केन्द्रीय भूमि जल बोर्ड

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

भारत सरकार

Central Ground Water Board

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

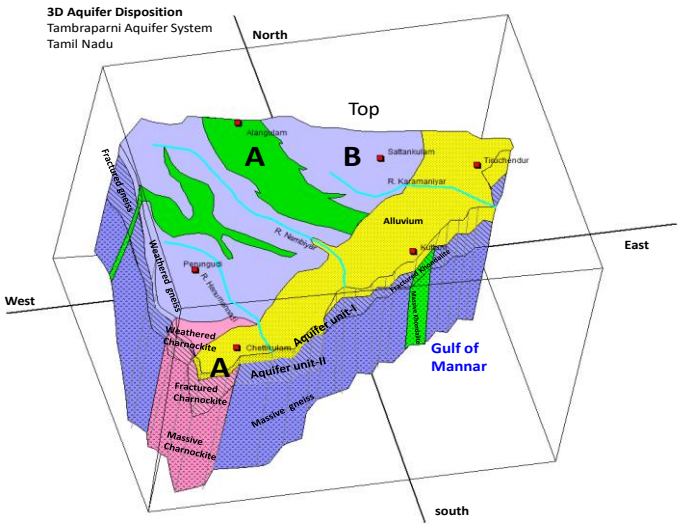
for Nambiyar Aquifer System
Tamil Nadu

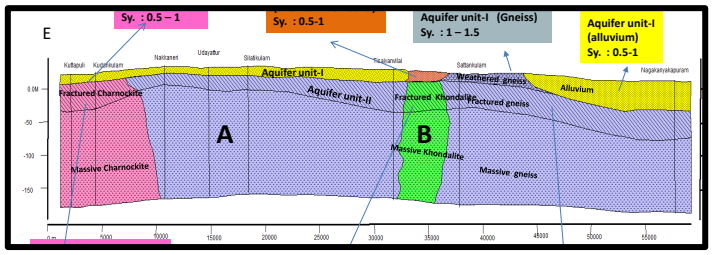
दक्षिण पूर्वी तटीय क्षेत्र, चेन्नई

South Eastern Coastal Region, Chennai

सरकारी उपयोग के लिए

REPORT ONAQUIFER MAPPING AND AQUIFER MANAGEMENT PLANFOR THE NAMBIYAR AQUIFER SYSTEM, TAMIL NADU





भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन विभाग
नदी विकास और गंगासंरक्षण
केंद्रीय भूजल बोर्ड
दक्षिण पूर्वी तटीय क्षेत्र
चेन्नई

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES
RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL GROUND WATER BOARD
SOUTH EASTERN COASTAL REGION
CHENNAI

Foreword

Groundwater is the major source of freshwater that caters the demand of ever growing domestic, agricultural and industrial sectors of the country. This renewable resource has been indiscriminately exploited in some parts of the country by several users as it is easily available and reliable. Intensive and unregulated groundwater pumping in many areas has caused rapid and widespread groundwater decline. In India out of 6607 groundwater assessment units (Blocks/ mandals/taluks/firkas etc.), 1071 units are over-exploited and 914 units are critical. These units have withdrawal of groundwater is more than the recharge (over exploited) and more 90% of recharge (Critical).

Central Ground Water Board (CGWB) has taken up largest Aquifer mapping endeavour in the world, targeting total mappable area of country 23.25 lakh sq.km with a vertical extent of 300m in soft rocks areas and 200m in hard rock areas. The extent of aquifers, their potential, resource availability, chemical quality and its sustainable management options will be addressed by National Aquifer Mapping (NAQUIM). The NAQUIM programme will also facilitate participatory management of groundwater to provide long-term sustenance for the benefit of farmers. Currently, focus is on groundwater stressed areas of nine states comprising 5.25 lakh sq.km viz. Tamil Nadu, Haryana, Punjab, Rajasthan, Gujarat, Andhra Pradesh, Telangana, Karnataka and Bundelkhand region.

South Eastern Coastal Region (SECR), CGWB, Chennai under NAQUIM has been envisaged with the Mapping of an area of 70,102 sq.km during 2012-17 (XII Five Year Plan) in Tamil Nadu and UT of Puducherry. This report deals with the Aquifer mapping studies carried out in Nambiyar aquifer system covering an area of 1882 sq.km with 1865 sq.km as mappable area. The basin comprises of water stressed Tirunelveli and Thoothukudi districts with 16 firkas. Four firkas are Over exploited and Critical firkas which are mainly dependent on groundwater (85%) for its drinking water needs. The major issues in the basin include declining groundwater levels, massive and poor yielding aquifer and groundwater quality issues in pocket. Aquifer units have been deciphered firkas-wise and regions of high yielding zone and low yielding zone have been demarcated for the different aquifers in the Nambiyar aquifer system. The area is mainly comprised of Charnokite&Khondalite group of rocks, and Gniessic group of rocks with recent sediments which form two aquifer units namely Aquifer unit-I (weathered rock) and Aquifer Unit –II (fractured/Jointed zone). In order to arrest the declining groundwater levels and increase the sustainability of wells, firka wise groundwater management plans in supply and demand side have been formulated.

I hope this report will be useful for the district administrators, water managers, stakeholders including farmers in knowing the aquifer and managing it resources effectively in the Nambiyar aquifer system.

Dr AAsokan
Regional Director

EXECUTIVE SUMMARY

Detailed hydrogeological studies were conducted in the Nambiyar Aquifer system areas wherein huge existing data pertinent to geology, geophysics, hydrology, hydrochemistry were collected, synthesized and analysed to bring out this report. This report mainly comprises the lateral and vertical extent of the aquifers with their geometry, aquifer properties of the study area which are considered to be measuring scales for groundwater availability and potentiality. Aided through these parameters a sustainable management plan has been suggested through which the groundwater needs can be fulfilled in a rational way.

The study area experiences tropical climate with 879 mm annual normal rainfall covering 1882 km^2 area in Tirunelveli and Thoothukudi. About 69% of the geographical area is under agricultural activity of which 86% is groundwater irrigation. The main crops irrigated are paddy, sugarcane, groundnut, maize, cotton, ragi and other minor crops are turmeric, vegetables and flowers.

Two main aquifers units exist in the hard rock region of the Nambiyar aquifer system constituted by 1. Weathered zone at the top followed by 2. Discrete anisotropic fractured/fissured zone at the bottom in the western and central parts of the study area. The predominant water levels are in the range of 2-10 m bgl during pre-monsoon season (May 2019) and 2-10 mbgl during post-monsoon season of January 2020. The annual extractable groundwater availability is 260 MCM and the gross groundwater extraction for all uses is 200 MCM and the stage of groundwater development is of 77% (2017).

The major issues in the region are over exploitation condition and decline in groundwater level and low sustainability, massive formation with non-availability of fracture which leads to water scarcity problem etc.

In hard rock regions aquifer systems can be conceptualized as weathered zone down to the depth of 23 m with average thickness of 12 to 18 m and fractured zone between 5 m and 197mbgl. The weathered zone is disintegrated from the bed rock (upper part–saprolite zone) and partially/semi -weathered in the lower part (soft rock zone) with transmissivity varying between 1 & 110 m^2/day and specific yield of 0.5 - 1.5%. The fractured zone is fractured gneiss or CharnockiteorKhondalitewhich occur in limited extent, associated sometimes with quartz vein. The average transmissivity of this zone varies between 1&130 m^2/day and storativity varies from 0.002 to 0.01. The fast growing urban agglomerations shares the portion of groundwater which is being used for irrigation purpose with either resultant shortage in resources for irrigation needs or creates excessive draft in groundwater potential areas while catering to both the demands. The study formulates management strategies for supply side as well as demand side. The supply side measures include construction of artificial recharge structures of 11 Check dams, 5 nala bands, 15 recharge shafts in addition to the 200 farm ponds and 44 tanks earmarked for rejuvenation with recharge shafts in all the 2 OE& 2 Critical firkas of the basin.

The estimated recharge to groundwater system through these structures will be in the order of 22 MCM. Demand side management is also recommended by change in irrigation practices from the conventional flooding to Ridge & furrow method for paddy and to drip irrigation for sugarcane and banana crops. This intervention would save 1.83 MCM of water annually. By ensuring both supply and demand side interventions the stage of groundwater development would be lowered from 117 to 82%.

The existing regulatory measures may be modified suitably for optimal utilization of groundwater as well as for sustainable development of rural agricultural based economy. To achieve this goal opinion pool has to be obtained from more user groups and valid suggestions gathered may be incorporated in the regulatory acts.

CONTRIBUTORS' PAGE

Overall Supervision and Guidance

Shri. C. Paul Prabhakar, Regional Director

Groundwater exploration
Data collection & Generation

Dr. N. Ramesh Kumar	:	Scientist –B (Hg)
Dr. S. Sakthi Murugan		Scientist –B (Hg)

Aquifer Disposition

Dr. N. Ramesh Kumar	:	Scientist –B (Hg)

Groundwater management plan

Dr. N. Ramesh Kumar	:	Scientist –B (Hg)

Map preparation

Smt. Navanetham	:	Draftsman

Scrutiny & Report Processing

Smt. Mini Chandran	Scientist-D (Hg)

Principal Author

Dr. N. Ramesh Kumar
Scientist B (Hg)

AQUIFER MAPPING AND MANAGEMENT PLAN FOR THE NAMBIYAR AQUIFER SYSTEM, TAMIL NADU

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Annexure

AQUIFER MAPPING AND MANAGEMENT PLAN FOR THE NAMBIYAR AQUIFER SYSTEM, TAMIL NADU

1.0. INTRODUCTION

National Project on Aquifer Mapping (NAQUIM) initiated by Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India with a vision to identify and map the aquifers at the micro level with their characteristics, to quantify the available groundwater resources, topropose plans appropriate to the scale of demand and institutional arrangements for participatory management in order to formulate a viable strategy for the sustainable development and management of the precious resource which is subjected to depletion and contamination due to indiscriminate development in the recent past.

Groundwater is being increasingly recognized as a dependable source of supply to meet the demands of domestic, irrigation and industrial sectors of the country. The development activities over the years have adversely affected the groundwater regime in many parts of the country. Hence, there is a need for scientific planning in development of groundwater under different hydrogeological situations and to evolve effective management practices with involvement of community for better groundwater governance.

Aquifer Mapping has been taken up in Nambiyar Aquifer systemto formulate strategies for sustainable management plan for the aquifer system in accordance with the nature of the aquifer, the stress on the groundwater resource and prevailing groundwater quality which will help in drinking water security and improved irrigation facility. It will also facilitate better management of the vulnerable areas.

1.1. Objectives:

The objectives of the aquifer mapping project in Nambiyaraquifersystemcan broadly be stated as

- To define the aquifer geometry, type of aquifers and their lateral and vertical extent
- To define 2D and 3-D dispositions of the aquifer units.
- To determine the groundwater regime scenario
- To determine the hydrogeochemical characteristics of the aquifer units
- To estimate the availability of groundwater resources in the aquifer system
- To develop asustainable groundwater management plan for the aquifer system.

1.2. Scope of the Study:

The important aspect of the aquifer mapping programme is the synthesis of the large volume of data already generated during specific studies carried out by CGWB and various Government organizations with a new data set generated that broadly describe the aquifer system. The available generated data are assembled, analysed, examined, synthesized and interpreted from available sources. These sources are predominantly non-computerized data, which is to be converted into computer based GIS data sets.

Data gaps have been identified after proper synthesis and analysis of the available data collected from different state organisations like TWAD Board, PWD, Agricultural Engineering Department, etc.In order to bridge the data gap, data generation programme has been formulated in an organised way in the study area. Exploration work has been carriedout in different segments of the regions and aquifer parameters have been estimated. Groundwater monitoring regime has been strengthened by establishing additional monitoring wells. 2D and 3D sections have been prepared twice, one prior to the

generation of data based on the data collected, assembled and synthesized through different sources and two, after generation of data at identified gaps. The aquifer geometry prepared with the denser set of data points have finer details of the subsurface disposition and are realistic.

1.3.Issues of the study area

The main issues pertaining to the Nambiyar aquifer system are as follows (Figure 1)

a. Over exploitation and Declining GW resources in Hard rock areas

b. Poor aquifers – massive & compact formations

c. High EC in isolated pockets

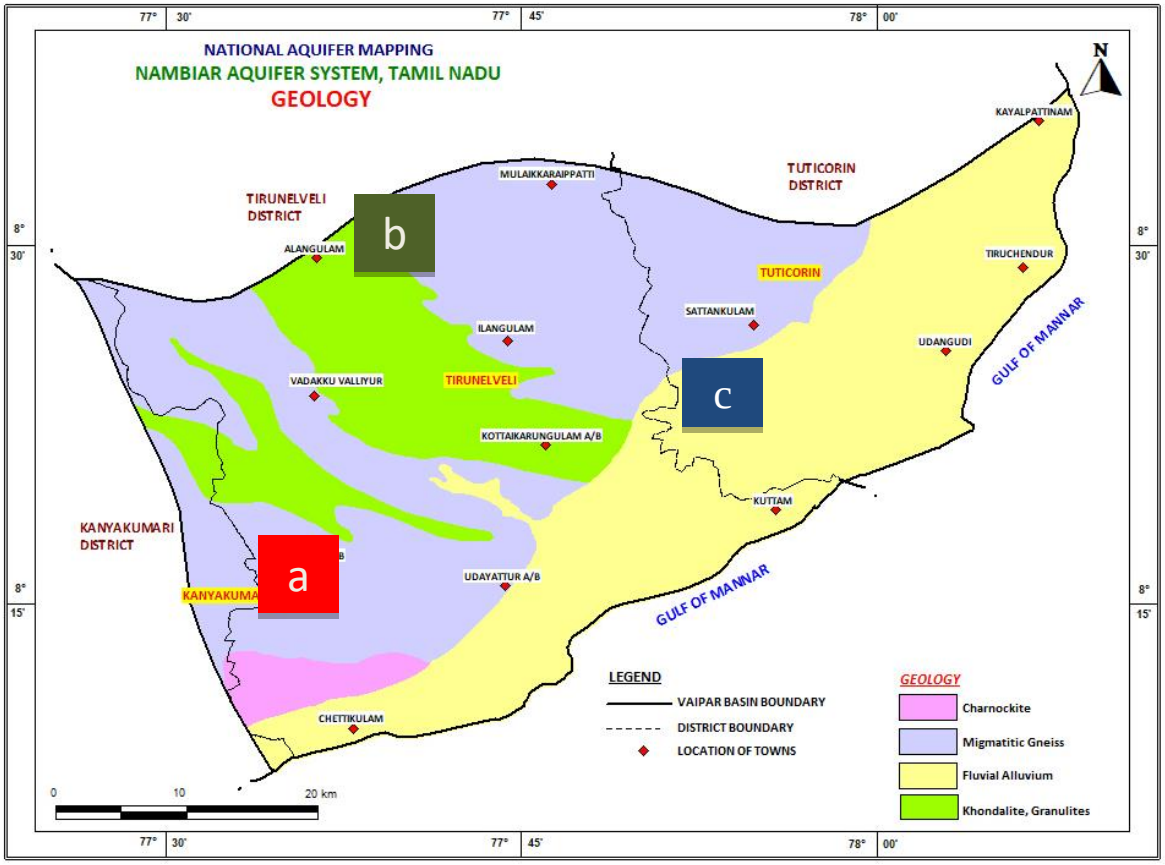


Figure.1. Issues pertaining to the Nambiyar Aquifer system

1.4. Approach & Methodology

Integrated multi-disciplinary approach involving geological, geophysical, hydrological and hydrogeological and hydrogeochemical components were taken up in 1:50000 scale to meet the objectives of study. Geological map of the study area has been generated based on the GSI maps, geophysical data have been generated through vertical electrical soundings and geoelectrical layers with different resistivity have been interpreted in corroboration with the litho stratigraphy of the observation wells and exploratory wells down to depths of 200 m bgl for hard rock. Hydrological and Hydrometeorologicaldata have been collected from the state PWD and IMD departments. Drainage, Soil and Geomorphology of the sub-basin were prepared based on the IRS –IC data, obtained from Institute of Remote Sensing, Anna University, Chennai.

Based on the data gap analysis, data generation process has been scheduled through establishing observation wells, pinpointing exploratory sites for drilling through in-house and outsourcing, collecting groundwater samples for geochemical analysisin order to study groundwater regime, geometry of the aquifer and aquifer parameters, and quality of the groundwater respectively. Groundwater recharge and draft have been computed through different methods and resources of the aquifer system estimated through groundwater balance method.

Based on the above studies management strategies have been developed both on the supply side through artificial recharge and water conservationenhancing the groundwater resources and on demand side through change in irrigation pattern for sustainable management of the groundwater resource.

1.5. Study area

The Nambiyaraquifer system covering an area of 5506 sq.km comprises of 1025 sq.km of hilly area and 4481 sq.km of mappable area between latitudes 08°27'37”N- 09°12'42”N and longitudes 77°08'57”E - 78°09'32”E. It is bounded by the Thambraparniaquifer system in the North, Kodaiyar Aquifer system in the West and the Bay of Bengal sea on the East and south. The aquifer system hoststwo districtsvizTirunelveli district and Thoothukudi district). This aquifer system covers 16 firkas out of which 4 are over exploited/critical firkas**(Table1).**The major part of the basin area comes under Tirunelvelidistrict. Nambiyar River and Hanumannadhicarries floodwater and drains Tirunelveli, whereas Karamaniyarcarries flood water and drains in Tirunelveli, Thoothukudi districts and its environs. The rivers irrigate its banks and carry only the flood discharge during the northeast monsoon period for a few days. The administrative map of the Nambiyar aquifer system is presented as **Figure 2**.

Table.1 Districts and Firkas of the NambiyarAquifer system

Sl. No	District	Area (Sq. Km.)	No. of firkas	OE and critical firkas	Safe and semi critical firkas
1	Tirunelveli	1270	11	2	9
2	Thoothukkudi	595	5	2	3
Total		4481.03	16	4	12

1.6. Data availability

During the aquifer mapping period, existingdataof CGWB i.e.exploration, depth to 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 have been collected from Tamil Nadu Water Supply and Drainage Board. Cropping pattern and soil data have been collected from Agricultural Department. Groundwater level and groundwater exploration data have been collected from Public Works Department. Thematic layers such as geology (GSI), soils, landuse&landcover,geomorphology, etc., from various State Government agencies has been collected, compiled and used in this study.

1.7. Data adequacy

Exploratory well data is available for 66 wells drilled by CGWB (30 Nos.) and State Departments (36Nos. upto the depth of 45 meters). Water level (Total 86 Nos of stations: 35 existing and 51 established during the studies) and water quality monitoring data (98 Nos of stations: 62 existing and 36 established during the studies). Long term water level is available for 35 stations and waterquality data available for 29 stations. i.e., more than ten years. Eighty four vertical electrical sounding (VES) data are available. Cropping pattern and soil data have been collected from Agricultural and Statistics Department. After plotting the available historical data on 1:50,000 scale maps, data gaps were identified and data generation process was taken up in those gap areas to generate the Aquifer map on the desired resolution of 1:50,000 scale toposheets.

1.8. Data Gap Analysis & Data Generation

Dug wells 51 Nos. have been established to monitor the first phreatic aquifer and 12 bore wells drilled down to a depth of 200 m bgl to know the aquifer characters of semi-confined aquifer system. Thirty six samples were collected from the established monitoring wellspertaining to the first phreatic aquifer and from12 Nos. of irrigation/domestic bore wells pertaining to the second semi-confined aquifer in order to assess the groundwater quality for drinking and irrigation purposes.

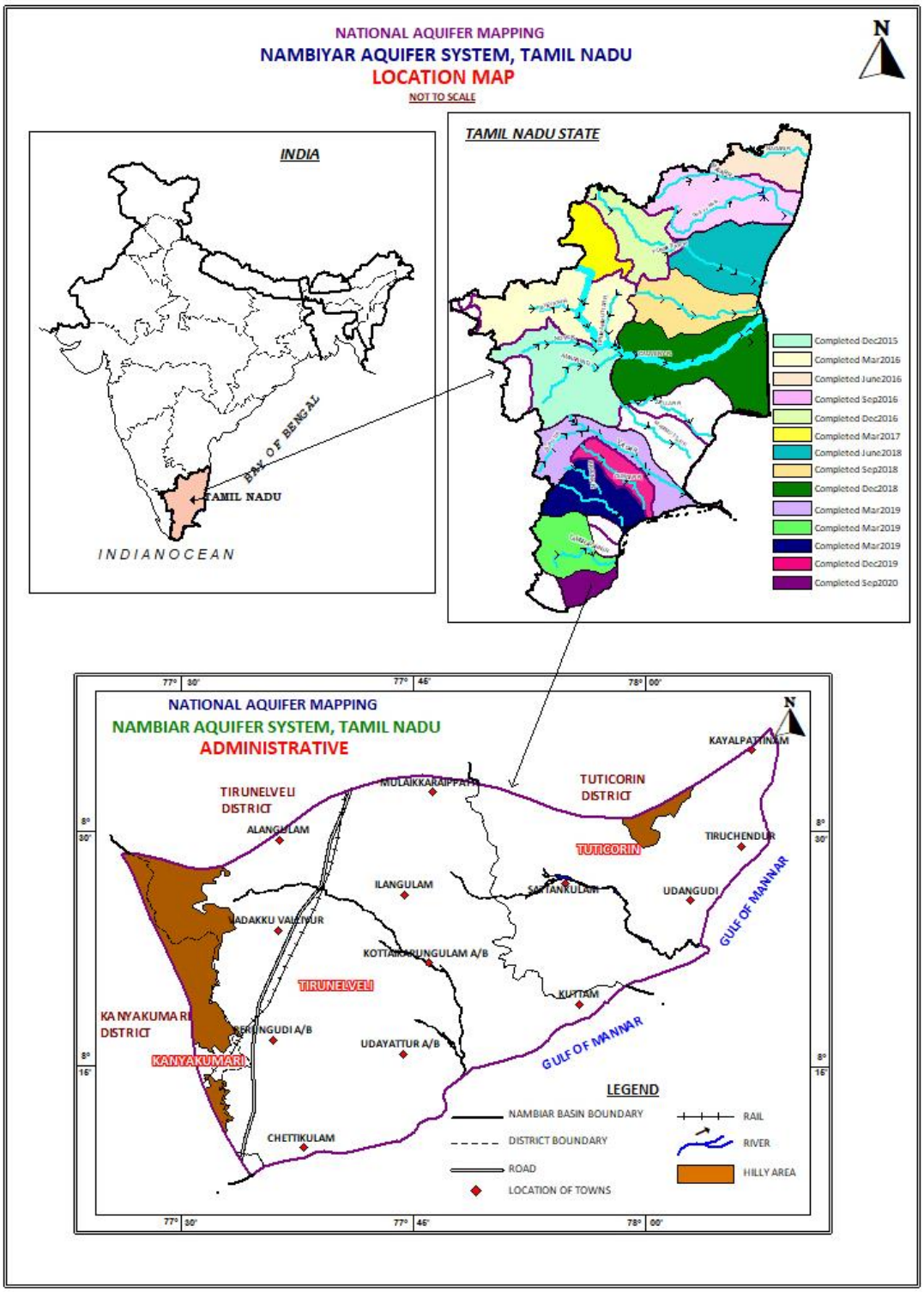


Figure 2. Administrative setup of the Nambiyar aquifer system

1.9. Climate and Rainfall

The basin area experiences semi arid to dry humid climate, being hot and dry for the greater part of the year. The period from April and May recording maximum temperature and the temperature goes up to 43 º C during May month. Average monthly maximum temperature Maximum is 33.16^0 C and Average monthly minimum temperature 24.54^0 C (PWD, Tamilnadu).

