozhikode Corporation	260
2	Kunnamanglam	Kuruvathoor	148
3	Balussery	Naduvannur, Ulliyeri, Balussery a& Kayanna	240
4	Chelannur	Chelannur, Kakkodi, Kakkur, Nanminda & Thalakulathur	1560
5	Perambra	Perambra,Nochad,Koothali,Changaroth, Chakkittipara, Cheruvannur & Maruthonkara	2246
6	Thodannur	Thiruvallur, Maniyur, Villiappally & Ayanchery	1688
7	Thuneri	Puramery, Thuneri and Edacheri	666
8	Kunnumal	Kunnummal, Velom, Nadapuram& Kuttiyadi	1353
9	Vadakara	Eramala, Azhiyur, Chorode, Onchiyam and Vadakara	1255
10	Meladi	Meppayur, Thurayur, Keezhariyur, Thikodi, Payyoli and Arikulam	2507
11	Panthalayani	Chengottukavu, Chemanchery, Atholi ,Koyilandy, Moodadi and Arikulam	2646
Total			**14569**

Source: District irrigation plan, 2018

Besides the major irrigation schemes, the district is irrigated by several minor irrigation schemes, lift irrigation schemes, community irrigation schemes, wells and tanks. The net area irrigated of Kozhikode district (source wise) is given in table 1.9

Table 1.9: Net Area Irrigated (Source wise) of Kozhikode district in hectare

Source		Area irrigated (hectares)
Small Stream (Thodu / Canal)	Government	844.39
	Private	13.96
Ponds	Government	40.3
	Private	325.27
Well	Government	21.32
	Private	1810.28
Borewell/Tubewell		28.19
Lift & Minor Irrigation		103.72
From River & Lake	Pump	80.58
	Other Methods	376.53
Other Sources		334.24

Source: Agricultural Statistics, 2020-21

1.15 Recharge practices

The study area is having ideal sites for implementing ground water conservation structures and rainwater harvesting structures.

Groundwater is being augmented through the recharge structures by departments/ agencies of State such as, Agricultural Department, Coconut Development Board, PWD, Soil Conservation Department and Irrigation department. Recently, Irrigation department is taking up Repair, Renovation and Restoration (RRR) of surface water bodies which will be of immense use in groundwater augmentation in addition to the increase in storage capacity of the tanks.

1.16 Geology

The major part of the district is underlain by crystalline rocks of Archean age forming the southwestern part of the peninsular shield. The crystalline rocks are extensively lateritised with the thickness of laterisation increasing towards the west. The alluvium forms along the coast as narrow band and along the flood plain of rivers. Geological Succession of the Kozhikode District is given in table 1.10 and geology succession of the district is shown in Fig. 1.9.

Crystallines: The major areas of the district are occupied by the crystallines rocks of Charnockite group and Hornblende biotite gneiss of migmatite group. Small area is occupied by granites and garnetiferous biotite gneiss in the eastern hilly areas. The basic dykes of dolerite and gabbro are intruding the country rocks. Charnockites are more prominent in the southern part, southeastern and northeastern part of the district. The Hornblende biotite gneiss is prominent in the central, northern and eastern part of the district. All the rocks have been laterised and the depth of laterisation varies from place to place.

Laterites: Laterite which is seen extensively all along the midland regions covers nearly 60% of the area. It is formed by the residual weathering and leaching of crystalline rock. The laterite seen is highly ferrogenous and cavernous. The zone of lateralization extends down to a depth of 10 to 12 meters. The thickness of lateritic zone is controlled by topography. Laterites grade downwards into lithomargic clay and ultimately to the hard-compact crystalline rock.

Recent Formations: These include beach sand, coastal alluvium, riverine alluvium and valley fill materials. Beach sands are seen as a very narrow strip all along the coast. These are essentially fine to medium grained sands, deposited by the waves and ocean currents. There is a narrow zone of recent alluvium which are seen mostly along the rivers and low-lying areas.
The thickness and extend of Tertiary formations in the district are very limited.

Structure and Tectonics: The crystalline rocks have undergone several phases of deformation resulting in intense folding of the rock units which can be noticed as plunging synform with its fold axis almost NW-SE. The rocks have undergone a series of brittle deformation at the later stage resulting in the formation of a number of lineaments and fractures. The prominent lineament directions are NW-SE, NE-SW and E-W.

Table 1.10 Geological succession of Kozhikode District

ERA	PERIOD	AGE	FORMATION	LITHOLOGY
CENOZOIC	QUATERNARY	Recent	Alluvium	Coastal alluvium, River alluvium and valley fill deposits.
		Sub-Recent	Laterites	Laterites derived from Tertiary Sediments and the Archean crystallines.
	TERTIARY	Oligocene to Eocene	Vaikom Beds	Sands, medium to coarse gravel, clay, and streaks of lignite
Undated			Basic Intrusives	Dolerite & Gabbro
ARCHEAN			Granite	Granite and Granite Gneiss
			Metaultramafite, Meta- Pyroxinites, Garnetiferous biotite gneiss+_ Sillimanite	
			Migmatite Group	Hornblende biotite gneiss, Granite gneisses and Garnet biotite gneiss.
			Charnockite Group	Charnockites, Pyroxene granulites

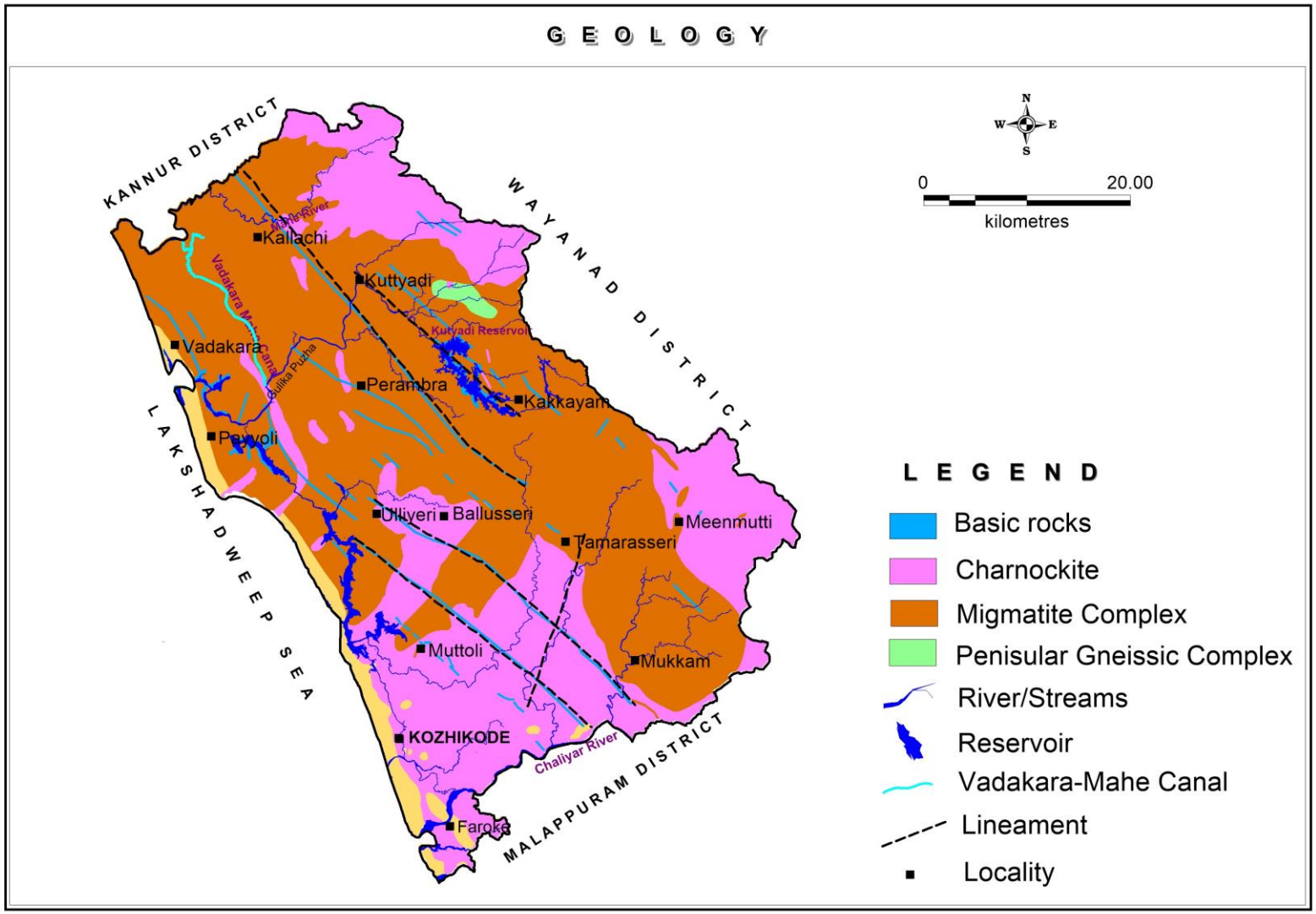


Figure 1.9 Geology map of the area

1.17 Previous work and present status of data

Central Ground Water Board has carried out Ground Water Exploration, Systematic hydrogeological surveys have been carried out by the Scientists of Central Ground Water Board, Kerala Region. During 1980-81. Shri S.V.N.S. Rao carried out Hydrogeological investigations in the tribal areas of Tamarasseri -Kuttiyadi area. Ground water exploration studies were carried out from 1986 onwards. The ground water management studies were carried out by Shri K. Balakrishnan during the year 1998-1999. In addition to the routine work, CGWB has also taken up several short-term investigation studies, exploration activities, pollution studies, geophysical activities in the district. Smt. D. Dayamalar carried out Mapping of waterlogged areas and feasilibility of anti water logging measures in the coastal tract of Kerala in AAP 2000-2001. Smt Sreelatha and N.C Nayak carried out Iron content in shallow aquifer of Kerala during 2001. Sh. K. Ravichandran and Smt. Bindhu J. Viju carried out a study of Arsenic content in ground water of Kerala in 2003. National Aquifer Mapping Programme for the coastal aquifer system of Kozhikode district were carried out by Sh. Vijesh V.K in AAP 2015-2016.

The present status of data shows that in crystallines, 23 borewells drilled up to depth ranging from 114 to 200 m bgl. The prominent lineament directions are NW-SE, NE-SW and E-W. The yield of the well's ranges from negligible to 540 lpm and transmissivity values range from 8.5 to 104 m^2/day. The productive lineaments are NE-SW, N-S and E-W. The quality of water is generally good and potable. In Sedimentary terrain, two tubewells were drilled to a depth of 132 m bgl. Zones were encountered up to 28 mbgl. The yield of tube wells ranges from 120 to 600 lpm. The thickness of alluvium is about 20 m near Vadakara and is absent further north. The width of alluvium is about 3 – 7 km in the district. Laterite is absent except at Meladi where the thickness is about 18 m. Vaikom formation is encountered at Meladi where the thickness is 13 m. The basement encountered is very shallow in the northern part about 15 and 29 m bmsl at Badagara and Meladi respectively.

To get a realistic picture about the groundwater conditions in the study area, Central Ground Water Board has established 96 Ground Water Monitoring Wells which includes 81 dug wells and 15 piezometers tapping various formations. In addition to these monitoring wells, SGWD has established 50 wells in the study area which includes 17 dug wells and 33 piezometers which are monitored monthly. The groundwater monitoring wells established by CGWB are monitored four times a year and for the qualitative analysis, water samples have been collected during premonsoon (April) monitoring.

1.18 Industries and Mineral resources

The major economic mineral in the district is iron ore. Important occurrences are at Cheruppa, Nadungattur, Nanminda, Naduvallur and Alampara. Mercury occurs in the native state as minute globules in laterite, capping the hornblende-biotite gneiss at Murat, southeast of Vadakara. Primary clay (china clay) occurs at several places in the midland region. Large quantity of lime shell is reported from the lower reaches of Beypore, Korappuzha, Murat and Agalapuzha riverbeds. One mining lease is in force for mining of iron ore to M/s General Mining Corporation in Thalakolathur, Atholi villages of Koyilandy taluk in 86.06 ha of land. Usually, ordinary earth is mined for leveling of ground for construction of buildings. The area comes under zone III and indicates moderate seismicity. Quartz, Iron ore, Granite Building stone Laterite Building stone, Brick clay, Ordinary Sand. River sand are the mineral deposits found in the district. For administrative purpose, the hard-crystalline rocks which do not have any economic minerals are classified as granite dimension stones and granite (building stones).

Large scale industries and PSU units in the district are Kerala Feeds Ltd, Hi-tech bamboo flooring Tile factory, Kerala SIDCO Tool Room cum Training Centre, SAIL-SCL Kerala Ltd., Malabar Spinning and Weaving Mills, Kerala Soaps and Oils Ltd, KSIE. Medium to small scale industries are also operating in the district.

2.0 DATA COLLECTION AND GENERATION

2.1 Data collection and data gap analysis

Collection, compilation, and generation for aquifer mapping studies are carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various activities (Table - 2.1).

Table 2.1. Brief activities showing data compilation and generations.

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and subsurface geoelectrical and gravity data generation	Vertical Electrical Sounding (VES), borehole logging, TEM etc.
		Hydrological Parameters on ground water recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of subsurface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including heavy metals.
3	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydrochemical data.
4	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers, and stakeholders etc. and putting in public domain

Periodical data pertaining to water levels, pumping tests were collected during aquifer mapping studies apart from water sample collection to assess the groundwater quality. In addition, geophysical data has been generated through conducting Geo-electrical soundings and TEM after evaluation of data gap analysis.

The status of availability of existing data for various items are described in the subsequent section and its summary is given in Table 2.2 and shown in Figure 2.1.

Table 2.2 Status of data availability for data gap analysis

Sl No	Item	Data Availability				Total
		CGWB		State Departments		
		Hard Rock	Soft Rock	Hard Rock	Soft Rock	
1	Ground Water Monitoring stations – Dug Wells	61	20	15	2	98
2	Ground Water Monitoring stations – Piezometers	9	6	33	-	48
3	Ground Water Exploration	33	2	33	-	68
4	Geophysical	60	5	-	-	65
5	Ground Water Quality Stations- Aquifer-I	15	8	15	2	40
6	Ground Water Quality Stations- Aquifer-II	27	2	-	-	29

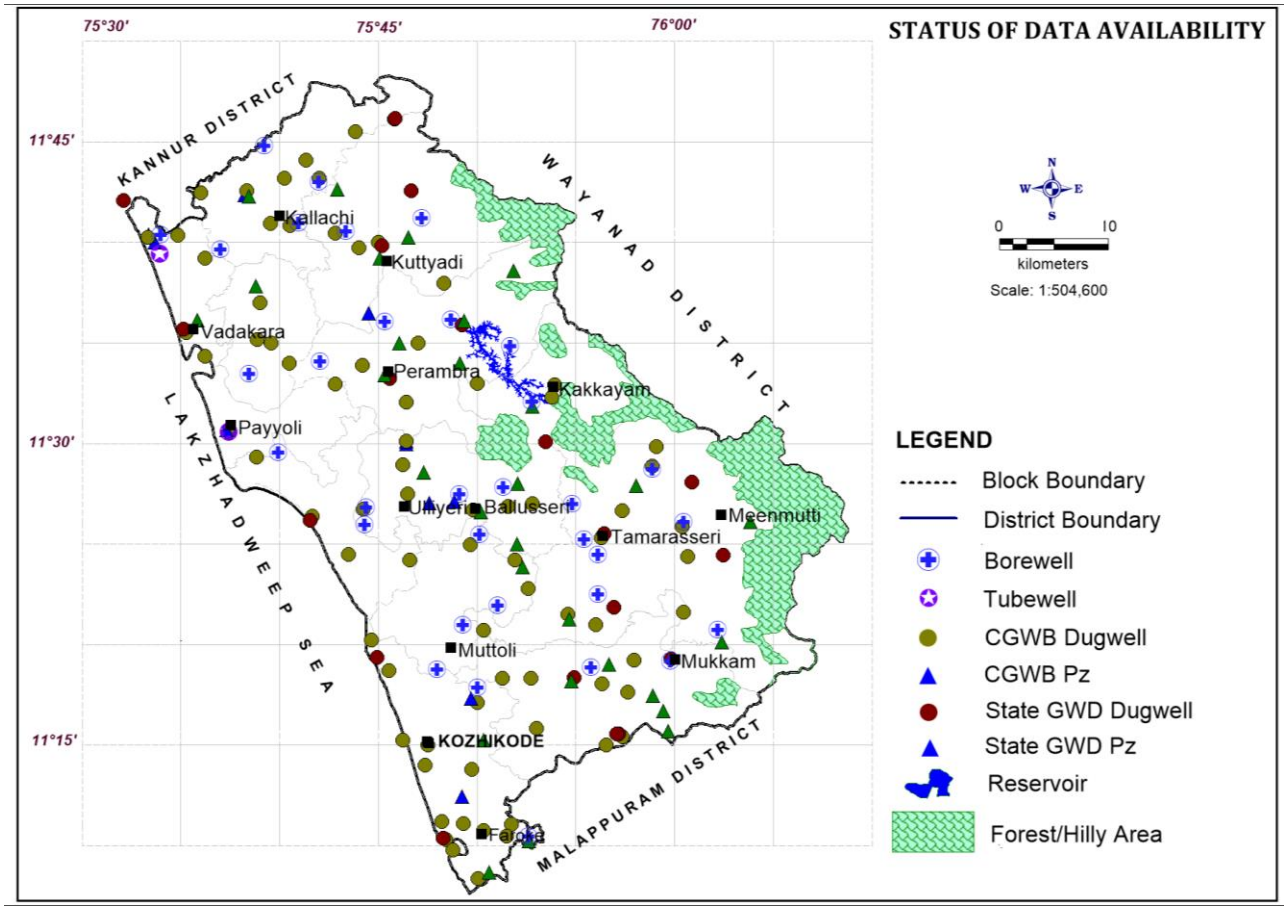


Figure 2.1 Status of data availabilty for data gap analysis

2.2 Hydrogeological data

The periodical monitoring of groundwater level implies the groundwater recharge and discharge (natural and manmade) occurring in the aquifer systems. There were 146 (Nos.) of groundwater monitoring wells existed earlier, to the present studies, which were monitored periodically. To fill data gap, 26 Nos. of additional key observation wells shown in Figure – 2.2, were established and monitored two times (Pre and Post monsoon) during the aquifer mapping field studies, to record the temporal and special changes in the aquifer system. The details of monitoring wells are presented as Annexure - I. The groundwater level monitoring was carried out four times in a year since April 2021 to Jan 2022.

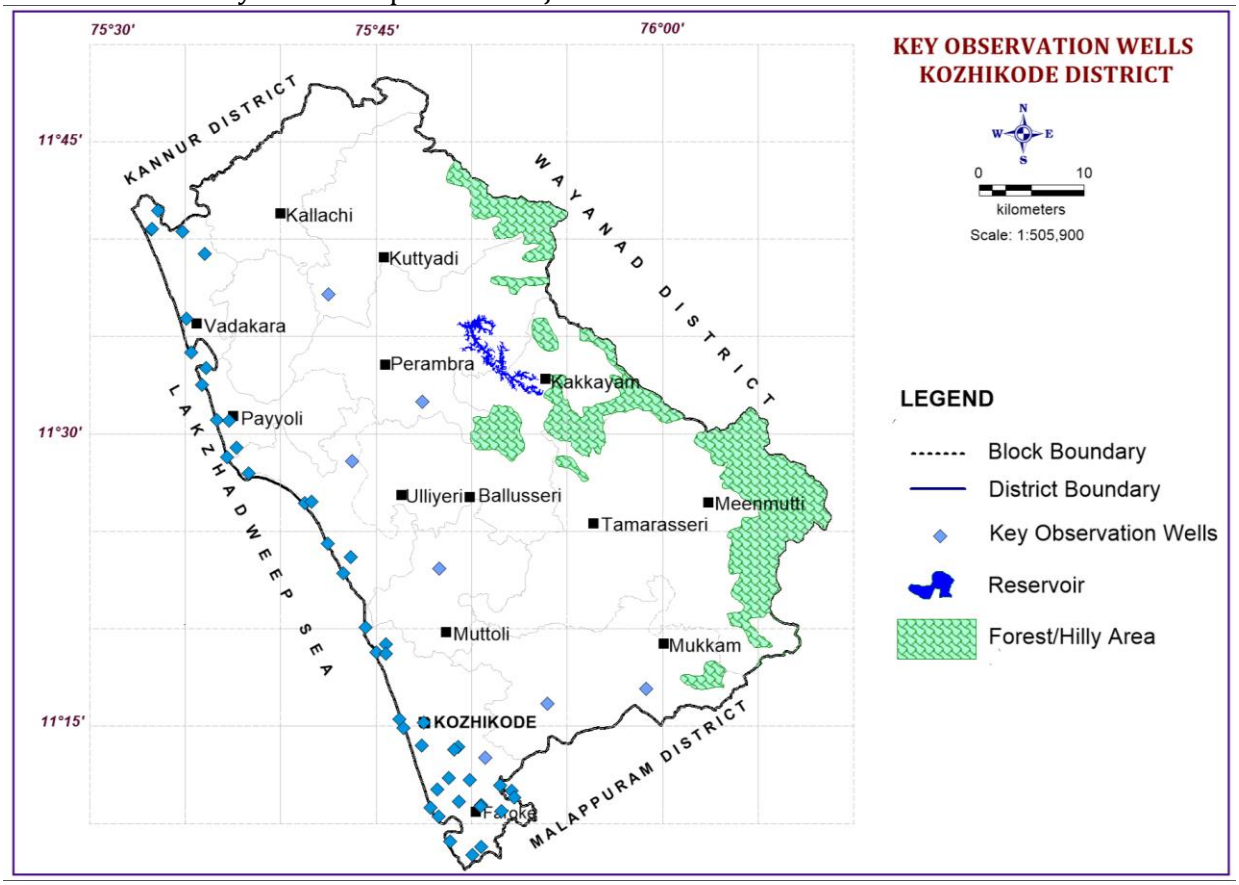


Figure 2.2. Key observation wells for monitoring regime

2.3 Hydrochemical data

The groundwater quality of the study area was studied by collecting water samples from 23 periodic monitoring wells. 35 water samples were collected during groundwater exploration studies in sedimentary and hard rock terrains. To fill the data gap, 7 water samples were collected during micro level study (Figure 2.3). The details of water quality monitoring stations are given in Annexure – II. In addition to that 30 Water Samples were collected from Dugwells for Heavy metal analysis to assess the groundwater quality for drinking and irrigation purpose.

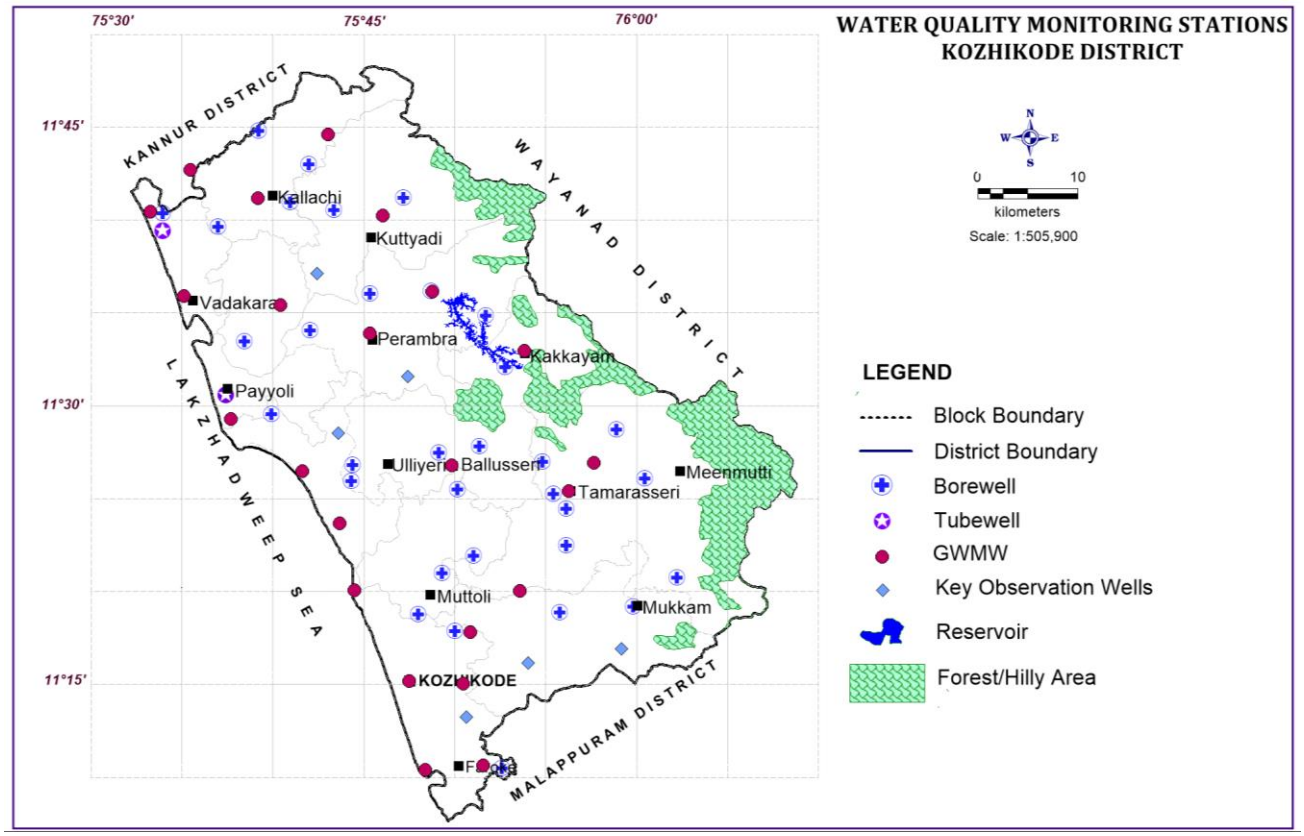


Figure 2.3 Water quality stations for groundwater parameters

2.4 Geophysical data

In Kozhikode district for ground water exploration geophysical surveys consisting of VLF profiling and VES techniques were conducted at the sites which were selected based on systematic/ reappraisal surveys and structural geomorphic maps.The objectives of the survey were to locate the lineaments which inferred from the topographical and photogeological maps, to pin point the potential sites for exploatory drillings and to quantify the various geoelectrical parameters in selected places such as fracture pattern, direction and width.

A total of 6.61-line Km profiling and 50 VES were conducted in the district. The geophysical surveys carried out indicated resistivity of 175-300 ohm.m for fractured charnockites, while massive rock recorded resistivity values of more than 600 ohm.m. The exploratory drilling at Chelekkad and Palleri sites confirmed the resistivity findings with high yield of more than 50,000 lph. After data gap analysis, 15 Nos VES and 75 Nos TEM were carried out in both soft rock and hard rock areas.

