

# **IDENTIFICATION OF RECHARGE AND DISCHARGE AREAS OF PALAR BASIN IN TAMILNADU**

**Study Group**

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## **PREFACE**

Groundwater recharge is a basic pre-requisite for efficient groundwater resource development and management, which is particularly vital for Palar basin with widely prevalent semi-arid and arid climate. In case the natural recharge is not sufficient, it has to be met through artificial recharge. To provide scientifically, appropriate locations for constructing artificial recharge structures, each hydro-geomorphic unit will be evaluated for its recharge potential and suitably a map showing such groundwater recharge potential zones for appropriate recharge will be prepared. Using remote sensing and geographic information system (GIS) it is possible to take number of different thematic maps of the same area and overlay them on top of one another to form a new integrated layer. This study was aimed to identify the groundwater recharge zones, to be used for better and improved groundwater resources of Palar basin. The thematic layers considered in this study are geomorphology, soil, landuse/landcover, slope (%), drainage density and lineament density, which are prepared using satellite imagery and other conventional data. The thematic layers were first digitized from satellite imagery, supported by ancillary data such as topo-sheets and field investigation data, finally all thematic layers were integrated using ArcGIS software to identify the groundwater recharge zones for the Palar basin located in Tamilnadu and generated a map showing these groundwater recharge potential zones namely Excellent, Very Good, Good, Moderate and poor on knowledge based weightage factors.

This study was carried out by V.S.Jeyakanthan, Sc-F, Y.R.Satyaji Rao, Sc-G and R.Venkataramana, Sc-E from Kakinada Regional Centre of National Institute of Hydrology and Tirupti Mugali, Sc-D from National Institute of Hydrology, Roorkee.

Director

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## ABSTARCT

The Palar basin have a total catchment area of 10,273 sq.km within Tamilnadu. The Weighed Index Overlay Analysis (WIOA) technique implemented in this study to identify the recharge zones of Palar basin using maps of drainage density, soil, slope, geomorphology, geology, land use/cover, lineament density and ground water level fluctuations. Each parameter in the thematic map was assigned ranks from 1 to 5 based on the values obtained from analytical hierarchy process. The study area contains Geomorphologic units predominantly such as Alluvial plain, Bajada, Buried pediments, Flood plain, Inselberg, etc. The units, which are having high infiltration characteristics, are assigned rank 5. The moderate units are assigned the rank 2 to 4 and the units which have less infiltration characteristics are assigned the rank 1. The slope of the study area classified into five classes. The less to moderate slope (1% to 20%) have high recharge capabilities, hence these units assigned ranks 5 and 4. The higher slopes (> 20%) are assigned ranks 1 to 3. The LULC of the Palar basin consists of crop land (46.27%), fallow land (8.05%), deciduous forest (21.60%), forest blank (1.62%), forest plantation (1.98%), built-up area (4.64%), wasteland (9.56%) and water body (6.28%). The land use/cover units assigned ranks according to their recharge characteristics. In the study area, the lineament density, ranges from 0 to 120 km/km<sup>2</sup>. The lineament density was classified into five categories, viz., 0-10.8, 10.9-26.3, 26.4-42.3, 42.4-62.0, and 62.1–120.0 km/km<sup>2</sup>. The lineament density was relatively high in the central portion of the study area, which lies between the altitude 100 to 200 m. The high lineament density shows high recharge characteristics and provided high rank (5) value. Likewise, the parameters in the drainage density, soil and geology have also been ranked. Based on the above said analysis the recharge/discharge zones of the Palar basin have been classified as low, moderate, moderate to good, good and excellent. Further, stable isotope analysis has been carried out in the month of June 2022 and collected 90 samples from groundwater, stream water, pond/lake water. The stable isotope analysis of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  has been carried out at NIH, Roorkee laboratory. The stable isotope values of these samples reveals that the groundwater recharge takes place in the central portion of the Palar basin, which is in between the contour levels 100 to 200 m and discharges at the downstream of the basin. This is also supported by WIOA results in the Palar river basin. Hence, recharge structures such as check dam, Nalla bund, recharge shaft can be constructed in the identified zones to increase the water availability of the Palar basin.

# CHAPTER - 1

## INTRODUCTION

Rapid industrial development, urbanization and increase in agricultural production have led to fresh water shortages in many parts of the world. In view of increasing demand of water for various purposes like agricultural, domestic and industrial etc., a greater emphasis is being laid for a planned and optimal utilization of water resources. The water resources of the basins remain almost constant while the demand for the water continues to increase. The utilizable water resources of India are estimated to be 1121 BCM out of which 690 BCM is surface water resources and 431 BCM is groundwater resources. Due to uneven distribution of rainfall both in time and space, the surface water resources are unevenly distributed. Also, increasing intensities of irrigation from surface water alone may result in alarming rise of water table creating problems of water-logging and Stalination, affecting crop growth adversely and rendering large areas unproductive. This has resulted in increased emphasis on development of ground water resources. The simultaneous development of groundwater, specially through dug wells and shallow tube wells, will lower water table, provide vertical drainage and thus can prevent water-logging and Stalination. Areas, which are already waterlogged, can also be reclaimed.

On the other hand, continuous increased withdrawals from a groundwater reservoir in excess of replenishable recharge may result in regular lowering of water table. In such a situation, a serious problem is created resulting in drying of shallow wells and increase in pumping head for deeper wells and tube wells. This has led to emphasis on planned and optimal development of water resources. An appropriate strategy will be to develop water resources with planning based on conjunctive use of surface water and groundwater. For a sustainable development of water resources, it is imperative to make a quantitative estimation of the available water resources. For this, the first task would be to make a realistic assessment of the surface water and groundwater resources and then plan their use in such a way that full crop water requirements are met and there is neither water-logging nor excessive lowering of groundwater table. It is necessary to maintain the groundwater reservoir in a state of dynamic equilibrium over a period of time and the water level fluctuations have to be kept within a particular range over the monsoon and non-monsoon seasons. Groundwater is a dynamic system.

India has been the second largest populated country in the world. To satisfy the growing needs for food in the country, agriculture activity has been increased considerably. Foreign policies of the government have made many multinational companies to invest in industrial sectors in India which have increased the number of industries. Overall development in various fields such as agriculture, industry and urbanization has led to an increase in demand for water particularly in India. Depletion of water levels in aquifers and decline in design yield of wells due to excessive pumping in the absence of adequate knowledge on groundwater availability are becoming a major concern across the globe (Babikar et al. (2005) in central Japan; Kendy et al. (2003) in north China; Konikow and Kendy (2005); Pandey et al. (2010) in Kathmandu Valley; Reddy (2005) in Andra Pradesh; Saha et al. (2007) in Bihar; Shah et al. (2000) in Colombo, Wada et al. (2010, 2012), Lapworth et al. (2015) in northwest India; Krishan et al. (2015) in northern Punjab; Krishan et al. (2014) in Punjab) (Krishanmurthy and Srinivas 1995; Jaiswal et al.2003; Sener et al.

2005; Yoshihide et al. 2012; Pandey et al. 2013; Nampak et al. 2014). All the above factors have increased the demand for water in India which would be a crucial problem in the near future. This has led to the over exploitation of groundwater in many parts of our country (Prasad et al. 2007). Hence, there is a need for proper planning, development and management of water (Rakesh Kumar et al. 2005). Therefore, it is imperative to investigate the suitable areas for ground water extraction to increase the fresh water availability and control the water scarcity. Several conservative methods such as geological, hydrogeological and geophysical techniques were employed to delineate the groundwater potential zones.

However, recently, with the use of remote sensing and GIS technologies, mapping of ground water potential zones has become easier and less expensive compared to conventional methods. Satellite data provide quick and useful baseline information about various factors controlling directly or indirectly the occurrence and movement of groundwater such as geomorphology, soil, land slope, landuse/land cover, drainage patterns and lineaments. In addition, geographical information system (GIS) provides an excellent framework for efficiently handling large and complex spatial data for natural resources management (Machiwal et al. 2011). Several studies were carried out in the past two decades for identifying the groundwater recharge zones using GIS and remote sensing data. The methodology proposed in the literature, Krishanmurthy and Srinivas (1995) in Karnataka; Saraf and Choudhury (1998) in Kandi region of Jammu district, Rao and Jugran (2003) in Chittoor area of Andhra Pradesh; Girish Gopinath and Seralathan (2004) in Muvattupuzha river basin, Kerala; Sikdar et al. (2004) and Basudeo Rai et al. (2005) in Nambuir district, Kanyakumari; Amin Shaban et al. (2006) in Lebanon; Solomon and Quiel (2006) in Eritrea; Ganapuram et al. (2009) in Musi basin; Suja Rose and Krishnan (2009) in Nambiyour basin, Kanyakumari; Chowdhury et al. (2010) in Manipur district, West Bengal, Upper Langat basin; Machiwal et al. (2010) in Mamundiyyar basin; Dar et al. (2010) and Manap et al. (2011) in Malaysia; Khodaei and Nassery (2011) in Urmich Northwest of Iran; Abdalla (2012) in Central Eastern desert, Egypt; Gumma and Pavelic (2013) in Saharan Africa; Sharma et al. (2014) in Punjab; Lapworth et al. (2014) in northwestern India; MacDonald et al. (2014) in Indo-Gangetic basin; Preeja et al. (2011) in Tropical River Basin, Kerala; Arkoprovo Biswas (2012) in Ganjam district, Orissa; Selvam et al. (2014) in Tuticorin, Tamil Nadu; Domingos Pinto et al. (2015) in Comoro watershed, Timor Leste; Shashank Shekhar and Arvind Chandra Pandey (2014) in Palamu district, Jharkhand; Ramu and Vinay (2014) in Mysore taluk, Karnataka; Soumen Dey (2014) in Puruliyadi district, West Bengal; Rajvir Singh et al. (2014) in Mewat district, Haryana; Abhay et al. (2011) in Chandrapur and Gadchiroli districts of Maharashtra), to demarcate groundwater recharge zone of an area, in which several selected thematic maps from different sources such as remote sensing data, geophysical data and conventional data are integrated in the GIS environment to generate groundwater potential. So, for the study area, exploration of groundwater by Boolean overlay, weighed index overlay analysis and fuzzy logic model (Lohani et al. 2014; Lohani and Krishan 2015a, b) were used to identify groundwater potential zones.