Maximum evaporation takes place during the month of August. Average pan evaporation in 180.05 mm/month. Averagerelative humidity in 72.17 %. Average wind velocity in 4.59 km/hour. Occasional thundershowers during April and May bring welcome relief.The afternoon sea breezes also bring some relief in the coastal parts. With the onset of the southwest monsoon by the end of May or beginning of June, there is some drop in temperature.

There are 16Raingauge stations located in the study area, which are maintained by the state agnesis. The average annual rainfall of the regions is 879 mm with 35 to 48 rainy days. The normal rainfall of the district is 814 mm (IMD normals-1970-2000). Rains are received during both southwest (June to September) and northeast (October to December) monsoon seasons. There is a considerable spatial variability in the distribution of rainfall, which shows a gradual decrease towards east. Rainfall is the major source of recharge for the area. Northwest monsoon always exceeds the southwest monsoon. The firkas located in the western side of the study area always experiences more rainfall than theircounterpart on the eastern side.

1.10. Physiography and Drainage

The term physiography deals with the actual existing in-situ conditions of the land, depending upon the structures, formational changes and available natural agencies such as hydrogiene and epigiene agents. Physiographically, the Nambiyar aquifer system region comprises of three sub-river basins i.eNambiyar, Hanumannadhi and Karamaniyar**(Figure.3).**

Nambiyar and its streams originate from the eastern slopes of the western ghats near NalikkalMottai at an altitude of about 1060m. Nambiyar has three main tributaries of streams which are seasonal viz. Tamaraiar, Kombaiar and Kodumudiar. Nambiyarcarries floodwater and drains Tirunelveli district in the middle part of the aquifer system and drains into the Gulf of mannar after traversing a total distance of 59 kms. There are around 9 numbers of anicuts viz. Mailannani, Dalavalpuram, Rajakkamangalam, Malapudur, Kananallur, Vijayan, Kovankulam, Islapuram&Pulimangalam.

Karamaniyar which flows in the eastern part of the aquifer system has a number of small seasonal streams and gets its flows mainly from the surpluses of Vijayanarayanan tank and monsoon rainfall runoff. The Karamaniyar river flows into the Gulf of Mannar near Manapadu village in Tirunelveli district. The Karamaniyar river feeds about 75 tanks and covering ayacut area of 2976 hectares.

Hanumanadhi originates in the eastern slopes of the western ghats at an altitude of 1100m in the Mahendragiri hill region. Hanumanadhi has number of small streams which feeds few tanks, they join with Hanumanadhi river at different confluence points. It flows in the hill ranges and pediment for a distance of about 32km and flows into the Gulf of Mannar. Totally 11 small anicuts found across the Hanumandhi viz. Sivanpilli anicut, Senthilkathayan anicut, Thandayarkulam anicut, Sanjetti anicut, Perungudi anicut, Vadakkankulam anicut,

Adankarkulam anicut, Sakkilianparaianicut,Kanjaneri anicut, Alaganeri Anicut and Koliankulam.

The maximum and minimum elevations of the Nambiyar aquifer system are from 1657 m amsl in the West to sea level in the East. The nominal topography is generally sloping towards the Southeast. The general trend of dipping ranges from northwest to southeast. The Hydraulic gradient and the flow lines of ground and surface water are towards east, the Gulf of Mannar.

There area number of system and non-system rain fed tanks in the study area. These water bodies were very specifically used for catering to the drinking water needs of the area and few are occasionally used for irrigationpurposes.

1.11. 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. Three major geomorphic units can be demarcated viz. hills & Plateaus, Piedmont zone and plains with few units of urban areas and coastal landforms. The eastern part adjoining to beach and shores covers coastal geomorphic units. The inland topographical units are being described as the piedmont geomorphology.

Nearly 59 % of the region is covered by Piedmont zone and is represented in **Figure.4**. These are terrestrial erosional surface inclined at a low angle and lacking significant relief. The piedmont regions are characterized by the occurrence of boulders, cobbles, pebbles, gravels, sand, silt and clay of varying lithology. Formed by coalescence of several alluvial fans by streams covering large area at the foothills, with gentle slopes, in humid to sub humid in regions (upper humid to sub humid regions).

The Hills&Platueauscover an area of about 8%. These structure hills cover the western part of the Aquifer system with the maxium elevation of 1657 m above mean sea level.

About 33 % of the region is covered by plains. These plains are the inland topography where the terrain sediment such as laterite, limestoneand other calcareous sedimentary have been leached and washed away by erosion. When these plains are weighed against its potential for groundwaterthey fare poor owing to its low Groundwater storage capacity. The surface of these formations are showing a honeycomb structure and the water level are medium to high from the top surface. These were located in the eastern part of the aquifer system.

Plain area is occupied by river alluvium. In these areas the thickness of the alluvial sand varies from 1 to 29 m. **Figure 5** illustrates the level I classification of geomorphological features of the Nambiyaraquifer 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 groundwater presence. The step like projection bordering the sandy terrain and the shoreline are called as beach terraces. These terraces are undulated and according to the forces of the tide and their deposition. These terraces were having a very low groundwater gradient that too towards the sea as they are slopping towards them.Teri sand deposit form dune complexes as a coastal landscape of the aquifer system in few pockets. These dunes were created by the action of winds.

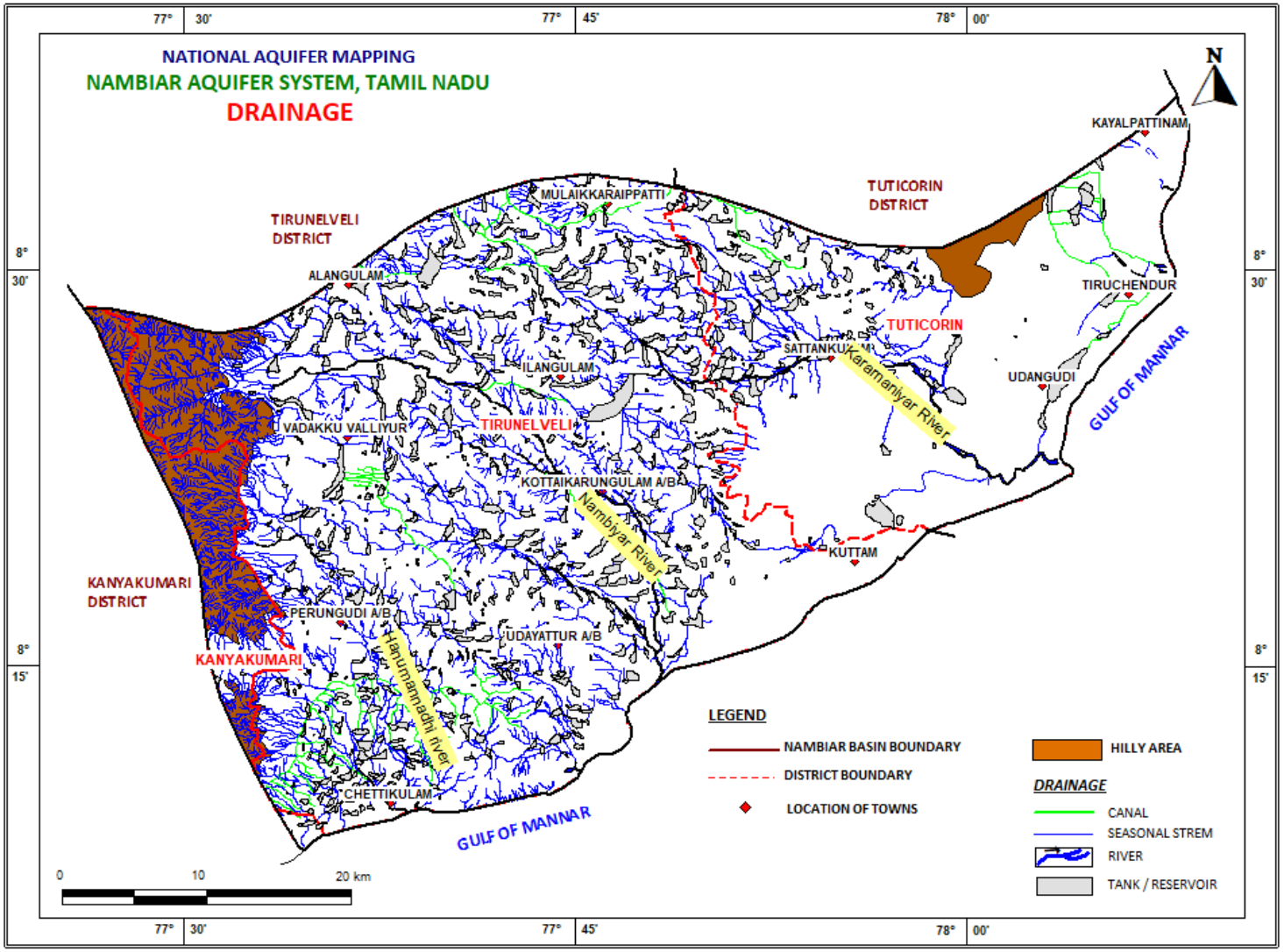


Figure3. Drainage of the Nambiyar aquifer system

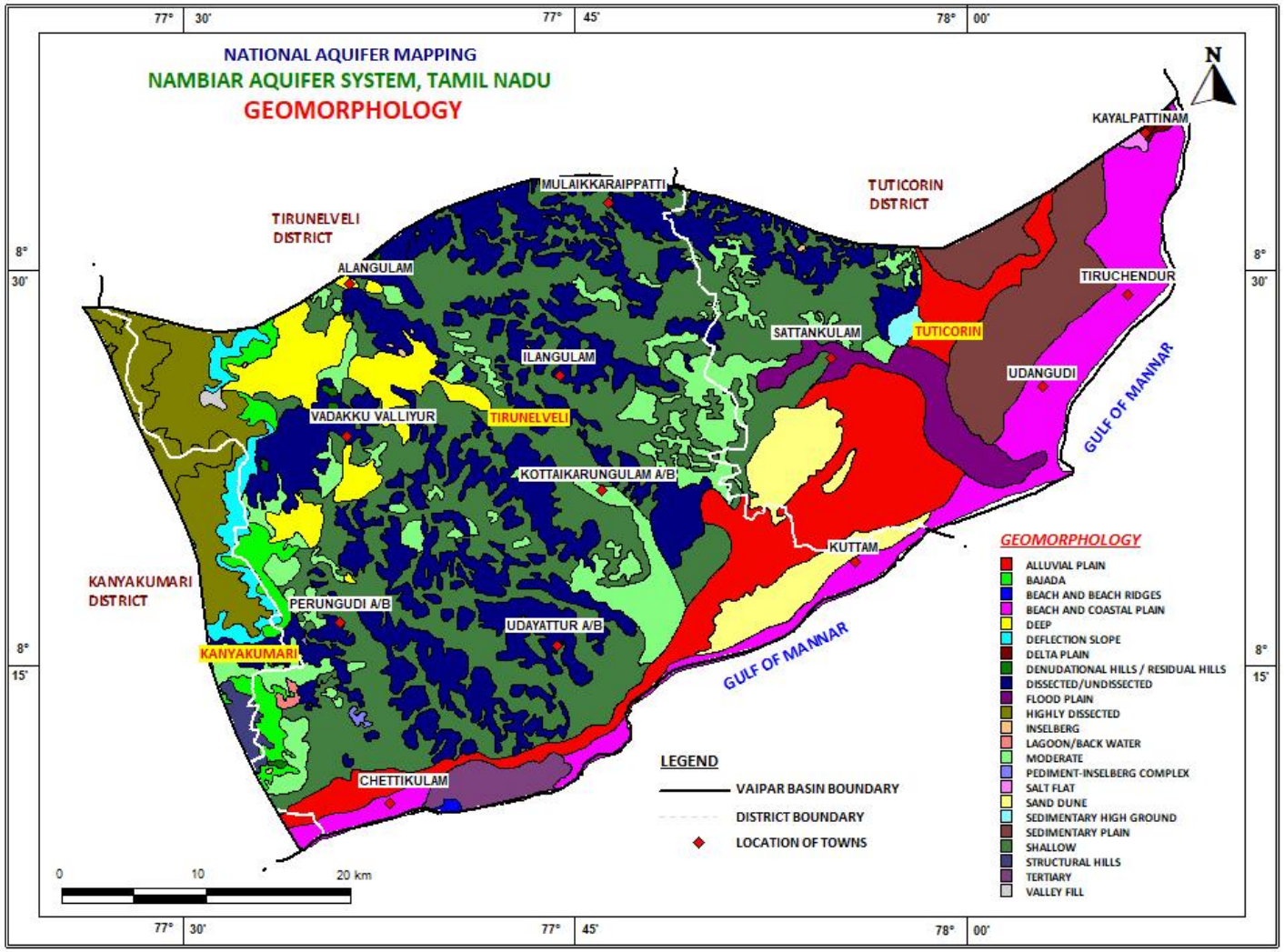


Figure 4. Geomorphology of Nambiyar Aquifer System

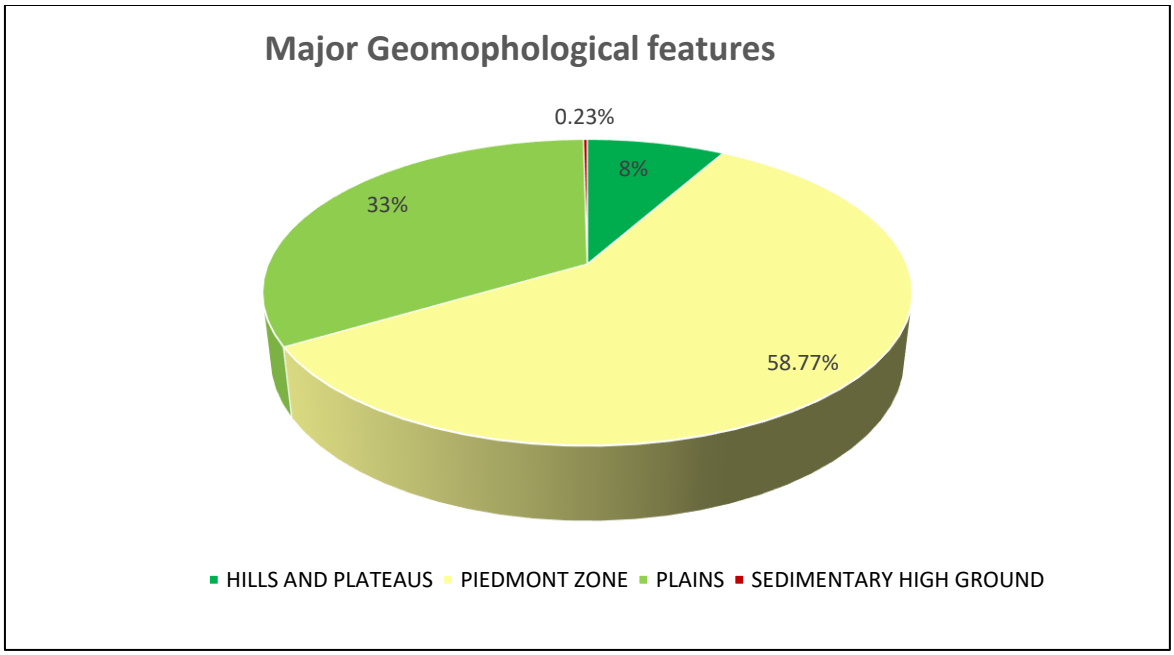


Figure 5. Level I classification of geomorphology of the Nambiyaraquifer system.

1.12. Landuse and Land cover

Agricultural land occupies nearly 1305 sq.km i.e., 69% of the Nambiyar aquifer system and spread throughout the study area. Deciduous forest occupies nearly 176 sq.km of thearea taking the green area to 9% **(Figure 6&7).** Water bodies, Waste land and built up/urban area occupies 8%, 9% and 5 % respectively.

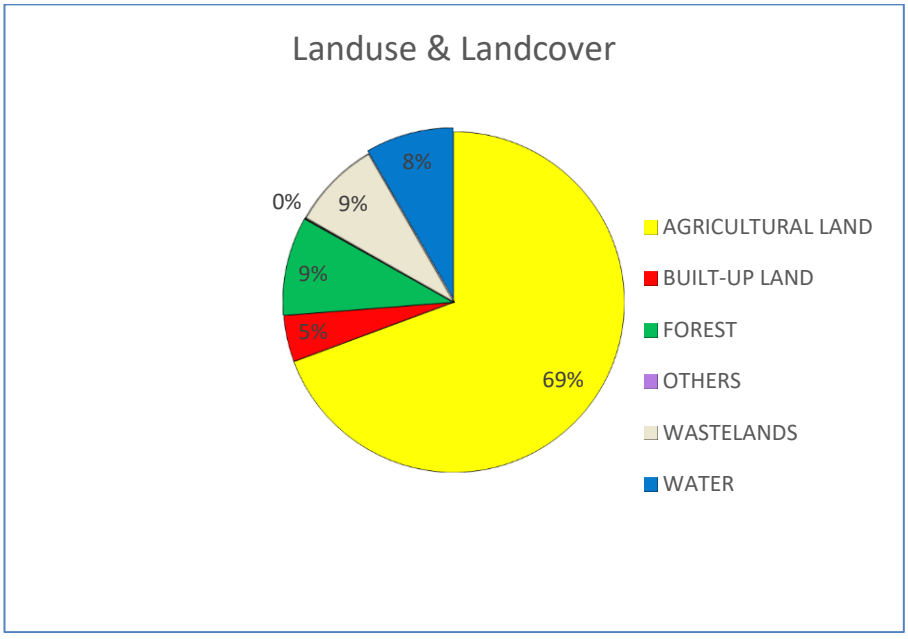


Figure. 6. Level 1 Landuse/Land analysis diagram of the Nambiyar aquifer system

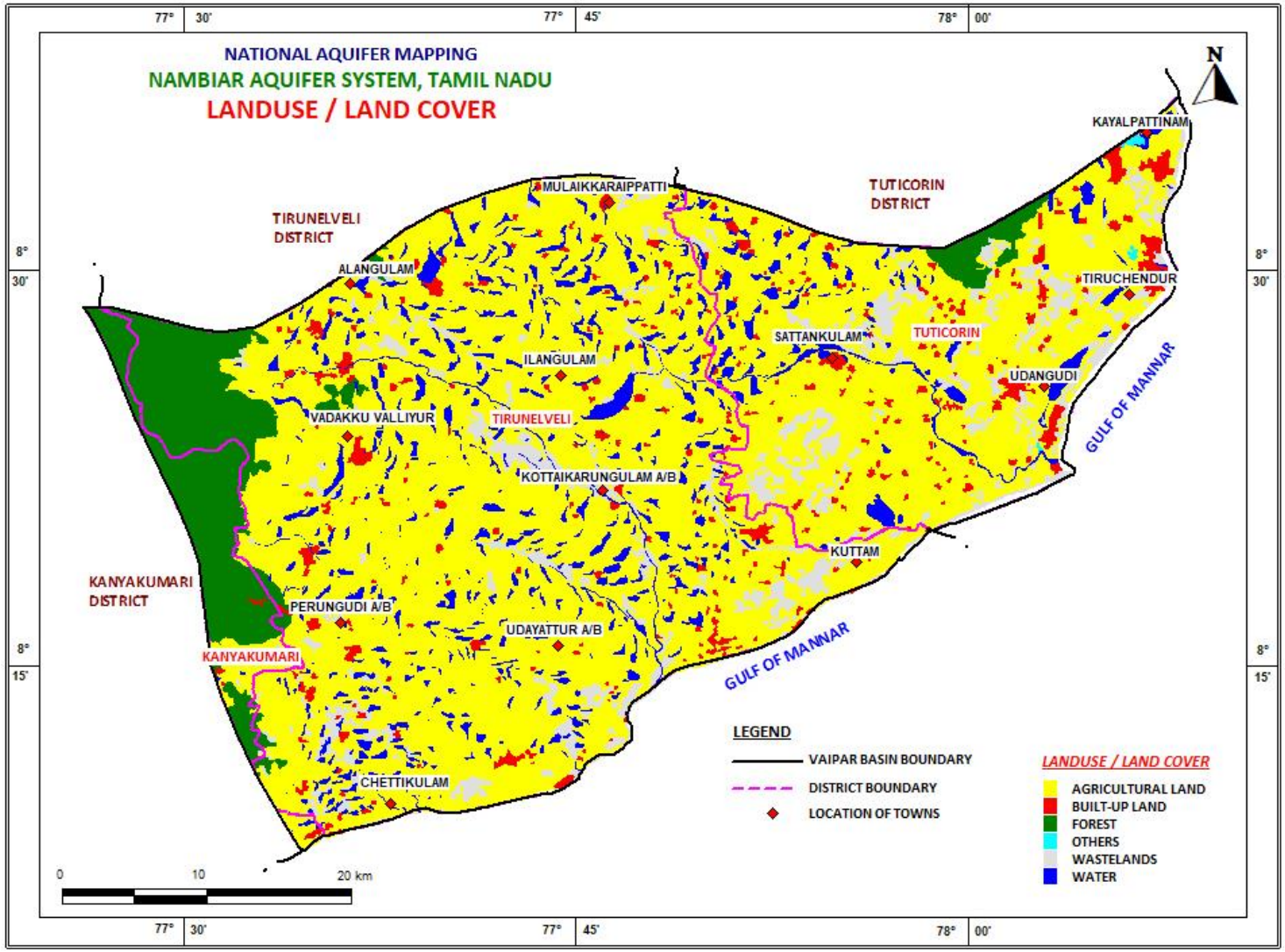


Figure 7. Level-3 Landuse/Land cover of the Nambiyar aquifer system

1.13. Soils

Soils play a major role in hydrologic control of the infiltrating water. Soils are generally classified by taking their color, texture, fertilities and chemical combinations includes salts, minerals and the solution effect over them. The major soil types in the study area are inceptisols,alfisols, vertisols,entisolsand forest soils **(Figure.8).**

Entisols are alluvial soils comprising sand and sandy materials occurring along the beaches, at the confluence of rivers and by the side of the rivers & channels. Because of their permeability, these soils while being good storehouses of groundwater are not fit for paddy cultivation. Inceptisols 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 northern and central parts of the area. The Inceptisols are suitable for agricultural and hold moderate groundwater reserves. Vertisols are clayey soil with high specific water retention capacity but poor in supporting agriculture. The rate of infiltration 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 occur in the study area.

