Application of RS and GIS Technique for Identifying Groundwater Potential Zone in Gomukhi Nadhi Sub Basin, South India

Punitha Periyasamy, Mahalingam Sudalaimuthu, Sachikanta Nanda, Arasu Sundaram

***Abstract*—**India holds 17.5% of the world's population but has only 2% of the total geographical area of the world where 27.35% of the area is categorized as wasteland due to lack of or less groundwater. So there is a demand for excessive groundwater for agricultural and non agricultural activities to balance its growth rate. With this in mind, an attempt is made to find the groundwater potential zone in Gomukhi Nadhi sub basin of Vellar River basin, TamilNadu, India covering an area of 1146.6 Sq.Km consists of 9 blocks from Peddanaickanpalayam to Virudhachalam in the sub basin. The thematic maps such as Geology, Geomorphology, Lineament, Landuse and Landcover and Drainage are prepared for the study area using IRS P6 data. The collateral data includes rainfall, water level, soil map are collected for analysis and inference. The digital elevation model (DEM) is generated using Shuttle Radar Topographic Mission (SRTM) and the slope of the study area is obtained. ArcGIS 10.1 acts as a powerful spatial analysis tool to find out the ground water potential zones in the study area by means of weighted overlay analysis. Each individual parameter of the thematic maps are ranked and weighted in accordance with their influence to increase the water level in the ground. The potential zones in the study area are classified viz., Very Good, Good, Moderate, Poor with its aerial extent of 15.67, 381.06, 575.38, 174.49 Sq.Km respectively.

***Keywords*—**ArcGIS, DEM, Groundwater, Recharge, Weighted Overlay.

I. Introduction

WATER plays an important role in the development of a society. Water Resources planning follows a resource based approach to development especially for attaining self-sufficiency in food production. The rationale of resource based planning is the assumption that economic developments depend on the natural resources available in the region as these are assumed to provide the main income opportunities for the population of that region. Being an agrarian State Tamil Nadu, India is mainly depending upon its water resources for agricultural activities, food production and domestic uses. Groundwater is one of the greatest hidden natural resources of the earth's crust. It has emerged as an important and indispensable resource in the absence of adequate surface water resources to meet out the different sectoral demands. The present paper identifies the groundwater potential zones by analyzing the satellite imageries of the respective period and GIS enables integration and management of multi thematic data. Thematic layers on drainage, slope, soil, geology, geomorphology, landuse and landcover, and lineament were prepared and these layers were analysed by overlay analysis with water level and rainfall for generating the groundwater potential zonation map [11]-[14].

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II. Study Area

The Vellar river basin is one of the seventeen major river basins of Tamil Nadu. The sub basins of Vellar River Basin are Upper Vellar, Swetha Nadhi, Chinnar, Anaivari Odai, Gomukhi Nadhi**,** Manimuktha Nadhi, Lower Vellar. Out of the 7 sub basins Gomukhi Nadhi Sub Basin was chosen so as to undergo a detailed study to find out the groundwater potential zones. The basin is bounded by Pennaiyar and Paravanar basins in the north, Cauvery basin in the west and south and the Bay of Bengal in the east near PortNova (Fig. 1).

The sub basin is situated between the co-ordinates of N latitude 11.86 to 11.52 and E longitudes 78.61 to 79.2 has total geographical aerial extent of 1146.6 Sq.Km covering 9 blocks from Peddhanaickanpalayam to Virudhachalam.

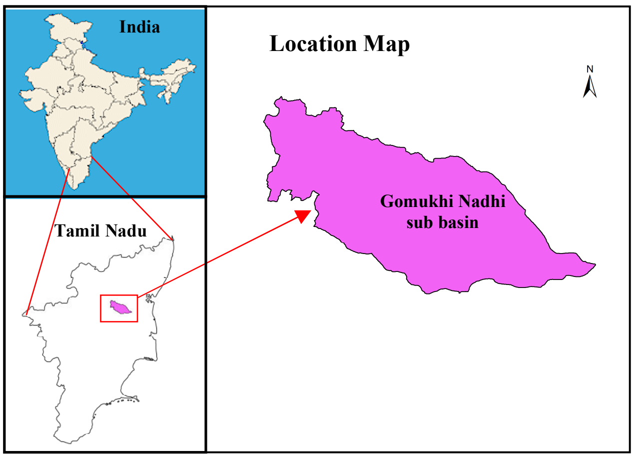

Fig. 1 Location map of the study area

III. Materials and Methods

The methodology involves delineation of water bodies from

Survey of India toposheets 58/I 9,10,13,14 on 1:50000 scale. Satellite data IRS P6 LISS III & pan marged data of 2010 was used for mapping Drainage, landuse and landcover, geomorphology and lineament maps [3], [8]. The slope map was prepared from SRTM data in ArcGIS Spatial Analyst module.

