FINAL REPORT
of
MAJOR RESEARCH PROJECT
UNIVERSITY GRANTS COMMISSION
NEW DELHI

[F.N. 40-301/2011(SR), & 30 JUN 2011 W.E.F. JUNE 30, 2011]

For

GEOLOGY SUBJECT ENTITLED

Integrated Artificial Rainwater Harvesting Structure and Groundwater Resource Development in Hard Rock Terrain Using Geophysical Data Remote Sensing and GPS in GIS: A Case of Sarabanga Sub-Basin of Cauvery River, South India.

Submitted by

Dr. S.VENKATESWARAN.M.Sc.,M.Phil.,Ph.D.

Professor and Head, Principal Investigator

Name of the Organization

PERIYAR UNIVERSITY

A State University

NAAC Reaccredits with A - CGPA 3.15

DEPARTMENT OF GEOLOGY

PERIYAR PALKALAI NAGAR

SALEM – 636 011

TAMILNADU

OCTOBER-2015

DECLARATION

I declare that the work presented in this report ***"INTEGRATED ARTIFICIAL RAINWATER HARVESTING STRUCTURE AND GROUNDWATER RESOURCE DEVELOPMENT IN HARD ROCK TERRAIN USING GEOPHYSICAL DATA REMOTE SENSING AND GPS IN GIS: A CASE OF SARABANGA SUB-BASIN OF CAUVERY RIVER, SOUTH INDIA."*** is original and carried throughout independently by me during the complete tenure of Major Research Project of University Grants Commission, New Delhi.

Date:

Place: Salem-11

Principle Investigator

ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude to University Grants Commission, New Delhi for the financial support extended for completing this work.

I am thankful to Periyar University for necessary help rendered to me for the completion of this report.

I wish to record my sincere thanks to Public Works Department (PWD), Statistical Department, Tamilnadu Water Supply and Drainage Board (TWAD), Govt.of Tamil Nadu, Central Ground Water Board (CGWB), Geological Survey of India (GSI) and Soil Survey of India (SSI) for their data and technical support to carry out the research work.

I also express my sincere thanks to the Salem collectorate officials for providing attribute data with respect to village level information.

I sincerely thank the Director, NRSC, Hyderabad for providing IRS-P6 LISS IV satellite data that has been used for preparing land use, land cover, geomorphology and lineament maps.

I am also thankful Project Fellow Dr.M.Vijay Prabhu has helped me for the completion of this project work and also thank other research scholars Dr.M.Thangaraju, Dr.M.Elangomannan, Dr.K.L.K.Vallal, Dr.S.Vediyappan, Dr.P.Jayapal, Dr.P.Pragatheeswaran, Dr.S.Karuppannan, Mr.R.Suresh, Mr.Ananda Prakesh, Mr.Mohammed Rafi, Mr.Panner Selvam, Mr.R.Ayyandurai Mr.R.Kannan, Miss.S.Deepa and Mr.S.Satheeshkumar in the Hydrogeological Laboratory, Department of Geology, Periyar University.

I use this occasion to express my deep sense of thanks to my colleagues, office staff of my Department for their valuable help to finish this Major Research Project successfully.

Prof.Dr.S.Venkateswaran
Principle Investigator

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Annexure – IX

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

BRIEF REPORT OF THE UGC MAJOR RESEARCH PROJECT "WATER GIS"

1. Title of the Project: Integrated Artificial Rainwater Harvesting Structure and Groundwater Resource Development in Hard Rock Terrain Using Geophysical Data Remote Sensing and GPS in GIS: A Case of Sarabanga Sub-Basin of Cauvery River, South India.

2. Principal Investigator(s) and Co-Investigator(s):

Principal Investigator	Co-Investigator
Dr.S.VENKATESWARAN, M.Sc.,M.Phil.,Ph.D. Professor and Head & Principle Investigator Department of Geology Periyar University Salem, Tamil Nadu 636 011 Mobile: 09443415209, Fax-0427-2345124 Email-geosvenkat@gmail.com provnkdswrn@gmail.com	**Mr.R.SURESH, M.Sc., M.Phil.,** Assistant Professor Department of Geology Periyar University, Salem - 636011 Telephone: 0427-2345766. Ext.262. Fax: 0427-2345565; 0427-2345124 Mobile: 09940991972 Email- Calcite15@yahoo.com

3. Implementing Institution(s) and other collaborating Institution(s): Periyar University, Salem, Tamil Nadu- 636 011.

4. UGC approval letter no and date: **40-301/2011(SR) & 30 JUN 2011**

5. Date of implementation: **1.07.2011**

6. Tenure of the project: **01.07.2011 to 31.06.2015**

7. Total grant allocated: **Rs.11,59,388/-**

1st Installment Rs.5,55,800/- (Project Grand Rs.4,11,800/- and Project Fellow Fellowship Rs.1,44,000/-(Annexure-I)

2nd Installment Rs.5,14,830/- (Project Grand Rs.1,12,000/-Enhancement of Fellowship Arrear and HRA for the period of 12.08.2011 to 12.08.2014 (Three Years Rs.4,028,30/-) Enclosed photocopy of Sanction letter (Annexure-II)

8. Total grant received: **Rs.10, 70,630/-** (1st Installment Rs.5,55, 800/- + 2nd Installment Rs.5,14,830/-)

9. Final expenditure:

Items	Total grant allocated	Total grant received
1st Installment (UC attached as on 14.03.2013)	Rs.5,55,800/- (Project Grand and Project Fellow Fellowship)	Rs.5,55,800/-
2nd Installment (Final UC attached)	Project Grand Rs.5,14,830/- Enhancement of Fellowship Arrear and HRA for the period of 12.08.2011 to 12.08.2014 (Three Years)	Rs.5,14,830/-
1st+2nd Installment	Rs.11,59,388/-	Rs.10,70,630/-
Balance Amount	(Rs.11,59,388/-- Rs.10,70,630/-)	**Rs.88,758/-**
Balance amount has to be reimburse to the PI is **Rs.88,758/-(Eighty Eight Thousand Seven Hundred and Fifty Eight Only)**		

10. Title of the Project: Integrated Artificial Rainwater Harvesting Structure and Groundwater Resource Development in Hard Rock Terrain Using Geophysical Data Remote Sensing and GPS in GIS: A Case of Sarabanga Sub-Basin of Cauvery River, South India.

11. Objectives of the project:

- To understand the hydrometeorological, hydrogeomorphological, geology and soil characteristics of the study area.
- To demarcate the groundwater potential zones using geo electric measurements.
- To determine the quality of groundwater to evaluate their suitability for domestic, irrigational and industrial purposes.
- To identify the Hydrochemical patterns and develop a hydrogeochemical model.
- To integrate various thematic maps using GIS software version 10.1, to demarcate groundwater potential zones of the study area.
- To identify suitable locations for constructing artificial groundwater recharge structures.

12. **Whether objectives were achieved :** Yes fully achieved

(A) Methodology adopted for this study

The systematic methodology adopted in this project has been given below.

- Preparation of base map in 1:50,000 scale using Survey of India Toposheets No.58 E/10, 13, 14, 58 I/1 and 2 published during the Year 1973.
- Data pertaining to rainfall, water level, geology and other relevant geographical data have been procured from professional scientific organizations.
- Preparation of thematic maps with geology, geomorphology and land use/land cover have been generated using remotely sensed satellite data IRS-P6- LISS IV geo coded data of 1:50,000 scale.
- After adequate field checks, thematic maps such as lineament map, lineament density and lineament frequency map, etc., had been finalized.
- Various thematic maps have been integrated by using GIS platform to locate groundwater potential zones in the study area.
- Resistivity data have been used to identify different layer parameters and to map favorable zones for sustainable groundwater development.
- To compare seasonal quality variation in groundwater for Pre and Post-monsoon seasons for the years 2011 and 2012.
- To prepare geospatial interpolation techniques to evaluate the groundwater quality using GIS software. Groundwater quality parameters were compared with the Bureau of Indian Standards (BIS,1991) and World Health Organization (WHO) standards, so as to evaluate the suitability of groundwater for different purposes.
- Integrate all the results using Geo spatial techniques to derive suitable sites for artificial groundwater recharge structures.

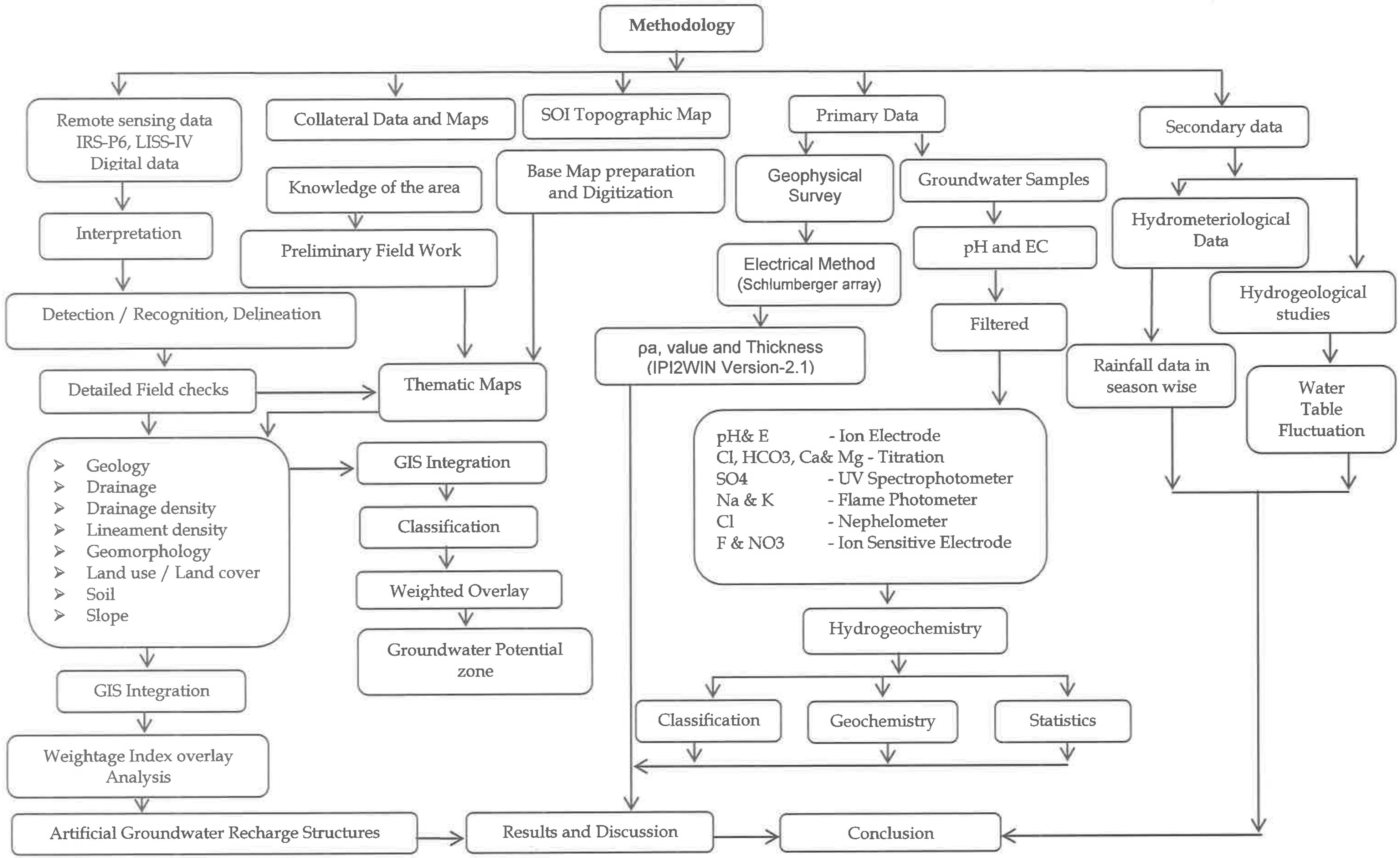

Fig.1.1 Flow Chart depicting the broad methodology adopted in the study

(B) Brief Review of Previous Literatures

Knowledge of the occurrence, replenishment and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters and over drafting of groundwater resources. However, in recent times, emphasis has shifted to the exploration of groundwater resources in hard rock area, which occupies nearly 65 percent of the total area of India. Previous studies pertaining to groundwater potentiality, groundwater chemistry have been attempted either individually or in combination by a number of researchers.

Detailed geological mapping and geophysical surveys were carried out in the district level by the Geological Survey of India (GSI) under different seasonal programme to bring out the surface and subsurface geology and structure. The Institute of Remote Sensing, Anna University has prepared a geomorphological map at taluk level by using IRS satellite Imagery False Color Composite (FCC) in 1:50,000 scale. Geological Survey of India (GSI) has carried out a state wise study on the impact of ongoing large scale pumping of the groundwater regime. Systematic hydrogeological Surveys, photogeological studies, groundwater exploration and long term monitoring of the groundwater regime are also being carried out by the State Groundwater Division of Public Works Department (PWD). Tamil Nadu Water supply and Drainage board (TWAD) has carried out extensive exploration work in groundwater for sighting suitable areas to drill bore wells to provide the protected drinking water supply under Rural Water Supply scheme (RWS). Central Groundwater Board (CGWB,2009) has carried out systematic hydrogeological surveys by establishing its own observation wells to study groundwater fluctuation and groundwater exploration by electrical logging at regional level for the whole district is designed for bore wells within the study area.

2.Rain fall and Water level

The connections between scientific knowledge and the human context of water are examined to understand how the complex task of living with water may be judiciously approached (Narasimhan, 2005).Namias (1968) studied the trend of rainfall of Central Park Observatory, New York and related it to general circulation aberration. This was highly helpful in correlating rainfall and water level. Raju (1998) noted that of the total rainfall received in the country goes as 59% is lost by way of direct evaporation, 29% as runoff and 12% constitutes the infiltration. Out of the runoff, nearly 40% is again lost by way of direct evaporation, leaving only 17% of the rainfall as available flow in surface water bodies. This underlines the need to look at subsurface water studies more.

Man uses water for domestic, agricultural, social and industrial purposes. The increase of the population and its needs have led to the deterioration of surface and sub surface water. Groundwater levels may show seasonal variations due to rainfall (Todd, 1980a). The spatial pattern of groundwater utilization shows good correspondence with dynamic groundwater level in Water Balance studies in the overexploited Rasipuram Area, Tamil Nadu, (Ballukraya, 2004).

Water levels systematically measured in open wells are studied by means of maps, graphs and sections. Commonly used maps are the water table contour maps, water level change maps, depth to the water level maps, water level profiles and well hydrographs. If the details of well construction and aquifer geometry are known, water level contour maps can be classified more precisely as piezometric maps, water table maps or potentiometric maps (Davis and De Wiest, 1966). The water table map can summaries all information about (i). The state, extent of the zone of saturation, gradient, direction of movement along with the behavior of groundwater and (ii). The nature of outflow from and inflow into the groundwater system. Representation of water table by conventional contour type maps showing the elevation of water level Above Mean Sea Level is rather generalized in nature, being not capable of bringing out the pertinent features of the dynamics of groundwater flow and is often liable to subjective errors (Biswas and Chatterjee, 1967). This is true in case of hard rock areas, where groundwater occurs in weathered, jointed, fractured and fissured pockets of variable dimensions (Narayana Rao, 1972).

Study on the hydrogeology of an area will help in understanding characteristic of the aquifer system, fluctuation in groundwater level, flow and recharge mechanisms. Importance of hydrogeology was well documented by VenTe Chow (1964). Detailed work on hydrology and water resources engineering were initiated by several authors (Hvorsleve, 1951; Hantush, 1960; Walton, 1970; Nutbrown, 1976; Parizek, 1976; Black and Kipp, 1977; Thomas, 1979; Todd, 2005; Karanth, 1987; Ramesam, 1987; Ward and Robinson, 1989; Raghunath, 2002; Ballukraya and Ravi, 1999; Shinstine et al. 2002. Singh and Gupta (1999) studied about infiltration studies and artificial recharge.

The occurrence and movement of groundwater in a watershed of a hard rock terrain are mainly controlled by secondary porosity caused by fracturing of the underlying rocks (Srivastava and Bhattacharya 2006). A detailed study on evaluation of groundwater development prospects in Kadalundi river basin of Kerala state was carried by Narasimha Prasad et al. (2007). Based on the hydrological properties and hydraulic parameters, the alluvial plain has been divided into three zones in parts of south Ganga plain, Bihar by Dipankar Saha (2007). Estimation of water balance and sediment yield pertaining to two forest watersheds in Kerala state was carried by Suresh Babu et al. (2007). Geomorphology of an area is one of the most important features in evaluating the groundwater potential and prospect (Kumar et al. 2008). Groundwater flows preferentially through a network of voids, conduits, joints, and fractures (CGWB 2009). Secondary structures like joints and fractures are developed with the intrusion of dolerite dykes and quartz veins (Sankaran et al. 2010b). Lineaments are the linear, rectilinear, curvilinear features of tectonic origin observed in satellite data. These lineaments normally show tonal, textural, soil tonal, relief, drainage and vegetation linearity and curvilinerities in satellite data (Sukumar et al., 2014).

3. Hydrogeophysics

Geophysical resistivity surveys are regularly used for studies related to groundwater investigations. Resistivity profiling delineates the lateral changes in resistivity that can be correlated with steeply dipping interfaces between two geological formations in the subsurface. Resistivity sounding determines the thickness and resistivity of different horizontal or low dipping subsurface layers, including the aquifer zone. However there are some limitations in such investigations, as they fail to distinguish between formations of similar resistivites such as saline clay and saline sand, which causes low resistivity due to water quality. Ambiguity regarding low resistivity also arises from the enhanced mobility of ions in areas of high geothermal activity. An integration of geophysical method combined with chemical data largely resolves the uncertainty.

The electrical resistivity method is widely used in groundwater exploration studies (Todd, 1959) because it's least expensive of all geophysical methods requiring no specially trained technicians to operate the instrument. Water barren formations can be identified based on the contrast in electrical resistivity (Zohdy et al., 1974) Master curves and tables for Vertical Electrical Sounding (VES) enhanced the development in resistivity surveys (Orellana and Mooney, 1966). The resistivity of highly weathered saturated gneisses of Archaean age ranges from 27 to 120 Ω m. Electrical resistivity method is proved to be more appropriate for groundwater studies in hard rock terrains (Ratnakar Dhakate et al., 2008; made a significant observation regarding depth and exploration using DC electrical methods within a specified domain of the resistivity, layer thickness and electrode spacing. Electrical resistivity surveys were also conducted in shales for the estimation of resistivity and the depth to basement by Balakrishnan et al., (1979) and found fruitful results. Balasubramanian et al., (1985) worked on the resistivity method by the combination of isoresistivity and isopach map to classify the freshwater and saltwater horizons. The involvement of computer in the analysis of the resistivity data for direct interpretation was carried out to attain significant results (Basokus, 1990). The earth resistivity surveys were used to define groundwater contamination in Rameswaram, Tamil Nadu, India. Similar work was done by Saha et al., (2007) to identify the hidden Oldham fault in the Assam valley of northeastern, India using geophysical and seismological investigations.

Geoelectrical survey is considered as the most successful geophysical method for detection of groundwater/aquifers. There is substantial change in groundwater resistivity with chemical contamination of water. The Resistivity/conductivity contrast between fresh water and contaminants contain an ionic concentration of radicals, which is considerably higher than that found in fresh groundwater. In general, increased ionic concentration or Total Dissolved Solids (TDS) results in higher electrical conductivity (low resistivity). Thus, an aquifer zone containing contaminants can be delineated by resistivity method. But when the contrast in resistivity between fresh groundwater and contaminated groundwater is very low, it is difficult to distinguish an aquifer zone containing contaminant from the zone with natural groundwater.

4. Hydrogeochemistry

The demand for freshwater is continues to grow in the human population. The diversion of fresh water to supply agricultural, industrial, domestic and municipal needs results in stretching hydrological systems both natural and manmade to limits within the country. A continuous supply of fresh water may already be in scarce and may vary both seasonally and geographically. The study of geochemistry of groundwater is an important aspect for its suitability towards drinking, irrigation and industrial purposes. Each groundwater system in any area has a unique chemistry due to chemical alteration of meteoric water, recharging of the aquifer system (Back 1966; Drever 1988; Hem 1985,1991). The hydrology and geochemistry of water have been discussed in the classic works of Stumm and Morgan (1981),Domenico and Schwartz (1990).The changes in the chemical quality of groundwater depend on many factors, such as soil water interaction, duration of rock water interaction, dissolution of mineral species, sea water and anthropogenic impacts (Stallard and Edmond 1983; Karanth 1991; Subba Rao 1995, 1999; Subba Rao et al. 2001, 2002, 2005, 2006; Aravindan et. al. 2005: Kalu and Casmir, 2010; Wilson Fantong et al., 2008; Pan Wu et al., 2009;SUN Yaqiao et al., 2007; Dipankar Saha et al., 2009; Subramani et al., 2009;GokmenTayfur et al., 2008; Aysen Davraz, 2008; Barbecot, 2000; Cartwright and Weaver, 2005; Cucchi et al., 2007; Franco Cucchi et al., 2008; Janardhana Raju, 2007; Zhu Gaofeng et al., 2009; Kumar et al., 2006). Various workers have carried out extensive studies on water quality. Laluraj et al. (2005), Srinivas et al. (2000)

and Jha and Verma (2000) have reported the degradation of water quality in Hyderabad and Bihar, respectively. Patnaik et al. (2002) have studied water pollution generated from major industries. Similarly, waste water effluents discharged in to streams may enter the aquifer system in downstream, which also affects the groundwater quality. Abbasi et al. (2002) have studied the impacts of wastewater inputs on the water quality. Jagdap et al. (2002) and Sunitha et al. (2005) classified the water in order to assess the water quality for various purposes. They are discussed about the lateral groundwater movement, water exchange between adjacent aquifers, sea water intrusions, contaminant transport and studies for artificial groundwater recharge. Similar studies were done by Mondal and Singh (2004);Das and Kaur (2007).

The hydrogeochemical interpretation of the data obtained and their graphical representation for a meaningful interpretation was put forth by Piper (1954). Later modifications of Piper diagram were done by Durov (1948).The representation chemical analysis data using various standard diagrams were also developed by various authors (Stiff, 1951; Collins, 1975). The calculation of mineral saturation index and thermodynamic equilibrium studies were initiated by Similar works were done by Srinivasamoorthy et al., (2008); Freeze and Cherry (1979).The utility of groundwater is categorized based upon the chemistry of the waters. The studies of groundwater and agricultural utility on the basis of the carbonates in water were done by Eaton (1950), and diagrams for the utility purpose were proposed by Doneen (1966) and USSL (1954), for agricultural utility and permeability conditions.

A number of studies on groundwater quality with respect to drinking and irrigation purposes have been carried out in the different parts of India (Durvey et al. 1997; Niranjan Babu et al. 1997; Majumdar and Gupta 2000; Dasgupta and Prohit 2001;Khurshid et al. 2002; Pulle et al. 2005; Hussain et al. 2005; Ravi kumar, et al 2010; BelgacemAgoubi, et al 2011). Several researchers evaluated the suitability of groundwater for irrigation using various parameters, e.g., Na percent, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Wilcox, and US Salinity Laboratory (USSL) classifications, etc. (Al-Bassam and

Al-Rumikhani 2003; Al-Futaisi et al. 2007; Elampooranan et al. 1999; Elango et al. 1991, 2003;Jeevanandam et al. 2006; Rajmohan et al. 1997;Subramani et al. 2005; Sujatha and Rajeshwara Reddy 2003).Water quality pertaining to shallow coastal aquifers has been recently been studied worldwide for different purposes (Baba et al., 2001; Babu, et al. , 2002).

Water is an indispensable natural resource for life on earth. Potable drinking water is the primary need of every human being. Groundwater and the surface water are the major source of drinking water in both urban and rural areas. The uses of factor analysis in the groundwater chemistry interpretation was done by Ashely and Lloyd (1978). Similar types of works relating to statistical analysis for the groundwater chemistry analysis was done by (Janardhana Raju et al., (2009); Hitchen et al., (1971). In the present study multivariable statistical methods have been used. From this technique one can predict the groundwater quality and also analyze dependent and independent. Statistical data has better representation than graphical representation due to the finite number of variables, variables are limited by convention to major ions and, superior relationship may be introduced by using certain procedures. The high concentration of bicarbonate when compared to carbonate in the water is the result of the reactions of soil CO2 with dissolution of silicate minerals (Bhardwaj et al. 2010). The fluoride contamination in the groundwater indicates the presence of fluoride bearing minerals (Krishna Kumar et al. 2011; Ramachandramoorthy et al. 2010). Water quality analysis is one of the most important issues in groundwater studies. Assessing and monitoring the quality of groundwater is important for sustainable use of these resources (Selvam 2012; Singaraja et al. 2012).

5. Identification of Artificial Recharge Structures

The Central Groundwater Board (CGWB) identified a number of techniques commonly used for artificial recharge. Among these, surface spreading methods were actively used. To ensure the effective and efficient operation of an artificial recharge system, the CGWB suggested a through and detailed hydrogeological study to be conducted before selecting the site and method of recharge. In particular, the following basic factors should be considered: the locations of geologic and hydraulic boundaries; the transmissivity, depth to the aquifer and lithology, storage capacity, porosity, hydraulic conductivity, and natural inflow and outflow of water to the aquifer; the availability of land; surrounding land use and topography; the quantity and quality of water to be recharged; the economic and legal aspects governing recharge; and the level of public acceptance.

In the past, several researchers from India and abroad have used remote sensing and GIS techniques for the delineation of groundwater potential zones with successful results (Karanth and Seshu Babu 1978;Venkatachalam et al. 1991; Ghose, 1993; Chi and Lee 1994; Kamaraju et al. 1995; Khan and Mohd 1997; Ravindran and Jeyaram, 1997; Pradeep, 1998; Shahid et al. 2000; Sarkar et al., 2001; Jaiswal et al. 2003; Rao and Jugran 2003; Natarajan and Shambu Kallolikar, 2004; Sikdar et al. 2004; Sener et al. 2005; Mills and Shata 2009). In these studies, the commonly used thematic layers are lithology, geomorphology, drainage pattern, lineament density, soil and topographic slope. The remote sensing systems provide synoptic coverage and accurate spatial information which enable the economical utilization over conventional methods of hydrogeological surveys. Rapid advances in the development of the Geographical Information System (GIS) which provides spatial data integration and tools for natural resource management have enabled integrating the data in an environment which has been proved to be an efficient and successful tool for groundwater studies (Nour 1996; Edet et al. 1998; Srinivasa Rao and Jugran 2003).

In the recent years digital technique is used to integrate various data to delineate groundwater potential zone but also to solve other problems related to groundwater. Various data are prepared in the form of thematic map using geographical information system (GIS) software tool. Surabuddin Mondal et al, (2007); Prasad et al, (2008); have been carried out weighted overlay analysis of thematic maps pertaining to hydrogeomorphology, geology, drainage, lineament, slope and relief derived high resolution IRS-1C, LISS III and PAN merged satellite images to evaluate groundwater prospects. Further, the data on yield of aquifer, as observed from existing bore wells in the area, has been used to validate the groundwater potential map.

Ravi Shankar and Mohan (2006); Ganapuramet, al (2009) have used Remote sensing data and geographic information system to locate potential zones for groundwater. Various maps (i.e., base, hydrogeomorphological, geological, structural, drainage, slope, land use/land cover and groundwater prospect zones) were prepared using the remote sensing data along with the existing maps. The groundwater availability of the basin is qualitatively classified into different classes (i.e., very good, good, moderate, poor and nil) based on its hydro geomorphological conditions.

In recent years the importance of coupling RS and GIS in groundwater potential assessment studies was realized by, many workers like Das et al.,(1997); Toleti et al. (2000); Bahuguna et al. (2003); Lokesha et al. (2005);Vijith (2007); Chowdhury et al. (2009); Suja Rose and Krishnan (2009); Pradeep Kumar et al, (2010); Vasanthavigar et al, (2011); Preeja et al, (2011); Venkateswaran et al,(2011) for identification and location of groundwater resources using remote sensing data is based on an indirect analysis of some directly observable terrain features like geomorphology, geology, slope, land use/ land cover and hydrologic characteristics. With the capabilities of the remotely sensed data and GIS techniques, numerous databases can be integrated to produce conceptual model for delineation and evaluation of groundwater potential zones.

Horton (1932) in his studies reveals about the drainage basin characteristics and its need for assessing the groundwater recharge zone studies. Chow (1964) stated influence of the geological parameters on construction the recharge structures.

Cohen and Durger (1967) conducted a series of artificial recharge experiments by injecting highly treated sewage effluents in the network of barrier injection well in Long Island, New York, so as to prevent the salt water intrusion from the Atlantic Ocean into the major aquifer of the Island. The artificial recharge practices in Hawai (Hargis and Peterson, 1970) mainly encircled the recharge wells, shafts, pits, induced recharge techniques and percolation ponds. Dixit (1972) opined that evaluation of groundwater potential in hard rock areas depends upon various geological and geomorphological factors and also focused with this for artificial recharge studies.

Since changes in groundwater storage, reflecting the groundwater balance in a basin is the difference between groundwater recharge and discharge, estimation of the recharge and discharge are the two main components in a groundwater balance study of a basin. The simple method of estimating groundwater recharge is by using the rainfall percentage factor. The water table contour maps with a view to find out the groundwater flow direction and to locate the probable recharge and discharge areas.

Asano and Wasserman (1980) conducted an experiment in California and suggested that recharge by injection is usually better where groundwater is deeper and in urban areas where the basin recharge is impractical. Huisman and Osthoorn (1983) suggested that the recharge depends upon the rate of infiltration and percolation and also capacity of horizontal movement of groundwater. Further suggested infiltration galleries or line wells parallel to the drainage for induced recharge.

Based on the results of the geoelectrical sounding coupled with the geological features of the study area (Venkateswara Rao et al., 2004). The varying thickness of weathered rock through the representation of contour diagram depicts clearly the extension of weathering. This layer constitutes the possibilities of water storage capacity (Singh et al., 2002).

Anbazhagan and Ramasamy (1993) studied that the evaluation of detailed geomorphology of an area can give potential clues for selecting suitable sites for artificial recharge. Elango and Mohan, (1997) suggested that percolation tanks can be effectively used for recharging techniques. Jyothiprakash et al. (1997) underline the influence of percolation ponds as recharging structure in small watershed. Cook and Walker (1990) advocated the importance of soil taxonomy in the selection of suitable sites for artificial recharge. Harinarayananet al. (2000) opined that Remote Sensing data can be used for groundwater development and management in watershed. In the guide on artificial recharge of groundwater by CGWB (2000), methods for selecting different sites were described. studied the role of Remote Sensing techniques in groundwater resources development in hard rock terrain.

The two critical factors controlling recharge are 1. the rate of direct recharge by infiltration and percolation into the aquifer system, and 2. the areal extent of over which recharge takes place. Jothiprakash et al. (2003) in their studies on Delineation of potential zones for Artificial Recharge using GIS. They give a weightage for each theme depending on its influence on groundwater recharge.

The check dam becomes relatively stable when the ratio of the dam farmland area to that of the controlled watershed is between 1:25 and 1:15. When the impounded water depth is less than 0.8m and the storage time is shorter than 3 - 7 days, a dam designed for enduring the biggest rainstorm in a century is found to be relatively stable (Zeng et al., 1994). Check dams are the widest spread structures for conserving soil and water in the Loess Plateau.

The constraints imposed by hard rock geology in recharge efforts through percolation tanks are high depth to water table below and around the recharge structure due to the occurrence of the recharge plume and shallow bed rocks, which prevent percolation of water (Muralidharan and Athawale, 1998) and the low infiltration capacity of the thin soils overlying the hard rock formations.

The scope for artificial recharge in an area is basically governed by the thickness of unsaturated material available above the water table in the unconfined aquifer. Depth to water level, therefore, provides the reference level to calculate the volume of unsaturated material available for recharge. Depth to water level recorded during post monsoon period is used for the purpose as areas where the natural recharge is not enough to compensate the groundwater withdrawal, can be easily identified using the water level data. The average water levels for a period of at least 5 years is to be used in order to nullify the effects of variation in rainfall (CGWB, 2007).

To design a system for artificial recharge of groundwater, infiltration rates of the soil must be determined and the unsaturated zone between land surface and the aquifer must be checked for adequate permeability and absence of polluted areas (Herman Bouwer, 2002); opined that percolation ponds are suitable for artificial recharge and can be used for sustainable drinking water supply in rural areas. Radhakrishna (2003) in his studies opined that groundwater recharge can be increased by the construction of various recharge structures. Ganesha Raj and Nijagunappa (2004) in their studies reveals about the influence of lineaments in recharge structures.

Hydrogeomorphological investigations and hydrogeophysical investigations were carried out to identify artificial recharge sites at Shamshabad basin of Ranga Reddy district, Andhra Pradesh (Bekkam, 2007). He located check dam, in fairly ground level after steeper slopes on the upstream side and where the drainage path is nearly straight on a moderate Pedi plain.

(C) Work done in the 1st Year:

- Project Fellow recruited and Preparation of base works were completed.
- Satellite data product purchased and important village coordinate registration were carried out.

Rainfall

- For understanding spatial variability of rainfall in the sub basin, daily rainfall data were collected from Public Work Department (PWD), Govt. of Tamil Nadu and converted into average seasonal rainfall.
- The ten year rainfall data (2002 – 2011) were collected in eleven rain gauge stations located in and around the study area.

- The rain gauge stations namely Edapadi, Kolathur, Kullampatti, Mettur, Omalur, Salem junction, Sankari, Yercaud, Danishpet, Chittur and Nangavall.
- The rainfall attributes were given as an input, interpolation raster maps were generated. Subsequently, these maps were classified with respect to our interest and converted into vector maps.
- High amount of rainfall received during Northeast (32.59 km^2) and Southwest (409.23 km^2) monsoon seasons.

Hydrograph

- For understanding hydrodynamic behavior the daily water level were collected and formulated season wise.
- The water level data attributes were given as an input, interpolation raster maps were generated. Subsequently, these maps were classified with respect to our interest and converted into vector maps.
- Shallow depth of water level were observed in Irupalli and Edapadi locations.

Geology and Geomorphology

- The occurrence of groundwater in a geological formation and the scope for its exploitation primarily depend on the formation of secondary porosity in the hard rock aquifer system.
- Geology map was procured from geological survey of India. Study area geology map is prepared with help of GIS tool.
- In the study area is mainly underlined by Fissile hornblende-biotite gneisses, Charnockite, Granite and Dunite etc.

Work done in the 2nd Year:

Hydrogeophysics

- Quantitative description of aquifers has become vital in order to address several hydrological and hydrogeological problems.

- Fluid transmissivity, transverse resistance, longitudinal conductance, hydraulic conductivity and aquifer depth were derived.
- In specific resistivity techniques are well-established and widely used to solve a variety of geotechnical, geological and environmental subsurface detection problems.
- Vertical Electrical Soundings (VES) were carried out on the groundwater sampling locations to understand the quantity and quality of groundwater.
- Schlumberger Vertical Electrical soundings (VES) survey was carried out at 93 locations with the maximum electrode spacing of 150 m.
- The field data were interpreted by curve matching techniques. For this work, the computer software IPI2WIN has been used.
- The aquifer and its thickness influence the storage of groundwater. GIS analyses were carried out to assess the potential zone. First weathered zone thickness and its resistivity were overlaid. It is highly helpful in assessing the best groundwater potential zones.

Hydrogeochemistry

- In order to meet the requirements for both drinking and irrigation purposes. The most important source of water for drinking and irrigation in many parts of the world is groundwater and hence both its quantity and quality gains importance.
- In order to assess the groundwater chemistry, a total of 90 representative groundwater samples were collected from dug and bore wells which are being extensively used for drinking and other irrigation purposes.
- The samples were analyzed for physico-chemical parameters (pH, EC), major cations (Ca, Mg, Na, K), major anions (CO_3, HCO_3, SO_4, Cl), minor cations (Mn, Fe) and minor anion (NO_3, F) as per standard procedures.

- Their attributes are added and will be analyzed in Arc GIS software. Spatial analysis tools to be used for the preparation of interpolation map.

Work done in the 3rd Year:

- The post monsoon representative groundwater samples are collected, analyzed and interpretation was carried out.
- The post monsoon Hydrochemical data used to prepare variety of spatial distribution maps.
- Final integration map of pre and post monsoon season are carried out. Further the Hydrochemical data were compared with BIS and WHO standards.
- Determining the irrigational suitability of hydrochemical data further projected into standard graphical projection.
- Soil map, collected from the Soil survey of India and further field verification has been done.
- Satellite image is to be processed with the help of ERDAS image processing software, to generate maps like Geomorphology, Land use/land cover and lineament.
- The final integration of rainfall, water level, geology, geomorphology, geophysics, geochemistry and remote sensing data is to be analyzed in GIS environment, to identify the suitable sites for artificial rainwater harvesting structure.
- The significance of the research is to generate data pertaining to water resources at village level.
- The final output map is to be verified with the Ground trough information.

(v) Year wise plan of work and targets achieved (Progress of the work from the Major Research Project "WATER GIS")

WORK ELEMENTS	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	26-26	27-28	29-30	31-32	33-34	35-36
Project Staff recruitment, Preparation of base works.	■	■																
Satellite data purchasing and Secondary data collection			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Rainfall and Water Level data interpretation and preparation of thematic maps				■	■													
Satellite Image interpretation - Digital Image Processing, theme generation and GPS data						■	■											
Primary maps, scanning and digitalization							■	■	■	■	■	■	■	■	■	■	■	
Pre-monsoon Water Sample collection and Geophysical survey and GPS point capture								■	■									
Analysis, interpretation of Hydrochemical data and hydrophysical data									■	■								
Thematic preparation and analysis in GIS environment										■	■							
Ground trough verification											■	■	■	■	■	■	■	
Post-Monsoon season water sample collection,												■	■					
Post-Monsoon season water sample data analysis and interpretation													■	■				
Soil study, soil map preparation and field validation														■	■	■	■	
To identify location of the artificial recharge strecture														■	■	■		
Village wise work plan preparation															■	■	■	
Final cross verification															■	■	■	
Finalization of thematic maps, Tables and Figures																	■	
Final Report Preparation and Submission																		■

THE BRIEF OUTLINE OF THE RESEARCH IS GIVEN IN FIVE CHAPTERS.

First Chapter describes about objectives of the study, review of previous investigations, general description and natural resource characteristic of the study area with reference to location, Administrative setup, Agricultural setup, Groundwater evaluation and Importance of groundwater. It includes Brief Literature Review about Geology, Soil and Geomorphology, Rainfall and water level, Hydrogeophysics, Hydrogeochemistry, Artificial groundwater recharge and scope of the present investigation have been described in detail. It also includes Geology, soil, Hydrogeomorphology, geomorphic units, Hydrogeomorphic units, Lineament, Lineament density and frequency, Land use and Land cover, Topography and Slope.

Second chapter embodies on the rainfall and water level analysis of Sarabanga sub basin. Monthly rainfall and water level data have been collected systematically and categorized into four seasons namely winter season, summer season, southwest monsoon and northeast monsoon. Assessment have been made and represented in the form of rainfall average and water level season wise. The analytical results were taken into GIS platform and varieties of thematic maps have been developed and analyzed. Water table fluctuation and grid deviation map for pre and post monsoon season have been discussed.

Third Chapter emphasize on Geophysical studies and deals with the results of Vertical Electrical Soundings (VES) systematically on the entire Sarabanga sub basin and adopted appropriate methodology for the interpretation of the resistivity curves. The Vertical Electrical Sounding has been used to access different layer resistivity and aquifer thickness overlay with geology and to demarcate groundwater potential zones. The resistivity data were interpreted using curve matching techniques and systematically characterizing the subsurface condition based on the geo electrical parameters such as ρ, h, S, T and λ have been successfully applied for demarcating aquifer geometry in the study area.

Fourth Chapter deals with the chemical characteristics of the groundwater in the study area. Systematic water samples were collected from entire Sarabanga sub basin. The study includes pH, EC, cations, anions, total hardness etc., and assessment has been made for the suitability of groundwater for drinking and irrigational purposes with reference to BIS and WHO Standard limit. In addition to that hydrogeochemical data have been projected in the Piper's trilinear diagram, Gibb's diagram, USSL diagram, Wilcox's diagram and Doneen's diagram. Finally scaling, corrosion and multivariate statistical and correlation analysis have been derived.

Fifth Chapter integrates all the thematical maps with Weightage index assigned and the most favorable areas were demarcated for artificial recharge structure with the help of Geospatial technology.

CHAPTER-I

GEOLOGICAL SETTING

1. Sarabanga Sub Basin

The Sarabanga is one of the main tributary of the river Cauvery. It lies entirely in the Salem district of Tamil Nadu state, India. It is a linear sub basin stretching in northeast to southwest direction with the general gradient towards the southwest and originating on the western slopes of the Shevaroy hills at an altitude of 1630 m Above Mean Sea Level (AMSL).

1.1 Administrative Setup

Salem district is one of the biggest districts in Tamil Nadu. It is bounded on the North by Dharmapuri district, on the South by Namakkal and Erode districts, the Western ghats in the West and on the East by Villupuram District. The geographical area of the district is 5205.30sq.km. It has 4 Revenue Divisions Salem, Attur, Mettur, and Sankagiri and it is divided into 11 Taluks viz., Attur, Mettur, Omalur, Sankari, Salem, Salem West, Salem East, Yercaud, Gangavalli, Idappadi, and Valapadi. This district has three Municipalities viz., Idappadi, Attur and Mettur and one Salem Corporation and 385 Villages. Salem District has Panchayats with 646 Revenue villages including 34 Town panchayats and 20 Panchayat Unions. Land slope generally ranges from 500 ft to 1200 ft. AMSL with the exception of Yercaud which is at 5000 ft. AMSL.

Table.1.1 Administrative Setup of the Sarabanga Sub basin.

SI. No	Taluk	Area in Hectares	Name of block	No. of Villages
1	Omalur	66646	Omalur Tharamangalam Kadayampatti	47 18 22
2	Idappadi	32030	Idappadi Konganapuram	14 10
3	Mettur	77715	Mecheri Nangavalli	20 14
Total	3	176391	7	145

The District is intersected by numerous hills namely Shervaroy Hills and Kalrayan Hills adorn the district with natural beauty and forest wealth. The Administrative Setup and location map of the Sarabanga sub basin has been shown in Table1.1 and Fig.1.2.

1.2 Transport and Communication

The Sarabanga sub basin is well connected with major cities in Tamil Nadu by rails and road network. The important urban centers in the district are well connected by roads. The upgradation of the road as a six lane highway under the Golden Quadrilateral programme by National Highway Authority of India (NHAI) has facilitated the easy flow of traffic.

Major National Highways originate from Salem are NH-47 and NH-68. Salem city is on NH-7 which is the main transit hub to the city of Coimbatore, NH-47 from Kanyakumari to Salem via Coimbatore making it a transit hub. It is also well connected with the state capital Chennai. It is well connected on road network by buses from outstations like Madurai, Bangalore, Coimbatore and Chennai. Salem is the main transit hub for buses to Bangalore from most parts of Tamil Nadu. Salem Junction Railway station is located in the suburb of Suramangalam, 5 km to the west of Salem town.

Salem is a divisional headquarters in the Southern Railway which had been carved out of the existing Palakkad and Tiruchchirapalli divisions in the year 2007. Salem Junction is a very important railway station in the Southern Railway. It is connected by rails to all important cities and towns in the rest of the country. The station is well connected by buses to other parts of the city.

Salem Airport is located on Salem Bangalore Highway (NH-7) in a place called Kaamalapuram near Omalur, which is about 20 km from the city. Airports Authority of India (AAI) had spruced up the airport and made it ready for operation in 1993.

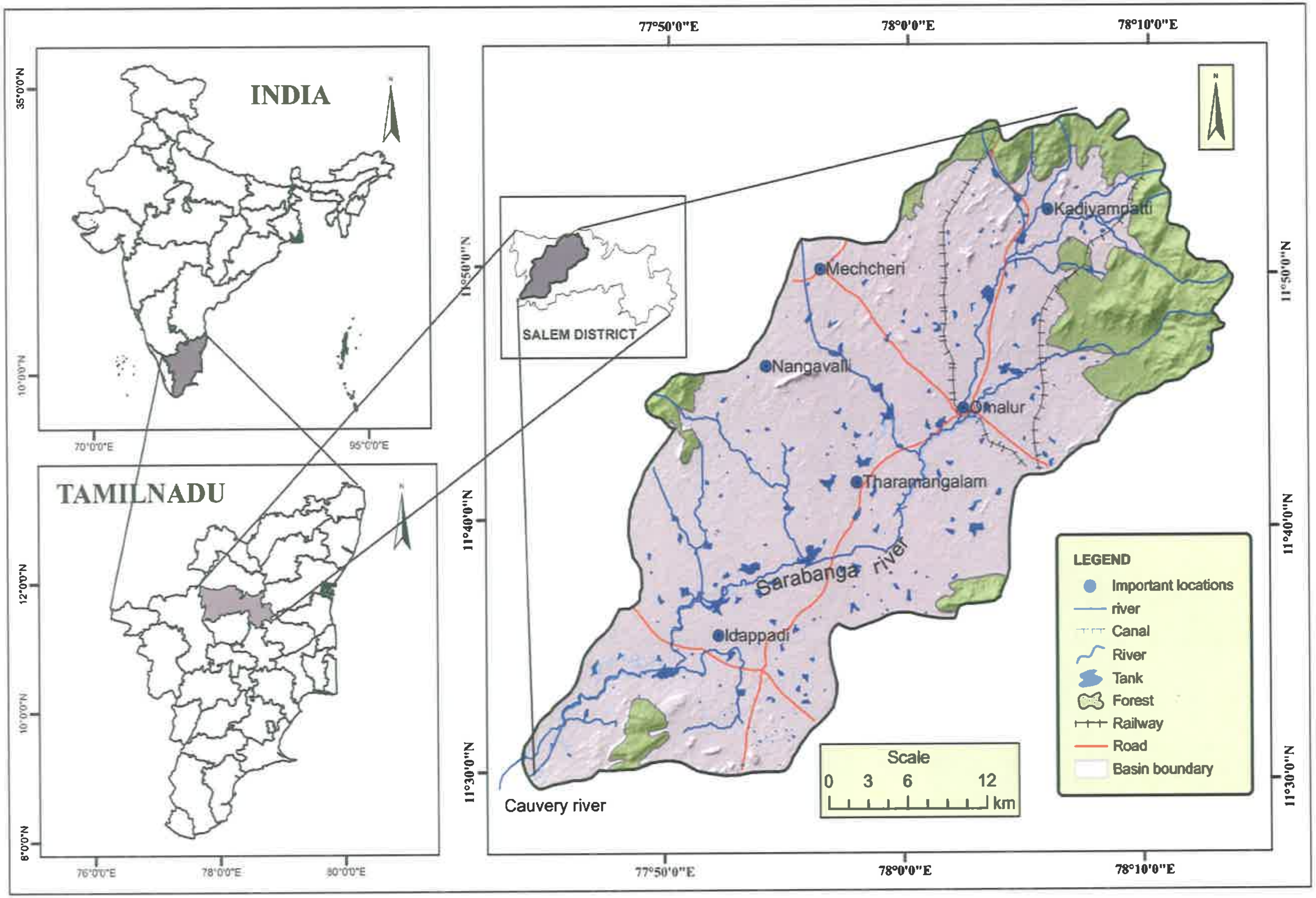

Fig.1.2.Location map of Sarabanga sub basin

1.3 Agriculture

Millets and other cereals are the principal crops in Salem district, which covers major part of the study area followed by Oil seeds, Rice, and Sugarcane. Important Food Crops include Paddy, Cholam, Cumbu, Ragi, Red gram, Green gram, Black gram, Horse gram, Turmeric, Sugarcane, Mango, Banana, Tapiaco, Groundnut and Gingelly. Important Non food Crops are Cotton, Castor Seed, Coffee and Fodder Crops. Farmers adopting high yielding varieties of crops like Cotton and Maize are cultivated. Hybrids and BT varieties are extensively adopted in the district.

Tapioca is extensively cultivated by the farmers of Salem. Salem holds a monopoly in Tapioca production. The tubers are used primarily to produce starch. A variety of food items like chips, fryums, papads, Noodles and vermicelli are also produced from tapioca. Tapioca and castor Research centre functioning in Salem is engaged in Research and Developmental activities to produce high yielding and disease resistant varieties. Sagoserve is run by the state Government, to provide a competitive market where farmers gain a broader profit margin without the hassle of the middle-men dealings.

The Sheep Research station located at Mecheri in Mettur developed and introduced the popular Mecheri Breed. The breed is popular among the farmers and is reared mainly for meat purposes. Salem Diary has an impressive milk production and the district stands first in milk production. A variety of milk products have been introduced by the Diary recently and are effectively marketed.

1.4 Climate

Sarabanga sub basin is characterized by a subtropical climate with moderate humidity and temperature. The weather is quite pleasant from November to February and becomes hot from March to June. The maximum temperature ranges from 24°C to 40°C and the minimum temperature ranges from 13°C to 28°C. Salem receives scanty rainfall, dry climate and has moderate weather throughout except during the monsoon season. Generally the first two months of the year are pleasant, but summer onset begins in March. The highest temperature is normally recorded during the month of May. The scanty showers during this period do not provide any relief from the oppressive heat. There is a light improvement in the climate during June to July period. During this pre monsoon period, the mercury reverses its trend and by August, the sky gets overcast heavily but the rains are meager. The northeast monsoon sets in vigorously only during September to November and by December, the rains disappear rendering the climate clear and pleasant.

1.5 Geology of Sarabanga Sub Basin

The geology map was collected from Geological Survey of India (GSI). The map was traced, scanned, digitized in GIS platform. In the field, the rock samples were collected and identified to assess the hydrogeophysics and hydrogeochemistry characteristics of groundwater. The study area is mainly underlined by Fissile hornblende biotite gneisses, Charnockite, Granite etc. Fissile hornblende biotite gneisses are the dominant group of rocks covering major parts of the study area, followed by the Charnockite rocks. The assessment of qualitative nature of groundwater in any terrain may be almost impossible without an understanding of the Petrography, Structural characteristics of various geologic units.

1.5.1 Alkaline Rocks-Syenite

Alkaline rock, any of various rocks in which the chemical content of the alkalies (potassium oxide and sodium oxide) is great enough for alkaline minerals to form. Such minerals may be unusually sodium rich, with a relatively high ratio of alkalies to silica (SiO_2), as in the feldspathoids. Other alkaline minerals have a high ratio of alkalies to alumina (Al_2O_3), as in aegirine pyroxene and the sodic amphibole riebeckite.

Alkaline igneous rocks are those with an excess of alkali metals (Na_2O + K_2O) over silica. Rocks under saturated with alkali metals are known as sub alkaline. Alkaline rocks are relatively rare; however, they exhibit significant variation in mineralogy and, therefore, comprise a large number of rock types.

Many alkaline rocks are silica under saturated and contain feldspathoid minerals, mainly nepheline and leucite, many also contain alkali feldspars. They can, however, be silica saturated and over saturated. A subset of alkaline rocks is potassic or ultra potassic, such as kimberlites, lamproites and shonsonites. Alkaline rocks are found in a wide range of tectonic environments but are particularly common in ocean islands and continental rifts. The occurrence of alkaline rocks can be extrusive or intrusive. Extrusive alkaline rocks comprise both lavas and pyroclastic rocks formed by accumulation of eject from explosive eruptions. Alkaline parental magmas generally originate by melting of mantle rocks at smaller degrees of partial melting or greater depth than sub alkaline magmas. It occupies in patches and covers spatially about 26.82 sq.km.

1.5.2 Basic Rocks -Dolerite

Basic igneous rocks are those with an SiO_2 content between 45 and 53 weight percent. Basic igneous rocks include basalt, dolerite and gabbro. The mineralogy of basic rocks is typically dominated by pyroxene and calcic plagioclase (>50% anorthite). They commonly include olivine as a nonessential mineral, and can include quartz, alkali feldspar, amphiboles and micas. Many alkaline igneous rocks are also basic rocks. A rock dominated by pyroxene is also basic. Extrusive basic rocks are predominantly lavas. Basic magmas are typical products of partial melting of the upper mantle. Basalts, dolerites and gabbros comprise the bulk of oceanic crust and where they are produced largely by magmatism at mid ocean ridges. Basic rocks are, however, found in every tectonic setting including continental rifts and at subduction zones. Many intermediate and acid igneous rocks can be generated by crystal fractionation of basic magmas. It occupies as a small patch in the northeast direction and spatially covers an area of 2.70 sq.km.

1.5.3 Charnockite

Coarse grained rock of approximately granitic composition granoblastic texture, Feldspar (to allow cations such as Na+, K^+, Ca^+, to enter the lattice and maintain the electrical balance, there is substitution of some Al_3^+ in place of Si_4^+. with pyroxene group of minerals mostly ortho pyroxenewas presented (the principle orthopyroxene minerals are enstatite and hypersthene). Enstatite (a rock forming materials of the orthopyroxene group $MgSiO_3$, an important primary constituent of basic igneous rock). With the addition of more iron, in to hypersthene. Quartz crystalline silica (SiO_2) it crystallizes in the trigonal system, commonly forming hexagonal prisms) some may have formed by crystallization of an anhydrous magma under plutonic conditions, others by high grade regional metamorphism of igneous rocks. With the addition of more iron, in to hypersthenes, quartz (crystalline silica sio_2 it crystalline in the trigonal system, commonly forming hexagonal prisms. Some may have formed by crystallization of an anhydrous magma under plutonic conditions, others by high grade regional metamorphism of igneous rocks.

A leucocratic, medium to coarse grained plutonic igneous rock composed principally of quartz and feldspar, with biotite and hornblende as the commonest mafic minerals. Muscovite may be present. Quartz forms between 20 and 60% of the felsic components, Quartz (crystalline silica SiO_2 it crystalline in the trigonal system, commonly forming hexagonal prisms) and alkali feldspar forms 35 to 90% of the total feldspar. In Sarabanga sub basin charnockite occupies the upper region of the Shevaroy hills. It spatially covers over 288.22 sq.km.

1.5.4 Fissile Hornblende Biotite Gneiss

Gneiss is a common and widely distributed type of rock formed by high grade regional metamorphic processes from preexisting formations that were originally either igneous or sedimentary rocks. It is foliated (composed of layers of sheet like planar structures). The foliations are characterized by alternating darker and lighter colored bands, called "gneissic banding". It is indicative of high grade metamorphism where the temperature is high enough, say 600-700

°C, so that enough ion migration occurs to segregate the minerals. Within the banded structure are mostly elongated and granular structures rather than sheets or plates. Gneiss often forms from the metamorphism of granite or diorite. The most common minerals in gneiss are quartz, potassium feldspar, and sodium feldspar. Smaller amounts of muscovite, biotite and hornblende are common. Gneiss can also form from gabbro or shale.

Fissile hornblende biotite gneiss is a megascopically crystalline metamorphic rock characterized by segregation of constituent minerals into layers or bands of contrasting colour, texture and composition typical gneiss will show bands of mica and other flaky minerals alternating with layers of equidimensional minerals like feldspar, quartz, and hornblende, biotite etc. It is a major type of rock that covers spatially about 782.8 sq.km.

1.5.5 Granitic/Acidic Rocks

Major exposures of granite are found in Sarabanga sub basin near puduppalaiyam. It occurs in isolated outcrops surrounded by Charnockite. The granites are different from Charnockite in the two ways. i. In their small areal extent and linear dyke ii. In the absence of any preferred structural fractures. It covers the lower reaches of the sub basin and spatially covers over 93.39 sq.km.

1.5.6 Ultrabasic Syenite Carbonatite Complex

Syenite is a coarse grained intrusive igneous rock of the same general composition as granite but with the quartz either absent or present in relatively small amounts (<5%). The feldspar component of Syenite is predominantly alkaline in character (usually orthoclase). Plagioclase feldspars may be present in small quantities, less than 10%. When present, ferromagnesian minerals are usually hornblende amphibole, rarely pyroxene or biotite. Biotite is rare, because in a syenite magma most aluminium is used in producing feldspar. Syenites are usually either peralkaline with high proportions of alkali elements relative to aluminum, or peraluminous with a higher concentration of aluminum relative to alkali elements (K, Na, Ca).In Sarabanga sub basin syenite is occupied in southwestern part. It is spatially covered 29.56 sq.km.

Syenites are formed from alkaline igneous activity, generally formed in thick continental crustal areas, or in Cordilleran subduction zones. To produce a syenite, it is necessary to melt a granitic or igneous protolith to a fairly low degree of partial melting. This is required because potassium is an incompatible element and tends to enter a melt first, whereas higher degrees of partial melting will liberate more calcium and sodium, which produce plagioclase, and hence a granite, adamellite or tonalite. At very low degrees of partial melting a silica under saturated melt is produced, forming a nepheline syenite, where orthoclase is replaced by a feldspathoid such as leucite, nepheline or analcime. The Geology map of Sarabanga sub basin is shown in Fig 1.3.

1.5.7 Quartzite

Quartzite is very resistant to chemical weathering and often forms ridges and resistant hilltops. The nearly pure silica content of the rock provides little for soil, therefore, the quartzite ridges are often bare or covered only with a very thin layer of soil and (if any) little vegetation. This type of rock exhibited as a vein in the upstream region and it spatially covers an area of 2.0 sq.km. The field photographs of rock types are given in Photo.1.

1.5.8 Ultramafic/Ultrabasic Rocks- Dunite,Peridotite,Pyroxenite

Ultramafic (also referred to as ultrabasic) rocks are igneous and meta-igneous rocks a with very low silica content (less than 45%), generally >18%MgO, high FeO, low potassium, and are composed of usually greater than 90% mafic minerals (dark colored, high magnesium and iron content). The Earth's mantle is composed of ultramafic rocks. In the Sarabanga sub basin patches of ultramafic rocks with magnesite mineral and occupies in the northeastern part spatially covering an area of 20.96 sq.km. Spatial distribution of Geology is shown in Table 1.2.

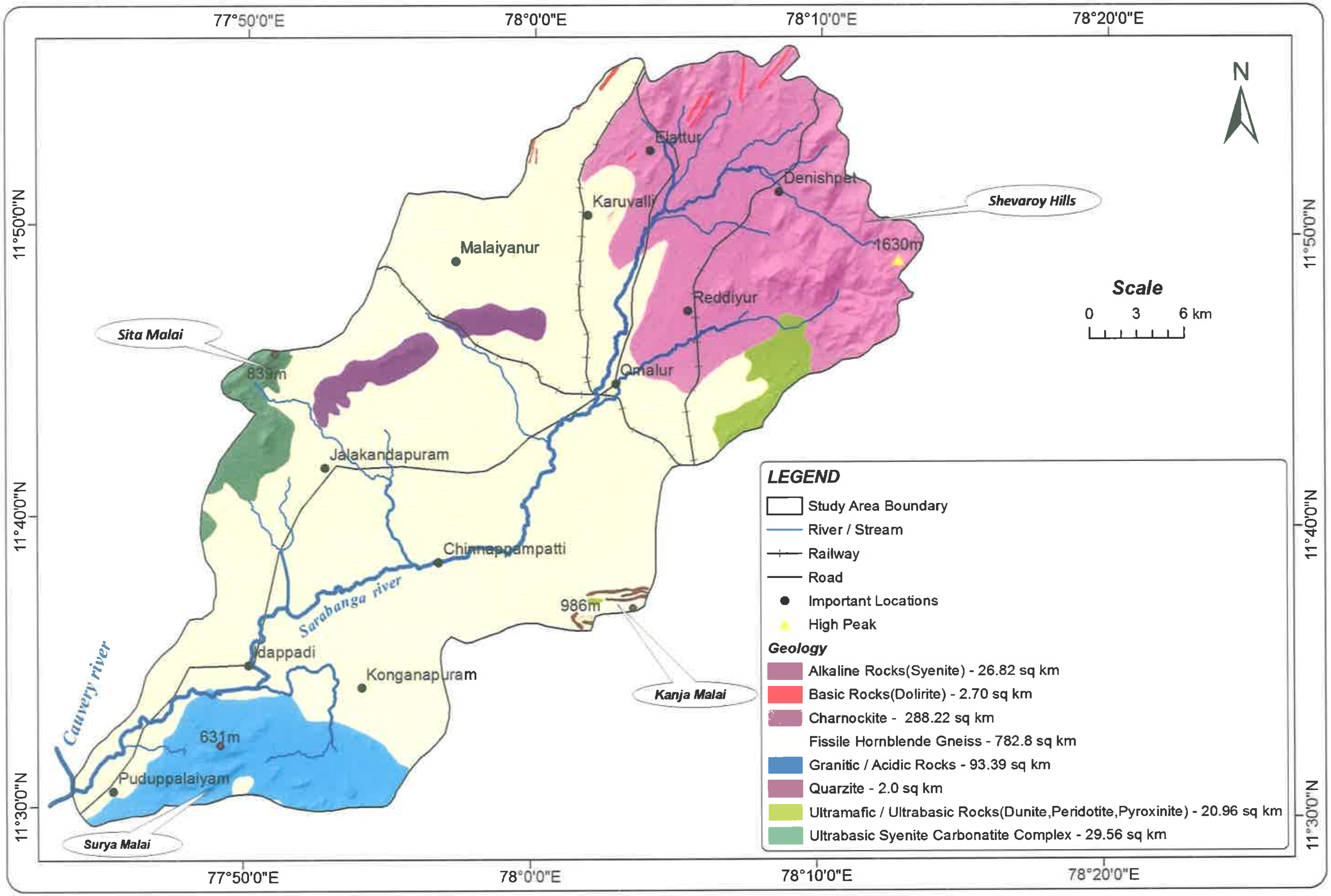

Fig.1.3.Geology map of Sarabanga sub basin *Source: Geological Survey of India - 2005*

Photos-1. Field Photographs showing various rocks

a. Hornblend Biotite Gneiss out crop with linear trending at Sathapady village

b. Gneissic Rock Exhibiting black and white bands with displacement at Chinnasoragai village

c. Gentle dipping Syenite out crops at Mulakkadu village

d. Weathered out crops of Syenite at Anaipallam village

Table 1.1 Spatial Distribution of Geology.

SI.No	Geological unit	Area in sq.km
1	Alkaline rocks-Syenite	26.82
2	Basic rocks-Dolerite	2.70
3	Charnockite	288.22
4	Fissile Hornblende Biotite Gneiss	782.8
5	Granitic/ Acidic rocks	93.39
6	Ultrabasic Syenite Carbonatite Complex-Dunite,Peridotite,Pyroxenite	29.56
7	Quartzite	2.0
8	Ultramafic / Ultrabasic rocks	20.96
	Total	**1246.46**

1.6 Soil

Soils play an important role in encouraging or discouraging the recharge of groundwater and determining the quality parameters of groundwater. The soil types of the area are broadly grouped into i. Alfisols ii. Entisols iii. Inceptisols and iv. Vertisols. The various soil types and their distribution are shown in Fig.1.4 .Alluvial Soil is seen along the Sarabanga river courses. The geological map and soil map of the entire sub basin have been prepared by undertaking intensive field work and by updating the maps of the Soil Survey of India.

1.6.1 Alfisols

Alfisols form in semiarid to humid areas, typically under hardwood forest cover. They have a clay enriched subsoil and relatively high native fertility. "Alfi" refers to aluminium (Al) and iron (Fe). Because of their productivity and abundance, the Alfisols represent one of the more important soil orders for food and fiber production. They are widely used both in agriculture and forestry, and are generally easier to keep fertile than other humid climate soils.

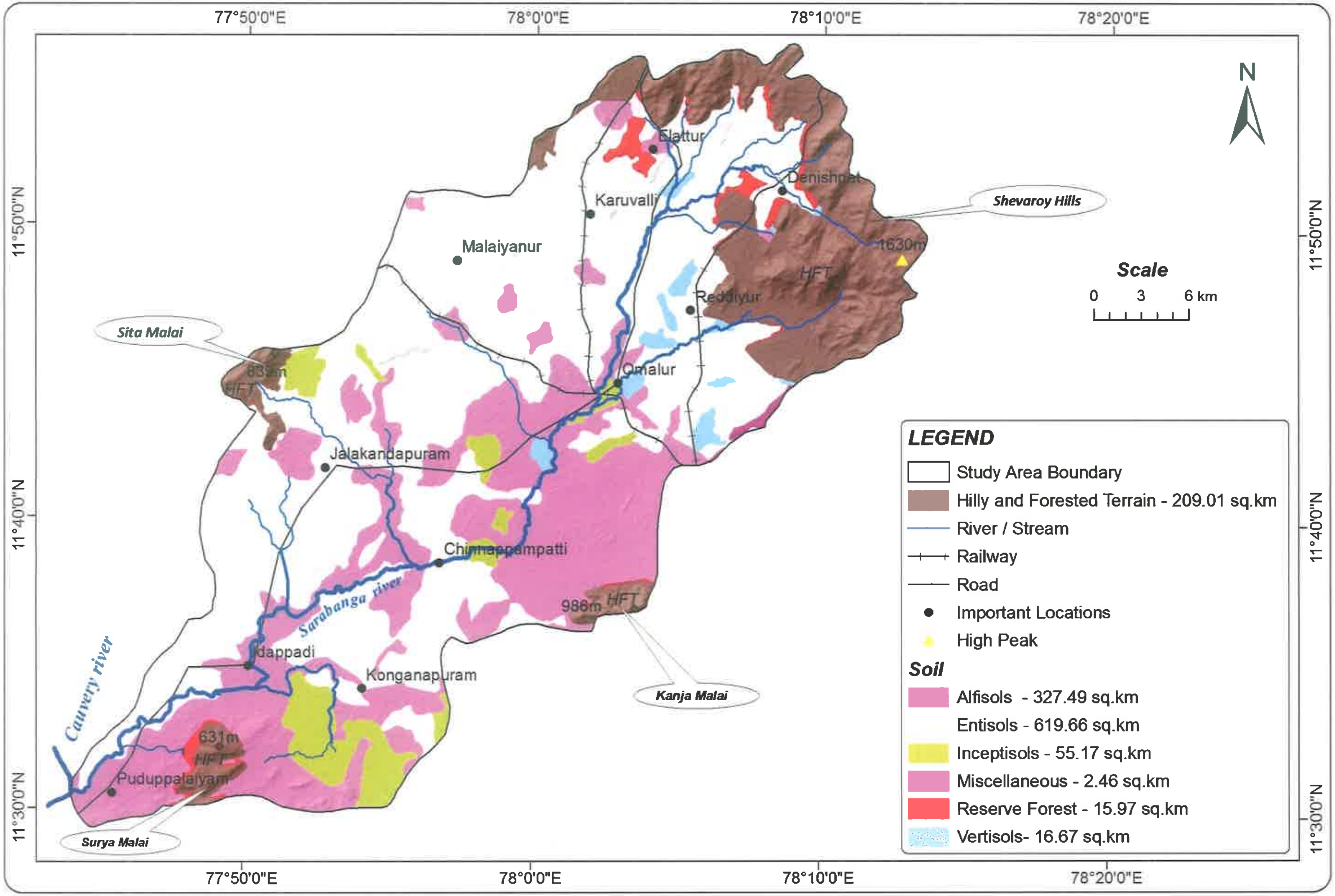

Fig.1.4.Soil map of Sarabanga sub basin *Source:Soil Survey of India*

Though those in Australia and Africa are still very deficient in nitrogen and available phosphorus. Those in monsoonal tropical regions, however, have a tendency to acidify when heavily cultivated, especially when nitrogenous fertilizers are used.

Alfisols have undergone only moderate leaching. By definition, they have at least 35% base saturation, meaning calcium, magnesium, and potassium are relatively abundant. This is in contrast to Ultisols, which are, the more highly leached forest soils having less than 35% base saturation. In the study area Alfisols are spread over southern and eastern part with minor intercalation of some parts and it is the second largest type of soil that spatially covers an area of 327.49 sq.km.

1.6.2 Entisols

Entisols are defined as soils that do not show any profile development other than a horizon. An entisol has no diagnostic horizons, and most are basically unaltered from their parent material, which can be unconsolidated sediment or rock. Most entisols are known as rudosols or tenosols, whilst arents are known as anthroposols. In the Sarabanga sub basin, Alfisols are spread over maximum percentages generally in the south, eastern and northeastern part spatially covering an area of 619.66 sq.km.

1.6.3 Inceptisols

They form quickly through alteration of parent material. They are older than entisols. They have no accumulation of clays, iron oxide, aluminium oxide or organic matter. They have an ochric or umbric horizon and a cambic subsurface horizon. Inceptisols are present in minor intercalations in the southwestern part and spatially covers an area of 55.17 sq.km.

1.6.4 Vertisol

Vertisol is a soil in which there is a high content of expansive clay known as montmorillonite that forms deep cracks in drier seasons or years. This heaving of the underlying material to the surface often creates a microrelief known as gilgai. Vertisols typically form from highly basic rocks, such as basalt, in climates that are seasonally humid or subject to erratic droughts and floods, or to impede drainage. Depending on the parent material and the climate, they can range from grey or red to the more familiar deep black.

Vertisols are espatially suitable for rice because they are almost impermeable when saturated. Rain fed farming is very difficult because vertisols can be worked only under a very narrow range of moisture conditions they are very hard when dry and very sticky when wet. However, in Australia, vertisols are highly regarded, because they are among the few soils that are not acutely deficient in available phosphorus. Some, known as "crusty vertisols", have a thin, hard crust when dry that can persist for two to three years before they have crumbled enough to permit seeding. This type of soil has been scattered as minor patches in central and northeastern part and spatially covers an area of 16.67 sq.km. Table 1.3 show spatial distribution of soils.

Table 1.3 Spatial Distribution of Soils

SI. No	Soil types	Area in sq.km
1	Alfisols	327.49
2	Entisols	619.66
3	Inceptisols	55.17
4	Vertisols	16.67
5	Miscellaneous	2.46
6	Reserve Forest	15.97
7	Hill and Forested Terrain	209.01
	Total	1246.46

1.7 Hydrogeomorphology

Geomorphology consolidated and weathered materials cover the bed rock. On the basis of favorability of potential flood plain and buried weathered pediplain geomorphological features are good potential zones, Pediment, Pediment inselberg complex, Pediplain buried are moderate potential zones Dome type denudational hill, dome type residual hills and Structural hill are low potential zones.

This is connected with a good drainage network of the streams and tanks, having clay, silt, sand, etc. The dome type dome type residual hills have been observed in the east, west and southern part of the study area. The ridge type's structural hills occupy northeast, west and southern part of the study area. Buried weathered Pediplain are covered in major part.

Topographical, geomorphological, hydrological, geological and hydrogeological conditions play a significant role in the planning and execution of measures to be undertaken in watershed development programs. For example, topographic features can be considered in the selection of favorable sites in most of the recharge areas. Evaluation of the drainage characteristics of a basin, using quantitative morphometric analysis in relation to geomorphological features.

1.8 Hydrogeological Aspects

Detailed knowledge of geological and hydrological features of the area is necessary for adequately selecting the site and the type of recharge structure. In particular, the features, parameters and data to be considered are geological boundaries hydraulic boundaries, inflow and outflow of waters, storage capacity, porosity, hydraulic conductivity, transmissivity, natural discharge of springs, water resources available for recharge, natural recharge, water balance, lithology, depth of the aquifer, and tectonic boundaries. The aquifers best suited for artificial recharge are those aquifers which absorb large quantities of water and do not release them too quickly. Theoretically this will imply that the vertical hydraulic conductivity is high, while the horizontal hydraulic conductivity is moderate. These two conditions are not often encountered in nature.

The evaluation of the storage potential of subsurface reservoirs is invariably based on the knowledge of dimensional data of reservoir rock, which includes their thickness and lateral extent. The availability of subsurface storage space and its replenishment capacity further govern the extent of recharge. The hydrogeological situation in each area needs to be appraised with a view to assess the recharge capabilities of the underlying hydrogeological formations. The unsaturated thickness of rock formations, occurring beyond three meters below ground level should be considered to assess the requirement of water to build up the sub-surface storage by saturating the entire thickness of the vadose zone to 3 meter below ground level. The upper 3 m of the unsaturated zone is not considered for recharging, since it may cause adverse environmental impact e.g. water logging, soil salinity, etc. The Sarabanga sub basin geomorphological features flood plain and buried weathered pediplain are holding maximum quantity of groundwater.

1.9 Geomorphic Units

Landform expressions seen on air photos and satellite imagery give valuable information regarding drainage and sub surface geology of an area. The geomorphological map of the Sarabanga sub basin was prepared using satellite imagery of the region and the relevant aerial photographs were visually analyzed and various morphogenetic land forms were delineated it is shown in Fig.1.5.

1.9.1 Dome type Residual Hills

These are the resistant isolated, steep sided, usually smoothened and rounded hill of curcuma denudation rising abruptly above the surroundings over the level plains. These residual hills exhibit conical to rounded forms with steep to very steep slopes. Groundwater potential in this unit is very poor. The study area outcrops with an elevation ranging from 250 to 400 m Above Mean Sea Level (AMSL) and located in southern, southeastern, northwestern and northeastern boundaries. Dome type residual hills spatially cover about 4.55 sq.km.

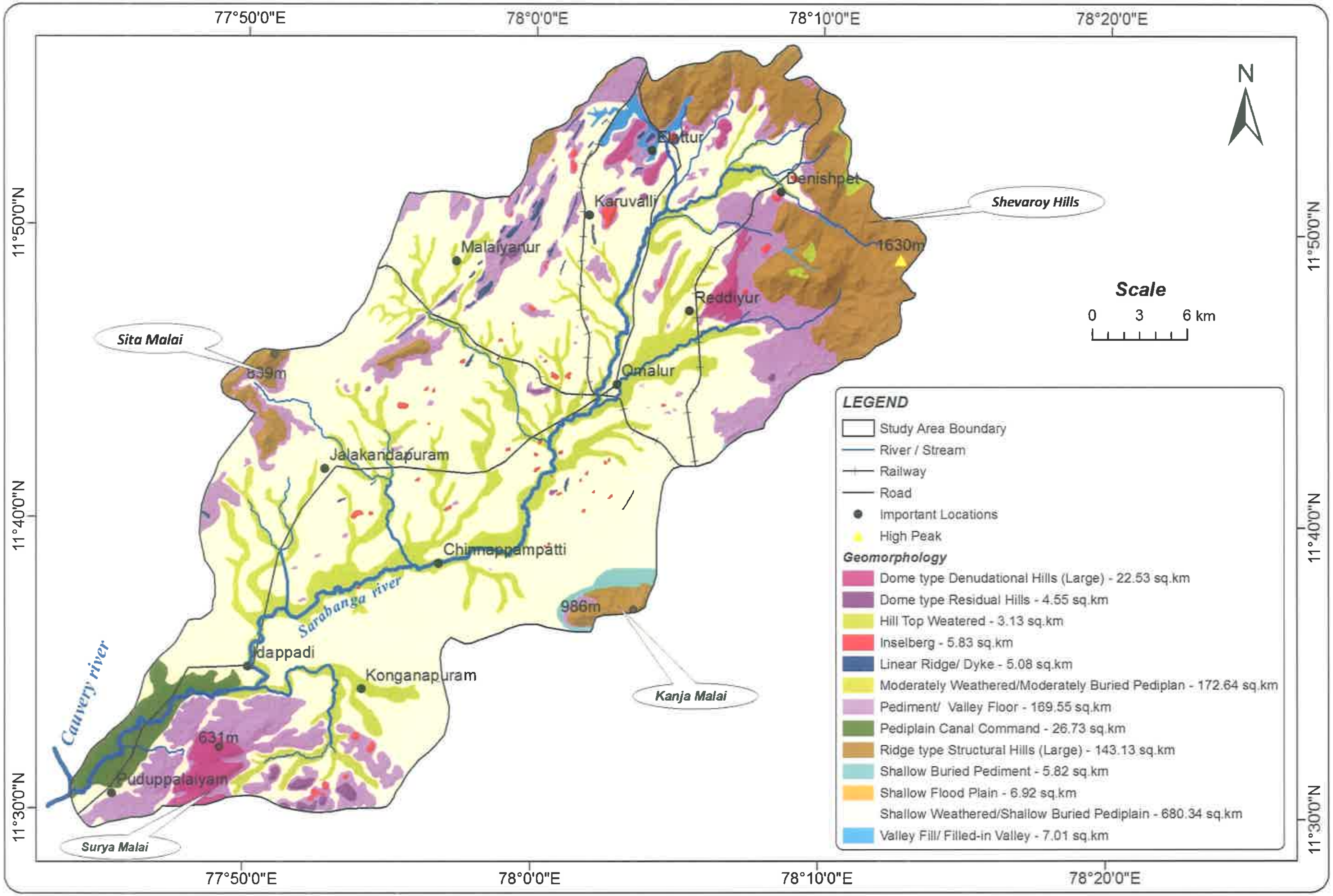

Fig.1.5 Geomorphology map of Sarabanga *Source:IRS P6 LISS IV Image - 2010, NRSC, Hyderabad.*

1.9.2 Dome type Denudational Hills

Dome type Denudational hills are the remnants of the natural dynamic process of denudation and weathering. The geomorphic forms of denudational hills occur as exfoliation domes, bornhardts, linear ridges, mesas, low mounds and tors with partial scree or debris covered at the foot slopes.

The geomorphic expression and shape of the Dome type denudational hills are controlled by lithology, and spacing of structural features like joints and fractures occurring in them. The Dome type denudational hill features classify into a. denudational hills in granites, gneisses and migmatites, b. denudational hills in gneiss formations and c. denudational hills in basic intrusives (dykes). Of these, the denudational hills in granites, gneisses and migmatites are the most extensive and occur almost in the entire area. The denudational hills in basic intrusives occur as narrow linear ridges within the pediplain where dykes are seen.These types of landforms are located within the Residual hills. Dome type Denudational hills and spatially covers an area of 22.53 sq.km and groundwater potentiality is very poor.

1.9.3 Inselberg

Inselberg are defined as "prominent steep-sided hills of solid rock, rising abruptly from a plain of low relief" (Whittow, 1984). Further on, Whittow remarks that inselbergs are characteristic for tropical landscapes, A prominent, isolated, residual knob, hill, or small mountain, usually smoothed and rounded, rising abruptly from an extensive lowland erosion surface in a hot dry region; generally bare and rocky although the lower slopes are commonly buried by colluvium. These types of landforms are present in isolated patches of the lower reached and spatially covers an area of 5.83 sq.km.

1.9.4 Linear Ridges/Dyke

The linear ridges are narrow, low relief and generally barren. Structural features in linear ridges are mostly strike controlled. Linear ridges /Dyke are found in the northern, northeastern. Linear ridges/Dyke are generally above ground level and act as groundwater barriers. The down streamside is not favorable for groundwater development. Linear ridges /Dyke are seen in the upper portion of the sub basin and spatially cover an area of 5.08 sq.km.

1.9.5 Moderately Weathered/Moderately Buried Pediplain

This type of landforms is characterized by a gently undulating to flat topography spreading over the granites and gneisses formations. The Moderately weathered/moderately buried Pediplain is mostly covered medium to coarse gravel and at with places pebbly soil, sheet wash, rill and gully erosion are quite common in the study area. Moderately weathered /moderately buried Pediplain occupies adjacent to the major river coarse and spatially covers an area of 172.64 sq.km.

1.9.6 Pediment/ Valley Floor

This type of landforms is characterized by a very steep topography spreading over within the valley floor. Pediment/ Valley Floor occupies adjacent to the structural and denudational hills and spatially covers an area of 169.55 sq.km

1.9.7 Ridge type Structural Hills

A complex erosional process shapes the structural hills predominantly by erosion, circum denudation, weathering and mass wasting. The dip of the strata controls the rate of denudation processes in these structural hills. These hills are linear to arcuate exhibiting definite trends composed of varying lithology. Ridge type Structural Hills (Large) are seen generally from the northeast to southwest direction. In this region, surface runoff is fairly high and infiltration is low due to less thickness of soil cover and steep slope. As a consequence, groundwater potential is very poor in structural hills. They occupy the northern and northeastern part of the study area spatially covering an area of 143.13 sq.km.

1.9.8 Shallow Buried Pediment

The term pediment is defined, Linear ridges /Dyke as an eroded rock surface of considerable extent at the foot of a mountain slope or a face formed under arid to semi arid climate erosion. The pediments have very than cover of soil, but its thickness may increase away from the pediment junction. The pediment overlies all the litho units with gentle to moderate slopes (50 to 120 and is generally characterized by rugged appearance with number of small outcrops and supports scanty vegetation. The zone of weathering is highly variable on different lithological units. Sheet erosion and gulleying are very active in the zone of dissociated Shallow buried pediment exposing the underlying weathered mantle of bedrock at number of places. The dissected Shallow buried pediment spatially occupies an area of 5.82 sq.km.

1.9.9 Shallow Flood Plain

On either side of Sarabanga River, shallow flood plain deposits towards the northeastern part and stretches of floodplain are encountered in the southeast, southwest and southern part. of the study area. These areas may have moderate to good groundwater potential as they are porous and often recharged by the irrigated water. Shallow flood plain spatially covers an area of 6.92 sq.km.

1.9.10 Shallow Weathered/Shallow Buried Pediplain

This type of landforms is characterized by a gently undulating to flat topography spreading over the Fissile Hornblende Gneissic formations. This region has poor water potential zone due to deep and very less fracture zones. Shallow weathered/shallow buried Pediplain occupies major part of the study area spreading from northeast to southwest and central part and spatially covers an area of 680.34 sq.km. Table 1.4 shows GIS result on spatial area of Geomorphic units.

Table 1.4 Spatial Distribution of Geomorphic Units

SI. No	Geomorphic units	Area in sq.km
1	Dome type Denudational Hills	22.53
2	Dome type Residual Hills	4.55
3	Hilltop Weathered	3.13
4	Inselberg	5.83
5	Linear Ridge/ Dyke	5.08
6	Moderately weathered/moderately buried Pediplain	172.64
7	Pediment/ Valley Floor	169.55
8	Pediplain Canal Command	26.73
9	Ridge type Structural Hills	143.13
10	Shallow Buried Pediment	5.82
11	Shallow Flood Plain	6.92
12	Shallow weathered/shallow buried Pediplain	680.34
13	Valley Fill/ filled in valley	7.01
	Total	1246.46

Later, a careful check was made in the field and a geomorphological map has been finally prepared in the scale of 1:250,000. The purpose of such an approach is to identify and mark hydromorphic units in as much as the surface and groundwater have a tendency to follow the morpho tectonic pattern of the region.

A similar approach has been employed for areas in different parts of India and in Tamil Nadu. Vincent et al., (1978) have employed land sat data for groundwater exploration in the North Western Tamil Nadu. Singh and Singh (1980) have tried to apply remote sensing techniques to hydrogeological studies in the Chaggar river basin of Punjab and Haryana. Singh et al., (1980) have also employed LANDSAT imageries to understand the groundwater features of Punjab and Haryana. Venkateswaran et.al has used LANDSAT imagery and aerial photographs in the evaluation of the hydrogeological conditions in Ponnaiyar river basin of Tamil Nadu.

Raghavasamy et al.,(1983) have used photogeomorphic techniques for the appraisal of zones of potential groundwater Radhakrishnamoorthy et al., (1980) have used LANDSAT imagery and aerial photographs in the evaluation of hydrogeomorphology and land use of the same area.

1. 10 Hydrogeomorphic Units

The hydrogeomorphic units with groundwater potential zones of the Sarabanga sub basin derived out of this study have been shown in Fig. 1.6. It could be seen that high and very high groundwater potential zones occur in the flood plains or river courses (inter sub basin area) where the drainage density and stream frequency are very low. Other favorable geomorphic units for tapping groundwater were identified.

1.11 Lineament

Lineaments are the linear, rectilinear, curvilinear features of tectonic origin observed in satellite data. These lineaments normally show tonal, textural, soil tonal, relief, drainage and vegetation linearity and curvilinerities in satellite data. All these linear features were interpreted from the satellite data and the lineament map prepared for the part of Salem district. The long linear natural feature was interpreted using the image interpretation elements and edge enhancement techniques in ERDAS imagine software. The prominent directions of these are NE-SW and NW-SE and shown in Fig.1.7. The lineament map was prepared in GIS environment.

1.11.1 Lineament Density / Lineament Frequency

In the hard rock areas, the movement and occurrence of groundwater depends mainly on the secondary porosity and permeability resulting from folding, faulting and fracturing etc. The Remote Sensing data, which offer synoptic view of large area, help in understanding and mapping the lineaments both on regional scale and local scale.

Use of Remote Sensing technique is quite easy to analyze the lineament with different spectral bands. The lineaments control the movement and storage of groundwater. In the present investigation, lineament map from satellite data has been prepared. Using this map, the lineament density is shown in Fig.1.8 and lineament frequency map is shown in Fig.1.9. It was prepared in GIS environment. The lineament density has been classified from less than 0.5 to more than 2 km/sq.km and lineament frequency is classified from less than1and more than 1 km/sq.km. Wherever the lineament density and frequency is more, that area is more favorable for artificial recharge. The results of the lineament density and lineament frequency have been given in Table 1.4.

Table 1.4 Spatial GIS Output of Lineament Density/ Lineament Frequency

Lineament Density in km/sq.km	Area in sq.km	Lineament Frequency in km / sq.km	Area in sq.km
< 0.5	437.29	Less than 1	822.51
0.5 - 1.0	433.55		
1.0 - 1.5	308.58	Greater than 2	427.15
1.5 - 2	69.86		
>2	0.34		

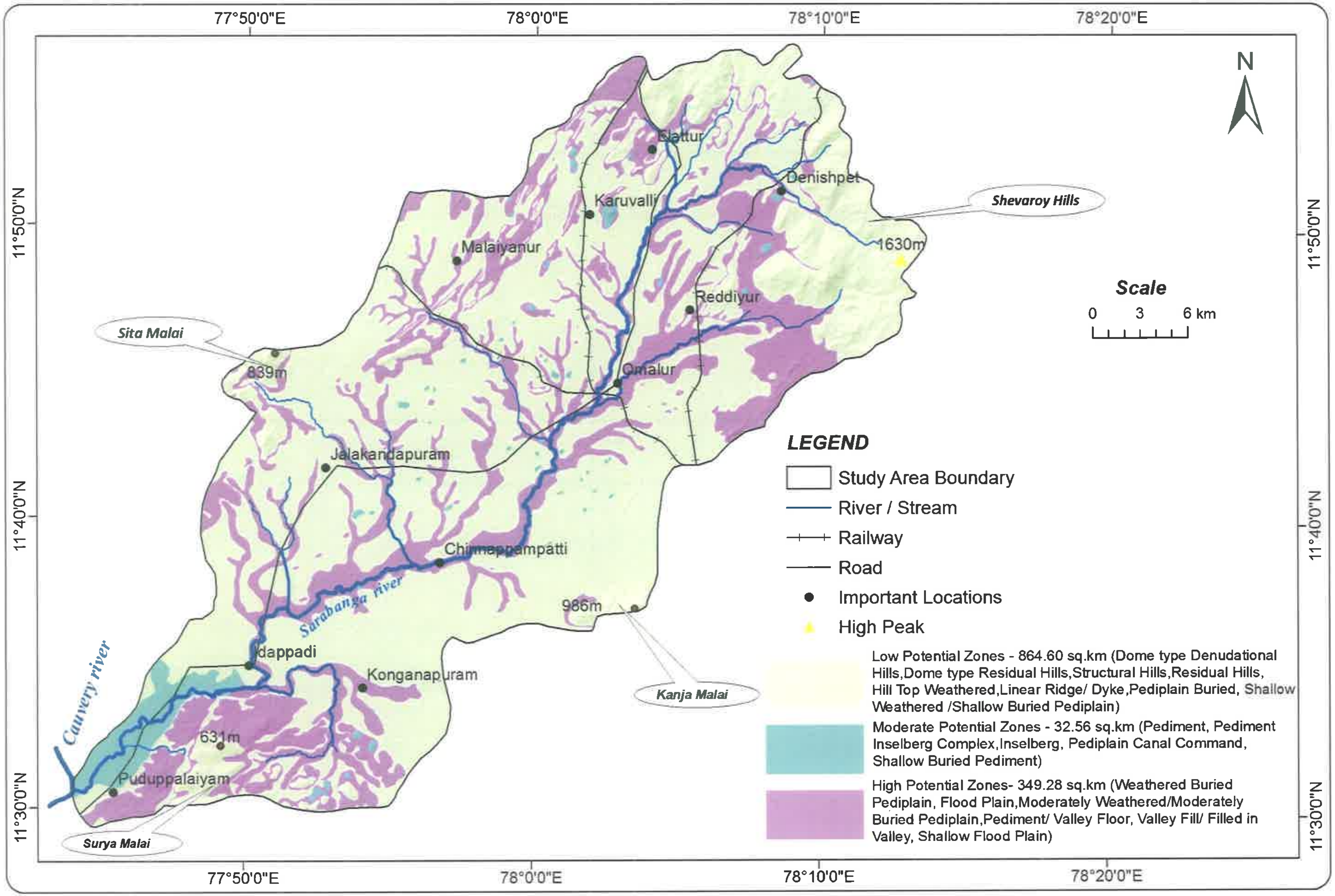

Fig.1.6 Hydrogeomorphological with Groundwater Potential Zone Map of Sarabanga Sub basin

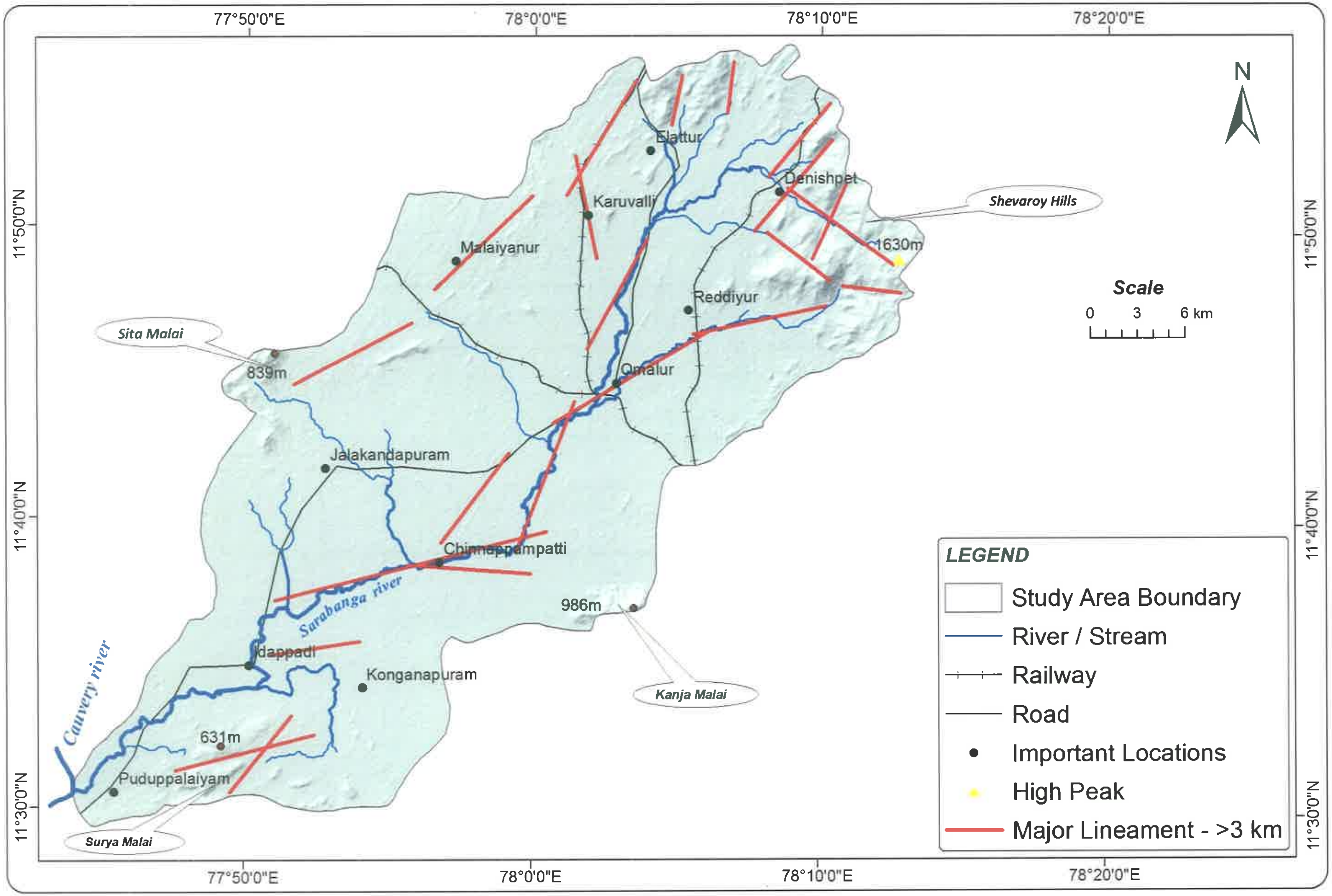

Fig.1.7. Lineament map of Sarabanga sub basin Source:IRS P6 LISS IV Image - 2010, NRSC, Hyderabad.