1.14.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 maximum and minimum elevations of the Nambiyar aquifer system are from 1657 m amsl in the West to sea level in the East. The nominal topography is generally sloping towards the Southeast. The general trend of dipping follows a Northwest-Southeastdirection. The Hydraulic gradient and the flow lines of ground and surface water are towardsthe east, the sea.

1.15. Agriculture

Agriculture is the main stay of the rural population in the entire study area. The total irrigated area of the Nambiyar aquifer system through gound water is20300 Ha. which includes paddy and nonpaddy. Intensive crops irrigated are Paddy, sugarcane and banana. Less water intensive crops irrigated are maize, Cholam, groundnut and chilly. The other crops include cotton, ragi, turmeric, flowers, vegetables etc.

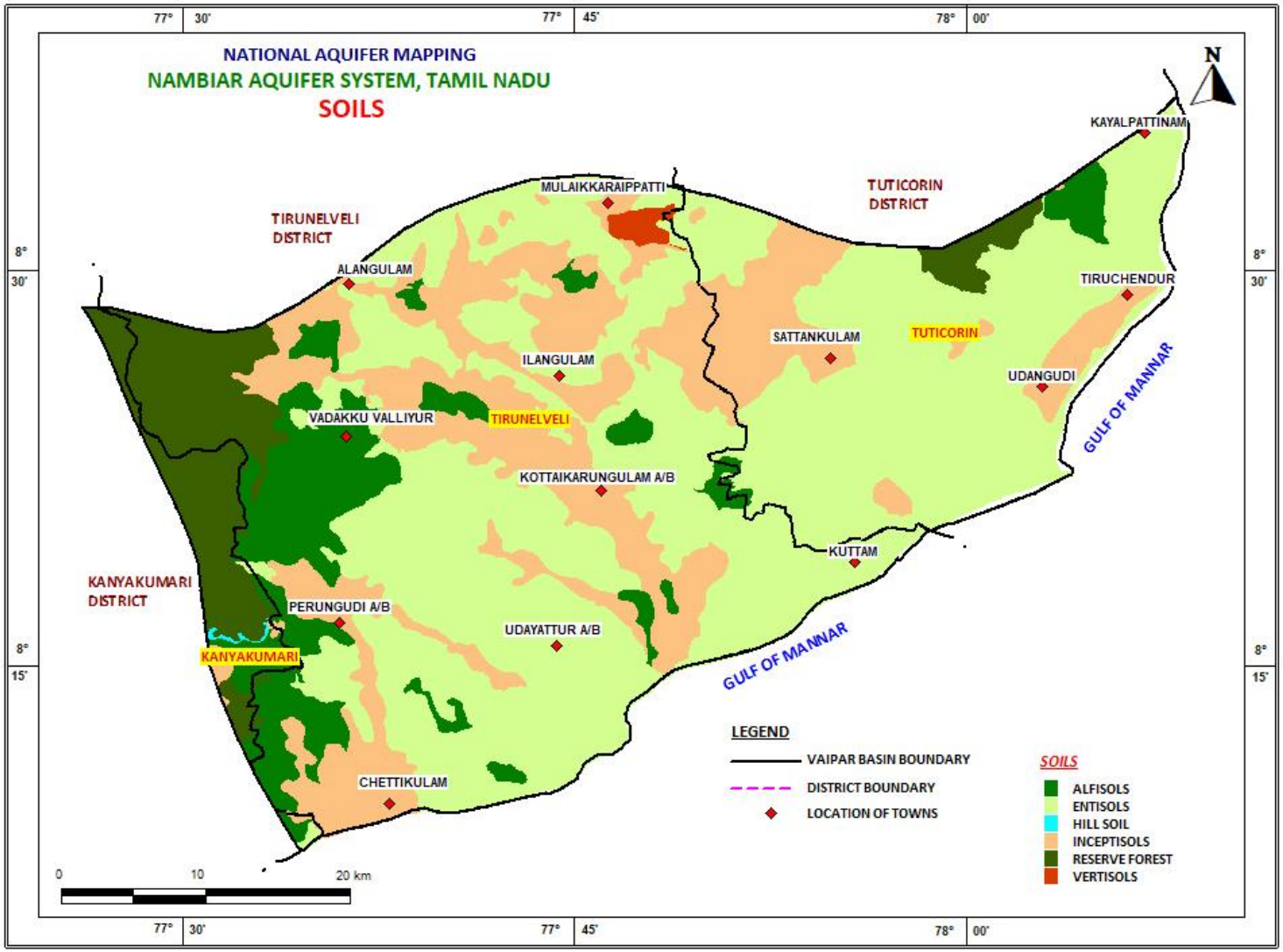


Figure8: Soils of Nambiyar aquifer system

1.16 Geology

Geologically, the Nambiyar aquifer system comprises ofcrystalline rocks of Archaean age consisting of Khondalite, Charnockites, gneisses, basic and acidintrusives groups. Khondalite, Charnockites and Gneiss form the major rock types and constitute the residual hills aroundnorth western, western and central and eastern parts of the study area. A layer of fluvial/coastal alluvium occupies the eastern part of the study area **(Figure 9).** Geologic succession of the Nambiyar aquifer System is presented in **Table2.**

Table 2. Geological succession of the Nambiyar Aquifer System

Period	Age	Lithology
Quaternary	**Holocene to Recent**	Soils, River alluvium, Kankar, Tuffaceours limestone, Teri sands laterite & Coastal sand
Archaean	**Acid intrusives**	Pegmatites, Quartz veins, pink
		Granites grey granites, leucogranites
	Basic intrusives	Basic dykes - dolerites
	Migmatite complex	Garnetiferous-quartzo-feldspathic gneisses, hornblende biotite gneiss.
	Charnockite group	Charnockites, pyroxene granulites,
	Khondalite group	Crystalline limestone, CalcGranulites, garnetiferousbiotite-
		Sillimanite graphite-gneiss, granulites, quartzites

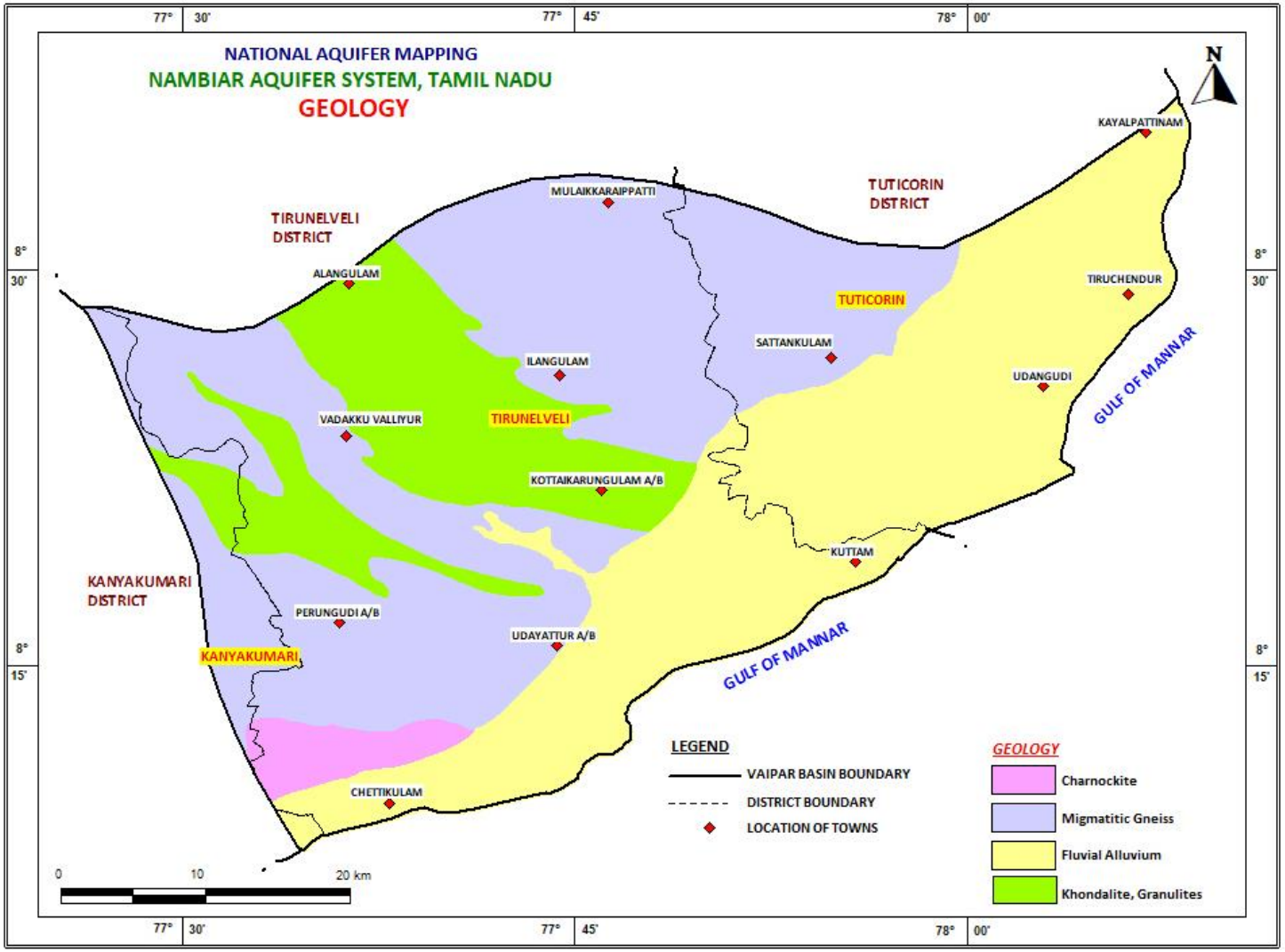


Figure 9. Geological map of the NambiyarAquifer system

1.16.1. Precambrian Rocks

Crystalline rocks of the area is mainly represented by Khondalite, Charnockites and gneisses groups. Acid intrusive and basic dykes are observed in several locations of the study area.

1.16.1.1 Khondalite group

Khondalite group of rocks include garnetiferousbiotite gneiss and granulites with or without graphite and sillimanite, calc-granulite, quartz and Crystalline limestones. Garnetiferousbiotite gneiss and granulite with graphite or sillimanite or both occurring together are seen in the southwestern part of the Nambiyar aquifer system. Isolated occurrence of garnetiferous graphite gneiss and granulite with or without sillimanite occurs at places.Also bands of garnetiferous graphite gneiss occur within the Charnockites are noticed in the area. These rocks are generally medium to coarse grained, bluish white to light brown in colour and contain quartz, feldspar, garnet and sillimanite with varying amounts of graphite. The rocks are well foliated and at places, massive and granulitic and contains small clusters of sillimanite.

Calc- granulite occurs sporadically in garnetiferoussillimanite graphite gneiss. A few narrow bands of calc-granulite are seen in association with charnockite and garnetiferousbiotite gneiss. The bands vary in length from 5 to 15 m with widths varying from 1 to 5m.

The calc-granulites are generally greenish grey in colour, fine to medium grained and contain chiefly pyroxene and feldspar. The calc-granulite occurring near Sanganeri and Kudankulam is medium grained, greyish and contains graphite flakes.

Crystalline limestones occur along with calc-granulites and garnetiferousgranulites near Sanganeri. It is white and exclusively composed of calcite at places. It occurs as small bands. The limestone bands near Thalaiyuttu consists of coarse-grained calcite rich rocks of varied colours. A number of narrow bands of quartzite are seen in different parts of the district. They are commonly associated with charnockite and occasionally with gametiferousbiotite-gneiss and pinkish granitoid.

1.16.1.2 Charnockite Group

The Charnockite group comprises pyroxene granulites and charnockites. Narrow bands and lenses of pyroxene granulites occur inter-banded with the charnockites, khondalites and garnetiferousquartzo-feldspathic granulite. The bands and lenses of pyroxene granulite are parallel to the foliation of the rock. Pyroxene granulite band truncate against charnockite at places. These rocks are dark grey in colour, fine to medium grained and contains chiefly pyroxenes and feldspar and in many places contain large flakes of biotite. These rocks exhibits spheroidal weathering at places.

Charnockites are the predominant rock unit in the hill ranges of the district. Isolated low mounds of charnockites are also seen in the plains. Charnockites are generally massive, medium to coarse grained, bluish to greenish in colour and acid to intermediate in composition. Gneissic charnockites occur in many places with considerable amount of biotite. It is composed of bluish quartz, greyish feldspar and pyroxenes. In a few places, it contains reddish and pinkish garnet and also graphite. Pegmatoidalcharnockite occurs as irregular patches within medium to coarse-grained charnockite. Foliations are very distinct on weathered charnockites and concentration of biotite and garnet is seen along foliation planes in Kudankulam area. Charnockite is also associated with garnetiferousquartzofeldspathicgranulite

and gneiss. Charnockite contains bands of quarzo-felspathic material imparting it a banded and gneissic appearance. The garnetiferouscharnockite retrogrades to garnetiferousbiotite-gneiss at places.

1.16.1.3 Migmatite complex

The Khondalite and charnockite groups of rocks appear to have undergone varying degree of migmatisation giving rise to a greyish migmatisedcharnockite, garnetiferousbiotite-gneiss and whitish garnetiferous granulite, each having a gradational contact with the other as seen at several places especially in the area NE of Tenkasi. It also occurs as low mounds and low ridges and grades into garnetiferousbiotite gneiss. The rock is medium to coarse grained, more leucocratic than charnockite and contains chiefly quartzand feldspar with varying amounts of biotite and a little ferro-magnesium minerals. Pinkish garnet and blue cordierites also occur at places. Garnetiferousbiotite-gneiss occupies larger part of the plains in the district. It is greyish white in colour, fine to medium grained and contains quartz, feldspar, biotite and pink garnet. This rock is also know as leptynite and is believed to be the migmatised product of Khondalites

1.16.1.4 Basic Intrusives

Basic intrusives are seen as small dykes. Fine grained basalt and medium grained dolerite dykes occur in south/southeast of Kudankulam observatory. The dykes have widths varying from less than a metre to 25 m and vary in length from 100 to 300 m. Most of these dykes cut across the foliation of the country rock. The dykes are grey in colour, hard and massive and show spheroidal weathering. Basic dykes are seen in a number of wells situated in the khondalitic and charnockitic country in the southern part of the district. They are dark grey to black and fine grained to porphyritic containing phenocrysts of pyroxenes and feldspar. Dolerite dykes are very few in this district. The dyke near Maruduappapuram is dark grey to black in colour, fine grained and composed chiefly of pyroxenes and plagioclase.

1.16.1.5 Acidic Intrusives

A number of prominent conformable bands of granitoids of different types are seen in several places. Pinkish granitoidleucogranite and greyish granitoid are common. Veins of pegmatite intrusion are seen in all the rock types, varying in thickness from a few centimetre to 1.5 m. Few Quartz veins trending N 20° W, NNW-SSE and N-S directions are also seen. Leucogranite of different dimensions are seen in northern part of the district, generally occurring parallel to the regional trend of foliation. Greyish granitoid rocks occur in a few places in close association with charnockite. Mappable bands of pinkish granitoid rocks are seen in the district associated with charnockite and garnetiferousbiotite gneiss. They occur parallel to the regional foliation and occupy low mounds and ridges in several places in the plain country e.g., north of Senkottai and around Tenkasi. The width of granitoid rocks ranges from 5 to 15 m and lengths vary from 1 m to 3 km. Granitoids occur as linear bodies conformable with the country rock. The grey granitoid rocks have a gradational contact with associated country rock, whereas the white and pinkish types have relatively sharp contacts.

1.16.1.6 Laterites

Isolated cappings of laterite over gneisses, granulites and charnockites are seen in many parts of the aquifer system. It is generally reddish to greyish red in colour, cavernous and Oolitic at places. The thickness of the laterite varies from a few centimetres to about 5 metres. Well exposed patches are noticed along Radhapuram-Edakkadu, VijayaNarayanam-Kumarapuram, Ittamoli, Nanguneri and Uramozhi areas.

1.16.1.7 Kankar

The occurrence of kankar and tuffaceouslimestones are very common in the district. They occur generally on the river courses and tanks. Where, there is a large flow and seepage of water during the rainy seasons. These exposures are seen over a wide area as thick and massive beds of sheet tufa resulting from the deposition of lime leached out from the underlying gneisses and charnockites and the segregation of the calcareous matter brought down by the following water. It is generally whitish, friable but hard and massive at places and shows nodular and pisolittic structures.

1.16.1.8 Teri sands

Teri sands occur north of Tisaiyanvilai (Ittamali Teri) and Northeast of Sattankulam (Kudiramoli Teri) with a considerable thickness ranging from 20 to 35 m. These are reddish in colour and medium to coarse grained sand deposit. It directly overlie the basement sandstone formation at few places and in the near coastal dunes it rest on discrete calcrete horizon. These coastal red dune sands have been reported to be a valuable source of heavy miners such as ilmenite, rutile, zircon, monazite and sillimanite.

2.0 DATA COLLECTION AND GENERATION

Periodical data pertaining to groundwater levels, quality, pumping tests and slug 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 after evaluation of data gap analysis.

2.1. Hydrogeological data

The periodical monitoring of groundwater level reflects the groundwater recharge and discharge (natural and manmade) occurring in the aquifer systems. It also reveals the interaction between surface and sub-surface water systems. In Nambiyar Aquifer system area, 33 Nos. of groundwater monitoring wells (which included 12 CGWB monitoring wells&11 State department wells) and 12 piezometers of CGWB are monitored periodically. The locations of monitoring wells are presented as **Figure 10.** In addition to this during the studies about 51 numbers of dugwells are established for monitoring of pre and post monsoon water levels.

2.2. Hydrochemical data:

The groundwater quality of the NambiyarAquiferSystem was studied by analysing available water quality data i.e CGWB monitoring open wells 36 numbers and State government monitoring wells 33 numbers. Long term record was available only for 23 numbers of open wells. The sample locations in the Nambiyar aquifer system is presented in **Figure 11**.

2.3. Geophysical data

The geophysical survey was conducted in the study area consisting of Vertical Electrical Soundings (VES) by employing Schlumberger configuration with maximum half current electrode separation of 300m. The objective of the study is to decipher the sub surface conditions such as weathered and fractured layer resistivities, thicknesses and massive formations up to the depth of 200 m bgl. A total number of 84 VES were carried out and geo

electric layers inferred through interpretation of the results obtained. The locations of the VES are presented in **Figure 12.**

2.4 Groundwater Exploration data

Data of 66 Nos. of exploratory wells were drilled in the Nambiyar aquifer system (30 Nos. CGWB and 36 Nos. State department wells) prior to National Aquifer Mapping project was compiled and analysed (**Figure 13**). These wells were plotted on 1:50,000 scale topographical map and as per the NAQUIM guidelines for the hard rock& soft rocks, data requirements were identified on the plotted topographical map. Based on the data requirements, 12 Nos. of exploratory wells have been recommended for drilling through outsourcing activity as part of the data generation. The data such as lithology, fracture depth, yield, water level, aquifer properties were generated and utilised to depict the prevailing aquifer systems of the basin **(Annexure-1).**Similarly wells drilled by state department, 36 Nos. wells drilled upto to the depth of 45 m bgl was used for deciphering the first aquifer.

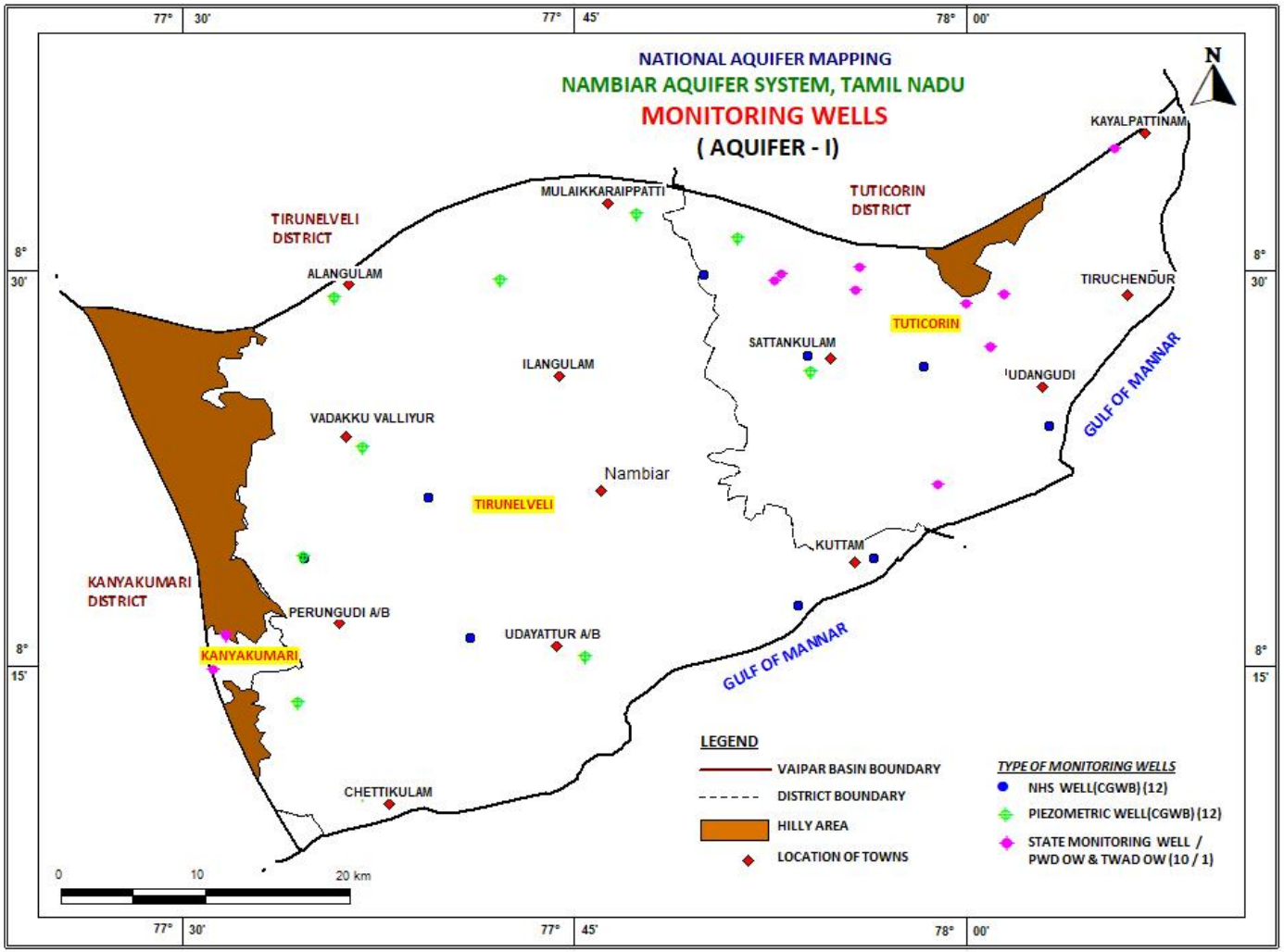


Figure 10. The locations of monitoring wells of the Nambiyar aquifer system.