2.5 Groundwater exploration data

A total of 35 exploratory wells, in which 15 (Figure 2.4) were drilled in the hard rock terrains and 2 were drilled in sedimentary terrain under Groundwater exploration activity of the CGWB prior to National Aquifer Mapping project. Other than exploration wells, 15 piezometers are also constructed in the study area. These wells were plotted on the 1:50,000 scale topographical map. As per the National Aquifer Mapping guidelines for the hard rock, data requirements were identified on the plotted topographical map. Based on the data requirements, 18 of exploratory wells and 7 Observation well were drilled in the aquifer mapping area. The data such as lithology, fracture depth, yield, water level, aquifer properties were generated and utilized to depict the prevailing aquifer systems of the area and is given in Annexure – III.

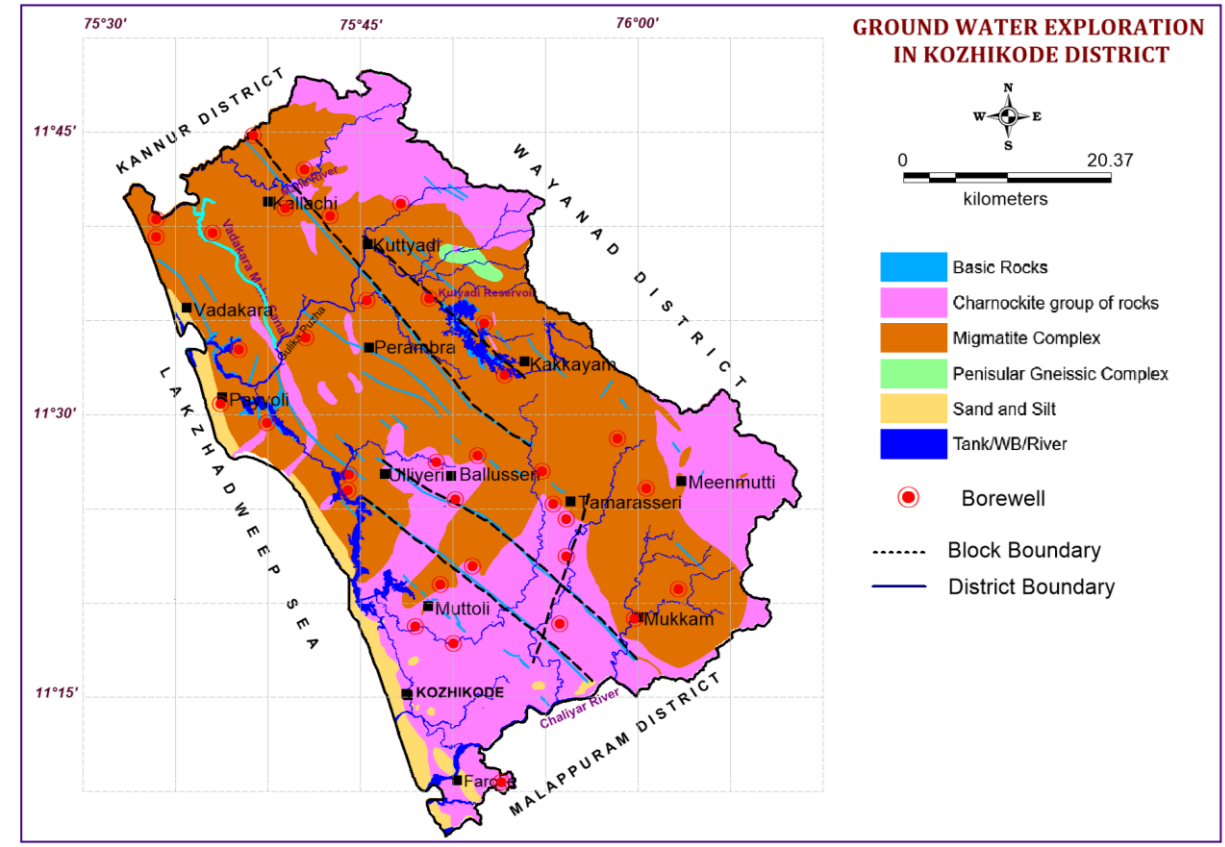


Figure 2.4 Ground water exploration in Kozhikode District

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data on geological, geophysical investigations carried out by CGWB, water level and hydrochemical data from the integrated monitoring stations of CGWB and State departments were used to map the aquifer systems in the district. The locations of validated exploratory wells are given in Annexure – IV.

3.1 Geophysical studies

In Kozhikode District geophysical surveys consisting of Vertical Electrical Soundings (VES) and Very Low Frequency (VLF) were carried out to know the subsurface conditions to recommend sites for ground water exploration also to provide additional information for aquifer mapping and management studies. In Kozhikode district, 65 Nos of VES and 6.61-line km profiling were carried out in both soft rock and hard rock areas. The geophysical surveys carried out indicated resistivity of 175-300 ohm.m for fractured charnockites, while massive rock recorded resistivity values of more than 600 ohm.m. The exploratory drilling at Chelekkad and Palleri sites confirmed the resistivity findings with high yield of more than 50,000 lph.

Ground TEM were carried out by employing Coincident loop configuration of 40*40m and 20*20m loops, depending on the availability of the space. The obtained TEM data has been downloaded from instrument and stored in computer. The downloaded data has been processed and a profile pseudo sections have been prepared by using TEM fast software. In Kozhikode district, a total of 75 TEM in 3 villages namely Sivagiri, Chathamangalam, Pantherpadam was carried out by employing Coincident loop configuration of 40*40m and 20*20m (75 TEM) loops depending on availability of the space. The interpreted results of VES in Kozhikode district is presented in Annexure V. The interpreted results has given rise to 3 to 6 layered geoelectric sections. The main types of curve are H, HK, HA, QH, KHA, AKH, KHK,HKQ, KHK & KHKH etc. Based on the results of Geophysical surveys (VES), borewells has been recommended and encountered good yield. The representation of different field curves in Kuttikattoor and Kunnamangalam is shown in figure 3.1.

3.2. Hydrogeological data interpretation

The Aquifer System in the district can be broadly divided into hardrock aquifers, sedimentary aquifers, and laterite aquifers. The hard rock and laterite aquifers constitute the major aquifer system of the district while the sedimentary aquifers are seen along the coast and river courses. The data generated, as discussed in section 2.5, such as lithology, fracture depth, yield, water level, aquifer properties were and utilized to depict the prevailing aquifer systems of the study area. The aquifer mapping studies reveal that the presence of two distinct aquifer systems. They are Phreatic Aquifer-I (Shallow Aquifer System) and Deeper Fracture Aquifer-II (Fracture Aquifer System).

3.2.1. Phreatic Aquifer – I (Shallow Aquifer System)

It comprises of laterite/ weathered partially weathered and first fracture to some extent in Hornblende biotite gneisses, Charnockites and Migmatite complex. Laterite forms the potential aquifer, and it is hydraulically connected with deeper fracture zones.Recent Alluvium forms the aquifer in the coastal area. Weathered/Overburden thickness ranges from 2 to 36 mbgl and is increasing towards west to north western part. Maximum thickness upto 36 m is observed along coastal belt in Vadakara block. Overburden Thickness map is prepared based on ground water exploration data, VES and field observations and is shown in Figure 3.2. Average thickness is about 17m in the lower plateau region and valley portions. Depth of dug wells generally ranges from 3.85 to 18 mbgl. Depth to water level generally ranges from 0.82 to 13.13 m bgl in premonsoon and 0.33 to 12.85 mbgl in post monsoon period. The wells located in this aquifer zone yield groundwater of <5 to 20 m^3/day and sustains 1 to 5 hrs of pumping.

To understand the aquifer disposition, geological sections have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs,

electrical logs of boreholes and VES data interpretation using the RockWorks17 software, three dimensional (3D), Section lines & two dimensional (2D) lithological sections were prepared and is given in Figure 3.3,3.4 and 3.5 respectively.

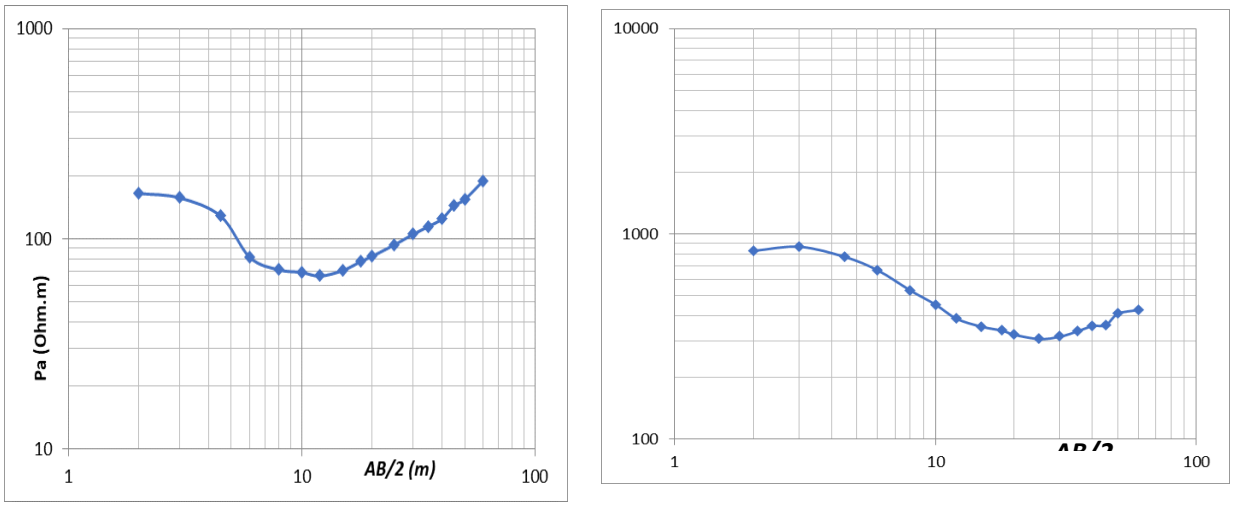


Figure 3.1: Representation of different field curves in Kuttikattoor, Kunnamangalam of Kozhikode.

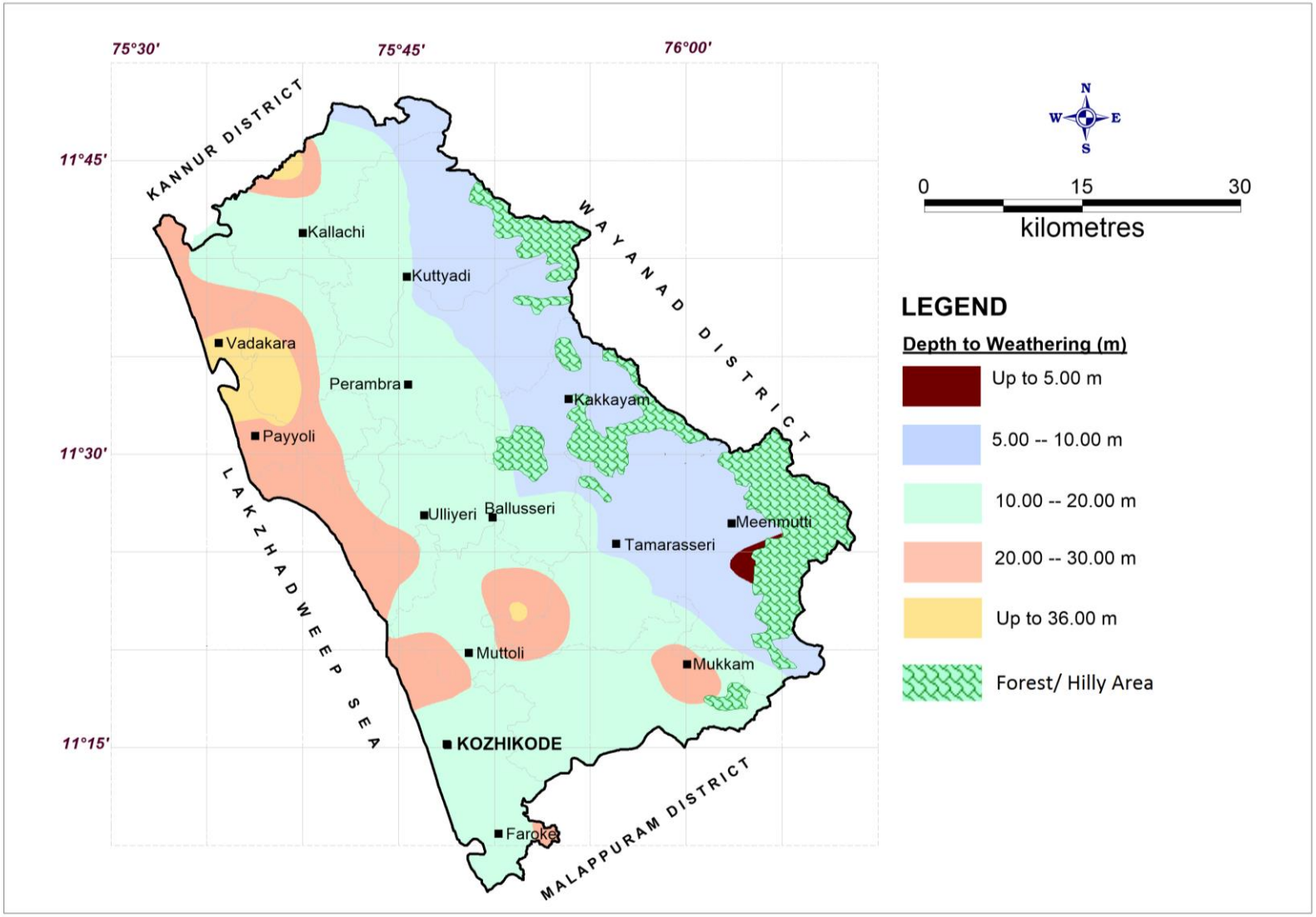


Figure 3.2 Overburden map of Kozhikode district

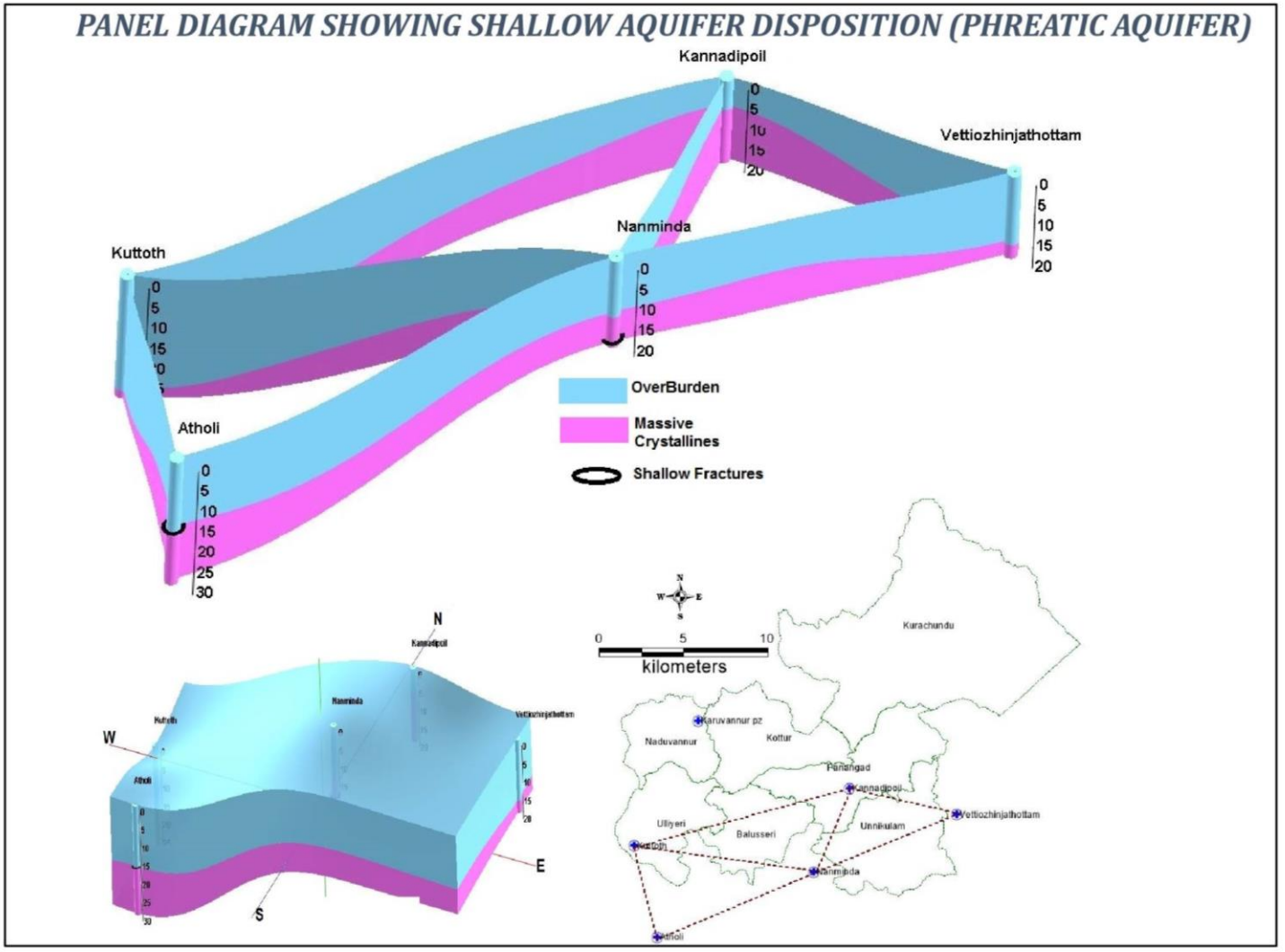


Figure 3.3 Panel Diagram showing Shallow Aquifer Disposition (Phreatic Aquifer)

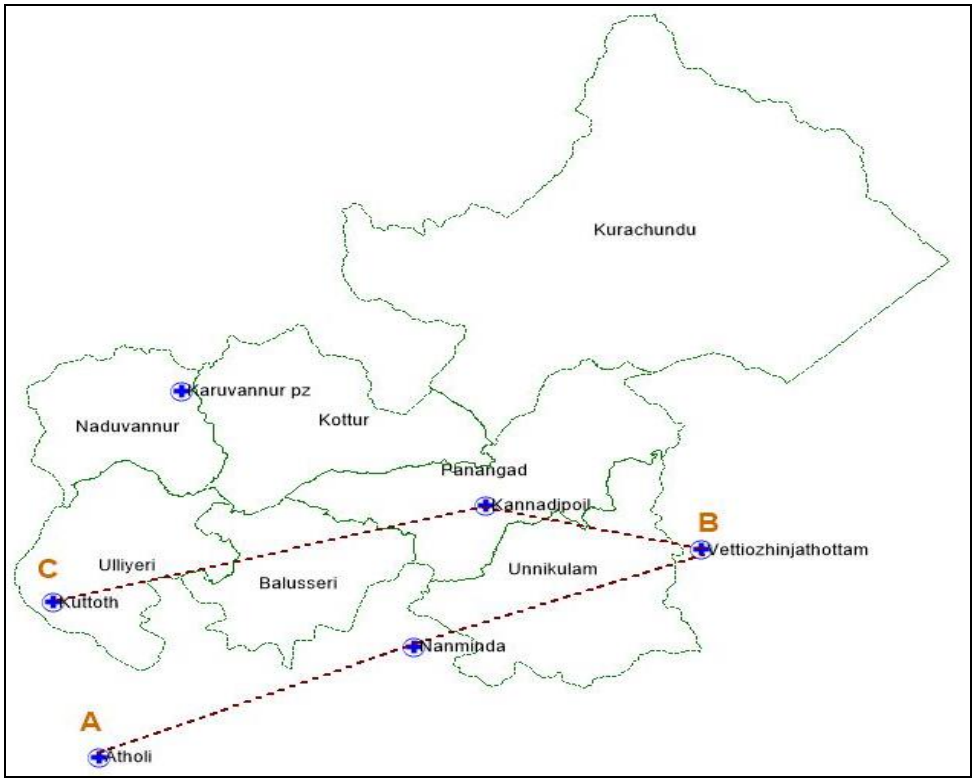
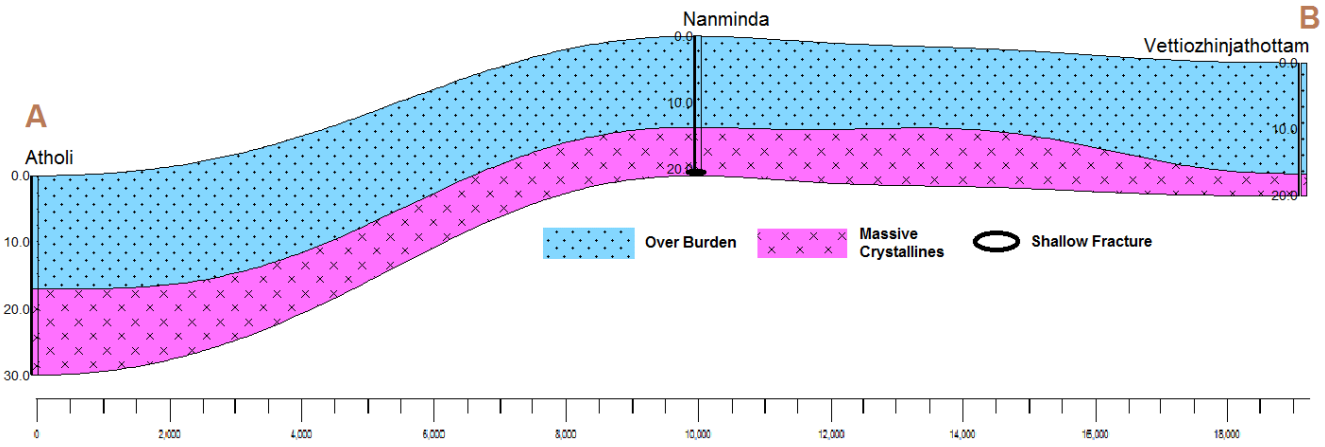


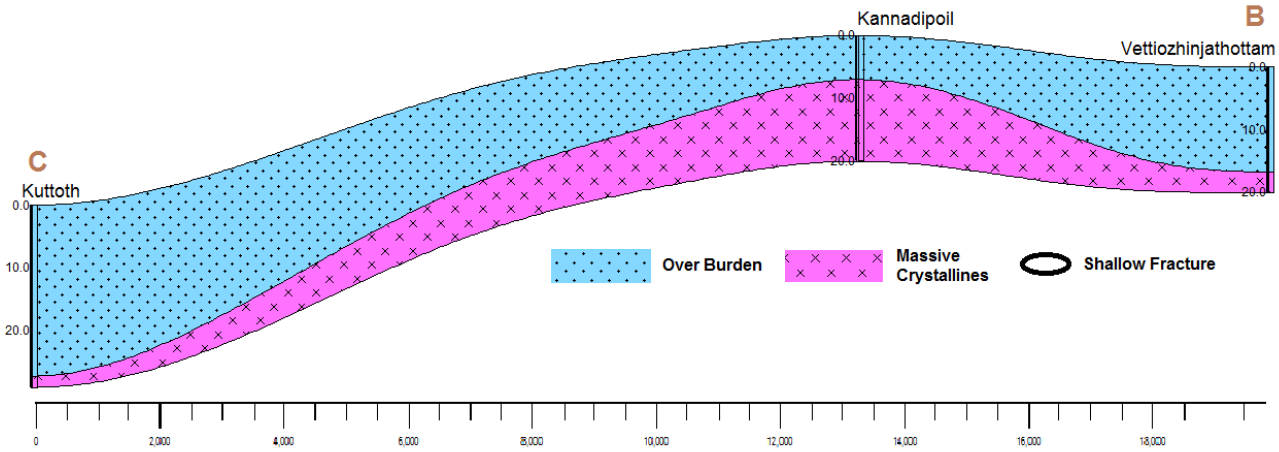
Figure 3.4 Section lines for 2D Aquifer disposition of Balussery Block (Aquifer-I)

The weathered rocks form potential aquifers and the thickness of weathered portion ranges from 3 m to 36 meters. The shallow aquifer in these formations is developed by open dug wells and shallow bore wells. The design of dug wells in consolidated crystalline are 3m dia. and 12 m depth and shallow bore wells can be drilled up to a depth of 50 mbgl.

Section from Atholi to Vettozhinjathotam indicates that weathered aquifer spreads with an average thickness of about 12 m. Shallow fracture zones are encountered at Nanminda at a depth of 19m.



Section from Kuttoth to Vettozhinjathotam shows that the area is having an undulating topography and shallow aquifer spreads from 5 to 28 m bgl. Overburden thickness is more at Kuttoth in midland areas and thins out at Kannadipoil.



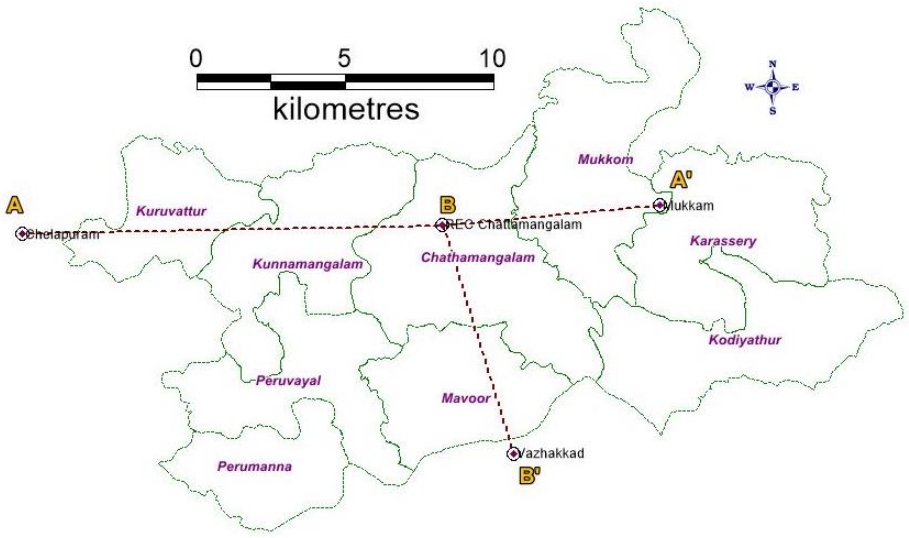
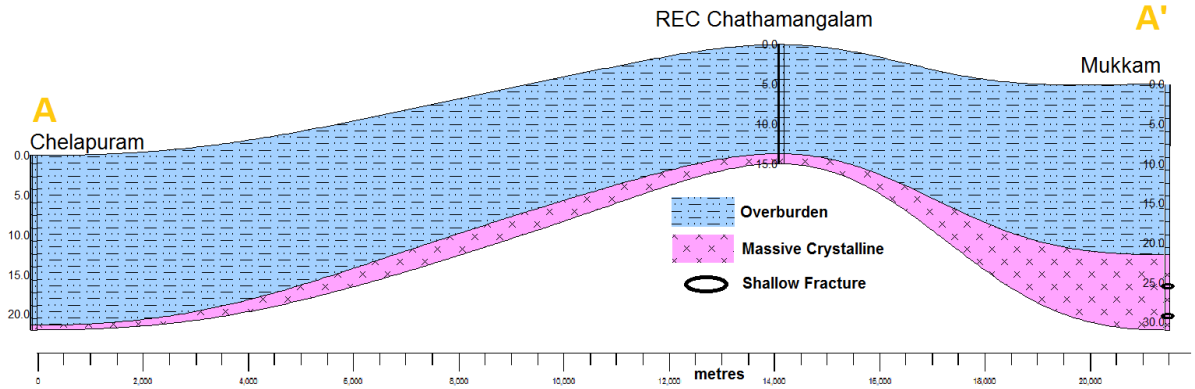


Figure 3.5 Section lines for 2D Aquifer disposition of Kunnamangalam Block (Aq-I)

Section from Chelapuram to Mukkam indicates that overburden thickness is more at Chelapuram and Mukkam and is lesser towars Chattamangalam and having an average thickness of about 15 m. Shallow fracture zones are encountered at Mukkam at a depth of 26 and 30 m.