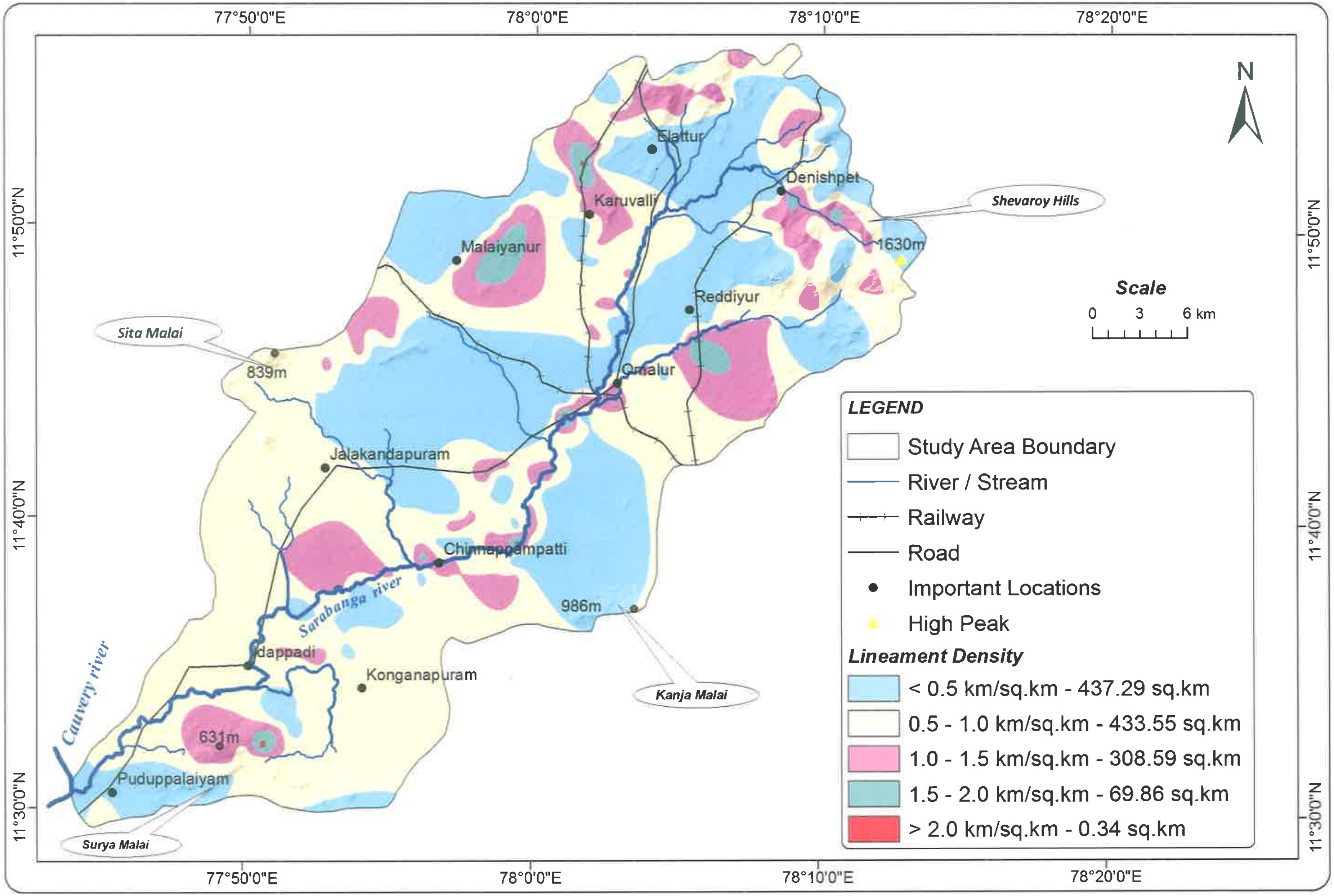

Fig.1.8.Lineament density map of Sarabanga sub basin

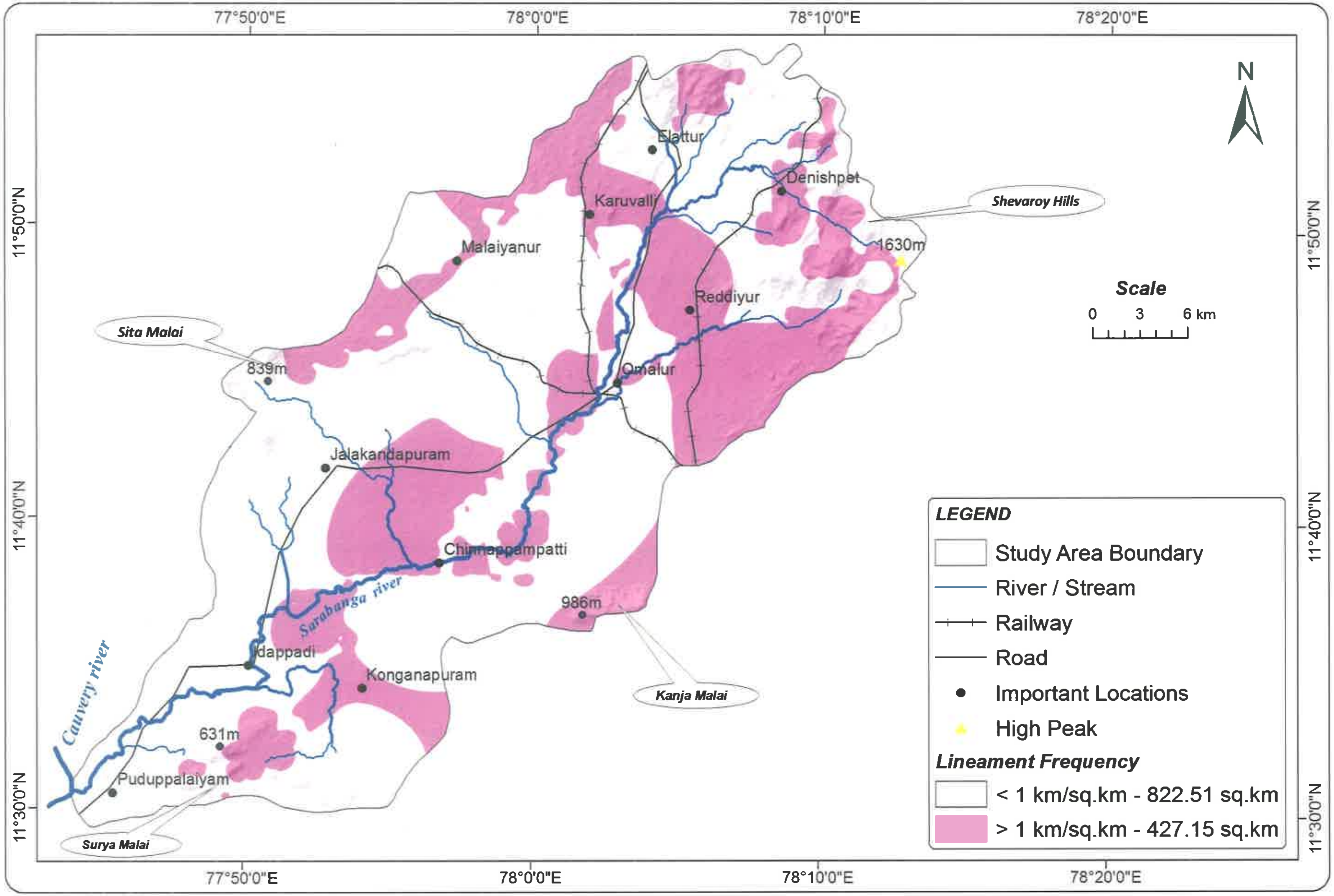

Fig.1.9.Lineament frequency map of Sarabanga sub basin

1.12 Land Use / Land Cover

Land use maps are the basic tools for the planning and show various artificial uses of land. The classification is useful for the present and in future planning. The term land use relates to the human activity associated with a specific piece of land, while land cover relates to the type of features present on the surface of the earth. Urban buildings, lakes, residual hills, rocky out crop are all examples of land cover types. Agricultural, afforestation, and mining activities are a few land use categories in the study area. Land use/land cover map of the study area is prepared with the help of topographic maps, satellite imagery, existing maps and field knowledge. The land use land cover map was prepared by using latest cloud free satellite data. Using ERDAS software, the land use and land cover map was prepared. The land use classification adopted in the present study is based on National Remote Sensing Center classification NRSC.

1.12.1 Crop Land

Crop lands occur on varieties of terrain, often association with terrain pattern such as river plains. The Tonal contrast of crop land varies from bright red to red depends upon the health of the crop. In the present study area, crop lands are found in the random of the imagery. In the study area some places of dry crop lands are demarcated based on the tonal variation. The area under agricultural tree crops, planted adopting certain agricultural management techniques. This includes coconut, eucalyptus, etc., in the study area these plantations are found all over the imagery. The important wet crops in the study area are sugarcane, paddy, cotton and limited extent horticulture. However, the major part of the area covered by dry crops such as maize, groundnut, raggy, sorghum and lentils. It is identified by dark red tone and its peculiar square pattern. The crop land occupies an area of 715.70 sq.km. Land use/ land cover map of Sarabanga sub basin has been shown in Fig.1.10.

1.12.2 Fallow Land

Fallow lands are inferred by the absence of vegetation in the first phase. They show a grayish yellow tone and fine to medium texture. They differ from similar wasteland units such as land without scrub, by their field pattern.

Moreover they are mainly seen to be surrounded by agricultural lands. The fallow lands are distributed in all over the investigation area. The fallow land occupies in the northeastern, southwestern and central part covering an area of 9.65 sq.km.

1.12.3 Land With Scrub

Land with scrub is a type of waste land mostly observed in the south, southwestern and northeastern parts of the study area. It is identified by its dark red color, medium to coarse texture and present in isolated patches spreading over an area of 71.16 sq.km.

1.12.4 Land Without Scrub

Land without scrub is another type of waste land inferred by its distinct light grey to white color and medium to coarse texture. It is devoid of vegetation and observed in isolated patches around the scrub land. It occupies mostly in the southeastern and southern part of the study area which is about 43.69 sq.km.

1.12.5 Barren Rocky/ Stony Waste

It is defined as the rock exposures of varying lithology often barren and divided of soil cover and vegetation. They occur amidst hill forest as opening or scattered as isolated exposures or loose fragments of boulders or as sheet rocks on plateau and plain. It appears as light blue tone, with irregular shape with moderate texture. It is occupies an area of 10.48 sq.km.

Table 1.5 Spatial Distribution of Land Use / Land cover.

SI. No	Land use Land cover	Area in sq.km
1	Crop land	715.70
2	Fallow land	9.65
3	Land with scrub	71.16
4	Land without scrub	43.69
5	Barren Rocky/ Stony Waste	10.48
6	Buildup Land	43.64
7	Mining process	9.36
8	Plantations	163.23
9	Water bodies	19.81
10	Forest	159.69
	Total	**1246.46**

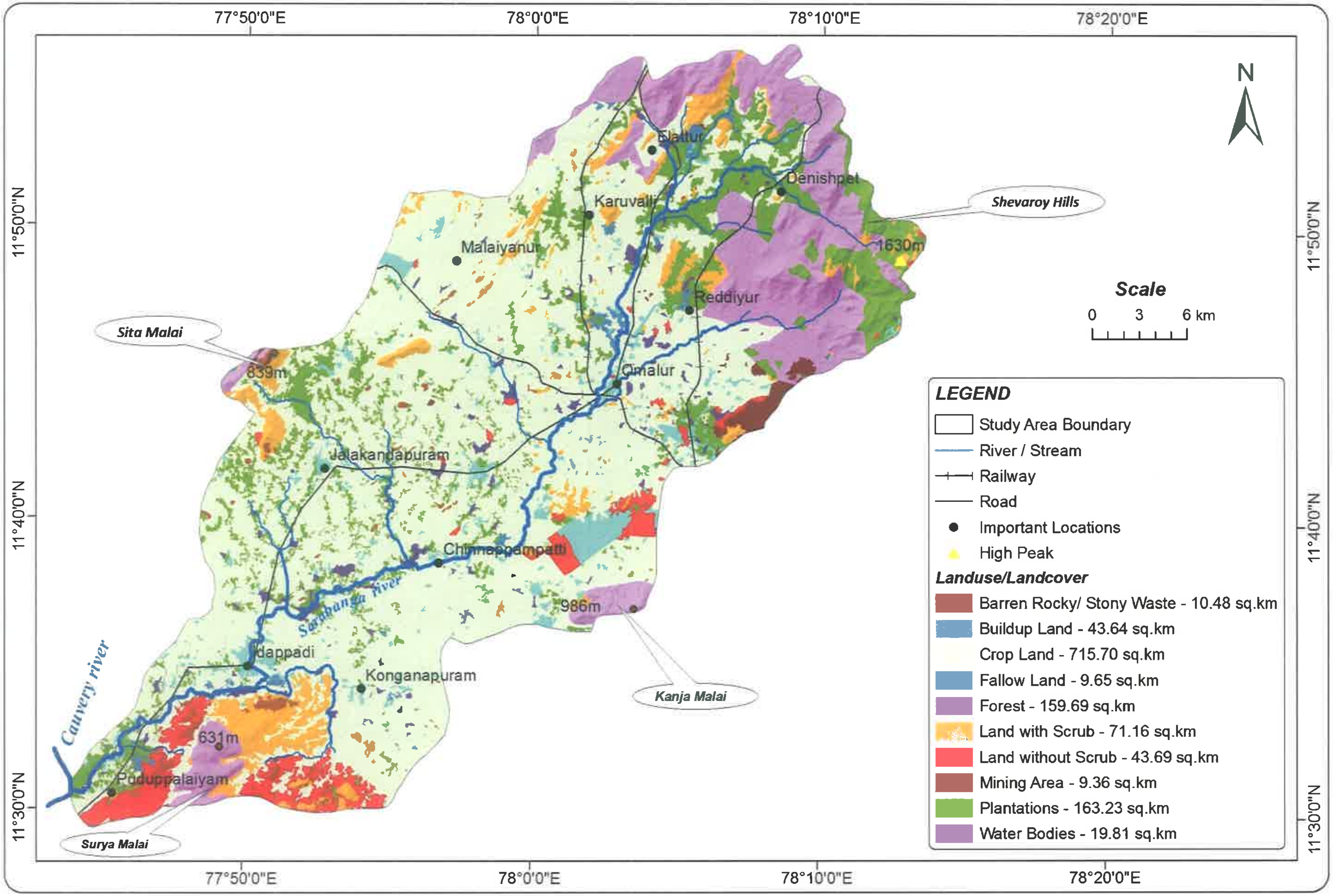

Fig.1.10.Land use/ land cover map of Sarabanga sub basin *Source:IRS P6 LISS IV Image - 2010, NRSC, Hyderabad.*

1.12.6 Buildup Land

It is defined as an area of human habitation developed due to non agriculture use and that which has a cover of buildings, transport and communication utilities in association with water, vegetation and vacant land. The build up land has been observed in Omalur, Danishpet, Konganapuram, Tharmangalam, Jalakandapuram, Nangavalli, Edapadi and adjoining areas with pinkish blue and square pattern. It occupies about 43.64 sq.km of the study area. Table 1.5 shows spatial distribution of Land use / Land cover.

1.13 Topography

The elevation and contour map of Sarabanga sub basin is shown in Fig.1.11 and Satellite Image of Sarabanga sub basin is shown in Fig.1.12. The sub basin appears to be boxed by the surrounding hills the interior of the sub basin divided almost in to two halves. The Shevaroy reserve forest is a high land and runs from west to east along the northeastern border at an altitude of 1630 m Above Mean Sea Level (AMSL). The sub basin has been classified as <250 amsl , 500 - 750 m amsl, 750 - 1000 m amsl, 1,000 - 1,250 m amsl and 1,250 to 1,500 m amsl from this altitude the sub basin floor stretches down to as far below as 250 m amsl in the southern part of the region.

1.14 Slope

The slope is measured in degrees using the method proposed by A layout grid of 2 cm has been prepared and overlaid on the topographic map and the average slopes have been delineated by counting the contour crossings along various intersecting lines. Tangency contacts, which are not true crossings, are counted as crossing each one. The procedure has been repeated with an oblique grid covering substantially the entire area, and a slope map has been prepared. Identified slope category were classified into seven classes which varies from 0-1% (Level to Nearly Level), 1-3 % (Very Gently Sloping), 3-5% (Gently Sloping), 5-10 % (Moderately Sloping), 10-15% (Moderately Steep), 15-30% (Steep) and > 35% (very Steep).

General slope track is from NW-SE and NE-SW directions of the study area and shown in Fig. 1.13. Since, slope is also a criterion for infiltration of precipitation, most of the area has favorable slope from groundwater potential point of view.

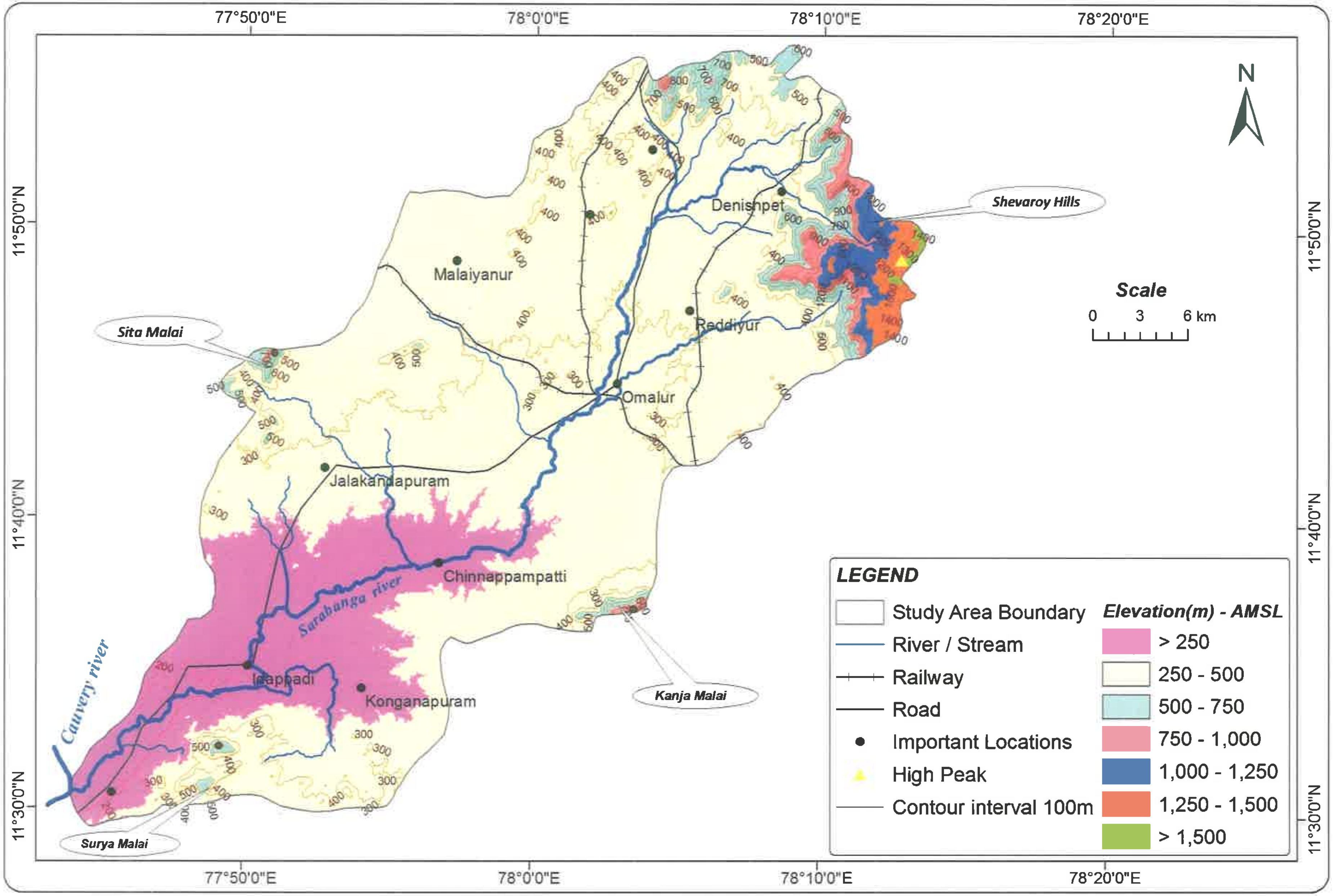

Fig.1.11.Elevation map of Sarabanga sub basin *Source: SRTM Data*

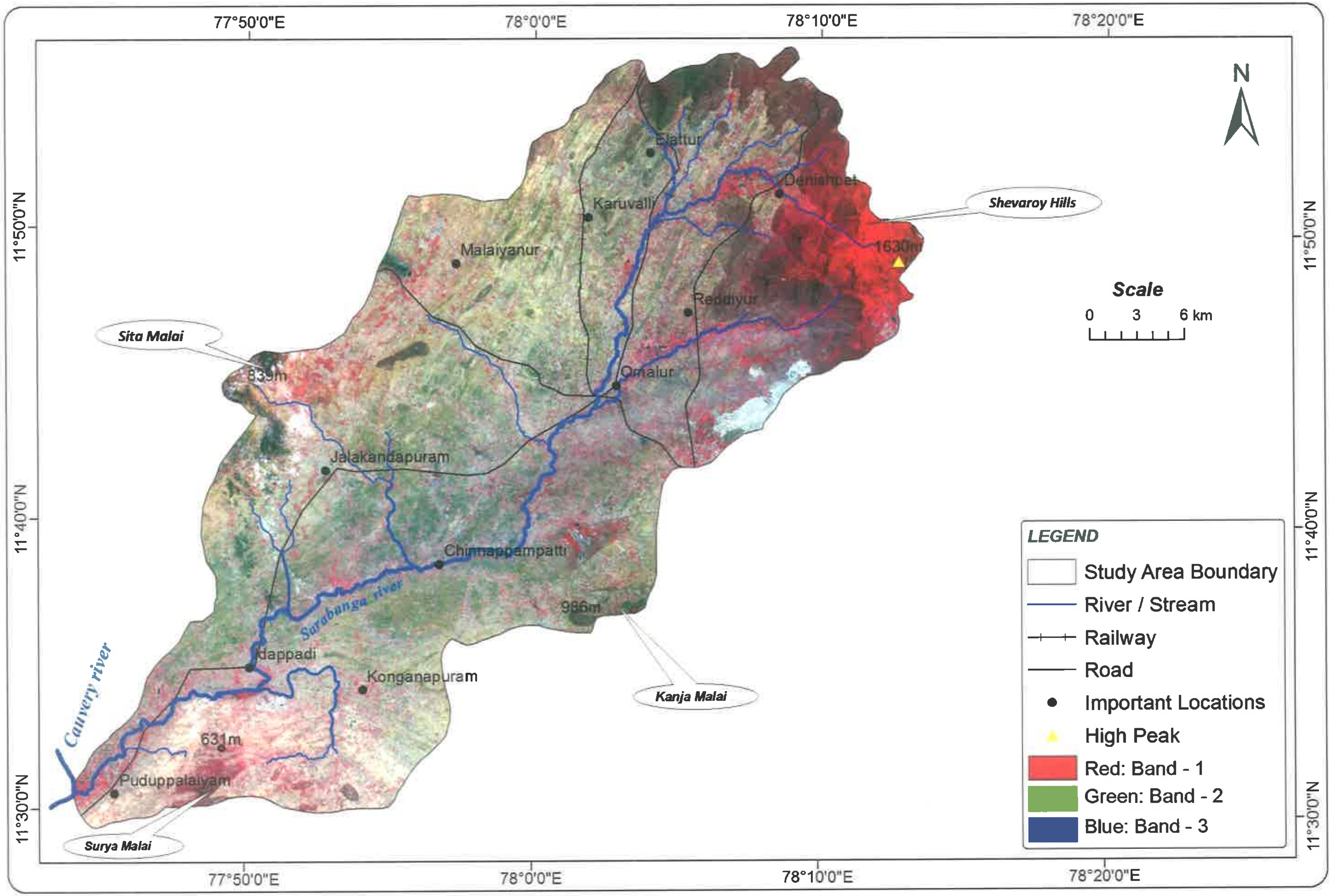

Fig.1.12.Satellite Image showing Sarabanga sub basin *Source:IRS P6 LISS IV Image - 2010, NRSC, Hyderabad.*

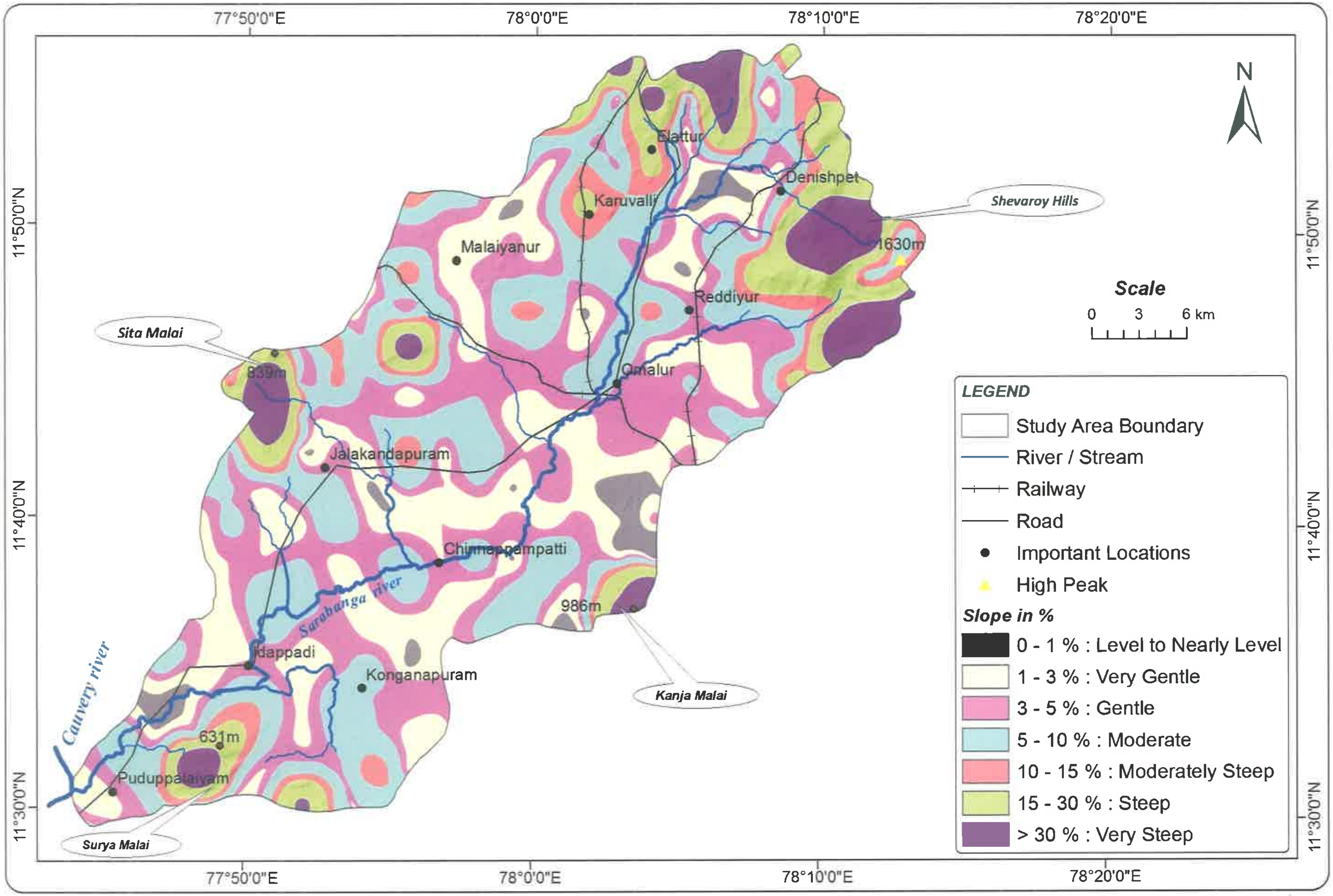

Fig.1.13.Slope map of Sarabanga sub basin *Source: SRTM Data*

CHAPTER-II

RAIN FALL AND WATER LEVEL

2.1 Rain Fall

The state of the atmosphere with respect to the temperature, humidity, wind, cloudiness etc. at any given time is generally referred to as the weather. The rainfall process is essentially random in nature. The magnitudes of the rainfall can be estimated only with some probability attached to them. Therefore, the analysis of the rainfall data obtained over a long period in the past would help the hydrologist to make reasonable probabilistic estimates of rainfall to be used in various designs.

In India as a whole and in particular Tamil Nadu the rainfall regime more or less synchronizes with the agricultural calendar year which has been divided in to four seasons as follows

Southwest monsoon	-	June to September
Northeast monsoon	-	October to December
Winter	-	January to February
Summer	-	March to May

Southwest Monsoon: During the latter part of May, the landmass of India warms up and a low pressure develops which draws air from the ocean in the South. Early in June the southwest Monsoon burst on the West Coast on the Western Ghats. The rainfall of southwest monsoon in Tamil Nadu is influenced by Western Ghats, for or near, according to the strength of the monsoon.

As a matter of fact Western Ghats acts as a barrier and deny the full blast of the monsoon winds to the state. Because of this, Tamil Nadu receives the minimum rainfall during this season when compared to the other states of India. However, this monsoon fetches about one third of the annual rainfall of the state and the timely monsoon helps in filling up the various reservoirs, rain fed tanks etc., thus paving the way for the commencement of agricultural operation in the year.

Northeast Monsoon: With the retreat of the southwest monsoon and due to the reversal of the pressure distribution which normally begins in early October to be created, a low trough in the south Bay of Bengal to form as Northeasterly wind. This monsoon is generally established in Tamil Nadu by the mid October and is active during November. This is the principal monsoon of the state, as it brings about half of the annual rainfall. When compared to the normal rainfall of this monsoon, in various states of the country, it is seen that the southern states, particularly Tamil Nadu and Kerala, are most benefited.

Winter and Summer Seasons: The rainfall in these two seasons are not due to the monsoon winds and hence its quantum of rainfall in the state insignificant.

Rain fall pattern in Sarabanga sub basin: precipitation is the main source of groundwater. The pattern of precipitation is essentially of a tropical monsoon type where the effect of the winter monsoon is dominant. The Normal Rainfall of the study area is 787.10 mm which is lower than the state average of 943 mm. The Northeast Monsoon period is the major rainy season accounting for 66 percent of the normal rainfall followed by Southwest Monsoon (30 percent).The average annual isohyets and monthly average isohyets maps of 11 Rain gauge station have been details are shown in Tables 2.1 and 2.2 Fig.2.1 Rain Gauge Station location map of Sarabanga sub basin.

Average annual rainfall of Sarabanga sub basin is shown in Fig. 2.2 result shows that spatially 156 sq.km area falls in very high rainfall zones and 137 sq.km area falls in medium rainfall zones and rest of the area 663 sq.km falls in low rainfall zones. Very high rainfall spatially occupied Northeastern part of the study area.

The southwest monsoon rainfall of Sarabanga sub basin is shown in Fig. 2.3 reveals that spatially 315 sq.km area falls in the very high rainfall category and 636 sq.km area falls in high rainfall category and 164 sq.km area falls in low rainfall category. The very high rainfall zone present in northeastern part and low rainfall southwestern part of the study area.

The Northeast monsoon rainfall of Sarabanga sub basin is shown in Fig. 2.4 reveals that spatially 40 sq.km area falls in the very high rainfall category and 169 sq.km area falls in high rainfall category and 528 sq.km area falls in low rainfall category. The very high rainfall zone present in southwest and northwestern part and low rainfall central and northeastern part of the study area.

The Winter season GIS rainfall of Sarabanga sub basin is shown in Fig.2.5 reveals that a small portion of the study area is under very high rainfall noticed in Northeastern part of shevaroy hills at the range of (More than 9 mm) and are classified as very high rainfall zone is occupied at an area of 52 sq.km.

The Summer season GIS rainfall of Sarabanga sub basin is shown Fig.2.6 reveals that spatially 69 sq.km area fell in the very high rainfall area and 412 sq.km area falls in the medium rainfall category zone and low rainfall category 381 sq.km .The high rainfall area is located in near to the hill and forest.

Table.2.1. Long term Mean Monthly and Annual Rainfall in mm analysis over Sarabanga sub-basin (mm) 2002-2011

Month	Edapadi	Kolathur	Kullampatti	Mettur	Omalur	Salem	Sankagiri	Yercaud	Denishpet	Chittur	Nangavalli	Average Rainfall
June	68.79	55.14	31.10	43.15	42.55	33.19	30.81	92.31	54.02	42.55	41.46	48.64
July	54.88	57.79	58.26	48.14	108.80	82.47	59.71	182.93	104.01	108.80	91.30	87.01
August	105.89	124.97	122.32	117.87	139.62	118.19	101.11	216.10	157.20	138.12	140.93	134.76
September	105.63	122.34	112.67	152.66	137.73	138.72	71.56	236.11	181.84	137.73	97.43	135.86
SW Monsoon	**335.19**	**360.23**	**324.34**	**361.82**	**428.70**	**372.58**	**263.19**	**727.45**	**497.07**	**427.20**	**371.12**	**406.26**
October	138.47	202.13	191.05	254.16	173.44	178.28	165.20	257.11	161.84	171.44	156.437	186.32
November	147.98	152.36	120.63	189.41	88.21	98.90	131.87	159.01	114.17	96.71	102.71	127.45
December	114.39	103.59	98.42	129.44	88.37	107.13	104.70	110.32	73.65	88.37	84.37	100.25
NE Monsoon	**400.84**	**458.08**	**410.10**	**573.01**	**350.02**	**384.32**	**401.78**	**526.44**	**349.66**	**356.52**	**343.52**	**414.03**
January	1.00	3.00	0.00	1.00	1.00	1.00	1.00	3.30	2.16	0.76	0.00	1.29
February	4.00	15.00	9.00	3.00	0.00	1.00	1.00	12.18	1.32	0.38	0.00	4.26
Winter Season	**5**	**18**	**9**	**4**	**1**	**2**	**2**	**15.48**	**3.48**	**1.14**	**0**	**5.55**
March	35.34	24.52	30.52	40.64	29.22	19.95	20.23	34.46	34.58	9.22	43.08	29.25
April	60.702	79.181	65.51	82.6	58.50	57.15	49.52	97.18	70.78	48.5	57.63	66.11
May	96.84	123.59	106.82	102.16	102.74	102.56	86.34	134.38	97.55	102.74	90.667	104.22
Hot Season	**192.88**	**227.29**	**202.85**	**225.40**	**190.46**	**179.66**	**156.09**	**266.02**	**202.91**	**160.46**	**191.38**	**199.58**

Table.2.2.Average Monthly and Annual Rainfall in Sarabanga sub basin (mm) 2002-2011

SI. No	Rain gauge station	Coordinates		AMSL in m	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
		Latitude N	Longitude E														
1	Edapadi	11°34'50.80"	77°49'48.92"	213	0.98	3.96	35.34	60.702	96.84	68.79	54.88	105.89	105.63	138.47	147.98	114.39	933.85
2	Kolathur	11°50'56.80"	77°45'24.92"	227	3.1	14.78	24.52	79.181	123.59	55.13	57.786	124.97	122.34	202.13	152.36	103.59	1063.48
3	Kullampatti	11°41'47.53"	78°13'30.92"	214	0.2	8.8	30.52	65.51	106.82	31.10	58.261	122.32	112.67	191.05	120.63	98.42	946.30
4	Mettur	11°45'31.06"	77°45'35.87"	216	0.59	3.37	40.64	82.6	102.16	43.15	48.14	117.87	152.66	254.16	189.41	129.44	1164.19
5	Omalur	11°44.48'19"	78°02'38.75"	227	0.76	0.38	29.22	58.5	102.74	42.55	108.8	139.62	137.73	173.44	88.21	88.37	970.32
6	Salem	11°41'45.05"	78°7'59.92"	286	0.76	0.61	19.95	57.15	102.56	33.19	82.472	118.19	138.72	178.28	98.9	107.13	937.93
7	Sankagiri	11°27'20.80"	77°53'15.72"	225	0.5	1.04	20.23	49.522	86.34	30.81	59.71	101.11	71.56	165.2	131.87	104.7	822.60
8	Yercaud	11°43'28.21"	78°12'31.35"	459	3.3	12.18	34.46	97.18	134.38	92.31	182.93	216.1	236.11	257.11	159.01	110.32	1386.32
9	Denishpet	11°51'29.65"	78° 9.15.51"	381	2.16	1.32	34.58	70.78	97.55	54.02	104.01	157.2	181.84	161.84	114.17	73.65	954.91
10	Chittur	11°38'20.80"	77°48'25.46"	357	0.76	0.38	9.22	48.5	102.74	42.55	108.8	138.12	137.73	171.44	96.71	88.37	945.32
11	Nangavalli	11°45'25.45"	77°38'32.51"	347	0	0	43.08	57.63	90.667	41.46	91.303	140.93	97.431	156.44	102.71	84.37	906.02

Above Mean Sea Level (AMSL)

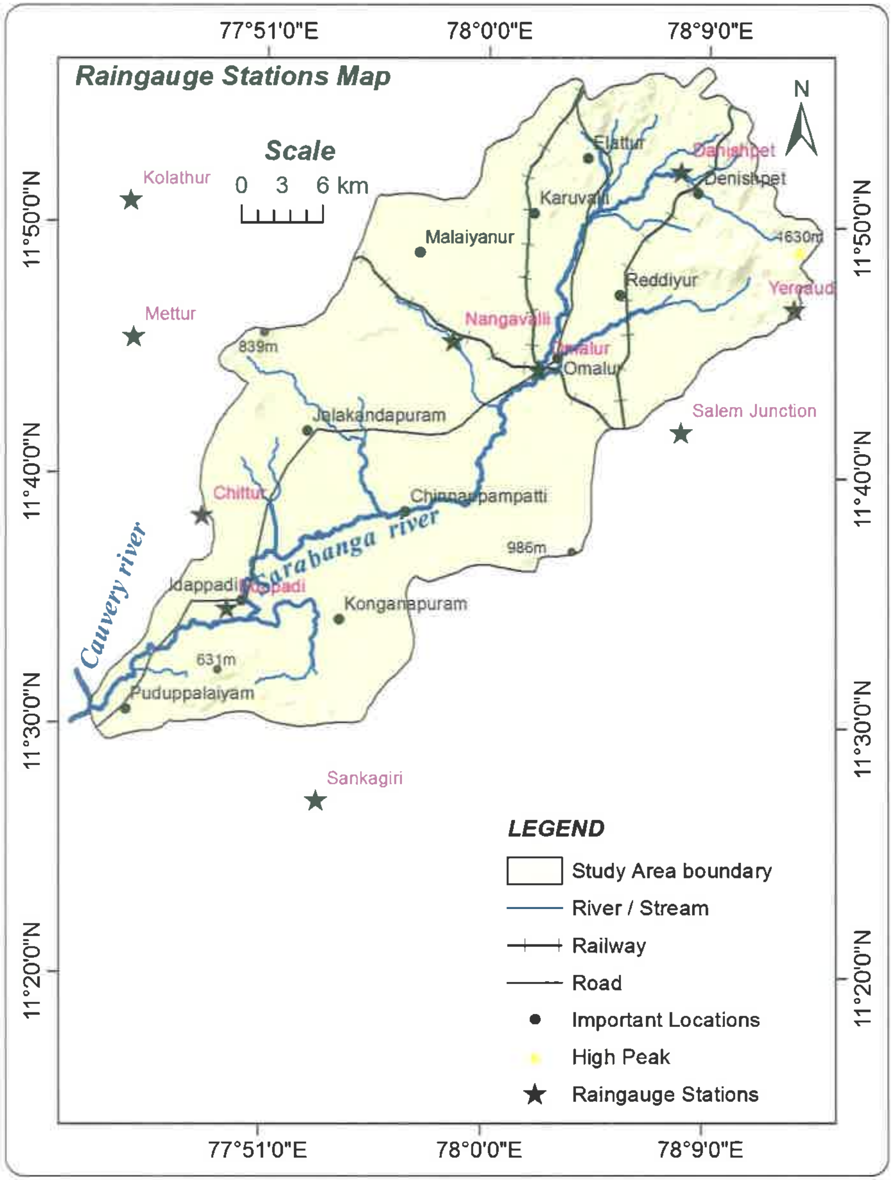

Fig.2.1.Rain Gauge Station location map of Sarabanga sub basin.

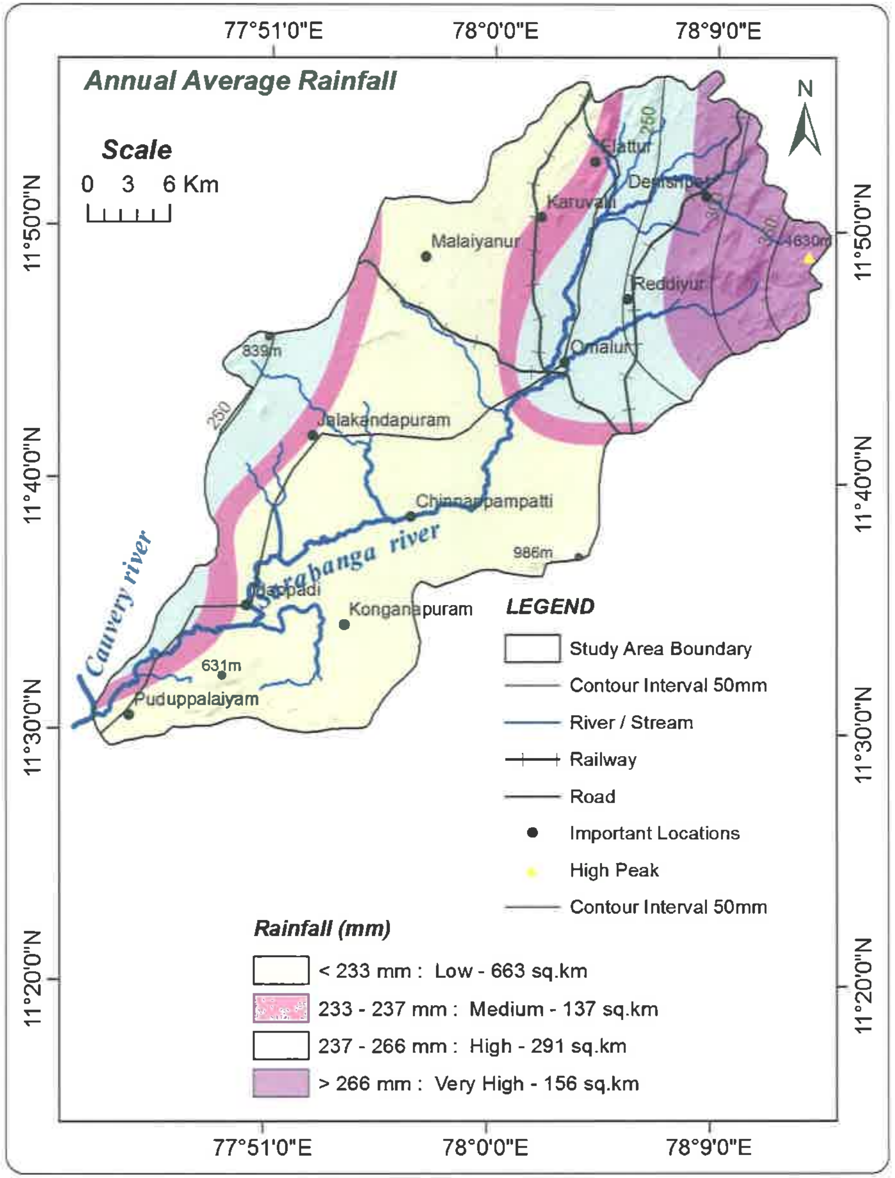

Fig.2.2.Map showing average annual rainfall of Sarabanga sub basin.

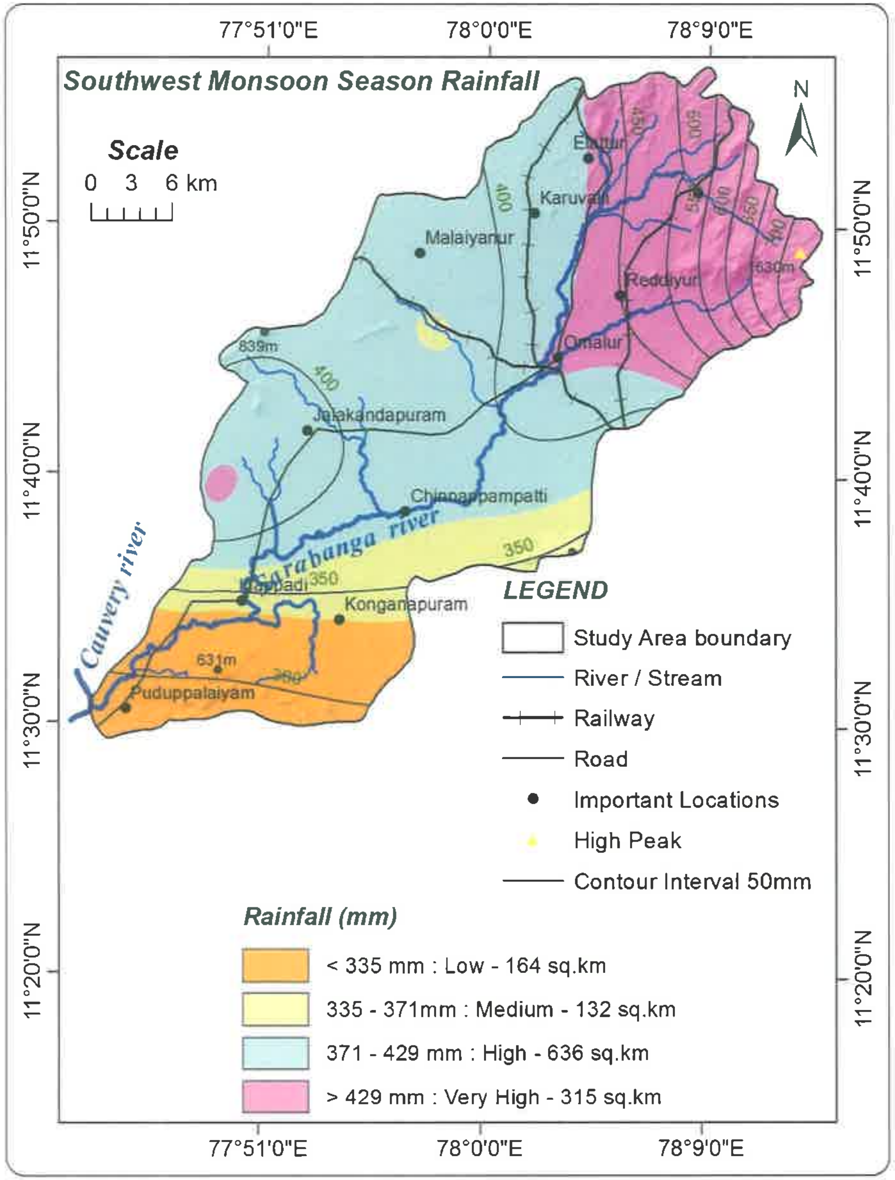

Fig.2.3.Map showing Southwest monsoon season rainfall of Sarabanga sub basin.

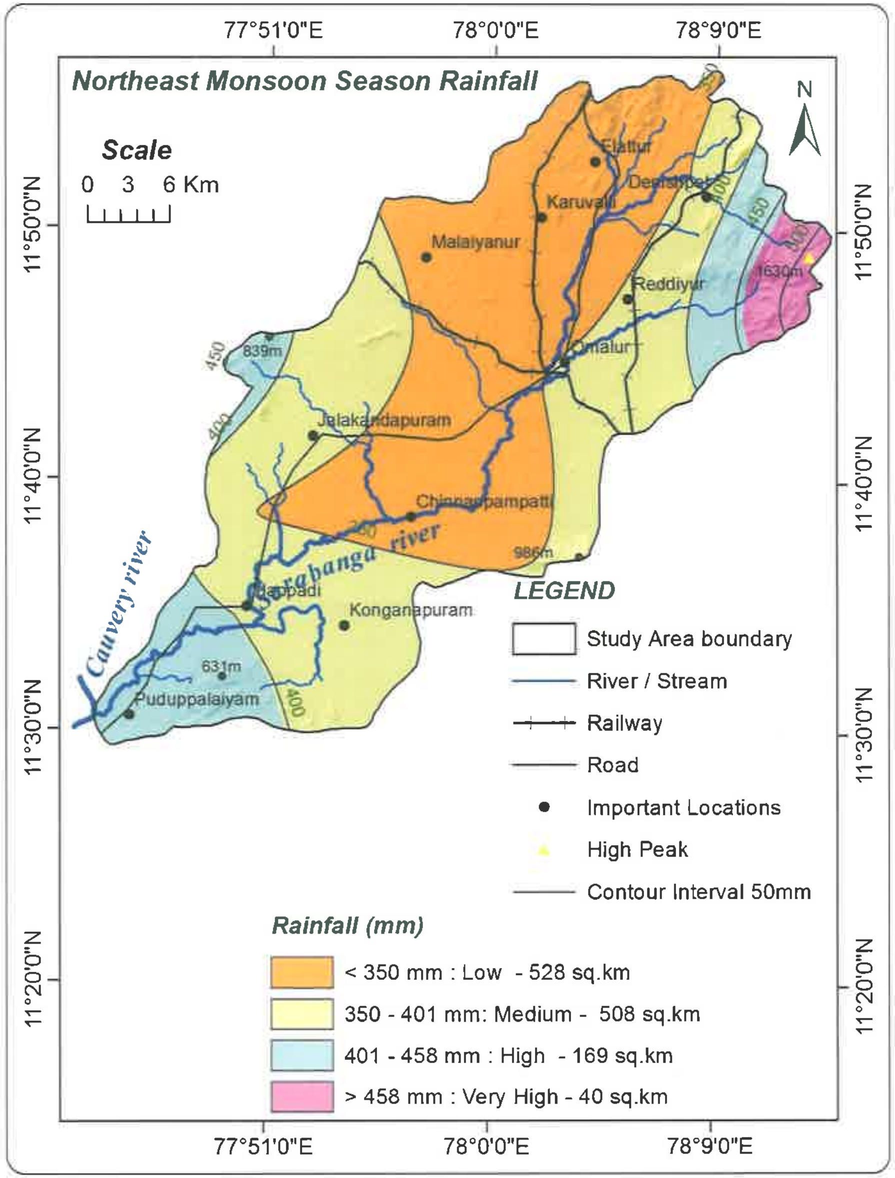

Fig.2.4.Map showing Northeast monsoon season rainfall of Sarabanga sub basin.

2.2 Temperature

The daily variation in temperature varies from a minimum around sun rise, to a maximum from 1/2 to 3 hours after the sun has reached its zenith, after which there is a continuous fall during the nights to sunrise again. Accordingly, maximum and minimum observations are best made in the period from 8.00 A.M. to 9.00 P.M. after the minimum has occurred. The mean daily temperature is the average of the maximum and minimum and is normally within degree of the true average as continuously recorded. The hot weather begins early in March, the highest temperature being reached in April and May. The weather cools down progressively from about the middle of June and by December, the mean daily maximum temperature drops to 30.2°C, while the mean daily minimum drops to 19.2°C and 19.6°C in January in Salem and Mettur respectively. The following table 2.3 shows the minimum, maximum temperature and humidity of the study area.

2.3 Humidity

The weather is pleasant during the period from November to January. Mornings in general are more humid than the afternoons, with the humidity exceeding 75% on an average. In the period June to November the afternoon humidity exceeds 60% on an average. In the rest of the year the afternoons are drier, the summer afternoons being the driest.

2.4 Water Table

Evaluation of hydraulic properties of aquifers is an important aspect of any groundwater resource assessment. This helps the investigator in estimating the groundwater potential of an area and in modeling the groundwater systems.

Water level observation well locations and Water table contour maps are shown in Fig.2.7 and Fig.2.8. The water table below ground level of the 18 monitoring wells have been reduced with respect of Mean Sea Level (MSL) with the help of spot levels given in the relevant topographic sheets.

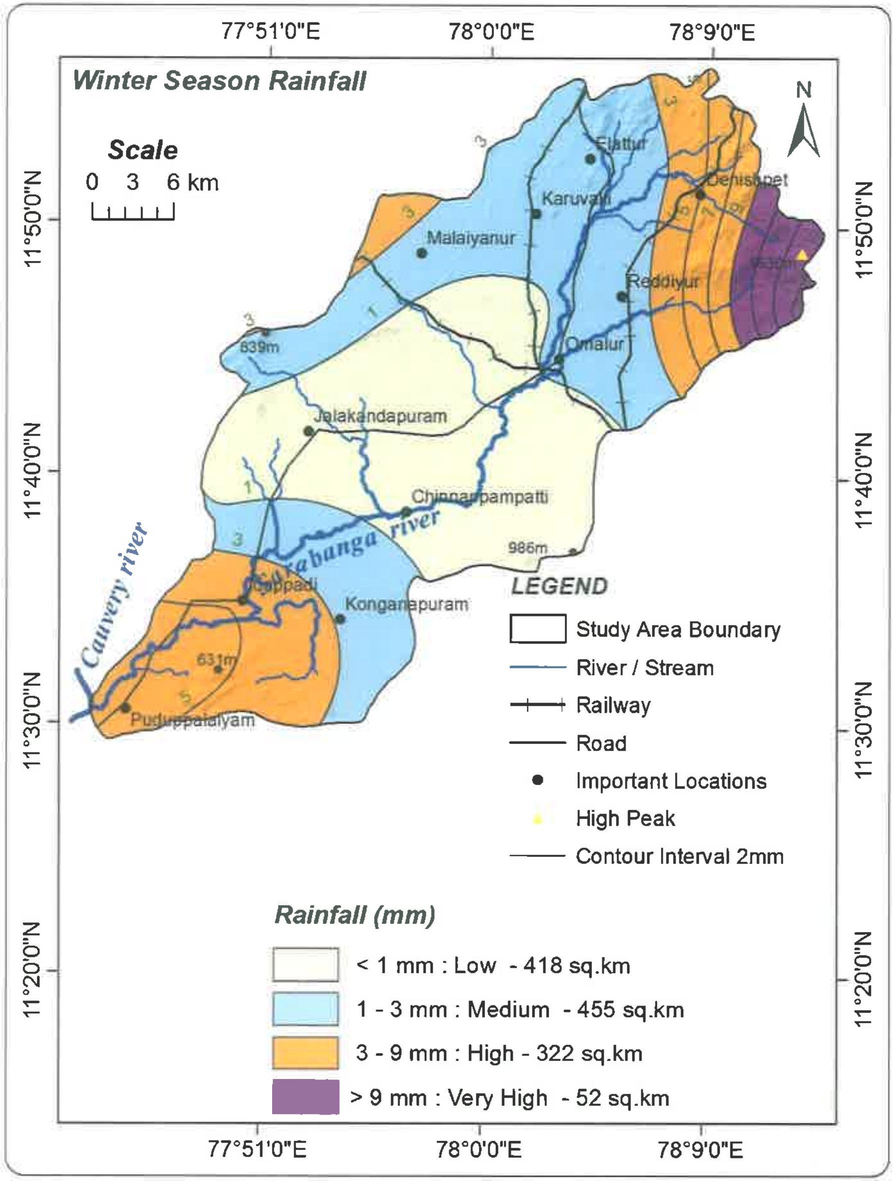

Fig.2.5.Map showing Winter monsoon season rainfall of Sarabanga sub basin.

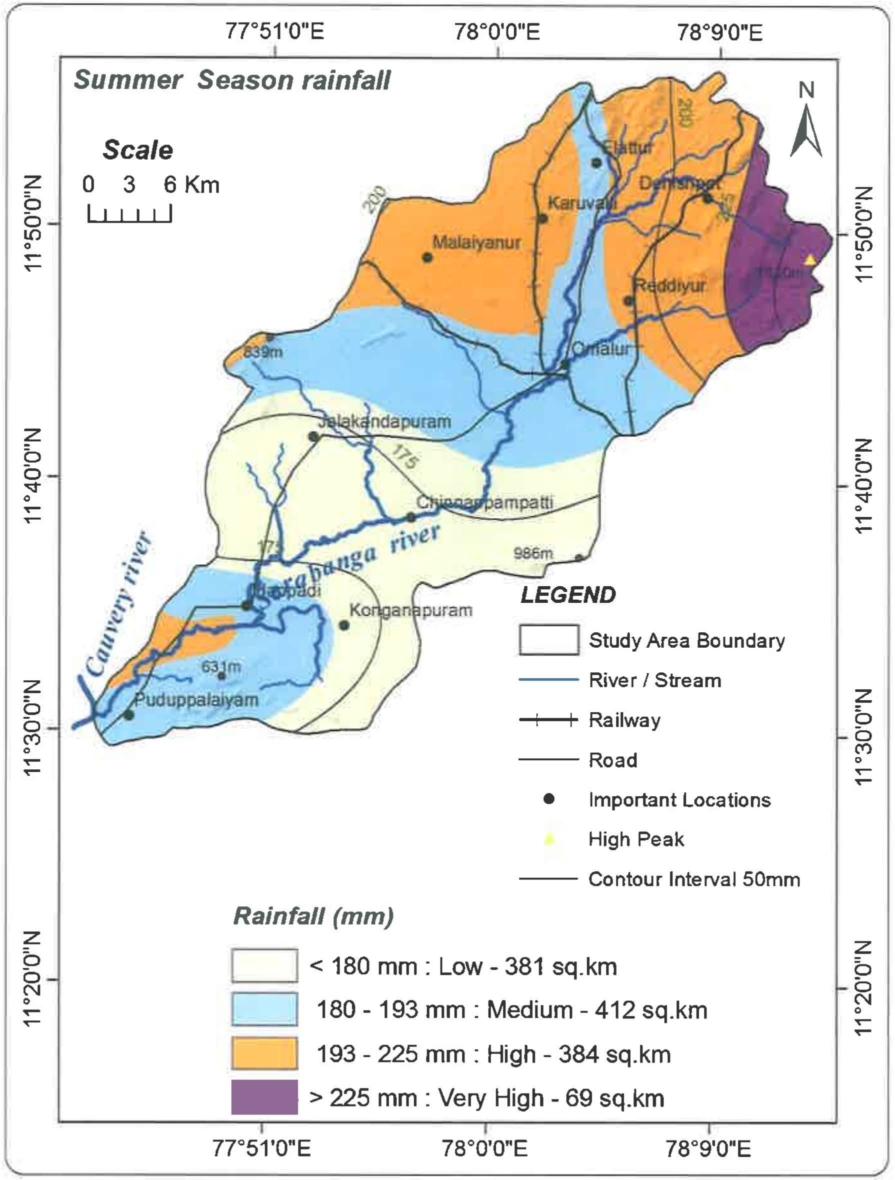

Fig.2.6.Map showing Summer monsoon season rainfall of Sarabanga sub basin.

Table 2.3 Temperature and Humidity of Sarabanga Sub Basin

Year and Month	Temperature °C Maximum		Temperature °C Minimum		Humidity in %	
	Highest	Mean	Lowest	Mean	8.30 Hours	17.30 Hours
June	38.6	34.2	22.5	24.5	78	54
July	35.8	32.5	21.4	23.4	80	58
August	35.9	31.9	21.2	23.2	83	61
September	34.6	32.0	22.0	23.1	82	63
October	35.2	32.9	21.2	23.2	81	61
November	33.8	29.1	19.4	21.9	89	75
December	32.4	28.3	16.7	20.5	84	64
January	33.1	31.3	17.0	19.7	78	43
February	34.2	32.4	15.4	20.3	73	40
March	37.4	35.5	17.6	22.2	71	30
April	37.3	35.3	21.5	24.5	75	48
May	37.7	35.7	21.2	25.2	71	43

Water table and contour maps prepare for the southwest monsoon season are shown in Fig. 2.9. and 2.10. It is found that the water level contours generally follow the topography and two separate groundwater regimes for one quadrant to another. The altitude of water table varies from 206 to 470.02 m above mean sea level. The southwest Monsoon season monthly water level data interpretation reveals that water level contour Tholasampatti, Tharamangalam, Muthunaichenpatti location water level is very near to the surface in the study period because this location is highly infiltrate water in the rainy season. The groundwater flows generally towards the southwest of Sarabanga sub basin. The configuration of water table contours brings about the effluent nature.

The northeast monsoon season monthly average water level data results reveals that Omalur, Elattur, Tholasampatti, Tharamangalam, and Muthunaichenpatti locations are observed and the water level is very near to the surface in the study period because this location is susceptible to high amount of infiltration during the rainfall. Water table and contour maps prepare for the northeast monsoon season are shown in Fig. 2.11. and 2.12.and Field Pho.2.1

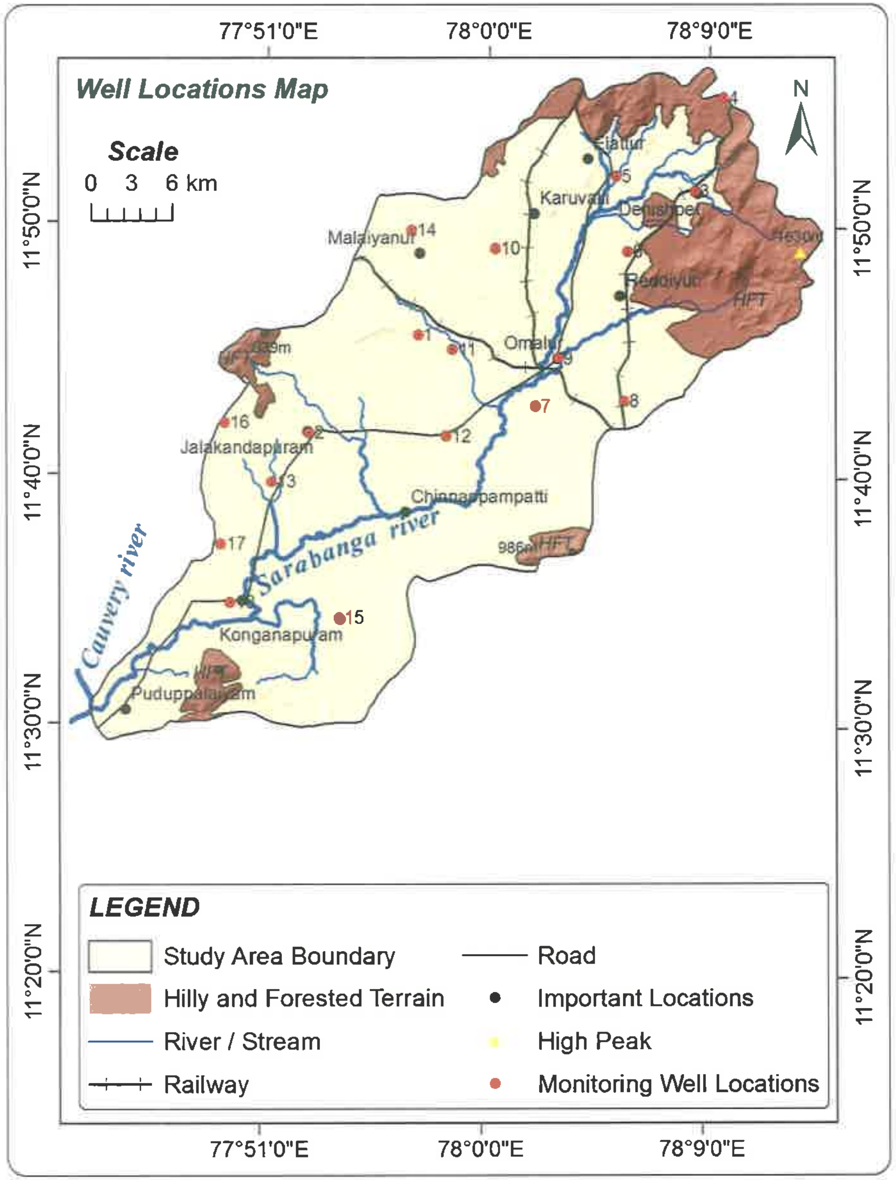

Fig.2.7.Map showing Water level observation well locations of Sarabanga sub basin.

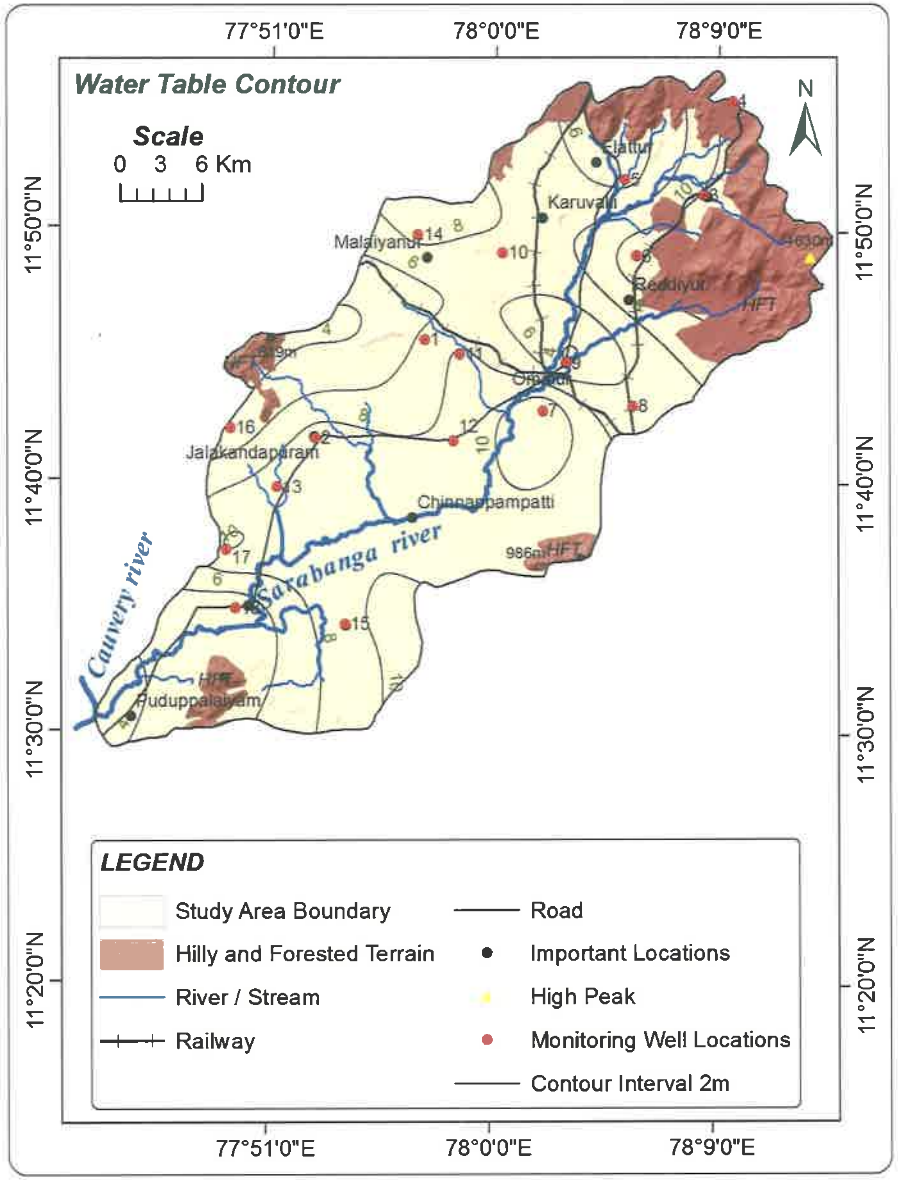

Fig.2.8.Map showing Water table contour of Sarabanga sub basin.

Photos-2. Field Photographs showing agricultural farm dug wells

a.Shallow depth of water level in a dug well at Danishpet village.

b. Water level measurement in a dug well at Mecheri village

c. Shallow depth of water level in a dug well during post monsoon at Chinnayercaud village

d. Rectangular Dug well in the thick weathered zone at Olaipatti village

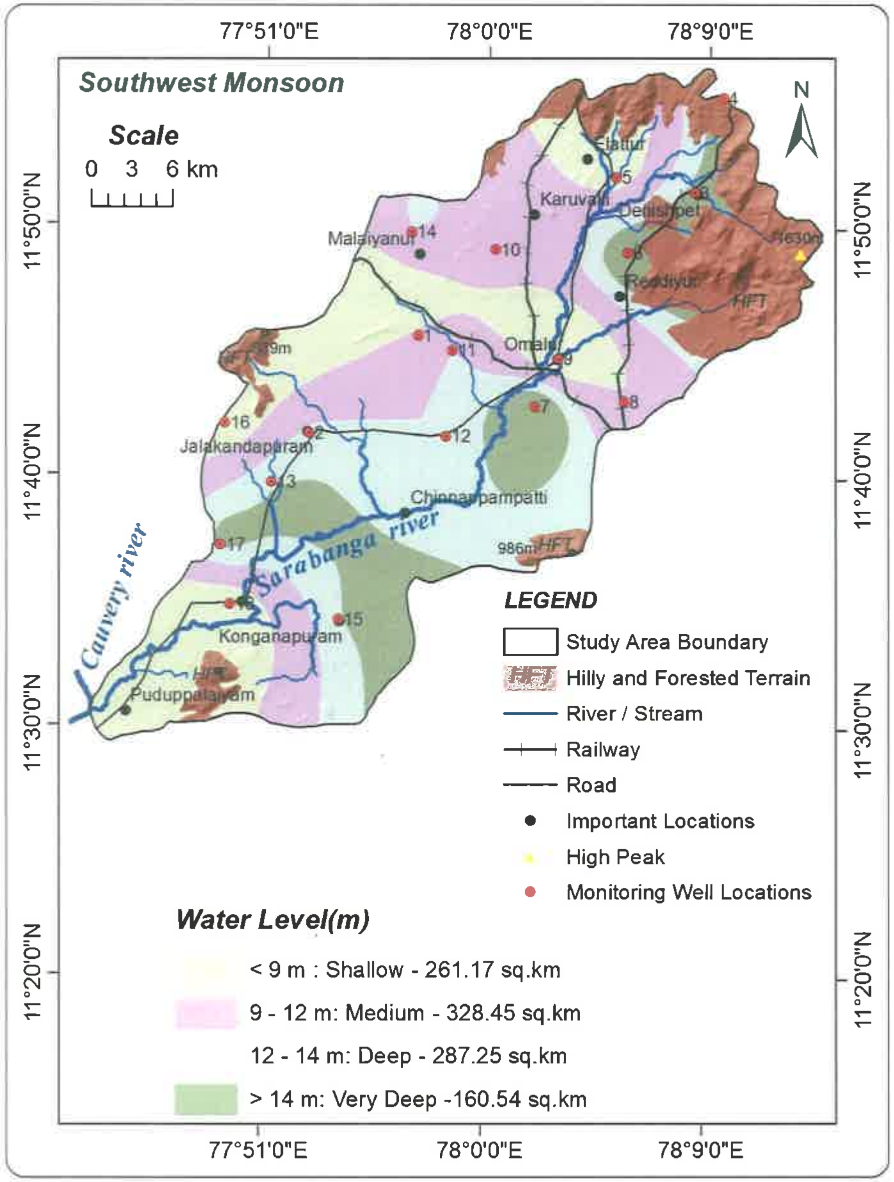

Fig.2.9.Map showing depth to Water level (BGL) during Southwest monsoon season.

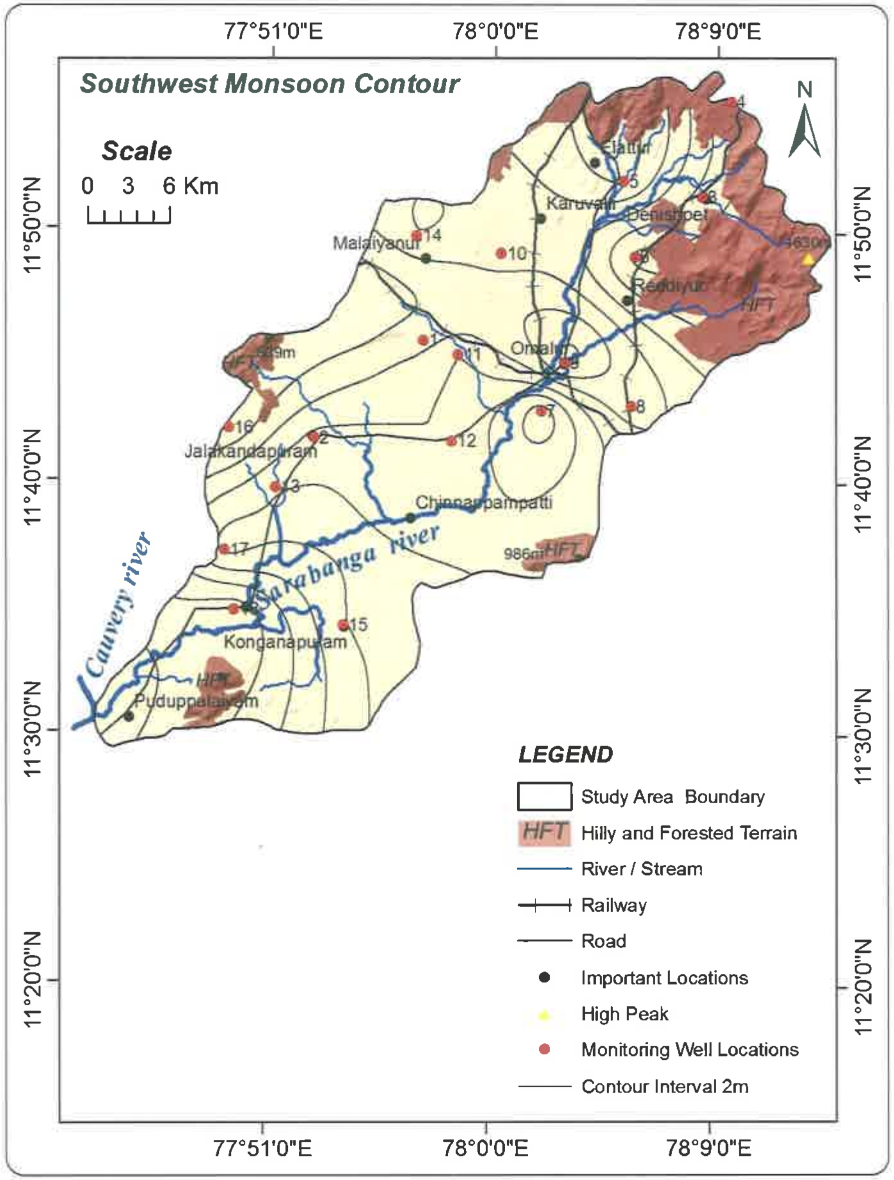

Fig.2.10.Map showing depth to Water level (BGL) Contour of Southwest monsoon season.

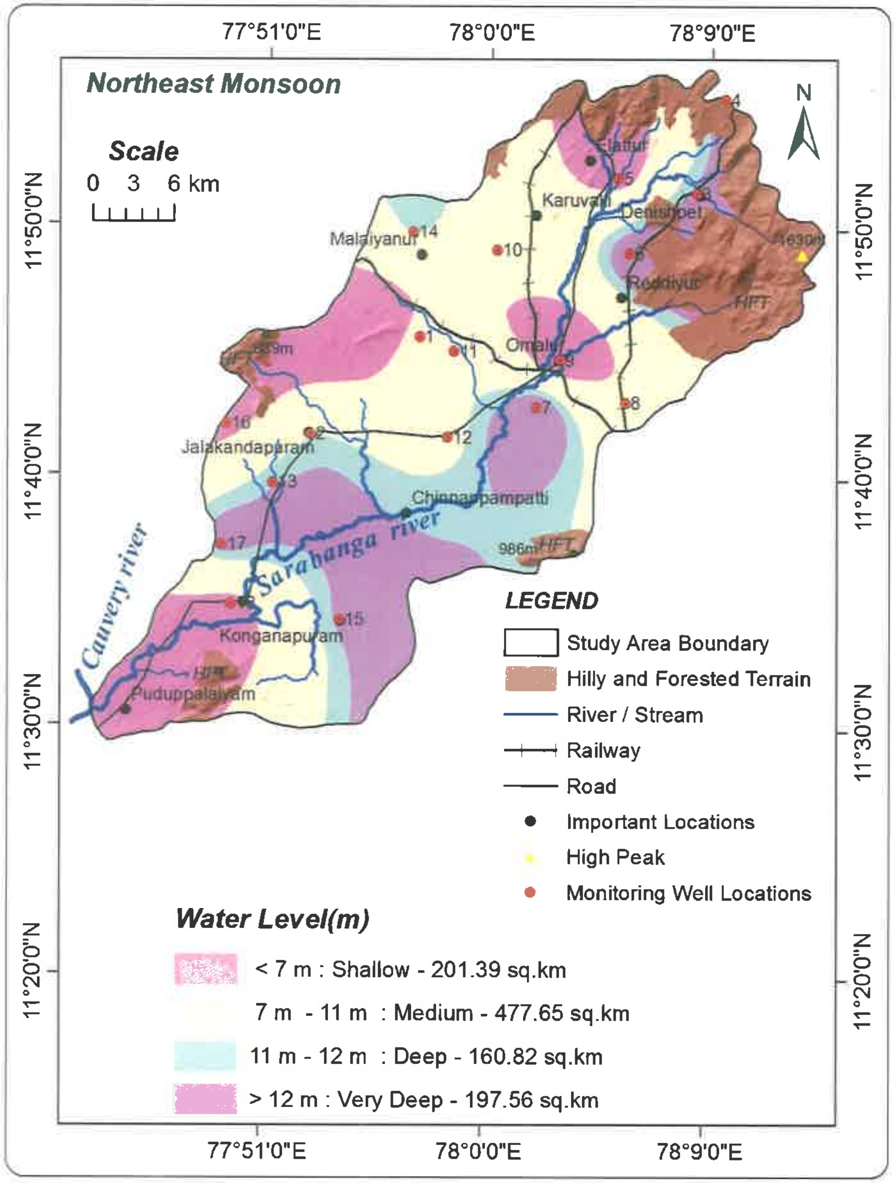

Fig.2.11.Map showing depth to water level (BGL) during Northeast monsoon season.

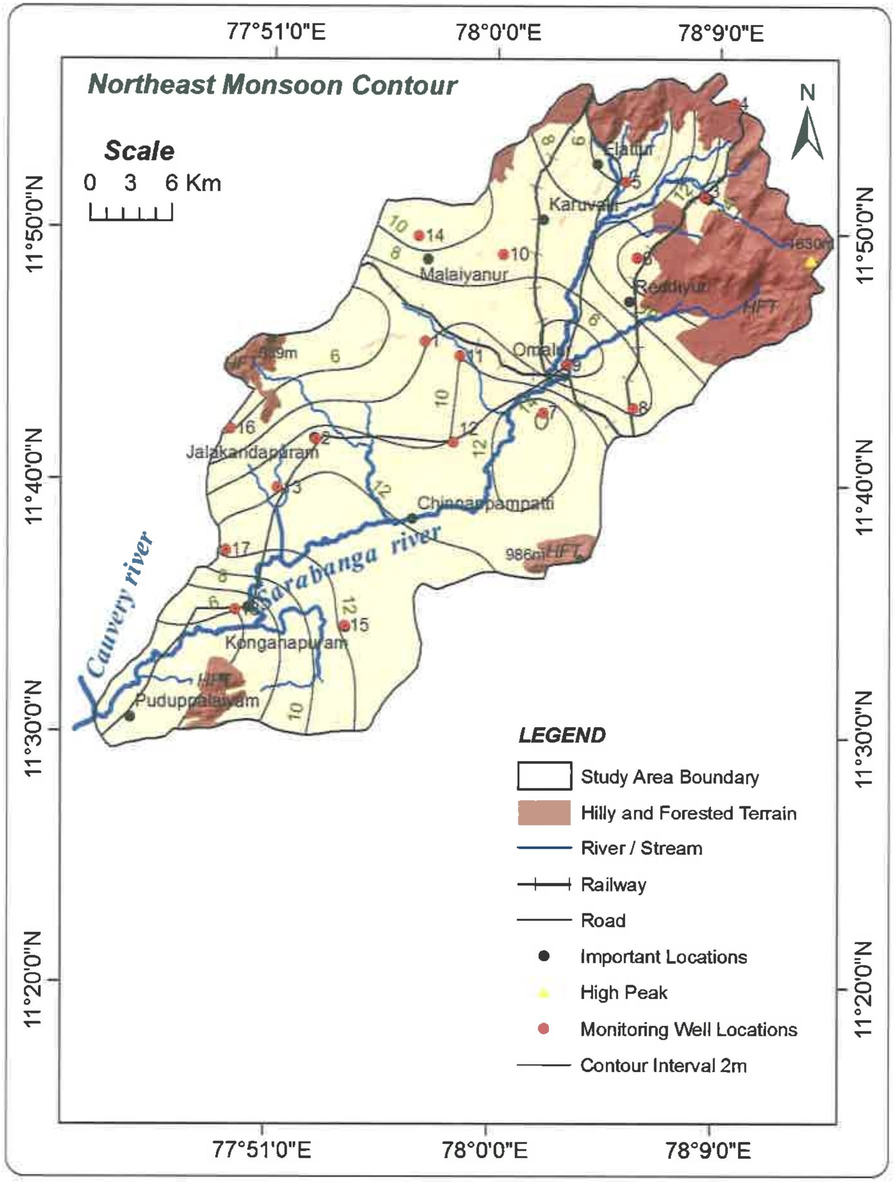

Fig.2.12.Map showing depth to water level (BGL) contour during Northeast monsoon season.

2.5 Water Table Fluctuation in Different Seasons

The water table configuration has similarity with the surface topography, when only the water table slope is less than the surface slope. The altitude of water table in the southwestern part of the basin is above 13.32 m Average Mean Sea Level (AMSL), which has the slope gradient of less than 4.24, 4.67, and 4.66 m AMSL in the southern part of Muthunaichenpatti ,Thinnapatti and Karupur of the sub basin. However, except for a few days after a heavy rainfall, no effluent flow is noticed in the streams which indicate water table lies below the stream end.

It is a well established fact that the occurrence and movement of groundwater depends upon lithology, landforms and structure. If these factors are favorable then the aquifer conditions are satisfying for good groundwater potential. A good aquifer is one which can be recharged during the period of monsoon when rain water gets infiltrated and recharged. This means that during the pre monsoon period aquifers used to have a low water table condition compared to post monsoon period. The difference in water table can be calculated once the water table of both seasons is recorded. Water level measurement for both monsoons was carried out during field work in 2011-2012. Depth to water table from ground surface was measured with the help of measuring tape. Altitude is measured with the help of GPS. These water table data are converted to mean sea level referenced data by using altitude value. After getting the MSL referenced water level data, water table contour map is prepared with the help of Arc GIS 9.3 software in total water level data of period. Wells are evenly distributed throughout the study area. Water table conditions of pre and post monsoon season are shown in Table 4.4. Generally, depth to water level ranges from 4.24 to 13.32 m below ground level in the south and southeastern parts of the basin. The regional deeper water level in the basin is due to more abstraction shown in Table 4.4 and water level less than 13.32 m below ground level is mainly due to less abstraction. 18 wells were interpolated for both pre monsoon and post monsoon seasons.

Pre monsoon: Generally, in the pre monsoon season the water level change due to the rise of groundwater level and it is more from nearby nallas and lakes. But in the discharge area, the rise of groundwater level is generally poor. The data analyses of water level of pre monsoon in the study area show the highest value in two major locations in and around Mecheri, Lokur and Konganapuram due to their higher elevation of 9.87m, 9.86 m and 9.98 m AMSL. Moderate to lower level is observed in rest of the study area. The shallowest water level is observed at Tholasampatti, and Muthunaichenpatti which is having water level of less than 2.02 and 2.36 meters AMSL. Moderate water level was observed in the remaining wells of the study area especially from NE to SW which follow the same topography. The pre monsoon water table contour fluctuates between 0.07 m to 3.49m (AMSL) due to variation in relief of the terrain. Lower values are found in south western part whereas higher values are found in the Northeast, South and Southwestern part.

Post Monsoon: During the post monsoon period, the water level has responded fairly in whole of the study area compared to the Pre monsoon. It follows the general trend of topography. The water level is highest in the Pakkanadu and Irupalli and moderate to lower in the rest of study area. Comparing the data of pre monsoon water level it has not shown much improvement in the western and southeastern part of the study area as it is found to be at the elevation difference. In the eastern part of the study area, the water level has slightly recovered when compared to pre monsoon especially northern part of Theevattipatti, southern part of Omalur. The moderate levels are recorded in the middle part of the basin from NE to SW. The post monsoon water table varies in the range of 1.58 m to 10.45 m (AMSL) is shown in Fig.2.12. Similar to pre monsoon water level, Southwestern and Northwestern part of the study area shows shallow water table due to less relief whereas North and Northwestern part shows an elevated water table.

Summer: Groundwater occurs under phreatic conditions in the weathered mantle of crystalline rocks as well as in the shallow aquifers in porous weathered zone area in the Sarbanga sub basin, Depth to water levels in large diameter wells in the area provides valuable information regarding the groundwater regime in the phreatic zone and is one of the guiding factors for selection of areas for recharge and augmentation. Summer season water level high in Danishpet, Thinnapatti, Muthunaichenpatti and Makkanur is shown in Fig.2.13.

Winter: Groundwater level fluctuation entirely depends on the rate of precipitation. Actually high rainfall is received in monsoonal seasons but shallow water level was noticed in winter season because of the gradual infiltration rate. Winter season water level high in western part of Theevattipatti, Omalur, Pakkanadu and Edapadi is shown in Fig.2.14.

Water Table Fluctuation: Water level fluctuation is an effect computed from the difference in hydraulic head between the maximum and minimum water level observed from digging wells. Water level fluctuation may be effected due to following conditions (Davis and De Wiest, 1966).

Table 2.4 Water Table Data in (m) of Sarabanga sub basin

SI.No.	Observation Wells Name	Pre Monsoon water level m	Post Monsoon water level m	Water Level Fluctuation m
1	Olaipatti	6.88	6.56	0.32
2	Jalagandapuram	9.33	6.27	3.06
3	Danishpet	7.52	5.68	1.84
4	Lokur	9.86	6.37	3.49
5	Theevattipatti	5.37	3.22	2.14
6	Thinnapatti	8.82	6.59	2.24
7	Muthunaichenpatti	2.36	1.58	0.78
8	Karupur	5.21	4.39	0.83
9	Omalur	6.93	5.22	1.71
10	Marakottai	9.00	7.18	1.82
11	Tholasampatti	2.02	1.95	0.07
12	Tharamangalam	3.37	2.10	1.27
13	Irupalli	9.50	9.75	-0.25
14	Mecheri	9.87	8.82	1.04
15	Konganapuram	9.98	8.88	1.11
16	Pakkanadu	7.75	10.45	-2.70
17	Makkanur	6.93	6.48	0.45
18	Edapadi	5.48	5.26	0.21

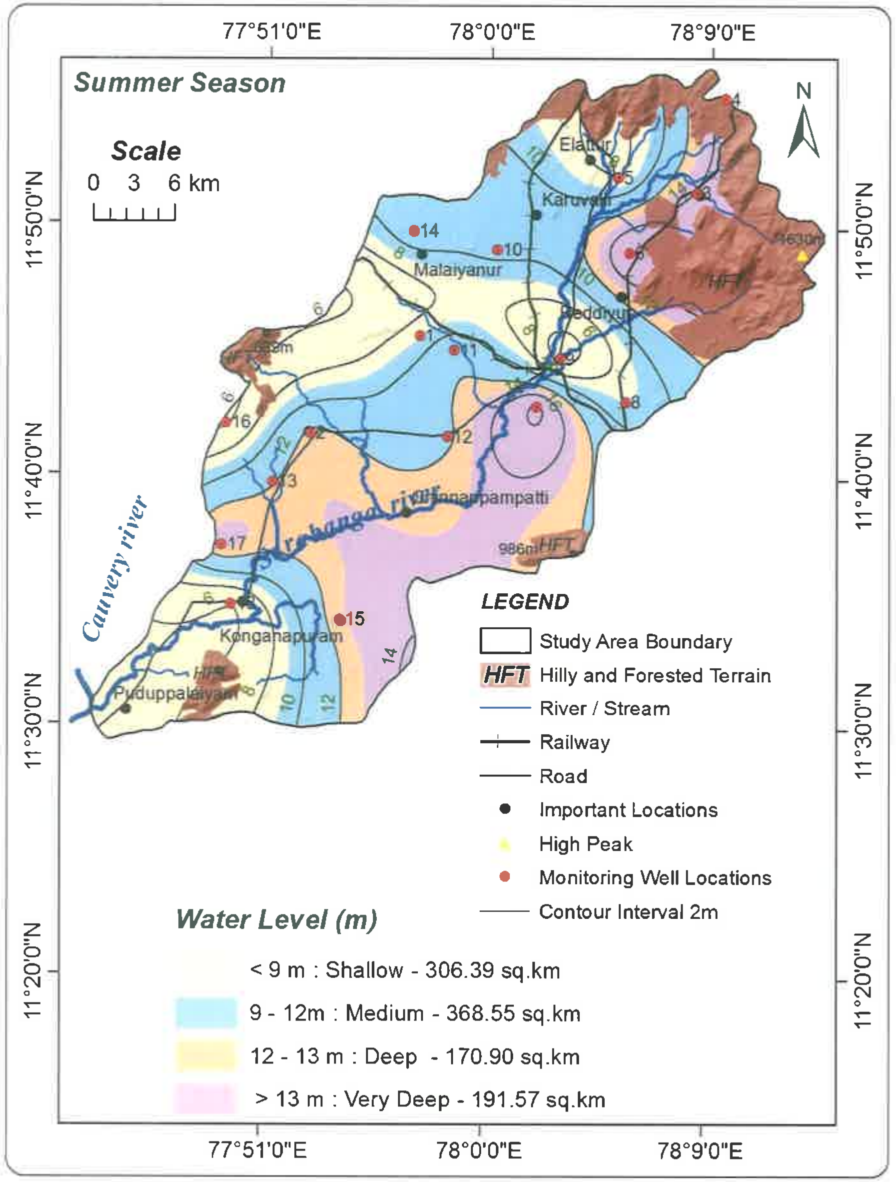

Fig.2.13.Map showing average water level during Summer season of Sarabanga sub basin.

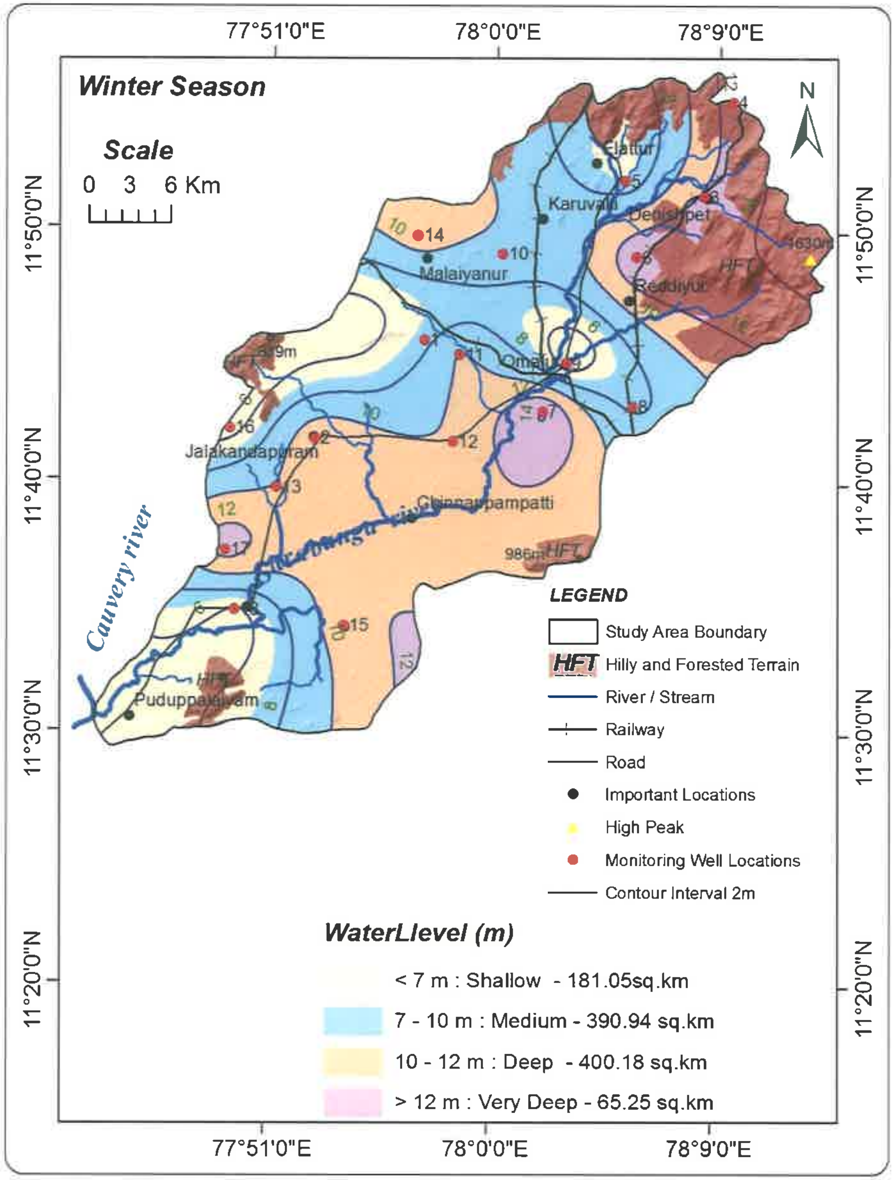

Fig.2.14. Map showing average water level during Winter season of Sarabanga sub basin.

i. Fluctuation due to change in groundwater storage;

ii. Fluctuation brought about by atmospheric pressure in contact with the water surface in wells;

iii. Fluctuation results due to deformation of aquifers, and

iv. Fluctuation due to disturbances within the well; that is, minor fluctuations are attributed due to chemical or thermal changes in and near the wells.