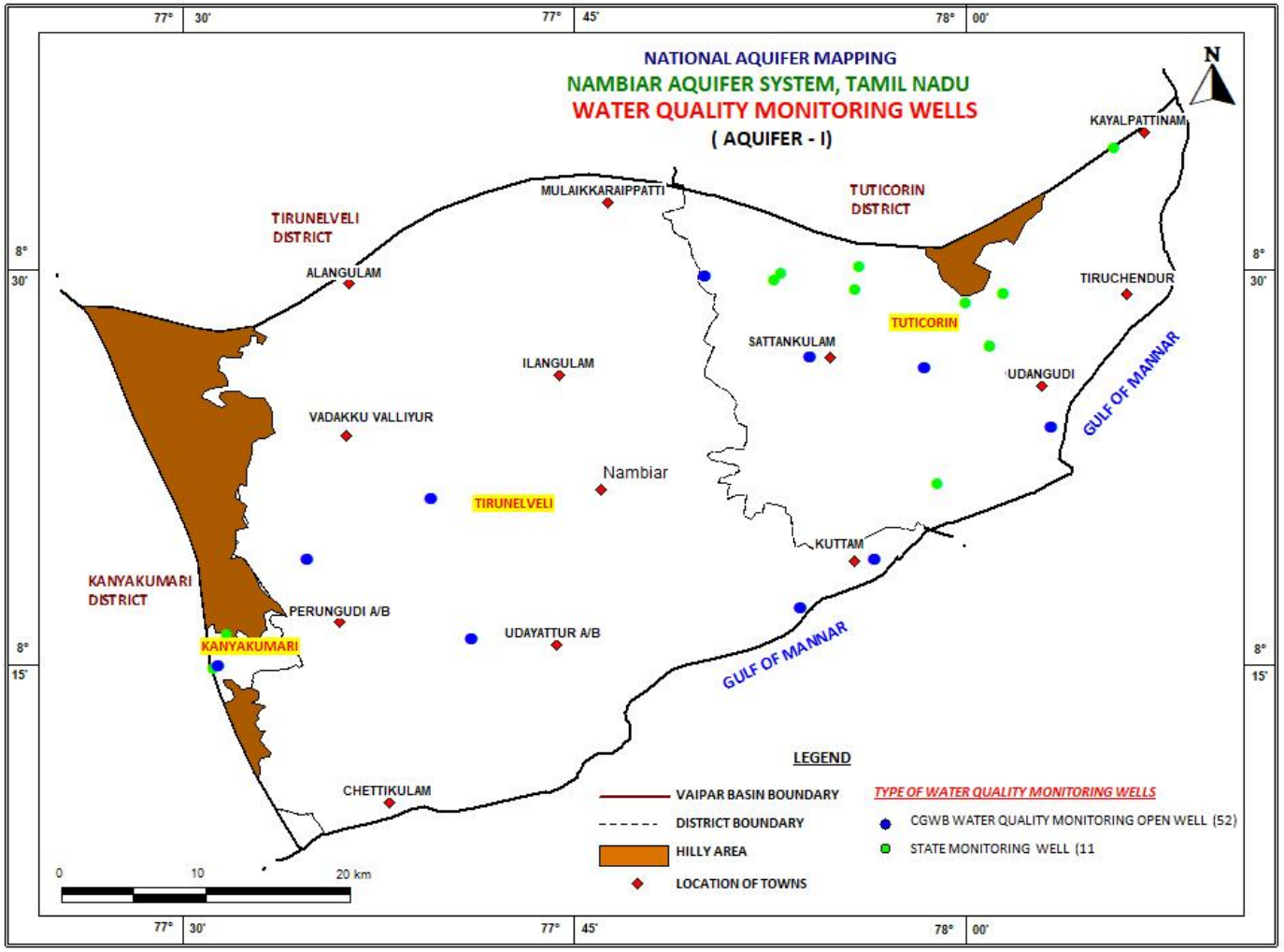


Figure 11. Locations of Groundwater quality Monitoring Wells ofNambiyar Aquifer System

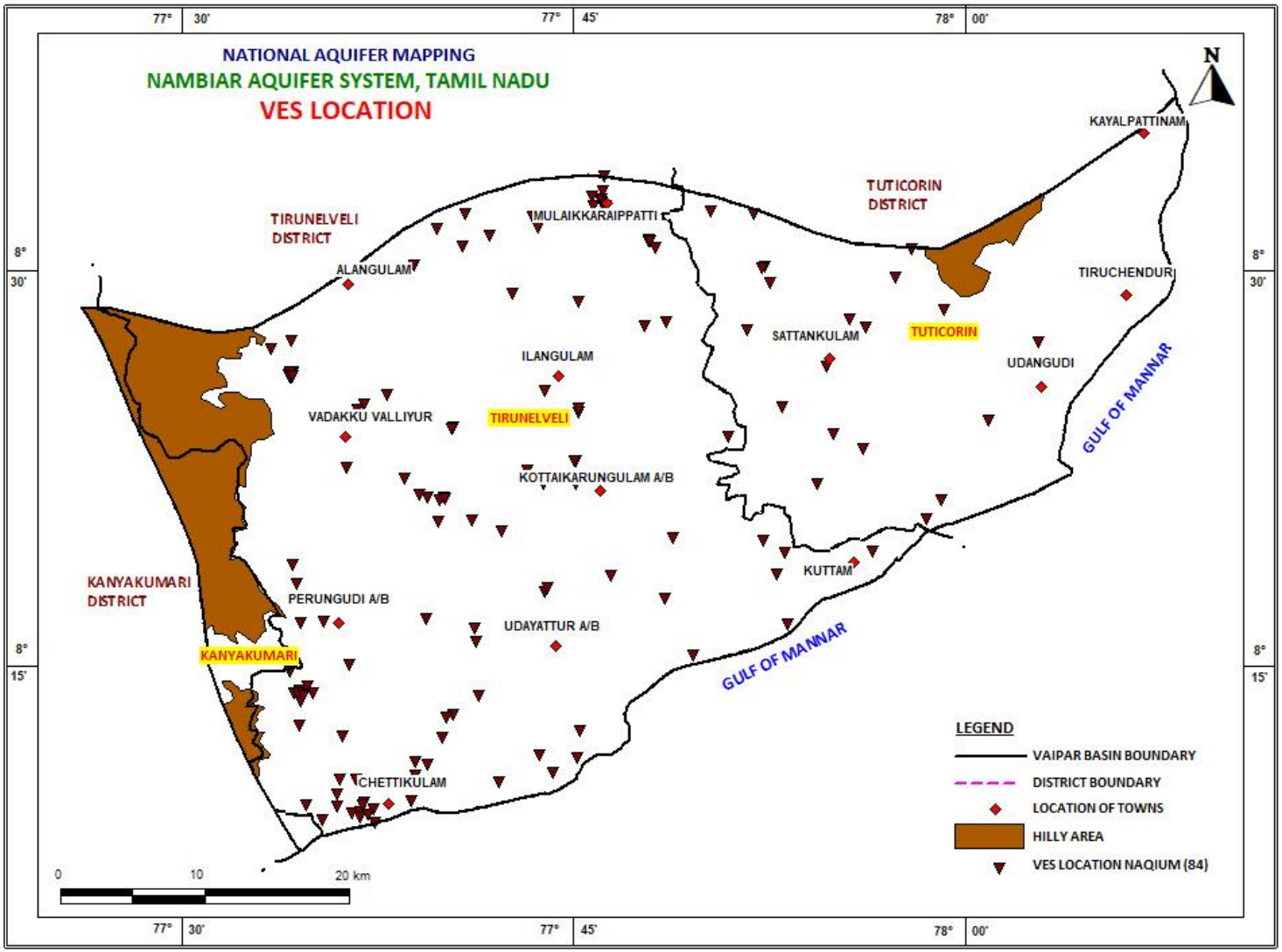


Figure 12. Locations of Vertical Electrical Soundings (VES) of Nambiyar Aquifer System

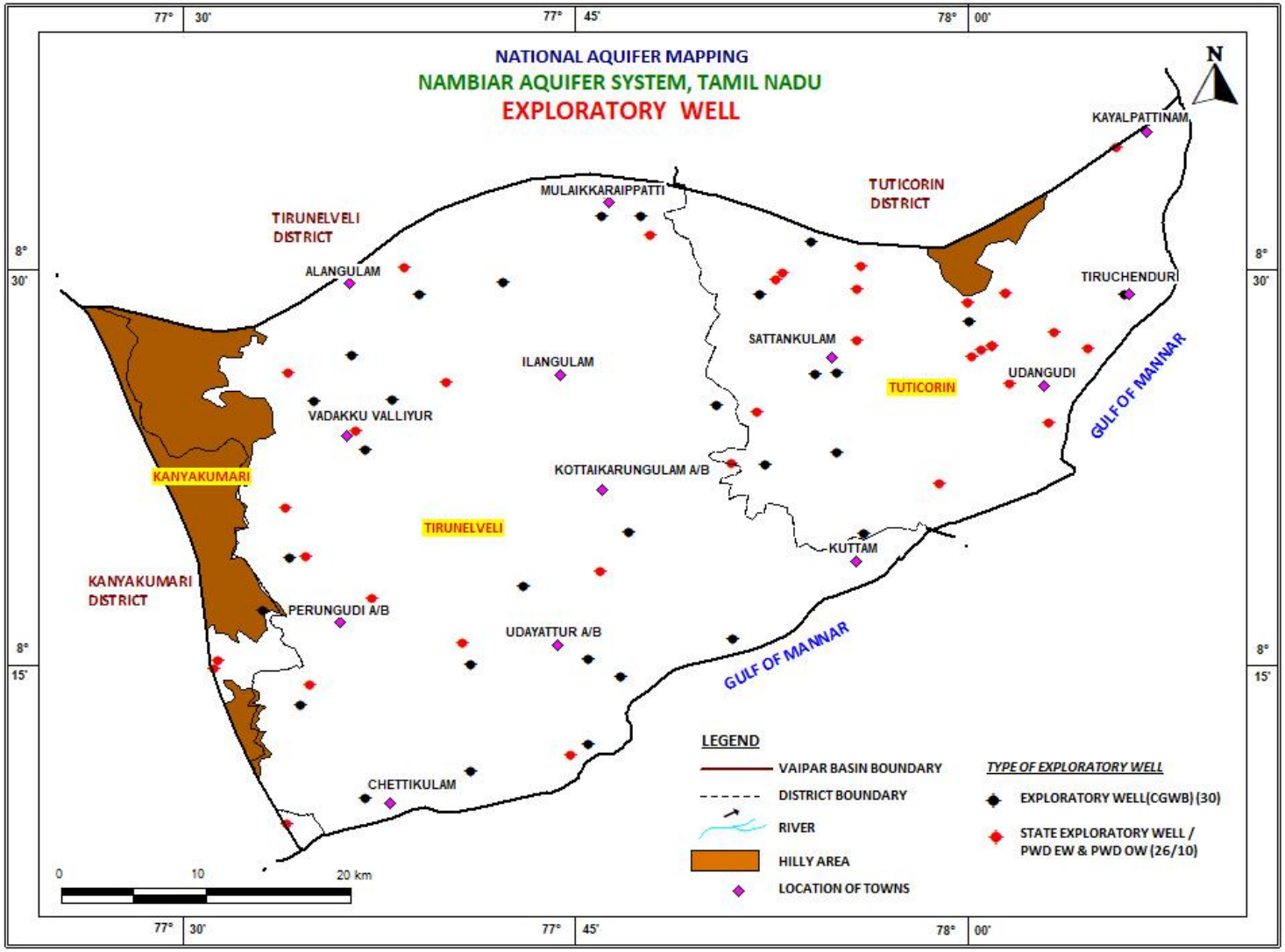


Figure 13. Locations of all Exploratory WellsofNambiyar Aquifer System

3. 0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydrogeological Data Interpretation and aquifer disposition

Nambiyar aquifer system area is divided into A and B regions. A-Region represents area underlined by Charnockite&Khondaliterocks, B region represents area underlined by Gniess rocks. Aquifer units falling in "A" regions are named as A1 & A2, whereas aquifer units falling in "B" regions are named as B1 & B2.

3.1.1.Hydrogeology of Charnockite&Khondalite rock region (A):

Hard rock region comprising of CharnockiteandKhondaliterocks is found in the western and northern portions of the Nambiyar aquifer system. The charnockite formation &Khondalite rocks cover in western and central part of the study area, the area encompasses 9firkas**(Table 3).** The Charnockite and Khondalite formation form two aquifer units namely the weathered and fracture/jointed aquifer unit.

3.1.1.1. Aquifer Unit I – Alluvium&Weathered (A1)

The Alluvium unit-I composed of River Alluvium, teri sand, Coastal alluvium, sandstone and weathered rock of charnockites and khondalite rocks. The River alluvium occur in the flood plains of Nambiyar, Hanumannadhi and Karamaniyar rivers and its tributaries. Teri sands occur north of Tisaiyanvilai (Ittamali Teri) and Northeast of Sattankulam (Kudiramoli Teri). Coastal Alluvium occurs along the coastal part of gulf of Mannar. These alluviul formations has a minimum of 7 to maximum of 80 m thickness with the average thickness of 20-40 m . Yield of these unit ranges from 0.1-14.76m^3/hr and during monsoon the well tapping this unit sustains for 1-2 hrs of pumping. The weathered aquifer unit occurs from the ground level and has a minimum thickness of 4.5 m and maximum thickness of 23 m with average thickness of 12-15m. 2D disposition along NNW toSSWand West to East clearly shows the vertical and lateral distribution of the CharnockiteandKondalite rock formations. Yield of this weathered aquifer unit ranges from 0.078 to 3.5 m^3/hr with average of <1 m^3/hr. During monsoon period the wells tapping this aquifer unit sustains for 1-2 hrs/dayof pumping, while during non-monsoon period (May to July) wells sustains for <1 to 2 hours of pumping.Groundwater occurs in unconfined condition.

Table3.Firkas in hard rock region (Region A) of the Nambiyar aquifer system.

Formation	Firkas
Khondalite (7 firkas)	Panagudi, vadakkuvaliyur, Alangulam, Kottaikarungulam, Kuttam&Udayathur
Charnockiticregion : (2 firkas)	Chettikulam&Perungudi

The aquifer parameter such as transmissivity in this aquifer unit ranges from 0.1 to 130 m^2/day. The Specific yield of this aquifer unit ranges from 1 to 1.5% with highly potable groundwater quality. The general EC of this aquifer unit ranges from 369 -3690µS/cm with the average range of 500 to 1100 µS/cm. There are some isolated pockets adjoining Udankudi, Tiruchenthur, Perungudi&Chettikulam area groundwater quality is beyond permissible limit for drinking and irrigation purposes.

3.1.1.2. Aquifer Unit II (Fractured/Jointed)

This aquifer unit comprises of fractured, jointed Charnockite and Khondalite formed due to tectonic activity. Top of this aquifer unit occurs from 0.5 to 23m bgl&ground level at some places). Based on the analysis of the 46 wells it is observed that there is a possibility of occurrence of 3 to 4 Fractures/joints upto 197 m bgl in the Charnockite and Khondaliteregion**(Figure 15).**The distribution of the fractures with depth is given in **Table 4**.The yield of this aquifer unit II ranges from 0.3 to 12 (majority <4) lps. During monsoon period the wells tapping this aquifer unit sustains for 1 to 3hrs /day of pumping, while during non-monsoon period (May to July) sustains for 1 to 2 hour/day of pumping.Transmissivity of this aquifer unit ranges from 1 to 219 m^2/day**(Table 5).**The general EC of this aquifer unit ranges from 600 to 800µS/cm with the minimum and maximum of 465 to 1060 µS/cm.

Table 4 . Distribution of fractures in the hard rock formation

Gneissic formation (25 wells analysied)		**Charnockite&Khondalite region (21 wells analysied)**	
Depth (m bgl)	**Frequency of occurrence of fracture**	**Depth (m bgl)**	**Frequency of occurrence of fracture**
Nil fracture	02 wells	Nil fracture	0 wells
0 to 50	18 wells	Upto 50	13 wells
50 to 100	09 wells	50 to 100	05 wells
100 to 150	05 wells	100 to 150	03 wells
150 to 195	07 wells	150 to 195	04 wells

Table 5. Salient features of the aquifer units in Charnockite&Khondalite- hardrock region of Nambiyar aquifer system

Type of Aquifer	**Formation**	**Top of the aquifers (mbgl)**	**Thickness/ occurrence of fractures (m)**	**Range of Yield (m^3/h)**	**Sustainability (hrs)**	**Aquifer parameter (Transmissivity – m2/day)**	**Groundwater quality EC values (µs/cm)**	**Suitable for Drinking**
Aquifer unit – A-I	**Teri sand/River Alluvium/Coastal Alluvium/SST**	**G.L - 1**	**7 – 80 (Avg. - 20-40 m)**	**0.10-14.76 Majority (< 1)**	**Monsoon : 1-2 hrs& Non monsoon: (May, Jun &July) < 1 to 2**	**99.26-1070**	**369-2590 (Avg 500-1100)**	**Yes – except few isolated pockets**
	Weathered Charnockites&Khondalite	**0.5 - 2**	**4.5 – 23 (Avg. - 12 -15 m)**	**0.078-3.5 Majority (< 1)**	**Monsoon : 1-2 hrs& Non monsoon: (May, Jun &July) < 1 to 2**	**1-130**	**369-3690 (Avg 500-1100)**	**Yes – except few isolated pockets**

Aquifer Unit – A-II	**Jointed & Fractured Charnockite&Khondalite**	**5– 23 Nil at some places**	**24 -184 (Avg. 40 -60 m) (2 to 3 fractures exist) Mostly confined to 60 m bgl. Nil at few places**	**0.3 – 12 (Majority <4)**	**Monsoon: 1-3 hrs& Non monsoon 1 to 2 hrs**	**1 -219**	**465-1060 (Avg 600-800)**	**Yes - except few isolated Pockets**

3.1.2.Hydrogeologyof Gniessicrock area of the aquifer system (B)

Hard rock region comprising of gneissic rock formations occupymost part of the aquifer system.Gneissicrockencompasses 12 firkas**(Table 6).**The Gneissic rock formation form two aquifer units namely the Aquifer Unit-I (B1-weathered rock and weathered rock overlined by Coastal Alluvium in coastal part) and Aquifer Unit-II (B2-fracture/jointed aquifer unit of Gniessic rock).

3.1.1.1. Aquifer Unit I – Weathered (B1)

The weathered aquifer unit occurs from the ground level and has a minimum thickness of 4 m and maximum thickness of 22 m with average thickness of 12-18 m. 2D disposition along NNW to SSW and West to East clearly shows the vertical and lateral distribution of the Gniessic rock formations. Yield of this weathered aquifer unit ranges from 0.014 to 6.7 m^3/hr with average of <1 m^3/hr. During monsoon period the wells tapping this aquifer unit sustains for 2 to 3hrs/day of pumping, while during non-monsoon period (May to July) wells sustains for < 1 to 2 hour/day of pumping. Groundwater occurs in unconfined condition.

Table 6.Firkas falling in Gniessic rock region of theNambiyar aquifer system

Formation and number of firkas	Name of the firkas
Gniess rock (12firkas)	Nanguneri, Mulaikaraippatti, Ilangulam, santhankulam, Srivenkateswarapuram, UIangudi, Pallankurichi, Kottaikarangulam, Udayathur, Perungudi, Panagudi and Alangulam.

The aquifer parameter such as transmissivity in this aquifer unit ranges from <1 to 110 m^2/day. The Specific yield of this aquifer unit ranges from 1.5 to 2% with highly potable groundwater quality. The general EC of this aquifer unit ranges from 245 -3290 µS/cm with the average range of 1000 to 1600 µS/cm.

3.1.1.2. Aquifer Unit II (Fractured/Jointed) (B2)

This aquifer unit comprises of fractured and jointed Gniessic rock formed due to tectonic activity. Top of this aquifer unit occurs from 5 to 85 m bgl& ground level at some places). Based on the analysis of the 46 wells it is observed that there is a possibility of occurrence of 3 to 4 Fractures/joints exists up to 195 m bgl in the Gniessic rock region**.** The distribution of the fractures with depth is given in **Table 4**. The yield of this aquifer unit II ranges from nil to

27(majority <4) lps. During monsoon period the wells tapping this aquifer unit sustains for 1 to 5hrs /day of pumping, while during non-monsoon period (May to July) sustains for 1 to 2 hour/day of pumping. Transmissivity of this aquifer unit ranges from 1.7 to 716 m^2/day **(Table 7).** The general EC of this aquifer unit ranges from 800 to 1500 µS/cm with the minimum and maximum of 600 to 3350 µS/cm.

Table 7. Salient features of the aquifer units in Gniessicrock region of Nambiyar Aquifer System

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of fractures (m)	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter (Transmissivity – m2/day)	Groundwater quality EC values (µs/cm)	Suitable for Drinking
Aquifer unit – B- I	Weathered gneiss	1 or 2	4 - 22 (Avg. 12-18 m)	0.014 - 6.7 Majority (< 1)	Monsoon : 2-3 hrs& Non monsoon: (May,Jun&July) < 1 to 2	0.10 - 110	245-3290 (General range: 1000-1600)	Yes - except few isolated pockets
Aquifer Unit – B- II	Jointed & Fractured Gneiss	5 – 85 Nil at some places	9.5 – 155 (Avg. 60-80 m) (3 to 4 fractures exist) Mostly confined to 75 m bgl Nil at few places	Nil – 27 Majority (<4)	Monsoon: 1-5 hrs& Non monsoon 1 to 2 hrs	1.7 - 716	600-3350 (General range: 800 – 1500)	Yes

3.2.Groundwater Level

During Aquifer Mapping studies in Nambiyar aquifer system 35 Groundwater monitoring wells were monitored regularly in different formations in order to know the behaviour of the groundwater regime. The water levels were monitored from 2009 to 2019 (four times in a year). The depth of dug wells ranged from 3.00 to 29.00mbgl.