The soil layer was prepared by digitizing the soil map obtained from the Department of Agriculture, Tamil Nadu. Rainfall and water level data for the respective periods are used for analysis of hydrosystem. Geology and structure of the Gomukhi Nadhi sub basin is generated based on the published District Resources maps of Geological Survey of India.

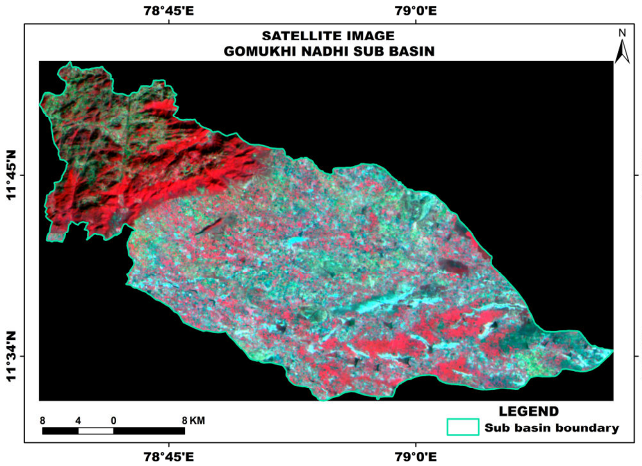

Fig. 2 Satellite Image of the study area – IRS P6 - 2010

IV. Resource Maps

Drainage, Slope, Soil, Geology, Geomorphology, Landuse and Landcover, Lineament, Rainfall and Water Level have been analysed to understand the basic resources of the study area.

A. Drainage

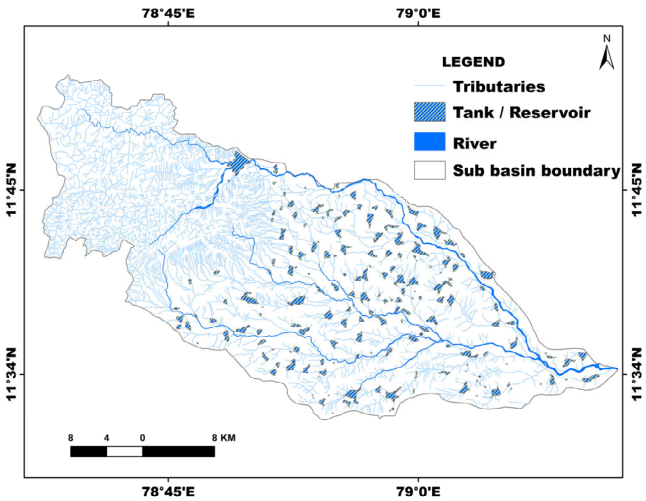

Fig. 3 Drainage map

Gomukhi Nadhi originates from the eastern slopes of the Kalrayan hills in Kallakurichi Taluk at an altitude of about 1298 metres. The river flows for a length of 13 km at which point the Gomukhi Nadhi reservoir has been constructed across the river at about 16km to the north west of Kallakurichi town. About 44 km below this reservoir, a tributory called Mayuranadhi joins the Gomukhi Nadhi on its right flank. Mayuranadhi runs for a length of 38km from its origin which is also on the south eastern slopes of Kalrayan hills, northwest of Chinna Salem taluk. Two sub tributaries, namely Thirumanimukthanadhi on the right flank and Namasivayapuram Odai on the left, join the Mayuranadhi. At 8 km below the confluence of the Mayuranadhi, the Gomukhi Nadhi joins the Manimukthanadhi.

B. Slope

Slope is an important factor for the identification of groundwater potential zones. Higher degree of slope results in rapid runoff and increased erosion rate with feeble recharge potential [7]. The slope map of the study area was prepared based on SRTM data using the spatial analysis tool in ArcGIS 10.1. The study area has maximum of elevation is 1266 m (a peak) in the southern slope of Kalrayan hills. The elevation ranges from 1020 m to 1183 m in the north western part of the sub basin. The slope decreases gradually towards Virudhachalam block shown in Fig. 4.