**1.1 Objective:** Identification of recharge and discharge areas using hydro-geological and Isotopic signatures.

# CHAPTER – 2

## STUDY AREA

### 2.1 Physiography

The Palar River Basin is one of the major river basins in Tamilnadu. The main Palar River originates in Nandhi Durg, Kolar district at an elevation of 800 m above MSL in eastern part of Karnataka State. It flows through Kolar and Bangarupet Taluks where it forms the very large Bethamangal tank, which is the main source of water supply to Kolar Gold Field and Bharath Earth Movers Limited. It leaves Karnataka border and flows through Andhra Pradesh for a small distance in Kuppam Taluk in Chittoor District and enters Vellore District of Tamil Nadu and passes through west of Vaniambadi Town and flows into the Bay of Bengal, east of Maduranthagam and south of Mahabalipuram.

The total area of Palar River Basin is 17,633.19 sq.km which includes an area of 3,123 sq.km in Karnataka state, 4,267 sq.km in Andhra Pradesh and 10,273.19 Sq Km in Tamil Nadu. It lies between 78°24'43" E, 12°36'26" N and 80°09'54" E, 12°31'26" N from east to west and between 79° 14'23"E, 13°10'21" N and 78°41'51" E, 12°14'05" N in north to south. The Index map is given in Figure 1. The basin area (10,273.19 Sq Km) within Tamilnadu only has been considered in this study.

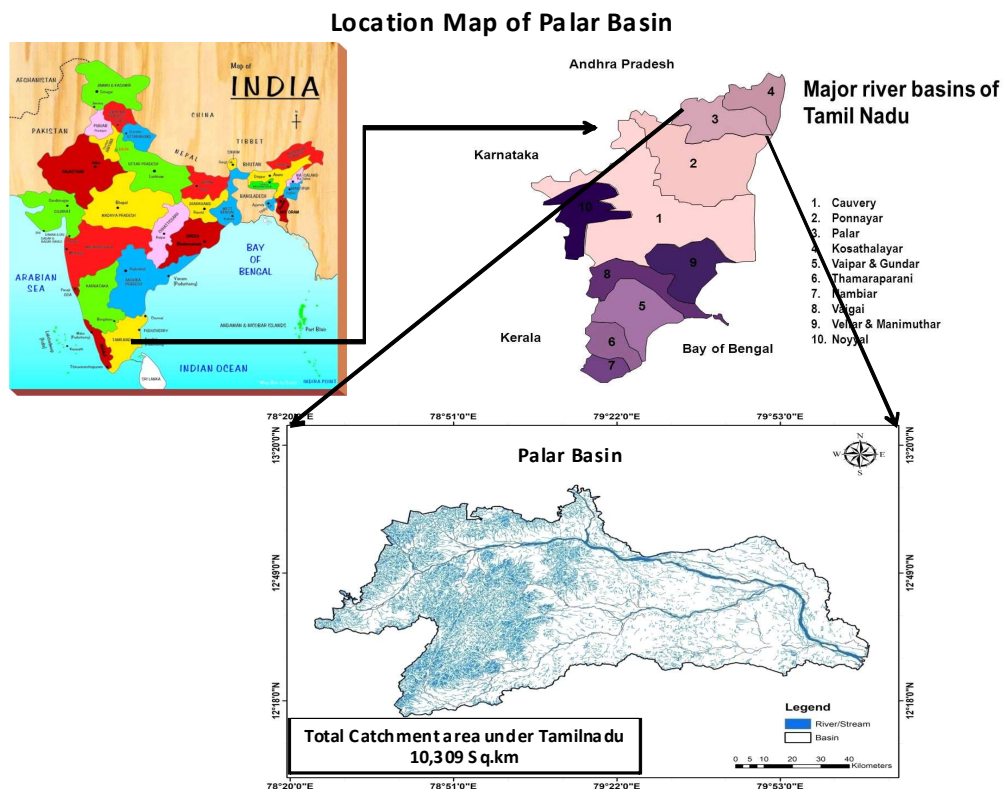


Figure.1. Study area

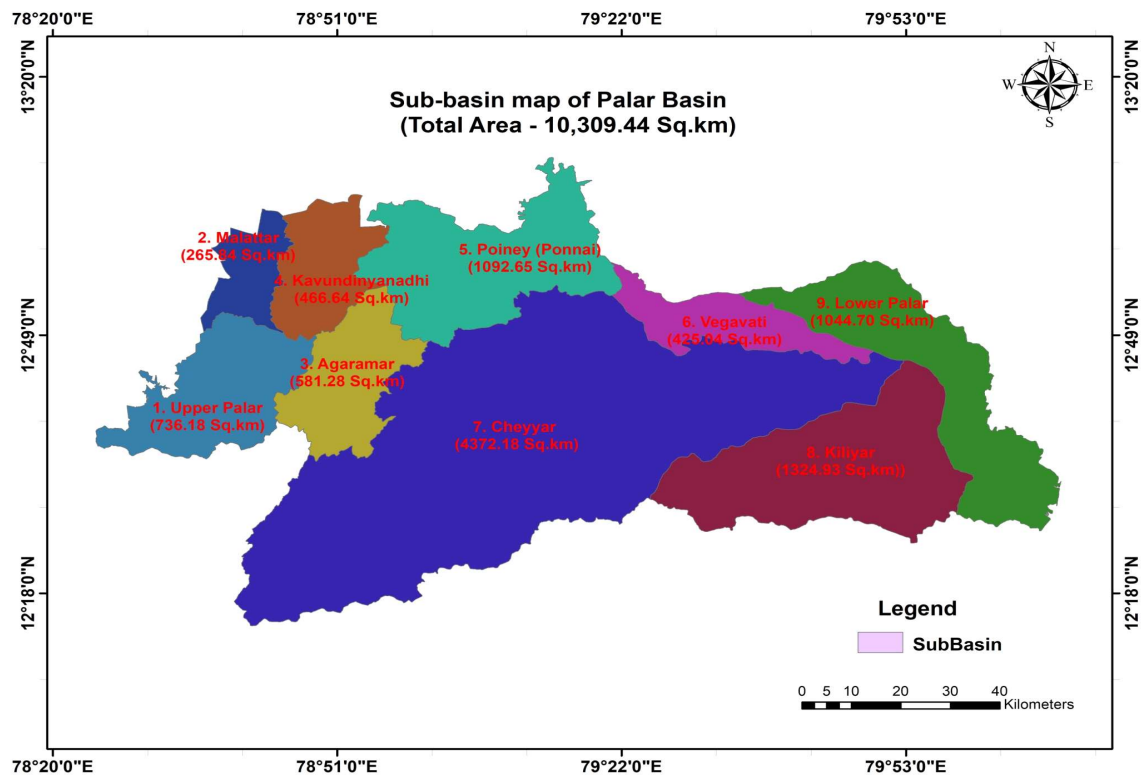


Figure.2. Sub-basin map

## 2.2 Sub-basins

The basin is bordered on the northwest by Andhra Pradesh state, northeast by Chennai River Basin, southwest by Penniyar river basin and northeast by Varahanadhi river basin. The basin Tamilnadu covers Vellore, Thiruvannamalai, Kancheepuram, Thiruvallur, Villupuram and Krishnagiri districts of Tamilnadu. The important tributaries are 1.Poineyar 2.Kaudinya Nadhi 3.Malattar 4. Cheyyar 5.Agaramar 6.Kamandalar 7.Naganadhiar 8.Killiyar 9.Vegavathiar. In this basin there are 50 blocks either partly or fully falling in the above districts. The sub-basin map of Palar basin is given below.

This basin is divided into three major topographical divisions namely, (i) the hill ranges of Eastern Ghats (ii) the plateau region and (iii) the coastal plains. The general trend of slope is steep to moderate. After rolling from the higher relief of hill ranges (305 to 91 m) a plain undulating terrain is mapped. It is narrow and combined with frequent low relief zones up to 76 to 91 m range. After 76 m it shows moderate to gently sloping open relief before the coastal zone. Near the coastal zone the relief is very less (0.5 m). It is almost a plain topography gently sloping towards the Bay of Bengal.

## 2.3 Geomorphology

The geomorphology of an area is the external appearance of landforms that gives a reliable picture of the underground strata and its physio-chemical condition. The different formations and the layer confirms and cogent to its geomorphology. Four major geomorphic units can be

demarcated. They are hilly regions, plains, urban areas and coastal landforms. The eastern part adjoining to beach and shores cover coastal geomorphic units. The inland topographical units are being described as the piedmont geomorphology.

Nearly 60% of the region is covered by Pediment zones. A pediment is an erosional landform with a very gently sloping inclined bedrock surface, typically sloping down from the base of a steeper retreating desert cliff, or escarpment that has eroded away. It is thinly covered with fluvial gravel that has been washed over it from the foot of mountains produced by cliff retreat erosion. Pediments include the deep buried pediments, moderate and shallow buried channels.

About 27% of the aquifer system is covered by Hills and Plateaus characterized by elevated areas where the occurrence of groundwater in this particular landform is meagre. About 11% of the system covers flood plains consisting of sandy clay are found along the rivers. The thickness of the alluvial sand varies from 1 to 7 m and the flood plain itself is found spread over a width varying from 0.25 to 5.0 km from the riverbanks.

About 2% of the aquifer system is covered with surface water bodies and Sathanur Anicut is a major surface water storage system existing in the system. The coastal landforms include the beaches, beach ridges and beach terraces. The beaches are landforms covered by sand and sandy materials having high porosity and unconsolidated loose formation with voids and spaces. Beach Ridges are elevated sandy tops adjoining the beaches and are good horizons for ground water presence. The step like projection bordering the sandy terrain and the shoreline are called as beach terraces. These terraces are undulating and according to the forces of the tide and their deposition. These terraces have a very low groundwater gradient that too towards the sea as they are sloping towards them.

## **2.4 Soil**

Soils play a major role in hydrologic control of the infiltrating water. Soils are generally classified by taking their colour, texture, fertilities and chemical combinations includes salts, minerals and the solution effect over them. The major soil types in the study area are red soil, black cotton soil, sandy loam and forest loam. Red soils are the major soil group found in the study area and consists of the red sandy to brownish clayey soil fragments derived from parent rock and is spread all along the westward side. The red soils are suitable for agricultural hold moderate groundwater reserves.