Though, the fluctuations of water level in wells result due to several causes, the long term fluctuation of water level in wells is due to changes in groundwater storage. The average annual water level fluctuations of the eighteen monitoring wells have been presented in Table 2.5. It has been found that a minimum water level fluctuation of 0.07 meters is found in Tholasampatti and a maximum of 3.49 meters in Lokur.

However the groundwater fluctuation varies from less than 0.29 meters in the north and southwest part of the study area. This is due to the influent nature of the infiltration from the western part of drainage and due to recharge from the uplands of northern part southwestern and western parts have less water table fluctuation. From the fluctuation map, it is found that maximum recharge of water level is found in west and southwest part of Olaipatti, Tholasampatti, Makkanur and Edapadi.

Northeastern and central part of the study area shows medium to high fluctuation in water level with less than 1.07 to 1.91 m. water table fluctuation variations is shown in Fig. 2.15.

2.6 Deviation of Water Table

Deviation of water table method of representing the geological data seems to be more convenient, objective and informative and brings out more sharply, the regional trend by eliminating the local interferences Biswas (1967), Hence, this method has been adopted in the present study and analysis. The water levels monitored from 2011 to 2012 in the Sarabanga sub basin Table.2.5 have been used and the following steps have been adopted in preparing the grid deviation water table map.

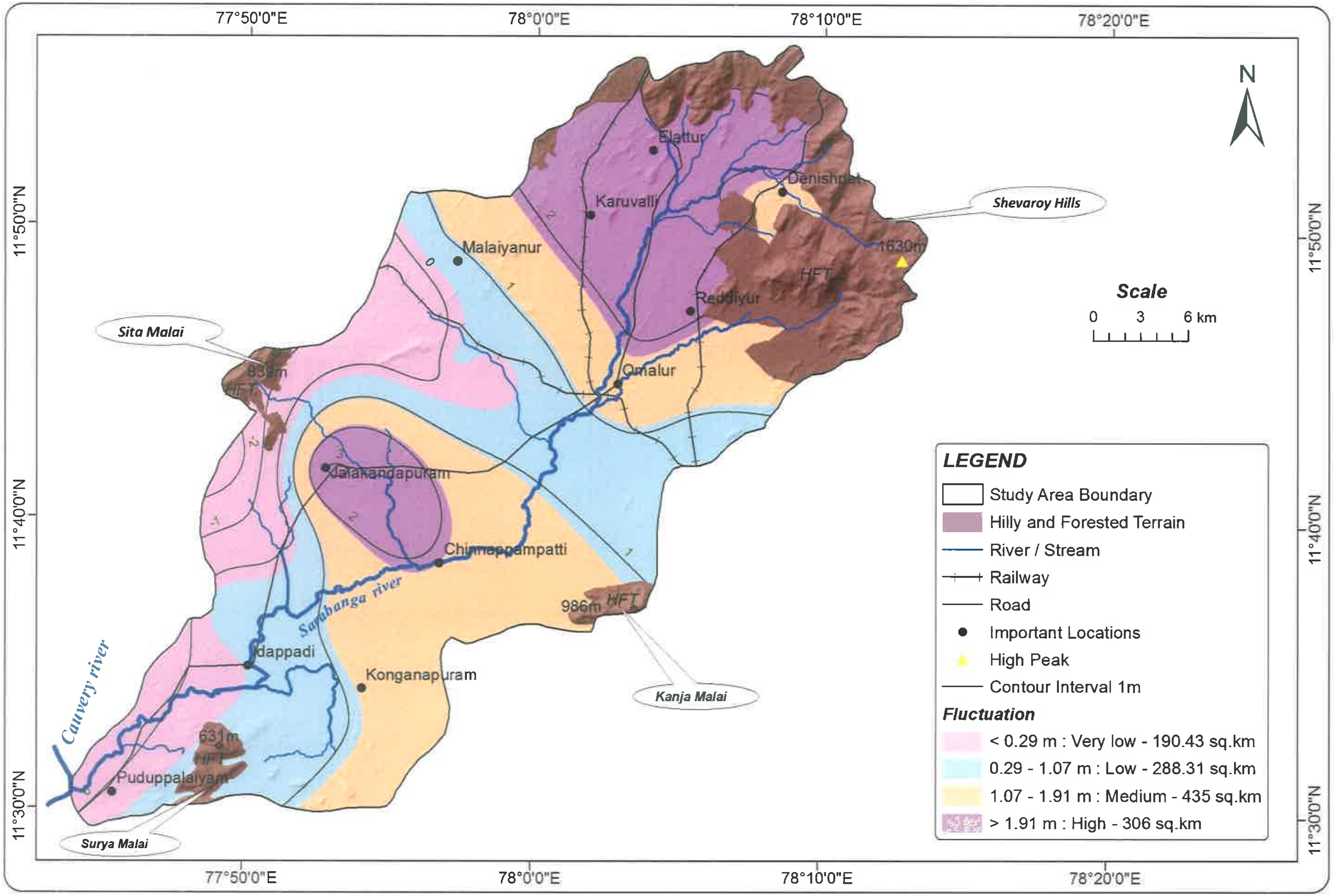

Fig.2.15.Long term water level fluctuation map between January 2002 and December 2011.

Monthly water levels measured below the measuring points have been recalculated to water level altitudes Above Mean Sea Level (AMSL).Average elevation of water table (A1) for each observation well has been computed after calculating the monthly averages of water levels.

An average value (A2) of all the average elevations of water table computed in step 2 has been determined for the Sarabanga sub basin. This is called the Sarabanga sub basin average and the deviation D = (A1 - A2) from the Sarabanga sub basin average water level altitude and the average elevation of water levels of individual observation wells have been determined.

The desired deviation map results from an objective contouring of the deviations (result of step of each location of the Sarabanga sub basin. It could be seen that in Fig.2.16 the entire Sarabanga sub basin is characterized by positive and negative horizons separated by a zero line (representing the grid average). The positive zone lies in the south, southeastern and southwestern side of the upstream area denoting the high elevations and recharge horizon and the negative zone lies in the lower reaches of the Sarabanga sub basin indicating the discharge horizon.

The wide spacing of the contours and their disposition are suggestive of flat gentle gradient of water table and high permeability of the formation material. The wide shaped "U" and closely spaced negative contours indicate steep gradient of water table. The positive and negative areas hint at the recharge and discharge zones respectively. Artificial recharge projects through infiltration ponds can be planned in the recharge zone demarcated in the Sarabanga sub basin.

Table 2.5 Deviation of water table in the Sarabanga Sub basin

SI. No.	Observation Wells Name	Water Levels in Meters		
		BGL	AMSL	Grid Deviation
1	Olaipatti	8.61	313.61	3.00
2	Jalagandapuram	11.89	296.89	23.00
3	Danishpet	5.09	386.09	-73.00
4	Lokur	5.02	470.02	-157.00
5	Theevattipatti	7.14	347.14	-32.00
6	Thinnapatti	4.64	347.64	-35.00
7	Muthunaichenpatti	4.24	272.24	40.00
8	Karupur	4.66	318.66	-6.00
9	Omalur	5.22	282.22	31.00
10	Marakottai	5.65	379.65	-66.00
11	Tholasampatti	6.21	301.21	13.00
12	Tharamangalam	5.97	270.97	43.00
13	Irupalli	12.16	278.00	42.16
14	Mecheri	11.39	351.00	-31.61
15	Konganapuram	12.75	239.00	81.75
16	Pakkanadu	5.95	288.00	25.95
17	Makkanur	13.32	213.00	108.32
18	Edapadi	5.83	206.00	107.83

Grid Average 308.96 (m AMSL)

BGL = Blow Ground Level

AMSL = Above Mean Sea Level

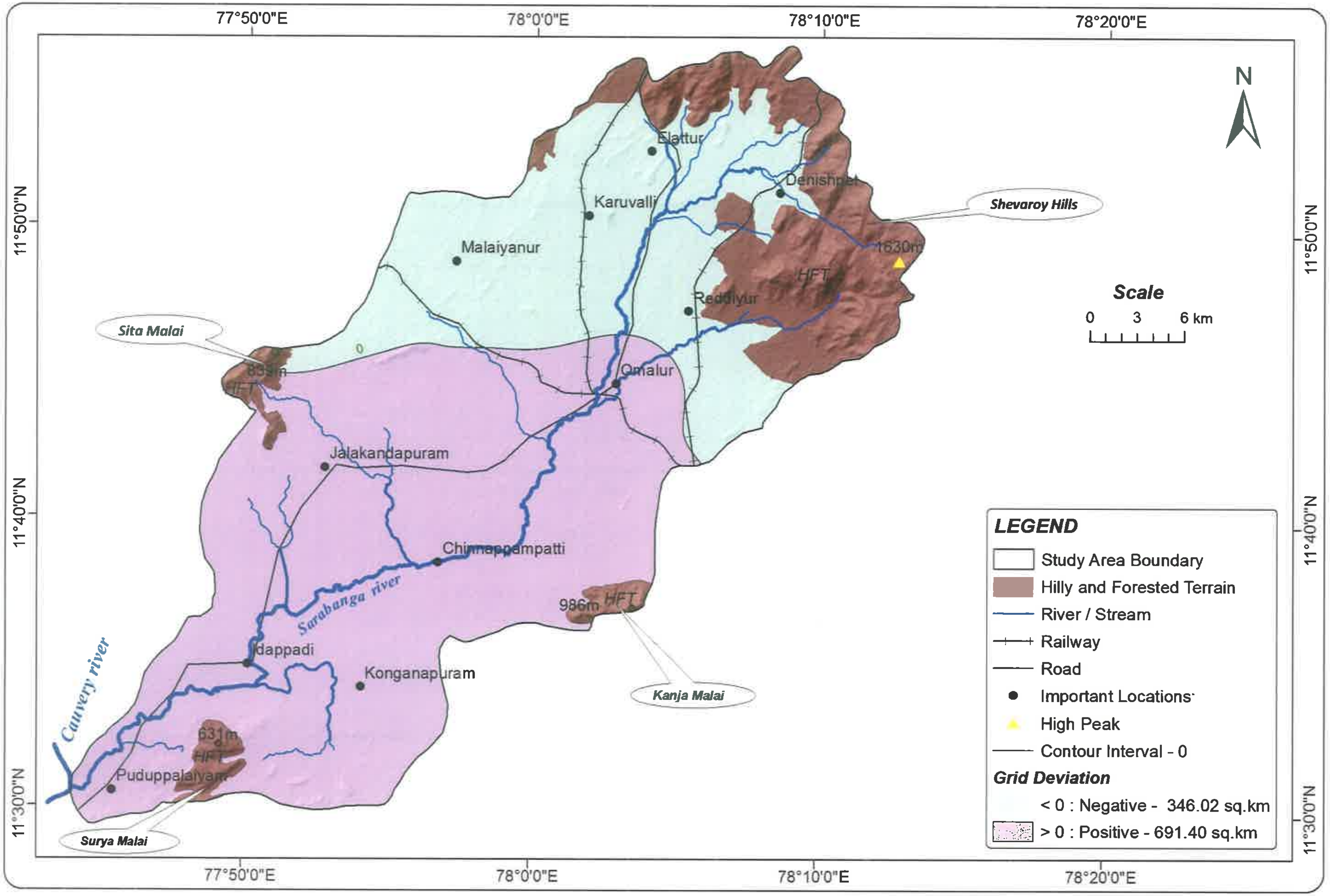

Fig.2.16.Grid deviation map water table of Sarabanga sub basin.

CHAPTER III

HYDROGEOPHYSICS

3.1. Geophysical Field Survey

For evaluating the groundwater potential zones in the Sarabanga sub basin under study, Vertical Electrical Sounding of 93 locations were carried out with the help of Resistivity meter Model SSR - MP - AT made in integrated geo instruments and services Pvt. Ltd. Hyderabad. The maximum depth of investigation up to 150 m. The spread was generally in steps of one meter interval up to twenty meters two meters interval up to thirty meters and five meters interval up to hundred meters ten meters interval up to two hundred meters. Geophysical survey locations map of Sarabanga sub basin is shown in Fig.3.2.and Field Pho.3.

3.2 Interpretation of VES Data

The primary objective of conducting electrical soundings is to transform the field data in terms of sub surface geology or hydrogeology so that suitable maps can be drawn for different geo electrical thematic maps can be drawn for geo electrical parameters of interest. To achieve this main objective, it is very essential to analyze the field data and interpret them suitably. The field VES data are computed and using IPI2 Win software various resistivity layer given in Figs.3.3 to 3.5 and various aquifer thickness layers given in Figs.3.6 to 3.10.

3.2.1 Analytical Method

In analytical methods field apparent resistivity values are plotted against electrode spacing over log - log graphs and the resultant field curves are matched with the master curves calculated theoretically. The resulting sounding curves might be of various types depending upon the geological hydrogeological situations and the maximum electrode spread employed. The simplest sounding curves are the ascending and descending type of layers .

Ascending type curves are obtained where the ground has a two layered structure, with a top soil or weathered layer and a hard and compact basement.

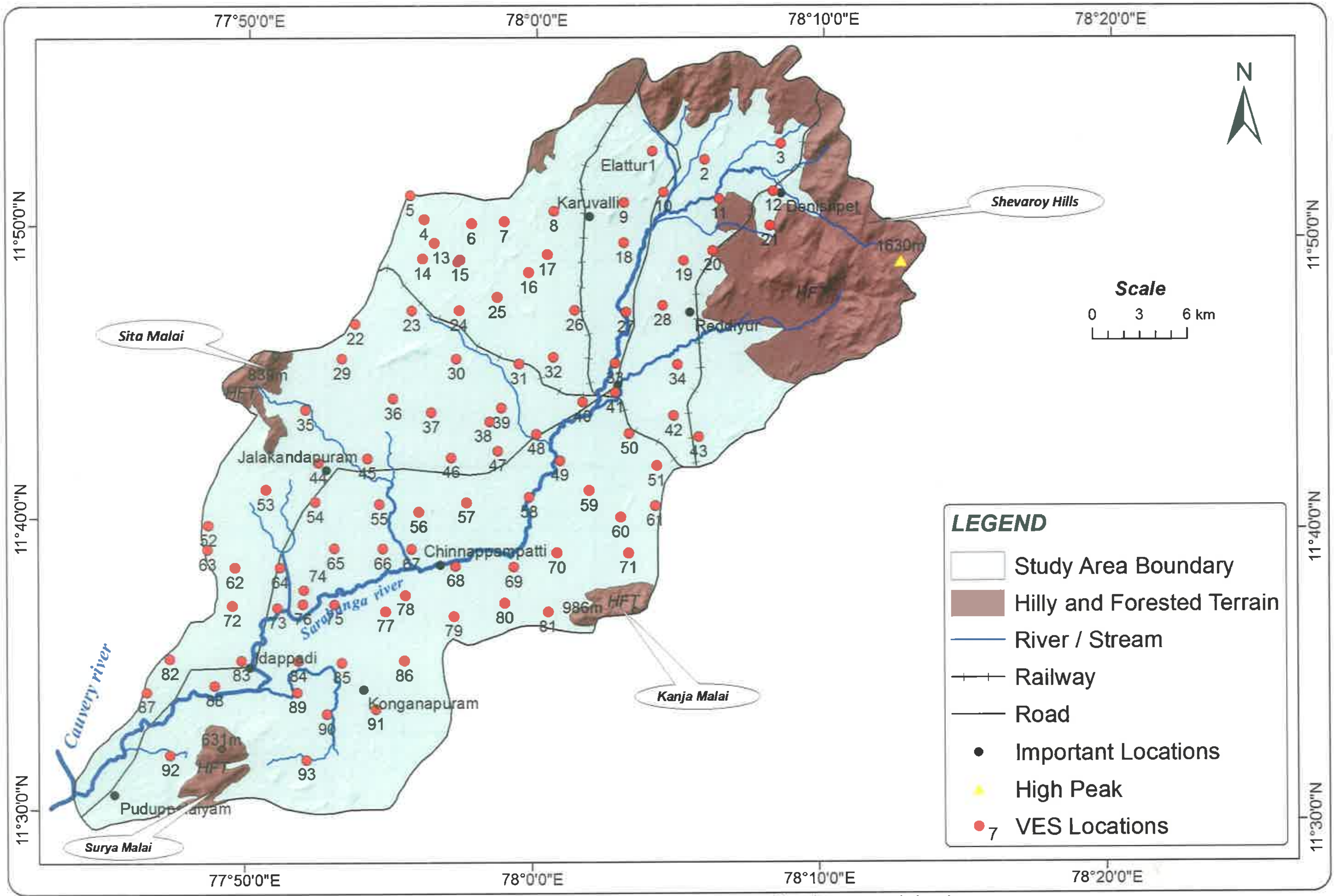

Fig. 3.2. Geophysical survey locations map of Sarabanga sub basin.

Photos-3. Field Photographs of geophysical field operation

a. Geophysical field operation at Elattur village

b. Geophysical field operation at Sadaiyampalaya village

c. Geophysical field survey at Jalakandapuram village

d. Geophysical field survey at Chinnanagalur village

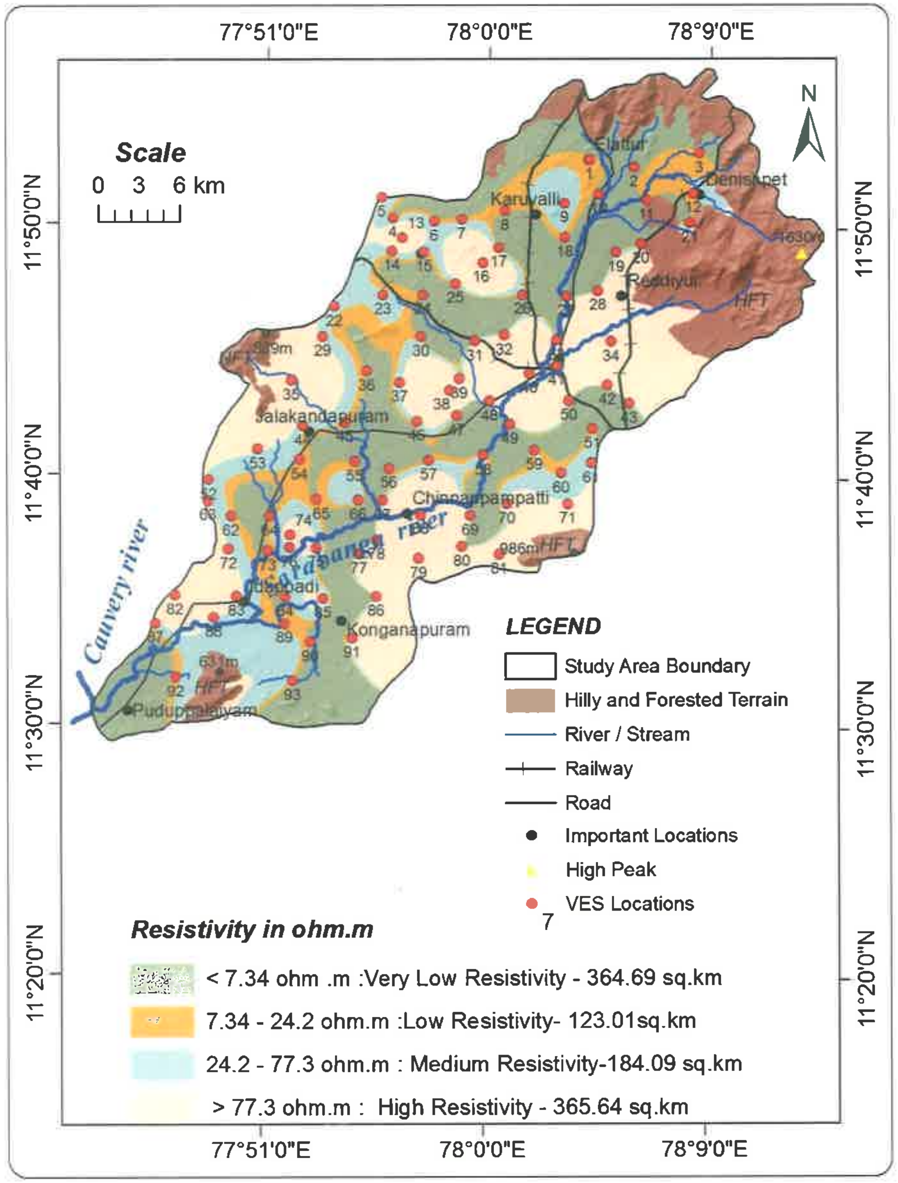

Fig.3.3.Map showing Iso apparent resistivity of first layer in the study area.

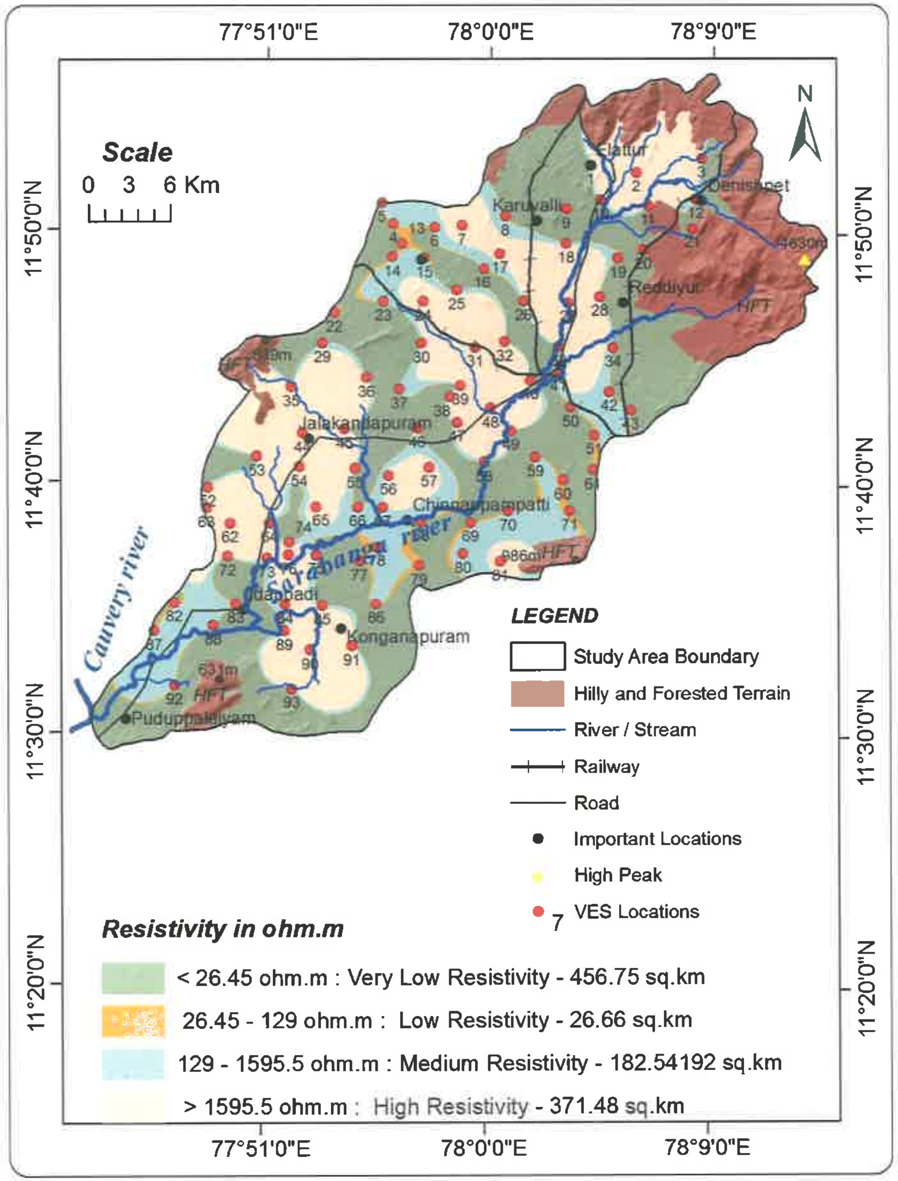

Fig.3.4.Map showing Iso apparent resistivity of second layer in the study area.

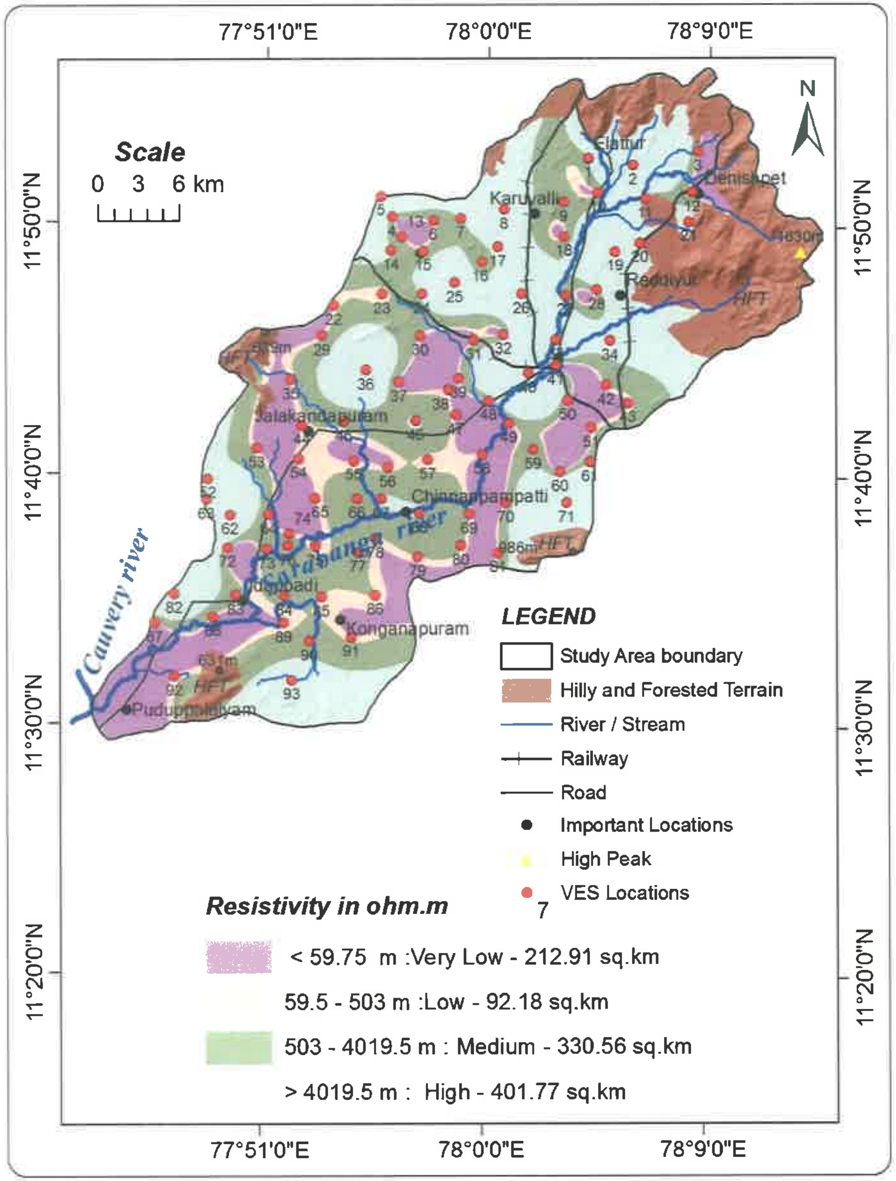

Fig3.5.Map showing Iso apparent resistivity of third layer in the study area.

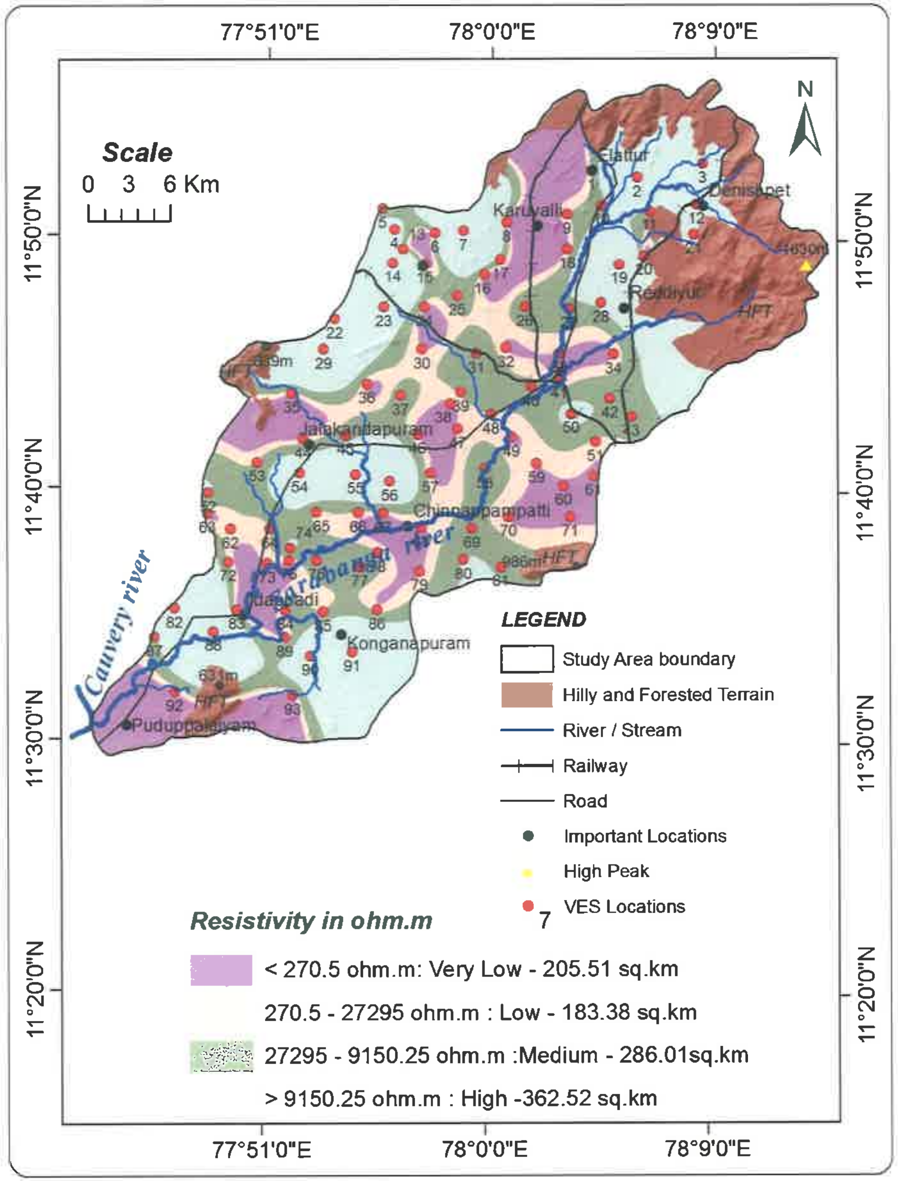

Fig.3.6.Map showing Iso apparent resistivity of fourth layer in the study area.

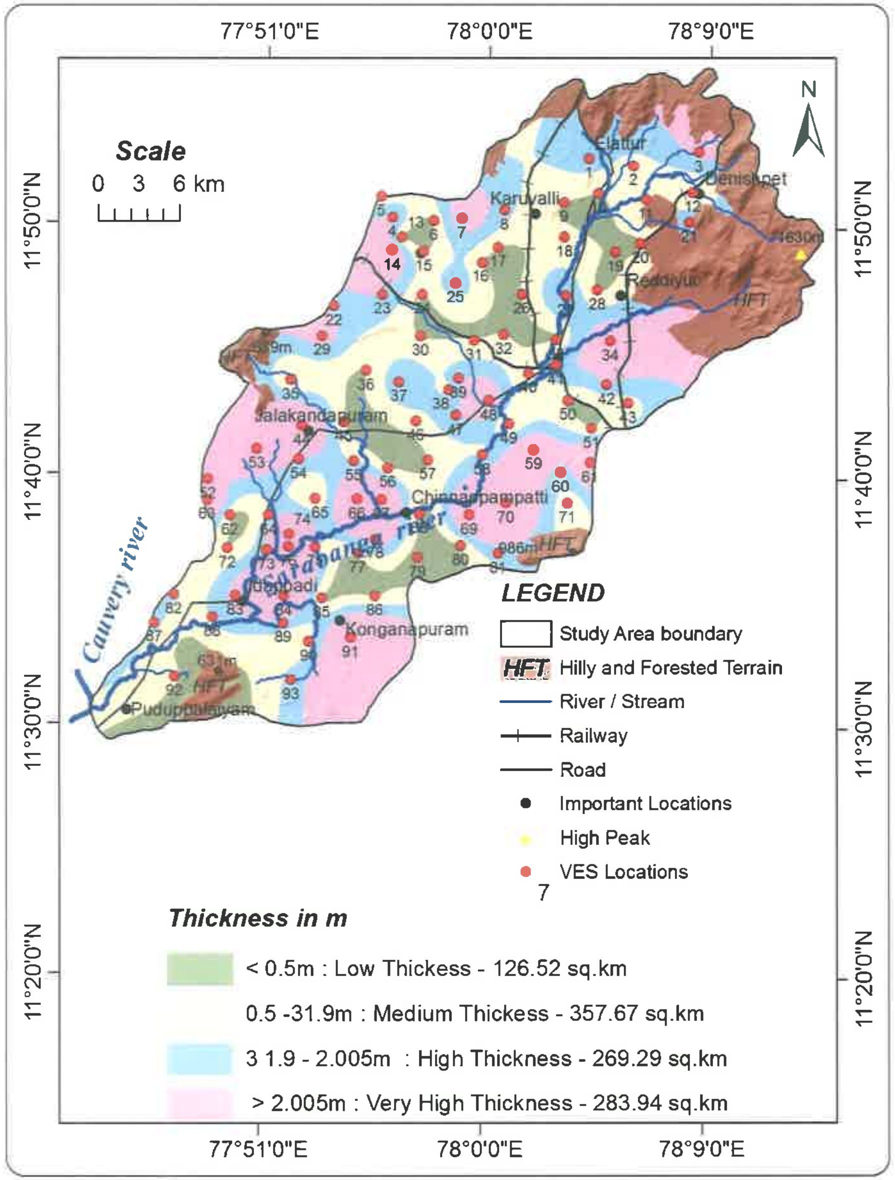

Fig.3.7.Map showing aquifer thickness of first layer in the study area.

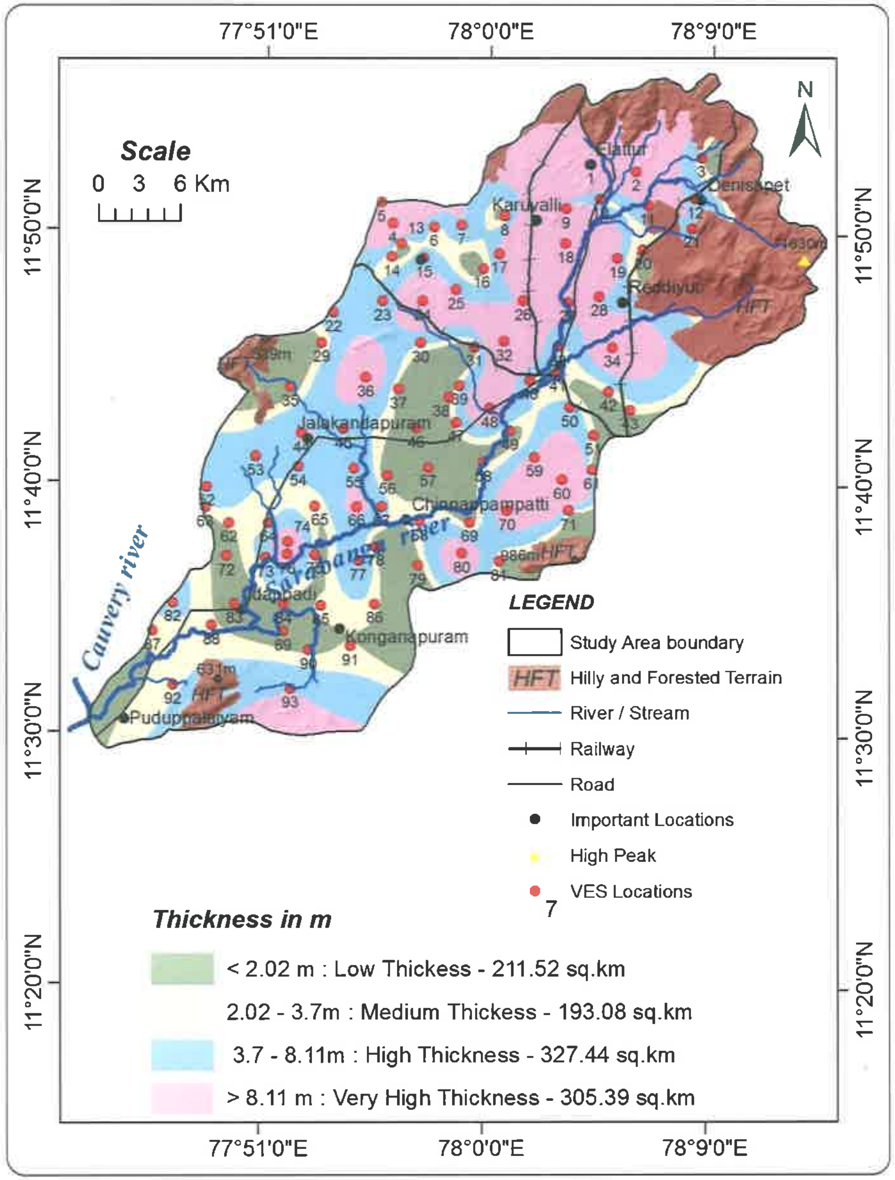

Fig.3.8.Map showing aquifer thickness of second layer in the study area.

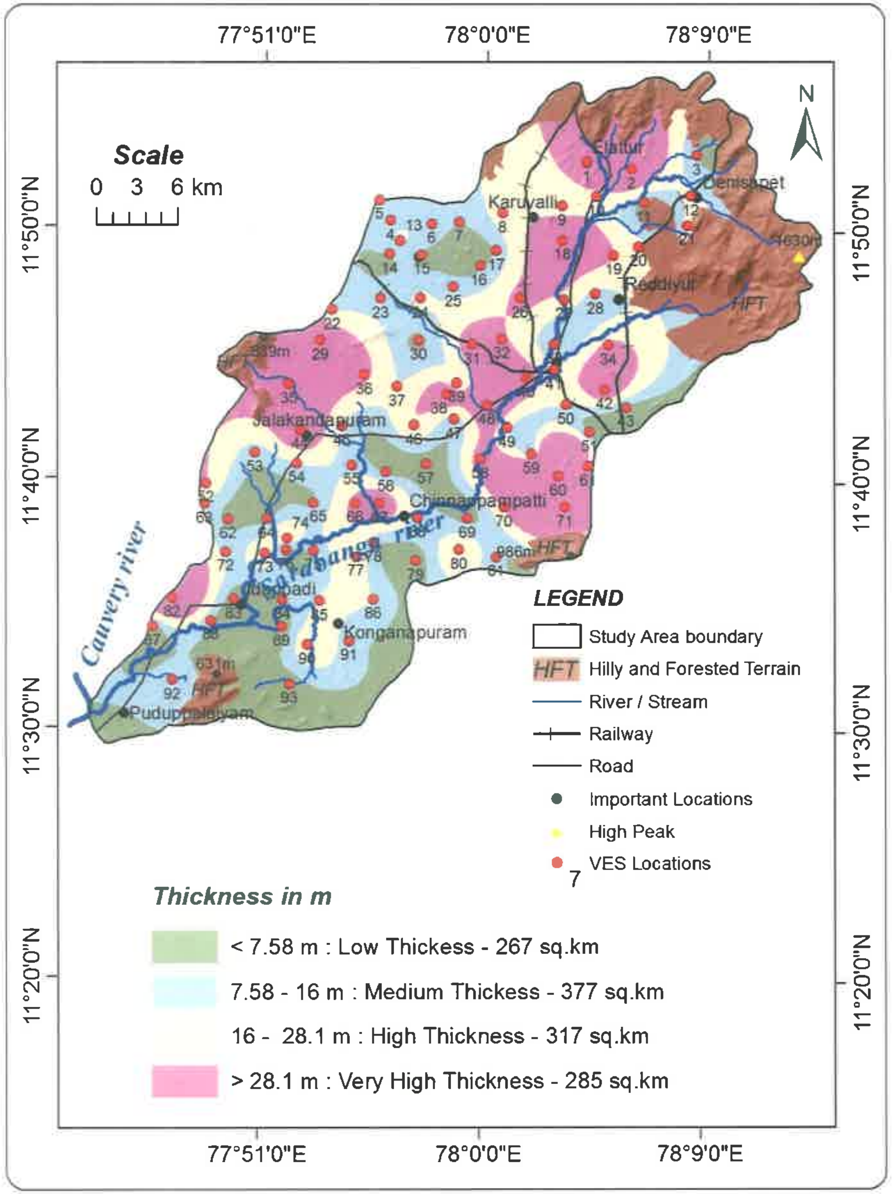

Fig.3.9.Map showing aquifer thickness of third layer in the study area.

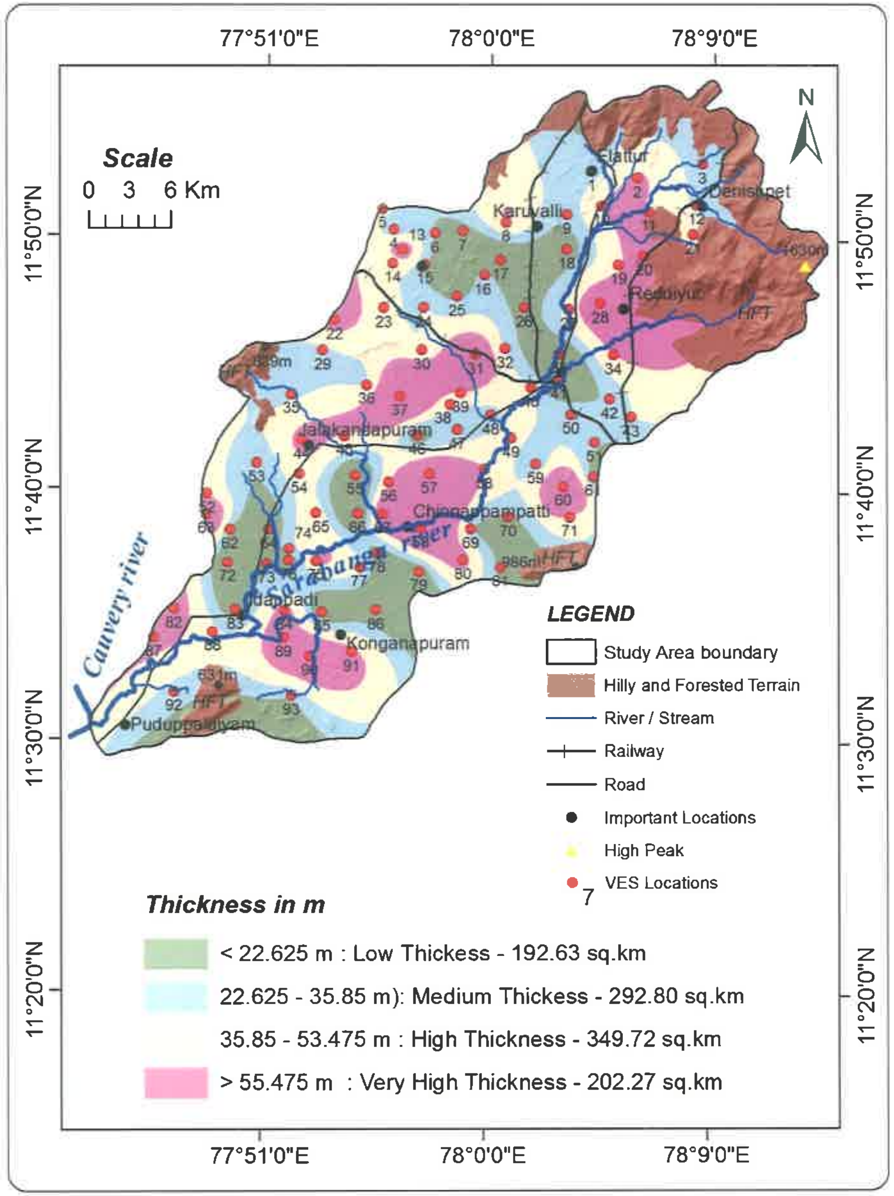

Fig.3.10.Map showing aquifer thickness of fourth layer in the study area.

3.2.2 Sounding Curve Types

H- Type curve: In case of three layered ground structure, four types of sounding curves are possible. If ρ_1, ρ_2, ρ_3 are the resistivity of the three successive layers, a sounding curve central low ($\rho_1 > \rho_2 < \rho_3$), is said to be an H-type curve. This type of sounding curves are obtained generally in hard rock terrains which consists of dry top soil of high resistivity as first layer, water saturated weathered layer of low resistivity as the second layer and compact hard rock of very high resistivity as the last layer.

A-Type curve: It is also obtained in the hard rocks with a conductive top soil. In this case, resistivity of the layers will be continuously increasing ($\rho_1 < \rho_2 < \rho_3$).

K-Type curve: This type of sounding curve showing a maximum (hump) flanked by low resistivity ($\rho_1 < \rho_2 > \rho_3$) are called K-type curves. Such curves result in various situations. In basaltic areas, where compact and massive trap exists between a top black cotton soil and lower vesicular basalt, this type of curve is very common. In coastal areas also, these curves will be encountered due to fresh water aquifer underlying clayey layer and overlying saline layer.

Q-Type curve: This type sounding curve with continuously decreasing resistivity ($\rho_1 > \rho_2 > \rho_3$) is called Q-type curve. In coastal areas, where saline water is present, these curves are obtained. There are eight 4-layer curves (HK, HA, KH, KQ, AA, AK, QQ, QH). There could be more complicated sounding curves representing multi layer situations like HKHK, KHKH, and HAA and so on.

Resistivity sounding is mainly employed for groundwater exploration and engineering problems. It is necessary to know the disposition and characteristics of various layers in both the cases. In groundwater exploration, while the target is fresh water bearing layer, foundation engineering, it is the hard and compact basement. However, disposition and characteristics of other layers are no less important for implementing these programs properly. Water bearing layers in coastal and alluvial areas will be indicated by higher resistivity when compared to low of adjacent layers of clay or saline water. In hard rocks and basalts, the water bearing layers exhibit lower resistivity than non water bearing layers.

Although vertical electrical sounding are employed to discern the subsurface geological section, what we actually obtain after quantitative interpretation is only a geoelectrical section. This because the resistivity method is governed only by the resistivity contrast between various subsurface layers which need not always correspond to the geological boundaries. Geoelectrical and geological boundaries coincide only when there is a pronounced resistivity contrast between geological layers.

For reliable interpretation of data, the first and foremost thing is accuracy in measurements. That is why, utmost care has to be taken while making the measurements starting from site selection, proper electrical connections, etc. it is also necessary to calculate the resistivity values and to plot the sounding curve on the spot. If there are prominent deviations from the smoothness of the curve, the measurements has to be verified by repeating. A geologist or a hydrogeologist with a geophysicist will make an ideal combination for proper interpretation of the geophysical data.

However, the resistivity sounding technique has the following inherent disadvantages. The resolving power of this method is poor and is particularly true for deeper boundaries. Due to the principle of suppression of middle layer with resistivity intermediate between enclosing beds will have practically no influence on the resistivity curve as along as its thickness is small in comparison to its depth. Hence the layers with small thickness cannot be recognized.

A conductive layer sandwiched between two layers of higher resistivites will have the same influence on the curve as long as the ration of its thickness to resistivity (h/ρ) remains the same. Similarly, a resistivity layer sandwiched between two conducting layers will have the same influence on the curve as long as the product of its resistivity and thickness. Hence the thickness and resistivites of sandwiched layers of small thickness cannot be determined uniquely. Iso Apparent Resistivity and contour map of Sarabanga sub basin shown in Fig.3.11.

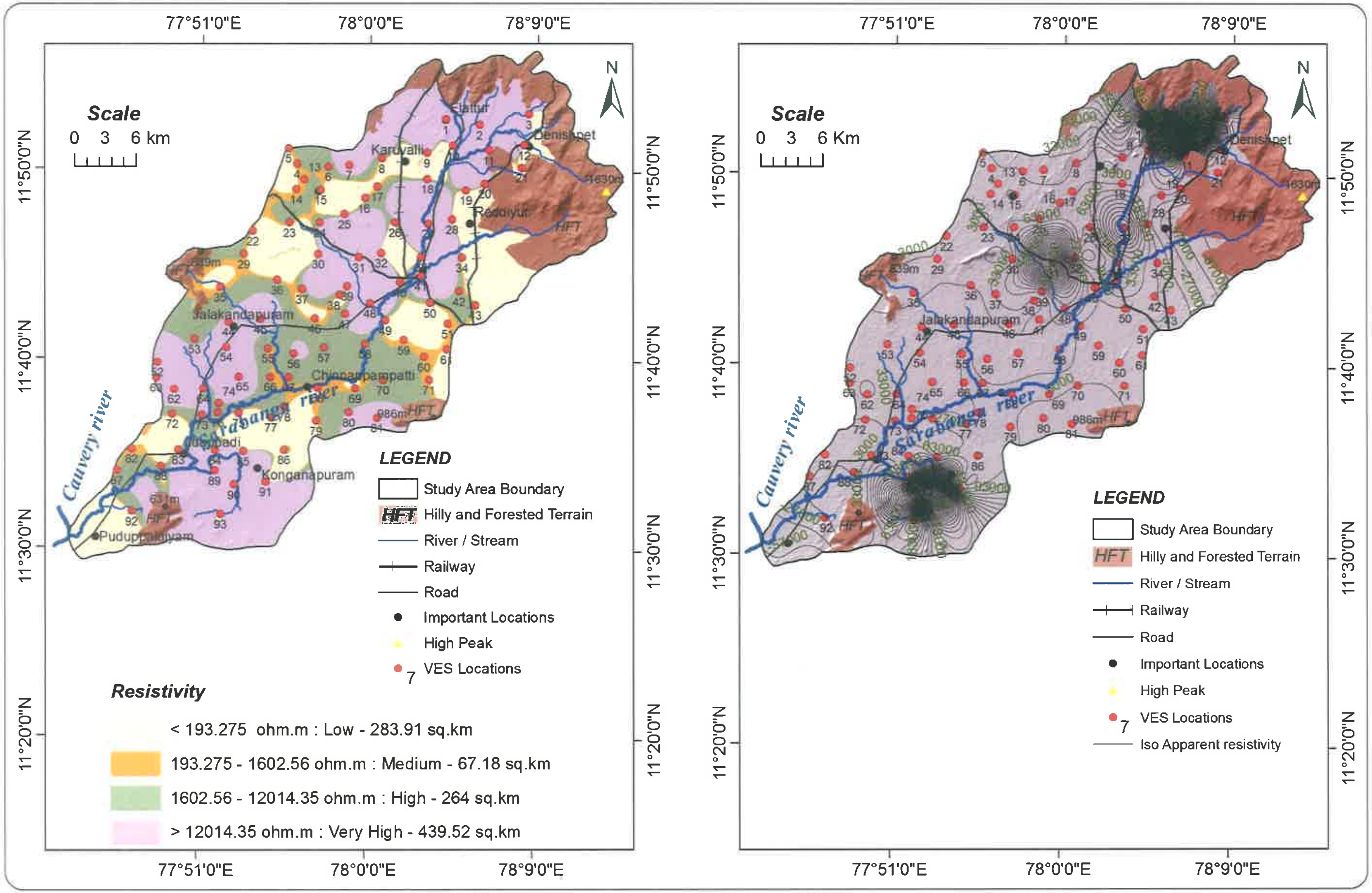

Fig.3.11.Map showing Iso Apparent resistivity (ρ= ρ1+ ρ2+ ρ3+ ρ4) Contour of aquifer in the study area.

3.3 Data Processing

The resistivity data (apparent resistivity) obtained from the field was analyzed in two stages. Stage one in the field manually by plotted data on the log papers, the curve were drawn in such a way that the half distance current electrodes (AB/2) as X-axis and the apparent resistivity (ρa) as Y-axis. Stage two is done by using the computer program called IPI2 Win version 2.1. In order to comparing and smooth the field curves with master curves. Which is the software used in the interpretation of the field curves to acquire the thickness, depth and resistivity of the layers. This information's from IPI2 Win computer program is compared with information about some auxiliary points.

3.4 Results and Discussions

Numerous geophysical investigations have been done in various locations over the globe to demarcate the potential zones of groundwater and thick and low resistivity horizons are considered as favorable for development. Normal potable groundwater in areas of crystalline rocks may have resistivity of the order of 30 to 150 ohm m. In the sedimentary areas, resistivity values may reach as low as 1 ohm mts. (Sakthimurugan and Balasubramanian 1991, Subramanian 2001).

In Igneous and crystalline rocks, the groundwater usually can be tapped from weathered zones and these are generally found at comparatively shallow depths. Such zones and pockets have lower resistivity values when compared to the more compact and fresh rocks and can be easily located by resistivity surveys. Water trapped in joints and fissures of the undecomposed rocks may also be detected by relatively low resistivity values. Resistivity investigations have been successfully employed in South Africa for locating hidden dykes which have impounded groundwater near their margins. Balakrishna and Ramanujachary (1979); Balakrishna et.al., (1983); Sharma(1982); Patangay and Murali,(1984); Sharma and Sastri (1986) and Balasubramanian (1985); Venkateswaran.S (2010) are a few notable works published in relation to such studies in hard rock terrains.

3.4.1 Geohydrologic Interpretation

The apparent resistivites and thicknesses of the different layers as interpreted from the analyses of the resistivity sounding curves of the VES data from 93 locations. A perusal of this table shows that in most of the locations, the aquifer consists of four layers and the third layer presumably a weathered one. Even this weathered layer has attained a maximum thickness of hardly about 20 m. It is this lack of depth persistence to weathering along with the paucity of fractured zones, which accounts for the poor groundwater potential and development in the Sarabanga sub basin under consideration. Aquifer thickness and contour maps have been shown in Fig.3.12.

3.4.2 Behavior of Resistivity and Thickness

The behavior of resistivity and thickness highly varies from place to place. The overlay analysis map has been prepared for the resistivity and thickness horizons have been demarcated spatially. Fig.3.13 shows lower apparent resistivity horizons with respect to depths in variation. This may be due to an unequal anisotropic behavior of the subsurface. The resulting sounding curves might be of various types depending on the geological and hydrogeological situations and the maximum electrode spread employed. In the case of three layered ground structure, four types of sounding curves are possible. Table 3.1 shows the Vertical Electrical Sounding Results from Numerical computer techniques ρ (Ohm.m), h (m).

It could be seen that most of the VES location obtained H-type curve (50 out of 93 VES). H-type curve generally exhibit in hard rock terrains which consists of dry top soil of high resistivity as the first layer, saturated weathered layer of low resistivity as the second layer and compact hard rock of very high resistivity as the last layer. Sixteen combinations are demarcated for this type of overlay that include VLR versus VHT, VLR versus HT, VLR versus MT, VLR versus LT, LR versus VHT, LR versus HT, LR versus MT, LR versus LT, MR versus VHT, MR versus HT, MR versus MT, MR versus LT, HR versus VHT, HR versus HT, HR versus MT and HR versus LT.

Table.3.1.Vertical Electrical Sounding Results from Numerical computer techniques ρ (Ohm.m),h(m).

SI. No.	Location Name	Latitude	Longitude	Resistivity Ohm-m/Thickness m								Total Thickness 'h' m	Curve Types
				ρ_1	h_1	ρ_2	h_2	ρ_3	h_3	ρ_4	h_4		
1	Elathur	11°52'53.33"N	78° 4'15.03"E	11.6	1.61	77	39.82	3890	42.9	2749	27.4	111.73	A
2	Muttanampatti	11°52'28.36"N	78° 5'52.86"E	1.95	0.93	52507	20.8	51555	57.3	50659	56.2	135.23	KQ
3	Periyavadagampatti	11°52'29.21"N	78° 5'49.17"E	10.7	2.26	487	2.18	37	7.5	30563	29.12	41.06	KH
4	Kukkalpatti	11°50'19.90"N	77°56'6.33"E	10.4	2.06	119	27.5	1596	12	17588	24	65.56	A
5	Kuppakalipatti	11°51'9.01"N	77°55'37.81"E	108	0.5	210	20.2	36742	9.14	572	43.6	73.44	AK
6	Amaram	11°50'12.04"N	77°57'45.88"E	24.9	0.5	309	3.48	797	12.7	353	22.4	39.08	AK
7	Andiyur	11°50'17.08"N	77°58'53.51"E	15.1	2.69	4012	8.02	4012	7.52	96130	16.1	34.33	A
8	Maniyakkaranur	11°50'38.87"N	78° 0'37.98"E	15.9	1.46	1.43	1.85	7457	21.2	29.4	52.8	77.31	HK
9	Rangappanur	11°50'59.16"N	78° 3'4.30"E	43.4	0.5	30.2	6.24	2393	21.3	2317	26.3	54.34	HK
10	Agraharam	11°51'21.03"N	78° 4'26.35"E	0.019	0.5	8.07	3.41	539	24.9	6342	53.1	81.91	AK
11	ChinnaYercaud	11°51'8.23"N	78° 6'23.72"E	4.49	1.09	38.6	9.46	235	3.63	5862	52	66.18	AA
12	Danishpet	11°51'29.65"N	78° 8'9.15"E	24.2	0.5	37.1	6.77	24.4	17.1	9584	33.3	57.67	KH
13	Kolippatti	11°49'32.65"N	77°56'27.78"E	255	0.5	58.9	1.1	710	17.1	425	68.1	86.8	HK
14	Karappatti	11°48'59.83"N	77°56'27.71"E	32.3	3.3	22.7	2.16	4027	7.64	87111	40	53.1	HA
15	Malalyyanur	11°48'57.52"N	77°57'21.09"E	25	0.56	329	5.96	1141	6.56	326	23.3	36.38	AK
16	Bommiyampatti	11°48'58.82"N	77°57'19.07"E	525	0.5	85.4	1.58	11.7	6.54	2.44	27.1	35.72	Q
17	Marakkottai	11°49'9.94"N	78° 0'23.91"E	1.76	0.493	2357	8.2	7599	8.56	4979	0.104	17.357	A
18	Kanjinayakkanpatti	11°49'35.79"N	78° 3'4.63"E	10.6	0.672	8.68	92.2	67.6	46.328	58.41	13.99	153.19	HK
19	ChinnaNagalur	11°49'0.84"N	78° 5'10.41"E	12.3	0.5	104	7.54	54222	28.6	56457	48.4	85.04	A
20	Tinnappatti	11°49'21.76"N	78° 6'11.16"E	0.173	0.5	315	2.03	36965	19	2.54	78.5	100.03	AK
21	Kanjeri	11°50'13.71"N	78° 8'10.26"E	22.8	1.67	31.7	7.72	10386	17	70542	45.1	71.49	A
22	Palakkaranur	11°46'44.81"N	77°53'43.49"E	39.1	1.84	40.1	6.91	54.7	17.2	38217	63.7	89.65	A
23	Kalikavundanur	11°47'13.60"N	77°55'42.26"E	29.7	1.93	227	4.42	13.7	12.4	28826	41.5	60.25	KH
24	Sengattur	11°47'14.77"N	77°57'20.05"E	0.68	0.5	4483	18.3	4614	17.7	344	36.3	72.8	k
25	Sattappadi	11°47'42.16"N	77° 58'39.27"E	23	1.59	31.8	7.67	15593	11.4	6449	20.7	41.36	A
26	Semmandapatti	11°47'17.22"N	78° 1'22.69"E	17.2	0.5	163.9	8.9	21843	31.5	6435	17.43	40.9	AK
27	Darapuram	11°47'14.03"N	78° 3'10.20"E	11	1.93	51682	15.2	2379	23.7	6838	43.3	84.13	KH
28	Sattur	11°47'36.80"N	78° 4'15.49"E	28.5	0.5	9.23	9.53	1756	13.2	11655	72.9	96.13	HQ
29	Nangavalli	11°45'32.38"N	77°53'16.53"E	58.3	2.49	32.2	2.01	290	44.8	56930	32.9	82.2	HA
30	Olaippatti	11°45'34.22"N	77°57'15.41"E	1.11	0.5	3.96	4.04	381	5.54	398	38.9	48.98	A

Cont...

Sl. No.	Location Name	Latitude	Longitude	Resistivity Ohm-m/Thickness m								Total Thickness 'h' m	Curve Types
				ρ_1	h_1	ρ_2	h_2	ρ_3	h_3	ρ_4	h_4		
31	Maramangalam	11°45'39.67"N	77°59'26.33"E	1.85	0.51	66792	0.255	34.9	36.5	9037	79	116.265	KH
32	Palikkadai	11°45'39.67"N	78° 0'37.57"E	1.77	0.5	2126	24.9	3.19	30.3	3.31	33.1	88.8	KQ
33	Balbakki	11°45'29.33"N	78° 2'47.27"E	1.36	0.5	4.285	3.86	27196	8	187	7.39	19.75	AQ
34	Mailappalaiyam	11°45'27.08"N	78° 4'57.27"E	6015	2.93	4.74	16.3	6542	30.5	84.5	52.8	102.53	HQ
35	Sanarpatti	11°43'47.25"N	77°52'0.65"E	523	0.503	1.25	0.518	105	38.4	743	33.1	72.521	HA
36	PeriyaSoragai	11°44'11.33"N	77°55'3.30"E	0.622	0.5	51.2	13.2	15382	31.3	196	35.6	80.6	AQ
37	Siranganur	11°43'43.98"N	77°56'23.20"E	55.2	1.82	251	0.812	10.8	16.3	4546	109	127.932	KH
38	Amarakundi	11°43'27.62"N	77°58'25.26"E	809	1.16	855	0.877	163	39.4	32.6	39.7	81.137	Q
39	Periyerippatti	11°43'54.37"N	77°58'49.23"E	22	1.83	2244	3.65	152	20.1	3692	53.6	79.18	KH
40	Vellakavundanur	11°44'9.13"N	78° 1'39.76"E	6545	0.547	37.1	3.7	56796	35.1	3978	36.1	75.447	HK
41	Omalur	11°44'28.30"N	78° 2'47.15"E	32.8	1.95	4215	4.7	116	18.4	0	2.46	25.05	KQ
42	Vettalaikkaranur	11°43'42.80"N	78° 4'49.02"E	58.6	1.9	126	2.36	527	42.8	7715	25.7	72.76	AA
43	Karuppur	11°42'59.46"N	78° 5'43.40"E	0.104	0.949	31.3	2.59	36.9	5.93	5289	35.4	44.869	AA
44	Jalakandapuram	11°41'59.10"N	77°52'28.71"E	47.3	4.11	178155	8.47	194	42.9	261	59.4	114.88	KH
45	Chinnakovundanur	11°42'9.08"N	77°54'10.48"E	16.2	0.51	1261	5.8	1082	16	5990	52.7	75.01	AA
46	Vellakkalpatti	11°42'13.32"N	77°57'4.32"E	39.7	0.902	0.826	1.09	4528	25.9	174	15.6	43.492	HK
47	Chikkampatti	11°42'26.78"N	77°58'42.99"E	0.63	1.86	3756	2.59	0.189	11.17	490	27.4	43.02	KH
48	Mottaiyanteruvu	11°43'2.00"N	78° 0'3.61"E	10.1	2.94	97639	16.6	142	43.6	2614	31.3	94.44	KH
49	Ellavur	11°42'8.47"N	78° 0'53.78"E	0.627	0.5	11.5	1.1	5.11	19	0.603	43.7	64.3	AQ
50	Pakalpatti	11°43'4.69"N	78° 3'17.51"E	5.31	0.5	10.21	5.43	13.4	15.9	11695	31.3	53.13	AA
51	Nallakovundanpatti	11°41'58.95"N	78°41'14.80"E	0.031	0.5	13.2	2.49	27	4.68	1903	25.7	33.37	AA
52	Puliyampatti	11°39'47.92"N	77°48'40.12"E	63.1	2.26	957	7.4	31	27.9	9505	50.6	88.16	KH
53	Ramakavundanur	11°41'2.87"N	77°50'39.12"E	90.2	3.52	771	4.59	184	11.3	2709	24.6	44.01	KH
54	Sivadanur	11°40'37.80"N	77°52'21.96"E	25.4	1.95	1490	5.13	215	15.4	25083	43.4	65.88	KH
55	Nattakkattanur	11°40'35.32"N	77°54'36.73"E	2.56	1.19	8.71	7.52	1.48	12.5	22296	2.19	23.4	KH
56	Tadikaranpatti	11°40'19.93"N	77°55'59.17"E	3.54	0.5	2797	0.175	24.4	4.93	32041	53.1	58.705	KH
57	Kuttakkattanur	11°40'39.53"N	77°57'36.93"E	14.4	0.5	2382	0.76	56.6	3.46	614	101	105.72	KH
58	Attikkattanur	11°40'52.74"N	77°59'48.53"E	32.3	1.22	228	1.6	22.5	35.1	6326	53.9	91.82	KH
59	Kanganur	11°41'5.79"N	78° 1'53.29"E	20.6	3.31	88	9.23	2665	5.75	299	26.2	44.49	AA
60	Maramangalattupatti	11°40'13.00"N	78° 2'59.12"E	24.8	1.48	5.15	35	3.82	252	33.8	93.38	381.86	QH
61	SarkarGollapatti	11°40'37.08"N	78° 4'12.34"E	72.7	3.74	20.3	0.789	3827	1.66	39.3	9.71	15.899	HK
62	Nattappatti	11°38'59.23"N	77°49'35.06"E	21.1	0.5	64623	2.38	21623	5.16	1985	18.2	26.24	KQ

Cont...

Sl. No.	Location Name	Latitude	Longitude	Resistivity Ohm-m/Thickness m								Total Thickness 'h' m	Curve Types
				ρ_1	h_1	ρ_2	h_2	ρ_3	h_3	ρ_4	h_4		
63	Reddippatti	11°38'59.23"N	77°48'38.51"E	87.5	4.13	9969	3	79969	17.5	254	99.7	124.33	AK
64	Panmalaiyur	11°38'24.17"N	77°51'9.96"E	4.34	1.4	1634	3.18	110	6.16	2512	11.2	21.94	KH
65	Tirumalur	11°39'4.39"N	77°53'2.42"E	5.3	0.5	4176	2.25	62.9	7.09	2198	44.1	53.94	KH
66	Samudram	11°39'3.65"N	77°54'44.83"E	62.1	4.61	129	9.66	2871	32.4	1735	0.663	47.333	AK
67	Upparappatti	11°39'2.82"N	77°54'44.90"E	9.37	4.12	1354	5.12	4423	41.5	22	94	144.74	AK
68	Chinnappampatti	11°38'29.91"N	77°57'15.55"E	1479	0.331	33.4	3.28	4240	13.9	1.66	106	123.511	HK
69	Mattaiyampatti	11°38'29.91"N	77°59'17.52"E	23.3	3.86	2.73	1.55	585	5.29	4491	24.4	35.1	HA
70	Sittanur	11°38'58.11"N	78° 0'47.42"E	95.6	4.01	106	12	503	28.3	95.5	19.8	64.11	AK
71	Nallakkampatti	11°38'58.11"N	78° 3'16.54"E	85.9	0.77	2.32	2.52	48912	32.4	9.29	50.4	86.09	HK
72	Makkanur	11°37'4.31"N	77°49'29.60"E	84.2	0.5	120	1.37	160	13.5	2570	6.83	22.2	AA
73	Kottapalayam	11°37'4.74"N	77°51'5.39"E	1.58	1.65	1557	5.27	1736	21.6	537	22.3	50.82	KQ
74	Kartikanakkanur	11°37'38.07"N	77°51'59.33"E	119	4.66	488	13.2	301	24.7	9411	31.3	73.86	KH
75	Oddapuram	11°37'8.72"N	77°53'4.16"E	85.7	0.957	17.5	1.67	48.8	8.97	6481	55.5	67.097	HA
76	Kottapalayam	11°37'8.84"N	77°51'57.66"E	65	6.57	7260	13.1	1758	5.9	718	12.3	37.87	KQ
77	Sadayampalayam	11°36'54.17"N	77°54'50.19"E	68.6	0.678	14.3	8.02	1260	23.2	7045	40.1	71.998	HA
78	Pachchallyur	11°37'28.96"N	77°55'31.03"E	51.4	2.82	98.2	0.197	294	8.7	2782	14.9	26.617	AA
79	Konangiyur	11°36'45.78"N	77°57'13.98"E	8133	0.16	78	0.918	344	2.62	31.6	8.68	12.378	HK
80	Velaiyachettippatti	11°37'14.50"N	77°58'59.12"E	0.216	0.5	475	13.1	825	26.6	9188	60.8	101	KA
81	Nallanampatti	11°36'56.88"N	78° 0'29.40"E	567	1.62	2127	2.39	301	9.69	7696	19	32.7	KH
82	Pattakkaranur	11°35'12.30"N	77°47'21.03"E	448	1.31	14	4.87	19710	63.1	66105	66.2	135.48	HA
83	Kalaravallipattipudur	11°35'10.29"N	77°49'50.95"E	103	2.34	6.56	0.914	1129	2.57	124	16.6	22.424	HK
84	Nachchiyur	11°35'9.53"N	77°51'49.35"E	10.6	4.32	3188	1.22	1161	6.88	3635	59.1	71.52	KH
85	Kundarasampalayam	11°35'7.08"N	77°53'20.58"E	112	0.5	376	2.66	500	17.1	3336	6.25	26.51	AA
86	Ayyampalayam	11°35'13.10"N	77°55'30.11"E	112	0.5	376	2.58	496	15.4	1472	13.1	31.58	AA
87	Tannirdasanur	11°34'3.34"N	77°46'32.99"E	57	1.4	150	2.44	37.9	4.63	8200	61.7	70.17	KH
88	Marikavundankuttai	11°34'17.88"N	77°48'54.73"E	81.9	1.28	224	2.38	25.3	8.27	49606	40.9	52.83	KH
89	Annamalaipalaiyam	11°34'5.16"N	77°51'47.82"E	16.2	1.53	181	0.859	8.9	2.06	894	63.4	67.849	KH
90	Kavadikkaranur	11°33'20.97"N	77°52'50.09"E	4.59	0.974	59377	1.6	2166	24.1	29706	79.5	106.174	KH
91	Madattur	11°33'31.59"N	77°54'32.19"E	85.9	4.94	2769	2.12	155	11.6	39634	58.6	77.26	KH
92	Kurukkuparaiyur	11°31'54.42"N	77°47'23.55"E	16	0.59	10.8	3.27	176	12.6	166	30.64	47.1	HK
93	Pullipalikadu	11°31'47.41"N	77°52'8.53"E	14.6	1.44	39	7.79	7367	2.22	142	24.6	36.05	AK

ρ_1, ρ_2, ρ_3… Resistivity (Ohm-m) h_1, h_2, h_3…. Thickness (m)

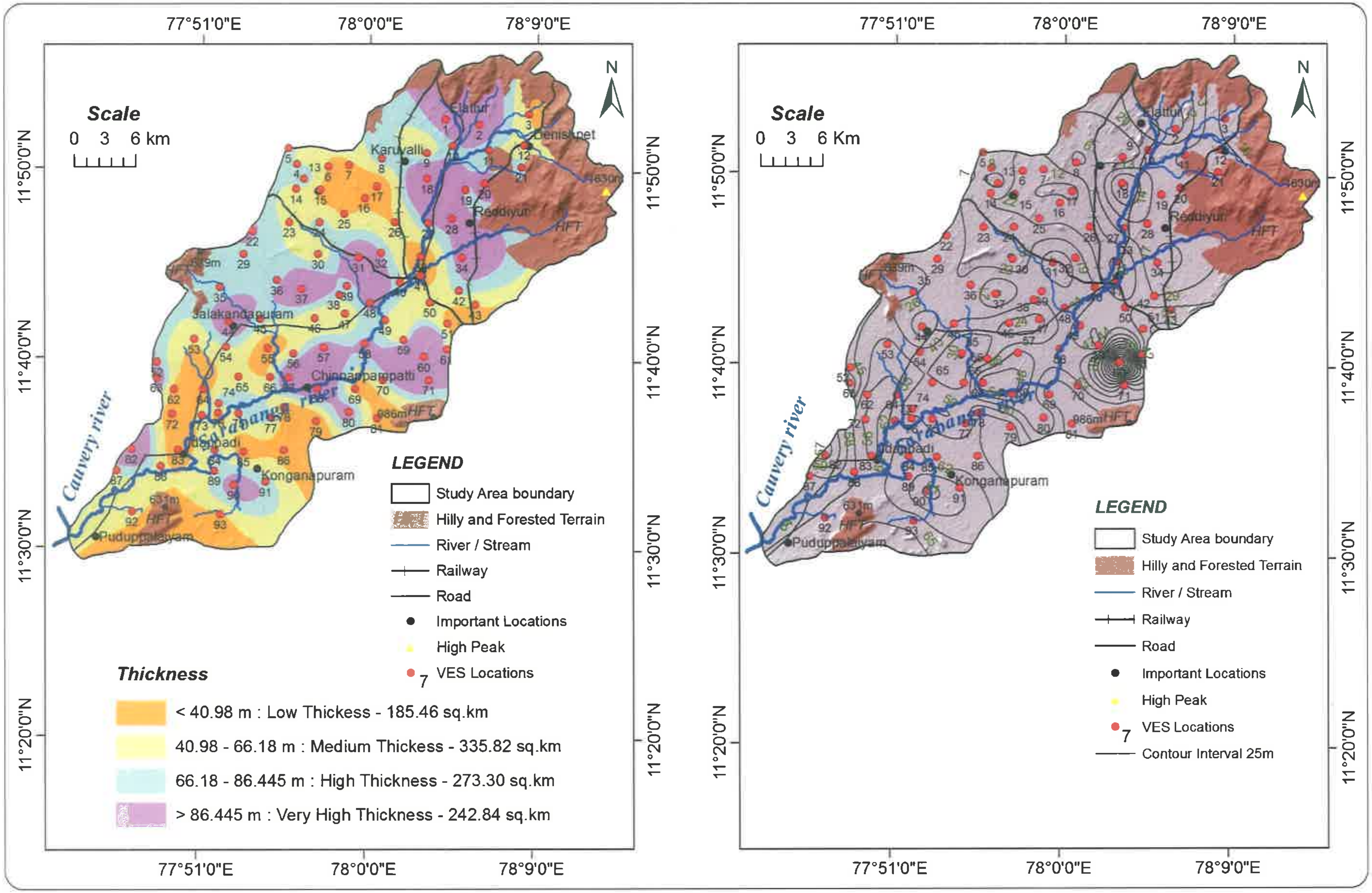

Fig.3.12.Map showing aquifer thickness Contour of aquifer in the study area.

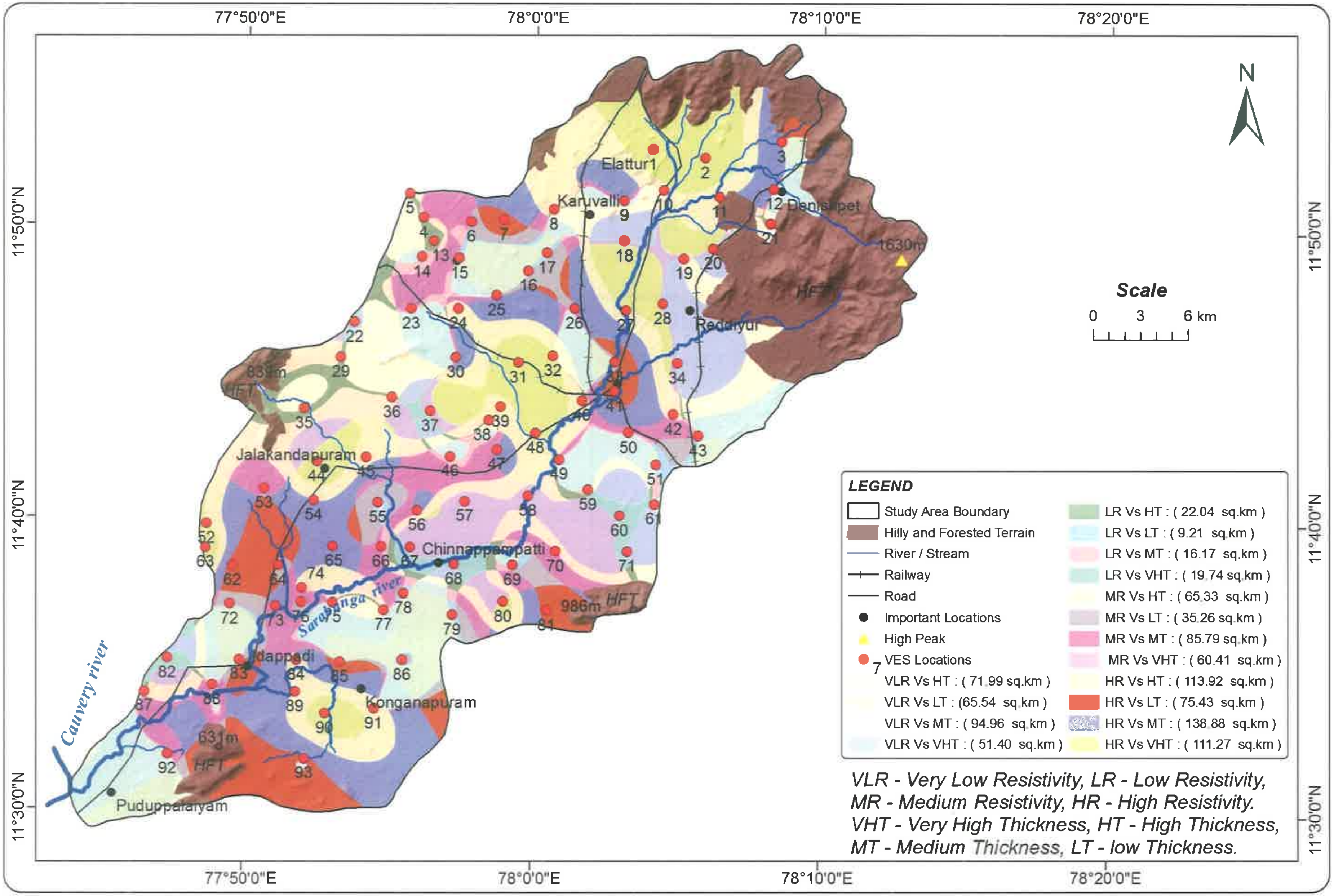

Fig.3.13.Map showing Iso apparent resistivity versus aquifer thickness overlay analysis in the study area.

3.4.3 Resistivity and Thickness Overlay with Geology

The interpreted results of the geophysical studies form the basis for the preparation of this user oriented map. This could be used for developing available groundwater in the Sarabanga sub basin. Groundwater potential zone map has been prepared with a combination of Iso resistivity ($\boldsymbol{\rho}= \rho_1+ \rho_2+ \rho_3+ \rho_4$) and aquifer thickness ($\mathbf{h}=h_1+h_2+h_3+h_4$) maps (Fig.3.14 and Legend). The potential zones have been demarcated with the help of geology overlay analyses getting 76 combinations.

GIS overlay analyses had been carried out to assess the potential zones. Iso Apparent Resistivity ($\rho=\rho_1+\rho_2+\rho_3+\rho_4$) ohm.m and aquifer thickness ($h=h_1+h_2+h_3+h_4$) maps overlay with geology map were carried out and 78 overlay combinations were derived. Out of this, the best 24 combinations viz., *VLR versus VHT* : Fissile Hornblend Biotite Gneiss (23.80 sq.km), *VLR Vs VHT* : Charnockite (27.60 sq.km), *LR Versus VHT* : Fissile Hornblend Biotite Gneiss (19.16 sq.km), *LR Versus VHT* : Charnockite (0.58 sq.km), *VLR Versus HT* : Fissile Hornblend Biotite Gneiss (51.65 sq.km), *VLR Versus HT* : Charnockite (10.32 sq.km), *VLR Versus HT* : Alkaline Rock (0.02 sq.km), *VLR Versus HT* : Ultramafic/ Ultrabasic rocks (1.32 sq.km), *VLR Versus HT* : Alkaline Rock (8.66 sq.km), *LR Versus HT* : Fissile Hornblend Biotite Gneiss (17.47 sq.km), *LR Versus HT* : Charnockite (0.36 sq.km), *LR Versus HT* : Alkaline Rock (0.03 sq.km), *LR Versus HT* : Ultrabasic Syenite Carbonatite Complex (1.90 sq.km), *LR Versus HT* : Alkaline Rock (2.28 sq.km), *VLR Versus MT* : Fissile Hornblend Biotite Gneiss (76.38 sq.km), *VLR Versus MT* : Charnockite (5.43 sq.km), *VLR Versus MT* : Alkaline Rock (0.09 sq.km), *VLR Versus MT* : Ultramafic / Ultrabasic rocks (7.48 sq.km), *VLR Versus MT* : Alkaline Rock (2.76 sq.km), *VLR Versus MT* : Granitic / Acidic Rock (2.8 sq.km), *LR Vs MT* : Fissile Hornblend Biotite Gneiss (15.55 sq.km), *LR Vs MT* : Charnockite (0.61 sq.km), *LR Vs MT* : Alkaline Rock (0.02 sq.km), *LR Vs MT* : Granitic / Acidic Rock (0.54 sq.km) were considered as the best groundwater potential zones in Sarabanga sub basin.

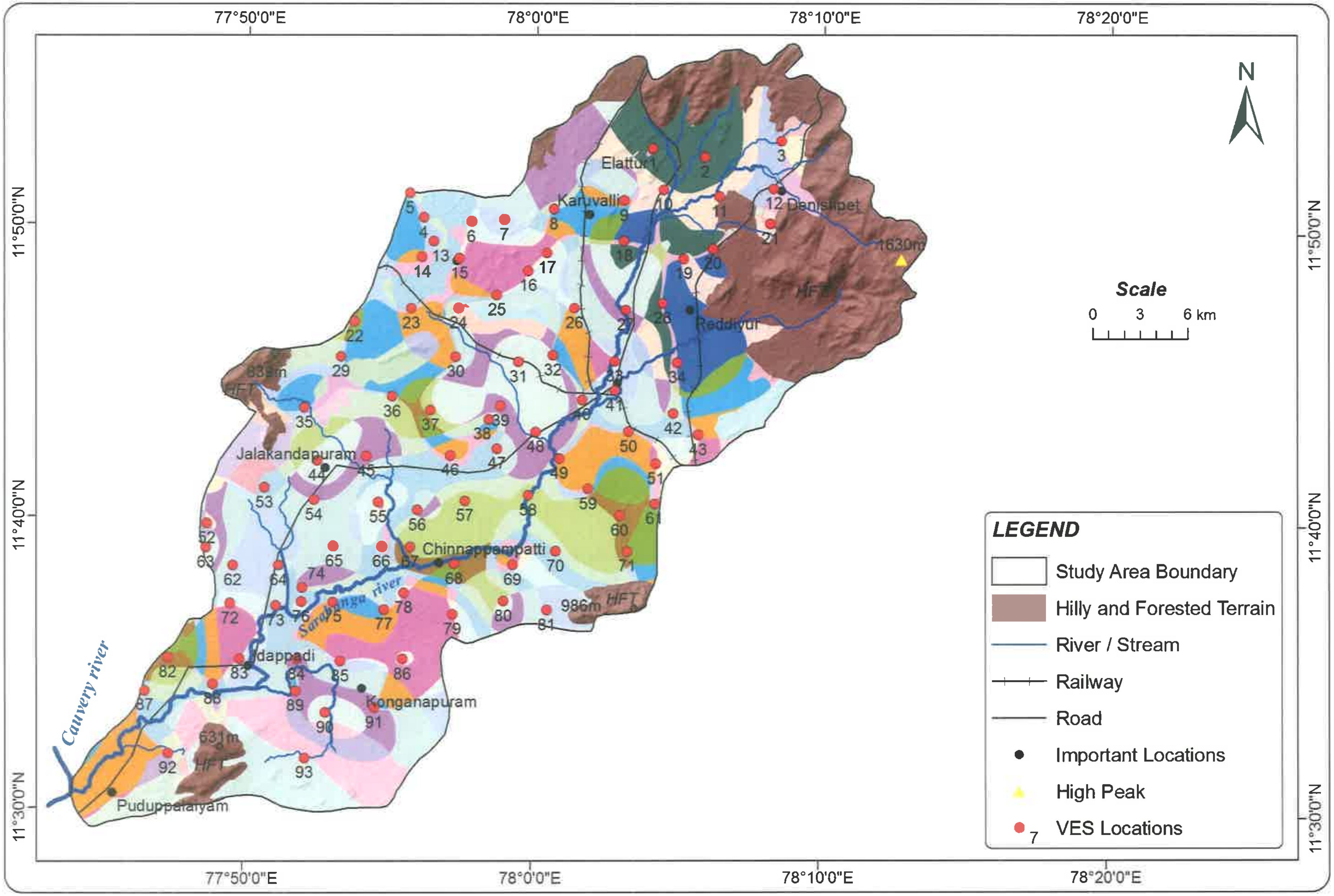

Fig.3.14. Map showing Iso apparent resistivity versus aquifer thickness overlay with geology in the study area.