Groundwater level

During Aquifer Mapping studies in Kozhikode district, 96 National Ground water observation wells (GWMW) of CGWB and 30 key wells established in different formations were used to study the behaviour of the groundwater regime. Out of total 30 key wells, 6 wells were established in Migmatite Complex formations, 10 in Charnockite and 14 are in sedimentary

formation. The water levels were monitored from April 2021 to January 2022, four times in a year from ground water observation wells and during pre- and post-monsoon periods from key wells. The depth of observation wells ranged from 2.70 to 15.00 mbgl in sedimentary terrain and 4.37 to 18.00 mbgl in hard rock terrain.

Pre-monsoon depth to water level (April 2021)

The water level data from GWMWs and Key wells, pertaining to the period of April 2021 (pre-monsoon), was used to prepare the depth to water level map (Figure – 3.11) of Kozhikode district. The depth to water level varies from 0.82 mbgl (Kodenchery) to 13.13 mbgl (Kottakkadavu). Water level range from 0 to 2 mbgl in about 3 % of the study area, >2 to 5 mbgl in 53%, >5 to 10 mbgl in 43% and >10 mbgl in 1% of the study area. Major part of the study area shows water level in the range of >2 to 5 mbgl and is observed in Central and eastern part, followed by 5 to 10 mbgl water level together covering about 96% of the area as shown in Fig. 3.6.

Post-monsoon depth to water level (November 2021)

The depth to water level map for the post monsoon period (November 2021) is presented as (Figure – 3.7). The depth to water levels during this period is varied from 0.33 mbgl (Kallachi) to 12.85 mbgl (Vellimadukunnu). Water levels ranging from 0 to 2 mbgl is about 14 % of the study area, whereas >2 to 5 mbgl is about 56%. Water levels ranging from >5 to 10 mbgl is about 29%. Water levels ranging from >10 mbgl is 1% of the study area. Major part of the study area shows water level in the range of >2 to 5 mbgl and is observed in South, Central, North and eastern part of the study area and followed by >2 to 5 mbgl water level in northeastern and southern part.

Water level fluctuation

Water level fluctuation in the observation wells in an area between two periods is indicative of the net changes in the groundwater storage during the period in response to the recharge and discharge components and is an important parameter for planning for sustainable groundwater development. The seasonal water level fluctuation in the area has been analyzed using the water level data of April 2021 & November 2021, which indicate the extent of replenishment of the shallow aquifer due to the monsoon rainfall. The water level fluctuation in the study area ranged from a slight decline in parts of Kuttiyadi to a rise of about 2 m in all parts of the district and is shown in Figure 3.8. In general, this falling trend is not at all alarming and most of the areas indicate a rising trend. This may be due to the canal command irrigation in the district.

The long-term water level fluctuation over the past decade (2012-2021) indicates that during pre-monsoon there is a rise in water level in the order of 0.0009 to 2.36 m/year and fall in the order of 0.03 to 2.316 m/yr whereas during the post monsoon, rise in water level is in the order of 0.01 to 2.61 m/year and the fall is in the order of 0.01 to 1.89 m/year. The Decadal depth to water level in the Ground Water Monitoring Wells of CGWB during pre-monsoon period is shown in Figure 3.9.

Pumping test of phreatic aquifer

Many of dug wells in the area have less than one-meter water column during most of the years and about 50% of wells get dry during summer, especially in the highland areas. The wells located in favorable hydrogeological settings like topographic lows, river alluvium, etc., can sustain at a rate upto 20 m^3/day for 3 to 5 hrs of pumping. The yield of large diameter wells tapping the weathered mantle of crystalline rocks sutain at rate upto 15m^3/day for a drawdown of 2 to 3 m and can sustain 1 to 3 hours of pumping. In high land areas yield varies upto 5 m^3/day.

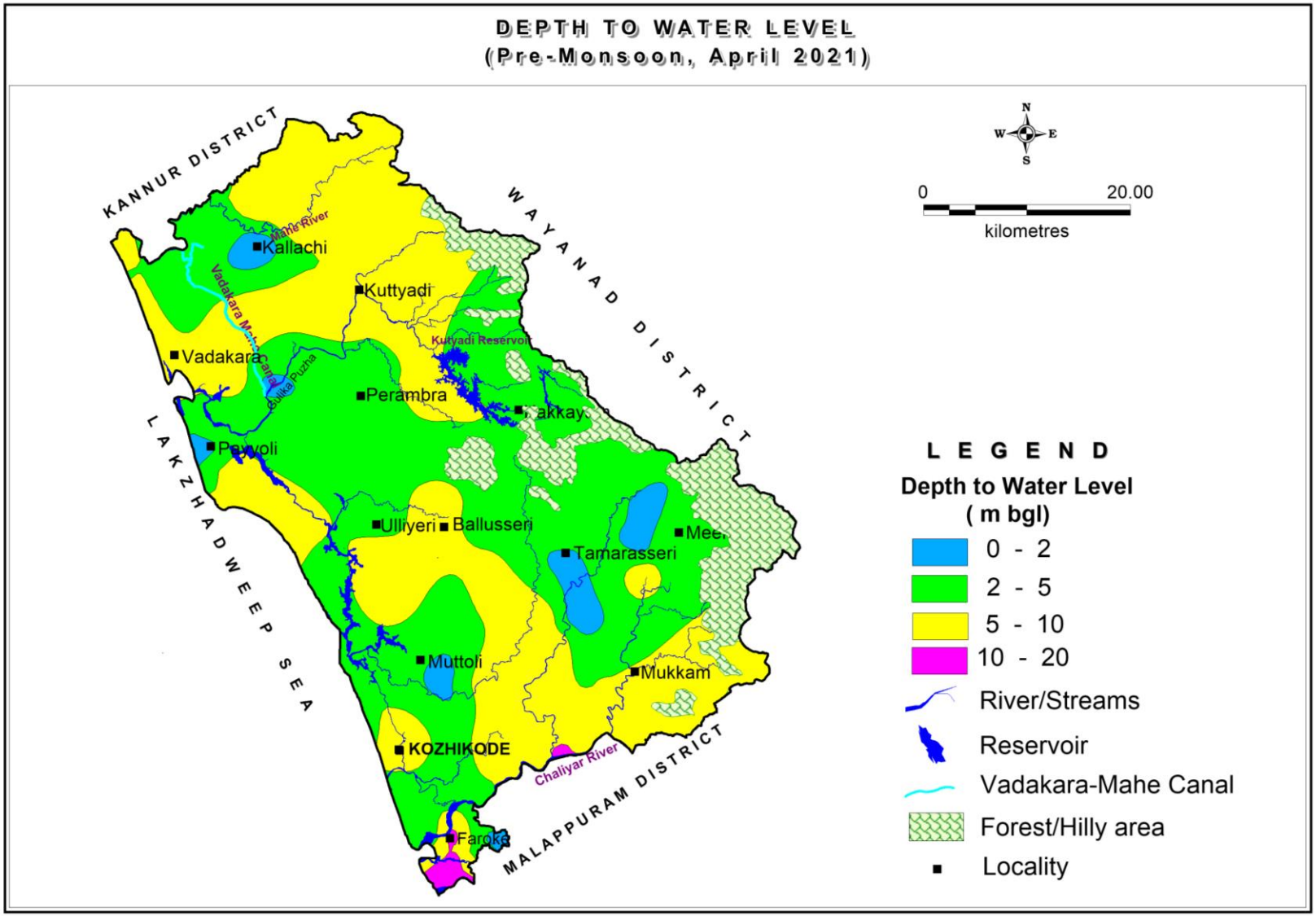


Figure 3.6 Pre-monsoon depth to water level (April 2021)

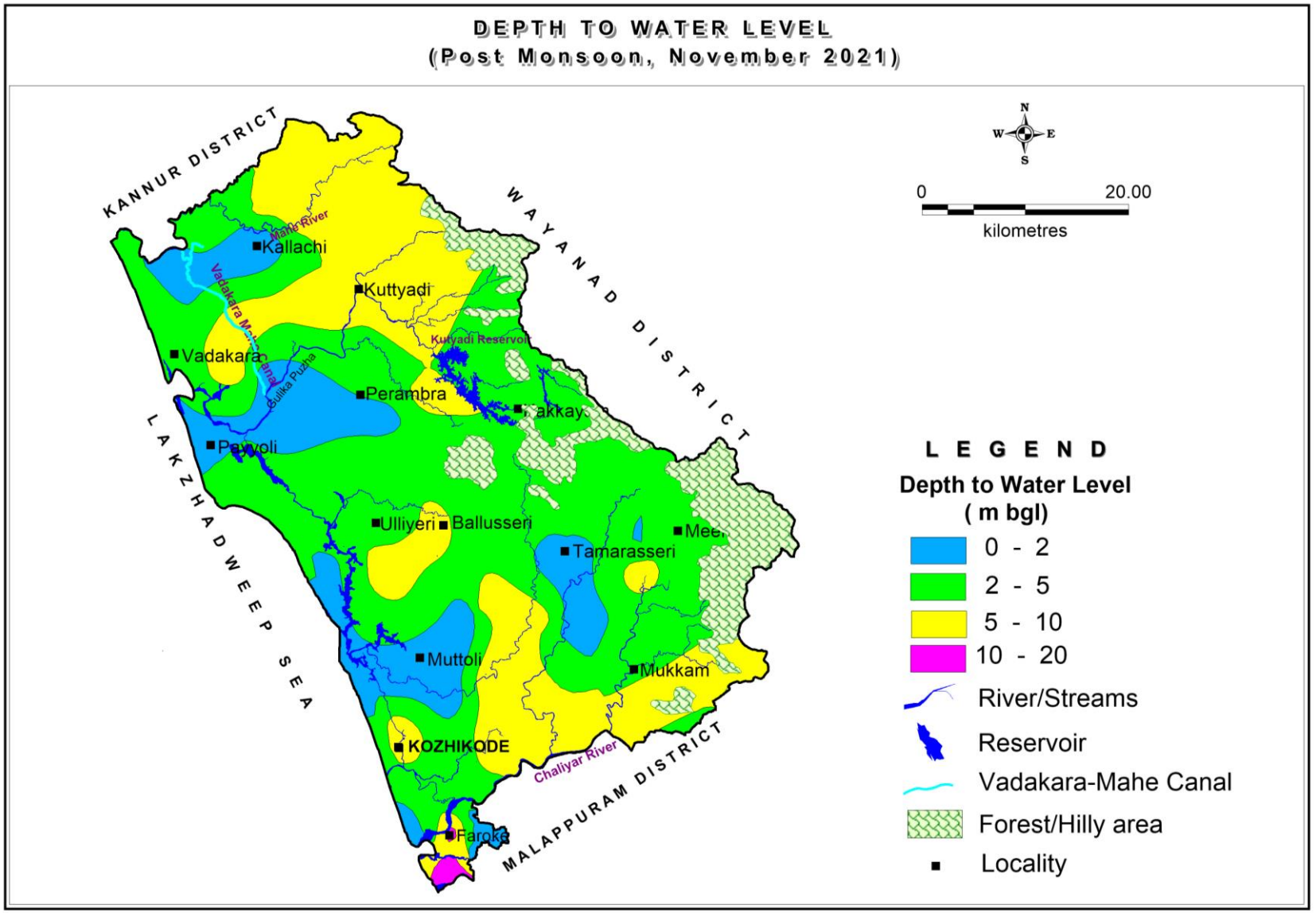


Figure 3.7 Post-Monsoon depth to water level (November 2021)

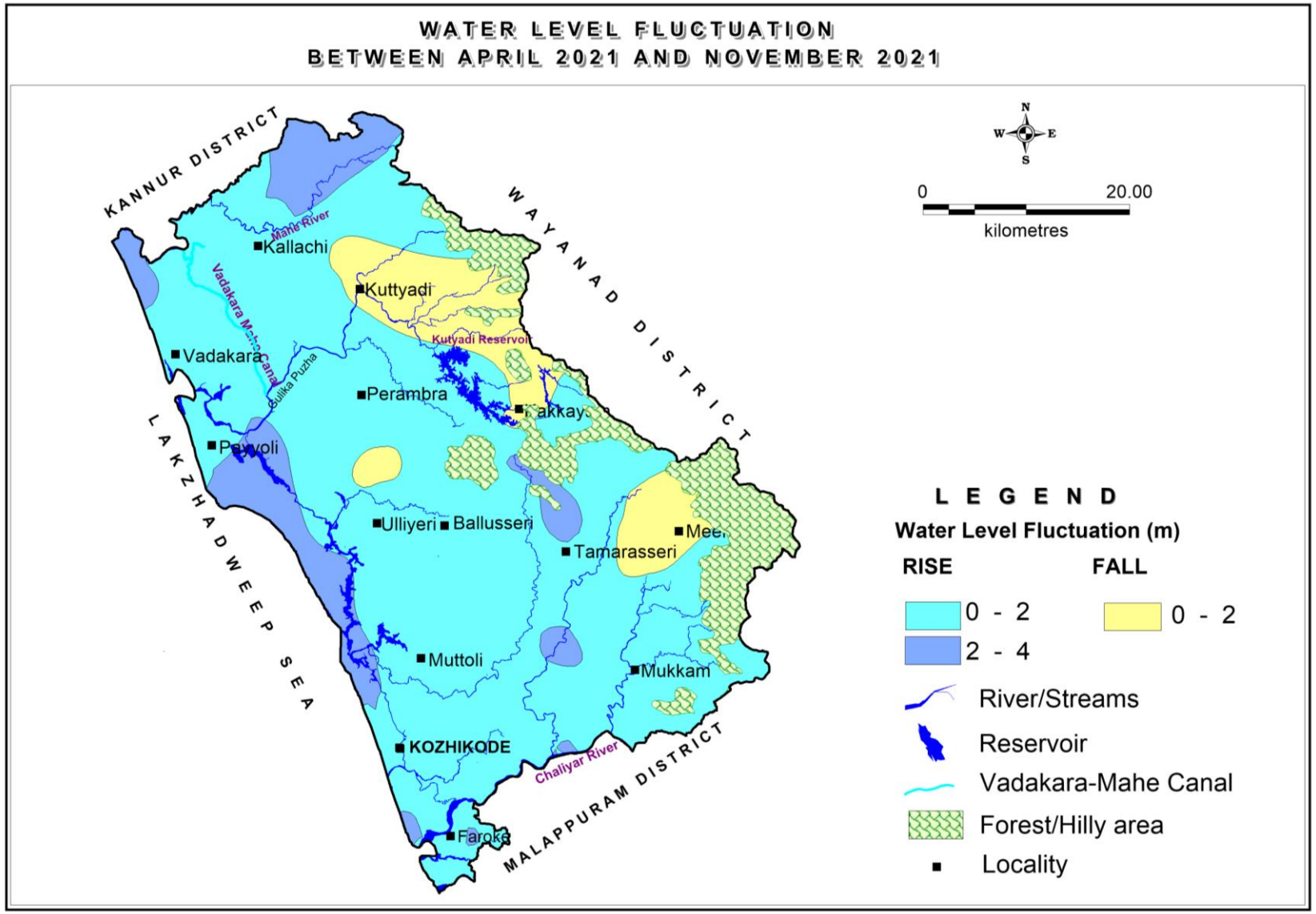


Figure 3.8 Water level fluctuation (April Vs November 2021)

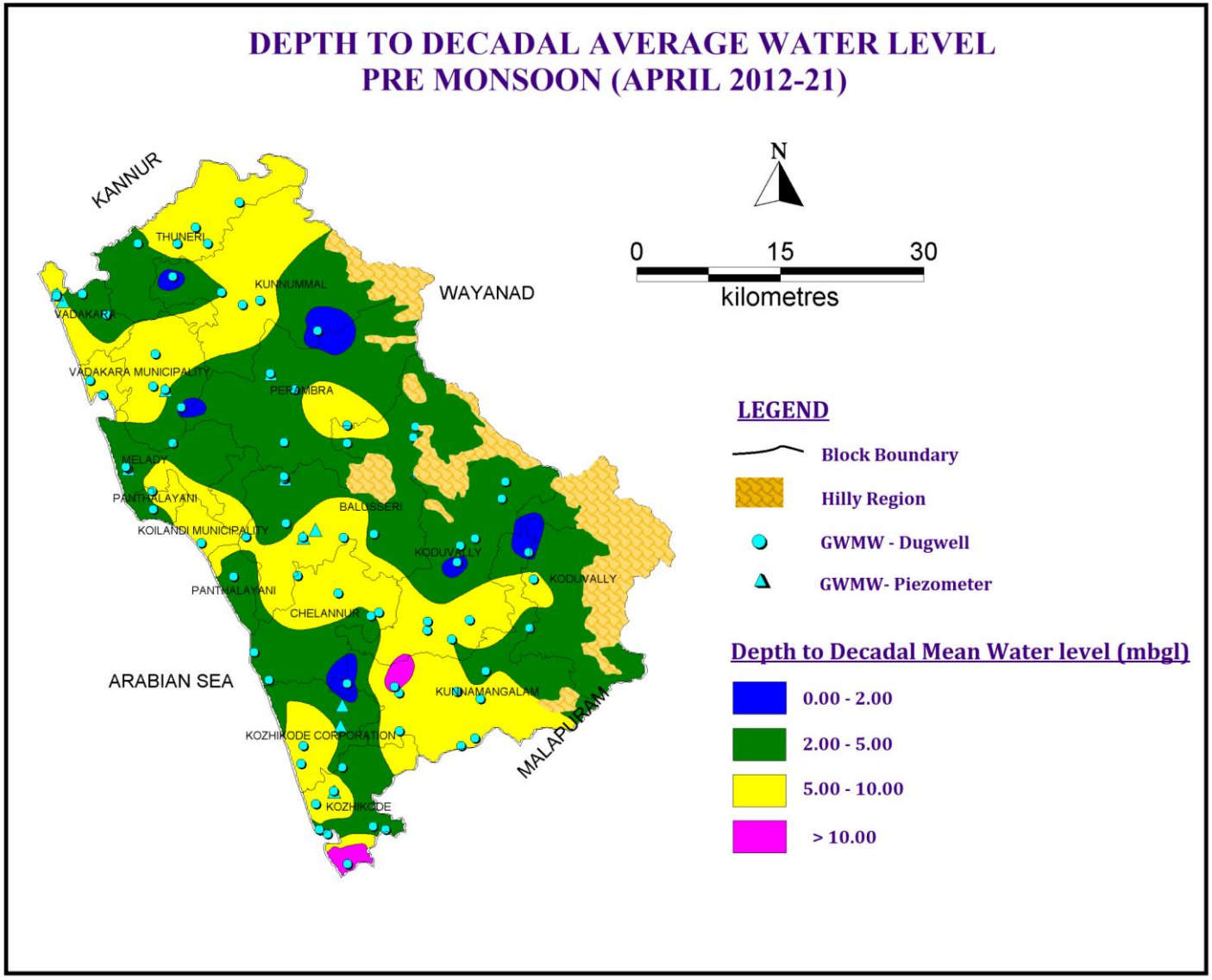


Figure 3.9 Decadal Water level fluctuation (April 2012 - 2021)

Hydro chemical data interpretation (Phreatic Aquifer-I)

The chemical characteristics of ground water in the shallow aquifer system of Kozhikode district has been studied using the analytical data of groundwater samples collected from exploration, Network stations of Central Ground Water Board and from the established key observation wells. The details of analysed samples locations along with the results is detailed in annexure VI.

The electrical conductivity (EC) of water samples collected from shallow aquifer of GWMW ranges between 53 (Kakkayam) and 870 (Ramanattukara) microsiemens/cm at 25^{0}C with an average EC of 240 microsiemens/cm at 25^{0}C. The EC is a measure of mineralization in water and it depends on degree of weathering and mineralization. The pH value of water ranges from 4.00 to 9.73 with an average pH of 7.04. Total hardness of water samples ranges between 39.1 and 357.8 mg/l as $CaCO_3$.The water from the shallow aquifers is good and potable. As per the drinking water standards of Bureau of Indian Standards (BIS), all the major chemical constituents including fluoride in the groundwater of Kozhikode district is within the permissible limit and is suitable for all purposes in majority of samples. The water samples collected from Vadakara, Beypore and Devarkoil have Nitrate composition above permissible limit.

Chemical data of representative samples from the Phreatic Aquifer-I presented by plotting them on a Hill Piper-tri-linear diagram for pre-monsoon water samples. These diagrams reveal the analogies, dissimilarities, and different types of waters in the study area, which are identified and listed in Annexure-V. The concept of hydrochemical facies was developed to understand and identify the water composition in different classes. Majority of the samples were behaved in same way except few samples. The prominent type in Phreatic Aquifer are Ca^{2+}- HCO_3 type , Mixed Type, No Dominant Type& HCO_3 type of water in this method and is shown in Figure 3.10.

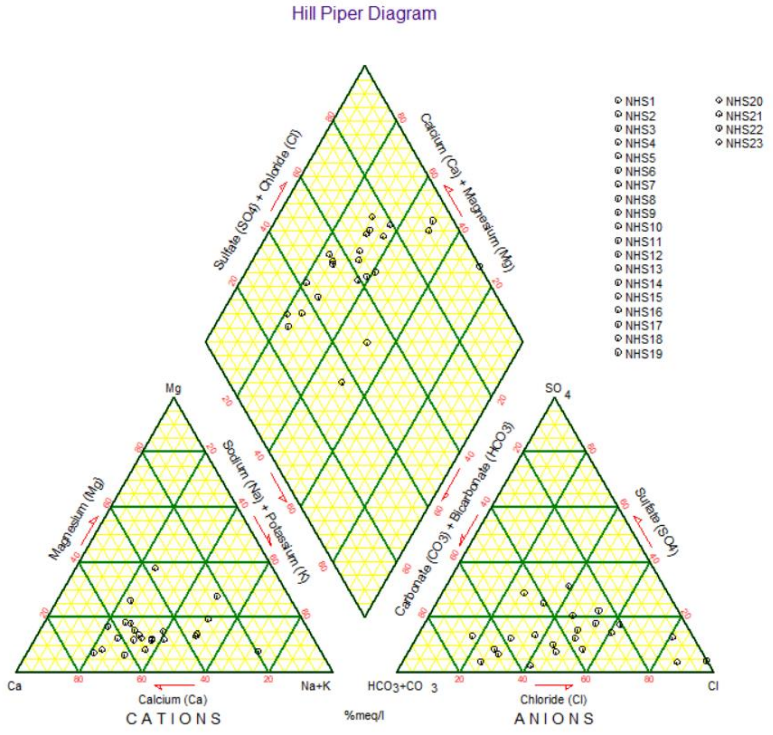


Figure 3.10 Hill piper diagram of phreatic aquifer-I

Wilcox classified groundwater for irrigation purposes based on percent sodium and Electrical conductivity. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained. When the Sodium Absorption Ratio (SAR) and specific conductance of water are known, the classification

of water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagram. The groundwater in hard rock terrains of Kozhikode district is in general Ca-HCO_3 type & mixed type during pre monsoons. About 98% of the samples are grouped within C1S1 and C2S1 classes (Fig 3.11). Based on Wilcox diagram, samples fall in Low conductivity zone and is suitable for Irrigation.

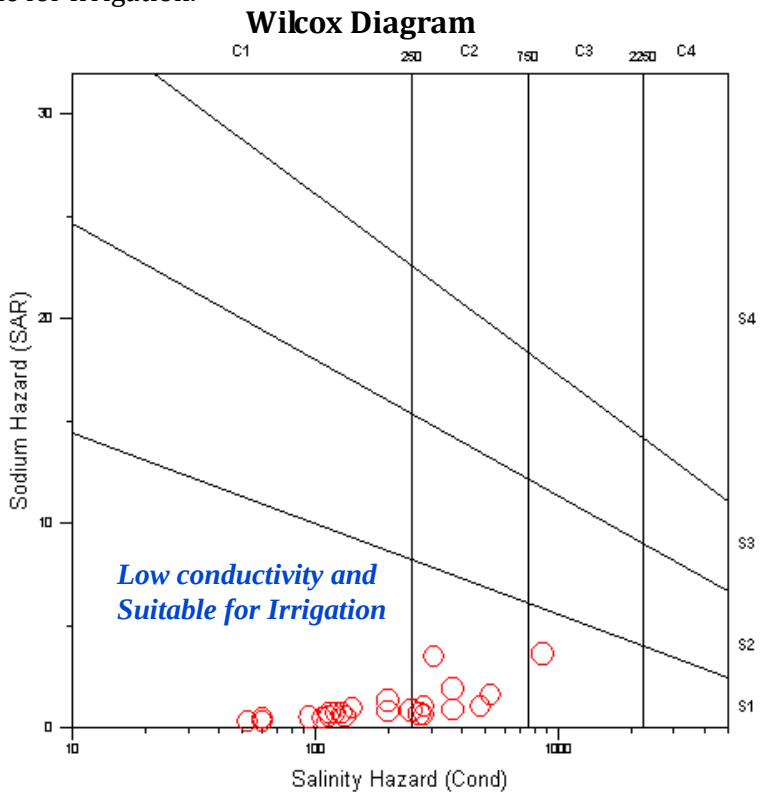


Figure 3.11 Wilcox diagram of phreatic aquifer-I

Groundwater in phreatic aquifers in the study area is colourless, odourless, and slightly alkaline in nature. And the ground water is potable & fit for domestic, drinking, irrigation & industrial purpose.