Black cotton soil is clayey soil with high specific water retention capacity but poor in supporting agriculture. The rate of infiltration varies is very low in this type and ranges from 1 to 3 cm / hr for fine red sandy clay, clayey sand, sandy clay, sand fine to medium, sand medium to coarse and very coarse and gravel and for weathered rock, fractured and jointed rock it varies from 0.2 to 0.5 cm / hr. which normally occurs in the study area.

## **2.5 Slope**

The slope of any terrain plays a vital role in allowing the infiltration of water into the subsurface system. In regions of gentle slope the runoff will be slow and will have more time for percolation of rainwater, whereas steep slope facilitates high runoff allowing less

residence time for rainwater to percolate. The elevation of the Palar Aquifer system ranges from 1240 m amsl in the west to sea level in the east.

## **2.6 Agriculture**

Agriculture is the main stay of the rural population in the entire study area. Agricultural land occupies nearly 5124 sq.km i.e., 57% of the Palar aquifer system area and spread throughout the basin with main water intensive crops irrigated which are paddy, sugarcane and banana. The less water intensive crops irrigated are maize, tomato, groundnut, chilly and Jasmine. The other crops include cotton, ragi etc., and other minor crops are, turmeric, flowers and vegetables. More than 80% of the total requirement of irrigation is met from groundwater resources.

## **2.7 Geology**

Geologically, the Palar aquifer system comprises of marine, estuarine and fluvial alluvium under lained by Precambrian gneisses and Charnockites. The charnockites form the major rock types and constitute the residual hills around southern part of the study area. Beds of upper Gondwanas are found in and around central and northern portions. These Upper Gondwana formations with type area Sathyavedu comprises of conglomerates, shale, and sandstone, and are covered by a thick cover of laterite. Intrusive rocks trending, dark coloured continuous ridges of dolerite dykes are common in many places in the aquifer system. Pegmatite and quartz veins occur as thin stringers cutting all the rock types of the area.

## CHAPTER – 3

### METHODOLOGY

There are several methods such as geological, hydrogeological, and geophysical techniques, which can be applied to determine the recharge and discharge zones. Many factors affect the occurrence and movement of groundwater in a region, including topography, lithology, geological structures, depth of weathering, extent of fractures, primary porosity, secondary porosity, slope, drainage patterns, landform, land use/land cover, and climate. A Weighed Index Overlay Analysis (WIOA) used in this study to identify the recharge zones in the Palar basin. (WIOA) is a simple and straight forward method for combined analysis of multiclass maps. A weight represents the relative importance of a parameter vis-à-vis the objective. WIOA method takes into consideration the relative importance of the parameters and the classes belonging to each parameter. There is no standard scale for a simple weighed overlay method. For this purpose, criteria for the analysis should be defined and each parameter should be assigned importance (Saraf and Choudhury 1998). Each parameter in the thematic map of geology, geomorphology, soil and land use/land cover was assigned ranks from 1 to 5 (low, moderate, moderate to good, good and excellent) based on values obtained from analytical hierarchy process. The parameters of the thematic maps lineament density, drainage density and slope, land use/landcover, soil, geology and geomorphology were made into five classes and the rank was assigned based on their influence towards groundwater.

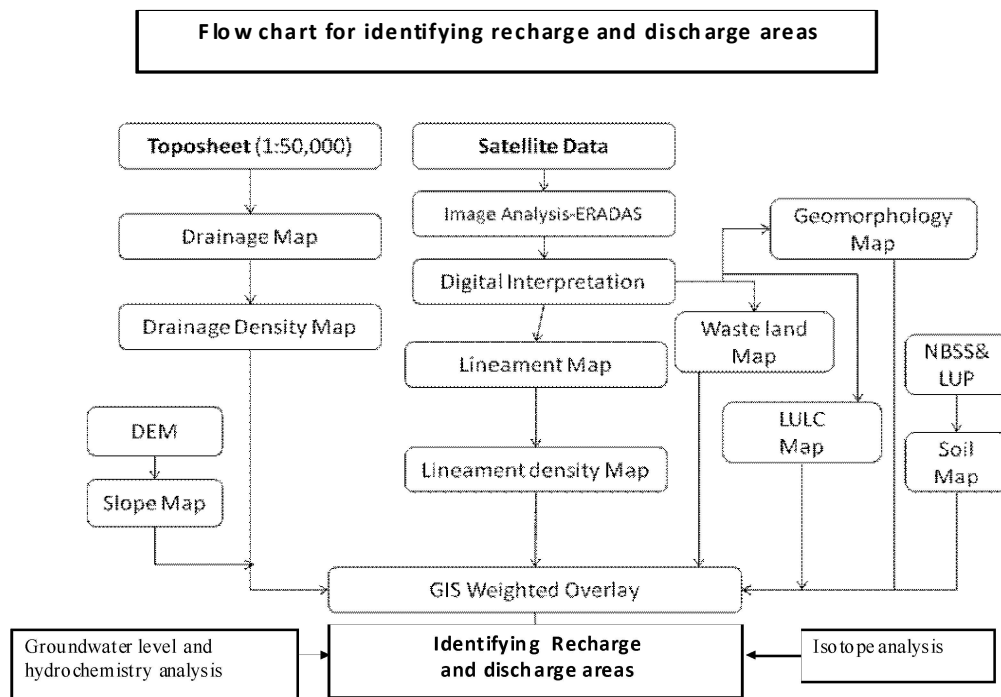


Figure.3.1 Flow chart showing identification of recharge and discharge areas.

The above said input maps have been prepared. Combined with the rainfall, flow of the Palar river with the isotopic analysis and hydrochemistry data will be utilized to identify the recharge and discharge zones in the Palar basin. A flow chart in this regard is given in Figure 3.

### 3.1 Drainage Pattern in Palar Basin.

When the water table was near bed level of river there were a number of spring channels in the bed of the river, and during a large part of the year these spring channels dries out and groundwater in the deep, and sandy river bed are the main source for farmers and for drinking water supply schemes. The drainage map is shown in the following Figure 3.2.

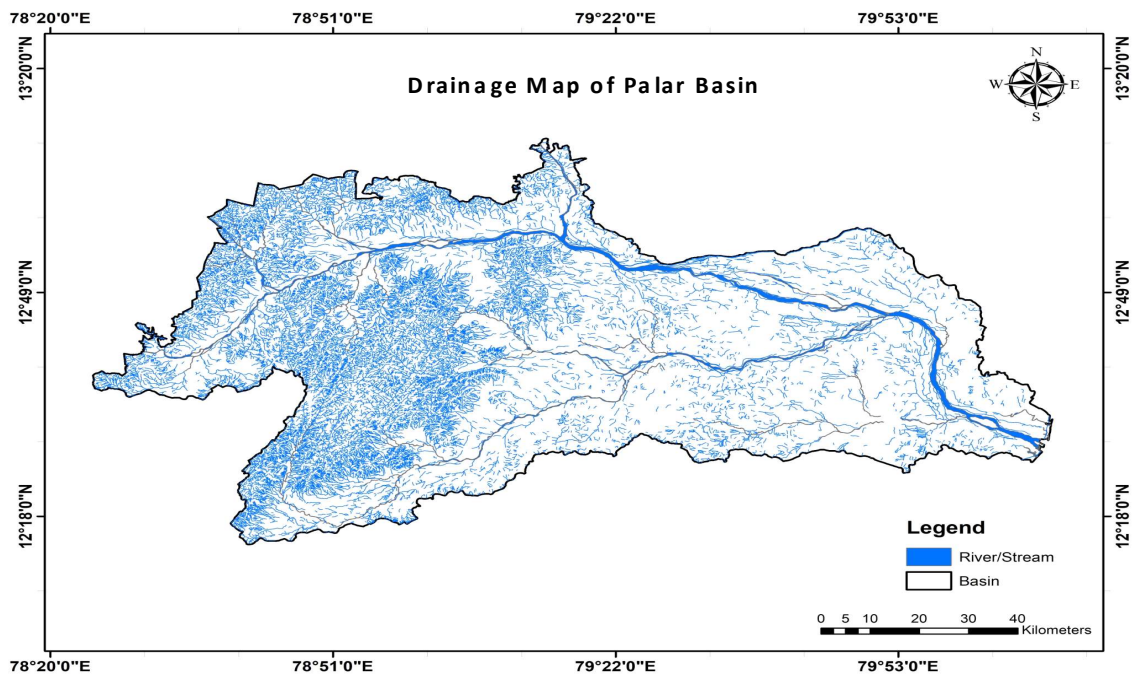


Figure.3.2 Drainage map of Palar basin

### 3.2 Geology of Palar Basin

The geology of the Palar Basin is presented in the following Figure. Out of the total area extent, 10,273.19 sq.km is occupied by Archaean crystalline formations like Gneisses and Charnockites and the remaining 1383 sq.km is predominantly covered by sedimentary formations such as upper Gondwana, Alluvium including coastal deposits. Geology of Palar basin is given in Figure 3.3.