3.2.1. Depth to Water level for aquifer I (May2019)

The water level data pertaining to the period of May 2019 (pre monsoon) was used for the preparation of depth to water level map of the basin. The depth to water level during May 2018 varied from 2.3 to 25.05mbgl. Major part of the basin shows water level in the range of 5 to 10mbgl.Isolated pockets had water levels in the range of 2 to 10mbgl. Water levels with 10 to 20 mbgl are observed in the southern part of the aquifer system.The Depth to water level map for aquifer I-Premonsoon as **Figure 14.**

3.2.2. Depth to Water level for aquifer I (Jan-2019)

To prepare the depth to water level map for the period of January 2020, based on GWMW data collected from the basin area are used. The depth to water level during Jan 2020 varied from 0.31 to 9.85mbgl.Water level in the range of 2 to 5mbgl found in majority of the area, whereas the shallow water level 0-2 m bgl are found in the isolated pockect in the western and easter part of the study area. Water level of 5-10mgbl are found in the southern part along the coastal area of the aquifer system.Depth to water level map for aquifer I-Postmonsoonis shown in**Figure 15.**

3.2.3. Decadal Water Level Scenario of the aquifer system

Decadal water level scenario maps are prepared for pre-monsoon and post-monsoon period. The analysis shows that during the Pre monsoon period (May 2009- May 2018) 55% of the well shows water level between 5 and 10 m bgl and 45% of the wells shows water level 2 to 5 m bgl. Whereas during the post monsoon period (Jan 2010 – Jan 2019) 54% of the wells shows water level i.e. 5 to 10 m bgl, and 36% of well shows very shallow water level between 2 and 5. Shallow water level less than 2 m bgl is noticed in 9 % of the well. The studies show that the basin is responding to the rainfall recharge and aquifer got rejuvenated after the rain. Depth to water level (Aquifer-I) – decadal average- Premonsoon of the Nambiyar Aquifer System presented as **Figure 16**. Depth to water level (Aquifer-I) – decadal average- Postmonsoon of the Nambiyar aquifer system is shown in**Figure17.**

3.3 Pumping Tests

The yields of the wells in the study area are widely varied. Many of the dug wells in the area have less than one meter water column during most part of the year. About 10 to 15 % ofwells located in the Northern parts get dry during summers months. The wells located in favourable hydrogeological settings like shear zones, topographic lows, river alluvium etc., are able to sustain at a rate of 110 lpm for 2 to 3 hrs of pumping. The yield of large diameter wells tapping the weathered mantle of crystalline rocks ranges from <1 to 3.5lps for a drawdown of 2 to 4 m and are able to sustain 1 to 2 hours of pumping. The specific capacity of the porous weathered formation ranges from 7 to 35 lpm/m/dd. The transmissivity values of the weathered formation computed from pumping tests ranges from 1 to 110 m^2 /day. At a very few places the weathered mantle extends down to 23 m bgl.

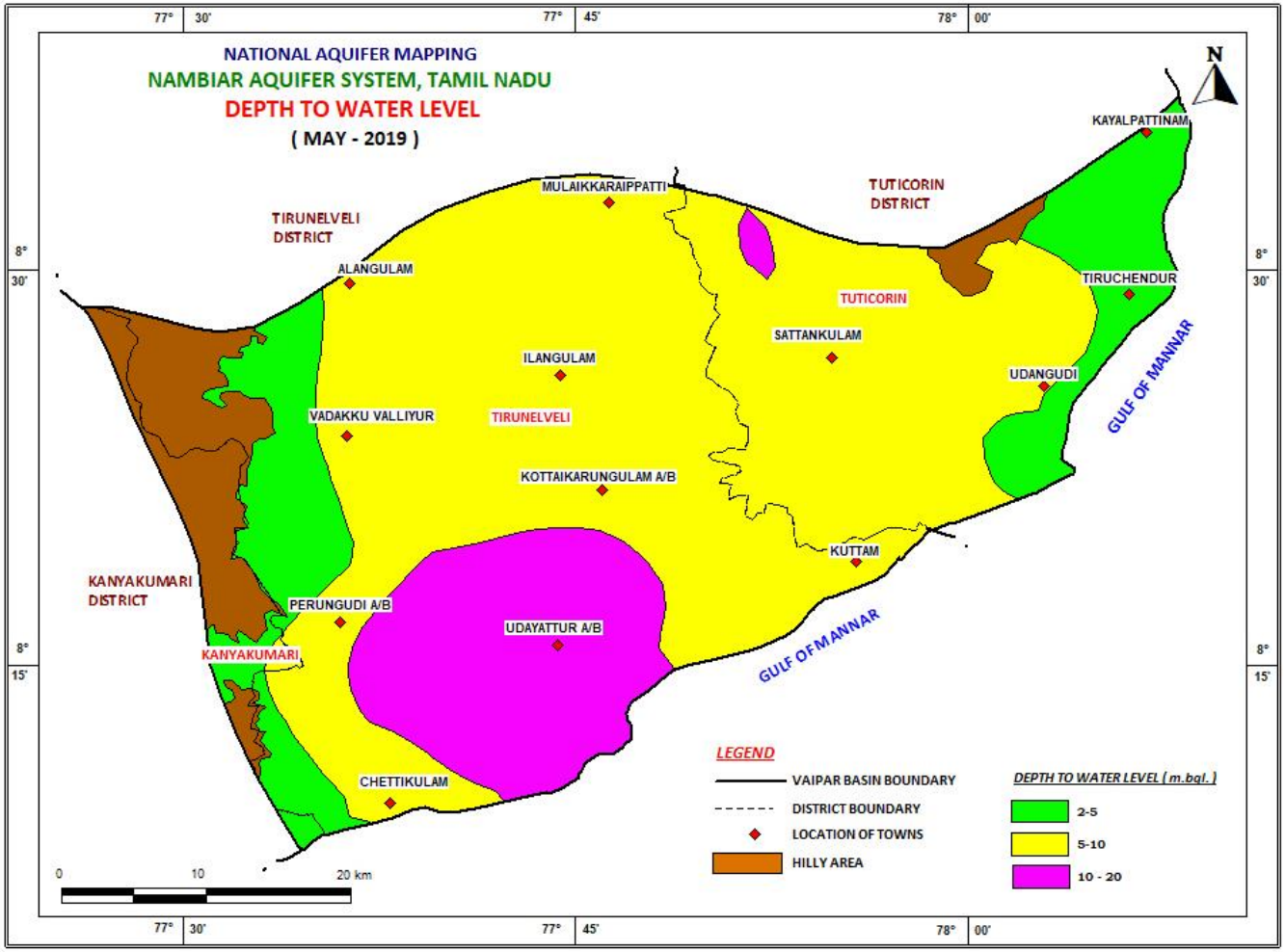


Figure 14. Depth to water level (Aquifer-I) – Premonsoon of the Nambiyar aquifer system

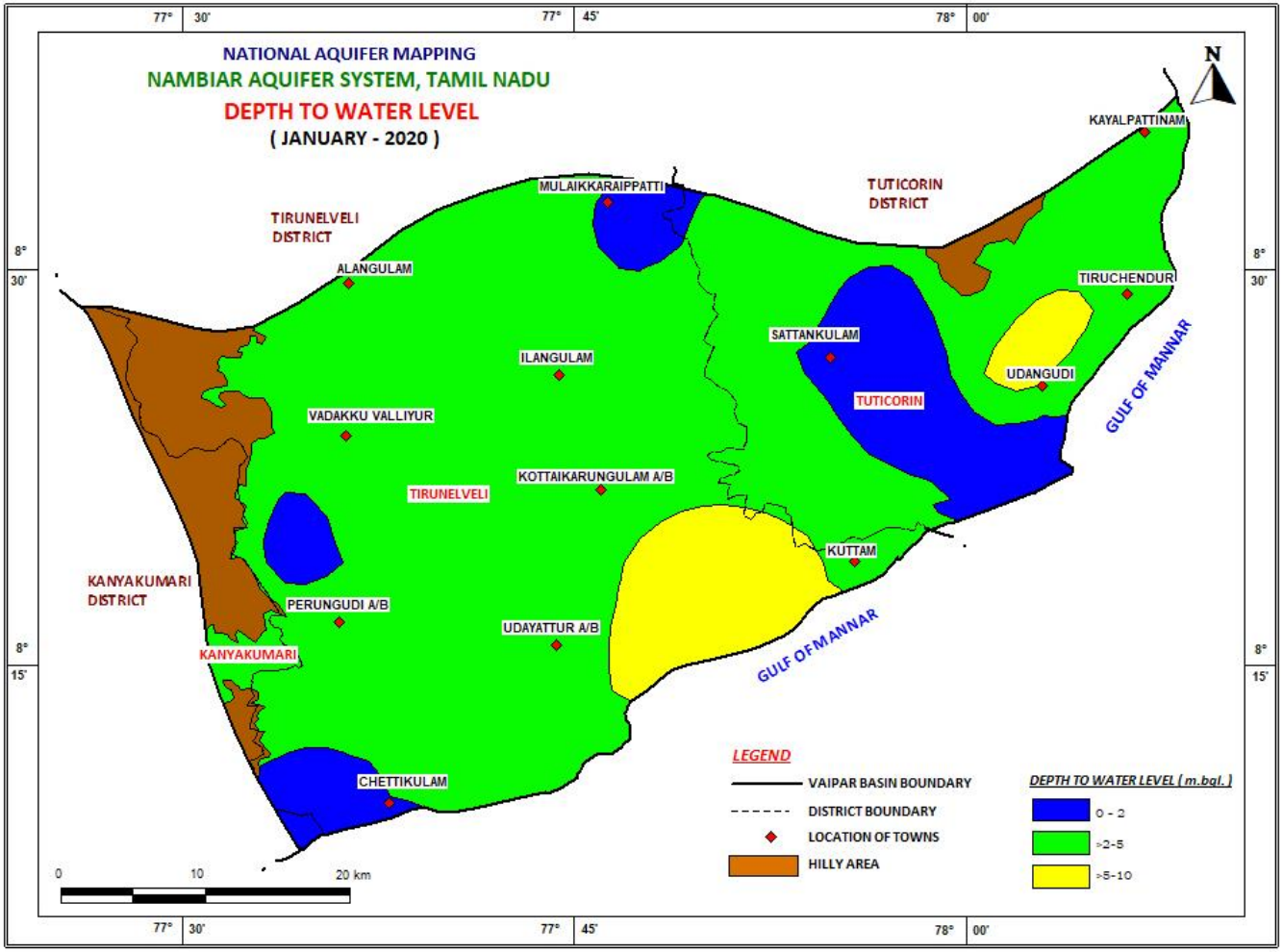


Figure 15. Depth to water level (Aquifer-I) – Postmonsoon of the Nambiyar aquifer system

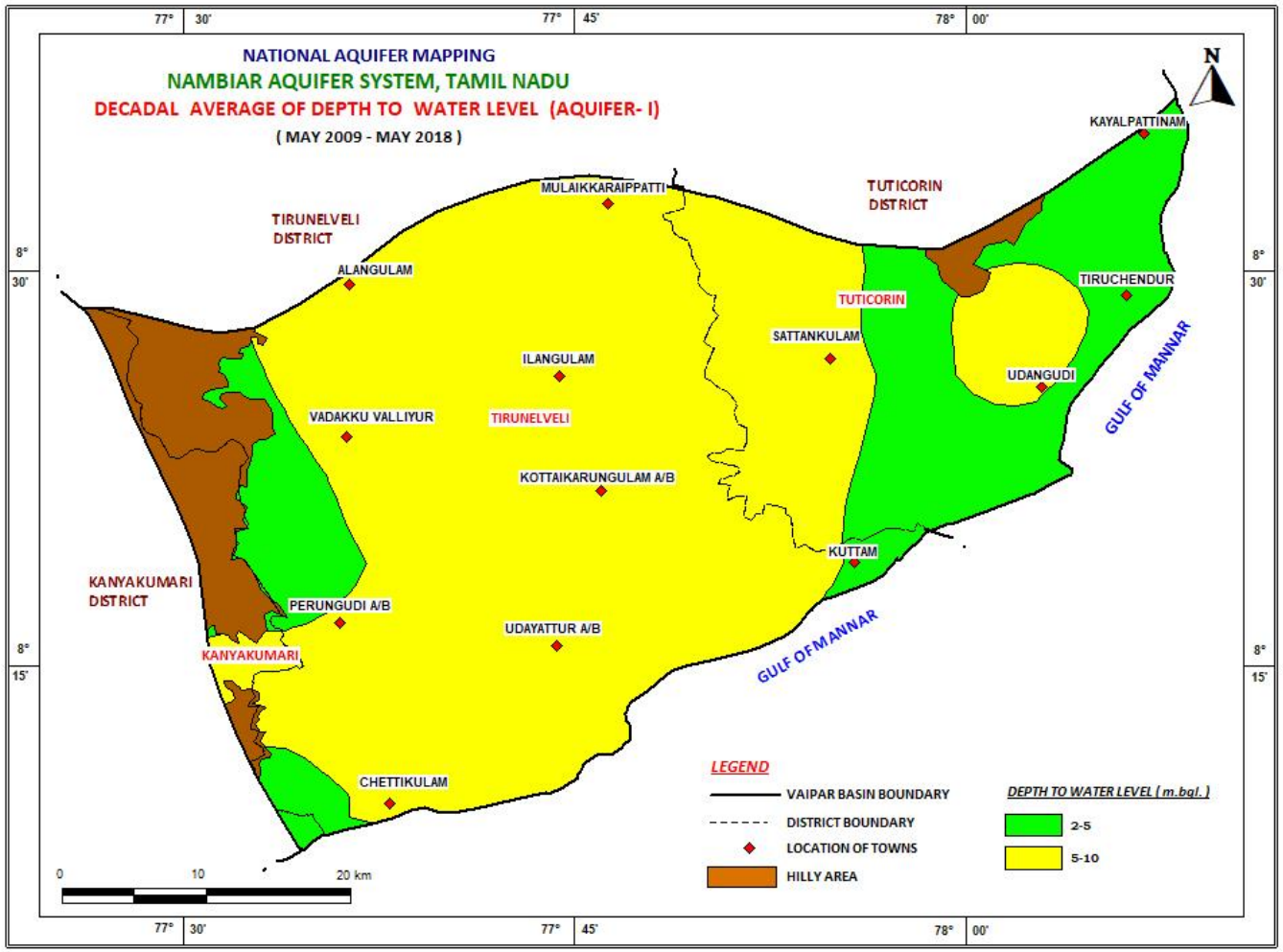


Figure 16. Depth to water level (Aquifer-I) – decadal average- Premonsoon

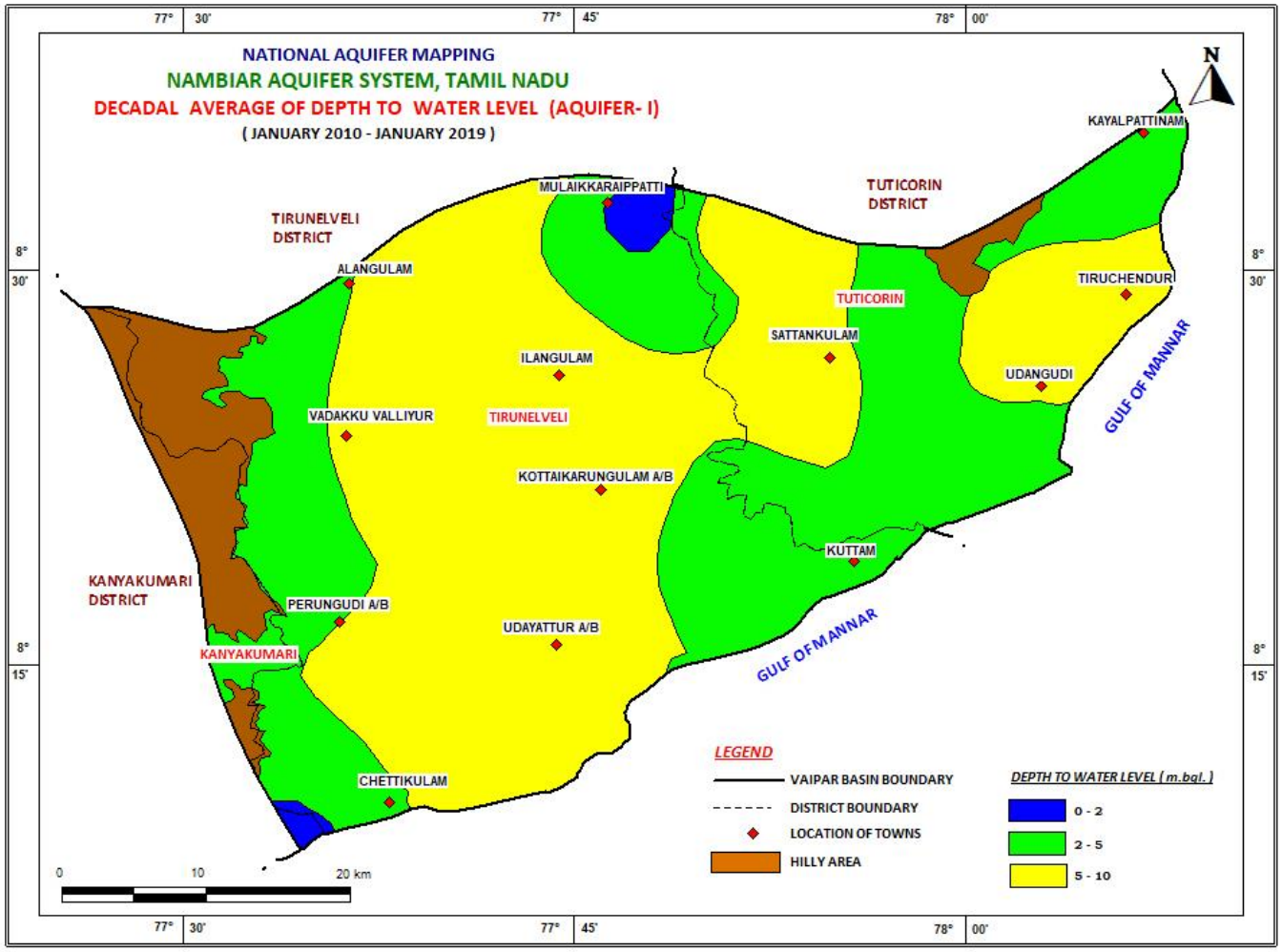


Figure 17. Depth to water level (Aquifer-I) – decadal average- Postmonsoon

3.4 Groundwater quality

3.4.1. Electrical Conductivity:

Electrical conductivity is the indicator of the total mineral content of water and hence it indicates the total dissolved solids (TDS) present in water. TDS of water determines its usefulness to various purposes. Generally water having TDS <500 mg/L is good for drinking and other domestic uses. However, in the absence of alternative sources TDS up to 2000 mg/L may be used for drinking purposes. The distribution of EC in different aquifers are shown in **Figure 18& Table 8**.In phreatic aquifer the groundwater quality is fresh, about 14 % of the samplesshowEC value less than 750 µs/cm at 25ºC. About 50 % of the groundwatersampleshave moderateECvarying between 751 and 2250µs/cm at 25º C, whereas8% of Groundwater showing EC between 2251 and 3000 µs/cm at 25º C indicating that the groundwater is slightly mineralized and about 28% of groundwater wells the EC is more than 3000 µs/cm at 25ºC indicating that the groundwater is highly mineralized. The fractured zone groundwater quality is fresh in about 5 %, as indicated by the EC value which is less than 750 µs/cm at 25ºC. In about 75% of the groundwater, the EC varies between 751 and 2250µs/cm at 25º C indicating that groundwater is moderately fresh and 5 % of groundwater is between 2251 and 3000 µs/cm at 25º C indicating that the groundwater is slightly mineralized. Only in 15% ofgroundwatersamples the EC is more than 3000 µs/cm at 25ºC, which occupies the coastal part of the study area.

Table 8. Distribution of EC in the aquifer unit-I.

Ec (us/cm)	Percentage of sample (%)
0-750	14
>750-1500	22
>1500 - 2250	28
>2250-3000	08
> 3000	28

3.4.2. Chloride:

About 44 % of the groundwater samples of phreatic aquifer has the chloride concentration 0 to 250 mg/l and about 44 % of groundwater sample has the chloride concentration 250 to 1000 mg/l. High chloride concentration >1000 mg/I is reported in 12% of the wells. The distribution of chloride concentration in Aquifer-I is presented in **Figure 19** and **Table9.**

Table 9. Distribution of chloride concentration in aquifer

Cl (mg/l)	Percentage of sample
0 -250	44
>250-1000	44
>1000	12

3.4.3. Fluoride

The important fluorine-bearing minerals are fluorite (Calcium fluoride), apatite (Complex fluoride- bearing silicate), certain amphiboles and micas. The concentration of fluoride in groundwater is limited due to the low salinity of most fluoride in groundwater. It is limited due to the low solubility of most fluorides. The solubility of fluoride in pure water at 25^{o}C is only 8.7 ppm of fluoride. Groundwater in most areas contains less than 1.5 ppm fluorides, but in firkas i.e. Tisayanvila, Radhapuram, Panagudi&Tiruchendur,the concentration is more than 1.5 ppm **(Figure 20).**

3.4.4. Nitrate

Nitrogen is a very minor constituent of rocks, but is a major constituent of the atmosphere. Nitrogen and oxygen of the atmosphere are combined by electrical charging during lightning and dissolve in rainwater. The average nitrate content in rainwater is reported to be 0.2 ppm (Riffenburg, 1926). In most part of the aquifer system the concentration of Nitrate is <45 mg/l which is well within the permissiable limit, whereas few samples fromfirkas like Levinjipuram, Radhapuram, Panagudi, Samugarengapuram, Tisayanvila, Pallakurichi, Udangudi&Srivenkateswarapuramhave Nitrate concentration > 45 mg/l**(Figure 21).** This is due to the mixing of sewaragewaterwith the ground water in urban areas and also the increase in concentration of Nitrate is due to the leaching effect of Nitrogen fertilizers applied in the agriculture field in the study area.

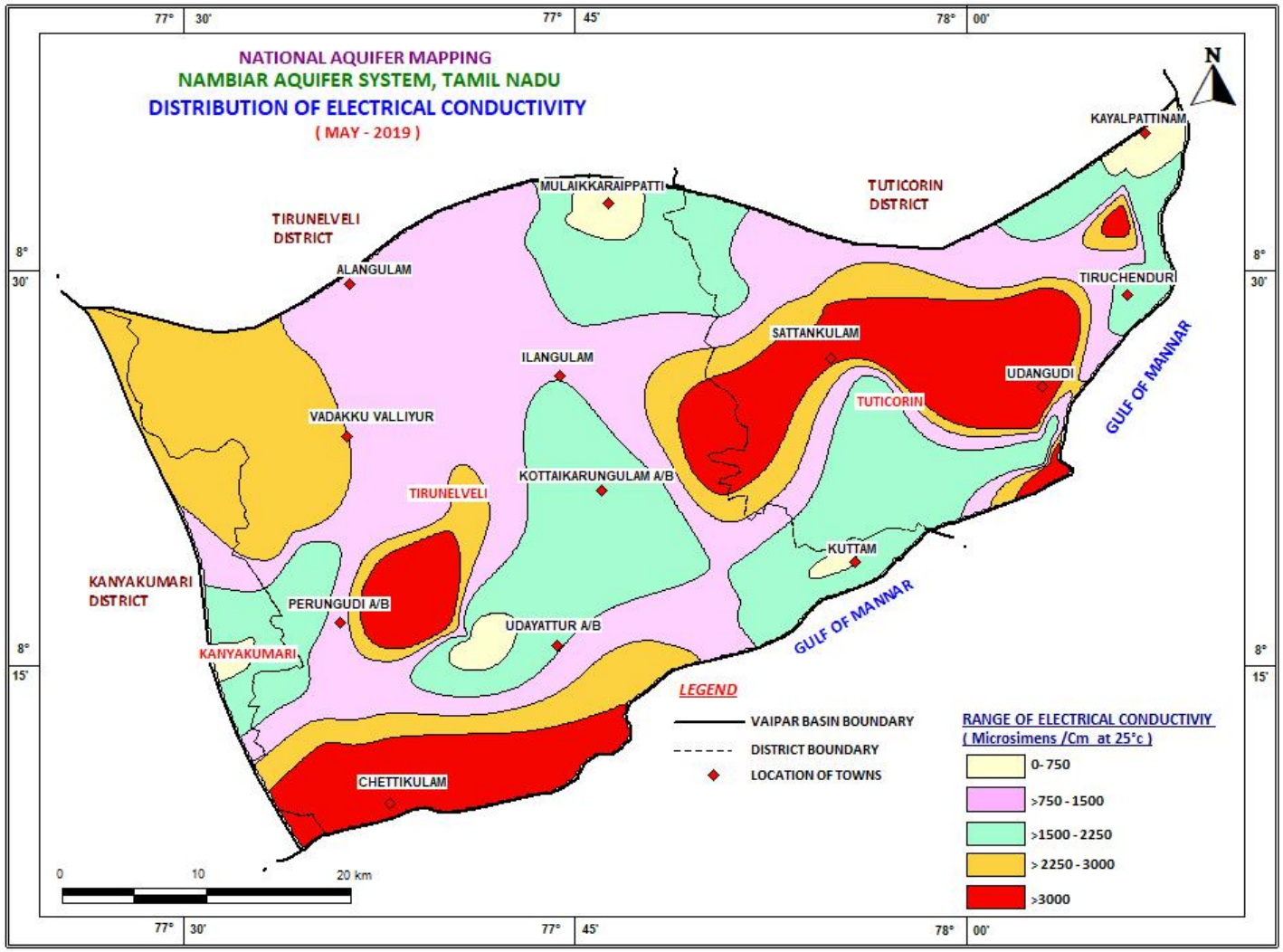


Figure 18. Distribution of EC in Aquifer I of the Nambiyar Aquifer system.