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LEGEND

- VLR Vs HT : Alkaline Rock - 0.02 sq.km
- VLR Vs HT : Alkaline Rock - 8.66 sq.km
- VLR Vs HT : Charnockite - 10.32 sq.km
- VLR Vs HT : Hornblend Biotite Gneiss - 51.65 sq.km
- VLR Vs HT : Ultramafic/ Ultrabasic rocks - 1.32 sq.km
- VLR Vs LT : Charnockite - 2.50 sq.km
- VLR Vs LT : Granitic / Acidic Rock - 11.14 sq.km
- VLR Vs LT : Hornblend Biotite Gneiss - 52.56 sq.km
- VLR Vs LT : Ultramafic/ Ultrabasic rocks - 0.4 sq.km
- VLR Vs MT : Alkaline Rock - 0.09 sq.km
- VLR Vs MT : Alkaline Rock - 2.76 sq.km
- VLR Vs MT : Charnockite - 5.43 sq.km
- VLR Vs MT : Granitic / Acidic Rock - 2.8 sq.km
- VLR Vs MT : Hornblend Biotite Gneiss - 76.38 sq.km
- VLR Vs MT : Ultramafic/ Ultrabasic rocks - 7.48sq.km
- VLR Vs VHT : Charnockite - 27.60 sq.km
- VLR Vs VHT : Hornblend Biotite Gneiss - 23.80 sq.km
- LR Vs HT : Alkaline Rock - 0.03 sq.km
- LR Vs HT : Alkaline Rock - 2.28 sq.km
- LR Vs HT : Charnockite - 0.36 sq.km
- LR Vs HT : Hornblend Biotite Gneiss - 17.47 sq.km
- LR Vs HT : Ultrabasic Syenite Carbonatite Complex - 1.90 sq.km
- LR Vs LT : Charnockite - 0.01 sq.km
- LR Vs LT : Granitic / Acidic Rock - 0.1 sq.km
- LR Vs LT : Hornblend Biotite Gneiss - 9.08 sq.km
- LR Vs MT : Alkaline Rock - 0.02 sq.km
- LR Vs MT : Charnockite - 0.61 sq.km
- LR Vs MT : Granitic / Acidic Rock - 0.54 sq.km
- LR Vs MT : Hornblend Biotite Gneiss - 15.55 sq.km
- LR Vs VHT : Charnockite - 0.58 sq.km
- LR Vs VHT : Hornblend Biotite Gneiss - 19.16 sq.km
- MR Vs HT : Alkaline Rock - 0.3 sq.km
- MR Vs HT : Alkaline Rock - 2.38 sq.km
- MR Vs HT : Charnockite - 0..81 sq.km
- MR Vs HT : Hornblend Biotite Gneiss - 53.06 sq.km
- MR Vs HT : Ultrabasic Syenite Carbonatite Complex - 8.77 sq.km
- MR Vs LT : Charnockite - 0.91 sq.km
- MR Vs LT : Granitic / Acidic Rock - 1.15 sq.km
- MR Vs LT : Hornblend Biotite Gneiss - 34.01 sq.km
- MR Vs MT : Alkaline Rock - 0.08 sq.km
- MR Vs MT : Charnockite - 0.47 sq.km
- MR Vs MT : Granitic / Acidic Rock - 3.77 sq.km
- MR Vs MT : Hornblend Biotite Gneiss - 77.50sq.km
- MR Vs MT : Ultrabasic Syenite Carbonatite Complex - 3.95 sq.km
- MR Vs VHT : Alkaline Rock - 0.23 sq.km
- MR Vs VHT : Charnockite - 4.31 sq.km
- MR Vs VHT : Hornblend Biotite Gneiss - 55.87 sq.km
- MR Vs VHT : Ultrabasic Syenite Carbonatite Complex - 0 sq.km
- HR Vs HT : Alkaline Rock - 5.56 sq.km
- HR Vs HT : Basic Rocks - 0.04 sq.km
- HR Vs HT : Basic Rocks - 0.01 sq.km
- HR Vs HT : Charnockite - 22.85 sq.km
- HR Vs HT : Granitic / Acidic Rock - 7.91 sq.km
- HR Vs HT : Hornblend Biotite Gneiss - 76.20 sq.km
- HR Vs HT : Ultrabasic Syenite Carbonatite Complex - 1.33 sq.km
- HR Vs LT : Charnockite - 1.67 sq.km
- HR Vs LT : Granitic / Acidic Rock - 23.78 sq.km
- HR Vs LT : Hornblend Biotite Gneiss - 1.44 sq.km
- HR Vs LT : Hornblend Biotite Gneiss - 48.34 sq.km
- HR Vs LT : Quartzite - 0.03 sq.km
- HR Vs LT : Quartzite - 0.13 sq.km
- HR Vs LT : Ultramafic/ Ultrabasic rocks - 0.01 sq.km
- HR Vs MT : Alkaline Rock - 4.31 sq.km
- HR Vs MT : Basic Rocks - 0.000824 sq.km
- HR Vs MT : Charnockite - 12.95 sq.km
- HR Vs MT : Granitic / Acidic Rock - 27.27 sq.km
- HR Vs MT : Hornblend Biotite Gneiss - 92.72 sq.km
- HR Vs MT : Ultrabasic Syenite Carbonatite Complex - 0.9 sq.km
- HR Vs MT : Ultramafic/ Ultrabasic rocks - 0.03 sq.km
- HR Vs VHT : Alkaline Rock - 0.1 sq.km
- HR Vs VHT : Basic Rocks - 0.01 sq.km
- HR Vs VHT : Basic Rocks - 0.05 sq.km
- HR Vs VHT : Charnockite - 45.87 sq.km
- HR Vs VHT : Granitic / Acidic Rock - 2.09 sq.km
- HR Vs VHT : Hornblend Biotite Gneiss - 62.16 sq.km
- HR Vs VHT : Ultrabasic Syenite Carbonatite Complex - 0.98 sq.km

Table.3.2 Geo Electrical Parameters of VES Locations of Sarabanga sub basin

SI. No.	Location Name	Latitude	Longitude	Curve Type	Aquifer Resistivity (Ohm.m)	Aquifer Thickness BGL H (m)	Aquifer Thickness AMSL (m)	MSL (m)	Total Transverse Resistance T(Ohm.m^2)	Total Longitudinal Conductance S (Mho)	Aquifer Anisotropy $\lambda=\sqrt{TS}/H$
1	Elattur	11°52'53.33"N	78° 4'15.03"E	A	3303.30	111.73	84.33	350	6727.60	0.67	0.60
2	Muttanampatti	11°52'28.36"N	78° 5'52.86"E	KQ	2847035.8	135.23	135.23	352	154722.95	0.48	2.01
3	Periyavadagampatti	11°52'29.21"N	78° 5'49.17"E	KH	3652.50	41.06	41.06	352	31097.70	0.42	2.78
4	Kukkalpatti	11°50'19.90"N	77°56'6.33"E	A	1428.00	65.56	65.56	359	19313.40	0.44	1.40
5	Kuppakalipatti	11°51'9.01"N	77°55'37.81"E	AK	1919.40	73.44	73.44	331	37632.00	0.18	1.11
6	Amaram	11°50'12.04"N	77°57'45.88"E	AK	3924.30	39.08	39.08	356	1483.90	0.11	0.33
7	Andiyur	11°50'17.08"N	77°58'53.51"E	A	30170.24	34.33	34.33	364	104169.10	0.18	4.01
8	Maniyakkaranur	11°50'38.87"N	78° 0'37.98"E	HK	30.32	77.31	77.31	365	7503.73	3.18	2.00
9	Rangappanur	11°50'59.16"N	78° 3'4.30"E	HK	643.26	54.34	54.34	340	4783.60	0.24	0.62
10	Agraharam	11°51'21.03"N	78° 4'26.35"E	AK	200.94	81.91	81.91	332	6889.09	26.79	5.25
11	ChinnaYercaud	11°51'8.23"N	78° 6'23.72"E	AA	140.12	66.18	20.6	344	6140.09	0.51	0.85
12	Danishpet	11°51'29.65"N	78° 8'9.15"E	KH	634.41	57.67	57.67	381	9669.70	0.90	1.62
13	Kolippatti	11°49'32.65"N	77°56'27.78"E	HK	1007.19	86.8	86.8	341	1448.90	0.20	0.20
14	Karappatti	11°48'59.83"N	77°56'27.71"E	HA	173.43	53.1	53.1	343	91193.00	0.20	2.54
15	Malalyyanur	11°48'57.52"N	77°57'21.09"E	AK	2158.24	36.38	36.38	339	1821.00	0.12	0.40
16	Bommiyampatti	11°48'58.82"N	77°57'19.07"E	Q	66.12	35.72	35.72	348	624.54	11.68	2.39
17	Marakkottai	11°49'9.94"N	78° 0'23.91"E	A	517.82	17.357	17.357	374	14936.76	0.28	3.76
18	Kanjinayakkanpatti	11°49'35.79"N	78° 3'4.63"E	HK	402.13	153.19	153.19	322	86.88	11.37	0.21
19	ChinnaNagalur	11°49'0.84"N	78° 5'10.41"E	A	2974.40	85.04	85.04	330	110795.30	0.11	1.32
20	Tinnappatti	11°49'21.76"N	78° 6'11.16"E	AK	5985.00	100.03	100.03	343	37282.71	33.80	11.22
21	Kanjeri	11°50'13.71"N	78° 8'10.26"E	A	538.90	71.49	71.49	390	80982.50	0.32	2.25
22	Palakkaranur	11°46'44.81"N	77°53'43.49"E	A	689.72	89.65	89.65	357	38350.90	0.54	1.60
23	Kalikavundanur	11°47'13.60"N	77°55'42.26"E	KH	2814.80	60.25	60.25	319	29096.40	0.99	2.82
24	Sengattur	11°47'14.77"N	77°57'20.05"E	k	12487.20	72.8	72.8	309	9441.68	0.85	1.23
25	Sattappadi	11°47'42.16"N	77°58'39.27"E	A	362.52	41.36	41.36	331	22096.80	0.31	2.01
26	Semmandapatti	11°47'17.22"N	78° 1'22.69"E	AK	5162.85	40.9	40.9	326	22024.10	0.08	1.06
27	Darapuram	11°47'14.03"N	78° 3'10.20"E	KH	296085.4	84.13	84.13	294	60910.00	0.19	1.29
28	Sattur	11°47'36.80"N	78° 4'15.49"E	HQ	121.84	96.13	96.13	312	13448.73	1.06	1.24
29	Nangavalli	11°45'32.38"N	77°53'16.53"E	HA	1442.56	82.2	82.2	347	57310.50	0.26	1.49
30	Olaippatti	11°45'34.22"N	77°57'15.41"E	A	21.94	48.98	48.98	305	784.07	1.58	0.72

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Sl. No.	Location Name	Latitude	Longitude	Curve Type	Aquifer Resistivity (Ohm.m)	Aquifer Thickness BGL H (m)	Aquifer Thickness AMSL (m)	MSL (m)	Total Transverse Resistance T(Ohm.m²)	Total Longitudinal Conductance S (Mho)	Aquifer Anisotropy $\lambda=\sqrt{TS}/H$
31	Maramangalam	11°45'39.67"N	77°59'26.33"E	KH	713923.0	116.265	116.265	290	75865.75	1.33	2.73
32	Palikkadai	11°45'39.67"N	78° 0'37.57"E	KQ	109.56	88.8	88.8	289	2134.27	19.79	2.31
33	Balbakki	11°45'29.33"N	78° 2'47.27"E	AQ	34.28	19.75	19.75	278	27388.65	1.31	9.58
34	Mailappalaiyam	11°45'27.08"N	78° 4'57.27"E	HQ	144.57	102.53	102.53	301	12646.24	4.07	2.21
35	Sanarpatti	11°43'47.25"N	77°52'0.65"E	HA	48.00	72.521	72.521	328	1372.25	0.83	0.46
36	PeriyaSoragai	11°44'11.33"N	77°55'3.30"E	AQ	1602.56	80.6	80.6	298	15629.82	1.25	1.73
37	Siranganur	11°43'43.98"N	77°56'23.20"E	KH	4091.30	127.932	127.932	304	4863.00	1.57	0.68
38	Amarakundi	11°43'27.62"N	77°58'25.26"E	Q	1294.22	81.137	81.137	274	1859.60	1.46	0.64
39	Periyerippatti	11°43'54.37"N	77°58'49.23"E	KH	45104.40	79.18	79.18	280	6110.00	0.23	0.48
40	Vellakavundanur	11°44'9.13"N	78° 1'39.76"E	HK	1302.21	75.447	75.447	278	67356.10	0.11	1.14
41	Omalur	11°44'28.30"N	78° 2'47.15"E	KQ	77556.00	25.05	25.05	280	4363.80	0.22	1.23
42	Vettalaikkaranur	11°43'42.80"N	78° 4'49.02"E	AA	5392.80	72.76	72.76	304	8426.60	0.14	0.46
43	Karuppur	11°42'59.46"N	78° 5'43.40"E	AA	185.61	44.869	44.869	314	5357.30	9.38	4.99
44	Jalakandapuram	11°41'59.10"N	77°52'28.71"E	KH	15503.40	114.88	114.88	285	178657.30	0.54	2.69
45	Chinnakovundanur	11°42'9.08"N	77°54'10.48"E	AA	20176.00	75.01	75.01	269	8349.20	0.06	0.30
46	Vellakkalpatti	11°42'13.32"N	77°57'4.32"E	HK	21.39	43.492	43.492	267	4742.53	1.44	1.90
47	Chikkampatti	11°42'26.78"N	77°58'42.99"E	KH	13426.00	43.02	43.02	268	4246.82	62.11	11.94
48	Mottaiyanteruvu	11°43'2.00"N	78° 0'3.61"E	KH	81818.20	94.44	94.44	265	100405.10	0.61	2.62
49	Ellavur	11°42'8.47"N	78° 0'53.78"E	AQ	218.50	64.3	64.3	262	17.84	77.08	0.58
50	Pakalpatti	11°43'4.69"N	78° 3'17.51"E	AA	162.34	53.13	53.13	287	11723.92	1.82	2.75
51	Nallakovundanpatti	11°41'58.95"N	78°41'14.80"E	AA	61.78	33.37	33.37	880	1943.23	16.50	5.37
52	Puliyampatti	11°39'47.92"N	77°48'40.12"E	KH	26700.30	88.16	88.16	270	10556.10	0.95	1.14
53	Ramakavundanur	11°41'2.87"N	77°50'39.12"E	KH	8712.30	44.01	44.01	269	3754.20	0.12	0.47
54	Sivadanur	11°40'37.80"N	77°52'21.96"E	KH	22946.00	65.88	65.88	273	26813.40	0.15	0.97
55	Nattakkattanur	11°40'35.32"N	77°54'36.73"E	KH	108.88	23.4	23.4	255	22308.75	9.77	19.96
56	Tadikaranpatti	11°40'19.93"N	77°55'59.17"E	KH	13789.21	58.705	58.705	251	34865.94	0.35	1.87
57	Kuttakkattanur	11°40'39.53"N	77°57'36.93"E	KH	8241.72	105.72	105.72	261	3067.00	0.26	0.27
58	Attikkattanur	11°40'52.74"N	77°59'48.53"E	KH	8002.80	91.82	91.82	255	6608.80	1.61	1.12
59	Kanganur	11°41'5.79"N	78° 1'53.29"E	AA	506.00	44.49	44.49	269	3072.60	0.36	0.74
60	Maramangalattupatti	11°40'13.00"N	78° 2'59.12"E	QH	1297.80	381.86	381.86	280	67.57	75.59	0.19
61	SarkarGollapatti	11°40'37.08"N	78° 4'12.34"E	HK	33.70	15.899	15.899	296	3959.30	0.34	2.30
62	Nattappatti	11°38'59.23"N	77°49'35.06"E	KQ	36127.0	26.24	26.24	245	88252.10	0.03	2.06

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SI. No.	Location Name	Latitude	Longitude	Curve Type	Aquifer Resistivity (Ohm.m)	Aquifer Thicknes s BGL H (m)	Aquifer Thickness AMSL (m)	MSL (m)	Total Transverse Resistance T(Ohm.m^2)	Total Longitudinal Conductance S (Mho)	Aquifer Anisotropy $\lambda=\sqrt{TS}/H$
63	Reddippatti	11°38'59.23"N	77°48'38.51"E	AK	25323.8	124.33	124.33	242	90279.50	0.44	1.60
64	Panmalaiyur	11°38'24.17"N	77°51'9.96"E	KH	10065.44	21.94	21.94	234	4260.34	0.38	1.85
65	Tirumalur	11°39'4.39"N	77°53'2.42"E	KH	29607.84	53.94	53.94	239	6442.20	0.23	0.71
66	Samudram	11°39'3.65"N	77°54'44.83"E	AK	1150.31	47.333	47.333	235	4797.10	0.16	0.59
67	Upparappatti	11°39'2.82"N	77°54'44.90"E	AK	2068.00	144.74	144.74	242	5808.37	4.73	1.14
68	Chinnappampatti	11°38'29.91"N	77°57'15.55"E	HK	175.96	123.511	123.511	238	5754.06	63.96	4.91
69	Mattaiyampatti	11°38'29.91"N	77°59'17.52"E	HA	14.44	35.1	35.1	253	5102.03	0.75	1.76
70	Sittanur	11°38'58.11"N	78° 0'47.42"E	AK	2999.80	64.11	64.11	264	800.10	0.42	0.29
71	Nallakkampatti	11°38'58.11"N	78° 3'16.54"E	HK	75.17	86.09	86.09	285	49009.51	6.52	6.57
72	Makkanur	11°37'4.31"N	77°49'29.60"E	AA	1620.00	22.2	22.2	222	2934.20	0.10	0.79
73	Kottapalayam	11°37'4.74"N	77°51'5.39"E	KQ	11975.10	50.82	50.82	216	3831.58	1.10	1.28
74	Kartikanakkanur	11°37'38.07"N	77°51'59.33"E	KH	12053.60	73.86	73.86	229	10319.00	0.15	0.54
75	Oddapuram	11°37'8.72"N	77°53'4.16"E	HA	156.98	67.097	67.097	225	6633.00	0.30	0.66
76	Kottapalayam	11°37'8.84"N	77°51'57.66"E	KQ	8831.40	37.87	37.87	221	9801.00	0.12	0.92
77	Sadayampalayam	11°36'54.17"N	77°54'50.19"E	HA	331.76	71.998	71.998	237	8387.90	0.59	0.98
78	Pachchallyur	11°37'28.96"N	77°55'31.03"E	AA	854.34	26.617	26.617	236	3225.60	0.09	0.65
79	Konangiyur	11°36'45.78"N	77°57'13.98"E	HK	204.36	12.378	12.378	257	8586.60	0.29	4.06
80	Velaiyachettippatti	11°37'14.50"N	77°58'59.12"E	KA	12635.00	101	101	259	10488.22	2.38	1.56
81	Nallanampatti	11°36'56.88"N	78° 0'29.40"E	KH	20610.63	32.7	32.7	280	10691.00	0.04	0.62
82	Pattakkaranur	11°35'12.30"N	77°47'21.03"E	HA	883.40	135.48	135.48	208	86277.00	0.35	1.29
83	Kalaravallipattipudur	11°35'10.29"N	77°49'50.95"E	HK	16.86	22.424	22.424	205	1362.56	0.30	0.90
84	Nachchiyur	11°35'9.53"N	77°51'49.35"E	KH	21933.44	71.52	71.52	213	7994.60	0.43	0.82
85	Kundarasampalayam	11°35'7.08"N	77°53'20.58"E	AA	6429.60	26.51	26.51	236	4324.00	0.05	0.54
86	Ayyampalayam	11°35'13.10"N	77°55'30.11"E	AA	5790.40	31.58	31.58	252	2456.00	0.05	0.36
87	Tannirdasanur	11°34'3.34"N	77°46'32.99"E	KH	694.50	70.17	70.17	204	8444.90	0.17	0.54
88	Marikavundankuttai	11°34'17.88"N	77°48'54.73"E	KH	1852.48	52.83	52.83	200	49937.20	0.35	2.52
89	Annamalaipalaiyam	11°34'5.16"N	77°51'47.82"E	KH	372.86	67.849	67.849	227	1100.10	0.40	0.31
90	Kavadikkaranur	11°33'20.97"N	77°52'50.09"E	KH	1430985.0	106.174	106.174	245	91253.59	0.23	1.35
91	Madattur	11°33'31.59"N	77°54'32.19"E	KH	32120.40	77.26	77.26	246	42643.90	0.13	0.98
92	Kurukkuparaiyur	11°31'54.42"N	77°47'23.55"E	HK	136.08	47.1	47.1	220	368.80	0.60	0.31
93	Pullipalikadu	11°31'47.41"N	77°52'8.53"E	AK	86.58	36.05	36.05	274	7562.60	0.47	1.66

Below Ground Level (BGL), Above Mean Sea Level (AMSL)

3.4.4 Other Geoelectric Parameters

A geoelectric layer is characterized by two fundamental parameters; its resistivity 'ρ' and its thickness 'h'. The other geoelectric parameters which can be derived from these two are

i. Total longitudinal unit conductance (S),

ii. Total transverse unit resistance (T)

iii. Aquifer anisotropy (λ)

The coefficient of anisotropy (λ) of a formation can be obtained using the formula $\lambda = \sqrt{TS}/H)$

T is the total transverse resistance (ohm.mt^2), S is the longitudinal conductance (mhos) and H is the total thickness of the formation (m)

3.4.5 Hydrogeological Significance of S, T and λ

Variation in 'S' from one VES to the other have been used in a quantitative sense to indicate changes in the total thickness of low resistivity materials (Zohdy 1969). Large 'S' values are indicative of shallow basement. It has also been reported that high 'S' values are indicative of low aquifer transmissivities. Balasubramanian (1986) has successfully utilized the geoelectric parameters in assessing the groundwater potential zones of hard rock terrains in the south India. The property 'T' has been used to indicative varying thickness of high resistivity materials and or variations in their transverse resistance. Increasing 'T' values are an indicative of an increase in the thickness of the resistive materials. It has noticed (Matzner,1983) that increasing TS have coincided with high transmissivities of aquifers.

Aquifer anisotropy (λ) can be used as a measure of finding out the extent of anisotropism prevailing in an area of interest. The λ, T and S values have been computed and shown in Table 3.2. It could be seen that the transverse resistance values ranges from 17.84 to 100405.10 ohm meter. The values of longitudinal conductance and aquifer anisotropy value ranges from 0.03 to 77.08 ohms, and 0.19 to 19.96 ohms. A comparative study of transverse resistance map has been shown in Fig. 3.15. It is inversely proportional to each other, reveals a less permeable thick zone. Considering, simultaneously the longitudinal conductance map shown in Fig.3.16 and aquifer anisotropy shown in Fig.3.17 of groundwater development map could be seen that high longitudinal conductance values are characteristic of deeper basement topography only in certain parts of the area is understudy.

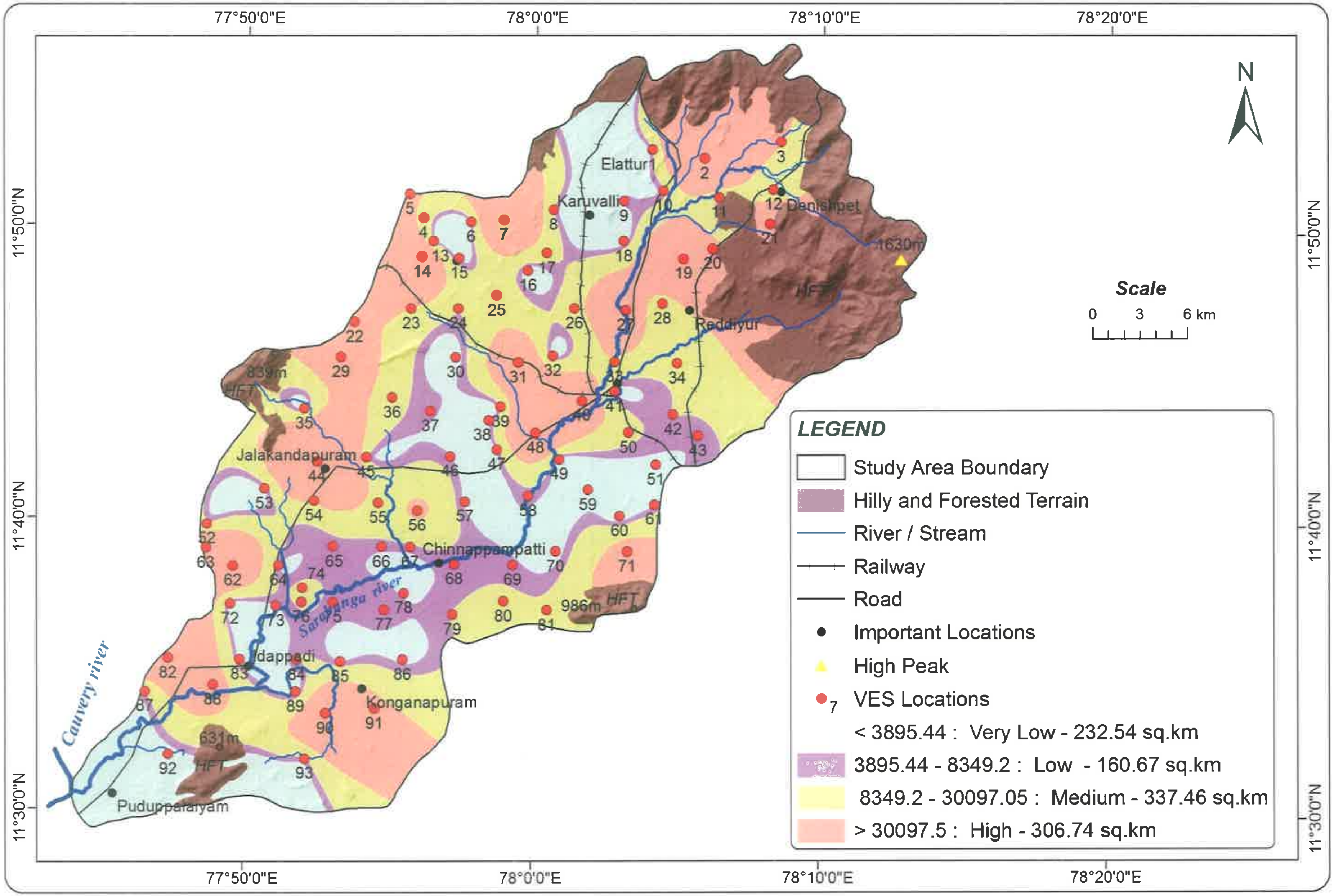

Fig.3.15.Map showing transverse resistance in the study area.

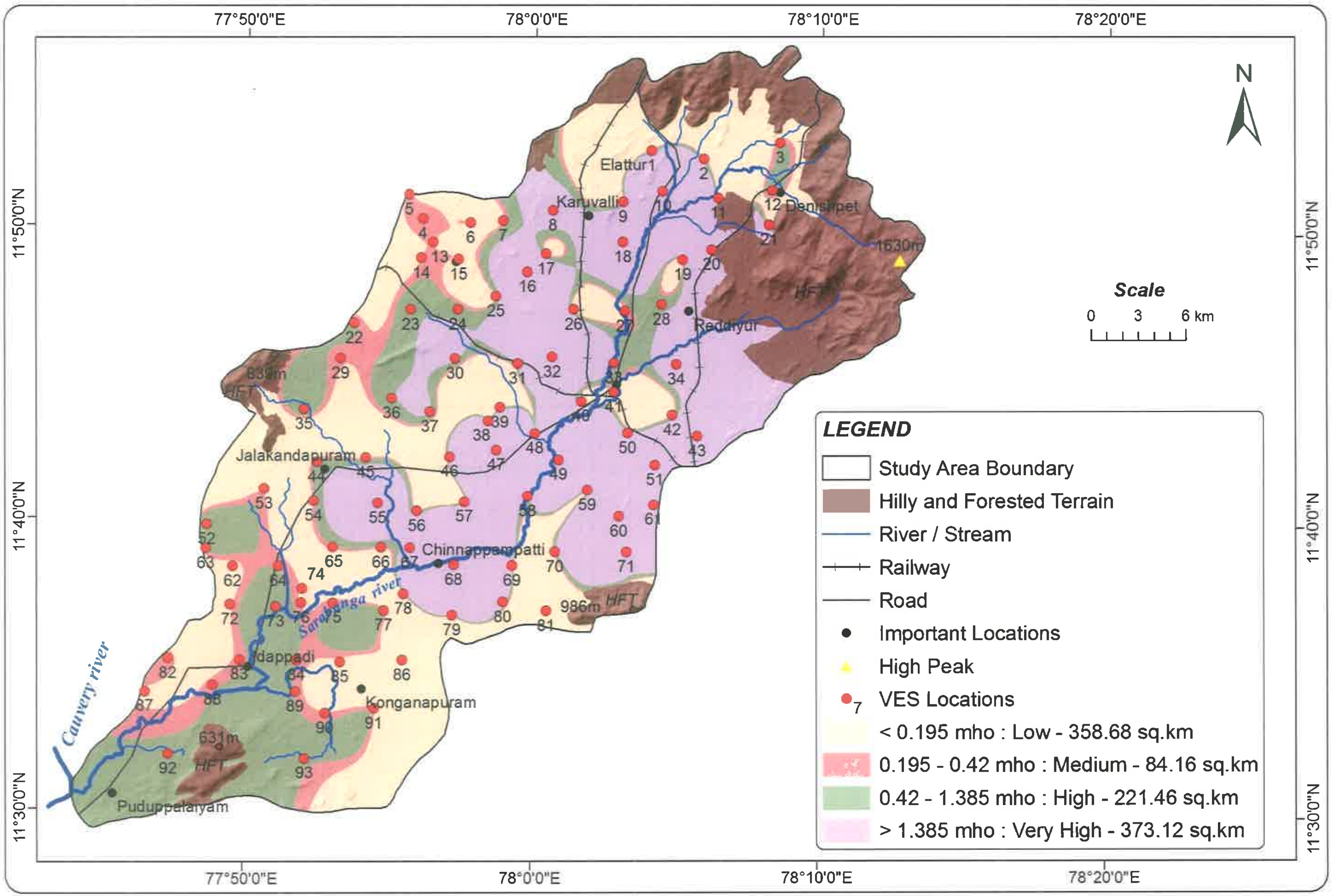

Fig.3.16.Longidutinal Conductance Map Of Sarabanga sub basin.

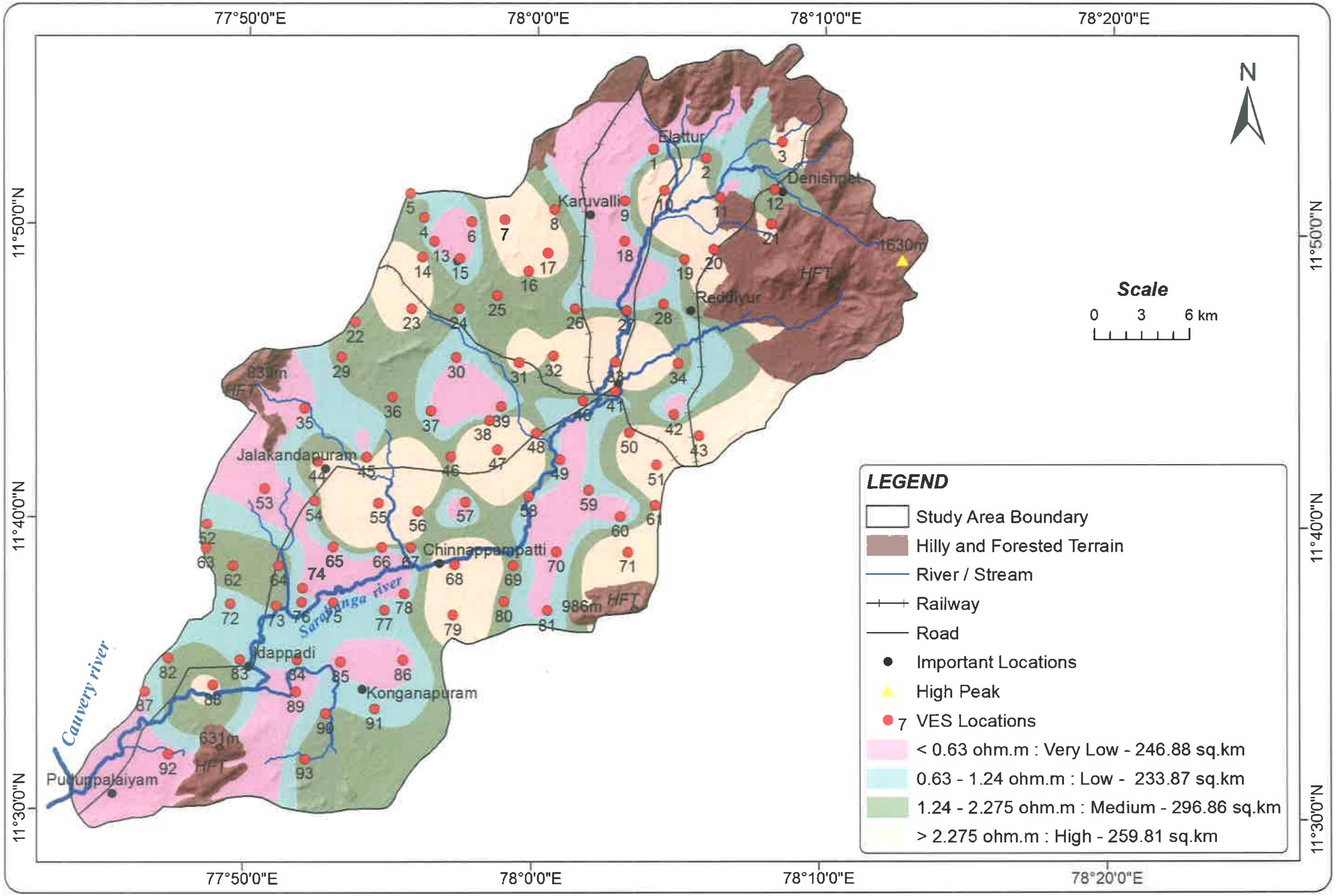

Fig.3.17.Map showing aquifer anisotropy in the study area.

CHAPTER IV
HYDROGEOCHEMISTRY

4.1 Groundwater Sampling and Chemical Analysis

In order to assess the groundwater chemistry, a total of 90 representative groundwater samples were collected from dug and bore wells which are being extensively used for drinking and other irrigation purposes in the investigation area during pre and post monsoon 2012. The results are given in Table 6.1. The groundwater samples were collected in a well cleaned 1000 ml polyethylene bottles. pH and electrical conductance were measured in the field by using Elico pH meter and conductivity meter. Ca and Mg were determined titrimetrically using standard EDTA, and chloride was determined by silver nitrate titration (Volgel, 1968). Carbonate and bicarbonate were estimated with standard sulphuric acid and sulphate was determined gravimetrically by precipitating $BaSO_4$ from $BaCl_2$. Na and K by Elico flame photometer (APHA, 1995).

The sample location map of the study area is given in Fig 6.1. Field photographs are shown in Pho.4. The samples were analyzed for physical and chemical parameters (pH, EC), major cations (Ca, Mg, Na, K), major anions (CO_3, HCO_3, SO_4, Cl), minor cations (Mn, Fe) and minor anion (NO_3, F) as per standard procedures and the results in ppm value are given in Table 4.1 and 4.2. For the drinking water purposes, World Health Organization (WHO) standard limit was used to demarcate sample suitability. Their attributes are added and analyzed in ArcGIS software. Spatial analysis tools were used for the preparation of interpolation map. The maps were interpolated by using inverse distance methods for the spatial distribution map preparation.

The major cations and anions were plotted on the Piper's trilinear diagram and projected to a common diamond shaped field to know the type of water. USSL diagram widely used for evaluating water for irrigation on the basis of SAR was proposed by Richard (1954). In this diagram, the SAR is plotted against EC value.

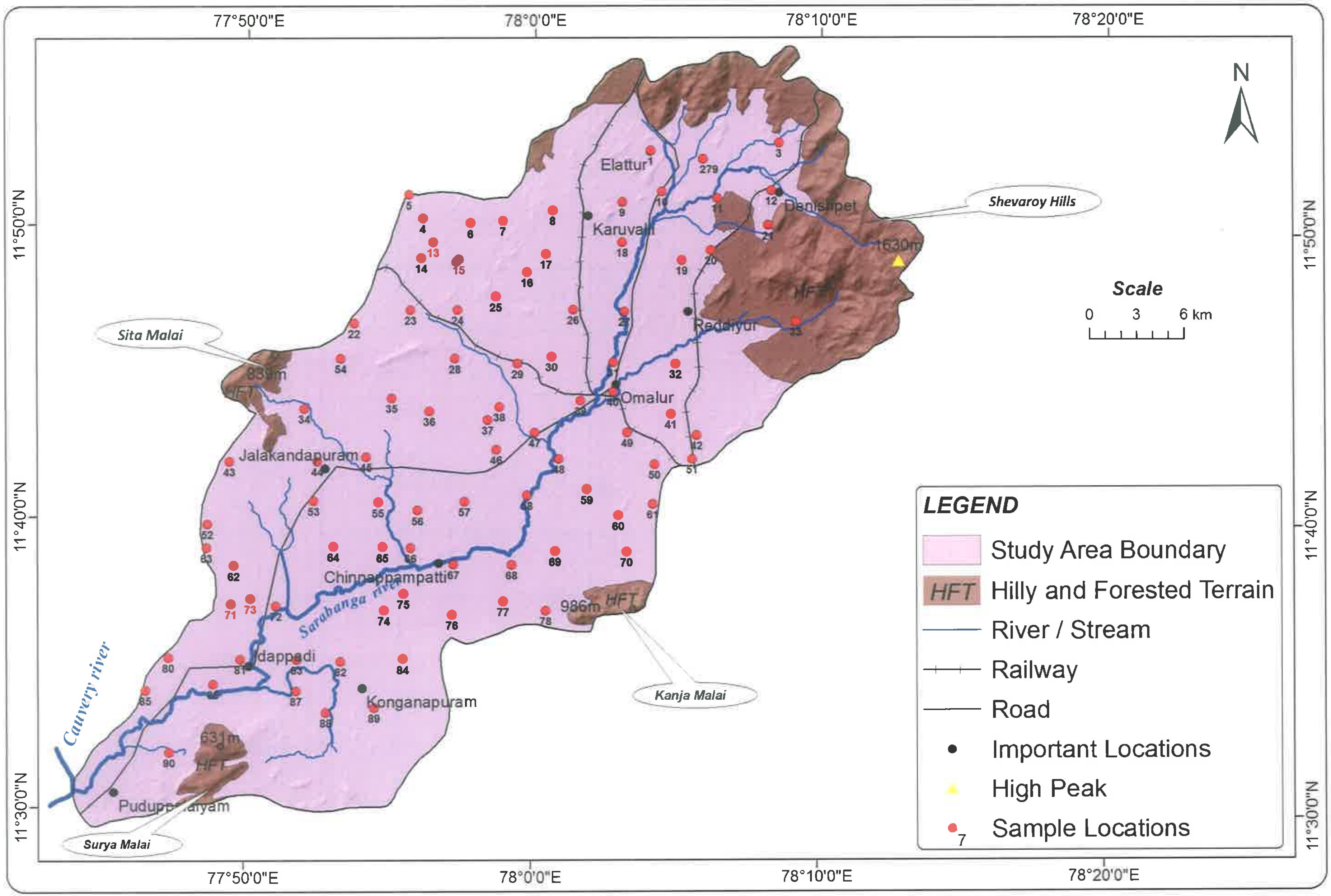

Fig.4.1.Map showing groundwater sampling location in the study area.

Photos-4.Field Photographs showing dug and bore wells

a. Water sample collection at Tharamangalam village

b. Water sample collection at Mecheri village

c. Water sample collection at Nachipalayam village

d. Water sample collection at Konganapuram village

Table.4.1. Chemical Analysis of Groundwater samples Sarabanga sub Basin Ionic concentration in ppm Pre monsoon

Sl.No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
1	Elathur	11°52'53.33"N	78° 4'15.03"E	1610	7.28	151.9	62.4	56.9	393.0	0.0	40.8	270.6	0.0	0.3	0.1	1.9	1.1	1127
2	Muttanampatty	11°52'28.36"N	78° 5'52.86"E	1630	7.21	144.1	64.8	55.8	563.2	0.0	39.9	161.7	0.0	0.0	0.0	9.0	1.3	1141
3	Periavadagampatti	11°52'29.21"N	78° 5'49.17"E	2000	7.50	120.0	52.8	66.7	399.1	0.0	37.9	187.9	0.0	0.0	0.0	10.9	1.5	1400
4	Kukalpatti	11°50'19.90"N	77°56'6.33"E	1583	6.64	114.0	49.4	151.9	552.2	30.3	62.0	163.5	0.0	0.3	0.0	30.7	1.1	1108
5	Kupakalipatti	11°51'9.01"N	77°55'37.81"E	1852	5.92	113.4	51.6	144.9	368.0	4.2	56.7	307.4	0.0	0.3	0.0	1.3	0.9	1296
6	Amaram	11°50'12.04"N	77°57'45.88"E	1898	6.53	133.1	64.6	178.5	518.1	28.2	85.5	277.3	0.0	0.0	0.0	43.5	1	1272
7	Andiyur	11°50'17.08"N	77°58'53.51"E	1086	6.73	53.1	30.4	131.3	319.7	17.4	52.4	129.1	0.0	0.0	0.0	26.9	1.2	760
8	Maniyakaranur	11°50'38.87"N	78° 0'37.98"E	1220	8.86	113.2	51.6	65.6	417.4	0.0	34.1	172.7	0.0	0.3	0.1	10.9	1.7	854
9	Rangappanur	11°50'59.16"N	78° 3'4.30"E	1390	9.19	118.0	49.6	70.0	431.4	0.0	25.9	174.1	0.0	0.3	0.1	13.4	1.5	973
10	Agraharum	11°51'21.03"N	78° 4'26.35"E	6050	9.10	203.2	87.1	27.8	829.3	0.0	37.9	122.3	0.0	0.0	0.1	1.3	1.9	4235
11	Chinnayercaudu	11°51'8.23"N	78° 6'23.72"E	1847	8.41	159.5	68.5	63.7	468.0	0.0	67.2	244.0	0.0	0.0	0.1	10.2	2.4	1293
12	Danishpet	11°51'29.65"N	78° 8'9.15"E	1870	9.15	132.9	59.1	77.4	401.5	0.0	69.2	218.8	0.0	0.0	0.1	13.4	1.8	1309
13	Kolipatti	11°49'32.65"N	77°56'27.78"E	1952	8.93	151.1	64.8	175.3	662.1	36.3	72.0	235.1	0.0	0.3	0.0	38.4	0.8	1367
14	Karapatti	11°48'59.83"N	77°56'27.71"E	2898	8.72	193.2	36.8	342.8	576.0	31.5	137.8	487.6	0.0	0.3	0.0	66.6	1.9	2029
15	Malayanur	11°48'57.52"N	77°57'21.09"E	2592	8.89	188.8	75.5	214.9	579.1	31.5	100.4	410.6	0.0	0.0	0.0	49.3	0.6	1815
16	Bommiyampatti	11°48'58.82"N	77°57'19.07"E	1840	8.46	139.1	66.2	168.7	608.4	33.3	57.2	255.3	0.0	0.0	0.0	41.0	0.8	1287
17	Marakottai	11°49'9.94"N	78° 0'23.91"E	1730	7.34	132.1	55.2	60.1	428.4	0.0	40.8	191.8	0.0	0.0	0.1	13.4	1.7	1211
18	Kanjanayakanpatti	11°49'35.79"N	78° 3'4.63"E	2400	7.61	151.9	64.8	38.0	339.3	0.0	82.1	244.3	0.0	2.0	0.1	4.5	1.6	1680
19	Chinnanagalur	11°49'0.84"N	78° 5'10.41"E	2600	7.25	240.1	103.2	60.1	150.1	0.0	298.3	500.0	0.0	0.3	0.1	1.9	1.3	1820
20	Tinnapatti	11°49'21.76"N	78° 6'11.16"E	1840	7.17	176.0	76.9	56.9	382.0	0.0	61.5	343.6	0.0	0.3	0.1	9.0	2	1288
21	Kanjeri	11°50'13.71"N	78° 8'10.26"E	2500	7.41	224.0	93.6	58.9	227.6	0.0	56.2	575.9	0.0	0.0	0.1	4.5	1.5	1750
22	Palakaranur	11°46'44.81"N	77°53'43.49"E	1057	8.83	91.2	17.5	124.0	479.0	26.1	29.3	65.6	0.0	0.0	0.0	14.1	0.7	739
23	Kalikovundanur	11°47'13.60"N	77°55'42.26"E	4048	8.46	243.9	112.7	473.8	806.1	44.1	160.9	828.0	1.1	0.6	0.0	105.6	2.2	2834
24	Sangattur	11°47'14.77"N	77°57'20.05"E	4617	8.64	311.8	128.5	530.7	759.7	41.4	166.7	1099.6	0.0	0.6	0.0	90.2	1.9	3230
25	Sattapadi	11°47'42.16"N	77°58'39.27"E	1123	8.98	88.8	19.2	130.9	295.9	16.2	192.1	72.0	0.0	0.0	0.0	14.7	0.6	786
26	Semmandapatti	11°47'17.22"N	78° 1'22.69"E	2100	7.14	163.9	69.6	67.9	192.8	0.0	102.3	389.0	0.0	0.0	0.1	9.0	2.7	1470
27	Dharapuram	11°47'14.03"N	78° 3'10.20"E	3200	7.30	276.0	122.5	62.0	306.3	0.0	299.2	530.1	0.0	0.0	0.1	1.9	1.5	2240
28	Nangavalli	11°45'32.38"N	77°53'16.53"E	1884	8.91	137.9	38.7	197.2	637.7	34.8	34.1	208.2	0.0	0.3	0.0	48.6	0.8	1319

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Sl. No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
29	Olaipatti	11°45'34.22"N	77°57'15.41"E	2122	8.76	203.0	40.1	201.6	829.9	45.3	53.3	193.6	0.0	0.3	0.0	54.4	0.8	1483
30	Maramangalam	11°45'39.67"N	77°59'26.33"E	3967	8.91	213.4	106.8	445.5	689.5	37.8	185.4	765.6	0.0	0.3	0.0	83.8	2.2	2777
31	Palikkadai	11°45'39.67"N	78° 0'37.57"E	3200	7.51	144.1	64.8	20.1	277.6	0.0	181.1	320.2	0.0	0.0	0.1	9.0	1.9	2240
32	Balbakki	11°45'29.33"N	78° 2'47.27"E	1360	7.31	112.0	50.8	55.8	391.7	0.0	20.7	179.8	0.0	0.0	0.1	6.4	1.3	952
33	Mayilampalayam	11°45'27.08"N	78° 4'57.27"E	2000	7.21	171.9	74.4	64.0	266.0	0.0	106.1	373.7	0.0	0.3	0.1	4.5	1.5	1400
34	Kuruvamnpatti	11°46'54.78"N	78° 9'9.15"E	2100	7.81	152.3	63.0	74.1	335.6	0.0	146.5	400.0	0.0	0.3	0.1	6.4	1.6	1450
35	Sanarpatty	11°43'47.25"N	77°52'0.65"E	2305	8.60	131.1	52.7	503.1	843.9	46.2	93.7	379.1	0.0	0.0	0.0	53.8	1.3	1613
36	Periyasoragai	11°44'11.33"N	77°55'3.30"E	2700	8.46	146.5	62.4	323.8	593.1	32.4	132.1	434.4	0.0	0.3	0.0	62.7	1.1	1890
37	Siranganur	11°43'43.98"N	77°56'23.20"E	2307	8.86	142.7	55.7	314.8	627.9	34.2	97.0	401.8	0.0	0.3	0.0	62.7	0.8	1615
38	Amarakunthi	11°43'27.62"N	77°58'25.26"E	1556	8.52	110.8	37.8	174.6	561.4	30.6	59.1	160.6	0.0	0.3	0.0	37.8	0.6	1172
39	Periyapatti	11°43'54.37"N	77°58'49.23"E	2297	8.92	185.6	77.9	73.2	250.8	0.0	62.9	457.1	0.0	0.3	0.1	10.2	2.3	1608
40	Velakavundanur	11°44'9.13"N	78° 1'39.76"E	2457	8.54	159.1	67.4	42.1	377.7	0.0	175.3	342.9	0.0	0.3	0.1	10.2	1.9	1720
41	Omalur	11°44'28.30"N	78° 2'47.15"E	2784	8.78	111.4	50.1	47.4	192.2	0.0	100.4	330.5	0.0	0.0	0.1	0.0	1.4	1949
42	Vethalaikaranur	11°43'42.80"N	78° 4'49.02"E	2266	9.07	198.2	85.0	72.0	295.3	0.0	68.7	476.9	0.0	0.0	0.1	0.0	2.1	1586
43	Karuppur	11°42'59.46"N	78° 5'43.40"E	2289	8.59	184.0	77.3	70.0	344.8	0.0	64.4	395.0	0.0	0.3	0.1	10.2	1.7	1602
44	Pakkanadu	11°41'57.43"N	77°49'24.51"E	2645	7.82	196.0	44.5	299.7	714.5	39.0	113.8	369.5	0.0	0.6	0.0	59.5	1.3	1851
45	Jalakandapuram	11°41'59.10"N	77°52'28.71"E	2049	8.04	187.2	41.0	225.8	756.0	41.4	99.4	224.8	0.0	0.3	0.0	46.7	0.8	1434
46	Chinnakovundanur	11°42'9.08"N	77°54'10.48"E	2653	8.50	198.4	52.7	306.8	784.7	42.9	106.1	372.3	0.0	0.3	0.0	55.7	0.8	1857
47	Chickkampatti	11°42'26.78"N	77°58'42.99"E	3200	7.32	208.0	91.2	38.0	381.4	0.0	86.0	390.8	0.0	0.3	0.1	10.9	2	2240
48	Mottaiyanteruvur	11°43'2.00"N	78° 0'3.61"E	2500	7.31	96.0	43.2	15.8	274.6	0.0	51.4	253.5	0.0	0.0	0.1	0.0	2.2	1750
49	Elayur	11°42'8.47"N	78° 0'53.78"E	4200	7.41	200.0	84.0	18.9	135.5	0.0	124.9	442.5	0.0	0.3	0.1	9.0	1.7	2940
50	Pakalpatti	11°43'4.69"N	78° 3'17.51"E	2700	7.59	220.0	93.6	34.1	404.6	0.0	156.1	354.6	0.0	0.3	0.1	0.0	1.1	1890
51	Nallakavundanpatty	11°41'58.95"N	78°41'14.80"E	760	7.59	65.5	27.8	53.8	331.3	0.0	15.4	72.7	0.0	0.0	0.1	0.0	1	532
52	Railway station	11°45'44.34"N	77° 58'52.38"E	2500	7.47	212.0	88.8	62.8	748.7	0.0	298.3	65.6	0.0	0.3	0.1	0.0	0.8	1750
53	Puliyampati	11°39'47.92"N	77°48'40.12"E	2191	8.72	122.4	45.6	260.6	667.6	36.6	60.0	256.7	0.0	0.3	0.0	38.4	1	1534
54	Sivadanur	11°40'37.80"N	77°52'21.96"E	1446	8.92	110.4	33.6	160.9	485.7	26.4	57.6	177.7	1.1	0.6	1.2	43.5	0.6	1012
55	Nattakattanur	11°40'35.32"N	77°54'36.73"E	6804	8.93	422.4	91.2	909.6	1304.0	71.1	264.2	1343.9	0.0	1.1	0.0	134.4	2.4	4763
56	Tadikaranur	11°40'19.93"N	77°55'59.17"E	3576	9.22	194.4	62.4	434.4	607.8	33.3	132.1	676.9	0.0	0.8	0.0	69.8	1.1	2503
57	Kuttakatanur	11°40'39.53"N	77°57'36.93"E	4260	9.12	259.1	110.4	489.4	778.0	42.6	192.1	864.2	0.0	0.3	0.0	103.0	1.5	2982
58	Attikattanur	11°40'52.74"N	77°59'48.53"E	7320	9.23	441.7	195.9	28.8	497.3	0.0	148.9	979.4	0.0	0.0	0.2	7.7	1.3	5124
59	Kanganur	11°41'5.79"N	78° 1'53.29"E	4200	9.36	254.3	103.7	19.0	303.3	0.0	217.6	426.6	0.0	0.0	0.1	16.0	1.5	2940

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Sl. No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
60	Maramangalathupatti	11°40'13.00"N	78° 2'59.12"E	1956	9.16	182.4	80.6	65.9	483.9	0.0	48.5	329.8	0.0	0.0	0.1	10.9	1.7	1369
61	Sarkarhollapatti	11°40'37.08"N	78° 4'12.34"E	3360	9.23	288.0	123.8	74.5	488.2	0.0	336.2	442.5	0.0	0.0	0.1	0.0	2.2	2352
62	Nattapatty	11°38'59.23"N	77°49'35.06"E	3012	8.48	211.2	43.2	378.0	850.6	46.5	144.1	403.2	0.0	0.8	0.0	67.2	2.1	2108
63	Reddipatty	11°38'59.23"N	77°48'38.51"E	10644	8.62	1022.4	187.1	1185.5	3314.6	181.2	623.9	1512.0	2.3	3.4	1.8	14.7	2.4	7451
64	Thirumalur	11°39'4.39"N	77°53'2.42"E	4668	8.94	302.4	122.5	526.8	686.5	37.5	240.2	1051.0	0.0	0.8	0.0	74.2	1.7	3268
65	Samudram	11°39'3.65"N	77°54'44.83"E	3540	8.74	163.1	62.4	551.8	879.9	48.0	132.1	628.7	2.3	3.1	1.8	81.9	2.2	2478
66	Upparapatty	11°39'2.82"N	77°54'44.90"E	3948	8.69	259.1	54.0	507.6	706.0	38.7	216.1	753.5	0.0	0.8	0.0	91.5	1.5	2764
67	Chinnapampatti	11°38'29.91"N	77°57'15.55"E	1259	9.16	67.1	33.6	168.1	402.1	21.9	65.8	158.5	0.0	0.0	0.0	33.9	0.8	881
68	Mattaiyampatti	11°38'29.91"N	77°59'17.52"E	5748	8.58	316.8	86.5	892.8	1095.3	59.7	192.1	1296.1	0.0	1.1	0.0	134.4	1.7	4024
69	Sittanur	11°38'58.11"N	78° 0'47.42"E	2664	8.86	316.8	62.4	331.4	1147.2	62.7	101.8	408.1	1.9	0.3	0.0	55.0	1.1	1865
70	Nallakampatti	11°38'58.11"N	78° 3'16.54"E	6048	8.81	134.5	79.2	765.7	155.6	8.4	240.2	1331.9	0.0	1.4	0.0	141.4	2.5	4234
71	Makkanur	11°37'4.31"N	77°49'29.60"E	5808	8.41	475.1	175.2	636.2	1138.0	62.1	192.1	1415.9	1.1	1.7	1.2	151.0	1.8	4066
72	Kottapalayam	11°37'4.74"N	77°51'5.39"E	4032	8.62	165.5	91.2	513.7	730.4	39.9	156.1	731.9	0.0	0.8	0.0	103.0	1.4	2822
73	Nachipalayam	11°37'16.07"N	77°50'9.34"E	2897	8.65	141.7	67.2	422.4	1307.0	71.4	132.1	131.9	2.3	2.2	1.8	72.3	1.8	2027
74	Sadaiyampalayam	11°36'54.17"N	77°54'50.19"E	2448	9.22	151.1	69.6	253.2	677.3	36.9	132.1	307.1	0.0	0.6	0.0	50.6	0.8	1714
75	Pachaliyur	11°37'28.96"N	77°55'31.03"E	6900	8.41	442.9	93.6	895.1	866.5	47.4	336.2	1536.1	0.0	2.2	0.0	149.1	2.2	4830
76	Konangiyur	11°36'45.78"N	77°57'13.98"E	1788	8.95	410.4	45.6	205.1	1368.1	74.7	89.8	211.3	0.0	0.0	0.0	48.0	1	1252
77	Valaiyachettipatti	11°37'14.50"N	77°58'59.12"E	2628	8.98	112.8	55.2	300.2	518.7	28.2	108.1	388.6	0.0	0.3	0.0	62.7	0.8	1840
78	Nallanampatti	11°36'56.88"N	78° 0'29.40"E	1596	8.89	194.4	38.4	196.7	801.8	43.8	53.8	189.7	0.0	0.3	0.0	43.5	1	1117
79	Muttampatty	11°59'15.05"N	78° 09'29.56"E	1644	9.08	136.9	46.8	164.4	599.8	32.7	60.0	191.8	0.0	0.0	0.0	38.4	1.7	1151
80	Pattakkaranoor	11°35'12.30"N	77°47'21.03"E	5664	8.47	223.2	93.6	917.1	763.4	41.7	216.1	1368.0	2.3	2.5	1.2	115.2	2	3965
81	Kalaravallipattypudur	11°35'10.29"N	77°49'50.95"E	10284	8.59	1003.2	170.4	1123.2	2172.3	118.8	575.9	2112.0	2.3	3.4	2.6	187.5	2.1	7199
82	Kundarasampalayam	11°35'7.08"N	77°53'20.58"E	4068	8.78	240.1	103.2	518.5	839.6	45.9	168.1	815.9	0.0	1.4	0.0	115.2	1.7	2848
83	Nachiyur	11°35'9.53"N	77°51'49.35"E	4620	8.71	278.4	122.5	605.0	1059.9	57.9	168.1	921.6	0.0	0.6	0.0	103.0	2.2	3234
84	Ayyampalayam	11°35'13.10"N	77°55'30.11"E	2897	8.65	141.7	67.2	422.4	1307.0	71.4	132.1	131.9	2.3	2.2	1.8	72.3	1.4	2027
85	Tannidasanur	11°34'3.34"N	77°46'32.99"E	7440	8.89	427.3	175.7	929.7	875.0	47.7	496.6	1721.2	0.0	0.0	0.1	53.1	1.2	5208
86	Marikovundankottai	11°34'17.88"N	77°48'54.73"E	1788	8.99	144.1	63.4	114.2	627.9	34.2	25.5	184.4	0.0	0.0	0.1	42.2	1.9	1252
87	Annamalayampalayam	11°34'5.16"N	77°51'47.82"E	2184	8.74	129.7	46.8	310.8	727.4	39.6	84.1	292.9	0.0	0.6	0.0	42.9	1.5	1529
88	Kavadikaranur	11°33'20.97"N	77°52'50.09"E	4236	8.65	261.5	124.8	494.3	731.6	39.9	240.2	912.0	1.1	0.6	1.2	87.0	2.3	2965
89	Madattur	11°33'31.59"N	77°54'32.19"E	2239	8.54	134.5	55.2	261.7	651.7	35.7	89.8	295.0	0.0	2.5	0.0	42.9	1.5	1567
90	Kurukuparaiyur	11°31'54.42"N	77°47'23.55"E	2520	8.76	167.9	72.0	268.6	659.6	36.0	46.6	434.0	0.0	0.0	0.0	7.0	1.7	1764

Electrical Conductivity- µS/cm² (EC), Total Dissolved Solids (mg/L)

Table.4.2. Chemical Analysis of Groundwater samples Sarabanga sub Basin Ionic concentration in ppm Post monsoon

SI. No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
1	Elathur	11°52'53.33"N	78° 4'15.03"E	1350	7.51	120	52.8	77	431.3	23.6	41.1	171.7	0.8	0.1	0.2	114	0.8	945
2	Muttanampatty	11°52'28.36"N	78° 5'52.86"E	1700	7.42	176	74.4	48	447.9	24.5	45.9	276.8	0.9	0.1	0.1	69	1.2	1190
3	Periavadagampatti	11°52'29.21"N	78° 5'49.17"E	1850	7.37	152	67.2	120	554.6	30.3	63.5	237.4	0.8	0.1	0.1	15	1.2	1295
4	Kukalpatti	11°50'19.90"N	77°56'6.33"E	1666	6.99	120	52	160	581.4	31.8	65.0	172.0	0.0	0.2	0.0	32	0.8	1166
5	Kupakalipatti	11°51'9.01"N	77°55'37.81"E	1950	6.86	132	62	192	426.0	23.3	90.0	346.0	0.0	0.3	0.0	42	0.6	1365
6	Amaram	11°50'12.04"N	77°57'45.88"E	1998	6.87	140	68	188	545.2	29.8	90.0	292.0	0.0	0.1	0.0	46	0.8	1339
7	Andiyur	11°50'17.08"N	77°58'53.51"E	1143	7.08	56	32	138	336.3	18.4	55.0	136.0	0.0	0.0	0.0	28	0.4	800
8	Maniyakaranur	11°50'38.87"N	78° 0'37.98"E	1770	7.02	104	45.6	209	688.0	37.6	53.8	144.4	0.1	0.1	0.0	33	1.5	1239
9	Rangappanur	11°50'59.16"N	78° 3'4.30"E	2300	7.47	140	60	276	608.3	33.2	54.4	384.8	0.1	0.1	0.1	94	1.2	1610
10	Agraharum	11°51'21.03"N	78° 4'26.35"E	970	7.27	44.8	21.1	135	411.9	22.5	40.1	46.5	0.1	0.1	0.0	23	1.6	679
11	Chinnayercaudu	11°51'8.23"N	78° 6'23.72"E	5300	7.36	192	84	870	575.6	31.4	196.5	1383.8	0.1	0.0	0.1	11	2.2	3710
12	Danishpet	11°51'29.65"N	78° 8'9.15"E	1350.0	7.2	100	40.8	122	432.1	23.6	42.0	167.7	0.1	0.0	0.1	17	1.4	945
13	Kolipatti	11°49'32.65"N	77°56'27.78"E	1627	7.44	126	54	146	551.9	30.1	60.0	196.0	0.0	0.2	0.0	32	0.6	1139
14	Karapatti	11°48'59.83"N	77°56'27.71"E	2520	7.58	168	32	298	501.0	27.4	120.0	424.0	0.0	0.2	0.0	58	1.6	1764
15	Malayanur	11°48'57.52"N	77°57'21.09"E	2197	7.53	160	64	182	490.5	26.8	85.0	348.0	0.0	0.0	0.0	42	0.2	1538
16	Bommiyampatti	11°48'58.82"N	77°57'19.07"E	1614	7.42	122	58	148	533.8	29.2	50.0	224.0	0.0	0.0	0.0	36	0.4	1129
17	Marakottai	11°49'9.94"N	78° 0'23.91"E	1260.0	7.1	88	36	125	480.6	26.3	37.0	110.1	0.0	0.0	0.0	12	1.4	882
18	Kanjanayakanpatti	11°49'35.79"N	78° 3'4.63"E	1800	7.5	128	52.8	174	568.7	31.1	42.0	240.4	0.1	0.1	0.0	0	1.2	1260
19	Chinnanagalur	11°49'0.84"N	78° 5'10.41"E	1830	7.36	76	31.2	294	600.5	32.8	44.7	226.3	0.1	0.0	0.1	1	1	1281
20	Tinnapatti	11°49'21.76"N	78° 6'11.16"E	2000.0	7.6	148	62.4	181	437.2	23.9	39.0	401.0	0.1	0.1	0.0	0	1.6	1400
21	Kanjeri	11°50'13.71"N	78° 8'10.26"E	3000.0	7.4	268	115.2	175	492.9	26.9	61.1	707.1	0.1	0.0	0.0	29	1.2	2100
22	Palakaranur	11°46'44.81"N	77°53'43.49"E	903	7.55	78	15	106	409.5	22.4	25.0	56.0	0.0	0.1	0.0	12	0.4	632

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SI. No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
23	Kalikovundanur	11°47'13.60"N	77°55'42.26"E	3520	7.36	212	98	412	700.7	38.3	140.0	720.0	1.0	0.6	0.0	92	1.8	2464
24	Sangattur	11°47'14.77"N	77°57'20.05"E	3880	7.26	262	108	446	638.3	34.9	140.0	924.0	0.0	0.4	0.0	76	1.6	2714
25	Sattapadi	11°47'42.16"N	77°58'39.27"E	936	7.48	74	16	109	246.7	13.5	160.0	60.0	0.0	0.1	0.0	12	0.4	655
26	Semmandapatti	11°47'17.22"N	78° 1'22.69"E	2200.0	7.9	148	64.8	232	511.5	27.9	52.5	414.1	0.1	0.0	0.1	69	2.2	1540
27	Dharapuram	11°47'14.03"N	78° 3'10.20"E	2200.0	7.9	148	64.8	232	511.5	27.9	52.5	414.1	0.1	0.0	0.1	69	1.2	1540
28	Nangavalli	11°45'32.38"N	77°53'16.53"E	1557	7.36	114	32	163	527.1	28.8	28.0	172.0	0.0	0.2	0.0	40	0.6	1090
29	Olaipatti	11°45'34.22"N	77°57'15.41"E	1798	7.42	172	34	171	703.2	38.4	45.0	164.0	0.0	0.2	0.0	46	0.6	1257
30	Maramangalam	11°45'39.67"N	77°59'26.33"E	3420	7.68	184	92	384	594.2	32.5	160.0	660.0	0.0	0.3	0.0	72	1.8	2394
31	Palikkadai	11°45'39.67"N	78° 0'37.57"E	2500.0	7.6	116	50.4	360	588.9	32.2	65.2	458.6	0.1	0.0	0.0	47	1.5	1750
32	Balbakki	11°45'29.33"N	78° 2'47.27"E	1170.0	7.4	86.4	37.44	102	491.1	26.8	20.4	80.8	0.1	0.0	0.1	88	1	819
33	Mayilampalayam	11°45'27.08"N	78° 4'57.27"E	3100.0	7.5	276	117.6	160	494.6	27.0	56.1	707.1	0.1	0.0	0.0	79	1	2170
34	Kuruvamnpatti	11°46'54.78"N	78° 9'9.15"E	2000.0	7.5	132	57.6	216	415.7	22.7	38.9	422.2	0.1	0.1	0.1	72	1	1400
35	Sanarpatty	11°43'47.25"N	77°52'0.65"E	1970	7.35	112	45	430	721.4	39.4	80.0	324.0	0.0	0.0	0.0	46	1.2	1379
36	Periyasoragai	11°44'11.33"N	77°55'3.30"E	2250	7.05	122	52	270	494.0	27.0	110.0	362.0	0.0	0.3	0.0	52	1	1575
37	Siranganur	11°43'43.98"N	77°56'23.20"E	1907	7.32	118	46	260	518.7	28.3	80.0	332.0	0.0	0.3	0.0	52	0.6	1335
38	Amarakunthi	11°43'27.62"N	77°58'25.26"E	1319	7.22	94	32	148	475.9	26.0	50.0	136.0	0.0	0.2	0.0	32	0.2	993
39	Periyapatti	11°43'54.37"N	77°58'49.23"E	1400.0	7.5	112	46.08	101	512.2	28.0	23.3	133.3	0.1	0.1	0.0	37	1.9	980
40	Velakavundanur	11°44'9.13"N	78° 1'39.76"E	2400.0	7.1	192	84	182	521.5	28.5	56.1	475.8	0.2	0.1	0.1	66	0.8	1680
41	Omalur	11°44'28.30"N	78° 2'47.15"E	2200.0	7.3	220	103.2	62	490.3	26.8	58.5	422.2	0.0	0.1	0.0	12	1	1540
42	Vethalaikaranur	11°43'42.80"N	78° 4'49.02"E	1320.0	7.3	92	40.8	126	456.2	24.9	20.6	158.6	0.1	0.1	0.1	22	1.8	924
43	Karuppur	11°42'59.46"N	78° 5'43.40"E	1900.0	7.3	156	67.2	139	627.7	34.3	31.5	249.5	0.1	0.1	0.1	11	1.2	1330
44	Pakkanadu	11°41'57.43"N	77°49'24.51"E	2320	6.86	172	39	263	626.9	34.2	100.0	324.0	0.0	0.5	0.0	52	1.2	1624
45	Jalakandapuram	11°41'59.10"N	77°52'28.71"E	1751	6.87	160	35	193	646.1	35.3	85.0	192.0	0.0	0.3	0.0	40	0.6	1226
46	Chinnakovundanur	11°42'9.08"N	77°54'10.48"E	2320	7.19	168	46	270	662.0	36.2	90.0	336.0	0.0	0.3	0.0	48	0.6	1624

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SI. No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
47	Chickkampatti	11°42'26.78"N	77°58'42.99"E	1680.0	7.4	92	40.8	210	615.8	33.6	30.8	173.7	0.1	0.1	0.0	81	1.8	1176
48	Mottaiyanteruvur	11°43'2.00"N	78° 0'3.61"E	1790.0	7.5	160	67.2	105	548.7	30.0	36.8	252.5	0.1	0.0	0.1	29	2	1253
49	Elayur	11°42'8.47"N	78° 0'53.78"E	1970.0	7.3	152	64.8	159	660.1	36.1	42.3	237.4	0.0	0.0	0.0	36	1.2	1379
50	Pakalpatti	11°43'4.69"N	78° 3'17.51"E	3600.0	7.1	232	96	404	536.6	29.3	119.1	858.6	0.0	0.1	0.0	78	0.8	2520
51	Nallakavundanpatty	11°41'58.95"N	78°41'14.80"E	1660.0	7.3	116	50.4	159	472.0	25.8	21.2	268.7	0.1	0.1	0.0	36	0.9	1162
52	Railway station	11°45'44.34"N	77° 58'52.38"E	1740.0	7.6	128	55.2	154	457.1	25.0	32.3	297.0	0.1	0.0	0.0	26	1.4	1218
53	Puliyampati	11°39'47.92"N	77°48'40.12"E	1826	7.27	102	38	217	556.1	30.4	50.0	214.0	0.0	0.3	0.0	32	0.8	1278
54	Sivadanur	11°40'37.80"N	77°52'21.96"E	1205	7.43	92	28	134	404.6	22.1	48.0	148.0	1.0	0.4	1.0	36	0.4	843
55	Nattakattanur	11°40'35.32"N	77°54'36.73"E	5670	7.44	352	76	758	1086.4	59.3	220.0	1120.0	0.0	0.9	0.0	112	2.4	3969
56	Tadikaranur	11°40'19.93"N	77°55'59.17"E	2980	7.68	162	52	362	506.5	27.7	110.0	564.0	0.0	0.8	0.0	58	0.8	2086
57	Kuttakatanur	11°40'39.53"N	77°57'36.93"E	3550	7.6	216	92	408	648.2	35.4	160.0	720.0	0.0	0.3	0.0	86	0.6	2485
58	Attikattanur	11°40'52.74"N	77°59'48.53"E	1850.0	7.4	184	76.8	71	455.4	24.9	32.7	336.4	0.1	0.1	0.1	16	0.8	1295
59	Kanganur	11°41'5.79"N	78° 1'53.29"E	6700.0	7.2	496	206.4	610	493.0	26.9	414.5	1757.6	0.1	0.1	0.0	6	1	4690
60	Maramangalathupatti	11°40'13.00"N	78° 2'59.12"E	1900.0	7.1	164	67.2	127	655.6	35.8	28.9	230.3	0.0	0.0	0.0	73	1.3	1330
61	Sarkarhollapatti	11°40'37.08"N	78° 4'12.34"E	2300.0	7.5	140	60	262	620.7	33.9	59.2	370.7	0.1	0.1	0.0	33	2	1610
62	Nattapatty	11°38'59.23"N	77°49'35.06"E	2510	7.07	176	36	315	709.0	38.7	120.0	336.0	0.0	0.6	0.0	56	1.8	1757
63	Reddipatty	11°38'59.23"N	77°48'38.51"E	8870	7.18	852	156	988	2762.0	150.9	520.0	1260.0	2.0	2.8	1.5	182	2.1	6209
64	Thirumalur	11°39'4.39"N	77°53'2.42"E	3890	7.45	252	102	439	571.8	31.2	200.0	876.0	0.0	0.8	0.0	62	1.4	2723
65	Samudram	11°39'3.65"N	77°54'44.83"E	2950	7.28	136	52	460	733.2	40.1	110.0	524.0	2.0	2.5	1.5	68	1.9	2065
66	Upparapatty	11°39'2.82"N	77°54'44.90"E	3290	7.24	216	45	423	588.4	32.1	180.0	628.0	0.0	0.6	0.0	76	1.2	2303
67	Chinnapampatti	11°38'29.91"N	77°57'15.55"E	1049	7.63	56	28	140	335.1	18.3	55.0	132.0	0.0	0.1	0.0	28	0.6	734
68	Mattaiyampatti	11°38'29.91"N	77°59'17.52"E	4790	7.15	264	72	744	912.5	49.8	160.0	1080.0	0.0	0.9	0.0	112	1.2	3353
69	Sittanur	11°38'58.11"N	78° 0'47.42"E	2220	7.38	264	52	276	956.2	52.2	85.0	340.0	1.5	0.2	0.0	46	0.7	1554
70	Nallakampatti	11°38'58.11"N	78° 3'16.54"E	5040	7.34	112	66	638	129.5	7.1	200.0	1110.0	0.0	1.1	0.0	118	2.4	3528

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Sl. No.	Location Name	Latitude	Longitude	EC	pH	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TDS
71	Makkanur	11°37'4.31"N	77°49'29.60"E	4840	7.01	396	146	530	948.5	51.8	160.0	1180.0	1.0	1.5	1.0	126	1.4	3388
72	Kottapalayam	11°37'4.74"N	77°51'5.39"E	3360	7.18	138	76	428	608.7	33.3	130.0	610.0	0.0	0.8	0.0	86	1	2352
73	Nachipalayam	11°37'16.07"N	77°50'9.34"E	2414	7.21	118	56	352	1089.2	59.5	110.0	110.0	2.0	1.8	1.5	60	1.2	1689
74	Sadaiyampalayam	11°36'54.17"N	77°54'50.19"E	2040	7.68	126	58	211	564.2	30.8	110.0	256.0	0.0	0.5	0.0	42	0.6	1428
75	Pachaliyur	11°37'28.96"N	77°55'31.03"E	5750	7.01	369	78	746	722.3	39.5	280.0	1280.0	0.0	1.8	0.0	124	1.8	4025
76	Konangiyur	11°36'45.78"N	77°57'13.98"E	1490	7.46	342	38	171	1140.1	62.3	75.0	176.0	0.0	0.1	0.0	40	0.8	1043
77	Valaiyachettipatti	11°37'14.50"N	77°58'59.12"E	2190	7.48	94	46	250	432.0	23.6	90.0	324.0	0.0	0.3	0.0	52	0.6	1533
78	Nallanampatti	11°36'56.88"N	78° 0'29.40"E	1330	7.41	162	32	164	668.2	36.5	45.0	158.0	0.0	0.2	0.0	36	0.8	931
79	Muttampatty	11°59'15.05"N	78° 09'29.56"E	1370	7.57	114	39	137	499.9	27.3	50.0	160.0	0.0	0.0	0.0	32	1.4	959
80	Pattakkaranoor	11°35'12.30"N	77°47'21.03"E	4720	7.06	186	78	764	636.2	34.8	180.0	1140.0	2.0	2.2	1.0	96	1.6	3304
81	Kalaravallipattypudur	11°35'10.29"N	77°49'50.95"E	8570	7.16	836	142	936	1810.0	98.9	480.0	1760.0	2.0	2.8	2.2	156	1.5	5999
82	Kundarasampalayam	11°35'7.08"N	77°53'20.58"E	3390	7.32	200	86	432	699.7	38.2	140.0	680.0	0.0	1.2	0.0	96	1.5	2373
83	Nachiyur	11°35'9.53"N	77°51'49.35"E	3850	7.26	232	102	504	883.5	48.3	140.0	768.0	0.0	0.4	0.0	86	1.8	2695
84	Ayyampalayam	11°35'13.10"N	77°55'30.11"E	2414	7.21	118	56	352	1089.2	59.5	110.0	110.0	2.0	1.8	1.5	60	1.2	1689
85	Tannidasanur	11°34'3.34"N	77°46'32.99"E	6200	7.41	356	146.4	775	729.0	39.8	413.7	1434.3	0.1	0.0	0.1	44	1	4340
86	marikovundankottai	11°34'17.88"N	77°48'54.73"E	1490	7.49	120	52.8	95	523.2	28.6	21.2	153.5	0.1	0.0	0.0	35	1.8	1043
87	Annamalayampalayam	11°34'5.16"N	77°51'47.82"E	1820	7.28	108	39	259	606.0	33.1	70.0	244.0	0.0	0.5	0.0	36	1.2	1274
88	Kavadikaranur	11°33'20.97"N	77°52'50.09"E	3530	7.21	218	104	412	609.7	33.3	200.0	760.0	1.0	0.5	1.0	72	2	2471
89	Madattur	11°33'31.59"N	77°54'32.19"E	1866	7.12	112	46	218	542.9	29.7	75.0	246.0	0.0	2.2	0.0	36	1.2	1306
90	Kurukuparaiyur	11°31'54.42"N	77°47'23.55"E	2100	7.3	140	60	224	549.6	30.0	38.9	361.6	0.1	0.0	0.0	6	1.4	1470

Electrical Conductivity- µS/cm² (EC), Total Dissolved Solids (mg/L)

Wilcox's (1955) diagram has been drawn using Na percentage in terms of equivalent per million (epm) of the common cations Na% Vs TDS in epm value was used for the Doneen's classification. They have also attempted at the classification of soils, based upon their permeability index which in turn is influenced by the sodium content of irrigation water. The GIBB'S diagram (1970) interpretation is carried out to assess the factors controlling groundwater chemistry quality criteria.

4.2 Result and Discussion

Characterization of groundwater in terms of geochemical types is an essential component of scientific management of groundwater resources in order to monitor the quality of groundwater in an aquifer, and also for identification of recharge areas (Schoeller, 1967). Moreover, geochemistry of groundwater is also related to the nature of host rock as well as the overlying rock types. An understanding of chemical quality of water is essential in determining its usefulness for drinking purposes (WHO, 1996). Presentation of geochemical data in the form of graphical charts such as Piper's diagram and Gibb's diagram etc. help in recognizing various hydrogeochemical types in a groundwater basin. The following discussion describes the hydro geochemistry of the groundwater in the study area with specific emphasis on the control exercised by lithology.

Proper management of this vital resource needs special attention through continuous monitoring and identification of the problem area as well as delineation of safe zone. GIS has been used extensively in analyses of results where groundwater quality is being monitored. In the present study, detailed investigation of water chemistry, from dug well and bore well was carried out for groundwater quality. Chemical analysis of groundwater samples Sarabanga sub basin ionic concentration in epm pre and post monsoon have been given in Tables 6.3 and 6.4.

Table.4.3 Chemical Analysis of Groundwater samples Sarabanga sub Basin Ionic concentration in epm Pre monsoon

SI. No	Location	Ca	Mg	Na	K	TSC	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TSA
1	Elathur	7.58	5.13	2.17	0.18	15.06	6.44	0	0.85	7.63	0.00	0.01	0.008	0.03	0.06	15.08
2	Muttanampatty	7.19	5.33	2.17	0.15	14.84	9.23	0	0.83	4.56	0.00	0.00	0.006	0.14	0.07	14.84
3	Periavadagampatti	5.99	4.34	2.17	0.43	12.93	6.54	0	0.79	5.3	0.00	0.00	0.006	0.17	0.08	12.94
4	Kukalpatti	5.69	4.06	5.62	0.58	15.95	9.05	1.01	1.29	4.61	0.00	0.01	0.000	0.48	0.06	16.49
5	Kupakalipatti	5.66	4.24	5.84	0.27	16.01	6.03	0.14	1.18	8.67	0.00	0.01	0.000	0.02	0.05	16.08
6	Amaram	6.64	5.31	6.11	0.97	19.03	8.49	0.94	1.78	7.82	0.00	0.00	0.000	0.68	0.05	19.75
7	Andiyur	2.65	2.5	4.96	0.44	10.55	5.24	0.58	1.09	3.64	0.00	0.00	0.000	0.42	0.06	10.99
8	Maniyakaranur	5.65	4.24	2.65	0.12	12.66	6.84	0	0.71	4.87	0.00	0.01	0.010	0.17	0.09	12.68
9	Rangappanur	5.89	4.08	2.67	0.22	12.86	7.07	0	0.54	4.91	0.00	0.01	0.010	0.21	0.08	12.86
10	Agraharum	10.14	7.16	0.53	0.4	18.23	13.59	0	0.79	3.45	0.00	0.00	0.010	0.02	0.10	18.05
11	Chinnayercaudu	7.96	5.63	2.48	0.17	16.24	7.67	0	1.4	6.88	0.00	0.00	0.010	0.16	0.13	16.25
12	Danishpet	6.63	4.86	2.67	0.41	14.57	6.58	0	1.44	6.17	0.00	0.00	0.010	0.21	0.09	14.57
13	Kolipatti	7.54	5.33	6.89	0.43	20.19	10.85	1.21	1.5	6.63	0.00	0.01	0.000	0.6	0.04	20.84
14	Karapatti	9.64	3.03	13.8	0.65	27.12	9.44	1.05	2.87	13.75	0.00	0.01	0.000	1.04	0.10	28.26
15	Malayanur	9.42	6.21	7.49	1.09	24.21	9.49	1.05	2.09	11.58	0.00	0.00	0.000	0.77	0.03	24.99
16	Bommiyampatti	6.94	5.44	6.74	0.35	19.47	9.97	1.11	1.19	7.2	0.00	0.00	0.000	0.64	0.04	20.13
17	Marakottai	6.59	4.54	2.17	0.26	13.56	7.02	0	0.85	5.41	0.00	0.00	0.010	0.21	0.09	13.56
18	Kanjanayakanpatti	7.58	5.33	1.09	0.33	14.33	5.56	0	1.71	6.89	0.00	0.07	0.010	0.07	0.08	14.40
19	Chinnanagalur	11.98	8.49	2.17	0.26	22.9	2.46	0	6.21	14.1	0.00	0.01	0.010	0.03	0.07	22.89
20	Tinnapatti	8.78	6.32	2.17	0.18	17.45	6.26	0	1.28	9.69	0.00	0.01	0.010	0.14	0.11	17.46
21	Kanjeri	11.18	7.7	2.17	0.23	21.28	3.73	0	1.17	16.24	0.00	0.00	0.010	0.07	0.08	21.28
22	Palakaranur	4.55	1.44	4.88	0.3	11.17	7.85	0.87	0.61	1.85	0.00	0.00	0.000	0.22	0.04	11.42
23	Kalikovundanur	12.17	9.27	19	0.94	41.38	13.21	1.47	3.35	23.35	0.03	0.02	0.000	1.65	0.12	43.19
24	Sangattur	15.56	10.57	20.9	1.28	48.31	12.45	1.38	3.47	31.01	0.00	0.02	0.000	1.41	0.10	49.84
25	Sattapadi	4.43	1.58	5.01	0.4	11.42	4.85	0.54	4	2.03	0.00	0.00	0.000	0.23	0.03	11.68
26	Semmandapatti	8.18	5.72	2.17	0.46	16.53	3.16	0	2.13	10.97	0.00	0.00	0.010	0.14	0.14	16.54
27	Dharapuram	13.77	10.07	2.17	0.31	26.32	5.02	0	6.23	14.95	0.00	0.00	0.010	0.03	0.08	26.31
28	Nangavalli	6.88	3.18	7.47	0.65	18.18	10.45	1.16	0.71	5.87	0.00	0.01	0.000	0.76	0.04	19.00
29	Olaipatti	10.13	3.3	7.49	0.75	21.67	13.6	1.51	1.11	5.46	0.00	0.01	0.000	0.85	0.04	22.58
30	Maramangalam	10.65	8.78	17.45	1.13	38.01	11.3	1.26	3.86	21.59	0.00	0.01	0.000	1.31	0.12	39.44
31	Palikkadai	7.19	5.33	0.43	0.26	13.21	4.55	0	3.77	9.03	0.00	0.00	0.010	0.14	0.10	17.68

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SI. No	Location	Ca	Mg	Na	K	TSC	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TSA
32	Balbakki	5.59	4.18	2.17	0.15	12.09	6.42	0	0.43	5.07	0.00	0.00	0.010	0.1	0.07	12.10
33	Mayilampalayam	8.58	6.12	2.17	0.36	17.23	4.36	0	2.21	10.54	0.00	0.01	0.010	0.07	0.08	17.24
34	Kuruvamnpatti	7.6	5.18	3.17	0.03	15.98	5.5	0	3.05	11.28	0.00	0.01	0.010	0.1	0.08	19.98
35	Sanarpatty	6.54	4.33	10.38	6.76	28.01	13.83	1.54	1.95	10.69	0.00	0.00	0.000	0.84	0.07	28.92
36	Periyasoragai	7.31	5.13	12.31	1.04	25.79	9.72	1.08	2.75	12.25	0.00	0.01	0.000	0.98	0.06	26.85
37	Siranganur	7.12	4.58	12.21	0.87	24.78	10.29	1.14	2.02	11.33	0.00	0.01	0.000	0.98	0.04	25.81
38	Amarakunthi	5.53	3.11	6.98	0.36	15.98	9.2	1.02	1.23	4.53	0.00	0.01	0.000	0.59	0.03	16.59
39	Periyapatti	9.26	6.41	2.52	0.39	18.58	4.11	0	1.31	12.89	0.00	0.01	0.010	0.16	0.12	18.58
40	Velakavundanur	7.94	5.54	1.27	0.33	15.08	6.19	0	3.65	9.67	0.00	0.01	0.010	0.16	0.10	19.84
41	Omalur	5.56	4.12	1.26	0.47	11.41	3.15	0	2.09	9.32	0.00	0.00	0.010	0	0.07	14.62
42	Vethalaikaranur	9.89	6.99	2.57	0.33	19.78	4.84	0	1.43	13.45	0.00	0.00	0.010	0	0.11	19.78
43	Karuppur	9.18	6.36	2.5	0.32	18.36	5.65	0	1.34	11.14	0.00	0.01	0.010	0.16	0.09	18.40
44	Pakkanadu	9.78	3.66	11.4	0.96	25.8	11.71	1.3	2.37	10.42	0.00	0.02	0.000	0.93	0.07	26.82
45	Jalakandapuram	9.34	3.37	8.95	0.51	22.17	12.39	1.38	2.07	6.34	0.00	0.01	0.000	0.73	0.04	22.96
46	Chinnakovundanur	9.9	4.33	11.98	0.8	27.01	12.86	1.43	2.21	10.5	0.00	0.01	0.000	0.87	0.04	27.92
47	Chickkampatti	10.38	7.5	1.09	0.33	19.3	6.25	0	1.79	11.02	0.00	0.01	0.010	0.17	0.11	19.30
48	Mottaiyanteruvur	4.79	3.55	0.43	0.15	8.92	4.5	0	1.07	7.15	0.00	0.00	0.010	0	0.12	12.77
49	Elayur	9.98	6.91	0.43	0.23	17.55	2.22	0	2.6	12.48	0.00	0.01	0.010	0.14	0.09	17.55
50	Pakalpatti	10.98	7.7	1.09	0.23	20	6.63	0	3.25	10	0.00	0.01	0.010	0	0.06	20.01
51	Nallakavundanpatty	3.27	2.29	2.17	0.1	7.83	5.43	0	0.32	2.05	0.00	0.00	0.010	0	0.05	7.84
52	Railway station	10.58	7.3	2.17	0.33	20.38	12.27	0	6.21	1.85	0.00	0.01	0.010	0	0.04	20.39
53	Puliyampati	6.11	3.75	10.02	0.77	20.65	10.94	1.22	1.25	7.24	0.00	0.01	0.000	0.6	0.05	21.31
54	Sivadanur	5.51	2.76	6.47	0.31	15.05	7.96	0.88	1.2	5.01	0.03	0.02	0.160	0.68	0.03	15.97
55	Nattakattanur	21.08	7.5	37.15	1.41	67.14	21.37	2.37	5.5	37.9	0.00	0.04	0.000	2.1	0.13	69.42
56	Tadikaranur	9.7	5.13	16.9	1.17	32.9	9.96	1.11	2.75	19.09	0.00	0.03	0.000	1.09	0.06	34.14
57	Kuttakatanur	12.93	9.08	19.41	1.1	42.52	12.75	1.42	4	24.37	0.00	0.01	0.000	1.61	0.08	44.29
58	Attikattanur	22.04	16.11	0.52	0.43	39.1	8.15	0	3.1	27.62	0.00	0.00	0.020	0.12	0.07	39.09
59	Kanganur	12.69	8.53	0.52	0.18	21.92	4.97	0	4.53	12.03	0.00	0.00	0.010	0.25	0.08	21.92
60	Maramangalathupatti	9.1	6.63	2.61	0.15	18.49	7.93	0	1.01	9.3	0.00	0.00	0.010	0.17	0.09	18.49
61	Sarkarhollapatti	14.37	10.18	2.61	0.37	27.53	8	0	7	12.48	0.00	0.00	0.010	0	0.12	27.53
62	Nattapatty	10.54	3.55	14.82	0.95	29.86	13.94	1.55	3	11.37	0.00	0.03	0.000	1.05	0.11	31.10
63	Reddipatty	51.02	15.39	46.75	2.82	115.98	54.32	6.04	12.99	42.64	0.06	0.12	0.230	0.23	0.13	116.82
64	Thirumalur	15.09	10.07	20.66	1.32	47.14	11.25	1.25	5	29.64	0.00	0.03	0.000	1.16	0.09	48.42

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Sl. No	Location	Ca	Mg	Na	K	TSC	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TSA
65	Samudram	8.14	5.13	22.12	1.1	36.49	14.42	1.6	2.75	17.73	0.06	0.11	0.230	1.28	0.12	38.33
66	Upparapatty	12.93	4.44	20.03	1.2	38.6	11.57	1.29	4.5	21.25	0.00	0.03	0.000	1.43	0.08	40.15
67	Chinnapampatti	3.35	2.76	6.68	0.37	13.16	6.59	0.73	1.37	4.47	0.00	0.00	0.000	0.53	0.04	13.73
68	Mattaiyampatti	15.81	7.11	35.79	1.78	60.49	17.95	1.99	4	36.55	0.00	0.04	0.000	2.1	0.09	62.77
69	Sittanur	15.81	5.13	12.42	1.17	34.53	18.8	2.09	2.12	11.51	0.05	0.01	0.000	0.86	0.06	35.50
70	Nallakampatti	6.71	6.51	30.57	1.6	45.39	2.55	0.28	5	37.56	0.00	0.05	0.000	2.21	0.14	47.80
71	Makkanur	23.71	14.41	24.94	1.6	64.66	18.65	2.07	4	39.93	0.03	0.06	0.160	2.36	0.09	67.44
72	Kottapalayam	8.26	7.5	20.14	1.29	37.19	11.97	1.33	3.25	20.64	0.00	0.03	0.000	1.61	0.07	38.83
73	Nachipalayam	7.07	5.53	16.7	0.98	30.28	21.42	2.38	2.75	3.72	0.06	0.08	0.230	1.13	0.09	31.97
74	Sadaiyampalayam	7.54	5.72	9.7	0.77	23.73	11.1	1.23	2.75	8.66	0.00	0.02	0.000	0.79	0.04	24.59
75	Pachaliyur	22.1	7.7	32.56	3.74	66.1	14.2	1.58	7	43.32	0.00	0.08	0.000	2.33	0.12	68.69
76	Konangiyur	20.48	3.75	7.93	0.58	32.74	22.42	2.49	1.87	5.96	0.00	0.00	0.000	0.75	0.05	33.54
77	Valaiyachettipatti	5.63	4.54	11.69	0.8	22.66	8.5	0.94	2.25	10.96	0.00	0.01	0.000	0.98	0.04	23.68
78	Nallanampatti	9.7	3.16	7.72	0.49	21.07	13.14	1.46	1.12	5.35	0.00	0.01	0.000	0.68	0.05	21.81
79	Muttampatty	6.83	3.85	6.57	0.34	17.59	9.83	1.09	1.25	5.41	0.00	0.00	0.000	0.6	0.09	18.36
80	Pattakkaranoor	11.14	7.7	35.69	2.46	56.99	12.51	1.39	4.5	38.58	0.06	0.09	0.160	1.8	0.11	59.25
81	Kalaravallipattypudur	50.06	14.01	44.45	2.58	111.1	35.6	3.96	11.99	59.56	0.06	0.12	0.340	2.93	0.11	114.78
82	Kundarasampalayam	11.98	8.49	19.62	1.72	41.81	13.76	1.53	3.5	23.01	0.00	0.05	0.000	1.8	0.09	43.81
83	Nachiyur	13.89	10.07	22.75	2.09	48.8	17.37	1.93	3.5	25.99	0.00	0.02	0.000	1.61	0.12	50.53
84	Ayyampalayam	7.07	5.53	16.7	0.98	30.28	21.42	2.38	2.75	3.72	0.06	0.08	0.230	1.13	0.07	31.97
85	Tannidasanur	21.32	14.45	37.04	1.99	74.8	14.34	1.59	10.34	48.54	0.00	0.00	0.010	0.83	0.06	75.71
86	marikovundankottai	7.19	5.21	4.49	0.28	17.17	10.29	1.14	0.53	5.2	0.00	0.00	0.010	0.66	0.10	17.94
87	Annamalayampalayam	6.47	3.85	12.1	0.83	23.25	11.92	1.32	1.75	8.26	0.00	0.02	0.000	0.67	0.08	24.02
88	Kavadikaranur	13.05	10.26	19.62	1.10	44.03	11.99	1.33	5	25.72	0.03	0.02	0.160	1.36	0.12	45.74
89	Madattur	6.71	4.54	10.02	0.80	22.07	10.68	1.19	1.87	8.32	0.00	0.09	0.000	0.67	0.08	22.90
90	Kurukuparaiyur	8.38	5.92	9.81	1.10	25.21	10.81	1.2	0.97	12.24	0.00	0.00	0.000	0.11	0.09	25.42

Total Solids Cations (TDS), Total Solids Anions (TSA)

Table.4.4. Chemical Analysis of Groundwater samples Sarabanga sub Basin Ionic concentration in epm Post monsoon

SI. No.	Location Name	Ca	Mg	Na	K	TSC	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TSA
1	Elathur	5.99	4.34	3.04	0.18	13.55	7.07	0.79	0.86	4.84	0.02	0.00	0.02	1.78	0.04	15.50
2	Muttanampatty	8.78	6.12	1.91	0.10	16.92	7.34	0.82	0.96	7.81	0.02	0.00	0.02	1.08	0.06	18.09
3	Periavadagampatti	7.58	5.53	4.70	0.31	18.11	9.09	1.01	1.32	6.69	0.02	0.00	0.01	0.23	0.06	18.48
4	Kukalpatti	5.99	4.28	5.91	0.61	16.79	9.53	1.06	1.35	4.85	0.00	0.01	0.00	0.50	0.04	17.34
5	Kupakalipatti	6.59	5.10	6.78	0.92	19.39	6.98	0.78	1.87	9.76	0.00	0.01	0.00	0.66	0.03	20.09
6	Amaram	6.99	5.59	6.43	1.02	20.04	8.93	0.99	1.87	8.23	0.00	0.00	0.00	0.72	0.04	20.80
7	Andiyur	2.79	2.63	5.22	0.46	11.10	5.51	0.61	1.15	3.84	0.00	0.00	0.00	0.44	0.02	11.56
8	Maniyakaranur	5.19	3.75	8.35	0.43	17.72	11.28	1.25	1.12	4.07	0.00	0.00	0.01	0.52	0.08	18.38
9	Rangappanur	6.99	4.93	9.91	1.23	23.06	9.97	1.11	1.13	10.85	0.00	0.00	0.01	1.47	0.06	24.66
10	Agraharum	2.24	1.74	5.39	0.28	9.65	6.75	0.75	0.83	1.31	0.00	0.00	0.01	0.36	0.08	10.10
11	Chinnayercaudu	9.58	6.91	36.09	1.02	53.60	9.43	1.05	4.09	39.03	0.00	0.00	0.01	0.17	0.12	53.90
12	Danishpet	4.99	3.36	4.87	0.26	13.47	7.08	0.79	0.87	4.73	0.00	0.00	0.01	0.27	0.07	13.82
13	Kolipatti	6.29	4.44	5.74	0.36	16.83	9.04	1.00	1.25	5.53	0.00	0.01	0.00	0.50	0.03	17.36
14	Karapatti	8.38	2.63	12.00	0.56	23.58	8.21	0.91	2.50	11.96	0.00	0.01	0.00	0.91	0.08	24.57
15	Malayanur	7.98	5.26	6.35	0.92	20.52	8.04	0.89	1.77	9.81	0.00	0.00	0.00	0.66	0.01	21.18
16	Bommiyampatti	6.09	4.77	5.91	0.31	17.08	8.75	0.97	1.04	6.32	0.00	0.00	0.00	0.56	0.02	17.66
17	Marakottai	4.39	2.96	5.04	0.23	12.63	7.88	0.88	0.77	3.10	0.00	0.00	0.00	0.19	0.07	12.89
18	Kanjanayakanpatti	6.39	4.34	6.87	0.41	18.01	9.32	1.04	0.87	6.78	0.00	0.00	0.00	0.00	0.06	18.08
19	Chinnanagalur	3.79	2.57	10.61	1.28	18.25	9.84	1.09	0.93	6.38	0.00	0.00	0.01	0.02	0.05	18.43
20	Tinnapatti	7.39	5.13	7.13	0.43	20.08	7.16	0.80	0.81	11.31	0.00	0.00	0.01	0.00	0.08	20.18
21	Kanjeri	13.37	9.47	6.96	0.38	30.19	8.08	0.90	1.27	19.94	0.00	0.00	0.00	0.45	0.06	30.71
22	Palakaranur	3.89	1.23	4.17	0.26	9.56	6.71	0.75	0.52	1.58	0.00	0.00	0.00	0.19	0.02	9.77
23	Kalikovundanur	10.58	8.06	16.52	0.82	35.98	11.48	1.28	2.91	20.30	0.03	0.02	0.00	1.44	0.09	37.56
24	Sangattur	13.07	8.88	17.57	1.07	40.59	10.46	1.16	2.91	26.06	0.00	0.01	0.00	1.19	0.08	41.88
25	Sattapadi	3.69	1.32	4.17	0.33	9.51	4.04	0.45	3.33	1.69	0.00	0.00	0.00	0.19	0.02	9.73
26	Semmandapatti	7.39	5.33	8.35	1.02	22.09	8.38	0.93	1.09	11.68	0.00	0.00	0.01	1.08	0.12	23.29
27	Dharapuram	7.39	5.33	8.35	1.02	22.09	8.38	0.93	1.09	11.68	0.00	0.00	0.01	1.08	0.04	23.29
28	Nangavalli	5.69	2.63	6.17	0.54	15.03	8.64	0.96	0.58	4.85	0.00	0.01	0.00	0.63	0.06	15.69
29	Olaipatti	8.58	2.80	6.35	0.64	18.37	11.52	1.28	0.94	4.62	0.00	0.01	0.00	0.72	0.03	19.12
30	Maramangalam	9.18	7.57	15.04	0.97	32.76	9.74	1.08	3.33	18.61	0.00	0.01	0.00	1.13	0.09	33.99

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SI.No.	Location Name	Ca	Mg	Na	K	TSC	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TSA
31	Palikkadai	5.79	4.14	14.26	0.82	25.01	9.65	1.07	1.36	12.93	0.00	0.00	0.00	0.73	0.08	25.94
32	Balbakki	4.31	3.08	4.00	0.26	11.65	8.05	0.89	0.42	2.28	0.00	0.00	0.01	1.38	0.05	13.08
33	Mayilampalayam	13.77	9.67	6.26	0.41	30.11	8.11	0.90	1.17	19.94	0.00	0.00	0.00	1.23	0.05	31.41
34	Kuruvamnpatti	6.59	4.74	8.35	0.61	20.29	6.81	0.76	0.81	11.91	0.00	0.00	0.01	1.13	0.05	21.48
35	Sanarpatty	5.59	3.70	8.87	5.78	23.94	11.82	1.31	1.67	9.14	0.00	0.00	0.00	0.72	0.06	24.72
36	Periyasoragai	6.09	4.28	10.26	0.87	21.49	8.10	0.90	2.29	10.21	0.00	0.01	0.00	0.81	0.05	22.37
37	Siranganur	5.89	3.78	10.09	0.72	20.47	8.50	0.94	1.67	9.36	0.00	0.01	0.00	0.81	0.03	21.33
38	Amarakunthi	4.69	2.63	5.91	0.31	13.54	7.80	0.87	1.04	3.84	0.00	0.01	0.00	0.50	0.01	14.06
39	Periyapatti	5.59	3.79	3.91	0.28	13.57	8.39	0.93	0.49	3.76	0.00	0.00	0.01	0.58	0.10	14.26
40	Velakavundanur	9.58	6.91	7.13	0.46	24.08	8.55	0.95	1.17	13.42	0.00	0.00	0.01	1.03	0.04	25.17
41	Omalur	10.98	8.49	2.43	0.15	22.05	8.04	0.89	1.22	11.91	0.00	0.00	0.00	0.19	0.05	22.30
42	Vethalaikaranur	4.59	3.36	4.96	0.31	13.21	7.48	0.83	0.43	4.47	0.00	0.00	0.01	0.34	0.09	13.66
43	Karuppur	7.78	5.53	5.48	0.33	19.12	10.29	1.14	0.66	7.04	0.00	0.00	0.01	0.17	0.06	19.37
44	Pakkanadu	8.58	3.21	10.00	0.84	22.63	10.27	1.14	2.08	9.14	0.00	0.02	0.00	0.81	0.06	23.53
45	Jalakandapuram	7.98	2.88	7.65	0.43	18.95	10.59	1.18	1.77	5.41	0.00	0.01	0.00	0.63	0.03	19.62
46	Chinnakovundanur	8.38	3.78	10.52	0.72	23.40	10.85	1.21	1.87	9.48	0.00	0.01	0.00	0.75	0.03	24.19
47	Chickkampatti	4.59	3.36	8.35	0.46	16.75	10.09	1.12	0.64	4.90	0.00	0.00	0.00	1.27	0.09	18.12
48	Mottaiyanteruvur	7.98	5.53	4.09	0.28	17.88	8.99	1.00	0.77	7.12	0.00	0.00	0.01	0.45	0.11	18.46
49	Elayur	7.58	5.33	6.35	0.33	19.59	10.82	1.20	0.88	6.69	0.00	0.00	0.00	0.56	0.06	20.22
50	Pakalpatti	11.58	7.89	16.17	0.82	36.46	8.79	0.98	2.48	24.21	0.00	0.01	0.00	1.22	0.04	37.80
51	Nallakavundanpatty	5.79	4.14	6.35	0.33	16.61	7.73	0.86	0.44	7.58	0.00	0.01	0.00	0.56	0.05	17.23
52	Tholasampatti(R.S)	6.39	4.54	6.09	0.36	17.37	7.49	0.83	0.67	8.37	0.00	0.00	0.01	0.41	0.07	17.86
53	Puliyampati	5.09	3.13	8.35	0.64	17.20	9.11	1.01	1.04	6.03	0.00	0.01	0.00	0.50	0.04	17.75
54	Sivadanur	4.59	2.30	5.39	0.26	12.54	6.63	0.74	1.00	4.17	0.03	0.01	0.13	0.56	0.02	13.29
55	Nattakattanur	17.56	6.25	30.96	1.18	55.95	17.80	1.98	4.58	31.58	0.00	0.03	0.00	1.75	0.11	57.85
56	Tadikaranur	8.08	4.28	14.09	0.97	27.42	8.30	0.92	2.29	15.91	0.00	0.03	0.00	0.91	0.04	28.45
57	Kuttakatanur	10.78	7.57	16.17	0.92	35.44	10.62	1.18	3.33	20.30	0.00	0.01	0.00	1.34	0.03	36.90
58	Attikattanur	9.18	6.32	2.78	0.18	18.46	7.46	0.83	0.68	9.49	0.00	0.00	0.01	0.25	0.04	18.76
59	Kanganur	24.75	16.97	23.91	1.53	67.17	8.08	0.90	8.63	49.57	0.00	0.01	0.01	0.09	0.05	67.33
60	Maramangalathupatti	8.18	5.53	5.04	0.28	19.03	10.74	1.19	0.60	6.49	0.00	0.00	0.00	1.14	0.07	20.26
61	Sarkarhollapatti	6.99	4.93	10.61	0.46	22.99	10.17	1.13	1.23	10.45	0.00	0.00	0.00	0.52	0.11	23.67
62	Nattapatty	8.78	2.96	12.35	0.79	24.88	11.62	1.29	2.50	9.48	0.00	0.02	0.00	0.88	0.09	25.91
63	Reddipatty	42.51	12.83	38.96	2.35	96.65	45.26	5.03	10.83	35.53	0.05	0.10	0.20	2.84	0.11	100.00

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SI.No.	Location Name	Ca	Mg	Na	K	TSC	HCO_3	CO_3	SO_4	Cl	PO_4	Fe	NH_3	NO_3	F	TSA
64	Thirumalur	12.57	8.39	17.22	1.10	39.28	9.37	1.04	4.16	24.70	0.00	0.03	0.00	0.97	0.07	40.35
65	Samudram	6.79	4.28	18.43	0.92	30.42	12.02	1.34	2.29	14.78	0.05	0.09	0.20	1.06	0.10	31.94
66	Upparapatty	10.78	3.70	16.70	1.00	32.17	9.64	1.07	3.75	17.71	0.00	0.02	0.00	1.19	0.06	33.44
67	Chinnapampatti	2.79	2.30	5.57	0.31	10.97	5.49	0.61	1.15	3.72	0.00	0.00	0.00	0.44	0.03	11.44
68	Mattaiyampatti	13.17	5.92	29.83	1.48	50.40	14.95	1.66	3.33	30.46	0.00	0.03	0.00	1.75	0.06	52.30
69	Sittanur	13.17	4.28	10.35	0.97	28.77	15.67	1.74	1.77	9.59	0.04	0.01	0.00	0.72	0.04	29.59
70	Nallakampatti	5.59	5.43	25.48	1.33	37.82	2.12	0.24	4.16	31.30	0.00	0.04	0.00	1.84	0.13	39.83
71	Makkanur	19.76	12.01	20.78	1.33	53.88	15.54	1.73	3.33	33.28	0.03	0.05	0.13	1.97	0.07	56.21
72	Kottapalayam	6.89	6.25	16.78	1.07	30.99	9.98	1.11	2.71	17.20	0.00	0.03	0.00	1.34	0.05	32.42
73	Nachipalayam	5.89	4.61	13.91	0.82	25.22	17.85	1.98	2.29	3.10	0.05	0.06	0.20	0.94	0.06	26.64
74	Sadaiyampalayam	6.29	4.77	8.09	0.64	19.78	9.25	1.03	2.29	7.22	0.00	0.02	0.00	0.66	0.03	20.49
75	Pachaliyur	18.41	6.41	27.13	3.12	55.08	11.84	1.32	5.83	36.10	0.00	0.06	0.00	1.94	0.09	57.23
76	Konangiyur	17.07	3.13	6.61	0.49	27.29	18.68	2.08	1.56	4.96	0.00	0.00	0.00	0.63	0.04	27.96
77	Valaiyachettipatti	4.69	3.78	9.74	0.66	18.88	7.08	0.79	1.87	9.14	0.00	0.01	0.00	0.81	0.03	19.73
78	Nallanampatti	8.08	2.63	6.43	0.41	17.56	10.95	1.22	0.94	4.46	0.00	0.01	0.00	0.56	0.04	18.17
79	Muttampatty	5.69	3.21	5.48	0.28	14.66	8.19	0.91	1.04	4.51	0.00	0.00	0.00	0.50	0.07	15.30
80	Pattakkaranoor	9.28	6.41	29.74	2.05	47.48	10.43	1.16	3.75	32.15	0.05	0.08	0.13	1.50	0.08	49.38
81	Kalaravallipattypudur	41.72	11.68	37.04	2.15	92.59	29.66	3.30	9.99	49.63	0.05	0.10	0.29	2.44	0.08	95.65
82	Kundarasampalayam	9.98	7.07	16.35	1.43	34.83	11.47	1.27	2.91	19.18	0.00	0.04	0.00	1.50	0.08	36.51
83	Nachiyur	11.58	8.39	18.96	1.74	40.66	14.48	1.61	2.91	21.66	0.00	0.01	0.00	1.34	0.09	42.11
84	Ayyampalayam	5.89	4.61	13.91	0.82	25.22	17.85	1.98	2.29	3.10	0.05	0.06	0.20	0.94	0.06	26.64
85	Tannidasanur	17.76	12.04	30.87	1.66	62.34	11.95	1.33	8.61	40.45	0.00	0.00	0.01	0.69	0.05	63.09
86	marikovundankottai	5.99	4.34	3.74	0.23	14.30	8.57	0.95	0.44	4.33	0.00	0.00	0.01	0.55	0.09	14.95
87	Annamalayampalayam	5.39	3.21	10.09	0.69	19.37	9.93	1.10	1.46	6.88	0.00	0.02	0.00	0.56	0.06	20.02
88	Kavadikaranur	10.88	8.55	16.35	0.92	36.70	9.99	1.11	4.16	21.43	0.03	0.02	0.13	1.13	0.11	38.10
89	Madattur	5.59	3.78	8.35	0.66	18.38	8.90	0.99	1.56	6.94	0.00	0.08	0.00	0.56	0.06	19.09
90	Kurukuparaiyur	6.99	4.93	8.17	0.92	21.01	9.01	1.00	0.81	10.20	0.00	0.00	0.00	0.09	0.07	21.19

Total Solids Cations (TDS), Total Solids Anions (TSA)

4.2.1 Hydrogen ion Concentration

pH of groundwater is important in determining the hydrological processes. Processes such as carbon absorption, ion exchange, and flocculation may be affected by pH. The pH of water indicates its quality and provides information regarding types of geochemical equilibrium or solubility calculations (Hem, 1985). A taste of the acidity of water is pH, which is a measure of the hydrogen-ion concentration. The pH scale ranged from 0 to 14. A pH of 7 indicates neutral water; greater than 7, the water is basic; less than 7, it is acidic. A one unit change in pH represents a 10 fold difference in hydrogen-ion concentration. For example, water with a pH of 6 has 10 times more hydrogen-ions than water with a pH of 7. Water that is basic can form scale; acidic water can corrode.