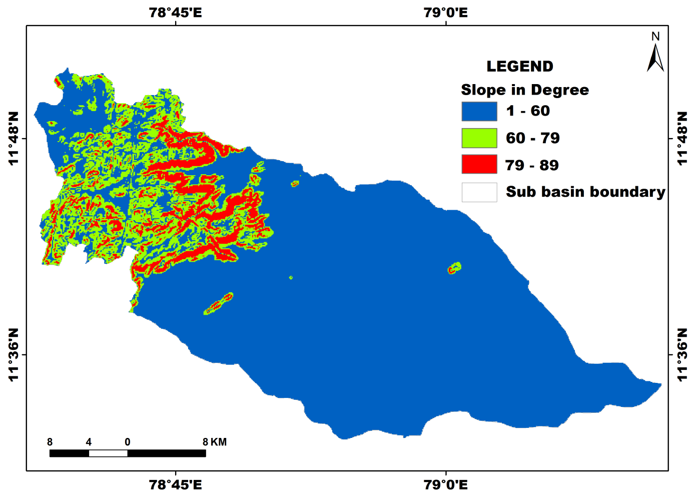

Fig. 4 Slope map

C. Geology

Archean group of rocks include mixed gneisses and charnockites occupy the study area (Fig. 5). Charnockites occupy the major portion of the middle part of the basin especially in Chinnaselam, Kalrayan Hills, South – West of Kallakurichi and North – West of Mangalur.

Gneissic rocks include Fissile hornblende gneiss and Magmatic gneiss occupies the western and eastern portion of the sub basin. Fissile hornblende gneiss occurs in North-West of Kalrayan Hills, Thalaivasal and Peddhanaickanpalayam Blocks. Virudhachalam, Nallur, Kallakurichi and a major portion of Mangalur, Thiyagadurgam blocks are occupied by

Magmatic gneiss [10].

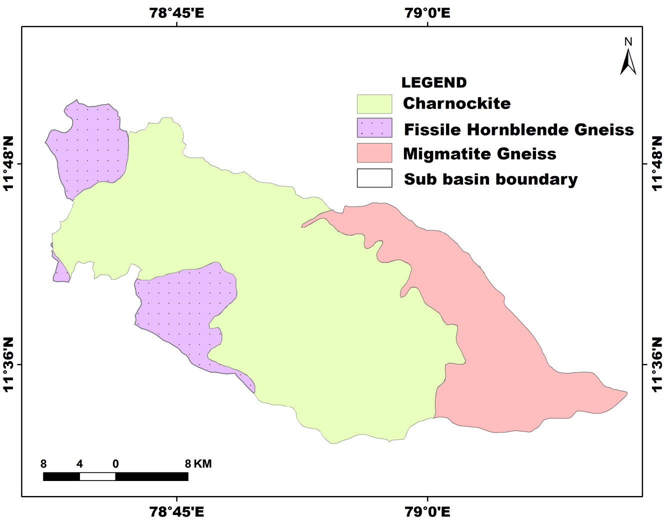

Fig. 5 Geology map

D. Soil

Soil is one of the natural resources, which has the most direct impact on groundwater development. The major soil types found in this sub basin are Inceptisols, Alfisol and Vertisol. Due to different stage of weathering of parent material, the above soil types are met with in combination.