3.2.2 Fracture Aquifer System (Aquifer-II)

Depth of Exploratory wells drilled in the hard rock area of Kozhikode district ranging from 103 mbgl to 200 m.bgl and for sedimentary terrain ranging from 27 mbgl to 32 m.bgl. Drilling data of the exploratory wells in sedimentary terrain shows that the Zone Depth ranges from 10.8 to 28 m.bgl and discharge of tubewells varies from 120 lpm to 600 lpm. Drilling data of the exploratory wells has revealed the presence of productive fractures in migmatite gneisses and charnockites in the hardrock terrain. Fracture Zones encountered in crystalline rocks are at the depth range of 11 to 196 m.bgl and the potential fracture zones depth ranges from 50 to 110 m.bgl in the study area. Discharge of the bore wells varies from meagre to 1050 lpm. As per the data integration, wells drilled in Charnockite yield more than the wells drilled in biotite gneiss. 33 bore wells data have been utilized for fracture analysis. It shows that 1st fracture encountered in 14 wells with depth vary from 10.00 to 48.00 mbgl. 2nd fracture encountered in 13 bore wells with depth varying from 50.00 to 110.00 mbgl. Similarly, 3rd fracture encountered in 11 bore wells with depth vary from 120 to 196 mbgl. Intermediate fractures form the potential aquifers in the crystallines. Borewells in the study area are generally tapped in the ranges of 50 to 110 m depth below ground level.

Deeper Aquifer - II

It comprises of mainly of fractures (secondary porosity) developed during tectonic disturbances, occurs at depth generally ranges from 28 to 196 mbgl. The maximum yield of

wells tapping this aquifer varies up to 17.5 lps. The Transmissivity value of the aquifer ranges between 2.54 and 104 m^2 /day while the discharge values vary from meagre to 1050 lpm. Storativity of the aquifer ranges from 0.00010 to 0.0002 in the study area. Groundwater occurs under semi-confined to confined conditions.

Aquifer disposition (2D Sections)

Based on the validated lithologs of the exploratory wells and the geophysical data interpretations during field studies as part of Aquifer Mapping, 2D models and sections of the aquifer system of the studyarea has been deciphered by using ROCKWORKS software.

Lithological cross-sections have been prepared (Figure 3.12 a,b,c&d) using the lithologs of boreholes drilled in the crystalline and sedimentary rocks for a better perspective of the subsurface geology and the panel diagram are shown below.

Section along Kuttoth– Vettiozhnijithottam direction tapped both Phreatic and deeper aquifers; Phreatic aquifer having thickness varying from 5 to 28 m. Deeper Aquifer is having maximum thickness up to 200m bgl depth. The shallow fractures are encountered at a depth of 19 m in Nanminda have a discharge of 6.1 lps. Intermediate fractures are encountered in bore holes of Nanminda and Vettiozhnijithottam at a depth range from 65.5 to 150.9 with discharge from 2.5 lps at Vettiozhnijithottam to 6.1 lps at Nanminda.

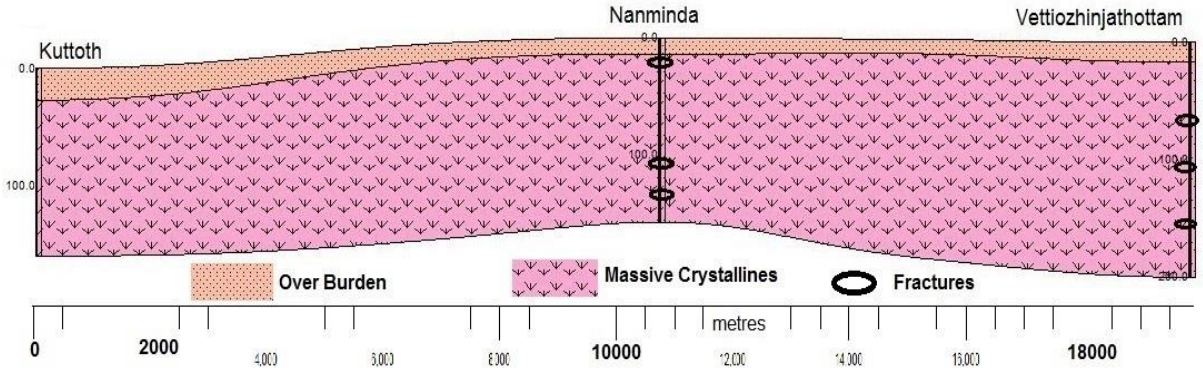


Figure 3.12a Kuttoth– Vettiozhnijithottam cross section showing aquifer disposition

Section along Chelappuram to Mukkam direction of kunnamangalam block shows that shallow fracture is encountered at Mukkam bore holes with discharge upto 3 lps with a maximum depth of 24 mbgl. Intermediate fracture is encountered at all three borewells depth ranges of 51 to 93.5 m bgl with discharge ranges from 1 to 3 lps. Potential fractures are in the depth range from 50 to 94 mbgl.

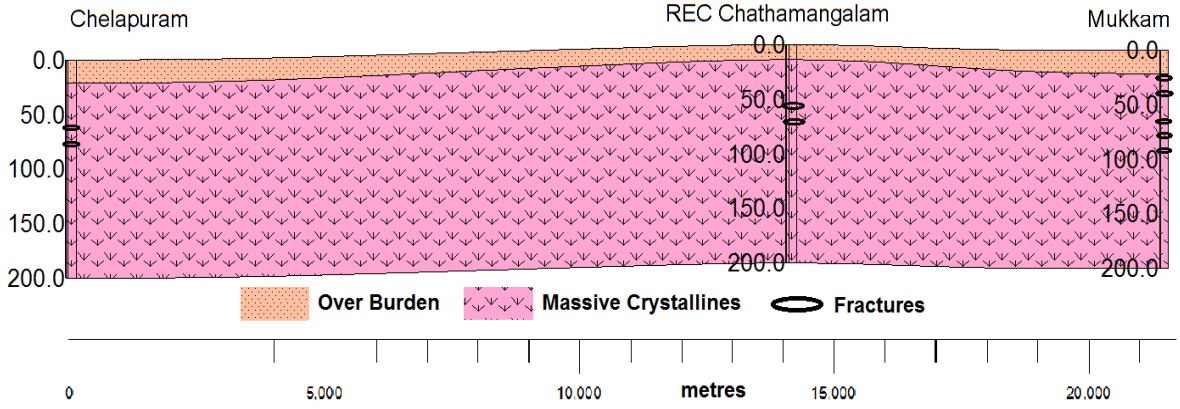


Figure 3.12b Chelappuram to Mukkam cross section showing aquifer disposition

Section along Feroke to Nadakkavu direction shows that, Laterite thickness is more at Feroke and is decreasing towards Nadakkavu. Alluvium is exposed in all bore wells except

Feroke. Shallow fractures are encountered in Nadakkavu, Meenchanta and Nallalam borewells. Intermediate fracture is encountered in all borewells depth ranges from 45 to 80 m bgl.

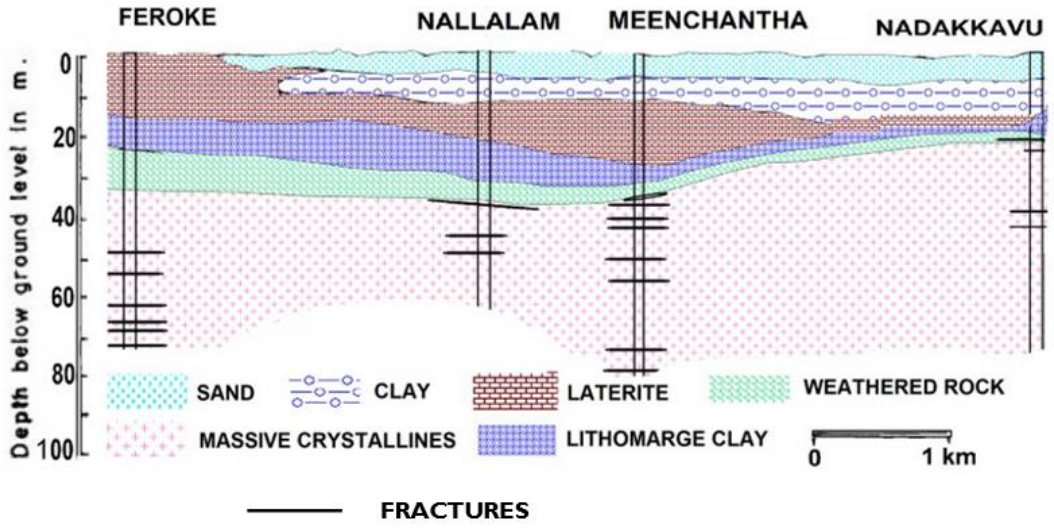


Figure 3.12c Feroke to Nadakkavu cross section showing aquifer disposition

Section along Feroke to Mukkali direction shows that, Laterite thickness is more at Meladi and Feroke and is absent in Mukkali (Alluvium thickness > 20m). Alluvium is exposed in all bore wells except Feroke. Vaikom beds is encountered in only one of the boreholes with 13 m thick i.e., Meladi. Details are given in table 3.1.

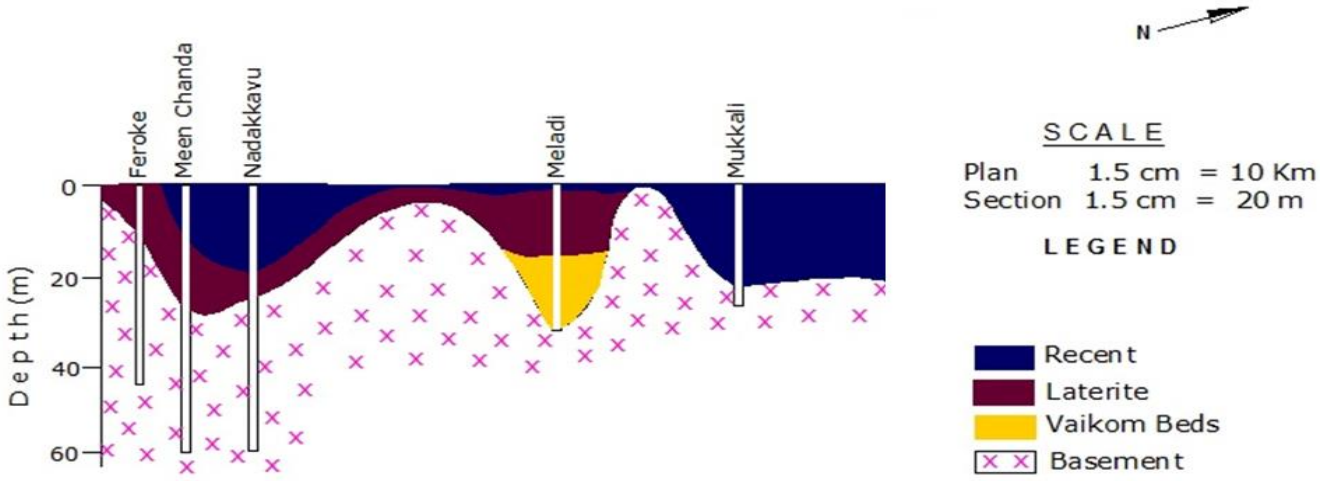


Figure 3.12d Aquifer disposition in coastal aquifer system of Kozhikode district

Aquifer disposition (3D Sections)

To understand the aquifer disposition in the study area, geological models and fence diagram have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs of boreholes drilled by CGWB and resistivity profiling 3D lithological model has been prepared shown in Figure 3.13 and panel diagrams are prepared based on the fence lines connecting with the bore wells and are shown in Figure 3.16 and 3.17.

The 3D lithological fence will represent the much clear representation of sub-surface lithology in space. The fence diagram depicts the vertical and laterial variation of aquifer along all directions and represents an undulating terrain with laterite formation at central to northwestern side and weathered formation on western side. Thickness of fractured aquifer is considerably high in northwestern & southeastern compare to east and west of the area and is shown in Figure 3.13. The rocks have undergone a series of brittle deformation at the later stage

resulting in the formation of a number of lineaments and fractures. The prominent lineament directions are NW-SE, NE-SW and E-W. The productive lineaments are NE-SW, N-S and E-W.

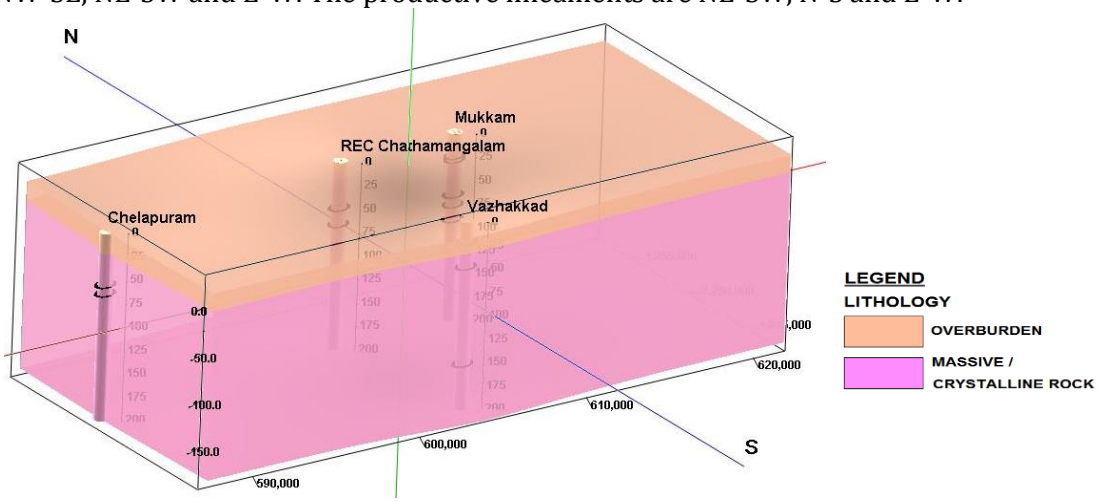


Figure 3.13 3D Model showing aquifer disposition

Groundwater occurs under semi confined to confined conditions in the fractured portions of the crystalline rocks. The studies carried out in the district indicate that the intersections of fractures are most potential followed by NE-SW, N-S, and E-W fractures.

The fractured deep aquifers were explored up to a depth of 200 mbgl by CGWB. The depth of casing ranges from 5.5 to 41.50 m and potential fractures encountered between 50 to 110 mbgl. The thickness of fracture varies from less than a meter to more than 10 metres. The yield of bore wells ranges from 0.50 to 17.5 lps. The transmissivity ranges from 2.5-104 m^2/day and storativity ranges from 1.0 X 10^{-3}- 2 X 10^{-3}.

Piezometric head

The data on piezometric head have been collected from 34 exploratory wells tapping the fracture systems in the area. The integrated data on water level and piezometric heads are ranges from 1.26 to 47.78 mbgl and with an average piezometric head of 9.54 m bgl.

Yield of wells

The yield of wells tapping the fracture aquifer system varies up to 15 lps. The area wise yield details have shown below,

- Up to 15 Lps in parts of Perambra, Balussery and Koduvally blocks.
- Up to 10 Lps in parts of Kunnmangalam, Panthalayani, Koduvally and Balussery blocks.
- meagre to 3 Lps in parts of all twelve development blocks

Hydro chemical data interpretation (Fracture Aquifer system-II)

Quality of groundwater in the fractured aquifer system have been studied using the analytical data of water samples collected from during exploratory bore wells drilled by CGWB. However, these samples have been collected represent the cumulative quality of all water yielding fractures in the well, they have been used only to get an idea about the water quality of the deeper aquifer as a whole and is potable at all locations except few locations (Kannore, Ramanattukara and Avalakuttoth).

For the deeper aquifer in hard rock terrains, the ground water quality is good and electrical conductivity ranges from 82 to 500(µs/cm at 25°C); higher values are also observed at Kuttoth (2930 µs/cm), and Paleri (2340 µs/cm at 25°C) and are within in permissible limit, quality is deteriorated at Kannore (13400 µs/cm), Ramanattukara (10300 µs/cm), and Avalakuttoth (4630 µs/cm at 25°C). The Deeper Aquifer tapping the coastal Tertiary formations and recent formations are found to be brackish. The water samples from the tubewells drilled at Badakara having Electrical conductivity of 168 µs/cm and Meladi of 2100 µs/cm at 25°C and

chloride content ranges from 26 to 781 mg/l (Annexure- VII). The Piper diagram and Wilcox Diagram of deeper aquifer is shown 3.14 and 3.15 repsectively.

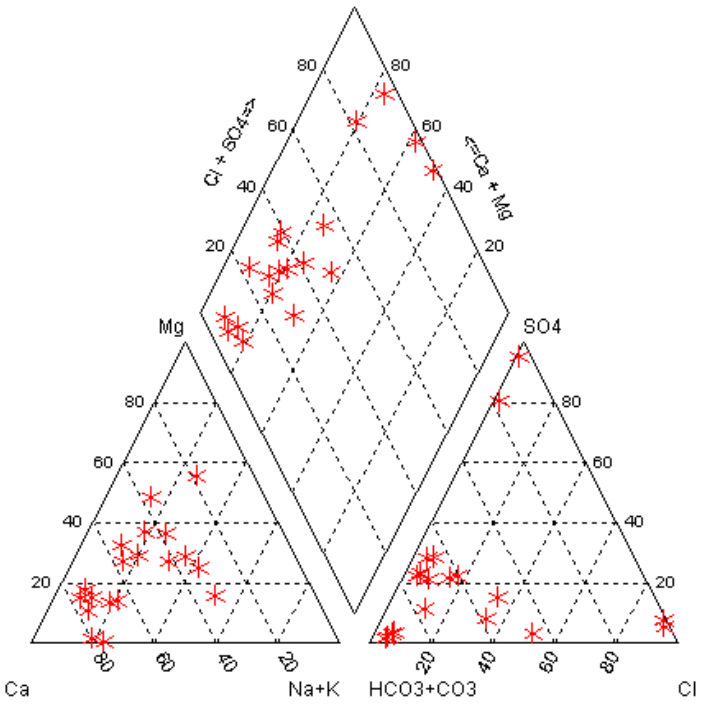


Figure 3.14 Piper diagram of Deeper aquifer-II

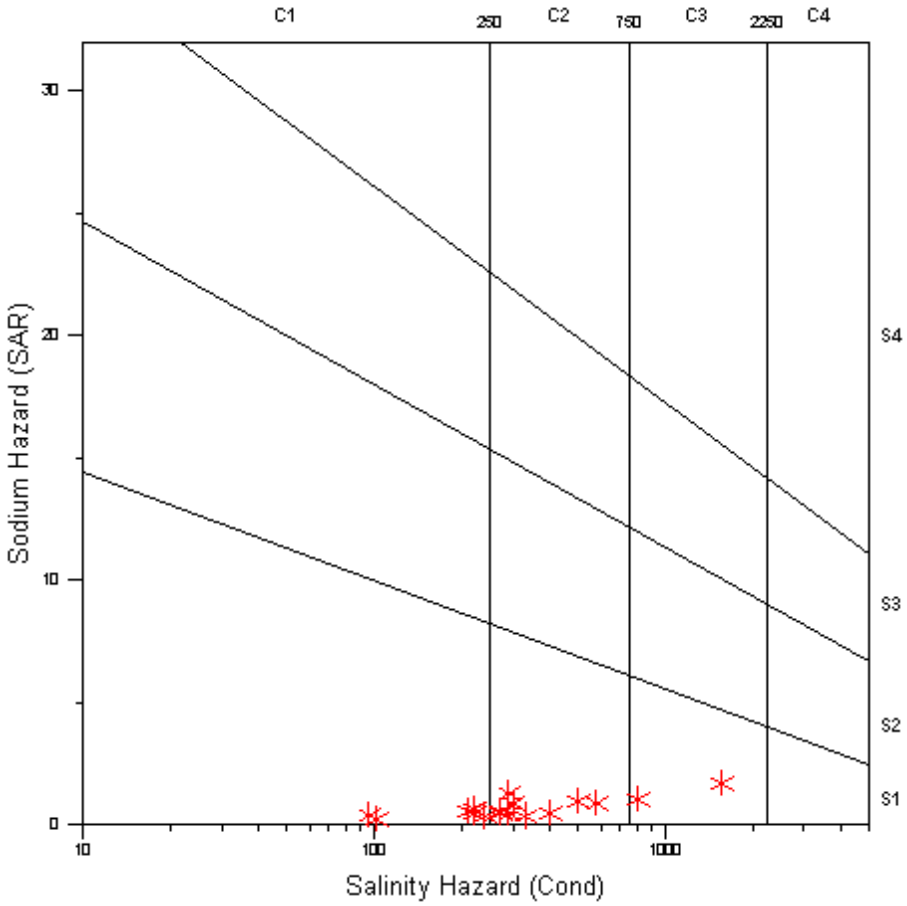


Figure 3.15 Wilcox diagram of deeper aquifer-II

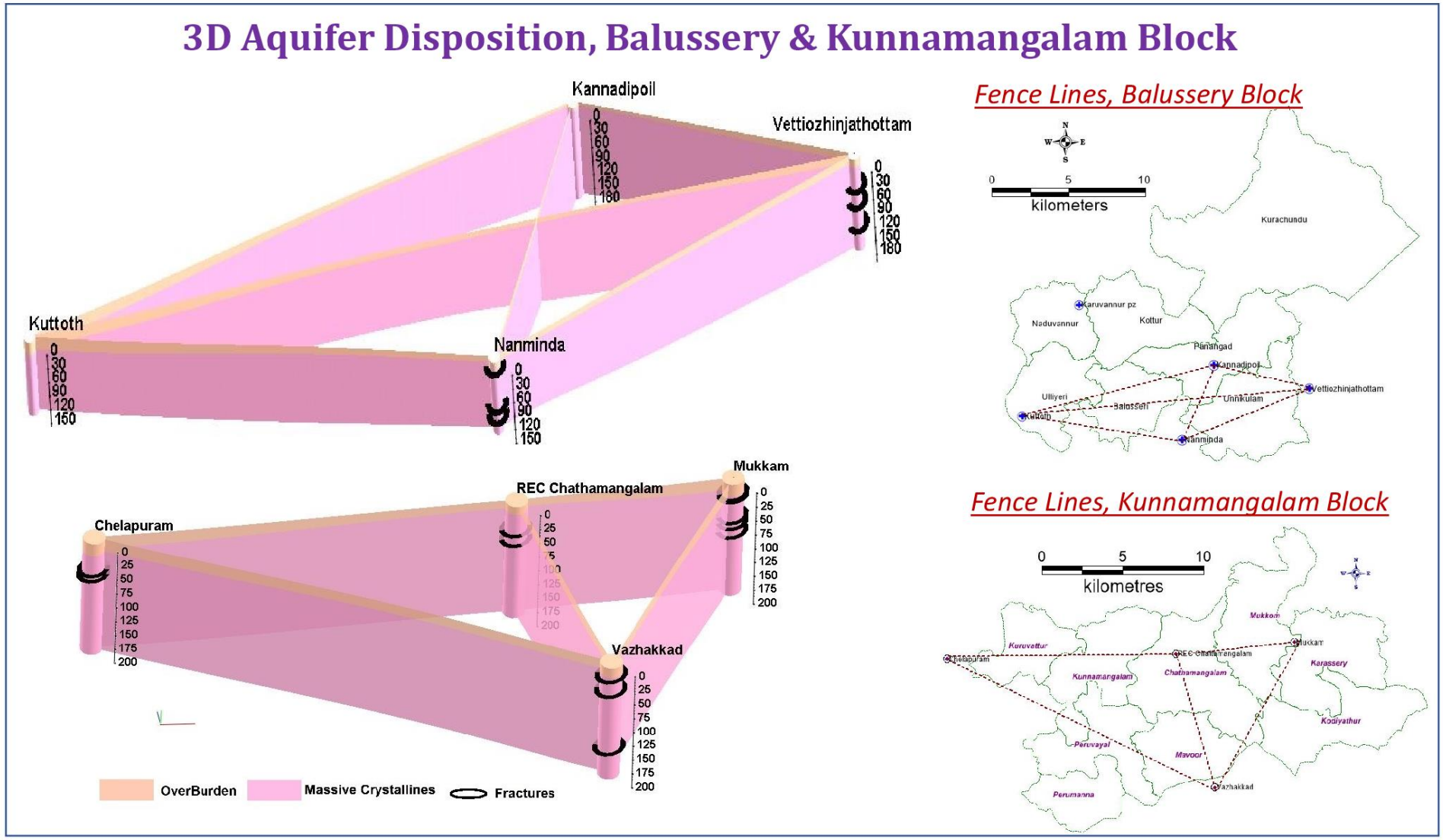


Figure 3.16 Panel diagram showing block wise aquifer disposition

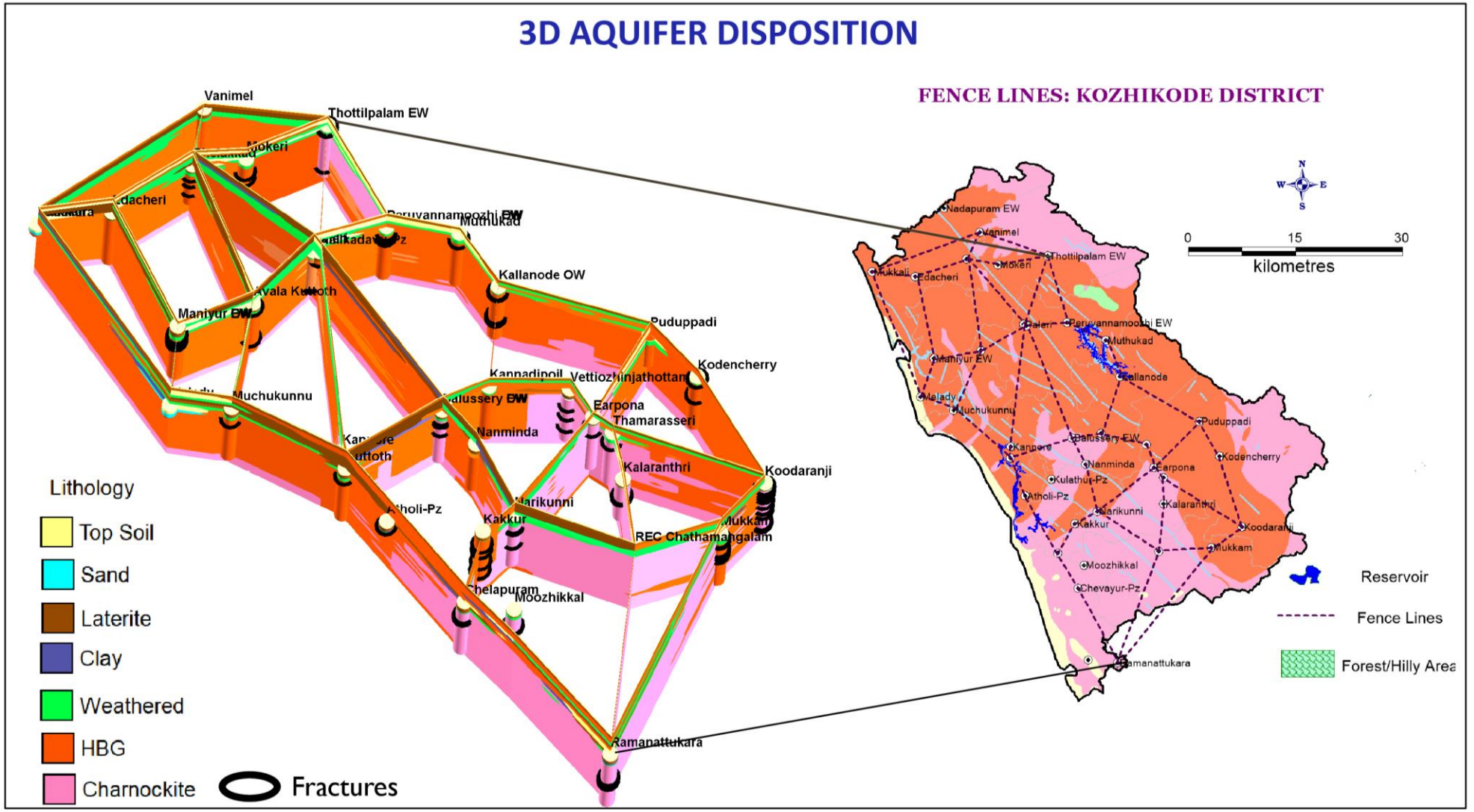


Figure 3.17 Panel diagram showing aquifer disposition of Kozhikode District

Table 3.1: Converted details of formation encountered in the boreholes of Kozhikode district

Location & Coordinates	RL (m amsl)	Depth drilled (m bgl)	Depth constructed (m bgl)	Thickness in meters						Depth to basement (m bgl)
				Recent	Laterite	Warkali	Quilon	Vaikom	Alleppey	
Badagara 11⁰ 40'32" 75⁰ 33'16"	6.01	27	20	20.75	0	0	0	0	0	20.75
Meladi 11⁰ 30'41" 75⁰37'18"	2.215	32	31	0	17.75	0	0	13	0	30.75

3.3 Groundwater and its relation to geological structures (Fracture analysis)

Geological structures like fractures, lineaments, faults, joints, intrusive rocks etc influence the occurrence and movement of groundwater. Such information extracted from field investigations as well as from the study of topo-sheets and imagery was utilized to identify potential lineaments and fractures in the area.