According to U.S. Environmental Protection Agency criteria, water for domestic use should have a pH between 5.5 and 9. pH of the groundwater during pre-monsoon ranged from 5.92 to 9.36 with an average value of 8.3 indicating the overall basic nature. During post-monsoon, the pH ranged from 6.86 to 7.90 with a mean of 7.33 indicating acidic to basic nature of the groundwater due to monsoonal effect. The pre and post monsoon pH results have been given in Table 4.5. Spatial distribution of Hydrogen Ion Concentration in groundwater samples have been shown in Fig.4.2.

Table 4.5 pH – Limiting values with respect to WHO standard

Sl. No.	Limiting Values	Potability Nature	Well Locations	
			Pre Monsoon Samples	Post Monsoon Post
1	< 6.5	Desirable	1	-
2	6.5 – 9.5	Allowable	3	5
3	> 9.5	Not Potable	86	85

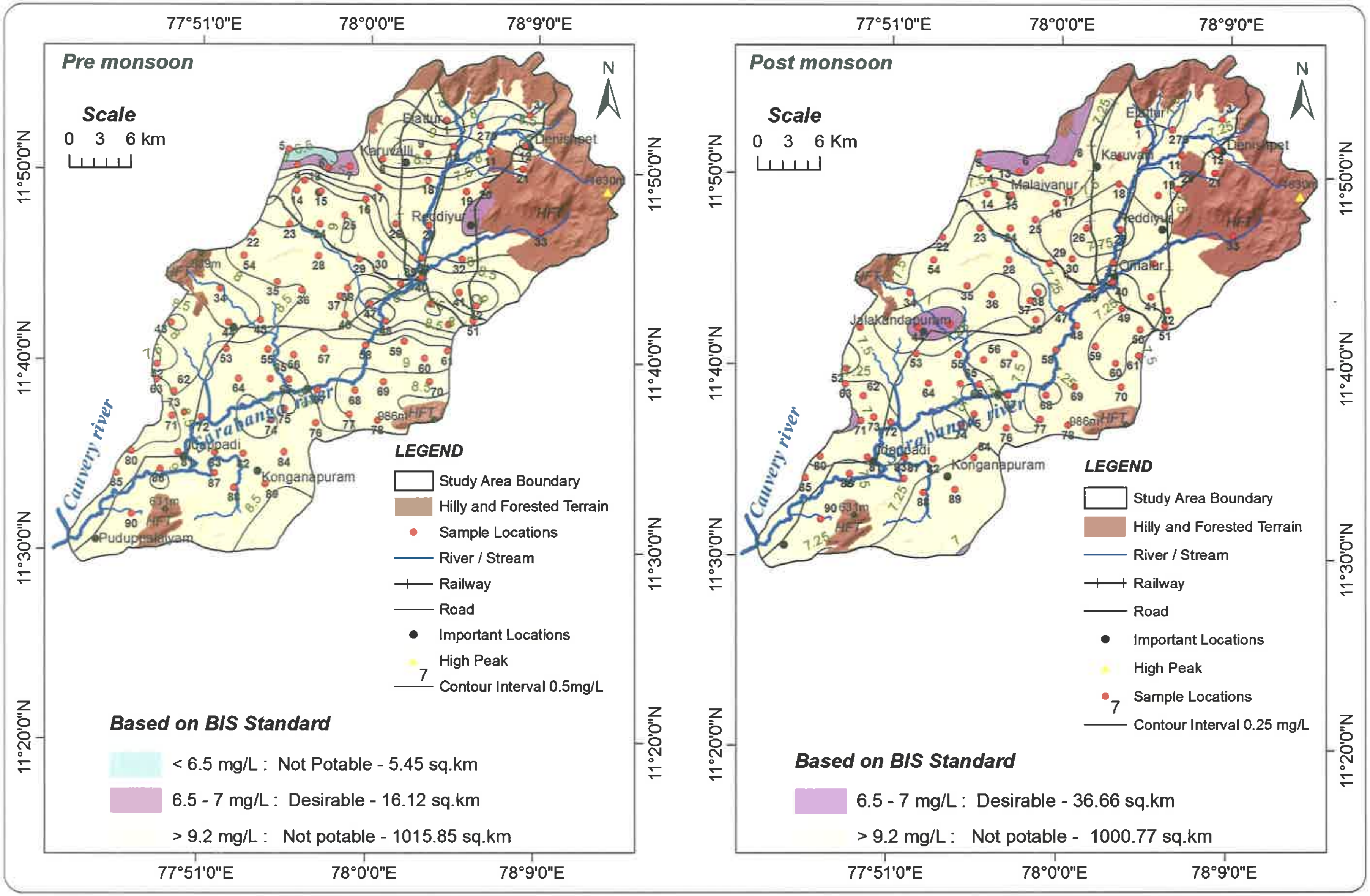


Fig.4.2.Spatial distribution of Hydrogen Ion Concentration in groundwater.

4.2.2 Electrical Conductivity

Electrical conductivity is an important indicator of water quality assessment. EC of water is an indirect measure of its dissolved constituents. EC is expressed in terms of the specific electrical conductivity, which is defined as the reciprocal of electrical resistance in Ohm (Ω), in relation to a water cube of edge length 1 cm at 25°C. In practice, EC is often expressed in terms of milli Siemens (mS) and micro Siemens (µ.S).

EC values of the groundwater samples ranged from 760 to 10644 µs/cm during pre monsoon period. In post monsoon season, it has been placed in between 903 to 8870 µs/cm. As per the WHO (1996) standard, EC values of groundwater samples were found to be high in 30 locations during pre-monsoon and 24 locations during post monsoons season that falls in the downstream region. The pre and post monsoon EC results have been given in Table 4.6. while spatial distribution of Electrical Conductivity of groundwater samples have been shown in Fig.4.3.

Table 4.6 EC - Limiting values with respect to WHO standard

Sl. No	Potability Nature	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Good (250 – 750)	-	-
2	Permissible (750 – 2000)	1,2,3,4,5,6,7,8,9,11,1213,16,17, 20,22,25,28,32,33,38,51,54,60,6 7,76,78,79,86	1,2,3,4,5,6,7,8,10,11,12,13,16,17 ,18,19,22,25,28,29,32,35,37,38,3 9,42,43,45,47,48,49,51,52,53,54, 58,60,67,76,78,79,86,87,89
3	Doubtful (2000 -3000)	14,15,18,19,21,26,29,34,35,36,3 7,39,40,41,42,43,44,45,46,48,50 ,52,53,69,73,74,77,84,87,89,90	9,14,15,20,26,27,31,34,36,40,41, 44,46,56,61,62,65,69,73,74,77,8 4,90
4	Un suitable (Above 3000)	10,23,24,27,30,47,55,56,57,58,5 9,61,62,63,64,65,66,68,70,71,72 ,75,80,81,82,83,85,88	11,21,23,24,30,33,50,55,57,59,6 3,64,66,68,70,71,72,75,80,81,82, 83,85,88

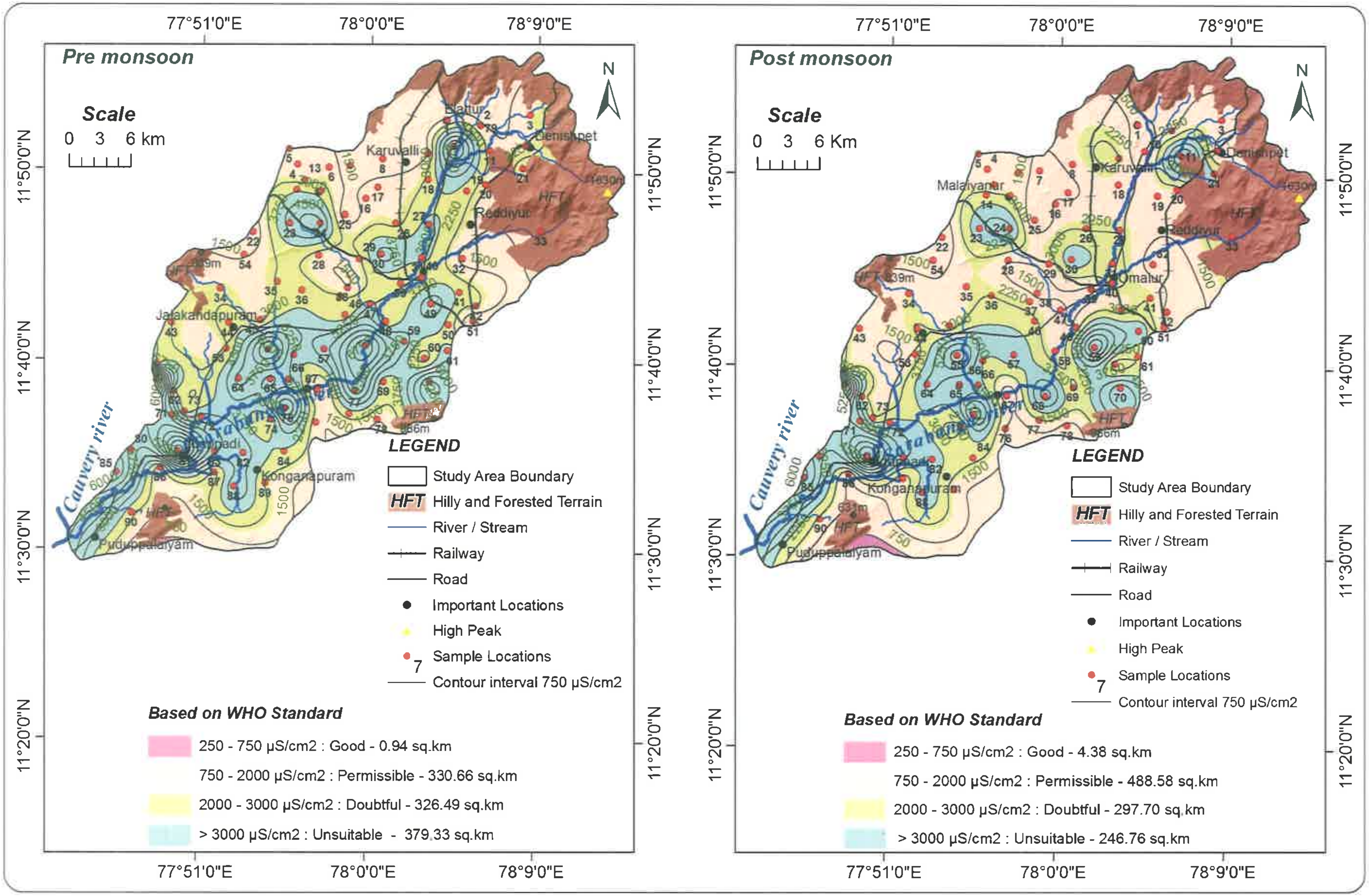


Fig.4.3.Spatial distribution of Electrical Conductivity in groundwater.

4.2.3 Total Dissolved Solids

Total dissolved solids refers to the total amount of all inorganic and organic substances - including minerals, salts, metals, cations or anions that are dispersed within a volume of water. The principal constituents are usually the cations - calcium, magnesium, sodium, potassium and iron - and the anions - carbonate, bicarbonate, chloride, sulphate, nitrate and fluoride in groundwater.

While TDS is not considered a primary pollutant, high TDS levels typically indicate hard water and may lead to scales and aesthetic problems such as bitter or salty taste. Water is not considered to be desirable for drinking when the quantity of dissolved minerals exceeds 1,000 mg/L (milligrams per liter). Water with a few thousand mg/L of dissolved minerals is classified as slightly saline, but it has been sometimes used in areas where less mineralized water is not available. Water from some wells and springs contains very large concentrations of dissolved minerals and cannot be tolerated by humans and other animals or plants.

Table 4.7 TDS - Limiting values with respect to WHO standard

Sl. No.	Potability Nature in mg/L	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Desirable (< 500)	-	-
2	Allowable (500 – 1500)	1,2,3,4,5,6,7,8,10,12,13,16, 17, 18,19,20,22,25,28,29,32,34,35, 37,38,39,42,43,45,47,48,49,51, 53,54,58,60, 67,74,76,78,79, 86,87,89,90.	1,2,3,4,5,6,7,8,9, 11,12, 13,20, 22, 25, 28,29, 32,33,34,38,45,51,54,60, 67, 76,78,79,86
3	Not Potable (> 1500)	9,11,14,15,21,23,24,26,27,30, 31,33,36,40,41,44,46,50,52,55, 57,59,61,62,63,64,65,66,68,69, 70,71,72,73,75,77,80,81,82,83, 84,85,88	10,14,15,18,19,21,23,24,27,3031,35, 36,37,39,40,41,42,43, 4,46,47,48,49, 50,52,53,55, 6,57,58,59,61,62,63,64, 65, 6,67,68,69,70,71,72,73,74, 75, 77,80,81,82,83,84,85,87, 88,89,90

The pre and post monsoon TDS results have been given in Table 4.7. and spatial distribution of Total Dissolved Solids of groundwater samples have been shown in Fig.4.4. During pre monsoon, 33 and 57 locations come under allowable and not allowable categories, whereas during post monsoon, 57 and 46 locations comes under allowable and not allowable categories.

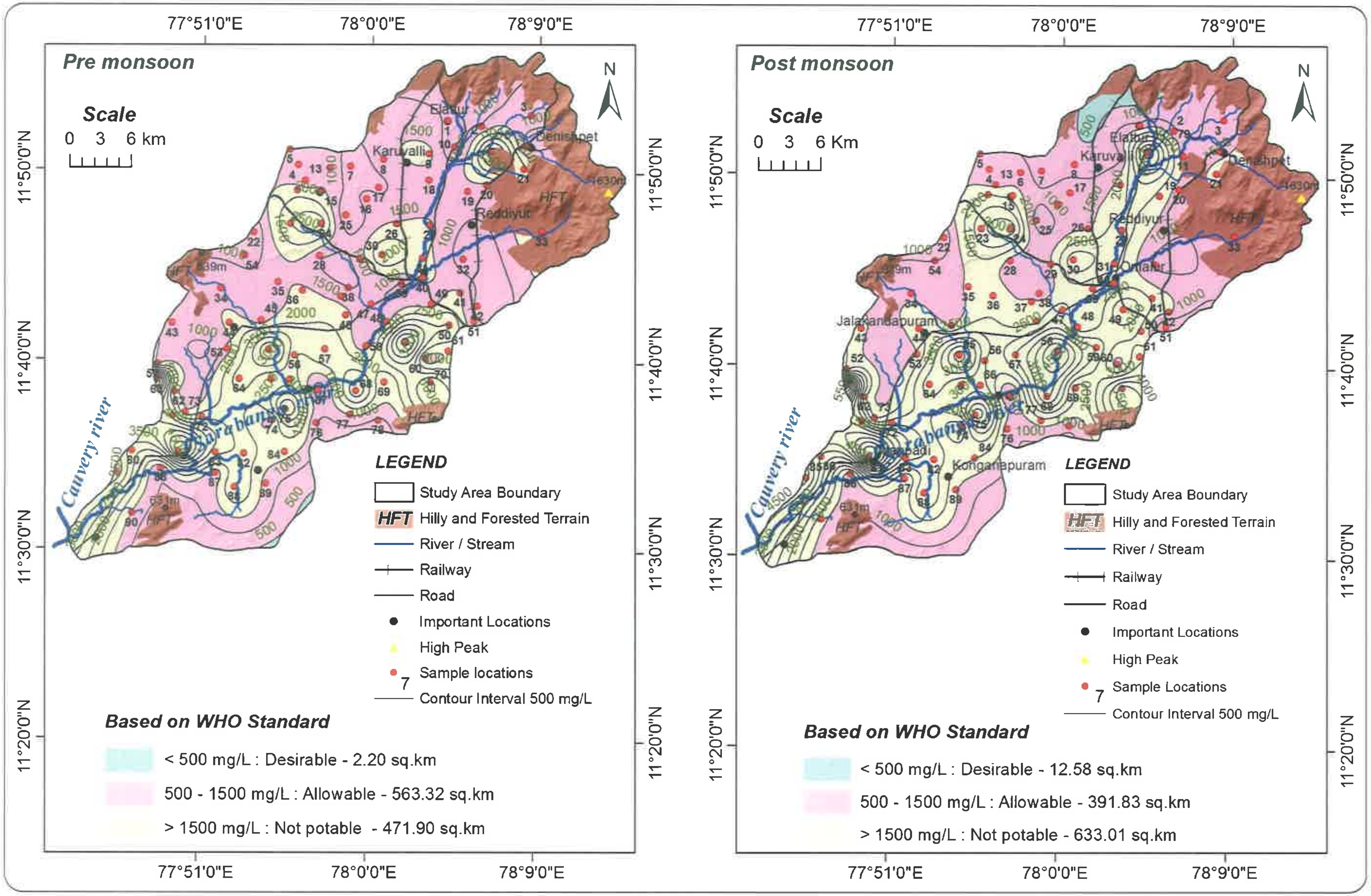


Fig.4.4.Spatial distribution of Total Dissolved Solids in groundwater.

4.2.4 Calcium

Calcium is the second dominating ion in the groundwater of the study area. During pre-monsoon calcium concentration in the groundwater of the study area ranged from 53.1 to 1022.4 mg/L, with an average value of 209.6 mg/L. During post-monsoon calcium concentration ranged from 44.8 to 852 mg/L. with a mean of 178.7 mg/L. In pre monsoon 84.2% samples fell within the desirable and allowable limit, 35.39% samples and post monsoon 80.27% samples fell within the desirable and allowable limit, 19.77% samples fell above the WHO limit. It is because of the rate of decomposition of feldspar group of minerals. The desirable limit of calcium in drinking water is 75 mg/l. If the presence of calcium is more in drinking water, it will cause formation of renal calculi (Kidney stones).

Table 4.8 Calcium limiting values with respect to WHO standard

Sl. No	Potability Nature in mg/L	Well Locations	Well Locations
		Pre Monsoon	Post Monsoon
1	Desirable Limit (< 75)	67,51,7	7,25,10,67
2	Allowable Limit (75 – 200)	1,2,3,4,5,6,11,12,13,14,15,16,17,18,20,22,25,26,28,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45, 46,48,49,53,54,56,60,65,70,72,73,74,84,86,87,89,90	1,2,3,4,5,6,11,12,13,14,15,16,17,18,20,22,26,32,33,34,35,36,37,38,39,40,42,43,44,45,46,48,49,51,52,53,54,60,61,62,65,70,72,73,74,77,78,79,80,84,86,87,89,90
3	Not Potable (>200)	10,19,21,23,24,27,29,30,47,50,52,55,57,58,59,61,62,63,64,66,68,69,71,75,76,80,81,82,83,85,88	21,23,24,33,41,50,55,57,59, 64, 68,69,71,75,76, 81,82,83,85,88

The pre and post monsoon calcium values have been given in Table 4.8. and spatial distribution of calcium in groundwater samples have been shown in Fig.4.5. During pre monsoon, 3, 56 and 31 locations comes under desirable, allowable and not potable categories respectively whereas, during post monsoon season, 4, 64 and 22 locations comes under desirable, allowable and not potable categories. This may be attributed to fluctuation in precipitation.

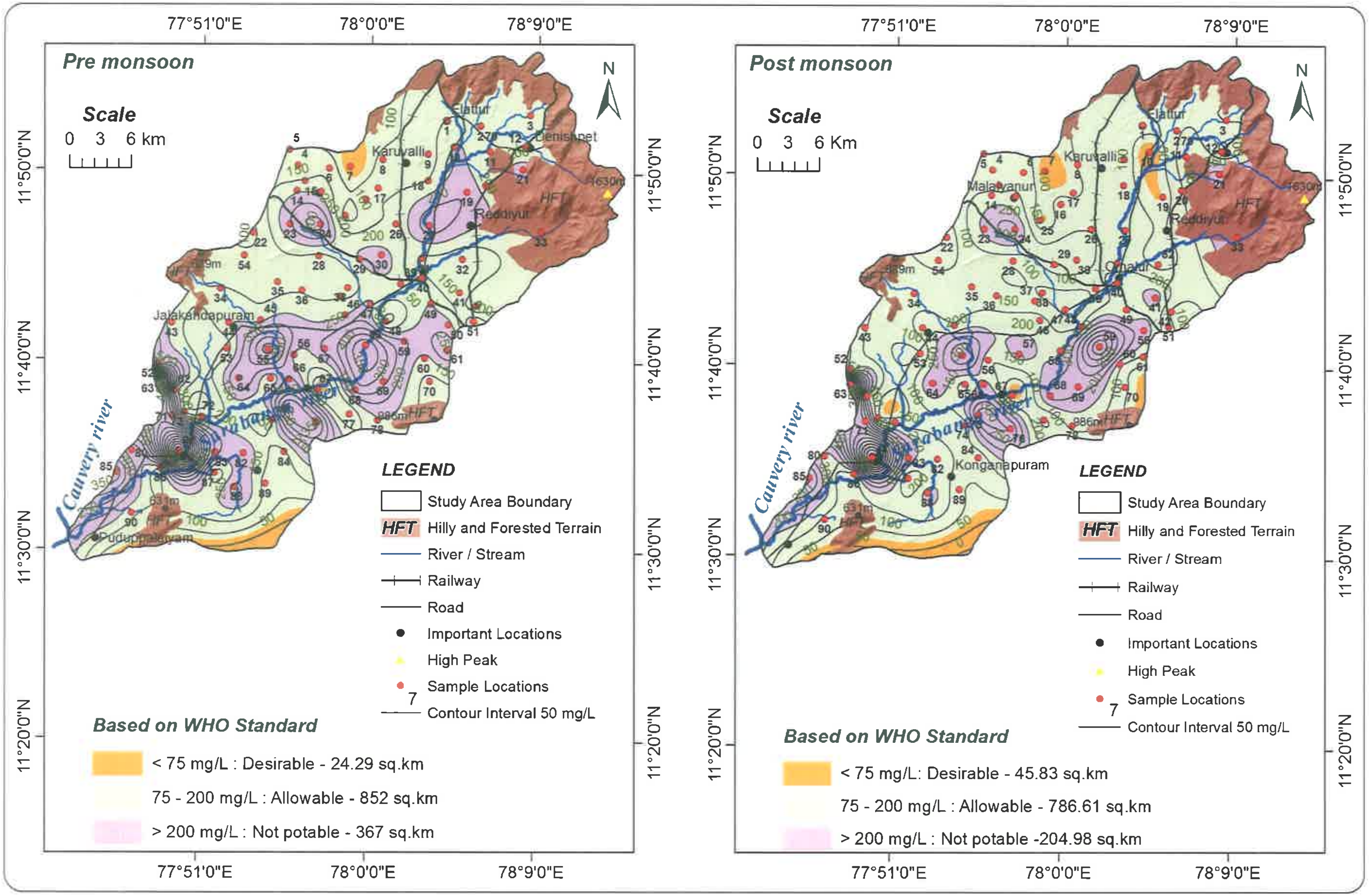


Fig.4.5.Spatial distribution of Calcium in groundwater.

4.2.5 Magnesium

The desirable limit of magnesium in drinking water is 150 mg/L (WHO, 1983). Magnesium is the third dominating ion in the groundwater; limiting values for magnesium are given in Table 4.9. During pre monsoon magnesium concentration in the groundwater ranged from 18 to 98 mg/L, with an average value of 74.4. During post monsoon, the Mg values ranged 15 to 206.4 mg/L, with a mean of 63.9 mg/L. Spatial distribution of Magnesium in groundwater samples have been shown in Fig.4.6.

Table 4.9 Magnesium limiting values with respect to WHO standard

Sl. No.	Limiting Values	Potability Nature in mg/L	Well Locations	Well Locations
			Pre Monsoon	Post Monsoon
1	< 50	Desirable Limit	4,7,9,14,22,25,28,29,38,44, 45,4851,53,54,62,67,76,78, 87	7,8,10,12,14,17,19,22,25,28,29, 32,35,37,38,39,42,44,45,46,47, 53,54,62,66,67,76,77,78,87,89
2	50-150	Allowable Limit	1,2,3,5,6,8,10,11,12,13,15, 16,17,18,19,20,21,23,24,26 ,27,30,31,32,33,34,35,36,3 7,39,40,41,42,43,46,47,49, 50,52,55,56,57,59,60,61,64 ,65,66,68,69,70,72,73,74,7 5,77,79,80,82,83,84,86,88, 89,90	1,2,3,4,5,6,9,11,13,15,16,18,20, 21,23,24,26,27,30,31,33,34,36, 40,41,43,46,48,49,50,51,52,55, 56,57,58,60,61,64,65,68,69,70, 71,72,73,74,75,79,80,81,82,83, 84,85,86,88,90
3	> 150	Not Potable	58,63,71,81,85	59,63

During pre monsoon, 65, 20 and 5 locations comes under desirable, allowable and not potable categories whereas during post monsoon season, 31, 57 and 2 locations comes under desirable, allowable and not potable categories.

4.2.6 Sodium

Sodium concentration is good if it is less than 250 mg/L (WHO, 1996) concentration. Sodium is found to be the most abundant ion in the groundwater. During pre monsoon season sodium concentration in the groundwater ranged from 9.89 to 1075 mg/L, with an average value of 242 mg/L.

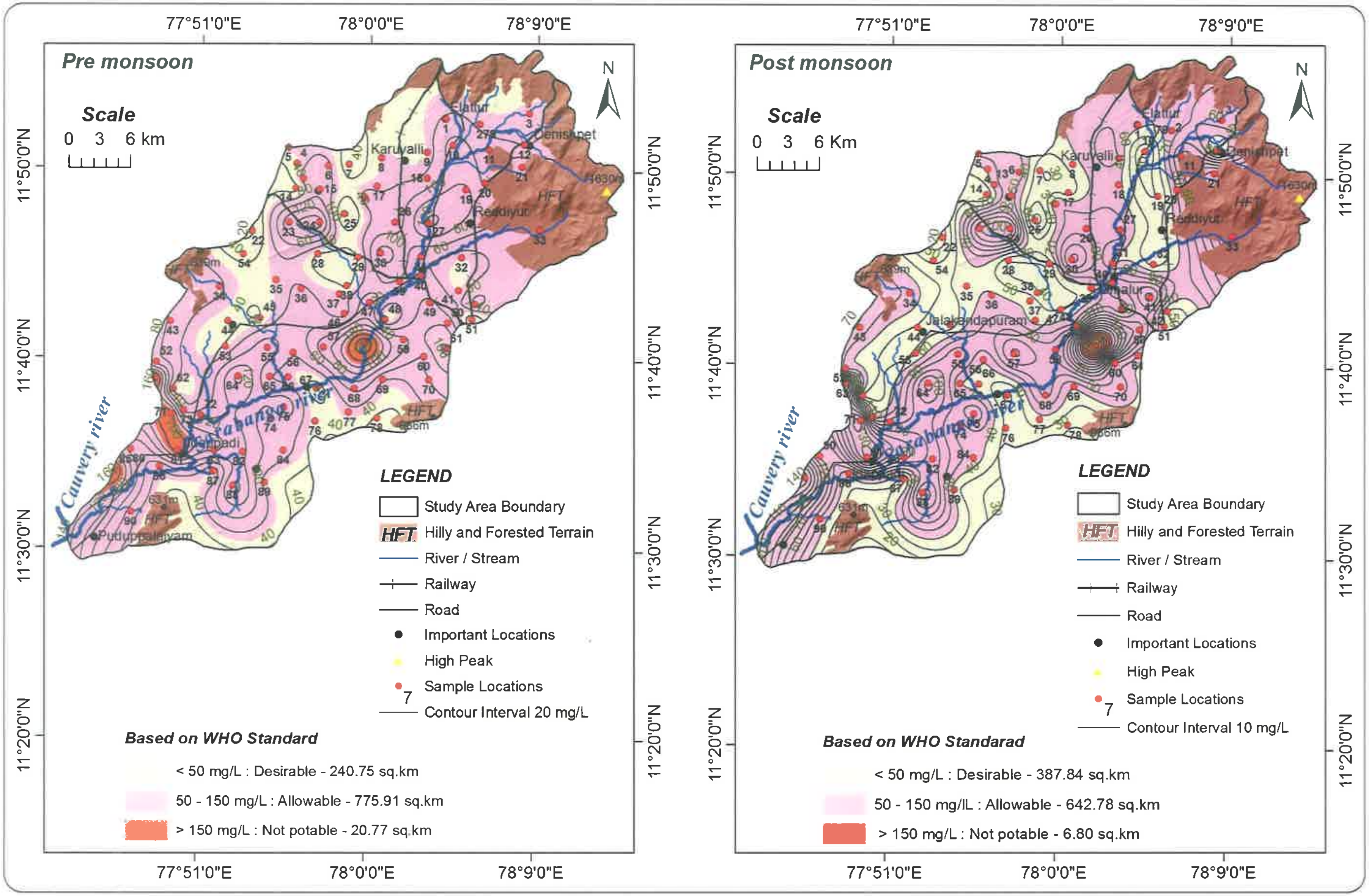


Fig.4.6.Spatial distribution of Magnesium in groundwater .

During post monsoon season sodium concentration ranged from 1.9 to 38.9 mg/L, with a mean of 11.3 mg/L. given in Table 6.10. Spatial distribution of Sodium in groundwater samples have been shown in Fig.4.7.

Table 4.10 Sodium – Water sample Locations and its Limiting Zone

Sl. No.	Potability Nature in mg/L	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Potable (< 50)	14,23,24.30,35,36,37,44,45,46, 53,55,56,57,62,63,64,65,66,67, 68,70,71,72,73,74,75,77,80,81, 82,83,84,85,87,88,89,90	-
2	Not Potable (50 – 200)	2,4,5,6,7,8,9,11,12,13,15,16,17, 22,25,26,28,29,34,38,39,42,43, 52,54,60,61,67,76,78,79	1,2,3,4,5,6,7,8,9,10,12,13, 5,16,17,18, ,20,21,22, 25,26 27,28,29, 32, 33,34, 38,39,40, 41,42,43,45, 7,48,49,51,52, 53,54,58,60,67,74,76,78,79, 86,89,90
3	(>200)	14,23,24,30,35,36,37,44,45,46, 53,55,56,62,63,64,65,66,68,69, 70,71,72,73,74,75,77,80,81,82, 83,84,85,87,88,89,90	9,11,14,19,23,24,30,31,35,36,37,44, 46,50,55,56,57,59,61,62,63,64,65, 66,68,69,70,71,72,73,75,77,80,81, 82,83,84,85,87,88

During pre monsoon, 20, 32 and 38 locations comes under desirable, allowable and not potable categories for Sodium concentration in groundwater samples, whereas during post monsoon season, 50 and 40 locations comes under allowable and not potable categories.

4.2.7 Potassium

Among the cations, potassium occupies the last position in the order of abundance in the groundwater; Potassium concentration is good if it is less than 10 mg/L for drinking water (WHO, 1996). Potassium concentration ranged from 1.17 to 264.3 mg/L and 0.10 to 5.78 mg/L in pre and post monsoon season respectively. Potassium content in water more than 10 of mg/L is indicative of pollution given in Table 4.11. The maximum admissible level of potassium in drinking water is less than 10 mg/L. Spatial distribution of Potassium in groundwater samples have been shown in Fig.4.8.

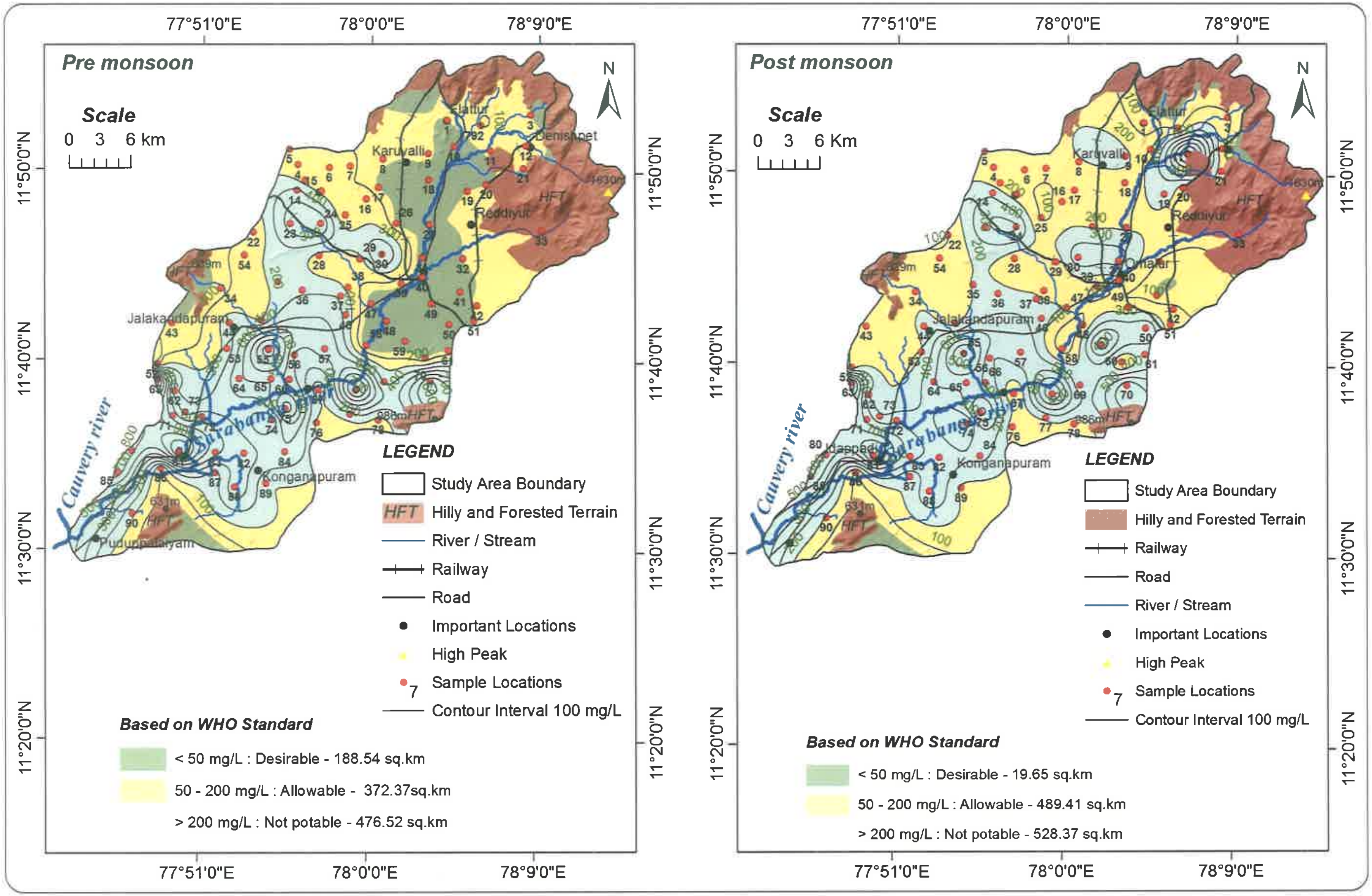


Fig.4.7.Spatial distribution of Sodium in groundwater.

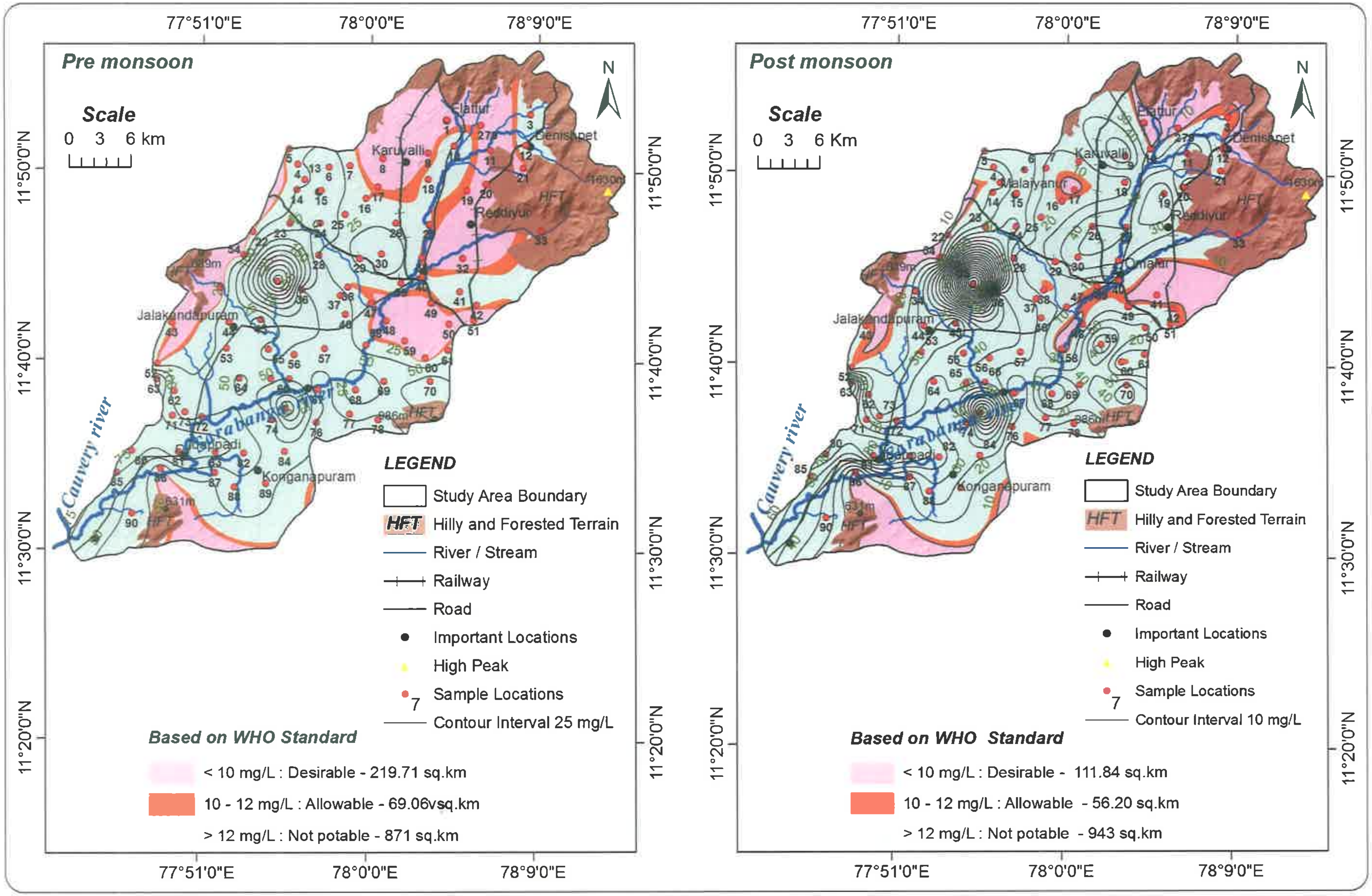


Fig.4.8.Spatial distribution of Potassium in groundwater.

Table 4.11 Potassium – Water sample Locations and its Limiting Zone

Sl. No.	Potability Nature in mg/L	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Desirable (<10)	1,2,8,9,11,20,21,32,34,48,49,50,51 59,60,74	1,2,17,41,54,58,79,86
2	Allowable (10 -12)	6,5,17,19,22,31,8	3,10,12,16,22,32,38,39,48,60,67
3	Not Potable (>12)	3,4,6,7,10,12,13,14,15,16,18,23, 24,25,26,27,28,29,30,33,35,36, 37,38,39,40,41,42,43,44,45,46,47, 48,52,53,54,55,56,57,58,61,62,63, 64,65,66,67,68,69,70,71,72,73,74, 75,76,77,78,80,81,82,83,84,85,87, 88,89,90,	4,5,6,7,8,9,11,13,14,15,18,19, 20,21,24,25,26,27,28,29,30,31, 32,33,34,35,36,37,40,42,43,44, 45,46,47,49,50,51,52,53,55,56, 57,59,61,62,63,64,65,68,69,70, 71,72,73,74,75,78,80,81,82, 83,84,85,87,88,89,90

In the groundwater samples of 20, 32 and 38 locations, the concentration of Potassium during pre monsoon comes under desirable, allowable and not potable categories while during post monsoon season, 50 and 40 locations comes under allowable and not potable categories.

4.2.8 Bicarbonate

The hardness of groundwater is determined by the quantity of dissolved cations present in the nature. These are usually calcium and magnesium. The anions associated with these cations to determine whether the hardness is permanent or temporary. If it is caused by bicarbonate the hardness is temporary and can be removed.

The bicarbonate concentration of the groundwater samples in pre monsoon ranged from 135.4 to 3314.6 mg/L, with an average value of 642 mg/L, during post monsoon season, it ranged from 129.5 to 2762 mg/L, with a mean of 622.8. Bicarbonate water sample locations and its limiting zone given in Table 4.12. The highest value was recorded near the downstream and the lowest value was observed in upper reaches of the catchments in the sub basin. Spatial distribution of bicarbonate in groundwater samples have been shown in Fig.4.9.

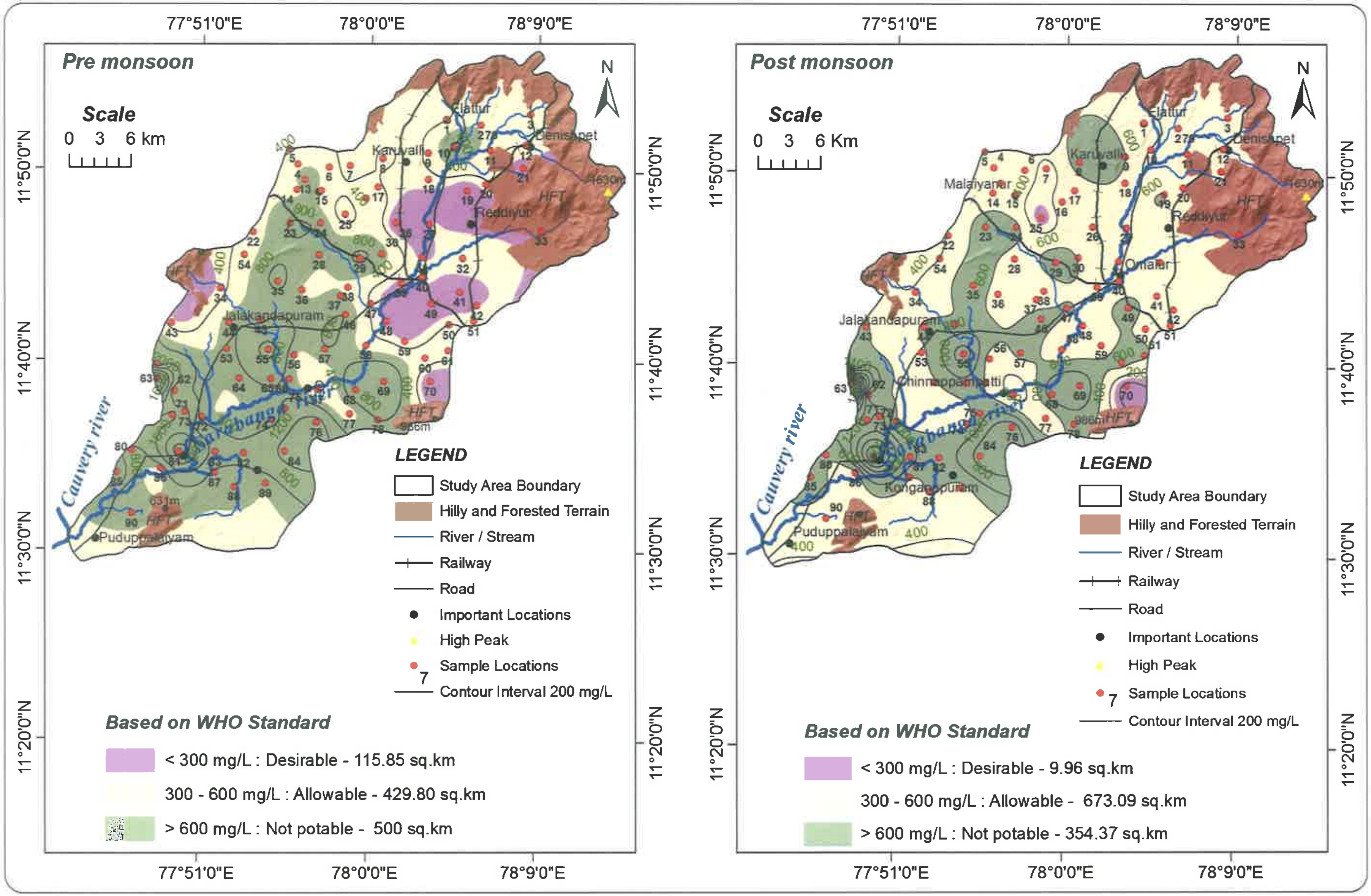


Fig.4.9.Spatial distribution of Bicarbonate in groundwater.

Table 4.12 bicarbonate – Water sample Locations and its Limiting Zone

Sl. No	Potability Nature in mg/L	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Desirable (< 200)	2,3,4,7,8,9,10,17,22,25,29,32,38,51, 52, 54, 67, 73,78,79,84.	1,4,7,8,10,12,13,17,22,25,28,29,32,38,39,42,45,47,54,67,73,76,78.
2	Allowable (200 – 600)	1,5,6,11,12,13,14,15,16,18,19,20,21, 26, 27,28, 31,33,34,35,36,37,39,40,41, 42,43,44,45,46,47,48,49,50,53,59,60, 61,62,69,74,76,77,86,87,89,90	2,3,5,6,9,14,15,16,18,19,20,26,27, 31,34,35,36,37,40,41,42,43,44,46, 48,49,51,52,53,56,58,60,61,62,65, 69,74,77,79,87,89,90.
3	Not Potable (>600)	23,24,30,55,56,57,58,63,64,65,66,68, 70,71,72,75,80,81,82,83,85, 88.	11,21,23,30,33,50,55,57,59,63,64, 66,68,70,71,72,75,80,81,82,83,85, 86,87,88.

In the groundwater samples of 12, 35 and 43 locations, the concentration of Bicarbonate during pre monsoon comes under desirable, allowable and not potable categories while during post monsoon season, 2, 52 and 36 locations comes under desirable, allowable and not potable categories.

4.2.9 Chloride

Chloride concentration ranged from 65.6 to 2112 mg/L and 46.5 to 1760 mg/L during pre and post monsoon seasons respectively. The high chloride concentration was noticed in only a few locations for both seasons.

It is due to replacement of hydroxide to chloride in the gneissic rocks (Kuroda and Sandell, 1953). Based on the WHO standard, only four samples fell under not acceptable and allowable zone have been given in Table 4.13. Chlorides in drinking water are generally not harmful to human beings. High concentrations may affect some persons who already suffer from diseases of heart or kidneys. Chlorides are not directly involved in corrosion, but they accelerate the rate of corrosion of steel and aluminum. In the investigation area, high concentration may be due to sewage contamination. Spatial distribution of Chlorides in groundwater samples have been shown in Fig.4.10.

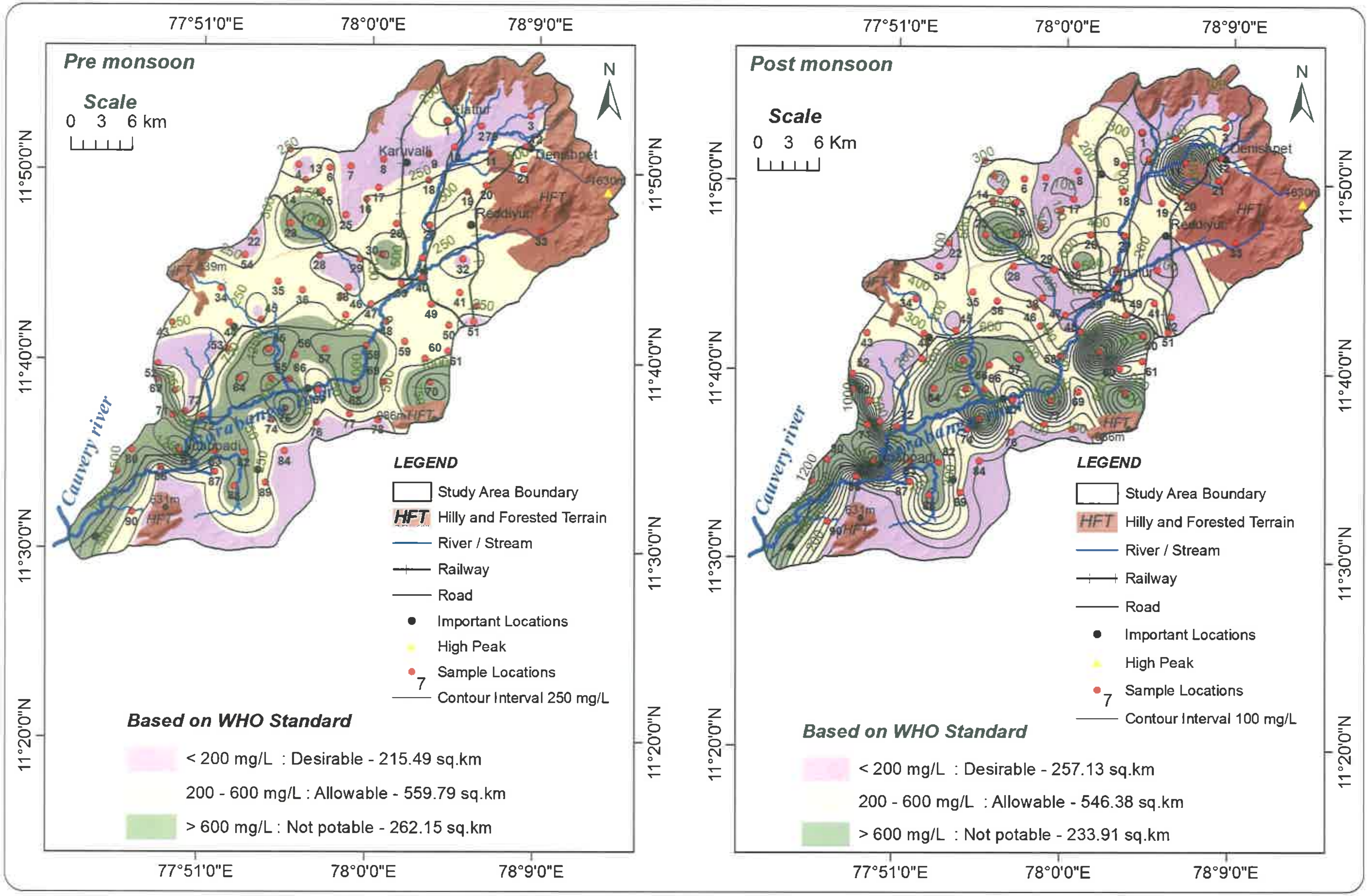


Fig.4.10.Spatial distribution of Chloride in groundwater.

Table 4.13 Chloride limiting values with respect to WHO standard

Sl. No.	Potability Nature in mg/L	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Desirable (<300)	19,21,25,26,31,33,39,42,45,46, 47,48, 49,70	25,70
2	Allowable (300 – 600)	1,2,3,4,5,6,7,8,9,11,12,14,15,17,18,20 ,22,27,32,34,36,38,40,43,47,50,51,54, 58,59,60,61,67,77,79	1,2,3,4,5,6,7,10,11,12,13,14,15,1 6,17,18,20,21,22,26,27,28,30,31, 32,33,34,36,37,38,39,40,41,42,4 8,50,51,52,53,54,56,58,59,64,66, 67,74,77,79,86,89,90
3	Not Potable (>600)	10,13,16,23,24,28,29,30,35,37,44,45, 46,52,53,55,56,57,62,63,64,65, 66,68, 69,71,72,73,74,75,76,78,80,81,82,83, 84,85,86,87,88,89,90	8,9,19,23,24,29,35,43,44,45,46,4 7,49,55,57,60,61,62,63,65,68,69, 71,72,73,75,76,78,80,81,82,83,8 4,85,87,88

During pre monsoon, 21, 47 and 22 locations comes under desirable, allowable and not potable categories for Chloride concentration in groundwater samples whereas during post monsoon season, 25, 41 and 24 locations comes under desirable, allowable and not potable categories.

4.2.10 Sulphate

Sulphur readily undergoes oxidation reduction reactions and transformations in the near surface environment. When exposed to weathering processes, it tends to be oxidized (ultimately to sulphate, SO_4) and is commonly either lost to the atmosphere as gaseous compounds or leached by groundwater in the near surface zone. Much of the sulphur removed by leaching may be used and transformed by biological organisms but ultimately is either removed in solution, lost to the atmosphere or re precipitated as sulfate or sulfide minerals elsewhere. These processes of transformation from one state to the other transport in solution, biogenic assimilation, and re precipitation all form part of an ongoing sulphur cycle in near surface environment (Granat et al., 1976).

In general, sulphide minerals in rocks undergo near surface chemical and or biological oxidation during uplift and erosion. Sulphur is readily leached and transported during this process. Thus, significant sulphur mobility will occur when sulphur bearing rocks are present in a region undergoing uplift.

Sulphate ion when combined with calcium or magnesium in water induces permanent hardness to the water. The sulphate concentration in the groundwater during pre monsoon season ranged from 15.3 to 623.9 mg/L, with an average value of 133.5 mg/L. During post monsoon season, sulphate concentration ranged from 20.4 to 520 mg/L, with a mean of 101 mg/L have been given in Table 4.14. Spatial distribution of Sulphate in groundwater samples have been shown in Fig.4.11.

Table 4.14 Sulphate - Water sample Locations and its Limiting Zone

Sl. No.	Potability Nature in mg/L	Well Locations Pre Monsoon	Well Locations Post Monsoon
1	Desirable (< 200)	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,20,21,22,23,24,25,26, 28,29,30,31,32,33,34,35,36,37,38, 39,40,41,42,43,44,45,46,47,48,49, 50,51,53,54,56,57,58,60,62,65,67, 68,69,71,72,73,74,76,77,78,79,82, 83,84,86,87,89,90,	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31,32,33,34, 35,36,37,38,39,40,41,42,43,44, 45,46,47,48,49,50,51,52,53,54, 56,57,58,60,61,62,65,66,67,68, 69,70,71,72,73,74,76,77,78,79, 80,82,83,84,86,87,88,89,90
2	Allowable (200 - 400)	19,27,52,55,59,61,64,66,70,75,80, 81,85,88	55,59,63,64,75,81,85
3	Not potable (>400)	63	-

In the groundwater samples of 75, 19 and 1 locations, the concentration of Sulphate during pre monsoon comes under desirable, allowable and not potable categories while during post monsoon season, 83 and 3 locations comes under desirable and allowable categories.

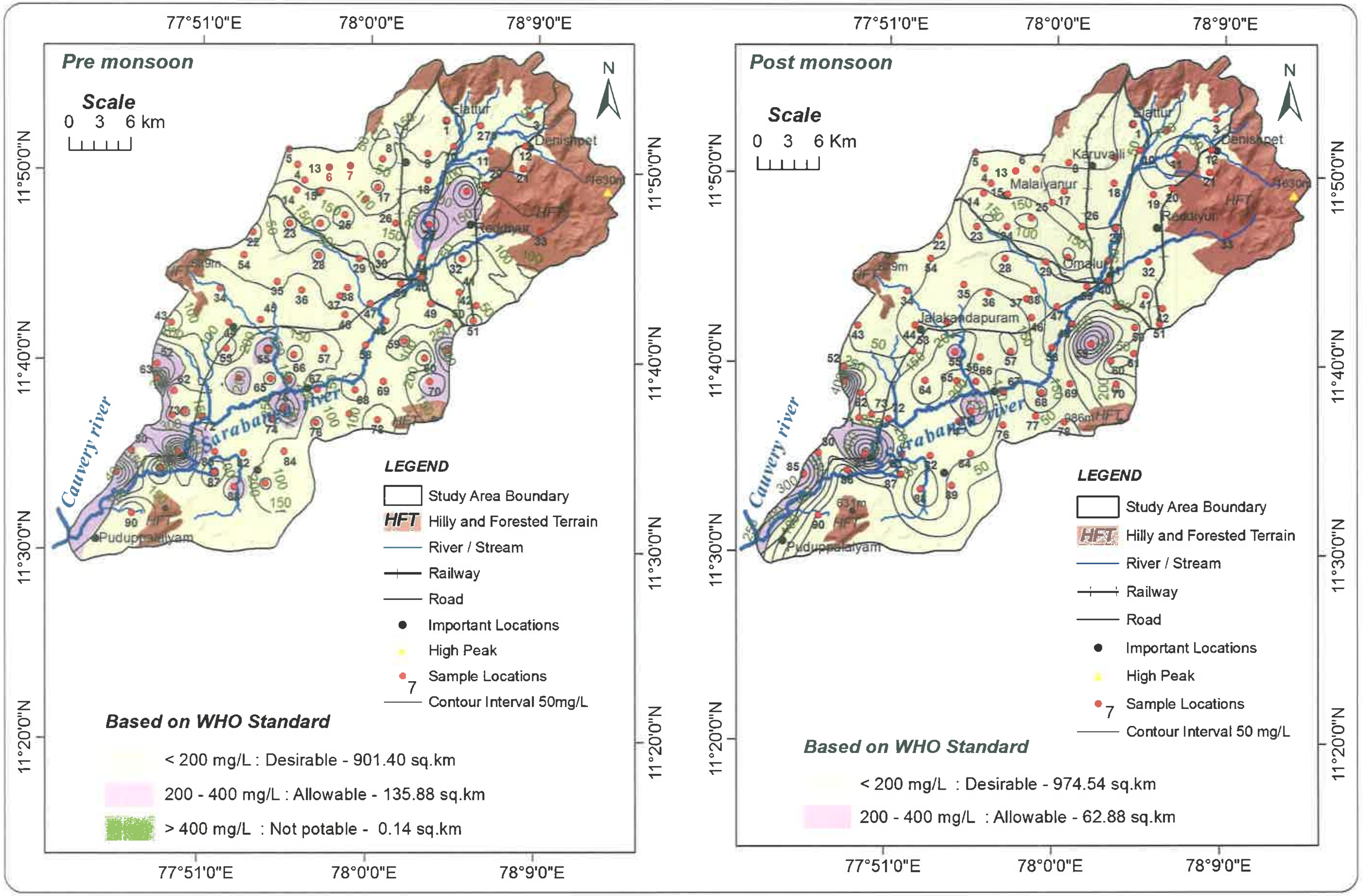


Fig.4.11.Spatial distribution of Sulphate in groundwater.

4.2.11 Nitrate

The desirable limit of nitrate in drinking water is 45 mg/L (WHO, 1983). The limiting values for nitrate are given in Table 4.15. During pre monsoon, nitrate concentration in the groundwater of the study area ranged from 0 to 187.5 mg/L, with an average value of 44.3 mg/L. During post monsoon, the dug well NO_3 values ranged from 0 to 182 mg/L, with a mean of 53.2 mg/L.

Nitrate is also an indicator of pollution. Due to application of large amount of fertilizers, the nitrate content in groundwater is increasing all over the world. However high nitrates have been recorded in some places where there is no agricultural activity. This may be due to nature of soil. The removal of nitrate from water is not an easy process .Spatial distribution of Nitrate in groundwater samples have been shown in Fig.4.12.

Table 4.15 Nitrate – Water sample Locations and its Limiting Zone

Sl. No.	Potability Nature in mg/L	Well Locations	Well Locations
		Pre Monsoon	Post Monsoon
1	Desirable (< 50)	1,2,3,4,5 ,6 ,7, 8,9,10,11,12,13, 16,17,18,19,20,21,22,25,26,27, 31,32,33,34,38,39,40,41,42,43, 47,48,49,50,51,52,53,54,58,59, 60,61,63,67, 78,79, 89, 90	3,4,5,6,7,8,10,11,12,13,15,16,17,18, 19,20,21,22,25,28,29, 31,35,38,39, 41,42,43,45, 46,48,49,51,52,53,54, 58,59,61,67,69,74,76,78,85,86,87, 89,90
2	Not Potable (> 50)	14,15,23,24,28,29,30,35,36,37, 44,45,46,55,56,57,62,64,65,66, 68,69,70,71,72,73,74,75,76,77, 80,81,82,83,84,85,86,88	1, 2, 9, 14, 23, 24, 26, 27, 30, 32,33, 34, 36, 37, 40, 44,47, 50, 55,56, 57, 60,62, 63, 64,65,66, 68,70, 71, 72, 73, 75 , 79, 80, 81, 82, 83, 84, 88

During pre monsoon, 50 and 40 locations comes under desirable, and not potable categories for Nitrate concentration in groundwater samples whereas in post monsoon season, 49 and 41 locations comes under desirable and not potable categories.

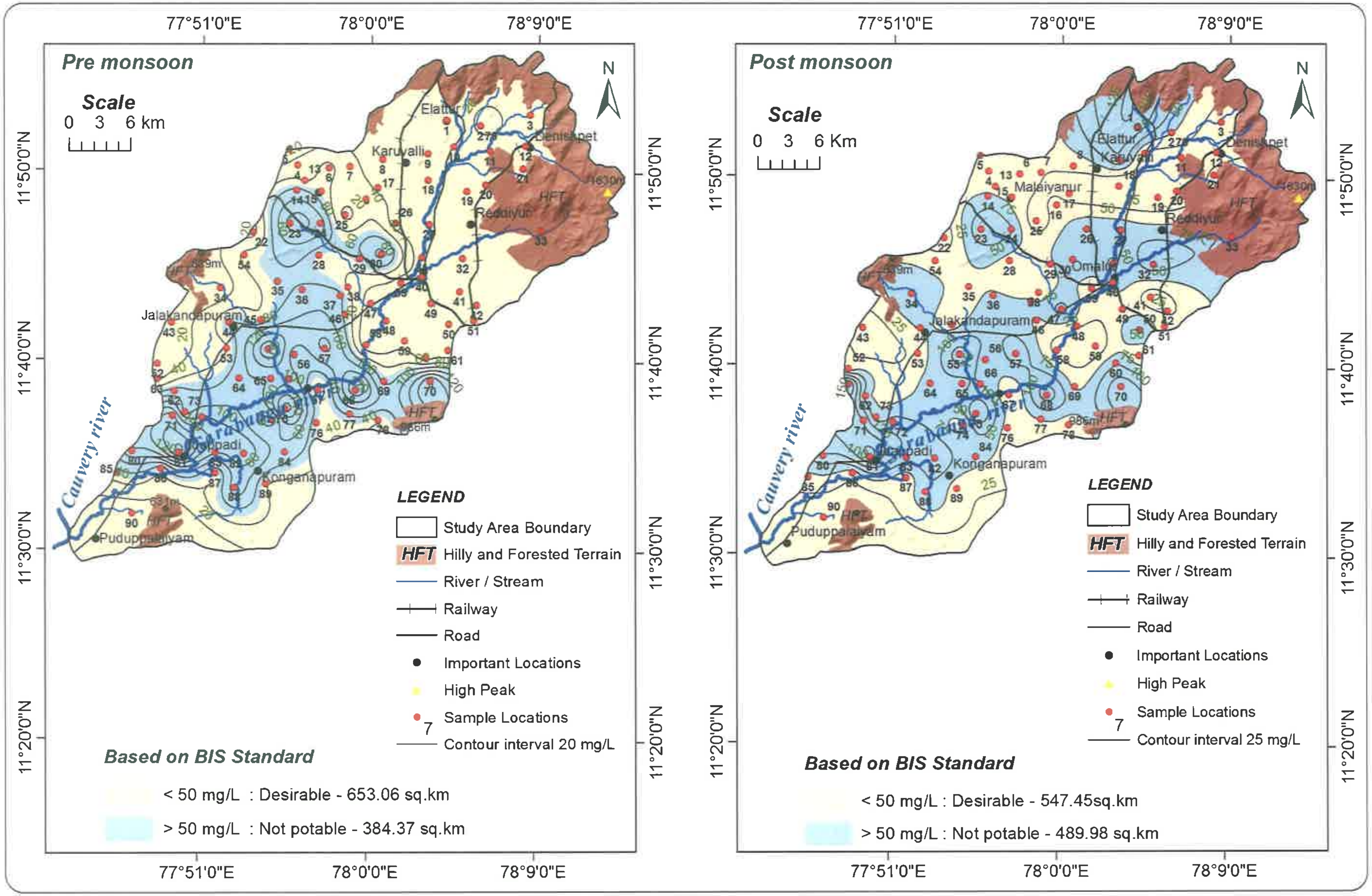


Fig.4.12.Spatial distribution of Nitrate in groundwater.

4.2.12 Fluoride

The maximum level of fluoride, which the human body may tolerate is 1.5 mg/L. This is based on the fluoride content in water. Keeping in view the various sources through which fluoride finds entry into the body, a level of ± 1.0 mg/L fluoride in water is considered as the optimum level to prevent both dental caries and various forms of fluorosis. The maximum limit prescribed by BIS (Bureau of Indian Standards) for fluoride in drinking water is 1.5 mg/L.

In pre monsoon minimum concentration values of Fluoride were observed as 0.2 mg/L at Malaiyanur village and maximum concentration values were observed as 2.6 mg/L in Kalaravallipattipudur village. During the post monsoon, the minimum concentration values of 0.2 mg/L at Amarakundi village have been observed and for the maximum concentration values of 2.4 mg/L at Kalaravallipattipudur village respectively.

Sources of fluoride: Water and food mainly agricultural crops are contaminated with fluoride as the earth's crest in India is heavily loaded with fluoride containing minerals/salts. Fluorite, Topaz, Appetite and phosphatic nodules are the fluoride containing minerals, which are widely spread in India. The number of samples fall in the above said zone is shown in Fig.4.13 and Table 4.16. Field Pho.5 showing dental and skeletal fluorosis.

Table 4.16 Fluoride – Water sample Locations and its Limiting Zone

SI. No.	Potability Nature in mg/L	Water sample locations	
		Pre monsoon	Post monsoon
1	Desirable (< 0.9)	4,5,6,7,13,15,16, 22, 25, 28, 29,33,34,37,38,45,46,48,51, 52,54,61,67,72,74,77	1,2,3,4,5,6,7,8,10,12,13,16,17,18,19,22,25,28,29,32,35,37,38,39,42,43,45,47,48,49,51,52,53,54,58,60,67, 76,78,79,86,87,89
2	Allowable (0.9 – 1.5)	8,17,19,18,21,27,32,35,36,41,42,44,53,60,69,76,78,85	9,14,15,20,26,27,31,34,36,40,41,44,46,56,61,6265,69,73,74,77,84,90
3	Not potable (> 1.5)	1,2,3,9,10,11,12,14,16,23,24 26,30,31,39,40,43,49,50,55, 56,57,58,59,62,63,64,65,66, 68,70,71,73,75,79,80,81,82, 83,84,86,87,88,89,90	11,21,22,24,30,33,50,55,57,59,63,64,66,68,70,71,72,75,80,81, 82,83,85,88

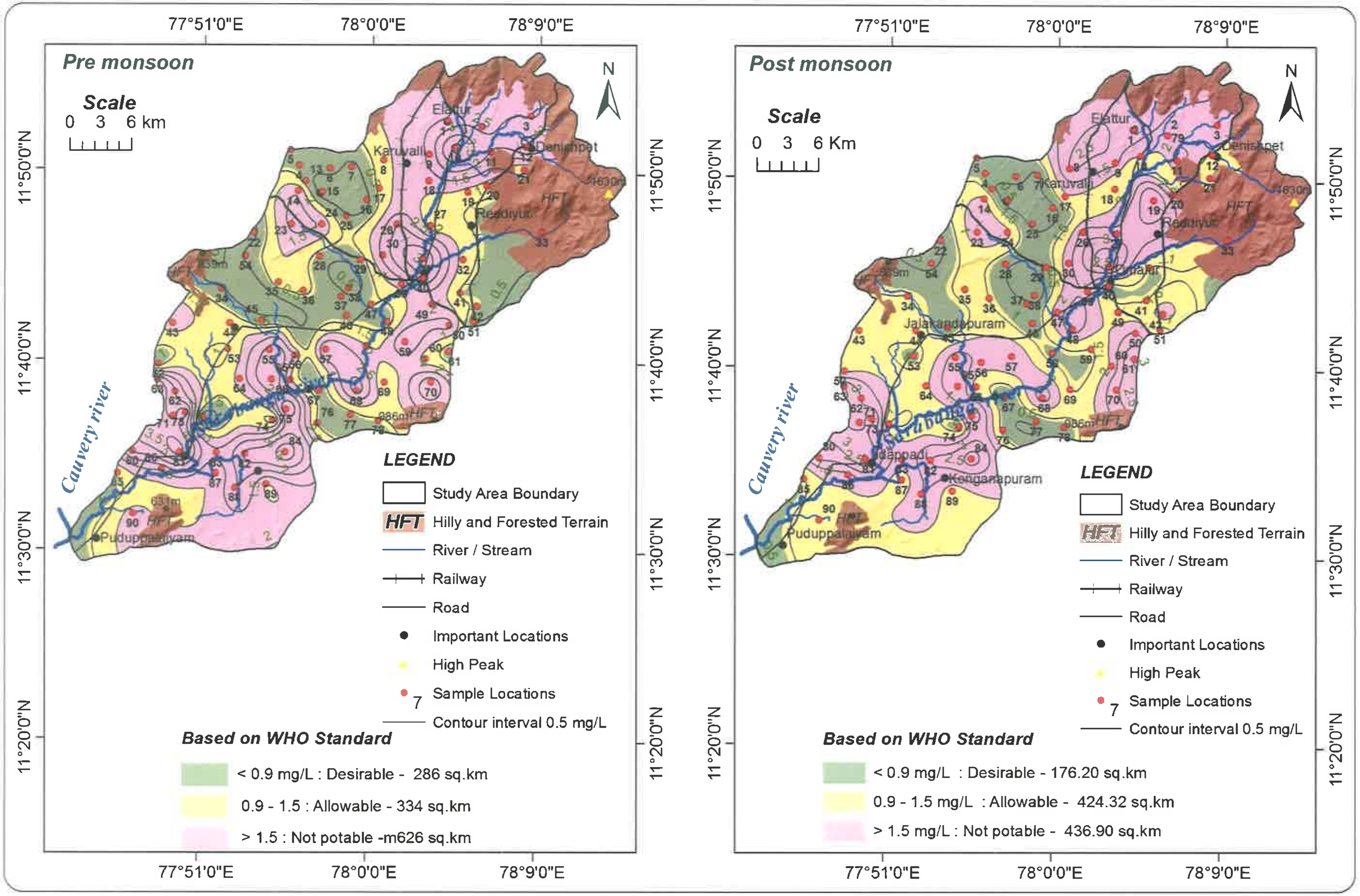


Fig.4.13.Spatial distribution of Fluoride in groundwater.

Photos-6. Field Photographs showing Dental and Skeletal Fluorosis

a. A boy severely affected by dental fluorosis at Nachiyur village

b. A adult severely affected by skeletal fluorosis at Kalarvallipattipudur village

Fluoride leaches out from the minerals and contaminates the groundwater. In areas that are rich in fluoride containing minerals, well waters may contain fluoride up to a maximum level of 10 mg/L or even more. In general the decreasing order of fluoride content in various food items is cereals followed by leafy vegetables, pulses, fish, meat and fruits. Pan Supari and Tobacco have very high fluoride content. Tea has the highest fluoride content among various food items. However the Indian way of preparing tea with calcium rich milk nullifies the harmful effects of fluoride to some extent.

In the groundwater samples of 26, 19 and 45 locations, the concentration of Fluoride during pre monsoon comes under desirable, allowable and not potable categories while during post monsoon season, 43 23 and 24 locations comes under desirable, allowable and not potable categories.

Excess Fluoride Consumption and Health Hazards: Fluoride when consumed or inhaled in excess more than 1.00 mg/L can cause several kinds of health problems. It affects the young and the old alike. Fluoride is also known to induce ageing. An individual may suffer from any one of the following or combined, Skeletal Fluorosis, Dental Fluorosis and Non Skeletal manifestations. Fluoride can also damage a foetus if the mother consumes water/food with high concentration of fluoride during pregnancy/breast feeding. The Symptoms of the Fluorosis are severe pain in the back bone, severe pain in the joints, severe pain in the hip region (pelvic girdle), Stiffness of the back bone Immobile/stiff joints

Dental Fluorosis: Dental fluorosis is prevalent in children who are born and brought up in an endemic area of fluorosis. Dental fluorosis can occur in milk teeth and permanent teeth.

Symptoms of Dental Fluorosis:

- Yellowish white – Glistening teeth – becomes dull – loses its Shine – develops a yellow - loses its shine - develops a yellow - white spots
- Yellow – white spots turn brown and present it in horizontal streaks

- If the brown streaks are in middle of the teeth, it indicates that child has been exposed to high fluoride in food or water or both from the age of 2 years up to 4 years.
- Dental fluorosis is not only a cosmetic problem but is also known to cause social problems.

4.2.13 Prevention and Control of Fluorosis:

Fluorosis although is untreatable, can be easily prevented. If it is dental fluorosis, masking of the ugly looking brown black teeth is possible either by capping or by laminated veneering.

Preventive and control Measures:

- Fluorosis: If the water has fluoride concentration of more than 1.00mg/l, do not use for cooking and drinking.
- Intake of Vitamin C in large amount is advisable. Vitamin C rich food items should be consumed.
- Diet should have adequate calcium. Drink more milk and consume calcium rich vegetables.
- Avoid all possible sources (s) of high fluoride containing items viz. water, food, drugs and toothpaste.
- Pain in the back, hip or joints should not be dismissed as casual, hospital intervention should be sought.

4.3 Sodium Absorption Ratio

The sodium or alkali hazard in the use of groundwater for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Absorption Ratio (SAR). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If groundwater used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium.

Sodium concentration in groundwater is very important, since increase of sodium concentration in water effects deterioration of the soil properties reducing permeability. The processes leading to the cation exchange reaction in soil may be studied from sodium absorption ratio (U.S. Salinity Laboratory, 1954). SAR is expressed as, Na/√ (Ca + Mg)/2, where the concentration is expressed in mg/L.

Classification of water with reference to SAR is given by Herman Bouwer, (1978). The SAR ranged from 0.04 to 4.2 and 0.25 to 4.44 during pre and post monsoon periods. Out of 90 samples, pre and post monsoon seasons fell under safe category and shown in Table 4.17.

Table 4.17 Sodium Absorption Ratio - Classification

Sl.No	Limiting Values	Water Quality	Water Sample Locations	
			Pre monsoon	Post monsoon
1	0 - 6	No problem	All samples	All samples
2	6 - 9	Increasing problem	-	-
3	>9	Severe problem	-	-

4.4 Kelley's Ratio

Kelley et al., (1940) have suggested that the sodium problem in irrigation water could conveniently be worked out on the basis of the values of Kelley's ratio. The Kelley's ratio was calculated for all the water samples of the study area. It varied from 0.01 to 2.3 mg/L during pre monsoon and 2.31 to 17.94 mg/L in post monsoons season. The formula used in the estimation of this ratio is expressed as Na/(Ca + Mg).

4.5 Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate is defined as RSC = (CO_3 + HCO_3) – (Ca + Mg), where all concentrations are expressed in mg/L. The water having excess of carbonate and bicarbonate over the alkaline earth mainly calcium and magnesium, in excess of allowable limits affects agriculture unfavorably

(Richards, 1954). Table 4.18 shows that ninety two percent of samples were safe for agricultural purposes and the rest were marginal for irrigational use for both the seasons.

Table 4.18 Classification of Residual Sodium Carbonate

SI. No.	Category	Pre monsoon (No. of samples)	Post monsoon (No. of samples)
1	Safe (<1.25)	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20,21,23,24,25,2 6,27,30,31,32,33,34,36,37,39,40, 41,42,43,44,45,46,47,48,49,50,5 1,5254,55,56,57,58,59,60,61,63, 64,66,67,68,69,70,71,72,74,75,7 6,77,79,80,81,82,83,85,86,88,89, 90	1,2,3,4,5,6,7,9,11,12,13,14, 15,16, 18,20,21,23,24,25,26,27,30,31,33, 34,36,37,39,40,41,42,43,44,45,46, 48,49,50,51,52,54,55,56,57,58,59, 60,61,62,63,64,66,67,68,69,70,71, 72,74,76,77,79,81,82,83,85,88,89, 90
2	Marginal (1.25 – 2.5)	28,29,38,53,78	17,28,29,32,38,53,78
3	Unsuitable (>2.50)	22,35,65,73,84,87	8,10,19,35,47,73,84

4.6 Chemical Relationships for Irrigational Purposes

4.6.1 Results from Piper's Trilinear Diagram

Piper's diagrams, also called trilinear diagrams are drawn by plotting the proportions (in equivalents) of the major cations ((Ca^{2+}, Mg^{2+}, (Na^{+}+K^{+})) on one triangular diagram, the proportions of the major anions (Alkalinity CO_3+HCO_3, Cl, SO_4) on another, and combining the information from the two triangles on a quadrilateral. The position of this plotting indicates the relative composition of a groundwater in terms of the cation, anion pairs that correspond to four vertices of the field. The main drawback that Piper's trilinear diagrams have in their plotting shows the chemical character of the groundwater according to the relative concentration of its constituents, but not according to the absolute concentrations.

On the basis of chemical analysis, groundwater is divided into six facies and given in Table. 4.19. The plot shows that the groundwater samples fall in the field of mixed $NaHCO_3$, NaCl, $CaHCO_3$, CaMgCl and CaCl respectively, according to the order of their dominance. From the plot, it is observed that 96% of samples fall in alkaline earths (Ca^{2+} and Na^+), HCO_3^- and Cl^- exceeds the other anions. Organized in the groundwater chemical evolution where the water rock interaction processes are considered important in the definition of their calcium-bicarbonate-chloride type visible in a Piper diagram in which dispersion in the cation (Sodium and Calcium) and anion (Bi-carbonate and Chloride) content of the groundwater samples is shown in Fig.4.14. This could be associated either to lithological heterogeneities or due to anthropogenic activities.

Table. 4.19 Pre and Post Monsoon Hydrochemical Facies of Groundwater

Facies	Total No. of Samples Pre Monsoon	Percentage (%)	Total No. of Samples Post Monsoon	Percentage (%)
$CaHCO_3$	18	20	19	21.1
NaCl	5	5.5	7	7.7
Mixed $CaNaHCO_3$	3	5.5	6	11.0
Mixed CaMgCl	11	12.2	20	22.2
CaCl	15	16.6	1	1.11
$NaHCO_3$	38	42.22	37	41.11

4.6.2 Gibb's Diagram

The source of the dissolved ions in the groundwater can be understood by diagram (Gibbs, 1970). It is a plot of $Na^+ + K^+ / (Na^+ + K^+ + Ca^{2+})$ Vs TDS and $Cl^- / (Cl^- + HCO_3^-)$ Vs TDS. The Gibbs's diagrams suggest that the chemical weathering of the rock forming minerals and evaporation are the main processes which contribute ions to the water. Pre and post monsoon Gibb's diagrams have been shown in Fig. 4.15.