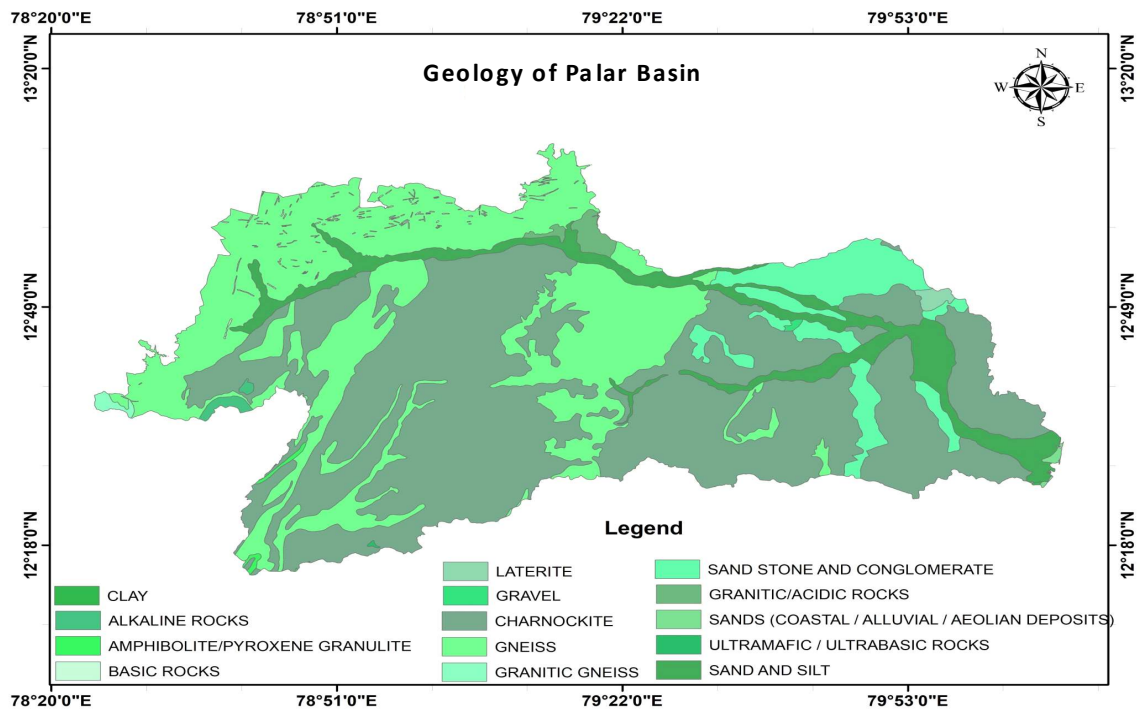


Figure3.3 Geology of Palar basin

Groundwater in the basin occurs in 1) Unconsolidated and semi consolidated formations and 2) Weathered, fissured and fractured crystalline rocks. The ground water occurs under water table conditions and the depth of the wells ranges from 5 to 15 m bgl. The depth to water level ranged from 2.89 to 8 m bgl during May 2006 and 1.05 to 3.40m bgl during Jan'2007. The unconsolidated alluvium occurs mainly along the banks of Palar and Cheyyar rivers and the sand layers of this alluvium form the potential aquifer. Between Walajabad and Kancheepuram, small diameter dug wells tap the alluvium with depths ranging between 6 and 12 m bgl. Ground water in fissured crystallines is developed by means of dug wells, dug-cum-bore wells and bore wells. The wells range in depth between 6 and 17.00 m bgl. The depth to water level ranged from 3.50 – 8.34 m bgl during May 2006 and 1.32 – 7.53 m bgl during January 2007.

### 3.3 Lineament pattern in Palar Basin

The pattern of dyke, joints and fractures shows that the area was once subjected to much structural disturbances as seen in the outcrops of dykes and rocks. One prominent set of dyke is running south of Uttiramerur - Wandiwash road in E -W direction to a length of 5.5 km with a width of 10-15 m. Three major important faults are noticed in the basin area such as 1. Amudi fault 2. Javadi hills fault and 3. Malattar fault. These faults occupy southwestern part of the basin. Minor faults are presumed along the Cheyyar river course near Polur in NE-SW direction. Similarly river Malatar follows fault line in NW-SE direction. The lineament is provided in the Figure 3.4.

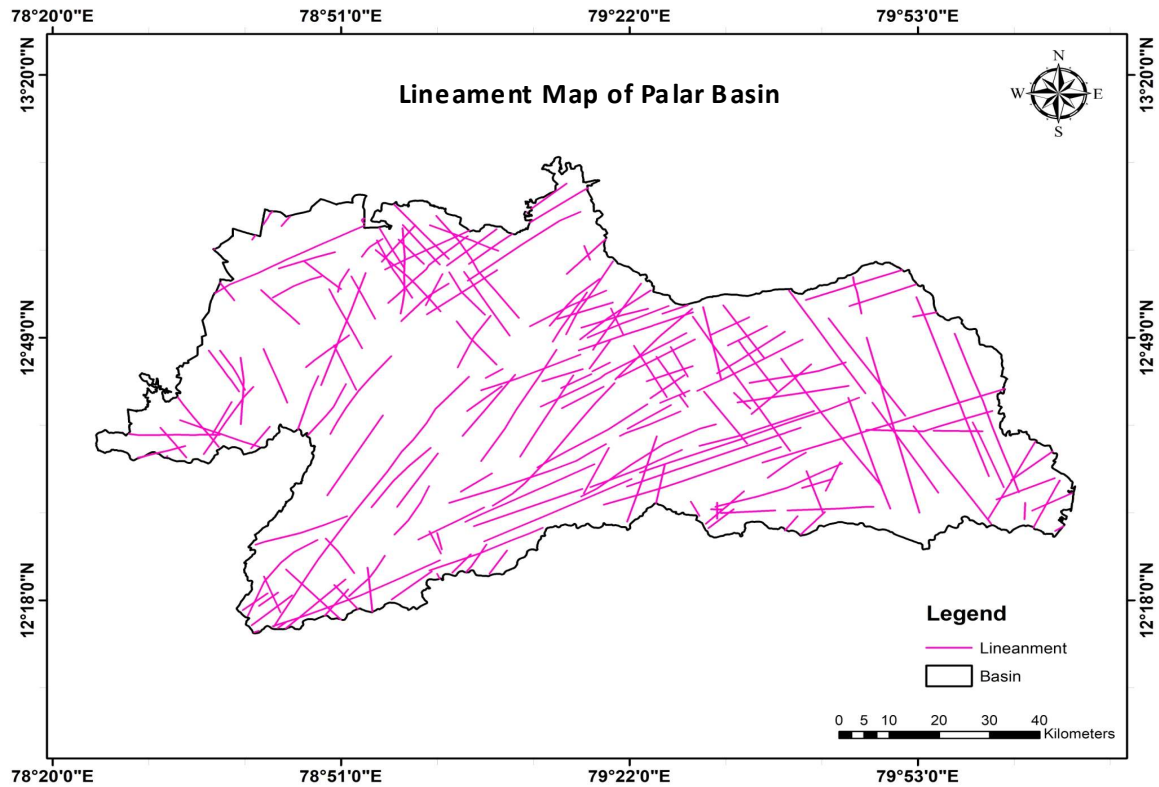


Figure.3.4.Lineament map of Palar basin

### 3.4 Geomorphology of Palar Basin

The Palar basin is mostly covered by structural hills and pediplain areas. Fluvial landforms are extensively covering the Palar river and its environ in this area while denudation land forms are developed in the hilly areas. The river alluvium seen along the course of Palar River on its banks as well as on the interfluvial zone between the confluence of Poini river and Cheyyar river with Palar. The sandstone and shale are common around the low-lying areas of the river Palar and Cheyyar confluence. These sandstones are sedimentary in deposition and occur as beds in patches. The beds are composed mainly of white to pink clays, shales and feldspathic sandstone. Landforms of fluvial origin occur predominantly in the eastern part of the study area like maduranthagam, uthiramerur, vayalur, kalpakkam, and thirukalukundram areas. The Geomorphology map is given in the Figure 3.5.

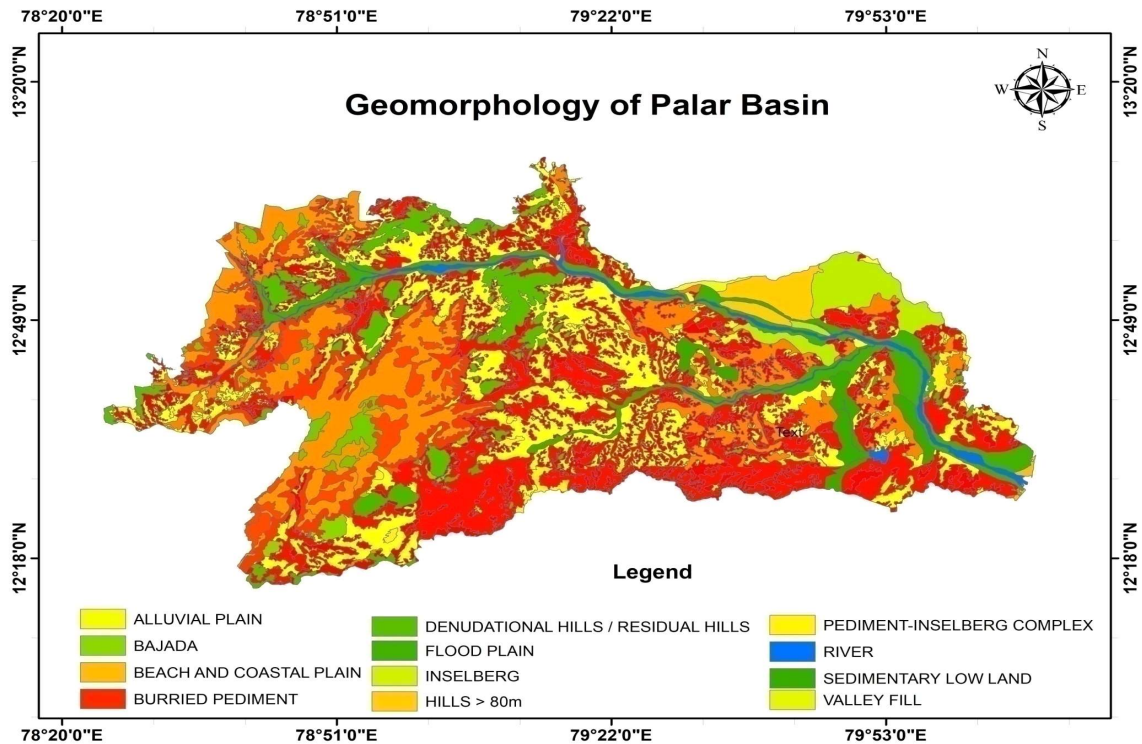


Figure3.5 Geomorphology of Palar basin

### 3.5 Soil Types of Palar Basin

The predominant soil order found in this river basin is Inceptisol, Alfisol, Entisol, Ultisols and Vertisol. Due to different stages of weathering of parent material, the above soil types are met with in combination. The chief order of soil seen here is Inceptisol. The Soil map of the Palar Basin is given in the Figure 3.6.