The crystalline rocks have undergone several phases of tectonic deformations resulting in intensive folding oftherock units which can be noticed as antiforms and syn forms with trend of fold axis varying from NW-SE to E-W, and the development of numerous sets of foliation, lineaments and fractures. Foliation and joints are important structural features in addition to the folds. The general trend in the crystalline rocks is NW-SE with dips of 50^0 to 80^0 in NE or SW directions. The prominent fractures are in the NW-SE, WNW –ESE, NE-SW and E-W directions as per the study of landsat imageries and bhuvan -NRSC data. The drainage in the area is controlled by these fracture systems. The dolerite and gabbro dykes are trending in NNW-SSE direction, majority of the highly fractured rocks are oriented in NE-SW direction and shown in rose diagram. Rose diagram is shown in Figure 3.18 and Lineament map of the study area is shown in Figure 3.19 and the number of lineaments and its direction is given in table 3.2 respectively.

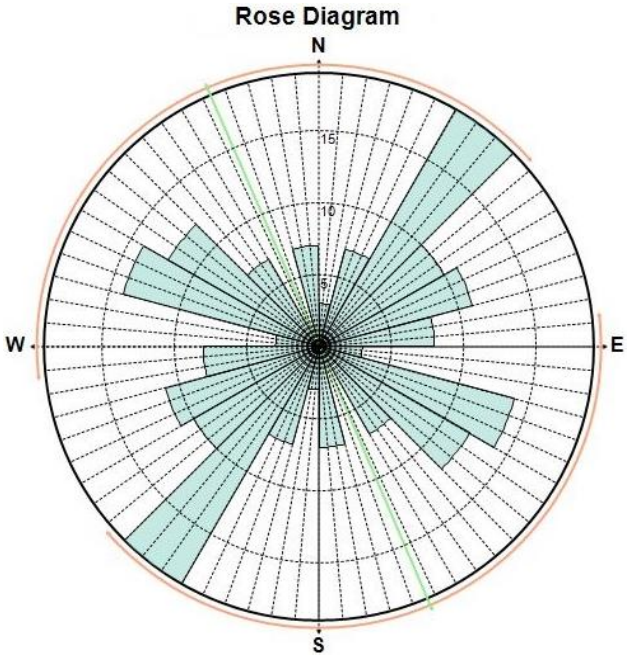


Figure 3.18 Rose diagram of the lineaments in the study area

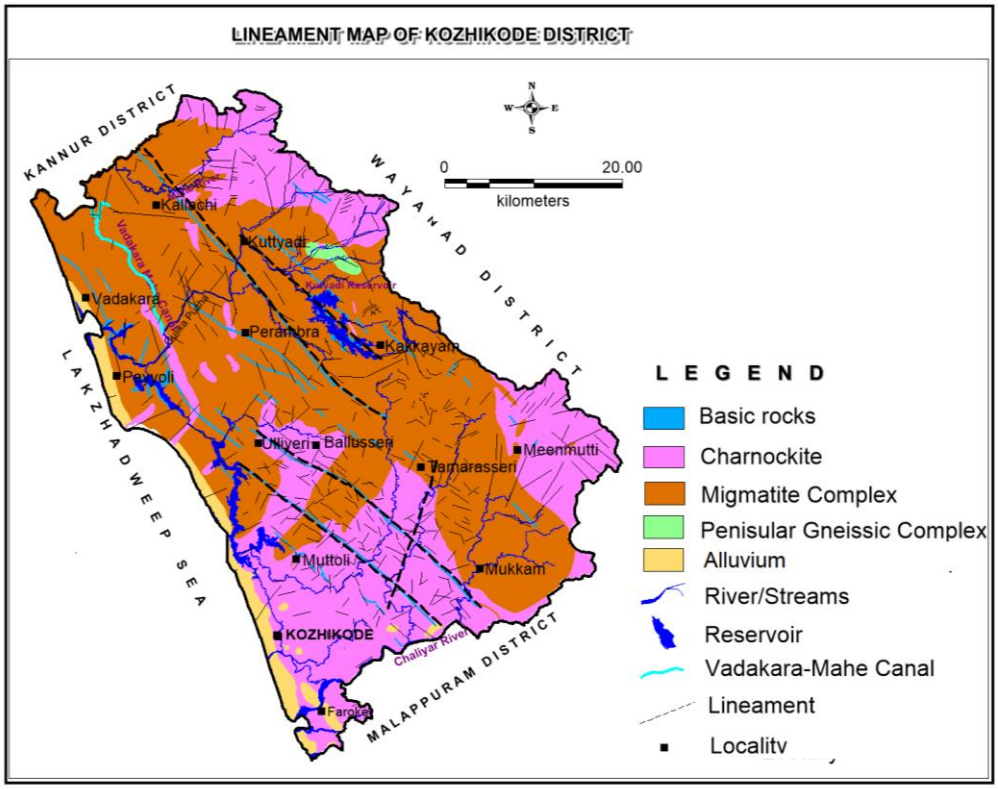


Figure 3.19 Lineament map of the Kozhikode District

Table 3.2: Lineaments in different directions and its percentage with maximum yield

Lineament Direction	No.of Lineaments	Total Lineaments (%)	Up to Discharge (lps)
NS	2	4	3
EW	6	12	10
NE-SW	20	40	17.5
NW-SE	15	30	15
NNE-SSW	3	6	10
NNW-SSE	4	8	8

Based on exploratory data, 32 exploratory wells were considered for fracture analysis in which 14 wells drilled in Charnockite and 18 wells drilled in Migmatite gneiss. In Charnockite terrain three set of fractures are encountered up to depth of 180 m bgl in which potential two to three set of fractures are identified at depth up to 110m bgl. However, some potential fractures are also identified upto 160m depth. In gneissic terrain three sets of fractures are encountered up to depth of 196 m bgl in which potential set of fractures are identified at depth up to 99m bgl. General potential fractures are ranges from 50 to 110m bgl.

3.4 Aquifer maps

Aquifer maps brings together various aspects of the aquifers and their ground water resources in the form of a map, which can then be used by the stakeholders to plan their sustainable development and management.

The processes of digitisation, preparing GIS dataset of aquifer thickness, depth of occurrences of water bearing zones, their water bearing and transmission properties, depicting geophysical parameters, water quality parameters, ground water resources and visualization of the aquifer units in three dimension including fence and cross section is used for the preparation of aquifer maps.

3.4.1 Aquifer map of phreatic aquifer system

Based on the weathered zone thickness, aquifer geometry, water levels, ground water yield and hydraulic properties, the aquifer map of the phreatic aquifer system is prepared. The western part of the study area shows high ground water potential is upto 20 m^3/day (cub. m/day) of 3 to 5 hours of pumping, north, central, southern and western parts ground water potential is upto 15 m^3/day of 1 to 3 hours of pumping, south-eastern to eastern part ground water potential is upto 10 m^3/day of 1 to 2 hours of pumping and in northeastern to eastern part the weathered thickness is limited and the ground water potential is up to 5 m^3/day in 1 hours of pumping. By integrating the available data along with aquifer mapping, an aquifer map of the phreatic aquifer system has been prepared and is shown in Figure 3.20. The Phreatic Aquifer map categorised the area into three categories based on the type of aquifer, depth to water level, average depth of the wells, sustainable yield, ground water quality as well as the groundwater prospects. The aquifer with a thickness upto 36 m is noticed in the study area.

Category I- Alluvium: Extensive along the coast except in central coastal portion of the district as thin strip. Thickness upto 8 m in the southern part and is lessthan 5m in the northern part. Ground water occurs in phreatic condition. Dugwells feasible throughout filter points wells where thickness exceeds 5m. Dugwells usually depth range of 4 to 8 m and having diameter of 1.5 m. Filter points wells having as depth of 6m. These are the more promising sites of groundwater. The aquifer materials possess high porosity and permeability. The depth to water level is shallow with a yield up to 20 m^3/day.

Category II - Laterite: The weathered laterite seen in the midland part of the district where the thickness of this aquifer varies from 10 -20 m belongs to this category. Normally, dug wells collapse at the lithomargic zone and groundwater occurs at a deep-water level. Area is suitable for dugwell, dug cum borewell and borewell. Wells dry during summer shows the less yielding capacity of this aquifer. Recharge pits and percolation tanks can be suggested in this aquifer to maintain the groundwater level during lean period. Dugwells may yield up to 15 m^3/day.

Category III - Massive rocks: The hilly area seen on the eastern part of the study area are characterised by structural and deudational hills with high drainage density and thin soil cover are included under this category. This represents the run-off zone with low groundwater prospects. Top weathered zone forms the potential phreatic aquifers. The intervening valleys with gentle to moderate slopes where having high degree of weathering contribute low to moderate groundwater potential yield (5 to 10 m^3/day). Depth range of dugwells is 5 to 18 m and having dia morethan 4m.

3.4.2 Aquifer map of fractured aquifer system

By integrating the exploration details, lithological cross sections and aquifer properties an aquifer map for fractured aquifer is prepared and is depict in Figure 3.21. The success rate of wells drilled in hard rocks depends upon the development of interconnected secondary porosity. Lineament controlled valleys hold promising sites for borewell. Based on the available data two to three sets of fractures are identified in the study area. Borewells generally tapped in the second set of fracture i.e intermediate are generally good and potential in ranges from 50 to 110 m bgl (upto 15 lps) and second potential range is up to 150 m bgl of the study area.

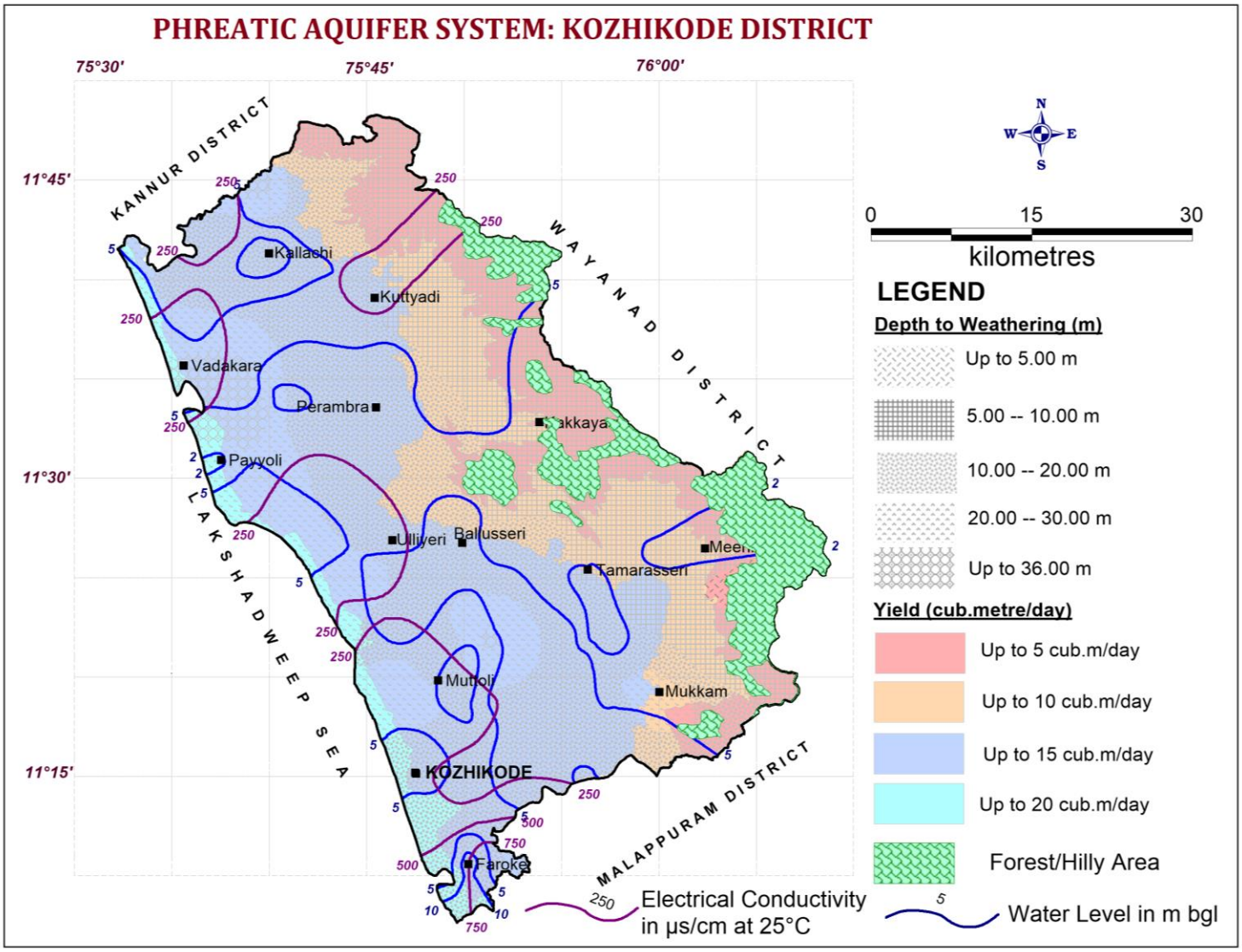


Figure 3.20 Aquifer map of Phreatic Aquifer System

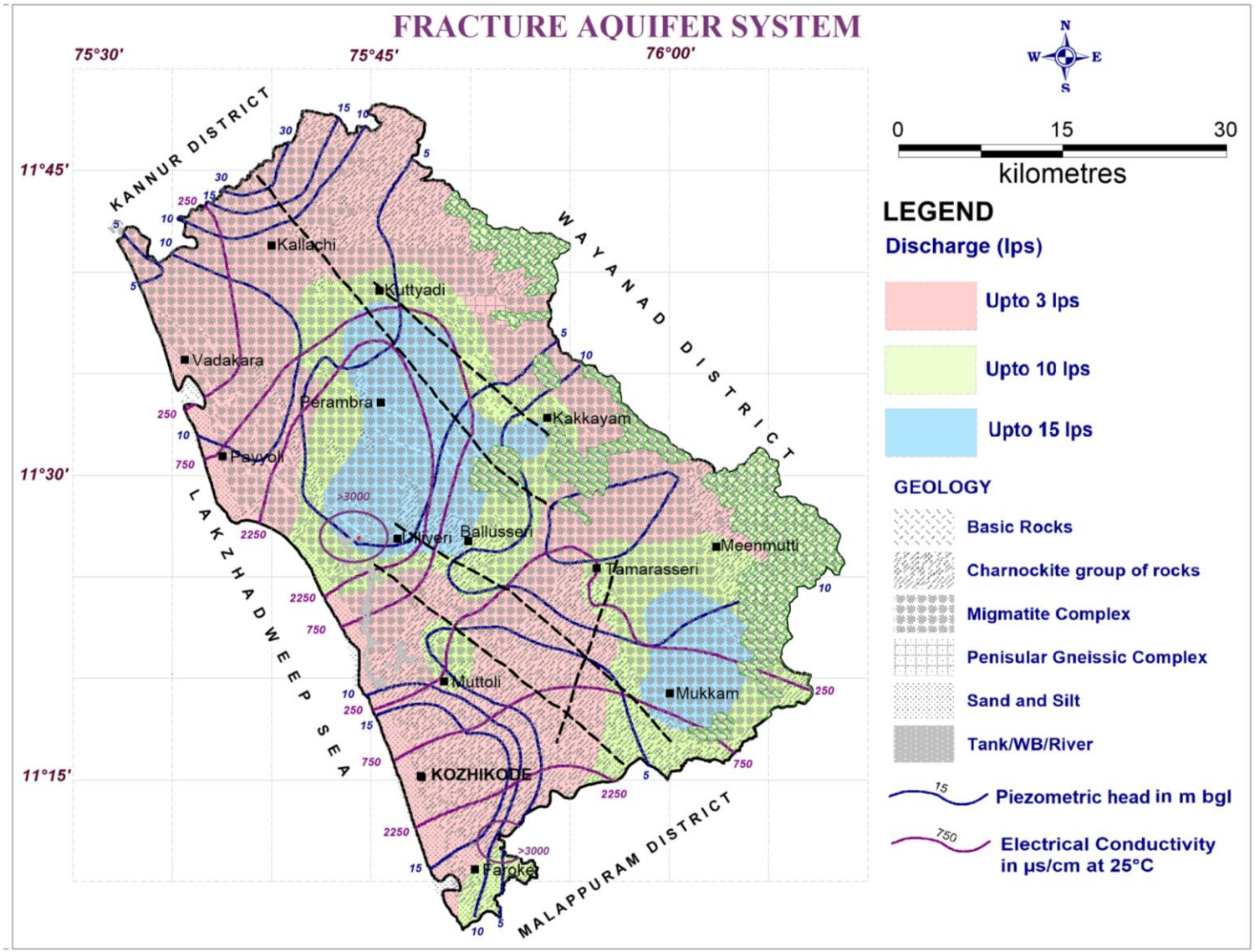


Figure 3.21 Aquifer Map of Fractured Aquifer System

4.0 GROUNDWATER RESOURCES

Groundwater resource estimation of the area have been carried out by taking Dynamic and In-storage resources of unconfined aquifer and confined aquifers present upto 200m depth in hard rock aquifers and 300m depth in alluvium. The assessment of dynamic groundwater Resources of the study area has been carried out based on Groundwater Estimation Committee (2015) methodology. The occurrence of potential aquifers (productive zones) has been demarcated based on aquifer mapping. The groundwater resource of each aquifer zone has been calculated considering the specific yield of the formation. The specific yield value for the unconfined aquifer has been taken as 2.5% to 16% whereas for the confined aquifer, the storativity value has been considered.

4.1 Groundwater resources in the phreatic zone (Aquifer-I)

4.1.1 Dynamic groundwater resources

The study area is blessed with groundwater resources in the Alluvium and weathered zone (Aquifer-I) which can be developed in the future. The groundwater in the shallow weathered zone is mostly developed through dug wells for domestic and agricultural purposes and to a limited extent for industrial–purposes. Despite these abundant resources, some areas experience shortage of groundwater during summer months, due to the unplanned and non-scientific development of groundwater besides the topographic control.

The total annual recharge of groundwater has been computed using average water level fluctuation in Groundwater Monitoring Wells and specific yield of the respective aquifers. Groundwater extraction is mainly for domestic and irrigation purposes in the area. In view of the non-availability of data on the number of wells being used for domestic purposes, the groundwater extraction for domestic uses has been computed as the product of the population (2011 projected for 2017) and the per-capita water requirement (assumed as 150 L/day/person) and the share of groundwater varying from 25 to 100% based on availability of surface water sources for domestic water supply.

The groundwater extraction has been computed by multiplying the number of irrigation wells in each block with the corresponding unit draft. The Total Annual Extractable Groundwater Resource has been computed as 311.30 Million Cubic Metre (MCM) whereas the gross groundwater extraction is 177.61 MCM, thus keeping a balance of 78.16 MCM for future development. Rainfall recharge accounts for about 90 percent of the annual recharge, with the remainder contributed by other sources. The stage of groundwater extraction is 57.05%. Out of 12 blocks, two blocks viz. Balussery and Kunnamangalam are in Semi critical and the rest are in Safe category and is shown in Fig. 4.1.

4.1.2 In-storage in Aquifer-I

The quantum of groundwater available for development is usually restricted to long term average recharge or dynamic resources. For sustainable groundwater development, it is necessary to restrict it to the dynamic resources. Static or in-storage groundwater resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage groundwater resources be taken up at this stage.

The computation of the static or in-storage groundwater resources of alluvium/ weathered zone has been done after delineating the aquifer thickness and evaluating the specific yield of the aquifer material. Aquifer thickness is computed by taking the difference of average depth of weathering in each block from groundwater exploration data and average depth to water level in the pre-monsoon period. Since specific yield studies for the static zone of weathered zone is not readily available, 50% of the specific yield value assigned for dynamic zone has been considered for computation. Thus, the total annual exploitable groundwater resource is the sum of dynamic resources (311.30 MCM) and the in-storage (236.33 MCM) which comes about 547.65 MCM.

Table 4.1 Ground water resources estimated for aquifer-I (Dynamic & Instorage) for Kozhikode District

#	Block	(Non-Command area) (Sq.Km.)	Annual Extractable Ground Water Recharge of unconfined Aquifer/ Dynamic (mcm)	Existing Gross Ground Water Extraction for irrigation (mcm)	Existing Gross Ground Water Extraction for domestic and industrial water supply	Existing Gross Ground Water Extraction for All uses (5+6) (mcm)	Provision for domestic, and industrial use up to 2025 (mcm)	Net Ground Water Availability for future use (4-5-8) (mcm)	Stage of Ground Water Extraction {(7/4) * 100} (%)	Phreatic Instorage Aquifer Thickness (m)	In storage Ground Water Resources of Unconfined Aquifer (mcm)	Ground Water Resources Aquifer-I (mcm) (4+12)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	**Ballussery**	139.53	24.65	9.08	11.54	20.61	18.77	4.03	83.64	27	11.30	35.95
2	**Chelannur**	138.66	23.01	4.12	11.70	15.82	19.04	7.19	68.76	33	13.73	36.74
3	**Koduvally**	272.98	44.63	5.56	15.72	21.28	25.49	13.52	47.69	26	21.29	65.92
4	**Kozhikode**	163.51	27.15	4.67	13.37	18.03	21.73	0.74	66.42	33	26.98	54.13
5	**Kunnamangalam**	169.94	28.72	6.35	17.04	23.39	27.72	5.32	81.47	30	15.29	44.01
6	**Kunnummal**	131.52	25.01	3.58	10.75	14.33	17.49	3.93	57.31	27	7.10	32.11
7	**Melady**	84.07	20.06	1.97	6.44	8.41	10.47	7.61	41.93	32	43.04	63.10
8	**Panthalayani**	98.55	32.42	2.66	9.54	12.20	15.52	14.24	37.62	31	48.88	81.30
9	**Perambra**	179.02	34.06	4.15	8.93	13.08	14.53	15.38	38.41	27	14.50	48.56
10	**Thodannur**	96.77	15.85	1.80	7.30	9.11	11.88	2.16	57.45	32	9.29	25.14
11	**Tuneri**	114.97	16.66	2.69	7.94	10.63	12.92	1.05	63.82	32	11.04	27.70
12	**Vadakara**	72.28	19.10	2.07	8.64	10.70	14.05	2.98	56.04	32	13.88	32.98
	TOTAL	**1661.8**	**311.30**	**48.70**	**128.91**	**177.61**	**209.62**	**78.16**	**57.05**		**236.33**	**547.65**

The block wise groundwater resources estimated for the area is given in Table 4.1.

4.2 Groundwater resources in Aquifer-II

Assessment of groundwater resources of Aquifer-II (Fracture Aquifer System) assumes crucial importance since over-exploitation of these aquifers may lead to far more detrimental consequences than that of shallow unconfined aquifers. In view of the small amounts of water released from storage in the semi-confined aquifers, large scale pumpage from semi-confined to confined aquifers may cause decline in piezometric levels over a wide area and large-scale reduction in head over the years may lead to land subsidence. To assess the groundwater resources of the semi-confined aquifers, groundwater storage approach is recommended. Moreover, there is a need of more observation wells tapping exclusively deeper aquifers. The storativity for Aquifer-II (Semi confined to Confined In-storage) of the study area varies from 0.001 to 0.008 in fracture aquifer system.

It is assumed that groundwater developmental activity has not started from the fracture aquifer system of the study area. The groundwater resources in the deep fracture aquifer system are estimated based on the depth of occurrence of fracture and on the assumption that the Storativity of the fracture and associated matrix as about 10% of the storativity/ specific yield of the in-storage zone in aquifer-1. The total water resource in the fracture system thus computed is about 430.50 MCM (Table.4.2).