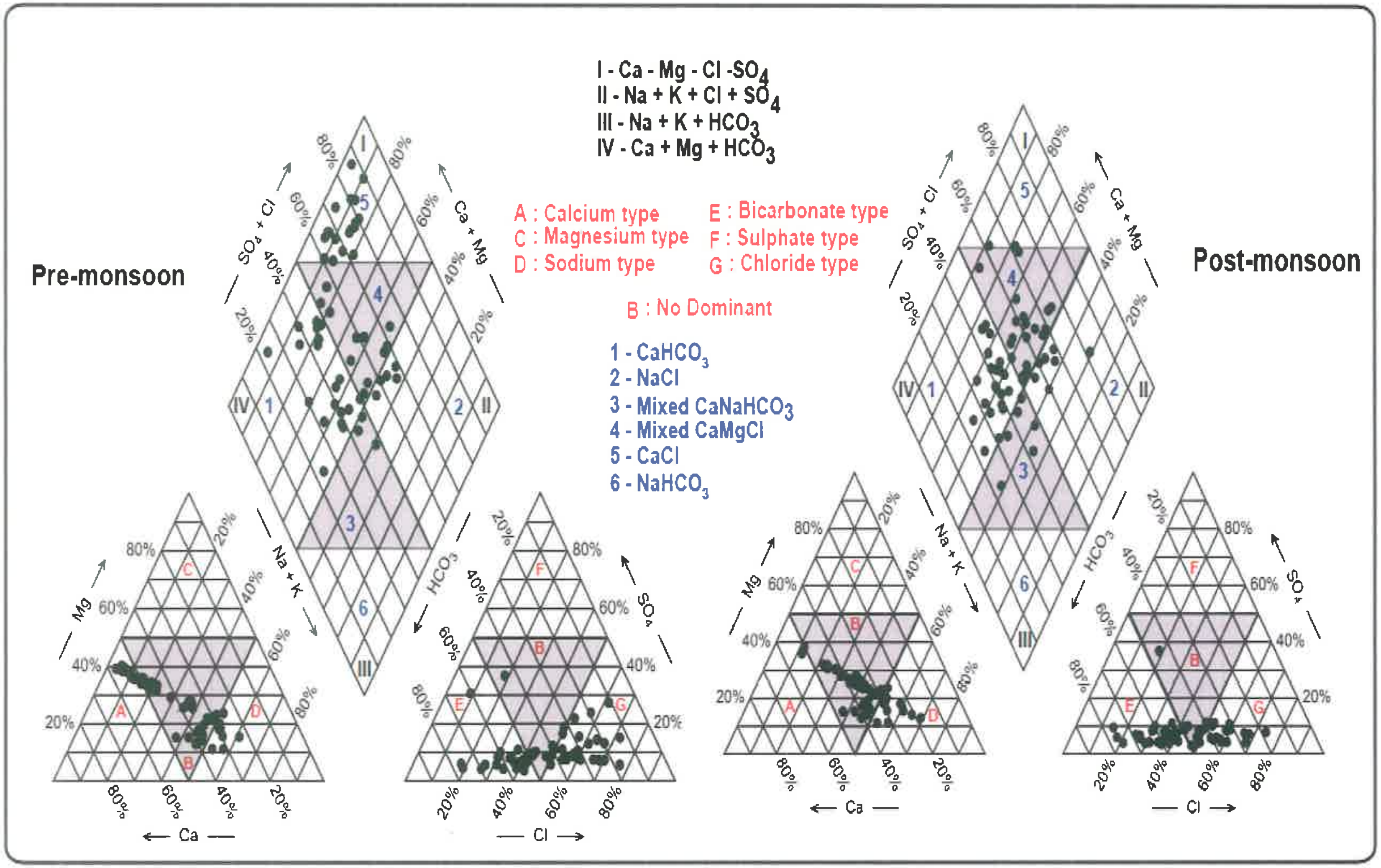


Fig.4.14. Hill Piper plot for the Water Samples Pre Monsoon and Post Monsoon

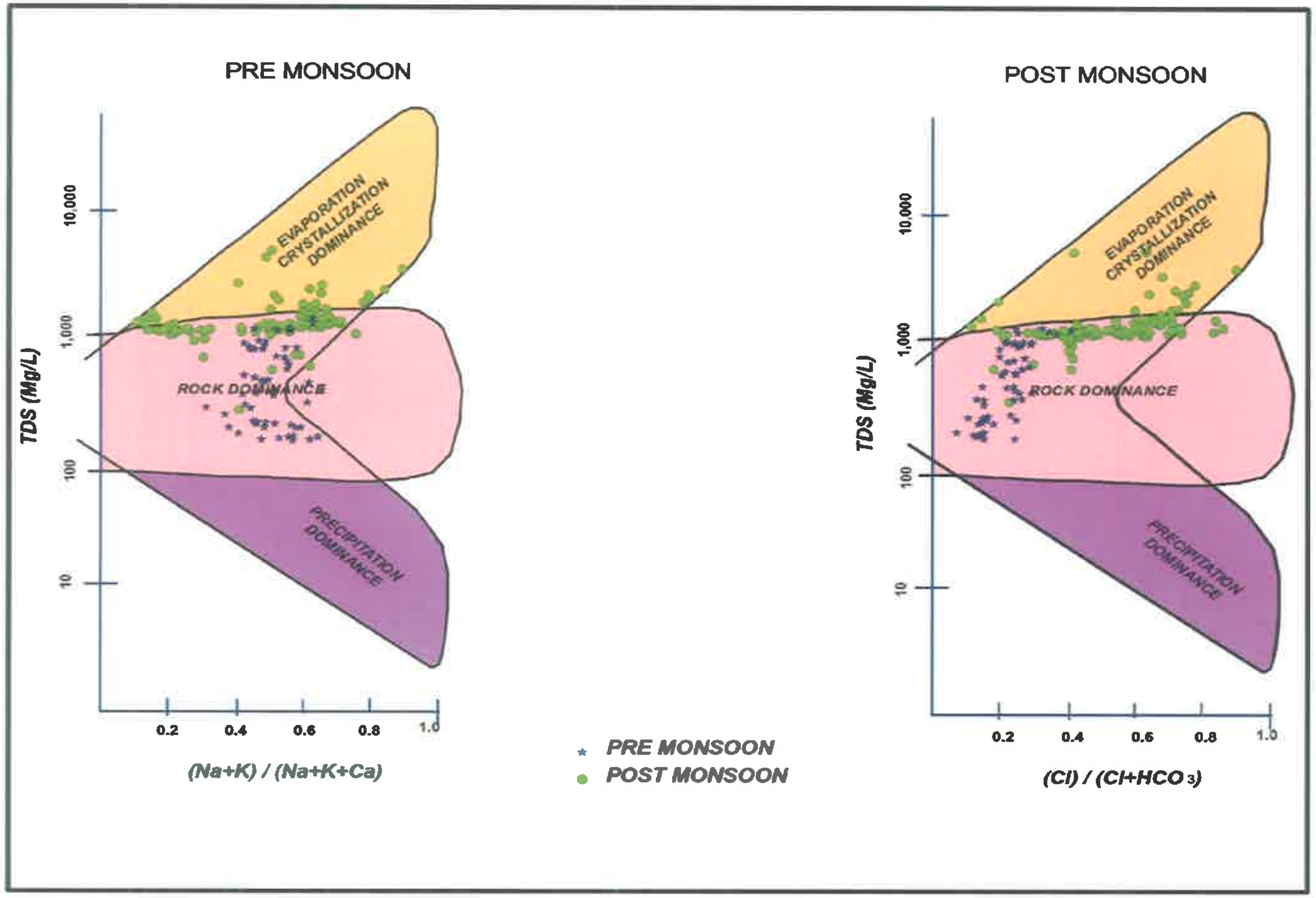


Fig.4.15 Gibbs Plot Mechanism Controlling the Chemistry of Water Sample

It shows that all the Pre and Post Monsoon season samples $Na^+ + K^+ / (Na^+ + K^+ + Ca^{2+})$ fell in the rock dominance. It is interesting to note that during pre and post monsoon seasons $Cl^- / (Cl^- + HCO_3^-)$ Vs TDS. 25 % and 15 % of samples fall in evaporation crystalline domain. The variation of Gibb's ratio with pre monsoon and post monsoon has been given in Table 4.20.

Table.4.20 Groundwater in the Gibb's Domains.

	Class	Sample No	Total
Pre Monsoon	ECD	8,21,22,25,28,29,45,46,47,48,53,56,57,58, 61,62,66,68,69,73,78,79,81,83,85	25
	RD	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 23, 24, 26, 27, 30, 31, 32,33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 49, 50, 51, 52, 54,55, 59, 60,63, 64, 65 ,67, 70, 71, 72, 74, 75,76, 77, 80, 82, 84, 86, 87, 88, 89, 90	65
	PD	-	-
Post Monsoon	ECD	24,55,58,63,64,68,69,70,73,75,80,81,83,84,85	15
	RD	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 4 0, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 59, 60, 61, 62, 65, 66, 67, 69, 72, 74, 76, 77, 78, 79, 82, 86, 87, 88, 89, 90	75
	PD	-	-

ECD- Evaporation Crystallization domain *PD- Precipitation domain*

RD-Rock domain

4.6.3 USSL Diagram

U.S. Salinity Laboratory diagram (1954) interpretation has been given in Fig 4.16. The two most significant parameters of sodium and salinity hazards indicate usability for agricultural purposes. The pre and post monsoon USSL classification of groundwater in the study area has been given in Table 4.21. The pre monsoon season samples fell under 33 Location (36.67%) and 57 Location (63.33%) samples occurred within C_3-S_1, C_4-S_1, and post monsoon samples fell under 52 Location (57.78%) and 38 Location (42.22%) samples occurred within C_3-S_1, C_4-S_1 domain and suitable for irrigation purposes.

Table 4.21 USSL Classification Fields and Sample Locations

	Class	Sample No	Total	Percentage
Pre Monsoon	C1-S1	-	-	-
	C2-S1	-	-	-
	C3-S1	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 16, 17, 20, 22, 25, 26, 28, 29, 32, 33, 34, 38, 45, 51, 60, 67, 76, 78, 79, 87, 89.	33	36.67
	C4-S1	10, 14, 15, 18, 19, 21, 23, 24, 27, 30, 31, 35, 36,37, 39, 40, 41, 42, 43, 44, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 61, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 74, 75, 77, 80, 81, 82, 83, 84, 85, 86, 88, 90.	57	63.33
Post Monsoon	C1-S1	-	-	-
	C2-S1	-	-	-
	C3-S1	1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13,15,16, 18, 19, 20, 22, 25, 26, 27, 28, 29, 32, 34, 35, 36, 37, 38, 39, 41, 42, 43, 45, 47, 48, 49, 51, 52, 53, 54, 58, 60, 67, 74, 76, 77, 78, 79, 86, 87,89, 90.	52	57.78
	C4-S1	9, 11, 14, 17, 21, 23, 24, 30, 31, 33, 40, 44, 46, 50, 55, 56, 57, 59, 61, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 75, 80, 81, 82 ,83, 84, 85, 88.	38	42.22

C1-S1, C2-S1- Good water type

C1-S2, C2-S2, C3-S2, C3-S1- Moderate water type

C1-S3, C2-S3, C3-S3, C4-S3, C5-S3, C4-S2, C5-S2, C5-S1, C1-S4, C2-S4, C3-S4, C4-S4, C5-S5 – Bad water type

4.6.4 Wilcox's Diagram

Wilcox (1955) used sodium percentage and specific conductance in evaluating the suitability of groundwater to irrigation. Sodium percentage determines the ratio of sodium to total cations viz., sodium, potassium, calcium and magnesium.

All concentration values are expressed in equivalents per million.

$$Na\% = \frac{Na+K}{Ca+Mg+Na+K} \times 100$$

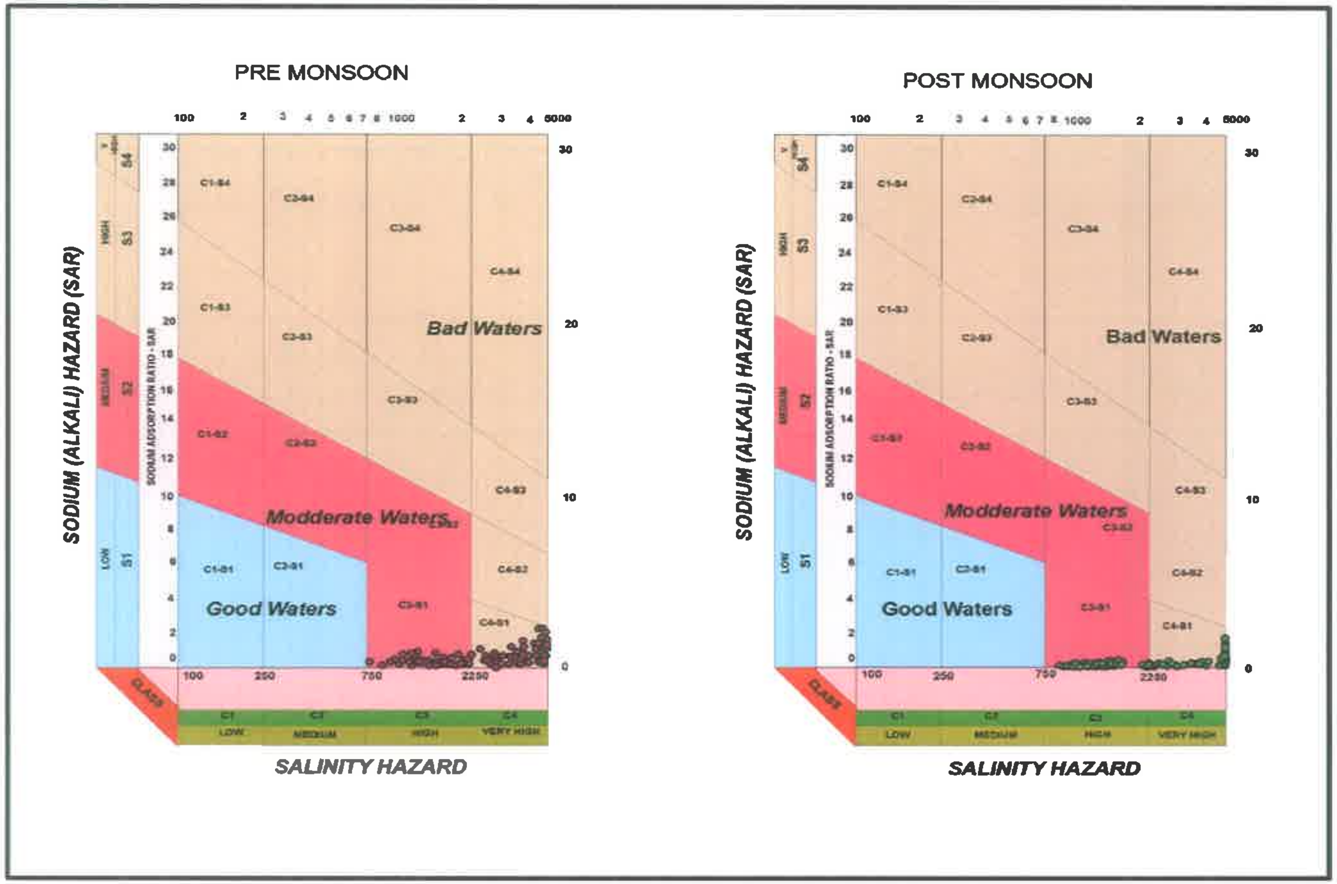


Fig.4.16. USSL Classification of Groundwater Samples Pre Monsoon and Post Monsoon

The pre and post monsoon results have been given in Table 4.22. The groundwater near the upstream is good for irrigation and the contaminations are found to be higher near downstream as given in Fig.4.17. Above said results were taken into GIS environment for spatial distribution map preparation.

Table 4.22 Wilcox's Classification Fields and Sample Locations

	Class	Sample No	Total	Percentage
Pre Monsoon	Excellent to Good	10	1	1.1
	Good Permissible	1,2,4,5,6,7,8,9,11,12,13,16,17,20,22,25,28,32,38,51,54,60,67,76,78,79,86,	27	30
	Good Permissible To Doubtful	Nil	NIL	-
	Doubtful To Unsuitable	3,14,15,18,19,21,26,29,33,34,35,36,37,39,40,41,42,43,44,45,46,48,50,52,53,69,73,74,77,84,87,89 90	33	36.66
	Unsuitable	23,24,27,30,31,47,49,55,56,57,58,59,61,62,63,64,65,66,68,70,71,72,75,80,81,82,83,85,88	29	32.22
Post Monsoon	Excellent to Good	Nil	NIL	-
	Good Permissible	1,2,3,4,5,6,7,8,10,12,13,16,17,18,19,22,25,28,29,32,35,37,38,39,42,43,45,47,48,49,51,52,53,54,58,60,67,78,79,86,87,89,90	43	47.70
	Good Permissible To Doubtful	76	1	1.1
	Doubtful To Unsuitable	9,14,15,20,26,27,31,34,36,40,41,44,46,56,61,62,65,69,73,74,77,84,	22	24.44
	Unsuitable	11,21,23,24,30,33,50,55,57,59,63,64,66,68,70,71,72,75,80,81,82,83,85,88	24	26.66

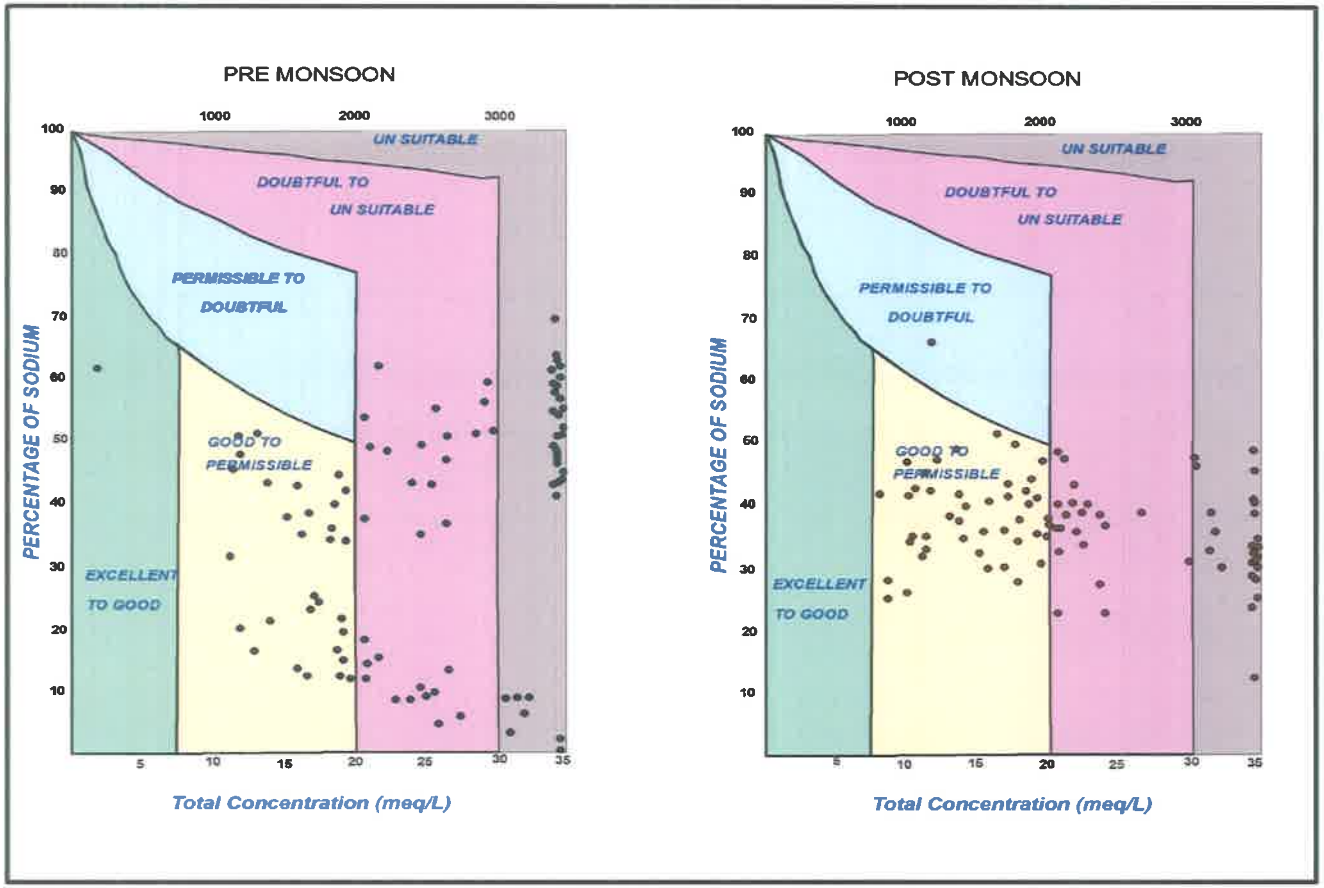


Fig.4.17. Wilcox (1955) Diagram for Classification of Groundwater Based on EC and Na %

4.6.5 Doneen's Permeability Index

The soil permeability is affected by long term use of irrigation water. It is influenced by sodium, calcium, magnesium and bicarbonate contents of soil. Doneen's (1948) evolved a criterion for assessing the suitability of water for irrigation based on Permeability Index (PI). Groundwater samples during pre and post monsoon season show that majority of the samples fall under Class-I as shown in Fig 4.18 and Table 4.23 indicates that the groundwater is good for irrigation in both seasons. Above said results were taken into GIS environment for spatial distribution map preparation.

Table.4.23 Doneen's plot Groundwater samples of Sarabanga sub basin

SI.NO	Class	Pre Monsoon	Post Monsoon
1	CLASS-I	All Samples	All Samples
2	CLASS-II	-	-
3	CLASS-III	-	-

4.7 Hydrogeochemical Studies for Drinking Purposes of GIS Analysis

Using the WHO standards, the quality of drinking water was categorized. The erratic behavior of groundwater geochemical elements were spatially given through GIS study. It shows that in the study area, Calcium, Magnesium, Sodium, Potassium, Chloride, Sulphate, Nitrate, Fluoride, Total Dissolved Solids (TDS), Electrical Conductivity (EC) and Hydrogen ionic concentration (pH) were observed in potable and not potable limit have been given in Table. To find out the spatial distribution of these elements in the study area, GIS was employed. The geochemical locations were digitized and the corresponding values of its attributes were given as an input. Using this data, the interpolation raster maps were generated. Subsequently, these maps were classified with respect to WHO standard and converted into vector maps. These maps were clipped with the boundary to arrive within the boundary of the study area. Groundwater quality classification (WHO's Standard) and Physical, chemical parameters of groundwater chemistry pre and post monsoon seasons have been given in Tables.4.24.and 4.25.

Table 4.24 Groundwater quality classification (WHO's Standard)

Parameters	Based on the WHO standard		Pre monsoon 2011		Post monsoon 2012	
			Sq.Km	%	Sq.Km	%
EC	250 – 750	Good	0.94	0.09	4.38	0.42
	750 – 2000	Permissible	330.66	31.89	488.58	47.11
	2000- 3000	Doubtful	326.49	31.48	297.70	28.71
	>3000	Unsuitable	379.33	36.58	246.76	23.80
TDS in mg/L	<500	Desirable	2.20	0.21	12.58	1.21
	500- 1500	Allowable	563.32	54.32	391.83	37.78
	>1500	Not potable	471.90	45.51	633.01	61.04
Ca in mg/L	<75	Desirable	24.29	2.34	45.83	4.42
	75- 200	Allowable	852	82.16	786.61	75.85
	>200	Not potable	367	35.39	204.98	19.77
Mg in mg/L	<50	Desirable	240.75	23.22	387.84	37.40
	50- 150	Allowable	775.91	74.82	642.78	61.98
	>150	Not potable	20.77	2.00	6.80	0.66
Na in mg/L	<50	Desirable	188.54	18.18	19.65	1.89
	50-200	Allowable	372.37	35.91	489.41	47.19
	>200	Not potable	476.52	45.95	528.37	50.95
K in mg/L	<10	Desirable	69.06	5.95	111.84	10.06
	10-12	Allowable	219.71	18.94	56.20	5.05
	>12	Not potable	871	75.1	943	84.87
Cl in mg/L	<200	Desirable	215.49	20.77	257.13	24.80
	200- 600	Allowable	559.79	53.96	546.38	52.69
	>600	Not potable	262.15	25.27	233.91	22.56
SO_4 in mg/L	<200	Desirable	901.40	86.92	974.54	93.98
	200-400	Allowable	135.88	13.07	62.88	6.06
	>400	Not potable	0.14	0.01	0	0
NO_3 in mg/L	<50	Desirable	653.06	62.95	547.45	52.76
	>50	Allowable	384.37	37.05	489.98	47.23
F in mg/L	<0.9	Desirable	286	22.95	176.20	16.99
	0.9-1.5	Allowable	334	26.8	424.32	40.92
	>1.5	Not potable	626	50.24	436.90	42.13

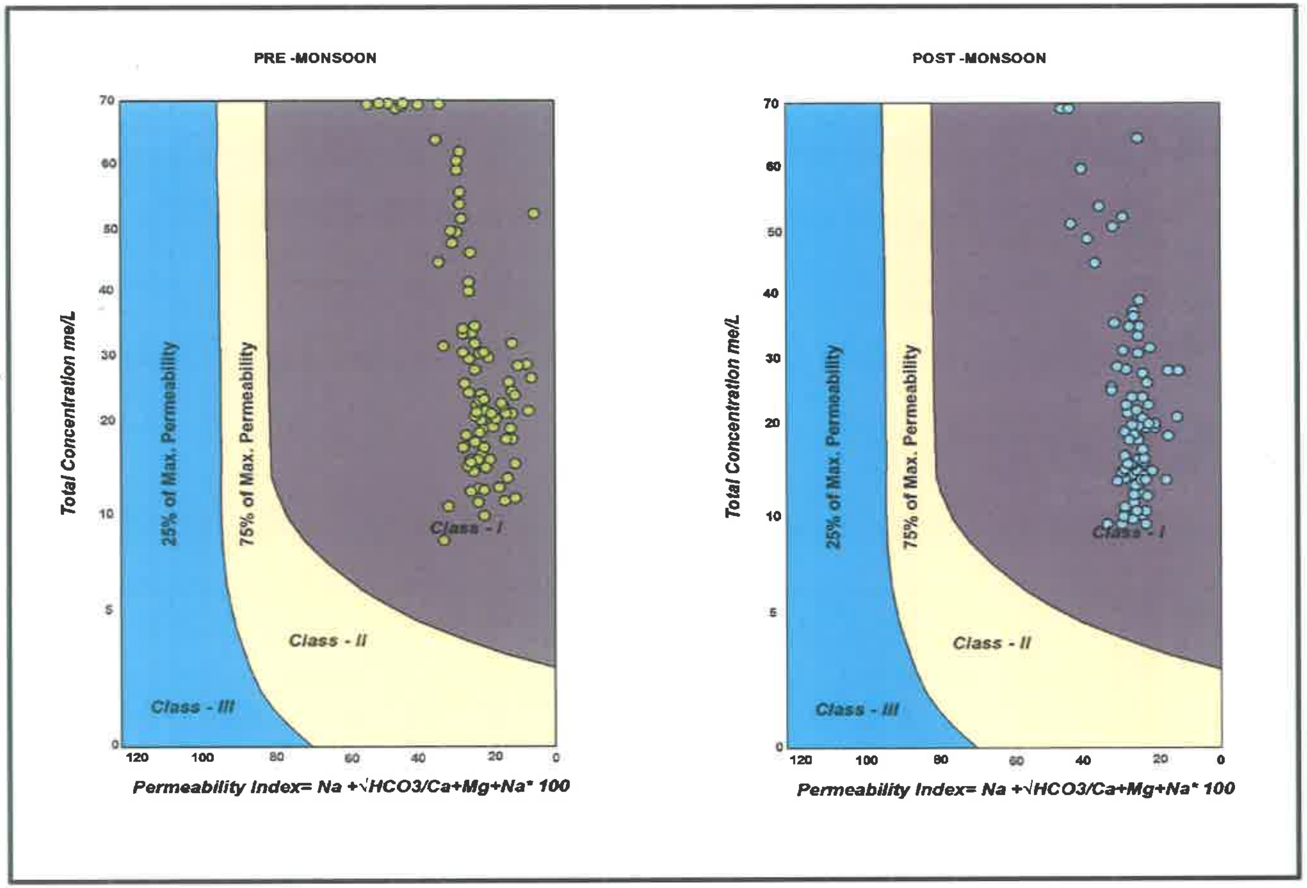


Fig.4.18. Doneen's Plot of Water Samples Pre Monsoon and Post Monsoon

Table 4.25 Physical and chemical parameters of groundwater chemistry pre and post monsoon seasons

Parameters	Pre Monsoon July-2011				Post Monsoon January - 2012			
	Min	Max	Average	SD	Min	Max	Average	SD
pH	5.92	9.36	8.3	1.06	6.86	7.90	7.33	0.57
EC	760.0	10644	3062.9	7581.1	903.0	8870.0	2591.1	6278.9
TDS	532	7450.8	2144	5306.8	632	6209.0	1813.8	4395.2
Ca	53.1	1022.4	209.6	812.8	44.8	852.0	178.7	673.3
Mg	17,5	195.9	74.4	121.5	15.0	206.4	63.9	142.5
Na	9.89	1075	242	833	1.9	38.9	11.3	27.6
K	1.17	264.3	242	22.3	0.10	5.78	0.08	5.7
Fe	0	3.4	0.5	2.9	0	2.8	0.4	2.4
HCO_3	135.4	3314.6	642	2672.6	129.5	2762	622.8	2139.2
CO_3	0	181.2	27.2	154	7.1	150.9	34.0	116.9
Cl_2	65.6	2112	492.9	1619.1	46.5	1760	456.5	1303.5
SO_4	15.3	623.9	133.5	490.4	20.4	520.0	101	419
NO_3	0	187.5	44.3	143.2	0	182	53.2	128.8
PO_4	0	2.3	0.2	2.1	0	2.0	0.3	1.7
F	0.2	2.6	1.5	1.1	0.2	2.4	1.18	1.22

Note: Ionic concentration in mg/L except pH and EC

One of the powerful physical parameter is electrical conductivity based on WHO standard. Most of the study area fell in not potable nature because due to the heavy rock water interaction and the meager amount of water infiltrated in the hard rock terrain, it is also due to poor porosity and permeability.

4.8 Water Chemistry and Scaling

Depending upon its specific chemistry, water can promote scaling, corrosion or both. Scale can be formed from a variety of dissolved chemical species but two reliable indicators are hardness and alkalinity. Calcium carbonate is the most common form of scale deposition attributable to groundwater. Total hardness is primarily a measure of the calcium and magnesium salts in water. In addition, other minor contributing components to hardness can be aluminium, manganese, iron and zinc. Two types of hardness are generally recognized: carbonate (sometimes referred to as temporary hardness) and non carbonate hardness. Carbonate hardness, dependent upon the nature of the water is composed of calcium or magnesium carbonates and bicarbonates. Carbonate hardness contributes most to scale formation. Non carbonate hardness is normally a small component of the total hardness and is characterized by much higher solubility. As a result its role in scale formation is generally negligible.

Calcium hardness is a key parameter in evaluating scale formation. It generally constitutes 70% or more of the total hardness in water. For worst case evaluations or in the absence of sufficient information, calcium hardness can be considered equal to total hardness. If a calcium ion value is available from a water chemistry analysis, calcium hardness (as $CaCO_3$) can be calculated by multiplying the calcium ion value by 2.5.

Alkalinity is a measure of water's ability to neutralize acid. In the range of normal groundwater chemistry, alkalinity is as a result primarily of bicarbonate content of the water. At pH values of greater than 8.3 carbonate and hydroxide can also contribute to alkalinity. Two measures of alkalinity are of interest, Methyl Orange ("M" alkalinity or total alkalinity) and Phenolphthalein ("P" alkalinity). Since "P" alkalinity measures that portion of the alkalinity effective at very high pH, the "M" alkalinity is the value of interest in evaluation scale potential.

4.8.1 Relationship between Hardness and Alkalinity

In order to evaluate the general character (scale forming or corrosive) of a particular water sample it is necessary to know the total dissolved solids (TDS), pH and temperature in addition to the calcium hardness and the "M" alkalinity.

Total dissolved solids are a general indication of the quality of a water source. As TDS increases water quality problems are more likely to occur. Whether these problems are on the corrosion or scaling end of the spectrum is dependent upon other indicators. The pH value of most groundwater is in the range of 5.0 on the acid end of the spectrum to 9.0 on the alkaline end. Scaling problems are common at pH value above 7.5.

4.8.2 Langelier's Saturation Index (LSI) and Ryznar's Stability Index (RSI).

Two indices commonly used in the water treatment industry to evaluate the nature of a water source are the Langelier's Saturation Index (LSI) and Ryznar's Stability Index (RSI). In both cases these indices are bases upon a calculated pH of saturation for calcium carbonate (pHs). The pHs value is then used in conjunctions with the waters actual pH to calculate the value of the index as follows:

$$LSI=pH-pHs$$

$$RSI=2pHs-pH$$

Interpretation of Langelier's Saturation Index and Ryznar's Stability Index for the Sarabanga sub basin has been given in Table 4.26. It produces a slightly different value numerically but is interpreted in a similar fashion.

Table 4.26 Langelie'sr Saturation Index and Ryznar's Stability Index

SI. No	LSI Index Limit	Value Indication	RSI Index Limit	Value Indication
1	2.0	Scale forming but non corrosive	4.0-5.0	Heavy scale
2	0.5	Slightly scale forming and corrosive	5.0-6.0	Light scale
3	0.0	Balanced but pitting corrosion possible	6.0-7.0	Little scale or corrosion
4	-0.5	Slightly corrosive but non-scale forming	7.0-7.5	Heavy corrosion
5	-2.0	Serious corrosion	7.5-9.0	Corrosion significant
6	-	-	>9.0	Corrosion intolerable

It is important to point out that the accuracy of the RSI and LSI is much greater as a predictor of scaling than of corrosion. This results from the fact that both methods are bases upon the saturation of calcium carbonate. The assumption implicit in the calculations that if the calcium carbonate content exceeds the level that can be maintained in solution, scale will occur. At lower pH corrosion will occur. In terms of general corrosion in systems constructed of primarily ferrous materials, this is a valid assumption for corrosion. In water flow systems where the material are more likely to be copper or cupper nickel there are other chemical species that can cause serious corrosion that are not accounted for in the RSI/LSI calculations. Calculation of the value for pHs can be done using the monograph found in various references or through the use of the following equation.

pHs = (9.3+A+B) – (C + D)

Where:

A= (log $(TDS)^{-1}$)/10	TDS in ppm
B= (-13.12 log (K) + 34.55	temperature in ^0C
C= (log (calcium hardness))-0.4	Ca hardness in ppm (as $CaCO_3$)
D= (log (M alkalinity)	M Alkalinity in ppm as ($CaCO_3$)

Spatial distribution of LSI and RSI during pre and post monsoon seasons has been given in Table 4.27 and Fig.4.19. Heavy corrosion have been identified in the following villages such as Kukalpatti, Kupakalipatti, Amaram, Andiyur, Maniyakaranur, Agraharum, Danishpet, Marakottai, Chinnanagalur, Palakaranur,Sattapadi, Balbakki, Periyasoragai, Amarakunthi, Vethalaikaranur, Sivadanur, Chinnapampatti, Nallakampatti, Valaiyachettipatti and Madattur and heavy scaling has been identified in Reddipatty and Kalaravallipattypudur.

4.8.3 Source and Cause of Corrosion

Corrosion is a complex series of reactions between the water and metal surfaces and materials in which the water is stored or transported. The corrosion process is an oxidation/reduction reaction that returns refined or processed metal to their more stable ore state. With respect to the corrosion

Table: 4.27 Interpretation for the Langelier Saturation Index and Ryznar Stability Index of Sarabanga sub basin

Well No.	pH	Ca	HCO_3	TDS	T⁰C	pH_s	LSI Index	Indication	RI Index	Indication
1	7.51	120	454.9	945	32	7.12	0.39	Slightly scale forming and corrosive	6.72	Little scale or corrosion
2	7.42	176	472.4	1190	31	6.96	0.46	Slightly scale forming and corrosive	6.50	Little scale or corrosion
3	7.37	152	584.9	1295	28	6.99	0.38	Slightly scale forming and corrosive	6.62	Little scale or corrosion
4	6.99	120	613.2	1166	31	7.01	-0.02	Slightly corrosive but non-scale forming	7.04	Heavy corrosion
5	6.86	132	449.3	1365	29	7.15	-0.29	Slightly corrosive but non-scale forming	7.45	Heavy corrosion
6	6.87	140	575	1339	30	7.00	-0.13	Slightly corrosive but non-scale forming	7.13	Heavy corrosion
7	7.08	56	354.7	800	31	7.57	-0.49	Slightly corrosive but non-scale forming	8.05	Heavy corrosion
8	7.02	104	725.6	1239	29	7.04	-0.02	Slightly corrosive but non-scale forming	7.07	Heavy corrosion
9	7.47	140	641.5	1610	28	7.00	0.47	Slightly scale forming and corrosive	6.53	Little scale or corrosion
10	7.27	44.8	434.4	679	30	7.59	-0.32	Slightly corrosive but non-scale forming	7.90	Heavy corrosion
11	7.36	192	607	3710	31	6.87	0.49	Slightly scale forming and corrosive	6.37	Little scale or corrosion
12	7.2	100	455.7	945	28	7.27	-0.07	Slightly corrosive but non-scale forming	7.34	Heavy corrosion
13	7.44	126	582	1139	29	7.05	0.39	Slightly scale forming and corrosive	6.67	Little scale or corrosion
14	7.58	168	528.4	1764	27	7.03	0.55	Scale forming but non corrosive	6.47	Little scale or corrosion
15	7.53	160	517.3	1538	29	7.01	0.52	Scale forming but non corrosive	6.50	Little scale or corrosion
16	7.42	122	563	1129	31	7.04	0.38	Slightly scale forming and corrosive	6.67	Little scale or corrosion
17	7.1	88	506.9	882	30	7.24	-0.14	Slightly corrosive but non-scale forming	7.38	Heavy corrosion
18	7.5	128	599.8	1260	28	7.06	0.44	Slightly scale forming and corrosive	6.61	Little scale or corrosion
19	7.36	76	633.3	1281	31	7.20	0.16	Slightly scale forming and corrosive	7.05	Heavy corrosion
20	7.6	148	461.1	1400	30	7.07	0.53	Scale forming but non corrosive	6.55	Little scale or corrosion
21	7.4	268	519.8	2100	29	6.80	0.60	Scale forming but non corrosive	6.20	Little scale or corrosion
22	7.55	78	431.9	632	32	7.31	0.24	Slightly scale forming and corrosive	7.07	Heavy corrosion
23	7.36	212	739	2464	31	6.72	0.64	Scale forming but non corrosive	6.08	Little scale or corrosion
24	7.26	262	673.2	2714	29	6.71	0.55	Scale forming but non corrosive	6.16	Little scale or corrosion

Cont……

Well No.	pH	Ca	HCO_3	TDS	T^0C	pH_s	LSI Index	Indication	RI Index	Indication
25	7.48	74	260.2	655	28	7.63	-0.15	Slightly corrosive but non-scale forming	7.78	Heavy corrosion
26	7.9	148	539.4	1540	30	7.01	0.89	Scale forming but non corrosive	6.12	Little scale or corrosion
27	7.9	148	539.4	1540	31	6.99	0.91	Scale forming but non corrosive	6.08	Little scale or corrosion
28	7.36	114	555.9	1090	30	7.10	0.26	Slightly scale forming and corrosive	6.83	Little scale or corrosion
29	7.42	172	741.6	1257	32	6.76	0.66	Scale forming but non corrosive	6.10	Little scale or corrosion
30	7.68	184	626.7	2394	29	6.89	0.79	Scale forming but non corrosive	6.10	Little scale or corrosion
31	7.6	116	621.1	1750	28	7.10	0.50	Slightly scale forming and corrosive	6.60	Little scale or corrosion
32	7.4	86.4	517.9	819	30	7.23	0.17	Slightly scale forming and corrosive	7.07	Heavy corrosion
33	7.5	276	521.6	2170	31	6.75	0.75	Scale forming but non corrosive	6.00	Little scale or corrosion
34	7.5	132	438.4	1400	27	7.20	0.30	Slightly scale forming and corrosive	6.90	Little scale or corrosion
35	7.35	112	760.8	1379	29	7.00	0.35	Slightly scale forming and corrosive	6.64	Little scale or corrosion
36	7.05	122	521	1575	30	7.11	-0.06	Slightly corrosive but non-scale forming	7.17	Heavy corrosion
37	7.32	118	547	1335	32	7.06	0.26	Slightly scale forming and corrosive	6.80	Little scale or corrosion
38	7.22	94	501.9	993	31	7.20	0.02	Slightly scale forming and corrosive	7.18	Heavy corrosion
39	7.5	112	540.2	980	29	7.13	0.37	Slightly scale forming and corrosive	6.76	Little scale or corrosion
40	7.1	192	550	1680	28	6.93	0.17	Slightly scale forming and corrosive	6.76	Little scale or corrosion
41	7.3	220	517.1	1540	31	6.84	0.46	Slightly scale forming and corrosive	6.37	Little scale or corrosion
42	7.3	92	481.1	924	30	7.24	0.06	Slightly scale forming and corrosive	7.19	Heavy corrosion
43	7.3	156	662	1330	29	6.91	0.39	Slightly scale forming and corrosive	6.52	Little scale or corrosion
44	6.86	172	661.1	1624	30	6.86	0.00	Balanced but pitting corrosion	6.86	Little scale or corrosion
45	6.87	160	681.4	1226	28	6.90	-0.03	Slightly corrosive but non-scale	6.94	Little scale or corrosion
46	7.19	168	698.2	1624	30	6.85	0.34	Slightly scale forming and corrosive	6.50	Little scale or corrosion
47	7.4	92	649.4	1176	29	7.14	0.26	Slightly scale forming and corrosive	6.89	Little scale or corrosion

Cont......

Well No.	pH	Ca	HCO_3	TDS	T^0C	pH_s	LSI Index	Indication	RI Index	Indication
48	7.5	160	578.7	1253	31	6.92	0.58	Scale forming but non corrosive	6.34	Little scale or corrosion
49	7.3	152	696.2	1379	30	6.88	0.42	Slightly scale forming and corrosive	6.47	Little scale or corrosion
50	7.1	232	565.9	2520	32	6.78	0.32	Slightly scale forming and corrosive	6.46	Little scale or corrosion
51	7.3	116	497.8	1162	31	7.12	0.18	Slightly scale forming and corrosive	6.94	Little scale or corrosion
52	7.6	128	482.1	1218	32	7.07	0.53	Scale forming but non corrosive	6.55	Little scale or corrosion
53	7.27	102	586.5	1278	30	7.13	0.14	Slightly scale forming and corrosive	6.98	Little scale or corrosion
54	7.43	92	426.7	843	29	7.31	0.12	Slightly scale forming and corrosive	7.19	Heavy corrosion
55	7.44	352	1145.7	3969	28	6.39	1.05	Scale forming but non corrosive	5.33	Light scale
56	7.68	162	534.2	2086	30	6.99	0.69	Scale forming but non corrosive	6.30	Little scale or corrosion
57	7.6	216	683.6	2485	31	6.74	0.86	Scale forming but non corrosive	5.89	Light scale
58	7.4	184	480.3	1295	30	6.96	0.44	Slightly scale forming and corrosive	6.52	Little scale or corrosion
59	7.2	496	519.9	4690	31	6.53	0.67	Scale forming but non corrosive	5.86	Light scale
60	7.1	164	691.4	1330	32	6.81	0.29	Slightly scale forming and corrosive	6.53	Little scale or corrosion
61	7.5	140	654.6	1610	29	6.97	0.53	Scale forming but non corrosive	6.44	Little scale or corrosion
62	7.07	176	747.7	1757	28	6.84	0.23	Slightly scale forming and corrosive	6.60	Little scale or corrosion
63	7.18	852	2912.9	6209	30	5.58	1.60	Scale forming but non corrosive	3.98	Heavy scale
64	7.45	252	603	2723	31	6.74	0.71	Scale forming but non corrosive	6.02	Little scale or corrosion
65	7.28	136	773.3	2065	32	6.87	0.41	Slightly scale forming and corrosive	6.45	Little scale or corrosion
66	7.24	216	620.5	2303	30	6.80	0.44	Slightly scale forming and corrosive	6.37	Little scale or corrosion
67	7.63	56	353.4	734	29	7.60	0.03	Slightly scale forming and corrosive	7.57	Heavy corrosion
68	7.15	264	962.3	3353	28	6.58	0.57	Scale forming but non corrosive	6.01	Little scale or corrosion
69	7.38	264	1008.4	1554	30	6.49	0.89	Scale forming but non corrosive	5.59	Light scale

Cont…

Well No.	pH	Ca	HCO_3	TDS	T⁰C	pH_s	LSI Index	Indication	RI Index	Indication
70	7.34	112	136.6	3528	32	7.73	-0.39	Slightly corrosive but non-scale forming	8.11	Heavy corrosion
71	7.01	396	1000.3	3388	31	6.33	0.68	Scale forming but non corrosive	5.65	Light scale
72	7.18	138	642	2352	29	7.00	0.18	Slightly scale forming and corrosive	6.82	Little scale or corrosion
73	7.21	118	1148.7	1689	28	6.82	0.39	Slightly scale forming and corrosive	6.43	Little scale or corrosion
74	7.68	126	595	1428	30	7.03	0.65	Scale forming but non corrosive	6.39	Little scale or corrosion
75	7.01	369	761.8	4025	31	6.49	0.52	Scale forming but non corrosive	5.96	Light scale
76	7.46	342	1202.4	1043	32	6.24	1.22	Scale forming but non corrosive	5.03	Light scale
77	7.48	94	455.6	1533	30	7.28	0.20	Slightly scale forming and corrosive	7.08	Heavy corrosion
78	7.41	162	704.7	931	29	6.85	0.56	Scale forming but non corrosive	6.29	Little scale or corrosion
79	7.57	114	527.2	959	30	7.11	0.46	Slightly scale forming and corrosive	6.66	Little scale or corrosion
80	7.06	186	671	3304	31	6.83	0.23	Slightly scale forming and corrosive	6.60	Little scale or corrosion
81	7.16	836	1908.9	5999	29	5.79	1.37	Scale forming but non corrosive	4.41	Heavy scale
82	7.32	200	737.9	2373	31	6.74	0.58	Scale forming but non corrosive	6.17	Little scale or corrosion
83	7.26	232	931.8	2695	28	6.64	0.62	Scale forming but non corrosive	6.02	Little scale or corrosion
84	7.21	118	1148.7	1689	30	6.78	0.43	Slightly scale forming and corrosive	6.36	Little scale or corrosion
85	7.41	356	768.8	4340	31	6.50	0.91	Scale forming but non corrosive	5.59	Light scale
86	7.49	120	551.8	1043	32	7.04	0.45	Slightly scale forming and corrosive	6.58	Little scale or corrosion
87	7.28	108	639.1	1274	30	7.06	0.22	Slightly scale forming and corrosive	6.85	Little scale or corrosion
88	7.21	218	643	2471	29	6.80	0.41	Slightly scale forming and corrosive	6.40	Little scale or corrosion
89	7.12	112	572.6	1306	31	7.08	0.04	Slightly scale forming and corrosive	7.04	Heavy corrosion
90	7.3	140	579.6	1470	29	7.02	0.28	Slightly scale forming and corrosive	6.74	Little scale or corrosion

Langelier Saturation Index (LSI), Ryznar Stability Index (RSI)

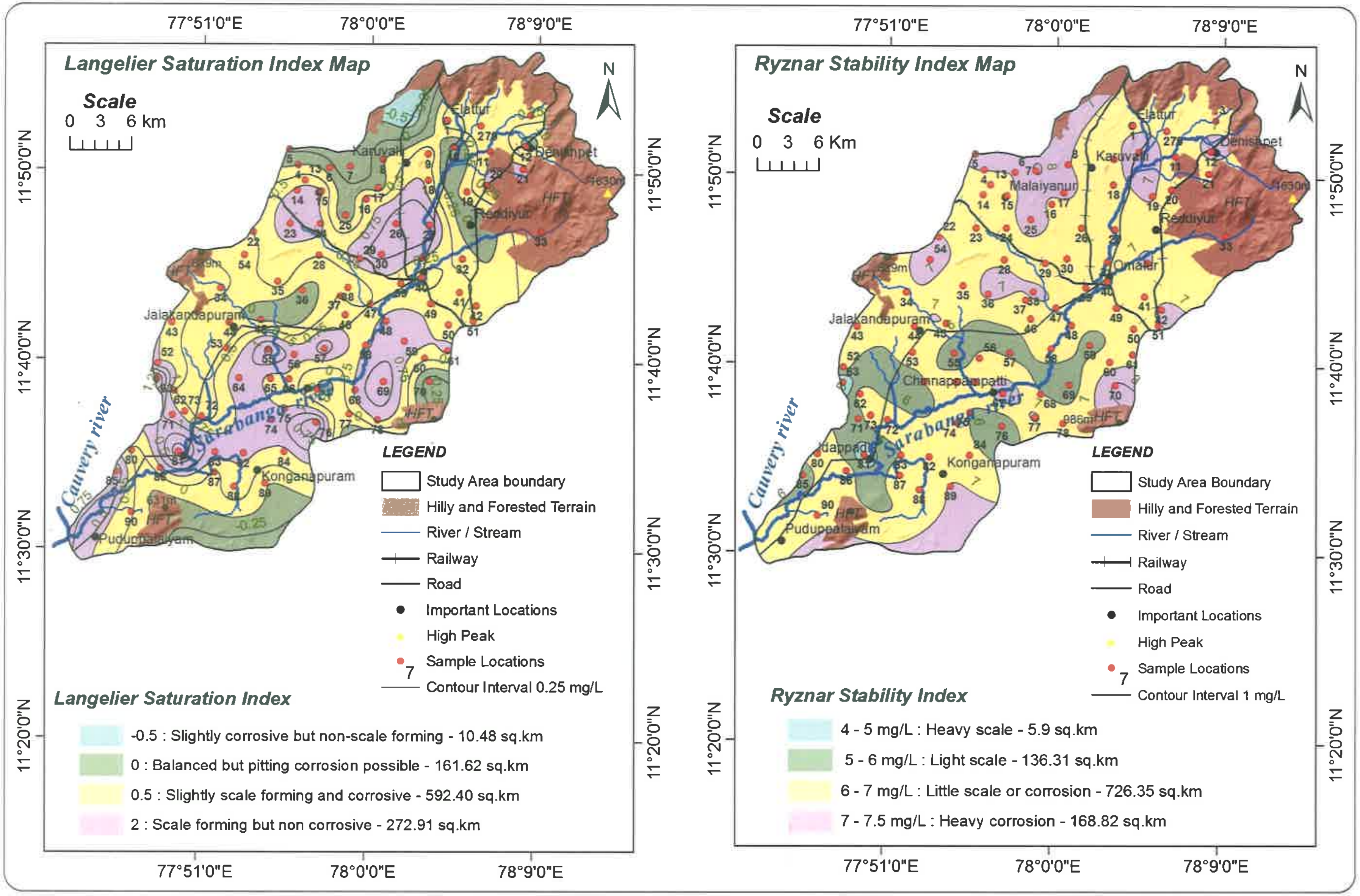


Fig.4.19.Spatial distribution of Langelier Saturation Index and Ryznar Stability Index pre and post monsoon season in the study area.

Potential of water, the primary concerns include the potential presence of Toxic Metals, such as lead and copper; deterioration and damage to the household plumbing, and aesthetic problems such as: stained laundry, bitter taste, and greenish blue stains around basins and drains. The primary health concern is the potential for the presence of elevated levels of lead and copper in the water. The primary source of lead includes the use of lead pipes, lead lined tanks.

4.8.4 Corrosivity Ratio (CR) Tendency of Groundwater

Groundwater extracted from this sub basin for various purposes, is being transported by conventional metallic pipes. These metallic pipes may or may not be suitable for the transport of water. This fact could be highlighted using the corrosivity ratio proposed by Ryzner (1944) have used this index to evaluate the corrosive tendencies of 8 abarmati river waters in Gujarat, and by Balasubramanian (1986) in the Tambaraparani river basin, and Rengarajan and Balasubramanian (1990) in Tamil Nadu, India.

$$\text{Corrosivity Ratio (CR)} = \frac{(\text{Cl ppm}/35.5)+2(SO_4\text{ppm}/96)}{2\,(HCO_3\text{ppm}+CO_3\text{ppm})/100}$$

A corrosivity NCH (ppm) = (Ca+Mg) - (HCO_3 +CO_3) X 50 ratio map has been drawn and the safe zones with CR <1.0 has been delineated. In summer, the safe zone is less than the winter season. It may be added that in unsafe areas Poly Venyl Chloride pipes will have to be used. Spatial Distribution of corrosivity ratio in groundwater during pre and post monsoon seasons has been shown in Fig.4.20.

Nearly all metals will corrode to some degree. The rate and extent of the corrosion depends on the degree of dissimilarity of the metals and the physical and chemical characteristics of the media, metal, and environment. In water that is soft, corrosion occurs because of the lack of dissolved cations, such as calcium and magnesium in the water. In scale forming water, a precipitate or coating of calcium or magnesium carbonate forms on the inside of the piping shown in Pho.6. This coating can inhibit the corrosion of the pipe because it acts as a barrier and also causes the pipe to clog. Water with high levels of sodium, chloride, or other ions will increase the conductivity of the water and promoting corrosion. Corrosion can also be accelerated by.

- Low pH (acidic water)and high pH (alkaline water)
- High flow rate within the piping,
- High water temperature,
- Oxygen and dissolved CO_2,
- High dissolved solids, such as: salts, sulfates,
- Corrosion related bacteria and electro chemical corrosion, and
- Presence of suspended solids, such as sand, sediment, corrosion by-products and rust.

4.9 Correlation Analysis

The correlation matrix forms the basis for factor analysis. Since one of the goals of factor analysis is to obtain "factors" that help to explain these correlations, the variables must be related to each other for the factor model to be appropriate. Correlation coefficient is commonly used to measure and establish the relationship between two variables. It is a simplified statistical tool to show the degree of dependency of one variable to the other. First of all the correlation matrix for all possible pairs of variables, was calculated. A correlation analysis is a bivariate method, was applied to describe the degree of relation between two chemical parameters. The correlation matrixes for 9 variables were prepared for both pre and post monsoon periods. The pictogram of correlation matrix of groundwater has been shown in Fig.4.21. Hydrogeochemical model of groundwater is shown in Fig.4.22. The correlation matrix shows high levels of positive and negative correlations among different elements. The chemical budget of ions in the groundwater of the study area depends on the factors such as anthropogenic activities, rock water interactions, river water seepage and saline water intrusions. (Chan 2001; Giridharan et. al 2008).

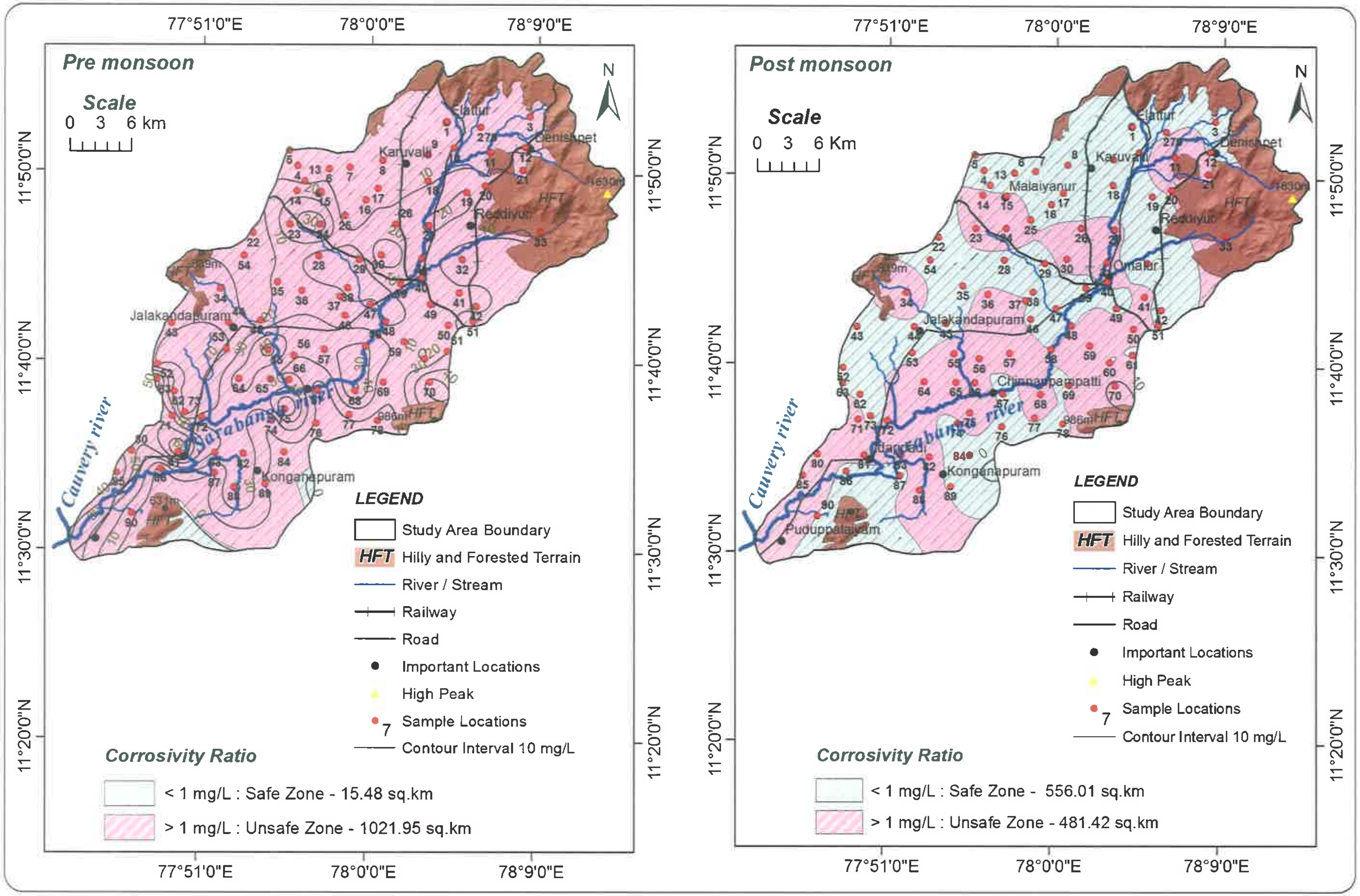
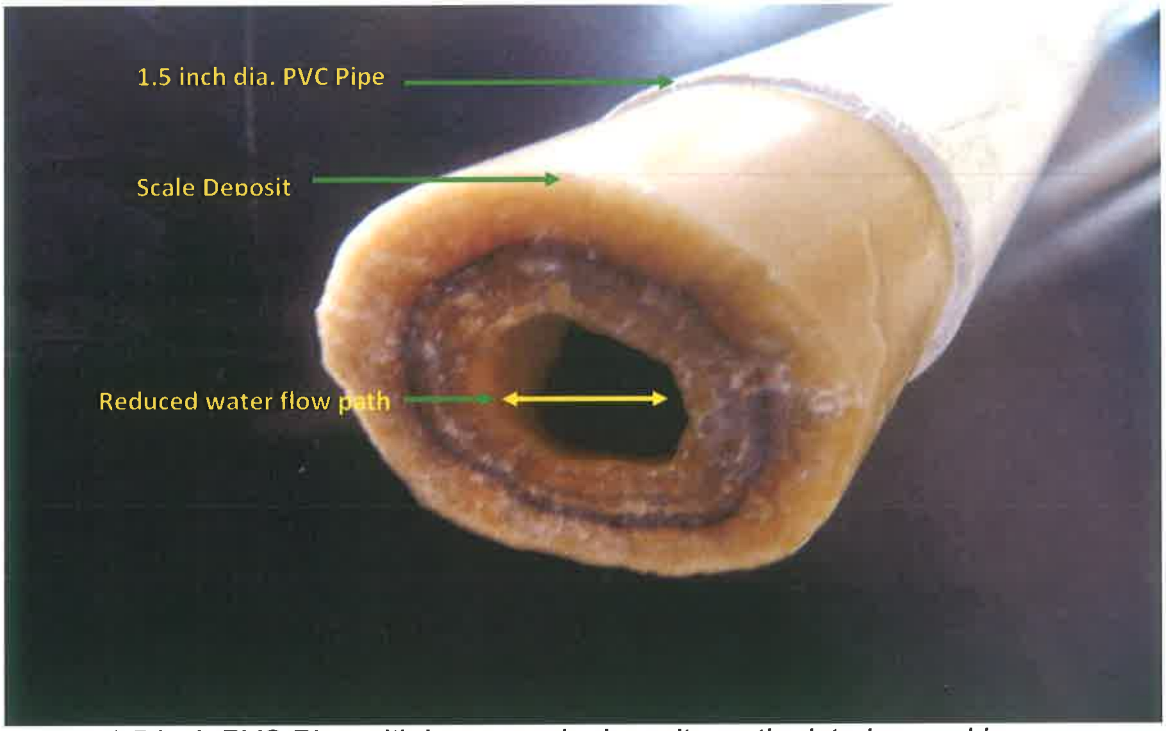
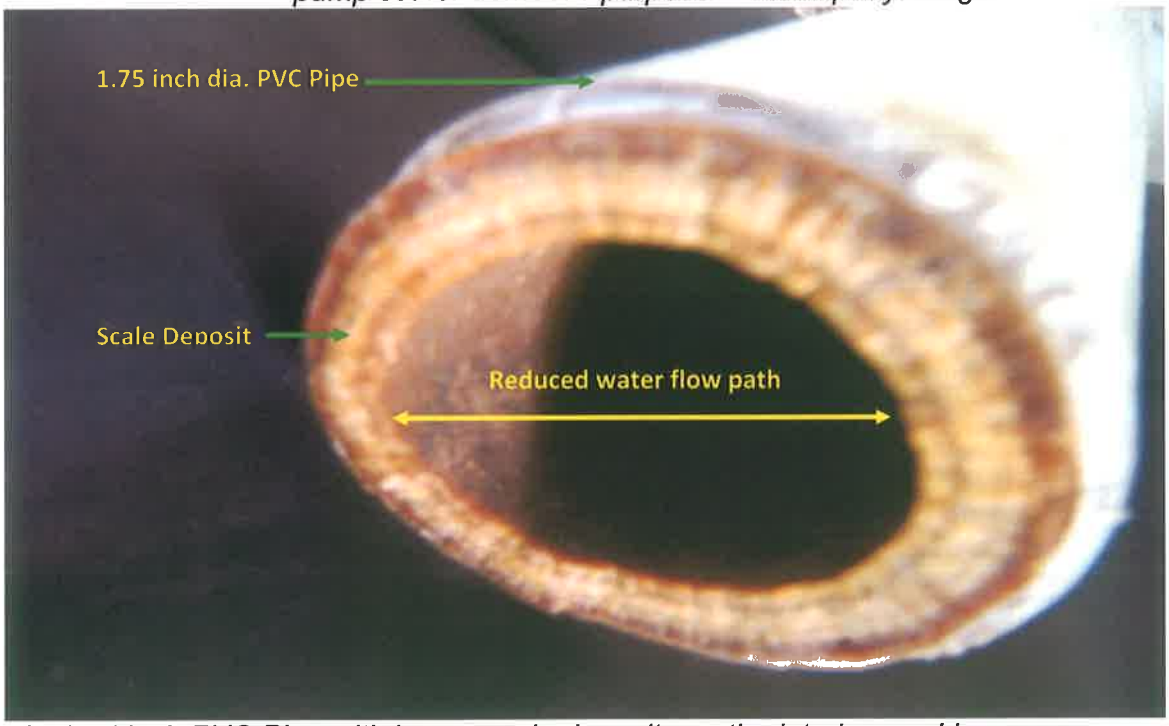


Fig.4.20.Spatial Distribution of corrosivity ratio in groundwater during pre and post monsoon seasons.

Photos-5. Field Photographs showing scale deposits inside the PVC Pipes



a. 1.5 inch PVC Pipe with heavy scale deposits on the interior used in compresso pump set for domestic purpose at Reddipatty village



b. 1.75 inch PVC Pipe with heavy scale deposits on the interior used in compressor pumpset for irrigational use at Konangiyur village

The result of the correlation analysis is considered in the subsequent interpretation. A high correlation Coefficient (near 1 or $^{-1}$) means a good relationship between two variables and its value around zero meant for no relationship between them at significant level (p) of < 0.05. Being more precise it can be said that parameters showing r > 0.6 are considered to be strongly correlated whereas r > 0.5 - 0.6 shows moderate correlation (Kurumbein and Graybill 1965).

Table.4.28 Symmetrical Correlation Matrix of Major Ions - Pre Monsoon

Correlation Matrix for Pre monsoon									
Parameters	**Ca**	**Mg**	**Na**	**K**	**HCO_3**	**NO_3**	**Cl**	**F**	**SO_4**
Ca	1								
Mg	0.751	1							
Na	0.662	0.486	1						
K	0.428	0.312	0.658	1					
HCO3	0.787	0.425	0.727	0.513	1				
NO3	0.412	0.307	0.833	0.586	0.484	1			
Cl	0.766	0.765	0.856	0.576	0.507	0.709	1		
F	0.436	0.400	0.458	0.306	0.425	0.410	0.461	1	
SO4	0.806	0.718	0.693	0.452	0.583	0.414	0.771	0.388	1

The pre monsoon symmetrical correlation matrix of major ions has been given in Table 4.28. A good correlation is exhibited between Ca with Mg, Cl, NO_3 , K, Na; Mg with Cl, NO_3, K, Na; Na with K, NO_3, Cl, HCO_3; K with NO_3, Cl. Cl with SO_4. Ca is strongly correlated with Mg, Cl; K is strongly correlated with NO_3 and K. Moderate correlation exhibits between HCO_3 and other ions. Poor correlation exhibits between F and other ions, SO_4 and other ions. Cl shows good correlation with Ca, Mg and Na indicating dissolution and leaching of secondary salts. This indicates domination of secondary leaching which is a minor indication of chemical weathering along with anthropogenic activities.

Table.4.29. Symmetrical Correlation Matrix of Major Ions - Post Monsoon

Correlation Matrix for Post monsoon									
Parameters	**Ca**	**Mg**	**Na**	**K**	**HCO_3**	**NO_3**	**Cl**	**F**	**SO_4**
Ca	1								
Mg	0.760	1							
Na	0.695	0.599	1						
K	0.415	0.336	0.572	1					
HCO3	0.797	0.417	0.585	0.398	1				
NO3	0.585	0.421	0.623	0.433	0.569	1			
Cl	0.763	0.824	0.894	0.526	0.407	0.555	1		
F	0.328	0.273	0.516	0.301	0.439	0.464	0.385	1	
SO4	0.836	0.710	0.862	0.535	0.624	0.548	0.851	0.330	1

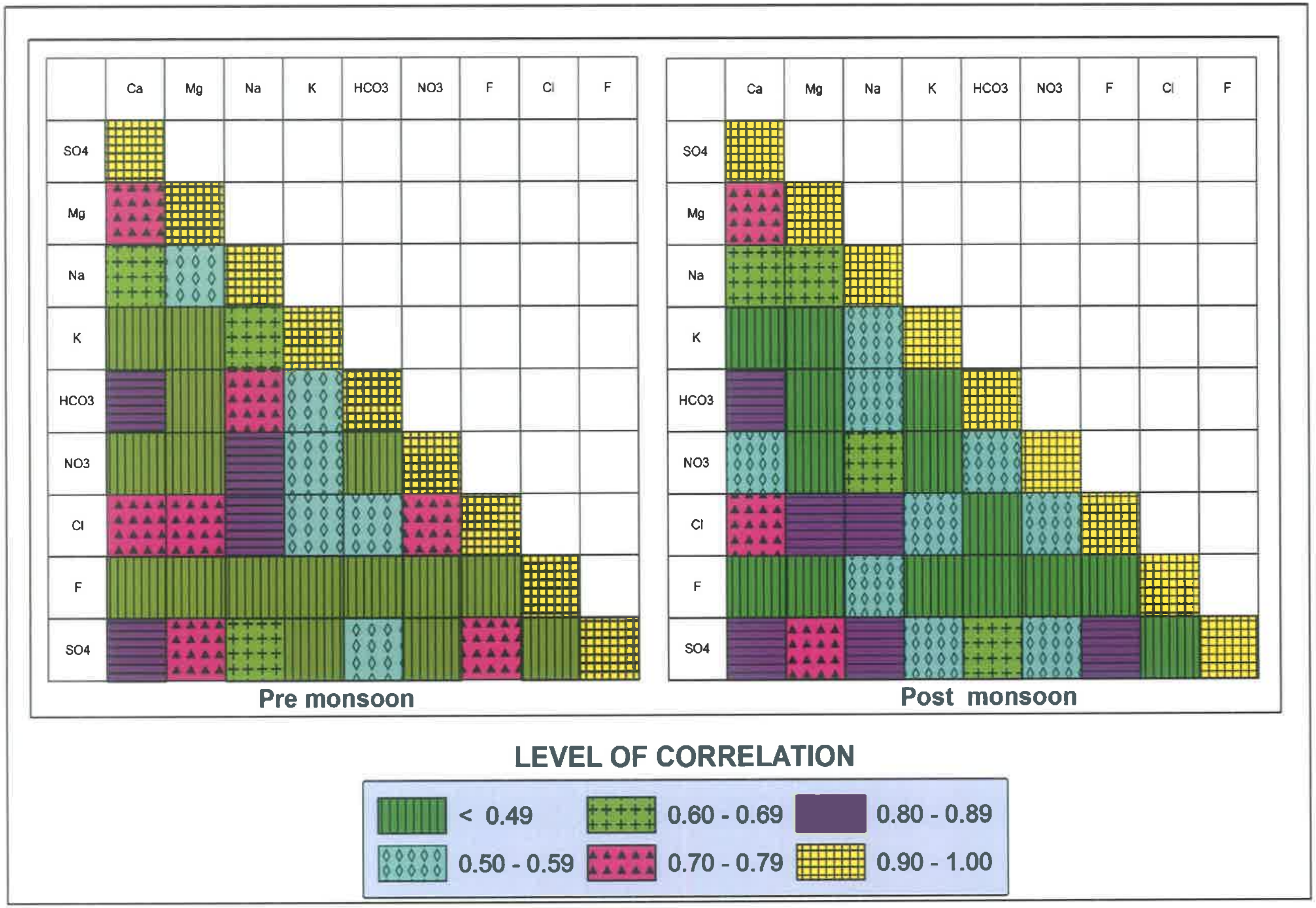


Fig.4.21.Map showing pictogram of correlation matrix of groundwater in the study area

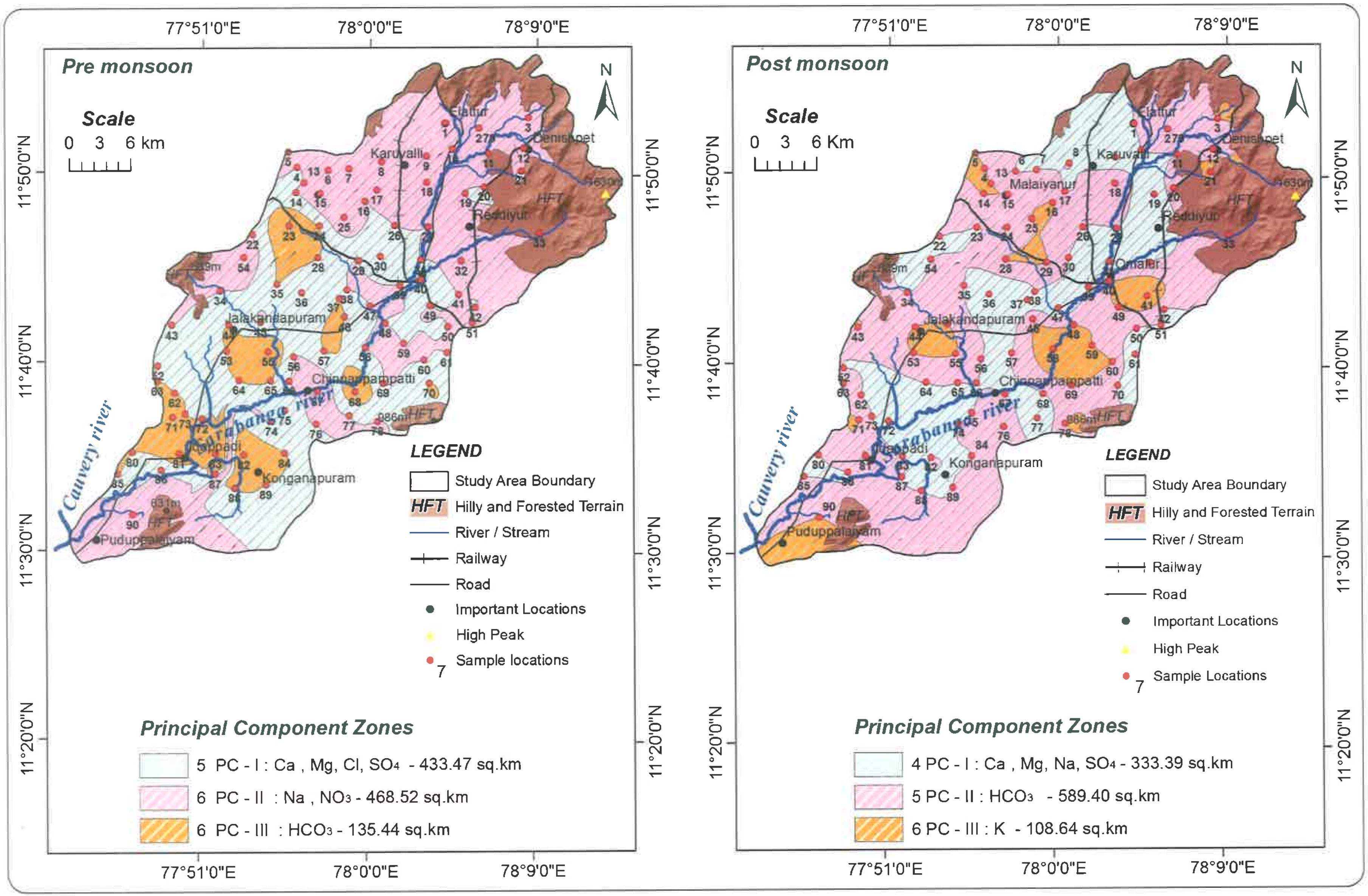


Fig.4.22. Hyderogeochemical model of groundwater in sarabanga sub basin.

Post monsoon symmetrical correlation matrix of major ions has been given in Table.4.29. It has exhibited good correlation between Ca with Mg, Na, Cl, NO_3, SO_4; Mg with Na, Cl, NO_3, K, SO_4 ; Na with , Cl, K, NO_3, SO_4; K with NO_3, Cl, SO_4;Cl with SO_4 ; NO_3 with SO_4, Cl .Ca is strongly correlated with Mg; Mg, Cl, are strongly correlated with Cl; Na with Cl, K, SO_4; Cl with Na, K; Moderate correlation exhibits between Ca and K, Mg, K and other ions. In general domination of secondary leaching, chemical weathering and anthropogenic activities are dominant in the study area. During pre monsoon, the variation of Na with Cl is related to nitrate but in post monsoon, the variation is unrelated to nitrate reflecting that some contribution from the anthropogenic activities is expected in pre monsoon season and the dissolution of dispersed halite would have contributed to the water chemistry during post monsoon. In post monsoon, Cl is correlated with NO_3. This may be due to impact of agricultural practice. In general weathering along with anthropogenic activities is dominant during post monsoon season.

CHAPTER-V

SITE SELECTION FOR ARTIFICIAL RECHARGE

5.1.Weighted Index Overlay Analysis

Weighted Index Overlay Analysis (WIOA) is a simple and straight forward method for a combined analysis of multiclass maps. The efficacy of this method lies in that the human judgment can be incorporated in the analysis. A weight represents the relative importance of a parameter vis-a-vis the objective. WIOA method takes into consideration the relative importance of the parameters and the classes pertaining to each parameter. There is no standard scale for a simple weighted overlay method. For this purpose, criteria for the analysis are defined and each parameter is assigned importance (Saraf and Choudhury, 1998).Determination of weightage of each class is the most crucial in integrated analysis, as the output is largely dependent on the assignment of appropriate weightage. Consideration of relative importance leads to a better representation of the actual ground situation (Choudhury,1999).Considering the hydrogeomorphic conditions of the area, weighted indexing was adopted to delineate groundwater prospective zones and recharge zones.

The present study was been extended further to combine the surfaces created for groundwater quantity parameters such as rainfall, water level, geophysics, geochemistry geology, geomorphology and soil to generate groundwater quantity and quality data of the study area. The idea was to get a scenario that represents the overall situation of the area in context of above parameters at a particular time. In order to have the resultant groundwater information, the surfaces created for three parameters (Good, Medium. Poor) were used as input theme for the model. Weighted overlay analysis technique was used to generate various thematic maps.

Hydrometeorological Data: Rainfall and evaporation are two of the most important parameters, which are required for proper planning of artificial recharge schemes. Detailed information pertaining to the amount, duration and intensity of rainfall in a given area is a necessary pre-requisite for planning recharge schemes.

Evaporation data is useful for assessing the potential losses from the free surfaces of ponds and other surface water storage structures. Data related to daily/seasonal/monthly evaporation losses is helpful for identification of most effective recharge schemes in an area. The period/duration of groundwater recharge with minimum evaporation losses can be determined from this data.

Geophysical Data: Geophysical studies can provide useful information pertaining to the characteristics of subsurface lithological formations, which influence the type of recharge mechanism suitable for a particular area. These studies are normally taken up to complement the data collected through hydrogeological investigations. The main purpose of applying geophysical methods for the selection of appropriate sites for artificial recharge studies is to assess the unknown sub surface hydrogeological conditions economically, adequately and unambiguously. They are usually employed to narrow down the target zone and to pinpoint the probable sites for artificial recharge structures. The application of geophysical techniques is also useful for bringing out a comparative picture of the subsurface litho environment and to correlate them with the hydrogeological setting. Besides defining the subsurface structure and lithology, geophysical studies have been elaborately discussed in earlier chapter V. In the context of artificial groundwater recharge, Geophysical studies are particularly useful for gathering information pertaining to

- Stratification of aquifer systems and spatial variability of hydraulic conductivity of different zones.
- Negative or nonproductive zones of low hydraulic conductivity in unsaturated and saturated zones.
- Vertical hydraulic conductivity discontinuities such as dykes, faults etc.
- Moisture movement and infiltration.
- Direction of groundwater flow under natural/artificial recharge processes.
- Salinity changes in aquifers with depth / saline water ingress.

Aquifer Geometry: The data on subsurface hydrogeological units and their thickness and depth of occurrence are necessary to bring out the disposition and hydraulic properties of the unconfined, semi confined and confined aquifers in the study area. For surface water spreading techniques, the area of interest is generally restricted to shallow depths. The main stress on knows whether the surface rock types are sufficiently permeable to maintain high rate of infiltration during artificial groundwater recharge.

Hydrogeological Data : A detailed understanding of the hydrogeology of the area is of prime importance in ensuring successful implementation of any artificial recharge structure. A desirable first step toward achieving this objective is to synthesize all available data on various hydrogeological parameters from different agencies. Regional geological maps indicate the location of different geological strata, their geological age sequence boundaries/contacts of individual formations and structural expressions like strike, dip, faults, folds, fractures, intrusive bodies etc. These maps also indicate the correlation of topography and drainage to geological contacts.

Maps providing information on regional hydrogeological units, their ground water potential and general pattern of groundwater flow and chemical quality of groundwater in different aquifers are also necessary. Satellite imagery provides useful data on geomorphic units and lineaments, which govern the occurrence and movement of groundwater, especially in hard rock terrain. A detailed hydrogeological study, aimed at supplementing the regional picture of hydrogeological set up available from previous studies, is imperative to have precise information about the promising hydrogeological units for recharge and to decide on the location and type of structures to be constructed.

Hydrogeochemical Data : A detailed study of the quality of source water is vitally important whenever direct recharge techniques are contemplated. In cases where in situ precipitation or water supplied from canals are used for recharge, no constraints on account of water quality may arise. However, in cases where waters in the lower reaches of rivers or recycled municipal/industrial waste waters are proposed to be used, the quality of water requires to be precisely analyzed.

5.2 Infiltration Basin Method

Infiltration basins require a substantial amount of land area with a suitable geology, allowing the water to infiltrate into the aquifer and percolate to the groundwater table. It is simple to maintain and regular restoration of infiltration capacity and removal of clogging layers is relatively easy though time consuming. This method also allows for natural, quality improving processes to take place in the infiltration ponds and subsoil. Construction is normally comparatively simple and low cost. Impermeable topsoil may, however, raise the costs (Herman B., 1996). The infiltration from a recharge basin produces a groundwater mound above the original water table. The groundwater mound grows over time and once the infiltration stops, it decays gradually.

Well Infiltration: Infiltration wells or injection wells are used where permeable soils and/or sufficient land area for surface infiltration are not available. Well infiltration calls for very high quality of the infiltration water if clogging of the well screen and the aquifer in the vicinity of the well is to be avoided. The construction is more complicated and costly and restoration of the hydraulic conductivity around the wells may be unfeasible if not impossible. The best strategy for dealing with clogging of recharge wells is to prevent it by proper treatment of the water before injection. This means removal of suspended solids, assailable organic carbon, nutrients like nitrogen and phosphorous, and microorganisms.

Soil Infiltration: The main problem in infiltration systems for artificial recharge of groundwater is clogging on the infiltrating surface and resulting reduction in infiltration rates. Clogging is caused by physical, biological and chemical processes .Physical processes are accumulation of inorganic and organic suspended solids in the recharge water, such as clay and silt particles, algae cells, microorganism cells and fragments, and sludge flock in sewage effluent. Another physical process is downward movement of fine particles in the soil that were in the applied water or in the soil itself, and accumulation of these fine particles at some depth where the soil is denser or finer, and where the form a thin subsurface clogging layer. The depth of this layer ranges from a few mm to a few cm or more. In the soils literature, this fine particle movement and accumulation deeper down are called "wash out wash in".

Chemical clogging processes include precipitation of calcium carbonate, gypsum, phosphate ($PO4^{3-}$-P), and other minerals, solids and deposits in the soil.

Bacteria also produce gases (nitrogen, methane) that block pores and accumulate below clogging layers to create vapor barriers to infiltration. Gas is also formed in soils below recharge basins or in trenches or wells when there charge water contains entrained or dissolved air and/or is cooler than the soil or aquifer itself. The water then warms up in the soil or aquifer; air goes out of solution and forms entrapped air, which reduces the hydraulic conductivity.

For infiltration basin method, streams are more ideal for recharge. The rate of recharge directly depends upon the permeability of the materials between the bottom of the basin and the water table. Irregular land surface can be used without much preparation (Arul, 2000). Drainage map was prepared and stream order numbers were assigned in GIS platform. Map of streams were selected for analysis. Water level and aquifer thickness maps were used for the overlaying analysis.

Weighted Index Overlay Analysis (WIOA) is a simple and straight forward method for a combined analysis of multi class maps (Saraf and Choudhury, 1998). The weightage of each class is very crucial in an integrated analysis, as the output is largely dependent on the assignment of appropriate weightage. Consideration of relative importance leads to a better representation of the actual ground situation (Choudhury,1999). Considering the hydrogeomorphic conditions of the area, weighted index has been adopted for the Infiltration basin method to delineate the best sites. The maps used for the Infiltration basin method has been given in Table 5.2. The Weightage of the maps to identify suitable recharge areas for Infiltration basin method (water level and aquifer thickness) has been given in Table 5.3.The water level map was superimposed on aquifer thickness map to get a new map (map-1). The resultant map-1 was intersected with drainage map to obtain the final map-2. The results of the final map and village integration map has been given in Table 5.4 and Fig.5.1. The final output map obtained for Infiltration basin method was superimposed over the village index map, to find actual location. Weightage index value 6 and 5 for streams were assigned and demarcated as the suitable and most suitable locations for recharge through Infiltration basin method.

Table 5.2 Assigned weightages for locating Suitable Location Site for Infiltration Basin Method

Class	Weightage	Maps	
		Water level m	Aquifer thickness m
Poor	1	(< 7.34)	(<41.9)
Medium	2	(7.34-10.75)	(41.9 m -69.8)
Good	3	(>10.75)	(>69.8)

Table 5.3 GIS Analysis – Infiltration Basin Method

Sl. No.	Maps used		GIS analysis - operation	Result map
1	Water level	Aquifer thickness	Union	Map – 1
2	Map - 1	Drainage	Intersect	Final Map

Table 5.4 GIS Results – Infiltration Basin Method – Number of Streams and its Class

Sl.No.	Class	No. of streams	No. of Villages
1	Good	54	26
2	Moderate	577	119

For this method, the streams were taken as the best location for recharge. 67.92 km length of the stream falls as best recharge drainage for this method. 633 stream locations have been found suitable for the construction of artificial recharge structures. 54 (11 Villages) out of 629 (43 Villages) stream location area shad been identified as the most suitable sites while rest of the 577 locations had been classified moderate category and 119 villages had been identified as the best locations for Infiltration basin method.

5.3 Ditch and Furrow Method

The ditches may be dug sub parallel to the contours to draw water at an upstream point of the contours and return surplus water to the stream at a downstream point. A series of ditches can be excavated within the riverbed. Common types are contour, lateral and dendritic. In areas of irregular topography, shallow, flat bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge from source stream or canal. Channel method is adopted for natural stream channels by widening, leveling and lengthening them. It is suitable for irregular areas where slopes are too steep for basin construction. Low check dams and dykes can be constructed across a stream where a wide bottom occurs (Arul, 2000). For the selection of site by channel method the following maps such as Drainage map, Land use/Land cover map, Topsoil, Weathered Zone and Fracture Zone Thickness Maps and Slope map were considered.This technique requires less soil preparation than the recharge area and is less sensitive to silting. For the ditch and furrow method, the drainage, slope, land use/land cover and aquifer thickness maps were taken for GIS analysis. The weightages assigned to the individual themes has been given in Table 5.5. GIS analysis details for ditch and furrow method has been given in Table 5.6. The results of the final map and village integration map have been given in Table 5.7 and Fig.5.2. For this method, 76 streams have been identified as the best locations that fell in 21 villages.

Table 5.5 Assigned Weightages for GIS Analysis - Ditch and Furrow Method

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
	Weightage	1	2	3
1	Slope (0 – 5^0)	< 10^0	5 to10^0	> 5^0
2	Land use and land cover	(Other Features)	(Land with scrub)	(Land without Scrub)
3	Aquifer Thickness	(<41.9 m)	(41.9 m -69.8 m)	(>69.8 m)

Table 5.6 GIS Analysis - Ditch and Furrow Method

Sl. No.	Maps used		GIS analysis - operation	Result map
1	Aquifer Thickness	Land use and land cover	Intersect	Map - 1
2	Map - 1	Slope	Intersect	Map - 2
3	Map - 2	Drainage	Intersect	Final map

Table 5.7 GIS Results - Ditch and Furrow Method - Number of Streams and Class

Sl. No.	Class	Area in sq.km	No. of streams	No. Villages
1	Good	105.02	76	21
2	Medium	373.30	904	180

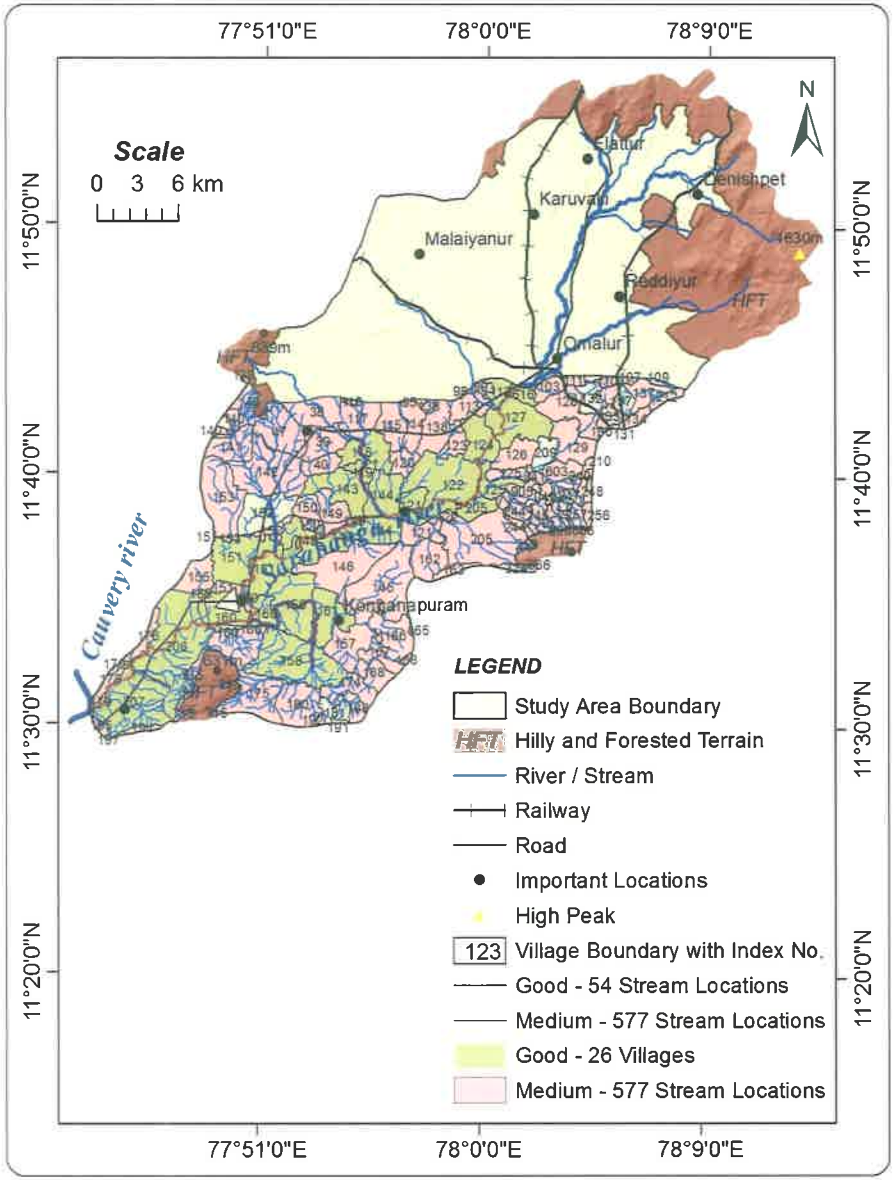


Fig.5.1.Feasible sites for Infiltration Basin artificial recharge structure.

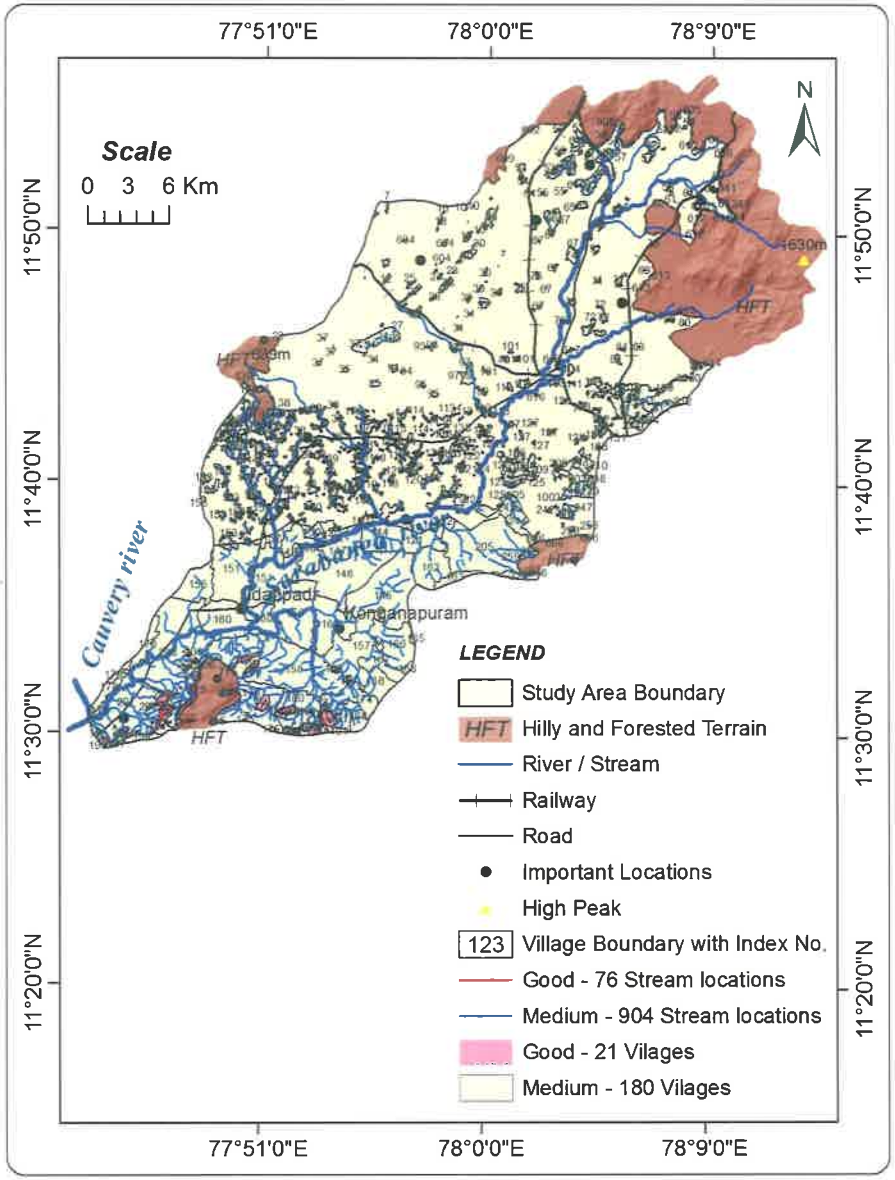


Fig.5.2.Feasible sites for Ditch and Furrow artificial recharge structure.

5.4 Channel Method

Channel method is adopted for natural stream channels by widening, leveling and lengthening them. It is suitable for irregular areas where slopes are too steep for basin construction. Low check dams and dykes can be constructed across a stream where a wide bottom occurs (Arul, 2000). For the selection of site by channel method the following maps such as Drainage map, Land use/Land cover map, Topsoil, Weathered Zone and Fractured Zone Thickness Maps and Slope map were considered.

The weightage factors have been given in Table 5.8. The intersect operation in GIS environment has been used (Table 5.9) in the above order for the demarcation of artificial recharge sites. In the analysis, 980 streams to a total length of 114.58 km. were found to be favorable for the channel method recharge. The GIS final map and village integration map and results have been given in Table 5.10 and Figs. 5.3.Totally 201 villages were identified as favorable for channel method recharge.