The moderate and poor ground water potential zones occupied major portion in Palar river basin area. The good ground water potential zones are identified along the river course. Poor ground water potential zones are encountered in the north western part of the basin area including Vaniyambadi, Ambur, Gudiyatham, Vellore and surrounding areas. The moderate ground water potential zones are occurred in the central and north eastern portion of the basin including Arani, Arcot, Gudiyatham, Polur and Kancheepuram areas. Good potential zones are identified along the river alluvium, flood plain areas of the basin in and around Cheyyar, Uthiramerur, maduranthagam and Chengam areas.

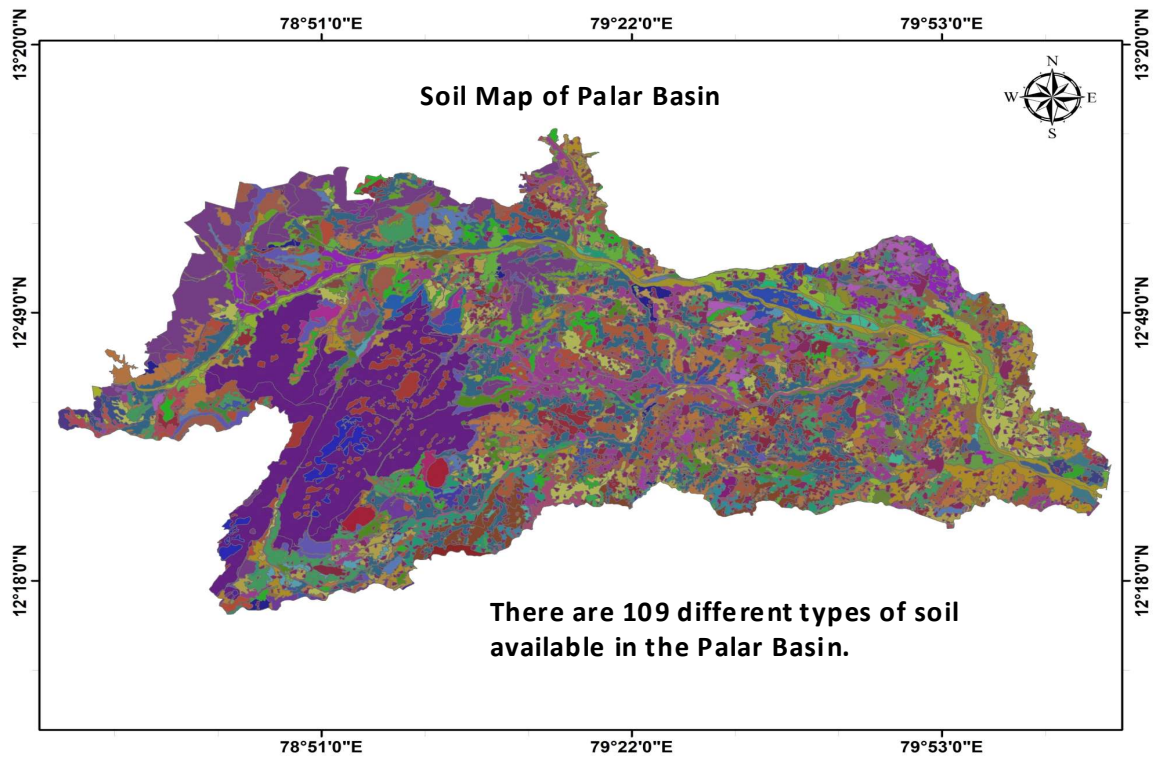


Figure 3.6 Soil map of Palar basin

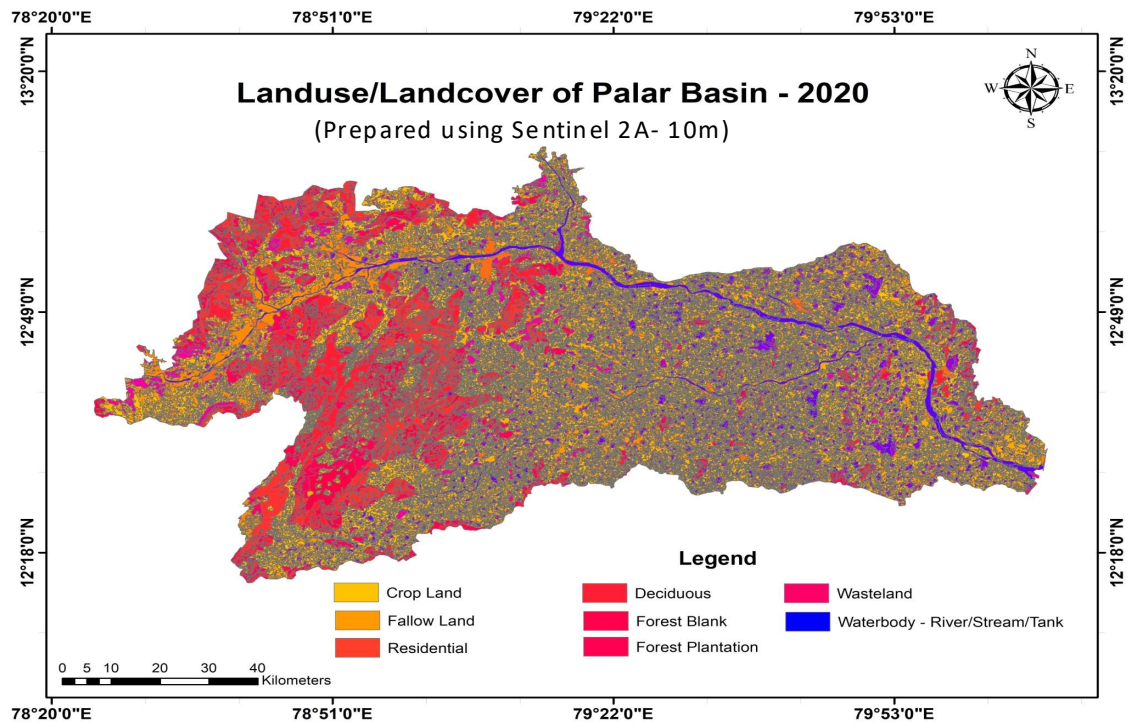


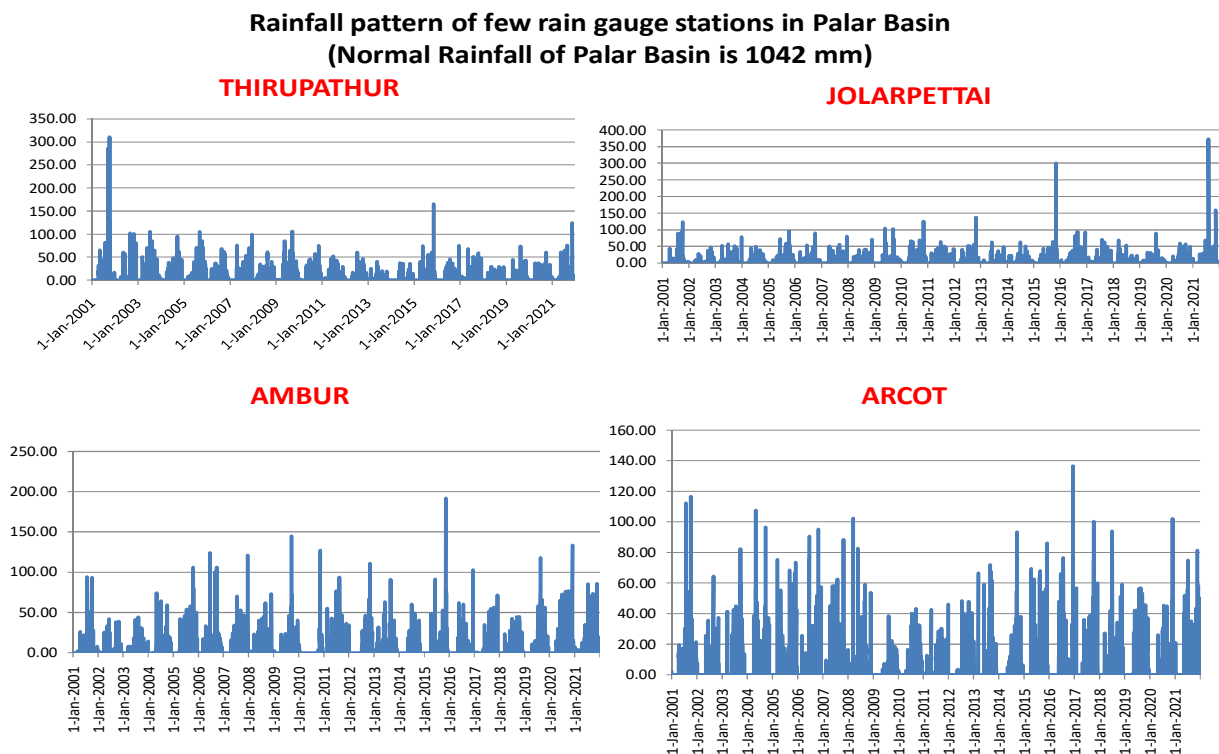
Figure 3.7 Landuse/Landcover map of Palar basin

### 3.6 Landuse-landcover (LULC) in Palar Basin

Landuse-landcover (LULC) map has been prepared for the year 2020 using Sentinel-2A satellite data with spatial resolution of 10 m. The LULC of Palar basin consists of crop land (44.18%), fallow land (10.31%), deciduous forest (21.60%), forest blank (1.62%), forest plantation (1.98%), built-up area (3.46%), wasteland (10.57%) and water body (6.28%). The Landuse-landcover map is given in the Figure 3.7.