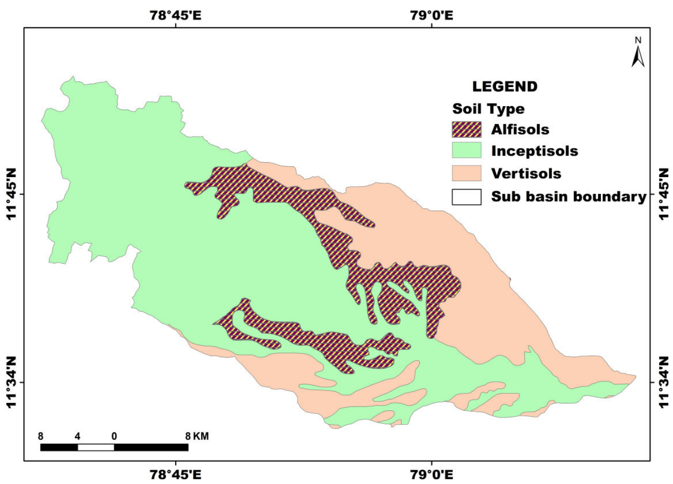

Fig. 6 Soil map

E. Geomorphology

There are mainly two types of landforms found in the study area which are described in Fig. 7. The denudational land forms in the study area are sub divided into various geomorphic units such as Structural Hill, Hilltop Valley, Bazada, Pediment, Buried pediment Deep, Buried pediment Moderate, Buried pediment Shallow, Pediment composed of Black Cotton Soil, Out Crop. The fluvial land forms are sub divided into various geomorphic units such as Duri Crust, Valley Fill in the study area.

The characteristics, lithology, texture and groundwater prospects of each geomorphic unit falling in different landforms are described in Table I [9].

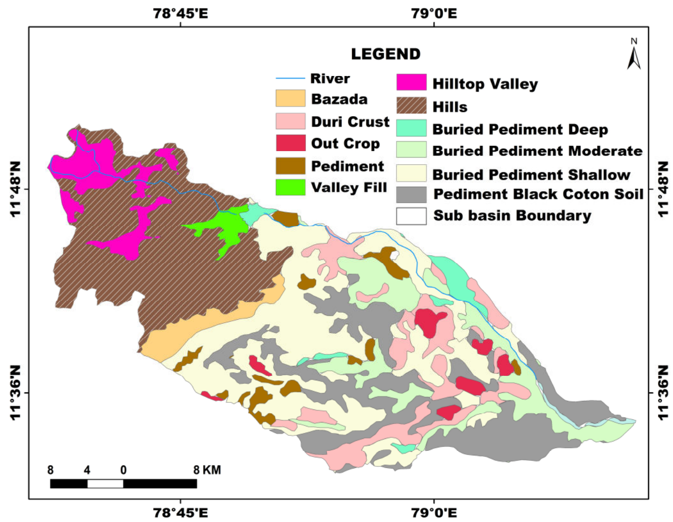

Fig. 7 Geomorphology map

TABLE I
DESCRIPTION OF THE GEOMORPHIC UNIT

Geomorphic Unit	Description	Groundwater Prospects
Structural hill	Linear to arcuate hills showing definite trend lines	Very poor – moderate along valleys
Hilltop valley	Essentially formed over horizontally layered rocks marked by extensive flat top and steep slopes	Good – Moderate along fractures/joints/lineaments/ and their intersections.
Bazada	Coalescence of alluvial fans at the foot hills in arid and semi arid regions have gentle slopes	Moderate - Poor
Pediment composed of outcrop	Rocky outcrops cover at the top and containing by less and partial weathering; Rock cut surface with thin veneer of soil cover	Poor
Pediment black cotton soil	Black cotton soil cover at the top and comprised by less and partial weathering;	Poor
Pediment	Mostly thin sheet wash material cover at the top and comprised by less and partial weathering	Poor - varies with underlying lithology - presence of fracture/ lineaments
Buried pediment shallow	Flat and smooth buried pediplain/ pediment with very thick (0-5m) over burden	Moderate – Poor
Buried pediment moderate	Flat and smooth buried pediplain/ pediment with very thick (5-20m) over burden	Good- Moderate
Buried pediment Deep	Flat and smooth buried pediplain/ pediment with very thick (more than 20m) over burden	Good
Valley fill	Unconsolidated sediments – boulders, pebbles, gravels, sand and silt	Good – Very good
Duricrust	Poor drainage facility. Induced evaporation and percolation cause thin salt incrustation. Very fine silty clay	Very poor

F. Landuse and Landcover

The information on land use is essential for effective management of the water resources in the sub basin. Traditionally the land use statistics have been compiled from village records. The present land use pattern has been assessed in relation to the groundwater development of this basin and the same is shown in Fig. 7. They are classified as Alkalinity/Salinity, Barren Land, Black Cotton Soil, Crop Land, Dry Crop, Harvested Land, Hilly Area, Water Body, Outcrop, Forest Land, Settlement, Shrub Land [1], [6].