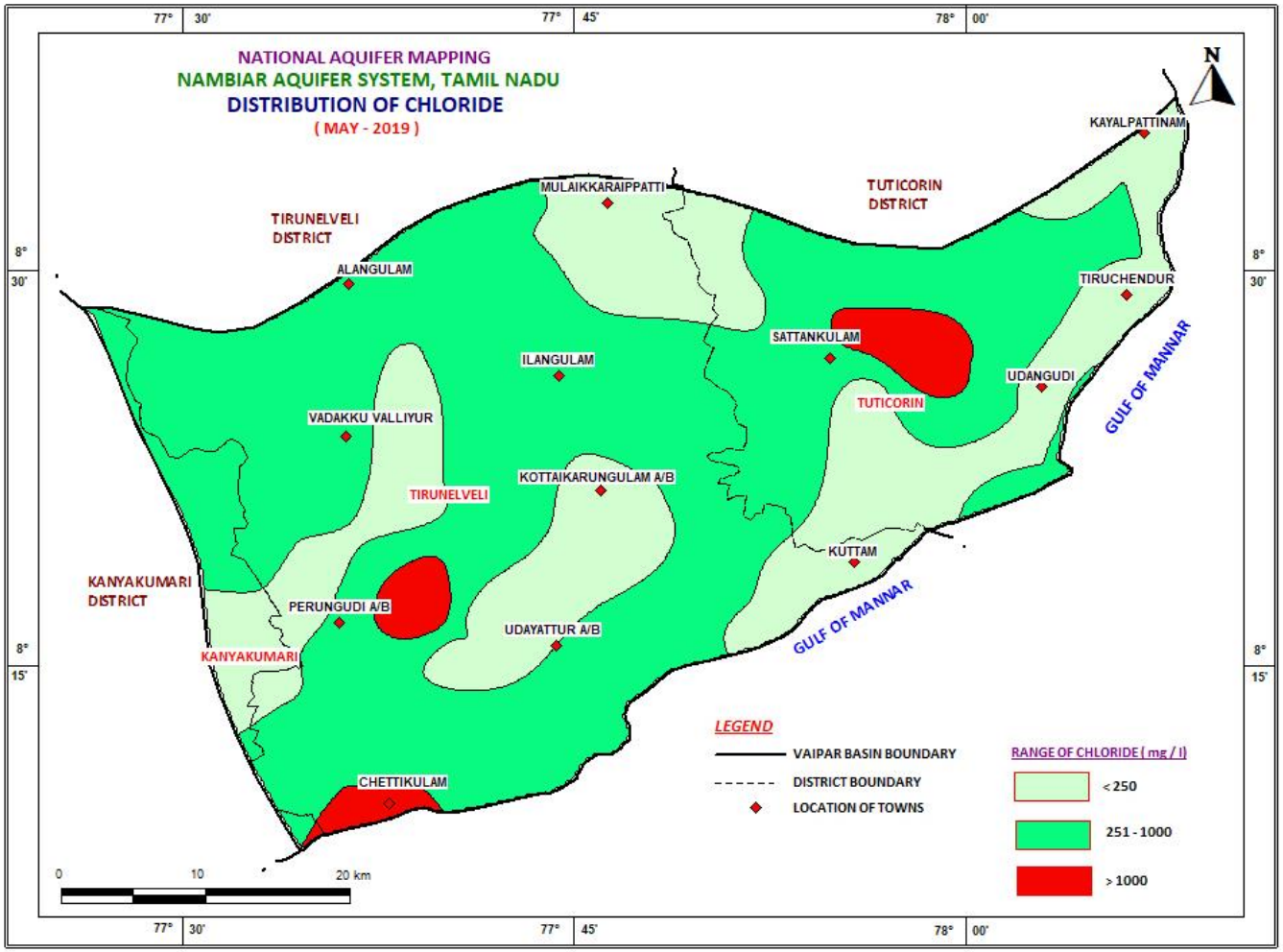


Figure 19. Distribution of Chloride in Aquifer-I of the Nambiyar Aquifer system

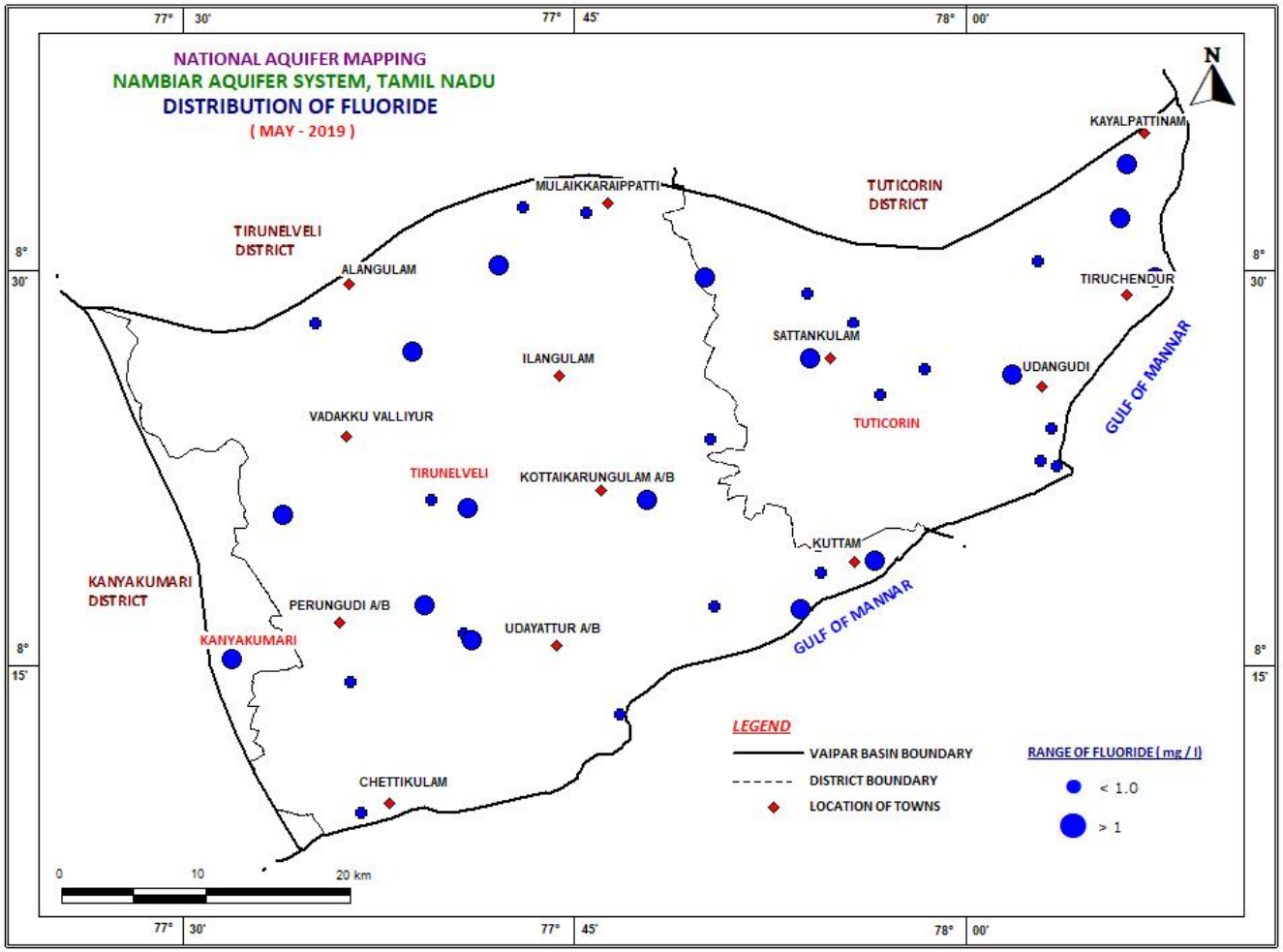


Figure 20. Fluoride concentration in Aquifer-I of the Nambiyar Aquifer system

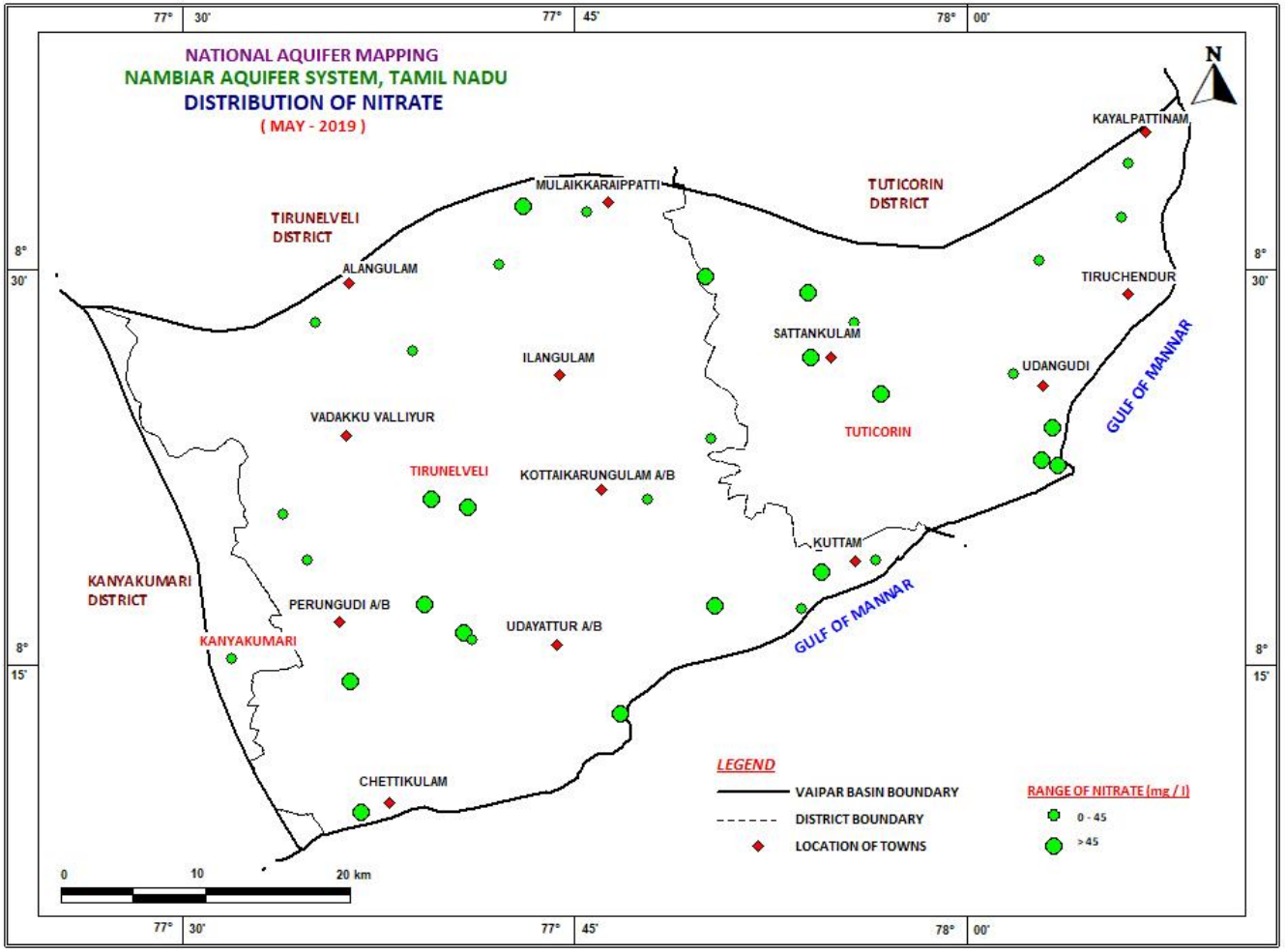


Figure 21. Nitrate concentration in Aquifer-I of the Nambiyar Aquifer system

3.5. Aquifer Maps

3.5.1. 2D&3D models showing Aquifer Dispossition

Aquifer Disposition (Vertical & Lateral) is generated based on the inputs of data collected through geological, geophysical, hydrogeological, and hydrochemical studies. In particular the aquifer disposition and aquifer characterization has been brought mainly by analyzing the data collected from different groundwater agenesis such as 66 nos. of lithologs, 84 Nos. of VES data, water level data of 35 wells, 12 hydrograph of dugwells with long term trend, 12piezometric head data of the piezometers tapping different aquifer units, 62hydrochemical data and field inputs gathered during the study period.2D & 3D aquifer disposition models of the aquifer system have been deciphered by using ROCKWORKS software and generated numbers of 2D cross section along different directions of the Nambiyar aquifer system. All such 2D cross sections were verified and the model was calibrated to bring out the 3D aquifer disposition of the aquifer system. The type cross sections generated in different direction of the aquifer system is given in **Figures 22, 23 and** the 3D aquifer disposition is show in **Figure 24**.

4.0. GROUNDWATER RESOURCES

The dynamic groundwater resources have been estimated as on 2017 based on the methodology suggested by Ground Water Estimation Committee (GEC) 2015.

The groundwater recharge is calculated both by groundwater fluctuation-specific yield method and by rainfall infiltration method. The annual replenishablegroundwater recharge is the summation of four components viz.,

i) Monsoon recharge due to rainfall

ii) Monsoon recharge from other sources

iii) Non-monsoon recharge due to rainfall

iv) Non-monsoon recharge due to other sources

Firka-wise dynamic groundwater resources have been taken from the approved resources estimation done as on March 2017, jointly by State PWD of Tamil Nadu and CGWB, to arrive at the total resources available in the study basin. A total of 16 Firkas are falling in the study area.

4.1. Annual Extractable Groundwater Resources

The annual extractable groundwater resources availability refers to the available annual recharge after allowing for natural discharge in the monsoon season in terms of base flow and subsurface inflow/outflow. This annual extractable groundwater resources includes the existing groundwater withdrawal, natural discharge due to base flow and subsurface inflow/ outflow in the monsoon season and availability for future development. As the groundwater development progresses the natural discharge gets suitably modified and comes down to negligible quantities due to interception by different groundwater structures. Hence, natural discharges in the monsoon season may not be considered and the total annual groundwater recharge may be taken as annual extractable groundwater resources.Theannual extractable groundwater resources of the basin for the year 2017 is arrived at 26004Ham, out of which the availability for 11 firkas of Tirunelvelidistrict is 17095 ham, 5 firkas of Thoothukudi is 8909 ham (**Figure 25**).

4.2. Annual Groundwater Extraction

The gross annual groundwater extraction has been assessed by using Unit draft method for irrigation draft component and by adopting formula suggested by GEC 2015 for domestic and industrial draft components. The existing annual groundwater extraction of the basin for the year 2017 is arrived at 19958 Ham, out of which the groundwater draft for 11firkas of Tirunelveli district is 12171 ham and 5 firkas of Thoothukudi is 7786ham.The total gross annual groundwater extraction of the aquifer system is 19958 ham.against the annualextractablegroundwater resources of 26004 ham **(Figure 25).**

4.3. Stage of Groundwater Extraction and Categorization

The stage of groundwater extraction is defined by

Stage of groundwater extraction (%) = (Existing gross annual groundwater extraction/ Annual extractable groundwater resources) x 100

Based on the stage of groundwater extraction four categories i.e.**a) Safe, b) Semi-critical, c) Critical and d) Over-exploited** have been suggested by GEC-2015.

The stage of groundwater extraction is calculated for all the 16firkas of the aquifer system.

Based on the above categorization 4 out of the 16 firkas of the Nambiyar aquifer system falls under over exploited and critical categories. In Tirunelveli district out of 11 Firkas2firkas falls in over exploited and critical categoriesand9firkas falls under semi-critical and safe categories. In Thoothukudi district out of 5 firkas,2firkas falls in over exploited and critical categories and 3 firkas fall in semi-critical and safe categories (**Figure 26**). The total stage of extraction of Nambiyar aquifer system is 77%.

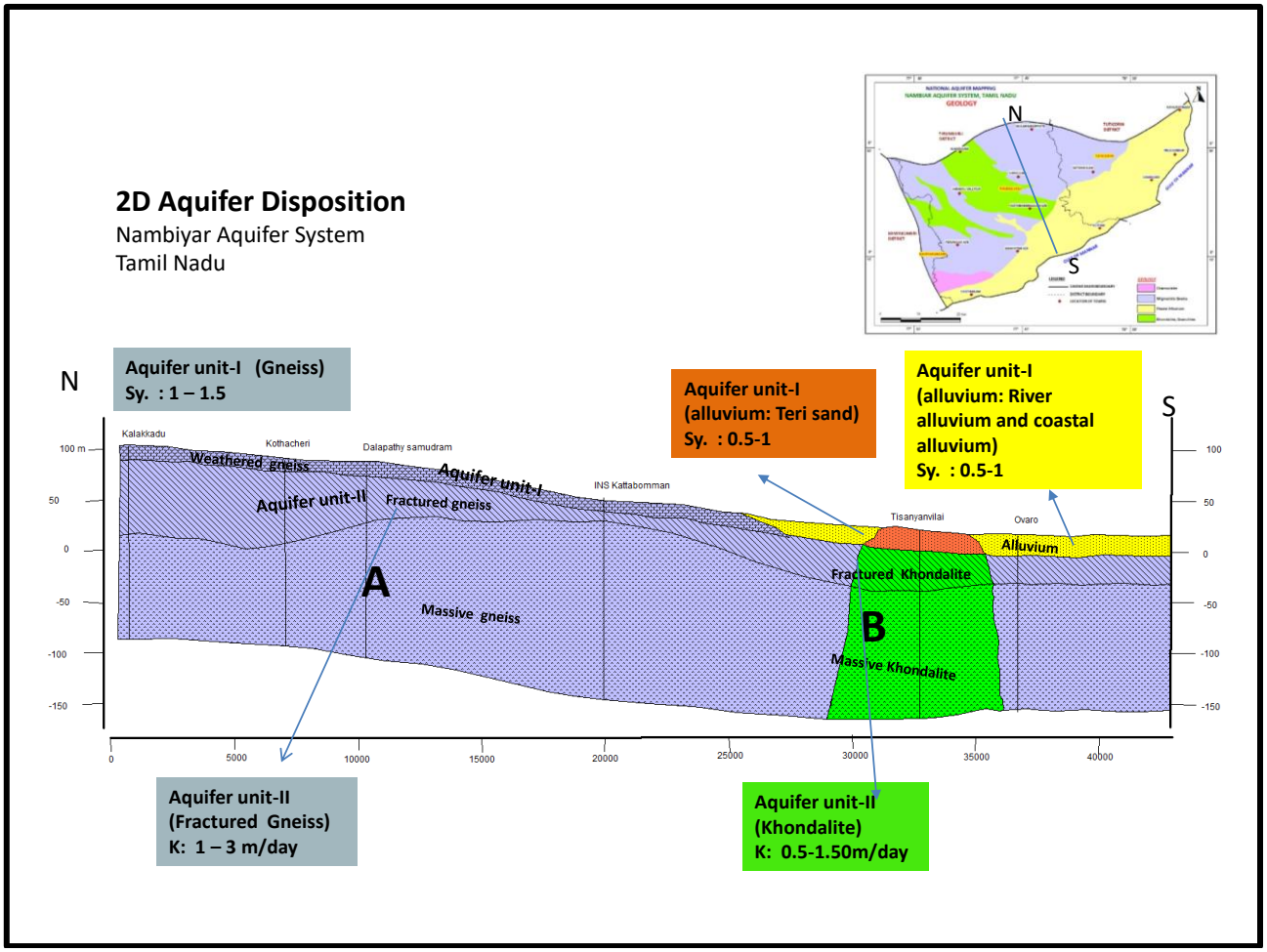


Figure 22. 2D disposition of the Nambiyar Aquifer system along N-S Direction.