### 3.7 Rainfall in Palar Basin

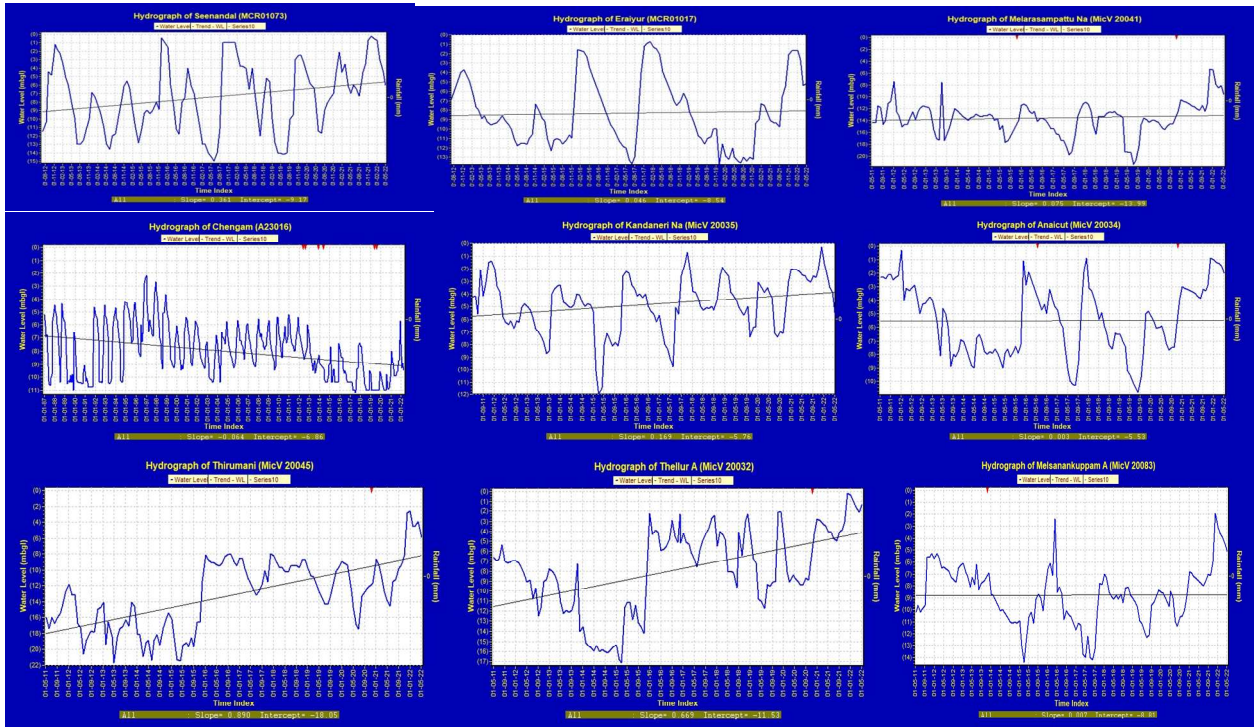
There are around 33 rainfall stations are maintained by the Tamilnadu government in the Palar basin. The rainfall data for the period 2000 to 2021 has been collected from all the existing rainfall stations. These data will be utilized in the analysis. The Maximum Annual Rainfall of this basin is 2854.10 mm in Agaramar (1985-86). Minimum Annual Rainfall of this basin is 203.5 mm in Kavundhiyanadhi (1971-72). Average annual rainfall of the Palar basin is 1042.60 mm. The rainfall pattern of few raingauge stations in the Palar basin is given below.



### 3.8 Groundwater Fluctuation in Palar Basin

The Tamilnadu government is maintaining around 310 observation wells in the Palar basin. The groundwater observation data for the period 2000 to 2021 has been collected from all the observation wells. These data will be utilized in the analysis. The groundwater changes in the observations wells of few stations are given below.

## Ground Water Trend Lines (2010 – 2022) of few Observation Wells in the Palar Basin



### 3.9 Collection of water samples.

Water samples have been collected from 91 observation wells in the Palar basin during June 2022. These samples will undergo isotopic and hydro-chemistry analysis tests. The results obtained from these tests and post-monsoon tests will be utilized for the identification recharge and discharge zones in Palar basin. The following figure shows the collection of water samples in the Palar basin.

91 Nos. of water samples collected from Palar basin for the Pre-m onson season



## CHAPTER – 4

### RESULTS AND DISCUSSION

#### 4.1 Drainage density

Drainage density indicates closeness of spacing of channels as well as nature of surface material. It is the measure of total length of the stream segment of all orders per unit area. It is affected by factors which control the characteristic length of the stream-like resistance to weathering, permeability of rock formation, climate, vegetation, etc. The drainage density indicates the relative run off of an area. Places where the density is high, runoff would be more and of less drainage density, runoff would be less. In the study area, the density ranges from 0 to 1.46 km/km<sup>2</sup>. The drainage density map reveals that the drainage density is more in the western part of the study area and less in the central and eastern part which indicates that the rate of infiltration in the eastern part of the study area will be more when compared with the western part. So the places where the runoff is less, recharge will be good and the groundwater potential in that place will also be good. The ranks were assigned to the drainage density according to its respective influence of recharge characteristics.

#### 4.2 Lineament

The lineament density indicates the relative recharge capacity of an area. Places where the density is high, infiltration would be more and of less lineament density, infiltration would be less. In the study area, the density, ranges from 0 to 120 km/km<sup>2</sup>. The study area based on the lineament density was classified into five categories, viz., 0–10, 10.1–26.0, 26.1–42.0, 42.1–61.0 and 61.1–120.0 km/km<sup>2</sup>. The lineament density was relatively high in central, eastern northwestern and southwestern parts of the study area. The ranks were assigned to the according to its respective influence of groundwater holding and recharge characteristics.

#### 4.3 Geomorphology

The identification and characterisation of various landforms and structural features in the study area is very important from geomorphological study point of view. Many of these features are favourable for occurrence and recharge of groundwater and are classified in terms of groundwater recharge potentiality. Geomorphologic units are delineated based on the image characteristics such as tone, texture, shape, colour and associations. By overlapping the base map over the geocoded FCC image, the geomorphologic units and landforms, the structural information and structural trend lines are incorporated. Structural hills are observed on western part of the study area, which are the linear or acute hills exhibiting definite trend lines and mostly act as runoff zones due to its sloping topography. This shows poor potentiality for groundwater occurrence and recharge. Valleys are low lying depressions formed longitudinally along the streams or amongst the ridge portions, which shows excellent potential for groundwater occurrence and recharge. Buried pediplain are flat and smooth surface with shallow overburden and are usually crisscrossed by fractures / lineaments, faults, etc. and are considered to be good for groundwater occurrence and recharge. Pediplain is a broad gently sloping or nearly flat erosion surface or plain of low relief, typically developed by running water; it is considered as moderate for groundwater occurrence and recharge. The ranks were

assigned to the individual landform, according to its respective influence of groundwater occurrence, holding and recharge.

#### **4.4 Soil**

Alluvium soil is loose, unconsolidated soil or sediments, which has been eroded, reshaped by water in some form. These soils are considered as good for groundwater occurrence, holding and recharge potential. Black cotton soils are well-known for their ability to retain moisture. These soils have moderate effect as a controlling factor for groundwater occurrence and recharge potential in the study area. Structural hills are mostly less prone to infiltration and subsequently causing poor in groundwater occurrence and recharge potential. The ranks were assigned to the individual soil type, according to its respective influence of groundwater occurrence, holding and recharge.

#### **4.5 Slope**

The precipitous terrain causes rapid runoff and does not store water easily. Slope of any terrain is one of the factors allowing the infiltration of groundwater into subsurface or in other words groundwater recharge. In the gentle slope area, the surface runoff is slow allowing more time for rainwater to percolate, whereas, steep slope area facilitates high runoff allowing less residence time for rainwater to percolate and hence comparatively less infiltration. The ranks are assigned to the individual slope class, according to its respective influence of groundwater occurrence, holding and recharge characteristics. The study area was classified into three categories and the slope is represented in percentage (%): nearly level (0–10%), moderate slope (10.1–36.0%), high slope (36.1–120%). The slope map of the study area reveals that the slope was high in the hilly terrain which was situated in the north and northeastern parts of the study area.

#### **4.6 Geology**

Groundwater occurrence in a particular area depends on the porosity and permeability of the rocks. So, the geology map was important for the present study since the occurrence of groundwater was controlled more by the geological formations. The different geological units of this study area are gneiss, charnockite, Black Clay, Laterite, and Conglomerates, Sandstone, alluvium, and limestone. The youngest formations in the area are the alluvium, which was deposited on the worn-down and eroded surface of Tertiary and Gondwana rocks by the major rivers. It is noted that the alluvial plains in the eastern part of the area, entirely spans the lower reaches of Palar and Cheyyar and branches off into two separate plains farther east. Alluvium consists of coarse-grained materials which has high groundwater potential. The ranks are assigned to the individual slope class, according to its respective influence of groundwater recharge characteristics.

#### **4.7 Isotope analysis**

The results obtained for the isotopic composition of groundwater and surface water of PRB are given in Table 4.1. The average  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values of groundwater are falling within the ranges of that earlier reported for this region (Deshpande et al. 2003). The groundwater having the  $\delta^{18}\text{O}$  values range from -4 to -6.5 ‰ reflects their recharge by winter monsoon

rains while that falling in the range of -1 to -4 ‰ indicate (Figure.4.1) that they are recharged either by summer monsoon rains or post recharge, they have experienced evaporation effect. The d-excess of different water in PRB suggests the following order for the degree of evaporation effect during the sampling period: OW < PZ < Stream water < Lake < pond water.

The relationship between  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  in different water samples have been plotted along with global meteoric water line (GMWL) to better understand the source and dominant mechanisms controlling isotopic composition of groundwater in the PRB (Figure.4.1). It is noted that most samples are falling away from the GMWL indicating that the water of PRB have experienced secondary processes effect after its recharge from precipitation. The groundwater samples are close to GMWL from lower end except few piezometers and open well which are above GMWL suggesting their meteoric origin and lesser effect of recycled moisture source in PRB. The groundwater line derived for open well is  $\delta^2\text{H} = [(5.13 \times \delta^{18}\text{O}) - 6.65]$ ,  $R^2 = 0.8$ , while that for piezometer is  $\delta^2\text{H} = [(5.98 \times \delta^{18}\text{O}) - 2.01]$ ,  $R^2 = 0.86$ . These groundwater lines of PRB during the sampling season are showing expected trends in the sub-humid to drier Peninsular Indian region based on available literature. The three days HYSPLIT backward trajectory of air mass over the PRB obtained for two seasons indicates that the moisture is derived from the Bay of Bengal during winter monsoon while its source is located in the Arabian Sea during the summer monsoon (Figure 4.2). However, as per the observation of rainfall for sampling period, there was no significant influence of summer monsoon rains on groundwater.