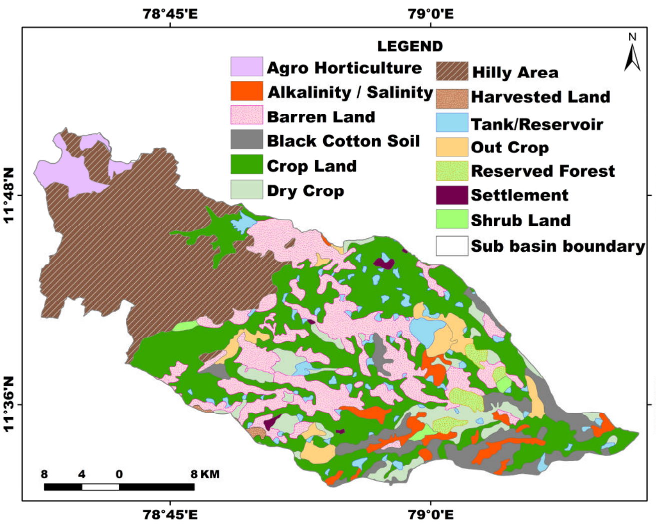

Fig. 7 Landuse and landcover map

G. Lineament

Lineament map was generated using satellite imagery of IRS P6 2010 data and shown in Fig. 8. The structure of the rock, geology of the area, tone, texture, shape, etc studied using the satellite imagery and interpreted with field hydrogeological data to prepare the lineament map for Gomukhi Nadhi sub basin.

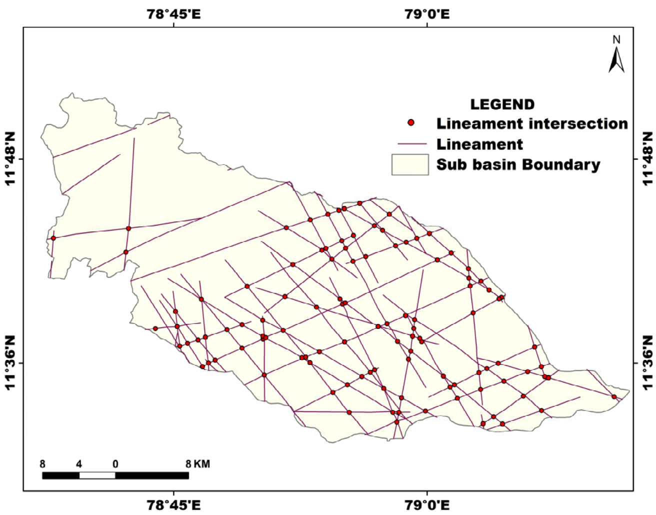

Fig. 8 Lineament map

The groundwater movement is more along these lineaments. Groundwater potential is very good in the lineament intersection zones. Lineament map was overlaid on the other thematic maps for targeting groundwater potential zones.

TABLE II
STRUCTURAL FEATURES

Structural Features	Characteristics	Hydrogeology	Ground water Potential
Lineament	Linear features may be a geological contact/fault/ shear or fractured jointed zone	Infiltration is good in fracture/ jointed lines and in geological contact.	Good
Lineament intersection zone	Irregular fractures with varying density criss cross and conjugate system of joints	Recharge from run off water, water bodies acting deep conductive of groundwater from long distance	Very Good

H. Rainfall

Rainfall data were collected from 6 rainguage stations located in and around the study area namely Athur, Sankagiri, Gomukhi Reservoir, Manimukthanadhi Reservoir, Kattumailur, Memathur are the main rainguage stations, which influence the rainfall in the study area. Gomukhi Nadhi sub basin lies in the tropical monsoon zone. As the monsoons bring heavy rainfall, it improves the recharging of groundwater as well as improves the storage of surface water. Hence, the monsoon period is hydrologically significant for water resources analysis. But in the case of non-monsoon, it is insignificant.

The isohyet map for the annual rainfall for the year 2011 (Fig. 9) was prepared using ArcView GIS Software. The annual rainfall isohyet map shows that the major portion of the sub basin receives maximum rainfall between 960-1044mm. The minimum rainfall received in the southwestern portion of the sub basin and around Kattumailur rainguage stations are noticed. Annual rainfall varies from 876 mm to 1211 mm.