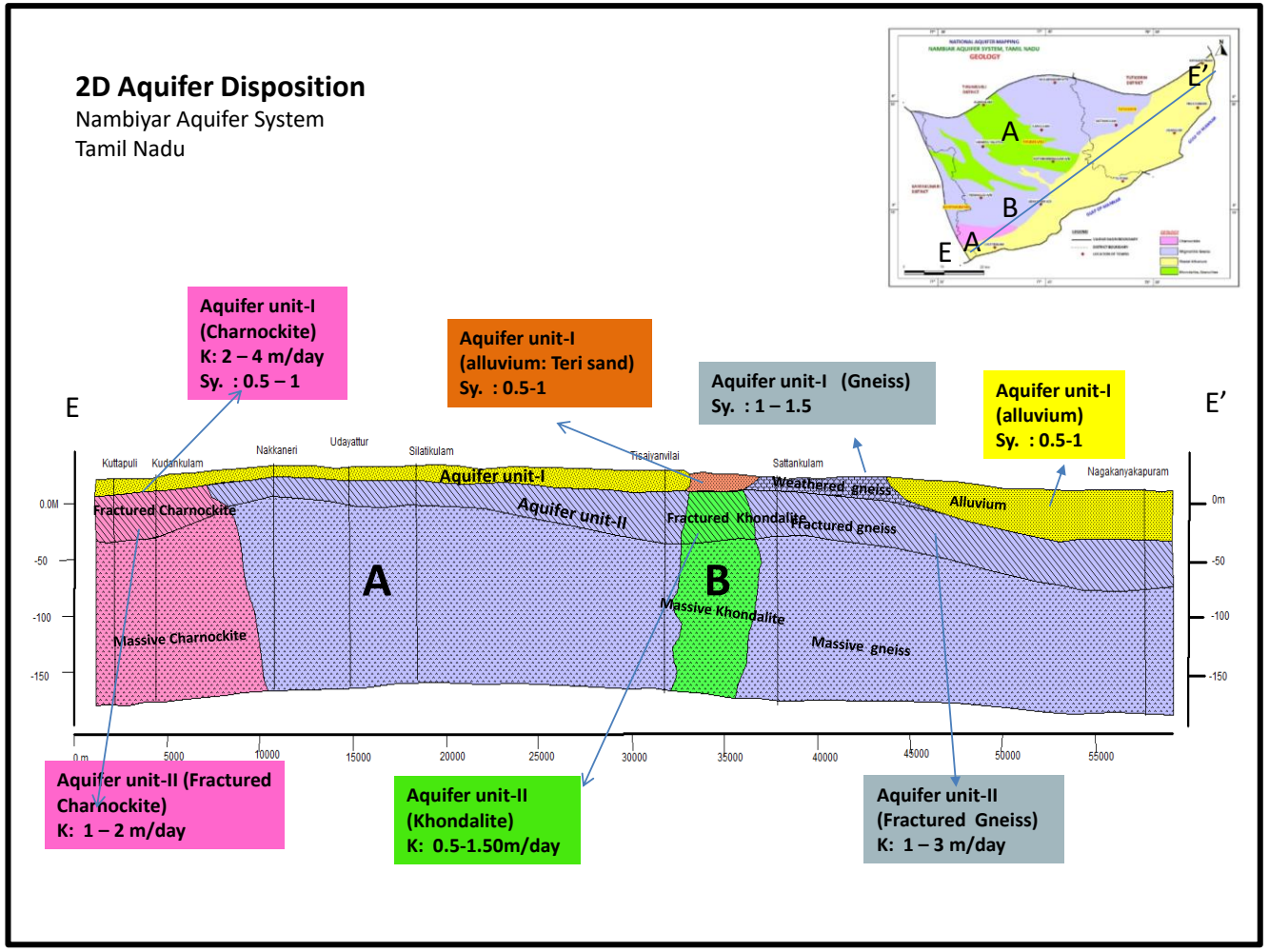


Figure 23. 2D disposition of aquifer system alongSW–NE direction.

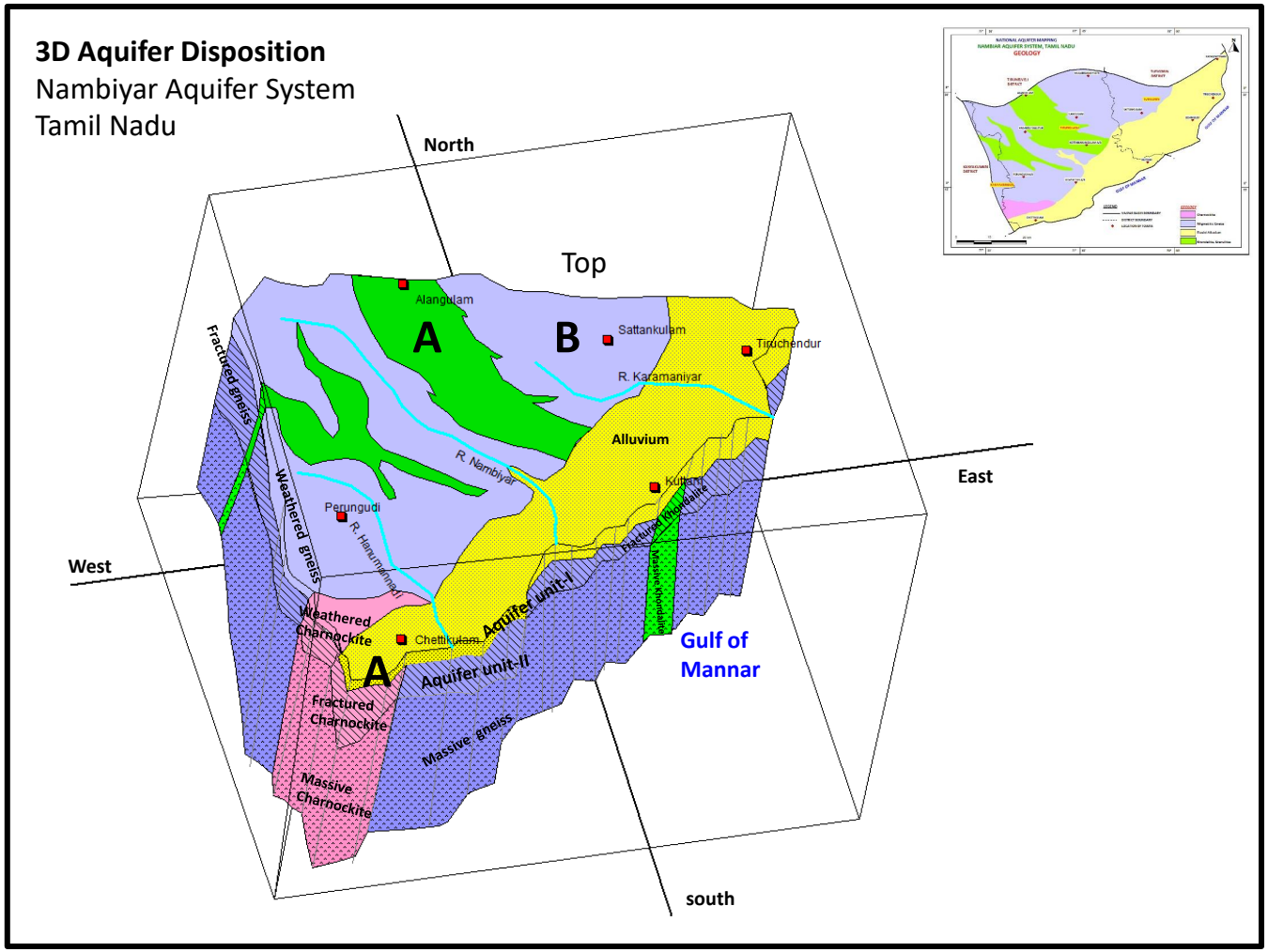
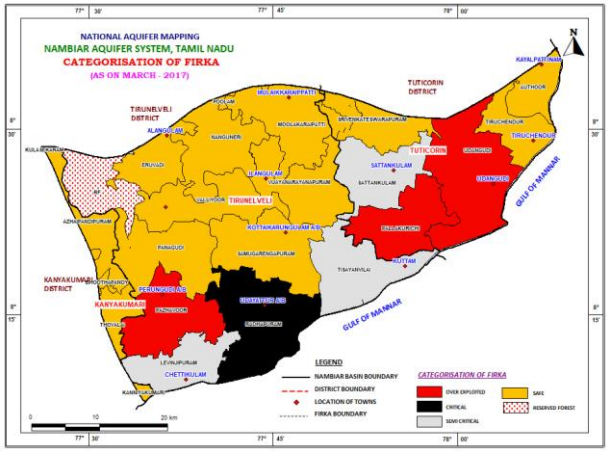


Figure 24. 3D disposition of aquifer system.

State of Groundwater extraction



Total Firkas – 16

Over Exploited - 3
Critical - 1
Semi Critical - 4
Safe - 8

District	2013			2017		
	Resources	Draft		Resources	Draft	Stage of GWE
THOOTHUKKUDI	9412.55	7797.84	82.85	8909.03	7786.42	87.40
TIRUNELVELI	17826.21	11390.00	63.89	17094.85	12171.40	71.20
Total Basin (ham)	**27238.77**	**19187.84**	**70.44**	**26003.89**	**19957.82**	**76.75**
Total Basin (MCM)	**272**	**192**		**260**	**200**	**77**

Figure 25. Stage Groundwater Extraction of Nambiyar Aquifer system

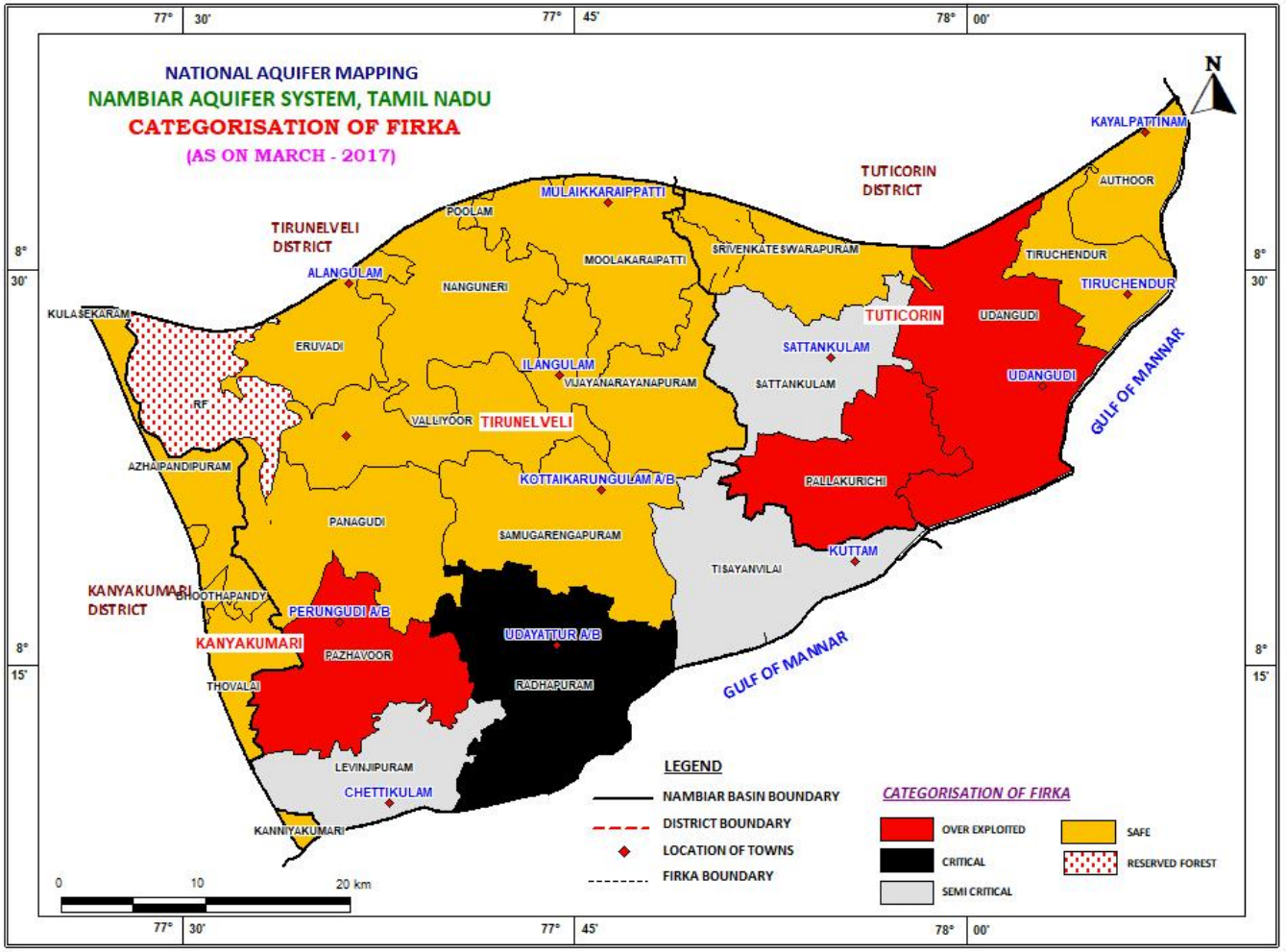


Figure 26. Categorisation of firka – Nambiyar aquifer system

5.0. GROUNDWATER RELATED ISSUES

Groundwater is extensively utilized for irrigation in the entire basin area for the past two decades, especially in the 4 over-exploited and critical firkas out of the 16 firkas of the study area. Anthropogenic contamination in the basin is restricted to the urbanized centers of Tirunelveliarea.

5.1.Geographical distribution & Resource Availability

In the study areanorthern and northwestern partis reeling under over development. Over all out of 16 firkas of the study areas 4 firkas are over exploited and critical.In these areas the groundwater has been extensively developed by constructing groundwater abstraction structures like dug wells, dug cum borewells and borewells. Groundwater developments in these firkas are to be restricted

Further, there is ample scope for groundwater development in the 12 safe and semi-critical firkas. Whereas these area are under developed due to the poor yielding aquifer system and also due to the high EC concentration in few firkas along the coast. Based on the out put of the aquifer mapping studies a management plan is chalked out for the further management of resources available in the aquifer system.

5.2. Less potential and Poor yielding Aquifer

Fracture analysis of the borewells drilled in the study area reveals that almost the entire area is covered under hard rock terrain represented by Region A-Charnockite&Khondalite group of rocks and Region B- Gneiss group of rock. In both the region the rocks are low potential with poor yielding fractures. In the Region-A most of the fractures occurs within 40-60 m bgl and the frequency of occurrence of fractures are promising in these depth zone. In some areas the fracture system existupto the depth of 197 m bgl, but the frequency of occurrence of fractures in these depth ranges is low. In Region B-Gneiss rock terrain most of the fractures occurs within the depth range of 60-80 m bgl. In Granitic Gneiss region most of the fractures area confined to 100 – 150 m bgl. Comparatively Charnockite&Khondalite aquifers yield less than granitic gneiss and it occupies about 30% of the study basin. In these areas water scarcity problem exist and the people are struggling to meet their domestic demands. Fracture analysis chart in Hard rock area of the Nambiyar aquifer system is given in **Figure 27.**

5.3. Groundwater quality issues

Threat of groundwater pollutionexistsall along the river course of Nambiyar,Karamaniyar and Hanumannadiespecially near the urban centres. High EC and Cl values are reported in few pockets of the aquifer system all along the coast of gulf of Mannarand also few samples are reported for high F (Tisayanvila, Radhapuram, panagudi&Tiruchendurfirkas) and high NO_3 in Levinjipuram, Radhapuram, Panagudi, Samugarengapuram, Tisayanvila, Pallakurichi, Udangudi&Srivenkateswarapuramfirkas.

5.4. Future Demand Scenario and Stress on Aquifer system

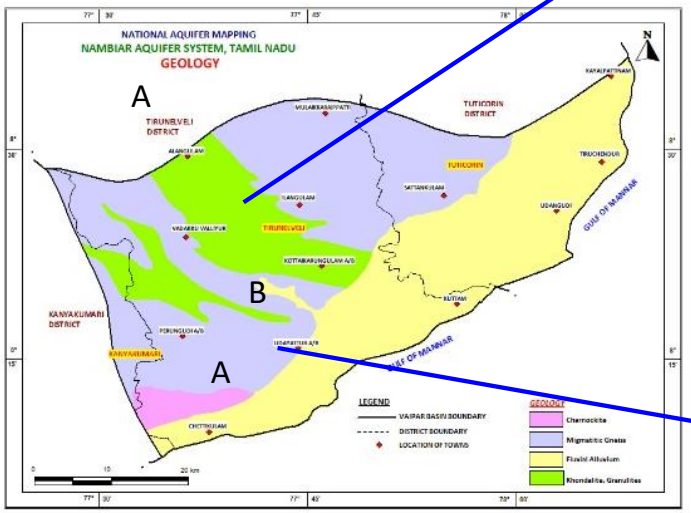
Future groundwater demand projected for domestic utilization upto the year 2025 is calculated as 8 MCM. This will have minimal additional stress on the aquifer system compared to the existing groundwater draft. However, draft can be regulated through increasing the water efficiency practices in irrigation sector. Already the dependency on groundwater for domestic and drinking needs is decreasing in groundwater contaminated areas as the alternative surface/

river sources are being harnessed. About 12 firkas falls in safe category which has a potential to develop groundwater resources but precation should be taken in such a way that the groundwater in these firkas should not get deterioted.

Nambiyar Aquifer System – Fracture analysis

No. of Bore Wells analysed : 46

Depth of Bore Wells (28 nos). : > 150 m bgl



Charnockites & Khondalite region-A

No. of Bore Wells analysed : 21
Most of the fractures occurs within : 40-60 mbgl
Frequency of occurrence of fracture upto : 197 mbgl

- Nil Fracture : 0 Wells
- 0 - 50 m depth : 13 Wells
- 50– 100 m depth : 05 Wells
- 100 – 150 m depth : 03 Wells
- 150 – 197 m depth : 04 Wells

Granite Gneiss region -B

No. of Bore Wells analysed : 25
Most of the fractures occurs within : 60-80 mbgl
Frequency of occurrence of fracture

- Nil Fracture : 02 Wells
- 0 - 50 m depth : 18 Wells
- 50– 100 m depth : 09 Wells
- 100 – 150 m depth : 05 Wells
- 150 – 197 m depth : 07 Wells

Figure 27. Fracture analysis chart in Hard rock area.

6 .0. MANAGEMENT STRATEGIES

The groundwater management strategies are inevitable either when there is much demand to the resource than the available quantity or when the quality of resource deteriorates due to contamination in a given geographical unit. In recent years groundwater resources are used extensively for irrigation in the study area. In addition, to meet the domestic requirements of the fast growing urban agglomerations and establishment of Industries in the coastal area of the study area the administrators are compelled to allocate a considerable quantum of resource which otherwise is being used for irrigation purpose. So, the urbanization and Industrialization has a negative impact on the food production as well as grabbing the employment of the agricultural laborers.Also the limited groundwater resources available in the less fractured and jointed aquifer system of the study area, unequal distribution of groundwater resources in these areas creates more demands for the resources. 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 area of Nambiyar aquifer system, the sustainable management plan for groundwater is being proposed after a thorough understanding of the aquifer disposition down to a depth of 200m bgl in the hardrock area.

6.1Sustainable Management Plan

The groundwater resource of 16firkas of the aquifer system are estimated.Gross groundwater extraction of 200 MCM is estimated for the 16 firkasas per the GEC 2015 against the annual extractable groundwater reources260 MCM. Excess groundwater was withdrawn from the 4 Over Exploited and Critical firkasout of 16 firkas of the study area. Therefore, the usage of groundwater in these over exploited and critical firkas has to be reduced by 30 to 50 percent of the existing draft for the sustainability of the resource in these firkas, or else the availability has to be augmented through artificial recharge methods to bridge the gap between draft and availability. The draft can be reduced through application of water efficiency methods in irrigation sector and through changing the irrigation practices from wet to dry cash crops.

6.2Augmentation Plan

Augmentation of groundwater can be achieved through construction of percolation ponds and recharge shafts where the top soil zone is clayey which does not allow infiltration. Normally it can be achieved through capturing surface runoff. Surface water transfer also can be planned in the absence of surface runoff during droughts. It needs uncommitted runoff from the adjoining localities to transport to the needy areas through diversion channels.

In the study area southwestern and easternpartare subjected to Over-exploitation. Normally due to over exploitation of groundwater the water levels are depleting in this zone. The natural rainfall recharge is insufficient to recoup the extracted groundwater.Artificial Recharge and Water Conservation Plans are proposed in the OE&Criticalfirkasof the basin through utilizing the uncommitted surface runoff of 54 MCM.

6.2.1. Artificial Recharge Plan

Based on the water level monitoring in different seasons across the basin, as well as 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 first aquifer of the 4 Over Exploited and Criticalfirkashas been estimated as 114MCM. But the annual uncommitted runoff is only 54 MCM which is less than 50% of

required water to fill the available void space of aquifer-I. Artificial recharge and Water conservation plan is prepared for the over exploited and criticalfirkas of the basin area through harnessableannual uncommitted runoff of 49 MCM only with a total out lay of 9.8 crore rupees.

The suggested artificial recharge structures are mainly masonry check dam, Nala bunds, Recharge ponds and Recharge Shafts in addition to removal of silt in the surface tanks. Selection of the site locations of these structures are based on the critical analysis of the hydrogeological, geophysical and exploration data of the basin**(Figure 29).** Particularly geomorphological and drainage aspects are being given more weightage in selection of the Artificial Recharge structures.

A total number of 11 check dams, 5 nala bunds, 18 recharge shafts and 200 recharge ponds are proposed in the OE and critical firkas of the basin. A total number of 44 Recharge Rejuvenation ponds are selected for desilting followed by construction of recharge shafts within the tanks. The expected recharge through these artificial recharge structures is in the order of 22 MCM (Figure 28).

The expected benefit by the recharge structures in the 4 Over Exploited and Critical firkasarea will be helpful to arrest decline in groundwater levels or increase pumping hours or increase in sustainability of well yield.

Supply Side Management

Present stage of GW Extraction of OE&C firkas (4 nos.) of the Basin: 117.17%

ARTIFICIAL RECHARGE /CONSERVATION MEASURES		
Artificial Recharge Structures Proposed	Masonry Check dams :	11
	Nala bunds :	5
	Recharge shafts (Tanks:18) :	18
	Repair, Renovation and Restoration of water bodies with Recharge shafts (Tanks 44) :	44
	Recharge ponds(farm ponds)	200
Tentative total cost of the project (Rs.)	:	9.80 Cr
Vol. of unsaturated zone available for Recharge (upto 3m bgl)	:	114 MCM
Uncommitted Surplus runoff	:	54 MCM
Harnessable runoff	:	49 MCM
Expected recharge	:	22 MCM
Expected outcome	Arrest Decline in Groundwater levels (or) Increase pumping hours (or) Increase in sustainability of well yield (or)	
Implication of supply side management proposal may bring down the stage of GW extraction : From 117.66 to 84.66 %		

Figure 28. Supply side management of Nambiyar aquifer system.