The relationship between average  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values in different water samples of PRB along with GMWL and local meteoric water line obtained from GNIP data of Bangalore (GNIP-B; Kumar et al. 2010) have been plotted to trace the connectivity between groundwater and surface water and to identify the varying degree of secondary processes effect, if any (Figure 4.3). The overall groundwater line derived for PRB is  $\delta^2\text{H} = [(5.47 \times \delta^{18}\text{O}) - 4.87]$ ,  $R^2 = 0.8$ . The overall groundwater line of PRB for sampling period shows similar trend as that derived for Bangalore groundwater during pre-monsoon (B-PM-GWL; Majee et al. 2024). The average stream water and average lake water is falling in or close to overall PRB\_GWL though the deviation range is higher. This indicates that surface water (stream and lake) is originally recharged by groundwater, and post recharge, they have experienced higher degree of evaporation due to larger surface exposure area. The average pond water is much away from the groundwater line of PRB though their deviation is still reaching it from the lower end. This indicates that pond water has not only undergone significant evaporation but also getting relatively lesser recharge from groundwater during this sampling period. Thus, it can be suggested that groundwater is discharging water to river, lake and pond in PRB at different rates based on aquifer connectivity while post recharge, these water bodies undergo significant evaporation during non-monsoon season.

The relationship of isotopic composition of groundwater in PRB with elevation has been plotted to identify the recharge sites (Figure 4.4). It is noted that there is no elevation effect in PRB if the overall groundwater isotopic composition is considered. However, the higher elevation effects are observed both for open well (lapse rate = -0.28 ‰ for  $\delta^{18}\text{O}$  per 100m,  $R^2$

= 0.1) and piezometer (lapse rate = -0.4 ‰  $\delta^{18}\text{O}$  per 100m,  $R^2 = 0.12$ ) when only the groundwater lying at elevation greater than 100m above msl are considered. The lapse rates obtained for groundwater are similar to that of global elevation effect (lapse rate = -0.28 ‰ for  $\delta^{18}\text{O}$  per 100m; Poage and Poage, 1998). However, these lapse rates of PRB are not significant as reflected by lower  $R^2$  values. This suggests that the groundwater in PRB is being recharged by different monsoon moisture source at different stretches or receives varying amount of monsoon rainfall input. The HYSPLIT backward trajectory confirms the same monsoon source within the season (not drawn here) throughout the PRB stretch. This suggests that the groundwater isotopic composition in PRB is controlled by monsoon rainfall input. The groundwater samples (most open wells and all piezometers) below 100m elevation are showing much lower isotopic composition though they are close to coast. This lower isotopic composition is due to the higher recharge by the winter monsoon in the lower reaches of the PRB as supported by the spatial distribution map of winter monsoon rainfall amount. Thus, it can be suggested that the groundwater at lower elevation which receives higher winter monsoon are potential recharge sites and needs to be conserved for future use.

Table 4.1: The ranges (minimum and maximum) of stable isotope ratios of oxygen and hydrogen and d-excess values of different water samples in the Palar river basin during sampling period. Note: OW: open well, PZ: piezometer, SW: stream/river water, LW: lake water and PW: pond water.

Water Type	No. of samples	(in ‰)	Minimum	Maximum	Average	Standard deviation
OW	60	$\delta^{18}\text{O}$	-6.40	-1.00	-3.78	1.15
		$\delta^2\text{H}$	-42.77	-5.17	-25.89	6.78
		d-excess	-7.35	16.22	4.33	4.49
PZ	23	$\delta^{18}\text{O}$	-5.39	-1.24	-3.81	1.29
		$\delta^2\text{H}$	-35.11	-3.19	-24.79	8.33
		d-excess	-7.52	9.55	5.66	4.04
SW	3	$\delta^{18}\text{O}$	-3.03	3.07	0.29	3.09
		$\delta^2\text{H}$	-21.52	8.75	-5.40	15.23
		d-excess	-15.77	2.75	-7.72	9.49
LW	4	$\delta^{18}\text{O}$	-0.08	3.31	1.60	1.90
		$\delta^2\text{H}$	-9.67	11.46	1.76	10.85
		d-excess	-15.01	-5.34	-11.06	4.73
PW	2	$\delta^{18}\text{O}$	0.53	3.71	2.12	2.25
		$\delta^2\text{H}$	-8.59	4.49	-2.05	9.25
		d-excess	-25.20	-12.82	-19.01	8.76

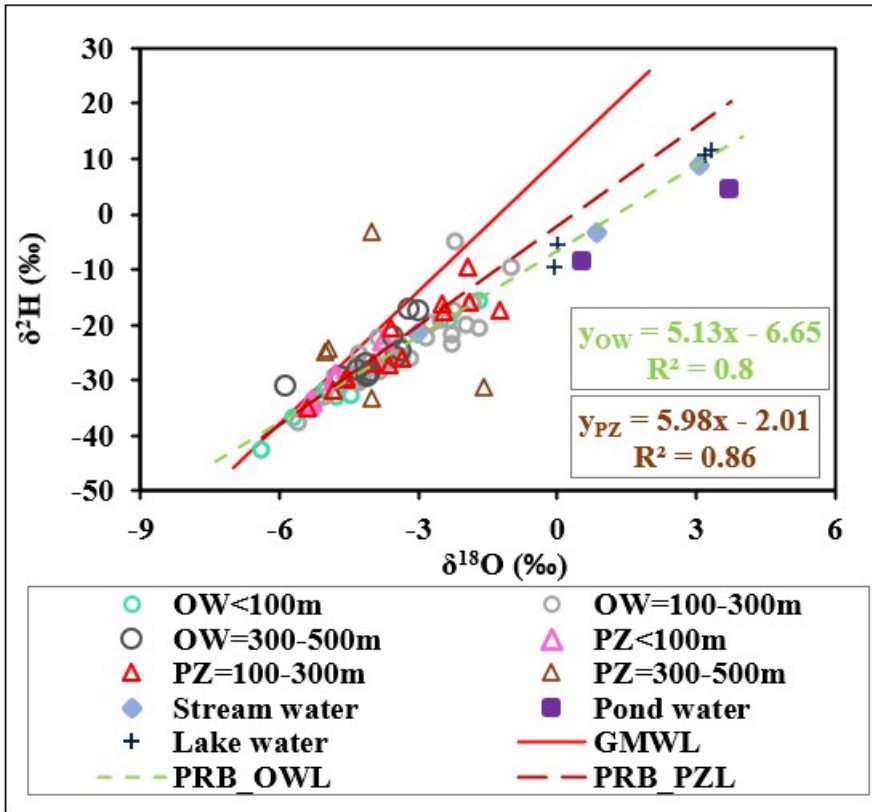


Figure 4.1: Plot of  $\delta^{18}\text{O}$  vs  $\delta^2\text{H}$  in groundwater and surface water of Palar river basin. The global meteoric water line (GMWL; Craig, 1961) is also drawn to compare the groundwater line obtained for open wells and piezometers in the studied river basin.

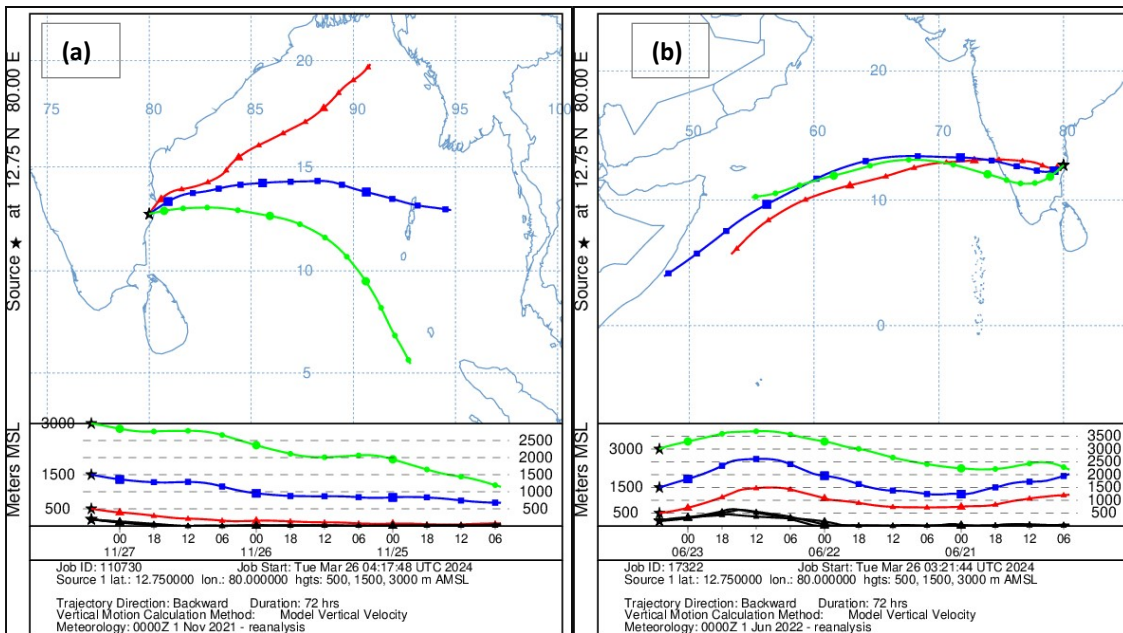


Figure 4.2: Backward trajectory of three days for the air mass over sampling location during November 2021 ((a) winter monsoon month) and June 2022 ((b) summer monsoon: also sampling month) using NOAA HYSPLIT model.