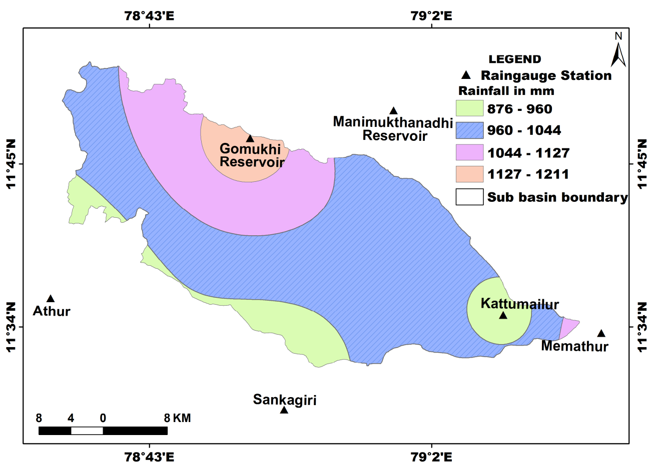

Fig. 9 Annual rainfall isohyet map - 2011

I. Water Level

Water level distribution maps showing the depth to groundwater table for pre monsoon (July 2010) and post monsoon (January 2011) have been prepared. From the water level analysis it reveals that, there is a depletion in water table ranges from 1m to 17 m bgl occurred during the pre monsoon and post monsoon periods. The fluctuations differ from well to well and are found to be in the range of 4m to 17m in Pre monsoon and 1m to 6m in Post monsoon. Water level Distribution is shown in Figs. 10 and 11.

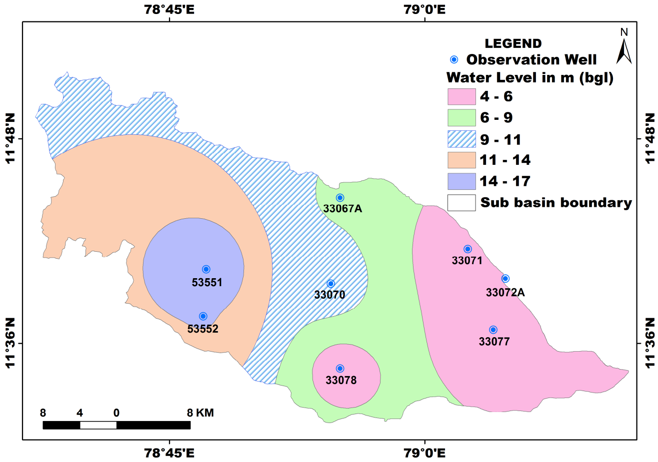

Fig. 10 Water level distribution map – pre monsoon 2010

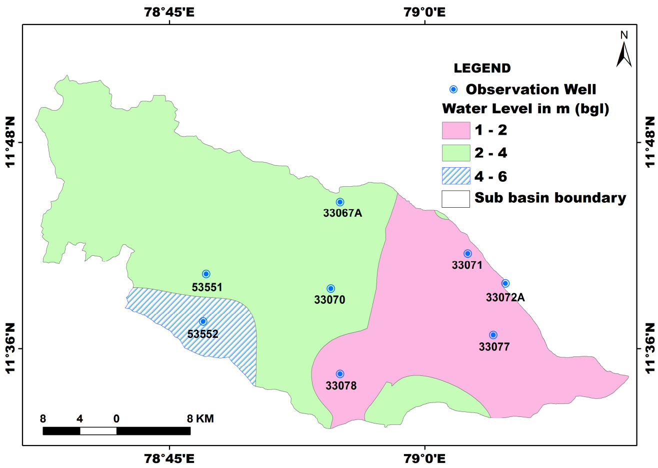

Fig. 11 Water level distribution map – post monsoon 2011

V. Groundwater Potential Evaluation

Geographical Information System (GIS) plays a more important role in the evaluation of groundwater potential. Arc GIS and Arc view were used to create database for spatial and non-spatial data. Raster Overlay Analysis is a necessary component to bring together data representing the Phenomenon. Using the Boolean logic rules to combine different layers is one of the easiest methods, through “Yes” or “No” rules. Most Boolean logical based overlay procedures in GIS do not allow for the fact that variables may not be equally important and the decisions about threshold values are often subjective. Hence to quantify the parameters in the analysis Mathematical Overlay method was adopted [5]. The final result is in the form of a raster layer, where each grid cell acquired a value through the additive overlay process. The higher the value of the grid cell, the more preferred the cell is Groundwater Potential Zone.