Table 4.2 In-storage resources estimated for aquifer-II (Kozhikode District)

Sl. No.	Assessment Unit/ Block	Mapped Area in Sq.Km.	Aquifer-II (Semi - confined) Thickness (m)	Storativity/ Specific Yield (%)	In storage Ground Water Resources of Semi- confined to Confined Aquifer (mcm)
1	2	3	5	6	7
1	Ballussery	139.53	115	0.0015	24.07
2	Chelannur	138.66	110	0.0015	22.88
3	Koduvally	272.98	115	0.0015	47.09
4	Kozhikode	163.51	105	0.0025	42.92
5	Kunnamangalam	169.94	110	0.0015	28.04
6	Kunnummal	131.52	115	0.001	15.12
7	Melady	84.07	110	0.008	73.98
8	Panthalayani	98.55	110	0.008	86.72
9	Perambra	179.02	115	0.0015	30.88
10	Thodannur	96.77	110	0.0015	15.97
11	Tuneri	114.97	110	0.0015	18.97
12	Vadakara	72.28	110	0.003	23.85
	TOTAL	**1661.8**			**430.50**

The total ground water resources of the study area are the sum of dynamic resources and static resources and calculated to be 978.15 mcm.

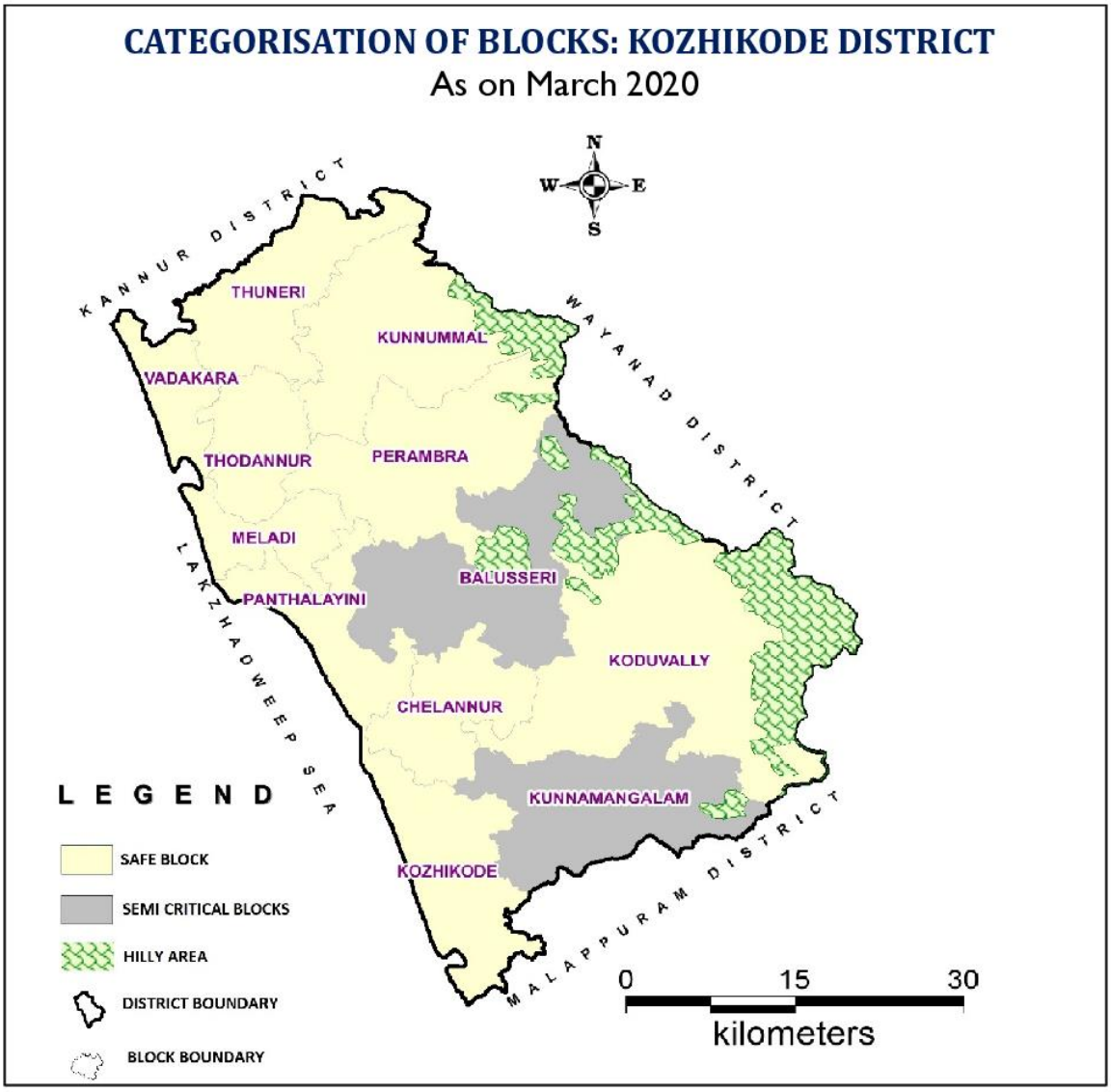


Figure 4.1 Categorization of blocks in the district (GEC 2020)

5.0 GROUND WATER RELATED ISSUES

Groundwater issues in the area can be categorised into geogenic and anthropogenic activities, which affects natural resource either in a quantitative or, qualitative manner. Anthropogenic activities or natural like rapid urbanization, change in land-use and cropping pattern, indiscriminate dumping of bio-degradable and non-biodegradable waste into abandoned wells, surface water sources, wet land filling, cultivable land encroachments, soak pits, illegal sand mining in riverbeds and paddy fields have adverse effects on the quantity and quality of the water. Quarrying of the rocks create localized groundwater problems in the area. Geogenic activities like iron contamination, salinity ingress in wells or rivers are also existed in the area.

As per the groundwater resource estimation for 12 development blocks in the district, 2 blocks fall under Semi Critical category whereas the remaining 10 falls under safe category. The semi critical blocks viz. Balussery and Kunnamangalam are covered by hard rock terrains. Even though the blocks in the study area falls in safe or semi critical category drying up of wells is experienced during summer season and in rain deficient years.

In the study area groundwater is utilized mostly through dug wells. In high land terrain bore wells are also common as the dug wells in this area usually dries up during summer. In high land area springs are also a good source for drinking water. Except for iron and nitrate above the permissible limits specified for drinking in certain locations, the water quality is generally good in the area as per CGWB and National Rural Drinking Water Project (NRDWP) report, 2019. In Kozhikode district, although there are no major problems to be highlighted, experience minor issues that can be rectified by adopting site specific management practices. A few issues are discussed below:

- *Water scarcity* - Acute and widespread water scarcity being faced in the parts of midland areas and hilly areas in summer period due to drying up of dug wells. With reduced summer flow, the five important rivers that pass through the district are facing sustainability issues. Extensive depletion of aquifer in parts of many panchayats has been reported across the district. As per the study, the panchayats experiencing water scarcity problem are in parts of Vanimel, Chekkiad (Thuneri Block); Kavilumpara, Naripatta, Kayyakody & Maruthonkara (Kunnumal Block); Chakkittipara, Kayanna (Perambra Block); Kurachund, Panangad,Ulliyeri & Balussery (Balussery Block); Puthupadi, Kodanchery, Koodaranjhi, Kattipara & Tamarassery (Koduvally Block); Peruvayal, Kuruvattur, Chattamangalam, Kodiyathoor ,Kakkad, Thazhekod,Karassery (Kunnamangalam Block); Narikunni, Kakkur and Nanminda (Chelannur Block), Arikulam (Panthalayani block). Drinking water shortage is severe in Beypore, Vellayil, West Hill, Puthiyappa, Koyilandy, Payyoli and Chombal areas along the Kozhikode coast. Dug wells in midland region get dried up if monsoon is delayed or if there are no summer showers as the laterite formations which are highly porous with low retention capacity loose water as base-flow in the summer months. The increased dependence on bore wells in midland areas leads to drying up of dug wells in lateritic mounds and slopes, which affects the drinking water needs of those areas. 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. The water availability is meagre especially in hilltops, steep slopes, and isolated hillocks. Rapid urbanization resulting in increased water consumption and reduced water conservation and groundwater recharge. Recent changes in land use and cropping pattern, resulting in conversion of land from agricultural to non-agricultural uses and consequent reduction in water conservation and groundwater recharge.
- *Coastal Erosion & Salinity*–In Kozhikode coast, especially in the southern part, the low-lying areas are mostly threatened by salinity problem and is observed in nearby wells and can be due to seasonal variation. The coastal areas stretching from Kadalundikadavu to Azhiyur (78 km) experiences coastal erosion frequently and the stretch Kadalundikadavu to Chaliyar experience severe coastal erosion which leads degrading ground water quality

nearby coastal aquifer. Many wells in Payoli, Thuravur, Thikodi, Koyilandy, Azhiyur near Mahi River, Kottakkal near Kottakkal port, Puthiyanirathukadavu near Elathur, Kothi near east Kallayi and Kadalundikadavu areas have become unusable due to salinity. Higher EC values are also get in deeper aquifers as in Paleri (2340 µs/cm), Kuttoth (2930 µs/cm) at 25^{o}C, and is more deteriorated at Avalakuttoth (4630 µs/cm), Ramanattukara (10300 µs/cm) and Kannore (Ulliyeri) (13400 µs/cm) at 25^{o}C .In general, the quality problems are seen highly localised which is found along the coastal area where the streams are confluence with sea particularly during summer months.

- *Groundwater depletion*–Depletion of groundwater is observed in semi- urbanised areas such as Kozhikode, Balussery and Kunnamangalam Blocks due to huge withdrawal of groundwater. Various sand mining activities may also observe in the area which may result the contamination of the river water and the groundwater in hydraulic connection with it. This declining water table trend, if not checked, would assume an alarming situation soon affecting the economy.
- *Quarrying* – Quarrying of rocks create localized groundwater depletion in the area. Charnockites occupying a major part of the area are a good source of granite dimension stone as well as building material. Localised quarrying for Granite building stones is highly rampant in the Peruvayal, Kuruvattur, Chattamangalam, Kodiyathoor, Kakkad, Thazhekod, Balussery, Naduvannur, Sivapuram, Unnikulam villages. In addition to granite building stone, quarrying/mining of laterite is common in the fringing area of soft rock and hard rock. Migmatite gneiss and biotite gneiss as building material are quarried many places. Frequent blasting of rocks in the above villages and its surrounding area has affected the shallow aquifer system and resulted in groundwater flow pattern change and consequent drying up of dugwells and borewells. Cutting of forest and removal of vegetal cover for the purpose of quarrying activity increases the run-off and reduce infiltration of rainwater. Removal of over burden comprising of laterite, lithomarge and weathered rock for quarrying activity in effect removes the phreatic aquifer of the area.
- *Groundwater quality problems* – Iron above permissible limit (>1 mg/l) are observed at certain pockets in panchayaths of Thikkodi (Meladi Block), Arikulam, Chengottukavu (Panthalayini block), Chellannur (Chellannur block), Kadalundi (Kozhikode block), Chakittipara (Perambra block). Nitrate above permissible limit (>45 mg/l) are observed in certain pockets are observed in Vadakara, Thikodi, Chemancheri, Chelavur, Kozhikode town and Devarkoil. Studies carried out by research institutions and state departments reported coliform bacteria in groundwater samples collected from the area. As per those studies, post-monsoon samples showed significantly high coliforms compared to the pre-monsoon. Thermo-tolerant coliforms are high during monsoon season. This seasonal change could be because of rainfall, overland flow, nutrient load, and temperature change. The water scarced areas, locations of tidal ingress, quality issues are depicted in figure 5.1.
- *Participatory ground water management issues* - Lack of scientific understanding of groundwater situation at grassroots level, lack of attention to demand management measures and near-absence of community participation in groundwater management have led to the concept of participatory groundwater management, under which efforts shall be made to train all the stakeholders including the farmers/youths in villages through para-hydrogeologists for sustainable management of water resources.

Periodical maintenance of the existing structures, checking of drinking water quality of wells and checking for leakage from drinking water and septic tank pipelines will ensure safe drinking water. Also, conducting awareness programmes to maintain hygienic conditions around drinking water sources by the concerned government, non-government organisations, and local institutions would lead to safer drinking water provisions. An ideal groundwater management approach will be one that will not only construct structures but also take an effort to sensitize and involve the community to work on the issue.

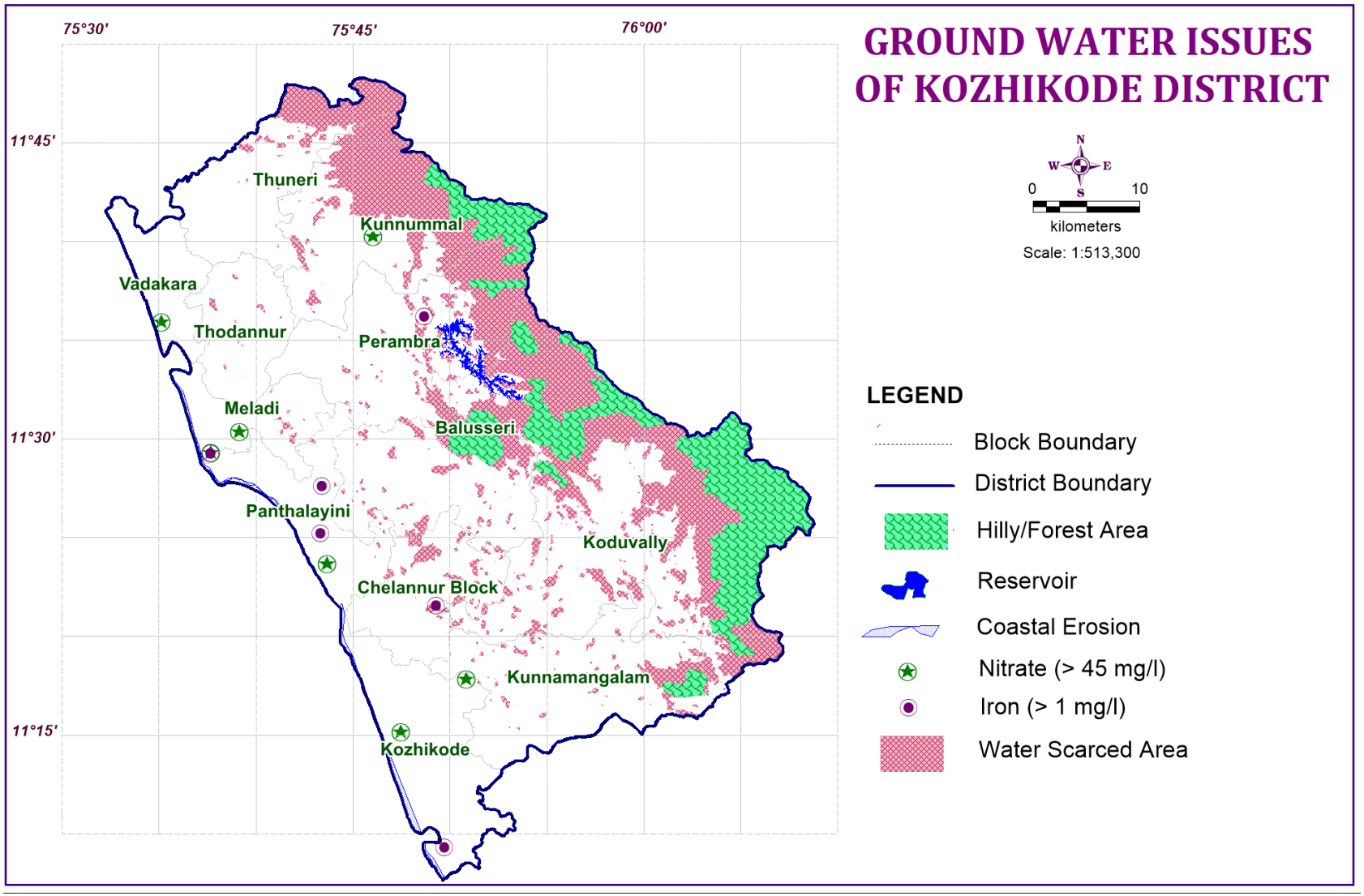


Figure 5.1 Groundwater Issues of the Kozhikode District

6.0 MANAGEMENT STRATEGIES & AQUIFER MANAGEMENT PLAN

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

Even though the study area receives good annual rainfall close to 3570 mm and has salubrious climatic conditions, it has been experiencing increasing incidents of water scarcity in summer for meeting the irrigation as well as domestic requirements. Even in the years of normal rainfall, summer water scarcity problems are there in the midland and highland regions of the study area. This ironic situation araised mainly due to natural reasons such as undulating topography with steep slopes resulted in high run-off and low recharge. Besides, this the limited thickness of aquifer material and shallow depth to massive bed rock in the eastern part of the area limits groundwater storage in the aquifer system. Development of water resources needs a scientific management system co-ordinating the efforts of all concerned agencies for a speedy development of the agricultural sector in the area. While formulating various groundwater development and management plans, geology of the area should be given prior importance.

6.1 Sustainable management plan

An accurate account of the total available resources is a prerequisite for an effective groundwater management. From the resource estimation of 12 development blocks, two blocks viz. Balussery and Kunnamangalam are categorised as semi critical and the remaining are safe. So, there is scope for further groundwater development for irrigation in majority of the blocks of the study area where the stage of extraction is low. Eventhough the scope for resource development is high; the availability of the resource is not uniformly distributed in the block. Hence, the groundwater development should be coupled with management of water resources through rainwater harvesting and artificial recharge schemes by recommending 40 check dams, 55 vented cross bars ,7 percolation ponds and 3 sub surface dykes with limited field checks in Kozhikode district as given in table 6.1.

Farmers may be encouraged to adopt modern irrigation techniques like drip and micro irrigation to have optimal use of the available resources and community irrigation schemes must be encouraged in water stressed blocks and adjacent safe blocks. An area of 11.14 sq. km. can be brought for adopting micro irrigation to increase the water-use efficiency by saving a substantial amount of water. Since it supplies water directly to the crop, rather than the land around, water losses occurring through evaporation and distribution are significantly reduced. There is water saving of 30-70 per cent for different crops like arecanut, nut meg, banana, and plantains under drip method of irrigation. Effective rainfall management like field bunding, contour bunding/trenching, staggered trenching, land levelling, mulching etc can be adopted. Capacity building, entry point activities, ridge area treatment, drainage line treatment, soil and moisture conservation, nursery raising, afforestation, horticulture, pasture development, livelihood activities for the asset-less persons and production system & micro enterprises for small and marginal farmers etc.

6.2 Groundwater Augmentation plan

Augmentation of groundwater can be achieved through periodic repair, restoration, and renovation of water bodies like tanks (27 nos), check dams (30 nos.), vented cross bars (394 nos), percolation ponds (3796 nos) and cleaning of existing water bodies like ponds and tanks (196 nos with an area of 107 Sq.Km.) and strengthening carrying capacity of traditional water sources, is recommended for increasing the storage capacity as well as infiltration rate. Normally it can be achieved through capturing surface runoff. Topography of the area are suitable for various artificial recharge structures such as check dams, contour bunding,

trenching, pitting, terrace cultivation and sub-surface dykes. It needs uncommitted runoff from the adjoining localities to transport to the needy areas through diversion channels. In the uplands, wherever IInd/IIIrd order streams occur we may construct Checkdams, Vented Cross Bars and Nallah Bunds to augument the groundwater recharge.

6.3 Supply -Side Aquifer Management Plan

6.3.1 Short-term local solutions for ground water management

To provide quality drinking water, there should be an integrated water resources management system in water supply. The distribution of water should be equitable across users particularly marginalised and poorer user groups in water scarced areas like Vanimel, Chekkiad (Thuneri Block); Kavilumpara, Naripatta, Kayyakody & Maruthonkara (Kunnumal Block); Chakkittipara, Kayanna (Peranbra Block); Kurachund, Panangad,Ulliyeri & Balussery (Balussery Block); Puthupadi, Kodanchery, Koodaranjhi, Kattipara & Tamarassery (Koduvally Block); Peruvayal, Kuruvattur, Chattamangalam, Kodiyathoor ,Kakkad, Thazhekod,Karassery (Kunnamangalam Block); Narikunni, Kakkur and Nanminda (Chelannurr Block) . The main solutions are to prepare comprehensive water management system and water allocation plans on a participatory approach, involving users, planners and policy makers at all levels to enable the community and stake holders to monitor and judicious management of the ground water as common pool resources themselves.

In views of rapid urbanization in urbanised areas Kozhikode Muncipal Corporation, Koyilandy, Vadakara, Kunnmangalam and Balussery the domestic water needs are increasing multifold and the water wastage component is increasing mainly because of leakages through distributor system areas. Wastewater collection and disposal are equally important like supply of protected water in maintaining public health. Effective implementation of roof top rainwater harvesting (Storage) is essential for all areas for resource sustainability.

The areas around Perambra, Ulliyeri and Mukkam villages have high groundwater potential zones with varying fracture depths which can be developed for agricultural as wells as rural water supply schemes.

The major irrigation scheme of the district is Kuttiyadi irrigation project across the Kuttiyadi River. In many places the canals and aqueducts are in conditions of serious leakages. In northern parts of the district like Avala pandy and Velom Ayanchery which are major rice growing tracts, there are instances of inundation of paddy fields due to seepage of water from Kuttyadi canals resulting in even complete crop loss of Mundakan crop when canals are opened in February. Majority of the existing Minor irrigation structures like tanks, ponds and VCB's are dilapidated and needs repair. So urgent lining works of canals are required.

A drinking water project with installed capacity of 174 MLD water, from Kuttiyadi irrigation project reservoir is completed and now 150 MLD of water is drawing from the reservoir to supply water to major parts of Kozhikode district under the JBIC scheme. On request sufficient water is released to Kuttiady River through the Spill way and Canal sluice to reduce the salinity near intake well of Kerala Water Authority at Gulikappuzha pumping station in Velom gramapanchayath for supply of drinking water to Vatakara Municipality and adjoining gramapanchayaths.

6.3.2 Long-term local solutions for ground water management

To supplement the domestic demand in water scarce panchayats, high land areas, Low water storage capacity areas due to low volume of aquifer and high rates of baseflow it is proposed to construct community-based Roof top harvesting preferably for storage. Large diameter dug wells are preferably to construct in identified low yielding panchayats to meet the domestic demand. And identification of one or two perennial tanks in each water scarced panchayath, to be developed as sources of water for domestic and other uses in water scarce situations. Such tanks identified shall be desilted, renovated and their supply channels repaired to ensure that they receive sufficient water during the monsoons. Steps shall also be taken to

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

Numerous springs (46 Nos) are seen in the district along the slope of the eastern hill ranges, which are perennial sources for drinking water. These have not been developed so far efficiently. As per aquifer mapping studies it is found that 31 nos of the springs can be developed to meet domestic requirements during summer period. Attention may be given for the proper development of springs as the spring water can be supplied to the down streams just by gravity flow. The details of the springs and its potential is given in table 6.1.

Table 6.1 Details of springs identified for future possibility in Kozhikode District

S.No	Village	Springs	Approx. Discharge in Summer (lpm)	Storage Structure	Future Possibility
1	Chakkittapara	Kolathur estate	20	NA	Can be developed
2	Chelannur	Palullakandy	30	NA	Can be developed
3	Chelannur	Iruvalloor	30	NA	Can be developed
4	Chelannur	S N College Chellannur	10	Tank	Can be developed
5	Edakkde	Edakkara	60	Tank	Can be developed
6	Eravattoor	Kallod	100	Pond	Can be developed
7	Kadavoor	Thamarasseri	12	NA	Can be developed
8	Kakkur	Thirthankara	360	NA	Can be developed
9	Kakkur	Mepatichalil	30	NA	Can be developed
10	Kidavoor	Chamel	72	NA	Can be developed
11	Kidavoor	Poolode	108	NA	Can be developed
12	Kidavoor Village	Velliyormela	5	NA	Can be developed
13	Mudadi	Mudadi	30	Tank	Can be developed
14	Muthukad	Narendradev colony	120	Tank	Can be developed
15	Peruvanna	Manjalarikunnu	12	NA	Can be developed
16	Peruvannamuzhi	Payyanikotta	20	Tank	Can be developed
17	Peruvannamuzhi	Charican kannu	900	NA	Can be developed
18	Pilla Peruvanna	Elamkad	10	Pond	Can be developed
19	Poonoor	Kattapara	20	Tank	Can be developed
20	Poonoor	Channal	12	NA	Can be developed
21	Puthupadi	Jawakundu	22	NA	Can be developed
22	Puthupadi	Cheraplat	22	Tank	Can be developed
23	Quilandi	Thankamala	10	Tank	Can be developed
24	Quilandi	Kakkayam kunnu	1200	NA	Can be developed
25	Raroth village	Ambayathodu Pullumala	11	NA	Can be developed
26	Raroth village	Ambayathode	16	Tank	Can be developed
27	Raroth village	Poonoor estate	7	NA	Can be developed
28	Thalakkalathur	Orumburathu	30	NA	Can be developed
29	Thalakkalathur	Thazhe oringal	20	NA	Can be developed
30	Thamarasseri	Ponoor	30	NA	Can be developed
31	Thamarasseri	Shamrode estate	12	NA	Can be developed

Several abandoned quarries are identified in the study area, which can be converted to water harvesting structures as storage. Bases on available data on abandoned quarries (244.51 ha) collected from Kerala Land use Board, and by taking an approximate of 2m water column in the quarries the quantum of water stored is estimated, and calculated to be 4.89 MCM and is given in table 6.2.

The existed water stored in the quarries should be pumped out and the quarries should be completely cleaned after which a retaining wall should be constructed around them to prevent the inflow of polluted water from adjoining areas. If the inflow of water from surrounding areas is facilitated, then the water should be purified before usage. In that way, quarries can be used as rainwater storage tanks which is used for Domestic and irrigation purpose during lean period.

Table 6.2 Block wise avg. area of abandoned quarries and water storage (mcm)

Block	Abandoned Quarry Area(ha)	Water storage during Summer (MCM)
Balussery	20.63	0.41
Chellannur	32.35	0.65
Koduvalli	39.27	0.79
Kunnamangalam	102.52	2.05
Kunnumal	14.69	0.29
Perambra	9.05	0.18
Thodannur	15.84	0.32
Tuneri	10.17	0.20
Total	**244.51**	**4.89**

6.3.3. Artificial Recharge Plan

Large scale implementation of roof-top rainwater harvesting through existing dug wells in coastal plains, midland and foothills of highland areas on priority based on their vulnerability to droughts to be taken up. Recharge of monsoon rainfall through many such wells is expected to improve groundwater availability over a period. In the highlands the aquifer system is thin with high gradient which leads to fast drain of aquifers and for such areas rainwater harvesting as storage cum recharge is highly recommended.