Table 5.8 Assigned Weightages for GIS analysis - Channel method

SI. No.	Criteria	Classes		
		Poor	**Medium**	**Good**
	Weightage	**1**	**2**	**3**
1	Slope (0 - 5^0)	< 10^0	5 to10^0	> 5^0
2	Land use and land cover	(Other Features)	(Land with scrub)	(Land without Scrub)
3	Aquifer Thickness	(<41.9 m)	(41.9 m -69.8 m)	(>69.8 m)

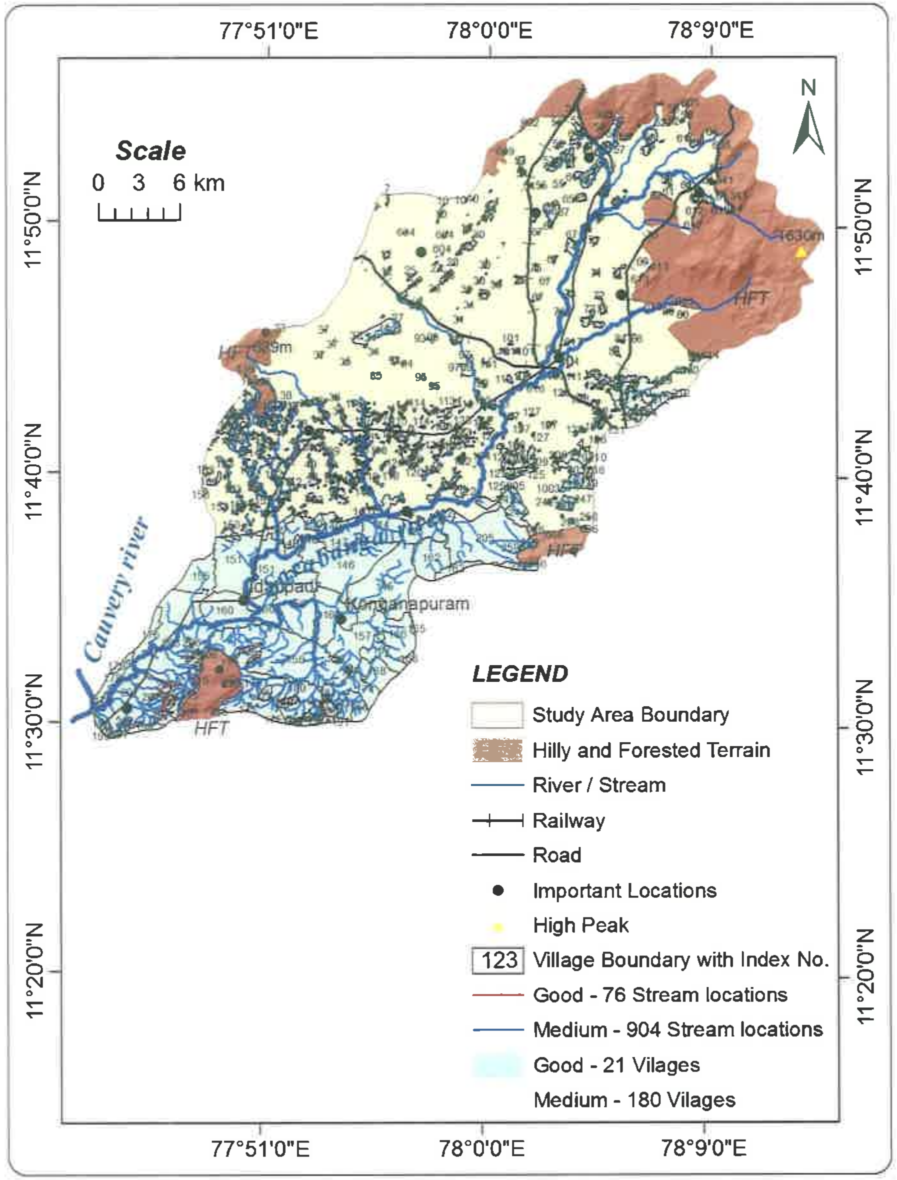


Fig.5.3.Feasible sites for Channel artificial recharge structure.

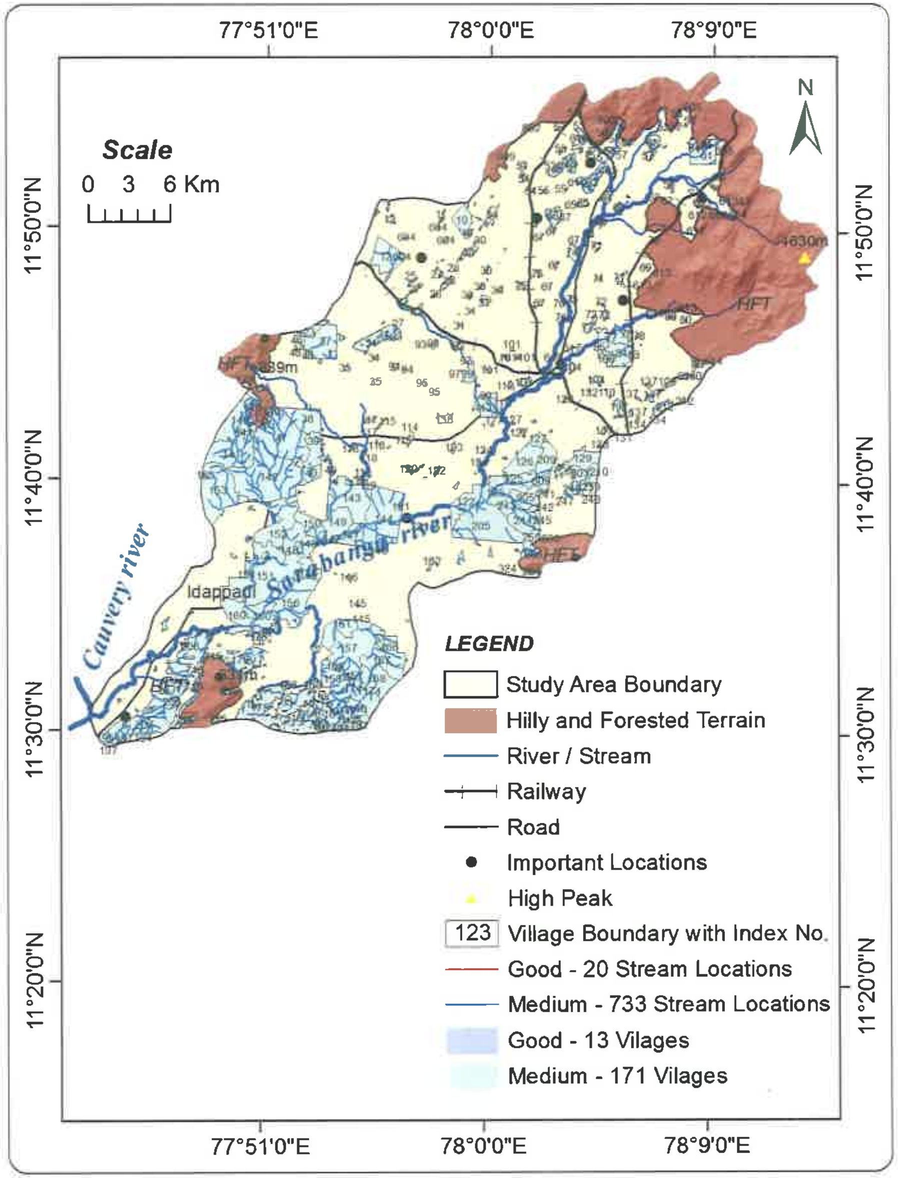


Fig.5.4.Feasible sites for Flooding artificial recharge structure.

Table 5.9 GIS overlay analysis - Channel method

SI. No.	Maps used		GIS analysis - operation	Result map
1	Aquifer Thickness	Land use and land cover	Intersect	Map - 1
2	Map - 1	Slope	Intersect	Map - 2
3	Map - 2	Drainage	Intersect	Final map

Table 5.10 GIS Results - Channel method – Number of streams with its class

SI. No.	Class	Area in sq.km	No. of streams	No. Villages
1	Medium	373.30	904	180
2	Good	105.02	76	21

5.5 Flooding Method

Flooding method involves inundating agricultural or waste lands with a thin sheet of water to a depth of a few centimeters to one meter depending on the nature of the terrain. This method is more suitable for relatively flat terrains. The land use and land cover, slope, soil permeability and soil thickness maps were used for identifying areas suitable for flooding method. The assigned weightages have been given in Table 5.11 and maps were analyzed by means of intersection operation techniques using GIS platform has been given in Table 5.12.

Table 5.11Assigned Weightages for GIS Analysis - Flooding Method

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
1	Slope	> 30%	5-30%	2 (0-5%)
2	Land use and land cover	0	1	2 (Waste land)
3	Top soil thickness m	< 1.9	1 (1.9 – 2.005)	2 (>2.005)

Table 5.12 GIS Overlay Analysis for Flooding Method

Sl.No.	Maps used		GIS analysis-operation	Result map
1	Top soil thickness	Land use and land cover	Intersect	Map- 1
2	Map - 1	Slope	Intersect	Final map

The number of streams with its class has been given in Table 7.13 and village integration map has been given in Fig. 5.4. Flooding method of recharge were constructed in 1.49Sq.km area and 13 villages have been found more suitable locations and 303.06 Sq.km area and 172 villages have been identified as medium range for this method of recharge

Table 5.13 GIS Result - Flooding Method – Number of Streams with its Class

Sl.No.	Class	Area in sq.km	No. of Villages
1	Good	1.49	13
2	Moderate	303.06	172

5.6 Irrigation Method

Recharge by irrigation and agricultural practices also constitute artificial recharge and such recharge is termed as incidental recharge. Recharge in agricultural lands can be enhanced by increasing depression storage and retention of excess rainfall by terracing and contour bundling and by providing protective covers of vegetation (Natarajan and ShambuKallolikar, 2004). This method is specifically designed for paddy cultivated areas. During the preparation of the field for paddy, the soil is made impervious for water retention. Percolation of water in the paddy area is very less. This has serious effect on the recharge of aquifer in this area. A pit is constructed in the field where the slope is maximum. The level of the soak pit is slightly below the optimum level of water in the paddy field. In this way the excess water percolates through the soak pit to the subsoil. The weightage index and GIS analysis are given in Tables 5.14 and 5.15. Isohyetal map (Medium and High Rainfall), Agricultural Land (Land with Scrub and Fallow Land) and Soil Permeability map were taken for the GIS integration. The GIS output results have been given in Table 5.16 and village overlay map in Fig. 5.5. 8 villages have been identified as the best suited locations for this method and categorized as good class for artificial recharge.

5.7 Check Dam Method

Check dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as alluvial formations. The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharging of stored water within a short span of time.

Table 5.14 Assigned Weightages for GIS Analysis - Irrigation Method

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
1	Rainfall	1 Low Rainfall	2 Medium Rainfall	3 High Rainfall
2	Agricultural land	0	0	2 (Land with scrub, fallow land)
3	Soil permeability	0	0	1 (Medium permeability)

Table 5.15 GIS Overlay Analysis- Irrigation Method

Sl. No.	Maps used		GIS analysis - operation	Result map
1	Rainfall	Land use/land cover	Union	Map - 1
2	Map - 1	Soil permeability	Union	Final map

Table 5.16 GIS Result - Irrigation Method – Number Locations with Class

Sl.No.	Class	Area in sq.km	No. of Villages
1	Good	0.72	8
2	Moderate	69.66	141

The following criteria were fixed for check dam site selection like Slope, (Slope 5° - Good, Slope 10° - Medium, Slope More than 20° - Not suitable), Top soil thickness, Weathered zone thickness, Fractured zone thickness (Medium, High thickness), Land use (Irrigation land) and pH Less than 7.5 and more than 8.5. With reference to the above said criteria, maps were taken for an overlay analysis with weightage index in GIS. The weightage index and GIS analysis has been given in Tables 5.17 and 5.18.

The final results have been given in Table 5.19. In this method 732 locations are favorable for the construction of check dam. 70 locations out of 732 sites are more suitable locations for this type of artificial recharge structures. 662 locations are of medium category. Village integration map in Fig. 5.6 reveals that only 19 villages are more suitable locations and 131 villages have been found to be good for check dam construction.

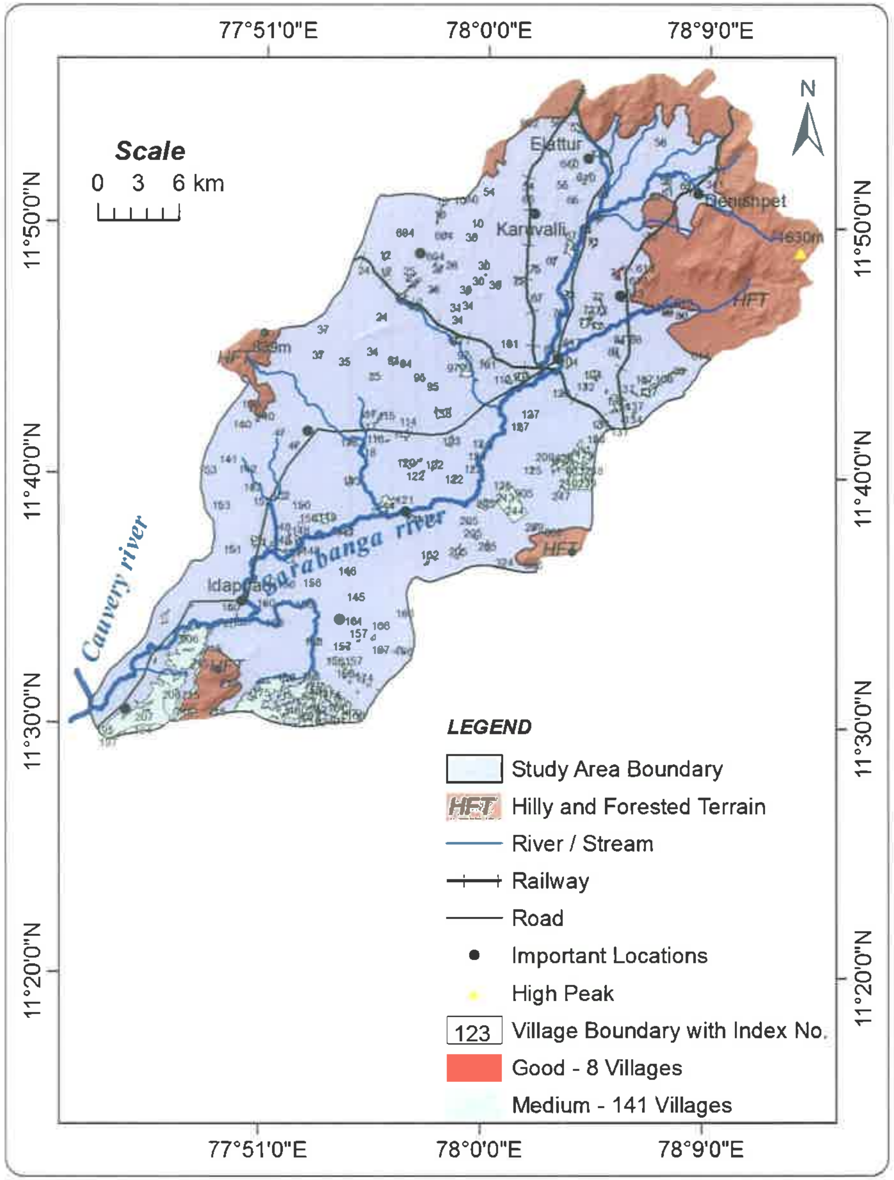


Fig.5.5.Feasible sites for Irrigation artificial recharge structure.

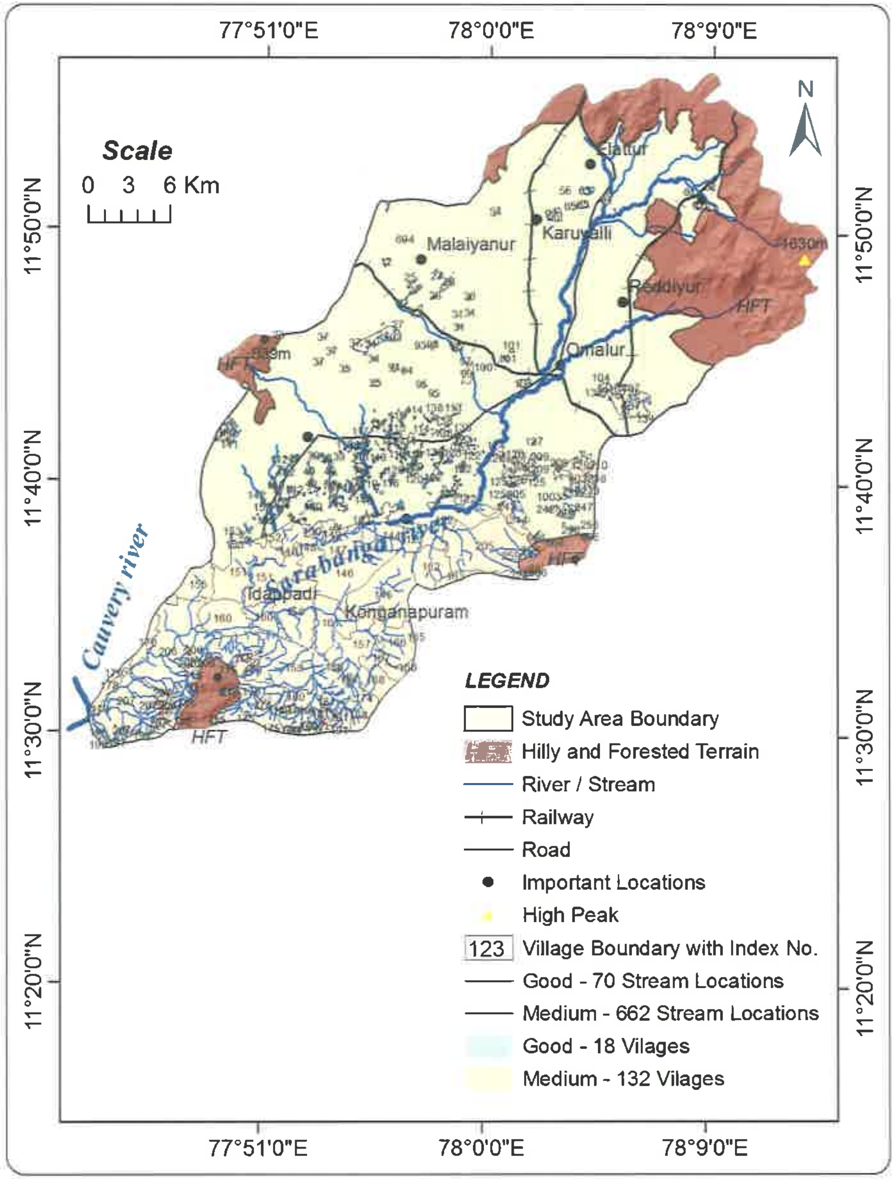


Fig.5.6.Feasible sites for Check Dam artificial recharge structure.

Table 5.17 Assigned Weightages for GIS Analysis - Check Dam

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
1	Slope	1 (Slope >10°)	2 (Slope 5-10°)	3 (Slope 0-5°)
2	Aquifer thickness	1 (<41.9 m)	2 (41.9 m -69.8 m)	3 (>69.8 m)
3	Land use	0	0	2 (Irrigation land)
4	pH	0	0	2 (pH Less than 7.5 and more than 8.5)

Table 5.18 GIS Overlay Analysis - Check Dam

Sl. No.	Maps Used		GIS Analysis - Operation	Result Map
1	Drainage	slope	Intersect	Map- 1
2	Map 1	Aquifer thickness	Union	Map – 2
3	Map 2	Land use	Union	Map – 3
4	Map 3	pH	Union	Map – 4
5	Map 4	Drainage	Intersect	Final map

Table 5.19 GIS Result - Check Dam Method – Number of Streams with its Class

Sl. No.	Class	No. of streams	No. of Villages
1	Good	70	19
2	Moderate	662	131

5.8 Percolation Pond Method

These are the most prevalent structures in India as a measure to recharge the groundwater reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures are more in hard rock formation, where the rocks are highly fractured and weathered. The effectiveness of percolation pond was explained by Elango and Mohan (1997). The percolation tanks are, however, also feasible in mountain fronts occupied by talus and screed deposits. The important aspects considered for the construction of percolation tanks are 2nd and 3rd order streams favorable for recharge and Uncultivable lands most favorable for recharge. Drainage, land use/land cover map, water level and soil permeability maps were used for GIS analysis and feasible locations of percolation ponds were demarcated.

The assigned weightage index depends on favorability of recharge. The weight index and GIS analysis have been given in Tables 5.20 and 5.21. The GIS map and village integration map results have been given in Table 5.22 and Fig. 5.7.

Table 5.20 Assigned Weightages for GIS Analysis - Percolation Pond Method

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
1	Land use/ Land cover	0	0	2 (Waste land)
2	Water level	3 (<7.34 m.)	2 (7.34 – 10.75 m)	1 (> 10.75 m)
3	Soil Permeability	1 (Permeability Slow)	2 (Permeability Moderate)	3 (Permeability) Rapid)

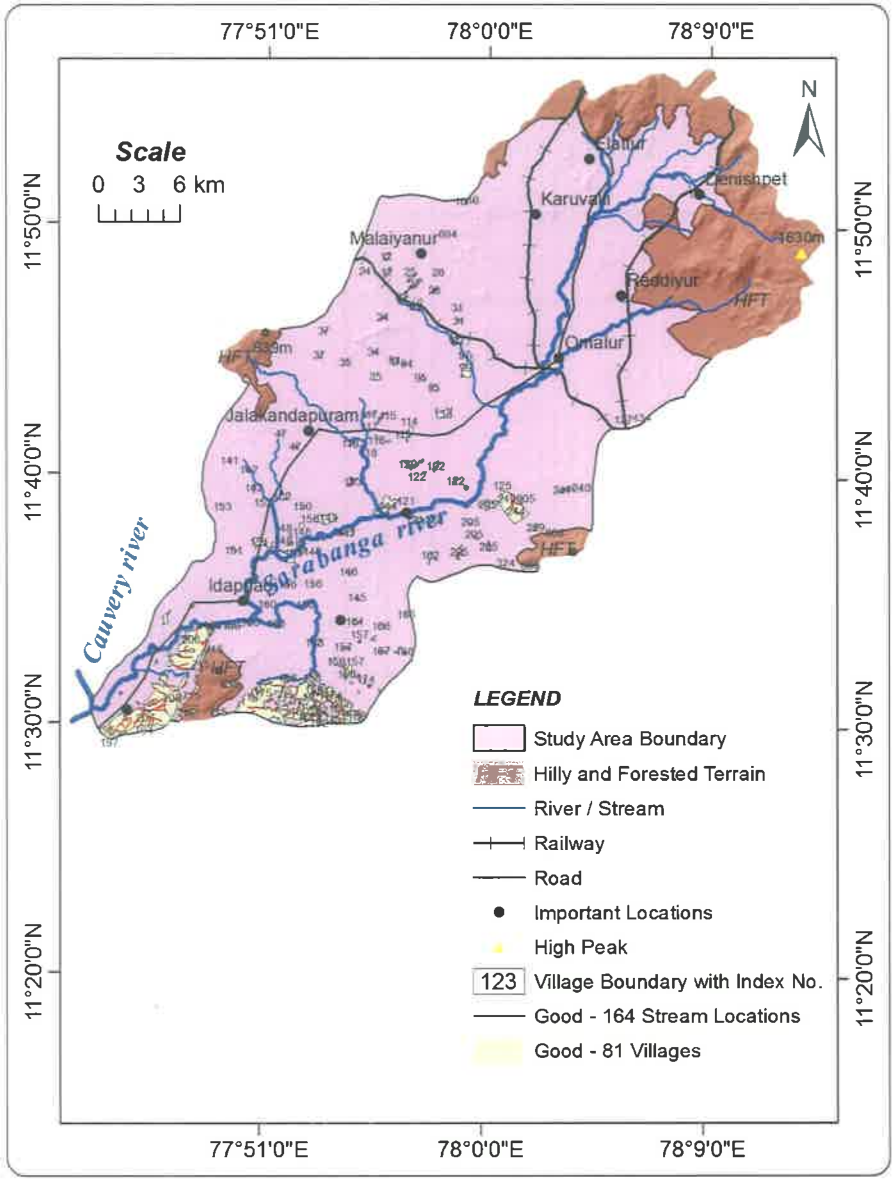


Fig.5.7.Feasible sites for Percolation Pond artificial recharge structure.

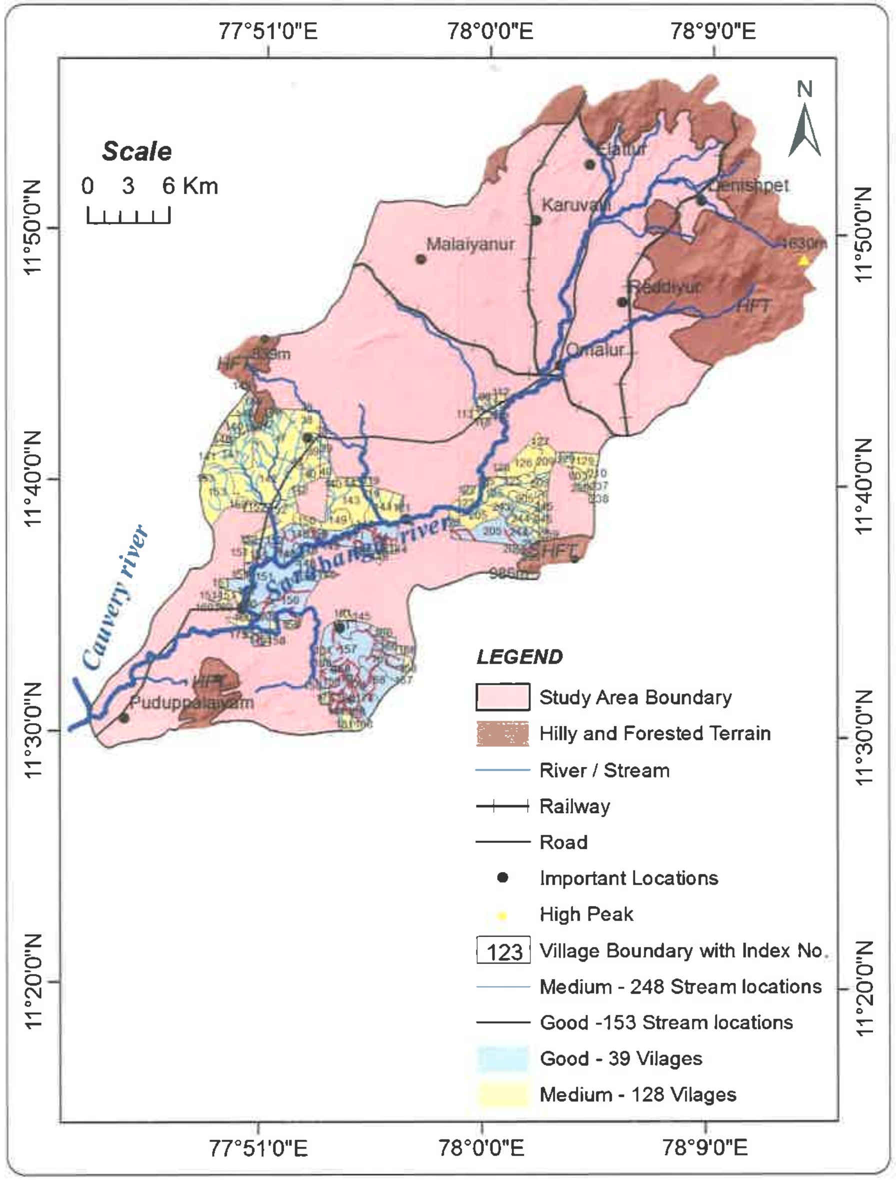


Fig.5.8.Feasible sites for Subsurface Dyke artificial recharge structure.

Table 5.21 GIS Overlay Analysis- Percolation Pond Method

Sl. No.	Maps used		GIS analysis-operation	Result map
1	Drainage (2nd& 3rd order)	Land use and Land cover	Intersect	Map - 1
2	Map - 1	Water level	Intersect	Map - 2
3	Map - 2	Soil permeability	Intersect	Final map

Table 5.22 GIS Result - Percolation Pond/Infiltration Method– Number of Stream with Class

Sl. No.	Class	No. of Streams	No. of Villages
1	Good	164	81

164 locations which fell in 81 villages have been found to be more suitable for this method of recharge. The above said locations have been noticed in deeper water level, waste land, higher soil permeability areas and 1stand 2nd order stream combinations.

5.9 Subsurface Dyke Method

To arrest the subsurface flow of the water, dyke could be constructed on a stream. The construction of dyke helps to exploit the groundwater during summer season. The dyke should not be constructed on the very deep bed rock. Site selection criteria and required maps for subsurface dyke method the following details are required such as Drainage, Slope (moderate), Water table (Medium to high), Aquifer thickness (more topsoil in the upstream side) and Depth to bed rock, shallow down side stream or dyke regions are favorable for the construction of subsurface dykes.

The assigned weightage index to demarcate the most favorable area has been given in Table 5.23. Overlay analysis Table 5.24 has been carried out using the above said maps. GIS output map and village overlay map have been given in Table 5.25 and Fig.5.8.

Table 5.23 Assigned Weightages for GIS Analysis for Subsurface Dyke

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
1	Water level m	1 (> 10.75)	2 (7.34 – 10.75)	3 (<7.34)
2	Aquifer thickness m	1 (<41.9)	2 (41.9 m -69.8)	3 (>69.8)
3	Slope	0	0	2 (0-5°)

Table 5.24 GIS Overlay Analysis- Subsurface Dyke

Sl. No.	Maps used		GIS analysis - operation	Result map
1	Aquifer thickness	Water level	Intersect	Map - 1
2	Map - 1	Aquifer thickness	Intersect	Map - 2
3	Map - 2	Slope (0-5°)	Intersect	Map - 3
4	Map - 3	Drainage	Intersect	Final map

Table 5.25 GIS Output - Subsurface Dyke – Number of Streams with its Class

Sl. No.	Class	No. of streams	No. of Villages
1	Good	153	39
2	Moderate	248	128

153 locations which fell under 39 villages have been found to be more suitable for this method of recharge. The above said locations fall under high aquifer thickness, deeper water level and lower slope areas.

5.10 Nala Bund Method

These dams are constructed on a narrow volleyed nalas to store water. The slope of the upstream side should not be more the 5 % in order to maintain proper balance. Bigger nalas can be constructed in second order stream. A Nala bund acts like a mini percolation tank.

The weightage index and overlay analysis table has been given in Tables 5.26 and 5.27. For site selection rainfall, drainage, slope and aquifer thickness maps were taken and analyzed in GIS. The GIS output has been given in Table 5.28 and Fig 5.9.In this method, 1134 locations fell in 179 villages have been found favorable for the construction of Nala bund.

Table 5.26 Assigned Weightages for GIS Analysis -Nala Bund

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
1	Rain fall	1 Low Rainfall	2 Medium Rainfall	3 High Rainfall
2	Aquifer Thickness	1 (<41.9 m)	2 (41.9 m -69.8 m)	3 (>69.8 m)
3	Slope	0	0	2 (0 – 5°)

Table 5.27 GIS Overlay Analysis -Nala Bund

Sl. No.	Maps used		GIS analysis - operation	Result map
1	Aquifer thickness	Rainfall	Union	Map - 1
2	Map - 1	Slope (0-5°)	Union	Map - 2
3	Map - 2	Drainage	Intersect	Final Map

Table 5.28 GIS Output for the Site Selection of Nala bund with Number of Streams and its Class.

Sl.No.	Class	No. of streams	No. of Villages
1	Good	420	50
2	Medium	714	129

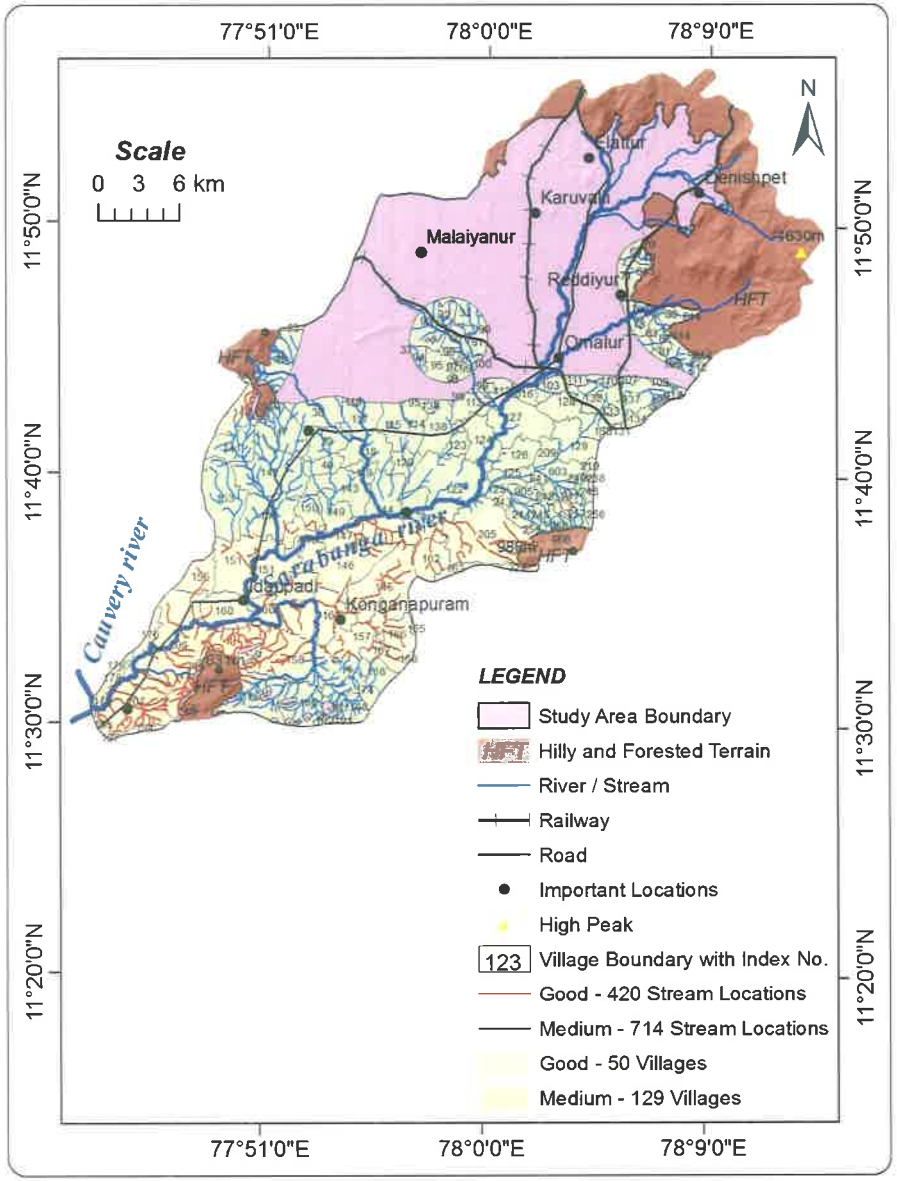


Fig.5.9.Feasible sites for Nala bunds artificial recharge structure.

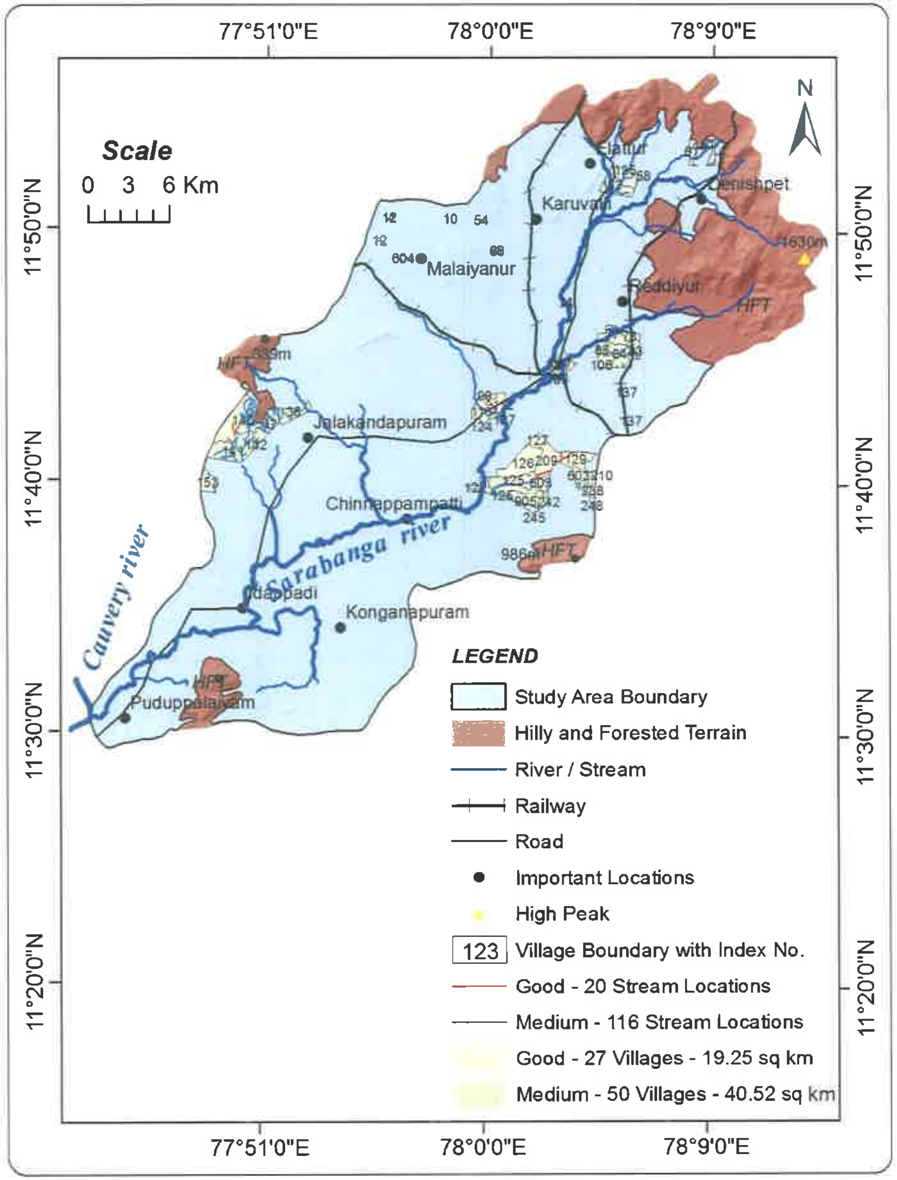


Fig.5.10.Feasible sites for Pit artificial recharge structure.

3.11 Pit Method

Artificial recharging through pit method is applied to the areas where impervious layer is found on the top. For Pit method, the Drainage density map, Water level map, Topsoil thickness map, Soil permeability map and weathered zone thickness map were taken for GIS analysis.

For best site demarcation, the weightage index and GIS overlay analysis criteria used has been given in Tables 5.29 and 5.30. The GIS results with village integration map for site selection have been given in Table 5.31 and Fig.5.10.In this method 136 locations have been identified as favorable for this recharge structure.

Table 5.29 Assigned Weightages for GIS Analysis - Pit Method

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
	Weightage	1	2	3
1	Drainage density	> 5 Km/Sq.km	3 to 5 Km/Sq.km	< 3 Km/Sq.km
2	Water level	(> 10 m)	(5 – 10 m)	(<5 m.)
3	Topsoil Thickness	> 0.54 m	0.54 to 1.36 m	< 1.36 m
4	Soil permeability	(Rapid permeability)	(Moderate permeability)	(Low permeability)
5	Weathered zone thickness	(< 2.77 m)	(2.77 m – 17.91 m)	(> 17.91 m)

Table 5.30 GIS Overlay Analysis- Pit Method.

Sl. No.	Maps used		GIS analysis – operation	Result map
1	Drainage density	Water level	Union	Map - 1
2	Map - 1	Topsoil Thickness	Union	Map - 2
3	Map - 2	Soil Permeability	Union	Map - 3
4	Map - 3	Weathered Zone Thickness	Union	Map - 4
5	Map - 4	Drainage	Intersect	Final map

Table 5.31 GIS Results of Number of Streams with its Class - Pit Method

Sl. No.	Class	No. of streams	No. of Villages
1	Good	20	27
2	Moderate	116	50

5.12 Desilting of Existing Tanks

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure. Most of the tanks are filled with particles like soil, vegetation and other transported materials viz., drainages and streams. This type of tanks can store minimum amount of water, therefore can remove the deposited materials. From the GIS weightage analysis that has been carried out in Sarabanga sub basin Tables 5.32, 5.33 and Table 5.34 and the possible desiltation of already existing water bodies have been shown in Fig.5.11.

Table 5.32 Assigned Weightages for GIS Analysis – Desilting of Existing Tanks

Sl. No.	Criteria	Classes		
		Poor	Medium	Good
	Weightage	1	2	3
1	Aquifer Thickness	(<41.9 m)	(41.9 m -69.8 m)	(>69.8 m)
2	Soil permeability	(Low permeability)	(Moderate permeability)	(Rapid permeability)

Table 5.33 Overlay Analysis for Desilting of Existing Tanks

Sl.No.	Maps used		GIS analysis-operation	Result map
1	Tank	Aquifer Thickness	Union	Map - 1
2	Map -1	Soil Permeability	Union	Final map

Table 5.34 GIS Result of Desilting of Existing Tanks

Sl.No.	Class	No. of Tanks	Area in sq.km	No. of Villages
1	Good	39	51.9	22

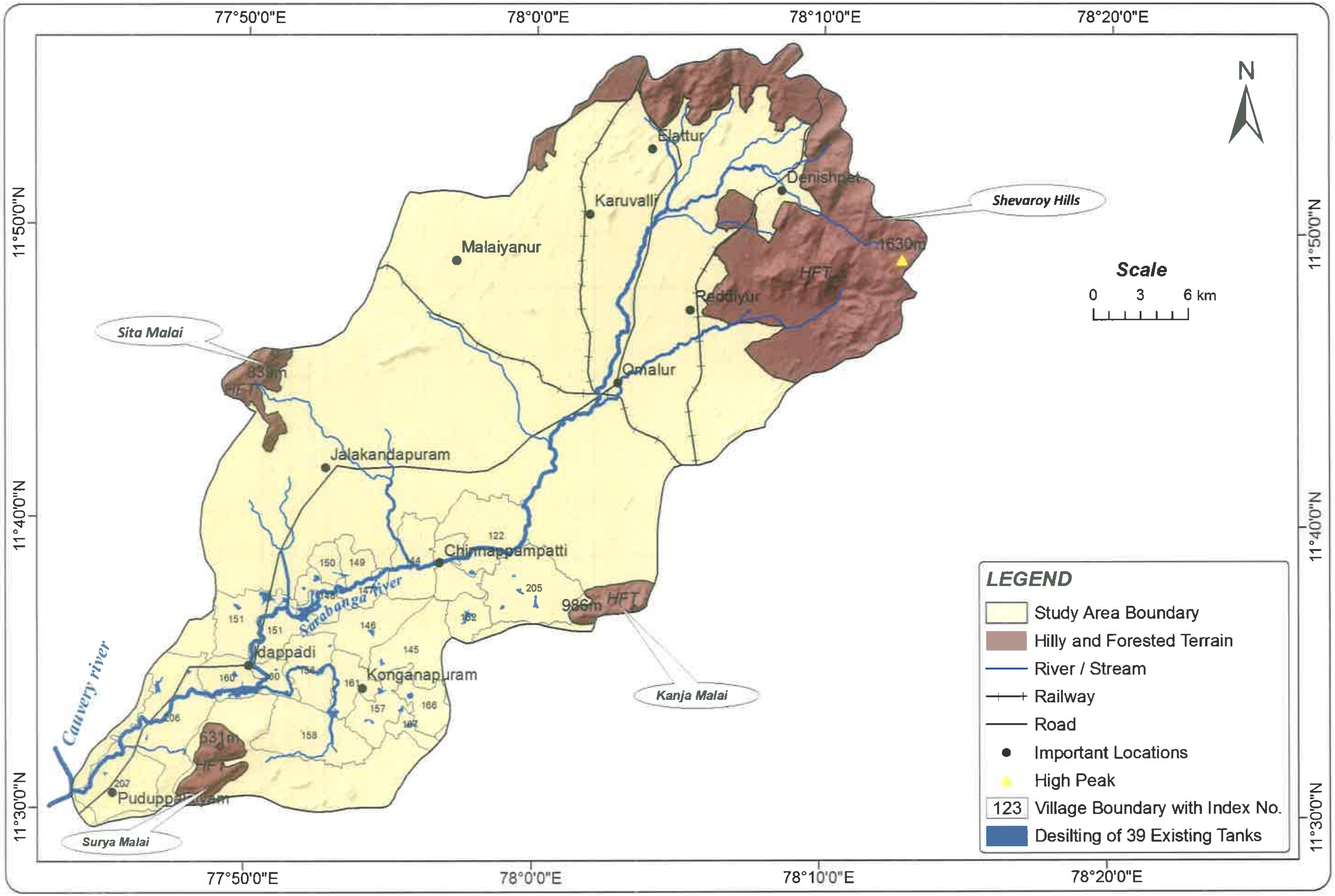


Fig.5.11.Feasible sites for Desilting existing tanks artificial recharge structure.

Table 5.35 Recommended Methods and Village Index Numbers

Sl. No.	Artificial Recharge methods	No. of Villages	Village Index Numbers	Area (sq.km)
1	Basin Method	26	112,118,119,121,122,124,125,127,143, 144,144,147,148,151, 51,156,158,160, 160,160,161, 179,205,206,207,616	218.820
2	Ditch and Furrow Method	21	47,140,147,148,153,157,158,174,175, 180,181,192,195,197 205,206,207,259, 324,666,715	10.502
3	Channel Method	21	47,140,147,148,153,157,158,174,175, 180,181,192,195,197 205,206,207,259, 324,666,715	10.502
4	Flooding Method	13	47,61,140,141,147,148,153,157,158, 174,181,605,666	1.490
5	Irrigation Method	8	70,71,80,83,140,613,614,680	0.718
6	Check Dam	18	147,148,157,158,174,175,180, 181,192, 195,197,205,206,207 259,324,666,715	10.316
7	Percolation Pond Method	81	10,12,24,25,27,28,31,33,34, 35,37,47, 92,93,94,95,97,99, 100,113,114,115, 117,118,120 121,122,125,131,134,137, 138,138,141,142,143,144,145,146,147, 148,149,150,151,151,152 153,156,157, 158,160,160,161 162,166,167,168,174, 175,180 181,191,192,194,195,197,205, 206,207,240,243,244,245,247,259,324, 604,666,715,905,1003	51.901
8	Sub Surface Dyke	39	122,143,144,145,146,147,147 148,148, 149,150,151,151,152 156,157,157,158, 158,160,160 161,166,167,168,168,174, 174 175,175,181,181,205,243,244 259, 259,666,666	84.647
9	Nala Bunds	50	121,122,139,140,143,144,145 146,147, 148,149,150,151,151 152,153,155,156, 157,158,160 160,161,162,163,165,166, 167 168,175,176,178,179,179,194 195, 197,205,206,207,243,244,246,247,257, 259,324,666,715 1003	246.878
10	Pit Method	27	73,74,76,77,99,103,104,112,113,122, 124,125,125,126,127 129,137,140,141, 209,120,237 238,239,248,603,617	19.255
11	Desilting of Existing Tanks	22	122,144,145,146,147,148,149 150,151, 151,156,157,158,160, 160,161,162,166, 167,205,206 207	260.023
	Total	334		915.052

39 tanks which fell in 22 villages have been identified as suitable for Desilting of existing tanks. The numbers of existing tanks have been worked to remove sediments in order to store higher amount of water and in turn enhance

the groundwater storage. Artificial recharge projects through, *i. Infiltration Basin Method, ii. Ditch and Furrow Method iii. Channel Method, iv. Flooding Method, v. Irrigation Method, vi. Check Dam, vii. Percolation Pond Method, viii. Sub Surface Dyke, ix. Nala Bunds, x. Pit Method,* and *xi. Desilting of Existing Tanks* were elaborately analyzed. The important findings has been given in Table.5.35.

The investigations were carried out in accordance with updated hydrogeological methodology. Key findings have been made in GIS environment for identifying micro level village wise favorable areas amenable to different artificial recharge structures have been derived for sustainable development of groundwater resources in the Sarabanga sub basin, Cauvery river. Such advancements will certainly enable us to develop and manage precious groundwater resources in a real sustainable and environment-friendly way.

13. Achievements from the project:

i) **Paper Presented in the National Conference**

- Groundwater prospect zones identification using geophysical data in GIS environment –A case study of Sarabanga sub basin Cauvery River, Tamil Nadu, India conducted by Association of Hydrologists of India and Center for Applied Geology Gandhigram Rural Institute- Gandhigram, Dindigul District, Tamil Nadu. National Seminar on HYDROCARE2012@GRI-DU on 11th &12th December, 2012 Oral Presentation Session-II.
- Delineation of groundwater potential zones using Geophysical and Geospatial Techniques in the Sarabanga sub basin, Cauvery River, Tamilnadu in Coastal Tech-2014. National Conference on Coastal Tech-2014 conducted by Department of Industries and Earth Sciences(DIES),Tamil University, Thanjavur March 13 – 14. (Full Paper published in Coastal Tech-2014 edited volume ISBN: 978-81-928646-6-2).
- Drainage Basin Morphometry to Identifying Zones for Artificial Recharge: A Case Study of Sarabanga Sub Basin, Cauvery River, South India, National Level Conference on Disaster Mitigation and Management towards Sustainable Development (DMSD-2015) held at Periyar University, Salem-11. (Paper presented on 16th April 2015).
- Artificial Recharge Mechanism in the Case of Sarabanga Sub Basin, Cauvery River, South India. National Level Conference on Disaster Mitigation and Management towards Sustainable Development (DMSD-2015) held at Periyar University, Salem-11. (Paper presented on 16th April 2015).
- Identification of Groundwater Potential Zones using Geospatial Techniques in the Sarabanga Sub Basin, Cauvery River, Tamil Nadu. National Level Conference on Disaster Mitigation and Management towards Sustainable Development (DMSD-2015) held at Periyar University, Salem-11. (Paper presented on 17th April 2015).

ii) **Paper Presented in the International Conference**

- Groundwater Quality Mapping using Geospatial Techniques in Sarabanga Sub Basin Cauvery River Tamil Nadu India an International Conference held at Hyderabad. (Paper presented on 29th October 2014).

- Delineation of Artificial Recharge Zones Using Geospatial Techniques in Sarabanga Sub basin, Cauvery River, Tamil Nadu an International Conference held at Mangalore. (Paper presented on 13th March 2015).

iii) Research Paper Publications out of the Project

- S.Venkateswaran1*, M.Vijay Prabhu2 and S.Karuppannan2 Delineation of Groundwater Potential Zones Using Geophysical and GIS Techniques in the Sarabanga Sub Basin, Cauvery River, Tamil Nadu, India. International Journal of Current Research and Academic Review. ISSN: 2347-3215 Volume 2 Number 1 (January, 2014) pp. 58-75.

- Venkateswaran.S, Vijay Prabhu.M, Suresh.M and Suresh.R Morphometric analysis for characterizing landforms study on Sarabanga Sub-basin, Cauvery River, Tamil Nadu, India. International Journal of Lakes and Rivers Vol. 5, No 2(2012) pp. 133-140. Refereed (ISSN 0973 – 4570).

- S.Venkateswaran, M.Vijay Prabhu, M.Suresh and S.A.Palanisamy Assessment of Rainfall Variability in GIS Environment at Sarabanga Sub-Basin, Cauvery River, South India International Journal of Geology, Earth and environmental Sciences 2012 Vol. 2 (2) May-August, pp. 18-24. Refereed ISSN: 2277-2081 (Online) An Online International Journal Available at http://www.cibtech.org/jgee.htm.

- M.Vijay Prabhu and S.Venkateswaran, Delineation of Artificial Recharge Zones Using Geospatial Techniques in Sarabanga Sub basin, Cauvery River, Tamil Nadu published in the Aquatic Proceedia Elsevier International Journals.

- M.Vijay Prabhu and S.Venkateswaran, Groundwater Quality Mapping using Geospatial Techniques in Sarabanga Sub Basin Cauvery River Tamil Nadu India an International Conference held at Mangalore. (Full length paper presented ICHWAM-2014 held at Hyderabad on 29th October 1st November 2014 and published editorial volume-II pages 915-924 edited volume II ISBN:978-81-8424-952-1).

iv) Name and designation of project personnel

Dr.M.Vijay Prabhu- Project Fellow

v) Strengthening Hydrogeology laboratory in the Department of Geology

The following items has been procured out of this project

- Personal computer with printer

- Hand held GPS with Arc Pad Version 10 .
- IRS P6 LISS IV Satellite data product for the entire sub basin
- Chemical and Glasswares
- Text , reference books and reprints.

vi) Name of the M.Phil., scholars who underwent field training

- Mr.R.Kannan
- Mr.A.M.Sakthivel
- Miss.A.Meena
- Miss.V.Priyanga
- Mr.R.Sakthivel
- Miss.T.Sowndharya Devi
- Mr.S.Satheesh kumar
- Mr.G.Prithiviraj
- Miss.V.Logatharunya
- Mrs.K.Divya

vii) Name of the Ph.D., scholars underwent field training

- Mr.R.Ayyandurai
- Miss.S.Deepa

14. Summary of the findings:

Sarabanga river originates on the western slope of Shevaroy hills in Salem District, Tamilnadu, at an altitude of 1630 m amsl. The Sarabanga sub basin lies mainly over the Archaean crystalline rocks and Spatially spread about 767.02 Sq.km, chiefly of Fissile Hornblende Biotite Gneiss, followed by 135.94 Sq.km of Charnockite, 17.87 Sq.km of Syenite, 0.16 Sq.km of Quartzite, 9.25 Sq.km of Ultramafic and 80.25 Sq.km of Granite. Occurrence of groundwater is noticed mainly in the weathered and fractured zones.

The rainfall data interpretation during the period between 2002 and 2011 shows that the rainfall pattern has widely fluctuated. Average annual rainfall ranged from 822.60 mm to 1386.32 mm. The lowest rainfall has been observed in the year 2002. The high rainfall has been noticed in the year 2005. The highest average seasonal rainfall has been recorded during the southwest monsoon of about 406.26 mm, and during the northeast monsoon of about 414.03 mm. The lowest average seasonal rainfall recorded in winter and summer seasons ranges from 5.55 mm and 119.58 mm respectively.

Water level data from 18 observation wells from 2002 to 2011 have been used to prepare a grid deviation water table map. Recharge and discharge zones have been delineated. Artificial recharge projects through infiltration Ponds can be planned in the recharge zone demarcated in the sub basin.

The annual water level fluctuation varies from 2.02 m at Tholasampatti to a maximum of 9.98 m at Konganapuram in the pre monsoon and post monsoon season. The Water level varies from minimum level of 1.58 m at Muthunaichenpatti to a maximum of 10.45 m at Pakkanadu. Studies of selected well hydrographs drawn for a ten year period from 2002 has revealed that a long term declining trend in water table has been observed in some wells. This may be attributed to the over extraction of groundwater. The water table contours generally follow the topography and the groundwater flow generally from northeast to southwest direction.

Geophysical surveys reveal that highly weathered Fissile Hornblende Biotite Gneiss and Charnockite are favourable for groundwater potential zones and massive Charnockites had been observed below 150 m in the selected locations. For the demarcation of groundwater potential zone, a pragmatic approach is needed for the selection of water well sites. The aquifer and its thickness influence the storage of groundwater.

GIS overlay analyses had been carried out to assess the potential zones. Iso Apparent Resistivity ($\rho= \rho_1+ \rho_2+ \rho_3+ \rho_4$) ohm.m and aquifer thickness ($h=h_1+h_2+h_3+h_4$) maps overlay with geology map were carried out and 78 overlay combinations were derived. Out of this, the best 24 combinations viz., *VLR versus VHT* : Fissile Hornblend Biotite Gneiss (23.80 Sq.km), *VLR Vs VHT* : Charnockite (27.60 Sq.km), *LR Versus VHT* : Fissile Hornblend Biotite Gneiss (19.16 Sq.km), *LR Versus VHT* : Charnockite (0.58 Sq.km), *VLR Versus HT* : Fissile Hornblend Biotite Gneiss (51.65 Sq.km), *VLR Versus HT* : Charnockite (10.32 Sq.km), *VLR Versus HT* : Alkaline Rock (0.02 Sq.km), *VLR Versus HT* : Ultramafic/ Ultrabasic rocks (1.32

Sq.km), *VLR Versus HT* : Alkaline Rock (8.66 Sq.km), *LR Versus HT* : Fissile Hornblend Biotite Gneiss (17.47 Sq.km), *LR Versus HT* : Charnockite (0.36 Sq.km), *LR Versus HT* : Alkaline Rock (0.03 Sq.km), *LR Versus HT* : Ultrabasic Syenite Carbonatite Complex (1.90 Sq.km), *LR Versus HT* : Alkaline Rock (2.28 Sq.km), *VLR Versus MT* : Fissile Hornblend Biotite Gneiss (76.38 Sq.km), *VLR Versus MT* : Charnockite (5.43 Sq.km), *VLR Versus MT* : Alkaline Rock (0.09 Sq.km), *VLR Versus MT* : Ultramafic / Ultrabasic rocks (7.48 Sq.km), *VLR Versus MT* : Alkaline Rock (2.76 Sq.km), *VLR Versus MT* : Granitic / Acidic Rock (2.8 Sq.km), *LR Vs MT* : Fissile Hornblend Biotite Gneiss (15.55 Sq.km), *LR Vs MT* : Charnockite (0.61 Sq.km), *LR Vs MT* : Alkaline Rock (0.02 Sq.km), *LR Vs MT* : Granitic / Acidic Rock (0.54 Sq.km) were considered as the best groundwater potential zones in Sarabanga sub basin.

Groundwater samples have been collected from 90 representative wells for pre and post monsoon seasons and analyzed for their major ionic concentration. The groundwater has been classified using the criteria of *Piper's, Gibb's schemes U.S. Salinity Laboratory, Doneen's and Wilcox's schemes.* A set of spatial variation maps depicting for pre and post monsoon seasons viz., *i. Hydrogen ion Concentration (pH), ii. Electrical conductivity (Ec), iii. Total Dissolved Solids (TDS), iv. Calcium ion Concentration (Ca), v. Magnesium ion Concentration (Mg), vi. Sodium ion Concentration (Na), vii. Potassium ion Concentration (K), viii. Bicarbonate ion Concentration (*HCO_3*), ix. Chloride ion Concentration (Cl), x. Sulphate ion Concentration (*SO_4*), xi. Nitrate ion Concentration (*NO_3*), xii. Fluoride ion Concentration (F) and xiii. Corrosivity Ratio Index (CR),* of groundwater has been prepared to project the regional quality behavior of groundwater.

From the Piper's Trilinear diagram, most of the water samples fell under the domain of mixed Ca-Mg-Cl types, Ca-HCO_3, and Ca-Cl type according to the order of dominance. It has been observed that 65% of samples fell under alkaline earths.

Gibb's diagram shows that most of the samples fell in the rock dominant field during the pre and post monsoon seasons. However, some of the samples fell in Evaporation Crystalline Dominance during the post monsoon period. It clearly states that chemical weathering of the rock forming minerals has been the main process which contributed to the ions of the groundwater chemistry changes during pre and post monsoon seasons. U.S. Salinity Laboratory diagrams illustrate that about 37% and 58% of groundwater samples. During the pre and post monsoon seasons fell under C3–S1 category which is suitable for irrigation purposes.

Wilcox's diagram interpretation reveals that 31% and 48% of groundwater samples, During pre and post monsoon seasons fell in the irrigation suitable domain. Doneen's Permeability Index plot shows that the majority of the groundwater samples fell in Class-I category for both pre and post monsoon seasons and it is suggested that it is suitable for irrigation purposes.

In pre monsoon minimum concentration values of Fluoride were observed as 0.2 mg/L at Malaiyanur village and maximum concentration values were observed as 2.6 mg/L in Kalaravallipattipudur village. During the post monsoon, the minimum concentration values of 0.2 mg/L at Amarakundi village have been observed and for the maximum concentration values of 2.4 mg/L at Kalaravallipattipudur village respectively.

The principal components contributing to the chemistry of the groundwater have been identified as follows: The first principal component is weighted on the group Ca, Mg, Cl, SO_4 and Ca, Mg, Na+K for pre and post monsoon seasons. This dominance of the chloride ion is again indicative of the long residence time of groundwater in the aquifer. With the help of the positive scores made by the individual samples with reference to the principal components, hydrogeochemical model has been developed for pre and post monsoon seasons. In general chemistry of groundwater in this sub basin does not seem to be varying much from one season to the other.

Corrosivity map has been drawn using *Langelier's Saturation Index* and *Ryznar's Stability Index* and the safe zone with CR<1.0 has been delineated. In pre monsoon (23 Sq.km) the safe zone is less than that of the post monsoon (638 Sq.km). It may be added that in unsafe areas, Poly Vinyl Chloride (PVC) pipes have to be used.

Artificial recharge projects through, *i. Infiltration Basin Method, ii. Ditch and Furrow Method iii. Channel Method, iv. Flooding Method, v. Irrigation Method, vi. Check Dam, vii. Percolation Pond Method, viii. Sub Surface Dyke, ix. Nala Bunds, x. Pit Method, xi. Desilting of Existing Tanks* can be planned in the study area. Finally *a village Index map* was overlaid with Final Weightage Integration overlay analysis maps have been derived in GIS platform. Various artificial groundwater recharge methods have been analyzed to evaluate the best suitable locations along with village index numbers. The findings have been given below:

S.No	Artificial Recharge Methods	No. of Villages	Area (sq.km)
1	Infiltration Basin Method	26	218.820
2	Ditch and Furrow Method	21	10.502
3	Channel Method	21	10.502
4	Flooding Method	20	1.490
5	Irrigation Method	8	0.718
6	Check Dam Method	19	10.316
7	Percolation Pond Method	81	51.901
8	Sub Surface Dyke Method	39	84.647
9	Nala Bunds Method	50	246.878
10	Pit Method	27	19.255
11	Desilting of Existing Tanks Method	22	260.023
	Total	334	915.052

Percolation Pond, Nala Bunds and Subsurface Dyke methods were the most favorable for artificial recharge structures in the investigated area. The methodology adopted and the results obtained in the present investigation could be used as a positive tool for sustainable development and management practices of groundwater resources in the Sarabanga sub basin, Cauvery River Tamil Nadu.

15. Contribution to the society

Artificial recharge studies are practiced worldwide, so Indian scenario. Some of the research focusing solve this problem. The increasing trend of water leads to affect every life living on the earth. The present study broadly focuses on watershed development through the application of latest technology with the help of integrated various geospatial analyses of Rainfall, Water level, Geology and Geomorphology, Geophysics, Geochemistry. Integrated all the results to finalize suitable localities for artificial recharge structures. The study focus on enhances the groundwater storage and prevent to minimize the water level declined.

16. Whether any Ph.D., enrolled/produced out of the Project

Mr.Vijay Prabhu has been worked as a Project Fellow and awarded Ph.D., degree in the Department of Geology, Periyar University, Salem-11, Tamil Nadu under my guidance and supervision.

17. No of Publications out of the Project:

- S.Venkateswaran[1*], M.Vijay Prabhu[2] and S.Karuppannan[2] Delineation of Groundwater Potential Zones Using Geophysical and GIS Techniques in the Sarabanga Sub Basin, Cauvery River, Tamil Nadu, India. International Journal of Current Research and Academic Review. ISSN: 2347-3215 Volume 2 Number 1 (January, 2014) pp. 58-75.

- Venkateswaran.S, Vijay Prabhu.M, Suresh.M and Suresh.R Morphometric analysis for characterizing landforms study on Sarabanga Sub-basin, Cauvery River, Tamil Nadu, India. International Journal of Lakes and Rivers Vol. 5, No 2(2012) pp. 133-140. Refereed (ISSN 0973 - 4570).

- S.Venkateswaran, M.Vijay Prabhu, M.Suresh and S.A.Palanisamy Assessment of Rainfall Variability in GIS Environment at Sarabanga Sub-Basin, Cauvery River, South India International Journal of Geology, Earth and environmental Sciences 2012 Vol. 2 (2) May-August, pp. 18-24. Refereed ISSN: 2277-2081 (Online) An Online International Journal Available at http://www.cibtech.org/jgee.htm.

- M.Vijay Prabhu and S.Venkateswaran, Delineation of Artificial Recharge Zones Using Geospatial Techniques in Sarabanga Sub basin, Cauvery River, Tamil Nadu published in the Aquatic Proceedia Elsevier International Journals.

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Delineation of Groundwater Potential Zones Using Geophysical and GIS Techniques in the Sarabanga Sub Basin, Cauvery River, Tamil Nadu, India

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KEYWORDS

Groundwater; Sarabanga; Geophysical data; GIS; Potential Zones.

A B S T R A C T

Water plays a vital role in the development of agricultural activities in the study area. The surface water resources are inadequate to fulfill the water demand. Productivity through groundwater is quite high as compared to surface water, but groundwater resources have not yet been properly exploited. Keeping this view, the present study to delineate various groundwater potential zones for the assessment of groundwater availability in the Sarabanga Sub-basin, Cauvery River and Tamil Nadu. 93 Schlumberger Vertical Electrical Sounding (VES) survey were carried out in the study area. The field data were interpreted by IPI2WIN software to determine the resistivity and thickness of the different layers. Results of geophysical data were used to prepare spatial distribution map using GIS. Integration analysis was carried with thickness of first and second layer fracture zone with the corresponding resistivity maps. This map was superposed over geology map. The suitable potential zones for groundwater were delineated from first layers combinations of low resistivity with more thickness in areas occupied by hornblende-biotite-gneisses and Charnockite. The depth for the construction of tube-wells and dug-wells were suggested. The spatial distribution variations in different resistivity layer results are given in the findings.

Introduction

Agriculture is the largest consumer of water in the country, because crop yield depends primarily on two factors, the total amount and the time distribution of water throughout the growing season. This demand will be met out mainly by surface and sub surface water resources. Exploration for groundwater is necessary for agricultural development. Agriculture is the main occupation for the majority of the population of the study area. The main source for irrigation in the area is groundwater. Groundwater is the largest available source of fresh water. It has become crucial not only to find out groundwater potential zones, but also to monitor and conserve this important resource (Rokade *et al*., 2004). GIS overlay analysis is highly helpful in locating the groundwater potential zones (Rokade *et al*., 2007) (Gurugnanam *et al*., 2008).

Schlumberger resistivity survey is the most suitable method for groundwater investigations in hard rock area compared to other geophysical methods. Delineation of fracture zones in low permeability hard rock area is still a very challenging task. Geophysical surveys for groundwater exploration in hard rock areas have been attempted by many authors Ronning *et al*.,(1995), Kaikkonen and Sharma (1997), Ramteke *et al*.,(2001), Krishnamurthy *et al*.,(2003), Sharma and Baranwal (2005),Porsani *et al*.,(2005), Flathe (1955),and Fitterman and Stewart (1986).

GIS has emerged as a powerful technology for instruction, for research, and for building the stature of programs (Openshaw1991; Longley 2000; Sui and Morrill 2004). GIS is an important technology for geologists.

Vertical electrical sounding (i.e. Schlumberger sounding) is effectively used for groundwater studies due to the simplicity of the technique, easy interpretation and rugged nature of the associated instrumentation. The technique is widely used in soft and hard rock areas (Van Overmeeren, 1998,Urish and Frohlich, 1990,Ebraheem *et al*., 1997). However, groundwater investigations in hard rock areas are often more difficult, as tube-wells must be located exactly to be successful. Tube-wells drilled without proper geophysical and hydrogeological study often fail to produce ground water. In the present study, detailed geophysical study was conducted. The interpreted results were taken in to GIS. In GIS, multiple thematic maps overlay analyses were carried out.

Study Area

The study area, lies between the latitudes 11°46’ N to 12°09’39” N and longitudes 78°12’27” E to 78°36’65” E covering an area of 1178.56 km^2. Out of which plain land covers an area of 1015.79 km^2 (Fig.1). The study area falls in Salem district of Tamil Nadu. The major source for recharge of water in this area is rainfall, during monsoon season. The average annual rainfall is 852 mm (2000 to 2009). As the study area is underlain by the Archean crystalline rocks surrounded by wavy hills and hillocks, groundwater mostly occurs in the fractured zones.

Materials and Methods

Base map was prepared from toposheets 57L/4, 8, 58 I/1, and 5 of 1:50,000 scale. The toposheet was registered and digitized for the drainages (Sarabanga sub-basin). The geology map was collected from Geological Survey of India (GSI). The map was traced, scanned, digitized and then taken to GIS. In the field, the rock samples were collected and identified to assess the quantity characteristics of groundwater.

Schlumberger Vertical Electrical Soundings (VES) surveywas carried out at 93 locations (Fig.1). Latitude and longitude of the survey locations was captured using GPS. Geophysical Schlumberger VES

(Vertical Electrical Sounding) survey was carried out maximum electrode spacing of 300 m. The current electrode (AB/2) spacing varied from 1 to 150 m and the potential electrode (MN/2) spacing varied from 0.5 to 15 m. All the data were plotted in the field to check the quality of data and to avoid mistakes. The field data were interpreted by IPI2WIN software to determine the resistivity and thickness of the different layers. Their attributes are added and analyzed in ArcGIS version 9.3 software. Spatial analysis tools were used for the preparation of interpolation map. The maps were interpolated by using inverse distance methods to arrive the spatial distribution map. Integration analysis was carried with thickness of first and second layer fracture zone with the corresponding resistivity maps. This map was superposed over geology map. The suitable zones for groundwater were low resistivity with more thickness in areas. The depth for the construction of tube-wells and dug-wells were suggested in the present investigation.

Result and Discussion

The interpreted sounding results show the top soil thickness and resistivity, weathered zone thickness and resistivity, and fracture zone thickness and resistivity. This result was taken as point information in GIS environment.

Geology

The study area is mainly underlain by fissile hornblendebiotite gneiss,charnockite and granite. Fissile hornblendebiotite gneiss is the dominant group of rocks covering major parts of the study area followed by the charnockite and granite rocks.. Hornblende-biotite-gneiss is relatively porous and can be considered as favorable for groundwater storage (Fig.2). This rock and its associated combinations usually act as a favorable zone for groundwater.

Resistivity and thickness of fracture zones

The results of the analysis giving first layer minimum and maximum resistivity and thickness values is shows in Table 2. The maximum resistivity value was observed in Reddipatti (VES No.63) as 79969 (ohm-m) at a depth of 17.50 m. The high resistivity indicates that the formation is compact at this depth. It is also evidenced in the field that, borehole is drilled near by this location dose not yield good amount of water. Low resistivity values indicate the water bearing formation. The highest fracture zone thickness was observed in Maramangalattupatti (VES No.60) having thickness of 25.5 m with its resistivity of 3.82 (ohm-m). This result shows drastic variation in resistivity and thickness values in the study area. The field evidence also proves that low resistivity (LR) areas with resistivity value of 3.82 ohm-m yield good groundwater at a depth of 25.5 m. Similarly, the high thickness zone indicates good amount of groundwater storage.

The results of the analysis showing minimum and maximum resistivity and thickness in the second layer are shows in Table 5. The maximum resistivity value was observed in Andiyur (VES No.7) as 96130 (ohm-m) at 16.1 m depth. Generally, the said location is favorable for groundwater only during northeast monsoon season. The high thickness and low resistivity values were noticed at Siranganur (VES No.37). This area is

Table.1 Geophysical Investigations Locations and its fracture zone resistivity and fracture zone thickness and total thickness and curve types are briefly mentioned

VES No.	Village Name	Resistivity Ohm-m /Thickness m				Total Thickness 'h' m	Curve Types
		ρ_1 &h_1	ρ_2 &h_2	ρ_3 &h_3	P_4 &h_4		
1	Elattur	11.6/1.61	77/39.82	3890/42.9	0	84.33	A
2	Muttanampatti	1.95/0.93	52507/20.8	51555/57.3	50659/56.2	135.23	KQ
3	Periyavadagampatti	10.7/2.26	487/2.18	37/7.5	3056329.12	41.06	KH
4	Kukkalpatti	10.4/2.06	119/27.5	1596/12	17588/24	65.56	A
5	Kuppakalipatti	108/0.5	210/20.2	36742/9.14	57243.6	73.44	AK
6	Amaram	24.9/0.5	309/3.48	797/12.7	35322.4	39.08	AK
7	Andiyur	15.1/2.69	4012/8.02	4012/7.52	96130/16.1	34.33	A
8	Maniyakkaranur	15.9/1.46	1.43/1.85	7457/21.2	29.4/52.8	77.31	HK
9	Rangappanur	43.4/0.5	30.2/6.24	2393/21.3	2317/26.3	54.34	HK
10	Agraharam	0.019/0.5	8.07/3.41	539/24.9	0.027/53.1	81.91	AK
11	ChinnaYercaud	4.49/1.09	38.6/9.46	235/3.63	5862/6.42	20.6	AA
12	Danishpet	24.2/0.5	37.1/6.77	24.4/17.1	9584/33.3	57.67	KH
13	Kolippatti	255/0.5	58.9/1.1	710/17.1	425/68.1	86.8	HK
14	Karappatti	32.3/3.3	22.7/2.16	4027/7.64	87111/40	53.1	HA
15	Malalyyanur	25/0.56	329/5.96	1141/6.56	326/23.2	36.38	AK
16	Bommiyampatti	525/0.5	85.4/1.58	11.7/6.54	2.44/27.1	35.72	Q
17	Marakkottai	1.76/0.493	2357/8.2	7599/8.56	4979/0.104	17.357	A
18	Kanjinayakkanpatti	10.6/0.672	8.68/92.2	67.6/46.32	5847/13.99	153.19	HK
19	ChinnaNagalur	12.3/0.5	104/7.54	54222/28.6	56457/48.4	85.04	A
20	Tinnappatti	0.173/0.5	315/2.03	36965/19	254/78.5	100.03	AK
21	Kanjeri	22.8/1.67	31.7/7.72	10386/17	70542/45.1	71.49	A
22	Palakkaranur	39.1/1.84	40.1/6.91	54.7/17.2	38217/63.7	89.65	A
23	Kalikavundanur	29.7/1.93	227/4.42	13.7/12.4	28826/41.5	60.25	KH
24	Sengattur	0.68/0.5	4483/18.3	4614/17.7	344/36.3	72.8	k
25	Sattappadi	23/1.54	31.8/7.67	15593/11.4	6449/20.7	41.36	A
26	Semmandapatti	17.2/0.5	163.9/8.9	21843/31.5	4895/35.7	40.9	AK
27	Darapuram	11/1.93	51682/15.2	2379/23.7	6838/43.3	84.13	KH
28	Sattur	28.5/0.5	9.23/9.53	1756/13.2	11655/72.9	96.13	HQ
29	Nangavalli	58.3/2.49	32.2/2.01	290/44.8	56930/32.9	82.2	HA

30	Olaippatti	1.11/0.5	3.96/4.04	381/5.54	398/38.9	48.98	A
31	Maramangalam	1.85/0.51	66792/0.255	34.9/36.5	9037/79	116.265	KH
32	Palikkadai	1.77/0.5	2126/24.9	3.19/30.3	3.31/33.1	88.8	KQ
33	Balbakki	1.36/0.5	4.285/3.86	27196/8	187/7.39	19.75	AQ
34	Mailappalaiyam	6015/2.93	4.74/16.3	6542/30.5	84.5/52.8	102.53	HQ
35	Sanarpatti	523/0.503	1.25/0.518	105/38.4	743/33.1	72.521	HA
36	PeriyaSoragai	0.622/0.5	51.2/13.2	15382/31.3	196/35.6	80.6	AQ
37	Siranganur	55.2/1.82	251/0.812	10.8/16.3	4546/109	127.932	KH
38	Amarakundi	809/1.16	855/0.877	163/39.4	32.6/39.7	81.137	Q
39	Periyerippatti	22/1.83	2244/3.65	152/20.1	3692/53.6	79.18	KH
40	Vellakavundanur	6545/0.547	37.1/3.7	56796/35.1	3978/36.1	75.447	HK
41	Omalur	32.8//1.95	4215/4.7	116/18.4	1058/45.8	25.05	KQ
42	Vettalaikkaranur	58.6/1.9	126/2.36	527/42.8	7715/25.7	72.76	AA
43	Karuppur	0.104/0.949	31.3/2.59	36.9/5.93	5289/35.4	44.869	AA
44	Jalakandapuram	47.3/4.11	178155/8.47	194/42.9	261/59.4	114.88	KH
45	Chinnakovundanur	16.2/0.51	1261/5.8	1082/16	5990/52.7	75.01	AA
46	Vellakkalpatti	39.7/0.902	0.826/1.09	4528/25.9	174/15.6	43.492	HK
47	Chikkampatti	0.63/1.86	3756/2.59	0.189/11.17	490/27.4	43.02	KH
48	Mottaiyanteruvu	10.1/2.94	97639/16.6	142/43.6	2614/31.3	94.44	KH
49	Ellavur	0.627/0.5	11.5/1.1	5.11/19	0.603/43.7	64.3	AQ
50	Pakalpatti	5.31/0.5	10.21/5.43	13.4/15.9	11695/31.3	53.13	AA
51	Nallakovundanpatti	0.031/0.5	13.2/2.49	27/4.68	1903/25.7	33.37	AA
52	Puliyampatti	63.1/2.26	957/7.4	31/27.9	9505/50.6	88.16	KH
53	Ramakavundanur	90.2/3.52	771/4.59	184/11.3	2709/24.6	44.01	KH
54	Sivadanur	25.4/1.95	1490/5.13	215/15.4	25083/43.4	65.88	KH
55	Nattakkattanur	2.56/1.19	8.71/7.52	1.48/12.5	22296/2.19	23.4	KH
56	Tadikaranpatti	3.54/0.5	2797/0.175	24.4/4.93	32041/53.1	58.705	KH
57	Kuttakkattanur	14.4/0.5	2382/0.76	56.6/3.46	614/101	105.72	KH
58	Attikkattanur	32.3/1.22	228/1.6	22.5/35.1	6326/53.9	91.82	KH
59	Kanganur	20.6/3.31	88/9.23	2665/5.75	299/26.2	44.49	AA
60	Maramangalattupatti	24.8/1.48	5.15/35	3.82/252	33.8/93.38	381.86	QH
61	Sarkar Gollapatti	72.7/3.74	20.3/0.789	3827/1.66	39.3/9.71	15.899	HK
62	Nattappatti	21.1/0.5	64623/2.38	21623/5.16	1985/18.2	26.24	KQ

63	Reddippatti	87.5/4.13	9969/3	79969/17.5	254/99.7	124.33	AK
64	Panmalaiyur	4.34/1.4	1634/3.18	110/6.16	2512/11.2	21.94	KH
65	Tirumalur	5.3/0.5	4176/2.25	62.9/7.09	2198/44.1	53.94	KH
66	Samudram	62.1/4.61	129/9.66	2871/32.4	1735/0.663	47.333	AK
67	Upparappatti	9.37/4.12	1354/5.12	4423/41.5	22/94	144.74	AK
68	Chinnappampatti	1479/0.331	33.4/3.28	4240/13.9	1.66/106	123.511	HK
69	Mattaiyampatti	23.3/3.86	2.73/1.55	585/5.29	4491/24.4	35.1	HA
70	Sittanur	95.6/4.01	106/12	503/28.3	95.5/19.8	64.11	AK
71	Nallakkampatti	85.9/0.77	2.32/2.52	48912/32.4	9.29/50.4	86.09	HK
72	Makkanur	84.2/0.5	120/1.37	160/13.5	2570/6.83	22.2	AA
73	Kottapalayam	1.58/1.65	1557/5.27	1736/21.6	537/22.3	50.82	KQ
74	Kartikanakkanur	119/4.66	488/13.2	301/24.7	9411/31.3	73.86	KH
75	Oddapuram	85.7/0.957	17.5/1.67	48.8/8.97	6481/55.5	67.097	HA
76	Kottapalayam	65/6.57	7260/13.1	1758/5.9	718/12.3	37.87	KQ
77	Sadayampalayam	68.6/0.678	14.3/8.02	1260/23.2	7045/40.1	71.998	HA
78	Pachchallyur	51.4/2.82	98.2/0.197	294/8.7	2782/14.9	26.617	AA
79	Konangiyur	8133/0.16	78/0.918	344/2.62	31.6/8.68	12.378	HK
80	Velaiyachettippatti	0.216/0.5	475/13.1	825/26.6	9188/60.8	101	KA
81	Nallanampatti	567/1.62	2127/2.39	301/9.69	7696/19	32.7	KH
82	Pattakkaranur	448/1.31	14/4.87	19710/63.1	66105/66.2	135.48	HA
83	Kalaravallipattipudur	103/2.34	6.56/0.914	1129/2.57	124/16.6	22.424	HK
84	Nachchiyur	10.6/4.32	3188/1.22	1161/6.88	3635/59.1	71.52	KH
85	Kundarasampalayam	112/0.5	376/2.66	500/17.1	3336/6.25	26.51	AA
86	Ayyampalayam	112/0.5	376/2.58	496/15.4	1472/13.1	31.58	AA
87	Tannirdasanur	57/1.4	150/2.44	37.9/4.63	8200/61.7	70.17	KH
88	Marikavundankuttai	81.9/1.28	224/2.38	25.3/8.27	49606/40.9	52.83	KH
89	Annamalaipalaiyam	16.2/1.53	181/0.859	8.9/2.06	894/63.4	67.849	KH
90	Kavadikkaranur	4.59/0.974	59377/1.6	2166/24.1	29706/79.5	106.174	KH
91	Madattur	85.9/4.94	2769/2.12	155/11.6	39634/58.6	77.26	KH
92	Kurukkuparaiyur	16/0.59	10.8/3.27	176/12.6	166/30.64	47.1	HK
93	Pullipalikadu	14.6/1.44	39/7.79	7367/2.22	142/24.6	36.05	AK

Table.2 Maximum and minimum values of first layer resistivity and thickness variation in entire Sarabanga Sub-Basin

Max./Min.	Village Name	Fracture zone Resistivity and Thickness	Village Name	Fracture zone Thickness and Resistivity
Maximum	Reddipatti (63)	79969 Ωm. (17.5 m)	Maramangalattupatti (60)	252 m.(3.82 Ωm)
Minimum	Chickampatti (47)	0.189 Ωm. (11.17 m)	Salur (52)	1.66 m. (3827 Ωm)

Table.3 Maximum and minimum values of second layer resistivity and thickness variation in entire Sarabanga Sub-Basin

Max./Min.	Village Name	Fracture zone Resistivity and Thickness	Village Name	Fracture zone Thickness and Resistivity
Maximum	Andiyur (7)	96130 Ωm. (16.1 m.)	Siranganur(37)	109 m. (10.8 Ωm.)
Minimum	Agraharam(10)	0.027Ωm. (53.1 m)	Marakottai (17)	0.104 m. (7599Ωm.)

Table.4 Spatial distribution results of first layer resistivity of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone - First layer resistivity (Ohm-m)	Area in Km^2	Area in Percentage
Very low resistivity	Less than 917.58	174.68 km^2	17.17 %
Low resistivity	917.58 – 6394.38	557.38 km^2	54.78 %
Medium resistivity	6394.38 – 29214.39	258.48 km^2	25.40 %
High resistivity	More than 29214.39	26.90 km^2	2.64 %

Table.5 Spatial distribution results of first layer thickness of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone - First layer thickness (m)	Area in Km^2	Area in Percentage
Low thickness	Less than 10.48	235.77 km^2	22.73 %
Medium thickness	10.48 to 21.29	239.64 km^2	23.10 %
High thickness	21.29 to 40.94	449.17 km^2	43.30 %
Very high thickness	More than 40.94	112.86 km^2	10.88 %

Fig.1 Geophysical survey and water sample collection locations of entire Sarabanga Sub-basin (Interval between the two points average of 4Kms)

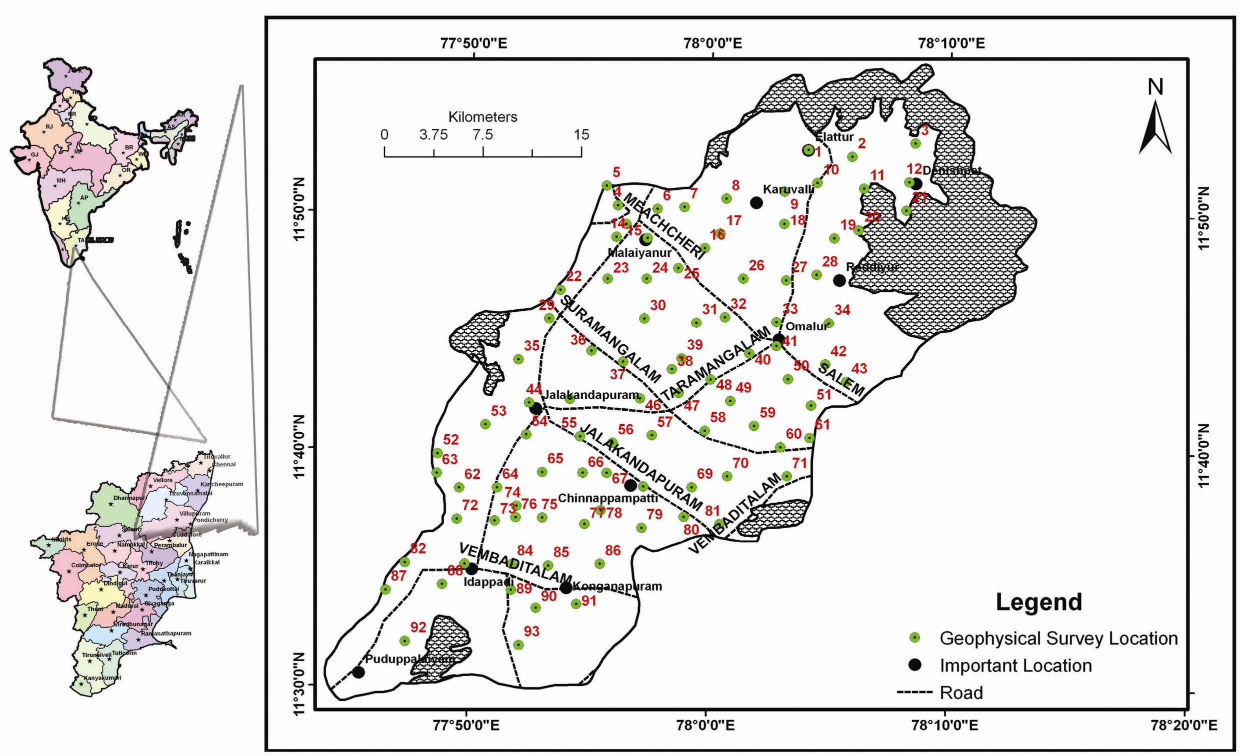
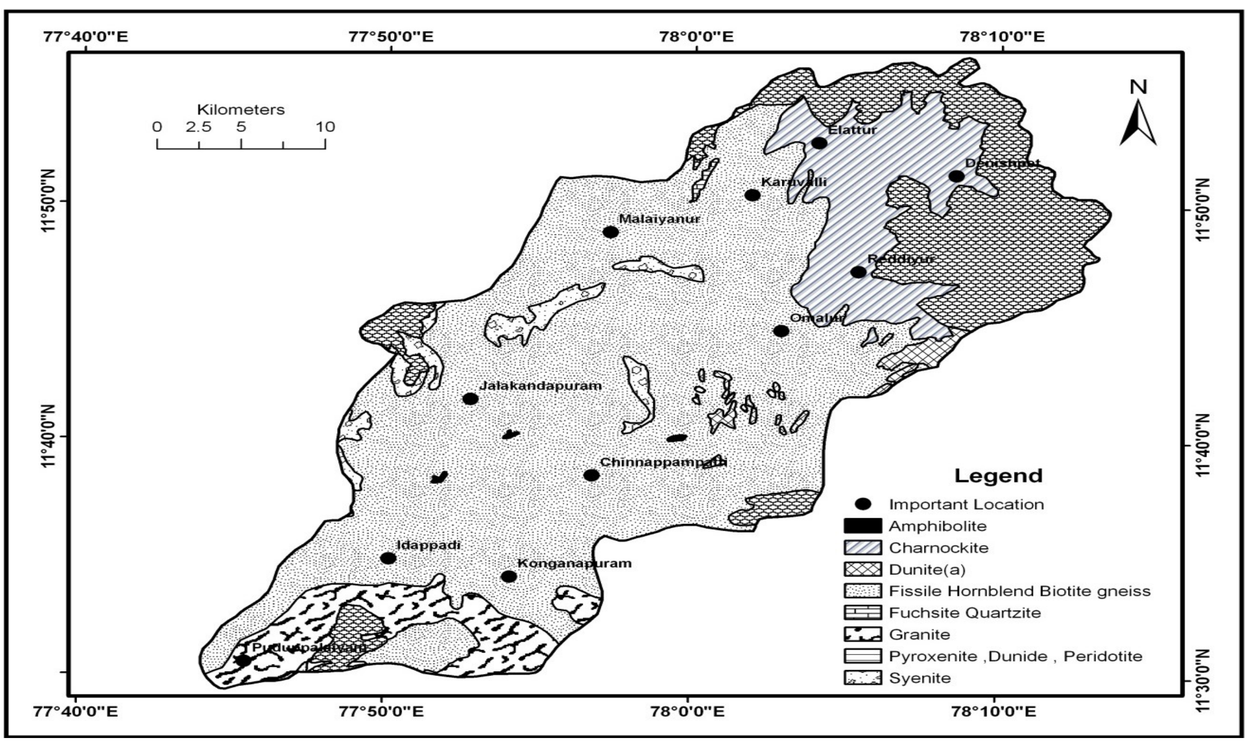


Fig.2 Geological variation map and its spatial distribution of the Sarabanga Sub-Basin



highly suitable for storage of huge amount of groundwater.

Spatial distribution results of subsurface first layer

The spatial resistivity distribution map (Fig.3) was prepared using the geophysical results. The results of the spatial distribution map are given in the Table 4.In the present investigation, first layer resistivity can be classified in to four classes, such as first fracture zone very low resistivity, first fracture zone low resistivity, first fracture zone medium resistivity and first fracture zone high resistivity. Groundwater potential zones are relates by 1VLR (Very Low Resistivity). Very low resistivity zones cover an area of 174.68 km^2.

Similarly spatial distribution map of first layer thickness (Fig.4)was prepared using GIS which is given in Table 5. The first layer thickness can also be classified in to four classes, such as First layer Low Thickness, first layer medium thickness, and first layer high thickness and first layer very high thickness, out of which the best groundwater potential area is indicated by 1VHT (Very High Thickness). Very high thickness zones cover an area of 112.86km^2.

Spatial distribution results of subsurface second layer

The spatial resistivity distribution map (Fig.5) and the results of spatial distribution (Table 6) indicates that second layer resistivity can be classified in to four classes, such as second layer very low resistivity, second layer low resistivity, second layer medium resistivity and second layer high resistivity. Deeper groundwater favorable zones relate to 2VLR (Very Low Resistivity) values. Very low resistivity zones cover an area of 152.96km^2.

Similarly spatial distribution map of second layer thickness (Fig.6)was prepared using GIS which is given in the Table 7.Thesecond layer thickness can also be classified in to four classes, such as second layer low thickness, second layer medium thickness, second layer high thickness and second layer very high thickness, the best groundwater potential area is indicated by 2VHT (Very High Thickness). The possibility of the best groundwater potential areas are related to 2VHT (Very High Thickness) zones. Very high thickness zones cover an area of 67.13km^2.