The groundwater potential zonation map has been generated by integrating the spatial and non- spatial data of Drainage, Slope, Soil, Geology, geomorphology, landuse and landcover, lineament, rainfall, and water level. Appropriate weightages were given based on the properties and characteristics of the layers shown in Table III [4].

TABLE III
The Phenomenon and Need of the Thematic Layers

Map Layer	Phenomenon	Need
Drainage	Structure of water holding	Major source of water
Slope	Runoff - Infiltration	Groundwater Recharge
Soil	Soil	Result of physical surface processes and the lithology
Geology	Geology	Increase or decrease in level of the water table
Geomorphology	Physical processes on the earth’s surface that produce different landforms	A geomorphic unit is a composite unit that has specific characteristics
Landuse and landcover	Purpose for which land has been put to use	Indicates the state of current use.
Lineament (including intersection)	Planes/Zones of structural weakness in the rocks	Easy movement of water along weak planes
Rainfall	Rainfall	Major source of water
Pre-Monsoon Water Level	Depth at which water occurs in the unconfined zone (top zone) below ground level (bgl)	Tells us the scarcity of easily accessible water

VI. Result

The GIS environ helped to generate groundwater potential zones in the sub basin. (Fig. 12) The block layers are overlaid with groundwater potential zone map [2]. Based on the outcome of the result, blockwise groundwater potential was evaluated and tabulated in Table IV. It is observed that the potential zones in the study area are classified viz., Very Good, Good, Moderate, Poor with its aerial extent of 15.67, 381.06, 575.38, 174.49 Sq.Km respectively.

VII. Conclusion and Recommendation

Based on the study the following conclusions and recommendations were arrived.

1) By analyzing with the sufficient parameters in the GIS platform, the ground water potential zone map is generated and the block boundaries were overlaid. From this map, blocks having good potential may be utilized for groundwater extraction and blocks that have less or poor potential needs to special investigation for groundwater development and management.
2) The geomorphic units like Bazada, Buried Pediment Deep, Buried Pediment Moderate, Valley fills are good groundwater potential zones whereas buried pediment shallow and pediment are moderate groundwater potential zones
3) The lineaments and the intersection of lineaments are favourable structures for groundwater exploration. Lineament zones were integrated with favourable geomorphic units, to delineate the favourable potential zones to target further exploration of secondary deeper aquifer.

4) During pre monsoon period, the water level was 4 to 17 m bgl and in post monsoon period it was only 1 to 6 m. The groundwater level in the western part of the sub basin seems to be very deep (11m to 17m) in summer season. In the rest of the area, considerable fluctuation of water level is observed due to shallow thickness of weathered zone and limitation in the storage capabilities of the aquifer.
5) Gomukhi Nadhi sub basin lies within the tropical monsoon zone. As the monsoon period brings heavy rainfall, it improves the recharging of groundwater as well as storage of surface water. Hence, the monsoon period (June to November) is hydrologically significant for water resources analysis. From the study it is recommended that it is necessary to harvest the rainfall during monsoon season.
6) Tanks (Surface water bodies) are the main source for ground water recharge. Siltation of the tank not only reduces the storage capacity, but also decreases the rate of groundwater recharge. Hence the condition of the tanks may be restored. Steps have to be taken to minimize soil erosion in the catchments area to avoid siltation.
7) Artificial groundwater recharge structures are recommended in poor and moderate groundwater potential zones of the sub basin after conducting proper hydro – geological investigations and site suitability analysis.
8) In order to protect the environment and safe guard the aquifer zone, only agricultural activities may be recommended, industrial activities which will pollute the recharge aquifer are not advisable around the area where the recharge structures are made to augment groundwater.