Based on the average post-monsoon depth to water level data in the observation wells for the period 2016-20 and water level trends for the period 2012-2021, an area of about 662 sq.km, excluding reserved forests has been identified as suitable for implementation of artificial recharge. After having better understanding of the disposition and extent of the aquifer system through exploratory drilling, pumping tests etc., the potential volume of void space available within the weathered zone of Phreatic aquifer has been estimated as 2112 MCM.

Construction of a series of 40 Nos Check Dams, 55 Nos Vented Cross bars along river courses and in second to third order streams at strategic identified locations having road/rail bridges, construction of regulators, which will help in storing non-monsoon base flow along stretches of river without problems of land submergence and Percolation tanks (7 Nos) in hard rock formation where the rocks are highly fractured and weathered .The quantum of water expected to be recharge through these artificial recharge structures is of 3.09 MCM. The unit capacity of a Check dam and vented cross bars is 0.03 MCM, for percolation pond is 0.033 MCM and for Sub surface dyke is 0.003 MCM.

Selection of sites for these structures is based on the critical analysis of the hydrogeological, geophysical and exploration data of the district. Particularly geomorphological and drainage aspects are being given more weightage in selection of the Artificial Recharge structures. Sites for construction of subsurface dykes are located in areas where there is a great scarcity of water during the summer months or where there is need for additional water for irrigation. Some emphasis also needs to be laid on finding sites where land ownership conditions would make constructions more feasible. Single ownership is ideal in the absence of which it has to be implemented on a cooperative basis.

The feasible numbers of recharge structures proposed for the district are with limited field checks and the numbers will be changed due to suitability of land and area. It may also be necessary to modify standard designs of common recharge augmentation structures to suit local conditions. The cost of structures constructed will also vary depending upon the local availability of construction material and topographic settings. Details of block-wise feasible management structures proposed is given in table 6.3 and is shown in figure 6.1.

Table 6.3 Details of management structures feasible in the area

Block Name	Proposed Artificial Recharge Structures Feasibility (Nos.)				Quantum Water Estimated to be Recharged (MCM)
	Check Dam	Vented Cross Bars	Percolation Tank	Sub Surface dykes	
Balussery	5	6	1	2	0.37
Chelannur	0	3	0	0	0.09
Koduvally	8	7	0	0	0.45
Kozhikode	0	3	1	0	0.12
Kunnamangalam	9	7	1	1	0.52
Kunnummal	3	11	1	0	0.45
Melady	0	2	0	0	0.06
Panthalayani	0	0	1	0	0.03
Perambra	7	7	1	0	0.45
Thodannur	2	2	0	0	0.12
Tuneri	5	6	0	0	0.33
Vadakara	1	1	1	0	0.09
Total	**40**	**55**	**7**	**3**	**3.09**

6.4 Demand -Side Aquifer Management Plan

Demand side management can be accomplished through change in irrigation pattern. Block wise details of area proposed under drip and sprinkler irrigation area given in table 6.4.

Table 6.4 Details of area identified for micro irrigation in the district

S.No	Name of Block	Drip Irrigation (Ha)	Sprinkler irrigation (Ha)	Total Area (Ha)
1	Balussery	40	150	190
2	Chellannur	20	80	100
3	Koduvalli	50	100	150
4	Kozhikode	10	30	40
5	Kunnamangalam	40	150	190
6	Kunnumal	20	100	120
7	Meladi	15	30	45
8	Panthalayani	5	20	25
9	Perambra	44	105	149
10	Thodannur	5	20	25
11	Tuneri	5	50	55
12	Vadakara	5	20	25
	Total	**259**	**855**	**1114**

Farmers may be encouraged to adopt modern irrigation techniques like drip and micro irrigation to have optimal use of the available resources especially in semi-critical blocks - Balussery and Kunnamnaglam blocks. An area of 11.14 sq. km. can be brought for adopting micro irrigation (drip irrigation- 2.59 sq. km. and sprinkler irrigation-8.55 sq. km) to increase the water-use efficiency by saving a substantial amount of water. Since it supplies water directly to the crop, rather than the land around, water losses occurring through evaporation and distribution are significantly reduced.

There is water saving up to 50% and productivity improvement in the range of 30-60% for different crops like coconut, arecanut, nut meg, banana, vegetables under drip method of irrigation.

6.4.1. Creation of irrigation potential through ground water

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

- The scheme is not to be planned in areas classified as over-exploited, critical and semi critical areas. Further eligibility criteria have been laid down in subsequent paras.
- Groundwater development will be carried out preferably through Dug wells, Dug Cum Bore wells in hard rock area tapping shallow aquifers and shallow/deep tube wells in alluvium areas tapping prolific aquifers. Bore wells are to be taken up in areas where hydro-geological setup and ground water aquifer justifies their suitability.
- Promoting efficient water conveyance and precision water applicatiob devices like drips, sprinklers, pivots, rain-guns in the farm (Jal Sinchan).
- The State agencies involved in planning and execution of ground water schemes shall formulate the proposals in consultation with State Ground Water Department & CGWB duly considering nature of aquifer system in the area, spatio-temporal behaviour of water level, ground water resource availability, artificial recharge structures suitable for that area, sites for their construction etc.
- To minimize the failure of wells geophysical and hydro-geological investigations may be carried out for proper site selection.

Eligibility criteria

Ground Water irrigation facility through Dug wells, Dug cum Bore wells, Tube wells and Bore wells etc. can be funded for schemes in areas other than Over Exploited (OE), Critical or Semi-Critical meeting the following criteria:

- Less than 60 % of the annual extractable groundwater resources have been developed.
- Average annual rainfall of 750 mm or more to have availability of enough water for recharge.
- Shallow groundwater levels within range of 15m below ground level or less during pre-Monsoon period. Ground water development for irrigation can be planned in such a way that after implementation of the project, where ground water is available and not under semi critical category or above 60% of Stage of extraction and which are not supported under PMKSY (WR), PMKSY (Watershed) and MGNREGS.
- However, as already mentioned scheme in unclassified areas shall be considered on case-to-case basis depending upon various criterions laid down in the guidelines.

- The beneficiary under this scheme shall be small and marginal farmers only with priority to be given to SC/ST and women farmers.
- The scheme is applicable for individual farmer, group of farmers/ cooperatives, Govt. Scheme utilising Govt. Land etc.

Considering the above guidelines, creation of additional irrigation potential through ground water can only be admissible only in seven blocks viz., Koduvalli, Kunnumal, Meladi, Panthalayani, Perambra, Thodannur and Vadakara. By considering the topographic characteristics, landuse pattern and availability of cultivable waste land area (1353 ha) only limited abstraction structures (812 DWs and 361 BWs) are feasible and is given in table 6.5.

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

Some of the local educated people may be identified and imparted basic training on ground water, relevance of aquifer mapping, participatory management, etc. These trained persons, called para- hydrogeologists will be responsible for basic data collection like water level monitoring, well inventory, awareness raising etc. They can also be entrusted with activities like water budgeting, assessment of crop water requirements etc. Capacity building, entry point activities, ridge area treatment, drainage line treatment, soil and moisture conservation, nursery raising, afforestation, horticulture, pasture development, livelihood activities for the asset-less persons and production system & micro enterprises for small and marginal farmers etc. Scientific integrated watershed management at micro level so as to enhance ground water recharge, minimise soil erosion and promote green cover

In views of rapid urbanization, available information on the quality of drinking water supplies in the urbanised to semi urbanised area of the district clearly indicates high level of bacterial contamination and limited nitrate contamination at pockets. This poses a serious risk to public health. In order to address this, selection of appropriate safe sanitation system to suit the local soil characteristics and hydrogeology. Revamping /rehabilitation, wherever economically feasible, of existing deep (3m & above) single leach pit latrines which penetrate the free ground water table. Sanitary disposal of garbage from domestic and market sources and cattle wastes through composting. Sanitary protection of existing and new dug wells by lining. Effective disinfection of water supply from traditional sources to leave a minimum residual Cl 2 of 0.5 mg/l. Double chamber soak pits and proper waste disposal strategies are to be implemented. An effective and sustained programme of community awareness and education aimed at promoting personal and environmental hygiene. For the geogenic contamination, concentration of Iron >1 mg/l observed at pockets in panchayaths of Thikkodi (Meladi Block), Arikulam, Chengottukavu (Panthalayini block), Chellannur (Chellannur block), Kadalundi (Kozhikode block), Chakittipara (Perambra block) can be removed by aeration and Filtration/or by oxidation and filtration processes. Nitrate above permissible limit (>45 mg/l) are observed in certain pockets are observed in Vadakara, Thikodi, Chemancheri, Chelavur, Kozhikode town and Devarkoil can be removed by double chamber soak pits and boiled water for drinking.

Participatory Ground Water Management (PGWM) should be an aquifer-based and community-centric approach that has emerged as an alternative for managing groundwater as a common pool resource. The units of groundwater management should be aquifers, watersheds and habitations. Groundwater management requires long term engagement. Management should catalyse community action. Groundwater management should integrate formal and peoples' knowledge.

Table 6.5 Feasibility of additional abstraction structures possible for groundwater development, where SOE <60%

S.No.	Block	Area of cultivable waste to develop (Ha)	Area Proposed for irrigation by DW (Ha)	Area Proposed for irrigation by BW/TW (Ha)	No. of DW feasible	No. of BW feasible
1	Koduvalli	195	117	78	117	52
2	Kunnumal	112	67	45	67	30
3	Meladi	186	112	74	112	50
4	Panthalayani	290	174	116	174	77
5	Perambra	289	173	116	173	77
6	Thodannur	188	113	75	113	50
7	Vadakara	93	56	37	56	25
	Total	**1353**	**812**	**541**	**812**	**361**

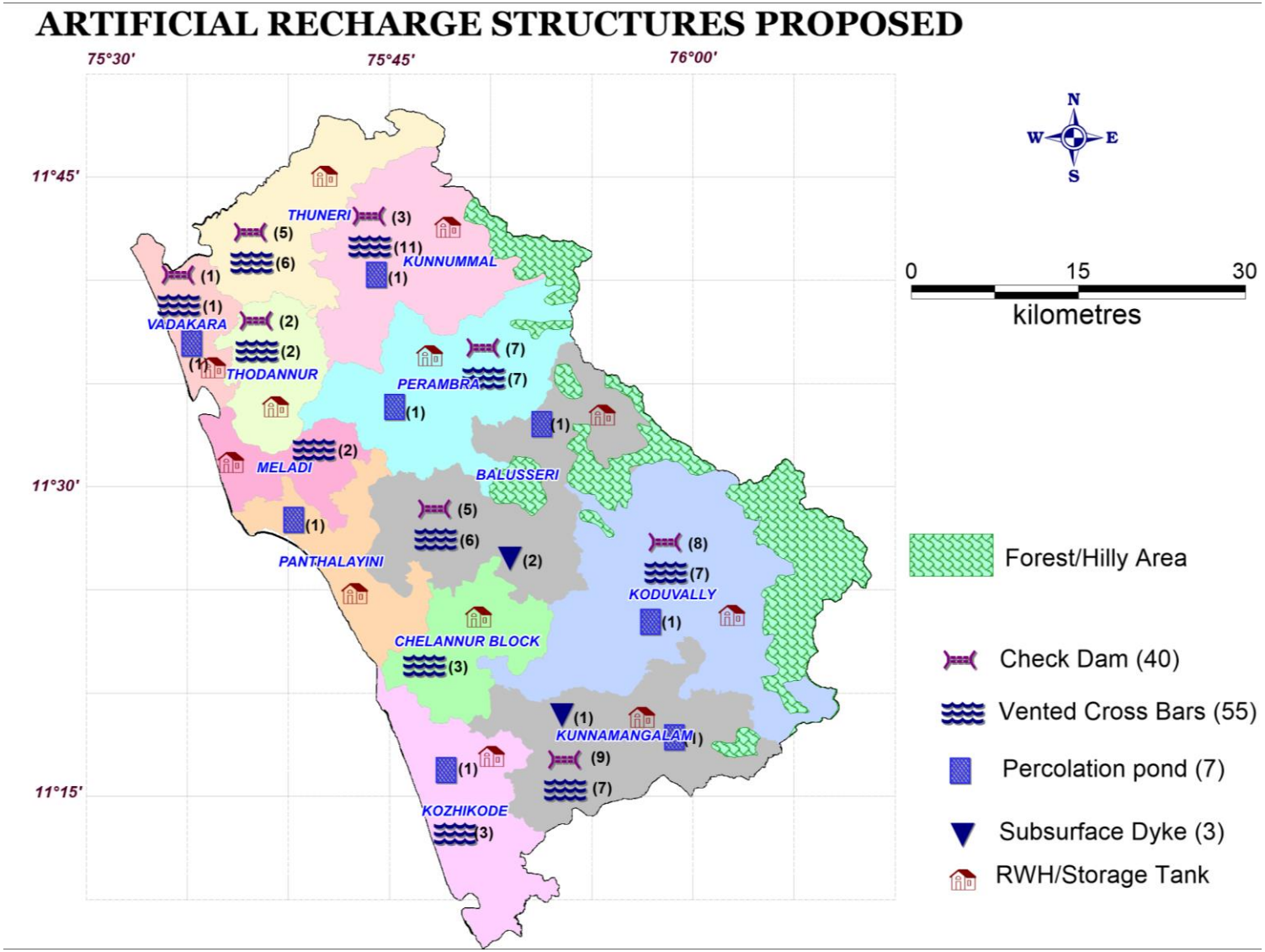


Figure 6.1 Feasible water conservation structures proposed in Kozhikode District

ANNEXURES

Annexure-I: Details of water level monitoring stations of Kozhikode District

Block	GP/Municipality/ Corporation	Well No	Well_Type	Latitude(°)	Longitude(°)	April-2021 Water Level (m bgl)	November-2021 Water Level (m bgl)
Balusseri	Balusseri	KKDOW 014	Dug Well	11.501	75.891	3.720	1.150
Koduvally	Koduvally	KKDOW 012	Dug Well	11.408	76.041	6.980	3.200
Koduvally	Koduvally	KKDOW 013	Dug Well	11.468	76.014	4.150	2.780
Koduvally	Koduvally	KKDOW 160	Dug Well	11.426	75.941	3.700	2.850
Koduvally	Koduvally	KKDOW161A	Dug Well	11.426	75.941	10.110	7.840
Kozhikode	Kozhikode	KKDOW 018	Dug Well	11.323	75.749	6.630	3.220
Kozhikode	Kozhikode	KKDOW 156	Dug Well	11.173	75.804	4.180	0.470
Kunnamangalam	Kunnamangalam	KKDOW 157	Dug Well	11.260	75.953	7.790	5.500
Kunnamangalam	Kunnamangalam	KKDOW 158	Dug Well	11.306	75.915	7.210	4.230
Kunnamangalam	Kunnamangalam	KKDOW 159	Dug Well	11.322	75.997	9.050	6.230
Panthlayani	Panthalayani	KKDOW 174	Dug Well	11.436	75.692	6.470	3.630
Perambra	Perambra	KKDOW 016	Dug Well	11.598	75.821	6.160	3.400
Perambra	Perambra	KKDOW 175	Dug Well	11.554	75.760	2.130	0.390
Kunnummal	Kunnummal	KKDOW 017	Dug Well	11.664	75.753	5.570	3.740
Thuneri	Thuneri	KKDOW 020	Dug Well	11.769	75.764	13.870	9.400
Thuneri	Thuneri	KKDOW 177	Dug Well	11.702	75.535	8.830	6.240
Vadakara	Vadakara	KKDOW 176	Dug Well	11.595	75.585	5.700	4.050
Balusseri	Balusseri	KKDPZ 194	Piezometer	11.398	75.872	14.005	12.370
Koduvally	Koduvally	KKDPZ 191	Piezometer	11.465	75.968	5.415	3.315
Koduvally	Koduvally	KKDPZ 193	Piezometer	11.355	75.911	11.015	19.905
Koduvally	Koduvally	KKDPZ 212	Piezometer	11.435	76.064	3.390	1.860
Koduvally	Koduvally	KKDPZ 216	Piezometer	11.335	76.040	13.990	10.850
Kozhikode	Kozhikode	KKDPZ 197	Piezometer	11.171	75.877	1.430	-0.070
Kozhikode	Kozhikode	KKDPZ 211	Piezometer	11.145	75.843	23.800	17.590
Kozhikode	Kozhikode (corporation)	KKDPZ 210	Piezometer	11.254	75.839	31.310	28.300

Block	GP/Municipality/ Corporation	Well No	Well_Type	Latitude(°)	Longitude(°)	April-2021 Water Level (m bgl)	November-2021 Water Level (m bgl)
Kunnamangalam	Kunnamangalam	KKDPZ 183	Piezometer	11.291	75.982	12.775	9.860
Kunnamangalam	Kunnamangalam	KKDPZ 184	Piezometer	11.317	75.944	4.892	5.162
Kunnamangalam	Kunnamangalam	KKDPZ 185	Piezometer	11.364	75.949	7.440	5.250
Kunnamangalam	Kunnamangalam	KKDPZ 203	Piezometer	11.260	75.951	9.880	7.040
Kunnamangalam	Kunnamangalam	KKDPZ 204	Piezometer	11.279	75.990	12.480	4.730
Kunnamangalam	Kunnamangalam	KKDPZ 205	Piezometer	11.262	75.994	6.040	3.570
Kunnamangalam	Kunnamangalam	KKDPZ 209	Piezometer	11.303	75.913	4.020	2.310
Balusseri	Balusseri	KKDPZ 189	Piezometer	11.443	75.836	5.060	3.110
Balusseri	Balusseri	KKDPZ 195	Piezometer	11.417	75.867	30.815	6.855
Balusseri	Balusseri	KKDPZ 196	Piezometer	11.467	75.868	5.170	4.290
Perambra	Perambra	KKDPZ 186	Piezometer	11.567	75.819	8.500	7.185
Perambra	Perambra	KKDPZ 187	Piezometer	11.583	75.768	3.749	2.814
Perambra	Perambra	KKDPZ 190	Piezometer	11.531	75.880	13.948	9.823
Perambra	Perambra	KKDPZ 192	Piezometer	11.476	75.788	18.914	18.214
Perambra	Perambra	KKDPZ 202	Piezometer	11.557	75.756	20.922	28.652
Perambra	Perambra	KKDPZ 213	Piezometer	11.602	75.823	4.080	3.110
Perambra	Perambra	KKDPZ 214	Piezometer	11.643	75.864	21.680	20.285
Kunnummal	Kunnummal	KKDPZ 188	Piezometer	11.653	75.751	1.750	0.510
Kunnummal	Kunnummal	KKDPZ 199	Piezometer	11.711	75.716	3.666	0.976
Kunnummal	Kunnummal	KKDPZ 200	Piezometer	11.671	75.775	6.755	4.355
Kunnummal	Kunnummal	KKDPZ 201	Piezometer	11.710	75.778	4.357	3.672
Thodannur	Thodannur	KKDPZ 206	Piezometer	11.630	75.647	7.948	5.038
Thuneri	Thuneri	KKDPZ 208	Piezometer	11.705	75.641	8.240	7.280
Thuneri	Thuneri	KKDPZ 215	Piezometer	11.769	75.764	5.040	3.825
Vadakara	Vadakara	KKDPZ 207	Piezometer	11.602	75.597	11.702	8.822
Chelannur	Atholi	CGWB	Dug Well	75.900	11.504	2.4	4.5

Block	GP/Municipality/ Corporation	Well No	Well_Type	Latitude(°)	Longitude(°)	April-2021 Water Level (m bgl)	November-2021 Water Level (m bgl)
Kozhikode	Azhinjilam	CGWB	Dug Well	75.870	11.172	0.58	1.85
Vadakara	Badagara (Vadakara)	CGWB	Dug Well	75.588	11.592	4.46	5.78
Balussery	Balusseri	CGWB	Dug Well	75.830	11.445	5.73	6.93
Balussery	Balussery pz	CGWB	Bore Well	75.803	11.453	6.6	8.11
Kozhikode	Beypore	CGWB	Dug Well	75.807	11.172	1.01	3.58
Tuneri	Bhumivathukkal	CGWB	Dug Well	75.700	11.720	5.85	7.9
Kozhikode	Calicut Beach	CGWB	Dug Well	75.856	11.372	2.07	3.07
Kozhikode	Chaliyam	CGWB	Dug Well	75.814	11.168	1.89	2.42
Kunnamangalam	Chelavur	CGWB	Dug Well	75.883	11.300	7.58	8.52
Chelannur	Chemencheri	CGWB	Dug Well	75.725	11.408	1.27	3.92
Kunnamangalam	Cheruvannur pz	CGWB	Bore Well	75.821	11.208	4.17	7.26
Kozhikode	Cheruvannur West	CGWB	Dug Well	75.822	11.185	3.15	3.93
Kunnamangalam	Chevayur	CGWB	Dug Well	75.792	11.250	11.05	12.02
Tuneri	Chiulavi (Niravamal)	CGWB	Dug Well	75.689	11.735	6.38	8.61
Vadakara	Chombala(pz)	CGWB	Tube Well	75.561	11.667	2.62	5.45
Vadakara	Chombala(w1)	CGWB	Tube Well	75.556	11.673	2	4.95
Vadakara	Chombala(w2)	CGWB	Tube Well	75.556	11.673	1.95	4.85
Vadakara	Chombala(w3)	CGWB	Tube Well	75.556	11.673	1.84	5.05
Vadakara	Chombala(w4)	CGWB	Tube Well	75.556	11.673	1.85	5.05
Kunnamangalam	Chulur	CGWB	Dug Well	75.939	11.301	5.05	5.7
Kunnumal	Devarkoil	CGWB	Dug Well	75.750	11.667	7.48	6.8
Kozhikode	Elattur	CGWB	Dug Well	75.744	11.338	1.52	3.71
Kozhikode	Feroke DW	CGWB	Dug Well	75.839	11.179	11.72	11.64
Kozhikode	Iringallur	CGWB	Dug Well	75.829	11.230	2.08	3.15
Balusseri	Kakkayam	CGWB	Dug Well	75.899	11.549	3.13	3.1
Tuneri	Kallachi	CGWB	Dug Well	75.667	11.689	0.35	0.89

Block	GP/Municipality/ Corporation	Well No	Well_Type	Latitude(°)	Longitude(°)	April-2021 Water Level (m bgl)	November-2021 Water Level (m bgl)
Kozhikode	Kallai	CGWB	Dug Well	75.789	11.233	3.2	4.68
Chelannur	Kannankara (Chelannur)	CGWB	Dug Well	75.833	11.308	0.75	1.74
Chelannur	Kannoor	CGWB	Dug Well	75.737	11.446	4.1	4.95
Kozhikode	Karaparamba	CGWB	Dug Well	75.792	11.250	2.34	3.19
Balusseri	Kariyathumpara	CGWB	Dug Well	75.897	11.539	3.05	2.65
Perambra	Karuvannur	CGWB	Dug Well	75.773	11.502	2.95	3.18
Perambra	Karuvannur pz	CGWB	Bore Well	75.774	11.500	0.49	0.72
Tuneri	Kayapanachi	CGWB	Dug Well	75.634	11.720	3.77	4.9
Koduvally	Kodencherry	CGWB	Dug Well	76.007	11.431	1.94	0.82
Koduvally	Koduvalli	CGWB	Dug Well	75.910	11.358	6.65	7.94
Perambra	Koothali	CGWB	Dug Well	75.783	11.583	3.65	4.6
Kozhikode	Kottakadavu	CGWB	Dug Well	75.834	11.139	12.34	13.13
Kozhikode	Kozhikode	CGWB	Dug Well	75.792	11.250	10.95	12.82
Kunnamangalam	Kunnamangalam	CGWB	Dug Well	75.879	11.305	8.19	9.68
Vadakara	Kunnumakkara	CGWB	Dug Well	75.581	11.673	1.05	2.53
Perambra	Kurachund	CGWB	Dug Well	75.773	11.502	5.04	3.83
Kuunumal	Kuttiyadi	CGWB	Dug Well	75.733	11.663	7.73	7.94
Kunnamangalam	Malayamma	CGWB	Dug Well	75.933	11.350	2.03	5.65
Kunnamangalam	Manassery	CGWB	Dug Well	75.966	11.320	2.05	3.68
Perambra	Mattanodu	CGWB	Dug Well	75.833	11.550	7.3	8.91
Kunnamangalam	Mavoor-i	CGWB	Dug Well	75.956	11.257	5.77	7.27
Kunnamangalam	Mavoor-ii	CGWB	Dug Well	75.942	11.250	8.16	10.35
Meladi	Meladi	CGWB	Tube Well	75.624	11.510	0.72	1.82
Meladi	Melady 1	CGWB	Dug Well	75.622	11.511	0.85	1.82
Perambra	Meppayur	CGWB	Dug Well	75.833	11.533	2.73	4.07
Vadakara	Mukkali	CGWB	Dug Well	75.556	11.671	2.67	5.2

Block	GP/Municipality/ Corporation	Well No	Well_Type	Latitude(°)	Longitude(°)	April-2021 Water Level (m bgl)	November-2021 Water Level (m bgl)
Perambra	Muliyangal	CGWB	Dug Well	75.773	11.534	1.23	2.44
Perambra	Mullankunnu	CGWB	Dug Well	76.725	10.153	0.68	1.3
Koduvally	Murampathy	CGWB	Dug Well	76.011	11.406	6.1	6.09
Tuneri	Nadapuram	CGWB	Dug Well	75.667	11.533	1.65	3.76
Perambra	Naduvannur	CGWB	Dug Well	75.786	11.409	6.03	7.15
Kozhikode	Naduvattom	CGWB	Dug Well	76.480	9.272	4.82	7.84
Kozhikode	Nallalam	CGWB	Dug Well	75.792	11.250	1.43	3.46
Balusseri	Nanminda	CGWB	Dug Well	75.600	11.578	4.37	6.55
koduvally	Narikunni	CGWB	Dug Well	75.856	11.372	0.93	2.47
Kunnamangalm	Nayarkuzhi	CGWB	Dug Well	75.961	11.294	5.7	6.55
Thodannur	Orkattery	CGWB	Dug Well	75.604	11.654	1.5	3.03
Kozhikode	Pavangad	CGWB	Dug Well	75.759	11.312	1.05	3.21
Perambra	Perambra	CGWB	Dug Well	75.942	11.438	2.1	4.93
Koduvally	Perumpally	CGWB	Dug Well	75.956	11.444	2.34	4.23
Tuneri	Pudukayam	CGWB	Dug Well	75.731	11.758	7.2	7.13
Koduvally	Pudupadi	CGWB	Dug Well	75.985	11.497	2.2	9.64
Vadakara	Pudupanam	CGWB	Dug Well	75.600	11.578	4.19	2.63
Chelannur	Punnasseri	CGWB	Dug Well	75.864	11.375	5.59	4.97
Kunnamangalam	Puthur New	CGWB	Dug Well	75.950	11.368	1.13	7.46
Panthlayani	Quilandy	CGWB	Dug Well	75.694	11.440	3.75	6.33
Kozhikode	Ramanattukara (R2)	CGWB	Dug Well	75.858	11.175	1.81	4.54
Koduvlly	Tamarasseri	CGWB	Dug Well	75.938	11.422	0.79	1.5
Balusseri	Thenamkuzhi	CGWB	Dug Well	75.859	11.448	2.18	3.8
Meladi	Thikkodi	CGWB	Dug Well	75.647	11.489	3.57	6.71
Thodannur	Thiruvallur	CGWB	Dug Well	75.675	11.567	1.02	1.73
Koduvally	Thiruvambady	CGWB	Dug Well	76.008	11.360	3.1	3.88