GIS Analysis

The fracture zone first layer resistivity map was superimposed over fracture zone first layer thickness map and output map 1 was derived (Fig.7). Its results are given in the Table 8. The result shows sixteen numbers of combinations. It is highly helpful in assessing the best groundwater potential zones. The sixty two combinations are LT-VLR, LT-LR, LT-MR, LT-HR, MT-VLR, MT-LR, MT-MR, MT-HR, HT-VLR, HT-LR, HT-MR, HT-HR, VHT-VLR, VHT-LR,VHT-MR, VHT-HR Among these LR& MT (Low Resistivity and Medium Thickness) combination covers a large area of 0.429 km^2. The second dominant polygons are MR&MT groups. It covers an area of 0.121 km^2. LR& HT combination comes in third level and covers an area of 0.241 km^2. VLR-VHT and VLR-HT combinations cover an area of 0.031 km^2 and 0.106 km^2 these combinations favors shallow depth of groundwater. This is also verified in the field. This area is highly suitable for construction of dug well. Similarly, the fracture zone second layer resistivity map was superimposed over

Table.6 Spatial distribution results of second layer resistivity of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone – Second layer resistivity (Ohm-m)	Area in Km^2	Area in Percentage
Very low resistivity	Less than 2468.59	152.96 km^2	14.74 %
Low resistivity	2468.59 – 10790.53	539.63 km^2	52.02 %
Medium resistivity	10790.53 – 43202.32	323.00 km^2	31.13 %
High resistivity	More than 43202.32	21.85km^2	2.11 %

Table.7 Spatial distribution results of second layer thickness of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone – Second layer thickness (m)	Area in Km^2	Area in Percentage
Low thickness	Less than 19.86	160.74 km^2	15.49 %
Medium thickness	19.86 to 38.76	405.26 km^2	39.06 %
High thickness	38.76 to 60.73	404.32 km^2	38.97 %
Very high thickness	More than 60.73	67.13 km^2	6.47 %

Table.8 Integration results of first layer resistivity and thickness of different class and its distribution percentage in overallSarabanga Sub-Basin

Sl.No.	Class	Area in Km^2	Sl.No.	Class	Area in Km^2
1	LT& VLR	0.075	9	HT& VLR	0.106
2	LT& LR	0.148	10	HT& LR	0.241
3	LT& MR	0.023	11	HT& MR	0.108
4	LT& HR	0.004	12	HT& HR	0.014
5	MT& VLR	0.195	13	VHT& VLR	0.031
6	MT& LR	0.429	14	VHT& LR	0.136
7	MT&MR	0.121	15	VHT& MR	0.198
8	MT& HR	0.007	16	VHT & HR	0.034

Table.9 Integration results of second layer resistivity and thickness of different class and its distribution percentage in overallSarabanga Sub-Basin

Sl.No.	Class	Area in Km^2	Sl.No.	Class	Area in Km^2
1	LT& VLR	0.053	9	HT& VLR	0.097
2	LT& LR	0.110	10	HT& LR	0.344
3	LT& MR	0.019	11	HT& MR	0.291
4	LT& HR	0.005	12	HT& HR	0.041
5	MT& VLR	0.123	13	VHT& VLR	0.072
6	MT& LR	0.383	14	VHT& LR	0.154
7	MT&MR	0.233	15	VHT& MR	0.040
8	MT& HR	0.019	16	VHT & HR	0.005

Table.10 Groundwater potential zone delineation with resistivity, thickness and geology overlay results

Sl.No.	Combinations			Area in Km^2	Sl.No.	Combinations			Area in Km^2
	1st Layer	2nd Layer	Geology			1st Layer	2nd Layer	Geology	
1	High Thickness -High Resistivity -Very High Thickness -Very Low Resistivity -Charnockite			0.05	27	Medium Thickness -Low Resistivity -Medium Thickness -Very Low Resistivity Fissile HornblendBiotite gneiss			5.58
2	High Thickness -High Resistivity -Very High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			1.05	28	Medium Thickness -Low Resistivity -Medium Thickness -Very Low Resistivity Syenite			0.12
3	High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity -Dunite(a)			2.93	29	Medium Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Dunite(a)			2.22
4	High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			17.39	30	Medium Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss			34.52
5	High Thickness -Low Resistivity -High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss			31.05	31	Medium Thickness -Low Resistivity -Very High Thickness -Very Low Resistivity -Dunite(a)			0.36
6	High Thickness -Low Resistivity -High Thickness -Low Resistivity -Syenite			3.27	32	Medium Thickness -Low Resistivity -Very High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			6.47
7	High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Charnockite			0.05	33	Medium Thickness -Very Low Resistivity -High Thickness -Medium Resistivity -Granite			1.93
8	High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Dunite(a)			3.64	34	Medium Thickness -Very Low Resistivity -High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			0.53

9	High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	25.83	35	Medium Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Syenite	0.53
10	High Thickness -Very Low Resistivity - High Thickness -Low Resistivity - Amphibolite	0.27	36	Very High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity - Dunite(a)	0.94
11	High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	14.93	37	Very High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	10.24
12	High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Syenite	0.93	38	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity - Charnockite	2.00
13	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Charnockite	0.02	39	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity - Fissile HornblendBiotite gneiss	0.00
14	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Dunite(a)	0.07	40	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity -Charnockite	0.65
15	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	1.15	41	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	2.40
16	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Syenite	0.07	42	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity -Fuchsite Quartzite	0.05
17	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity Dunite(a)	0.00	43	Very High Thickness -Low Resistivity -High Thickness -Very Low Resistivity - Charnockite	0.84
18	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity Fissile HornblendBiotite gneiss	2.48	44	Very High Thickness -Low Resistivity -Very High Thickness -Low Resistivity - Charnockite	0.09
19	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity Syenite	1.32	45	Very High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	0.39
20	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Charnockite	0.14	46	Very High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	0.04
21	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Dunite(a)	0.01	47	Very High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	0.01
22	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Fissile HornblendBiotite gneiss	4.31	48	Very High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Charnockite	0.10
23	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Syenite	1.62	49	Very High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	0.46
24	High Thickness -Very Low Resistivity - Medium Thickness -Very Low Resistivity -Dunite(a)	0.05	50	Very High Thickness -Very Low Resistivity - Very High Thickness -Very Low Resistivity - Dunite(a)	0.02
25	High Thickness -Very Low Resistivity - Medium Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss	1.61	51	Very High Thickness -Very Low Resistivity - Very High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	0.29
26	High Thickness -Very Low Resistivity - Medium Thickness -Very Low Resistivity -Syenite	0.17	**Total Area**		185.17

Fig.3 Spatial Distribution Map of First Fracture Zone Resistivity types and its area of the Sarabanga Sub-Basin

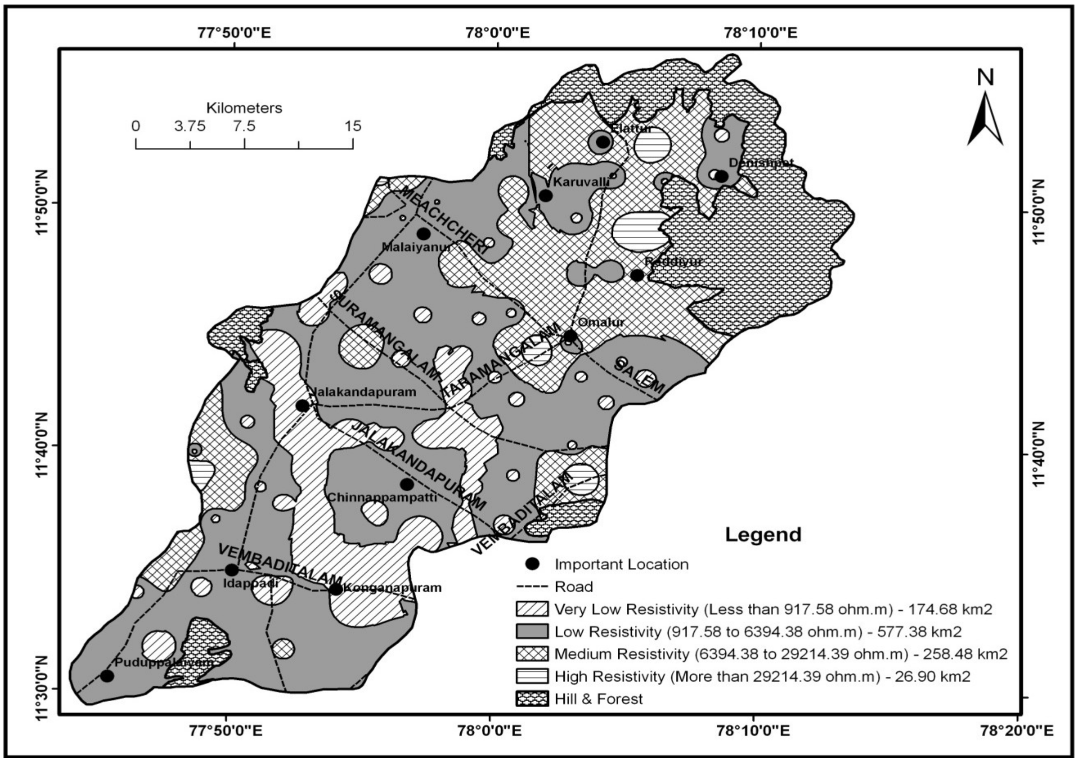


Fig.4 Spatial Distribution Map of First Fracture Zone Thickness types and its area of the Sarabanga Sub-Basin

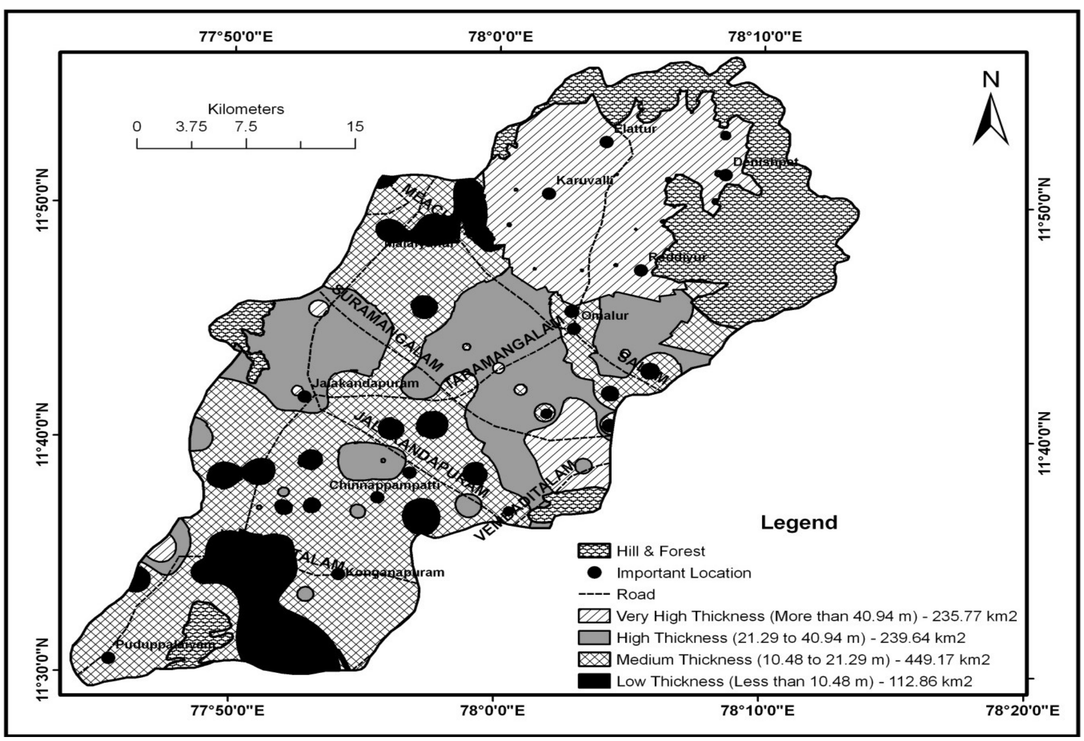


Fig.5 Spatial Distribution Map of First Fracture Zone Resistivity types and its area of the Sarabanga Sub-Basin

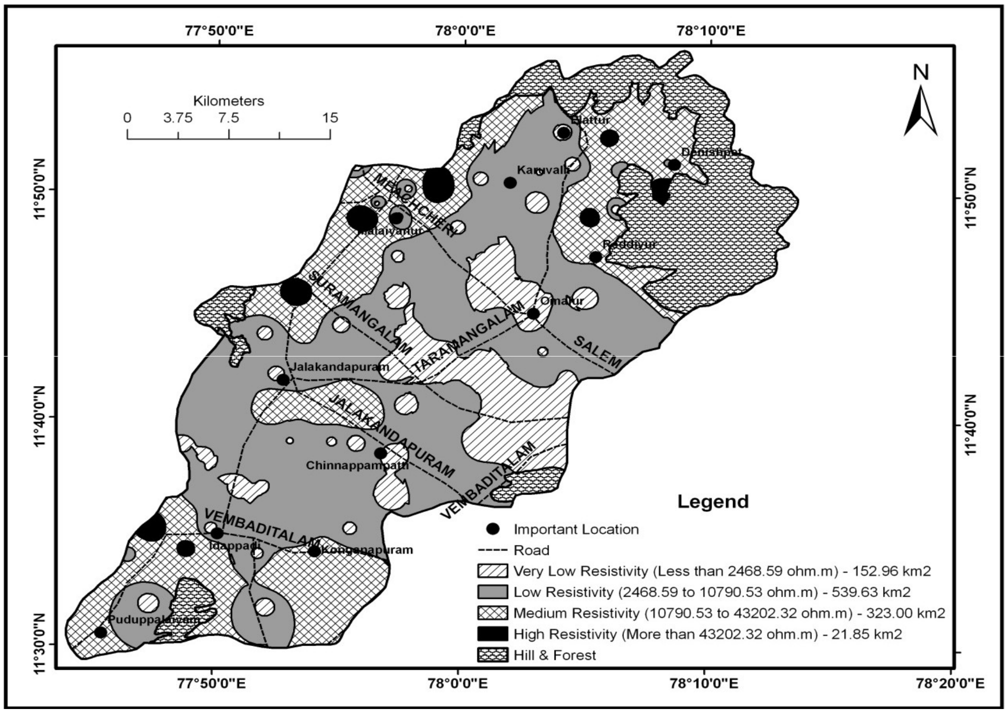


Fig.6 Spatial Distribution Map of Second Fracture Zone Thickness types and its area of the Sarabanga Sub-Basin

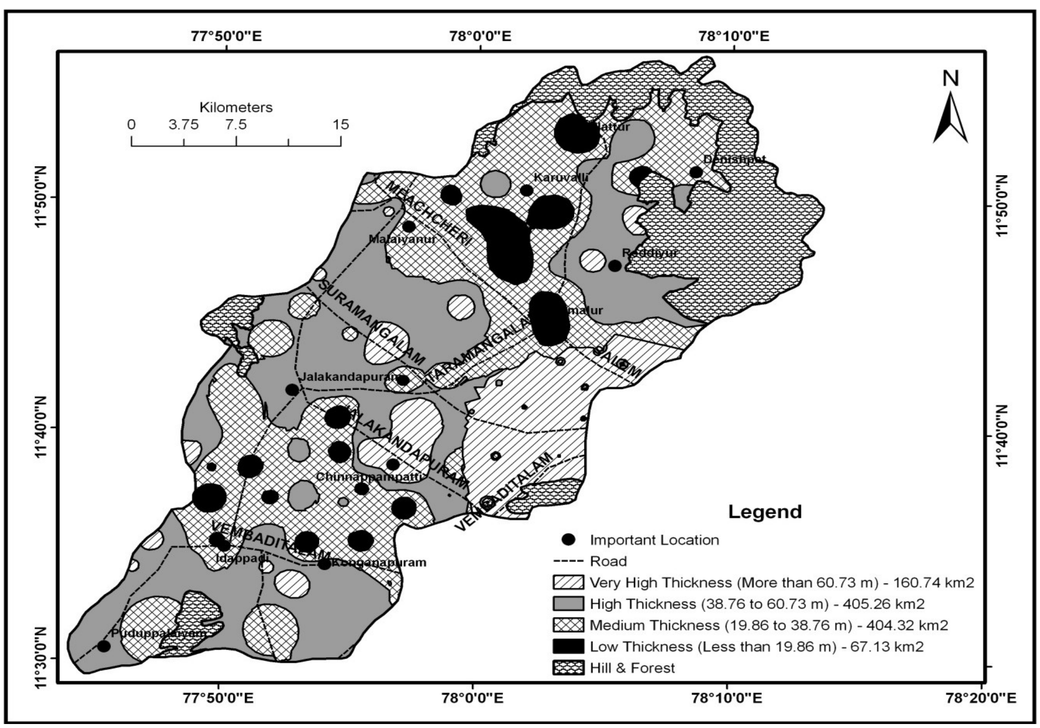


Fig.7 Spatial DistributionIntegration map of first layer resistivity and first layer thickness types and its area of the Sarabanga Sub-Basin

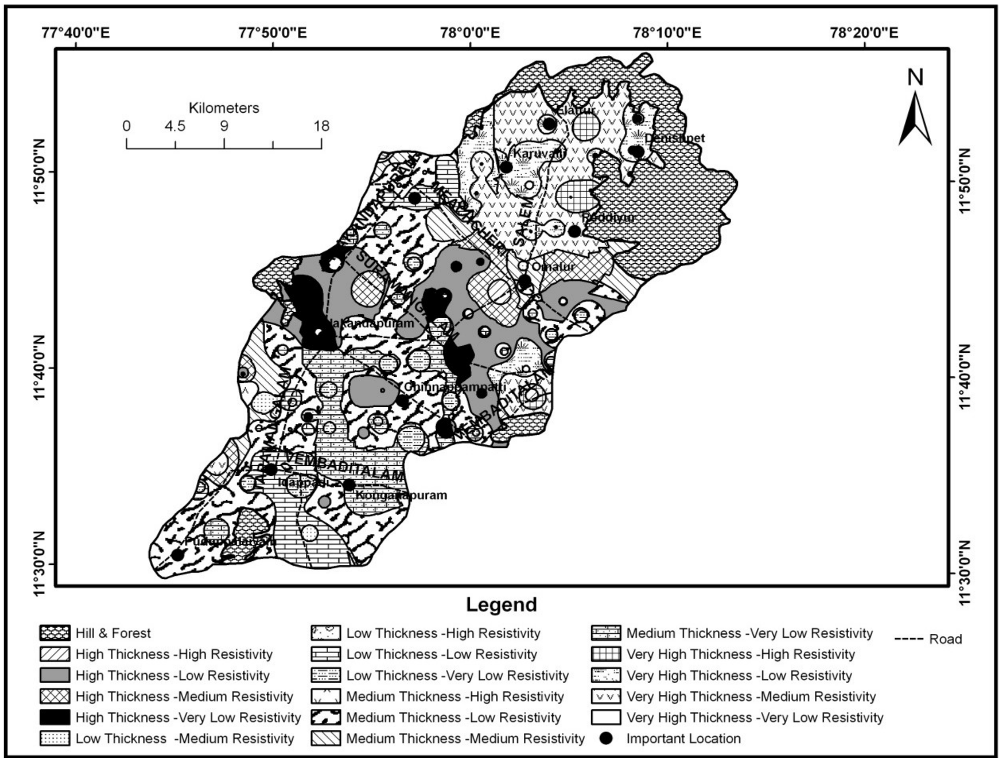


Fig.8 Spatial DistributionIntegration map second layer resistivity and second layer thickness types and its area of the Sarabanga Sub-Basin

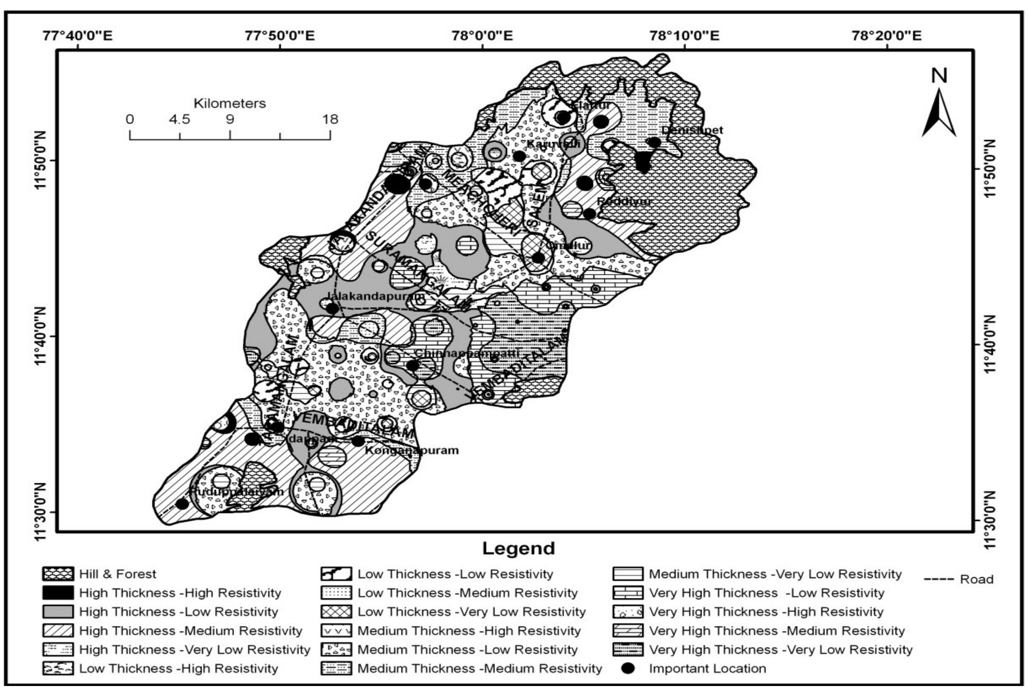
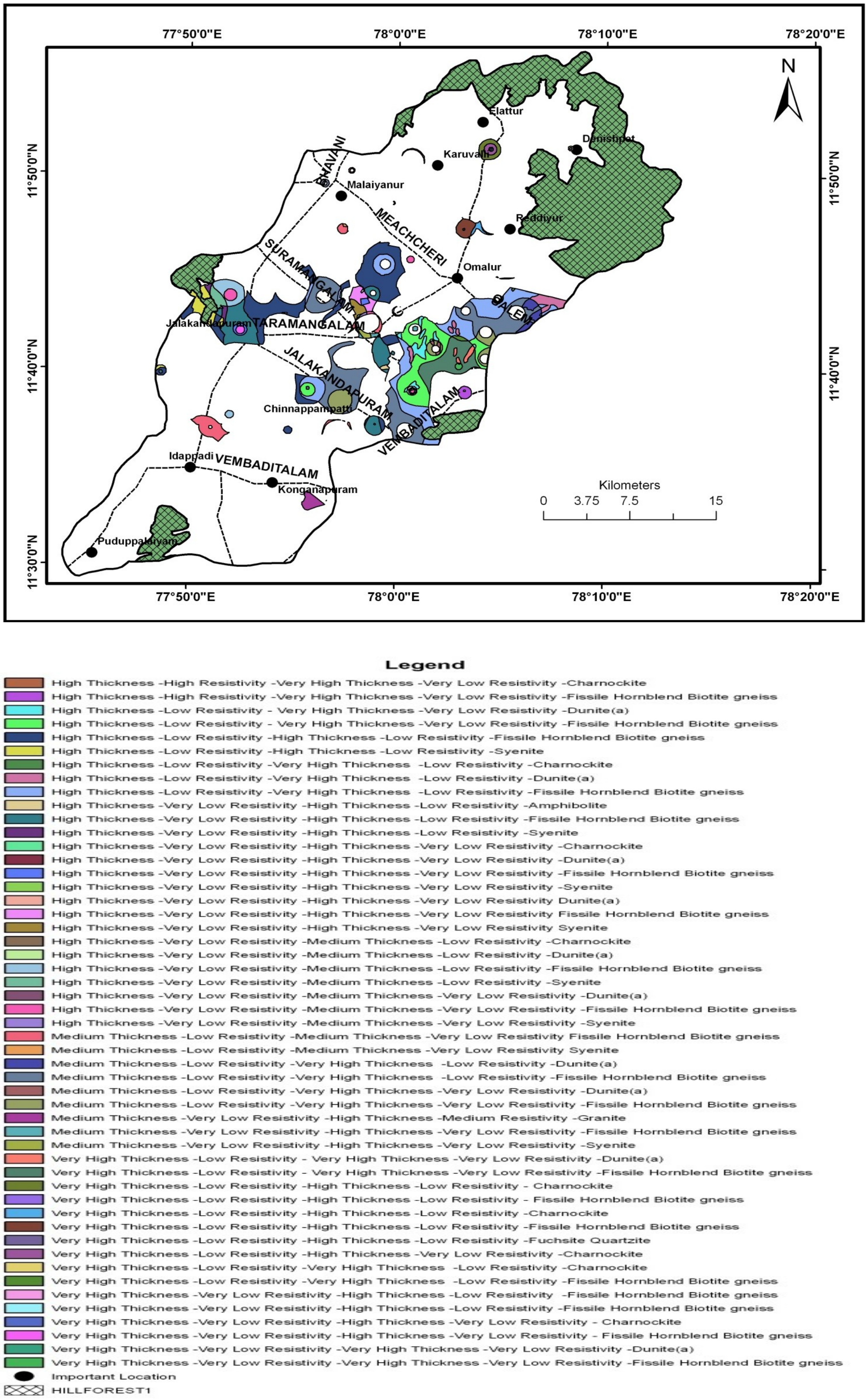


Fig.9 Integration results map of first and second layers resistivity and second layer thickness overlay with geology and its output types area of the Sarabanga Sub-Basin



fracture zone second layer thickness map and the output map-2 was derived (Fig.8). The output map 2 and its results are given in the Table 9. The 2VLR&2VHT combination covers an area of 0.072 km^2. This is the very smallest combination among this group. This combination shows deeper depth of water level and high thickness of water bearing formation. This area is recommended for the construction of tube well.

The output map of 1st layer was superposed over the output map of 2nd layer giving a final output map 3(first and second layers resistivity and thickness integration map). This final output map 3 was superposed over geology map giving the resultant output map 4 showing 51best combinations for groundwater exploration.

The combinations like (Fig.9) very high thickness-very low resistivity-very high thickness-very low resistivity in fissile hornblende biotite gneiss 0.29 km^2, very high thickness-very low resistivity-very high thickness-very low resistivity in dunite(a) 0.02 km^2 and very high thickness-very low resistivity-high thickness-very low resistivity in fissile hornblende biotite gneiss0.46 km^2 are high groundwater potential zones which are also verified in the field. This combination in alluvium is noticed in the foot hill areas and river course and is recommended for the construction of dug wells or tube wells. The overlay analysis combinations Next category of groundwater favorable zones is given in the Table 10.

The final map gives 351 combinations (Lithology along with first and second layer resistivity and thickness). The very high thickness-very low resistivity-very high thickness-very low resistivity combination is good and found in the fissile hornblendebiotite gneiss region, very high thickness-very low resistivity-very high thickness-very low resistivity in dunite and very high thickness-very low resistivity-high thickness-very low resistivity in fissile hornblendebiotite gneiss covering an area of 0.29 km^2, 0.02 km^2 and 0.46 km^2. Field verification of surrounding area bore wells and dug wells are good groundwater potential zones. Next, a very high thickness -very low resistivity -high thickness -low resistivity -fissile hornblendebiotite gneiss and very high thickness -low resistivity -very high thickness-low resistivity -fissile hornblendebiotite gneiss covering areas of 0.05 km^2& 0.39 km^2respectively are also good for groundwater potential. These combinations are the best for constructing dug wells and bore wells.

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Morphometric analysis for characterizing landforms study on Sarabanga Sub-basin, Cauvery River, Tamil Nadu, India

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Abstract

GIS and image processing techniques have been adopted for the present investigation to identify the morphological features and analyzing their properties. The Sarabanga Sub-basin Cauvery River fall in Salem district, Tamil Nadu, India, have been taken in the present investigation .Morphometric analysis was carried out at sub basin level using Spatial Analysis System (ArcGIS ver. 9.3). The basin morphometric parameters such as linear and aerial aspects of the Sarabanga river basin were determined and computed. Sarabanga river is the one of the tributary of Cauvery river drained in the middle of the sub basin.It is 6th order drainage basin and drainage pattern mainly in subdendritic to dendritic type. It is observed that the drainage density value is low which indicates the basin is highly permeable subsoil and thick vegetative cover. The circularity ratio value reveals that the basin is strongly elongated and highly permeable homogenous geologic formations. This study would help the local people to utilize the groundwater resources for sustainable development of the basin area. The morphometric analysis suggests that the comparison of all the fifteen micro watersheds shows that the nos 4, 8, 9, 10 and 13 micro watersheds have the lowest drainage density, and hence are better suited for construction of artificial groundwater recharge structures.

Keywords: Geographic Information System (GIS), Morphometric analysis; Artificial recharge; image processing techniques,

Introduction

The optimal and sustainable development of the groundwater resource is prerequisite so that it is assessed rationally to avoid any future problems regarding its qualitative and quantitative availability. About 70% of population in India is dependent on agriculture, directly or indirectly. India has diverse geographical features and varied climates. It has 14 major basins through which drain numerous rivers, while rivers in the southern India are rain fed, with little perennial water. Accordingly, the importance of water has been recognized and greater emphasis is being laid on its economic use and better management. The basin morphomatric characteristics of the various basins have been studied by many scientists using conventional methods (Horton, 1945; Smith, 1950; Strahler, 1957) and remote sensing and GIS methods (Krishnamurthy and Srinivas, 1995; Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Keller et al., 1982; Mayer, 1990; Cox, 1994; Merritts, et al., 1994; Lupia Palmieri et al., 1995 and 2001; Currado and Fredi, 2000; Pike, 2002; Della Seta, 2004; Della Seta et al., 2004. The fastly emerging spatial information technology (SIT) viz. remote sensing, GIS, and GPS has effective tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process. An attempt is made here to find out holistic stream properties from the measurements of various stream attributes and identifying zones for artificial recharge.

Study Area

The study area, lies between the latitudes 11°46’ N to 12°09’39” N and longitudes 78°12’27” E to 78°36’65” E covering an area of 1178.56 km^2. Out of which plain land covers an area of 1015.79 km^2 (Fig.1). The study area falls in Salem district of Tamil Nadu. The major source for recharge of water in this area is rainfall, during monsoon season. The average annual rainfall is 852 mm (2000 to 2009). The study area is underlaid by the Archaean crystalline rocks surrounded by wavy hills and hillocks.

Methodology

The base map was prepared using toposheet nos. 57L/4, 8, 58 I/1, and 5 of 1:50,000 scale. In the present study base map showing drainage details have been prepared from toposheets (SOI). The Sarabanga Sub-Basin was further subdivided into 15 micro watersheds, the drainage channels were classified into different orders using Strahler’s (1964) classification. The primary basin parameters such as basin area, basin perimeter, basin length and stream length were obtained which were further used to obtain the derived parameters such as drainage density, Drainage Texture, Bifurcation Ratio, Stream length Ratio, Stream Frequency, Form Factor, Elongation Ratio and Circulatory Ratio. Were calculated and taken into the present investigation.

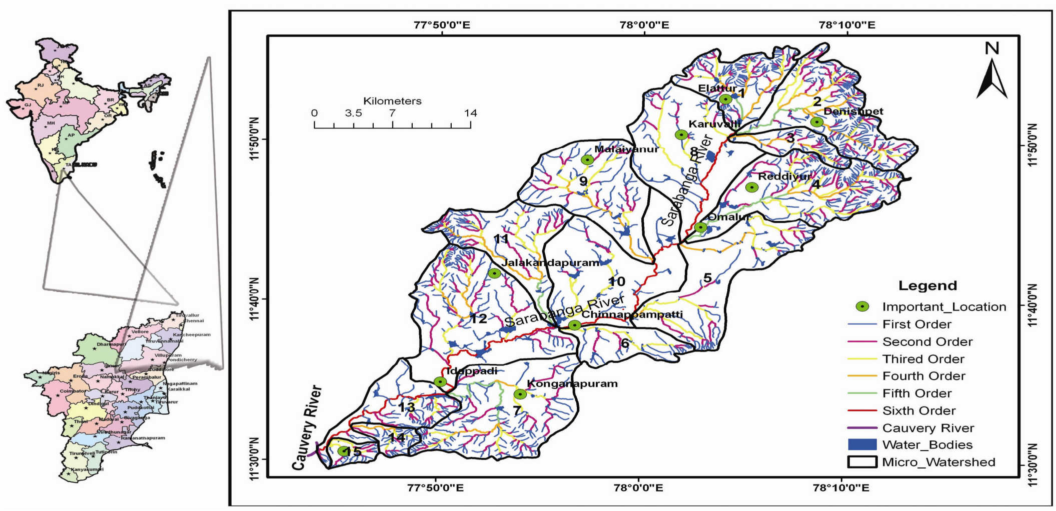

Fig.1 Study Area Map of Sarabanga Sub basin micro watersheds.

Results and Discussion

The development of drainage networks mainly depends on the underlying geology, precipitation, exogenic and endogenic processes of the area. The drainage pattern of the basin ranges from dentritic to sub dentritic at higher elevations and parallel to sub parallel in the lower elevations. A radial drainage pattern was also observed in the areas with isolated hillocks. Based on the drainage orders, the Sarabanga river basin has been classified as sixth order river basin.

Linear parameters

Stream order analysis shows that the main sub basin is fall under sixth order category. Based on the network pattern it has been further sub divided in to fifteen micro watersheds. The micro watershed no 13 were identified second order stream, three watersheds (5,6,15) under third order stream, three watersheds (3,9, and 14) under fourth order stream, five watersheds (1,2,7,11,13) under fifth order stream and three watersheds (8,10,12) under sixth order stream (Table 1). The sixth order stream is found in the unclassified area. Analysis of cumulative length of streams (L) shows that micro watersheds 2,4 and 11 have the highest L value, whereas, micro watersheds 6,13 and 15 have the lowest L value. The existence of high (L) value is due to structural complexity, high relief and impermeable bedrock. Analyses of bifurcation ratio (Rb) shows lower (Rb) values in the micro watersheds of 3, 6 and 9 are attributed to the characteristics of less structural disturbances which, in turn, has not distorted the drainage pattern (Strahler, 1964). Whereas, the higher (Rb) values in the micro watersheds of 5, 7 and 14 indicate high structural complexity and low permeability of the sub surface strata.

Table 1. Linear Morphometric Parameters of Sarabanga Sub basin micro watersheds.

micro watershed no	Basin Length Lb (km)	Perimeter P (km)	Drainage Order (in Number)						Total Number N	Cumulative Length L (km)	Bifurcation Ratio Rb
			N_1	N_2	N_3	N_4	N_5	N_6			
1	11.09	38.57	129	68	25	17	2	0	241	353.00	3.65
2	16.41	54.37	216	117	52	46	7	0	438	660.00	2.95
3	12.33	27.09	47	25	11	9	0	0	92	137.00	1.79
4	23.04	56.02	183	94	53	19	8	2	359	535.00	2.58
5	29.67	71.01	51	30	29.91	0	0	0	111.91	172.82	5.08
6	11.91	31.36	22	8	9	0	0	0	41	60.00	1.21
7	18.93	51.48	149	65	22	2	1	0	239	329.00	4.56
8	18.47	50.35	47	19	11	1	3	1	82	117.00	3.71
9	17.87	48.42	126	54	17	11	0	0	208	290.00	2.35
10	20.25	60.57	41	7	7	3	2	1	61	81.00	2.54
11	19.07	48.41	135	58	28	20	5	0	246	357.00	2.45
12	20.89	62.22	143	67	32	4	1	1	248	353.00	3.45
13	15.23	51.09	23	6	0	0	0	0	30	37.00	3.83
14	5.82	17.61	37	14	2	1	0	0	54	71.00	3.88
15	4.94	14.69	21	10	2	0	0	0	33	45.00	3.55

Areal parameters

Drainage density indicates that the low Dd exists in micro watersheds 4, 8, 9, 10 and 13 having high permeable sub surface material and are under dense vegetation cover and low relief (Table 2). In contrast, high Dd values are observed in micro watersheds 2, 14 and 15 may be due to the presence of impermeable sub surface material, sparse vegetation and high relief. The measurement of drainage density provides a numerical measurement of landscape dissection and runoff potential. Analysis of stream frequency (Fu) shows low values of Fu existing in micro watersheds 8 and 10, 13 which are having high permeable geology and low relief. Where high value of Fu is noticed in 1 and 2 micro watersheds, where impermeable sub-surface material, sparse vegetation and high relief conditions prevails. Texture ratio (T) indicates that highest T values are found in micro watersheds 1, 2 and 4 whereas the lowest T values are noticed in micro watersheds 6, 10 and 13. Thus it can infer that T values depend on the underlying geology, infiltration capacity of bedrock and relief aspects of the individual micro watersheds.

Analysis of form factor (Rf) reveals that micro watersheds having low Rf have less side flow for shorter duration and high main flow for longer duration and vice versa. This condition prevails in micro watersheds 3, 4 and 13. High Rf exists in micro watersheds 1, 5 and 15 with high side flow for longer duration and low main flow for shorter duration causing high peak flows in a shorter duration. Circulatory ratio (Rc) values approaching 1 indicates that the basin shapes are like circular and as a result, it gets scope for uniform infiltration and takes long time to reach excess water at micro watershed outlet, which further depend on the existing geology, slope and land cover. The micro watersheds 5 and 15 are having highest Rc value of 1.01 and 0.66 respectively, which support the above concept. Analysis of elongation ratio (Re) indicates that the areas with higher Re values have high infiltration capacity and low runoff. The micro watersheds 5 and 15 are characterized by high Re and 3, 4 and 11 micro watersheds have low Re respectively. The micro watersheds having low Re values are susceptible to high erosion and sedimentation load. Constant of channel maintenance (C) depends on the rock type, permeability, climatic regime, vegetation cover and relief as well as duration of erosion (Schumm, 1956). The micro watersheds 3 and 14 have low C values of 0.43 and 0.37 respectively. It indicates that these micro watersheds are under the influence of high structural disturbance, low permeability; steep to very steep slopes and high surface runoff. The micro watersheds of 5 and 13 have highest C values of 1.94 and 1.46 respectively and are under very less structural disturbances and less runoff conditions.

Table 2. Areal Morphometric parameters of micro watersheds

micro watershed no	Area A (km^2)	Stream Frequency Fu	Drainage density Dd	Texture Ratio T	Form factor Rf	Circulatory Ratio Rc	Elongation Ratio Re	Constant of channel Maintenance C
1	57.4	4.20	2.18	3.34	0.47	0.48	0.77	0.46
2	92.24	4.75	2.33	3.97	0.34	0.39	0.66	0.43
3	23.51	3.91	2.02	1.73	0.15	0.40	0.44	0.50
4	107.54	3.34	1.95	3.27	0.20	0.43	0.51	0.51
5	103.08	2.2	2.18	1.4	0.56	1.01	1.17	1.94
6	36.22	1.13	1.12	0.70	0.26	0.46	0.57	0.89
7	122.48	1.95	1.46	2.89	0.34	0.58	0.66	0.68
8	116.28	0.71	0.69	0.93	0.34	0.58	0.66	1.45
9	108.22	1.92	0.99	2.60	0.34	0.58	0.66	1.01
10	124.97	0.49	0.72	0.68	0.30	0.43	0.62	1.40
11	74.43	3.31	1.67	2.79	0.20	0.40	0.51	0.60
12	173.24	1.43	1.14	2.30	0.40	0.56	0.71	0.88
13	69.81	0.43	0.68	0.45	0.30	0.34	0.62	1.46
14	14.19	3.81	2.69	2.10	0.42	0.57	0.73	0.37
15	11.29	2.92	2.35	1.43	0.46	0.66	0.77	0.43

Drainage morphometry and its impact on landform characteristics

The underlying geology, exogenic and endogenic activities, drainage morphometry and considerable changes in climate during the Quaternary, influences the genesis and morphology of landforms (Subramanyan, 1981). In this study area, the denutation hills are located in the micro watersheds (4, 7, 11, 14, 15) pediplain covers nearly 60 percentage of the sub basin. The structural hills found in the following micro watersheds (1, 2, 3, 4, 7, 11) are identified and mapped as major landforms on the upper reaches. These landforms are associated with high drainage density, high bifurcation ratio and high cumulative length of first, second and third order streams. Rolling plains, foot slopes, narrow valleys and main valley floors are analyzed and mapped as landforms of the Sarabanga sub basin (Fig. 2). Which are formed by the influence of permeable geology, moderate to nearly level plains, medium to low drainage density (< 2.0), low cumulative length of streams having fourth and fifth order streams.

Landforms of upper reaches

The fluvio-denudational geomorphological processes are actively involved in landscape reduction processes at upper reaches. The physio-chemical weathering and multiple slope dissections under the influence of steep slopes, high drainage density and precipitation conditions lead to the development of ridge-valley land systems in the north eastern and north western part of the area. The occurrences of alluvium and colluvium deposits at places are dissected by incoming third and fourth order streams. They are noticed in the upper parts of micro watershed nos. (1, 2, 3, 4, 5, 8). Foot slopes are low in relief and consist of deposited sediments that are regularly carried out from upland catchments. The deposited sediments are admixed with sandy loam and clay. The majority of these landforms are occupied in the micro watershed nos. 7, 13, 14 and 15 of the study area.

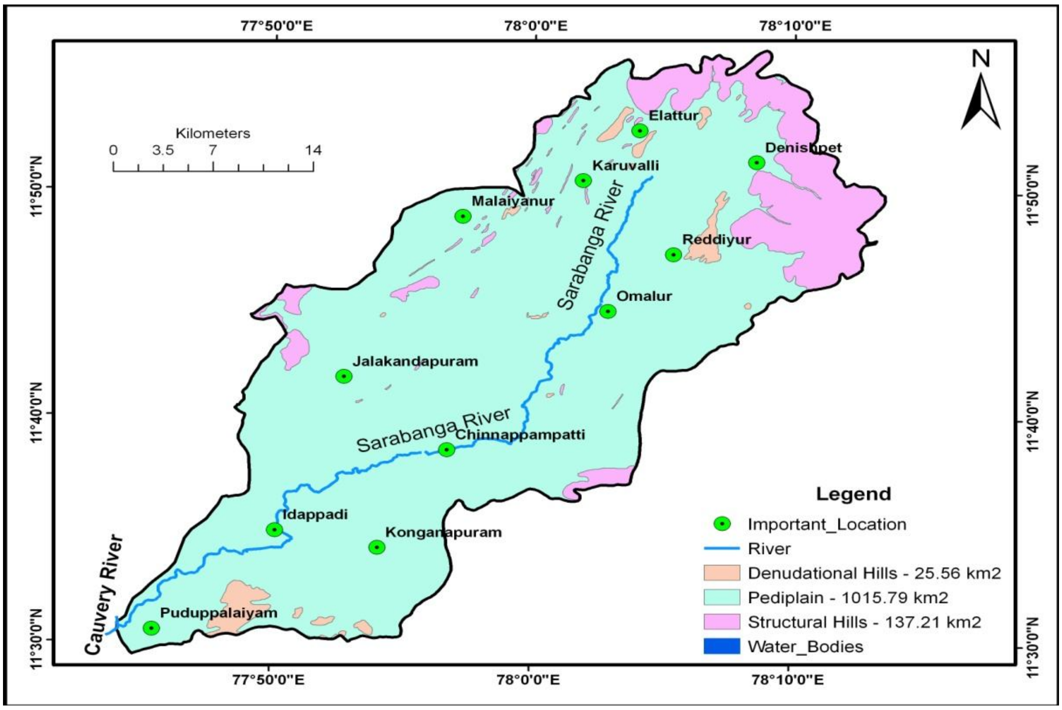

Fig. 2 Geomorphology with important location of Sarabanga Sub basin micro watersheds.

Conclusions

The study reveals that remotely sensed data and GIS based approach in evaluation of drainage morphometric parameters and their influence on landforms, geology at river basin level is more appropriate than the conventional methods. GIS based approach facilitates to analyze different morphometric parameters and to explore the relationship between the drainage morphometry on one hand and properties of landforms and geology on other hand. Geomorphology spatial variation in the upper parts of micro watershed nos. (1, 2, 3, 4, 5, 8). Foot slopes are low in relief and consist of deposited sediments that are regularly carried out from upland catchments. The majority of these landforms are occupied in the micro watershed nos.7, 13, 14 and 15 of the study area. The sixth order stream is found in the unclassified area. Analysis of cumulative length of streams (L) shows that micro watersheds 2,4 and 11 have the highest L value, whereas, micro watersheds 6,13 and 15 have the lowest L value. The existence of high (L) value is due to structural complexity, high relief and impermeable bedrock.

The micro watersheds 3 and 14 have low C values of 0.43 and 0.37 respectively. It indicates that these micro watersheds are under the influence of high structural disturbance, low permeability; steep to very steep slopes and high surface runoff. The micro watersheds of 5 and 13 have highest C values of 1.94 and 1.46 respectively and are under very less structural disturbances and less runoff conditions. The present scenario where water resources are becoming scarce, this exercise of calculating the various attributes of a drainage basin plays a significant role in locating sites for artificial recharge structures.

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Research Article

ASSESSMENT OF RAINFALL VARIABILITY IN GIS ENVIRONMENT AT SARABANGA SUB-BASIN CAUVERY RIVER SOUTH INDIA

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ABSTRACT
Rainfall being the predominant from of precipitation causing stream flow, especially the flood flow in a majority of rivers in India. In the present study, an attempt has been made to assessment the rainfall variation and monitoring with respect to spatial distribution in Sarabanga Sub-basin, Cauvery River, South India. In this work were exiguities by GIS Technique. To achieve the aim of rainfall variations during winter (Jan. & Feb.), summer (Mar. to May), southwest monsoon (Jun. to Sep.) and northeast monsoon (Oct. to Dec.) were analyzed for the period from 2001 to 2010. These results were taken into GIS platform to prepare the spatial distribution maps. The spatial distribution maps of Southwest- and Northeast- monsoon season showed that 52.47 km^2 and 281.28 km^2 of the study area received high rainfall during the respective monsoon seasons. Annual average rainfall spatial distribution map for the years 2001-2010 revealed that 74.43 km^2 falls under high rainfall zone in the study area. The results suggest that the model reproduces the number and spatial distribution maps of rainfall extremes with some accuracy, but that mean rainfall and rainfall variability is estimated over dry regions of Sarabanga sub-basin, Cauvery River, South India.

Key Words: *Rainfall, Spatial Distribution, Monsoon Season*

INTRODUCTION
To date, many studies on rainfall variability has been used data at relatively low resolutions, either spatially such as that of global climate models (GCMs; e.g. Reason 1998; Goddard and Graham 1999; Cook 2000; Rautenbach and Smith 2001; Nicholson 2003) or at a coarse temporal resolution from monthly, seasonal to annual rainfall totals (e.g. Richard and Poccard 1998; Landman *et al.,* 2001; Thiam and Singh 2002; Bartman *et al.,* 2003). As the identification of extreme rainfall events is a function of scale, with the ability to highlight rainfall extremes increasing in step with the data resolution (Williams *et al.,* 2007). An improved understanding of extreme daily rainfall at high spatial resolution is important, because recent rainfall related disasters have highlighted the impact that rainfall variability and extremes have on society. It is generally agreed that developing countries suffer more from extreme rainfall events than developed countries because, being environmentally and socioeconomically vulnerable before the extreme event occurs, developing countries are more sensitive to such disasters. Mozambique, for example, experienced an extreme rainfall event associated with Tropical Cyclone Eline during 21–25 February 2000, resulting in severe flooding and displacing over a million people (Layberry *et al.,* 2006).
Since groundwater is a major drinking water resource and critical for irrigation in all parts of the world, evaluating and predicting the availability and accessibility of groundwater under changing boundary conditions is one of the central tasks in Integrated Water Resources Management (IWRM) (Villholth, 2006; Holman, 2006). IWRM with respect to groundwater has two main objectives namely to provide water in sufficient quantity and quality equitably to different consumers and at the same time to maintain and guarantee a sustainable qualitative and quantitative status of the groundwater resource itself (Hiscock *et al.,* 2002). A ‘good status’ of groundwater refers to its function in water supply (drinking water, irrigation, industrial use etc.) but also to its role as a long term reservoir to sustain aquatic ecosystems (wetlands) and to provide a source of discharge in dry periods.

Research Article

GIS has emerged as a powerful technology for instruction, for research, and for building the stature of programs (Openshaw 1991; Longley 2000; Sui and Morrill 2004). GIS is an important technology for geologists (Baker and Case 2000).

Study Area

The study area, lies between the latitudes 11°46' N to 12°09'39" N and longitudes 78°12'27" E to 78°36'65" E covering an area of 1178.56 km^2. Out of which plain land covers an area of 1015.79 km^2 (Figure 1). The study area falls in Salem district of Tamil Nadu. The major source for recharge of water in this area is rainfall, during monsoon season. The average annual rainfall is 852 mm (2000 to 2010). The study area is underlaid by the Archaean crystalline rocks surrounded by wavy hills and hillocks.

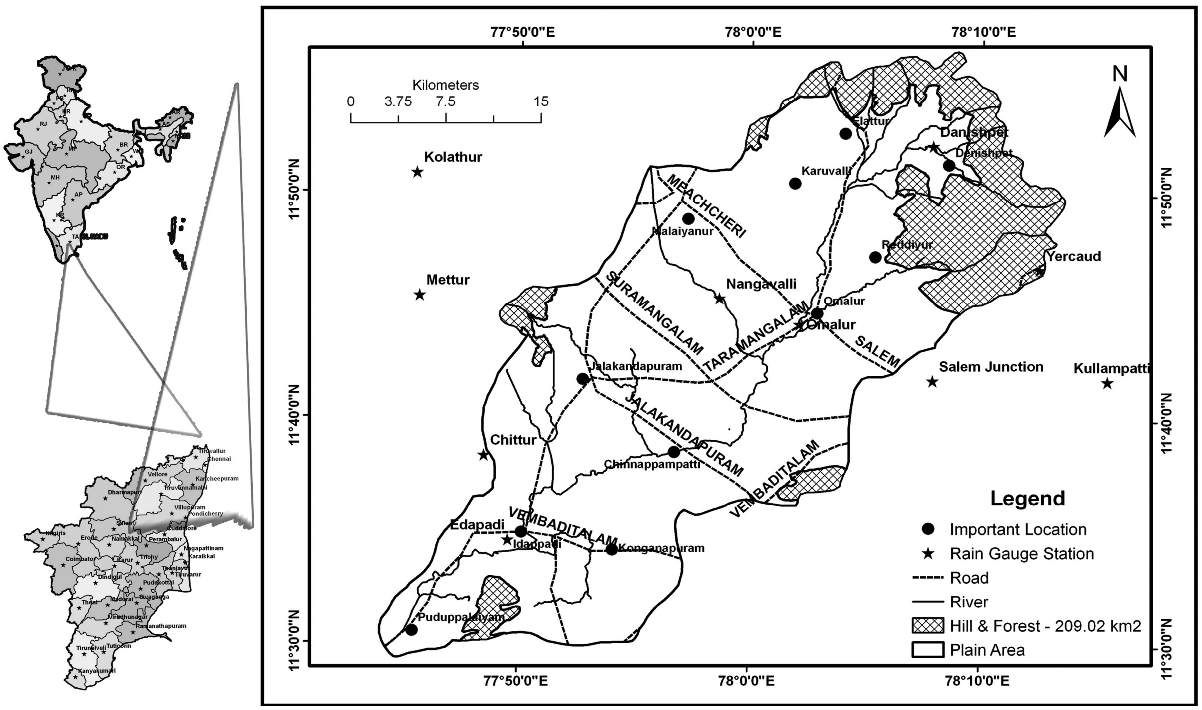

Figure: 1 Study Area

MATERIALS AND METHODS

The daily rainfall data were collected from Public Work Department (PWD), Govt. of Tamil Nadu and converted into average seasonal rainfall like Winter (January and February), Summer (March, April and May), South West (June, July, August and September), and North East (October, November and December) monsoon rainfall. From this, the average annual rainfall for the last ten years was calculated. The ten years rainfall data (2001 – 2010) are calculated in nine rainfall stations at Edapadi, Kolathur, Kullampatti, Mettur, Omalur, Salem junction, Sankari, Yercaud, Danishpet, Chittur, Nangavall in and around the study area. Based on the daily rainfall data, month wise and seasonal wise average rainfall was calculated. Finally using the above, the annual average rainfall was calculated and interpreted.

To find out the spatial distribution of the rainfall variation in the study area, GIS was employed. The rainfall location was digitized and the corresponding values (Average winter, summer, southwest, northeast and annual average rainfall) of its attributes were given as an input. Using this data, the interpolation raster maps were generated. Subsequently, these maps were classified with respect to our interest and converted into vector maps. These maps were clipped with the boundary to arrive within the boundary of the study area.

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RESULTS AND DISCUSSION

Eleven rainfall stations were studied, Out of Eleven stations one station i.e Yercaud showed a good response of rainfall. Four stations namely Kolathur, Mettur, Omalur and Salem junction show a moderate rainfall as the other four stations, namely Edapadi, Kullampatti, Sankagiri and Danespet show a low rainfall. 10 years (2001to 2010) data were collected from Public Work Department (PWD) Govt. of Tamil Nadu and were interpreted (Table 1 and Figure 2). High rainfall noticed in 2005, lowest rainfall noticed in 2002. The average Southwest monsoon rainfall is 400 mm and average Northeast monsoon rainfall is 405 mm. In summer and winter season, the average rainfall is noticed as 198 mm and 5 mm the details are listed in Table 2 and shown in Figure 3.

Table 1: Average annual rainfall data in mm (2001 - 2010)

Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Rainfall in mm	934	862	1005	1139	1221	1003	937	1051	930	991

Table 2: Average annual seasonal rainfall data of the study area in mm (2001 –2010)

Stations	Winter	Summer	Southwest Monsoon	Northeast Monsoon
Edapadi	5	193	335	401
Kolathur	18	227	360	458
Kullampatti	9	203	324	410
Mettur	4	225	362	573
Omalur	1	190	429	350
Salem Junction	1	180	373	384
Sankagiri	2	156	263	402
Yercaud	14	256	686	477
Danishpet	2	192	465	300
Chittur	1	160	427	357
Nangavalli	0	191	371	344
Average	5	198	400	405

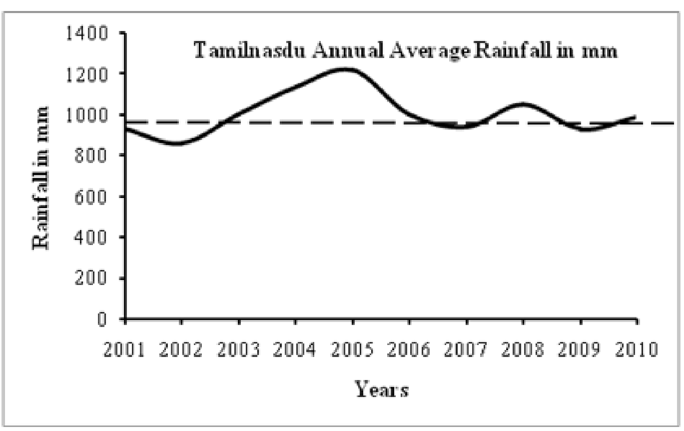

Figure 2: Fluctuation graph of rainfall data for the Period of 2001 – 2010

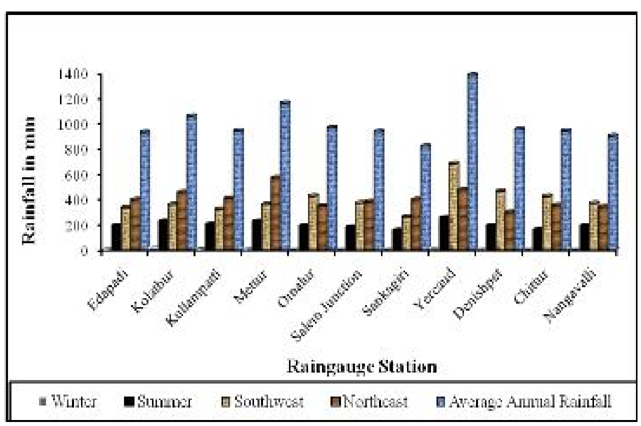

Figure 3: Season wise graph of rainfall for the period – 2001 to 2010

Gis Results

GIS is an analytical technique associated with the study of locations of geographic phenomena together with their spatial dimension and their associated attributes like table analysis, classification, polygon classification and weight classification.

The Winter, Summer, Southwest monsoon Northeast monsoon and Annual average rainfall thematic maps as described above have been converted into raster form considering 30m as cell size to achieve considerable accuracy. These were then reclassified and assigned suitable weightage and spatial distribution results (Table 3). The results of winter season, summer season, southwest monsoon season, northeast monsoon and average annual rainfall data for the period 2001-2010 were used in the spatial distribution maps. GIS spatial distribution maps and its results are shown in Figure 4 to 8 and given Table 3. The winter season GIS map reveals that a small portion of the study area are high rainfall noticed in North eastern part of sevaroys hills at the range of (More than 5.22 mm) and are classified as high rainfall zone is occupied 1.46 km^2 (Figure 4).

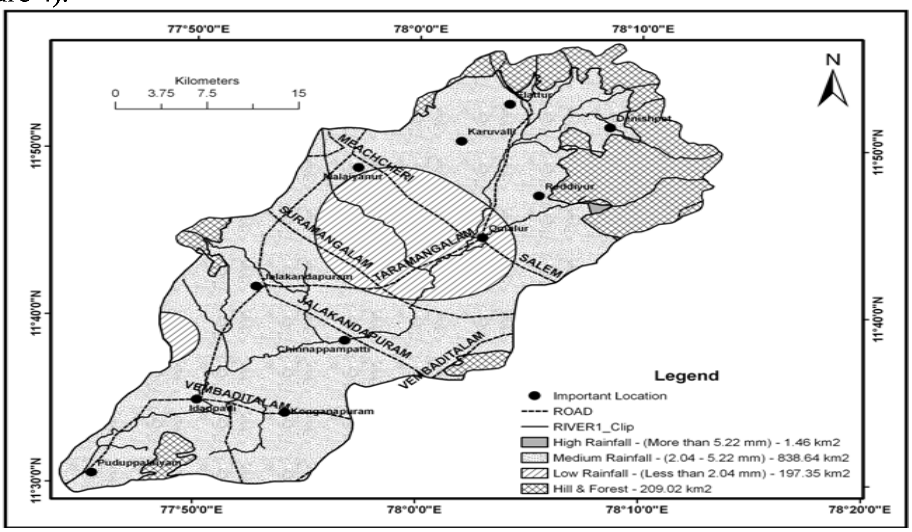

Figure 4: Annual average rainfall Winter Season – Spatial Distribution Map

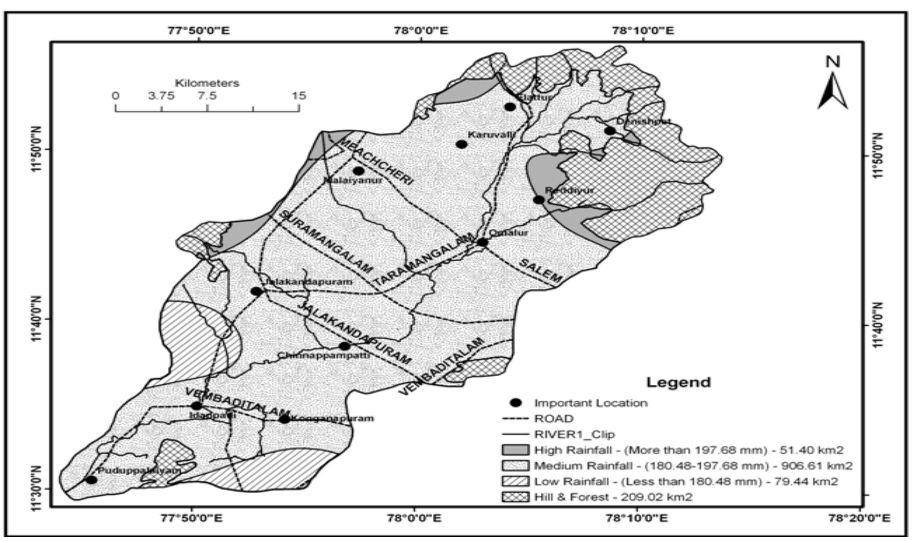

Figure 5: Annual average rainfall Summer Season – Spatial Distribution Map

Summer season GIS image reveals that spatially 51.40 km^2 area fell in the high rainfall area and 906.61 km^2 area falls in the medium rainfall category zone (Figure 5). The high rainfall area is located in near to the hill and forest (more than 500 ft height).

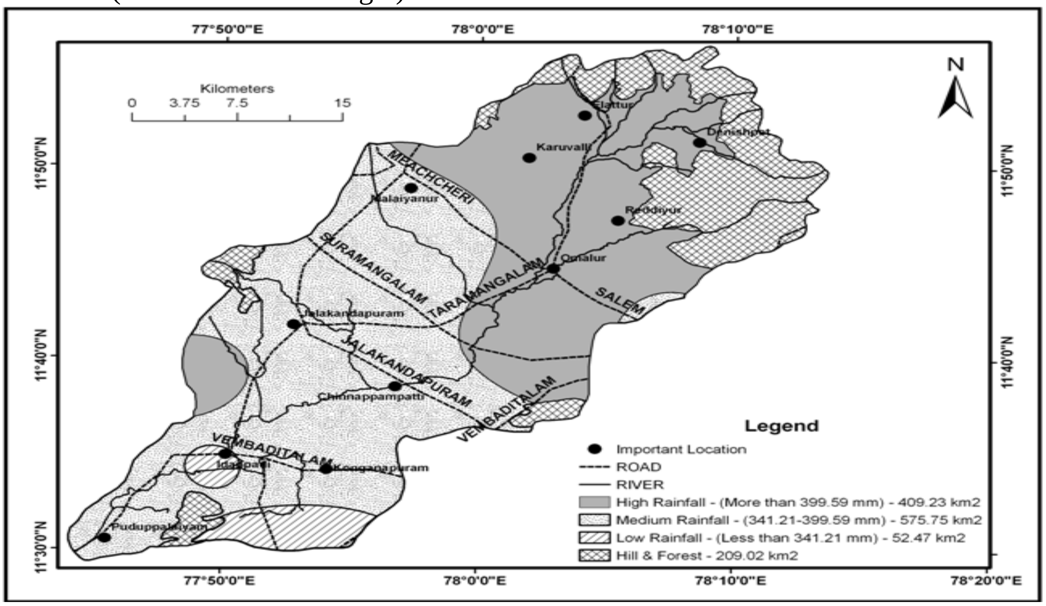

Figure 6: Annual average rainfall Southwest Monsoon Season – Spatial Distribution Map

The southwest monsoon GIS map (Figure 6) reveals that spatially 409.23 km^2 area falls in the high rainfall category and 575.75 km^2 area falls in moderate rainfall category. The high rainfall zone present in upper part of the study area.

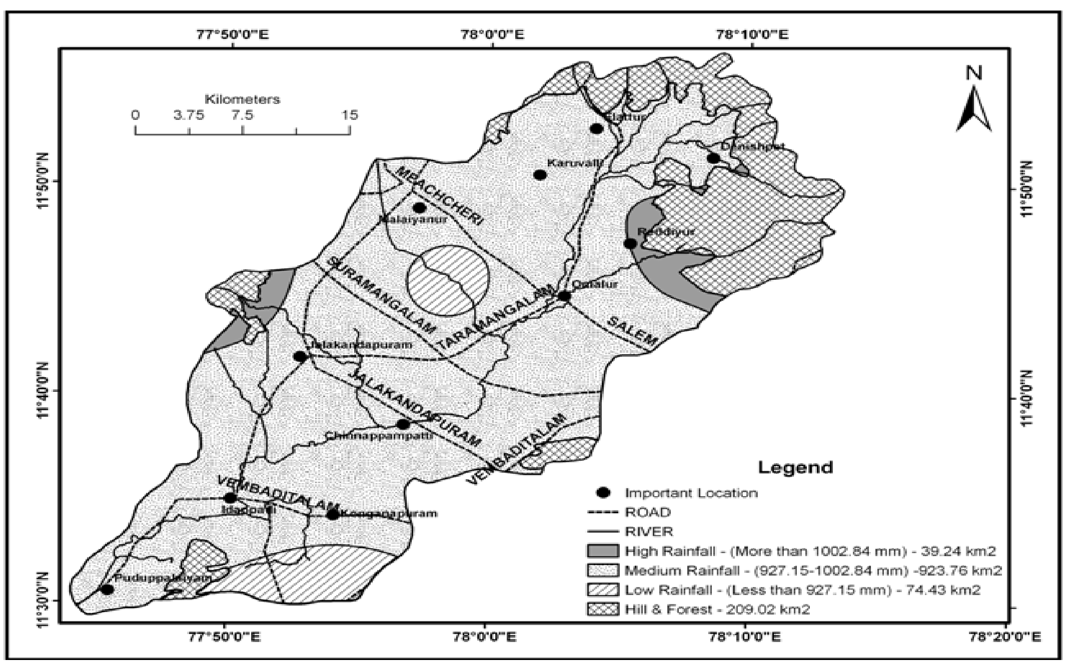

Figure 7: Annual average rainfall Northeast Monsoon Season – Spatial Distribution Map

Northeast monsoon GIS image reveals that spatially 39.24 km^2 areas falls in the high rainfall category, 923.76 km^2 area falls in moderate rainfall zones and rest of the area 74.43 km^2 falls in low rainfall zones.

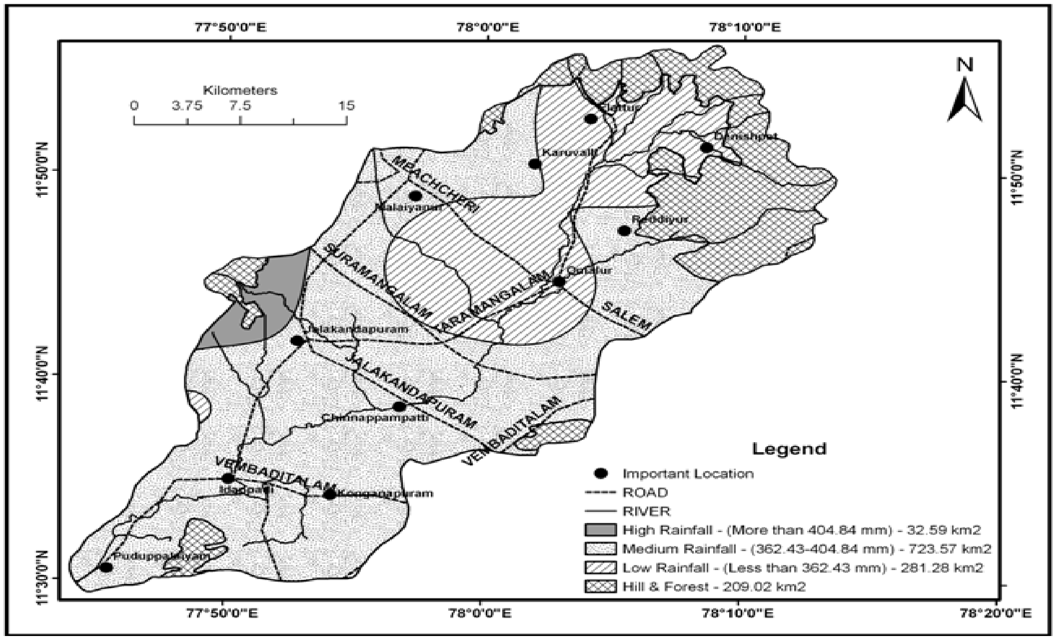

Figure 8: Annual average rainfall in 2001 to 2010 – Spatial Distribution Map

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Table 3: Average seasonal rainfall data spatial distribution results

Sl.No.	Rainfall Seasons	Class Category	Area in km^2	Area in Percentage
1	Winter	High Rainfall	1.46	0.13
		Medium Rainfall	838.64	80.84
		Low Rainfall	197.35	19.02
2	Summer	High Rainfall	79.44	7.66
		Medium Rainfall	906.61	87.39
		Low Rainfall	51.40	4.95
3	Southwest Monsoon	High Rainfall	52.47	5.06
		Medium Rainfall	575.75	55.50
		Low Rainfall	409.23	39.45
4	Northeast Monsoon	High Rainfall	281.28	27.11
		Medium Rainfall	723.57	69.75
		Low Rainfall	32.59	3.14
5	Annual Average	High Rainfall	74.43	7.18
		Medium Rainfall	923.76	89.04
		Low Rainfall	39.24	3.78

Average annual rainfall spatial distribution result shows that spatially 32.59 km^2 area falls in high rainfall zones and 723.57 km^2 area falls in moderate rainfall zones and rest of the area 281.28 km^2 falls in low rainfall zones. High rainfall spatially occupied southwestern part of the study area.

CONCLUSION

GIS tool is highly helping in this study, to demarcating the different spatial distribution zones. It shows that higher amount of rainfall received in the Northeast and Southwest monsoon seasons, spatially 409.23 km^2 are precipitated for 79.86%. The study concludes that result the high amount of rainfall water received only monsoonal season but Non-monsoonal season in meager amount of rainfall is received. Therefore this study area rainfall is not sufficient for the purpose of irrigational as well as domestic purposes due to the deforestation. The results suggest that to develop the dance forest in the hilly region.

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INTERNATIONAL CONFERENCE ON WATER RESOURCES, COASTAL AND OCEAN ENGINEERING (ICWRCOE 2015)

Delineation of Artificial Recharge Zones Using Geospatial Techniques In Sarabanga Sub Basin Cauvery River, Tamil Nadu

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Abstract

A case study has been conducted to delineation of artificial recharge zones using geospatial techniques in Sarabanga sub basin Cauvery River, Tamil Nadu. The groundwater storage change from place to place and there isneed to identify recharge zones throughgeospatial technology as an important strategy for water management system.However conventional methods alone it is not an easy task to study the surface parameters of a large area to identify suitable sites for artificial recharge, since many controlling parameters must be independently derived and integrated, which involves additional cost, time and manpower. Modern remote sensing technologies have many advantages over older, conventional methods due to their synoptic coverage, improved spatial resolution, and their capabilities for multi-spectral and multi-temporal analysis. In addition, unlike conventional methods for demarcation of suitable areas for groundwater replenishment are able to take into account the diversity of factors that control groundwater recharge. Based on the GIS overlay analysis the possible combinations for recharge sites based on geology, geomorphology, lineament, lineament density, drainage density, Landuse and Landcover combinations covers an area of 915.052 Sq.kmand are suitable for various artificial recharge structures. The results show that by expanding the artificial recharge system, the recharge volume can be increased even for small flood events.

Peer-review under responsibility of organizing committee of ICWRCOE 2015

Keywords: Geospatial Techniques; Lithology; Artificial Recharge; Geology; Geomorphology; subtract;

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1. Introduction

Artificial recharging is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. In India, this method has been in use for quite some time and its historical evolution is briefly outlined. It has been used for many beneficial purposes although the primary objective of this technology is to preserve or enhance groundwater resources. A variety of methods developed and applied to artificially recharge groundwater both in the urban and rural sectors have been reviewed. Various artificial recharge experiments have been carried out in India by different organizations, and have established the technical feasibility of the artificial recharge of unconfined, semi-confined and confined aquifer systems. The studies on artificial recharge techniques are mostly site-specific and descriptive in nature, which gives little insight into the potential success of implementing this technology in other locations.Many assessments of groundwater conditions made with remote sensing techniques have been reported (Krishnamurthy and Srinivas 1995; Bastiaansen et al. 1998; Venkata et al.2008; Chowdary et al. 2009; Jasrotia et al. 2009). Geographic Information System (GIS) techniques have many advantages over older, improved georeferenced thematic map analysis and interpretations (Thapinta and Hudak 2003; Dixon 2005; Martin et al. 2005). Cowen (1988) defined GIS as a decision support system involving the integration of spatially referenced data in a problem solving environment. In addition, unlike conventional methods, GIS methods for demarcation of suitable areas for groundwater replenishment are able to take into account the diversity of factors that control groundwater recharge. Thematic map integrated various features derived from data in a GIS environment (Krishnamurthy et al. 1996; Murthy 2000; Saraf and Choudhury 1998; Baker et al. 2001; Henry et al. 2007; Tabesh et al. 2009). However only a limited number of studies have taken the approach of specifically mapping potential artificial recharge zones, and as such there is no integrating of multi-criteria analysis using the weighted aggregation method, associated with GIS techniques to derive the groundwater recharge map. It is a new approach adopted for mapping groundwater recharge zones.In recent years, a shift in groundwater resources management approaches from the traditional concept towards the new model using the geographical information system utilities can be recognized (Rowshon et al. 2009; Koch and Grünewald 2009; Al-Qudah and Abu-Jaber 2009). The GIS techniques applications in hydrogeological mapping can be almost divided into two parts: hydrological analysis (Patil et al. 2008; Naik et al. 2009) and water resources development (Wu et al. 2008; Chowdary et al. 2009) on the one hand and water quality (Mantzafleri et al. 2009) on the other.

2. Study area

Sarabanga sub basin located between north latitudes 11°46’00’’ to 12°09’39” and east longitudes 78°12’27” to 78°36’65” (1178.56 km^2 in area) is laying entirely in the Salem district of Tamil Nadu state, India. Out of the total area, around 715.70 km^2 is covered with forest, 159.69 km^2 with agriculture, and 19.81 km^2 with water bodies. River Sarabanga and its tributaries are the major water sources of this study area. Itcover in an areal extent of 1178.56 km^2 and fell entirely in the Salem district. Sarabanga river originate on the western slope of Shevaroy hills at an altitude of 1630 m amsl, it’s appears only rainy seasons, people in this region entirely depends on the groundwater resources for their domestic, agricultural and industrial needs. ClimatologicallySarabanga sub basin is hot and semiarid and receives an average annual rainfall of 852 mm (2000-2009) out of which 90 % is received during the southwest (June-Sept) and the northeast (Oct-Dec) monsoon periods and the hot weather begins early in March, the highest temperature being reached in April and May. Weather cools down progressively from about the middle of June and by December, the mean daily maximum temperature drops to 30.2°c, while the mean daily minimum drops to 19.2°c and 19.6°c. The sub basin and its parts are easily approachable by metalled road from any part of the state. (Fig.1)

3. Materials and methods

The multiple parameter analysis for delineating the artificial groundwater recharge sites in the study area has been done by Geospatial technique. In this study, 9 spatial parameters such as geology, geomorphology, slope, land use and land cover, lineament density, drainage density, soil, aquifer thickness and rainfall are analyzed to construct various types of artificial recharge structures and give relevant weightages of different influenced parameter to explore the potential zone for groundwater recharge. For micro level study, 202 village maps were scanned and

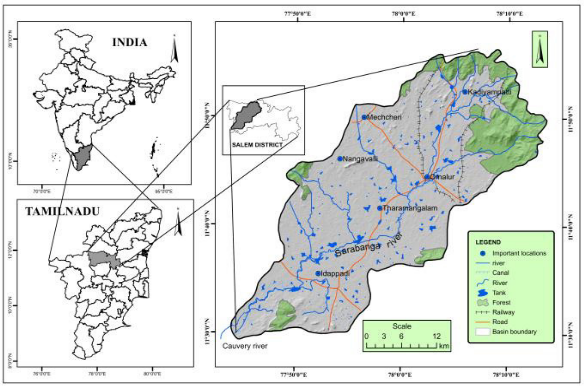

Fig.1.Location of the study area

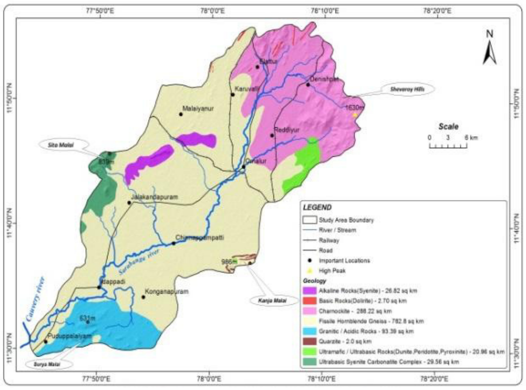

Fig.2.Geology of the study area

digitized in GIS environment with attributes (Village index numbers).

4. Data collection and preparation of geospatial database

Nine spatial parameters have been used for geospatial database preparation. Using Geospatial techniques, the thematic layers namely geology, geomorphology, slope, land use and land cover, lineament density, drainage density, soil, aquifer thickness and rainfall were prepared from the above data sources and projected with UTM–WGS 84 projection and coordinate system. The geological thematic layer was prepared from the published map of Geological Survey of India using digitizing technique in ArcGIS 10.1 environment. Similarly, the soil maps have been prepared from soil survey of India. Moreover, the slope map was prepared using SRTM data and the drainage density map was prepared from the Survey of India topographical map. The geomorphology and lineament density layer has been prepared from Landsat IRS P6 LISS IV image using visual interpretation technique and Landuse/land cover map was prepared using supervised classification method in Erdas Imagine 9.1 software. The average annual average rainfall map has been prepared from the rain gauge data collected from Indian Meteorological Department for the year 2002-2011. The attribute database of these different layers of various recharge methods are using weighted overlay index the suitable area to construct artificial recharge structures are recommended.

5. Assignment of weight to parameters

In the present study, the Geospatial technique was applied to integrate different thematic layers based on the assigned weights for suitable site selection. Here, the weight of the feature class of individual parameter was assigned at a scale of 1–10 as per the guidelines of Central Ground Water Board, Government of India (CGWB, 2007). Further, the feature classes of each parameters were quantitatively weighted as poor (weight=1–3), moderate (weight=3–5), high (weight=5–7), and very high (weight=7–9). For example, the layer that has aquifer and more permeable soil type with agricultural land is assigned with the weight as 7, as well as the layer with hard rock with less soil depth and poor permeability is assigned as 1. Similarly, all parameters were assigned with a suitable weight and assigned weightage are given in Table 1.

6. Results and discussion

The potential zones for groundwater recharge were explored by analyzing the different parameters such as geology, geomorphology, slope, land use and land cover, lineament density, drainage density, soil, aquifer thickness and rainfall through integrated geospatial technology.

7. Geology

The study area is mainly underlined by Fissile hornblende biotite gneisses followed by charnockite and granite etc. Fissile hornblende biotite gneisses are the dominant group of rocks covering major parts of the study area. The minor amount of alkaline rocks (syenite) and basic rocks (dolerite) are noticed in south and northeastern part. The younger alluvium formations are seen predominantly in the central part of the study area and are considered as highly permeable. Besides that, the southwest parts of the study area consist of fluvial deposits, which are laid on hornblende biotite gneiss and are considered as good zone for groundwater recharge. However, the hard rock materials composed of crystalline charnockite and quartzite vein present in the southern part of the study and it's not suitable for groundwater recharge (Fig. 2).

8. Aquifer Thickness

Aquifers are water-bearing unconsolidated layer of geological structure of an area. The aquifer thickness is the groundwater storage from the unit of area. The sub surface layer thickness is highly varied place to place. Based on Vertical Electrical Sounding was carried out at 93 locations using Schlumberger configuration with electrode spacing of 150 m to demarcate different layers of aquifers are classified in to low thickness (<19.86), medium thickness (19.86-38.76), high thickness (38.76-60.76) and very high thickness (>60.76) the groundwater potential of the study area.

Table 1.Assignment of weight for the feature classes of individual parameter

Name of parameter	Feature class	Assigned Weight(AW)	Name of parameter	Feature class	Assigned Weight(AW)
Slope (in percentage)	0-1%	7	Soil		
	1-3%	6		Alfisols	6
	3-5%	5		Entisols	5
	5-10%	4		Inceptisols	4
	10-15%	3		Vertisols Miscellaneous Reserve	3
	15-30%	2		Forest	2
	>30%	1			
Aquifer Thickness			Land use/land \cover	Crop land	7
	<40	7		Fallow land	6
	40-66	5		Land with scrub	5
	66-86	3		Land without scrub	4
	>86	1		Barren Rocky/ Stony Waste	3
				Buildup Land	2
				Forest	1
Annual rainfall (in mm)			Geology	Alkaline rocks-Syenite	4
				Basic rocks-Dolerite	3
	<233	1		Charnockite	5
	233-237	3		Fissile Hornblende Biotite Gneiss	6
	237-266	5		Granitic/Acidic rocks	3
	>266	7		Ultrabasic SyeniteCarbonatite Complex	2
				Ultramafic / Ultrabasic rocks	3

The thickness of the weathered, fractured zone and depth to bed rock were determined from VES data. Due to over exploitation of groundwater in the study area, only fractured layers act as aquifers. Therefore the thickness of fractured zone was taken into ArcGIS platform. It is well known that storage increases with the thickness of the aquifer. Therefore the higher thickness of the aquifer, the more is the storage and vise versa. Similar areas are found in flood plain and debris wash plain in and northeast part and gentle slope surface in northeast and southeast part of the study area. These areas are mainly prepared for the construction of artificial recharge structures to groundwater replenishment. The moderate amount of groundwater potential is observed in the low thickness area along river channel (Fig.3).

9. Land use and land cover

Land use/land cover is one of the major controlling factors in groundwater recharge processes. The term land use relates to the human activity associated with a specific piece of land, while land cover relates to the type of features present on the surface of the earth. Urban buildings, lakes, residual hills, rocky out crop are all examples of land cover types. Agricultural, afforestation, and mining activities are a few land use categories in the study area.The different types of land use/land cover present in the study area are crop land, plantations, land with shrubs, land without shrubs, buildup land, forest, and water bodies shown in Fig.4 and IRS P6 LISS IV image shown in Fig.5. The forest land cover and plantation are present predominantly in the hilly terrains in southern, northeastern and northwestern part of the study area. These land use types are not suitable for groundwater recharge due to utmost availability of heavy rainfall. The land uses such as crop land, fallow land, land with shrubs and land without shrubs are found in the southern part of the study area.These areas are prioritized first for groundwater recharge because of less availability of both surface and groundwater for domestic and irrigation purpose.

9. Artificial recharge

The practice of artificial recharging is increasingly emerging as a powerful tool in water resource management. i. Infiltration Basin Method, ii. Ditch and Furrow Method iii.Flooding Method, iv. Irrigation Method, and v. Desilting of Existing Tanks is some popular artificial recharge structures are implemented in the study area. By constructing suitable types of artificial recharge structures, groundwater resources can be augmented.

10. Weighted Index Overlay Analysis:

Weighted Index Overlay Analysis (WIOA) is a simple and straight forward method for a combined analysis of multi class maps. The efficacy of this method lies in that the human judgment can be incorporated in the analysis.A weight represents the relative importance of a parameter vis-a-vis the objective. WIOA method takesinto consideration the relative importance of the parameters and the classes pertaining to each parameter. There isno standard scale for a simple weighted overlay method. For this purpose, criteria for the analysis are defined and each parameter is assigned importance (Saraf and Choudhury, 1998). The present study was been extended further to combine the surfaces created for groundwater quantity parameters such as rainfall, water level, geophysics, geochemistry geology, geomorphology and soil to generate groundwater quantity and quality data of the study area. The idea was to get a scenario that represents the overall situation of the area in context of above parameters at a particular time. In order to have the resultant groundwater information, the surfaces created for three parameters (Very Good, Good, Medium. Poor) were used as input theme for the weighted layers. Weighted overlay analysis technique was used to generate various thematic maps and get useful information in short time.

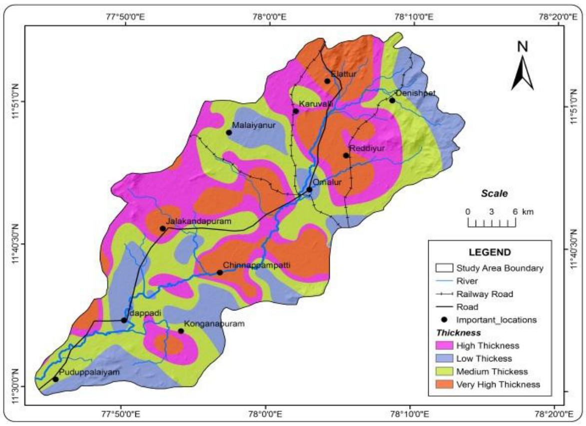

Fig.3.Aquifer thickness of the study area

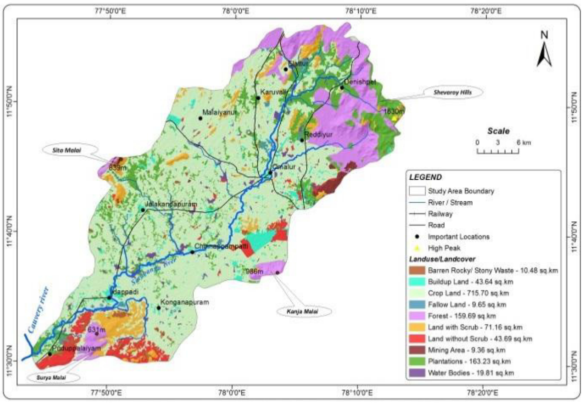

Fig.4.Landuse/Land cover of the study area

10.1. Infiltration Basin Method

Infiltration basins require a substantial amount of land area with a suitable geology, allowing the water to infiltrate into the aquifer and percolate to the groundwater table. It is simple to maintain and regular restoration of infiltration capacity and removal of clogging layers is relatively easy though time consuming. This method also allows for natural, quality improving processes to take place in the infiltration ponds and sub soil.For this method, the streams were taken as the best location for recharge. 67.92 km length of the stream falls as best recharge drainage for this method. 633 stream locations have been found suitable for the construction of artificial recharge structures shown in Fig.6. 54 (11 Villages) out of 629 (43 Villages) stream location areas had been identified as the most suitable sites while rest of the 577 locations had been classified moderate category and 119 villages had been identified as the best locations for Infiltration basin method.

10.2. Ditch and Furrow Method

The ditches may be dug sub parallel to the contours to draw water at an upstream point of the contours and return surplus water to the stream at a downstream point. In areas of irregular topography, shallow, flat bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge from source stream or canal. It is suitable for irregular areas where slopes are too steep for basin construction shown in Fig.7. Low check dams and dykes can be constructed across a stream where a wide bottom occurs. For the selection of site by Ditch and Furrow method the following maps such as Drainage map, Land use/Land cover map, Topsoil, Weathered Zone and Fracture Zone Thickness Maps and Slope map were considered. In particular method 76 stream location areas had been identified as the most suitable sites in 21 villages of the study area.

10.3. Flooding Method

Flooding method involves inundating agricultural or waste lands with a thin sheet of water to a depth of a few centimeters to one meter depending on the nature of the terrain. This method is more suitable for relatively flat terrains. The land use and land cover, slope, soil permeability and soil thickness maps were used for identifying areas suitable for flooding method.The GIS output results have been given in Table 2 and village overlay map in Fig.8. 13 villages have been identified as the best suited locations for this method and categorized as good class for artificial recharge. Flooding method of recharge was constructed in 1.49 Sq.km area and 13 villages and 303.06 Sq.km area and 172 villages have been identified as medium range for this method of recharge.

Table.2 Weightage assigned in various artificial recharge methods suitable parameters

Sl. No.	Name of the method	Maps used	Weightage Assigned	No of Streams in good category	No of Villages in good category	Area (sq.km)
1	Infiltration Basin Method	Water level	(< 7.34)1 (7.34-10.75)2 (>10.75)3	54	26	218.820
		Aquifer thickness	(<41.9)1 (41.9 m -69.8)2 (>69.8)3			
2	Ditch and Furrow	DrainageMap	-	76	21	10.502
		Slope (0 – 50)	< 100 1 5 to100 2 > 50 3			
		Land use and land cover	(Other Features)1 (Land with scrub)2 (Land without Scrub)3			
		Aquifer thickness	(<41.9)1 (41.9 m -69.8)2 (>69.8)3			
3	Flooding Method	Drainage Map	-	1.49	13	1.490
		Slope (0 – 50)	>30%0 5-30%0 >0- 5% 2			
		Land use and land cover	(Other Features)1 (Land with scrub)2 (Land without Scrub)3			
		Top soil thickness m	< 1.9 1 (1.9 – 2.005) 2 (>2.005) 3			
4	Irrigation Method	Rainfall	Low 1 Medium 2 High 3	0.72	8	0.718
		Agricultural land	(Land with scrub, fallow land) 2			
		Soil permeability	(High permeability)3 (Medium permeability)2 (Low permeability)1			
5	Desilting of Existing Tanks	Aquifer thickness	(<41.9)1 (41.9 m -69.8)2 (>69.8)3	39	22	260.023
		Soil Permeability	Slow 1 Moderate 2 Rapid 3			

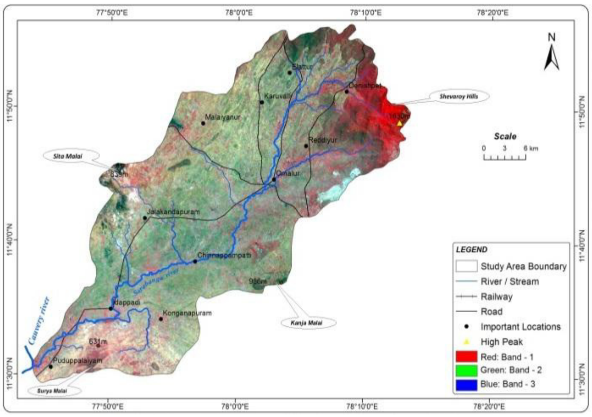

Fig.5.IRS P6 LISS IV image of the study area

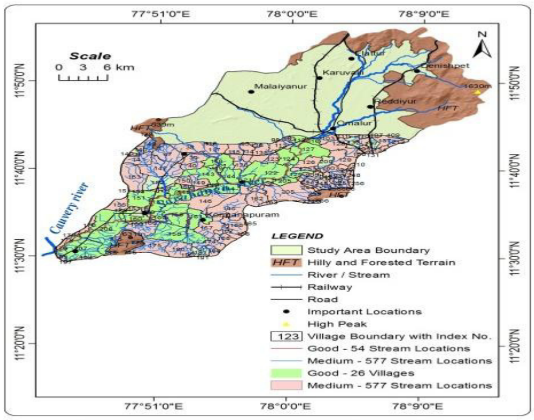

Fig.6. Feasible sites for Basin artificial recharge structure

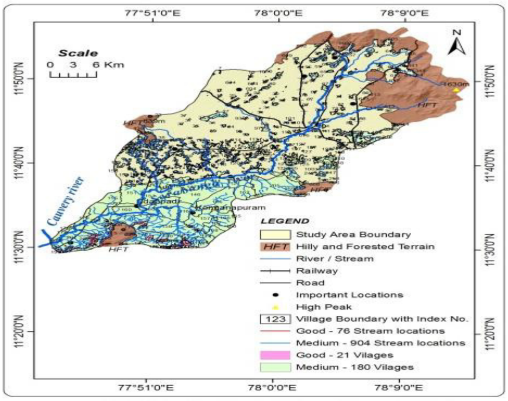

Fig.7. Feasible sites for Ditch and Furrow artificial recharge structure

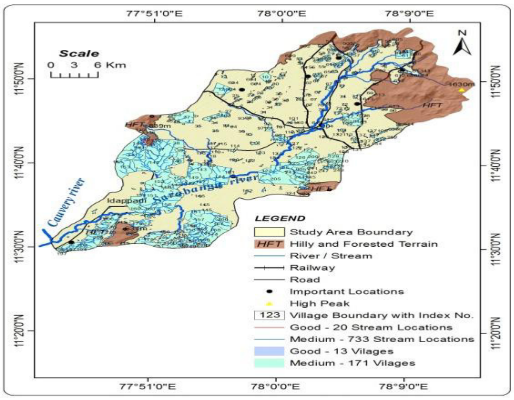

Fig.8. Feasible sites for Flooding artificial recharge structure

10.4. Irrigation Method

This method is specifically designed for paddy cultivated areas. During the preparation of the field for paddy, the soil is made impervious for water retention. Percolation of water in the paddy area is very less. This has serious effect on the recharge of aquifer in this area. A pit is constructed in the field where the slope is maximum. The level of the soak pit is slightly below the optimum level of water in the paddy field.

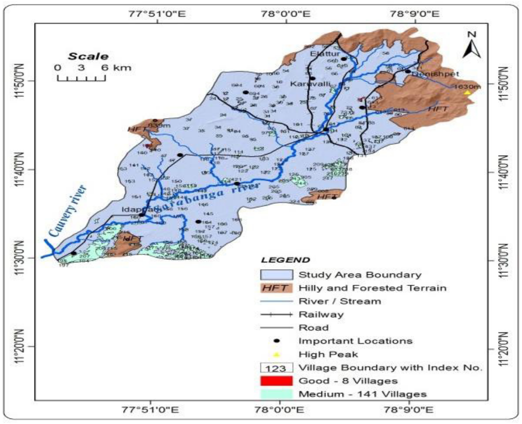

Fig.9. Feasible sites for Irrigation artificial recharge structure

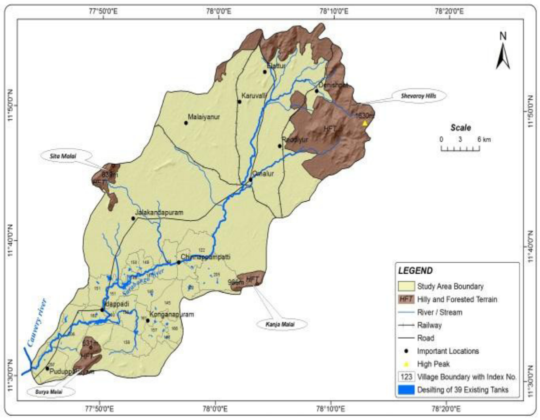

Fig.10. Feasible sites for Desilting of Existing Tanksartificial recharge structure

In this way the excess water percolates through the soak pit to the subsoil.Isohyetal map (Medium and High Rainfall), Agricultural Land (Land with Scrub and Fallow Land) and Soil Permeability map were taken for the GIS integration. The GIS output results have been given in Table 2 and village overlay map in Fig.9. 8 villages have been identified as the best suited locations for this method and categorized as good class for artificial recharge.

11.5. Desilting of Existing Tanks

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure. Most of the tanks are filled with particles like soil, vegetation and other transported materials viz., drainages and streams. This type of tanks can store minimum amount of water, therefore can remove the deposited materials. The GIS results with village integration map for site selection have been given in Table 2 and Fig.10 reveals 39 tanks which fell in 22 villages have been identified as suitable for Desilting of existing tanks. The numbers of existing tanks have been worked to remove sediments in order to store higher amount of water and in turn enhance the groundwater storage.

11. Conclusions

The investigations were carried out in accordance with updated hydrogeological methodology. Key findings have been made in GIS environment for identifying micro level village wise favorable areas amenable to different artificial recharge structures have been derived for sustainable development of groundwater resources in the Sarabanga sub basin, Cauvery river. Such advancements will certainly enable us to develop and manage precious groundwater resources in a real sustainable and environment-friendly way.

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