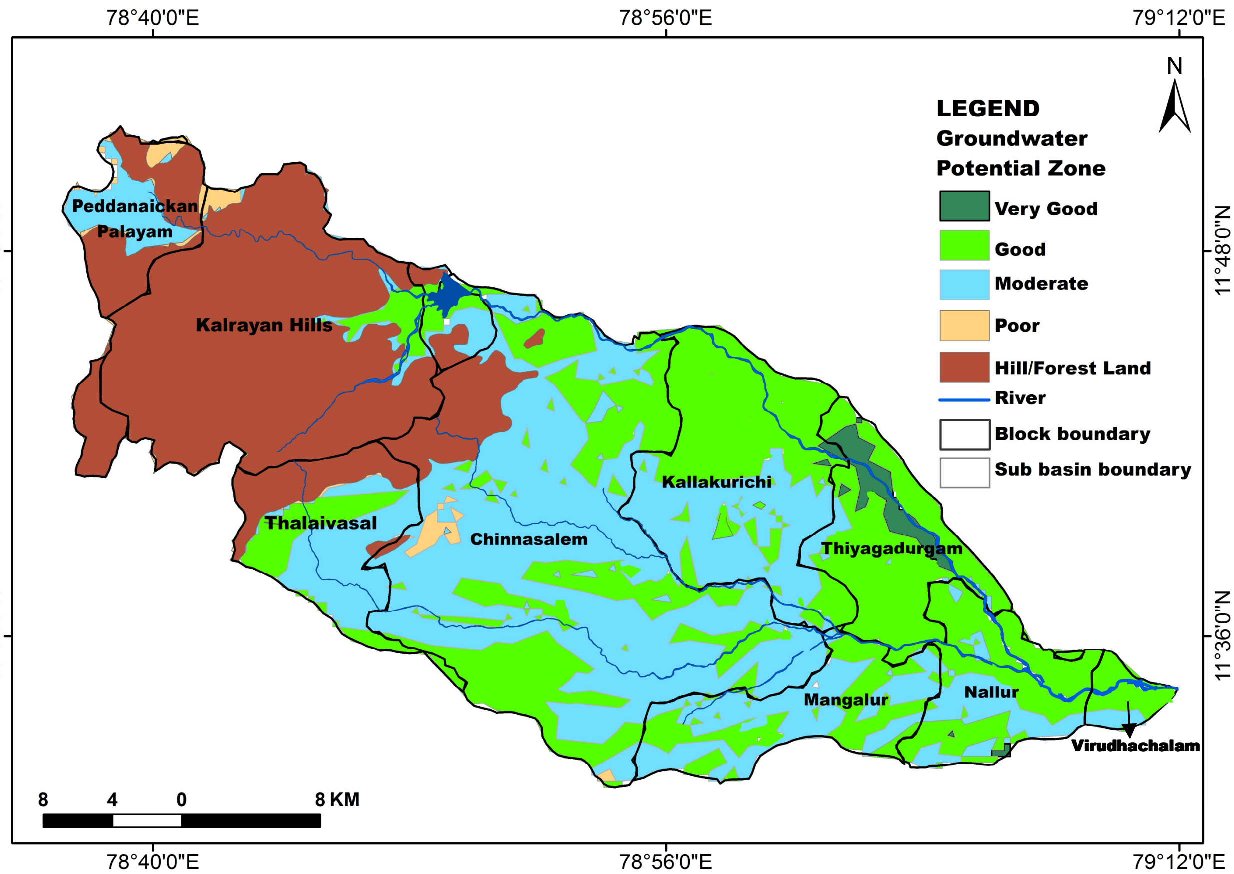

Fig. 12 Blockwise groundwater potential Zonation map

TABLE IV
BLOCKWISE SPATIAL DISTRIBUTION OF GROUNDWATER POTENTIAL ZONES

S.No	Block Name	Total Area of the Block in Sq.Km	Area in Sq.Km			
			Very Good	Good	Moderate	Poor
1	Peddanaickanpalayam	67.07	-	-	26.11	40.96
2	Kalrayan Hills	206.07	-	1.52	95.39	109.16
3	Thalaivasal	71.78	-	19.68	34.1	18.00
4	Kallakurichi	143.24	-	84.74	58.5	-
5	Chinnasalem	377.89	-	109.96	262.02	5.91
6	Mangalur	105.62	-	43.6	61.56	0.46
7	Thiyagadurgam	82.2	14.55	57.83	9.82	-
8	Nallur	86.58	1.12	58.6	26.86	-
9	Virudhachalam	6.15	-	5.13	1.02	-
	Total	1146.6	15.67	381.06	575.38	174.49

ACKNOWLEDGMENT

The authors wish to thank Mr. Karuppiah, Deputy Director, Institute for Water Studies, Public Works Department for supporting data and equipment in this research. Sincere gratitude is expressed for the timely advice and expert guidance contributed by Dr. Shivani Arasu and Dr. Arasu Sundaram, Disaster Management Cell, Anna Institute of Management for the project work. As weIl as wish to thank Ms. Viji, Ms. Nandhini and Mrs Latha Balasubramanian for the valuable contribution to the success of this research.

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