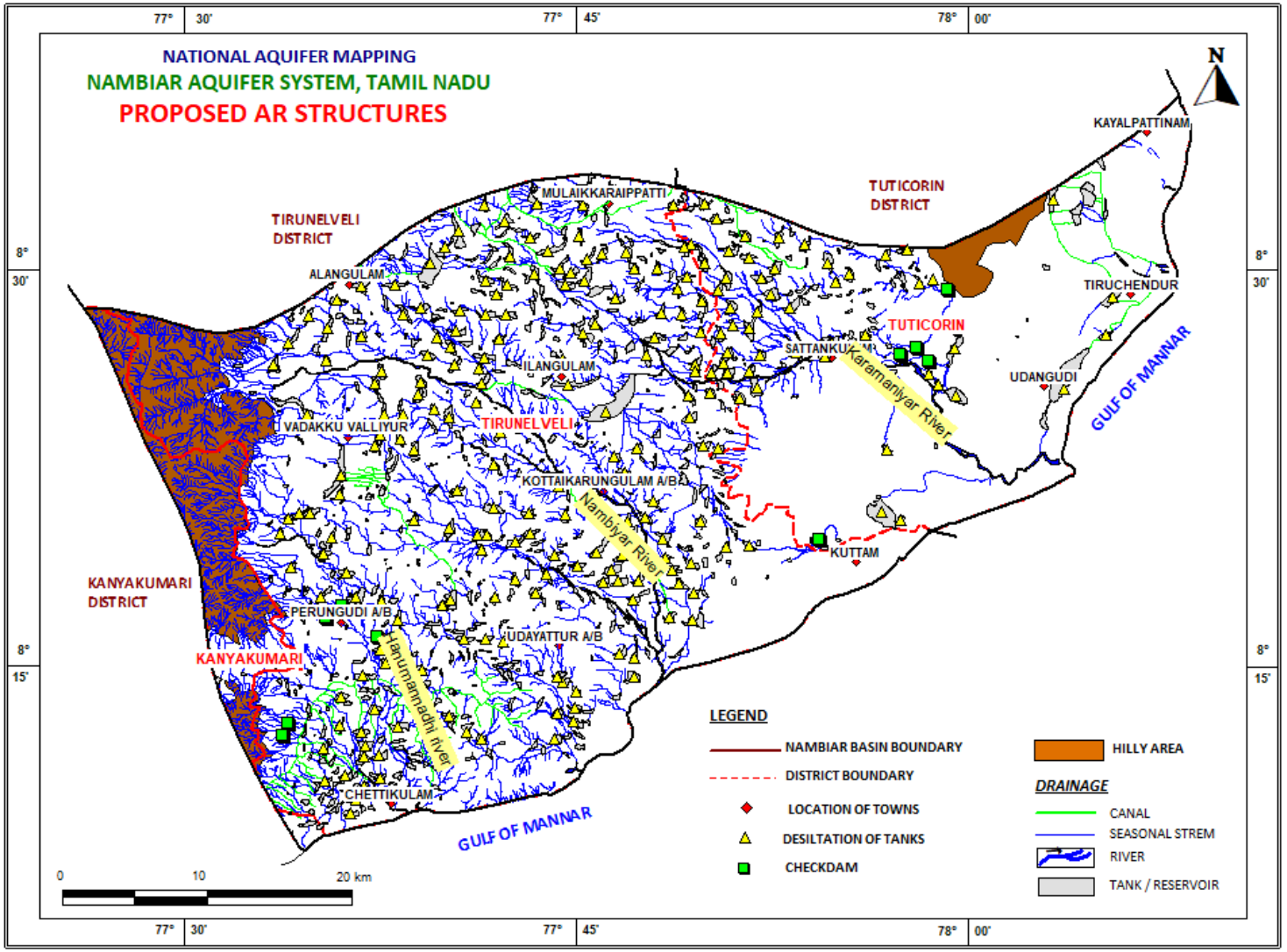


Figure 29. Location of Proposed Artificial Recharge sites

6.3. Demand side Management Plan

Demand side management can be accomplished through change in irrigationpattern. It is recommended to change the irrigation pattern for paddy, Sugarcane and Banana crops. The general practice for paddy irrigation is by flooding method. It is recommended for ridge and furrow method instead of flooding method in 50% area of the total paddy area 705 Ha. This would save groundwater annually of 1.27mcm.Similarly for banana crops shift from flooding to drip irrigation would save 0.56 mcm. The total water saved is 1.83mcm**(Figure 30).**

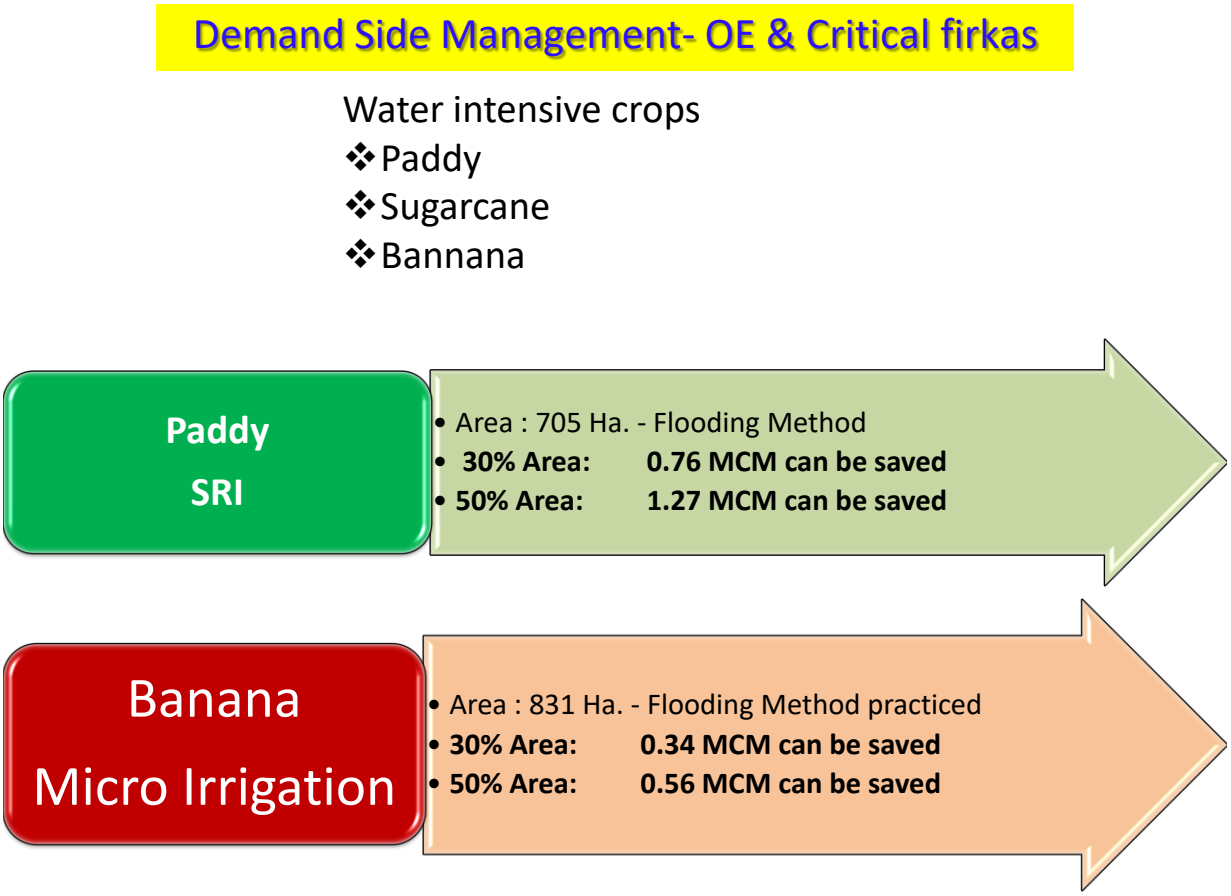


Figure 30. Demand side management of Nambiyar aquifer system.

The total cost for the change in the irrigation pattern for those water intensive crops would be 4.6 crores. If Scenario 1 - 30% Area is changed then water saved would be 1.1 MCM. The cost would be 2.76 crore and the Stage of Development would be lowered from 117 to 115%. In case of Scenario II wherein 50% Area is changed then Water saved would be 1.83 MCM and the Cost would be 4.6crore. The stage of Development would be lowered from 117 to 114 %.

If both the supply side and demand side are managed by augumenting22 mcm of water recharged with that of the 1.83 mcm water saved by adopting change in method of irrigation, it may be possible to bring down the existing stage of ground water extraction from 117 % to 82 %.

6.4. Future Demand Stress Aspects

In views of rapid urbanization the domestic water needs are increasing multifold. In this urbanization process the water wastage component is increasing mainly because of leakages through distributor system. Whereas in the agricultural irrigation sector the water demand mainly due to the enthusiasm of the farmers to increase the crop irrigation area.

Hence the policy makers at higher administrative level and rural development authorities at block level should educate the farmers in their jurisdiction in such a way that they should not venture to increase the farm irrigation area. Rather these authorities have to suggest high yielding crop varieties and high-value crops to grow with minimum water requirement with the technical guidance of local agricultural/ agronomic experts.

6.5. Strategies to overcome the future stresses

Future stresses are only hypothetical. If the sustainable management is taken up in a true spirit in consultation with local village level bodies the groundwater depletion will not occur in future. However, it is very difficult to overcome gluttonous user attitude thrives for fullest use of the resource to get maximum output. In this process the vital resource is lost. Therefore a thorough understanding of the consequences of indiscriminate usage of the water should be propagated among users mainly among farmers as they are bulk users of the resource in the study area.

Thedemand side strategies to overcome future stresses are mainly

- Promoting irrigation patternchange
- Agronomic Water Conservation
- Reducing Water use in Urban areas

Annexure-I

List of Proposed Artificial Recharge structures-Nambiyar aquifer sytem

S.No.	Proposed Structure	Longitude	Lattitude
1	Check Dam	77.9052	8.33039
2	Check Dam	77.9583	8.42085
3	Check Dam	77.9668	8.45135
4	Check Dam	77.9871	8.48765
5	Check Dam	77.9748	8.44293
6	Check Dam	77.9572	8.44649
7	Check Dam	77.6012	8.28803
8	Check Dam	77.5908	8.28055
9	Check Dam	77.6237	8.26895
10	Check Dam	77.5664	8.21394
11	Check Dam	77.5632	8.20683
12	Nallah Bund	77.5586	8.20943
13	Nallah Bund	77.5574	8.21291
14	Nallah Bund	77.5563	8.22323
15	Nallah Bund	77.5648	8.19898
16	Nallah Bund	77.5552	8.21678

Annexure-II

List of Proposed tank for desiltation

S.No.	DHQ_NAME	TEH_NAME	FirkaName	TYPE	LONGITUDE	LATITUDE	Tank area
1	THOOTHUKKUDI	SATHANKULAM	Pallakurichi	TANK	77.94	8.35	**2.59**
2	THOOTHUKKUDI	SATHANKULAM	Pallakurichi	TANK	77.95	8.39	**0.27**
3	THOOTHUKKUDI	SATHANKULAM	Pallakurichi	TANK	77.96	8.34	**0.23**
4	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.86	8.46	**0.74**
5	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.87	8.43	**0.70**
6	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.85	8.48	**0.51**
7	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.85	8.44	**0.51**
8	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.89	8.45	**0.44**
9	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.91	8.45	**0.40**
10	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.85	8.45	**0.34**
11	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.84	8.46	**0.34**
12	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.84	8.44	**0.34**
13	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.85	8.42	**0.31**
14	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.86	8.44	**0.28**
15	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.91	8.45	**0.24**
16	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.87	8.45	**0.23**
17	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.84	8.44	**0.23**
18	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.87	8.47	**0.23**
19	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.93	8.46	**0.21**
20	THOOTHUKKUDI	SATHANKULAM	Sattankulam	TANK	77.85	8.47	**0.21**
21	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.87	8.49	**0.67**
22	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.85	8.50	**0.64**
23	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.88	8.50	**0.54**
24	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.91	8.50	**0.53**
25	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.84	8.53	**0.47**
26	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.89	8.48	**0.45**
27	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.88	8.52	**0.45**
28	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.85	8.51	**0.44**
29	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.83	8.51	**0.42**
30	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.83	8.54	**0.42**
31	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.87	8.50	**0.40**
32	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.92	8.50	**0.38**
33	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.86	8.51	**0.36**
34	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.90	8.52	**0.34**
35	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.96	8.51	**0.31**
36	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.86	8.52	**0.28**
37	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.84	8.49	**0.23**
38	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.95	8.51	**0.23**
39	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.82	8.52	**0.20**
40	THOOTHUKKUDI	SATHANKULAM	Srivenkateswarapuram	TANK	77.92	8.49	**0.20**
41	THOOTHUKKUDI	TIRUCHENDUR	Tiruchendur	TANK	78.09	8.48	**0.83**
42	THOOTHUKKUDI	TIRUCHENDUR	Tiruchendur	TANK	78.05	8.54	**0.57**
43	THOOTHUKKUDI	TIRUCHENDUR	Tiruchendur	TANK	78.09	8.46	**0.24**
44	THOOTHUKKUDI	TIRUCHENDUR	Tiruchendur	TANK	78.12	8.49	**0.22**
45	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	78.06	8.43	**4.13**
46	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	77.99	8.42	**1.11**
47	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	77.99	8.45	**0.87**
48	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	77.98	8.43	**0.17**
49	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	77.97	8.49	**0.15**
50	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	77.97	8.44	**0.13**
51	THOOTHUKKUDI	TIRUCHENDUR	Udangudi	TANK	77.98	8.49	**0.10**
52	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.56	8.44	**0.53**
53	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.59	8.46	**0.51**
54	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.63	8.44	**0.36**
55	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.57	8.45	**0.33**
56	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.59	8.44	**0.28**
57	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.60	8.48	**0.28**
58	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.61	8.46	**0.25**
59	TIRUNELVELI	NANGUNERI	ERUVADI	TANK	77.58	8.47	**0.20**
60	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.64	8.21	**0.51**
61	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.62	8.20	**0.41**
62	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.62	8.19	**0.40**

63	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.68	8.21	**0.40**
64	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.60	8.18	**0.37**
65	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.62	8.19	**0.30**
66	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.61	8.16	**0.29**
67	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.61	8.17	**0.25**
68	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.59	8.18	**0.23**
69	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.61	8.17	**0.22**
70	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.69	8.21	**0.21**
71	TIRUNELVELI	RADHAPURAM	LEVINJIPURAM	TANK	77.62	8.18	**0.21**
72	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.76	8.49	**0.58**
73	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.78	8.55	**0.55**
74	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.73	8.51	**0.54**
75	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.73	8.54	**0.49**
76	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.82	8.51	**0.47**
77	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.80	8.46	**0.41**
78	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.79	8.50	**0.40**
79	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.75	8.55	**0.38**
80	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.70	8.53	**0.37**
81	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.78	8.51	**0.37**
82	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.75	8.50	**0.35**
83	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.75	8.54	**0.31**
84	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.82	8.50	**0.30**
85	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.77	8.51	**0.29**
86	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.78	8.48	**0.28**
87	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.81	8.54	**0.27**
88	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.76	8.51	**0.27**
89	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.82	8.47	**0.22**
90	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.80	8.47	**0.21**
91	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.69	8.54	**0.21**
92	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.71	8.51	**0.20**
93	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.75	8.52	**0.20**
94	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.72	8.52	**0.20**
95	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.74	8.50	**0.20**
96	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.81	8.49	**0.20**
97	TIRUNELVELI	NANGUNERI	Moolakaraipatti	TANK	77.80	8.50	**0.20**
98	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.66	8.50	**2.23**
99	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.68	8.53	**0.80**
100	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.61	8.49	**0.54**
101	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.64	8.47	**0.45**
102	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.69	8.49	**0.44**
103	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.65	8.43	**0.43**
104	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.67	8.45	**0.42**
105	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.67	8.52	**0.41**
106	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.72	8.50	**0.39**
107	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.69	8.47	**0.38**
108	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.67	8.41	**0.37**
109	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.63	8.49	**0.37**
110	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.65	8.42	**0.35**
111	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.71	8.47	**0.35**
112	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.67	8.46	**0.34**
113	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.66	8.45	**0.34**
114	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.65	8.48	**0.33**
115	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.71	8.49	**0.32**
116	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.74	8.49	**0.32**
117	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.69	8.45	**0.31**
118	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.70	8.46	**0.26**
119	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.67	8.44	**0.23**
120	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.66	8.46	**0.21**
121	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.68	8.48	**0.21**
122	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.70	8.49	**0.21**
123	TIRUNELVELI	NANGUNERI	NANGUNERI	TANK	77.66	8.41	**0.20**
124	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.58	8.35	**0.41**
125	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.63	8.29	**0.34**
126	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.64	8.28	**0.32**
127	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.57	8.35	**0.32**
128	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.59	8.32	**0.30**
129	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.59	8.33	**0.27**

130	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.67	8.29	**0.26**
131	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.57	8.31	**0.26**
132	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.60	8.36	**0.25**
133	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.60	8.37	**0.24**
134	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.65	8.34	**0.22**
135	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.60	8.31	**0.21**
136	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.57	8.34	**0.21**
137	TIRUNELVELI	RADHAPURAM	Panagudi	TANK	77.56	8.33	**0.20**
138	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.61	8.29	**0.77**
139	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.61	8.25	**0.45**
140	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.61	8.21	**0.34**
141	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.62	8.22	**0.33**
142	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.63	8.26	**0.30**
143	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.59	8.20	**0.30**
144	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.60	8.23	**0.29**
145	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.63	8.25	**0.26**
146	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.67	8.22	**0.25**
147	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.65	8.25	**0.21**
148	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.64	8.24	**0.21**
149	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.60	8.21	**0.20**
150	TIRUNELVELI	RADHAPURAM	PAZHAVOOR	TANK	77.59	8.29	**0.20**
151	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.67	8.29	**0.50**
152	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.79	8.24	**0.49**
153	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.75	8.22	**0.41**
154	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.79	8.26	**0.40**
155	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.74	8.20	**0.39**
156	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.74	8.24	**0.33**
157	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.68	8.27	**0.32**
158	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.72	8.27	**0.31**
159	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.71	8.31	**0.30**
160	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.78	8.26	**0.30**
161	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.74	8.22	**0.28**
162	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.70	8.27	**0.26**
163	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.66	8.29	**0.25**
164	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.75	8.22	**0.24**
165	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.75	8.23	**0.24**
166	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.72	8.30	**0.24**
167	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.69	8.27	**0.23**
168	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.74	8.24	**0.22**
169	TIRUNELVELI	RADHAPURAM	RADHAPURAM	TANK	77.70	8.29	**0.20**
170	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.76	8.32	**0.75**
171	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.78	8.32	**0.65**
172	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.70	8.35	**0.64**
173	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.77	8.31	**0.61**
174	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.71	8.33	**0.46**
175	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.78	8.30	**0.42**
176	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.77	8.30	**0.37**
177	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.72	8.33	**0.35**
178	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.69	8.33	**0.34**
179	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.67	8.34	**0.32**
180	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.72	8.35	**0.32**
181	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.79	8.34	**0.29**
182	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.75	8.31	**0.28**
183	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.74	8.35	**0.27**
184	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.79	8.30	**0.26**
185	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.79	8.29	**0.26**
186	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.70	8.38	**0.25**
187	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.80	8.35	**0.25**
188	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.73	8.31	**0.24**
189	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.74	8.36	**0.24**
190	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.81	8.28	**0.24**
191	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.67	8.36	**0.22**
192	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.69	8.32	**0.21**
193	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.69	8.33	**0.21**
194	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.74	8.32	**0.20**
195	TIRUNELVELI	RADHAPURAM	SAMUGARENGAPURAm	TANK	77.78	8.34	**0.20**
196	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.82	8.28	**0.72**

197	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.81	8.33	**0.45**
198	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.83	8.34	**0.42**
199	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.82	8.30	**0.37**
200	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.82	8.32	**0.37**
201	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.85	8.33	**0.29**
202	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.81	8.32	**0.24**
203	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.83	8.30	**0.23**
204	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.86	8.33	**0.23**
205	TIRUNELVELI	RADHAPURAM	TISAYANVILAI	TANK	77.81	8.31	**0.22**
206	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.60	8.37	**1.20**
207	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.70	8.40	**0.48**
208	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.63	8.41	**0.47**
209	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.65	8.39	**0.40**
210	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.69	8.43	**0.35**
211	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.70	8.40	**0.34**
212	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.58	8.41	**0.33**
213	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.62	8.43	**0.33**
214	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.64	8.39	**0.30**
215	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.67	8.41	**0.27**
216	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.63	8.40	**0.26**
217	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.62	8.39	**0.23**
218	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.69	8.42	**0.22**
219	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.64	8.41	**0.22**
220	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.69	8.44	**0.20**
221	TIRUNELVELI	RADHAPURAM	VALLIYOOR	TANK	77.74	8.40	**0.20**
222	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.77	8.41	**4.06**
223	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.75	8.43	**0.68**
224	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.75	8.46	**0.60**
225	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.82	8.42	**0.50**
226	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.82	8.41	**0.49**
227	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.83	8.48	**0.38**
228	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.83	8.39	**0.37**
229	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.83	8.44	**0.31**
230	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.76	8.47	**0.31**
231	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.78	8.37	**0.29**
232	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.84	8.39	**0.24**
233	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.79	8.45	**0.24**
234	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.83	8.44	**0.23**
235	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.77	8.38	**0.23**
236	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.84	8.42	**0.23**
237	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.79	8.39	**0.22**
238	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.74	8.44	**0.22**
239	TIRUNELVELI	NANGUNERI	VIJAYANARAYANAPuram	TANK	77.83	8.46	**0.22**

Annexure-III

Groundwater availability and stage of ground water extraction of the firkas of Nambiyar Aquifer system

Sl.No	District	Assessment Unit (Firka)	Command/ Non-command/ Poor GW Quality	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross Ground Water Draft for domestic and industrial water supply	Existing Gross Ground Water Draft for All uses (11+12)	Provision for domestic and industrial requirement supply to 2025	Net Ground Water Availability for future irrigation development (10-11-14)	Stage of Ground Water Development {(13/10)*100} %	Category
1	Thoothukudi	PALLAKURICHI	Total	1140.28	1888.70	69.54	1958.24	85.43	-833.85	172	Over Exploited
2	Thoothukudi	SATTANKULAM	Total	1588.98	1402.40	30.20	1432.60	37.10	149.48	90	Semi critical
3	Thoothukudi	SRIVENKATESWARAPURAM	Total	2082.78	1371.70	41.88	1413.58	51.45	659.62	68	Safe
4	Thoothukudi	TIRUCHENDUR	Total	2250.63	1034.40	35.53	1069.93	43.65	1172.58	48	Safe
5	Thoothukudi	UDANGUDI	Total	1846.37	1819.00	93.07	1912.07	114.33	-86.96	104	Over Exploited
6	Tirunelveli	ERUVADI	Total	2258.40	1196.10	46.66	1242.76	55.59	1006.71	55	Safe
7	Tirunelveli	LEVINJIPURAM	Total	1062.79	822.60	59.26	881.86	70.59	169.60	83	Semi critical
8	Tirunelveli	MOOLAKARAIPATTI	Total	1515.36	1255.55	34.25	1289.80	40.80	219.01	85	Semi critical
9	Tirunelveli	NANGUNERI	Total	1564.87	776.30	81.30	857.60	96.85	691.72	55	Safe
10	Tirunelveli	PANAGUDI	Total	1602.14	999.60	7.46	1007.06	8.88	593.66	63	Safe
11	Tirunelveli	PAZHAVOOR	Total	1276.69	1425.00	71.27	1496.27	84.90	-233.21	117	Over Exploited
12	Tirunelveli	RADHAPURAM	Total	1467.45	1306.20	42.09	1348.29	50.14	111.10	92	Critical
13	Tirunelveli	SAMUGARENGAPURAM	Total	1749.26	985.80	30.22	1016.02	36.00	727.46	58	Safe
14	Tirunelveli	TISAYANVILAI	Total	1454.72	923.55	9.04	932.59	10.77	520.40	64	Safe
15	Tirunelveli	VALLIYOOR	Total	1795.24	873.60	18.17	891.77	21.64	900.00	50	Safe
16	Tirunelveli	VIJAYANARAYANAPURAM	Total	1347.94	1200.20	7.17	1207.37	8.55	139.20	90	Semi critical