Block	GP/Municipality/ Corporation	Well No	Well_Type	Latitude(°)	Longitude(°)	April-2021 Water Level (m bgl)	November-2021 Water Level (m bgl)
Thodannur	Thodannur	CGWB	Dug Well	75.648	11.586	6.14	6.6
Thodannur	Thodannur(west)	CGWB	Bore Well	75.659	11.583	3.44	6.19
Tuneri	Thuneri pz	CGWB	Bore Well	75.637	11.706	3.19	479
Tuneri	Thuneri1	CGWB	Dug Well	75.634	11.720	3.35	4.4
Balusseri	Ulliyeri	CGWB	Dug Well	75.775	11.458	2.33	3.43
Balusseri	Unnikulam (R1)	CGWB	Dug Well	75.880	11.450	3.6	4.15
Kunnumal	Valayam	CGWB	Dug Well	75.671	11.720	5.4	6.45
Kunnumal	Vattoli	CGWB	Dug Well	75.713	11.674	3.85	4.46
Kunnamangalam	Vellimadakunnu	CGWB	Dug Well	75.792	11.250	12.85	13.06
Kunnamangalam	Vellimadakunnu pz	CGWB	Bore Well	75.828	11.289	6.1	19.73
Thodannur	Villyapalli	CGWB	Dug Well	75.650	11.617	6.1	7.11
Koduvally	West Pudupadi	CGWB	Dug Well	75.981	11.481	3.32	4.63

Annexure-II: Details of Water quality monitoring stations of Kozhikode District

S.No.	Block	Village	Latitude	Longitude	Source
1	Badagara	Badagara	11.598	75.585	Dugwell
2	Balusseri	Balusseri	11.447	75.83	Dugwell
3	Kozhikode	Beypore	11.173	75.806	Dugwell
4	Kozhikode	Chelavur	11.297	75.847	Dugwell
5	Panthalayini	Chemencheri	11.394	75.728	Dugwell
6	Kunnummal	Devarkoil	11.671	75.767	Dugwell
7	Kozhikode	Elattur	11.334	75.741	Dugwell
8	Balusseri	Kakkayam	11.55	75.897	Dugwell
9	Thuneri	Kayapanachi	11.712	75.591	Dugwell
10	Koduvalli	Koduvalli	11.334	75.893	Dugwell
11	Perambra	Koothali	11.602	75.812	Dugwell
12	Kozhikode	Kozhikode	11.253	75.792	Dugwell
13	Kunnamangalam	Mavoor II	11.251	75.841	Dugwell
14	Badagara	Mukkali	11.674	75.554	Dugwell
15	Thuneri	Nadapuram	11.687	75.653	Dugwell
16	Perambra	Perambra	11.565	75.755	Dugwell
17	Thuneri	Pudukayam	11.744	75.717	Dugwell
18	Koduvalli	Pudupadi	11.449	75.961	Dugwell
19	Panthalayini	Quilandy	11.442	75.694	Dugwell
20	Kozhikode	Ramanattukara	11.177	75.86	Dugwell
21	Koduvalli	Thamarasseri	11.424	75.938	Dugwell
22	Thodannur	Thiruvallur	11.591	75.673	Dugwell
23	Meladi	Tikkodi	11.488	75.628	Dugwell
24	Kunnamangalam	Vallikunnu	11.236	75.866	Dugwell
25	Kunnamangalam	Pannikode	11.271	76.008	Dugwell
26	Kunnamangalam	Agastiamuzhi	11.328	75.989	Dugwell
27	Koduvally	Maranchatty	11.323	76.065	Dugwell
28	Kunnamangalam	Kuruvattur	11.318	75.851	Dugwell
29	Poovaranthode	Koduvally	11.386	76.069	Dugwell
30	Puthur	Kunnamangalam	11.369	75.938	Dugwell

Annexure-III: Details of Ground Water Exploration in hard rock terrains of Kozhikode District

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 mbgl	Discharge (lps)	Draw down (m)	T m^2/day	S	EC	Cl ppm
1	Thamarasseri	11.4083	75.9361		135	Charnockite	16.7		13.3	9				213	43
2	Kuttoth	11.4333	75.7389		160	Horneblende biotite gneiss	27.2		12.67	7				2930	831
3	Edacheri	11.6611	75.6167		200	Horneblende biotite gneiss	7.25		NA	Nil				-	-
4	Chelakkad	11.6833	75.6833		145	Biotite gneiss	20	28-35 35-60 90-99	5.95	6.83		8.52		300	13
5	Paleri	11.6008	75.7556		145	Biotite gneiss	9.3	142 - 145	7.64	17		21.57		2340	518
6	Avala Kuttoth	11.5681	75.7014		185	Biotite gneiss	15	11-17 148-151	4.07	2.5				4630	1253
7	Kannadipoil	11.4639	75.8556		200	Horneblende biotite gneiss	7		3.3	4		12.46		286	2.1
8	Pudupadi	11.4786	75.9822		114.3	Horneblende biotite gneiss	21.2	35-38	5.68	0.17					
9	Vanimel	11.7167	75.7000		175	Horneblende biotite gneiss	30.5		8.9	0.2					
10	Nanminda	11.4194	75.8361	1996-97	157	Horneblende-biotite gneiss	13.7	NA/366	11.77	6.1	20.12	18.18	0.0001	204	8.5
11	Kalaranthri	11.3750	75.9361	1996-97	152.4	Charnockite	8.5	71.6-77.7/30	NA	0.5	NA	NA		286	7.1
12	Chelapuram	11.3125	75.8000	1996-97	200	Charnockite	21.4	56.3-65.5/60	NA	1	NA	NA		82	9.9
13	Kakkur	11.3500	75.8222	1996-97	190	Horneblende-biotite gneiss	11	56.3-80.7 129.5-169.2 /252	1.26	4.2	8.33	104	0.0001	292	19
14	Vettiozhinjathottam	11.4500	75.9139	1996-97	200	Charnockite	16.7	65.5-100.0 150.9-160.0/150	16.33	2.5	26	9.8		207	5.7
15	REC Chathamangalam	11.3153	75.9300		200	Charnockite	13.75	50.2-51.2 67.5-68.5/60	1.97	1					
16	Koodaranji	11.3456	76.0368	2020-21	200	Charnockite	8	28-28.5,38.5-39,76.5-77,120-120.5,169-169.5,177-177.5	8.2	984				290	0.32

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 mbgl	Discharge (lps)	Draw down (m)	T m^2/day	S	EC	Cl ppm
17	Mukkam	11.3200	75.9969	2020-21	200	Charnockite	20.5	25.5-26,29.5-30,67 - 67.5, 77.5 - 78, 93 - 93.5	9.65	600				500	1.9
18	Kodencherry	11.4351	76.0075	2020-21	200	GN	5.5		14.45	Dry					
19	Narikunni	11.3665	75.8511	2020-21	200	Charnockite	30.5	45.5-46,52.5-53,112.5-113	4.4	12.9				290	1.45
20	Moozhikkal	11.2982	75.8342	2020-21	200	Charnockite	16.5	69.5-70,75.5,-,76	7.28	0.84				270	0.72
21	Ramanattukara	11.1752	75.8773	2020-21	200	Charnockite	21	99.5-100,105.5-106,117.5-118	1.7	261.6				10300	0.8
22	Kallanode	11.5353	75.8803	2020-21	150	GN	5.5	19-20,124-124.5	2.47	504				220	1.4
23	Earpona	11.4208	75.9242	2020-21	200	Charnockite	6.05	47.5-48	11.9	88.8				400	0.52
24	Kannore, Ulliyeri	11.4466	75.7395	2021-22	200	Charnockite	10	37.5-38,50-50.5	2.75	986.4				13400	0.8
25	Balussery EW	11.4579	75.8186	2021-22	103	Charnockite	17.5	26.5-27,37.5-38	6.2	840					
26	Maniyur Ew	11.5580	75.6408	2021-22	200	HBl- Gneiss	35.5	39.5-40,52.5-53,56.5-57	47.78	200.4					
27	Muchukunnu	11.4931	75.6664	2021-22	200	HBl- Gneiss	26	46.5-47	6.65	30					
28	Muthukad	11.5811	75.8617	2021-22	200	HBl- Gneiss	17.5	28.5-29	4.5	120					
29	Peruvannamoozhi Ew	11.6035	75.8120	2021-22	200	HBl- Gneiss	9	19.5-20	2.8	600					
30	Thottilpalam EW	11.6866	75.7872	2021-22	200	Charnockite	7	8-8.5,14-14.5,170-170.5	3.94	204					
31	Mokeri	11.6761	75.7226	2021-22	200	HBl- Gneiss	16.5	56.5-57,82.5-+83	6.67	90					
32	Nadapuram EW	11.7468	75.6541	2021-22	200	HBl- Gneiss	34	94-95,174-175,195-196	40.23	180					

Annexure IV: Details of Validated Exploratory wells in Kozhikode District

Site _ID	Location	Longitude	Latitude	Elevation (mbmsl)	Total Depth (mbgl)	Casing Depth (mbgl)	Discharge (lpm)	SWL (mbgl)	Major lithology encountered	Fractured Zones (mbgl)
NAQ_KKD_1	Koodaranji	76.037	11.346	49.1	200	8	984	8.2	Charnockite	28-28.5,38.5-39, 76.5-77,120-120.5,169-169.5,177-177.5
NAQ_KKD_2	Mukkam	75.997	11.320	21.7	200	20.5	600	9.7	Charnockite	25.5-26,29.5-30,67-67.5,77.5-78,93-93.5
NAQ_KKD_3	Kodencherry	76.008	11.435	54.5	200	5.5	Dry	14.5	Migmatite Gneiss	6-9,75-78
NAQ_KKD_4	Narikunni	75.851	11.366	35.1	200	30.5	12.9	4.4	Charnockite	45.5-46,52.5-53, 112.5-113
NAQ_KKD_5	Moozhikkal	75.834	11.298	19.2	200	16.5	0.84	7.3	Charnockite	69.5-70,75.5-76
NAQ_KKD_6	Ramanattukara	75.877	11.175	12	200	21	261.6	1.7	Charnockite	99.5-100,105.5-106,117.5-118
NAQ_KKD_7	Kallanode	75.880	11.535	57.5	150	5.5	504	2.5	Migmatite Gneiss	19-20,124-124.5
NAQ_KKD_8	Earpona	75.924	11.421	64.8	200	6.05	88.8	11.9	Charnockite	47.5-48
NAQ_KKD_9	Kannore	75.740	11.447	8.7	200	10	986.4	2.8	Charnockite	37.5-38,50-50.5
NAQ_KKD_10	Balussery EW	75.819	11.458	24.6	103	17.5	840	6.2	Charnockite	26.5-27,37.5-38
NAQ_KKD_11	Maniyur EW	75.641	11.558	68.6	200	35.5	200.4	47.8	Hornblende biotite gneiss	39.5-40,52.5-53, 56.5-57
NAQ_KKD_12	Muchukunnu	75.666	11.493	36.9	200	26	30	6.7	Hornblende biotite gneiss	46.5-47
NAQ_KKD_13	Muthukad	75.862	11.581	62.8	200	17.5	120	4.5	Hornblende biotite gneiss	28.5-29
NAQ_KKD_14	Peruvannamoozhi EW	75.812	11.603	29	200	9	600	2.8	Hornblende biotite gneiss	19.5-20
NAQ_KKD_15	Thottilpalam EW	75.787	11.687	47	200	7	204	3.9	Charnockite	8-8.5,14-14.5, 170-170.5
NAQ_KKD_16	Mokeri	75.723	11.676	41.7	200	16.5	90	6.7	Hornblende biotite gneiss	56.5-57,82.5-83
NAQ_KKD_17	Nadapuram EW	75.654	11.747	121.6	200	34	180	40.2	Hornblende biotite gneiss	94-95,174-175,195-196

Site _ID	Location	Longitude	Latitude	Elevation (mbmsl)	Total Depth (mbgl)	Casing Depth (mbgl)	Discharge (lpm)	SWL (mbgl)	Major lithology encountered	Fractured Zones (mbgl)
NAQ_KKD_18	Thamarasseri	75.936	11.408	51	135	16.7	540	13.3	Charnockite	
NAQ_KKD_19	Kuttoth	75.739	11.433	9.3	160	27.2	420	12.7	Hornblende biotite gneiss	
NAQ_KKD_20	Edacheri	75.617	11.661	25.3	200	7.25			Hornblende biotite gneiss	
NAQ_KKD_21	Chelakkad	75.683	11.683	24	145	20	410	6.0	Biotite gneiss	28-35, 35-60, 90-99
NAQ_KKD_22	Paleri	75.756	11.601	13.7	145	9.3	1020	7.6	Biotite gneiss	142-145
NAQ_KKD_23	Avala Kuttoth	75.701	11.568	34.4	185	15	150	4.1	Biotite gneiss	11-17,148-151
NAQ_KKD_24	Kannadipoil	75.856	11.464	48.1	200	7	240	3.3	Hornblende biotite gneiss	
NAQ_KKD_25	Puduppadi	75.982	11.479	34.4	114.3	21.2	10		Hornblende biotite gneiss	
NAQ_KKD_26	Vanimel	75.700	11.717	68	175	30.5	12	8.9	Hornblende biotite gneiss	
NAQ_KKD_27	Nanminda	75.836	11.425	36.7	157	13.7	366	11.8	Hornblende biotite gneiss	
NAQ_KKD_28	Kalaranthri	75.936	11.375	31.7	152.4	8.5	30		Charnockite	71.6-77.7
NAQ_KKD_29	Chelapuram	75.800	11.313	16	200	21.4	60		Charnockite	56.3-65.5
NAQ_KKD_30	Kakkur	75.822	11.350	89	190	15	402		Hornblende biotite gneiss	56.3-80.7, 129.5-169.2
NAQ_KKD_31	Vettiozhinjathottam	75.914	11.450	39.7	200	16.7	150	16.3	Charnockite	65.5-100.0, 150.9-160.0
NAQ_KKD_32	REC Chathamangalam	75.930	11.315	65.3	200	13.75	60	2.0	Charnockite	50.2-51.2,67.5-68.5
NAQ_KKD_33	Vadakara	75.561	11.667	14.3	27	20	10.79	4.4	Alluvium	10.75-16.75
NAQ_KKD_34	Melady	75.624	11.510	13.7	32	23	2	1.9	Alluvium	23-28
NAQ_KKD_35	Mukkali	75.561	11.667	14.3	27	20.75	4.8	4.9	Alluvium	7.75-17.75
NAQ_KKD_36	Atholi-Pz	75.758	11.385	22	30	19.5	20	5.0	Hornblende biotite gneiss	17-19
NAQ_KKD_37	Kulathur-Pz	75.792	11.406	27	60	17.3	12	7.0	Hornblende biotite gneiss	18-19
NAQ_KKD_38	Chevayur-Pz	75.826	11.269	48	43	14.7	30	29.7	Hornblende biotite gneiss	41-42
NAQ_KKD_39	Kalikadavu-Pz	75.760	11.599	15.8	38	13.5		3.5	Biotite gneiss	25-26
NAQ_KKD_40	Feroke-Pz	75.839	11.179	16.7	60	12.8		11.8	Charnockite	22-23

Annexure-V: Interpreted Results of VES in Kozhikode District

Sl.No	Village	VES No.	Location		Interpreted Results										Depth to Massive rock (m)
					Resistivity (Ohm.m)					Thickness (m)					
			Latitude	Longitude	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4	h_5	
1	Kuttikattoor	1	11.2696	75.8760	106	347	11.8	95.8	6841	0.55	1.03	0.98	22.20	Ext.	24.76
2	Perumanna	2	11.2438	75.8814	338	93.73	328.3	37.46	8728	1.08	1.11	3.24	16.10	Ext.	21.52
3	Cheroopa-1	3	11.2615	75.9227	792	107	10.9	77.5		1.73	3.31	4.95	Ext.		
4	Cheroopa-2	4	11.2615	75.9229	995	30.3	VH			1.88	14.70	Ext.			16.58
5	Thattoor	5	11.2665	75.9597	423	150	1820			0.93	10.60	Ext.			11.53
6	Sivagiri	6	11.2943	75.8951	3902	1126	272	4580	13.7	2.05	7.92	10.10	16.70	Ext.	20.07
7	Chathamangalam	7	11.3079	75.9051	405.6	1076	107.9	1163		0.82	5.81	8.08	Ext.		14.71
8	Kattangal	8	11.3105	75.9421	1323	2612	406	4209		1.31	1.51	52.20	Ext.		55.02
9	Pottassery	9	11.3236	75.9737	388.4	550	59.08	541.4		2.12	10.03	19.97	Ext.		
10	Manassery-1	10	11.3126	75.9690	2520	605	1433	38.6		1.27	28.50	25.70	Ext.		
11	Manassery-2	11	11.3118	75.9685	1223	7958	899	127		0.62	0.38	23.70	Ext.		
12	Kuruvattoor	12	11.3188	75.8507	216.2	542.3	173.6	406.7	VH	1.40	1.50	6.73	19.65	Ext.	29.28
13	Pantherpadam	13	11.3192	75.8789	428.9	955.5	73.61	401.7		1.83	1.47	14.85	Ext.		18.15
14	Kunnamangalam	14	11.3055	75.8773	534.2	1058	284.2	9535		0.43	2.39	37.40	Ext.		40.22
15	Chethukadavu	15	11.3068	75.9025	305	1295	48	234		1.81	2.29	8.05	Ext.		

Annexure-VI: Analysis of water quality monitoring stations in Kozhikode District

#	Block	Village	Latitude	Longitude	Sour-ce	pH	EC *µs/cm* at 25^0C	CO_3	HCO_3	SO_4	Cl	NO_3	F	TH	Ca	Mg	Na	K
								< ……..……Concentration in mg/l……. >										
1	Badagara	Badagara	11.598	75.585	DW	7.20	370	0	45	22.75	50	53.6	0.0	134	44.69	5.71	23	9
2	Balusseri	Balusseri	11.447	75.830	DW	7.36	200	0	6.42	2.01	33.9	35.6	0.0	56	16.62	3.67	22.87	5.75
3	Kozhikode	Beypore	11.173	75.806	DW	7.40	530	0	96.3	46.6	74.59	32.4	0.0	185	59.36	9.13	50.66	13.98
4	Kozhikode	Chelavur	11.297	75.847	DW	4.00	310	0	0	3.5	55.24	62.43	0.0	47.1	13.54	3.24	54.7	4.66
5	Panthalayini	Chemencheri	11.394	75.728	DW	6.32	250	0	32.1	26.67	24.1	24.4	0.0	107.9	39.2	2.47	19.56	4.91
6	Kunnummal	Devarkoil	11.671	75.767	DW	6.40	280	0	25.7	18.3	31.51	55.1	0.0	97	31.3	4.6	22.9	5.34
7	Kozhikode	Elattur	11.334	75.741	DW	6.65	270	0	63.5	32.1	21.1	16.9	0.0	136	48.68	3.57	17.55	2.3
8	Balusseri	Kakkayam	11.550	75.897	DW	7.00	53	0	19.3	2.93	2.8	2.9	0.0	45	14.37	2.34	4.66	1.4
9	Thuneri	Kayapanachi	11.712	75.591	DW	6.70	370	0	12.84	19.9	92.3	17.9	0.0	98.6	17.71	13.25	43.36	2.22
10	Koduvalli	Koduvalli	11.334	75.893	DW	6.93	107	0	40	1.8	8.08	6.9	0.0	73.3	19.35	6.09	9.36	1.47
11	Perambra	Koothali	11.602	75.812	DW	6.93	61	0	9.8	1.73	5.57	12.2	0.0	39.1	11.84	2.34	4.65	2.58
12	Kozhikode	Kozhikode	11.253	75.792	DW	9.73	280	12	74.9	16.96	29.84	15.42	0.0	151	54.8	3.38	17.38	1.84
13	Kunnamangalam	Mavoor II	11.251	75.841	DW	7.13	142	0	37.4	3.14	9.7	6.05	0.0	39.6	11.38	2.72	13.61	8.27
14	Badagara	Mukkali	11.674	75.554	DW	7	115	0	20	9.66	9.59	6.47	0.0	42.3	14.71	1.36	10.21	1.87
15	Thuneri	Nadapuram	11.687	75.653	DW	6.81	200	0	24.9	8.7	20.3	9.12	0.0	85	27.18	4.18	16.51	3.31
16	Perambra	Perambra	11.565	75.755	DW	6.91	130	0	17.5	3.21	15	18.5	0.0	59.6	19.41	2.74	12.32	2.6
17	Thuneri	Pudukayam	11.744	75.717	DW	7.01	61	0	15	0.53	6.35	12.34	0.0	42.3	12.75	2.54	6.8	0.92
18	Koduvalli	Pudupadi	11.449	75.961	DW	6.88	122	0	19.9	5.29	15.51	9.95	0.0	45.7	13.8	2.75	11.4	3.47
19	Panthalayini	Quilandy	11.442	75.694	DW	7.08	480	0	174.7	18.4	42	29.17	0.0	358	70.9	44	45.19	17
20	Kozhikode	Ramanattukara	11.177	75.860	DW	7.74	870	0	268.3	58.5	116.8	23.1	0.0	331	80	31.9	149.8	14.9
21	Koduvalli	Thamarasseri	11.424	75.938	DW	7.81	133	0	32.4	4.23	19.1	2.11	0.0	77.1	25.68	3.17	11.13	2.22
22	Thodannur	Thiruvallur	11.591	75.673	DW	7.57	114	0	7.49	3.43	10.6	31.1	0.0	55	17.2	2.96	9.51	2.16
23	Meladi	Tikkodi	11.488	75.628	DW	7.55	95	0	7.49	5	13	12.05	0.0	41.6	13.54	1.9	7.56	6.22
24	Kozhikode	Vallikunnu	11.230	75.866	DW	8.26	95	0	21.6	12	4.2	5	0	27.8	8.5	1.7	9.52	1.9
25	Kunnmangalam	Pannikode	11.270	76.008	DW	8.2	102	0	17.7	0	19.8	8.2	0	19.3	6.8	0.64	15	4.6
26	Koduvally	Kuruvattur	11.310	75.851	DW	7.98	163	0	62	6.14	17	2	0	64.2	18.8	4.4	7.49	2.2

#	Block	Village	Latitude	Longitude	Sour-ce	pH	EC *µs/cm* at 25^0C	CO_3	HCO_3	SO_4	Cl	NO_3	F	TH	Ca	Mg	Na	K
								< …….……Concentration in mg/l……. >										
27	Kunnmangalam	Peruvazhikadavu	11.288	75.899	DW	3.37	52	0	0	0	9.9	10.3	0	12.8	3.4	1.1	2.94	0.94
28	Kunnmangalam	Chattamangalam	11.312	75.916	DW	7.38	85	0	21.7	0	18.4	9.8	0	23.5	6	2.14	7.8	1.2
29	Kunnmangalam	Agastiamuzhi(mukkom)	11.328	75.989	DW	7.75	300	0	75	8.27	49.7	4.5	0	96.3	27.8	6.84	33	1.02
30	Koduvally	Maranchatty	11.322	76.065	DW	3.7	155	0	0	0	15.6	32.8	0	21.4	5.1	2.16	7.8	1.8
31	Koduvally	Poovaranthod	11.386	76.069	DW	6.06	135	0	52	3	8.5	17	0	79	23.4	5.3	2.12	2.7

Annexure-VII: Analysis of water quality in Explotarory wells of Kozhikode District

Location	pH	EC (µS/cm at 25 °C)	Total Hardness (mg/l) as $CaCO_3$	Ca^{2+}	Mg^{2+}	Na^{1+}	K^{1+}	CO_3^{2}	HCO_3	Cl	SO_4^{2}	NO_3	F
			<……mg/l……>										
Balussery	8.3	220	145	32	16	13.6	2.8	10	107.6	4.5	3.4	0.23	0.21
Chekkiad	8.4	300	123	30	11.7	21.98	5.84	21.3	135.4	12.4	42.47	0	0.19
Maniyur	8.4	240	172.626	29.9	23.87	10.5	5.51	5	128	5.6	4	0	0.1
Mokeri	8.1	330	407.5	132	19	15.6	3.9	0	190.6	5.7	3.3	1.4	0.1
Muchukkunu	8	580	197.9	20	36	27.4	7.1	3	137.2	93.7	8.06	0	
Mudukkad	8.5	270	358.6	119	15	20	4.5	0	165.2	4.2	2.1	0.3	0.3
Peruvannamozhi	7.9	800	548	216	2.2	55.7	4.8	0	90.3	5.7	322	0.6	0.4
Peruvannamozhi-OW	8.1	96	252.9	89	7.5	13.9	5.9	0	61.5	10.2	17.8	3.4	0.1
Thottilpalam	7.6	1560	818.3	326	1.2	112	4.8	0	51.6	5.1	921	0	0.6
Thottilpalam-OW	8.3	102	217.5	73	8.6	7.6	3	0	41.3	3.8	4.8	0	0
Earpona	8.2	400	294	74	26.6	18	4	0	203	27.5	55	0.52	
Kallanode	7	220	166.8	55	7.19	18.3	3.46	0	133	7.88	46	1.4	
Kallanode-OW	7.1	210	167.6	56	6.78	15.87	3.1	0	140	5.12	46	1.06	
Kannore	6.9	13400	3235.5	874.9	256	1589	30.2		102	5282	581	0.8	
Koodaranjhi	7.1	290	157.9	35.1	17.1	36.6	6.3	0	127	49.1	29.5	0.32	0.5
Moozhikkal	7.7	270	190.5	48.5	16.9	17.2	8.67	0	165.1	5.33	39	0.72	
Mukkam	7.3	500	246.8	50.8	29.2	35.03	6	0	196.9	65.7	21	1.9	0.1
Narikunni	7.3	290	201.7	54.8	15.8	14.52	5.95	0	159	6.31	40.3	1.45	
Ramanattukara	7	10300	3090.5	708	322	1002	28	0	133.4	3988	314	0.8	

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