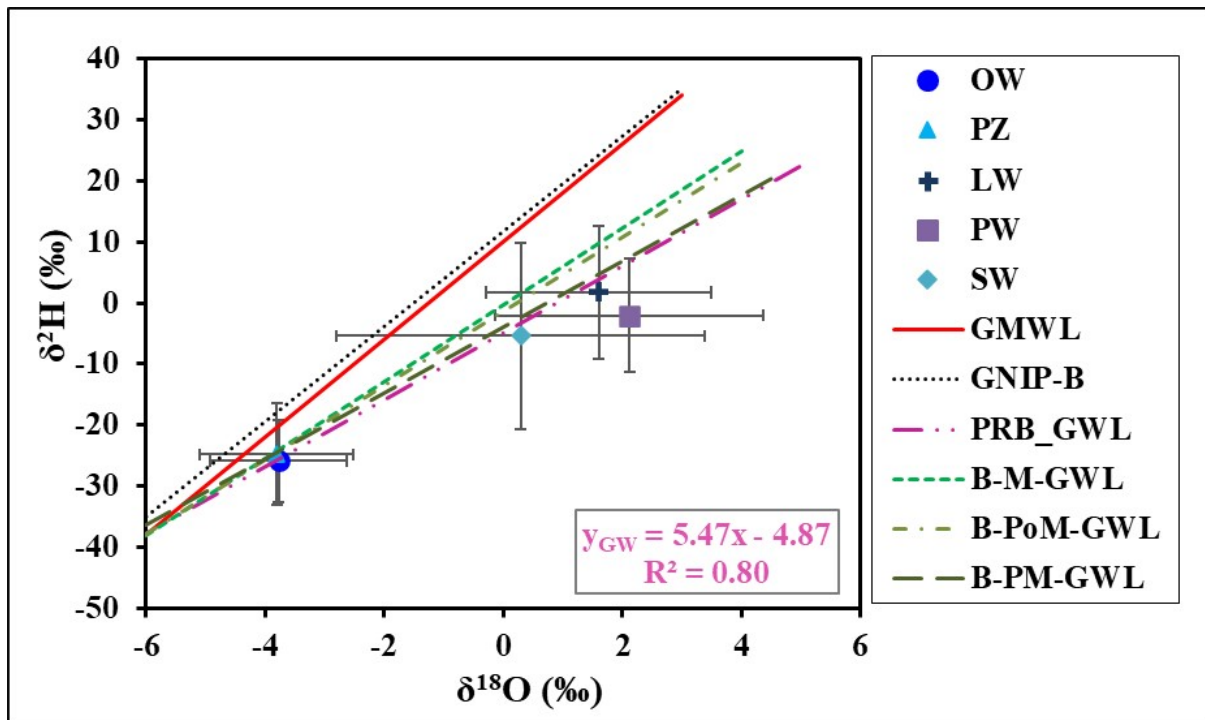


Figure 4.3: Plot showing average  $\delta^{18}\text{O}$  vs average  $\delta^2\text{H}$  in water samples of Palar river basin. The global meteoric water line (GMWL; Craig, 1961), LMWL of nearest GNIP station in Bangalore (GNIP-B; Kumar et al. 2010), and groundwater line of Bangalore (nearest available station data to river origin) obtained for different seasons (B-GWL; M - monsoon, PoM - post monsoon, PM: pre-monsoon; Majee et al. 2024) are also plotted for comparison.

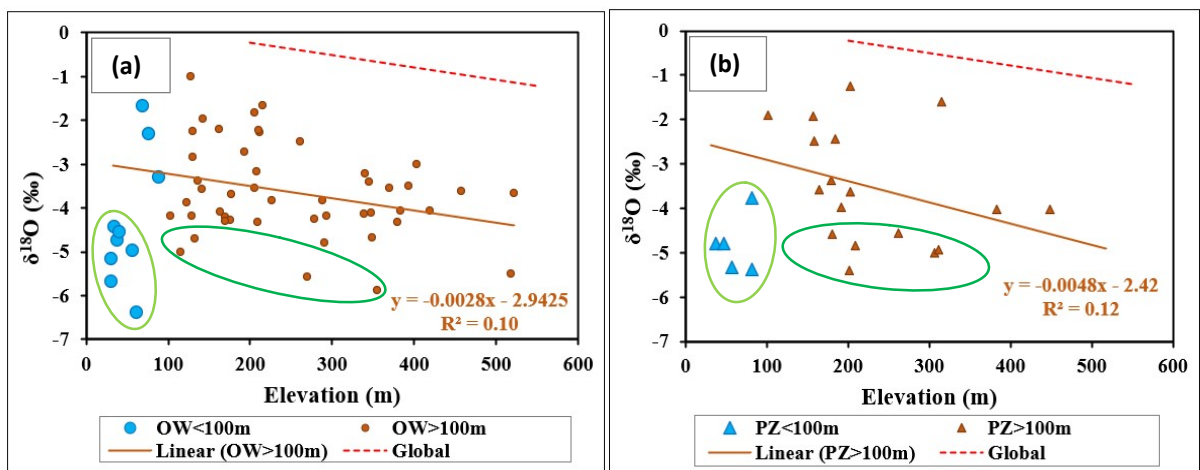


Figure 4.4: Plot of elevation (m above msl) of groundwater sampling location vs oxygen isotope ratios in (a) open well (OW) and (b) piezometers (PZ).

#### 4.8 Groundwater Recharge Zones of the Study Area

WIOA results with a groundwater recharge map is shown in Figure 4.5. The WIOA groundwater recharge map reveals that groundwater recharge is found under Excellent category in the few patches of the central and eastern side of the study area. The suitable soil, geomorphological units which is present in the portion of the study area, provides favourable condition for Excellent groundwater recharge conditions. The predominant portion of the study area covers Very Good to Good due to the presence of very good lineament and moderate drainage density condition. The groundwater recharge is found under the Moderate to poor category in the western portion of the study area due to the presence of hilly area.

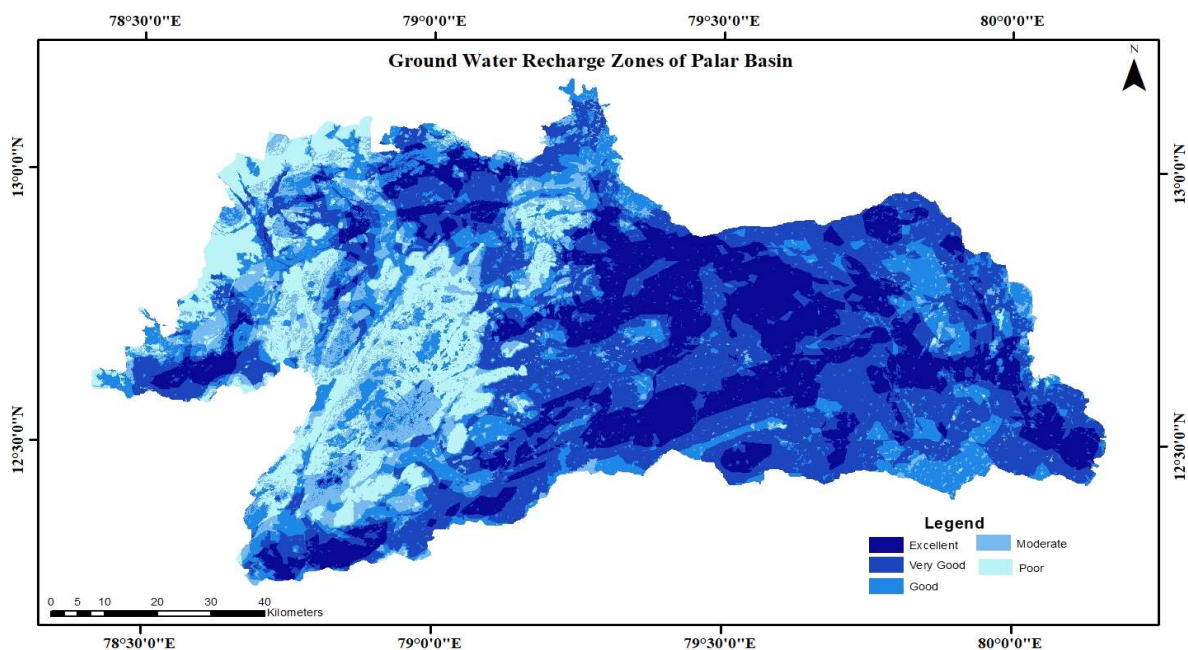


Figure 4.5. Ground Water Recharge Zones of Palar Basin

## CHAPTER – 5

### CONCLUSION

The Palar basin have a total catchment area of 10,273 sq.km within Tamilnadu. The Weighed Index Overlay Analysis (WIOA) technique implemented in this study to identify the recharge zones of Palar basin using maps of drainage density, soil, slope, geomorphology, geology, land use/cover, lineament density and ground water level fluctuations. Each parameter in the thematic map was assigned ranks from 1 to 5 based on the values obtained from analytical hierarchy process. The study area contains Geomorphologic units predominantly such as Alluvial plain, Bajada, Buried pediments, Flood plain, Inselberg, etc. The units, which are having high infiltration characteristics, are assigned rank 5. The moderate units are assigned the rank 2 to 4 and the units which have less infiltration characteristics are assigned the rank 1. The slope of the study area classified into five classes. The less to moderate slope (1% to 20%) have high recharge capabilities, hence these units assigned ranks 5 and 4. The higher slopes (> 20%) are assigned ranks 1 to 3. The LULC of the Palar basin consists of crop land (46.27%), fallow land (8.05%), deciduous forest (21.60%), forest blank (1.62%), forest plantation (1.98%), built-up area (4.64%), wasteland (9.56%) and water body (6.28%). The land use/cover units assigned ranks according to their recharge characteristics. In the study area, the lineament density, ranges from 0 to 120 km/km<sup>2</sup>. The lineament density was classified into five categories, viz., 0-10.8, 10.9-26.3, 26.4-42.3, 42.4-62.0, and 62.1–120.0 km/km<sup>2</sup>. The lineament density was relatively high in the central portion of the study area, which lies between the altitude 100 to 200 m. The high lineament density shows high recharge characteristics and provided high rank (5) value. Likewise, the parameters in the drainage density, soil and geology have also been ranked. Based on the above said analysis the recharge/discharge zones of the Palar basin have been classified as low, moderate, moderate to good, good and excellent. Further, stable isotope analysis has been carried out in the month of June 2022 and collected 90 samples from groundwater, stream water, pond/lake water. The stable isotope analysis of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  has been carried out at NIH, Roorkee laboratory. The stable isotope values of these samples reveals that the groundwater recharge takes place in the central portion of the Palar basin, which is in between the contour levels 100 to 200 m and discharges at the downstream of the basin. This is also supported by WIOA results in the Palar river basin. Hence, recharge structures such as check dam, Nalla bund, recharge shaft can be constructed in the identified zones to increase the water availability of the Palar basin.

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